Pearson
BTEC

BTEC International Level 3

Applied Science

Specification

First teaching from April 2020

ISSUE 3

Pearson
BTEC

Pearson BTEC International Level 3 Qualifications in Applied Science

Specification

First teaching April 2020

Issue 3

About Pearson

We are the world's leading learning company operating in countries all around the world. We provide content, assessment and digital services to learners, educational institutions, employers, governments and other partners globally. We are committed to helping equip learners with the skills they need to enhance their employability prospects and to succeed in the changing world of work. We believe that wherever learning flourishes so do people.

This specification is Issue 3. We will inform centres of any changes to this issue.
The latest issue can be found on our website.

VQ000528

Welcome

With a track record built over 40 years of learner success, our BTEC International Level 3 qualifications are recognised internationally by governments, industry and higher education. BTEC International Level 3 qualifications allow learners to progress to the workplace – either directly or via study at a higher level. Over 100,000 BTEC learners apply to university every year. Their Level 3 BTECs, either on their own or in combination with A Levels, are accepted by UK and international universities, and higher-education institutes for entry to relevant degree programmes.

Career-ready education

BTECs enable a learner-centred approach to education, with a flexible, unit-based structure and knowledge applied to project-based assessments. BTECs focus on the holistic development of the practical, interpersonal and thinking skills required to be successful in employment and higher education.

When creating the BTEC International Level 3 qualifications in this suite, we worked with many employers, higher-education providers, colleges and schools to ensure that we met their needs. Employers are looking for recruits who have a thorough grounding in the latest industry requirements and work-ready skills, for example, teamwork. Learners who progress to higher education need experience of research, extended writing and meeting deadlines. BTEC qualifications provide the breadth and depth of learning to give learners this experience.

BTEC addresses these needs by offering:

- a range of BTEC qualification sizes, each with a clear purpose, so that there is something to suit each learner's choice of study programme and progression plans
- internationally relevant content, which is closely aligned with employer and higher-education needs
- assessments and projects chosen to help learners progress; this means that some assessments and projects are set by you to meet local needs, while others are set by Pearson, ensuring a core of skills and understanding common to all learners.

We provide a full range of support, both resources and people, to ensure that learners and teachers have the best possible experience during their course. See *Section 10 Resources and support* for details of the support we offer.

Collaborative development

Learners who complete their BTEC International Level 3 qualification in Applied Science aim to go on to employment, often via the stepping stone of higher education. It was, therefore, essential that we developed these qualifications in close collaboration with experts from professional bodies, businesses and universities, and with the providers who will be delivering the qualifications. We engaged experts in the development of these qualifications to ensure that the content meets providers' needs and gives learners quality preparation to help them progress. We are grateful to all the university and further-education lecturers, teachers, employers, professional body representatives and other individuals who have generously shared their time and expertise to help us develop these new qualifications.

Summary of Pearson BTEC International Level 3 Qualifications in Applied Science specification Issue 3 changes

Summary of changes made between the previous issue and this current issue	**Page number**
The following specialist pathways have been withdrawn and subsequently removed from this issue. Pearson BTEC International Level 3 Diploma (720) Applied Science (Biomedical Science) Pearson BTEC International Level 3 Extended Diploma (1080) Applied Science (Biomedical Science) Pearson BTEC International Level 3 Diploma (720) Applied Science (Environmental Science) Pearson BTEC International Level 3 Extended Diploma (1080) Applied Science (Environmental Science)	Throughout
Unit 9: Biomedical Science and *Unit 10: Climate Change* have been made available as optional units for the Pearson BTEC International Level 3 Diploma (720) and the Pearson BTEC International Level 3 Extended Diploma (1080) Applied Science	

If you need further information on these changes or what they mean, contact us via our website at: qualifications.pearson.com/en/support/contact-us.html.

Contents

Introduction to the BTEC International Level 3 qualifications for the applied science sector

This specification contains all the information you need to deliver the Pearson BTEC International Level 3 Qualifications in Applied Science. We also refer you to other handbooks and policies. This specification includes all the units for these qualifications.

These qualifications are part of the suite of applied science qualifications offered by Pearson. In this suite, there are qualifications that focus on different progression routes, allowing learners to choose the one best suited to their aspirations. These qualifications are not regulated in England.

All qualifications in the suite share some common units and assessments, which gives learners some flexibility in moving between sizes.

In the applied science sector these qualifications are:

Pearson BTEC International Level 3 Certificate in Applied Science (180 GLH)

Pearson BTEC International Level 3 Subsidiary Diploma in Applied Science (360 GLH)

Pearson BTEC International Level 3 Foundation Diploma in Applied Science (540 GLH)

Pearson BTEC International Level 3 Diploma in Applied Science (720 GLH)

Pearson BTEC International Level 3 Extended Diploma in Applied Science (1080 GLH)

This specification signposts the other essential documents and support that you need as a centre in order to deliver, assess and administer the qualifications, including the staff development required. A summary of all essential documents is given in *Section 7 Administrative arrangements*. Information on how we can support you with these qualifications is given in *Section 10 Resources and support*.

The information in this specification is correct at the time of publication.

Qualifications, sizes and purposes at a glance

Title	Size and structure	Summary purpose
Pearson BTEC International Level 3 Certificate in Applied Science	180 GLH Equivalent in size to 0.5 of an International A Level. Three units which are all assessed by a Pearson Set Assignment. Mandatory content (100%).	This qualification is designed to support learners who want an introduction to the sector through applied learning. The qualification supports progression to higher education as part of a programme of study that includes other appropriate BTEC International Level 3 qualifications or International A Levels.
Pearson BTEC International Level 3 Subsidiary Diploma in Applied Science	360 GLH Equivalent in size to one International A Level. Six units of which three are mandatory and assessed using Pearson Set Assignment. Mandatory content (50%).	This qualification is designed to support learners who are interested in learning about the science industry alongside other scientific fields of study, with a view to progressing to a wide range of higher education courses, not necessarily in science-related subjects. The qualification is designed to be taken as part of a programme of study that includes other appropriate BTEC International Level 3 qualifications or International A Levels.
Pearson BTEC International Level 3 Foundation Diploma in Applied Science	540 GLH Equivalent in size to 1.5 International A Levels. Eight units of which seven are mandatory units and three units are assessed using Pearson Set Assignment. Mandatory content (89%).	This qualification is designed to support learners who want to study science-based qualifications as a one-year, full-time course, or for those wanting to take it alongside another area of complementary or contrasting study as part of a two-year, full-time study programme. The qualification would support progression to higher education if taken as part of a programme of study that included other BTEC International Level 3 qualifications or International A Levels.

Title	Size and structure	Summary purpose
Pearson BTEC International Level 3 Diploma in Applied Science	720 GLH Equivalent in size to two International A Levels. Eleven units, of which seven are mandatory and are assessed by Pearson Set Assignment. Mandatory content (67%).	This qualification is designed to support learners who want to study science-based qualifications as the main element alongside another area of complementary or contrasting study as part of a two-year, full-time study programme. The qualification would support progression to higher education if taken as part of a programme of study that included other BTEC International Level 3 qualifications or International A Levels.
Pearson BTEC International Level 3 Extended Diploma in Applied Science	1080 GLH Equivalent in size to three International A Levels. Sixteen units of which eight are mandatory units. Four units are assessed by Pearson Set Assignment. Mandatory content (56%).	This qualification is designed as a full-time course to support learners who want to study science-based qualifications as the main focus of a two-year, full-time study programme. The qualification would support progression to higher education in its own right.

Structures of the qualifications at a glance

This table shows all the units and the qualifications to which they contribute. The full structure for this Pearson BTEC International Level 3 in Applied Science is shown in *Section 2 Structure*. **You must refer to the full structure to select units and plan your programme.**

Key

	Pearson Set Assignment	M	**Mandatory units**	O	**Optional units**

Unit (number and title)	Unit size (GLH)	Certificate (180 GLH)	Subsidiary Diploma (360 GLH)	Foundation Diploma (540 GLH)	Diploma (720 GLH)	Extended Diploma (1080 GLH)
1 Principles and Applications of Biology I	**60**	**M**	**M**	**M**	**M**	**M**
2 Principles and Applications of Chemistry I	**60**	**M**	**M**	**M**	**M**	**M**
3 Principles and Applications of Physics I	**60**	**M**	**M**	**M**	**M**	**M**
4 Investigative Project Skills	**120**			**M**	**M**	**M**
5 Principles and Applications of Biology II	**60**			**M**	**M**	**M**
6 Principles and Applications of Chemistry II	**60**			**M**	**M**	**M**
7 Principles and Applications of Physics II	**60**			**M**	**M**	**M**
8 Contemporary Issues in Science	**120**					**M**
9 Biomedical Science	**60**		**O**	**O**	**O**	**O**
10 Climate Change	**60**		**O**	**O**	**O**	**O**
11 Functional Physiology of Human Body Systems	**60**		**O**	**O**	**O**	**O**
12 Human Regulation and Reproduction	**60**		**O**	**O**	**O**	**O**
13 Biological Molecules and Metabolic Pathways	**60**		**O**	**O**	**O**	**O**
14 Genetics and Genetic Engineering	**60**		**O**	**O**	**O**	**O**
15 Diseases and Infections	**60**		**O**	**O**	**O**	**O**
16 Applications of Inorganic Chemistry	**60**		**O**	**O**	**O**	**O**

Unit (number and title)	Unit size (GLH)	Certificate (180 GLH)	Subsidiary Diploma (360 GLH)	Foundation Diploma (540 GLH)	Diploma (720 GLH)	Extended Diploma (1080 GLH)
17 Electrical Circuits and their Applications	**60**		**O**	**O**	**O**	**O**
18 Astronomy and Space Science	**60**		**O**	**O**	**O**	**O**
19 Microbiology and Microbiological Techniques	**60**		**O**	**O**	**O**	**O**
20 Applications of Physical Chemistry	**60**		**O**	**O**	**O**	**O**
21 Applications of Organic Chemistry	**60**		**O**	**O**	**O**	**O**
22 Medical Physics Applications	**60**		**O**	**O**	**O**	**O**
23 Materials Science	**60**		**O**	**O**	**O**	**O**
24 Pollution and Waste Management	**60**		**O**	**O**	**O**	**O**
25 Water Quality	**60**		**O**	**O**	**O**	**O**
26 Animal Conservation	**60**		**O**	**O**	**O**	**O**
27 Ecosystems	**60**		**O**	**O**	**O**	**O**
28 Sustainable Energy	**60**		**O**	**O**	**O**	**O**

Qualification and unit content

Pearson has developed the content of the new BTEC International Level 3 qualifications in collaboration with employers and representatives from higher education, and relevant professional bodies. In this way, we have ensured that content is up to date and that it includes the knowledge, understanding, skills and personal attributes required in the sector.

The mandatory content ensures that all learners are following a coherent programme of study and that they acquire knowledge, understanding and skills that will be recognised and valued by higher education and employers. Learners are expected to show achievement across mandatory units as detailed in *Section 2 Structure*.

BTEC qualifications encompass applied learning that brings together knowledge and understanding with practical and technical skills. This applied learning is achieved through learners performing vocational tasks that encourage the development of appropriate vocational behaviours and transferable skills. Transferable skills are those such as communication, teamwork and research and analysis, which are valued in both higher education and the workplace. Opportunities to develop these skills are signposted in the units.

Our approach provides rigour and balance, and promotes the ability to apply learning immediately in new contexts.

Centres should ensure that content, for example content that references regulation, legislation, policies and regulatory/standards organisations, is kept up to date. The units include guidance on approaches to breadth and depth of coverage, which can be modified to ensure that content is current and reflects international variations.

Assessment

Assessment is designed to fit the purpose and objective of the qualification. It includes a range of assessment types and styles suited to vocational qualifications in the sector. All assessment is internal but some mandatory units have extra controls on assessment and are assessed using Pearson Set Assignments. Additionally, some units are synoptic.

Set assignment units

Some mandatory units in the qualifications are assessed using a set assignment. Each assessment is set by Pearson and will need to be taken under controlled conditions before it is marked by teachers.

Set assignment units are subject to external standards verification processes common to all BTEC units. By setting an assignment for some units, we can ensure that all learners take the same assessment for a specific unit. Learners are permitted to resit set assignment units during their programme. Please see *Section 6 Internal assessment* for further information.

Set assignments are available from June each year and are valid until the end of August in the following year. For detailed information on the Pearson Set Assignment, please see the table in *Section 2 Structure*. For further information on preparing for assessment, see *Section 5 Assessment structure*.

Internal assessment

All units in the sector are internally assessed and subject to external standards verification. Before you assess you will need to become an approved centre, if you are not one already. You will need to prepare to assess using the guidance in *Section 6 Internal assessment*.

For units where there is no Pearson Set Assignment, you select the most appropriate assessment methods according to the learning set out in the unit. This ensures that learners are assessed using a variety of methods to help them develop a broad range of transferable skills. Learners could be given opportunities to:

- write up the findings of their own research
- use case studies to explore complex or unfamiliar situations
- carry out projects for which they have choice over the direction and outcomes
- demonstrate practical and technical skills using appropriate tools/processes, etc.

For these units, Pearson will provide an Authorised Assignment brief that you can use. You will make grading decisions based on the requirements and supporting guidance given in the units. Learners may not make repeated submissions of assignment evidence. For further information, please see *Section 6 Internal assessment*.

Language of assessment

Assessment of the units for these qualifications are available in English but can be translated as necessary.

All learner work must be available for standardisation in English. A learner taking the qualification/s may be assessed in sign language where it is permitted for the purpose of reasonable adjustment. For information on reasonable adjustments, see *Section 7 Administration arrangements*.

Grading for units and qualifications

Achievement of the qualification requires demonstration of depth of study in each unit, assured acquisition of a range of practical skills required for employment or for progression to higher education, and successful development of transferable skills. Learners who achieve a qualification will have achieved across mandatory units, including synoptic assessment, where applicable.

Units are assessed using a grading scale of Distinction (D), Merit (M), Pass (P) and Unclassified (U). All mandatory and optional units contribute proportionately to the overall qualification grade, for example, a unit of 120 GLH will contribute double that of a 60 GLH unit.

Qualifications in the suite are graded using a scale of P to D*, **or** PP to D*D*, **or** PPP to D*D*D*. Please see *Section 9 Understanding the qualification grade* for more details. The relationship between qualification grading scales and unit grades will be subject to regular review as part of Pearson's standards monitoring processes, on the basis of learner performance and in consultation with key users of the qualifications.

1 Qualification purpose and progression

Pearson BTEC International Level 3 qualifications in Applied Science

In this section you will find information on the purpose of this qualification and how its design meets that purpose through the qualification objective and structure.

Who are these qualifications for?

The Pearson BTEC International Level 3 qualifications in Applied Science are designed for learners in the 16–19 age group, who wish to pursue a career in science-based industries via higher education to access graduate entry employment with science, or, alternatively through junior science-based employment.

Which size qualification to choose?

Choosing the most suitable size of qualification will depend on the learner's broader programme of study. For example, a learner who wishes to select a smaller qualification, such as the Certificate or Subsidiary Diploma, may choose to combine it with qualifications from other sectors, in order to support their desired progression. Smaller qualifications are also suitable for learners who are in employment and studying part-time.

Qualification structures have been designed to enable a learner who starts with the smallest qualification to progress easily to the larger qualifications.

What do these qualifications cover?

The content of this qualification has been designed to support progression to particular roles in applied-science industries, either directly into entry-level roles linked to these occupational areas or, more likely, via particular higher-education routes in the particular areas. The qualification content has been designed in consultation with employers, professional bodies and higher-education providers to ensure that the content is appropriate for the progression routes identified.

All learners will be required to take mandatory content that is directly relevant to progression routes in all the identified areas.

Learners will study mandatory units from the following:

- Unit 1: Principles and Applications of Biology I
- Unit 2: Principles and Applications of Chemistry I
- Unit 3: Principles and Applications of Physics I
- Unit 4: Investigative Project Skills
- Unit 5: Principles and Applications of Biology II
- Unit 6: Principles and Applications of Chemistry II
- Unit 7: Principles and Applications of Physics II.

Learners are given the opportunity to explore, through the optional units, a particular area of science if they wish, to support progression to applied science courses in higher education, and to link with relevant occupational areas. The particular scientific areas covered are physiology, applications of organic and inorganic chemistry, and astronomy and space science.

What could these qualifications lead to?

This qualification supports progression to job opportunities in the science industry at a variety of levels. Jobs available in these areas include:

- Chemical Technician
- Clinical Scientist.

After achieving this qualification, while learners can progress directly to entry-level science roles, it is likely that many will do so via higher study. This qualification is recognised by higher-education institutions as fully meeting admission requirements to many relevant courses in a variety of areas of the science sector, for example:

- BSc (Hons) in Chemistry with Analytical Science
- Higher National Diploma (HND) in Applied Science.

NB: Learners should always check the entry requirements for degree programmes with the relevant higher education provider.

How do these qualifications provide transferable employability skills?

In the BTEC International Level 3 units, there are opportunities during the teaching and learning phase to give learners practice in developing employability skills. Where we refer to employability skills in this specification, we are generally referring to skills in the following three main categories:

- **cognitive and problem-solving skills** – using critical thinking, approaching non-routine problems, applying expert and creative solutions, using systems and technology
- **interpersonal skills** – communicating, working collaboratively, negotiating and influencing, self-presentation
- **intrapersonal skills** – self-management, adaptability and resilience, self-monitoring and development.

There are also specific requirements in some units for assessment of these skills where relevant, for example, where learners are required to undertake real or simulated activities. These skills are indicated in the units and in *Appendix 2: Transferable employability skills*.

How do these qualifications provide transferable knowledge and skills for higher education?

All BTEC International Level 3 qualifications provide transferable knowledge and skills that prepare learners for progression to university. The transferable skills that universities value include:

- the ability to learn independently
- the ability to research actively and methodically
- the ability to give presentations and be active group members.

BTEC learners can also benefit from opportunities for deep learning, where they are able to make connections across units and select areas of interest for detailed study. BTEC International Level 3 qualifications provide a vocational context in which learners can develop the knowledge and skills required for particular degree courses, including:

- reading scientific and technical texts
- effective writing
- analytical skills
- practical skills
- preparation for assessment methods used in a degree.

2 Structure

Qualification structures

The structures presented below are for the following qualifications in this specification:

- Pearson BTEC International Level 3 Certificate in Applied Science
- Pearson BTEC International Level 3 Subsidiary Diploma in Applied Science
- Pearson BTEC International Level 3 Foundation Diploma in Applied Science
- Pearson BTEC International Level 3 Diploma in Applied Science
- Pearson BTEC International Level 3 Extended Diploma in Applied Science

Pearson BTEC International Level 3 Certificate in Applied Science

Mandatory units

There are three mandatory units, which are all set assignment units. Learners must complete and achieve a Pass or above in all mandatory units.

Pearson BTEC International Level 3 Certificate in Applied Science				
Unit number	**Unit title**	**GLH**	**Type**	**How assessed**
Mandatory units – learners complete and achieve all units				
1	Principles and Applications of Biology I	**60**	**Mandatory**	Set assignment
2	Principles and Applications of Chemistry I	**60**	**Mandatory**	Set assignment
3	Principles and Applications of Physics I	**60**	**Mandatory**	Set assignment

Pearson BTEC International Level 3 Subsidiary Diploma in Applied Science

Mandatory units

There are three mandatory units, which are all set assignment units. Learners must complete and achieve a Pass or above in all mandatory units.

Optional units

Learners must complete optional units to a minimum value of 180 GLH.

Pearson BTEC International Level 3 Subsidiary Diploma in Applied Science				
Unit number	**Unit title**	**GLH**	**Type**	**How assessed**
Mandatory units – learners complete and achieve all units				
1	Principles and Applications of Biology I	**60**	**Mandatory**	Set assignment
2	Principles and Applications of Chemistry I	**60**	**Mandatory**	Set assignment
3	Principles and Applications of Physics I	**60**	**Mandatory**	Set assignment
Optional units – learners must complete optional units to a minimum value of 180 GLH				
9	Biomedical Science	**60**	**Optional**	Internal
10	Climate Change	**60**	**Optional**	Internal
11	Functional Physiology of Human Body Systems	**60**	**Optional**	Internal
12	Human Regulation and Reproduction	**60**	**Optional**	Internal

Optional units – learners must complete optional units to a minimum value of 180 GLH *(continued)*				
13	Biological Molecules and Metabolic Pathways	**60**	**Optional**	Internal
14	Genetics and Genetic Engineering	**60**	**Optional**	Internal
15	Diseases and Infections	**60**	**Optional**	Internal
16	Applications of Inorganic Chemistry	**60**	**Optional**	Internal
17	Electrical Circuits and their Applications	**60**	**Optional**	Internal
18	Astronomy and Space Science	**60**	**Optional**	Internal
19	Microbiology and Microbiological Techniques	**60**	**Optional**	Internal
20	Applications of Physical Chemistry	**60**	**Optional**	Internal
21	Applications of Organic Chemistry	**60**	**Optional**	Internal
22	Medical Physics Applications	**60**	**Optional**	Internal
23	Materials Science	**60**	**Optional**	Internal
24	Pollution and Waste Management	**60**	**Optional**	Internal
25	Water Quality	**60**	**Optional**	Internal
26	Animal Conservation	**60**	**Optional**	Internal
27	Ecosystems	**60**	**Optional**	Internal
28	Sustainable Energy	**60**	**Optional**	Internal

Pearson BTEC International Level 3 Foundation Diploma in Applied Science

Mandatory units

There are seven mandatory units, of which three are set assignment units. Learners must complete and achieve a Pass or above in all mandatory units.

Optional units

Learners must complete an optional unit to a minimum value of 60 GLH.

Pearson BTEC International Level 3 Foundation Diploma in Applied Science				
Unit number	**Unit title**	**GLH**	**Type**	**How assessed**
Mandatory units – learners complete and achieve all units				
1	Principles and Applications of Biology I	**60**	**Mandatory**	Set assignment
2	Principles and Applications of Chemistry I	**60**	**Mandatory**	Set assignment
3	Principles and Applications of Physics I	**60**	**Mandatory**	Set assignment
4	Investigative Project Skills	**120**	**Mandatory**	Internal
5	Principles and Applications of Biology II	**60**	**Mandatory**	Internal
6	Principles and Applications of Chemistry II	**60**	**Mandatory**	Internal
7	Principles and Applications of Physics II	**60**	**Mandatory**	Internal
Optional units – learners must complete one optional unit				
9	Biomedical Science	**60**	**Optional**	Internal
10	Climate Change	**60**	**Optional**	Internal
11	Functional Physiology of Human Body Systems	**60**	**Optional**	Internal
12	Human Regulation and Reproduction	**60**	**Optional**	Internal
13	Biological Molecules and Metabolic Pathways	**60**	**Optional**	Internal
14	Genetics and Genetic Engineering	**60**	**Optional**	Internal
15	Diseases and Infections	**60**	**Optional**	Internal
16	Applications of Inorganic Chemistry	**60**	**Optional**	Internal
17	Electrical Circuits and their Applications	**60**	**Optional**	Internal
18	Astronomy and Space Science	**60**	**Optional**	Internal

Optional units – learners must complete one optional unit *(continued)*				
19	Microbiology and Microbiological Techniques	**60**	**Optional**	Internal
20	Applications of Physical Chemistry	**60**	**Optional**	Internal
21	Applications of Organic Chemistry	**60**	**Optional**	Internal
22	Medical Physics Applications	**60**	**Optional**	Internal
23	Materials Science	**60**	**Optional**	Internal
24	Pollution and Waste Management	**60**	**Optional**	Internal
25	Water Quality	**60**	**Optional**	Internal
26	Animal Conservation	**60**	**Optional**	Internal
27	Ecosystems	**60**	**Optional**	Internal
28	Sustainable Energy	**60**	**Optional**	Internal

Pearson BTEC International Level 3 Diploma in Applied Science

Mandatory units

There are seven mandatory units, of which three are set assignment units. Learners must complete and achieve a Pass or above in all mandatory units.

Optional units

Learners must complete optional units to a minimum value of 240 GLH.

Pearson BTEC International Level 3 Diploma in Applied Science				
Unit number	**Unit title**	**GLH**	**Type**	**How assessed**
Mandatory units – learners complete and achieve all units				
1	Principles and Applications of Biology I	**60**	**Mandatory**	Set assignment
2	Principles and Applications of Chemistry I	**60**	**Mandatory**	Set assignment
3	Principles and Applications of Physics I	**60**	**Mandatory**	Set assignment
4	Investigative Project Skills	**120**	**Mandatory**	Internal
5	Principles and Applications of Biology II	**60**	**Mandatory**	Internal
6	Principles and Applications of Chemistry II	**60**	**Mandatory**	Internal
7	Principles and Applications of Physics II	**60**	**Mandatory**	Internal
Optional units – learners must complete optional units to a minimum value of 240 GLH				
9	Biomedical Science	**60**	**Optional**	Internal
10	Climate Change	**60**	**Optional**	Internal
11	Functional Physiology of Human Body Systems	**60**	**Optional**	Internal
12	Human Regulation and Reproduction	**60**	**Optional**	Internal
13	Biological Molecules and Metabolic Pathways	**60**	**Optional**	Internal
14	Genetics and Genetic Engineering	**60**	**Optional**	Internal
15	Diseases and Infections	**60**	**Optional**	Internal
16	Applications of Inorganic Chemistry	**60**	**Optional**	Internal
17	Electrical Circuits and their Applications	**60**	**Optional**	Internal
18	Astronomy and Space Science	**60**	**Optional**	Internal

Optional units – learners must complete optional units to a minimum value of 240 GLH *(continued)*				
19	Microbiology and Microbiological Techniques	**60**	**Optional**	Internal
20	Applications of Physical Chemistry	**60**	**Optional**	Internal
21	Applications of Organic Chemistry	**60**	**Optional**	Internal
22	Medical Physics Applications	**60**	**Optional**	Internal
23	Materials Science	**60**	**Optional**	Internal
24	Pollution and Waste Management	**60**	**Optional**	Internal
25	Water Quality	**60**	**Optional**	Internal
26	Animal Conservation	**60**	**Optional**	Internal
27	Ecosystems	**60**	**Optional**	Internal
28	Sustainable Energy	**60**	**Optional**	Internal

Pearson BTEC International Level 3 Extended Diploma in Applied Science

Mandatory units

There are eight mandatory units, of which four are set assignment units. Learners must complete and achieve a Pass or above in all mandatory units.

Optional units

Learners must complete optional units to a minimum value of 480 GLH.

Pearson BTEC International Level 3 Extended Diploma in Applied Science				
Unit number	**Unit title**	**GLH**	**Type**	**How assessed**
Mandatory units – learners complete and achieve all units				
1	Principles and Applications of Biology I	**60**	**Mandatory**	Set assignment
2	Principles and Applications of Chemistry I	**60**	**Mandatory**	Set assignment
3	Principles and Applications of Physics I	**60**	**Mandatory**	Set assignment
4	Investigative Project Skills	**120**	**Mandatory**	Internal
5	Principles and Applications of Biology II	**60**	**Mandatory**	Internal
6	Principles and Applications of Chemistry II	**60**	**Mandatory**	Internal
7	Principles and Applications of Physics II	**60**	**Mandatory**	Internal
8	Contemporary Issues in Science	**120**	**Mandatory**	Set assignment
Optional units – learners must complete optional units to a minimum value of 480 GLH				
9	Biomedical Science	**60**	**Optional**	Internal
10	Climate Change	**60**	**Optional**	Internal
11	Functional Physiology of Human Body Systems	**60**	**Optional**	Internal
12	Human Regulation and Reproduction	**60**	**Optional**	Internal
13	Biological Molecules and Metabolic Pathways	**60**	**Optional**	Internal
14	Genetics and Genetic Engineering	**60**	**Optional**	Internal
15	Diseases and Infections	**60**	**Optional**	Internal
16	Applications of Inorganic Chemistry	**60**	**Optional**	Internal
17	Electrical Circuits and their Applications	**60**	**Optional**	Internal

Optional units – learners must complete optional units to a minimum value of 480 GLH *(continued)*				
18	Astronomy and Space Science	**60**	**Optional**	Internal
19	Microbiology and Microbiological Techniques	**60**	**Optional**	Internal
20	Applications of Physical Chemistry	**60**	**Optional**	Internal
21	Applications of Organic Chemistry	**60**	**Optional**	Internal
22	Medical Physics Applications	**60**	**Optional**	Internal
23	Materials Science	**60**	**Optional**	Internal
24	Pollution and Waste Management	**60**	**Optional**	Internal
25	Water Quality	**60**	**Optional**	Internal
26	Animal Conservation	**60**	**Optional**	Internal
27	Ecosystems	**60**	**Optional**	Internal
28	Sustainable Energy	**60**	**Optional**	Internal

Set assignment units

This is a summary of the type and availability of set assignment units. For more information, see *Section 5 Assessment structure*, and the units and sample assessment materials.

Unit	Type	Availability
Unit 1: Principles and Applications of Biology I	• An assignment set by Pearson and marked by the centre. • The advised period is 15 hours.	**Two available for each one-year period.**
Unit 2: Principles and Applications of Chemistry I	• An assignment set by Pearson and marked by the centre. • The advised period is 22 hours.	**Two available for each one-year period.**
Unit 3: Principles and Applications of Physics I	• An assignment set by Pearson and marked by the centre. • The advised period is 16 hours.	**Two available for each one-year period.**
Unit 8: Contemporary Issues in Science	• An assignment set by Pearson and marked by the centre. • The advised period is 20 hours.	**Two available for each one-year period.**

Employer involvement in assessment and delivery

You are encouraged to give learners opportunities to be involved with employers. For more information, please see *Section 4 Planning your programme*.

3 Units

Understanding your units

The units in this specification set out our expectations of assessment in a way that helps you to prepare your learners for assessment. The units help you to undertake assessment and quality assurance effectively.

Each unit in the specification is set out in a similar way. This section explains how the units work. It is important that all teachers, assessors, internal verifiers and other staff responsible for the programme review this section.

Section	Explanation
Unit number	The number is in a sequence in the sector. Numbers may not be sequential for an individual qualification.
Unit title	This is the formal title that we always use, it appears on certificates.
Level	All units are at Level 3.
Unit type	This shows if the unit is internal or assessed using a Pearson Set Assignment. See structure information in *Section 2 Structure* for details.
Guided Learning Hours (GLH)	Units may have a GLH value of 120 or 60. This indicates the numbers of hours of teaching, directed activity and assessment expected. It also shows the weighting of the unit in the final qualification grade.
Unit in brief	This is a brief formal statement on the content of the unit that is helpful in understanding its role in the qualification. You can use this in summary documents, brochures, etc.
Unit introduction	This is written with learners in mind. It indicates why the unit is important, how learning is structured and how it might be applied when they progress to employment or higher education.
Assessment	For internal set assignment units, this section states whether set assignments are required to be completed.
Learning aims	These help to define the scope, style and depth of learning of the unit. You can see where learners should be learning standard requirements ('understand') or where they should be actively researching ('investigate'). You can find out more about the verbs we use in learning aims in *Appendix 3: Glossary of terms used*.
Summary of unit	This section helps teachers to see at a glance the main content areas given against the learning aims and the structure of the assessment. The content areas and structure of assessment must be covered. The forms of evidence given are suitable to fulfil the requirement.

Section	Explanation
Content	This section sets out the required teaching content of the unit. Content is compulsory except when shown as 'e.g.'. Learners should be asked to complete summative assessment only after the teaching content for the unit or learning aim(s) has been covered.
Assessment criteria	Each learning aim has Pass and Merit criteria. Each assignment has at least one Distinction criterion. A full glossary of terms used is given in *Appendix 3: Glossary of terms used.* All assessors need to understand our expectations of the terms used. Distinction criteria represent outstanding performance in the unit. Some criteria require learners to draw together learning from across the learning aims.
Essential information for assignments	This shows the maximum number of assignments that may be used for the unit to allow for effective summative assessment and how the assessment criteria should be used to assess performance. For set assignment units, this section will include any conditions for taking the assignment.
Further information for teachers and assessors	This section gives you information to support the implementation of assessment. It is important that this is read carefully alongside the assessment criteria, as the information will help with interpretation of the requirements.
Resource requirements	Any specific resources that you need to be able to teach and assess are listed in this section. For information on support resources, see *Section 10 Resources and support*.
Essential information for assessment decisions	This section gives guidance on and examples for each learning aim or assignment of the expectations for Pass, Merit and Distinction standard.
Assessment controls	This section gives details of the rules that learners need to abide by when taking the assessment.
Links to other units	This section shows you the main relationships between different units. This helps you to structure your programme and make best use of available materials and resources.
Employer involvement	This section gives you information on the units, which can be used to involve learners with employers. This will help you to identify the kind of involvement that is likely to be most successful.
Opportunities to develop transferable employability skills	This section gives you guidance on how transferable employability skills might be developed in teaching and assessment of the unit.

Index of units

This section contains all the units developed for these qualifications. Please refer to *pages 4–5* to check which units are available in all qualifications in the applied science sector.

Unit 1: Principles and Applications of Biology I

Level: 3
Unit type: Internal set assignment
Guided learning hours: 60

Unit in brief

This unit covers cellular biology and the anatomy and physiology of body systems in health and disease.

Unit introduction

In this unit you will study key concepts in cellular biology, human anatomy and physiology.

The unit explores the fundamental structure and function of cells and the subcellular arrangement of organelles which are visible using electron microscopy. Knowledge of the ultrastructure of cells and how cellular components work to perform vital processes is fundamental to understanding how cells obtain energy, synthesise new molecules, communicate, proliferate and survive. Medical professionals need to understand the structure and workings of cells. They build on this knowledge to understand how the body stays healthy as well as the symptoms and causes of some diseases. This allows them to diagnose and treat illnesses.

You will also study the anatomy and physiology of the human lymphatic and musculoskeletal systems including the normal functioning of these systems in health and how malfunction of these systems leads to disease or disorder. You will examine each of the systems as a functioning unit, identifying their structure and function. By exploring the anatomy of these systems, through experimentation and use of simulations, you will develop your knowledge and understanding of their role in the human body. You will also gain an understanding of the impact of disorders of the two systems and associated corrective treatments.

The unit will be of particular interest if you are interested in health and disease, pathology, sports physiology. An understanding of the fundamental systems that make up the human body is a key requirement if you wish to progress to study health- and care-related programmes or biomedical sciences in further education and at university. It is an essential requirement for a career in sport- and health-related disciplines, for example, as a nurse, physiotherapist, histologist, personal trainer or exercise physiologist.

Assessment

This unit has a set assignment. Learners must complete a Pearson Set Assignment Brief.

Learning aims

In this unit you will:

A Understand the microscopic structure and the functions of eukaryotic cells and tissues

B Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments

C Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the microscopic structure and the functions of eukaryotic cells and tissues	**A1** Cell structure and function **A2** Specialised cells **A3** Tissue structure and function	This unit is assessed through a Pearson Set Assignment.
B Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments	**B1** Structure of the musculoskeletal system **B2** Function of the musculoskeletal system **B3** Health matters and treatments related to the musculoskeletal system	
C Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments	**C1** Structure of the lymphatic system **C2** Function of the lymphatic system **C3** Health matters and treatments related to the lymphatic system	

Content

Learning aim A: Understand the microscopic structure and the functions of eukaryotic cells and tissues

Know that cell theory is a unifying concept stating that cells are a fundamental unit of structure, function and organisation in all living organisms.

A1 Cell structure and function

- Understand the ultrastructure and function of organelles in the following cells:
  - eukaryotic cells (plant and animal cells) – plasma membrane, cytoplasm, nucleus, nucleolus, endoplasmic reticulum (smooth and rough), Golgi apparatus, vesicles, lysosomes, 80S ribosomes, mitochondria, centriole
  - eukaryotic cells (plant-cell specific) – cell wall, chloroplasts, vacuole, tonoplast, amyloplasts, peroxisomes, plasmodesmata, pits.
- Recognise cellular organelles from electron micrographs and the use of light microscopes.
- Understand the similarities and differences between plant and animal cell structure and function.
- Calculate magnification and size of cells and organelles from drawings or images.

A2 Specialised cells

- Understand cell specialisation in terms of structure and function to include:
  - palisade mesophyll cells in a leaf
  - root hair cells in plants
  - xylem cells in plants
  - phloem cells in plants
  - sperm and egg cells in human reproduction
  - red and white blood cells in humans
  - nerve cells in humans.

A3 Tissue structure and function

- Understand how differentiation leads to the formation of specialised tissues to include:
  - squamous epithelium (simple, cuboidal, columnar) in humans
  - stratified epithelium (squamous, stratified) in humans
  - ciliated epithelium in humans
  - endothelium in humans
  - muscle tissue in humans (skeletal, smooth, cardiac)
  - nervous tissue in humans (myelinated and non-myelinated neurons)
  - connective tissue in humans
  - differentiation in a zygote to form specialised tissues and structures of a human baby
  - ground tissue in plants (parenchyma, collenchyma, sclerenchyma)
  - vascular tissue in plants (xylem, phloem)
  - dermal tissue in plants (epidermis, stomata, guard cells, trichomes).
- Understand the structure and function of the specialised tissues listed above.

Learning aim B: Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments

B1 Structure of the musculoskeletal system

Structure and identification of major bones, muscles, joints and supporting apparatus by visual examination of diagrams or models and manipulative means in living subjects as appropriate.

- Axial skeleton, to include:
  - cranium, mandible and maxilla
  - vertebral column (cervical, thoracic and lumbar vertebrae, sacrum and coccyx, intervertebral discs)
  - ribs and sternum.
- Appendicular skeleton, to include:
  - limb bones (humerus, radius, ulna; femur, patella, tibia, fibula)
  - wrist, hand and digit bones (carpals, metacarpals, phalanges)
  - ankle, foot and digit bones (tarsals, metatarsals, phalanges, calcaneus)
  - shoulder girdle (scapula, clavicle)
  - pelvic girdle (ilium, pubis, ischium).
- Bone types: long bones, short bones, flat bones, irregular bones, sesamoid bones.
- Bone composition: periosteum, spongy/compact bone, bone marrow, mineral use.
- Identification of the major joint types and where they exist in the human body – gliding, condyloid, saddle, socket, ball and socket, pivot, hinge.
- Classification of joints: fibrous, cartilaginous, synovial.
- Composition and location of ligaments and tendons.
- Major muscle groups.
- Structure of muscle fibres.

B2 Function of the musculoskeletal system

Functions of each part of the musculoskeletal system and how each contributes to the effective functioning of the whole system.

- Skeletal functions: support, protection, attachment for skeletal muscle, storing minerals, producing blood cells, maintaining mineral homeostasis.
- Muscles, ligaments and tendons: the role of ligaments, tendons, skeletal muscle, process of muscle contraction (fast and slow twitch fibres).
- Movement due to interaction of muscles, bones, joints and attachment apparatus: flexion/extension, adduction/abduction, internal/external, rotation, circumduction.

B3 Health matters and treatments related to the musculoskeletal system

The causes, symptoms and common treatments involved in common disorders or dysfunction in the musculoskeletal system.

- Disorders to include: forms of arthritis; hip dysplasia; hypermobility; bone fracture and dislocation; repetitive strain injury (RSI); muscle, ligament and tendon trauma.
- Treatments for musculoskeletal disorders (including physiological reasoning behind the treatment), to include: physiotherapy; arthroscopy; joint replacement therapy; rest, ice, compression, elevation (RICE); splinting and casting.

Learning aim C: Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments

C1 Structure of the lymphatic system

Composition and location of component parts:

- spleen, thymus gland, tonsils, lymph glands, lymph vessels
- major lymph nodes – axillary, abdominal, inguinal, popliteal, supratrochlear
- presence of valves.

C2 Function of the lymphatic system

Location, processes, structures involved and importance of each function:

- formation and transport of lymphocytes and lymph
- removal of interstitial fluid from tissues
- maintenance of hydrostatic pressure
- absorption of fats from the digestive system.

C3 Health matters and treatments related to the lymphatic system

Symptoms, treatment and physiological reasoning behind treatment for disruption or dysfunction of the lymphatic system, to include:

- lymphadenitis
- lymphedema
- Hodgkin lymphoma.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the microscopic structure and the functions of eukaryotic cells and tissues		**A.D1** Analyse the process by which stem cells differentiate to become specialised cells, tissues and organs within plants and animals.
A.P1 Describe the structure and function of organelles within eukaryotic cells. **A.P2** Describe the different tissue types present within plants and animals.	**A.M1** Compare and contrast different tissue types within plants and animals.	
Learning aim B: Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments		**B.D2** Evaluate the effect of corrective treatment(s) associated with a musculoskeletal disorder.
B.P3 Explain the functional role of the musculoskeletal system in the human body. **B.P4** Describe the effect of disorder of muscles and joints and possible corrective treatment(s).	**B.M2** Compare how disorders of the musculoskeletal system can affect how muscles bring about movement of joints and the role of corrective treatment(s).	
Learning aim C: Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments		**C.D3** Evaluate the effect of corrective treatment(s) for a disorder of the lymphatic system.
C.P5 Describe the gross anatomy and function of the organs of the lymphatic system. **C.P6** Describe the effect of a disorder on the lymphatic system and possible corrective treatment(s).	**C.M3** Explain the physiological reasoning for corrective treatment(s) associated with a disorder of the lymphatic system.	

Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners.

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to: a well-equipped laboratory, textbooks and/or IT resources for research, light microscopes and prepared slides of different tissue types, photomicrographs showing the ultrastructure of cells.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will learners will provide a detailed analysis of the process of differentiation in plants and animals. They will select a range from epithelium, muscle, nerve and connective tissue and analyse the role of stem cells in the formation of the associated cells, tissue and organs.

Differentiation in plant meristematic cells to produce specialised cells and tissues must be included. This will include a range of tissues from ground, vascular and dermal tissue and associated cells and organs.

For Merit standard, learners will provide a detailed comparison of the microscopic structures found in animals (epithelium, nerve, muscle and connective tissue), and plants (ground tissue, vascular tissue, dermal tissue). Using diagrams to illustrate the structures, they will compare and contrast the differences in the appearance and structure of the tissues and relate these to the function of each tissue.

For Pass standard, learners will describe the structures of each of the organelles listed in the unit content. Learners will use light microscopes, photomicrographs and/or drawings of the organelles to link structure(s) to their function(s). References must be provided.

Learners will produce detailed descriptions of the plant and animal tissues listed in the unit content. The principle shapes and functions of different types of tissues must be described.

Learning aim B

For Distinction standard, learners will research disorders/dysfunctions of the musculoskeletal system. Learners will reach conclusions, based on referenced evidence they have produced from research, on the impact on health of one named disorder/dysfunction and its corrective treatment(s). A visit from or to a physiotherapist would aid understanding and help create a vocational context.

Learners will provide a detailed evaluation demonstrating in-depth, scientific knowledge of the anatomy and physiology of the effects of the condition, including major bones, muscle (groups), joints and movement at the joints. Learners will then establish how the disorder impacts the normal functioning/movement in the human body.

Learners will evaluate how the work of the medical professional uses corrective mechanisms and treatments in order to improve the functioning of the skeleton and its physical, physiological and social impact on human health. Learners will also explain the limitation of the corrective treatment(s) used.

For Merit standard, learners must provide a detailed comparison of **three disorders** affecting different aspects of the musculoskeletal system and how normal movement is affected. Learners must use the correct scientific and technical terms to clearly outline the type of joint, muscle movement at the joint, muscle attachment and the groups of muscles that are involved in bringing about normal movement. They must also explain the importance of the movement to the normal functioning of the human body and how each disorder differs in terms of its effect on normal function.

When comparing corrective treatments for each disorder, learners must consider scientific rationale for using that particular treatment over others.

Access to dissection of a small mammal, chicken bones/joints, or models of skeletons and joints and use of simulations would develop and aid learners' understanding. (Dissection is not compulsory.) The use of referenced diagrams or photographs to help learners to produce an analytical report on muscles, joints and associated movement should be encouraged. Correct use of scientific terms must be included in the report.

For pass standard, learners will explain how the structure of the human skeleton, muscles and joints form an essential system in the functioning of the human body by providing support, protection, movement and storage/production of minerals and blood cells.

Learners will identify and name **six major joints** in the human musculoskeletal system and fully explain the importance of their structure and role in the human body in terms of normal movement.

Learners will name **one disorder** of musculoskeletal system and outline how it impacts normal function of the human body. Learners will reference specific muscles or muscle groups and joints affected by the disorder and give an overview of the corrective treatment(s) associated with it.

Learning aim C

For Distinction standard, learners must base their evaluation on **one named disorder**. They will analyse the effect of the disease on the lymphatic system, the normal functioning of which will be explicitly explained. The implications of the disease on the health status of an individual suffering from the disorder will be addressed within the context of a patient case study.

Learners will evaluate the physiological basis of any treatment and discuss the impact of this on the restoration of normal lymphatic function. This will include benefits and problems faced by medical professionals when using corrective treatments. They will use correct scientific terminology throughout.

For Merit standard, learners will demonstrate detailed understanding of the anatomy and function of the lymphatic system, using correct scientific terminology to explain the rationale for use of corrective treatment for the effects of **a named disorder** of the lymphatic system. Learners will give detailed explanations of the disorder affecting the normal functioning of the lymphatic system and the associated corrective treatment.

For Pass standard, learners must describe the gross anatomy of the organs and associated structures that form the lymphatic system. Learners must label (for themselves) each structure of the lymphatic system and describe, in brief, the role it plays in the system.

Learners will describe how lymph is formed and its role in the health of the body.

Learners will also briefly describe **a named disorder** and its effect on the normal function of the lymphatic system, including the symptoms present in the human body and give an overview of the corrective treatment(s) associated with the disorder.

Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner's work. This may mean that learners be supervised.

Resources: all learners should have access to the same types of resources to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

Links to other units

This unit links to:

- Unit 5: Principles and Applications of Biology ll
- Unit 9: Biomedical Science
- Unit 11: Functional Physiology of Human Body Systems
- Unit 14: Genetics and Genetic Engineering
- Unit 15: Diseases and Infections.

Employer involvement

This unit would benefit from employer involvement in the form of:

University sports science departments may be able to provide support and guidance and access to models of joints and a skeleton. Physiotherapy departments may be able to offer information and access to examples of replacement joints and exercises that will assist in treatment and recovery from musculoskeletal dysfunction.

GP Surgeries may have specialist nurses who might be available to visit and provide information about management of lymphatic disorders such as lymphomas.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- analytical and observation skills
- use of microscopy
- production of biological drawings
- formal written communication
- self-management and planning skills
- ability to work in a scientific environment
- ability to carry out independent research.

Unit 2: Principles and Applications of Chemistry I

Level: 3
Unit type: Internal set assignment
Guided learning hours: 60

Unit in brief

This unit covers some of the key chemistry concepts in atomic structure, bonding, the Periodic Table and reacting quantities. Further key science concepts are considered in *Unit 6: Principles and Applications of Chemistry II.*

Unit introduction

Scientists and technicians working in the chemical industry need to have an understanding of atoms, electronic structure and bonding. In this unit, you will explore how the Periodic Table contains important information about elements in terms of the relative mass of their atoms, percentage of isotopes, and the particles in their atoms and their arrangement. In particular, knowledge of the attractive forces between protons and electrons are critical to understanding properties such as the size of atoms and ions. The arrangement of electrons is also important in understanding the chemical reactivity of an atom and you will examine the evidence for electronic configuration in the form of ionisation energies.

Bonding between atoms plays a very important role in determining the structure and therefore the physical properties of a substance. You will explore the different types of bonding and structure that exist, including how and why they arise. You will examine how changes in bonding and structure of elements and compounds within the Periodic Table are directly responsible for this.

You will investigate the chemistry of key groups of elements in the Periodic Table. You will compare and contrast your findings against selected elements outside of the groups to understand key differences. Reduction and oxidation are two important types of chemical reaction which you will learn to use to explain the chemistry of the elements that you have investigated and explain ways to extract them from their compounds for use in everyday applications.

Finally, you will understand the use of quantities to plan how much of a substance to use in a reaction and how much of a desired product you will make. The accurate and safe use of equipment and techniques will be covered so that you can carry out reactions, and you will be taught how to evaluate outcomes and consider how to improve the methodology.

The fundamental knowledge, practical skills, transferable skills – for example, organisation, self-assessment and problem-solving, and the ability to interpret data – developed in this unit will give you confidence when you undertake the more complex practical techniques involved in higher education science courses such as biochemistry, chemistry, forensic science and environmental science.

Assessment

This unit has a set assignment. Learners must complete a Pearson Set Assignment Brief.

Learning aims

In this unit you will:

A Understand how atomic and electronic structure influence the arrangement of elements in the Periodic Table

B Understand how bonding and structure influence physical properties of substances

C Investigate how the properties of elements change in the Periodic Table and methods of extraction from compounds

D Be able to determine reacting quantities in chemical reactions.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand how atomic and electronic structure influence the arrangement of elements in the Periodic Table	**A1** The Periodic Table and atomic structure **A2** Electronic structure	This unit is assessed through a Pearson Set Assignment.
B Understand how bonding and structure influence physical properties of substances	**B1** Bonding and structure **B2** Molecular shape, polarity and intermolecular forces	
C Investigate how the properties of elements change in the Periodic Table and methods of extraction from compounds	**C1** The s block elements **C2** The halogens **C3** Transition metals **C4** Noble gases **C5** Reduction and oxidation **C6** Extraction of elements	
D Be able to determine reacting quantities in chemical reactions	**D1** Reacting quantities **D2** Gravimetric and volumetric techniques	

Content

Learning aim A: Understand how atomic and electronic structure influence the arrangement of elements in the Periodic Table

A1 The Periodic Table and atomic structure

- Features and arrangement of the Periodic Table:
  - elements and symbols
  - atomic number, mass number, relative atomic mass.
  - groups and periods
  - s, p and d blocks
  - metal and non-metals.
- Atomic structure:
  - subatomic particles – protons, electrons, neutrons
  - charges, relative masses and locations of subatomic particles
  - atomic and ionic radius
  - factors influencing atomic radius and ionic radius – nuclear charge, number of shells, shielding, ion charge.
- Isotopes:
  - definition
  - determination of relative atomic mass and isotope composition
  - interpretation of mass spectra to determine relative atomic mass and isotope composition.

A2 Electronic structure

- Components of electronic structure:
  - energy levels/shells
  - subshells
  - electronic orbitals.
- Rules that determine electronic structure and exceptions:
  - Aufbau principle
  - Hund's Rule of Maximum Multiplicity
  - Pauli's Exclusion principle
  - exceptions to the rules.
- Representations of electronic structure:
  - s, p and d notation
  - electron in boxes.
- Ionisation energy:
  - definition for first and successive ionisation energies
  - evidence for electronic structure for an atom
  - factors affecting ionisation energy trends down a group and across a period – nuclear charge, number of shells, shielding, subshells, electron spin pair repulsion.

Learning aim B: Understand how bonding and structure influence physical properties of substances

B1 Bonding and structure

- Metallic bonding and giant metallic structures (e.g. iron, steel, aluminium) – lattice of cations, delocalised electrons, electrostatic attraction.
- Ionic bonding and giant ionic structures (e.g. NaCl, MgF_2, Al_2O_3) – electron transfer, formation of cations and anions, electrostatic attraction, lattice of ions.
- Covalent bonding and molecules:
  - electrostatic attraction for electrons between two nuclei
  - single, double and triple bonds, dative covalent (coordinate) bonds
  - giant covalent structures e.g. diamond, graphite, graphene, silicon dioxide
  - simple molecular structures e.g. H_2O, I_2, CO_2.
- Physical properties – melting point, boiling point, electrical and thermal conductivity, malleability and brittleness, solubility in water.
- Diagrams for different types of bonding and structure:
  - dot and cross diagrams for ionic and covalent bonding
  - electronic configurations of ions
  - 3 dimensional representations of molecules
  - lattice arrangements of atoms, ions and molecules.

B2 Molecular shape, polarity and intermolecular forces

- Electron pair repulsion theory – principles and rules, use to determine molecular shape.
- Electronegativity – definition, use to determine extent of bonding characteristics.
- Bond polarity and effect of shape on polarity of molecules.
- Intermolecular forces:
  - London dispersion forces/temporary dipole – induced dipole forces
  - permanent dipole – permanent dipole forces
  - hydrogen bonding – presence and nature of N-H, O-H and F-H bonds
  - effect of intermolecular forces on physical properties (i.e. melting and boiling points)
  - effects of hydrogen bonding (e.g. density of ice compared to water, higher than expected melting and boiling points).

Learning aim C: Investigate how the properties of elements change in the Periodic Table and methods of extraction from compounds

C1 The s block elements (the alkali metals and the alkaline earth metals)

- Appearance and physical properties (hardness, density, electrical conductivity, malleability, melting and boiling points).
- Reactivity and products with water.
- Reactivity and products with oxygen (restricted to simple oxides).
- Displacement reactions.
- Flame tests of ions and solubility of s block hydroxides and sulfates.
- Trends in physical and chemical properties down the group.
- Comparison of physical and chemical properties with transition metals (iron, copper).
- Balanced chemical equations for all reactions.

C2 The halogens

- Appearance and physical properties (colour, state of matter, density, solubility in water and organic solvents, melting and boiling point).
- Reactivity with metals.
- Displacement reactions.
- Reactivity of the metal halides with concentrated sulfuric acid.
- Test for halide ions using acidified silver nitrate and ammonia solution.
- Trends in physical and chemical properties down the group.
- Balanced chemical equations for all reactions.

C3 Transition metals

- Physical properties – tensile strength, hardness, density, melting and boiling points, catalysis, coloured compounds, formation of more than ion, formation of complex ions.
- Reactivity with:
  - oxygen
  - water
  - dilute acids.
- Balanced chemical equations for all reactions.

C4 Noble gases

- Physical properties – density, melting and boiling points, solubility.
- Chemical behaviour:
  - inert
  - examples of reactions with oxygen and fluorine with conditions.

C5 Reduction and oxidation

- Reduction:
  - loss of oxygen
  - gain of electrons.
- Oxidation:
  - gain of oxygen
  - loss of electrons.
- Oxidation number concept – rules of assignment of oxidation numbers.
- Redox equations:
  - half equations for oxidation and reduction
  - full equations showing oxidation and reduction.
- Reducing and oxidising agents.

C6 Extraction of elements

- Reduction and oxidation methods:
  - iron, zinc or lead from their oxides using a Blast furnace
  - titanium from titanium (IV) oxide using the Kroll or Armstrong process
  - copper from copper sulfide by roasting in air
  - magnesium from thermal reduction of its carbonate
  - bromine and iodine displaced from solutions of halides by chlorine.

- Electrolysis methods:
  - aluminium and oxygen from alumina using the Hall–Héroult process
  - sodium and chlorine/hydrogen, chlorine and sodium hydroxide from brine
  - magnesium and chlorine from magnesium chloride
  - zinc and oxygen from zinc sulfate (derived from a sulfide ore)
  - titanium from titanium (IV) oxide in the FCC Cambridge process.
- Production methods:
  - operating conditions
  - energy requirements
  - continuous and batch processes
  - atom economy and by-products
  - safety and environmental considerations.
- Comparison of methods in relation to properties of substances.
- Uses of the extracted elements according to their properties.

Learning aim D: Be able to determine reacting quantities in chemical reactions

D1 Reacting quantities

- The mole:
  - definition
  - Avogadro's constant.
- Relationship between mole, mass and molar mass.
- Relationship between mole, gas molar volume and volume of a gas.
- Relationship between mole, concentration and volume of a solution.
- Conservation of mass during a reaction.
- Associated calculations involving moles, mass and concentration.
- Use of chemical equations and stoichiometry in determining maximum amounts of a reactant needed or a product formed.

D2 Gravimetric and volumetric techniques

- Gravimetric techniques:
  - use of weighing scales and calibration
  - accurate transfer of a solid and heating to constant mass – oxidation of a metal, reduction of a metal oxide, decomposition of a hydrogencarbonate or hydrated compound
  - accurate transfer and mixing of solutions, precipitation, filtering, washing and drying the solid – formation of group 2 sulfates and hydroxides, silver chloride.
- Volumetric techniques:
  - preparation of a standard solution
  - accurate transfer of solution
  - use of a volumetric flask
  - use of a burette and pipette (and calibration)
  - titrations (restricted to acid-base neutralisation)
  - selection and use of indicators.

- Error analysis and improvements:
  - absolute, random and systematic error
  - uncertainty in measurements
  - percentage error
  - improvement in repeatability, reproducibility, precision and accuracy of measurements.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand how atomic and electronic structure influence the arrangement of elements in the Periodic Table		
A.P1 Describe how the Periodic Table and its features relate to atomic structure. **A.P2** Determine relative atomic mass and isotope composition of elements. **A.P3** Explain the rules used to determine the electronic structure of atoms and ions.	**A.M1** Explain trends in atomic and ionic radius down a group and across a period.	**A.D1** Analyse how ionisation energy changes down a group, across a period and successively for each electron in the atom of an element.
Learning aim B: Understand how bonding and structure influence physical properties of substances		
B.P4 Describe different types of bonding, intermolecular force and structure. **B.P5** Explain how bonding and structure influence physical properties.	**B.M2** Assess the use of electronegativity in determining bonding characteristics of a compound. **B.M3** Predict the shape and polarity of molecules using electron pair repulsion theory and electronegativity.	**B.D2** Analyse how melting/ boiling point changes for elements and their compounds across a period and down a group.
Learning aim C: Investigate how the properties of elements change in the Periodic Table and methods of extraction from compounds		
C.P6 Investigate the physical and chemical properties of s block elements and of the halogens. **C.P7** Explain the chemistry of s block elements and halogens in terms of oxidation number and electron transfer.	**C.M4** Compare the properties of s block elements with transition metals and halogens with noble gases. **C.M5** Explain the use of reduction and oxidation to extract elements from compounds.	**C.D3** Assess different industrial methods of extraction of elements from their compounds and their uses.

Pass	Merit	Distinction
Learning aim D: Be able to determine reacting quantities in chemical reactions		
D.P8 Calculate moles from mass, concentration and volumes, and vice-versa. **D.P9** Correctly prepare and dilute a standard solution for quantitative analysis.	**D.M6** Carry out a gravimetric technique to determine the mass of an analyte. **D.M7** Carry out volumetric techniques to determine the concentration of a solution.	**D.D4** Evaluate the accuracy of the procedures used in gravimetric and volumetric analysis and suggest improvements.

Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief.

A set assignment must be used to assess learners.

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory with a fume cupboard
- a range of elements and inorganic chemicals
- water and gas utilities, sinks and power sources
- weighing scales
- glassware for volumetric and gravimetric analysis
- health and safety policies and risk assessments.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will research or be provided with data on ionisation energy for elements. They will need to produce their own graphs of ionisation energy trends for elements down a group and across a period, and successive ionisation energies for a specific element, which they will analyse. They will analyse trends down groups based upon nuclear charge, number of electronic shells and the effect of shielding. They will also analyse trends across periods with consideration of the same factors but also the effect of subshells and electron spin pair repulsion. They will analyse how a logarithmic plot of successive energy for a specified element offers evidence of the electronic structure of its atom and therefore its position in the Periodic Table.

For Merit standard, learners will research or be provided with data on atomic and ionic radii of elements. They will explain trends down groups based upon nuclear charge, number of electronic shells and the effect of shielding. They will also explain trends across periods for atomic radii with consideration of the same factors. For ionic radii across periods, they will also need to explain the charge of the most common ion and the increased attraction or repulsion arising from the difference in protons to electrons.

For Pass standard, learners will identify key features within the Periodic Table, describing what these represent and how this provides information on the atomic structure of an element in terms of its number of subatomic particles and arrangement. Learners will also describe the significance of the relative atomic mass of an element and will be provided with problems to calculate relative atomic mass from percentage abundance of isotopes (and vice-versa). Learners will explain the main rules that are used by chemists to work out the electronic structure of elemental atoms, as well as reasons why expected patterns are not followed. They will further demonstrate their understanding by working out electronic configurations for a range of atoms, cations and anions.

Learning aim B

For Distinction standard, learners will research or be provided with melting or boiling point data for elements and their compounds (e.g. oxides, hydrides, chlorides). They will need to produce their own graphs of melting or boiling point trends for substances across a period or down a group, which they will analyse. They will explain the increases or decreases in these properties in terms of the bonding, intermolecular forces and structure present, with consideration of the energy requirement to melt or boil each substance.

For Merit standard, learners will research or be provided with electronegativity values for the elements. They will consider differences in electronegativity between elements in order to deduce the type of bonding (or percentage of bonding) present in a range of compounds. They will consider physical properties of the compounds to assess whether the use of electronegativity was an accurate means to predict the character of the bonding. Learners will also predict the shape of a range of simple molecules using electron pair repulsion rules. They will also use the shape and electronegativity difference between atoms to predict the polarity of the molecules.

For Pass standard, learners will describe in detail the different types of bonding (metallic, ionic and covalent, including dative covalent and multiple bonds), intermolecular forces (London dispersion forces, permanent dipole-permanent dipole and hydrogen bonding) and structure (giant metallic, ionic or covalent structures and simple molecular structures). In order to provide a comprehensive description, learners will need to draw their own diagrams to show models of bonding (e.g. dot-and-cross diagrams, ball-and-stick diagrams), intermolecular forces and structure (e.g. 2D and 3D lattices). Learners will then use these to explain physical properties of common substances (i.e. melting and boiling points, electrical and thermal conductivity, malleability and brittleness, solubility in water).

Learning aim C

For Distinction standard, learners must research or propose two different methods of extraction for a metal and a halogen. They will assess the two different methods of extraction for each element in terms of the key reactions, raw materials, conditions, energy requirements, type of process, atom economy, by-products, safety and environmental issues. They will also assess the uses of the metal and halogen extracted, justifying this in terms of their physical and chemical properties that are being utilised.

For Merit standard, learners will research the physical and chemical properties of selected transition metals and noble gases. They will compare and contrast the research for the transition metals against their research for s block elements, and the research of the noble gases against that for the halogens. The evidence must include discussion of why the properties are different and therefore justifies why the transition metals and noble gases are in separate groups of the Periodic Table. They must also identify and explain similarities which would account for why they are adjacent to the s block and halogen groups respectively.

Learners must research and explain one method of extraction of a metal and one method of extraction of a halogen. They will give full details of the source and extraction of the compound, the process of extraction of the element, any operating conditions and reagents used, and explain the chemistry involved in terms of reduction and oxidation. Equations will be given, and reduction and oxidation justified in terms of the oxidation number concept.

For Pass standard, learners will carry out an investigation into a range of physical and chemical properties of s block and Group 7 elements. This must be a combination of practical and research-based investigation in order to provide a complete overview of the properties of two groups.

Practical based activities for selected elements may include: observation of physical properties, reaction or solubility with water/organic solvents, reaction with oxygen, reaction with metals, acids or alkalis, displacement reactions, and solubility and chemical tests for their ions. Learners must provide evidence of two practical-based investigations and two research-based investigations for s block and for Group 7 which will illustrate a change in properties. They will supplement practical work with predictions for other elements in these groups which were not included in the practical work.

Learners must explain chemical properties of s block and Group 7 elements in terms of the ability of their atoms (and their ions) to lose or gain electrons. They will consider this with diagrams of half equations for the element. Explanations of chemical reactions will be supplemented with reduction-oxidation equations in which learners will identify the oxidation number of the elements in the reactants and products. They will use this information to identify which elements are being reduced or oxidised and indicate the number of electrons that are being transferred.

Learning aim D

For Distinction standard, learners will compare the accuracy of their outcomes from the quantitative analysis with the expected quantities or values for analytes and solutions held by the assessor or with the average quantities obtained by peers. This will allow learners to begin to make sound judgements for the evaluation of accuracy and precision of the gravimetric and volumetric techniques they have used. They will coherently discuss problems or issues with the quantitative procedures and link this correctly to the outcomes of mass and volume measured. They will include calculation of percentage errors in equipment, consideration of the calibration of instruments and identify the significance that these have upon the outcomes. Learners must make suggestions to improve the accuracy and precision of the techniques used (or suggestion of the use different techniques and equipment) in order to obtain reliable and valid outcomes. Where no problems or issues have been encountered, there must be justification of significant steps that were taken that maximised accuracy, precision and safety. Learners must provide a strong rationale for the significance of errors and how the suggested improvements will provide more accurate and reliable outcomes.

For Merit standard, learners will undertake one gravimetric and one volumetric technique with minimal supervision. They will be observed and assessed performing procedures to a high degree of accuracy and precision in order to obtain reliable and valid outcomes, with consideration for health and safety. Learners will demonstrate skill in a number of areas of gravimetric analysis such as calibrating weighing scales, weighing and transferring solids, heating to constant mass or preparing, separating and drying a precipitate. Learners will demonstrate skill in a number of areas of volumetric analysis such as calibrating a pipette and burette, measuring volumes, mixing solutions, and carrying out a titration with an indicator. They will be fully prepared in terms of equipment, reference material and consumables before attempting each step. Evidence of planning of the quantities required, risk assessment, tabulated and accurate measurements of mass and volume will be required. Learners will use the results to perform mole calculations, such as the determination of a percentage mass, formula or stoichiometric equation from their gravimetric analysis, and the calculation of a molar concentration from their volumetric analysis.

For Pass standard, learners must carry out a range of calculations involving the mole, determining it from mass, concentration and gas volume, and conversely using the mole to determine these quantities for a substance. They must also include demonstrate of the use of stoichiometric ratios from equations which are not 1:1 in order to determine the maximum amount of product from a reactant or vice versa.

Learners will prepare and dilute a standard solution for use in volumetric analysis. They will be observed and assessed making a solution by weighing a solid, making the solution to volume using a volumetric flask and shaking to ensure that it is mixed thoroughly. They will then make a dilute solution using a pipette to transfer an accurate volume from this solution, and again making a new solution to volume and shaking to mix. This solution will be used for quantitative analysis, such as a primary standard acid or base in a titration to standardise sodium hydroxide or hydrochloric acid for a volumetric analysis, or for a precipitation reaction in gravimetric analysis. Evidence of planning of the quantities required, risk assessment, tabulated and accurate measurements of mass, and the calculation of molar concentrations the solutions produced will be required.

Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner's work. This may mean that learners be supervised.

Resources: all learners should have access to the same types of resources to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

Links to other units

This unit links to:

- Unit 6: Principles and Applications of Chemistry II
- Unit 16: Applications of Inorganic Chemistry
- Unit 20: Applications of Physical Chemistry
- Unit 21: Applications of Organic Chemistry.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. It would be beneficial for an industry representative to explain the importance of the routine calibration of equipment in ensuring the reliability of results. A visit to a local laboratory would reinforce the importance of calibration of equipment and health and safety. Even if the local organisations that use science only operate on a small scale, their representatives will be able to reinforce the importance of the transferable skills this unit develops.

This unit would benefit from employer involvement in the form of:

- a visit to any commercial laboratory
- a speaker from a commercial laboratory.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- independent investigation and research skills
- practical and technical skills, using appropriate equipment, procedures and techniques
- scientific written and communication skills
- data interpretation, manipulation and presentation
- analytical and problem-solving skills
- self-management and planning skills
- evaluative and assessment skills.

Unit 3: Principles and Applications of Physics I

Level: 3
Unit type: Internal set assignment
Guided learning hours: 60

Unit in brief

This unit covers some of the main science concepts in physics with a focus on two key areas; electromagnetic waves used in communication and the fundamental aspects of forces and motion in transportation.

Unit introduction

Scientists and technicians working in science and science-related organisations must have a good understanding of core science concepts. A strong grasp of these concepts will enable you to use and apply this knowledge and understanding in vocational contexts when studying other units within this specification.

The topics covered in this unit are those from two key areas of physics; waves and motion. For waves, the principle focus is their application in communications – general wave principles, calculation of wave speed through different mediums, fibre optics in medicine for example and waves used in communication determined by the frequency, such as mobile phones and television. For motion, the fundamental aspects of speed, velocity and acceleration will be outlined using practical application linked to transportation. Transport design, forces involved and the main physical terms used, their units and definitions, will form the basis of mathematical work. Practical and research investigation will help to reinforce an understanding of the link between forces, energy and motion.

To complete the assessment task within this unit, you will need to draw on your learning from both subject areas. The knowledge and understanding you will learn in this unit will provide a strong basis for you to progress in the science sector and to a variety of science and related programmes such as higher nationals and degrees.

Assessment

This unit has a set assignment. Learners must complete a Pearson Set Assignment Brief, which will include a range of tasks inviting clear, open responses. These set tasks will assess discrete knowledge and understanding of the content in this unit with assessment availability determined by the centre.

Sample assessment materials will be available to help centres prepare learners for assessment.

Learning aims

In this unit you will:

A Understand the main features and practical uses of waves used in communication

B Explore the fundamental principles and applications of forces in transportation.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the main features and practical uses of waves used in communication	**A1** Working with waves **A2** Waves in communication **A3** Use of electromagnetic waves in communication	This unit is assessed through a Pearson Set Assignment.
B Explore the fundamental principles and applications of forces in transportation	**B1** Measurement and representation of motion **B2** Laws of motion **B3** Driving safely	

Content

Learning aim A: Understand the main features and practical uses of waves used in communication

A1 Working with waves

- Understand the features common to all waves and use the following terms as applied to waves:
  - periodic time
  - speed
  - wavelength
  - frequency
  - amplitude
  - oscillation
- Graphical representation of wave features
- Understand the difference between the two main types of wave:
  - transverse
  - longitudinal.
- Understand concepts of displacement, coherence, path difference, phase difference, superposition as applied to diffraction gratings.
- Understand the industrial application of diffraction gratings, to include:
  - emission spectra
  - identifying gases.
- Be able to use the wave equation:

  $v = f\lambda$
- Understand the concept and applications of stationary waves resonance.
- Musical instruments and speed of a wave on a string.
- Be able to use the equation:

  calculation of speed $v = \sqrt{\frac{T}{\mu}}$

A2 Waves in communication

- Understand the principles of fibre optics:
  - refractive index $n = \frac{c}{v} = \frac{\sin i}{\sin r}$
  - total internal reflection
  - calculation of critical angles at a glass–air interface

    $\sin c = \frac{1}{n}$
- Understand the applications of fibre optics in medicine to include endoscopes.
- Understand the applications of fibre optics in communication, to include:
  - analogue and digital signals: analogue-to-digital conversion, and broadband.

A3 Use of electromagnetic waves in communication

- Understand that all electromagnetic waves travel with the same speed in a vacuum.
- Be able to use the inverse square law in relation to the intensity of a wave: $I = \frac{k}{r^2}$
- Understand how the regions of the electromagnetic spectrum are grouped according to the frequency.
- Understand how the applications of electromagnetic waves in communications are related to frequency, including:
  - satellite communication
  - mobile phones
  - Bluetooth®
  - infrared
  - Wi-Fi.

Learning aim B: Explore the fundamental principles and applications of forces in transportation

B1 Measurement and representation of motion

- Standard SI units and other units of speed (ms^{-1}, km^{-1}, mph).
- Calculation of speed $v = \frac{d}{t}$
- Calculation of average or mean speed.
- Be able to explain Distance/time graphs and velocity/time graphs.
- Velocity as a vector quantity.
- Acceleration as the change of velocity with time and distance as the area under the graph.
- Principle of accelerometers.
- Equations of motion $v = u + at$, $s = ut + \frac{1}{2}at^2$, $s = (v + u)\frac{t}{2}$, $v^2 = u^2 + 2as$.

B2 Laws of motion

- Using light gates to simulate the principles of the 'Gatso' speed camera.
- Newton's First Law of Motion.
- Inertia, mass and weight definitions.
- Measuring frictional forces $F = \mu N$ where N is the normal reaction force.
- Air resistance, drag and terminal velocity:
  - understand gravitational field strength and weight
  - Newton's Second Law of Motion $F = ma$ and implications for transportation travelling at high speed with low mass or low speed with high mass
  - inertia as resistance to change in motion
  - factors needed to achieve flight – generating lift, considering air as a 'fluid', lift acting perpendicular to the motion of aircraft, geometry of the wings, velocity of the air and angle of aircraft to air flow, mass of air, principles of lift, drag, thrust and weight
  - Newton's third law of motion

  - factors needed to achieve orbit – thrust from burning propellants, sufficient speed, standard earth orbit (17,000 mph/27,360 kph) and geostationary orbit
  - principles of ship design – Archimedes Principle, reducing the density of materials e.g. iron to less than water by changing the shape, increasing volume, thrust provided by propellers.

B3 Driving safely

- Impact force controls – air bags, seat belts, helmets for motor bike users, passenger 'cells', crumple zones.
- Physical factors – stopping distance (addition of thinking distance and breaking distance), factors affecting stopping distance; increased vehicle mass, road surface conditions, poor tyre/brake quality, high speed, plotting graphs of thinking distance against speed from data.
- Global Positioning Satellite (GPS) – general principles i.e. satellite system allowing accurate determining of vehicle location, triangulation of 3 satellite signals for surface location (distance calc. from signal time lag and speed of light 3.0×10^8 ms^{-1}) vehicle tracking for crime related issues, vehicle route mapping.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the main features and practical uses of waves used in communication		**A.D1** Evaluate the uses of waves in communication.
A.P1 Describe the main features and characteristics of waves used in communication. **A.P2** Practically demonstrate the principles of fibre optics. **A.P3** Identify the main practical uses of all sections of the electromagnetic spectrum.	**A.M1** Explain, using diagrams and calculation, the main features of waves used in communication. **A.M2** Explain the principles of fibre optics using practical investigation.	
Learning aim B: Explore the fundamental principles and applications of forces in transportation		**B.D2** Analyse factors involved in motion.
B.P4 Describe the main measurements and calculations used in representing motion. **B.P5** Describe the main factors to be considered in motion. **B.P6** Outline methods used to reduce vehicle collision damage.	**B.M3** Demonstrate accurate application of calculations in motion. **B.M4** Explain the principles of methods used to reduce vehicle collision damage.	

Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learner.

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- scientific magazines, newspapers and relevant textbooks
- the internet, relevant DVDs, simulation models (if available)
- optical equipment, glass blocks, prisms, fibre optics cable, light boxes
- video and text aids to support motion principles (e.g. video time lag)
- visit to motor manufacturer
- practical materials for car safety design experiments (boxes, paper, aluminium etc.)
- variety of surfaces for modelling stopping distance.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will show a greater level of understanding of the use and features of electromagnetic waves used in communication. There will be a significant level of clarity in explaining the concepts of diffraction gratings, for example, and the applications of stationery waves and musical instruments. Total internal reflection will be well explained and investigated practically and their applications clearly explained. The features and uses of the electromagnetic wave types will be evaluated in depth.

For Merit standard, learners will demonstrate correct and appropriate usage of the terms used when referring to the electromagnetic spectrum and waves show a good level of understanding of the principles of a diffraction grating such as displacement, coherence, path difference, phase difference and superposition, although the explanations may not be detailed. Learners will outline clearly the use of diffraction gratings in industry, referring accurately to emission spectra and identification of gases. The equation for calculation of speed of wave on a string as in musical instruments must show clarity in workings. Practical work on refractive index must be accurate and the applications of total internal reflection clearly understood. Learners must be able to provide an example of calculating the intensity of a wave and produce well worded explanations of waves and their applications based on frequency.

For Pass standard, learners will produce a diagram list of the electromagnetic spectrum and label the relevant sections according to the range of identified wavelengths and frequencies. The applications of the regions of the electromagnetic spectrum should be clearly identified. A diagram of a single wave with frequency and amplitude aspects annotated should also be included. Learners should demonstrate an understanding of the difference between longitudinal and transverse waves. A basic understanding of the principle of diffraction gratings is acceptable and examples of calculations using the wave equation need not be used in context. A definition of resonance in context will be sufficient together with examples for musical instruments.

Learners will be able to obtain measurements of refractive index for different suitable materials and demonstrate how total internal reflection occurs and linking this to fibre optic cables and their applications. Learners should also show that they understand that all electromagnetic waves travel at the same speed in a vacuum.

Learning aim B

For Distinction standard, learners will show a greater level of understanding in the use of equations of motion, calculation in context and structural aspects of vehicles including road vehicles, aircraft, spacecraft and ships. Motion will be well explained with the aid of accurate distance/time and velocity/time graphs and forces involved in flight and collisions will be analysed in detail using practical experimentation and calculation. Principles of GPS will be clearly and accurately explained.

For Merit standard, learners will demonstrate correct and appropriate usage of the terms used throughout and clearly explain Newton’s Laws of motion in correct context accurately. Learners will be expected to show measurements of frictional force and explain clearly, air resistance, drag and terminal velocity. There will be evidence of good understanding in application of Newton’s Laws of motion and factors needed to achieve both flight and orbit will be clearly explained. The explanation of ship designs will focus on Archimedes principle and general physical aspects of materials and volume. Collision damage will focus on road vehicles and will include clear understanding of the key factors employed in vehicle design. Learners will be expected to produce a valid experiment into stopping distance with clear explanations. The principles of GPS will be explained accurately.

For Pass standard, learners will be expected to demonstrate a general understanding of calculations used when conveying the essential mathematics of motion. Graphs will show the main aspects clearly with labels where appropriate and correct units will be included for all relevant calculations. Examples of distance/time and velocity/time graphs will be included, and calculations of speed and acceleration calculated correctly. Learners will demonstrate a general understanding of accelerometers and the equations of motion. General understanding of methods used to reduce vehicle collision damage will be outlined and the principles of GPS will be clear but not based on a mathematical understanding.

Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner's work. This may mean that learners be supervised.

Resources: all learners should have access to the same types of resources to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

Links to other units

This unit links to:

- Unit 18: Astronomy and Space Science
- Unit 23: Materials Science.

Employer involvement

This unit would benefit from employer involvement in the form of a visit to a music centre or technical college which specialises in the physics of sound and quality. Learners could be shown how musical instruments are manufactured and tested. A visit to a motor car manufacturer could illustrate the development of crumple zones.

Opportunities to develop transferable employability skills

Study in this unit can provide learners with valuable mathematical skills linked to the physical factors associated with safer driving and musical instrumentation. Learners will be able to develop clear explanation of science principles in practical settings.

Unit 4: Investigative Project Skills

Level: 3
Unit type: Internal
Guided learning hours: 120

Unit in brief

This unit enables learners to gain an understanding and the skills required to undertake an investigative project.

Unit introduction

In this unit, you will carry out an investigative project that you have chosen in collaboration with your teacher.

You will choose one topic area that interests you and this will form the basis of your investigative project. You will carry out a scientific literature search and review, considering the project's aims and objectives, then produce a realistic plan and carry out the project safely using your scientific investigation skills, project management skills and what you have learnt from the other units. Finally, you will prepare an evaluative report that will consider the project outcomes and suggest amendments that may have improved those outcomes. To complete the assessment task within this unit, you will need to draw on your learning from across your programme.

Completing an investigative project is an excellent way for you to develop an understanding of the science-related workplace. The skills developed in this unit will be of considerable benefit for progression to higher education in a variety of science and science-related courses and to employment in the science or applied science sector.

Learning aims

In this unit you will:

A Undertake a literature search and review to produce an investigative project proposal

B Produce a working plan for an investigative project based on the proposal

C Safely undertake the project, collecting, analysing and presenting the results

D Communicate and evaluate the findings of the project.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Undertake a literature search and review to produce an investigative project proposal	**A1** Literature review **A2** Investigative project proposal	Produce a project proposal (including objective, hypothesis, variables, resources, safety and limitations), supported by a literature search.
B Produce a working plan for an investigative project based on the proposal	**B1** Schedule **B2** Plan **B3** Health and safety and ethical considerations	Produce a working plan, (including schedule, method, risk assessment and contingency planning), supported by a logbook of trial runs.
C Safely undertake the project, collecting, analysing and presenting the results	**C1** Experimental procedures and techniques **C2** Collect and collate data **C3** Data presentation and interpretation **C4** Analyse data	Observation records. Witness testimonies and/or annotated photographs of equipment/techniques in use by learner. Laboratory logbook authenticated by assessor/project supervisor. Report including data, processing and presentation, statistical analysis, conclusion and evaluation. Presentation by learner and notes on the investigative project outcomes to the class/supervisor. Observation records, witness testimonies or self-assessment record.
D Communicate and evaluate the findings of the project	**D1** Scientific report for the investigative project **D2** Scientific evaluation of findings	

Content

Learning aim A: Undertake a literature search and review to produce an investigative project proposal

Learners must select a relevant area of study linked to chemistry, physics or biology, or a combination of different fields.

A1 Literature review

- Identification of criteria, e.g. how many sources, what is the oldest date that will be looked at, which types of source will be excluded.
- Nature of study, which could include field work, laboratory-based work, sports facility, and workshop.
- Sources of information:
  - identification and location of relevant and reliable sources of information, e.g. journal articles, textbooks, websites
  - extraction – how to obtain the information from libraries, resource centres, organisations, government organisations, charities
  - recognising and using protocol for referencing of information sources, to include use of the Harvard referencing system.

A2 Investigative project proposal

- Rationale for area of study – suitable for interest/based on literature review.
- Background.
- Hypothesis – formulate a hypothesis or a null hypothesis based on relevant scientific ideas.
- Aims and objectives.
- Variables – independent, dependent and control.
- Select and justification of the use of equipment/techniques/standard procedures for quantitative and/or qualitative investigations.
- Suitable tables to record data and type of presentation (charts, graphs).
- Suitable statistical techniques to analyse data.
- Identification of potential limitations of the project, e.g. implications for resources, time constraints, use of facilities.
- Risks and hazards associated with the investigation.

Learning aim B: Produce a working plan for an investigative project based on the proposal

B1 Schedule

- Timeline for the project to include:
  - start date
  - completion date
  - milestones.

B2 Plan

- Relevant methods for processes/procedures which:
  - produce a clear, logically ordered method to designed obtain results
  - select relevant measurements and the range of measurements to be recorded
  - allow data to be collected accurately/reliably and to appropriate levels of precision
  - show how variables can be controlled/measured/monitored
  - show how the data/information will be recorded and presented
  - indicate how the data/information will be analysed using a statistical technique.
- Use of resources, e.g. participants, equipment and instrumentation, materials.
- Contingency planning and remedial actions, e.g. extra resources, schedule revision.

B3 Health and safety and ethical considerations

- Identification of hazards, the use personal protective equipment (PPE), how substances hazardous to health will be controlled, local and national health and safety legislation.
- Risk assessment, including type of hazard, level of risk, prevention and minimising of hazards.
- Ethical considerations, e.g. obtaining consent, maintaining confidentiality.

Learning aim C: Undertake the project, collecting, analysing and presenting the results

C1 Experimental procedures and techniques

- Assembly of relevant equipment and materials.
- Adhering to health and safety risk analysis, using PPE and controlling substances hazardous to health.
- Skills of transferring, handling and using equipment and materials.
- Use of equipment, instruments, sensors and techniques for taking measurements.
- Observation skills.
- Adhering to relevant health and safety legislation, operating standards and good practice (local, national and international).

C2 Collect and collate data

- Recording results with accuracy, integrity, precision.
- Maintenance of working laboratory logbooks and record keeping.
- Qualitative observations and inferences.
- Organisation of practical data in class intervals, tallying – tabulation data in a clear and logical format using correct headings with units where appropriate.
- Identification of anomalous data and take appropriate action.
- Recognition of when it is appropriate to take repeats

C3 Data presentation and interpretation

- Range of appropriate data presentation used (graph/chart/table).
- Correct units of experimental quantities used.
- Choice of data presentation explained.
- Correct presentation of chosen data format (plotting/labelling/scales).
- Identify trends/patterns in data.
- Compare primary and secondary data.
- Draw conclusions that are valid and relevant to the purpose of the investigation.
- Interpretation of statistical tests using tables of critical values and a 5% significance level, with reference to the null hypothesis.

C4 Analyse data

- Methods of data processing:
  - difference between initial and final measurements
  - calculating mean
  - use of formulae
  - transposition of formulae
  - conversion of units
  - use of standard form.
- Methods of statistical analysis:
  - standard deviation
  - use and interpretation of error bars
  - student's t-test
  - chi-square test
  - correlation analysis
  - assessment of experimental accuracy, reliability and precision.
- Validation of method and results:
  - fitness for purpose of methods used
  - repeatability
  - sources and magnitudes of errors in readings taken.

Learning aim D: Communicate and evaluate the findings of the project

D1 Scientific report for the investigative project

- Correct scientific principles:
  - structure and format
  - use of correct scientific terminology
  - past tense, including third person
- References and bibliography:
  - correctly written
  - included in appendix
  - correct use of the Harvard referencing system.

D2 Scientific evaluation of findings

- Evaluation of statistical results.
- Conclusions drawn from primary and secondary data using scientific principles.
- Explanation of anomalous data.
- Determine quantitative error in equipment (percentage error of measuring equipment).
- Discussion of qualitative sources of error.
- Strengths and weaknesses of method/techniques/standard procedures/equipment used.
- Evaluation of reliability of data collected during the investigation.
- Limitations of investigative project.
- Recommendations for improvement to the investigation.
- Assessment of information sources used and relevance to investigation experimental and literature investigations.
- Evaluation of proof, or otherwise, of hypothesis stated.
- Recommendations for further research.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Undertake a literature search and review to produce an investigative project proposal		
A.P1 Carry out a literature search and review into the chosen scientific area of the project. **A.P2** Produce a project proposal for a scientific investigation, to include a hypothesis, resources required and safety considerations.	**A.M1** Analyse a literature search and explain its relevance in informing the project proposal. **A.M2** Produce an appropriate project proposal for a scientific investigation, explaining the hypothesis, variables, resources, recording, analysis, safety, and potential limitations.	**A.D1** Justify the project proposal in terms of the selection of information from the literature search and decisions made to test the hypothesis.
Learning aim B: Produce a plan for an investigative project based on a proposal		
B.P3 Produce a working plan for the project, including a method, with health and safety considerations.	**B.M3** Produce a realistic working plan for the project, including a schedule, detailed method, risk assessments and contingency planning.	**B.D2** Assess the effectiveness of the working plan, justifying changes made after a trial run and during implementation.

Pass	Merit	Distinction
Learning aim C: Safely undertake the project, collecting, presenting, interpreting and analysing the results		**CD.D3** Evaluate practical aspects and conclusions from the project, including limitations, errors, improvements and recommendations for further investigation.
C.P4 Demonstrate practical skills to assemble relevant apparatus/equipment and materials, and carry out the project using safe working practices. **C.P5** Collect and record data for the project accurately and reliably. **C.P6** Process and present data in an appropriate format, with interpretation of the results. **C.P7** Apply statistical analysis to the data collected.	**C.M4** Assess the choice of experimental techniques, data collection and presentation in terms of accuracy, reliability and validity of outcomes. **C.M5** Assess outcomes from statistical data analysis and justify the choice of technique in assuring accuracy, reliability and validity.	
Learning aim D: Communicate and evaluate the findings of the project		
D.P8 Produce a report of the project findings with valid conclusions, using correct reporting protocols and scientific terminology.	**D.M6** Present the project report findings, analysis and conclusions, communicating coherently and using scientific language.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aim: B (B.P3, B.M3, B.D2)

Learning aims: C and D (C.P4, C.P5, C.P6, C.P7, D.P8, C.M4, C.M5, C.M6, CD.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory (and maybe a fume cupboard or access to suitable environments to carry out field work)
- materials/equipment and/or laboratory instruments/sensors that will enable them to carry out practical work
- appropriate science and maths software packages to help them present their data in the most appropriate way.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners must justify their project proposal in terms of the choice of investigation, the hypothesis they are going to test and how they are going to test it. This will be evidenced by learners identifying information that they have used and have not used from their literature search, and why. They will justify why the hypothesis is valid, measurable and builds upon the information from the literature search rather than simply repeat it. Where they have made their own choices or selections (e.g. resources, variables), they will give their own reasoning, which will be coherent and logical. Learners will show that they have considered more than one appropriate investigative approach to tackling the hypothesis and explain why they have settled upon their chosen approach.

For Merit standard, learners will show that they can analyse the information from a literature search to help them plan their work and explain its relevance to the intended investigative work. Assessors should look for evidence of information from the research being extracted and used, with an explanation of why it is useful. It is expected that the research will clearly influence the research project proposal, featuring in the background to the project section, and influencing the hypothesis, resources and safety considerations. Referencing within the project proposal to researched sources will also provide evidence.

Learners will produce an appropriate project proposal for their investigation which is structured and coherent. In addition to aims, objectives and scientific background, there will be explanation of the hypothesis, variables (independent, dependent and controlled), equipment and materials required, how the data collected will be recorded and analysed, and safety considerations. This will include any potential limitations of the project proposal, such as the accuracy of any graduated apparatus or limitations of instruments/sensors.

For Pass standard, learners must carry out a literature search on the scientific area for their project. They will review the information they have gathered, ensuring confirmation of information from different sources. This information will be used to form the basis of their project proposal and a summary of information will be expected as part of their proposal. Learners will be informed that when they are carrying out their search on the scientific topic, they are expected to give a comprehensive bibliography and list of references using a standard protocol, such as the Harvard system. Assessors should also look for the use of more than one source in order to confirm statements made by learners.

Learners will produce a project proposal for an investigation in a scientific area. This will include aims and objectives, background to the scientific area, a hypothesis, equipment and materials required, and safety considerations. Learners need to be aware that their investigation will need to be able to generate sufficient data to be able to identify trends or patterns in order to provide quantitative evidence to support or reject their hypothesis, and which can be subjected to analysis by one or more statistical techniques. Methods of data presentation and use of appropriate statistical techniques must be taught to learners and opportunities to practice them as part of the delivery of this unit.

Learning aim B

For Distinction standard, learners must assess the effectiveness of their working plan in different ways. The project supervisor or other independent qualified member of staff will provide feedback on the working plan which the learner will reflect upon and make decisions on how to modify the plan. They will also carry out a trial run and consider whether the method worked as expected or needs modifying. It is probable that changes will also be necessary during the investigation itself, such as to their timeline or internal/external factors requiring different equipment/instrumentation. In all instances, learners must make clear their justification for any changes and give evidence of why the change was needed.

For Merit standard, learners will produce a realistic and detailed working plan for the project that would provide a method that the assessor would be able to follow and carry out the experiment without reference to learner. A risk assessment will be presented which will clearly identify hazards, risks and control measures. Learners will also include contingency planning (for example, if they did not have enough time to complete the experiment or if a sensor/instrument stopped working).

For Pass standard, learners will produce a working plan for the project that would provide a method that the assessor would be able to follow and carry out the experiment. Relevant health and safety relating to the activity, equipment and materials will be given which will inform the assessor of hazards.

Learning aims C and D

For Distinction standard, learners will evaluate all of the information they have obtained from their literature research and practical investigation work, making judgements on its accuracy, reliability and validity, including whether the original hypothesis had been met (and if it was valid). They will include a discussion of the strengths and weaknesses of the techniques and equipment (including percentage error analysis), how the hypothesis should be modified or rewritten, and improvements to the method or use of alternative experimental approaches. Learners will also evaluate the effectiveness of their choice of statistical methods or graphs/calculations and the validity and usefulness of their research data, as well as considering how their experimental data compares to any published information and discussing the limitations of their project.

For Merit standard, learners must assess their choice of experimental techniques, data collection and presentation methods, in terms of the accuracy, reliability and validity. They will have previously justified the experimental techniques and methods they are using, so it is important that they are assessing whether the choices were suitable on the basis of the outcomes. Learners will be in a position to support (or not) their original hypothesis and justify their opinion based on both their collected primary data and any researched secondary data.

Learners will be able to succinctly interpret the statistical analysis of their data and discuss the validity of conclusions for the investigation within their report. They will also justify the choice of statistical analysis technique and why this was more suitable than other techniques in assuring accuracy, reliability and validity.

Learners will present the project report that has been written. They will start by giving the background and hypothesis to their investigation, and then how they carried out the investigation, findings, analysis and conclusions. The presentation can be made to a group or to their project supervisor, as appropriate for the learner. The learner can decide what will be the most appropriate medium for their presentation, but it must be coherent and use appropriate scientific language.

For Pass standard, learners will be observed assembling the apparatus/equipment effectively and efficiently, and selecting the correct materials before carrying out the experiment safely. Observation records, witness testimonies and annotated photographs are all valid forms of evidence.

Learners will take all measurements or readings accurately and reliably, and record this in a suitable format in their laboratory logbook, including noting approximations, decimal point accuracy, etc. Teachers should regularly check the laboratory logbook and diary of each learner and sign and date the section seen. The measurements must be presented formally in in an appropriate and logical format (i.e. tabulated, with headings and units).

Learners will process the data appropriately (i.e. rejecting anomalies, taking means, calculating differences, etc) and select a suitable presentation format (i.e. graphs, charts). They will interpret the data, identifying trends and patterns to draw a conclusion.

Learners will apply a statistical analysis method to the results of their experiment and be able to state what can be inferred about the experimental accuracy, reliability and precision of the investigation.

Learners will produce their report in the correct scientific format and in a formal manner, using all of the information and data they have collected throughout the project. The report will be written using accepted scientific terminology and protocol, such as impersonal, third party and past tense. Learners will use the findings from their investigation to draw a valid conclusion, using scientific principles and the results of the statistical analysis to explain if their original objectives and hypothesis have been met.

Links to other units

This assessment for this unit should draw on knowledge, understanding and skills developed from:

- Unit 1: Principles and Applications of Biology I
- Unit 2: Principles and Applications of Chemistry I
- Unit 3: Principles and Applications of Physics I
- Unit 5: Principles and Applications of Biology II
- Unit 6: Principles and Applications of Chemistry II
- Unit 7: Principles and Applications of Physics II.

Employer involvement

This unit would benefit from employer involvement in the form of:

- providing a workplace investigation project
- a visit to any commercial laboratory
- a speaker from a commercial laboratory.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- independent investigation and research skills
- taking responsibility for designing and completion of tasks
- practical and technical skills, using appropriate equipment, procedures and techniques
- working to appropriate standards and protocols
- application of safe-working practices
- using initiative and showing resourcefulness
- scientific written and communication skills
- data interpretation, manipulation and presentation
- analytical and problem-solving skills
- self-management and planning skills
- time management and organisation
- evaluative and assessment skills.

Unit 5: Principles and Applications of Biology II

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners will explore biological molecules and pathways, and their relevance to diseases, disorders, treatments and therapies.

Unit introduction

This unit gives you theoretical knowledge of biological molecules and pathways and their effect on the body. This knowledge will be used to gain an insight into the physiological and psychological effects of diseases and disorders.

Biological molecules are at the forefront of treating many diseases and disorders. You will have the opportunity to research how drugs and medicines are discovered, altered, designed and synthesised in order to treat disorders. New and innovative technological advances allow for the development of new medicines and alternative treatments. This unit requires you to become familiar with current treatments and their potential benefits, while understanding their potential adverse effects. You will also explore the moral, ethical and legal implications of treating or not treating individuals.

This unit will help you to progress to higher education and then to a career in health promotion, public health, teaching, health service management, medical sales, nursing, counselling and social work.

Learning aims

In this unit you will:

A Understand biological molecules and pathways and their effect on the body

B Understand the effects of physiological diseases and disorders and associated treatments

C Examine the development of innovative and future types of treatment for physiological and psychological diseases and disorders.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand molecules and pathways and their effect on the body	**A1** Structure and function of biological molecules **A2** Roles of proteins and lipids in maintaining physiological and psychological health **A3** Disruption of biological processes in living organisms	A report on biological molecules and how their structure affects their role, and how structural disruption can lead to physiological and psychological diseases and disorders.
B Understand the effects of physiological diseases and disorders and associated treatments	**B1** Physiological diseases and disorders **B2** Treatments for physiological diseases and disorders **B3** Effects on the body	A portfolio of evidence detailing the causes, effects and treatments used for physiological disorders.
C Examine the development of innovative and future types of treatment for physiological and psychological diseases and disorders	**C1** Drug and medicine discovery and development **C2** Innovative treatments **C3** Ethical, legal and moral issues	A report on the development and testing of drugs and medicines and associated ethical, moral and legal issues relating to treatments of physiological and psychological diseases.

Content

Learning aim A: Understand biological molecules and pathways and their effect on the body

Learners will develop an understanding of the structures, formation, functions and importance of proteins, nucleic acids and lipids in maintaining physiological and psychological health.

A1 Structure and function of biological molecules

- General structure and function of biological molecules:
  - carbohydrates
  - proteins, to include primary, secondary, tertiary and quaternary structures of globular and fibrous proteins
  - triglycerides
  - glycoproteins
  - high-density lipoproteins (HDLS) and low-density lipoproteins (LDLS)
  - phospholipids.
- Structure and function of specific biological molecules:
  - deoxyribonucleic acid (DNA)
  - ribonucleic acid (RNA), to include messenger RNA (mRNA), transfer RNA (tRNA) and short interfering RNA (siRNA)
  - adenosine triphosphate (ATP)
  - collagen.

A2 Roles of proteins and lipids in maintaining health

- Roles of proteins:
  - as enzymes that control metabolism
  - as peptide neurotransmitters
  - as antibodies
  - as hormones
  - for transport of other components
  - for body tissue growth and repair
  - for muscle contraction in animals (actin and myosin interaction – detailed knowledge
  - of the sliding filament theory not required)
  - for reducing the chance of blood clotting.
- Roles of lipids:
  - as energy sources
  - as insulation of nerves and organ protection
  - as phospholipids in membranes
  - in association with vitamins
  - in the production of hormones.

A3 Disruption of biological processes in living organisms

- Learners will explore the causes and effects of disruption to biochemical processes, to include:
  - cancer: prostate, cervical, breast, lung
  - coronary heart disease (CHD) – atherosclerosis, coronary vascular disease
  - diabetes – regulation of glucose metabolism by hormones.
  - Alzheimer's disease
  - anxiety and mood disorders
  - psychotic disorders
  - personality disorders
  - addiction disorders.

Learning aim B: Understand the effects of physiological diseases and disorders and associated treatments

B1 Physiological diseases and disorders

- Learners will research and understand the possible effects of the following:
  - cancer – e.g. prostate, cervical, breast, lung
  - coronary heart disease (CHD) – atherosclerosis, coronary vascular disease
  - diabetes – diabetes mellitus types 1 and 2.

B2 Treatments for physiological diseases and disorders

- Learners will understand the types of treatment, therapies and the associated benefits of each when used in relation to specific physiological diseases and disorders, e.g.:
  - radiotherapy, including brachytherapy
  - chemotherapy
  - hormone therapy
  - surgery
  - targeted biological therapy and immunotherapy, e.g. monoclonal antibody therapy, angiogenesis inhibitors, T-cell therapy
  - gene therapy, e.g. replacing a mutated gene, inactivating a mutated gene, introducing a new gene
  - stem cell therapy.

B3 Effects on the body

- Learners will understand the possible effects on the body of the treatments listed above:
  - positive effects (advantages and benefits), e.g. partial cure, cure, ability to lead a normal life
  - negative effects (disadvantages, potential harm), e.g. side effects of treatments
  - risks associated with treatments, e.g. exposure to increased levels of radioactivity during radiotherapy.

Learning aim C: Examine the development of innovative and future types of treatment for physiological and psychological diseases and disorders

C1 Drug and medicine discovery and development

- Learners will explore drug discovery and development to include:
  - drugs derived from natural sources, e.g. plants and animals
  - modification of natural products to develop drugs and medicines, e.g. isolation,
  - purification, optimisation of the active compound
  - process of drug development from discovery to regulatory approval, e.g. computer modelling using algorithms, cell modelling, clinical trials.

C2 Innovative treatments

- Learners will explore the development of innovative treatments for physiological diseases and disorders.
- Gene therapy:
  - identification, removal and modification of faulty genes
  - insertion of 'new' gene, vectors.
- Stem cell therapy:
  - to regenerate cells and tissues.
- Surgical techniques:
  - current research and development into less invasive ways to remove cells and tissues.

C3 Ethical, legal and moral issues

- Learners will explore the ethical, legal and moral issues relating to treatments and drug development and testing.
  - ethical, social and professional rules, for example, confidentiality, informed consent, rights of individual versus rights of society, 'do no harm', 'can it be done?', 'should it be done?'
  - use of animal testing
  - use of placebos
  - use of blind and double-blind clinical trials.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand biological molecules and pathways and their effect on the body		**A.D1** Evaluate the impact of disruption for one physiological and one psychological disease or disorder.
A.P1 Explain the importance of proteins, nucleic acids and lipids in maintaining physiological and psychological health.	**A.M1** Discuss how disruption to biological molecules and processes can lead to one physiological and one psychological disease or disorder.	
Learning aim B: Understand the effects of physiological diseases and disorders and associated treatments		**B.D2** Evaluate the effects and treatments of physiological diseases and disorders.
B.P2 Explain the effects of physiological diseases and disorders.	**B.M2** Analyse the associated effects of treatments of physiological diseases and disorders on the body.	
Learning aim C: Examine the development of innovative and future types of treatment for physiological and psychological diseases and disorders		**C.D3** Evaluate the ethical, legal and moral issues of drug/medicine development, testing and treatments for a physiological or a psychological disease or disorder.
C.P3 Describe the development and testing of a drug/medicine derived from a natural source and one that has been synthesised for a specific purpose.	**C.M3** Discuss the problems that may arise during development and testing drugs/medicine and treatments.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.M2, B.D2)

Learning aim: C (C.P3, C.M3, C.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to the internet and secondary sources for research.

Essential information for assessment decisions

To help ensure validity and authenticity of the work being submitted for assessment, each learner will individually choose from the disorders listed in the unit content to research and use for their assignment.

Learning aim A

For Distinction standard, learners will draw on secondary source material (referenced) to evaluate the relevance and/or significance of the normal and disrupted state of biological molecules for the **one physiological and one psychological disease or disorder** they have chosen. A conclusion on the significance of the disruption will be given and justified.

For Merit standard, learners will choose **one physiological and one psychological disease or disorder** from: cancer, coronary heart disease, diabetes, depression, dementia. Their discussion will give clear details, reasons and opinions as to how disruption of biological molecules may lead to the diseases or disorders that they have chosen. Learners will need to give clear details of the changes to the structure of molecules and their implications, for example, details of how inaccuracies in the secondary, tertiary and quaternary structure of proteins can affect their role. Learners will explain the importance of the accurate base pairing of nucleic acids in relation to diseases and disorders. They will explain the relevance of saturated and unsaturated fats to heart disease, atherosclerosis and the insulation of nerves, to enable the fast and accurate transmission of impulses.

For Pass standard, learners will explain the importance of proteins, nucleic acids and lipids in terms of their structure and roles in the body. The explanations must relate to the importance of these biological molecules in maintaining **physiological and psychological** health.

Learning aim B

For Distinction standard, learners will evaluate aspects of **two physiological diseases or disorders** and how they are similar and different in terms of causes, effects on the body and the individual, and effectiveness or otherwise of current treatments. Learners must give judgements that are supported by evidence.

For Merit standard, learners will analyse the effects of current treatments and therapies for **two physiological diseases or disorders** from the categories given in the unit content. Where applicable, positive and negative effects will be included, and learners must also analyse the risks of treatments in relation to potential benefits.

For Pass standard, learners will give clear explanations of the effects of **two physiological diseases and disorders.** Learners will include details of the associated biological molecules and their involvement in the disrupting processes resulting in the effects. The two diseases or disorders should be chosen from the categories given in the unit content.

Learning aim C

For Distinction standard, learners will evaluate the ethical, moral and legal issues relating to drug/medicine development and testing and the treatment(s) used for **one physiological or one psychological disease or disorder.** An understanding of the differences between ethics and morals will be demonstrated, and the dilemmas surgeons and health practitioners relating to 'do no harm' will be considered in relation to current treatments.

For Merit standard, learners will use the testing of drugs, medicines and treatments to discuss the problems that could arise during development and testing for **one physiological or one psychological disease or disorder.** Innovative treatments, e.g. gene transfer, stem cell therapy and/or minimally invasive surgery will also be included.

For Pass standard, learners will choose a **drug or medicine derived from a plant or animal source** that is used to treat a disease or disorder and briefly describe its development. They will also give a description of **the development of a synthetic drug or medicine** which is used for a named disorder or disease.

Learners must give an objective account of the stages of drug and medicine testing. They will need to include information on the requirements for drugs and medicines to be rigorously tested prior to being approved for use.

Learners must use technical language and demonstrate breadth of coverage of the unit content.

Links to other units

This unit links to:

- Unit 9: Biomedical Science
- Unit 11: Functional Physiology of Human Body Systems
- Unit 13: Biological Molecules and Metabolic Pathways
- Unit 15: Diseases and Infections.

Employer involvement

This unit would benefit from employer involvement in the form of:

- charities working with the diseases and disorders covered in this unit
- a pharmaceutical representative to discuss drug development and testing.

Opportunities to develop transferable employability skills

- formal written communication
- self-management and planning skills
- ability to work in a scientific environment
- ability to carry out independent research
- analytical skills.

Unit 6: Principles and Applications of Chemistry II

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit builds on and extends the range of key science concepts in chemistry that were covered in *Unit 2: Principles and Applications of Chemistry I*.

Unit introduction

It is important that scientists and laboratory technicians are able to use and apply key science concepts to work efficiently and effectively in science and science-related organisations. This unit builds on and extends the range of key science concepts that you covered in *Unit 2: Principles and Applications of Chemistry I*. A strong grasp of these concepts will enable you to use and apply this knowledge and understanding in vocational contexts when studying other units in this specification.

This unit includes: energetics, rate of reaction and equilibrium; structures, names, reactions and properties of commercially important organic compounds.

It is essential that chemists understand how the uses of chemical substances relate to their physical and chemical properties, as does their method of production and extraction. For example, knowledge of the energetics, rate and extent of chemical reactions is necessary for scientists working in industry in order to ensure safe, efficient processes are used in the production of chemical substances. Scientists and technicians working in a range of industries, such as the medical or plastics industries, need a good working knowledge of the structure of organic chemicals and their physical and chemical properties.

The knowledge and understanding you gain in this unit will give you a strong basis for progression in the applied science sector and to a variety of science and related programmes, such as higher nationals and degrees.

Learning aims

In this unit you will:

A Understand energy changes in chemical reactions

B Understand how rate and equilibrium influence chemical reactions

C Understand the principles of organic chemistry

D Understand the chemical behaviour, separation and applications of organic compounds.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand energy changes in chemical reactions	**A1** Energetics	A report of a practical investigation into endothermic and exothermic reactions, explaining how the different enthalpy changes arise. Calculations to show how enthalpy change for a reaction can be determined by experiment or by using other enthalpy changes. A discussion of the assumptions and sources of error that arise in measurements and calculations of enthalpy change.
B Understand how rate and equilibrium influence chemical reactions	**B1** Rate of reaction **B2** Dynamic equilibrium	A report of a practical investigation into the factors that affect rate of reaction and analyse gradients from graphs to determine rate. A report investigating the factors that affect equilibrium. Calculations to find K_c or equilibrium concentrations, how to interpret the values and the implications of K_c change with temperature. Explanation of the operational conditions for industrial equilibrium processes to obtain optimum rate and yield of product.

Learning aim	Key content areas	Assessment approach
C Understand the principles of organic chemistry	**C1** Structures and naming of organic compounds	A report that shows how to determine structures and names for a range of organic compounds, and the differences in bonding between saturated and unsaturated hydrocarbons. Diagrams of structures and bonding will be shown. The report will also provide an explanation and assessment of how functional groups, homologous series, structure and isomerism all characterise and influence physical properties and chemical behaviour.
D Understand the chemical behaviour, separation and applications of organic compounds	**D1** Reactions of alkanes and alkenes **D2** Reactions of halogenoalkanes and alcohols **D3** Organic chemistry mechanisms **D4** Preparation and testing of organic compounds **D5** Chromatographic techniques	A report which reviews the commercially important reactions of hydrocarbons, following the reactions and products from a specific molecule. A comparison of the reactions of alkanes and alkenes and explanation of the main reactions of halogenoalkanes and alcohols. Drawings of mechanisms will complement the comparisons and explanations. Observations and results from the preparation and testing of an organic compound. An explanation of the principles behind the chromatographic separations. Results from the paper chromatography or TLC of an organic compound mixture. Explanations of factors affecting separation and consideration of other separation techniques. An observation report with a checklist, completed by the teacher, including safety. Assessment of different ways to make an organic compound, including factors that would affect the yield and purity.

Content

Learning aim A: Understand energy changes in chemical reactions

A1 Energetics

- Enthalpy change – definition, symbol (ΔH), units (kJ)
- Endothermic and exothermic processes:
  - direction of energy transfer
  - sign conventions
  - reaction profile diagrams
  - Standard conditions for enthalpy change – symbol (ΔH^{o}), 1×10^{5} Pa (100 kPa), 298 K, units (kJ mol^{-1}).
- Calculate enthalpy changes from supplied data:
  - Hess energy cycles
  - average bond energies (and definition)
  - $\Delta H^{o}_{reaction}$ = sum of bond energies of reactants – sum of bond energies of products
  - standard enthalpy changes of combustion (and definition), ΔH^{o}_{c}
  - $\Delta H^{o}_{reaction} = \Sigma\Delta H^{o}(\text{products}) - \Sigma\Delta H^{o}(\text{reactants})$
  - limitations and assumptions of calculations.
- Measurement of enthalpy changes:
  - combustion of hydrocarbons and alcohols
  - neutralisation reactions
  - dissolving compounds
  - enthalpy change in the water in contact with a reaction
  - use of thermometer to record temperature, and calibration
  - specific heat capacity of water, c_p, 4.18 kJ kg^{-1} K^{-1}
  - use of equation $Q = mc_p\Delta T$
  - uncertainty in measurements and error analysis
  - limitations and improvements.

Learning aim B: Understand how rate and equilibrium influence chemical reactions

B1 Rate of reaction

- Rate of reaction:
  - definition
  - use of collision theory to explain changes in conditions
  - kinetic energy and activation energy.
- Consideration of the effect of conditions and factors:
  - concentration
  - surface area
  - temperature
  - catalyst.

- Methods of determining rate:
  - change in mass over time (due to loss of a gas)
  - change in volume of gas over time/time taken to collect a fixed volume of gas
  - time taken for a colour change/clock reaction
  - rate = change in quantity/change in time
  - draw tangents of volume/time or mass/time graphs to determine gradient (rate of reaction).

B2 Dynamic equilibrium

- Equilibrium:
  - reversible reactions
  - closed system
  - dynamic process and rate
  - microscopic and macroscopic properties
  - use of Le Chatelier's Principle to predict changes in conditions.
- Consideration of the effect of conditions and factors:
  - concentration
  - pressure
  - temperature
  - catalyst.
- Equilibrium constant, K_c:
  - writing expressions for homogeneous and heterogeneous equilibrium systems
  - calculating values for Kc (including units) from equilibrium concentrations and vice versa
  - determining the position of equilibrium from the magnitude of K_c
  - effect of temperature on value of K_c and implication of the direction of enthalpy change.
- Industrial reactions e.g. Haber process, Contact process.

Learning aim C: Understand the principles of organic chemistry

C1 Structure and bonding of organic compounds

- Ability of carbon to form four bonds, chains and rings.
- Hydrocarbons:
  - definition
  - saturated and unsaturated
  - alkanes and alkenes
  - straight-chain, branched and cyclic.
- Bonding and shape in hydrocarbons:
  - ability of carbon to form four covalent bonds, chains and rings
  - σ and π bonding in alkanes and alkenes
  - bond angles, lengths and strengths in alkanes and alkenes
  - symmetric and asymmetric molecules.
- Properties of organic molecules (alkanes, alkenes, halogenoalkanes and alcohols):
  - boiling point, melting point and solubility in water
  - intermolecular forces present in the molecule
  - effect of chain length of molecule
  - effect of branching of molecule
  - effect of functional group of molecule.

C2 Representations and naming of organic compounds

- Homologous series:
  - general formula (alkanes, alkenes, halogenoalkanes, alcohols)
  - functional groups (alkenes, halogenoalkanes, alcohols).
- Representations of organic molecules:
  - molecular formulae
  - structural formulae (displayed and condensed)
  - skeletal formulae
  - 3D representations using wedge/dashed line diagrams.
- Naming of organic molecules:
  - use of International Union of Pure and Applied Chemistry (IUPAC) nomenclature
  - alkanes, alkenes, halogenoalkanes, alcohols, branched and cyclic compounds.

C3 Isomerism and properties of organic compounds

- Isomerism:
  - structural isomerism
  - geometric isomerism – cis-trans stereoisomerism and E-Z stereoisomerism (including Cahn-Ingold-Prelog priority rules).
- Effect on physical properties of organic molecules (boiling point, melting point, solubility in polar and non-polar solvents).

Learning aim D: Understand the chemical behaviour, separation and applications of organic compounds

D1 Reactions of alkanes and alkenes

- Reactions of commercial importance:
  - separation of hydrocarbons from crude oil by fractional distillation
  - cracking of alkanes and purpose
  - combustion of alkanes and applications as fuel
  - polymerisation of alkenes and applications
  - hydration of alkenes (e.g. ethene to ethanol) and applications.
- Reactions of alkanes:
  - reasons for general lack of reactivity (bond energy, polarity)
  - substitution reactions with halogens.
- Reactions of alkenes:
  - reasons for reactivity (bond energy, electron density)
  - addition reactions with halogens, hydrogen halides and hydrogen.
- Conditions and equations for all reactions.

D2 Reactions of halogenoalkanes and alcohols

- Reactions of halogenoalkanes:
  - reasons for trend in reactivity of chloro, bromo and iodoalkanes (bond energy and polarity of C-Cl, C-Br and C-I)
  - substitution reactions with water, ammonia and aqueous sodium hydroxide
  - elimination reactions with sodium hydroxide in ethanol solution
  - conditions and equations for reactions.

- Reactions of alcohols:
  - substitution with hydrogen halides
  - elimination with concentrated sulfuric acid
  - oxidation with potassium dichromate and dilute sulfuric acid – effect of structure (i.e. primary, secondary and tertiary) upon the extent of oxidation of the O-H group.
- Conditions and equations for all reactions.

D3 Organic chemistry mechanisms

- Homolytic and heterolytic bond fission.
- Use of curly arrows in mechanisms (only for movement of a pair of electrons).
- Free radicals, electrophiles and nucleophiles.
- Free radical substitution of alkanes – initiation, propagation, termination and by-products.
- Electrophilic addition of alkenes, including formation and stability of carbocation, and formation of isomers from asymmetric alkenes.
- Nucleophilic substitution of halogenoalkanes and alcohols.
- Elimination of a hydrogen halide from a halogenoalkane.
- Elimination of water from an alcohol.

D4 Preparation and testing of organic compounds

- Heating under reflux – principles, equipment and set up.
- Distillation – principles, equipment and set up.
- Recrystallisation – principles and technique.
- Filtration – principles, equipment and technique:
  - filtration under gravity
  - filtration under reduced pressure (use of vacuum pump).
- Use of chemicals to remove impurities:
  - addition of water to remove impurities soluble in water
  - sodium carbonate to react with unreacted acid
  - anhydrous calcium chloride or molecular sieves to remove water.
- Drying – use of ovens, desiccators and evaporation.
- Tests for purity:
  - melting point determination
  - boiling point determination
  - chromatography.
- Tests for functional group:
  - bromine water (for alkenes)
  - warm with aqueous silver nitrate solution (for halogenoalkanes)
  - warm with potassium dichromate solution and dilute acid (for primary and secondary alcohols or aldehydes).
- Percentage yield – calculation and reasons for low yield (e.g. competing side reactions, conditions, transfer loss, volatile reactants or product).
- Examples of practical preparations:
  - oxidation of an alcohol (e.g. ethanol) to an aldehydes, ketone or carboxylic acid
  - dehydration of an alcohol (e.g. cyclohexanol) to alkene
  - hydration of an alkene (e.g. hex-1-ene) to an alcohol
  - preparation of a halogenoalkane (e.g. bromoethane, 2-chloro-2-methylpropane)
  - preparation of aspirin or paracetamol.

D5 Chromatographic techniques

- Principles – use in separation and identification, mobile and stationary phases, adsorption.
- Types – paper chromatography or thin layer chromatography (TLC).
- Preparative methods for samples – solvent extraction, filtration, capillary tubes to apply spots, concentration of spot, choice of solvent and vessel, use of locating agents.
- Calculation of Rf value.
- Interpretation of chromatograms – number of components and Rf values.
- Reasons for poor separation or inaccurate Rf values (e.g. overloading samples, disturbing plate/paper, solvent, temperature).
- Comparison with other types of separation.
- Examples of separations and identifications using chromatography:
  - plant pigments extracted from leaves/herbs using propanone
  - amino acids in a mixture using paper chromatography.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand energy changes in chemical reactions		**A.D1** Discuss assumptions and sources of error in measurement and calculation of enthalpy changes.
A.P1 Investigate endothermic and exothermic reactions.	**A.M1** Calculate enthalpy changes for a range of reactions using Hess energy cycles, average bond energies and standard enthalpy changes of combustion.	
Learning aim B: Understand how rate and equilibrium influence chemical reactions		**B.D2** Justify operational conditions for industrial equilibrium processes to obtain the optimum rate and yield of product.
B.P2 Investigate factors that affect rate of reaction. **B.P3** Investigate factors that affect systems in dynamic equilibrium.	**B.M2** Analyse gradients from tangents of graphs to accurately determine rate of reaction. **B.M3** Carry out calculations involving K_c and interpret changes in values with temperature.	
Learning aim C: Understand the principles of organic chemistry		**C.D3** Assess the effect of structure on the physical properties of organic compounds.
C.P5 Determine structures and names of organic compounds. **C.P6** Describe the difference in bonding between saturated and unsaturated hydrocarbons.	**C.M4** Explain the importance of functional groups, homologous series and isomerism.	
Learning aim D: Understand the chemical behaviour, separation and applications of organic compounds		**D.D4** Assess different ways to make an organic compound and the factors affecting the yield and purity.
D.P7 Review the chemistry of alkanes and alkenes, including reactions of commercial importance. **D.P8** Explain the reactions of halogenoalkanes and alcohols. **D.P9** Explain and use chromatography to separate mixtures.	**D.M5** Construct mechanisms for addition, substitution and elimination reactions. **D.M6** Demonstrate skilful preparation and testing of an organic compound. **D.M7** Analyse chromatograms and factors that affect the quality of the separation of mixture.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.M2, B.M3, B.D2)

Learning aim: C (C.P5, C.P6, C.M4, C.D3)

Learning aim: D (D.P7, D.P8, D.P9, D.M5, D.M6, D.M7, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory with a fume cupboard
- a range of organic chemicals
- gas and water utilities, sinks and power sources to allow reflux, distillation and vacuum filtration to be carried out
- Quickfit™ apparatus for reflux and distillation
- weighing scales
- melting-point apparatus
- chromatography paper, thin layer chromatography slides
- health and safety policies and risk assessments.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will research literature values for standard enthalpy changes of the reactions that they have investigated practically or calculated in response to questions. They will compare their enthalpy change values with the literature values and provide a detailed commentary on the differences. For enthalpy changes determined practically, learners will coherently discuss conditions which the experiments were conducted under and how this may affect the enthalpy change determined. They will also discuss the problems or issues with the procedures and link this correctly to the temperatures, masses and volumes measured. They will include calculation of percentage errors in equipment, consideration of the calibration of instruments and identify the significance that these have upon the outcomes. For enthalpy changes calculations for practical work and from bond energies or enthalpy changes of combustion, learners will discuss any assumptions which may not make the comparison valid.

For Merit standard, learners will calculate a range of standard enthalpy changes for reactions that cannot be determined practically. They will use a variety of methods for their calculations including Hess energy cycles, differences between the average bond enthalpies of products and reactants, and the equation $\Delta H^{o}_{\text{reaction}} = \Sigma\Delta H^{o}$ (products) – $\Sigma\Delta H^{o}$ (reactants) given the standard enthalpies changes of combustion of substances involved.

For Pass standard, learners will carry out investigations into endothermic and exothermic reactions. They will measure temperature changes of the solutions or water that absorb or release the heat due to the reaction. They will calibrate the thermometers used, accurately measure and record measurements of temperature, masses and volume, and carry out a risk assessment. Values for enthalpy change for each reaction will be calculated using the equation $Q = mc_p\Delta T$ and converted to kJ mol^{-1} for comparison. Learners will categorise each reaction as endothermic or exothermic, commenting upon the magnitude and sign of the enthalpy change, and explaining the underlying processes involved in terms of bond breaking, bond making and reaction profile diagrams.

Learning aim B

For Distinction standard, learners will research or be provided with two case studies of the industrial manufacture of a chemical product that involves a reversible reaction. They will analyse or suggest the operational conditions that are used and justify why these would give the optimum rate and yield. They will apply scientific principles such as collision theory and Le Chatelier's principle to explain the ideal conditions for rate and product yield, but why a compromise may be necessary. Learners will also discuss other methods and solutions to compensate for a low rate or poor yield.

For Merit standard, learners will draw tangents at appropriate points on their rate of reaction graphs and accurately calculate the gradients (with correct units) to determine the rate of reaction at the start, middle and near the end of the reaction. They will analyse the values of rates determined to identify how it changes during the course of the reaction and explain what is happening on a molecular level. They will also compare the initial rates determined for different graphs as the factor under investigation is changed (e.g. increased concentration) and identify whether this shows a directly proportional relationship. Learners will give a scientific explanation where a directly proportional relationship can be established or discuss potential errors and issues in the experiment where a directly proportional relationship cannot be established.

Learners will write expressions for equilibrium constants (K_c) for a range of systems in equilibrium, given the equation for the reversible reaction. They will perform calculations to determine the value of K_c (with correct units) from concentrations of reactants and products at equilibrium. They will also calculate the concentration of a reactant or a product where K_c and the concentrations of all other components are provided. Calculated values of K_c will be commented upon in terms of how far the reaction has gone to completion. Learners will also comment on the extent of equilibrium position and the direction of enthalpy change when values of K_c for the same reaction at different temperatures are provided.

For Pass standard, learners will carry out investigations to prove the effect of the four key factors (i.e. concentration, surface area, temperature and catalysis) upon the rate of reaction. Methods of studying rate of reaction that could be used include mass loss over time, volume of gas collected over time, or timed clock/colour change reactions. They will use a method of continuous monitoring to collect sufficient data to plot graphs for at least two of the factors (e.g. concentration and surface area). They must select the most appropriate scale for their graphs, using appropriate labels including units, and drawing a smooth, best-fit curve through the points, excluding identified anomalies. Learners will use collision theory, activation energy and scientific terminology accurately to explain conclusions drawn from their investigation of each factor.

Learners will investigate factors which effect a system in dynamic equilibrium. This will be a combination of practical and research-based investigation in order to provide a complete overview of the effect of concentration, pressure, temperature and catalysis. Learners will provide experimental results which include observations on the effect on the equilibrium position when at least one factor has been changed. Learners will apply Le Chatelier's Principle given the reversible reaction equation and associated enthalpy change, to explain or predict the change in equilibrium position caused when a condition is changed. They will also explain factors which have no effect upon an equilibrium position or situations where they do not apply.

Learning aim C

For Distinction standard, learners will assess the effect of structure on the physical properties (i.e. boiling point, solubility in water) of alkanes, alkenes, halogenoalkanes and alcohols. They will assess the effect on a physical property with increasing chain length or branching, or the difference between a straight chain and cyclic compound with the same number of carbon atoms. This will require an explanation in terms of strength of intermolecular forces present and the reasons for this. They will identify the functional group (or lack of it) on structures with the same number of carbon atoms, compare or predict the resulting effect on a physical property and provide justification for this. They will also assess the effect on a physical property of different types of isomerism for molecules with the same molecular formula.

For Merit standard, learners will explain the use and reasons for categorising organic molecules by functional group and homologous series. They will use general formulae for a homologous series to predict molecular formulae of members and predict the properties of molecules which have the same functional group. They will explain different forms of isomerism and how this can influence if molecules with the same molecular formula still have the same functional group or belong to the same homologous series.

For Pass standard, learners will draw structures for a range of alkanes, alkenes, halogenoalkanes and alcohols (including straight chain, branched and cyclic compounds) when supplied with the molecular formula, IUPAC name or in response to completing an equation. They will use a variety of ways to represent the structure of the molecules (displayed and condensed structural formulae, skeletal formulae and 3-dimensional representations). They will also be able to name a range of molecules and isomers (using IUPAC conventions) when provided with a structural or skeletal formula.

Learners will be able to describe the difference in bonding between alkanes and alkenes (to include straight chain, branched and cyclic structures) using a variety of models such as dot-and-cross diagrams, stick diagrams and representations of sigma and pi orbitals. They will also be able to describe the characteristics and effects of the different bonds, such as bond angles, lengths and energies, and the impact on the physical and chemical properties.

Learning aim D

For Distinction standard, learners will assess their method of preparation and testing of the organic compound that they have made and assess factors that may have given rise to a low yield or poor purity. Learners will also research or propose one other way that the organic compound that they have made could have been made starting from a different organic molecules (e.g. bromoethane from ethane or ethene). The preparation must consider names and formulae of starting materials and products, balanced equations, reaction conditions, method, equipment needed, hazards and risks. The learners must assess the reaction in the same way as their own preparation, identifying points where yield or purity may be affected.

For Merit standard, learners must construct at least one correct mechanism for electrophilic addition, nucleophilic substitution, free radical substitution and elimination. Sourced images of mechanisms are **not** acceptable evidence forms for this criterion. They will supplement their mechanisms with annotation or explanation of the reactive species involved and the bond breaking/bond making that occurs in each step using scientific terminology correctly and accurately throughout. They will include consideration of the stability of intermediates formed during the mechanism and the formation of different isomers as products.

Learners will provide the results/notes of practical work, a witness testimony or photographic evidence of working safely and a risk assessment for the preparation and testing of an organic compound. Learners will correctly and competently follow given techniques and procedures to prepare and test their organic compounds. The preparation will use some of the following techniques, depending on the reaction and product: heating under reflux, distillation, addition of chemicals to purify the product, filtration, and recrystallization. Quantities of reactants and of the isolated product must be recorded so that learners can calculate the percentage yield of the organic compound made. They will carry out a qualitative test to confirm a property of the organic compound made: boiling point, melting point, or appropriate tests to identify the presence of the desired functional group and absence of the starting compound's functional group. Learners will draw simple conclusions about the purity and yield of the product in order to judge the success of the preparation.

Learners will demonstrate safe working practices and a high level of proficiency when carrying out paper and thin-layer chromatography (TLC) with minimal supervision. They will produce chromatograms showing clear separation of spots, repeating the separations if they are not satisfied with the quality of the separation obtained. Learners will accurately calculated Rf values and compare these with literature values. Where there is poor match or separation they will consider factors that influence the position and separation of the components in the chromatogram to justify conclusions drawn about the identification of components in a mixture (for example the polarity of the components of the mixtures and the polarity of the solvents and effect of the size of a molecule on its mobility). Learners will then comment on the suitability of the chromatography technique for separation of the mixture and consider whether the use of other separation techniques such as distillation and recrystallisation may be more appropriate.

For Pass standard, learners must compare the reactions of alkanes and alkenes listed in the *Content* section. The evidence will include correct names and formulae of starting materials and products, balanced equations, reaction conditions. They will explain points of difference in the main reaction modes of alkanes and alkenes by considering bond energies, bond polarity and electron density, and the type of species that alkanes and alkenes react with. They must also review commercially important reactions of hydrocarbons. This will be exemplified with a specified hydrocarbon and following its pathway from fractional distillation of crude oil through to the cracking process and to the products of this process as fuels and as the feedstock for polymers, alcohols and other chemicals. Learners will provide equations and conditions for all reactions referred to. They will describe the use and importance of the reactions or the products.

Learners must provide explanations of reactions of typical halogenoalkanes and alcohols as listed in the *Content* section. This will include the effect reactivity for different halogenoalkanes (i.e. chloroalkanes, bromoalkanes and iodoalkanes) of different halogens structure on the oxidation reactions of alcohols (i.e. primary, secondary and tertiary structures).The evidence will include correct names and formulae of starting materials and products, balanced equations, reaction conditions and any products of commercial or biological importance.

Learners will explain the principles of chromatography and its use in organic chemistry to separate mixtures and identify compounds. They will follow instructions, demonstrating safe working practices and a good level of ability when carrying out either paper chromatography or thin layer chromatography to separate a mixture of organic compounds. Learners will comment on the suitability of the techniques for separation and the chromatogram produced for each technique (TLC and paper chromatography). At this standard, the chromatograms may not produce spots showing an optimum degree of separation (for example the spots may be too large and lacking in distinction). They will determine Rf values using paper chromatograms, using these to correctly identify components in a mixture.

Links to other units

This unit links to:

- Unit 2: Principles and Applications of Chemistry I
- Unit 16: Applications of Inorganic Chemistry
- Unit 20: Applications of Physical Chemistry
- Unit 21: Applications of Organic Chemistry.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities to do so. A visit to, or a speaker from, any commercial laboratory, no matter how small, will add value to this unit. Visits from chemical, biochemical, biotechnology and pharmaceutical manufacturers would be advantageous.

This unit would benefit from employer involvement in the form of:

- a visit to any commercial laboratory
- a speaker from a commercial laboratory.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- independent investigation and research skills
- practical and technical skills, using appropriate equipment, procedures and techniques
- scientific written and communication skills
- data interpretation, manipulation and presentation
- analytical and problem-solving skills
- self-management and planning skills
- evaluative and assessment skills.

Unit 7: Principles and Applications of Physics II

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers the important areas of thermal physics, materials and fluids and the essential aspects of radioactivity.

Unit introduction

In the first part of this unit, you will explore the main concepts that have formed the foundations of our understanding of heat energy, its transfer and importance in every day systems. Scientists and engineers need a good understanding of the properties and behaviour of different materials to ensure that they use materials which are 'fit for purpose'. When designing machines and engines, it is vital to know how materials behave under differing conditions and forces, for example, how vehicle suspension springs behave under tension and compression, or how heat is transferred in a refrigeration unit. You will develop your knowledge and understanding of the key areas in thermodynamics, highlighting important definitions relating to heat energy and developing an understanding of physical laws governing our present-day knowledge. You will also investigate the behaviour of a range of materials under conditions of stress and strain, how they change and what effects develop as a result. Your skills in investigation and research will be enhanced as will your knowledge of the dynamics of fluid motion through pipes and subsequent variations in drag and pressure.

The second part of this unit will focus on our understanding and current developments in the use of radioactivity, known science concepts and practical uses of ionising radiation in everyday life. You will look closely at aspects of the periodic table with an emphasis on key particles, forces and concepts which have become embedded in our knowledge from scientific investigation by eminent scientists. Ionising radiations will be a focus for developing an appreciation of the dangers and also important uses of specific radiations, with a particular link to the medical and energy production industries, identifying how ionising radiations have become quite acceptable in a variety of applications in the modern world.

The skills you learn in this unit can be applied to other areas of study and to workplace practices. This unit will support you in progressing to higher education courses or to employment in the science or applied science sector.

Learning aims

In this unit you will:

A Understand thermal physics, materials and fluids

B Investigate the properties and uses of radioactivity.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand thermal physics, materials and fluids	**A1** Thermal physics in domestic and industrial applications **A2** Materials in domestic and industrial applications **A3** Fluids in motion	A scientific report and diagrams. Use of terms and numerical values A presentation document. Outline of key materials used and mathematical definitions. Diagrams and text information with example applications of calculations used.
B Investigate the properties and uses of radioactivity	**B1** Structure of the atom and forces **B2** Ionising radiation **B3** Applications of radioactivity	Descriptions of important scientific experiments which have provided our current knowledge. Key definitions of terms used and outline of present-day understanding of ionising radiation. A report on specific radiation forms together with definitions. A case study of nuclear power station accidents. Journalistic-style document which highlights the current uses for ionising radiation for positive and negative purposes.

Content

Learning Aim A: Understand thermal physics, materials and fluids

A1 Thermal physics in domestic and industrial applications

- Be able to use the following quantities and units:
  - power, watt (W), kilowatt (kW), megawatt (MW), gigawatt (GW)
  - convert °C to K.
  - pressure (Pascals (Pa), Newton per metre squared (Nm^{-2})).
- Know the following definitions:
  - work done as energy transferred
  - work done as force × distance moved in direction of force ($W = F \times \Delta x$)
  - work done by a gas as pressure × change in volume of gas ($W = p \times \Delta V$).
- Be able to calculate efficiency using the relationships:
  - efficiency = useful energy output/total energy input
  - for heat engines:

    efficiency = $1 - \frac{Q_{out}}{Q_{in}}$
  - Maximum theoretical efficiency: $1 - \frac{T_C}{T_H}$
- Understand the following concepts:
  - law of conservation of energy
  - ideal gas equation $pV = NkT$
  - internal energy (U), first law of thermodynamics ($Q = \Delta U + W$)
  - isothermal and adiabatic processes
  - idealised engine cycles
  - second law of thermodynamics
  - heat engines, refrigerators and heat pumps
  - maximum theoretical coefficient of performance (COP).
- Understand the changes of state of substances used in domestic and industrial processes:
  - transfer of energy producing temperature change or changes of state, thermal capacity, thermal equilibrium
  - specific heat capacity from ($\Delta Q = mc\Delta T$)
  - specific latent heat from ($\Delta Q = \Delta mL$), fusion, vapourisation, condensation.

A2 Materials in domestic and industrial applications

- Understand the following concepts and apply them in domestic and industrial applications:
  - elasticity
  - stress-strain curves
  - elastic limit
  - strength
  - yield point
  - plastic deformation
  - creep
  - fatigue

  - ductility
  - brittleness
  - malleability
  - elastic hysteresis.
- Be able to use the following quantities and units:
  - density kgm^{-3}
  - tensile/compressive stress (Newton per metre squared (Nm^{-2}))
  - tensile/compressive strain (no units)
  - Young's modulus (Newton per metre squared (Nm^{-2})).
- Understand the following definitions:
  - density $\rho = \frac{m}{v}$
  - tensile/compressive stress = $\frac{F}{A}$
  - tensile/compressive strain = $\frac{\Delta x}{L}$
  - Young's modulus E = stress/strain
  - Hooke's law $F = k\Delta x$
  - work done in stretching/compressing a wire/spring,
    Elastic strain energy, $\Delta E(el) = \frac{1}{2} F\Delta x = \frac{1}{2} k(\Delta x)^2$

A3 Fluids in motion

Understand the following concepts and apply them in industrial and domestic situations:

- Fluid flow patterns, streamline and turbulent flow.
- Viscosity.
- Viscous drag.
- Mass of fluid flow per second for all points along a pipe or stream tube is constant.
- Non-Newtonian fluid flow.
- Rate of fluid flow and pressure.
- Bernoulli's principle.

Learning aim B: Investigate the properties and uses of radioactivity

B1 Structure of the atom and forces

- Basic model – Protons, neutrons, electrons, charges on each and relative sizes.
- Experiments by Rutherford, Geiger and Marsden to determine the structure of atoms.
- The periodic table of elements – atomic number and atomic mass.
- Isotopes – atoms of the same element with different numbers of neutrons in the nucleus.
- Forces and charges – Nuclear Force (holds protons together in the nucleus), Electric Force (repels protons from each other).
- Nucleus stability – dependent on number of protons and neutrons.

B2 Ionising radiation

- Radioactive decay and half-life.
- Ionising radiation – alpha, beta and gamma radiations and relative compositions, properties and mass.
- Effect of a magnetic field.
- Transforming the nucleus – alpha and beta decay principles.
- Nuclear fission principles.
- Detection of ionising radiation using the Geiger-Muller tube.
- Health hazards and radiation dosimeter badges in industry.
- Background radiation – natural sources (e.g. radon gas, cosmic rays) and human developed sources (e.g. buildings, medical uses as tracers, nuclear power, food and drink industry).
- Case study – dealing with nuclear power station accidents.

B3 Applications of radioactivity

- Nuclear power – generating electricity by splitting the nucleus of Uranium 235.
- Radiocarbon dating of rocks younger than 60,000 years and radioisotope dating of older rocks.
- Gamma and X-ray radiography in medical treatment and industry.
- Radioactive tracers in medical diagnosis and industrial flow monitoring.
- Production of Plutonium for nuclear weapons.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand thermal physics, materials and fluids		
A.P1 Describe the general applications of thermal physics in homes and industry. **A.P2** Outline the physical aspects of materials used in the home and industry. **A.P3** Describe the main aspects of fluids as applied to home and industrial situations.	**A.M1** Explain how the principles of thermal physics applies to the home and industry. **A.M2** Explain the physical aspects of materials in relation to their use in the home and industry. **A.M3** Explain the concepts of fluid flow as applied to the home and industrial situations.	**A.D1** Analyse the importance of thermal physics, materials and fluids in home and industrial situations.
Learning aim B: Investigate the properties and uses of radioactivity		
B.P4 Outline the structure of the atom, the periodic table and forces involved. **B.P5** Describe the essential aspects of ionising radiations. **B.P6** Describe the main applications of ionising radiations.	**B.M4** Explain the structure of atoms and forces involved. **B.M5** Explain the essential aspects of ionising radiations. **B.M6** Explain the main applications of ionising radiations.	**B.D2** Evaluate the uses of radioactivity in terms of benefits and risks.

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.M2, A.M3, A.D1)

Learning aim: B (B.P2, B.P3, B.P4, B.M2, B.M3, B.M4, B.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- scientific magazines, journals and textbooks
- the internet, relevant DVDs, simulation models
- radioactive materials and Geiger-Muller tubes if available, or simulations from electronic software
- range of materials and equipment for safe testing (weights, micrometre screw gauges, wires of various gauges, goggles, gloves)
- viscosity tube and materials/clamps/stands etc.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will explain in detail, the fundamental aspects and concepts listed for thermal physics, materials and fluids in motion in the context of both domestic and industrial applications. Learners' work will indicate a high level of structure in reporting, with clear presentation of practical investigation, results obtained and mathematical interpretation of results. Work will be clearly linked to the concepts investigated and demonstrate support for the methods used in domestic and industrial situations.

For Merit standard, learners will work with independence and produce descriptions of the essential features of thermal physics applicable to domestic and industrial contexts. Learners will present clear definitions of key aspects and concepts in thermal physics, materials and fluids with an appropriate level of understanding demonstrated by examples. Practical investigations in the most appropriate concepts will be performed diligently, with appropriate attention given to safe completion and accurate representation of data and information. Learners will demonstrate an understanding of the main concepts in this unit by providing key definitions with suitable examples in support. Mathematical presentation from experiments will be clear and accurate with few errors.

For Pass standard, learners will describe the main features of thermal physics which applies to both home and industry. Work produced should include accurate definitions and use of key measurements in electricity, temperature and pressure, 'work done' and efficiency. Physical concepts relating to energy, gases, law of conservation of energy and the second law of thermodynamics should also be outlined in general terms with practical activities and investigation into changes of state and specific heat capacity. Learners will provide clear definitions of key concepts in materials investigation with suitable practical evidence linked to density, tensile/compressive stress and strain, Hooke's Law and elastic strain energy. Concepts studied relating to fluids in motion should be clearly described in the context of appropriate industrial and domestic situations

Learning aim B

For Distinction standard, learners will evaluate the main uses of radioactivity in a number of significant applications. This work will be presented in a comprehensive report, which demonstrates the learners' ability to carry out effective research of current material and to assimilate the information appropriately and accurately. Aspects learned about ionising radiations for pass and merit standard will be included in this work to demonstrate the learner's clarity of understanding in the subject material. Where personal viewpoints are made concerning continued developments in the use of radioactive sources, effective justifications should be included.

For Merit standard, learners will work with greater independence to outline the main factors of importance in the Periodic Table, isotopes, nuclear and electric forces. Explanations of how the stability of the nucleus is dependent on the numbers of protons and neutrons will be clearly developed and half-life will be demonstrated using accurate graphs with a possible practical element included. Research and explanations of the use of ionising radiations and the problems involved in their use will be clear and comprehensively covered, with factual statements included throughout.

For Pass standard, learners will use the Periodic Table of elements to illustrate the key particles of atomic structure – protons, neutrons and electrons, providing their relative sizes and charges and including accurate definitions of atomic mass and atomic number. Learners will provide clear definitions and examples of isotopes, show an understanding of nuclear and electric force and how the stability of the nucleus is dependent on the number of protons and neutrons. A good description of radioactive decay and half-life will be presented. Clear description of the ionising radiations and the effect of a magnetic field on their direction will be given, together with coherent explanation of alpha and beta particle decay. Wherever possible, learners should be given the opportunity to demonstrate detection of ionising radiation using suitable radioactive sources and a 'Geiger-Muller' tube, which would then lead on to the production of a research activity on the uses and drawbacks of ionising radiations in society, which would include; the medical industry, nuclear power, radiocarbon dating, radioactive tracers and nuclear weapons.

Links to other units

This unit links to:

- Unit 8: Contemporary Issues in Science
- Unit 22: Medical Physics techniques
- Unit 23: Materials Science.

Employer involvement

This unit would benefit from employer involvement in the form of:

Guest speakers from nuclear power station or related visits to research laboratories/Universities or hospitals using ionising radiation for practical benefit or research.

Opportunities to develop transferable skills

- research techniques developed in a specialist subject area
- practical work and development of graphical representation of data sets
- effective appraisal of information to develop balanced judgements
- use of mathematical methods of explanation.

Unit 8: Contemporary Issues in Science

Level: 3
Unit type: Internal set assignment
Guided learning hours: 120

Unit in brief

This unit will enable learners to develop their skills and understanding in evaluating the impact of contemporary scientific issues and how they are discussed in publications.

Unit introduction

In this unit, you will explore contemporary science issues and their impact on the world we live in, developing your skills of analysis and interpretation.

You will consider a range of contemporary science issues from advances in medical treatments, including stem cell therapy and genetic engineering, to developments in nanotechnology and food technology. You will look at the environmental, ethical, moral, social, political and/or financial impact of these developments, including their potential benefits, disadvantages and risks.

You will develop your research and critical thinking skills by learning how to assess the reliability of sources of published scientific information and the presentation of science reporting and its relationship with the reporting medium and target audience. You will also gain an understanding of the influence of organisations and individuals on contemporary science issues and will put forward reasoned arguments about these issues. You will evaluate and interpret qualitative and quantitative evidence and justify your own judgements. To complete the assessment task within this unit, you will need to draw on your learning from across your programme.

The skills you develop in this unit will support you in progressing to a variety of science and science-related higher education courses and to employment in the science or applied science sector.

Assessment

This unit has a set assignment. Learners must complete a Pearson Set Assignment Brief.

Learning aims

In this unit you will:

A Understand scientific issues in terms of the economic, environmental, ethical and social impact and future developments

B Understand the influence of different organisations and individuals on scientific issues

C Understand how to interpret, analyse and evaluate scientific information

D Understand how science is reported and presented in different media and for different audiences.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand scientific issues in terms of the economic, environmental, ethical and social impact and future developments	**A1** Contemporary scientific issues **A2** Implications of scientific issues **A3** Research and development of a scientific issue	This unit is assessed through a Pearson Set Assignment.
B Understand the influence of different organisations and individuals on scientific issues	**B1** Organisations and individuals **B2** Scope of influence	
C Understand how to interpret, analyse and evaluate scientific information	**C1** Interpretation and analysis of scientific information **C2** Evaluation of scientific information	
D Understand how science is reported and presented in different media and for different audiences	**D1** Reporting media and target audiences **D2** Presentation of science reporting	

Content

Learning aim A: Understand scientific issues in terms of the economic, environmental, ethical and social impact and future developments

A1 Contemporary scientific issues

- The following are potential areas for learners to explore contemporary scientific issues:
  - energy sources, e.g. renewable and non-renewable, use of fuels in transport, carbon capture
  - medical treatments, e.g. proton beam therapy, prosthetics, stem cell therapy, cloning techniques, genetic engineering
  - pharmaceuticals, e.g. resistance to antimicrobials, performance-enhancing drugs in sport
  - chemicals, e.g. use of insecticides, plastic waste in oceans, acidification of oceans
  - nanotechnology, e.g. uses in cosmetics, health effects of using diesel fuel, space exploration
  - food technology, e.g. GM crops, food composition (fat, salt and sugar content), preservatives.

A2 Implications of scientific issues

- Economic – production, distribution and trade of goods, services or resources; supply and demand of goods, services or resources; impact on a macro and microeconomic scale; income, expenditure or investment in a scientific issue.
- Environmental – surroundings or conditions; biotic (living) and abiotic (non-living) elements of the environment; local and global environments; natural and developed environments; changes to the environment caused by a scientific issue
- Ethical – values held by individuals; rights and wrongs of a scientific issue; areas of conflict with other influences over a scientific issue (e.g. political, medical, legal, religious, social, economic).
- Social – types of interaction between individuals and collectives of people; improvements and deterioration in social factors caused by a scientific issue (e.g. health, employment, education, travel, communication).

A3 Research and development of a scientific issue

- To provide a solution to a specific problem.
- To improve the efficiency of existing technology.
- For commercial gain or for humanitarian purposes.
- To make new discoveries and further understanding.
- To explore the potential and application of a discovery.

Learning aim B: Understand the influence of different organisations and individuals on scientific issues

B1 Organisations and individuals

- Government and global organisation, e.g. World Health Organization (WHO), European Union (EU), United Nations (UN), environmental agencies, food standards agencies.
- Non-government organisations, professional bodies and associations, e.g. International Science Council (ICS) and its member unions, Médecins Sans Frontières.
- Universities and research groups/teams.
- Private and multinational organisations, e.g. oil companies, pharmaceutical companies, fair trade organisations.
- Voluntary pressure groups, e.g. charities, trusts, World Wildlife Fund (WWF), Greenpeace, Friends of the Earth.
- Individuals e.g. scientists, engineers, medical professionals, politicians, entrepreneurs, campaigners, journalists, members of the public.

B2 Scope of influence

- Areas of influence – e.g. research, education, political, economic, social, environmental, health.
- Type of influence – e.g. funding, investment, advisory, regulatory, legislative, advertising, marketing, campaigning.
- Spheres of influence – upon countries, governments, industries, private organisations, the public, the scientific community.

Learning aim C: Understand how to interpret, analyse and evaluate scientific information

C1 Interpretation and analysis of scientific information

- Qualitative evidence, e.g. reference to established sources of information.
- Quantitative evidence, e.g. numerical data, including calculations, graphs, tables and statistics.

C2 Evaluation of scientific information

- Validity and reliability of data, including:
  - sample size
  - number of references to publications
  - use and misuse of data, e.g. extracting or misquoting data
  - authenticity of data, e.g. date of publication, author/source of information in article(s).
- Evidence to support conclusions/claims made.

Learning aim D: Understand how science is reported and presented in different media and for different audiences

D1 Reporting media and target audiences

- Reporting medium:
  - specialist journals, e.g. Nature, other peer-reviewed journals
  - science magazines, e.g. New Scientist
  - TV
  - internet and social media
  - national and local newspaper articles
- The target audience:
  - general public
  - scientific community
  - pressure groups, e.g. lobbyist
  - political representatives.

D2 Presentation of science reporting

- Detail and accuracy.
- Level of language used.
- Style of writing and correct use of terminology, referencing and technical language.
- Visuals, e.g. use of graphs, diagrams, tables, charts.
- Biased viewpoint.
- Quantity and quality of scientific information, e.g. a scientific article versus tabloid extract.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand scientific issues in terms of the economic, environmental, ethical and social impact and future developments		**A.D1** Assess the probable implications of future developments within a scientific area.
A.P1 Describe contemporary scientific issues which have benefits and disadvantages for society. **A.P2** Describe further research and development within a scientific area.	**A.M1** Discuss the economic, environmental, ethical and social implications of a contemporary scientific issue. **A.M2** Justify further research and development in a scientific area.	
Learning aim B: Understand the influence of different organisations and individuals on scientific issues		**B.D2** Assess the impact of the influence of organisations and individuals upon a scientific issue.
B.P3 Identify organisations and individuals in connection with a range of scientific issues. **B.P4** Explain the role of organisations and individuals in connection with a scientific issue.	**B.M3** Discuss the influence that organisations and individuals have upon a scientific issue.	
Learning aim C: Understand how to interpret, analyse and evaluate scientific information		**C.D3** Evaluate the reliability and validity of the conclusions within the articles.
C.P5 Summarise conclusions on a scientific issue by different articles. **C.P6** Discuss information and references within the articles to support the conclusions being made on a scientific issue.	**C.M4** Assess how evidence presented within the articles has been interpreted and analysed. **C.M5** Assess the accuracy and authenticity of the articles.	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim D: Understand how science is reported and presented in different media and for different audiences</td><td rowspan="2">D.D4 Produce an article which evaluates a scientific issue for a professional audience, using selected sources and further research.</td></tr>
<tr><td>D.P7 Explain how a scientific issue is reported and presented for different audiences.
D.P8 Plan articles that report on a scientific issue for two different target audiences.</td><td>D.M6 Produce an article which discusses a scientific issue for a general audience, using information from selected sources.</td></tr>
</table>

Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners.

Further information for teachers and assessors

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will assess the implications of future developments within a scientific area. For each development that the learner has given, they must propose and discuss the positive and negative impacts that this would bring in terms of economic, environmental, ethical and social considerations, and explore how these are interrelated. They will be able to reach valid judgements and conclusions on the probable impacts of the development of the scientific area, through the application of evidence and information from their source material.

For Merit standard, learners will discuss the ethical, social, economic and environmental implications of a contemporary scientific issue. They must show the use of at least three different sources or references and citations in order to qualify the points made in their discussion of the four main implication areas. Learners will be expected to have considered several different impacts under each implication area.

Learners will justify why further research or development in the scientific area is required. This will could be specifically related to economic, environmental or social benefits that it would bring a society or as a solution to ethical, environmental or social problems that are faced. Learners will be expected to propose their own possible research and development suggestions in addition to current research and development that they have researched.

For Pass standard, learners will describe at least three different contemporary scientific issues in a related area (i.e. energy, medicine, pharmaceuticals, chemicals, nanotechnology or food technology) which have benefits or disadvantages for society. They will need to demonstrate a sound understanding of the scientific issues and how they relate to a modern society. They will consider how society functioned previously to the scientific issue/advancement so that they can fully describe the impact of the issue.

Learners will select one of the scientific issues and describe ways in which the issue could be researched further if there are disadvantages for society or how it could be developed further so that benefits are enhanced. Learners will need to show evidence of further reading to be able to identify and describe further research or developments of the scientific issue.

Learning aim B

For Distinction standard, learners will assess the impact of the influence of organisations and individuals upon a scientific issue. Learners will look at significant events, or developments, in the scientific issue and identify the impacts that arose, or will arise, from it. The event or development must be quantifiable in some way. They will explain how the influence of each organisation and individual is connected to the impacts identified, and whether they were a direct or indirect cause of the impact or, alternatively, how they were impacted. They will assess the relative magnitude of each group's contribution to the event/development to conclude which had the greatest influence.

For Merit standard, learners will discuss the influence that organisations and individuals have upon one specific scientific issue. They will need to clearly identify examples from articles or case studies where each named organisation or individual has had an influence on the scientific issue. They will expand upon the example by explaining the type of influence that has been exerted and who or what has been influenced. For each group, they will use their research of the organisation or individual to propose how they will respond to any future developments and how they could increase their influence.

For Pass standard, learners will identify organisations and individuals in at least three different contemporary scientific issues. Learners will need stimulus material such as articles or case studies of the scientific issue which reference a variety of organisations and individuals. They will need to state what type of organisation can be identified and for individuals that have been identified, whether they represent a particular type of organisation. Learners will be expected to identify at least one example of each major category of organisation in the *Content* section. They will need to reference sources to cite how the organisation or individual is involved with the issue.

Learners will select one of the scientific issues and explain the role of the organisation or individual in more detail, with respect to their purpose or motivation. Some background research will be expected to build up a succinct profile of the organisation or individual.

Learning aim C

For Distinction standard, learners will evaluate articles on the same scientific issue, by presenting reasoned judgements about the reliability and validity. They will consider the reliability of each article in terms of the quantity, quality and range of: the information and data that is used; the sources, references and citations used; and the experience and credibility of the author/source of the publication. They will use their comparison of conclusions and consideration of sources of information from each article (together with their own analysis, interpretation and research) to discuss whether one article has more validity over the others or if they have equal value. Learners should look for evidence that an article has, or would have, been reviewed independently or is cited elsewhere in other publications as a means to judge its reliability and validity. They will also identify any notable omissions of facts or evidence within the article that would influence the scientific issue.

For Merit standard, learners will assess the evidence presented in each article for themselves, drawing their own interpretations and analysis from it. Where the evidence is from a secondary source, they will return to the original source of the information cited or referenced by the article and draw their conclusions independently. They will discuss how closely their analysis matches that of the article, or whether an alternative interpretation is also possible.

Learners will also assess how accurately each article has used its sources and the information that it refers to. They will also assess the authenticity of each article, in terms of the author's credentials, experience and knowledge in the scientific area and how much of the article is based upon the author's own contribution and knowledge as opposed to using the work of others. They will also look for indications of whether the author or publication is taking an impartial approach to the scientific issue or whether they are promoting a particular viewpoint or conclusion.

For Pass standard, learners will examine a minimum of three different articles on the same scientific issue and summarise the conclusions or main points made by each. They will provide a comparison to establish which articles are making similar or related conclusions/points, and whether any articles are drawing an opposing conclusion or viewpoint.

Learners will identify the information within the articles which each author has used to arrive at their conclusions or key points. They will discuss the type of information that is presented (e.g. quantitative or qualitative evidence, expert or general opinion), where it is from (e.g. primary research, secondary data), and how it is presented (e.g. graphically, pictorially, cited, referenced). They will discuss any references made by the article to other sources of information in terms of number, relevance, date of publication and credibility of author/source.

Learning aim D

For Distinction standard, learners will produce an article which evaluates information and evidence for a scientific issue for their target audience of professionals. The article will follow the learner's plan for structure, content, detail, style and tone, but will also need to be clear, coherent, consistent and logical in its reporting. The article will use the learner's own further research integrated with the selected sources of information, to give a synthesised report. Learners will evaluate supporting and conflicting evidence, and will put forward their own conclusion or recommendation on the scientific issue.

For Merit standard, learners will produce an article which discusses a scientific issue for a general audience. The article will follow the learner's plan for structure, content, detail, style and tone, but will also need to be clear and coherent. The article will select and summarise the main points and evidence from the selected sources, including any supporting and conflicting statements.

For Pass standard, learners will examine a minimum of three different articles on the same scientific issue to explain how it is reported and presented for its target audience. The articles selected must come from very different publications or media. Learners will identify the intended audience for the article and will explain how the structure and content of the article is suited to them.

Learners will plan two articles on the same scientific issue but for different target audiences. One target audience will be the general public and the other will be a professional audience e.g. scientists, politicians, etc. Learners will need to show evidence that they have considered what would be an appropriate format and medium for each audience and for the issue that they will be reporting upon (i.e. blog, social media, information leaflet, newspaper article, specialist journal, research paper, etc). The plan will outline the purpose of the article, the intended structure, level of detail and accuracy, level of language and terminology, style of writing and visual aids, and the quality and quantity of scientific information that needs to be conveyed.

Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner's work. This may mean that learners be supervised.

Resources: all learners should have access to the same types of resources to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 2: Principles and Applications of Chemistry I
- Unit 3: Principles and Applications of Physics I
- Unit 5: Principles and Applications of Biology II
- Unit 6: Principles and Applications of Chemistry II
- Unit 7: Principles and Applications of Physics II.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- independent investigation and research skills
- scientific written and communication skills
- data interpretation and analytical skills
- formal written communication
- self-management and planning skills
- evaluative and assessment skills.

Unit 9: Biomedical Science

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit will help learners understand the role biomedical scientists play in identifying the causes of disease and in helping medical personnel to offer suitable treatments.

Unit introduction

This unit will help you understand three key areas of biomedical science: haematology, histology/cytology and biochemical balance. The analytical and diagnostic testing carried out in these three areas support other health professionals in screening, diagnosing, monitoring disease progression and treatment.

In this unit you will concentrate on biomedical science in relation to the human body, but many of the same techniques are used in veterinary science. Similar techniques are also valuable in the pharmaceutical industry, the blood and tissue transfusion and transplant service, forensic science and food technology.

You will have opportunities to investigate and understand blood and its importance, and how it can be used to diagnose and treat disease. Analysis of blood biochemistry provides important information to medical practitioners about the functions of the human body. You will consider the importance of maintaining 'norms' within the body and how deviations from these levels provide clues as to what is happening in the body to enable conditions to be diagnosed and treated. Having completed this unit, you will be in a position to know which branch of biomedical science interests you and what further courses you can pursue to enter the profession. This may be entering as a trainee technician or after completing a biomedical science-related degree course.

Learning aims

In this unit you will:

A Understand the principles of haematology and its use in medical diagnosis

B Examine the use of histology and cytology in medicine

C Examine the use of urinalysis as an analytical and diagnostic tool.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the principles of haematology and its use in medical diagnosis	**A1** The components of blood **A2** Changes to blood components and composition **A3** Diagnostic techniques used in haematology	Practical work to investigate microscopically the components of blood and use of diagnostic techniques to identify disease. Observation records will be required. A report explaining blood component structure and function along with causes and consequences of dysfunction Analysis of the use of diagnostic blood tests for different diseases.
B Examine the use of histology and cytology in medicine	**B1** Tissue investigation and consequences of diagnosis **B2** Role of informatics and record keeping	A report/presentation on the implications for society, the health service and individual patients of using histology and cytology in detecting and diagnosing disease occurrence, including how information is used and communicated to key stakeholders.
C Examine the use of urinalysis as an analytical and diagnostic tool	**C1** Urine composition **C2** Urinalysis	Practical work and a report on the use of urinalysis in diagnosing changes of health status.

Content

Learning aim A: Understand the principles of haematology and its use in medical diagnosis

A1 The components of blood

- Structure and function of the following blood components:
  - erythrocytes
  - leucocytes
  - thrombocytes (platelets)
  - plasma and serum.

A2 Changes to blood components and composition

- The effects of diseases and disorders on the overall composition of blood, including the effects on the structure and function of key blood components:
  - erythrocytic diseases associated with types of anaemia, thalassaemia, vitamin B12 and foliate deficiency, sickle cell anaemia
  - leucocytes (white blood cell) diseases associated with lymphocytosis, AIDS, infectious
  - mononucleosis
  - bone marrow failure
  - leukaemia
  - lymphomas such as Hodgkin and non-Hodgkin diseases
  - haemostasis and thrombosis, and their significance to the body
  - hepatitis B and C
  - syphilis
  - HIV.

A3 Diagnostic techniques used in haematology

- The principles behind haematological diagnostic techniques, including the practical application of these techniques, as appropriate:
  - counts of red blood cells and platelets
  - mean corpuscular and blood volumes
  - analysis for iron deficiency
  - coagulation/clotting
  - haemoglobin tests
  - blood grouping (typing).

Learning aim B: Examine the use of histology and cytology in medicine

B1 Tissue investigation and consequences of diagnosis

Types and methods of sample removal, preservation and examination, including consideration of appearance of normal and abnormal results, methods of recording these and the implications of the results on patients, their families, the health service and society in general.

- Cell and tissue specimen analysis:
  - screening (bowel cancer)
  - aspirates (cerebrospinal fluid, amniocentesis)
  - surgical removal of tissues for disease identification (cervical, breast, prostate tissue)
  - allergic reactions tested by skin tests
  - tissue typing for bone marrow transplantation
  - purposes of specimens taken in autopsies to establish causes of death.
- Implications of disease diagnosis to individuals, the health service and society:
  - importance of correct and timely diagnosis and treatment
  - prognosis and quality of life for individuals and their families
  - financial implications of screening costs for early diagnosis as opposed to cost of treatment when disease is diagnosed later
  - confirmation of diseases likely to cause epidemics and resulting plans for prevention.

B2 Role of informatics and record keeping

- Consideration of how information regarding diagnostic tests is recorded, stored and disseminated:
  - right information to right person at right time
  - processing and reporting, correct results matched with correct sample
  - medical records – accurate and complete
  - confidentiality.

Learning aim C: Examine the use of urinalysis as an analytical and diagnostic tool

C1 Urine composition

Main constituents of urine, including their biochemical sources in the body and how these vary in relation to healthy renal function:

  - water
  - organic solutes, e.g. urea, hormones, carbohydrates
  - inorganic ions, e.g. sodium, chloride and potassium.

C2 Urinalysis

- Urine sampling to prevent misleading results in urinalysis:
  - why cleanliness of genitalia and sterility of collection vessels before sample collection is important
  - the purpose of mid-stream sample collection
  - why specific times of day for sample collection are sometimes recommended
  - length of time between sample collection and testing, and preservation methods of samples that will not be tested immediately.
- For each of the key indicators present in urine, the following must be considered:
  - normal ranges (as appropriate)
  - when each kind of test (visual, chemical or microscope) is considered appropriate
  - problems presented in result interpretation and steps to counter this, e.g. use of optical readers in digital pregnancy tests and automation of result reading
  - the mechanisms each analysis uses
  - health implications of changes in these levels, to include how and why the changes are brought about.
- Key indicators used in urinalysis:
  - visual – colour and clarity
  - chemical tests using test strips: specific gravity for determining concentration, pH, blood, protein, glucose, bilirubin, urobilirubin, ketones, nitrite, human chorionic gonadotropin (HCG)
  - under the microscope: crystalline structures, trichomonads, blood cells, microorganisms, epithelial cells, casts.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the principles of haematology and its use in medical diagnosis		
A.P1 Explain the structure and function of the main components of blood. **A.P2** Explain how diseases affect the composition of blood. **A.P3** Correctly carry out diagnostic testing of blood.	**A.M1** Discuss the basis of diagnostic tests for different diseases.	**A.D1** Evaluate the use of diagnostic testing of blood in relation to the detection of diseases.
Learning aim B: Examine the use of histology and cytology in medicine		
B.P4 Explain the use of analytical investigation in disease screening. **B.P5** Explain the use of analytical investigations of tissue samples. **B.P6** Explain the use of informatics and data handling in biomedical science.	**B.M2** Analyse how the interpretation and informatics of diagnostic test results are used as a tool for planning appropriate treatment.	**B.D2** Evaluate the implications of screening and early disease diagnosis for the individual and for the health service and society.
Learning aim C: Examine the use of urinalysis as an analytical and diagnostic tool		
C.P7 Explain how urine composition may vary in relation to health. **C.P8** Correctly carry out simple urinalysis.	**C.M3** Analyse how the results of urinalysis are used in diagnoses of health status changes.	**C.D3** Evaluate the use of urinalysis in domestic and clinical settings.

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.D1)

Learning aim: B (B.P4, B.P5, B.P6, B.M2, B.D2)

Learning aim: C (C.P7, C.P8, C.M3, C.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- well-equipped haematology, histology/cytology and urinalysis laboratories and/or equipment
- appropriate research facilities.

Essential information for assessment decisions

Learning aim A

For distinction standard, learners must clearly link the disease and blood composition, and make judgements about the appropriate selection, implementation and interpretation of diagnostic tests by medical workers. They will give a detailed consideration of the implications of misdiagnosis of disease, with the accurate use of appropriate scientific terminology throughout.

For merit standard, learners must consider how diagnostic testing of blood relates to accurate identification of two diseases. They must discuss changes to the composition of blood with reference to normal ranges in humans. Learners will make reference to required equipment and techniques used in each diagnostic test. They must give sustained lines of reasoning, free of fundamental errors.

For pass standard, learners must link the structure and function of each of the main components of blood. They must select two diseases associated with dysfunction or abnormality of blood components, and clearly state the cause of each disease and its effect on blood composition with reference to key indicators in blood composition. Observation records will be required to validate learners' practical work. At this level, learners must be able to follow instructions, work methodically and demonstrate awareness of good health and safety practice.

Evidence of this should be identified in the write-up and records of the practical work produced by the learners should have a good level of accuracy in results/observations obtained.

Learning aim B

For distinction standard, learners must demonstrate an understanding of the value of screening for disease and how the early detection of disease can impact on prognosis and quality of life. They must evaluate the importance of early diagnosis leading to treatment and the implications of this, including a consideration of the associated emotional, economic and financial costs to the individual, the health service and society. Learners must demonstrate an understanding of the importance of accurately sampling and reporting diagnostic results, along with accurate medical records being available to the right people at the right time. It is expected that learners will access secondary data to support their conclusions about prevention and early treatment.

For merit standard, learners must provide a methodical and detailed examination of how the accuracy of testing and reporting of results to other health professionals is important in the treatment of the patient. They must consider how informatics are managed to ensure the prompt and accurate recording and dissemination of diagnostic test results. This will include an awareness of monitoring methods in automated sample analysis.

For pass standard, learners should consider the dual role of screening for disease and for detecting early signs of disease. They will describe different screening techniques and explain their role in early detection of disease. Learners should discuss the analysis of tissue samples removed surgically for examination in relation to how this can relate to the type of treatment that may be required. Learners must explain the use of informatics in biomedical science, including the management of data to maintain confidentiality while ensuring key personnel involved with the treatment of a patient have essential information in a timely and accessible format.

Learning aim C

For distinction standard, learners must demonstrate their understanding and knowledge of the normal biochemical functioning of body systems. They will need to be able to access and quote data identifying normal ranges of values for substances present in urine samples. Learners must evaluate the role of the biomedical scientist in providing the data requested by other health professionals to ensure effective monitoring of the progression and treatment of a patient in at least three cases. Learners will need to explain the issues related to sample collection, preservation and analysis in domestic and clinical settings, including a consideration of the implications of inaccurate interpretation of results and how errors can be reduced.

For merit standard, learners must identify and discuss how screening compares test results indicating abnormal values with normal values when attempting a diagnosis for particular diseases. They will make reference to how changes in health status along with contamination when collecting or preserving urine samples can cause abnormal levels of substances in three or more cases.

For pass standard, learners will provide clear details about how normal biochemical values are maintained in the body in relation to urine production, and why these are among the first tests ordered when diagnosing and treating patients.

Learners will carry out simple urinalysis tests, accurately identifying the changes in three or more substances in samples of urine and suggesting what these changes indicate in relation to health. They must specify how the samples of urine should be obtained in order to prevent misleading results.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 4: Investigative Project Skills
- Unit 5: Principles and Applications of Biology II
- Unit 11: Functional Physiology of Human Body Systems
- Unit 13: Biological Molecules and Metabolic Pathways
- Unit 19: Microbiology and Microbiological Techniques.

Employer involvement

This unit would benefit from employer involvement in the form of:

Centres may involve employers in the delivery of this unit if there are local opportunities. Visiting speakers from health centres, blood transfusion services, doctors' surgeries and pathology laboratories can give a valuable insight into their work.

All large hospitals have laboratories where blood products, cells and so on are dealt with. Since health and safety regulations may make it difficult to gain access, it is possibly best to approach the head of the medical services at a local hospital or the blood transfusion service to find out what access, speakers or other facilities are available to a centre teaching this unit.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- analytical and observation skills
- ability to work in a scientific environment
- ability to interpret results of biological investigations
- formal written communication
- self-management and planning skills
- ability to carry out independent research.

Unit 10: Climate Change

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers the principles, historic evidence and present-day understanding of the Earth's atmosphere.

Unit introduction

In this unit, you will explore the main forms of evidence that have been used to provide our current understanding of Earth's climate and the changes that occurred in the past. You will develop your knowledge of the key areas of atmospheric changes brought about by variations in gases, linked to both natural and human activities.

You will focus on the study of present-day scientific knowledge and gain an appreciation of the advances made in our understanding of the Earth's climate, based on historic patterns and science modelling. Your skills in analysis, investigation and research will be enhanced, and you will add to your knowledge of the effect of particular human activities and comparison with natural events, leading to a sound understanding and appreciation of their ultimate effect on our climate. You will be introduced to the many factors related to the atmosphere, and you will gain an insight to the practicalities and problems associated with maintaining the level of greenhouse gases at present and the difficulties faced by the Earth's inhabitants in reducing current levels in the short- and long term.

With new evidence and sound modelling of the Earth's climate, you will analyse the evidence for current and future changes in order to provide links with past climate change events, with a view to establishing possible ways of limiting the damage to the delicate balance of atmospheric gases. You will discuss current proposals and analyse them in the context of the science involved, and the possible effects on human industrial and technological development.

The skills you learn in this unit can be applied to other areas of study and to workplace practices. You can progress to further education to study science-related courses. You can also progress to the environmental science industry, which involves climate data analysis, research and development.

Learning aims

In this unit, you will:

A Understand the fundamental aspects of the Earth's atmosphere and its history

B Undertake research to develop an understanding of the evidence for atmospheric change related to 'greenhouse gases'

C Investigate the measures outlined by the Intergovernmental Panel on Climate Change (IPCC) to combat future climate change.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the fundamental aspects of the Earth's atmosphere and its history	**A1** Evidence and theory of early atmosphere composition **A2** Changes to the atmosphere with time **A3** Development and understanding of present-day atmosphere composition	A scientific report and diagrams, including correct use of terms and numerical values. A presentation that outlines the features and numerical values associated with early gaseous composition. Diagrams for all atmospheric levels. Descriptions of volatile components and sources of early atmospheric gases and elements.
B Undertake research to develop an understanding of the evidence for atmospheric change related to 'greenhouse gases'	**B1** Evidence of atmosphere changes since the start of industrialisation **B2** Nature and causes of greenhouse gases **B3** Possible future trends of atmosphere changes and their effects	Descriptions of research that gives evidence for atmospheric change. A report on the main causes of greenhouse gases and their behaviour. Discussion on scientific evidence and suggested changes to the atmosphere over time, based on a number of viewpoints.
C Investigate the measures outlined by the Intergovernmental Panel on Climate Change (IPCC)to combat future climate change	**C1** Climate change forums and the Intergovernmental Panel on Climate Change (IPCC) **C2** Changes to industrial methods and science innovation **C3** Changes that can be made by individuals	A report on the most recent meetings of the IPCC, and other forums, that address climate change. List and discuss the application of new scientific methods for industrial development that have a reduced effect on climate change. A report on what humans can change in their lives to help reduce their 'carbon footprint'.

Content

Learning aim A: Understand the fundamental aspects of the Earth's atmosphere and its history

A1 Evidence and theory of early atmosphere composition

- Development of the Earth from nebula gases and its initial surface as molten materials.
- Pre-biological life atmosphere consisting of methane, nitrogen, carbon dioxide, ammonia, carbon monoxide, water vapour and hydrogen.
- Physical evidence in ancient sedimentary rocks, indicating chemical reactions and biochemical processes.

A2 Changes to the atmosphere with time

- Evidence of photosynthesis approximately 3 billion years ago (3×10^9 years).
- Changes of atmosphere composition from 4.5 billion years to development of plant life.
- The Earth's crust in terms of:
  - rocks
  - oceans
  - atmosphere.
- Volatile compounds – nitrogen, oxygen, helium, argon, water, carbon dioxide, hydrogen, methane, ammonia, nitrous oxide and nitrogen dioxide, hydrogen sulphide, sulphur dioxide and hydrogen chloride.
- Sources (means of adding gas to the atmosphere) and sinks (removal of gas from the atmosphere).
- Residence time as the length of time that atmospheric molecules spend in the atmosphere.

A3 Development and understanding of present-day atmosphere composition

- Main gases and %age composition (nitrogen – 78%, oxygen – 21%, argon – 1%, carbon dioxide – 0.04% and other trace gases).
- Atmospheric layers:
  - troposphere
  - stratosphere
  - mesosphere
  - thermosphere
  - exosphere.
- Altitudes of atmospheric layers in kilometres.
- Characteristics in composition and properties of individual atmospheric layers.

Learning aim B: Undertake research to develop an understanding of the evidence for atmospheric change related to 'greenhouse gases'

B1 Evidence of atmosphere changes since the start of industrialisation

- Carbon (as carbon dioxide) in the atmosphere and its change in abundance over the last 200 years.
- The 'bio-geo-chemical' cycle (carbon as the main element in biological compounds and other substances, including carbonate rocks).
- The carbon cycle and fossil fuels (oil, coal and gas).
- Carbon sinks – soil, plants and oceans.
- Influence of 'Milankovitch cycles'.
- Graph of CO_2 levels in the atmosphere – steady peaks and troughs cycle pre-1950 (180–300 ppm), rapid increase (300 to 410 ppm) since 1950:
  - seven cycles of glacial advances and retreats in the last 800,000 years
  - changes to the orbit of the Earth having an important effect
  - effect of CO_2 and other gases on passage of infra-red radiation through the atmosphere
  - evidence from ice core drilling (Greenland, Antarctica, mountain glaciers)
  - evidence from sediments in the oceans, tree rings and coral reefs.
- Increase in methane levels (84 times more heat per unit mass than CO_2).
- Temperature patterns – five of the warmest years recorded since 2010, 0.4°C increase in temperature of oceans to depth of 700 m over last 50 years.
- Loss of ice sheets and glacial retreat, loss of snow cover.
- Sea level rise by 20 cm over last 100 years.
- Increase in extreme weather events (hurricane strength and abundance, increased rainfall).
- Increase in acidity of oceans.
- Melting of permafrost.

B2 Nature and causes of greenhouse gases

- Greenhouse gases; carbon dioxide (volcanic eruptions, deforestation, burning of fossil fuels such as wood and coal, change of land use), water vapour (rise in global temperature increases the amount of water vapour as clouds and rainfall in the atmosphere), nitrous oxide (burning fossil fuels and biomass, use of organic fertilisers), methane gas (produced from landfill sites, agriculture, ruminant digestion), chlorofluorocarbons (CFCs) – synthetic compounds used in industry that also destroy ozone in the atmosphere.

B3 Possible future trends of atmosphere changes and their effects

- Rise in atmospheric levels of CO_2 and the 'greenhouse effect'.
- Variation of warm and cold areas on the Earth's surface.
- Increase of hot- and cold weather extremes.
- Increase in wind speeds in general and in hurricane-force events.
- Increased sea level rise from glacial and polar ice melting.
- Changes in plant growth owing to climate changes, including: variation in growth height, suitability of growing crops in different parts of the world, displacement of populations from low- and high altitudes as a result of increased rainfall and sea level rise.

Learning aim C: Investigate the measures outlined by the Intergovernmental Panel on Climate Change (IPCC) to combat future climate change

C1 Climate change forums and the Intergovernmental Panel on Climate Change (IPCC)

- Intergovernmental Panel on Climate Change – IPCC.
- United Nations Framework Convention on Climate Change – UNFCCC.
- Conference of the Parties – COP, first meeting in Berlin and signing of Kyoto Agreement.
- Paris Agreement of 2016 – general focus on greenhouse gas emissions.
- Youth Climate Summit initiative.
- G8 summits.
- Confirmation of scientific data and scientific agreement.
- Agreement of scientific studies and findings in the scientific community that human activities are the main cause of current climate change.

C2 Changes to industrial methods and science innovation

- Recognising main greenhouse gas emitters: production of electricity and heat, transport, manufacturing, agriculture.
- Renewable energies – increased use of solar panels, wind turbines, geothermal energy in suitable locations, hydroelectric power in highland areas, continued development of hydrokinetic energy (using the movement of water in rivers, tides and waves).
- Nuclear power – low carbon emissions throughout its operating lifetime but implications of health issues and environmental damage that must be overcome.
- Increasing fuel efficiency in transportation, increased use of electric and hydrogen fuel cell cars, buses, trains, industrial transport.

C3 Changes that can be made by individuals

- Reduction in personal carbon emissions: limit dependency on fossil-fuel transport, sharing transport (e.g. carpools), walking to nearby destinations, using bicycles, reducing personal energy use (being aware of light or heating that is not needed), recycling all materials possible.
- Adapting in larger communities to lessen the impact of climate change.
- Introduce SMART meters to homes and workplaces.
- Installation of solar roof panels and heat pumps.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the fundamental aspects of the Earth's atmosphere and its history		**A.D1** Evaluate the evidence for and understanding of atmosphere changes over time.
A.P1 Describe the evidence and theories related to the composition of the early atmosphere.	**A.M1** Discuss the differences between the early and present-day atmospheres.	
Learning aim B: Undertake research to develop an understanding of the evidence for atmospheric change related to 'greenhouse gases'		**B.D2** Compare the effects of pre- and post-industrial activities on the Earth's surface and its atmosphere.
B.P2 Describe the evidence linking global warming to industrialisation. **B.P3** Describe the factors that cause greenhouse gases. **B.P4** Explain the possible effects of climate change on the biosphere and atmosphere.	**B.M2** Analyse the evidence related to global warming and climate change. **B.M3** Explain the effects of anthropogenic activities on the future atmosphere.	
Learning aim C: Investigate the measures outlined by the Intergovernmental Panel on Climate Change (IPCC) to combat future climate change		**C.D3** Evaluate methods to address climate change.
C.P5 Describe how the effects of climate change can be addressed.	**C.M4** Explain methods that can help to address climate change.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.P4, B.M2, B.M3, B.D2)

Learning aim: C (C.P5, C.M3, C.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- the internet
- relevant DVDs.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will evaluate the main points in the development of the Earth's atmosphere and the changes that have occurred over time. Evidence for the changes to the crust and volatile compounds will be evaluated to include strengths or weaknesses and the relevance or significance of the evidence for the changes. Secondary sources must be referenced.

For Merit standard, learners must discuss the differences between the early and present-day atmosphere. The discussion will include a diagram showing the components of the present-day atmosphere, its different layers and composition, with accurate figures. Learners will focus on the crust as the rocky outer mantle, the oceans and land surface in their description, and provide an appropriate timescale on how the Earth's atmosphere has changed with time. Sources and sinks and their role in adding/removing gas from the atmosphere will be discussed, along with changes to volatile compounds found in the atmosphere over time.

For Pass standard, learners will describe the main aspects of the atmosphere of Earth from current theories about its development. There will be a clear description of the gases in the early atmosphere and a suitable timescale in Earth's development. Learners will describe the main differences in the atmosphere before and after pre-biological life, and how the biochemical processes were thought to have begun, as evidenced in sedimentary rocks. The atmospheric layers will be outlined, giving suitable thicknesses and characteristics of each layer.

Learning aim B

For Distinction standard, learners will compare the effects of the increase in fossil fuel emissions and global temperature rise pre- and post-industrial activities. Links between global temperature rise and CO_2 emissions will be explored. Appropriate and detailed graphical representation must be included and sources referenced. Other factors linked to global warming like deforestation, use of organic fertilisers, sources of methane gas and CFCs will also be explored in relation to the Earth's surface and its atmosphere. The trends of weather patterns linked to climate change will be considered using referenced recent and historical data.

For Merit standard, learners will analyse the evidence linking increase in fossil fuel emissions, rise in global temperature, global warming and climate change. Factors, including orbital aspects, glacial retreats and ice core drilling or sediments, will be analysed and used to explain the link between increased CO_2 and climate change. Graphical representation of referenced secondary source data will be included. Greenhouse gases will be described, and their effects on global warming and climate change will be included. Information on the climatic effects such as warmest/wettest/driest years on record, glacial ice retreat/rise in sea level, will be analysed to explain how human activities may have contributed to these events will need to be analysed.

Continued human activities and the impact these may have in the future on atmospheric changes must be explained. Predicted future trends of the rise in sea level and weather extremes will be explained, together with the possible effects on world populations.

For Pass standard, learners will outline the importance of carbon in fossil fuels and describe the evidence linking increased use of fossil fuels and production of greenhouse gases to industrialisation and global warming. The Milankovitch cycles will be described. The nature and causes of greenhouse gases, carbon dioxide, water vapour, nitrous oxide, use of organic fertilisers, methane gas, chlorofluorocarbons (CFCs) must be described. The possible effects of climate change rise in atmospheric CO_2, the greenhouse effect, weather extremes (temperature and wind speeds), increased sea-level rise and changes to plant growth on the biosphere and atmosphere must be explained.

Learning aim C

For Distinction standard, learners will evaluate methods used by industry and individuals to address climate change by reducing emissions, increasing efficiency and/or reduction in use of fossil fuels, recycling materials, use of renewable sources and nuclear energy and their effectiveness in addressing climate change must be evaluated.

Learners will evaluate methods identified by the Intergovernmental Panel on Climate Change (IPCC) and one other climate change forum to address climate change.

For Merit standard, learners will produce a report that explains the methods that can be used to reduce carbon footprint and change the amount of greenhouse gases that are produced industrially and by individuals. This will include the use of renewable energy sources, nuclear power and scientific innovations to increase fuel efficiency. Learners will produce a report detailing two of the main climate change forums, their importance, dates of introduction and the member countries. Key decisions/recommendations/actions agreed at the meetings to help address climate change will be explained.

For Pass standard, learners will describe changes that can be made to address climate change. The changes will include descriptions of methods of energy production and innovations that could reduce our dependence on fossil fuels. The use of renewable and sustainable energy sources and increased fuel efficiency by individuals and industry and how this can help to reduce CO_2 emissions, to mitigate climatic issues must be described.

Learners will describe the role of the Intergovernmental Panel on Climate Change (IPCC). Key reports and recommendations/actions relating to addressing climate change which have been made at their meetings will be provided, with dates of the meetings and a list of the countries involved

Links to other units

This unit links to:

- Unit 8: Contemporary Issues in Science
- Unit 18: Astronomy and Space Science.

Employer involvement

This unit would benefit from employer involvement in the form of:

Guest speakers from innovation and development companies, which will give learners an idea of the range of employment opportunities in the field of 'green' manufacturing products and current development of alternative energies. A visit to electrical power companies linked to wind farms or solar panel development would help to put the material in this unit into context.

Opportunities to develop transferable skills

- research into the development of alternative energy for science reporting
- understanding of complex atmospheric models.

Unit 11: Functional Physiology of Human Body Systems

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners will focus on the physiological make up of three human body systems (digestive, endocrine and nervous systems), how the systems function and what occurs during dysfunction. Learners will also explore the role of homeostasis in controlling and coordinating the body systems.

Unit introduction

Physiology, the working of the human body, is a fascinating topic. In this unit, you will have the opportunity to explore growth and development of three body systems and homeostasis and its role in the body. There will be opportunity to research common disorders, their causes in relation to these systems and the impact they have on a person's life. The unit provides a strong foundation for human biology study, it gives you theoretical knowledge of the structure, function and role of the digestive, nervous and endocrine systems.

You will gain insight into the importance of homeostasis in maintaining a constant internal environment that allows the body systems to function properly. Knowledge and understanding of these systems will provide an insight into how biology works in action to make a positive impact on all our lives.

This unit will help you to progress to higher education and then to a career in health promotion, public health, teaching, health service management, medical sales, nursing, counselling and social work or sports and exercise therapy.

Learning aims

In this unit you will:

A Explore the physiology of the digestive system and the use of corrective treatments for dietary-related diseases

B Understand the structure, function and disorders of the endocrine and nervous systems

C Understand the role of homeostasis in controlling and coordinating the body systems.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Explore the physiology of the digestive system and the use of corrective treatments for dietary related diseases	**A1** Structure of the digestive System **A2** Function of the digestive System **A3** Health matters and treatments related to the digestive system	A lab book/record of investigations modelling then functioning of the various parts of the digestive system. Photographs and information from the investigations will be used to create an information leaflet that explains the role and location of organs and evaluates dietary disorder in the system and possible treatments. Observation records of practical work undertaken to assess the nutrient content of food will be required. Evidence and conclusions from the investigations will be incorporated.
B Understand the structure, function and disorders of the endocrine and nervous systems	**B1** Endocrine system **B2** Disorders of the endocrine system **B3** Nervous system **B4** Disorders of the nervous system	A booklet which: • explains the organisation and role of the endocrine and nervous systems and analyses the changes that occur throughout the life of individuals • discusses the impact of overproduction and underproduction of hormones • discusses the advantages/ disadvantages of the nervous system.
C Understand the role of homeostasis in controlling and coordinating the body systems	**C1** Homeostasis **C2** Interrelationship between nervous and endocrine system **C3** Disturbance of homeostasis	A leaflet which explains the relationship between the nervous and endocrine systems in maintaining homeostasis and analyses the disruptive effects of some substances on homeostasis.

Content

Learning aim A: Explore the physiology of the digestive system and the use of corrective treatments for dietary-related diseases

A1 Structure of the digestive system

- Location and structural features of the following parts of the digestive system and associated organs:
  - mouth, pharynx, oesophagus, stomach, small intestine (duodenum, jejunum, ileum)
  - large intestine, rectum, anus
  - associated organs: pancreas, liver, gall bladder.

A2 Function of the digestive system

- Processes involved in digestion, absorption and assimilation of nutrients:
  - mechanical and chemical digestion
  - action of enzymes (protease, amylase, lipase, hydrolysis and assimilation)
  - sites of nutrient absorption, active transport, diffusion
- Chemical tests for the presence of macro-nutrients found in foods: starch, proteins, lipids, reducing and non-reducing sugars, vitamin C content.

A3 Health matters and treatments related to the digestive system

- Dietary sources and importance of macronutrients and micronutrients including symptoms of deficiencies – fibre, lipids, protein, water, carbohydrates, vitamins (A, B, C, D) and minerals (iron, magnesium and iodine).
- Digestive system diseases and physiological reasoning behind treatments, e.g. coeliac disease, irritable bowel syndrome, colitis.

Learning aim B: Understand the structure, function and disorders of the endocrine and nervous systems

B1 Endocrine system

- Target organs, ductless glands, hormones, transported in blood.
- Hypothalamus – control of pituitary gland via releasing hormones, control of daily rhythms.
- Pituitary gland – control of growth, function of sex organs, osmoregulation.
- Thyroid gland – regulation of growth and function of many body systems, role in regulation of blood calcium levels.
- Pancreas – regulation of blood sugar via production of insulin and glucagon.
- Adrenal glands – the ‘fight or flight’ response via the hormone adrenaline, regulation of blood.
- pressure via the hormone aldosterone.
- Ovaries – production of oestrogen and progesterone (sex hormones).
- Testes – production of androgen hormones which are involved in the development of maleness and the production of sperm.

B2 Disorders of the endocrine system

- Learners will understand the significance and impact of:
  - under production of hormones, e.g. Cushing's disease, hypothyroidism
  - overproduction of hormones, e.g. gigantism (acromegaly), polycystic ovary syndrome.

B3 Nervous System

- Learners will understand the components, organisation and role of:
  - the central nervous system (CNS):
    - brain and spinal cord, motor neurons, sensory neurons, nerve cells, reflex arc
    - coordination of both voluntary and involuntary activities of the body
    - conduction of nerve impulses to and from the CNS.
  - the peripheral nervous system (PNS):
    - nerves and ganglia outside the brain and spinal cord
    - somatic nervous system
    - autonomic nervous system.
  - the parasympathetic nervous system.
  - the sympathetic nervous system.

B4 Disorders of the nervous system

- Learners will understand the causes and symptoms of:
  - Parkinson's disease
  - multiple sclerosis (MS)
  - motor neurone disease.

Learning aim C: Understand the role of homeostasis in controlling and coordinating the body systems

Learners will understand the purpose of homeostasis, and how different body systems are interrelated to maintain it, and the impact of different factors that can disrupt homeostasis throughout a person's life:

C1 Homeostasis

Learners will understand the purpose of homeostasis in relation to:

- terminology, optimum, variable, stimulus, receptors/sensors, control centres, effectors, feedback
- negative feedback loops, blood pressure, body fluids (osmoregulation), gas concentration, blood sugar levels
- positive feedback loops, blood clotting, labour contractions, lactation.

C2 Interrelationship between nervous and endocrine system

Learners will understand the relationship between the nervous and endocrine system:

- role of the autonomic nervous system, breathing, heartbeat
- role of adrenal glands (fight and flight, heart rate)
- hypothalamus, link between endocrine and nervous system
- regulation of hunger, sleep rhythms, secretion of various hormones
- peripheral nervous system, autonomic system, relaying information to the brain.

C3 Disturbance of homeostasis

Learners will understand the disruptive effects of different factors on homeostasis:

- ageing, weakening of feedback loops, heart failure, diabetes
- interruption, deficiency (pathways blocked and cells lack vitamins or minerals)
- genetics, e.g. diabetes
- lifestyle, nutrition, physical activity. Drug/alcohol abuse, too much sugary food, lack of exercise/too much exercise.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Explore the physiology of the digestive system and the use of corrective treatments for dietary related diseases		**A.D1** Evaluate the effect of dietary disease and corrective treatments on human health.
A.P1 Explain the role and location of organs involved in digestion **A.P2** Correctly carry out investigations to establish sources and importance of key nutrients for a balanced diet. **A.P3** Describe the symptoms of nutrient deficiency as a result of dietary-related disease.	**A.M1** Analyse the role of digestive enzymes on each part of the digestive system **A.M2** Explain the use of corrective treatments for nutrient deficiency.	
Learning aim B: Understand the structure, function and disorders of the endocrine and nervous systems		**B.D2** Evaluate the impact of changes to the nervous and hormonal systems throughout life.
B.P4 Explain the organisation of the endocrine system in relation to its function. **B.P5** Explain the organisation of the nervous system in relation to its function.	**B.M3** Analyse how the functions of the nervous and endocrine systems are interrelated.	
Learning aim C: Understand the role of homeostasis in controlling and coordinating the body systems		**C.D3** Evaluate the disruptive effects of factors affecting homeostasis.
C.P6 Explain the purpose and need for homeostasis.	**C.M4** Analyse the relationship between the endocrine and nervous system in maintaining homeostasis.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.M2, A.D1)

Learning aim: B (B.P4, B.P5, B.M3, B.D2)

Learning aim: C (C.P6, C.M3, C.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a well-equipped laboratory and IT resources, which could be used as a reference point.

Essential information for assessment decisions

It is expected that investigative work will be carried out in this unit. Health and safety considerations are paramount, and teachers must ensure that the necessary risk assessments are carried out and communicated to their learners. Refer to CLEAPSS and/or your centre's health and safety regulations if in doubt about any of the investigative work that has been suggested.

Learning aim A

For Distinction standard, learners will research dietary-related disorders of the digestive system. Learners must choose a named digestive system-related disease that affects the normal functioning of the body. They must explain how the named disease affects the system using correct biological terminology. Learners must also consider the effects on the person that is suffering from the disease and how medical intervention seeks to treat the effects of disease. Evaluations must also cover the implications to the health status of the individual and compare this with the healthy functioning of the digestive system.

For Merit standard, learners must analyse the mode of action of digestive enzymes as applied to each of the macronutrients listed in the unit content. This will include named enzymes, the location of enzyme secretion, the location of enzyme action (if different), substrates and products of each nutrient broken down with enzymatic assistance. This will be linked to the analysis of nutrients in foods.

Learners will need to consider how nutrient deficiency can be tackled in terms of corrective treatments. They must explain the corrective treatment for the deficiency of two nutrients and how they may relieve the symptoms described.

For Pass standard, learners must perform analytical tests to identify the nutrients present in dietary sources of macronutrients as listed in the unit content, they must also give detailed descriptions of nutrient-deficiency symptoms. Learners must describe the gross anatomy of the different areas of the digestive system as listed in the unit content. Learners should label each of the areas of the digestive system and describe, in brief, the role of the component labelled.

Learning aim B

For Distinction standard, learners will evaluate changes relating to age, and to degeneration and/or disorders of the nervous and hormonal systems. One endocrine and one nervous disease/disorder must be included. The impact of changes to the hormone and nervous systems throughout a person's life will be considered and analysed. This will include developmental milestones, gross and fine motor skills, puberty, menopause and emotional and intellectual changes.

For Merit standard, learners will analyse the benefits of having both a nervous and an endocrine system. Speed of transmission, longevity of response, role of synapses should be included. The relationship between the functions of the two systems in relation to coordination and control will be analysed in detail.

For Pass standard, learners will use their own referenced, secondary sourced diagrams to show the organisation of the endocrine system. These diagrams will be used to explain how the location of the organs/glands in the system is important in relation to the target organ and the speed of response. Names and details of the function(s) of the main hormones should be given for each gland. The implications of overproduction of one hormone and underproduction of a different hormone will be explained. The relationship between different hormones should be examined and discussed. This could be in relation to one gland producing a hormone(s) to control other glands or how two hormones can work together to control blood sugar levels.

Learners will use diagrams to provide a brief explanation of the organisation of the nervous system in relation to its functions. The central nervous system, peripheral nervous system, parasympathetic and sympathetic systems must be included.

Learning aim C

For Distinction standard, learners will evaluate two factors from ageing, deficiency, toxicity, genetics, lifestyle, that can have disruptive effects on homeostasis. An evaluation of the physiological effects must be given in terms of the impact on growth and development of the individual.

For Merit standard, learners will analyse how the endocrine and nervous system work together to maintain a constant environment for biological systems to work effectively. The hypothalamus and its links to both systems must be analysed in detail.

For Pass standard, learners will provide an explanation of homeostasis, what it is and why it is important to biological systems. An example of negative and positive feedback loops will be given. Correct scientific terminology must be used. Learners can submit secondary source diagrams of feedback loops but must provide a clear explanation of what they are showing and how they work.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 5: Principles and Applications of Biology II
- Unit 9: Biomedical Science
- Unit 12: Human Regulation and Reproduction
- Unit 15: Diseases and Infections.

Employer involvement

Centres can involve employers in the delivery of this unit if there are local opportunities to do so. GP Surgeries may have specialist nurses who might be available to visit and provide information about management of digestive system disorders, such as coeliac disease, irritable bowel syndrome and colitis.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- formal written communication
- self-management and planning skills
- ability to work in a scientific environment
- ability to carry out independent research
- analytical and observation skills.

Unit 12: Human Regulation and Reproduction

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit will give learners an understanding of how in the internal body environment is regulated and controlled within set parameters to enable key bodily process to take place.

Unit introduction

The human body is a complex organisation of systems that each needs to be controlled within a well-defined range of parameters. This unit will help your understanding of the key homeostatic principles that help provide this stable body environment. There have been many advances in human fertility in recent years, and there are opportunities to consider these and the hormonal control of the reproductive system. Fertility treatments will also be considered.

You will investigate the interrelationship and nervous control of the cardiovascular and respiratory systems, the homeostatic mechanisms in the body and the hormonal control of the reproductive system.

Knowledge of the mechanisms by which the body regulates systems within narrow parameters is an essential part of health and medical science-related occupations and other allied roles, including sport science and fitness, clinical science and veterinary science. Progression to higher education to study reproductive technologies or animal breeding leading to degree level is possible. It is equally possible to gain access to science technician or apprenticeships career pathways.

Learning aims

In this unit you will:

A Understand the interrelationship and nervous control of the cardiovascular and respiratory systems

B Understand the homeostatic mechanisms used by the human body

C Understand the role of hormones in the regulation and control of the reproductive system.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the interrelationship and nervous control of the cardiovascular and respiratory systems	**A1** Nervous system organisation **A2** Cardiovascular and respiratory system regulation and control	A report looking at the organisation and function of the human nervous system, along with the importance of coordinating the cardiovascular and respiratory systems
B Understand the homeostatic mechanisms used by the human body	**B1** Feedback and control **B2** Glands and organs **B3** Homeostatic mechanisms **B4** Impact of an imbalance	A presentation on the mechanisms used to maintain homeostasis and the importance of normal homeostatic function
C Understand the role of hormones in the regulation and control of the reproductive system	**C1** Structure and function of reproductive anatomy **C2** Reproductive processes	Learners put together a series of informative leaflets on the control of fertility.

Content

Learning aim A: Understand the interrelationship and nervous control of the cardiovascular and respiratory systems

Structure, function and processes involved in the nervous control of the cardiovascular and respiratory systems

A1 Nervous system organisation

- Components of the central and peripheral nervous systems.
- Neuron and glial cells, to include a comparison of myelinated and unmyelinated neurons.
- Transmission of action potentials and saltatory conduction, including interpretation of graphs.
- Transmission at synapses, neuromuscular junctions and neuroglandular junctions.
- Neurotransmitters.
- Stimuli detection by receptor cells and sense organs.
- Roles and regulation of the autonomic nervous system divisions (sympathetic and parasympathetic), to include different neurotransmitters, e.g. acetylcholine and dopamine.
- Stages in and role of voluntary and non-voluntary reflexes and reactions, to include afferent and efferent pathways and the role of interneurons.
- Neurological disorders, e.g. Parkinson's disease, multiple sclerosis.

A2 Cardiovascular and respiratory system regulation and control

- How changes in concentrations of oxygen and carbon dioxide come about.
- Role of chemoreceptors and baroreceptors.
- Gaseous exchange at tissues and alveoli.
- Autonomic nervous system; sympathetic and parasympathetic pathways.
- Role of medulla oblongata in coordination.
- Elasticity of blood vessels related to function.
- Control of heart rate – role and action of:
  - sinoatrial and atrioventricular nodes
  - bundle of His
  - Purkinje fibres.
- Control of inspiration, expiration and rate of ventilation:
  - changes in contraction and relaxation of diaphragm and intercostal muscles
  - relative air pressure changes.

Learning aim B: Understand the homeostatic mechanisms used by the human body

Processes, organs and hormones involved in maintaining the internal environment

B1 Feedback and control

- Positive and negative feedback loops, to include the part played by:
  - set point
  - receptors
  - coordinator(s)
  - effectors.

B2 Glands and organs

- Location, nature and hormone secretion from:
  - exocrine glands, e.g. sweat glands, Brunner's glands
  - endocrine glands, to include hypothalamus, pituitary gland, thyroid and parathyroid
  - endocrine and exocrine organs, e.g. pancreas, liver.

B3 Homeostatic mechanisms

- Stages involved in the regulation of:
  - water (osmoregulation), to include roles of:
  - antidiuretic hormone (ADH), atrial natriuretic peptide (ANP), angiotensinogen, aldosterone
  - hypothalamus, pituitary gland
  - kidney nephron (endothelial cells)
  - Cl^-, Na^+, K^+ ions
- Blood glucose, to include roles of:
  - secretion of insulin and glucagon by beta and alpha cells in the Islets of Langerhans
  - glycogen, glucose, glycogenesis, glycogenolysis, glucogenesis, gluconeogenesis
  - temperature, to include roles of:
  - vasodilation and vasoconstriction of arterioles leading to surface capillaries
  - pili erector muscles
  - sweat production
  - shivering.

B4 Impact of an imbalance

- Conditions caused by an imbalance of a homeostatic mechanism, to include effects on:
  - normal functioning and potential management strategies, e.g. dehydration, hyperglycaemia,
  - hypoglycaemia, diabetes, hypothermia, hyperthermia, syndrome of inappropriate antidiuretic
  - hormone (SIADH).

Learning aim C: Understand the role of hormones in the regulation and control of the reproductive system

C1 Structure and function of reproductive anatomy

- Female reproductive system: ovary, fallopian tube (oviduct), uterus, uterine horn, fimbriae, endometrium, cervix, vagina, labia.
- Male reproductive system: epididymis, seminal vesicle, Cowper's gland, prostate gland, testes, penis, scrotum, vas deferens, erectile tissue.

C2 Reproductive processes

Stages in the following, to include the interactions of hormones (to include progesterone, oestrogen, testosterone, FSH and LH as appropriate). Timescales for each should be referenced and links made to effects on fertility.

- Gamete development and release; infertility causes and identification in these stages:
  - oogenesis from oogonia; formation of primary, secondary and Graafian follicles; ovulation; formation and role of corpus luteum
  - normal/abnormal morphology of oocytes; ovulation disorders
  - spermatogenesis from spermatogonia, formation of primary and secondary
  - spermatocytes and spermatids, spermiation, role of Sertoli and Leydig cells
  - normal/abnormal morphology and abundance of sperm.
- Hormonal changes in the menstrual cycle.
- Processes leading to conception, how infertility can come about in these stages and potential treatments for assisting fertility:
  - wafting of ova through fallopian tubes, semen delivery, fertilisation (including role of acrosome in penetration of the zona pellucida), implantation
  - erectile dysfunction, antisperm antibodies, effects of menopause,
  - hypo/hyperthyroidism
  - sperm donation, artificial insemination (AI); in vitro fertilisation (IVF); hormone
  - replacement therapy; induction of ovulation.
- Contraceptive methods: oral, injection and implanted use of hormones to prevent pregnancy.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the interrelationship and nervous control of the cardiovascular and respiratory systems		**A.D1** Assess the role of the nervous system in coordinating the cardiovascular and respiratory systems.
A.P1 Describe the organisation and function of the nervous system in relation to cardiovascular and respiratory requirements.	**A.M1** Explain how nervous impulses are initiated, transmitted and coordinated in the control of the cardiovascular and respiratory systems.	
Learning aim B: Understand the homeostatic mechanisms used by the human body		**B.D2** Analyse the impact of homeostatic dysfunction on the human body.
B.P2 Describe how homeostatic mechanisms maintain normal function.	**B.M2** Explain the role of hormones in homeostatic mechanisms.	
Learning aim C: Understand the role of hormones in the regulation and control of the reproductive system		**C.D3** Evaluate how conception may be prevented and promoted.
C.P3 Describe the structure and function of reproductive anatomy. **C.P4** Describe how hormones are involved in gamete development and conception.	**C.M3** Explain how the regulation of male and female reproductive systems can affect human reproductive health.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.M2, B.D2)

Learning aim: C (C.P3, C.P4, C.M3, C.D3)

Further information for teachers and assessors

Resource requirements

There are no special resources needed for this unit.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will assess the nervous control of the cardiovascular and respiratory systems in maintaining a constant body environment. Learners need to consider the causes of changes, how they are detected internally and the interrelated stimulation of nervous pathways that bring about corrective measures for normal function. They will do this with reference to two neurological disorders affecting the central nervous or cardiovascular and respiratory systems.

For Merit standard, learners must explain the initiation and transmission of nervous impulses in relation to the cardiovascular and respiratory systems. They will use correct terminology throughout with reference to voluntary and non-voluntary stimulation and control of the systems. They will examine synaptic transmission in the parasympathetic and sympathetic nervous pathways. Learners must demonstrate an understanding of the importance of coordination of the cardiovascular and respiratory systems, in relation to changes to carbon dioxide and oxygen concentration in the blood.

For Pass standard, learners will provide a clear identification of human nervous system organisation and function, describing the basic structure of sensory and motor neurons and their role in transmitting information for involuntary control of heart rate and ventilation. They will label and use relevant diagrams to illustrate their work.

Learning aim B

For Distinction standard, learners will give a well-developed and detailed consideration of the interrelation of homeostatic mechanisms and the potential effects each system has on the others. They will examine a number of dysfunctions in each of the homeostatic mechanisms, explaining their impact on human health, potential methods to correct the dysfunction and the homeostatic consequences of these treatments.

For Merit standard, learners must include a developed explanation of the role of hormones in homeostatic mechanisms described in the unit content. There must be thorough consideration of the secretion of different hormones and their mode of action on target organs, including the responses of those organs. Learners will devise detailed, annotated feedback diagrams to illustrate points made.

For Pass standard, learners are to describe the body's requirement to maintain a constant internal environment (homeostasis) by both internal and external factors and how feedback systems maintain this for the mechanisms described in the unit content. They will demonstrate an awareness of the potential impact on human health when mechanisms fail to engage. Learners will use terminology in the correct context.

Learning aim C

For Distinction standard, learners must present a detailed account of the processes of gamete development and conception. They will explain at least four different methods of hormonal control, both in preventing conception taking place and in managing infertility.

Learners must provide a description of the method and the impact it has on the reproductive system of the male or female in order to prevent or promote conception. They will show well-developed lines of reasoning and use correct terminology with skill.

For Merit standard, learners will give a coherent account of the normal regulation of the male and female reproductive system, explaining how infertility can develop as result of physiological or morphological changes. At least four examples of infertility relating to issues such as meiosis during gametogenesis, obstruction of the male/female tubules, hormonal control of egg/sperm development, hormonal regulation and control of endometrium and implantation, development of zygote, erectile dysfunction and antisperm antibodies should all be researched and presented in evidence submitted by the learner.

For Pass standard, learners must identify the name, location and structure of each part of the male and female reproductive anatomy, using diagrams they independently label. A description of the function of each part will also be given. Learners are required to describe the action of hormones that are released during the production of sperm and ova and leading to conception. Learners are required to correctly annotate diagrams/graphs of the menstrual cycle, gametogenesis and processes leading to conception.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 5: Principles and Applications of Biology II
- Unit 11: Functional Physiology of Human Body Systems.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities.

An internet search may reveal a relatively local fertility clinic, which may be able to provide a visiting speaker to provide information relating to reasons for infertility and possible treatment options. Local gyms and universities or further education colleges may be able to accept visits from learners to use monitoring equipment to measure the effects of exercise on the cardiovascular and respiratory systems. An endocrinologist may be available from the local hospital to discuss with learners the work they do and the importance of the endocrine system and effects of imbalance within it.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- analytical and observation skills
- formal written communication
- interpretation of graphical information
- self-management and planning skills
- ability to work in a scientific environment
- ability to carry out independent research.

Unit 13: Biological Molecules and Metabolic Pathways

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers biological molecules and the metabolic pathways involved in chemical reactions to enable organisms to function normally.

Unit introduction

In this unit, you will study some of the chemical processes in living organisms. Biological molecules and metabolic pathways play a crucial role both in society and in various industries, such as health, chemical and environmental sciences. Examples of the importance of this field of study include improvements in the efficiency of photosynthesis to increase crop yields, the bioremediation of polluted soils, the development of new feedstocks and the production of biofuels. Water is a fundamental molecule involved in the biochemical processes that take place in living organisms. Due to its unique structure and properties, the water molecule gives organisms the ability to live and thrive in challenging conditions. The unit looks at the structure and functions of water and other molecules, including carbohydrates, proteins and fats, involved in a variety of biochemical systems and metabolic pathways. You will study the biochemical basis of systems within the body and look at respiratory systems in humans and photosynthetic systems in plants.

You will also investigate metabolic chemical pathways and understand how some substances can affect the metabolic pathways in living organisms. You will develop practical skills when investigating the effect of physical activity on respiration and during your practical work on photosynthesis. This practical work, which will be assessed, is aimed at developing your practical competences so you have skills required by employers.

Biological molecules and metabolic pathways are an area of science that overlaps and underpins many other branches of science such as pharmacology, physiology, microbiology and clinical chemistry. This unit will also support progression to higher education in biochemistry, biomedical science and bioinformatics-related courses.

Learning aims

In this unit you will:

A Understand the structure and function of biological molecules and their importance in maintaining biochemical processes

B Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways

C Explore the factors that can affect the pathways and the rate of photosynthesis in plants.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the structure and function of biological molecules and their importance in maintaining biochemical processes	**A1** Water **A2** Carbohydrates **A3** Proteins and nucleic acids **A4** Lipids **A5** Disruption of biochemical processes in living organisms	A report or a visual display with explanations, that include: • the molecular structure of proteins and the basic biochemical properties they show • links between molecular structure, their properties and role and importance in the human body, including the effect of disruption to biochemical processes in humans and plants.
B Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways	**B1** Respiration **B2** Effect of activity on respiration **B3** Effect of activity on requirements for oxygen and output of CO_2	A portfolio of evidence to include: • practical work and results, which can be recorded in lab notebooks, signed off by the teacher/observer • record of analysis, conclusions, evaluation and any research work can be by a written essay, diagrams, flow charts.
C Explore the factors that can affect the pathways and the rate of photosynthesis in plants	**C1** Pathways in photosynthesis **C2** Factors that can affect the pathways in photosynthesis	A portfolio of evidence to include: • practical work and results, which can be recorded in lab notebooks, signed off by the teacher/observer • record of analysis, conclusions, evaluation and any research work can be by a written essay, diagrams, flow charts.

Content

Learning aim A: Understand the structure and function of biological molecules and their importance in maintaining biochemical processes

A1 Water

- Structure:
  - contains hydrogen (H) and oxygen (O) atoms
  - structural and chemical formulae.
- Bonding:
  - in water molecule (covalent bonding)
  - between water molecules (hydrogen bonding).
- Importance:
  - as a solvent
  - medium for chemical reactions
  - pH regulation
  - electrolyte balance
  - temperature regulator
  - cohesion-tension in transpiration.

A2 Carbohydrates

- Structure and features:
  - contains carbon (C), hydrogen and oxygen atoms
  - monosaccharides, e.g. α and β glucose, galactose, fructose, ribose and deoxyribose
  - disaccharides, e.g. lactose, maltose and sucrose
  - polysaccharides, e.g. amylose, amylopectin, cellulose
  - use of iodine and Benedict's solution as tests for presence of carbohydrates.
- Importance:
  - energy production
  - energy storage
  - structural/building
  - lipid metabolism
  - prevention of protein breakdown for energy in animals.

A3 proteins and nucleic acids

Structural features

- Proteins:
  - primary structure, including peptide links to give polypeptides
  - secondary structure, including α-helices and β-pleated sheets
  - tertiary structure, to include ionic interaction, hydrogen bonding,
  - sulphur bridges and van der Waal's forces
  - quaternary structure, e.g. haemoglobin
  - classification as globular or fibrous
  - use of Biuret solution as a test for presence of protein.

- Nucleic acids:
  - nucleotide structure (deoxyribose or ribose, phosphate and purine or pyrimidine base)
  - polynucleotide structure with bonds made through condensation reactions
  - formation of the DNA double helix through complementary base pairing
  - importance of proteins and nucleic acids
  - enzymes that control metabolism
  - as Neurotransmitters
  - antibodies
  - hormones
  - tor transport of other components
  - body tissue growth and repair
  - muscle contraction in animals (actin and myosin interaction: detailed knowledge of the sliding filament theory not required)
  - blood clotting in animals
  - role of nucleic acids in coding for genes and controlling gene expression

A4 Lipids

- Structure:
  - carbon, hydrogen and oxygen in fats, oils and waxes
  - saturated and unsaturated fats, formation of diglycerides and triglycerides via esterification
  - reactions
  - use of emulsion tests to identify presence of lipids.
- Importance of lipids in animals:
  - energy sources
  - insulation and organ protection in animals
  - phospholipids in membranes
  - production of vitamins

A5 Disruption of biochemical processes in living organisms

- The causes and effects of disruption to biochemical processes, to include:
  - porphyria
  - lactose intolerance
  - diabetes mellitus
  - cystic fibrosis
  - exposure to carcinogens
  - interference in plant growth regulators, e.g. delaying or promoting fruit ripening using the effects of ethene and gibberellins; disruption of auxin transport; use of synthetic auxin.

Learning Aim B: Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways

B1 Respiration

- Adenosine triphosphate (ATP) as the universal energy currency.
- Stages and locations of aerobic and anaerobic respiratory pathways.
- Glycolysis: conversion of monosaccharides to pyruvate; production of lactic acid in anaerobic respiration and ethanol in yeast.
- Link reaction.
- Krebs cycle:
  - conversion of molecules in the cycle from citric acid to oxaloacetate
  - carbon dioxide (CO_2) production.
- Electron transport chain in ATP production:
  - reduction of coenzymes
  - cytochrome system and ATP synthase
  - importance of oxygen as final electron acceptor and nicotinamide adenine dinucleotide (NAD) as hydrogen acceptor.

B2 Effect of activity on requirements for oxygen and output of CO_2

- Recovery rates after exercise as measured by breathing rate.
- Short-term anaerobic respiration leading to oxygen debt.
- Effect of exercise on carbon dioxide output; potential damaging effects of excess CO_2 and lactic acid; bicarbonate buffering system of blood.

B3 Factors that can affect respiration

The causes and effects of the following on the ability of individuals to carry out processes leading to efficient respiration

- Cigarettes:
  - inhalation of toxins
  - tar
  - nicotine.
- Drugs:
  - ketamine
  - cocaine interferes with how the brain processes chemicals.
- Pollutants:
  - asbestos
  - oxidants causing inflammation and metabolic damage to the cells.
- Disease, e.g. asthma.

Learning aim C: Explore the factors that can affect the pathways and the rate of photosynthesis in plants

C1 Pathways in photosynthesis

- Light-dependent reaction:
  - stages in and location of photophosphorylation, including role of coenzymes, and photolysis
  - light energy converted to chemical energy held in ATP.
- Light-independent reaction:
  - stages in and location of the Calvin cycle
  - role of ribulose bisphosphate (RuBP) and ribulose bisphosphate carboxylase (RuBisCO)
  - production of glucose.

C2 Factors that can affect the pathways in photosynthesis

- Requirements for photosynthetic organisms, including sources and control of limiting factors e.g. light intensity, CO_2 concentration, temperature, water.
- Role of photosynthetic pigments (chlorophylls and carotenoids) in absorbing different wavelengths of light.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the structure and function of biological molecules and their importance in maintaining biochemical processes		**A.D1** Evaluate the effects of disruption of biochemical processes in living organisms.
A.P1 Explain the structure of biological molecules in living organisms.	**A.M1** Explain the links between the structure and function of biological molecules and their role in living organisms.	
Learning aim B: Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways		**B.D2** Evaluate the effects of harmful substances on the efficiency of respiration.
B.P2 Explain the stages involved in the human respiratory pathway. **B.P3** Carry out an investigation involving the effect of activity on respiration in humans. **B.P4** Describe factors that can affect respiration.	**B.M2** Analyse primary and secondary data to explain the effect of activity on respiration. **B.M3** Explain the harmful effects of factors on respiration.	
Learning aim C: Explore the factors that can affect the pathways and the rate of photosynthesis in plants		**C.D3** Evaluate the effect of factors on photosynthetic efficiency.
C.P5 Explain the stages involved in photosynthesis in plants. **C.P6** Carry out an investigation into a factor that affects the rate of photosynthesis.	**C.M4** Analyse primary and secondary data to explain the outcomes of an investigation into a factor that affects the rate of photosynthesis.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.P4, B.M2, B.M3, B.D2)

Learning aim: C (C.P5, C.P6, C.M4, C.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a well-equipped laboratory in order to carry out practical work to support learning. This unit is based on practicals, with research and tutorials backing up the outcomes from practical work.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners must present a detailed evaluation of the effects caused by disruption of biological molecules. This would include details of the structures of the biological molecules related to their function and importance in the human body. This provides the basis for analysing what happens if there is a disruption to the structure or function, leading to major changes in normal biochemical processes. Learners will identify where these are intentionally disrupted for human benefit. They will use scientific terminology with skill and with a lack of fundamental errors.

For Merit standard, learners must show their understanding of how the elements carbon (C), hydrogen (H) and oxygen (O) are the fundamental building blocks of biological molecules. Learners will demonstrate understanding that different carbohydrates, lipids and proteins are formed from the original elements of C, H, O. This must be extended to include how the addition of elements such as nitrogen, phosphorus and sometimes sulphur changes the structure and properties of the biological molecules. Using chemical diagrams, learners can show the CHO ratio in carbohydrates to other molecules. They should explore side group structure and function found in proteins. They can use diagrams to compare the structure of nucleic acids as a five-carbon sugar (pentose) with a phosphate group and nitrogenous bases, and how RNA and DNA have different functions in the body. Learners must give detailed explanations of how structure of biological molecules is linked to function and the role in the human body. They will use scientific terminology accurately in many cases.

For Pass standard, learners must demonstrate their knowledge of the structure of biological molecules in living organisms, for example, learners must show how simple sugars combine to form disaccharides and polysaccharides. They will show a similar understanding of other biological molecules such as proteins and lipids. Learners will use relevant scientific terminology, although there may be errors.

Learning aim B

For Distinction standard, learners must research factors (chemicals in cigarettes, drugs, pollutants and disease) and how they affect metabolic pathways in terms of how efficiently aerobic respiration can proceed. For example, the inhibitory effect of pesticides on enzyme reactions as part of neural conduction or pollutant particles preventing normal respiratory function, could be researched and evaluated. Learners will extend their analysis of primary and secondary data to help in their evaluation and in drawing conclusions. They must cite references.

For Merit standard, learners are expected to analyse and relate primary data from their investigations into effects of activity on respiration to secondary data. This may have been researched or be given to them by the teacher. They must use the analysis of primary and secondary data to form valid and detailed conclusions about their investigation. Learners must use the evidence obtained to link changes in respiration rates to the type of activity undertaken. Learners are expected to explain how two named examples of factors, from the unit content, can disrupt the respiratory pathways. For example, they could explain how oxidants inhaled as the result of a polluted atmosphere can overload the body's normal metabolism, causing inflammation and cell damage.

For Pass standard, learners must explain how the chemical stages in the human respiratory pathways are related and significant in energy release. Learners will use scientific terminology accurately in their explanations of the stages involved in respiratory pathways and demonstrate a clear understanding of the importance of each stage.

Learners will demonstrate the ability to carry out investigative work relating to effect of activity on respiration, in a competent and safe manner and in accordance to any health and safety instructions. Outline methods can be given and must be adapted by the learner to allow valid and authentic evidence to be generated. Anomalous results must be identified and, if possible, explained. Learners should be encouraged to repeat practical work to help eliminate errors and check the validity of results.

An observation sheet must be completed and submitted to validate the practical. It is good practice to encourage learners to use a laboratory notebook, which should be checked regularly by the teacher. This will help make learners aware of the importance of logbooks as a record of practical work being carried out. They must give clear, objective accounts of how factors affect respiration. These accounts could cover the breadth of the unit content in less detail or cover three factors each in greater detail.

Learning aim C

For Distinction standard, learners must demonstrate knowledge of optimum levels of the factors affecting the rate of photosynthesis. They must consider alterations to levels of these factors and the effect on photosynthetic efficiency, and the commercial importance and relevance of this. For instance, they could consider a conclusion about the relevance, in terms of yield and production costs, of increasing levels of light or carbon dioxide in a greenhouse. Learners will be expected to use their understanding of the main stages in photosynthesis when drawing their conclusions from the analysis of primary and secondary data.

For Merit standard, learners must draw accurate conclusions from an investigation into factors affecting the rate of photosynthesis and will refer to the stage in photosynthesis affected. It is expected that light intensity, carbon dioxide levels or temperature will have been investigated. In order to draw valid conclusions, learners must analyse their own data (primary) from their investigation along with secondary data, which may have been researched or given to them by the teacher. Learners will need to consider in their analysis of the data any difference between their results and those from published material.

For Pass standard, learners must describe the chemical stages in photosynthesis and give clear details of the stages in photosynthesis. Accurate scientific terminology must be used in the explanations of the importance of each stage of the process. Learners can follow given methods to competently and safely carry out investigative work into factors affecting the rate of photosynthesis. Different factors should be investigated by different learners and results collated for analysis. Anomalous results should be identified and discussed, and repeats carried out where possible. An observation record is required to validate the practical work carried out. Use of laboratory logbooks by learners, monitored by teachers, should be encouraged.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 5: Principles and Applications of Biology II
- Unit 9: Biomedical Science
- Unit 11: Functional Physiology of Human Body Systems
- Unit 12: Human Regulation and Reproduction
- Unit 14: Genetics and Genetic Engineering.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- planning scientific investigations
- analytical and observation skills
- ability to work in a scientific environment
- data analysis
- formal written communication
- self-management and planning skills
- ability to carry out independent research.

Unit 14: Genetics and Genetic Engineering

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners will study the basis of life itself. They will gain an understanding of the structure of DNA, cell division and the principles of Mendelian genetics and variation.

Unit introduction

Massive advances in DNA technology over the last 30 years have driven genetics forward at an extraordinary rate, creating enormous potential for future applications. This unit will allow you to develop a deeper practical and theoretical knowledge and understanding of genetics, and modern genetic engineering techniques and their uses. This may be of particular interest to learners wishing to follow a career in forensic science or research. There are often media reports of medical advances, for instance, growing replacement body parts for transplantation, and advances in treatments for life-threatening and debilitating diseases. There will be opportunities to follow up some of these reports and to extend your knowledge and understanding of what might be possible in the future.

You will investigate the mechanisms of cell division and carry out research to explain how the behaviour of chromosomes during cell division relates to variation. There will be an opportunity to demonstrate and expand your knowledge of genetics and variation, to include how genes control the characteristics of living organisms by synthesising proteins using nucleic acids as a code. The principles of Mendelian genetics will be used to outline and explain patterns of inheritance and how this can influence variation and evolution. You will explore modern genetic techniques and their uses and have the opportunity to extract and work with DNA.

This unit will provide a basis for progression in the fields of medical, veterinary science, agricultural, industrial or forensic science. Multiple pathways for career development are available. These may be through higher education courses, university, or by direct entry to these fields as science technicians or on apprenticeship schemes.

Learning aims

In this unit you will:

A Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis

B Explore how the process of cell division in eukaryotic cells contributes to genetic variation

C Explore the principles of inheritance and their application in predicting genetic traits

D Explore basic DNA techniques and the use of genetic engineering technologies.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis	**A1** Nucleic acids **A2** The basis of the genetic code **A3** Protein synthesis	A portfolio of evidence to include: • photographic evidence of DNA models made by learners • a leaflet/report explaining the structure of nucleic acids and how they code for protein synthesis • annotated diagrams of the stages of protein synthesis, how and where the stages occur and analysis of the impact of possible errors.
B Explore how the process of cell division in eukaryotic cells contributes to genetic variation	**B1** Human chromosome **B2** Cell division and its role in variation **B3** Practical demonstration of slide preparation of dividing cells	A portfolio of evidence to include: • a leaflet on the structure and function of human chromosomes • an observation record of microscope slide preparation of mitosis and meiosis • annotated diagrams identifying the stages in mitosis and meiosis • a report explaining and evaluating how the behaviour of the chromosomes during meiosis leads to variation.

Learning aim	Key content areas	Assessment approach
C Explore the principles of inheritance and their application in predicting genetic traits	**C1** Principles of classical genetics **C2** Further genetics	A portfolio of evidence to include: • an observation record to validate the practical work carried out on *Drosophila* • statistical analysis of the patterns of inheritance ratios from practical work • genetic diagrams and a report using appropriate terminology to predict and describe the results of genetic crosses.
D Explore basic DNA techniques and the use of genetic engineering technologies	**D1** DNA extraction **D2** Gel electrophoresis **D3** DNA amplification **D4** Transformation of cells **D5** Uses of genetic engineering	A portfolio of evidence to include: • a brief report on practical techniques carried out and their applications in industry and medicine • observation records to validate the practical work • a report on how restriction enzymes and electrophoresis work with an explanation of stem cell therapies and their uses.

Content

Learning aim A: Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis

A1 Nucleic acids

- Nucleotide structure, function and location of the following:
  - DNA, to include stages and enzymes involved in DNA replication
  - RNA, to include mRNA, tRNA, rRNA, siRNA.

A2 The basis of the genetic code

- Definitions of the following and their importance in gene expression:
  - TRiplet codes
  - codon
  - anticodon
  - degenerate code
  - non-overlapping.

A3 Protein synthesis

- Major stages involved in each stage (including location) and the effect of mutations on the end products.
- Transcription, to include introns, exons and splicing.
- Amino acid activation.
- Translation.
- Mutagenic agents, e.g. irradiation, chemical mutagens.
- Types of genetic mutations – missense, nonsense, silent, insertion, deletion, duplication, frameshift.

Learning aim B: Explore how the process of cell division in eukaryotic cells contributes to genetic variation

B1 Human chromosomes

The formation and structure of chromosomes, linked to their function:

- Centromere
- Chromatids
- Autosomes
- Sex chromosomes
- Chromosome number and karyotyping
- Homologous and non-homologous chromosomes.

B2 Cell division and its role in variation

- Stages of the cell cycle, to include cellular activities at each stage and the checkpoints involved in progressing from one stage to the next. Learners should be able to identify the stage a cell is in from given micrographs or specimens, describe the position of chromosomes and the events that take place within each stage of cell division.
- The cell cycle: G1, S phase, G2, division cytokinesis.

- The stages of mitosis, to include the similarities and differences between mitosis in animal and plant cells – interphase, prophase, metaphase, anaphase, telophase.
- The stages of meiosis in the production of gametes, including:
  - interphase, prophase I, metaphase I, anaphase I, telophase I, cytokinesis, interkinesis, prophase II, metaphase II, anaphase II, telophase II, cytokinesis.
- The role of centrioles (microtubule-organising centre).
- Haploid, diploid.
- Sex determination.

B3 Practical demonstration of slide preparation of dividing cells

- Equipment and techniques involved in the preparation of slides for examination using light microscopy.
- Mitosis, e.g. root tip squash.
- Meiosis, e.g. lily anther squash.

Learning aim C: Explore the principles of inheritance and their application in predicting genetic traits

C1 Principles of classical genetics

- Inheritance of straightforward phenotypic traits in animals and plants, their predicted proportions and statistical analysis of phenotypic outcomes.
- The differences and complexities involved in continuous and discontinuous variation.
- Mendel's laws of inheritance: segregation and independent assortment.
- Practical investigation of mono and dihybrid phenotypic ratios.
- Use of Punnett squares and other genetic diagrams, to include use of the terms: allele, genotype, phenotype, heterozygous, homozygous, carrier, affected/sufferer, non-affected/non-sufferer.
- Interpretation of Mendelian ratios from practical investigations.
- Chi-squared test.

C2 Further genetics

- Description of genetic interaction, phenotypic traits and reasoned prediction of inheritance of the following:
  - single gene disorders, e.g. Huntington's disease, sickle cell anaemia, cystic fibrosis
  - incomplete dominance/blending, e.g. Tay Sachs disease and co-dominance, e.g. blood groups
  - sex linkage, e.g. colour blindness, haemophilia
  - chromosome mutation, e.g. Down's syndrome, Turner syndrome
  - epistasis, e.g. albinism.

Learning aim D: Explore basic DNA techniques and the use of genetic engineering technologies

Principles and practical application (where appropriate) of the techniques, equipment and consumables in each of the following:

D1 DNA extraction

- Genomic and plasmid DNA extraction.

D2 Gel electrophoresis

- Use of restriction enzymes.
- Principles of electrophoresis.

D3 DNA amplification

- Polymerase chain reaction (PCR).
- Purpose of utilising PCR to amplify DNA:
  - DNA fingerprinting
  - cancer diagnosis
  - tissue typing
  - preimplantation genetic diagnosis/screening.

D4 Transformation of cells

- Use of vectors.
- Plasmids.
- Use of marker genes.
- DNA ligase.
- Screening to identify transformed cells.

D5 Uses of genetic engineering

- Genetically modified (GM) crops.
- Diagnostic tests and gene therapy.
- Pharming.
- Genetic screening including preimplantation genetic diagnosis (PGD).
- Stem cell therapies, e.g. Parkinson’s disease, macular degeneration, spinal cord injuries.
- Xenotransplantation.

Pass	Merit	Distinction
Learning aim A: Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis		**A.D1** Assess the impact of error in the stages of protein synthesis.
A.P1 Explain the structure and function of DNA and various nucleic acids.	**A.M1** Discuss the functional role of nucleic acids in DNA in the stages of protein synthesis.	
Learning aim B: Explore how the process of cell division in eukaryotic cells contributes to genetic variation		**B.D2** Evaluate how the behaviour of the chromosomes leads to variation.
B.P2 Prepare microscopic slides to observe and draw the stages of mitosis and meiosis. **B.P3** Explain the structure and function of human chromosomes.	**B.M2** Demonstrate skilful preparation of microscopic slides to observe and draw the stages of mitosis and meiosis. **B.M3** Discuss the behaviour of the chromosomes during the cell cycle stages of mitosis and meiosis.	
Learning aim C: Explore the principles of inheritance and their application in predicting genetic traits		**C.D3** Make valid predictions on patterns of monohybrid and dihybrid inheritance and variation using principles of inheritance.
C.P4 Carry out investigations to collect and record data for mono and dihybrid phenotypic ratios. **C.P5** Explain genetic crosses between non-affected, affected and carriers of genetic conditions.	**C.M4** Analyse data to explain the correlation between observed pattern of monohybrid and dihybrid inheritance. **C.M5** Apply Mendel's laws of inheritance to the results of genetic crosses.	
Learning aim D: Explore basic DNA techniques and the use of genetic engineering technologies		**D.D4** Evaluate possible future uses of genetic engineering technologies.
D.P6 Extract, separate and amplify DNA. **D.P7** Explain the use of genetic engineering technologies in industry and medicine.	**D.M6** Analyse the uses of genetic engineering technologies in industry and medicine.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.M2, B.M3, B.D2)

Learning aim: C (C.P4, C.P5, C.M4, C.M5, C.D3)

Learning aim: D (D.P6, D.P7, D.M6, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory
- commercially prepared materials/kits, which can be purchased to facilitate growing of *Drosophila* and for extracting DNA, gel electrophoresis, cell transformation and polymerase chain reactions.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will demonstrate a thorough understanding of the structure and function of DNA in relation to the stages of protein synthesis, with specific and accurate use of scientific terminology. Learners will make relevant links between possible errors that may occur during the different stages of protein synthesis, including transcription, translation and the cause and effect of mutations in DNA. They must also assess the impact of these errors to the end products of protein synthesis, which will be illustrated with examples.

For Merit standard, learners will clearly use their knowledge of the genetic code to discuss the functional role of nucleic acids in protein synthesis. Learners will discuss the locations of each stage in protein synthesis and how the genetic code allows proteins to be synthesised with minimal errors taking place.

For Pass standard, learners must explain the structure and main features of each nucleic acid listed in the unit content. Photographic evidence can be submitted and annotated if more kinaesthetic assessment tools are used, such as model making.

Learning aim B

For Distinction standard, learners will use the information from their practical work and discussion on meiosis and mitosis to evaluate the significance of chromosomal behaviour during cell division. Arguments must be provided for and against the behaviour of independent assortment and crossing over leading to variation within an organism.

For Merit standard, learners will skilfully prepare three microscope slides of squash preparations to show mitosis and meiosis, without guidance during assessment. They must use their slide preparations to produce diagrams to identify a minimum of four stages of mitosis and four stages of meiosis. The diagrams must demonstrate good practice – have a title, be drawn in pencil, have clear outlines (not sketched), no heavy shading, indicate the field of view, magnification and scale. Accurate labelling should be evident. Observation records will be required to validate the level of expertise demonstrated by the learner. Learners will provide a detailed discussion demonstrating an understanding of the behaviour of the chromosomes during mitosis and meiosis in each stage of cell division. Supplementary evidence using prepared slides and photomicrographs, provided and referenced by the learner, can be used to ensure all the required stages listed in the unit content can be identified.

For Pass standard, learners will correctly prepare three microscope slides to allow them to observe, draw and label a minimum of four stages of mitosis and four stages of meiosis. Learners will follow instructions to prepare the material and apply a stain/fixer, if appropriate, having had an opportunity to practice the skills during teaching and learning. They should demonstrate good technique in applying a cover slip to ensure exclusion of air.

Learners must handle the microscope safely, set it up independently and be able to manoeuvre the slide(s) to obtain a field of view under different magnifications. Good technique includes the use of a pencil and statement of the magnification used for the drawing(s) submitted. Photomicrographs and diagrams sourced and referenced by the learners could be used to aid the explanation of the structure of human chromosomes. Detailed statements are required which demonstrate understanding of how/why the structure relates to the function of the chromosomes.

Learning aim C

For Distinction standard, learners must demonstrate the ability to make valid predictions and analyse the outcomes of examples of monohybrid and dihybrid crosses between non-affected, affected and carriers of particular disorders and independent and linked genes. Learners must provide evidence of one disorder for monohybrid and one for dihybrid. Learners will use both their own data from investigations and use case studies to allow access to this criterion. Learners must include an explanation of why the observed ratio for each example is not exactly as would be expected.

For Merit standard, learners will use the data from practical work they have carried out and effectively apply the chi-squared test to analyse the correlation between the observed and expected phenotypic results. An outcome from the statistical test is required, identifying if the ratios obtained are statistically significant or due to chance. Learners must then apply and use Mendel's laws of independent assortment and segregation to analyse the results of the genetic crosses, and explicitly state conclusions.

For Pass standard, learners must follow instructions in a competent manner to obtain valid and reliable data from an investigation into monohybrid and dihybrid inheritance. An individual observation sheet will be required to validate their level of competency. Sufficient data to carry out a chi-squared analysis must be collected. Results can be shared/collated between individuals/ groups of learners. Spreadsheets can be used. Use of simulations prior to starting the assignment will provide a good basis for the learners to carry out their own practical work and statistical analysis. Learners must produce their own write up to include the data from their investigations. Competent completion of the task will be characterised by adherence to the instructions, a very low error rate and the gaining of results close to that expected by the tutor in the context of the investigation.

Learners must accurately construct genetic diagrams representative of genetic conditions and explain the relationship between the genotypic and phenotypic ratios. The correct terminology will be applied throughout. The evidence submitted does not have to be solely related to humans.

Learning aim D

For Distinction standard, learners will research the strengths and weaknesses, advantages and disadvantages of the genetic technologies explored in the relevant unit content. All sources consulted will be accurately referenced. They must use the research to support their own views, speculating in an informed manner about future uses of generic engineering technologies. They must provide counterarguments of the reliability and validity of the use of the technologies.

For Merit standard, learners will analyse the use of genetic technologies in relation to industry and/or medicine. The analysis will take into account the reasons and science behind the technologies, benefits to the relevant sector of industry or medicine, and include an appreciation of efficacy and cost. This may be achieved effectively through the detailed examination of one real-life example for each technology.

For Pass standard, learners will need to provide a laboratory record of how they have competently carried out three separate experiments: DNA extraction (chromosomes or plasmids), PCR and gel electrophoresis. An observation record is required to validate the competency of learners' participation in practical work, characterised by methodical preparation and avoidance of sample contamination. Learners will explain the genetic engineering technologies as listed in the unit content in terms of their relevance to industry and medicine, in addition to the basic principles behind how the technologies work.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 4: Investigative Project Skills
- Unit 5: Principles and Applications of Biology II
- Unit 13: Biological Molecules and Metabolic Pathways
- Unit 15: Diseases and Infections
- Unit 19: Microbiology and Microbiological Techniques.

Employer involvement

Centres could approach a local university to try to arrange visits for learners to allow them to view commercial equipment used for extracting and carrying out genetic engineering techniques as well as the more advanced techniques not possible in centres' laboratories.

It may be possible to arrange visits from research scientists to give talks about their current research projects. A visit to a crop research faculty or a visit from scientists or technicians working there could enhance learner knowledge and understanding of the genetic research being undertaken and possible future developments.

Agricultural and horticultural colleges may be able to accommodate visits form learners to see how genetics has led to improved varieties of plants and animals.

A visit to an industrial state-of-the-art laboratory is recommended to help the learners appreciate the sophistication of the modern-day high-tech laboratories compared with the basic equipment available in many educational laboratories.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- analytical and observation skills
- formal written communication
- self-management and planning skills
- ability to work in a scientific environment
- ability to carry out independent research.

Unit 15: Diseases and Infections

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners will gain understanding of different types of diseases, their causes and how humans try to prevent and treat them.

Unit introduction

The prevention and treatment of disease and infection is a key part of the work of health professionals around the world. It is important to understand what disease is and the causes of diseases and infections that affect humans. The main focus of this unit will be on the causes and impact of infectious and environmental diseases, their causes, prevention, transmission and treatment. There will be the opportunity to research the different types of pathogens and pollutants and the diseases they cause. Disease and infections have many causes and it is the knowledge of how pathogens and pollutants interact with the human body that forms the study of disease, which is also known as epidemiology. This unit will also give you the opportunity to better understand the effects of environmental pollution of air and water sources and the impact of pollutants on human health. Non-infectious diseases caused by dietary, genetic and degenerative factors will also be briefly studied in this unit.

You will gain an understanding of how the human body has natural defence mechanisms and can establish its own immunity to infectious disease. You will consider the periodic outbreak of infectious diseases and the problems associated with preventing their transmission and treating those affected. With global travel easily accessible to many people, pandemics are a real possibility, so you will investigate the role of organisations in preventing and treating infectious diseases.

The understanding and knowledge of factors that relate to the causes and management of disease is an essential requirement for those wishing to pursue a health science or bioscience related occupation. This could, for example, be in public health, microbiology, international health, the pharmaceutical industry or the food sector. This unit will help provide access to higher education to allow you to pursue these and related careers.

Learning aims

In this unit you will:

A Investigate different types of diseases and infections that can affect humans

B Examine the transmission of infectious diseases and how this can be prevented

C Investigate causes of environmental pollution and the effects of pollutants on human health

D Understand how the human body responds to diseases and infections.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Investigate different types of diseases and infections that can affect humans	**A1** Pathogens and infectious diseases **A2** Dietary diseases **A3** Genetic and degenerative diseases **A4** Progression of disease over time	Having researched a variety of infectious and non-infectious diseases, learners could produce case studies relating to their chosen diseases. The case studies would detail the causes and the effects the disease can have on body systems over time. The effect on the quality of life of the individual suffering from the disease must also be evaluated.
B Examine the transmission of infectious diseases and how this can be prevented	**B1** Methods by which infectious diseases can be spread **B2** Methods by which infectious diseases can be prevented from spreading **B3** Management of infectious diseases	In addition to research work, practical work and simulations should be used to ensure that learners are familiar with the methods by which infectious diseases can be transmitted. Prevention of transmission at a personal level and by organisations must be researched. A report or information leaflet can be produced as evidence.
C Investigate causes of environmental pollution and the effects of pollutants on human health	**C1** Water pollution **C2** Air pollution **C3** Radioactivity	Learners produce a detailed report examining how the introduction of contaminants into the natural environment causes risk to human health.
D Understand how the human body responds to diseases and infections	**D1** Defence mechanisms **D2** Non-specific **D3** Specific	Information leaflets detailing and comparing the components of the two defence mechanisms and their mode of action could be produced.

Content

Learning aim A: Investigate different types of diseases and infections that can affect humans

A1 Pathogens and infectious diseases

- Pathogens – types and characteristics, life cycle and actions:
  - bacteria: prokaryotic, rapid production, damage to cells, toxins
  - parasites: require host, endoparasite, ectoparasite
  - viruses: akaryotic, takes over host cell metabolism
  - fungus; eukaryotic, ectoparasitic
  - protozoa: eukaryotic, toxin release damages cells.
- Infectious diseases:
  - pathogenic organisms invading the body: HIV, malaria, hepatitis, gonorrhoea, Ebola, tuberculosis
  - zoonotic (from animal to human): ringworm, tapeworm, rabies, avian flu H5N1, ticks, mites, fleas.

A2 Dietary diseases

- Dietary:
  - dietary deficiency or excess
  - diabetes
  - anaemia
  - cardiovascular disease
  - obesity
  - liver disease.

A3 Genetic and degenerative disease

- Genetic – inherited through DNA or DNA mutation, e.g. cystic fibrosis, sickle cell anaemia:
  - patterns of inheritance
  - recessive alleles
  - Punnett square
  - mutation of DNA sequence.
- Degenerative – gradual decline in function, e.g. Alzheimer’s, osteoporosis, osteoarthritis.

A4 Progression of disease over time

- Asymptomatic.
- Latency of disease.
- Effect on ability to lead a normal life/work.

Learning aim C: Investigate causes of environmental pollution and the effects of pollutants on human health

Causes/effects on health of:

B1 Methods by which infectious diseases can be spread

- Direct contact – transmission:
  - human to human, body fluids
  - animal to human, animal waste (droppings).
- Indirect contact:
  - vectors – fleas, lice, ticks, mosquitoes
  - transmission – surfaces, infected water droplets (sneezes, vapour from coughing)
  - contamination – food or water, e.g. salmonella, typhoid.

B2 Methods by which infectious diseases can be prevented from spreading

- Prophylaxis:
  - antibiotics
  - antimalarial
  - antiviral.
- Personal protective equipment (PPE):
  - gloves
  - biohazard suits.
- Behaviours:
  - safe sex
  - mosquito nets
  - hand washing.
- Vaccination to prevent spread of disease:
  - vaccination programmes
  - types of vaccine (modified, attenuated, live antigens)
  - specificity to pathogen
  - stimulation of antibody production
  - herd immunity.
- Isolation/quarantine.

B3 Management of infectious diseases

- Work of national and global organisations:
  - World Health Organization (WHO)
  - Médicins sans Frontières
  - Oxfam
  - Unicef
  - WaterAid.

Learning aim C: Investigate causes of environmental pollution and the effects of pollutants on human health

C1 Water pollution

- Agricultural – pesticides and fertilisers, nitrates and phosphates, animal waste.
- Heavy metals.
- Plastics.
- Chemical and oil spillages.
- Illegal discharge of effluent.
- Point and non-point source pollution
- Cholera.

C2 Air pollution

- Industry – use of fossil fuels; coal, petroleum, wood.
- Transport – carbon monoxide, diesel particulate matter.
- Agriculture – methane from livestock, burning of agricultural waste.
- Natural sources – asbestos, smog, volcanic eruptions, sand and dust storms.

C3 Radioactivity

- Nuclear fuel, mining, power plants.
- Nuclear weapons
- Radiation – ultraviolet (UV): skin cancer.
- Radioactive isotopes.
- Nuclear accidents, power plants, chemical spillage.

C4 Methods of reducing pollution and the associated benefits on short and long term health

- Incentives to Reduce, Re-use, Recycle.
- Reduction of use of pesticides and fertilisers, reduction of use of fossil fuels.
- Alternative forms of transport and energy sources.
- Global organisations and their initiatives and potential solutions to reduce pollution and its effects, e.g. World Health Organization (WHO), Médicins sans Frontières, Oxfam, Unicef, WaterAid.

Learning aim D: Understand how the human body responds to diseases and infections

D1 Defence mechanisms categories:

- Non-specific: immediate response; physical barrier, phagocytosis.
- Specific: slower response, specific to pathogen; cell mediated (T-lymphocytes), humoral response (B-lymphocytes).

D2 Non-specific

- Physical barrier, e.g. skin, nasal hairs.
- Chemical barriers, e.g. mucus, stomach acid – hydrochloric acid (HCl), tear duct secretions.
- Process of phagocytosis: phagocyte, role of histamine, lysosomes, lysozyme.

D3 Specific

- Differentiate between cell-mediated and humoral response (lymphocytes, location of lymphocyte development and maturation):
    - cell-mediated response; response to invasion of non-self-material, T-lymphocytes action, role of antigens, viruses
    - humoral response; B-lymphocytes action, role of antibodies, role of antigens, memory cells, secondary immune response, interaction with T-cells.

Pass	Merit	Distinction
Learning aim A: Investigate different types of diseases and infections that can affect humans		**A.D1** Analyse how an infectious and a non-infectious disease will progress over time, and the effects this may have on affected individuals.
A.P1 Explain the characteristics of the five main types of pathogens and a disease caused by each. **A.P2** Explain the causes of non-infectious diseases in humans.	**A.M1** Assess the effect of a named infectious and non-infectious disease on body systems.	
Learning aim B: Examine the transmission of infectious diseases and how this can be prevented		**B.D2** Evaluate the role of organisations in limiting the spread of infectious diseases.
B.P3 Explain how infectious diseases can be transmitted.	**B.M2** Assess how infectious diseases can be prevented from spreading.	
Learning aim C: Learning aim C: Investigate causes of environmental pollution and the effects of pollutants on human health		**C.D3** Evaluate the impact of environmental pollution on human health and potential solutions.
C.P4 Describe the causes and effects of three environmental diseases.	**C.M3** Analyse methods that can be used to reduce the effects of environmental pollutants.	
Learning aim D: Understand how the human body responds to diseases and infections		**D.D4** Evaluate the roles of the cell-mediated and humoral responses to pathogens.
D.P5 Explain the components of the specific and the non-specific defences, in protecting the body.	**D.M4** Compare the roles of the specific and non-specific defence mechanisms in the human body.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.M2, B.D2)

Learning aim: C (C.P4, C.M3, C.D3)

Learning aim: D (D.P5, D.M4, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- general biology reference material
- online media databases
- biology software packages or apps.

There are a number of different kits available from scientific supply companies that help learners to understand how diseases are transmitted among humans.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will choose a named infectious disease and analyse how the pathogen, having entered the body, will cause infection, disruption and damage to the body systems. Learners must also choose a non-infectious disease and analyse the effects of this on the affected individual. Depending on the two diseases chosen, learners may need to include reference to the fact that individuals may experience asymptomatic periods. They must methodically examine the progress of the infection or diseases and relate this to the individual's ability to lead a normal life.

Learners could be encouraged to produce a case study for each of the diseases they have chosen. They could adopt a holistic approach to the learning aim and use diseases they have already studied. Alternatively, for this criterion, different diseases could be selected and analysed.

For Merit standard, learners will choose a named infectious disease, and the effects the pathogen has on the various body systems must be considered in detail. They will highlight the most important factors associated with damage caused to various body systems and draw conclusions as to their importance in relation to the impact they have on the overall function of the body.

Similarly, learners must choose a non-infectious disease and assess how it affects the various body systems and its overall impact on the body. For instance, learners may detail how the progressive nature of a disease such as multiple sclerosis will result in damage to the nervous pathways over time. The body systems affected will need to be identified and the impact of the effect to the systems assessed. In the case of multiple sclerosis, learners should also assess the impact of possible periods of remission. The diseases do not have to be chosen from the unit content.

For Pass standard, learners will identify and explain the main features of the five main categories of pathogens in the unit content. Learners will need to research and identify a named disease caused by each pathogen. Learners will use their research material to explain the involvement of the pathogens in causing the infectious diseases that have been identified. The characteristics of the pathogen for each of the five named diseases must be included in the evidence presented for assessment.

Learners are required to research the causes of non-infectious diseases and select one disease from each of the three categories in the unit content. Reasons as to how and why each named disease has arisen must be given. It is expected that Punnett squares/genetic diagrams will be used when learners are providing details for a genetic disease. However, these are unlikely to provide sufficient detail without a commentary explaining what they show. The examples of infectious and non-infectious diseases in the unit content do not have to be used. It is acceptable for learners to choose their own examples based on their own interests or experiences, but not for all of the learners to provide evidence for all the same diseases.

Learning aim B

For Distinction standard, learners will extend their knowledge, having explored how infectious diseases are caused and transmitted, to include an understanding of how organisations are working to limit the spread of infectious diseases. It is not expected that all methods listed in unit content B2 will be covered at this level, as they are not all used for every disease. Learners will need to evaluate the strengths and weaknesses, and advantages and disadvantages of the methods being used and their significance in limiting the spread of disease(s).

Learners can meet the criterion by choosing a named disease and providing a case study on organisations involved in preventing the spread of that disease. Alternatively, they can choose an organisation and evaluate the methods adopted to help prevent the spread of diseases the organisation is involved in. Examples of some suitable organisations are given in the unit content, but learners are free to choose their own.

For Merit standard, learners will assess the methods that can be used to prevent the transmission and spread of infectious diseases. They should assess each method in relation to specific examples of diseases in order to reach a conclusion about the effectiveness/relevance of the method in preventing the disease. For example, with the use of prophylaxis for preventing malaria, learners should consider the effectiveness of the method in relation to people remembering to take it, cost and possible side effects. They must consider vaccination programmes and cite their importance in the evidence presented.

For Pass standard, learners will need to become familiar with the methods by which infectious diseases can be transmitted. While much information will be acquired through research, it is expected that learners have the opportunity to investigate this practically (swabs of surfaces, and water samples cultivated on agar plates could be used, depending on availability of equipment and health and safety regulations in centres). Practical work will not be formally assessed. Alternatively, to engage learners and increase their understanding, simulation activities of ‘swapping body fluids’ and transmission by touching/shaking hands can be carried out. Assessment evidence requires learners to demonstrate knowledge and understanding of direct and indirect methods of transmission in the unit content.

Learning aim C

For Distinction standard, learners will evaluate how human activities and natural phenomena lead to pollution of air and water and consequently impact on public health. The evaluation will include details of the pollutants and their sources and the potential the pollutants have to cause disease. Learners will discuss the potential solutions global organisations are trying to implement in an attempt to protect the environment. Examples may include: alternative, clean energy sources (solar, wind, geothermal), responsible consumption of fuels, electric and hybrid vehicles, biodegradable plastics, substitution of nitrogen fertilisers, solid waste management, wastewater treatment and sanitation, reforestation. Learners will evaluate how these initiatives will effectively decrease pollution levels and lead to improvements in public health.

For Merit standard, learners will select a particular pollutant that has a major effect on the environment and produce a detailed analysis showing how the pollutant enters the environment and consequently impacts on human health. The methods used in an attempt to reduce the sources of the pollutant, its environmental impact and damage to human health will be explained in detail. Learners will also demonstrate a clear understanding of global initiatives that are working to reduce diseases and deaths caused by atmospheric and water pollution.

For Pass standard, learners will identify and describe the causes of three diseases caused by environmental pollutants. They must identify a disease caused by water pollution, air pollution and radioactive pollution and describe the possible sources of the pollutants and how these contaminate the environment. The effects of the pollutants on human health will be described in detail including symptoms and the short and long-term effects of each disease.

Learning aim D

For Distinction standard, learners will consider the relevance, significance, advantages and disadvantages, and strengths and weaknesses of having a cell-mediated and a humoral response to infection caused by a pathogen. They could produce an illustrated report as evidence. They must detail the significance of the speed and specificity of the response in relation to the defence process and progression of the disease in the body. Learners are expected to use examples of specific diseases in their evidence.

For Merit standard, learners will examine the key aspects and processes of the specific and non-specific defence mechanisms and their suitability for the purpose of defending the body. They must compare in detail similarities and differences, and reasons why it is beneficial to have both types available to help protect the body. Learners should include details on the speed and specificity of the response to the disease.

For Pass standard, learners will explain the defence systems of the body. They could produce an information leaflet that explains how and why the non-specific defences of physical and chemical barriers and phagocytosis works. Another section of the leaflet could explain the components and function of the specific defence system.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 9: Biomedical Science
- Unit 14: Genetics and Genetic Engineering
- Unit 19: Microbiology and Microbiological Techniques
- Unit 24: Pollution and Waste Management.

Employer involvement

A visit from an Environmental Health Department may afford learners an opportunity to understand the role of the department in identifying pathogens and sources of infection and in preventing transmission of pathogens. They may also be able to provide information in relation to environmental diseases and their prevention.

It may be possible to arrange a visit from a pharmacist/pharmacologist who will be able to discuss prophylaxis, vaccination and possible treatments for various types of pathogens.

Local representatives of local and national organisations and charities may be available to provide information about initiatives in which their organisations are involved to help prevent the spread of disease.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- cultivating microorganisms
- health and Safety procedures
- analytical and observation skills
- formal written communication
- self-management and planning skills
- ability to work in a scientific environment
- ability to carry out independent research.

Unit 16: Applications of Inorganic Chemistry

Level: 3
Unit type: Internal assignment
Guided learning hours: 60

Unit in brief

The unit covers four important inorganic chemistry topics: inorganic compounds and transition metal complexes, solubility and energetics of ionic compounds, acid-base equilibria and buffer action, and redox reactions.

Unit introduction

Inorganic compounds often show acid or base characteristics which are influenced by the type of bonding present. You will explore how this characteristic changes across a period, and review the applications of different acidic and basic compounds. Many compounds of biological importance are transition metal compounds and complexes. You will learn about compounds of transition metals, exploring terms related to complexes and investigating substitution, acid-base and redox reactions. You will make and explain detailed observations from the reactions of these inorganic compounds and transition metal complexes.

Some uses of inorganic compounds, such as fertilisers, rely upon the solubility of the ionic compound. You will explore how solubility of an ionic compound changes with temperature and use solubility product data to predict quantities that can be dissolved. Energetics plays a large role in determining the strength of the ionic lattice, the hydration of ions, formation of solutions and neutralisation. You will investigate the energetics involved, perform calculations to determine these enthalpy changes and consider the factors that influence the size of these values.

Acid-base equilibria are important industrially and biologically. For example, determining the acidity of wine and vinegar by acid-base titration, or phosphate and carbonic acid buffer systems that help to maintain pH in body cells. Compounds are often added to food products to ensure that the pH remains constant and the mixture stable. In this unit, you will learn how to determine the pH of solutions and the strength of acidity and carry out acid-base titrations using pH meters, learning how to select suitable indicators for titrations and how autotitrators work. You will also explore buffer action and the extent of the efficiency in applications.

Reduction-oxidation (redox) reactions, involving loss and gain of electrons, have applications in industry and analytically. The concepts of oxidation number and electron transfer will allow you to identify, balance and explain redox reactions. You will have the opportunity to apply redox in titrations to determine amounts of analytes and compare this with colorimetry as an analytical technique. Standard electrode potentials provide a means to predict the feasibility of a redox process occurring and you will investigate this in electrochemical cells and reactions.

Most of the chemistry in this unit is particularly applicable to the water testing and water treatment industries. For example, pH is routinely measured when testing the quality of effluent. Dichromate oxidation is used to determine chemical oxygen demand which gives an indication of the extent of contamination of water by organic substances. The corrosion of industrial water boilers must be carefully controlled and this work is often sub-contracted to specialists. The level of acidity and the concentration of transition metal ions is important when determining the nature and concentration of treatment chemicals. Aqueous effluent is often treated by neutralisation.

Learning aims

In this unit you will:

A Investigate patterns of chemical reactivity in the Periodic Table to understand the chemistry of inorganic compounds

B Investigate the solubility and chemical energetics of ions to understand the properties of inorganic compounds

C Investigate acid-base equilibria in order to understand acid-base titration procedures and applications of buffer solutions

D Investigate reduction and oxidation reactions in order to understand analytical and industrial applications.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Investigate patterns of chemical reactivity in the Periodic Table to understand the chemistry of inorganic compounds	**A1** Acid-base characteristics of inorganic compounds **A2** Characteristics of transition metal compounds and complexes	Report on the common applications of inorganic acids, bases and transition metal compounds. Results table for test tube reactions involving a range of inorganic compounds and transition metal complexes. A PowerPoint presentation analysing and explaining the changing acid-base character across a period and the types of reactions of transition metals complexes undergo.
B Investigate the solubility and chemical energetics of ions to understand the properties of inorganic compounds	**B1** Enthalpy changes involving ions **B2** Solubility of ionic compounds	Results of enthalpy change reactions of acids with alkalis and dissolving inorganic compounds. Calculations of theoretical enthalpy changes for hydration of ions and formation of ionic lattices. Results and graphs for solubility of different inorganic compounds. Calculated solubility product values for ionic compounds to predict whether a solution will be saturated. Factors which determine solubility and enthalpy values for ionic compounds are assessed.

Learning aim	Key content areas	Assessment approach
C Investigate acid-base equilibria in order to understand acid-base titration procedures and applications of buffer solutions	**C1** Acid-base equilibria **C2** Acid-base titrations and pH curves **C3** Buffer solutions	A report comparing calculated pH values with those experimentally determined for a range of acid/base solutions and concentrations. Results and graphs from four pH titrations, with explanation and justification of suitable indicators for titrations. Results showing how to determine K_a and more complex calculations involving the constant. Results and theory of buffer action. A report evaluating the use of buffer solutions and of acid-base titrations using indicators, pH meters and autotitrators.
D Investigate reduction and oxidation reactions in order to understand analytical and industrial applications	**D1** Redox reactions **D2** Redox titrations and colorimetry **D3** Electrochemical cells and electrode potentials	Results and calculation for determining the amount of an analyte in different redox titrations and by colorimetry. Comparison of three measured cell voltages with the voltages calculated using standard electrode potentials. Analysis of a range of redox reactions and electrochemical cells using equations and standard cell voltages. An evaluation of the use of and limitations of standard electrode potentials in analytical and large-scale contexts.

Content

Learning aim A: Investigate patterns of chemical reactivity in the Periodic Table to understand the chemistry of inorganic compounds

A1 Acid-base characteristics of inorganic compounds

- Definitions of acid, base and amphoteric.
- Oxides of Period 3 elements (Na_2O, MgO, Al_2O_3, SiO_2, P_4O_6, P_4O_{10}, SO_2, SO_3, Cl_2O, Cl_2O_7) and reactions with water, acids and bases.
- Hydroxides/oxoacids of Period 3 elements ($NaOH$, $Mg(OH)_2$, $Al(OH)_3$, $Si(OH)_4$, H_3PO_3, H_3PO_4, H_2SO_3, H_2SO_4, $HClO$, $HClO_4$) and interaction with water, acids and bases.
- Chlorides of Period 3 elements ($NaCl$, $MgCl_2$, Al_2Cl_6, $SiCl_4$, PCl_3, PCl_5, SCl_2) and interaction with water (hydration or hydrolysis).
- Predictions for oxides, hydroxides and chlorides other periods.
- Full and ionic equations for all reactions.
- Influence of the bonding and structure to explain acid-base behaviour of oxides, hydroxides and chlorides.
- Applications of inorganic compounds:
  - treatment of acidic effluent, soil and indigestion
  - removal of transition metal ions from wastewater
  - manufacture of fertilisers
  - hydrolysis of fat, protein and polymers
  - extraction of alumina and neutralisation of impurities in steel manufacture
  - analytical applications (e.g. determining acid content in food and drink).

A2 Characteristics of transition metal compounds and complexes

- Transition metal compounds:
  - incompleted subshell in ions
  - variable oxidation state
  - colour
  - catalysis (redox behavior, lowering of activation energy requirements)
  - complexion formation.
- Complex ions:
  - central ion with vacant orbitals
  - ligands (definition – monodentate examples: H_2O, NH_3, CN^-, Cl^-, OH^-, SCN^-; bidentate examples: diaminoethane, ethanedioate; multidentate: EDTA)
  - dative covalent bonds
  - co-ordination number
  - formulae representation e.g. $[Fe(H_2O)_6]^{3+}$
  - shape (octahedral, tetrahedral, square planar, linear) and 3D representation
  - colour (splitting of d-subshell, influence of charge, co-ordination number and ligands).

- Reactions of complex ions involving Cu^{2+}, Fe^{2+}, Fe^{3+}, Cr^{3+}, Co^{2+}, Mn^{2+}:
  - deprotonation of the aqua complex ions with sodium hydroxide and ammonia solution
  - acidity of aqua complex ions, testing with sodium carbonate
  - ligand substitution
  - redox reactions, in air and with reducing agents (e.g. iodide)
  - colour changes and precipitations accompanying the reactions.
- Observations for all reactions:
  - when reagents are added dropwise and in excess
  - colour changes
  - formation and redissolving of precipitates
  - ionic equations.
- Applications of transition metal compounds:
  - pigments (e.g. cobalt, chromium and titanium compounds in paint)
  - catalysts (e.g. iron and its oxides in the Haber process, vanadium(V) oxide in Contact process)
  - biological (e.g. role of iron in haemoglobin, role of manganese and copper ions in photosynthesis)
  - medical (e.g. cisplatin and carboplatin in cancer treatment).

Learning aim B: Investigate the solubility and chemical energetics of ions to understand the properties of inorganic compounds

B1 Enthalpy changes involving ions

- Definitions and experimental determination of standard enthalpy change of:
  - neutralisation
  - solution.
- Use of $mc_p\Delta T$ to determine enthalpy change of reactions in contact with water
- Definition and theoretical determination of:
  - standard enthalpy change of hydration
  - lattice energy.
- Use and definition of other standard enthalpy changes (formation, atomisation, ionisation energy, electron affinity) and Born-Haber cycles in calculations involving ionic compounds.
- Use of lattice energy and hydration enthalpies to determine enthalpy of solution using $\Delta H^o_{soln} = -\Delta H^o_{lat} + \Delta H^o_{hyd.}$
- Factors affecting magnitude of enthalpy values for ions and ionic lattices:
  - charge
  - ionic radius
  - polarising power of cation
  - polarisability of anion
  - comparison of literature and experimental values for lattice energy (e.g. group 1 halides, silver halides)
  - patterns in thermal stability of Group 2 carbonates and nitrates
  - patterns in solubility of group 2 hydroxides and sulfates.

B2 Solubility of ionic compounds

- Definition of solubility and saturated solution.
- Calculation of solubility of a compound at a given temperature.
- Solubility curves:
  - techniques and procedures to collect data (add known volumes of water from a burette to known mass of the compound, heat and stir until compound dissolves, cool and record temperature at first sign of precipitation)
  - interpretation of curves.
- Solubility product, K_{sp}
  - write expressions of K_{sp} for ionic compounds e.g. $K_{sp} = [Ca^{2+}_{(aq)}][OH^{-}_{(aq)}]^2$ for $Ca(OH)_{2\ (s)} \rightleftarrows Ca^{2+}_{(aq)} + 2OH^{-}_{(aq)}$
  - calculate maximum concentrations of ions of an ionic compound in a solution from K_{sp} values
  - common ion effect, precipitation of ionic compounds when solutions of ions are mixed and K_{sp} is exceeded
  - calculate value of an ionic product of ionic compounds and compare against literature K_{sp} values to predict whether precipitation will occur.

Learning aim C: Investigate acid-base equilibria in order to understand acid-base titration procedures and applications of buffer solutions

C1 Acid-base equilibria

- Definitions:
  - acids, bases and alkali (Brønsted-Lowry)
  - conjugate acids and bases
  - strong, weak, concentrated, dilute.
- pH scale, $pH = -\log[H^+]$ and $[H^+] = 10^{-pH}$
- Acid dissociation constant, K_a:
  - use the expression $K_a = \frac{[A^-][H^+]}{[HA]}$ to determine pH for a weak acid ($HA \rightleftharpoons H^+ + A^-$)
  - calculate K_a from pH
  - assumptions made in calculations
  - magnitude of K_a related to degree of dissociation
  - $pK_a = -\log K_a$
- Ionic product for water, K_w:
  - dissociation of water ($H_2O \rightleftharpoons H^+ + OH^-$)
  - $K_w = [H^+][OH^-] = 1 \times 10^{-14}\ mol^2\ dm^{-6}$ (at 25°C)
  - use of K_w to calculate pH for strong alkalis
  - $pK_w = -\log K_w$

C2 Acid-base titrations and pH curves

- pH titrations for:
  - strong acid/strong alkali
  - strong acid/weak alkali
  - weak acid/strong alkali
  - weak acid/weak alkali.

- Descriptions of the shapes of the pH/volume titration curves.
- Determination of equivalence point from:
  - mid-point of vertical stretch on pH/volume curve
  - spike in differential (ΔpH/Δvolume versus volume added) plot.
- Selection of indicator for an acid-base titration from supplied pH range data.
- Application of acid-base titrations in industry and for analytical processes, using:
  - different indicators
  - pH meters
  - autotitrators.

C3 Buffer solutions

- Buffer solutions:
  - definition
  - composition – a solution of a weak acid (or base) and a salt of the weak acid (or base)
  - investigate the action of buffer solutions
  - use of $\text{pH} = -\log K_a + \log\left(\frac{[A^-]}{[HA]}\right)$ for a buffer solution (Henderson-Hasselbalch equation)
  - applications (e.g. acidity regulators in food, citric acid-citrate in shampoo, carbonic acid-hydrogencarbonate buffers in controlling blood pH).

Learning aim D: Investigate reduction and oxidation reactions in order to understand analytical and industrial applications

D1 Redox reactions

- Reduction and oxidation definitions.
- Reducing agent and oxidising agent definitions.
- Oxidation number – rules and assigning numbers.
- Redox and half equations:
  - identifying oxidised and reduced species
  - constructing and balancing equations in terms of number of electrons transferred
  - deducing half equations from redox equations and vice versa.
- Displacement reactions for metals and halogens.

D2 Redox titrations and colorimetry

- Redox titrations – principles and use of different types.
- Oxidising agent titrant – potassium permanganate solution:
  - determination of iron(II) concentration by titration with potassium permanganate: $5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$
  - self-indicating colour change at end point.
- Reducing agent titrant – sodium thiosulfate titration:
  - determination of the concentration of iodine in a solution with sodium thiosulfate solution: $I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + 2S_4O_6^{2-}$
  - standardization of sodium thiosulfate with potassium iodate
  - use of starch indicator to provide sharp colour change at end point.

- Applications of redox titration:
  - permanganate titration to determine the amount of iron(II) in commercial iron tablets or amount of iron in steel wool
  - permanganate titration to determine concentration of ethanedioic acid (e.g. rhubarb leaves)
  - iodine/thiosulfate titration to determine the concentration of Cu^{2+} (e.g. metal plating industry)
  - iodine/thiosulfate titration to determine peroxide value of fats and oils (e.g. food industry)
  - iodine/thiosulfate titration to determine the concentration of hypochlorite (ClO-) in bleach

use of potassium dichromate in chemical oxygen demand kits and potential use as a titrant in water testing industries: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

- Colorimetry – principles and use.
- Techniques:
  - selection of filter (colorimeter) or fixed wavelength (spectrometer)
  - measurement and use of absorbance readings
  - use of Beer–Lambert law to determine the concentration
  - accurate dilution of stock solutions and blank to prepare a range of calibration standards to plot a calibration curve
  - determination of unknown solution concentration from reading from graph (graph paper) or from the equation of a linear trend line through the origin (Microsoft Excel).
- Comparison of redox titration and colorimetry techniques to determine the concentration of a solution.

D3 Electrochemical cells and electrode potentials

- Electrochemical cells:
  - equipment and techniques for measuring cell voltage
  - half cells using metal in solution of its own ions
  - half cells using platinum for non-metal elements or solutions of ions
  - use of standard cell notation e.g. $Zn_{(s)} | Zn^{2+}_{(aq)} ¦¦ Cu^{2+}_{(aq)} | Cu_{(s)}$.
- Standard electrode potential (E^o):
  - definition
  - standard hydrogen electrode (as a reference)
  - standard conditions (100 kPa, 298 K and 1 molar solutions).
- Calculation of voltage using table of standard electrode potentials:
  - comparison with experimentally determined values
  - predicting the spontaneity of a redox reaction (e.g. corrosion)
  - understanding the limitations of predictions.
- Applications of standard electrode potentials:
  - making batteries (e.g. alkaline battery, lead-acid battery, lithium battery)
  - fuel cells (e.g. alkaline hydrogen-oxygen fuel cell)
  - determination of corrosion behaviour (e.g. rusting) and prevention (e.g. sacrificial protection).

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Investigate patterns of chemical reactivity in the Periodic Table to understand the chemistry of inorganic compounds		
A.P1 Review the applications of inorganic acids and bases. **A.P2** Explain key features and applications of transition metal compounds.	**A.M1** Investigate the acid-base nature of inorganic compounds across Period 3. **A.M2** Investigate the reactions of transition metal complexes.	**A.D1** Analyse the reactions of Period 3 inorganic compounds and transition metal complexes.
Learning aim B: Investigate the solubility and chemical energetics of ions to understand the properties of inorganic compounds		
B.P3 Determine solubility curves for inorganic compounds. **B.P4** Investigate enthalpy changes of neutralisation and solution for inorganic compounds.	**B.M4** Predict the solubility of inorganic compounds by comparison of calculated ion product values against literature values for the solubility product, K_{sp} **B.M3** Perform calculations of enthalpy changes involving ions using enthalpy cycles.	**B.D2** Assess the effect of ionic charge and radius upon hydration enthalpy, lattice energy and solubility.
Learning aim C: Investigate acid-base equilibria in order to understand acid-base titration procedures and applications of buffer solutions		
C.P5 Compare experimentally determined pH values against calculated values. **C.P6** Plot pH curves for a range of acid-base titrations and determine the acid dissociation constant, K_a, for a weak acid. **C.P7** Investigate the action of a buffer solution.	**C.M5** Perform complex calculations involving pH and K_a, including rearrangement of equations. **C.M6** Explain the shape of pH curves and the use of appropriate indicators.	**C.D3** Evaluate the use of different acid-base titration techniques and the efficiency of buffer solutions.

Pass	Merit	Distinction
Learning aim D: Investigate reduction and oxidation reactions in order to understand analytical and industrial applications		**D.D4** Evaluate the use of redox reactions and standard electrode potentials in analytical and commercial applications.
D.P8 Investigate the concentration of analytes using redox titration and colorimetry. **D.P9** Compare experimentally determined cell voltages for metal/metal ion electrochemical cells with calculated values.	**D.M7** Analyse a range of redox reactions and electrochemical cells in terms of oxidation numbers, equations and standard electrode potentials involved.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim A: (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aim B: (B.P3, B.P4, B.M3, B.M4, B.D2)

Learning aim C: (C.P5, C.P6, C.P7, C.M5, C.M6, C.D3)

Learning aim D: (D.P8, D.P9, D.M7, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory with a fume cupboard
- a range of inorganic chemicals
- water utilities, sinks and power sources
- weighing scales
- glassware for volumetric analysis
- a colorimeter
- pH meters
- high resistance voltmeter, electrical wires and crocodile clips
- health and safety policies and risk assessments.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will analyse their investigations of the Period 3 oxides, hydroxides and chlorides, and the five selected transition metal aqueous complex ions undergo. They will identify the type of bonding and structure in the Period 3 compounds and explain how this affects the solubility in water and acid-base nature. With the transition metal aqua complex ions, learners must explain at least one example of a ligand substitution reaction with ammonia and with chloride ions, and one example of each of the deprotonation/precipitation reactions with each of the following reagents when added dropwise and in excess: hydroxide, ammonia and carbonate. They will produce a reaction scheme that would allow the transition metal ions to be identified in terms of colours observed and the presence/absence of a precipitate when certain reagents are added. Learners will use accurate terminology in explanations and correct notation in equations to explain the results.

For Merit standard, learners will carry out an investigation into the water solubility and acid-base properties of inorganic oxides, hydroxides and chlorides from Period 3. Learners will provide experimental results which include observations of solubility and pH measurements of solutions formed for oxides and chlorides of s block elements and at least two p block elements.

Learners will carry out a practical investigation into the reactions of transition metal complexes, using a selection of five aqueous transition metals ion solutions. Test tube reactions involving deprotonation, ligand substitution and redox will be investigated. Reagents to be added to the transition metal complex ion solutions will be sodium hydroxide, ammonium hydroxide and sodium carbonate (dropwise and in excess), ammonia (concentrated solution), chloride ions (from concentrated hydrochloric acid), iodide ions and exposure of products to air. Learners will be required to design and use suitable tables for recording results and make accurate observations from practical work. Observations involving colour change, precipitation, dissolving and effervescence will be made.

For Pass standard, learners will produce a report which reviews a wide range of applications of inorganic acids and bases. These should focus upon acids, bases and alkalis of Period 2 and 3 elements. For example, common acids such as hydrochloric acid, nitric(V) acid, sulfuric(VI) acid, phosphoric(V) acid and carbonic acid, and common bases such as sodium hydroxide, ammonia, calcium oxide and hydroxide, magnesium oxide and hydroxide. Equations to explain the acid or base behaviour must be given as part of the review.

Learners will also explain the key features of transition metal compounds which will include redox, catalysis, colour and formation of complex ions. They will need to refer to the electronic configuration of transition metals and their ions as starting point and use scientific terminology appropriately. The report will need to be illustrated with appropriate equations or diagrams. Learners should select an example of transition metals compounds or complexes for each key feature to explain how the property has an application.

Learning aim B

For Distinction standard, learners will assess how the charge and radius size of ions affects the magnitude of hydration enthalpy when interacting with water molecules. The magnitude of the lattice energy when combined with other ions and how the balance between the two enthalpy terms affects solubility (eg trends in group 2 hydroxides and sulfates). Data on ionic radii, hydration enthalpy, lattice energy and solubility will need to be provided to learners or researched as part of the assignment. They will also consider the polarising power of cations and polarisability of anions to explain why some ionic lattices are more energetically stable than expected (e.g. silver halides) and why some decompose more readily than others (e.g. the trend in Group 2 carbonates).

For Merit standard, learners will carry out a range of calculations (at least 10 questions) to determine the ionic product of a compound when two solutions are mixed. They will compare this value against the solubility product value (K_{sp}) to determine whether the compound formed remains in solution or will precipitate. Calculations will involve formation of ionic compounds of the formulae XY, X_2Y, and XY_2 involving ions with charges of +1, +2, -1 or -2 (e.g. AgCl, $BaSO_4$, Ag_2S, $Mg(OH)_2$, $PbBr_2$). They will also calculate the maximum concentration of two solutions that can mixed before K_{sp} is exceeded and precipitation will occur. Working and the correct answer for at least half of the questions of each type must be given to meet merit standard.

Learners will carry out a range of calculations (at least 10 questions) involving the standard enthalpy changes associated with ionic compounds (i.e. lattice energy, hydration enthalpy, standard enthalpy of solution). For lattice energy, this will involve the construction and use of Born-Haber cycles to determine a value from standard enthalpies of formation, atomisation, ionisation energy and electron affinity (or one of these values given the lattice energy). For enthalpies of solution or hydration, this will involve the construction of an energy cycle and the use of the equation $\Delta H^{o}_{soln} = -\Delta H^{o}_{lat} + \Delta H^{o}_{hyd}$. Questions will involve ionic compounds of the formulae XY, X_2Y, and XY_2 involving ions with charges of +1, +2, -1 or -2. Working and the correct answer for at least half of the questions of each type must be given to meet merit standard.

For Pass standard, learners will collect data for the solubility of two inorganic compounds in water at different temperatures to plot solubility curves (e.g. potassium nitrate and sodium chloride). Learners will demonstrate accurate skills for measuring the mass of the compound and the volume of water added to it. They will apply techniques to accurately determine the temperature at which the compound precipitates out of aqueous solution and calculate the solubility at that temperature in grams per 100 grams of water.At least five measurements of solubility for each compound are required to plot the solubility curves and learners will draw conclusions and comparisons about the solubility of the two compounds.

Learners will also carry out investigations into the enthalpy changes when acids neutralise alkalis and when ionic compounds dissolve in water. Four inorganic acids/alkali reactions (e.g. hydrochloric acid, sulfuric acid, sodium hydroxide, ammonium hydroxide) and four ionic compounds dissolving in water (e.g. sodium chloride, ammonium chloride, potassium chloride, sodium carbonate, calcium chloride, sodium hydrogencarbonate) will be investigated and the enthalpy change per mole calculated. They will make comparisons and draw conclusions about the enthalpy changes.

Learning aim C

For Distinction standard, learners will evaluate the good and bad points of acid-base titrations as an analytical technique. They will consider the cost of equipment and the need for calibration and maintenance of equipment. Learners must not assume that the more automated a process, the more accurate it will be. Learners will also explain buffer action that in an application (e.g. in the blood or shampoo) and evaluate the efficiency of buffer action in terms of the Henderson–Hasselbalch equation.

For Merit standard, learners will perform a series of complex calculations involving pH and acid dissociation constants. For example, learners could be given the pH and the concentration of a weak acid and asked to calculate the acid dissociation constant for a weak acid or calculate the pH of a buffer solution from the acid dissociation constant for a weak acid and concentrations of weak acid and salt.

Learners will explain the shape of the pH curves for each of the four titrations. They will use acid-base equations, calculations involving $[H^+] = 10^{-pH}$, and buffer action theory to support explanations of the pH changes observed.

For Pass standard, learners will measure pH values using a calibrated pH meter for a selection of solutions that include strong acids, strong alkalis and weak acids at different concentrations. They will compare these pH measurements with calculated pH values for the concentrations of the solutions supplied using the equation $pH = -\log[H^+]$. Learners will use suitable acid or base dissociation equations to explain their results and they will calculate the concentration of H^+ ions from the measured pH using the equation $[H^+] = 10^{-pH}$.

Learners will carry out pH titrations, adding 0.5 cm^3 of titrant at a time and measuring the pH with a pH meter. They will plot a “curve” of pH against volume of alkali added and a graph of ΔpH/Δvolume against volume of alkali (in Excel®). From these plots, they will determine the end point of each of the four titrations. For the pH curve of the weak acid/strong alkali, learners will determine the acid dissociation constant, K_a, for the weak acid, using the pH of the half-neutralised solution and the relationships pH = p K_a and $K_a = 10^{-pKa}$.

Learners will make an acidic buffer solution, calculating its pH and comparing that pH with the measured pH. Learners will be specific about the sizes of the pH changes observed and the quantities of acid and alkali added.

Learning aim D

For Distinction standard, learners will produce a report which will evaluate a range of analytical procedures involving redox reactions. They will give the types of industry that use them and evaluate the extent of how accurate and reliable the techniques are. Learners will consider alternative titrimetric and analytical procedures and will also report on a range of commercially available electrochemical cells (batteries and fuel cells) and methods of corrosion prevention. They will then evaluate the electrochemical cells and corrosion-resistance methods based upon these calculations and other factors such as expense of materials, durability and alternatives.

For Merit standard, learners will review the redox titrations carried out, and analyse the equation for the reaction. Learners will also be presented with a list of a further six equations, some of which are redox equations, but some equations should be of other reaction types. They will correctly identify the redox equations, showing how they have calculated change in oxidation numbers of the elements. Learners will be tasked with planning four electrochemical cells given the two half cells and the standard electrode potentials. They must write oxidation and reduction half equations. A labelled diagram of the planned electrochemical cell must be constructed by the learner.

For Pass standard, learners will carry out the Fe^{2+}/MnO_4^- titration to determine the concentration of a solution of Fe^{2+} ions (from iron tablets or steel wool) with given standardised potassium permanganate solution. They will also use sodium thiosulfate solution, standardised with potassium iodate (KIO_3), and use it to determine the concentration of at least two analytes in solution (iodine, hypochlorite, Cu^{2+}, peroxide). Learners will also use colorimetry to determine the concentration of at least one of the analytes. The accuracy of the concentration of the analyte determined by redox titration and colorimetry should be compared.

Learners will select three electrochemical cells to set up and measure the cell voltage produced. They will also write the reduction and oxidation half equations involved, redox equations for the overall cell reaction and calculate the standard cell voltages using standard electrode potentials for each electrochemical cell.

Links to other units

This unit links to:

- Unit 2: Principles and Applications of Chemistry I
- Unit 6: Principles and Applications of Chemistry II
- Unit 20: Principles and Applications of Physical Chemistry
- Unit 21: Applications of Organic Chemistry
- Unit 25: Water Quality.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities.

For example, it will be beneficial for learners to visit the testing laboratories of local companies that treat wastewater from industry. Speakers from the water treatment industry or specialist companies that treat boiler water to prevent corrosion will be able to explain the relevance of the chemistry in this unit.

This unit would benefit from employer involvement in the form of:

- a visit to any commercial laboratory
- a speaker from a commercial laboratory.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- independent investigation and research skills
- practical and technical skills, using appropriate equipment, procedures and techniques
- scientific written and communication skills
- data interpretation, manipulation and presentation
- analytical and problem-solving skills
- self-management and planning skills
- evaluative and assessment skills.

Unit 17: Electrical Circuits and their Applications

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers the principles of electricity, including measurements of electrical values and health and safety, the construction of circuits and their use in society today.

Unit introduction

In this unit, you will explore what electricity is, how to use measuring devices and construct circuits, as well as gain an understanding of the many varied applications of electricity in our everyday lives. Since Thomas Edison's first demonstration of the electric lamp in 1879, it is difficult to imagine life without electricity and the immediate effects it provides.

Despite advances in modern electronic devices, fundamental electrical principles still form the basis of electrical and electronic development in all aspects of life. This unit will provide you with the knowledge and skills necessary to undertake essential tasks related to electrical circuits and their components.

You will perform practical investigations and report on aspects of electrical measurement, using mathematical relationships to explain readings while developing an understanding of the importance of correct calculations to determine how circuits behave. You will study health and safety in relation to alternating current (AC) and direct current (DC) circuits and develop an understanding of the principles used by electrical safety devices. The different types of measuring devices will also be covered in detail, providing you with information about the methods used by various types of electrical equipment and the part played by transducer devices.

This unit will help you progress to further education, to specialised electrical qualifications or help you to pursue a career as a science technician working in industry, education, health or modern research laboratories. The unit will give you knowledge and understanding of key electrical concepts. It can also help to develop your confidence in the use of instruments and measuring devices under safe working conditions.

Learning aims

In this unit you will:

A Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits

B Construct series and parallel circuits for use in standard electrical applications and measure electrical values

C Examine AC and DC production and health and safety aspects in domestic and industrial applications

D Examine the uses of transducers, sensors and other measurement devices.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits	**A1** Electrical symbols, units and definitions **A2** Electrical formulae and relationships **A3** Electrical properties and uses of materials	A scientific report including use of terms, symbols, units and example calculations Practical investigation of ohmic/non-ohmic conduction devices. Practical circuit assembly, combination circuits and recorded results Records of measurement results of circuit values, resistance values, calculated and predicted comparison. Potential divider circuit work – diagrams and report.
B Construct series and parallel circuits for use in standard electrical applications and measure electrical values	**B1** Circuit characteristics **B2** Measurement devices	
C Examine AC and DC production and health and safety aspects in domestic and industrial applications	**C1** DC production **C2** AC production and transmission **C3** Domestic applications and mains supply **C4** Industrial applications **C5** Safety, human physiology, and electricity and legislation	A report using laboratory and research notes on domestic mains characteristics. A practical investigation into production of induced current/voltage. A general study of uses of AC and DC electricity in the home. A case study comparing industrial uses. A report on physiological study of electric shock effects (AC and DC). An industrial site visit to produce a site safety report and outline of safety devices.
D Examine the uses of transducers, sensors and other measurement devices.	**D1** Uses of passive transducers **D2** Uses of active transducers **D3** Uses of sensors and other measurement devices	Circuit construction and a report on transducers, sensors and other measurement devices. A report on applications and operation of transducers, sensors and measurement devices.

Content

Learning aim A: Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits

A1 Electrical symbols, units and definitions

- Symbols: cell, battery, switch, filament lamp, fixed resistor, thermistor, light-emitting diode (LED), light-dependent resistor (LDR), rheostat, capacitor, voltmeter, ammeter.
- Definitions: current (ampere), potential difference (volt), electrical charge (coulomb), resistance (ohm), conductance (siemen), electrical power (watt), capacitance (farad and sub-units).
- Definition of current in terms of rate of flow of mobile charge carriers.
- Definition of electromotive force (EMF) as measure of ratio of energy supplied per unit charge.
- Definition of conductance and resistance in relation to density of mobile charge carriers.

A2 Electrical formulae and relationships

- Energy supplied $W = VIt$
- Use of Ohm's Law $V = IR$
- Kirchoff's Laws.
- Power $P = IV$, $P = I^2R$
- Charge $Q = It$
- Conductance $G = \frac{L}{R} = \frac{L}{V}$
- Resistivity $R = \frac{pl}{A}\ (\Omega m)$
- Capacitors:
  - charge stored by capacitors $Q = CV$ in operation as a reservoir
  - charging and discharging graph representations
  - calculations of capacitances ($C_T = C_1 + C_2$ for parallel capacitors, $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$ for series capacitors).

A3 Electrical properties and uses of materials

- Conductivity and resistivity.
  - insulators and conductors
  - ohmic and non-ohmic conductors
  - capacitors as a filter in AC circuits
  - semiconductors.

Learning aim B: Construct series and parallel circuits for use in standard electrical applications and measure electrical values

B1 Circuit characteristics

- Correct assembly of series and parallel resistive circuits using up to three resistors in series, parallel and series–parallel combination.
- Calculation of resistance and conductance ($R_T = R_1 + R_2$ for series circuits $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ for parallel circuits and similarly for conductance).

B2 Measurement devices

- Use of ammeters and voltmeters (digital and analogue types for simple comparison).
  - nature of voltage drop across components as the energy dissipates per unit charge by a resistor (where the energy dissipated is transferred from electricity into heat)
  - potential divider circuits and potential divider calculation
  - internal resistance and EMF with use of $E = I(R + r)$.

Learning aim C: Examine AC and DC production and health and safety aspects in domestic and industrial applications

C1 DC production

- Battery (dry cell) construction (zinc, zinc chloride/ammonium chloride and carbon/ manganese dioxide).
- Passage of electrons as unidirectional.
- DC produced by thermocouples and solar cells.
- DC motor/generator (reverses polarity of AC motor).

C2 AC production and transmission

- Magnetic fields around permanent magnets and a wire carrying a current.
- Fleming's left hand rule.
- Fleming's right hand rule.
- Electromagnetic induction and Faraday's Law.
- Principles of Lenz's law.
- Transformer principles and equation (step-up and step-down).
- Transmission of power from 'supply' to 'load'.
- Power loss from cables (I^2R).

C3 Domestic applications and mains supply

- Domestic ring main circuit.
- Nature of AC voltage as changing polarity with instantaneous values varying sinusoidally.
- Root mean square (RMS).
- Peak and peak-to-peak voltages.
- Domestic fuse ratings.
- Powering DC equipment from AC supply.

- Earthing systems.
- Fuses.
- Significance of double insulation.
- Residual current and earth leakage circuit breakers (RCCB and ELCB).

C4 Industrial applications

- DC, e.g. transport, lifting gear, electrolysis.
- AC, e.g. induction furnace, speedometer.
- Line isolation monitors.
- Variable socket design.
- Isolating transformers (for outside use).

C5 Safety, human physiology and electricity and legislation

- Typical resistance values for current pathways in the body.
- Skin resistance and changes of environment, e.g. moisture levels of the skin, contact with the ground.
- Heart responses to electric shock.
- Principles of the defibrillator.
- Effect of the length of current exposure time and amount of electrical current.
- Safe levels of DC voltage.

Learning aim D: Examine the uses of transducers, sensors and other measurement devices

D1 Uses of passive transducers

- As defined by devices that change the electrical characteristics within a circuit by the influence of external physical factors (sensors) – for example, light-dependent resistor (LDR) and their practical uses, thermistors, reed switch, strain gauge and Wheatstone bridge arrangement, and potential divider circuits.
- Uses of light meters, automatic cameras, alarm systems.

D2 Uses of active transducers

- Production of EMF by conversion of energy from external physical source, e.g. operation and structure of a thermocouple.
- Piezoelectric devices and fundamental principles.
- Understanding of the need for signal amplification for these devices.

D3 Uses of sensors and other measurement devices

- Oscilloscopes for voltage measurement and AC/DC display.
- Multi-meters and range of measurements.
- Data-logging devices, such as those that sense and store information from physical sources for use with visual/audio display and processing.
- pH meters, temperature sensors, moisture sensors, pressure sensors, light sensors.

Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits</td><td rowspan="4">AB.D1 Evaluate, by calculation and graphical representation, the operation of a range of circuit assemblies using measured values.</td></tr>
<tr><td>A.P1 Explain principle electrical terms, quantities and relationships for given situations.</td><td>A.M1 Demonstrate, by calculation, the use of principle electrical terms, quantities and relationships for given situations.</td></tr>
<tr><td colspan="2">Learning aim B: Construct series and parallel circuits for use in standard electrical applications and measure electrical values</td></tr>
<tr><td>B.P2 Accurately construct a range of circuits and record appropriate values accurately using suitable measurement devices.</td><td>B.M2 Compare predicted and calculated fundamental electrical values for a range of circuit assemblies.</td></tr>
<tr><td colspan="2">Learning aim C: Examine AC and DC production and health and safety aspects in domestic and industrial applications</td><td rowspan="2">C.D2 Evaluate the principles of AC production and transmission for safe use in suitable applications.</td></tr>
<tr><td>C.P3 Explain the similarities and differences of AC and DC electrical circuits.
C.P4 Explain the dangers of working with electricity and its effects on human physiology.</td><td>C.M3 Compare RMS and peak values of AC electricity.
C.M4 Discuss the procedures and practices used to minimise risk when working with electricity.</td></tr>
<tr><td colspan="2">Learning aim D: Examine the uses of transducers, sensors and other measurement devices</td><td rowspan="2">D.D3 Evaluate the use of transducers, sensors and measurement devices in practical situations in terms of their fitness for purpose.</td></tr>
<tr><td>D.P5 Describe the basic principles of operation of transducers, sensors and electrical measurement devices.</td><td>D.M5 Demonstrate the correct basic principles and uses of transducers, sensors and electrical measurement devices in practical situations.</td></tr>
</table>

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, A.M1, B.M2, AB.D1)

Learning aim: C (C.P3, C.P4, C.M3, C.M4, C.D2)

Learning aim: D (D.P5, D.M5, D.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- DC electrical circuit boards and the components identified in unit content
- suitable range ammeters, voltmeters, multi-meters and high-impedance analogue or digital (DSO) oscilloscopes – single or dual trace
- a signal generator, microphone and speakers
- standard transformer packs
- 12 V DC power supplies and suitable single cells
- domestic wiring/fuse samples
- rheostats
- electrolysis apparatus
- RCCB and ELCB (for demonstration purposes)
- a variety of sensors for circuit use
- thermocouple components, piezoelectric example model
- data loggers and associated sensors (pH, moisture, light, temperature, pressure)
- a working model for AC transmission (demo).

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will perform fully independent calculations of essential electrical quantities using studied relationships. As many graphical representations for electrical relationships will be produced as are necessary (for example resistance, power, charge). Ohmic and non-ohmic examples will be used and evaluated. Learners will use data gathered from circuit construction and their calculations to compare measured and calculated values. They will provide a report with an evaluation of the operation of suitable circuits and the measured and calculated values obtained. This could also include a comparison of resistivity values obtained with the actual research values, for example. Any discrepancies between these values will be explained by example calculations and circuit and component understanding.

For Merit standard, learners will demonstrate competence in using correct electrical relationships and calculating values of electrical quantities. Teachers can provide formulae sheets that incorporate many or all examples of standard suitable calculations that can be performed by learners and assessed. These calculations will be linked to a variety of circuit situations to provide suitable reference and context. Learners will use the values obtained in their circuit measurements to make accurate circuit calculations. Using calculations, learners will be able to predict values of current, voltage and resistance at various points in circuits. These predicted values can then be generally compared to measured values obtained from a variety of both series and parallel circuits. Practical determination and subsequent calculation of resistivity values could be incorporated into the work to enhance the electrical investigative work and understanding of electrical relationships.

For Pass standard, learners will produce a comprehensive list all of the electrical terms and symbols given in the unit content, with a brief explanation of each. This may be carried out by producing a catalogue or poster. A list of the main electrical formulae used in this unit will also be provided by the teacher and accompanied by an explanation linking the formulae to their purpose in electrical circuit work.

Learners will be able to obtain measurements of voltage, current and resistance from the construction of series and parallel circuits and to record them in an appropriate tabular form for clarity. Circuit construction will incorporate a minimum of three resistors in a variety of configurations. There is no specific number of circuits to be completed, but teachers must ensure that they are varied and that learners are given guidance where necessary. In general, the expectation is that learners will construct functional series and parallel resistor circuits with resistors, filament lamps and capacitors.

Learning aim C

For Distinction standard, learners will provide a clear evaluation, with diagrams, to illustrate how AC electricity is produced, using the fundamental aspects of Fleming's left hand rule for electrical motors and right hand rule for electrical generators, and expanding this to include the generators in power stations. Learners will evaluate how electricity is transmitted to homes and industry and mathematically account for the need to use transformers and high voltages. The use of AC and DC in the home or industry will then be outlined in detail to identify the applications of AC and DC and the safety mechanisms in place. This will incorporate work covered at merit standard for safety devices and their operation, correct practices and procedures. It is expected that this work will be presented in a formal, well-written and well-organised report that attempts to combine all of the important aspects covered in the learning aim.

For Merit standard, learners will provide a thorough review of AC production and the relationships that determine movement and current flow direction from Fleming's left and right hand rules. Detailed explanation of the sinusoidal waveform, with labelled diagrams, will be used to outline the key aspects of AC representation and allow for a comparison between RMS and peak values of AC electricity. In addition, learners will produce work that demonstrates how a generator operates and include the use and operation of step-up and step-down transformers when transmitting AC on the national grid. Learners will give a valid discussion of how specific safety devices reduce risk from electricity, both AC and DC. Each device studied will be described with the aid of clearly labelled diagrams and explanatory notes on how the device is activated within its circuit. They will also include information on the ways in which organisations maintain health and safety in relation to hazards posed by the use of electrical equipment.

Learners will be able to discuss the operation of electrical safety devices and the safety practices and procedures used to help reduce or eliminate specific risks. They will include details of typical circuit breakers, line isolation monitoring, equipotential earthing systems and double insulation.

For Pass standard, learners will outline, by means of effective diagrams and clear descriptions, the essential similarities and differences between AC and DC when applied to simple electrical circuits. Learners' work will include AC changing in direction and DC one-directional current flow, loss of energy in DC circuits and power loss reduction of AC when transmitted, frequency of zero for DC and display as a horizontal line on an oscilloscope, no change in DC size with time, DC chemically produced in a cell or battery, AC from a generator, the use of a transformer to increase or decrease AC, and the fact that AC current cannot be stored in batteries.

Learners will illustrate the effects of both AC and DC on the human body with artistic work or a simple report that also reviews the work for covering differences between the two types of electricity. They will produce an explanation of the factors that contribute to the severity of the electric shock, such as the length of time involved and the amount of current.

Learning aim D

For Distinction standard, learners will produce an analytical account of the suitability of a chosen transducer/sensor/measurement device from those studied in the unit for a particular application. Evidence can focus on a working example of a device in industry and be presented as a case study, outlining its history, development and technological advancement to date. Alternatively, learners could present the work by developing an appraisal of each transducer/sensor/measuring device from initial practical study. This could then take the form of an evaluative report on the suitability of the equipment used for a given application, discussing its mode of operation, circuit suitability, accuracy and precision (i.e. fitness for purpose).

For Merit standard, learners will demonstrate qualitative research capabilities and may use various order catalogues from equipment manufacturers to supplement their work. Learners will produce circuit diagrams of the transducers and sensors chosen and explain their operation and uses, referring to levels of potential difference, current and resistance. Practical investigation of the devices will provide operational evidence and correct values obtained can be verified by the teacher or research text. A suitable transducer for practical construction and calibration is the thermocouple. Learners will also produce a detailed comparison of an analogue and digital measurement device (data logger) for a given use.

For Pass standard, learners will present a full list of various transducers and the uses of measurement devices commonly in operation from the unit content. The uses to which these devices are put will be clearly contextualised and evidence for this section will come from practical circuit work. Learners will demonstrate and describe the operational principles of at least one transducer and a range of sensors in simple circuits by carrying out suitable practical investigations, describing their findings using accepted reporting standards.

Links to other units

This unit links to:

- Unit 3: Principles and Applications of Physics I
- Unit 7: Principles and Applications of Physics II
- Unit 22: Medical Physics Applications
- Unit 23: Materials Science.

Employer involvement

It may be possible to arrange visits to regional electricity distributors, equipment and component manufacturers, large-scale industries and power stations. In addition, speakers from local electrical businesses, suppliers and manufacturers, or electricians will give learners an idea of how this unit links with everyday practice in industry.

Opportunities to develop transferable employability skills

- Knowledge and ability in building models, using circuit components.
- Selection and use of electrical equipment including meters and power supplies.
- Attention to safe working practice.
- Mathematical processing of results obtained and calculations for predicting values.
- Understanding of variation between domestic and industrial electricity uses.

Unit 18: Astronomy and Space Science

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers the principles and present-day understanding of developments in astronomy.

Unit introduction

In this unit, you will explore the main concepts that have formed the foundations of astronomy for hundreds of years. You will develop your knowledge and understanding of the key areas in astronomy and space flight, of the links between these exciting topics and related industries.

You will focus on the study of the Solar System and gain an appreciation of the advances made in space flight, their applications on Earth and the different scientific disciplines. Your skills in analysis, investigation and research will be enhanced as will your knowledge of key Solar System objects, leading to accurate night sky positioning and star mapping with ample opportunity for both short and long duration practical observation. You will be introduced to the many factors associated with space flight, gaining insight into the practicalities and problems associated with propelling an object beyond the Earth's atmosphere and sustaining an orbit.

With new and exciting planned missions for astronauts to Mars and the prospects of space tourism, the realities of interplanetary missions will be explored. In the light of renewed governmental and commercial plans for further development, you will gain an understanding of how physical laws are linked to complex deep-space exploration missions. You will discuss current theories in the formation and end of the Universe with an in-depth study of cosmological principles relating to the Big Bang theory, inflation and evolution as our current understanding allows.

The skills you learn in this unit can be applied to other areas of study and to workplace practices. You can progress to further education for science-related courses, and to the expanding space science industry, involving astronomical data analysis, research and development.

Learning aims

In this unit you will:

A Understand the fundamental aspects of the Solar System

B Undertake measurement and observation of astronomical objects

C Investigate the essential factors involved in space flight

D Understand the fundamental concepts outlined in astrophysics and cosmology.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the fundamental aspects of the Solar System	**A1** Features and characteristics of the Sun **A2** Features, characteristics and relationship factors of the Earth and Moon **A3** Features and characteristics of the inner and outer planets **A4** Features and characteristics of other Solar System objects	A scientific report and diagrams. Use of terms and numerical values. A presentation document. Outline of features/ numerical values associated with Earth and Moon. Diagrams and text information for all planets. Descriptions of smaller components. Case studies of spacecraft encounters.
B Undertake measurement and observation of astronomical objects	**B1** Earth-based telescope design and features **B2** Space-based telescope design, features and observatories **B3** Night-sky mapping and observations **B4** Daytime observation	Descriptions of important telescopes, optical and radio. Geographical positions. A report on specific telescopes using range of wavelengths. Investigating focal points of concave mirror and convex lens. Practical observation logs. Map of night sky and terminology definitions. Practical observation by projection of sunspot activity.
C Investigate the essential factors involved in space flight	**C1** Spacecraft design **C2** Practicalities and physics of spaceflight **C3** Future of space flight and exploration **C4** Factors and benefits associated with Earth-based applications of space technology	A report on spacecraft materials using specified named vehicles. Conditions for space flight. Maths associated with speed, gravitational forces, re-entry conditions. Case study: PowerPoint presentation on spacecraft design, Moon missions, Mars probes space stations, international plans. Space spin-offs: examples of research activities performed by astronauts.

Learning aim	Key content areas	Assessment approach
D Understand the fundamental concepts outlined in astrophysics and cosmology	**D1** Principles of star creation **D2** Principles of the 'death' of stars **D3** Observable characteristics and properties of stars **D4** Origin and theories of evolution of the Universe and astronomical dimensions	Information poster outlining the life cycle of stars. Report of star characteristics linked to star formation and death. Detailed Hertzsprung-Russell (H-R) diagram aspects. Trigonometric parallax principles outline. Presentation: origin and end of the Universe – current theories and evidence explained.

Content

Learning aim A: Understand the fundamental aspects of the Solar System

A1 Features and characteristics of the Sun

- Structure – corona, chromosphere, photosphere, convective zone, radiative zone, core.
- Nuclear fusion, mass-energy conversion $E = mc^2$ and proton-proton chain.
- Physical features: prominences, flares, solar winds, sunspots.
- The sunspot cycle.
- Physical parameters – diameter, average distance, rotation, mass, surface and core temperatures.
- The solar spectrum in visible and non-visible (UV, X-ray etc.) wavelengths.

A2 Features, characteristics and relationship factors of the Earth and Moon

- Internal structure of the Earth – crust, mantle, inner and outer cores, atmospheric composition.
- Rotations and orbital characteristics.
- Van-Allen radiation belts.
- Lunar features – surface detail, impact craters, phases, eclipses, composition, orbital characteristics, rotation, gravitational effects.

A3 Features and characteristics of the inner and outer planets

- Rocky and gaseous planets.
- Kepler's laws – inverse square relation of distance with gravitational attraction.
- Orbital plane and periods, distances, masses, diameters, ring systems, surface features.

A4 Features and characteristics of other Solar System objects

- Dwarf planets: locations and surface features.
- Numbers of moons orbiting the planets.
- Characteristic features of sample moons – surface, diameters, masses, asteroid belt position.
- Features of largest asteroids, e.g. NEAR Shoemaker to Eros, Rosetta/Philae to Comet 67P.
- Kuiper Belt and Oort Cloud.
- Short or period comets (generally less than 200 years orbit), e.g. Halley, Shoemaker-Levy 9.
- Long period comets and compositions (generally more than 200 years orbit), e.g. Hale–Bopp, Hyakutake, Kohoutek.
- Meteor showers, e.g. Perseids (August), Orionids (Oct.), Geminids (Dec.).
- Meteorite composition, to include stony (chondrites), stony-iron, iron (Widmanstätten lines from large crystal growth).
- Meteoroid origins, e.g. comet tails, asteroids and collisions with other objects, such as planets (Mars).

Learning aim B: Undertake measurement and observation of astronomical objects

B1 Earth-based telescope design and features

- Reflector and refractor telescopes – ray diagrams, focal point of concave mirror:
  - reflector – principle of prime focus of concave mirror and measurement, positioning of small, flat mirror before prime focus to reflect out of the telescope
  - refractor – determination of focal length of principle converging lens and eye piece converging lens, ratio to determine magnification.
- Merits of reflector/refractor design.
- Aspects of image clarity – spherical and chromatic aberration, resolving power.
- Charge-coupled devices (CCDs).
- Radio telescope design.
- Telescopes giving a collective high resolution of brighter astronomical objects, e.g. Very Large Telescope (VLT) from the European Southern Observatory (ESO) project in the Andes (Chile).
- Gravity wave detection (LIGO).

B2 Space-based telescope design, features and observatories

- Microwave – Wilkinson Microwave Anisotropy Probe (WMAP).
- Infrared – Spitzer, James Webb Space Telescope (JWST).
- Visible – Hubble Space Telescope (HST).
- Ultraviolet – HST.
- X-ray – Chandra X-ray Observatory, XMM-Newton.
- Gamma ray – INTEGRAL, Fermi Gamma-ray Space Telescope.
- Solar – Solar and Heliospheric Observatory (SOHO), Hinode.
- Gravity wave detection – Laser Interferometer Antenna (LISA).

B3 Night-sky mapping and observations

- Naked-eye observations of stars and major constellations (including Orion, Ursa Major, Cassiopeia, Crux (for students in southern hemisphere), Cygnus, Andromeda).
- Identification of brightest stars in these constellations using published star charts using both equatorial co-ordinates (right ascension and declination) and horizontal co-ordinates (altitude and azimuth).
- Identification of Polaris, Milky Way, Celestial equator, Magellanic Clouds (for students closer to equator or in southern hemisphere).
- Naked-eye observations of the apparent motion of the Moon plotted onto a suitable star chart.
- Naked-eye observations of the direct and retrograde motion of planets, plotted onto a suitable star chart.
- Explanations of the apparent motion of the Moon and planets.
- Telescopic (or binocular) observations of Jupiter's Galilean moons, phases of Venus and Saturn's ring'.

B4 Daytime observation

- Motion of the Sun and Moon.
- Principle of the sundial.
- Sunspot activity by projection.
- Eclipses and transits.

Learning aim C: Investigate the essential factors involved in space flight

C1 Spacecraft design

- Construction materials.
- Physical properties.
- Power supplies.
- Need for an oxidiser.
- Ceramic and carbon-carbon compound properties for protection.
- Fuel cells for electrical supply.
- Hazards – heat, cold, micro-meteorites, fuel components, radiation.

C2 Practicalities and physics of space flight

- Lift-off principles.
- Mass, propulsion, gimbals, need for staging, spacesuit design features.
- Costs.
- Distance and time.
- Communications.
- Effects on humans – radiation exposure, micro-gravity environment, astronauts in constant free-fall, psychological and physical effects.
- Gravitation.
- Escape velocity using $v = \sqrt[2G]{\frac{2gm}{r}}$
- Use of 'gravity assist', e.g. Voyager 1 and 2 case study.

C3 Future of space flight and exploration

- International Space Station (ISS) and its future.
- Proposed inter-planetary manned missions, e.g. Inspiration Mars, Mars landing, Orion.
- Interplanetary unmanned missions, e.g. SOLO, Juno, Mars Exploration Rover mission.
- International missions, e.g. Russia, China, Japan, European Space Agency (ESA).
- Space tourism, e.g. Spaceship 1, Genesis 1 space hotel, water purification, food, near weightless conditions for long duration, astronaut relationships, time and psychological aspects.
- Problems of space debris and grave yard orbits, e.g. NASA is currently tracking about half a million pieces, possible damage from very small particles to spacecraft, Inter-Agency Space Debris Committee (IADC), set up with 13 member countries to discuss the problem.

C4 Factors and benefits associated with Earth-based applications of space technology

- Materials and manufacturing.
- Health and medicine, transport, public safety, industry, computer technology, consumers, environmental and agriculture.
- Orbital types:
  - high Earth Orbit (including geostationary for telecommunications, including satellite TV)
  - medium Earth Orbit (for GPS and other positioning networks)
  - low Earth Orbit (mainly polar) for satellites monitoring Earth's resources and physical systems (e.g. crop growth, sea-levels, volcanic and tsunami activity, etc.)
- Experiments carried out by astronauts in space.

Learning aim D: Understand the fundamental concepts outlined in astrophysics and cosmology

D1 Principles of star creation

- Giant molecular clouds (nebulae), gravitational collapse, fragmentation (Jeans mass).
- Internal temperature rise, initial nuclear reactions – lithium, deuterium.
- Equilibrium: outward radiation pressure balances inward gravitational force.
- Protostar.
- Slower evolution to main sequence.

D2 Principles of the 'death' of stars

- Mass relation to life cycle – mass equal to the Sun, mass greater than the Sun.
- Core collapse.
- Red giants.
- White dwarfs.
- Electron-degenerate matter, Chandrasekhar limit.
- Supernovae.
- Neutron stars observed as pulsars.
- Black holes, accretion disc, event horizon, Schwarzschild radius, singularity.
- Stellar spectral energy distribution, temperature

D3 Observable characteristics and properties of stars

- Physical and chemical characteristics, mass, luminosity, apparent magnitude, absolute magnitude, $M = m - 5\log\left(\frac{d}{10}\right)$ (where *d* is the distance in parsec), black body radiation, stellar classification (O, B, A, F, G, K, M) based on spectral analysis of absorption lines.
- Hertzsprung–Russell (H–R) diagram.

- Spectra:
  - colours indicate specific chemical elements and relate to star surface temperature, e.g. blue dominant (hot), red dominant (colder)
  - absorption lines represent ions of specific elements and relate to temperature by thickness of the line
  - comparison to the Sun, e.g. absorption lines may be shifted to either red end (moving away from us) or blue end (moving towards us)
  - wavelength increase or decrease – Doppler effect.

D4 Origin and theories of evolution of the Universe and astronomical dimensions

- Units: astronomical unit, light year, parsec.
- Methods of determining distance, parallax, Cepheid variables, brightness variation, eclipsing binaries.
- Redshift and absorption of wavelengths, cosmic microwave background (CMB), abundance of hydrogen and helium isotopes.
- Galaxies including their formation, classification (spiral, barred-spiral, elliptical and irregular).
- Quasars.
- The Big Bang.
- Hubble's law, the Universe and its composition: matter, dark matter, dark energy, projected timeline (Big Bang to photon age), critical density, the fate of the Universe.
- Olbers' paradox.
- Possibility of life elsewhere in the Universe: SETI and results; definition of life, i.e. carbon based-life cycle – not necessarily complex organisms; use of the Drake Equation to estimate the likelihood of intelligent life in our galaxy, discovery of more than 2000 exoplanets by light variation of stars, possible life-supporting chemistry.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the fundamental aspects of the Solar System		
A.P1 Describe the main features of the Solar System and the Sun's influence.	**A.M1** Explain the effects of the interaction between the Sun, Earth and Moon and other Solar System objects.	**A.D1** Analyse the importance of the Sun in its Solar System.
Learning aim B: Undertake measurement and observation of astronomical objects		
B.P2 Describe how different types of telescopes are used for astronomical observation. **B.P3** Explain the relative positions of night-time astronomical objects. **B.P4** Explain the relevant positions and features of daytime astronomical objects.	**B.M2** Assess the findings of practical astronomical observations and their importance in astronomy.	**B.D2** Evaluate the findings and validity of practical astronomical observations in understanding the Solar System.
Learning aim C: Investigate the essential factors involved in space flight		
C.P5 Explain the main factors associated with achieving space flight for manned and unmanned exploration.	**C.M3** Assess the main factors and benefits associated with achieving space flight for manned and unmanned exploration.	**CD.D3** Evaluate the future of space flight and space exploration and research.
Learning aim D: Understand the fundamental concepts outlined in astrophysics and cosmology		
D.P6 Explain current knowledge and theories of the life cycles of stars. **D.P7** Describe the evidence linked to theories of the evolution of the Universe.	**D.M4** Assess the processes of star formation, their life cycles and evolution. **D.M5** Explain the evidence linked to theories of the evolution of the Universe related to observed phenomenon and its composition.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.P4, B.M2, B.D2)

Learning aims: C and D (C.P5, D.P6, D.P7, C.M3, D.M4, D.M5, CD.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- scientific magazines and astronomical journals
- the internet, relevant DVDs, simulation models
- portable telescopes (min. 50 mm refr./100 mm refl.), binoculars (10 × 50 mm) and projection attachments
- optical physics equipment, lenses (converging and diverging), mirrors (concave spherical and parabolic, if possible), suitable light sources.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will explain in detail, the natural forces allowing the Sun to remain in equilibrium and the eventual outcome when these forces change in terms of their expected life cycle, with the ultimate effects on the Solar System. Learners will explain the process of nuclear fusion, detailing the magnetic forces and features on the surface of the Sun and their associated effects. Learners will explain the composition of the Sun, with suitable illustrations, identifying the gases involved and the layered structure.

For Merit standard, learners will work with independence and produce descriptions of the main features in the Solar System. They will include such details as planetary axes of rotation, composition of planets, moons, asteroids, comets and meteors, planetary ring system labels, Van Allen radiation belts, surface features on chosen planets and moons etc.

For Pass standard, learners will describe the main features of the Solar System. They will include a brief definition of structure, the forces involved, orbital characteristics, rotation, atmospheric compositions and physical data. They will briefly describe the relationship of the Earth with the Moon and the Sun by including diagrammatic representation of the particular aspects that occur as a result of interactions on a regular basis, such as day and night, phases of the Moon, eclipses of the Sun and the Moon, tidal effects on the Earth. In addition, learners will describe, by written or diagrammatic form, the other Solar System objects. This will include all the known planets, prominent moons, asteroids, comets and other associated features such as the Kuiper belt and Oort cloud.

Learning aim B

For Distinction standard, learners will evaluate their own practical observations and suggested improvements. Errors in observations will be identified and relevant comments made relating to visual aspects, inaccuracies of measurement and suitability of equipment for purpose. Learners will collect data that is represented in a suitable format with observations set against an accurately illustrated star map. The validity of learners' observations will be determined by comparison with known astronomical data, for example, the size of sunspots, the position of the solar plane, a diagram of the surface of the moon and so on.

For Merit standard, learners will work with independence and assess their results from observations, drawing suitable conclusions. Their observation of the night sky and solar activity will show accuracy and precision and correct positioning of night sky objects against background field stars identified by right ascension and declination. Learners will use suitable objects, requiring the use of a telescope or binoculars, and using projection methods for the Sun.

For Pass standard, learners will present a list and associated diagrams or images identifying the types of telescopes used in modern astronomy. This activity could take the form of a poster or PowerPoint presentation, highlighting and naming the telescopes that use different parts of the electromagnetic spectrum. For light, learners will include both refractor and reflector telescopes (a detailed description of operation is not expected although the general mode of operation and principles will be outlined). This will include ray diagrams of both reflector and refractor telescope principles and some evidence of practical determination of focal lengths for converging lenses and prime focus for convex mirrors. They will keep logbooks and other suitable forms of presentation, detailing observational records to evidence practical observations taken over a length of time using suitable equipment. Learners will perform experiments to show that they have attempted to find the focal length of converging and diverging lenses, using a ray box and the focal length of a standard concave mirror using a twin-hole ray box. These pieces of equipment can then be used on objects to assess their effectiveness and the need for parabolic mirrors, for example. Learners will produce accurate ray diagrams and a log demonstrating observations of some aspects of the night sky and of the Sun. These activities will be carried out over a suitable time period and night sky observations will be set against their constellation position where appropriate. Their observations will be set onto a published map of a suitable portion of the night sky, with paths of objects shown against labelled constellations, and stars and distances accurately measured. Daytime observations will also be set against accurate sky-mapping. Sun-spot activity could be projected onto a circular template from which precise sunspot sketches can be made over a course of time. If this unit is delivered during times of solar or lunar eclipse, this will be a valuable opportunity for observation.

Learning aims C and D

For Distinction standard, learners will produce a comprehensive report demonstrating their knowledge and understanding of the history of space flight and the difficulties involved. They will include a discussion identifying a good selection of planned missions, manned and un-manned, proposed by various countries and organisations. Their work can be presented as a journalistic appraisal and will provide clear descriptions of the proposals and an evaluation of the developments of each space programme in terms of costs, difficulties that will be faced, benefits and other implications. Learners will also link this work to the improvement in our current understanding of the Universe – its origin, dynamic nature and theoretical future. This is a good opportunity for learners to present a discussion on the possibility of life on Earth being ‘unique’ and demonstrating clear thought on the probabilities of life elsewhere in the Universe and problems associated with space travel beyond the confines of the inner Solar System.

For Merit standard, learners will produce a well-worded report depicting examples of the products used in everyday life that have been discovered or developed as a direct result of space flight. Their report will outline at least five products from materials and manufacturing and learners will provide general outlines of the work carried out by astronauts, which are research based and linked to particular areas of science and industry. This may be presented in the form of a list or table, including a description and an indication of its relevance to society in general. Learners' work will be largely independent and will include research evidence, with correct referencing and bibliography. They will explain, in detail, the effects of space flight on the human body and provide some assessment of the implications of long-term space flight and what can be done to limit the problems, such as osteoporosis, change in blood flow, or drop in blood plasma levels. They will mention all effects on humans listed in the unit contents. Their evidence can take the form of a large poster or booklet, with clear labelling of the specific areas of the body that are affected.

Learners' work will also focus on the physical aspect of achieving and sustaining space flight for a vehicle. They will provide explanations that could be based on known launch and flight data and attempt to explain how an object achieves escape velocity and then maintains orbit. Calculations of escape velocity will be included and learners will provide some acknowledgement of the dangers involved, maybe provided by reference to well-known accidents such as Salyut 1, Apollo 1, Challenger and Columbia Space Shuttles.

Learners will also include a detailed explanation of the Hertzsprung-Russell diagram, including relevant stars by name at various points in the sequence. They will clearly present the current theoretical explanation of how stars form, using diagrams where necessary. This will include detail of pressure balance and imbalance, development of protostars to main sequence and eventual end. Clarity in explanation of the evidence for theories of the evolution of the Universe will be given by learners. This will involve information concerning galaxy movements, star formations and destructions, age of the Universe and further detail regarding the importance of redshift and the cosmic microwave background.

Learners will also provide detailed explanations of star evolution and will describe, in some detail, the variations of star types that occur, with reference to the H-R diagram. They will include spectral classes and the relationship with mass, as well as examples, by name, of the star types depicted. Learners will provide further expansion on the work to explain the variation in star evolution as a result of the mass of initial material, i.e. stars of mass equal to the Sun and those of mass greater than the Sun.

Learners will explain the methods used to measure astronomical distances and will show the limitations of trigonometric parallax to relatively short distances in addition to the principles behind Cepheid variables and eclipsing binaries. They will also appreciate the significance of the shift of wavelength from galaxies to indicate acceleration towards or away from our viewpoint.

Learners will also include sufficient explanation of Hubble's law, the reasons providing the current age of the Universe and the possible fate of the Universe based on density. They will give a clear explanation of Olbers' paradox.

For Pass standard, learners will produce a comprehensive list of the various factors that need to be considered to achieve space flight. Their list will include, for example, materials, fuels, escape velocity, hazards, costs, communication and effects on humans. They will provide a brief description of each, with the effects on humans completed by developing a case study identifying the issues that NASA faced in its preparations for astronaut training during the Apollo missions.

Learners will develop a clear document or sketch that illustrates the various stages of a star's life, and the different outcomes that can result from variations in the mass of the material that comprises the star. Brief notes will accompany each stage.

Learners will include a representation of the Hertzsprung-Russell diagram for stars. A further diagram will show how the stages in the life of stars depends on their mass in relation to the Sun. Notes to accompany labelled diagrams will be expected. A valid description of the principles of redshift and cosmic microwave background will be provided. These will be linked to the theory of the Big Bang. Additional descriptions of objects and measurements in the Universe, such as galaxies, nebulae, supernovae, distances and so on will enhance learners' work to outline the continued evolution of the Universe.

Learners will all present cosmological theories of the present day, attempting to describe, briefly, the general ideas of each by summarising relevant material and describing the evidence in support. They will include the essential physical laws that help to explain some key aspects.

Links to other units

This unit links to:

- Unit 8: Contemporary Issues in Science
- Unit 10: Climate Change.

Employer involvement

This unit would benefit from employer involvement in the form of guest speakers from observatories, aerospace, satellite and space development companies will give learners an idea of the range of employment opportunities in this field.

Opportunities to develop transferable skills

- Development of celestial coordinates and detailed cartographic techniques.
- Understanding of optical equipment – lenses and mirrors.
- Research activities for scientific reporting.
- Use of mathematical formulae for practical outcomes.

Unit 19: Microbiology and Microbiological Techniques

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners will explore the characteristics of microorganisms and develop practical skills relating to their study, including microscopy and the practice of aseptic technique.

Unit introduction

In this unit, you will discover how essential microorganisms are. They have been exploited for beneficial use for a long time, but more recently biotechnology has given microorganisms an important role in agriculture, food production and medicine. This is not to forget that some microorganisms can be disease causing and result in impaired health or even death for millions of people every year. Biomedical scientists are involved in a constant search for new antibiotics, antiseptics and preventative measures against disease-causing organisms.

Microbiology is a branch of biology that deals with microorganisms usually too small to be seen with the naked eye, including bacteria, viruses, some fungi and a group of even smaller organisms called prions. The latter are of interest because of the devastating diseases they cause in humans.

You will study microorganisms and the factors that affect their growth. You will also learn how to safely handle some types of microorganisms in a laboratory setting and develop the manipulative skills needed for good aseptic techniques, including risk analysis.

In the unit you will carry out practical work to prepare and use different types of growth media and different inoculation techniques safely. You will also experience the different methods used to measure microbial growth, as these techniques are very important in commercial laboratories. You will develop your skills using microscopes and their attachments to better be able to identify some microorganisms. Your research will ask you to look at other types of specialist microscopes, which are vital to understanding the structure of microbes.

The skills associated with microbiology are in great demand and microbiologists are at the centre of developments in areas such as biochemical and biomedical products, crop health and food production, livestock health, genetic engineering and forensic science. This unit will help you to progress to a wide range of microbiology-related courses in higher education, including medical microbiology and biomedical sciences.

Learning aims

In this unit you will:

A Understand the importance of microbial classification to medicine and industry

B Undertake microscopy for specimen examination in laboratories

C Undertake aseptic techniques to culture microorganisms

D Explore factors controlling microbial growth in industrial, medical and domestic applications.

Summary of unit

<table>
<tr><th>Learning aim</th><th>Key content areas</th><th>Assessment approach</th></tr>
<tr><td>A Understand the importance of microbial classification to medicine and industry</td><td>A1 Microorganisms and infectious agents
A2 Classification
A3 Microorganisms in medicine and industry</td><td rowspan="2">A research report using any appropriate format that covers four of the listed microorganisms.
Practical work setting up and using light microscopes and oil immersion lenses to look at the structure of microorganisms.
Scientific drawings of specimens, laboratory notebooks and practical write-ups supported by teacher observations.
A presentation of their work which also outlines the uses and limitations of the instruments used when compared with other types of microscopy, including specimen preparation and imaging.</td></tr>
<tr><td>B Undertake microscopy for specimen examination in laboratories</td><td>B1 Microscopes
B2 Specimen and slide preparation
B3 Setting up and using a compound light microscope</td></tr>
<tr><td>C Undertake aseptic techniques to culture microorganisms</td><td>C1 Safety and prevention of contamination in microbial culturing
C2 Growth media
C3 Inoculation and incubation</td><td rowspan="2">Laboratory notebooks recording the practical work done plus observations of practical work by suitably qualified staff.
Any parts not covered in practical work can be addressed by research reports.</td></tr>
<tr><td>D Explore factors controlling microbial growth in industrial, medical and domestic applications</td><td>D1 Growth requirements
D2 Growth inhibitors
D3 Measuring microbial growth</td></tr>
</table>

Content

Learning aim A: Understand the importance of microbial classification to medicine and industry

A1 Microorganisms and infectious agents

- Similarities and differences in relative sizes, structural features and means of reproduction/ replication in the following (both non-pathogenic and pathogenic examples should be examined):
  - bacteria (prokaryotes)
  - fungi, including yeasts (eukaryotes)
  - protozoa
  - viruses
  - viroids
  - prions.

A2 Classification

- Characteristics used to classify microorganisms, limited to bacteria, fungi and viruses:
  - Bacteria, to include reference to:
    - Gram staining
    - phenotypic classification, e.g. cocci, bacilli, spirilla
    - oxygen requirements (obligate and facultative aerobes/anaerobes).
  - Fungi:
    - Chytridiomycota, Zygomycota, Ascomycota and Basidiomycota
    - internal and external spore production.
  - Viruses, to include:
    - size
    - nucleic acid
    - capsid structure
    - host and disease.

A3 Microorganisms in medicine and industry

- Basic stages involved in classifying and using microorganisms:
  - identification of causes of disease
  - biowaste processing
  - food and beverage production
  - nitrogen fixation
  - antibiotic and hormone production
  - flora and fauna in the human digestive tract.

Learning aim B: Undertake microscopy for specimen examination in laboratories

B1 Microscopes

- Basic principles behind different types of microscopes and attachments, including the suitability and preparation of samples for use in each case.
    - definitions of resolution, magnification, focus, image
    - stereomicroscopes (dissection microscopes)
    - compound light microscope, to include the use of oil immersion lenses
    - phase contrast, to include uses of special lenses to convert the differences between transmitted and refracted light into variations in intensity
    - electron microscope, including transmission and scanning.

B2 Specimen and slide preparation

- Methods and equipment involved in preparing specimens, including relevant theoretical background, for viewing microorganisms under a compound light microscope. This should include practical application of the following techniques (as appropriate):
    - use of flat and concave slides
    - cover slips
    - wet and dry mounts
    - air drying and heat fixing
    - smear slides
    - staining, e.g. Gram staining, fuchsin, crystal violet, methylene blue

B3 Setting up and using a compound light microscope

- Component parts of the light microscope and their functions:
    - eyepiece and eyepiece graticules
    - objective lenses
    - coarse and fine focus knobs
    - stage and stage clips
    - illuminator
    - condenser and iris diaphragm.
- Using the microscope and correct procedures to follow:
    - preparation of microscope to use with a slide
    - adjustment of condenser
    - use of lowest power lens
    - use of other lens magnifications
    - calculation of actual size from scientific drawing of specimens.

Learning aim C: Undertake aseptic techniques to culture microorganisms

C1 Safety and prevention of contamination in microbial culturing

- Reasons for and practices in sector-specific safety equipment and procedures in laboratories where microbial investigation takes place.
- Awareness of the meaning of classifications of biosafety in levels 1–4.
- Personal protective equipment (PPE), e.g. nitrile gloves, eye protection, lab coat.

- Safety procedures to follow in a biosafety Level 1 microbiology practical:
  - attention to personal hygiene, hand washing
  - equipment sterilisation
  - mechanical pipetting
  - inoculation of plates
  - culture and examination of plates
  - safe disposal of materials, e.g. autoclaving.
- Biosafety cabinets:
  - negative/positive pressure
  - stainless steel construction
  - class I, II and III.

C2 Growth media

- Aseptic techniques and equipment required for preparation of growth media. Learners should prepare growth media where possible.
- Nutrient broths.
- Nutrient agar plates.
- Selective media:
  - MacConkey agar
  - mannitol salt agar
  - blood agar
  - potato dextrose agar.

C3 Inoculation and incubation

- Role of inoculation and incubation; aseptic techniques and equipment required (the practical application of these techniques by learners is expected):
  - inoculation of liquid and solid media, to include streaking and lawn spreads
  - importance of incubation temperature, e.g. why incubation at 37 °C is not recommended in school/college laboratories
  - use of tape strips to anchor but not seal petri dishes, inversion of dishes during incubation
  - length of incubation.

Learning aim D: Explore factors controlling microbial growth in industrial, medical and domestic applications

D1 Growth requirements

- Factors affecting growth of bacteria and fungi, including relevance to industrial, medical and domestic settings:
  - Nutrients
  - Light and temperature preferences
  - Oxygen requirements
  - pH levels
  - growth surfaces.

D2 Growth inhibitors

- Methods of inhibiting microbial growth in industrial, medical and domestic settings.
  (Where appropriate, these should be practically investigated by learners.)
  - irradiation
  - antimicrobials – antibiotics, antivirals
  - antifungals
  - disinfectants, e.g. household and industrial cleaning products, hand sanitisers
  - sterilisation procedures
  - osmotic potentials in strong salt/sugar solutions as preservatives
  - controlled atmospheres for food preparation.

D3 Measuring microbial growth

- Theoretical background and practical application of growth monitoring techniques, to include the interpretation of resulting data:
  - colorimetry for fungal, bacterial and viral growth showing turbidity
  - haemocytometer, such as in yeast cell counts
  - mycelial discs measured as increase in diameter or dry mass
  - counting bacterial colonies and use of serial dilution.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the importance of microbial classification to medicine and industry		**AB.D1** Evaluate the use of microscopy techniques to observe structures and classify microorganisms.
A.P1 Explain how the structures and characteristics of microorganisms are used to classify them.	**A.M1** Compare the characteristics of microorganisms used for classification.	
Learning aim B: Undertake microscopy for specimen examination in laboratories		
B.P2 Correctly set up and use a light microscope and oil immersion lens to observe structures of microorganisms under magnification. **B.P3** Illustrate, with accuracy, the structures of microorganisms observed using a light microscope and an oil immersion lens.	**B.M2** Compare the use of different microscopy techniques to observe the structures of microorganisms.	

Pass	Merit	Distinction
Learning aim C: Undertake aseptic techniques to culture microorganisms		**CD.D2** Evaluate own aseptic techniques used to culture microorganisms with specific reference to the type of media, methods of inoculation chosen and the biocontainment procedures carried out.
C.P4 Correctly prepare and inoculate growth media and measure microbial growth using aseptic techniques. **C.P5** Explain biocontainment procedures in your centre laboratory and within industrial laboratories.	**C.M3** Demonstrate skilful application of aseptic techniques in inoculation and preparation of growth media and in measuring microbial growth. **C.M4** Compare biocontainment procedures in your centre laboratory to those used in industrial laboratories.	
Learning aim D: Explore factors controlling microbial growth in industrial, medical and domestic applications		
D.P6 Carry out investigations into the effect of growth requirements on microorganisms. **D.P7** Explain how growth inhibitors affect microorganisms.	**D.M5** Analyse how growth of microorganisms is affected by changing environmental factors.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, B.P3, A.M1, B.M2, AB.D1)

Learning aims: C and D (C.P4, C.P5, D.P6, D.P7, C.M3, C.M4, D.M5, CD.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory
- materials/apparatus/equipment and/or laboratory instruments/sensors
- computers, DVDs and suitable texts, appropriate science and maths software packages (especially when working with the results of growth data, which may involve the use of graphs).

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will look at the structures that can be seen under different microscopes and evaluate the advantages and limitations in their use for medicine and industry. They will use their observations and knowledge of the characteristics of microorganisms to argue/reason for their placement in different groups and then evaluate the reasons for such a division. Their work will be detailed and comprehensive, using named examples of at least four of the microorganisms and infectious agents as part of the evaluation process.

For Merit standard, learners will show they understand the reasons for the classification of microorganisms, comparing the similarities and differences in size, structure, reproduction and their importance in medicine and industry. They will refer to how the structure of microorganisms is viewed using two types of microscope, including their own drawings of specimens viewed under a compound light microscope. They will compare photomicrographs of microorganisms taken using two types of microscopes, showing they understand the differences and similarities between them in terms of their characteristics and how these factors are used to put them into groups before commenting on their importance.

For Pass standard, learners will use the microscope and an oil immersion lens to look at microorganisms, following instructions to set up and use a light microscope correctly. Learners will produce accurately drawn and labelled diagrams of specimens they have viewed themselves, which will include the magnification used and a calculation of the actual size of objects they have drawn. Learners will use photomicrographs and annotated diagrams to describe the structures observed. They will use named examples where appropriate, and they can include other features providing they state under what circumstances they can be seen, i.e. oil immersion or electron microscope. Learners must use their own drawings in addition to published photomicrographs and other sources of information to explain how microorganisms are classified, making reference to four microorganisms from the unit content.

Learning aims C and D

For Distinction standard, learners will evaluate the impact of the use of the correct media and inoculation techniques on the successful growth of microbes, using their evaluation of practical work plus any research. They will also evaluate their own techniques in comparison with other learners and suggest areas for improvement. They will explain the biocontainment measures taken in the classroom that contributed to the successful growth of the microbes, as well as the importance of biocontainment procedures used in industry and the impact of this when not followed. Learners will list the factors that affect growth in microorganisms, evaluating how effective their methods were in being able to analyse the effects on growth of changing environmental factors and suggesting suitable alternatives or extensions to the methods or equipment that would enhance their results.

For Merit standard, learners will work in an efficient way with minimal guidance, demonstrating good aseptic technique that leads to little or no contamination of results. They will measure the resultant microbial growth with precision, leading to a coherent analysis of the results from which sensible conclusions can be drawn. Learners will refer to secondary data to support their analyses.

Learners will discuss their experience of the biocontainment measures used in their laboratory in relation to the systems used in industry. They will compare the two settings and explain the reasons for the differences.

For Pass standard, learners will demonstrate adherence to safety procedures, including the production of suitable risk assessments making it clear that they understand the reasons behind the precautions that must be taken when working with microorganisms. They will follow instructions to obtain results investigating the effect on microbial growth of changing at least one environmental factor. This will include learners preparing and inoculating both liquid and solid media. Learners' measurements will be accurate in terms of taking more than one measurement and averaging the result. They will describe what their results show in terms of microbial growth requirements and growth inhibitors. They will then give an explanation of the biocontainment measures they used for their work, and how these relate to biocontainment procedures in industrial laboratories. Learners may demonstrate isolated elements of knowledge and understanding, with basic but correct use of relevant terminology.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 5: Principles and Applications of Biology II
- Unit 9: Biomedical Science
- Unit 11: Functional Physiology of Human Body Systems
- Unit 14: Genetics and Genetic Engineering
- Unit 15: Diseases and Infections.

Employer involvement

It may be possible to arrange a visit to a local facility, hospital or university that has an electron microscope. The local Environmental Health Department may be able to support the centre by providing a visiting Environmental Officer to discuss their role in dealing with the effects of pathogens.

A visit to a microbiology laboratory would be very useful, and a local food-processing factory may be able to offer opportunities for a visit or provide a speaker and additional information.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- techniques in microscopy
- analytical and observation skills
- health and Safety (biocontainment)
- formal written communication
- self-management and planning skills
- ability to work in a scientific environment
- ability to carry out independent research.

Unit 20: Applications of Physical Chemistry

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers aspects of chemical thermodynamics, kinetics, equilibrium and how these physical chemical topics are used in industrial processes.

Unit introduction

In this unit, you will carry out practical work, perform calculations and investigate industrial processes. You will build on your knowledge of exothermic and endothermic reactions by measuring enthalpy changes in chemical reactions and exploring the accuracy of your measurements. You will use data to calculate the enthalpy changes expected in reactions as well as the other two functions of state, entropy and Gibbs energy. Entropy is a measure of the degree of disorder in a system. Spontaneous or feasible chemical reactions are often exothermic, but an increase in entropy is another driver of chemical change. You will be able to predict whether reactions are feasible under standard conditions by calculating changes in Gibbs energy.

The thermodynamic factors mentioned above will allow you to identify whether reactions may be feasible, but do not give an indication of the rate of the reactions. You will learn how to calculate the rates of chemical reactions from given data and to work out the relationship between the rate and the concentrations of the reactants. You will carry out practical investigations of factors affecting the rate of reaction and explain these factors in terms of collision theory. You will also learn how to describe the characteristic features of equilibrium reactions and to calculate the equilibrium constant, exploring the effects on equilibrium of changes in concentration, pressure, temperature and catalysts.

Finally, you will investigate how industrial chemical reactions may be controlled by using physical chemistry concepts. The fundamental concepts of thermodynamics, rate and equilibrium introduced in this unit are extended in higher education courses involving chemistry and biology. A range of industries that employ scientists make use of these topics. For example, process operators and the technicians in the bulk chemical, polymer, agrochemical and pharmaceutical industries use the concepts learned in this unit to optimise production.

Learning aims

In this unit you will:

A Investigate chemical thermodynamics in order to understand spontaneous reactions

B Investigate rate equations and activation energy to understand the chemical kinetics of reactions

C Investigate chemical equilibrium in order to understand the extent to which reactions go to completion

D Understand physical chemistry concepts and how industry controls chemical reactions.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Investigate chemical thermodynamics in order to understand spontaneous reactions	**A1** Enthalpy changes **A2** Entropy and Gibbs energy	A report explaining standard enthalpy changes and entropy, with examples of reactions. Practical report of determination of enthalpies of reactions, with accurate measurements and techniques, calculations and discussion of the assumptions and sources of error. Worksheets containing calculations, involving enthalpy changes, entropy changes and Gibbs energy, and assessment of the feasibility of reactions.
B Investigate rate equations and activation energy to understand the chemical kinetics of reactions	**B1** Rate of reaction	Practical report of the effect of concentration of different reactants, temperature and catalysis on rates of reaction, with accurate measurements and techniques, calculations and conclusions, and discussion of the assumptions and sources of error. Worksheets showing reasoning and calculation to determine rate equations and activation energy. Analysis of rate equations and activation energy for reactions to consider the mechanism of the reaction.

Learning aim	Key content areas	Assessment approach
C Investigate chemical equilibrium in order to understand the extent to which reactions go to completion	**C1** Chemical equilibrium	A report explaining the features of equilibrium and the effect of changing conditions, with examples of reactions. Practical report to determine the equilibrium constant for reactions using different methods, with accurate measurements and techniques, calculations and conclusions, and discussion of the assumptions and sources of error. Worksheets showing calculations and graph work involving the equilibrium constant (K_p or K_c), mole quantities, pressure, Gibbs energy, temperature, enthalpy and entropy, commenting on the feasibility and extent of the reaction where appropriate.
D Understand physical chemistry concepts and how industry controls chemical reactions	**D1** Industrial application of physical chemistry concepts	An explanation of the reason for three specified features of the operation of an industrial process. An explanation of three further factors that may be altered on the basis of physical chemistry concepts Analysis of other industrial processes in terms of the physical chemistry concepts involved.

Content

Learning aim A: Investigate chemical thermodynamics in order to understand spontaneous reactions

A1 Enthalpy changes

- Definitions of a range of standard enthalpy changes: combustion, formation, solution, hydration, neutralisation, bond dissociation, ionisation, electron affinity, atomisation, lattice, sublimation, fusion, vaporisation, interpretation of the sign and magnitude of values, literature values.
- Principle of conservation of energy.
- Measurement of enthalpy changes for reactions:
  - method of continuous monitoring of temperature over time and extrapolation of cooling/warming curve
  - comparison of measured values with literature values
  - sources of error
  - calculation of enthalpy changes from supplied experimental data.
- Possible experimental investigations:
  - displacement reactions (copper(II) sulfate with powdered zinc, iron, magnesium or tin)
  - solution of anhydrous sodium carbonate or ammonium chloride
  - neutralisation of acids with alkalis
  - combustion of alcohols using spirit burners.
- Hess's Law of Constant Heat Summation
- Straightforward calculation of enthalpy changes from supplied data:
  - standard enthalpy of reaction from standard enthalpies of formation ΔH_f°
  - $\Delta H^\circ_{\text{reaction}} = \Sigma\Delta H^\circ_f\text{(products)} - \Sigma\Delta H^\circ_f\text{(reactants)}$
  - standard enthalpy of reaction from standard enthalpies of combustion ΔH_c°
  - $\Delta H^\circ_{\text{reaction}} = \Sigma\Delta H^\circ_c\text{(reactants)} - \Sigma\Delta H^\circ_c\text{(products)}$
  - calculation of enthalpy of formation from bond enthalpies
  - use of energy cycles
  - complex calculations involving rearrangement of equations:
    - calculation of ΔH_f° of a reactant or product, given a standard reaction enthalpy and ΔH_f° for the other reactants and products
    - calculation of bond enthalpy for a particular bond, given the enthalpy of formation and the other values of bond enthalpy.

A2 Entropy and Gibbs energy

- Entropy as a measure of the degree of disorder.
- Symbol S and units J K^{-1} mol^{-1}.
- Standard entropy S°.
- $\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$
- $\Delta S^\circ_{\text{reaction}} = \Sigma S^\circ_{\text{products}} - \Sigma S^\circ_{\text{reactants}}$
- Comparison and rationalisation of ΔS° values for different reactions.
- Gibbs energy (G).
- ΔG and ΔG°.
- Units of ΔG, kJ mol^{-1}.
- $\Delta G = \Delta H - T\Delta S_{\text{system}}$

- Condition for a feasible (products predominating) reaction ΔG negative.
- Calculations using $\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$.
- Spontaneity/feasibility under standard conditions.
- Estimation of temperature at which reaction becomes feasible.
- Reactions that are thermodynamically feasible may be inhibited by kinetic factors.

Learning aim B: Investigate rate equations and activation energy to understand the chemical kinetics of reactions

B1 Rate of reaction

- Definition of reaction rate.
- Units of rate of reaction mol dm^{-3} s^{-1}.
- Rate as gradient of the tangent to a concentration/time graph.
- Calculation of rate from drawing tangents to concentration/time graphs and calculating gradient.
- Possible experimental investigations:
  - effect of concentration/particle size – propanone and iodine (in presence of acid), bromide with bromate(V) ions (in presence of acid), persulfate(VI) with iodide ions, sodium thiosulfate and hydrochloric acid, acid and carbonate, or crystal violet with sodium hydroxide
  - effect of temperature – sodium thiosulfate and hydrochloric acid, or persulfate (VI) with iodide
  - effect of a catalyst:
    - heterogeneous – effect of different potential catalysts on the decomposition of hydrogen peroxide, potassium manganate (VII) with ethanedioate ions
    - homogeneous – traffic light reaction: effect of cobalt (II) chloride on the rate of the reaction between potassium sodium 2,3-dihydroxybutanedioate and hydrogen peroxide.
- Possible ways of collecting concentration/time data:
  - volume or mass change, change in time
  - clock reaction (where reaction monitoring ends at a fixed time i.e. colour change, precipitation), fixed time
  - colorimetry (where reaction changes colour over time), change in time
  - quenching and titration (samples extracted from the reaction, quenched and titrated), sampling at set times
  - electrical conductivity (change in number of ions in solution), change in time.
- Order of reaction with respect to reactants – first order, second order, zero order, possibility of other orders.
- Initial rate of reaction as rate (slope of tangent) when time = 0 s when the reaction has just begun.
- Method of initial rates for working out order of reaction
- Concentration – time graphs:
  - zero order – proportional straight line (concentration has no effect on rate)
  - first order – exponential curve with constant half-life (directly proportional)
  - second order – exponential curve without constant half-life (proportional).

- Rate – concentration graphs:
  - zero order – horizontal line (concentration has no effect on rate)
  - first order – proportional straight line through origin (directly proportional)
  - second order – exponential curve without constant half-life; plot of rate vs [concentration]^2 is a directly proportional straight line.
- Overall order of reaction.
- Rate equations and rate constants.
- Units of rate constant.
- Explanation of factors affecting rate of reaction:
  - collision theory
  - for the effect of concentration, concentration affects the number of collisions per second
  - for the effect of particle size, surface area affects the number of collisions per second
  - for the effect of temperature and presence of a catalyst, include reaction profile showing activation energy, Ea, and the Maxwell–Boltzmann distribution of energies
  - Arrhenius equation – the relationship between rate constant and activation energy

    $k = Ae^{-\frac{E_a}{RT}}$
  - plot of $\ln(k)$ versus $\frac{1}{T}$ gives a graph of slope $\frac{-Ea}{R}$
  - straightforward application of the equation:

    $\ln\left(\frac{k_2}{k_1}\right) = -E_a\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ or $\ln(k_2) - \ln(k_1) = -E_a\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

Learning aim C: Investigate chemical equilibrium in order to understand the extent to which reactions go to completion

C1 Chemical equilibrium

- Features of adynamic equilibrium reaction:
  - once equilibrium is established, the forward and backward reactions continue to happen
  - once equilibrium is established, rate of forward and backward reactions are equal
  - shapes of graphs of concentration versus time for an equilibrium reaction
  - may be described using an equilibrium constant.
- Writing of the equilibrium constant in terms of concentration, K_c, for given equilibrium reactions, and units.
- Calculation of K_c given initial moles/concentration of reactants and equilibrium moles/concentration of products, or vice versa.

- Possible experimental investigations:
  - ethyl ethanoate-water/ethanoic acid-ethanol using acid-base titration
  - Fe^{3+} and $SCN^{-}/Fe(SCN)^{2+}$ system using colorimetry
  - acid-base indicators (e.g. bromocresol green, methyl red) using colorimetry
  - partition of a substance between two different solvents (e.g. ammonia and polar/non-polar solvents, using acid-base titration)
  - solid – aqueous equilibrium system (e.g. solubility of calcium hydroxide, using acid-base titration).
- Methods of determining K_c experimentally:
  - titration (samples extracted from the reaction, quenched and titrated)
  - colorimetry (where reaction changes colour over time), change in time.
- Equilibrium constant in terms of partial pressure, K_p.
- Writing of the expressions for K_p, for given equilibrium reactions, and units.
- Relationship between partial pressure of a gas (p), total pressure (p_T) and mole fraction (X) in a closed system: $p = Xp_T$
- Calculation of K_p given values of partial pressure or the total pressure and mole fractions at equilibrium, and vice versa.
- Calculation of K_p given initial partial pressures of reactants (or mole fractions and total pressure) and equilibirium moles or partial pressure of products (or mole fractions and total pressure), or vice versa.
- Re-establishment of equilibrium following an imposed change in concentration, pressure and temperature.
- Le Châtelier's principle.
- Explanation of the effect of changes in concentration on the position of equilibrium at constant temperature (K_c unaffected).
- Explanation of the effect of changes in pressure on the position of equilibrium at constant temperature (K_c (and K_p) unaffected).
- Explanation of the effect of changing temperature on the equilibrium constant:
  - in terms of whether the forward and backward reaction is favoured by an increase/decrease in temperature
  - K_c increases as temperature increases when the forward reaction is endothermic (backward reaction exothermic)
  - K_c decreases as temperature increases when the forward reaction is exothermic (backward reaction is endothermic)
  - K_c decreases as temperature decreases when the forward reaction is endothermic (backward reaction is exothermic)
  - K_c increases as temperature decreases when the forward reaction is exothermic (backward reaction is endothermic).
- Explanation of the effect of a catalyst on the position of the equilibrium.
- Use of the equation $\Delta G^{\circ} = -RT\ln(K)$ to show that reactions that are feasible in terms of ΔG have large values for the equilibrium constant and vice versa.
- Awareness that reactions are often not run under equilibrium conditions in order to keep the reaction happening. (One of the products may be constantly removed.)

Learning aim D: Understand physical chemistry concepts and how industry controls chemical reactions

D1 Industrial application of physical chemistry concepts

- Physical chemistry concepts:
  - exothermic and endothermic reactions: use of heat exchangers, hot spots, design of reaction vessels, mixing to dissipate heat, controlled addition of reagents
  - altering conditions for reactions that are not feasible under standard conditions:
    - Solvay process: $CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$
  - effect of particle size, concentration, temperature and presence of a catalyst on rate – the need to control (increasing or decreasing) rate by varying conditions, use of powdered reagents, use of mixing to enable more effective contact between reagents, variation of the temperature, preheating reactants, use of catalysts
  - running reactions under non-equilibrium conditions
  - optimising the operating temperature and pressure
  - taking account of the physical state and solubility of reactants and products to facilitate their separation
  - distillation and filtration
  - choice of materials for chemical plant based on chemical properties of reactants and products.
- Explaining features of industrial case studies, such as:
  - Haber process and associated process to produce hydrogen
  - Contact process
  - Solvay process
  - Oswald process
  - methanol and ethanol production
  - lime production.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Investigate chemical thermodynamics in order to understand spontaneous reactions		**A.D1** Assess the spontaneity of reactions, using Gibbs energy, and the limitations of the prediction.
A.P1 Explain standard enthalpy changes for a range of different reaction types. **A.P2** Demonstrate accurate determination of enthalpy changes and assess the quality of the results. **A.P3** Explain the concept of entropy and its significance for different chemical processes.	**A.M1** Perform complex calculations involving enthalpy changes, which require rearrangement. **A.M2** Calculate entropy changes for a range of reactions.	
Learning aim B: Investigate rate equations and activation energy to understand the chemical kinetics of reactions		**B.D2** Analyse how the rate equation and activation energy inform the kinetics of chemical reactions.
B.P4 Investigate the effect of concentration of different reactants on the rate of a reaction, determining accurate values from concentration-time plots. **B.P5** Investigate the effect of temperature and catalysis on the rate of reaction.	**B.M3** Demonstrate accurate determination of reaction order, overall rate equation, rate constant and its units from data. **B.M4** Carry out calculations to accurately determine the activation energy of a reaction from data on the rate constant at different temperatures.	

Pass	Merit	Distinction
Learning aim C: Investigate chemical equilibrium in order to understand the extent to which reactions go to completion		**C.D3** Analyse the relationship between equilibrium constant, temperature, enthalpy and entropy for a range of reactions.
C.P6 Explain the features of an equilibrium reaction and the effect of changing conditions. **C.P7** Determine the equilibrium constant for reactions using different experimental methods. **C.P8** Carry out calculations involving K_p and partial pressures of gases.	**C.M5** Perform complex calculations involving K_c, K_p, total pressure and mole fractions. **C.M6** Calculate and interpret values of Gibbs energy, equilibrium constant and temperature.	
Learning aim D: Understand physical chemistry concepts and how industry controls chemical reactions		**D.D4** Analyse the operation of a chemical process in terms of the physical chemistry concepts involved.
D.P9 Explain identified aspects of the operation of an industrial process in terms of physical chemistry concepts.	**D.M7** Discuss actions that may be taken to control a chemical process.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.M2, A.D1)

Learning aim: B (B.P4, B.P5, B.M3, B.M4, B.D2)

Learning aim: C (C.P6, C.P7, C.P8, C.M5, C.M6, C.D3)

Learning aim: D (D.P9, D.M7, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a well-equipped laboratory.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will perform a range of complex calculations to determine the value of standard Gibbs energy change. The problems will involve standard entropy changes, standard enthalpy changes and the determination of these from values for reactants and products for the reaction. Additionally, learners will estimate the temperature at which a reaction is likely to become feasible, using data for the standard enthalpy and entropy changes. The problems set will need to show working out and to provide evidence for distinction standard.

For Merit standard, learners will perform complex calculations involving enthalpy changes using a range of data from different standard enthalpy change types. This must include rearrangement, for example, calculating the enthalpy of formation of a substance, given other enthalpies of formation and the enthalpy of a reaction. Learners will be set at least five different questions, the majority of which will need to be correctly answered to provide evidence for merit standard.

Learners will calculate a range of standard entropy change for given reactions and comment on the size and sign of the values. Learners will interpret the size and sign of the change and relate this to the degree of disorder in the reactants and products.

For Pass standard, learners will be provided with a range of different equations and the associated enthalpy changes. Learners must identify the type of standard enthalpy change that is being represented in equations and explain how this relates to the definition. They must also write equations for standard enthalpy changes of specified reactions as part of the evidence.

Learners must accurately measure the enthalpy change of reaction for two different types of reaction – displacement, neutralisation or combustion.

Learners must explain qualitatively the concept of entropy in terms of disorder of particles.

Learning aim B

For Distinction standard, learners will analyse the rate equation for a range of reactions, proposing and justifying a mechanism for each one (at least 5 reactions will need to be provided and could be those considered at merit). They will also propose alternative mechanisms to the reactions and justify why these could not be correct in relation to the rate equation. Learners will assess the impact of activation energy on rate of reaction for at least 3 reactions. The mechanisms of each reaction will be examined and how the activation energy is used within each will be suggested. At least one of the reactions examined must be catalysed and the mechanism with and without the catalyst must be written by the learner. The mechanisms will be analysed and the learner will suggest how the catalyst has reduced the activation energy requirement for the reaction.

For Merit standard, learners will be set problems to fully determine rate equations, when given data for rate of reaction (for at least five problems). Some problems will present tabulated initial rate data and others will be graphical. Learners will inspect tabulated initial rate data and deduce orders of reaction (e.g. doubling the concentration of one reactant, while holding all other reactants constant, may quadruple the rate and indicates second order with respect to that reactant.) Similarly, learners will inspect concentration-time or rate-concentration graphs for characteristics that indicate order (e.g. constant half-life on concentration-time graph indicates first order). The orders of reaction involved should be first, second or zero order. Learners will clearly and logically explain their deductions and will write the overall rate equation for the reaction. They will then use the data to determine the rate constant and its units. Learners will also calculate the rate of reaction using the rate equation when multiple changes to the concentrations of all three reactants are made.

Learners will be set problems to fully determine the activation energy for reactions, when given rate constant and temperature data (for at least 5 problems). Some problems will present tabulated rate constant and temperature data and others will be graphical. At least one problem should give learners the opportunity to determine the value for the Arrhenius constant (A) given all other variables; the rate constant given temperature and the activation energy; the temperature given rate constant and activation energy.

The problems set will need to show working out and the majority correctly answered to provide evidence for merit standard.

For Pass standard, learners will carry out experiments to determine the effects on the rate of changing concentration of different reactants in at least two experiments (e.g. propanone and iodine, bromide with bromate (V) ions, persulfate (VI) with iodide ions, etc). By varying the concentration of one reactant while keeping the concentration of the other reactant constant, they will time the experiment. They will then repeat the experiment by changing the concentration of the second reactant while keeping the concentration of the first reactant constant. At least one of the experiments should involve the collection of continuous data at regular time intervals (e.g. reading of absorbance using a colorimeter or quenching and titration) as well as timed clock reaction methods. With continuous data, learners will plot concentration-time graphs, calculate the gradients from slopes of tangents of curves and hence correctly determine the exact relationship between the rate of reaction and the concentration of the reactant. With timed clock reactions, learners will plot 1/time vs concentration or $(\text{concentration})^2$ to determine the exact relationship between rate and the concentration of the reactant.

Learners will carry out experiments to examine the effect of temperature and catalysis upon rate. This will involve one experiment where the activation energy is determined when the temperature is varied and the reaction time is measured using a clock reaction (e.g. persulfate (VI) and iodide, sodium thiosulfate and hydrochloric acid, etc). Learners will plot ln(1/time) vs 1/T (K^{-1}), calculate the gradient and use it to determine the activation energy of the reaction (E_a = – gradient x 8.31 J K^{-1} mol^{-1}). A second experiment will investigate the quantitative effect of a catalyst on the rate of a reaction. For example, the reaction of persulfate (VI) and iodide at different temperatures could be repeated but with a catalyst of iron (II) ions. Data collected could provide a graph of ln(1/time) vs 1/T (K^{-1}), allowing the calculation of the activation energy with a catalyst.

Alternatively, the uncatalysed reaction of potassium manganate (VII) with ethanedioate ions could be monitored by colorimetry to give a concentration-time graph, and repeated with the addition of manganese (II) ions as a catalyst. Tangents at t=0 could be taken from both graphs to determine gradients and therefore rate of reaction. Learners will compare the values obtained with literature values or those of their peers/the assessor, noting whether their result is higher or lower and the extent of the difference. They will suggest reasons for differences observed.

Learners will state conclusion(s) for all practicals at pass level and will provide an appropriate explanation of the effects of the factor in terms of collision theory, reaction profiles, activation energy and the Maxwell-Boltzmann distribution curve.

The assessor should provide observation reports to supplement the learners' evidence.

Learning aim C

For Distinction standard, learners will analyse the relationship between equilibrium constant, temperature, enthalpy and entropy for a range of reactions. They will use a variety of equations in order to explore the links: $\Delta G^{\circ} = -RT\ln(K)$, $\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ and calculation of ΔH° and ΔS° for reactions from enthalpy and entropy data for the substances involved. Learners will be set at least 5 problems in order to calculate each of the terms when provided with values for the other three. Learners will also use graphical means in order to analyse the effect of temperature on a given equilibrium reaction (i.e. a graph of $\ln(K)$ versus $\frac{1}{T}$). From this they will determine the enthalpy change and entropy change from the gradient and the intercept respectively. The problems set will need to show working out and the majority correctly answered to provide evidence for distinction standard.

For Merit standard, learners will be set a range of complex problems involving K_c, K_p and total pressure and molar quantities. The problems will involve more than one step and include: calculation of the equilibrium constant given only initial mole quantities for reactants and the percentage conversion or amount of products at equilibrium; calculation of the total pressure of the equilibrium system, given only molar quantities and K_p; determination of the number of moles at equilibrium or initially for a reactant from K_p or K_c.The problems set will need to show working out and the majority correctly answered to provide evidence for merit standard.

Learners should be provided with the concentration data of the products and reactants at equilibrium (at the actual temperature NOT standard temperature) for three separate common equilibrium reactions in order that they are able to calculate the equilibrium constant Kc. Learners should be under sufficient supervision to ensure they work independently when performing the calculations. Learners should determine the expression for the equilibrium constant Kc at the temperature given, providing correct units and appropriate significant figures. Learners should then be provided with the Kc values at standard temperature for each of the three equilibria to enable them to determine a value for ΔGϴ/kJ mol-1 from the value of Kc provided, at the standard temperature of 298K. Learners are expected to show workings throughout. Learners must then interpret the Kc at standard temperature, which has been provided, by commenting upon the relative amounts of reactants and products that must be present and how complete the reaction is. Learners must also interpret what the sign and value of the standard change in Gibbs energy indicates for each equilibrium.

For Pass standard, learners will describe equilibrium reactions and show that they understand that concentrations of reactants and products remain constant once equilibrium has been reached, the reactions continue to happen, and the rates of forward and backward reactions are equal. Learners will sketch concentration/time diagrams for the reactants and products. Learners will explain the effects of concentration, pressure, temperature and catalysis on the position of an equilibrium for three different reactions which will have different numbers of molecules on both sides, a range of different states of matter and different signs for enthalpy change for the forwards reaction. Learners must also able to write an expression for K_c (with units) for the three reactions and what will happen to K_c when pressure, concentration or temperature is changed for the reaction.

Learners must calculate Kp given values of partial pressure or the total pressure and mole fractions at equilibrium, and vice versa. Learners should also calculate Kp given initial partial pressures of reactants (or mole fractions and total pressure) and equilibrium moles or partial pressure of products (or mole fractions and total pressure), or vice versa.

Learners must determine Kc experimentally using at least two different methods, e.g. titration (samples extracted from the reaction, quenched or titrated) and colorimetry (where reaction changes colour over time), change in time. Learners should document their practical work and show their results and calculations clearly using correct units and appropriate significant figures. There should be supporting evidence from their assessor/tutor in the form of an observation record.

Learning aim D

For Distinction standard, learners will review ways in which physical chemistry concepts are used in analysis of a process that they have investigated. This process should be different from the one used at merit and pass standard.

For Merit standard, learners will be presented with a chemical process. From this, they will identify and discuss three potential measures, other than those identified at pass standard, which may be used to control or affect the operation of the industrial process.

For Pass standard, learners will explain three specified features of the operation of the chemical process, as described at merit standard, for example, why the reaction vessel was in contact with a heat exchanger, why a powdered catalyst was used, why one of the products was continuously removed etc.

Links to other units

This unit links to:

- Unit 2: Principles and Applications of Chemistry I
- Unit 6: Principles and Applications of Chemistry II
- Unit 16: Applications of Inorganic Chemistry
- Unit 21: Applications of Organic Chemistry.

Employer involvement

This unit would benefit from employer involvement in the form of:

- a visit to any commercial laboratory
- a speaker from a commercial laboratory.

A visit to or a visiting speaker from a chemical plant, for example, bulk chemicals, agrochemicals, pharmaceuticals, polymers, will enhance the delivery of this unit. Industry representatives will be able to explain the importance of thermodynamics, kinetics and equilibrium concepts to their processes, for example, how heat from exothermic reactions is used, how the particle size of solid surface particles is optimised and how the yield of products may be maximised by removing one or more products to stop the reaction from reaching equilibrium.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- independent investigation and research skills
- practical and technical skills, using appropriate equipment, procedures and techniques
- scientific written and communication skills
- data interpretation, manipulation and presentation
- analytical and problem-solving skills
- self-management and planning skills
- evaluative and assessment skills.

Unit 21: Applications of Organic Chemistry

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners will explore the chemical reactivity of different functional groups and isomers in organic chemistry, as well as aromatic compounds. The skills required to plan, synthesise, test and identify a range of organic compounds are also covered.

Unit introduction

In this unit, you will learn that the majority of the substances we use every day are, or contain, organic compounds. This is because carbon, the basis of organic compounds, can form molecules consisting of chains and rings of atoms that enable it to bond with itself and with other elements to form useful products. Pharmaceuticals such as aspirin and paracetamol, synthetic fibres for our clothes such as acrylics and polyesters, fuels for our transport vehicles, soaps and detergents, dyes, flavourings, perfumes and liquid crystal display materials are just a few of the many organic substances that are manufactured on an industrial scale for us all to use. The number of known organic compounds is enormous and growing.

You will study a number of key classes of organic compounds that are important industrially, and will collect information about them, including their naming, reactions and properties. This will include aromatic compounds and their industrially useful reactions and a range of functional group compounds. This study will include how they can be converted into one another, which allows the synthesis of organic compounds with particular structures, fitting them for specific commercial uses. You will also learn about isomerism, the phenomenon whereby a number of organic compounds have the ability to form different arrangements of the same atoms.

You will then gain practical technical skills by carrying out a number of reactions to prepare and test organic compounds. You will learn how to interpret the information from a range of spectroscopic and instrumental chromatographic methods, which have become the techniques of choice for many industries. For example, a pharmaceutical laboratory technician will be trained to routinely use instrumental techniques, including infrared and ultraviolet-visible spectroscopy, gas chromatography and high-performance liquid chromatography techniques, with which you will become familiar.

This unit will support you in gaining access to higher education courses employment. It will open up an awareness of a wide range of exciting career paths such as research or analytical work, as a laboratory science technician or a science apprentice, in pharmaceuticals, chemistry, biochemistry or biotechnology. Being able to describe your understanding and practical experience in organic chemistry will help with interviews for advanced scientific apprenticeship roles, as well as degree courses in chemistry, biology or a biochemistry discipline.

Learning aims

In this unit you will:

A Understand the structures, isomerism and reactions of functional group compounds

B Understand the properties and reactions of aromatic compounds

C Investigate organic chemistry reactions in order to gain skills in organic synthesis

D Investigate spectroscopic and chromatographic techniques to identify organic compounds and determine quantities.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the structures, isomerism and reactions of functional group compounds	**A1** Isomerism **A2** Carbonyl compounds **A3** Carboxylic acids and derivatives **A4** Nitrogen containing organic compounds	A research report showing the different types of reactions for a range of functional groups and the significance of isomerism. Detailed understanding of the reactions using mechanisms will be shown. The effect of more than one functional group within an organic molecule will be considered. The report will propose detailed plans for the multi-step synthesis of organic molecules using this research.
B Understand the properties and reactions of aromatic compounds	**B1** Structure, properties and reactions of benzene **B2** Monosubstituted aromatic compounds	A research report of diagrams and explanations of how the structure of benzene was established. The typical reactions undergone by benzene and monosubstituted benzene rings will be explained. Detailed understanding of the reactions will be shown using mechanisms and diagrams to show the different effects of monosubstituents on reactivity. The report will propose detailed plans for the multi-step synthesis of organic molecules using this research.

Learning aim	Key content areas	Assessment approach
C Investigate organic chemistry reactions in order to gain skills in organic synthesis	**C1** Practical organic synthesis **C2** Practical techniques for synthesis **C3** Testing identity, estimating purity and determining yield	A portfolio of reactions that learners have carried out in the course of this unit, including observations of safe working and risk assessment
D Investigate spectroscopic and chromatographic techniques to identify organic compounds and determine quantities	**D1** Spectroscopic techniques **D2** Chromatographic techniques	A report which explains the principles and operation of MS, IR, NMR, GC and HPLC techniques. Completed exercises on matching percentage composition, mass spectra, infrared spectra, ^{1}H and ^{13}C NMR spectra to structural formulae of simple organic molecules. An account of how two unknown organic compounds have been identified from their percentage composition and combined spectroscopic techniques. A portfolio of qualitative and quantitative interpretation of chromatograms and peak area results for GC and HPLC.

Content

Learning aim A: Understand the structures, isomerism and reactions of functional group compounds

A1 Isomerism

- Structural, chain, positional, functional group, stereoisomerism, geometric, optical.
- Three-dimensional structures, representations and recognition.
- Different reactions of functional group isomers.
- Different isomer products from functional group reactions and mechanisms.
- Production of racemic mixtures or single optical isomer from mechanisms.
- Different boiling points of structural, chain and positional isomers.
- Cis and trans (E and Z) fats and difference in melting points.
- Natural occurrence of optical isomers – optical isomers of sugars and amino acids.
- Difference between starch and cellulose.
- Different therapeutic effects of optical isomers of drugs.

A2 Carbonyl compounds

- Aldehydes and ketones – functional group, nomenclature and structural formulae:
    - nucleophilic addition mechanism of HCN to the carbonyl group
    - nucleophilic addition and formation of optical isomers
    - reduction with $NaBH_4$ or $LiAlH_4$ to alcohols (and oxidation of alcohols to carbonyls)
    - addition-elimination mechanisms of aldehydes and ketones reaction with 2, 4-dinitrophenylhydrazine, hydrazine, oxime
    - oxidation of aldehydes with Tollens' reagent, Benedict's/Fehling's reagents, acidified potassium dichromate, and resistance to oxidation by ketones
    - equations and conditions for all reactions.

A3 Carboxylic acids and derivatives

- Carboxylic acids and esters – functional group, nomenclature and structural formulae:
    - weak acidity of carboxylic acids, reaction with metals, bases, alkalis and carbonates
    - condensation reaction of carboxylic acids with alcohols with conc H_2SO_4 to form esters
    - acid and alkaline hydrolysis of ester back into alcohol and carboxylic acid/salt
    - commercial importance of esters e.g. solvents, flavours and fragrances.
- Acyl chlorides and acid anhydrides:
    - reactions with water, alcohols, ammonia and amines
    - comparison of reactivity with carboxylic acids.
- Reactions of difunctional carboxylic acids and acyl chlorides to form polyesters.
- Equations and conditions for all reactions.

A4 Nitrogen containing organic compounds

- Amines – functional group, nomenclature and structural formulae:
    - structural features – lone pair of electrons; primary, secondary and tertiary
    - importance as bases and nucleophiles in reactions
    - nucleophilic substitution mechanism with halogenoalkanes
    - comparison of nucleophilic and free radical substitution mechanisms
    - condensation reaction with acyl chlorides and carboxylic acids to form amides.
- Amides – functional group, nomenclature and structural formulae:
    - alkaline and acid hydrolysis of amides into amine and carboxylic acid (or salts).
- Amino acids – difunctional molecule, acid-base characteristics, formation of polyamides/proteins.
- Reactions of difunctional amines and acyl chlorides to form polyamides.
- Synthesis of commercially important polyamides – nylon and Kevlar®.

Learning aim B: Understand the properties and reactions of aromatic compounds

B1 Structure, properties and reactions of benzene

- Structure of benzene ring.
- Delocalised pi bonding model of benzene ring versus Kekulé structure (ring of alternate double and single bonds).
- Evidence for delocalised model of benzene:
    - comparison of reactions with unsaturated hydrocarbons (e.g. bromine, hydrogen), resistance to addition
    - comparison of bond lengths (use of x-ray diffraction, infrared spectroscopy)
    - thermochemical data (e.g. hydrogenation).
- Carcinogenic risk.
- Combustion to form a smoky flame.
- Electrophilic substitution mechanisms of benzene:
    - nitration with concentrated nitric and sulfuric acids, reflux at 55^{o}C
    - sulfonation reaction with concentrated sulfuric acid to form benzene sulfonic acid
    - chlorination, alkylation and acylation (Friedel–Crafts) reactions.
- Importance of benzene in the manufacture of polymers, detergents and insecticides.

B2 Monosubstituted aromatic compounds

- Nomenclature and structure of aromatic compounds (–CH_3, –NO_2, –Cl, –OH, -NH_2).
- Activating and deactivating effect of substituent groups (–CH_3, –OH, -NH_2 –NO_2, –Cl) on the benzenering and prediction of effect of similar substituents.
- Electrophile directing effects of substituent groups (i.e. ortho, meta and para) and relative proportions of products.
- Electrophilic substitution mechanisms for nitration, chlorination and methylation of monosubstituted aromatic rings (–CH_3, –OH, -NH_2 –NO_2, –Cl).
- Comparison of conditions used for benzene with monosubstituted aromatic reactions.

- Phenol:
  - reaction of benzene sulfonic acid or benzenediazonium salt to form phenol
  - weak acidity of phenol, reaction with strong bases but not weak bases
  - bromination of phenol
  - condensation reaction with carboxylic acids.
- Azo dyes:
  - reduction of nitrobenzene to phenylamine with concentrated hydrochloric acid and tin
  - formation of benzenediazonium salt from phenylamine using sodium nitrite and hydrochloric acid below 5°C
  - formation of azo dye by coupling benzenediazonium ion with phenol and other activated benzene rings.
- Commercial importance of phenol, alkylbenzenes and azo-dyes.

Learning aim C: Investigate organic chemistry reactions in order to gain skills in organic synthesis

C1 Practical organic synthesis

- Examples of preparation of organic liquids:
  - preparation of ethyl ethanoate, ethyl benzoate or 3-methylbut-1-yl ethanoate (banana oil)
  - oxidation of alcohols (e.g. ethanol, cyclohexanol) to aldehydes, ketones or carboxylic acids
  - preparation of a halogenoalkane (e.g. 2-chloro-2-methylpropane) from an alcohol.
- Examples of preparation of organic solids:
  - preparation of aspirin or paracetamol
  - nitration of methyl benzoate, phenol, methylbenzene or methoxybenzene
  - preparation of an azo-dye.

C2 Practical techniques for synthesis

- Use of a range of practical techniques, including:
  - heating under reflux
  - distillation – simple, fractional and steam
  - solvent extraction and separation of immiscible liquids
  - precipitation, crystallisation and recrystallization
  - filtration (under gravity or under reduced pressure)
  - use of chemicals to remove impurities (addition of water, sodium carbonate, anhydrous calcium chloride, molecular sieves)
  - evaporation and drying – oven, desiccator, rotatory evaporator.

C3 Testing identity, estimating purity and determining yield

- Tests for functional groups, including:
  - C=C, decolourisation of bromine water
  - –Cl, -Br, -I, precipitate with warm aqueous silver nitrate
  - O-H, acidic fumes with phosphorus pentachloride
  - C=O, orange precipitate with 2,4-dintrophenylhydrazine, melting point determination
  - –CHO, silver mirror with Tollen's reagent, red precipitate with Benedict's solution
  - -COOH, effervescence with sodium carbonate
  - Phenol, purple colouration with iron (III) chloride
  - $–NO_2$, red-brown precipitate with iron (II) ammonium sulfate and ethanolic KOH.

- Tests for purity:
  - boiling point determination of liquids – distillation (large quantities), Siwoloboff method (small quantities)
  - melting point determination of solids – cooling curves (large quantities), melting point apparatus and capillary tubes (small quantities), mixed melting point technique
  - layer chromatography, gas chromatography, high performance liquid chromatography
  - infrared spectroscopy.
- Determination of percentage yield:
  - calculation
  - factors affecting yield (incomplete reactions, side reactions, conditions, limiting reagents, volatility, transfer loss, impurities).

Learning aim D: Investigate spectroscopic and chromatographic techniques to identify organic compounds and determine quantities

D1 Spectroscopic techniques

- Elemental percentage composition – use to determine of empirical formula.
- Mass spectroscopy:
  - general principles (vaporisation, ionisation, acceleration, deflection, detection)
  - spectra in terms of mass to charge ratio, $\frac{m}{z}$, and relative abundance
  - determination of relative molecular mass from the molecular ion peak
  - interpretation of fragmentation patterns to identify structural features.
- Infrared spectroscopy:
  - general principles (energy used to make bonds bend and stretch)
  - spectra in terms of wavenumber (cm^{-1}) and transmission
  - principles of operation and sample preparation – use of mortar and pestles, halide plates and discs, liquid films and solid mulls
  - use correlation chart of wavenumbers (and intensity of peaks) to identify functional groups present in an organic compound
  - use of relative transmission values of peaks to determine quantities of compounds (e.g. CO_2 in sample of air).
- 1H (proton) and 13C nuclear magnetic resonance (NMR) spectroscopy:
  - general principles and operation (radio waves in the presence of large magnetic field causing 1H or 13C nucleus to spin-flip/resonate)
  - use of tetramethylsilane (TMS) as a reference and of deuterated solvents
  - spectra in terms of chemical shift, δ, (ppm) and relative intensity of peak extent of electron deshielding of 1H or 13C nucleus causing chemical shift
  - number and type of chemically equivalent environments present for H or C atoms
  - area under peak (integration) relating to the number of H or C atoms present
  - simple peak splitting patterns and use of the n + 1 rule
  - use of correlation charts to identify environments present in an organic compound
  - distinguishing between isomeric structures on the basis of NMR.

D2 Chromatographic techniques

- Chromatography
  - separation of mixtures using partitioning between mobile and stationary phases
  - use of partition coefficients
  - industries/organisations using chromatography.
- Gas chromatography (GC):
  - general principles – separation by flow rate of carrier gas, controlled by temperature of the oven
  - operation and equipment – type of sample, microsyringe and injector port, carrier gas, column (packed/capillary), oven (control of temperature and flow rate), detector (e.g. flame ionisation detector), recorder, autosampler
  - mobile phase (carrier gases) and stationary phase (solid ceramic material, viscous liquid coatings).
- High performance liquid chromatography (HPLC):
  - general principles – system under pressure to make the separation faster
  - operation and equipment – type of sample, microsyringe and injection loop, pump, carrier solvent, column, detector (e.g. ultraviolet), recorder, autosampler
  - mobile phase (degassed solvent, polarity selected to match analyte), stationary phase (silica column with coating selected to match analyte), normal phase (polar column, non-polar solvent) and reverse phase (non-polar column, polar solvent).
- Parameters that may be altered:
  - different columns chosen to match the analytes
  - use of internet methods and column manufacturers' data in method development
  - different carrier gases, fixed or ramped oven temperature for GC
  - different polarity solvents, isocratic (fixed) or gradient elution of solvent for HPLC
  - wavelength of the UV detector in HPLC.
- Chromatograms and data:
  - chart layout – retention time and absorption/relative intensity
  - retention time as a measure of a component's identity (qualitative)
  - use of spiking to confirm the identity of a component
  - area under the peak as a quantitative measure
  - optimum resolution and separation of the peaks
  - construction of a calibration graph based on ratio area due to known concentrations/area due to internal standard
  - awareness of the possibility of coupling with mass spectroscopy.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the structures, isomerism and reactions of functional group compounds		
A.P1 Explain the different types of structural isomerism and stereoisomerism. **A.P2** Explain the reactions of carbonyl compounds. **A.P3** Explain the reactions of carboxylic acids and their derivatives. **A.P4** Explain the reactions of nitrogen containing organic compounds.	**A.M1** Assess the importance of isomerism in biological and industrial contexts. **A.M2** Construct a range of mechanisms for organic compounds. **A.M3** Explain the reactions of difunctional organic compounds, including polymerisation.	**A.D1** Plan the multi-step synthesis of functional group organic molecules.
Learning aim B: Understand the properties and reactions of aromatic compounds		
B.P5 Discuss the structure of benzene using sigma and pi bonding, providing evidence for delocalisation in the ring. **B.P6** Explain the reactions of benzene and mono-substituted aromatic compounds.	**B.M4** Analyse the effects of different mono-substituents on the electrophilic substitution mechanism of the benzene ring.	**B.D2** Plan the multi-step synthesis of aromatic organic molecules.
Learning aim C: Investigate organic chemistry reactions in order to gain skills in organic synthesis		
C.P7 Carry out the practical synthesis of organic compounds safely and qualitatively test products.	**C.M5** Explain the chemical reactions carried out in terms of the functional groups, reagents, mechanism and reaction conditions involved.	**C.D3** Evaluate the practical work carried out in terms of product yield and purity, and factors affecting this.

Pass	Merit	Distinction
Learning aim D: Investigate spectroscopic and chromatographic techniques to identify organic compounds and determine quantities		**D.D4** Analyse different spectra and percentage composition data to identify the structure of unknown organic compounds.
D.P8 Explain the principles and use of spectroscopic techniques to identify organic compounds. **D.P9** Explain the operation of GC and HPLC instrumentation to separate and identify organic compounds.	**D.M6** Relate different spectra and percentage composition data to the structure of known organic compounds. **D.M7** Determine the identity and amount of organic compounds using GC and HPLC chromatograms.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.P4, A.M1, A.M2, A.M3, A.D1)

Learning aim: B (B.P5, B.P6, B.M4, B.D2)

Learning aim: C (C.P7, C.M5, C.D3)

Learning aim: D (D.P8, D.P9, D.M6, D.M7, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory with a fume cupboard
- a range of organic chemicals
- gas and water utilities, sinks and power sources to allow reflux, distillation and vacuum filtration to be carried out
- Quickfit™ apparatus for reflux and distillation
- weighing scales
- melting-point apparatus
- thin layer chromatograms
- specimens of mass, infrared, 1H and 13C NMR spectra (or access to relevant instrumentation)
- specimens of GC and HPLC chromatograms (or access to relevant instrumentation)
- health and safety policies and risk assessments.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will be given at least three different starting materials and corresponding product materials to plan synthesis routes or detailed synthesis maps, involving at least two or more steps for each route. The synthesis routes must consider names and formulae of starting materials and products, balanced equations, reaction conditions, mechanisms and indication of any isomeric products that may be formed.

For Merit standard, learners will assess the biological and industrial importance of isomerism from well documented examples or case studies, such as optical isomers with different therapeutic properties or use of structural isomers in fuel applications. This could be done conveniently by providing evidence of relevant differences in properties between isomers and the possible consequences of not being aware of isomerism.

Learners will construct at least one correct mechanism for addition, substitution, addition-elimination and hydrolysis for an appropriate organic compound shown in the *Content*. They will supplement their mechanisms with annotation or explanation of the processes. They will include consideration of the stability of intermediates formed during the mechanism and the formation of different isomers as products. Sourced images of mechanisms are **not** acceptable evidence forms for this criterion.

For Pass standard, learners will explain the different types of structural isomerism, giving at least two examples of chain, positional and functional group isomers. They will use diagrams, molecular models and properties of the isomers where appropriate. Learners will explain the different types of stereoisomerism, giving at least two examples of geometric and optical isomers. They will use diagrams, molecular models and properties of the isomers where appropriate.

Learners will provide explanations of reactions of typical carbonyl compounds, carboxylic acids, carboxylic acid derivatives and nitrogen containing organic compounds shown in the *Content* section. The evidence will include correct names and formulae of starting materials and products, balanced equations, reaction conditions and any products of commercial or biological importance.

Learning aim B

For Distinction standard, learners will be given at least three different starting materials and corresponding product materials to plan synthesis routes or detailed synthesis maps, involving at least two or more steps for each route. The synthesis routes must consider names and formulae of starting materials and products, balanced equations, reaction conditions, mechanisms and indication of any isomeric products that may be formed.

For Merit standard, learners will need to provide evidence that they can construct and explain electrophilic substitution mechanisms for benzene and at least three monosubstituted benzene rings. They will use these mechanisms and other diagrams to account for the enhanced or reduced reactivity of the benzene ring and show predict the positions of further substitutions on the ring. Sourced images of mechanisms are **not** acceptable evidence forms for this criterion.

For Pass standard, learners will discuss the bonding and structure of benzene, using diagrams and models to assist their explanations. They will provide appropriate evidence, such as reactivity, bond length and enthalpy data to give valid reasons for the delocalised of electrons in the structure of benzene against the alternating double-single bond model (Kekulé structure).

Learners will provide explanations of reactions of benzene and typical monosubstituted aromatic compounds as shown in the *Content* section. The evidence will include correct names and formulae of starting materials and products, balanced equations, reaction conditions and any products of industrial or biological importance.

Learning aim C

For Distinction standard, learners must evaluate factors which will affect their syntheses and give detailed explanations of why these factors would affect the yield and purity. Learners will consider the strengths and weaknesses of the reaction conditions and reagents chosen for the reactions carried out. They will comment on the reliability of the techniques and methods used to prepare the products and provide percentage errors for measurements. They will also comment upon the reliability of the tests of the product's identity and purity. As part of their evaluation of the practical work, improvements should be proposed (e.g. change in conditions, reagents, time, equipment or techniques). While the evaluation is in the context of the practical work that they have carried out, how this could be relevant on an industrial scale should be considered e.g. efficiency and scalability.

For Merit standard, learners will provide relevant information to fully explain at least two of the reactions carried out to include the functional groups of the reactants, reagents and reaction conditions involved in the reactions, with appropriate reaction equations and mechanisms. The use or selection of reagents and reaction conditions, such as temperature and timing, need to be explained by the learner.

For Pass standard, learners will provide the results/notes from their portfolio of practical work during the study of this Unit, a witness testimony or photographic evidence of working safely and a safety assessment of at least two of the practical exercises undertaken. Learners will correctly and competently follow given techniques and procedures to prepare and test their organic compounds. Functional groups present should be tested for with the appropriate qualitative test. For organic liquids, learners should use the techniques of reflux and distillation, and add chemicals to purify the liquid they have made. They will measure the boiling point of the organic liquid prepared from reaction and extraction using an appropriate technique, and where possible, carry out an infrared spectrum, using a pure sample as a comparison. For organic solids, learners will use the techniques of vacuum filtration, filtration through filter paper, and recrystallisation.

They will measure the melting point of the organic solid prepared from reaction and extraction using an appropriate technique, and where possible, carry out a mixed-melting-point measurement or thin layer chromatography. Learners will draw simple conclusions about the purity of the samples based on the tests carried out.

Learning aim D

For Distinction standard, learners will correctly identify the structure of at least two unknown compounds (to include one functional group and one aromatic compound) in a logical way, having analysed percentage elemental composition, mass spectra, infrared spectra, ^{1}H NMR and ^{13}C NMR spectra. They will present a full written analysis of the logic used to elucidate the structural formulae of the compounds to justifying their identification and giving evidence of other possibilities that were rejected during the stages of the analysis.

For Merit standard, learners will correctly link the structure of at least four known simple compounds to percentage elemental composition, mass spectra, infrared spectra, ^{1}H NMR and ^{13}C NMR spectra in a logical way. They will calculate empirical formula from percentage elemental composition and determine molecular formulae from the compound's mass spectrum. Additionally learners will use the key feature of infrared spectra, namely the absence or presence of peaks for O-H, C-H, C=O, C=C and C-O, in order to determine which spectrum corresponds to an alkane, alkene, alcohol, ester, carboxylic acid, aldehyde or ketone. Learners will also use the displayed structural formulae of the compounds to work out the number of chemically equivalent hydrogens and carbons and proximity to an electronegative atom or benzene ring in order to match ^{1}H and ^{13}C NMR spectra to the appropriate structural formulae.

Learners will accurately identify the components of a mixture from retention times and/or spiking results for a GC chromatogram/chromatograms and the components of a mixture from retention times and/or spiking results for an HPLC chromatogram/chromatograms. They will also accurately use chromatograms or peak area data from either a GC or an HPLC chromatogram in order to determine the amount of an analyte present. This could involve the production of a calibration graph for the analyte. Learners may interpret their own data from GC and HPLC experiments or interpret given data.

For Pass standard, learners will explain the principles of mass spectrometry, infrared spectrometry, ^{1}H NMR and ^{13}C NMR spectrometry. Key components and processes must be explained and could be illustrated and annotated. Sourced images are not acceptable. The explanation must include reference to how each spectroscopic technique provides information about an organic molecule and the limitations of use of the technique on its own.

Learners will draw, on paper or computer, a block diagram of a capillary GC and an HPLC instrument to explain the function of the components. A photocopy from a book or a downloaded diagram is not acceptable. Learners will research at least two specific examples of how HPLC is used and two specific examples of how GC is used. Learners will explain how the techniques are used in the four applications.

Links to other units

This unit links to:

- Unit 2: Principles and Applications of Chemistry I
- Unit 6: Principles and Applications of Chemistry II
- Unit 16: Applications of Inorganic Chemistry
- Unit 20: Applications of Physical Chemistry.

Employer involvement

This unit would benefit from employer involvement in the form of:

- a visit to any commercial laboratory
- a speaker from a commercial laboratory.

Centres may involve employers in the delivery of this unit if there are local opportunities to do so. A visit to, or a speaker from, any commercial laboratory, no matter how small, will add value to this unit. Visits from chemical, biochemical, biotechnology and pharmaceutical manufacturers would be advantageous. Suitable laboratories include those analysing raw materials or products in the following manufacturing industries: food and drink, dairy, pharmaceuticals, polymers, dye, paints, coatings, road surfacing, ceramics, refractories, bulk chemicals, fuels and lubricants, cement kiln fuel, animal feed, transformer oils, cleaning products, fertilisers, wastewater treatment. In addition, there are laboratories that undertake sub-contracted and accredited analysis, for example, of water, soil, foodstuffs and petroleum products that offer wide-ranging expertise of benefit to learners.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills including:

- independent investigation and research skills
- appropriate equipment, procedures and techniques
- scientific written and communication skills
- data interpretation, manipulation and presentation
- analytical and problem-solving skills
- self-management and planning skills
- evaluative and assessment skills.

Unit 22: Medical Physics Applications

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit gives learners an understanding of the principles and production of ionising and non-ionising radiation, applications of medical physics, and their uses in the diagnosis and treatment of the human body.

Unit introduction

In this unit, you will gain an understanding of the physics that underpins the production of ionising and non-ionising radiation. This understanding will enable you to focus on a number of medical applications of physics and its importance in the diagnosis and treatment of patients.

Surgery today is faster, less invasive and more effective than ever, thanks in part to improvements in medical imaging technology as a result of developments in medical physics. Imaging gives the doctor a clearer understanding of the patient's condition so treatment can be planned more effectively and therapy delivered more precisely.

You will investigate and gain an understanding of a number of technological advances that have resulted in the use of faster, less invasive and more effective medical physics ionising and non-ionising radiation diagnosis and treatment technologies. You will also learn about health and safety, risks and the side effects of using ionising and non-ionising radiation.

The knowledge and understanding you will gain in this unit will support you as you consider applying for a role as a science technician or apprentice, particularly in physics or medical laboratory sciences. It can also support you in your progression to higher education in areas such as medical laboratory sciences, biomedical sciences or applied biology.

Learning aims

In this unit you will:

A Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications

B Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications

C Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications	**A1** Magnetic resonance imaging (MRI) **A2** Lasers **A3** Infrared thermography (IRT) **A4** Ultrasound	A research report showing the different types of non- ionising and ionising radiation techniques. Learners could produce visual presentations for the underlying principles and production. They could produce tables and use case studies for comparisons in justifying techniques used for diagnosis and treatment.
B Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications	**B1** X-rays **B2** Computerised tomography (CT) or computerised axial tomography (CAT) **B3** Gamma ray imaging **B4** Radiotherapy, Gamma Knife surgery and proton beam therapy	
C Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications	**C1** Safety precautions, side effects and risks for operators and patients of ionising radiation **C2** Safety precautions, side effects and risks for operators and patients of non-ionising radiation	A report showing the health and safety and risk implications for operators and patients with the use of case studies, and reference to legislative requirements and associated articles. Information from visits or visiting speakers.

Content

Learning aim A: Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications

A1 Magnetic resonance imaging (MRI)

- Uses radiofrequency waves and strong magnets to produce detailed images of soft tissues in the body.
- Instrumentation/production: main, circular, strong, permanent, superconducting magnet cooled by liquid helium; MRI scanner coils; sliding platform; radio frequency waves input; output signal receiver linked to a powerful computer.
- Magnetic resonance imaging principles from radio frequency input to output of high-resolution images (from protons in different environments), analysed by a radiologist.
- Diagnostic uses: brain and spine, joints, blood vessels, heart conditions, abnormal body water conditions.
- Benefits: non-contact, non-invasive, painless.

A2 Lasers

- Light of specific wavelength passes through a gain medium, which amplifies light with higher energy by stimulated emission.
- Reflectors send the light backwards and forwards in the gain medium until it has gained enough energy.
- High-energy amplified light emitted as a narrow beam or is spread out, depending on application, through a laser oscillator.
- Main types of medical lasers used for different procedures – carbon dioxide, argon, yttrium aluminium garnet (YAG), pulsed dye.
- Treatment, diagnosis and therapy uses, e.g. eye surgery, removal of kidney stones, removal of tumours.
- Benefits: can focus on a small area and damage less tissue surrounding the area to be treated; less pain, swelling and scarring than using traditional surgery.

A3 Infrared thermography (IRT)

- An infrared thermographic camera produces thermal images (thermograms) that show areas of abnormal body temperature, 'hot spots' on the skin that result from higher blood flow due to tumours.
- Uses, e.g. in screening programmes, cardiovascular/circulatory disorders, respiratory problems, dentistry.
- Benefits: fast, passive, non-contact and non-invasive, maps body surface temperature remotely.

A4 Ultrasound

- Used by radiologists and sonographers.
- Instrumentation – earthed case, coaxial cable, absorber, crystal and plastic cover, monitor screen.
- Pulses of ultrasound transmitted from the probe in the transducer into the body and reflected back.
- The density characteristics of the different structures inside the body are displayed as an image.

- Medical ultrasound usually 2 megahertz (MHz) and higher-frequency ultrasound
- Types:
  - external ultrasound scan, e.g. screening of fetus
  - internal ultrasound scan – produces images of organs in more detail
  - endoscopic ultrasound – long, thin flexible tube (endoscope) inserted into the body through mouth to examine stomach, gullet or lymph nodes in chest.
- Treatment uses – kidney stones, benign and malignant tumours.
- Diagnosis uses – narrowing of blood vessels, strokes and heart attacks; echocardiogram to measure blood flow rates.

Learning aim B: Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications

B1 X-rays

- High-frequency rays, ionising radiation waves pass through soft body tissue, absorbed by dense bones.
- Produces image on a photographic plate placed behind the required part of the body, image is processed by a computer.
- Image analysed by radiologist.
- Where x-rays are absorbed, e.g. by bones, they appear white; other areas are dark on the photographic film.
- X-ray imaging principles and production:
  - heated cathode filament produces negatively charged electrons
  - electrons accelerate to a positively charged tungsten anode, where some of their kinetic energy is transformed into x-rays.
- Treatment and diagnosis uses – cancers and breaks in bones, pneumonia, tuberculosis, screening for breast cancer, mammograms.

B2 Computerised tomography (CT) or computerised axial tomography (CAT)

- A series of x-rays create detailed images, called tomograms, of the inside of the body, layer by layer.
- Image examined by radiologist.
- CT scan is created by an x-ray tube that rotates around the body: the body is inside a tunnel and is moved continuously through a rotating beam of x-rays, a detector is on the opposite side of the body.
- Diagnosis and monitoring uses – brain tumours, certain bone conditions, injuries to internal organs such as the kidneys, liver and spleen, and the heart.

B3 Gamma ray imaging

- Principles include:
  - a short-lived, positron-emitting (positive electron e+) radioactive tracer (radionuclide) with a short half-life, e.g. iodine-123 (123I), technetium-99 (99T), is injected into the body
  - emitted positrons combine with nearby electrons (e-) to produce gamma rays
  - gamma ray emissions from the cancerous area produce an image for diagnosis
  - the body is inside a ring of detectors to give a signal, which is used by the computer to produce a three-dimensional functional image of inside the body given off by a radiotracer.

- Uses of positron emission tomography (PET) – imaging scans for diagnosis of cancer, detection of recurrent tumours.
- Benefits – high-energy, penetrating power.

B4 Radiotherapy, Gamma Knife surgery and proton beam therapy

- Radiotherapy – gamma rays externally or internally inside the body:
  - external beam radiotherapy uses linear accelerator, focuses high-energy gamma ray beams onto the area requiring treatment
  - a series of daily treatments over a number of days or weeks
  - uses – to treat cancerous tumours.
- Gamma Knife surgery:
  - a highly accurate therapeutic dose of gamma radiation for brain tumours
  - dose volume controlled for treatment required.
- Proton beam therapy:
  - an accelerator (synchrotron) accelerates charged protons accurately in a 3D pattern, giving greater control and precision and causing less damage to healthy cells
  - Bragg peak internal radiotherapy
  - cancerous cells lose ability to repair, divide and proliferate causing cellular death
  - uses – to treat cancerous and benign (non-cancerous) tumours, thyroid disease and some blood disorders
  - benefits – non-invasive and painless, less damage to healthy tissues.

Learning aim C: Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications

C1 Safety precautions, side effects and risks for operators and patients of non-ionising radiation

- Safe operating procedures for possible effects on patients and staff operators.
- Health and Safety Executive (HSE) – legislative requirements.
- Ultrasound:
  - internal ultrasound scanner, placed into the vagina or rectum, can cause discomfort
  - endoscopic ultrasound: long, thin flexible tube (endoscope) inserted into the body through the mouth can cause discomfort – patients are usually given painkillers and a sedative
  - for some scans, patients need to drink and retain lots of water to fill their bladder, or avoid eating for several hours.
- Lasers – treatment may not be permanent, use of protective clothing laser safety goggles is necessary, exposure limits necessary, use of film badges required.
- MRI – quite noisy, can be claustrophobic in tunnel, safety related to use of powerful magnets, e.g. removal of all ferromagnetic materials, implants and foreign bodies.

C2 Safety precautions, side effects and risks for operators and patients of ionising radiation

- Safe operating procedures for possible effects on patients and staff operators.
- HSE – legislative requirements associated with using radiation in diagnosis, treatment and therapy.
- X-rays, CT, radiotherapy, proton beam therapy and gamma rays have high-energy penetrating power of ionising radiation, Ionising Radiation (Medical Exposure) Regulations 2000:
  - safe operating procedures for ionising radiation applications and possible effects on patients and staff operators
  - occupational risk and exposure to high levels of radiation (100 mSv or more)
  - patient dose limits required
  - typical levels of exposure during medical tests in milliseverts (mSv), such as single chest x-ray (0.014 mSv); mammogram (0.4 mSv); CT scan to whole spine (10 mSv)
  - use of protective clothing and film badges required.
- Ionising radiation can damage healthy cells and cause cancer.
- CT scanning can be claustrophobic in the tunnel.
- Possible radiotherapy side effects are: tiredness, hair loss, loss of appetite, diarrhoea, sore skin.
- Gamma Knife surgery can cause discomfort in head control device, but has fewer side effects than radiotherapy.
- Proton beam therapy has fewer harmful side effects.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications		**AB.D1** Justify the choice of non-ionising and ionising radiation techniques in medical applications.
A.P1 Explain how the principles and production of non-ionising radiation technologies are used in medical applications. **A.P2** Explain why non-ionising radiation technologies are used for diagnosis and treatment of the human body.	**A.M1** Compare the principles, production and uses of different non-ionising radiation techniques in medical applications.	
Learning aim B: Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications		
B.P3 Explain how the principles and production of ionising radiation technologies are used in medical applications. **B.P4** Explain why ionising radiation technologies are used for diagnosis and treatment of the human body.	**B.M2** Compare the principles, production and uses of different ionising radiation techniques in medical applications.	

Pass	Merit	Distinction
Learning aim C: Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications		**C.D2** Discuss the consequences of poor health and safety when using non-ionising and ionising radiation technologies and the prevention and safety measures employed.
C.P5 Explain the health and safety risks, side effects and limitations of non-ionising and ionising radiation technologies. **C.P6** Explain how hospitals can employ health and safety measures, when using instrumentation, for the protection of operators and patients.	**C.M3** Compare the health and safety risks, side effects and limitations of non-ionising and ionising radiation technologies in medical applications to maximise the protection of operators and patients.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, B.P3, B.P4, A.M1, A.M2, AB.D1)

Learning aims: C (C.P5, C.P6, C.M3, C.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to appropriate library/learning resource centre physics/medical science books and access to the internet.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will give valid reasons for the justification of non-ionising and ionising radiation techniques for diagnosis and treatment purposes. They will do this using a number of scenarios of different medical cases that require diagnosis, treatment or screening, and they will rationalise their selection of the combination of non-ionising and ionising radiation techniques. Learners will consider patient choice and consent when considering the use of radiation therapy/techniques.

For Merit standard, learners will effectively apply their understanding of the principles and production of at least two non-ionising (i.e. MRI, lasers, IRT or ultrasound) and at least two ionising (i.e. x-rays, CT/CAT, gamma ray imaging, radiotherapy, Gamma Knife surgery and proton beam therapy) radiation technologies. They will succinctly compare the benefits and limitations of using these in the treatment and diagnosis of patients in a medical setting.

For Pass standard, learners will produce valid labelled diagrams/flow charts showing the principles and production of at least two non-ionising (i.e. MRI, lasers, IRT or ultrasound) and at least two ionising (i.e. x-rays, CT/CAT, gamma ray imaging, radiotherapy, Gamma Knife surgery and proton beam therapy) radiation technologies. They will use their understanding of the production and principles of non-ionising and ionising technologies to give reasons why these techniques are used for diagnosis and treatment.

Learning aim C

For Distinction standard, learners will put forward valid and effective reasons why precautions and measures are taken to protect patients and operators, and any consequences of not safeguarding patients and operators. They will coherently substantiate implications and health and safety measures, with underpinning scientific knowledge and an understanding of the relevant legislation and the role of the HSE.

For Merit standard, learners will effectively apply their knowledge of health and safety risks, side effects and limitations in order to make a valid comparison of the different technologies for both patients and operators in a medical setting. Learners will differentiate and order the level of health and safety risks according to the types of radiation technologies used and compare the impact this could have on patients and operators.

For Pass standard, learners will use their understanding of health and safety risks, side effects and limitations across a range of ionising and non-ionising radiation technologies, in order to give a thorough explanation in a medical setting. Learners will refer to appropriate health and safety measures in place to help protect both patients and operators in a medical setting by referring to the relevant legislation and the HSE.

Links to other units

This unit links to:

- Unit 3: Principles and Applications of Physics I
- Unit 7: Principles and Application of Physics II.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities, such as radiologists, oncologists and radiography technicians. Local hospitals could be contacted for possible work experience opportunities within a modern radiology department.

Opportunities to develop transferable employability skills

The material covered and described in this unit provides an overview of general principles used in treatment and diagnosis of medical conditions using complex physical science techniques. Learners undertaking study in this subject material will be able to develop an in depth understanding of the principles involved and the precision achieved by physicians in modern hospitals. Skills developed during study are transferable for all types of employment. These will include; dimensions of scale, clarity of nomenclature, precision and detail, importance of health and safety and techniques used, general principles of ionising and non-ionising radiation therapies.

Unit 23: Materials Science

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit will cover a level of understanding required by learners to classify a range of different materials, including their applications, benefits and limitations.

Unit introduction

Materials scientists are constantly researching new materials to replace traditional ones to bring about advances in new technologies, such as graphene and new composites used in display screens, electric circuits, solar and fuel cells. The ongoing search for new materials is not only necessary to replace traditional materials that are no longer sustainable in terms of their availability and cost but also to develop advances in new technologies. In this unit, you will gain an understanding of different types of new and traditional materials and their applications.

You will investigate how materials can be grouped into a number of main classifications and their different microscopic and macroscopic properties. A number of new, exciting developments are being made, such as in nanotechnology, where the properties of the materials at the microscopic level are not always the same as at the macroscopic level. You will also investigate polymers, and their properties, benefits, disadvantages and risks to the environment, and you will examine materials that are being used in everyday applications to reduce global warming and carbon dioxide emissions for a sustainable future.

This unit will support you in gaining access to higher education for the study of biological, chemical or physical sciences, or gain employment as a science technician or apprentice.

Learning aims

In this unit you will:

A Understand the classification and properties of different materials

B Examine the uses, benefits and limitations of developing nanotechnology materials

C Investigate the benefits and limitations of polymer technology

D Examine materials used in applications in order to reduce carbon emissions for a sustainable future.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the classification and properties of different materials	**A1** Classification of materials **A2** Macroscopic properties **A3** Microscopic structure	An investigative report showing the different types of materials. Learners could then produce a visual presentation of their classification using microscopic and macroscopic pictures, diagrams and data for the different materials and their properties.
B Examine the uses, benefits and limitations of developing nanotechnology materials	**B1** Definition of nanotechnology **B2** Uses of nanotechnology **B3** Benefits of nanotechnology **B4** Environmental impact and health and safety risks of nanotechnology materials	Learners could produce a report based on case studies, internet searches and class discussions about the benefits and risks of nanotechnology materials.
C Investigate the benefits and limitations of polymer technology	**C1** Polymers and their sources **C2** Benefits of polymers **C3** Limitations and environmental risks of polymers	A research report showing the different types of polymers, benefits and risks to the environment.
D Examine materials used in applications in order to reduce carbon emissions for a sustainable future	**D1** Wind turbine blades **D2** Solar photovoltaic cells **D3** Light-emitting diodes (LEDs) **D4** Fuel cells	Learners could research sources of information and compose a portfolio of case studies with reference to examples of everyday uses.

Content

Learning aim A: Understand the classification and properties of different materials

A1 Classification of materials

- Metals and alloys – ferrous and non-ferrous metals and alloys; iron and steels; noble metals (copper, silver and gold and their alloys); aluminium; rare earth metals e.g. Neodymium, Dysprosium, Europium, Lanthanum.
- Glass – soda-lime-silica glass, sodium borosilicate glass, aluminosilicate glass, oxide glass, toughened glass; glass can be coloured by adding metallic salts such as oxides of Antimony and compounds of Copper.
- Polymers (plastics) – thermosetting plastics (urea formaldehyde, Bakelite, polyurethane), thermoplastics (polythene, nylon, polyvinyl chloride, polystyrene, Teflon, thermoplastic resins).
- Ceramics – structural, refractories, white wares, special, fine ceramics.
- Carbon – diamond, graphite, graphene, carbon fibres, carbon nanotubes.
- Composites – reinforced plastics, carbon and glass fibre composites, carbon fibre-reinforced composites, metal composites, ceramic composites, sandwich structures, concrete composites.

A2 Macroscopic properties

- Melting point, boiling point.
- Strength, toughness, malleability.
- Electrical conductivity, thermal conductivity.
- Density.
- Biodegradability.

A3 Microscopic structure

- Atomic structure, bonding.
- Additives such as cross-linking agents, plasticisers.
- Reinforcing fibres/particles.

Learning aim B: Examine the uses, benefits and limitations of developing nanotechnology materials

B1 Defining nanotechnology

- Nanoscale – 1 to 100 nanometers, 1 nanometer is 1×10^{-9} of a meter.
- Use of scanning tunnelling microscope (STM) and atomic force microscope (AFM).
- Manipulation and control of matter on a near-atomic size (including atoms and molecules).
- Movement of individual atoms.
- Nanotechnology materials at this size can have unique different chemical, biological and physical properties compared with their larger counterparts at the macroscopic level.
- Researching, developing and utilising these properties is at the heart of nanotechnology.
- Types of nanoparticles defined by shape, to include nanotubes, nanowires, nanofilms, nanotunnels, nanoplates.

B2 Uses of nanotechnology

- Computing and instrumentation – nanoscale transistors, nanosensors, nanoelectronics.
- Energy – nano-solar panel films.
- Nanosolar cells nanomedicine – drug delivery, biomedical instrumentation.
- Chemotherapy nanoengineering – nanorobotics, nanoelectronics.
- Nanomachines and nanochemistry – nanosunscreens, nanocatalysts, nanocarbon tubes, graphene, nanospheres.

B3 Benefits of nanotechnology

- Improved biological, chemical and physical properties of materials, to include:
  - greater strength
  - lighter weight
  - greater chemical reactivity
  - scratch resistance
  - improved catalysis
  - improved electrical conductivity
  - antibacterial coatings.

B4 Environmental impact and health and safety risks of nanotechnology materials

- Environmental impact – the effects on the respiratory system through the use of nanoparticles from exhaust systems, on marine life through water systems by the use of, for example cosmetics and toothpaste.
- Health and safety risks – safe handling risks to employees, exposure levels, high toxicity, possible lung cell damage.

Learning aim C: Investigate the benefits and limitations of polymer technology

C1 Polymers and their sources

- Terminology – natural and synthetic, thermosetting and thermoplastics, polymerisation, monomer, polymer and co-polymer, polymer composites, elasticity and plasticity.
- Sources of starting materials – petroleum oil, sugars, corn starch, cellulose, hydroxycarboxylic acids.
- Additives to improve properties – fillers, plasticisers, cross-linking agents, impact modifiers, antioxidants, stabilisers and decolourants.

C2 Benefits of polymers

- Improved properties compared with some conventional materials – low thermal and electrical conductivity, lightweight and easy to handle, durable and resistant to corrosion, easy to shape during manufacture, good electrical and thermal insulating properties, strong and flexible, new biodegradable plastics.
- Uses of polymers – construction, transport, electronics and computing, sport and leisure, packaging, domestic household uses.

C3 Limitations and environmental risks of polymers

- Limitations – some have low strength, can be toxic and flammable, UV light sensitive, fatigue sensitivity, most are not biodegradable.
- Environmental impact – most are not biodegradable in the short term, risks to marine welfare, some plastics cannot be recycled, high toxicity.

Learning aim D: Examine materials used in applications in order to reduce carbon emissions for a sustainable future

D1 Wind turbine blades

- Materials used – glass fibre composites, aluminium.
- Key useful properties of materials used – high strength and stiffness, low density, durable corrosion resistant.
- Limitations of materials used – low fatigue resistance.
- Benefits of use of wind turbines.

D2 Solar photovoltaic cells

- Materials, e.g. silicon wafer, cadmium telluride (CdTe).
- Key useful properties of materials used – CdTe responds well to light in the solar spectrum.
- Benefits and limitations of materials used – CdTe is environmentally unfriendly, silicon is readily available, tellurium is a very rare element and therefore costly.
- Benefits of solar photovoltaic cells.

D3 Light-emitting diodes (LEDs)

- Materials, e.g. gallium arsenide (GaA), gallium nitride.
- Useful microscopic and macroscopic properties of materials used, e.g. electrons can travel very quickly, good conductor of thermal energy.
- Benefits and limitations of materials used – GaAs may be carcinogenic, gallium is expensive to extract.
- Applications – lighting, infrared beams.

D4 Fuel cells

- Materials – polymers for electrolyte membranes and ceramic-based electrolytes.
- Useful properties of materials used – decomposes water into hydrogen and oxygen more readily than many other materials.
- Benefits and limitations of materials used – easily obtained, are not environmentally friendly (disposal issues).

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the classification and properties of different materials		**A.D1** Analyse the microscopic and macroscopic structure of different given materials and classify them into groups according to their properties.
A.P1 Determine the classification of given materials by considering their properties.	**A.M1** Compare the microscopic structures and classifications of different given materials to determine their macroscopic properties.	
Learning aim B: Examine the uses, benefits and limitations of developing nanotechnology materials		**B.D2** Evaluate the uses, benefits, environmental impact and health and safety risks of using nanotechnology materials for given applications.
B.P2 Explain what is meant by a nanotechnology material. **B.P3** Explain the uses and benefits of nanotechnology materials.	**B.M2** Discuss the uses, benefits and health and safety risks of nanotechnology materials.	
Learning aim C: Investigate the benefits and limitations of polymer technology		**C.D3** Evaluate the methods of testing, the uses, benefits, limitations and environmental risks of different types of polymers for given applications.
C.P4 Explain the uses, benefits and limitations of polymers. **C.P5** Explain the benefits of using additives to modify the properties of plastics.	**C.M3** Justify the use of additives and the methods used for testing the suitability of different types of polymers for given applications.	
Learning aim D: Examine materials used in applications in order to reduce carbon emissions for a sustainable future		**D.D4** Evaluate the benefits and limitations of using the materials in order to reduce carbon emissions.
D.P6 Explain how materials can be used to reduce global emissions.	**D.M4** Compare methods used to reduce carbon emissions for materials used in given applications.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.M2, B.D2)

Learning aim: C (C.P4, C.P5, C.M3, C.D3)

Learning aim: D (D.P6, D.M4, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners should have access to books, magazines, journals and the internet.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will examine and interpret the atomic structure and bonding of two different unknown materials that they have been given to determine their behaviour and properties at the macroscopic level and classify them into their different classification groups.

For Merit standard, learners will explain how the microscopic structure of two different known materials determine their properties at the macroscopic level, which allows them to be classified into their different groups. Learners could be given a metal, a polymer or a form of carbon, metals and polymers as examples and explain how their microscopic properties determine their ability to conduct electricity.

For Pass standard, learners will be provided with at least three materials and will examine their macroscopic physical properties to draw conclusions and classify them into an appropriate group.

Learning aim B

For Distinction standard, learners will draw valid conclusions from the evidence of the health and safety risks, environmental impact and benefits of using nanotechnology materials and draw conclusions.

For Merit standard, learners will provide relevant aspects of the uses, benefits and risks of using nanotechnology materials to employees, the public and the environment.

For Pass standard, learners must define what is meant by a nanotechnology material by its size and type and that its properties may be different at the microscopic and macroscopic levels. They will explain the uses and benefits of at least two different nanotechnology materials.

Learning aim C

For Distinction standard, learners will draw valid conclusions from the evidence of environmental risks, limitations and benefits of using different types of polymers.

For Merit standard, learners will need to provide evidence and give valid reasons to justify the benefits of using polymers in at least three different applications, relating their molecular structure and any additives used to improve their properties.

For Pass standard, learners will investigate at least three types of polymers and their properties using the correct terminology to provide appropriate evidence and reasons for their suitability and limitations. Learners must explain the benefits of using at least three different types of additive and how they modify the properties of the polymers, such as the use of cross-linking agents to increase strength.

Learning aim D

For Distinction standard, learners will need to provide appropriate evidence and review the benefits and limitations to draw conclusions of using at least three different materials used in given applications to reduce carbon emissions.

For Merit standard, learners will need to identify the main factors and explain why the different methods are used to reduce carbon emissions for at least three different materials used in given applications.

For Pass standard, learners will investigate and provide appropriate information about the functions and suitability of at least three different materials used in given applications to reduce carbon emissions.

Links to other units

This unit links to:

- Unit 2: Principles and Applications of Chemistry I
- Unit 3: Principles and Applications of Physics I
- Unit 9: Biomedical Science
- Unit 10: Climate Change.

Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities to do so. Visits from rubber/composite manufacturers or sports equipment/clothing manufacturers, for example, would be advantageous.

Opportunities to develop transferable employability skills

Learners will develop skills related to research technique, understanding of materials used in everyday life and the need to recycle materials for a sustainable future.

Unit 24: Pollution and Waste Management

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers current knowledge and predictions, and global plans aimed at addressing the problems caused by pollution at present and in the immediate future.

Unit introduction

Levels of global pollution have been increasing at an alarming rate since industrialisation began. There is scientific evidence indicating that all countries need to take immediate action to prevent the situation becoming much worse and threatening the lives of countless millions of people and the possible extinction of a significant number of plant and animal species. In this unit, you will explore the main issues relating to the pollution of our planet and understand the meaning of 'pollution' and its many forms.

You will learn the accepted definition of pollution and current understanding of the causes of pollution and its effect on the land, the sea and the atmosphere. You will focus on factual aspects identified through many years of scientific research and experimentation. This unit gives an outline of pollution in three main sections: the main causes of global pollution; the known effects of pollution on plants and animals; and current and future plans to mitigate the ongoing problems of pollution. The last section gives an outline of current waste-management activities performed across continents in the hope of developing long-term solutions to managing the waste produced by, in particular, human activities.

The skills you learn in this unit can be applied to other areas of study and if appropriate to your workplace. This unit will support you in progressing to higher education in science related programmes that are linked to environmental science, climate analysis and research.

Learning aims

In this unit, you will:

A Investigate contributing factors of pollution

B Explore the effects of pollution on flora and fauna

C Investigate methods of waste management.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Investigate contributing factors of pollution	**A1** Polluting substances and their sources **A2** Facts and figures relating to pollution of water, land and atmosphere	A scientific report or news article, using appropriate terms and numerical values. Outline of numerical values associated with composition of pollutants and facts. Diagrams related to land, sea and the atmosphere, highlighting the movement of pollutants between them.
B Explore the effects of pollution on the Earth's flora and fauna	**B1** Evidence of pollution effects on the animal kingdom **B2** Evidence of pollution effects on the plant kingdom	Research article that provides evidence for the known effects of pollutants on animals, with examples. Discussion and scientific evidence related to the known effects of pollutants on plant life. This could take the form of a 'news' report on the problems of reduction in plant life on Earth.
C Investigate methods of waste management	**C1** Current methods of managing waste **C2** Future waste-management proposals and technological developments	A report on the most up-to-date methods of managing solid and liquid waste materials, stages in the process and the plastics problem. A journalistic report based on current and newly developed technology to deal with waste management for an increasing population.

Content

Learning aim A: Investigate contributing factors of pollution

A1 Polluting substances and their sources

- Definition of pollution as 'the introduction or presence of a substance in the environment that is harmful or poisonous'.
- Main forms of pollution – pollutants that change the physical form of the environment (in water, in soil, in air, radioactivity, plastics, litter, thermal pollution) and pollutants that affect the environment and which are difficult to measure (noise, light, other visual pollution, e.g. buildings).
- Water-pollutant sources – industrial waste, effluent, agriculture, oil industry, underground mining, other chemical waste, water transportation (pleasure boating and cruises, fishing industry, cargo and oil tankers).
- Water pollution and effect on oceans and seas, rivers and streams, reservoirs, household piping and storage of potable water in developing countries.
- Air-pollutant sources – industrial gases (chemical manufacturing, steel production, fashion industry, lead smelting, dye industry, tanneries), exhaust gases from transport (road traffic, air traffic, shipping and rail).
- Air pollution and effect on humans and animal health (nitrogen dioxide, sulphur dioxide and ozone are lung irritants, particulates cause lung inflammation and worsening of lung and heart disease, carbon monoxide prevents oxygen uptake by the blood, increase in asthma cases), climate and weather.
- Land-pollutant sources – agricultural activities (farming and use of agro-chemicals, pesticides, herbicides, fertilisers), deforestation and subsequent soil erosion, mining and extraction, development of industrial complexes, construction and urbanisation, sewage land fill, nuclear waste.
- Land pollution and effect on soil quality, soil erosion, changes in the water cycle following deforestation, climate patterns, human health (toxicity levels, air pollution and transmission of disease), effect on wildlife and plant life (damage to ecosystems, displacement and death of species, reduction in tourist industry.

A2 Facts and figures relating to pollution of water, land and atmosphere

- Main activities responsible for carbon emissions:
  - production of electricity and heat combined
  - industry and manufacturing
  - agriculture
  - regular changes of land use
  - general waste
- Top 10 nations responsible for carbon dioxide emissions: China, USA, Europe, India, Russian Federation, Japan, South Korea, Iran, Saudi Arabia, Canada.

- Quantities of various forms of pollution entering the environment annually and their effects in terms of:
  - tons of litter entering the oceans
  - percentage of waste from developing countries entering the environment without treatment
  - number of human deaths attributable to drinking unclean water
  - number of seabirds and mammals killed as a result of plastic waste
  - projected increase in the number of motor vehicles in use
  - area of rain forest cut down
  - estimated rise in number of cases of heart disease, asthma, bronchitis and cancer as a result of traffic pollution.

Learning aim B: Explore the effects of pollution on flora and fauna

B1 Evidence of pollution effects on the animal kingdom

- Historic use of pesticides, e.g. dichloro-diphenyl-trichloroethane (DDT), effects on animals and humans causing reproductive and neurological problems.
- Oil spills – effects of shipping, large oil platforms, spills at sea and effects on seabirds, fish and mammals as a result of accidents (Piper Alpha, Deepwater Horizon, Exxon Valdez).
- Acid rain – caused by combustion of fossil fuels and vehicles, releasing sulphur and nitrogen into the atmosphere, effects on aquatic organisms (less tolerant to lowered pH) and soil.
- Mining for metals and metal refining – increased levels of toxic metals into the air and water ecosystems.
- Plastic – effects on marine life (mammals, e.g. whales/dolphins, fish, sea turtles, seabirds).
- Case study – 'The Plastic Whale', Cuvier's Beaked Whale, island of Sotra, Norway.
- Coral reefs – process of dissolving $CaCO_3$ (calcium carbonate) by acid, damage caused by increase in acidity of oceans and increased temperature rises causing 'bleaching', land development, plastics, for example, Great Barrier Reef, Florida Reef.
- Light pollution – artificial light and effects on wildlife (amphibians, birds, mammals and insects).
- Changes in growth and physiology of animals in the presence of long-term pollutants.
- Animal adaptation to habitat change, e.g. the purple sea urchin.
- Immediate and long-term changes to food chains and food webs.
- Increase in numbers of asthma and bronchitis cases in humans from increasing levels of sulphur dioxide in the air.

B2 Evidence of pollution effects on the plant kingdom

- Plants are affected in different ways by the introduction of pollutants:
  - air pollution – effects shown on leaves and stems such as chlorosis (change in colour of leaves), restricted or stunted plant growth, plant stem tissue damage, increased ozone in the lower atmosphere reduces a plant's ability to photosynthesise, holes in the ozone layer in the upper atmosphere result in excess ultra violet light, which damages plants
  - water pollution – sources include sewage treatment run-off into waterways and excess nutrients (eutrophication and algal blooms), excess chemicals discharged by industries, changes in the pH of the water by chemical discharge damaging or killing plant life
  - land pollution – acid rain (reduction in organic compounds of aluminium, direct damage to plants and leaf damage, resulting in reduced photosynthesis, increased dissolving of essential nutrients, complex chemical changes in the soil, resulting in lack of nutrients and slow plant growth, reduced soil bacteria that break down the soil into nutrients, damage to leaf stomata which reduces photosynthesis, low plant recovery rates once damaged.
- Drop in number of plant species in last 50 years.
- Benefits of plants in urban areas.

Learning aim C: Investigate methods of waste management

C1 Current methods of managing waste

- Waste management: the actions performed to manage waste materials from beginning to end-disposal point (collection – transportation – treatment – disposal – monitoring – continued regulation and updating of the waste process).
- Reasons for regulated waste management: prevention of air, water and land contamination, protection of population health.
- Sources of solid waste: industry, residential, commercial.
- Material categories of waste: paper, metals, glass, plastics, organic.
- Hazardous categories of waste: toxic/non-toxic, flammable, radioactive, infectious.
- Effective waste-management process: waste generated – initial processing and organising waste – waste collection – separation of re-usable/recyclable waste – transport of disposable waste to landfill.
- Relative annual amounts of waste generated per person – top 10 countries.
- Case study: plastics as the preferred packaging (low cost, hydrophobic, bio-inert, easy moulding, high modulus), packaging film (impermeable to moisture and gas), expanded polystyrene (good thermal insulation), plastics as the greatest threat to life (plastic bags in the oceans and effect on marine life, micro-plastics – less than 5 mm entering the food chain, problems with increased use of 'biodegradable' and 'bioplastics').

- Waste-water treatment:
  - chemical, biological and physical processes combine to treat waste water and sewage effluent produced is returned to the water cycle.
  - 3-stage treatment
    - primary (sewage put in a large holding basin for macrobiotic and other components settle according to their mass, solid matter pumped out for further treatment
    - secondary (aerobic treatment using pumps to encourage bacterial and other microorganisms to consume the organic matter)
    - tertiary (chemical feed stations sanitise the water to 99% purity and then it is discharged back to the environment through local waterways).

C2 Future waste-management proposals and technological developments

- Waste hierarchy – 'Reduce, Re-use, Recycle' principle, suggested for the population to help develop a more sustainable future:
  - reduce the need to buy more than one item that performs the same job, add extra to an item that does not need it, purchasing an item you may never use
  - re-use items that can be used more than once and identify them clearly; in the home re-using screws, string and jars for example, and on a large scale re-use of large, metal, shipping containers for building homes and offices, old clothes, re-chargeable batteries
  - recycle items that can be used more than once for the same or different purpose (e.g. plastics, glass bottles), buy products that have already been recycled.
- Land-fill sites (better management of waste deposit and land-fill sites to increase the sorting methods for re-cycling, reduce the amount of waste material buried, position land-fill sites away from residential areas).
- Reduction in use of pesticides and fertilisers in agriculture – introduction and sustained use of organic farming methods as a cultural change to viewing crops and livestock in a holistic system to:
  - reduce pollution
  - protect the environment
  - reduce soil erosion
  - improve soil fertility by using sustainable biological activity
  - provide a high level of care for livestock
  - use renewable resources where possible.
- New technology and ideas:
  - Advanced Thermal Treatment (ATT) – use of pyrolysis and gasification to change waste products chemically, producing gas fuel
  - using technology in food outlets that logs food waste and provides informative read-outs
  - reinforce the idea of 'reprocessing' to replace 'waste' in media and general communication
  - advancement in waste-product identification and selection by computerised machines
    - electronic methods to charge consumers for the amount of waste they produce
    - increase responsibility on retailers and fast-food outlets for disposal of waste materials.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Investigate contributing factors of pollution		
A.P1 Describe the main sources of pollution. **A.P2** Describe the main activities responsible for carbon emissions.	**A.M1** Explain the effects of pollution in air, water and on land.	**A.D1** Evaluate the effects of pollution using supporting data.
Learning aim B: Explore the effects of pollution on flora and fauna		
B.P2 Describe the evidence relating to pollution effects on the animal kingdom. **B.P3** Describe the evidence relating to pollution effects on the plant kingdom.	**B.M2** Explain the effects of pollution on the plant and animal kingdoms.	**B.D2** Evaluate the effects of pollution on the plant and animal kingdoms.
Learning aim C: Investigate methods of waste management		
C.P4 Describe current methods of managing waste. **C.P5** Describe future proposals for waste management.	**C.M3** Explain current methods of waste management and future proposals.	**C.D3** Evaluate methods of waste management and future proposals.

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.M2, B.D2)

Learning aim: C (C.P4, C.P5, C.M3, C.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to scientific and ethical television programmes that focus on pollution and management of waste.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will explain in detail the main points of the development of pollution and the implications of each outlined source on the atmosphere, land surface and oceans. Learners will work with independence to produce a concise but comprehensive analysis of pollution and its effects on the Earth's surface. Learners will also evaluate the effects of pollution using supporting data taken from reliable sources.

For Merit standard, learners will work with independence and cover concisely but informatively all main pollutants, their sources and their effects on all forms of waterway (oceans, seas, lakes, rivers, streams), the air and land surface, relating specifically to air pollution and its effects, plant life and soils. Research into the available data on pollution, as identified in the unit will be used to illustrate the problems faced by scientists and world leaders in combating the effects of human development.

For Pass standard, learners will describe the main forms of pollution and its generalised effects on the environment. They will identify key water-, land- and air pollutants and will outline their effects on the systems involved. Learners will focus on the direct links between the pollution type and examples of the effect on plants and living organisms, including microscopic life, larger animals and humans. Learners should also focus on the effects of different types of pollution and the immediate and long-term effects to the atmosphere, oceans and land surface. This will include identification of pollutants in the atmosphere and the quality of air in all parts of the world. The effects of industry, manufacturing and tourism will feature as a link between normal human activities and the consequences which are involved in the cause of pollution. Direct links between air quality and human or animal health will be outlined, together with changes to climate, weather and other aspects as a result of deforestation, agricultural and industrial practices. Learners will conduct detailed research on the data available for aspects related to pollution as outlined in the unit content. Learners could compile a table that presents the information and data effectively.

Learning aim B

For Distinction standard, learners will analyse information on the effects of pollution on animal life. Information should be taken from appropriate sources and supported by evidence-based sources. Learners will present their research on case studies of oil rig or oil spill accidents, plastics in the ocean and coral-reef damage. Learners will demonstrate that they understand the causes and effects of pollution. They will explain clearly how animal species are adapting to the effects of pollution and include diagrams that show the changes to food chains and webs.'

For Merit standard, learners will work independently and explain the effects of human activities on our atmosphere and on the development of greenhouse gases. They will explain how food chains and webs are affected by pollution and waste management, giving examples of the changes. Explanation of the effects of warming of the seas and increased acidity of the oceans on animal life should include examples from research of the animal life most at risk. Learners should also include an explanation of the changes to coral reefs as a result of land development and investigate the effects on marine life of plastics in the ocean, they should use a suitable case study which is comprehensively covered.

For Pass standard, learners will outline the types of pollution and their effects on animals and plants. The effects of pollutants on animals will focus on the different forms of pollution and related research. Learners will identify historic examples of pollution, such as the effect of the use of DDT and oilrig disasters. Learners should show the different forms of pollution, giving links to their effects on associated wildlife, for example, plastic and its effects on marine life and the effects of changes to ocean chemistry on coral reefs. A case study can be presented, giving examples of cause and effect. Learners can focus on how some animal species have adapted to changes in pollution levels or on changes in food chains and food webs, illustrating at different trophic levels. Learners should include information from research highlighting the effects of acid rain and its causes, linking it to human health problems related to increased sulphur dioxide and nitrogen oxide.

Learning aim C

For Distinction standard, learners will produce a comprehensive report that demonstrates their knowledge and understanding of waste-management principles and processes. The use of researched data will be used appropriately to illustrate fundamental problems in managing increasing quantities of waste. A case study on plastics will demonstrate learners' ability to gather useful information, determine the focus of a report and present key findings to a high standard. Learners' work on waste-water treatment will be well researched and key findings on current and future methods will be analysed to a high standard.

For Merit standard, learners will produce a report that details waste-management methods and waste-management processes and regulations. Learners will present their work in the form of a coherent report that focuses on waste management and its separate stages. Data will be used effectively in the report to demonstrate a link between waste, recycling and technological development. A case study on plastics will be comprehensive and clear, outlining the benefits and issues effectively. Waste-water treatment will be detailed and technological development in the industry will be well explained, showing an understanding of new technologies used.

For Pass standard, learners will produce a comprehensive report on the current methods of waste management, showing clear understanding of the separate processes and the need for a regulated industry. Learners will identify sources of waste materials and how they are transported to the appropriate management sites. Learners will demonstrate a clear outline of what makes an effective waste-treatment process and will provide data on the countries that generate the most amount of waste. A case study of the plastics issue will be fluent and include the types of plastics available and their benefits and drawbacks. Learners will give a coherent explanation of the process of waste-water treatment and its stages. The future of waste management will be categorised under appropriate sections, highlighting new proposals and new technologies in the industry to manage waste.

Learners will demonstrate a good understanding of the waste hierarchy and may link this back to their own practices. Learners will show understanding of the processes carried out at land-fill sites and show an awareness of the need to reduce the use of pesticides and fertilisers in agriculture. Learners will complete their work by showing that they recognise the need to embrace new technologies and ideas in order to reduce human dependence on materials that cannot be fully recycled.

Links to other units

This unit links to:

- Unit 8: Contemporary Issues in Science
- Unit 10: Climate Change.

Employer involvement

This unit would benefit from employer involvement in the form of guest speakers. A visit to a recycling/waste-management plant would give learners an idea of the range of employment opportunities in the field and of the current state of development of the industry in coping with increasing waste, land-fill sites and plastics.

Opportunities to develop transferable skills

- Research into the development of recycling methods and outcomes.
- Understanding of complex ecosystem changes.

Unit 25: Water Quality

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit aims to develop an understanding of water quality, and the relevant skills and knowledge that can be applied in practice.

Unit introduction

Almost every living thing on our planet needs water to survive and, to humans, water is vital. Issues with water quality can cause serious problems for humans, for example, water pollution can cause devastation to fisheries and crop production. As a result, monitoring and controlling water quality is essential.

The properties of water are very unusual for a molecule of its size. For example, molecules of about the same molecular weight would exist as gases under normal atmospheric conditions. In this unit, you will understand the structure and bonding of water, and explore the reasons for anomalous behaviour. You will study the distribution of water around our planet by the hydrological cycle, better known as the water cycle. You will also consider the effects of different factors on different processes within the cycle. You will explore the concept of water footprint as a means to evaluate how efficiently water is used in products and industrial processes.

Water that we use and see in our everyday lives is not pure. As water comes into contact with the air and the earth, substances and microorganisms are dissolved or carried by its flow. You will study what is in our rivers, seas and drinking water, and how it has come to be there, either by natural processes or as a consequence of human activity. You will consider the advantages and disadvantages of the biotic and abiotic characteristics of water for aquatic life and for humans.

You will practise the water quality analysis skills used in the field and in industry, including performing a variety of biological, chemical and physical tests, recording results, interpreting data and suggesting improvements to an area of water. The practical element of the unit will help you to appreciate the impact of biological, chemical and physical factors on the aquatic habitat.

You will explore the measures that can be taken to treat water for different purposes and to reduce the impact of human activity on water quality. The knowledge and understanding you will learn from this unit will provide a strong basis for you to progress in the science sector and to a valuable world resource, in which water can be conserved and controlled so that we make the most efficient use of it.

Learning aims

In this unit, you will:

A Understand the properties and uses of water

B Understand how biological, chemical and physical factors influence water quality and aquatic species

C Investigate basic water quality of an aquatic habitat

D Understand the principles of water treatment and conservation.

Learning aim	Key content areas	Assessment approach
A Understand the properties and uses of water	**A1** Structure, properties and use of water **A2** The hydrological cycle **A3** The water footprint	A report that reviews a wide range of uses and applications of water, with explanation of its unique properties. The report should include an explanation of the hydrological cycle for the global distribution and recycling of water, with an assessment of the different factors that affect the balance of the processes involved. The report should also cover the use and evaluation of the water footprint concept for a range of products and users.
B Understand how biological, chemical and physical factors influence water quality and aquatic species	**B1** Factors affecting water quality **B2** Water content **B3** Pollutants **B4** Acidification **B5** Eutrophication	A report on the presence and impact of substances and microorganisms in water sources, with a comparison of typical water content from different sources. The report should include a discussion of how water quality of a river changes as it travels from source to mouth, and the impact of significant processes of acidification and eutrophication. The report should also evaluate the impact of a range of factors on two different species of aquatic life.

Learning aim	Key content areas	Assessment approach
C Investigate basic water quality of an aquatic habitat	**C1** Measuring and reporting on water quality	A report explaining biological, chemical and physical tests, and indicators of water quality. Learners' diaries, risk assessments, photographs and results of practical work carried out for the investigation of water quality for an aquatic habitat over a specified period of time. A report on the investigation, following a scientific format, giving conclusions and suggestions for improvements to the water quality of the aquatic habitat. An evaluation of the methods and techniques used, considering alternative approaches and other similar studies
D Understand the principles of water treatment and conservation	**D1** Water treatment **D2** Sewage treatment **D3** Water conservation and consumption control	A report explaining different methods of treatment, conservation, consumption and management of water resources, and their evaluation for different purposes.

Content

Learning aim A: Understand the properties and uses of water

A1 Structure, properties and use of water

- Bonding – covalent, polarity, hydrogen bonding.
- Properties – boiling point, melting point, density, surface tension, solvent, high specific heat capacity, amphoteric behaviour, reactivity with metals, inorganic and organic substances.
- Ice – structure, density, hardness.
- Use – as a solvent, transport for nutrients and waste, medium for chemical reactions, reactant in photosynthesis, pH regulation, electrolyte balance, temperature regulator, cohesion tension in transpiration, production of hydrogen (fuel).

A2 The hydrological cycle

- Processes in the cycle – evaporation, condensation, precipitation, infiltration, storage (snow, underground, oceans), snowmelt and runoff, plant uptake, evapotranspiration, equilibrium of the processes.
- Hydrological cycle in different climates – tropical, dry, moderate, continental, polar
- Impact of human activities and climate change on the hydrological cycle – agriculture, burning fossil fuels, deforestation, removal of groundwater and river water, construction of dams, urbanisation.

A3 The water footprint

- Definition – measurement of amount of water used to produce a product (e.g. food type, clothing, fuel, etc.).
- Uses – determining dependence and security of water supplies, reducing and managing water use.
- Components of water footprint:
  - green water footprint – water used from precipitation stored in soil, and evaporated, transpired or incorporated by plants
  - blue water footprint – water used from surface or groundwater resources and evaporated or incorporated into a product/transferred from a body of water to another or returned later
  - grey water footprint – fresh water used to assimilate pollutants to meet specific water quality standards (point-source pollution discharged to a freshwater resource from pipes, runoff or leaching from soil).
- Water footprint of products, companies, individuals and nations.
- Factors affecting water footprint – access and availability of water, geology, topography, climate, population and demographic.

Learning aim B: Understand how biological, chemical and physical factors influence water quality and aquatic species

B1 Factors affecting water quality

- Geographical features and location.
- Surface topographical features – height, north or south facing.
- Soil/geology.
- Climate.
- Seasonality (humidity, light, temperature, rainfall).
- Plant/animal life.
- Human activity – agriculture, animal rearing and fishing, deforestation, mining and construction, industry and manufacturing, sewage, waste and landfills, recreation, conservation.

B2 Water content

- Naturally occurring dissolved substances:
  - cations – potassium, sodium, calcium, magnesium, iron
  - anions – chloride, sulfate, hydrogencarbonate
  - silica
  - gases – oxygen, carbon dioxide
  - differing proportions in sea water and fresh water.
- Concept of total dissolved solids (TDS).
- Measurement of ppm or mg/l.
- Level of TDS in drinking water and ratings – excellent (<300 ppm), good (300–600 ppm), fair (600–900 ppm), poor (900–1200 ppm), unacceptable (>1000 ppm).
- Salt content and salinity:
  - marine water – high salinity
  - fresh water – low salinity.

B3 Pollutants

- Problems for water quality when materials are in excess.
- Point and non-point (diffuse) sources of pollutants, e.g. pipes leading to water from buildings and run off from fields or roads.
- Biological pollutants – mainly indication of human activity and contamination, disease causing:
  - pathogenic bacteria, coliforms, faecal streptococci, clostridium perfringens (e.g. cholera, anthrax, salmonella, typhoid fever – transmitted by sewage contamination)
  - viruses (e.g. poliomyelitis, hepatitis A – transmitted through faecal contamination)
  - protozoa (e.g. dysentery, cryptosporidiosis – from sludge fertiliser and livestock)
  - helminths/parasitic worms (e.g. tapeworms, nematode worms – from sewage and fertiliser sludge)
  - sewage fungus and algae blooms.

- Organic chemical material:
  - biodegradable and non-biodegradable – load and distance of travel, increase in decomposers, oxygen depletion, changes in species in the ecosystem
  - pesticides (e.g. DDT) – retention time and bioaccumulation, potential as carcinogens, immune system and endocrine disruptors
  - insecticides – organophosphates, inhibiting enzymes in the nervous systems of animals
  - synthetic oils, hydraulic fluids, plasticiser additives and lubricants (e.g. polychlorinated biphenyls (PCBs)) – persistent organic pollutant, increased risk of cancer, immune deficiency, problems with the reproductive and nervous systems
  - plastics and microplastics – non-biodegradable nature, ingestion by animals, bioaccumulation.
- Inorganic chemical material:
  - nitrates and phosphates – sources (e.g. fertilisers, detergents), increase in producers, oxygen depletion, eutrophication, blue baby syndrome, stomach cancer in certain individuals
  - iron (II) ions – oxidation/oxygen depletion, formation of iron(III) hydroxide suspension, reduction of light penetration
  - heavy metal ions (e.g. arsenic, cadmium, copper, lead, mercury) – concentration, lethal doses and toxicity, retention time and bioaccumulation in the food chain, diffusion and ingestion as methods of intake, effect on enzymes
  - acids – harmful to aquatic life with increasing acidity, dissolves heavy metals
  - cyanide and sulphide – interference with oxygen in respiratory reactions in cells
  - fluoride ions – mottling of teeth and bones in humans.
- Physical effects:
  - suspended solids – reduction of light penetration, impact on photosynthesis and visibility, respiratory distress, impact on spawning
  - immiscible liquids (e.g. oil) – coverage of water surface, plant and animal life, reduction of oxygen/carbon dioxide transfer, impact on life cycle of surface dwelling insects
  - increase in temperature of water – increase in metabolic rate of organisms or death, decrease in dissolved oxygen, restricted migration, imbalance of ecosystem
  - change in flow rate – displacement of plant or animal life (faster flow rate), large quantity of sediment or reduction in dissolved oxygen (slower flow rate)
  - changes in colour, odour and taste.

B4 Acidification

- Carbon cycle.
- Carbon dioxide – sources and absorption into water.
- Carbonic acid, hydrogen carbonate and carbonate formation, pH decrease.
- Impacts – coral reef, reef fish, food webs, fisheries, indigenous people.

B5 Eutrophication

- Nitrogen cycle.
- Nitrates and phosphates – sources and absorption into water.
- Phytoplankton and algae growth, reduction in photosynthesis.
- Blue-green algae (cyanobacteria) and unicellular green algae – differences, CO2/hydrogen carbonate fixation, nitrogen/nitrate fixation, phosphorus requirements, pH tolerance.
- Oxygen depletion, death of ecosystem, decomposition and toxicity.
- Reduction in photosynthesis, imbalance in carbon dioxide, change in hardness and pH or water.

Learning aim C: Investigate basic water quality of an aquatic habitat

C1 Measuring and reporting on water quality

- Sampling methods – judgemental, random, stratified, grid, cluster and grab sampling.
- Biological testing:
  - methods – use of test kits, probes, kick sampling, nets, indicator species
  - populations of invertebrates, vertebrates, macrophytes, algae
  - luminescence measurements
  - microbiological testing.
- Chemical methods and tests:
  - dissolved oxygen – fixing amount of oxygen in the sample, chemical oxygen demand (COD), test using potassium dichromate, dissolved oxygen probes
  - pH – pH probes
  - ammonium – test with Nessler's reagent, test with hypochlorite and phenol
  - nitrate – reduction with cadmium/zinc with acid to nitrite, formation of an azo dye
  - sulphate – formation of barium sulphate precipitate with barium ions, thorin test
  - hardness (carbonates/hydrogencarbonates), salinity and chlorine content.
- Physical methods and tests:
  - water quantity
  - flow – flowmeters
  - temperature – thermometers, temperature probes
  - turbidity – nephelometer (light meter), Secchi disk
  - total dissolved solids (TDS) – electrochemical probe (contacting sensors, electrodeless sensors)
  - geographical and surface topographical features – satellite imaging.
- Laboratory methods and equipment:
  - titration
  - colorimetry and spectrophotometry
  - gas chromatography, ion chromatography and mass spectrometry.

- Health and safety practices in water sampling:
  - environment (body of water, surroundings, weather conditions)
  - chemicals and equipment to be used
  - nature of the activity
  - personal protective equipment (PPE) – non-slip footwear, buoyancy aids, rescue lines
  - potential of harm to the environment.
- Scientific reporting format – title, abstract, introduction, method, results, accuracy, discussion, conclusions, evaluation, references and bibliography.

Learning aim D: Understand the principles of water treatment and conservation

D1 Water treatment

- Differences in quality of groundwater and surface water.
- Quality standards for water regarding bacteria, chemicals, appearance and taste.
- Local legislation and global standards for water quality.
- Different considerations for drinking water (potable), industrial processes (e.g. cooling), high pressure boilers, irrigation.
- Main processes:
  - screening/straining – removal of large debris using large metal screens
  - storage and settling – sediments settle
  - oxidising – aeration, organic and inorganic impurities are oxidised
  - flocculation – use of aluminium sulphate to cause colloids to clump together
  - filtration – sand and gravel filter the water, bacteria on surface decompose, dissolved nitrates and phosphates
  - pH correction – addition of lime to reduce acidity
  - disinfection – chlorination to kill pathogens, use ozone, use of UV light.
- Supplementary processes:
  - ion exchange – removal of nitrates
  - activated carbon – removal of organic substances
  - softening – removal of hardness, ion exchange or precipitation.
- Other methods:
  - reverse osmosis – sea water forced through permeable membrane at high pressure, consideration of cost of membranes
  - distillation – evaporation and condensation of water from sea water, consideration of energy requirements
  - fluoridation – addition of fluoride to prevent tooth decay, fluorosis.

D2 Sewage treatment

- Aim – control of disease, decompose organic material into harmless substances.
- Problems with discharge of sewage directly into sea or rivers.
- Main processes:
  - preliminary treatment – mechanical removal of large debris/screening
  - primary treatment – settling/sedimentation of suspended solids
  - secondary treatment – biological oxidation, decomposition of organic matter, filtering, activated sludge then sedimentation
  - tertiary treatment – removal of nitrate, phosphate and toxic compounds by nutrient stripping, UV light or filter membranes, use of lagoons
  - disposal of remaining sludge – farmland (used as fertiliser or soil conditioner), landfill, incineration.

D3 Water conservation and consumption control

- Examples:
  - rainwater harvesting
  - protection of groundwater
  - reuse of used water for gardens
  - taps off when not in use and not leaking
  - use of low flow taps and faucet aerators in basins
  - insulation of water pipes
  - less water use in short showers than in baths
  - use of short flush settings on toilets
  - different irrigation methods (e.g. drip irrigation, overhead irrigation) and weather-based control systems
  - waterless cleaning systems
  - water meters to monitor usage
  - minimising evaporation and runoff of water (e.g. evaporation pans)
  - education and outreach programmes
  - legislation and regulations.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the properties and uses of water		**A.D1** Evaluate the concept and use of the water footprint for a range of products, individuals and countries.
A.P1 Describe the importance and uses of water. **A.P2** Explain the steps in the hydrological cycle.	**A.M1** Explain the physical and chemical properties of water. **A.M2** Assess the impact of different climates and human activity on the hydrological cycle.	
Learning aim B: Understand how biological, chemical and physical factors influence water quality and aquatic species		**B.D2** Evaluate how biological, chemical and physical factors affect the life cycle of two named species of aquatic animal or plant life.
B.P3 Explain the presence and impact of substances and microorganisms in water sources. **B.P4** Compare differences in the content of marine and fresh water with drinking water.	**B.M3** Discuss changes in water quality of a selected river as it travels from source to mouth. **B.M4** Discuss acidification and eutrophication in aquatic habitats.	
Learning aim C: Investigate basic water quality of an aquatic habitat		**C.D3** Evaluate sampling techniques and tests used in determining water quality.
C.P5 Explain biological, chemical and physical indicators and tests for water quality. **C.P6** Investigate the basic water quality of an aquatic habitat over a period of time. **C.P7** Produce a report on the water quality of a given aquatic habitat.	**C.M5** Analyse and present conclusions, with recommendations, for the investigation of an aquatic habitat.	
Learning aim D: Understand the principles of water treatment and conservation		**D.D4** Evaluate the use of water treatment and conservation methods to meet different purposes.
D.P8 Explain different methods of water and sewage treatment.	**D.M6** Discuss methods to conserve and control consumption of water.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of four summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aim: B (B.P3, B.P4, B.M3, B.M4, B.D2)

Learning aim: C (C.P5, C.P6, C.P7, C.M5, C.D3)

Learning aim: D (D.P8, D.M6, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to an aquatic habitat so that they can experience the environments where water-quality testing is carried out on a regular basis. Habitats that support small invertebrates would be preferable.

The equipment required will include the normal safety gear used in laboratories and in the field, a range of dissolved oxygen meters, thermometers and chemical test kits, water sampling equipment, basic water-flow measurement equipment, record-keeping equipment and a calculator.

Tutors delivering this unit should be experienced in analysing water and evaluating the results in relation to the effects on aquatic life.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will evaluate the concept of water footprint for a range of products, individuals and countries. They will research the concept and objective of water footprint and discuss its advantages and limitations, comparing its usefulness against other similar measures such as carbon footprint. They will also compare the water footprint of a range of different products (for example crop- and animal products) in terms of the amount of water and the percentage of each component of water footprint (i.e. green, blue and grey) and draw conclusions on the effective use of water. They will also compare individuals and countries in terms of their water footprint, explaining differences and looking at this in the context of hydrology, climate, geology, topography, population and demographics.

For Merit standard, learners must explain the properties of water by first explaining the bonding and structure. They will produce diagrams to illustrate the bonding of water, show how the polarity of the bonds gives rise to hydrogen bonding and also how it gives rise to the unusual physical properties of water in comparison to other molecules of similar size and mass (for example methane). They will consider the chemistry of water, giving examples of substances with which it will react (i.e. metals, inorganic and organic compounds), considering its acid-base nature.

Learners will assess the impact of different climates and human activity on the hydrological cycle. They will review at least two different climates and associated conditions (for example sunlight, temperature, rainfall, airflow, seasonal changes, vegetation) and explain how the equilibrium of processes in the cycle is different in each case. They will assess the impact of human activities on processes in the cycle, including the effect of climate change.

For Pass standard, learners will describe the importance and use of water in a range of life processes and commercial applications.

Learners must explain the hydrological cycle. They will explain the scientific principles behind the processes of transportation of water and how it is stored in the atmosphere, in earth and in oceans. They will produce an annotated diagram of the hydrological cycle, which must be designed and produced by them – a sourced diagram is not acceptable evidence.

Learning aim B

For Distinction standard, learners need to evaluate how the life cycle of two named species of aquatic animal or plant from different aquatic environments can be affected by biological, chemical and physical factors. This will include factors that will promote or decrease the life cycle and population of the animal or plant. Learners will also evaluate the wider impact that presence or absence of the animal or plant will have on the ecosystem, and what measures would be required to restore the balance. Case studies such as the use of the pesticide DDT, mercury poisoning, or nitrogenous fertilisers would provide suitable starting points for learners' evaluations.

For Merit standard, learners will investigate a case study of a selected river as it travels from its source to its mouth. They will discuss the changes in the quality of the water as the river travels through different physical environments, and combines with other rivers or sources of water. They will consider natural processes and human activities that would influence the content of the water and the effect on the aquatic life present.

Learners will also discuss the processes of acidification and eutrophication. They will give a detailed explanation of how these processes occur naturally, including reference to the relevance of the carbon and nitrogen cycles, how human activity increases the rate of both processes and how each process can impact the other. Effects on aquatic habitats will also be explained and how the processes could be managed to restore the original environment.

For Pass standard, learners will explain the presence and impact of substances and microorganisms in water sources. They will look at a comprehensive range and identify whether their introduction is due to natural factors, human activity, or both. They will explain how the substances and microorganisms are introduced to the water by the factor. They will consider the effects of the substance or microorganism on the water, aquatic life and humans.

Learners will research secondary information and compare the differences in dissolved substances and microorganisms found in marine water (oceans and seas), fresh water (rivers) and water that has been treated for human purposes (i.e. drinking and washing). They could look at a range of bottled water products and check the information labels listing the contents of the water. They will identify a variety of substances that are dissolved in the different types of water and what makes them suitable to sustain the life processes that are present within it.

Learning aim C

For Distinction standard, learners need to evaluate the sampling techniques and tests used in water sampling, making judgements on accuracy, reliability and validity. They will include a discussion of the strengths and weaknesses of the sampling techniques and equipment used, improvements to the method, or use of alternative approaches (for example differences in on-site testing and off-site laboratory testing). Learners will need to compare data they have collected with that from another source. This could either be comparison with another learner's investigation data if it is in a similar but different location of the body of water (for example upstream or downstream of a river, ground water or surface water from the same location) or they could research secondary data from a similar study. They will explain similarities and differences in findings, accounting for the presence or absence of substances and microorganisms in their own investigation. They will also discuss the limitations of their investigation (for example environmental conditions that may be outside of their control).

For Merit standard, learners will analyse and present conclusions from their investigation of an aquatic habitat as part of their report. Evidence can be in the form of tables, graphs, charts, or other suitable formats that will allow trends and patterns to be observed from the specified period of time. They will discuss what the findings reveal about the presence and quantities of substances and what can be inferred about the water quality of the aquatic habitat. They will discuss how this will affect the ecosystem present and make recommendations to improve the quality of the water.

For Pass standard, learners will need to explain biological, chemical and physical indicators for water quality and related tests. They will outline the test or method and give the expected positive and negative outcomes. They will explain the science that underlies the test and the result.

Learners will carry out a range of water quality tests on an aquatic habitat, which should draw on methods and tests that are biological, chemical and physical in nature. This will be carried out over a specified period of time so that trends can be observed. Learners will produce photographic evidence, results tables and data, and a diary. They will carry out a risk assessment of the sampling of an aquatic habitat before carrying out the investigation. They will identify hazards and risks for the sampling activity, chemicals and equipment that they will use, and potential impacts for the environment.

Learners must produce a report on water quality for their investigation of the aquatic habitat. They will be expected to present the report using an appropriate format for scientific reporting. They will use all of the information and data they have collected throughout the project. The report will be written using accepted scientific terminology and protocol, such as impersonal, third party and past tense.

Learning aim D

For Distinction standard, learners will evaluate the use of different water treatment and conservation methods for different purposes. They will consider the scale and location of each purpose (for example a coastal community where the main source of potable water is from the sea) in order to evaluate the methods. They will consider advantages and disadvantages such as cost-effectiveness, abundance of resources and energy requirements.

For Merit standard, learners must discuss methods of water conservation and control of water consumption. They must research a range of methods that are relevant on an individual level and on a large commercial scale and discuss how significant each would be in conservation or controlling consumption of water.

For Pass standard, learners must explain different methods of water and sewage treatment. They will explain each stage of a process using scientific principles and will supplement the explanation with their own diagrams.

Links to other units

This unit links to:

- Unit 4: Investigative Project Skills
- Unit 10: Climate Change
- Unit 16: Applications of Inorganic Chemistry
- Unit 15: Diseases and Infection
- Unit 19: Microbiology and Microbiological Techniques.
- Unit 24: Pollution and Waste Management
- Unit 27: Ecosystems.

Employer involvement

Learners would benefit from having access to a working environment. This can be achieved by creating links with local businesses or charitable organisations which can benefit from taking on learners. Local authorities can be a useful source of information, as can business education alliances. Charitable organisations can often provide guest speakers to give lectures and demonstrations.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills, including:

- analytical and observation skills
- formal written communication
- self-management and planning skills
- the ability to work in a scientific environment
- the ability to carry out independent research.

Unit 26: Animal Conservation

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers some of the complexities of managing wildlife and animal conservation and the reasons for the increase in human-wildlife conflicts.

Unit introduction

We are familiar with the plight of pandas, tigers, rhinos and orangutans but, worryingly, most taxa contain species that have been identified as endangered or threatened with extinction, including birds, reptiles, fish, amphibians and invertebrates. Animal populations and numbers of animals within these populations are declining more rapidly than ever before. Some are declining because of natural disturbances but the majority are as a direct or indirect result of human activities. Animal conservation is the stewardship of wildlife and its management; it is important because all species have an integral role to play in their ecosystem, and damage to the population of one species can be detrimental to others, for example, fauna and flora.

Wildlife provides food and income to millions of people around the world. It can also be a source of inspiration and can nurture a sense of wonder. Animals are pivotal to the delicate and complex balances of cycles in ecosystems around the world.

Legislation, regulations and international agreements that focus on animal health, welfare and movement aim to protect wild populations from over-exploitation. Animals can also negatively impact human communities and some national animal management strategies deal with this more effectively than others. Conflicts of interests are many and various because so many parties want to benefit from wildlife, not all for the benefit of the wildlife itself. The engagement of local communities, whatever their motivations, is vital in successful animal conservation.

Translocation of animals is an essential, but highly risky tool in animal conservation. There should be measurable benefits, not only to the individual relocated animals, but wider benefits to the ecosystem, populations or species.

Learning aims

In this unit, you will:

A Understand the necessity for animal conservation and its regulation

B Understand the social, economic and ethical issues associated with animal conservation

C Be able to plan for translocation of an animal.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the necessity for animal conservation and its regulation	**A1** Essential requirements of animals and how they affect distribution and behaviour **A2** Reasons why animal populations are threatened **A3** The role of legislation and international agreements in animal conservation **A4** The motivations of local people to engage with animal conservation initiatives	A portfolio of evidence, such as analysis of case studies, maps, diagrams, basic biology of named focal species and causes for their situation, interpretation of regulations and role of regulatory organisations and the engagement of local people.
B Understand the social, economic and ethical issues associated with animal conservation	**B1** Wildlife management strategies around the globe **B2** Human-wildlife conflicts **B3** Views of different interest groups	
C Be able to plan for translocation of an animal	**C1** Initial assessment and suitability of animal(s) and proposed location **C2** Feasibility, design and risk assessment **C3** Release and implementation **C4** Importance of health monitoring, adjustment and evaluation	A plan for the translocation of a named species, from a named location to a named release location, considering the source animal, source and release locations, regulations, socio-economic aspects, public engagement, funding, risk assessment, ongoing monitoring and management.

Content

Learning aim A: Understand the necessity for animal conservation and its regulation

A1 Essential requirements of animals and how they affect distribution and behaviour

- Biotic and abiotic requirements:
  - food and water, territory, shelter, mate, climate-related requirements (e.g. temperature, humidity).
- Distribution: size of territory, richness of territory – importance of criteria for identifying location for translocation and release of animal(s).
- Behaviour: solitary, groups (e.g. packs) – nutritional strategies, mate preferences; importance of criteria for selection of animal(s) for translocation and release.

A2 Reasons why animal populations are threatened

- Habitat destruction.
- Lack of genetic diversity, lack of time to adapt.
- Hunting, over-fishing and direct exploitation.
- Pollution.
- Invasive species.
- Pet trade and traditional medicines.
- Diseases from reintroduced species.
- Growth in human population:
  - globalisation
  - emphasis on free trade
  - increase in trade and tourism.
- Indirect impacts.

A3 The role of legislation and international agreements in animal conservation

- General principles of local law or regulations:
  - animal health
  - animal welfare
  - international movement of endangered species.
- Levels of legislation: international, national, regional, local.
- Level of law enforcement.
- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES):
  - listed species, Appendices I, II and III.
- International Union for Conservation of Nature:
  - Red list of threatened species.
- Convention on the Conservation of Migratory Species of Wild Animals.
- Convention on Biological Diversity.
- World Trade Organization Agreement on Sanitary and Phytosanitary Measures.
- World Organisation for Animal Health (OIE) – animal health surveillance.
- International Air Transport Association (IATA) – transportation of animals regulations.

- Food and Agriculture Organization (FAO).
- United Nations Environment Programme (UNEP).
- World Wide Fund for Nature (WWF®) – TRAFFIC.

A4 The motivations of local people to engage with animal conservation initiatives

- Engaging local communities in tackling illegal wildlife trade.
- Banning ivory trade.
- Protecting landscapes (e.g. rain forests, sea ice).
- Dwindling subsistence resources (e.g. wild-meat consumption).
- Enhanced profitability (e.g. commercial harvesting).
- Alternative and/or complementary activities to generate revenue and/or employment (e.g. recreation).
- Good will.
- Local people being involved with animal conservation is more likely to be successful and the local people benefit:
  - more democratic forum; promotion of common good
  - stronger negotiating position
  - rediscover cultural management methods.

Learning aim B: Understand the social, economic and ethical issues associated with animal conservation

B1 Wildlife management strategies around the globe

- It is important for local people to be involved with animal conservation as it is more likely to be successful and will benefit the community:
  - more democratic forum; promotion of common good
  - stronger negotiating position
  - rediscover cultural management methods.
- North America; Europe; Southern Africa; Central Africa; Asia; South America:
  - ownership of wildlife: government, communities, private, not owned, other
  - hunting: seasonal, quotas, licensing, examinations
  - regulations and enforcement
  - funding and beneficiaries: benefits for local people, subsistence rights of local people recognized
  - incentives to manage sustainably
  - levels of commercial over-exploitation and illegal activity.

B2 Human wildlife conflicts

- Human wildlife interfaces, where human activities negatively affect animal populations and animals may negatively impact humans:
  - crop barriers to repel animals
  - use of electric fences
  - infrared heat sensors to warn farmers of approaching animals
  - prevention of animals being killed in retaliation for loss of lives and/or crops.
- Increasing where human population growth is high.

- Impacts on humans:
  - crop production pests (e.g. rodents)
  - direct threats to livestock and humans (e.g. apex predators, for example, wolves, lions)
  - spread of zoonoses (e.g. foot and mouth disease).
- Culling programmes: relocation of wildlife or, more rarely, humans.
- Site-specific and species-specific.

B3 Views of different interest groups

- Governments, municipalities, government agencies, academic institutions, NGOs, charities, donors.
- Farmers, landowners.
- Subsistence hunters, local and indigenous people.
- Recreational users, tourism companies and tourists, trophy hunters, photographers.
- Commercial, exporters, intermediaries.
- Those affected by wildlife management implementation (e.g. access to wildlife becomes prohibited).

Learning aim C: Be able to plan for translocation of an animal

C1 Initial assessment and suitability of animal(s) and proposed location

- Reasons for, and aims of animal movements; measurable benefits:
  - within indigenous range: reintroductions after extirpation (back to historical range), re-enforcements (adding to existing population)
  - outside of indigenous range, high risk: assisted colonization; ecological replacement.

C2 Feasibility, design and risk assessment

- Deciding whether translocation is an acceptable option.
- Habitat: suitability and availability of the requirements for focal species, including climate requirements.
- Conservation benefits versus costs and risks:
  - translocation, alternative conservation actions
  - focal species, associated communities, ecosystem functions
  - source and destination locations
  - risk to animals and risk to humans
  - ecological, social and economic aspects.
- Clearly defined goals: desired number and size of populations.
- Objectives detailing how the goals will be achieved.
- How monitoring and assessment will be carried out, exit strategy.
- Founder animals, populations – source and availability.
- Animal welfare:
  - origin and release countries, locations; comply with legislation, regulations and policies; internationally accepted standards for welfare
  - every effort should be made to minimise stress or suffering.

- Disease and parasite considerations:
  - maximise the success of translocated animals; minimise the risk of introducing a new pathogen to the destination area.
- Social feasibility:
  - engagement with national and regional conservation infrastructure
  - human communities have varied attitudes: socio-economic circumstances, community attitudes and values, motivations and expectations, behaviours and behavioural change, anticipated costs and benefits.
- Regulatory compliance:
  - international movement of animal
  - movement outside indigenous range
  - permissions to release
  - cross-border movements
  - veterinary and phytosanitary requirements
- Interdisciplinary team, including a veterinarian, social skills expertise, funding and financial management, biological and technical expertise.
- Risk assessment:
  - risk to source population
  - ecological risk
  - disease risk
  - associated invasion risk
  - gene escape
  - socio-economic risk
  - financial risk.

C3 Release and implementation

- Selecting release sites and areas:
  - legal requirements
  - public engagement
  - habitat management
  - interventions.
- Release strategy:
  - life stage, season
  - post-release dispersal/non-dispersal
  - multiple releases
  - minimising stress.

C4 Importance of health monitoring, adjustment and evaluation

- Cycle: implementation, monitoring, analysis, adjustment (biological and non-biological) until goals are met or declared unsuccessful.
- On release:
  - as disorientation
  - competitive disadvantages
  - stress
  - exposure to predation
  - exposure to diseases
  - lack of experience of finding food/hunting/knowing what is safe/good to eat.

- Demographic performance (population growth and spread).
- Behaviour monitoring.
- Ecological impact monitoring.
- Genetic monitoring.
- Health and mortality monitoring.
- Social, cultural and economic monitoring.
- Long-term management, funding and dissemination of information.

Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Understand the necessity for animal conservation and its regulation</td><td rowspan="4">AB.D1 Evaluate the role of local people in a named animal conservation project.</td></tr>
<tr><td>A.P1 Explain how natural disasters and human activities can cause a species to become threatened, endangered or extirpated.
A.P2 Explain how legalisation, regulations and international agreements attempt to protect animals from over exploitation and harm.</td><td>A.M1 Analyse the reasons why a named species has become threatened or endangered and legalisation, regulations and international agreements in place to protect it.</td></tr>
<tr><td colspan="2">Learning aim B: Understand the social, economic and ethical issues associated with animal conservation</td></tr>
<tr><td>B.P3 Explain the impact of human-wildlife conflicts on human communities.</td><td>B.M2 Analyse how the human-wildlife interface management strategies of a named country impacts on animal conservation.</td></tr>
<tr><td colspan="2">Learning aim C: Be able to plan for translocation of an animal</td><td rowspan="2">C.D2 Evaluate the necessity for long-term management and funding for wildlife relocations.</td></tr>
<tr><td>C.P4 Create a relocation plan for a named species into a specific location.</td><td>C.M3 Analyse the risks associated with relocation of wildlife.</td></tr>
</table>

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, A.M1, B.M2, AB.D1)

Learning aims: C (C.P4, C.M3, C.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to animals, this may include collections which may include animals in zoos, rehabilitation and rescue centres, wildlife parks and appropriate private collections. Risk assessments must be carried out for any visits and for any handling of, or other interaction with, animals. There must be an emphasis on the need for animal welfare during observation of animals or other activities involving animals.

Specialist speakers, for example, from the types of establishment mentioned above, from wildlife law enforcement agencies, quarantine officers and animal transportation organisations, should be invited to visit and to speak to learners about their work.

Learners should have access to scientific and ethical television programmes that focus on wildlife and conservation.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners must evaluate the factors that impact on local people engaging with wildlife management and conservation. This will be in relation to the chosen species and country used throughout the unit. National, regional, ethical, financial, legal and traditional considerations will be identified and their impact evaluated. The complexity of successful conservation should be discussed in relation to different approaches to conservation globally. An analysis, to ascertain how effective different strategies have been, should be linked to the conservation project being evaluated. This could include, aspects such as, strengths and weaknesses, advantages or disadvantages, alternative actions, the relevance or significance of evidence. Learners should conclude their evaluation with a considered judgement backed up by valid evidence/examples.

For Merit standard, learners must analyse why a chosen **named species** has become threatened or endangered. Factors for consideration are, habitat destruction, exploitation, pollution, invasive species/disease. The analysis needs to consider the role and effectiveness of legislation, regulations and international agreements in place to protect and conserve the named species.

The impact on conservation of the **named animal** and the human-wildlife interface in a conservation project in a **named country** must be analysed. The possible and perceived effects/consequences on the community of the animal species must be considered, along with the effects/consequences of the human community on the animal species. Conflict management strategies used to mitigate any issues must be analysed.

For Pass standard, learners must identify explain how human activities and natural disasters impact on animal survival. How these activities may result in a species becoming threatened, endangered or extirpated must be explained.

Using examples, learners must explain how legislation, regulations and international agreements attempt to protect animals from exploitation and harm.

Learners must explain how and why human-wildlife interfaces can negatively impact on animals and humans. Local community concern about potential effects of factors like, crop production, direct threats to humans, direct threats to wildlife, spread of disease, site and species-specific issues will be considered and explained.

Learning aim C

For Distinction standard, learners will evaluate the reasons why relocation of a species must be planned as a long-term investment which needs careful and thorough financial planning and management. Learners will consider factors such as: government permits, veterinary costs, disease screening, temporary holding and captive feeding, staffing, transport costs and GPS tracking for remote monitoring following release

For Merit standard, learners must analyse different aspects of animal relocation. The evidence produced will include: planning, physical transfer, release of the animals and long-term monitoring of animal welfare following their release. Learners will also include the benefits and risks involved in moving wildlife to a new location.

For Pass standard, learners will produce a relocation plan which outlines how the movement of a named animal species to a new location is planned, implemented and monitored. The relocation plan will demonstrate awareness of the importance of maintaining animal welfare during and after the relocation process. The evidence produced will include consideration of the potential risks involved in moving the animals both in the short and long-term and how these risks might be managed.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 5: Principles and Applications of Biology II
- Unit 8: Contemporary Issues in Science
- Unit 10: Climate Change
- Unit 14: Genetics and Genetic Engineering
- Unit 15: Diseases and Infections
- Unit 24: Pollution and Waste Management
- Unit 27: Ecosystems.

Employer involvement

This unit would benefit from employer involvement in the form of:

- employers visiting and speaking to learners
- learners visiting companies and organisations that work with animals
- work placements.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferable employability skills, including:

- analytical and observation skills
- formal written communication skills
- self-management and planning skills
- the ability to work in a scientific environment
- the ability to carry out independent research.

Unit 27: Ecosystems

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This units covers methods used to investigate the complex interdependencies of biotic (living) and abiotic (non-living) components that make up ecosystems.

Unit introduction

An ecosystem is a specific geographic area of plants, animals and microorganisms that interact with, and which are dependent on, minerals, water, soil and climate.

The climate and composition of the ecosystem dictates which plants are able to survive, and which in turn support animal life. The Earth is a series of connected ecosystems. In this unit you will learn how to measure populations in ecosystems and to understand the interrelations and interdependencies in ecosystems, as well as how energy flows and nutrients cycle through the system.

Ecosystems can be large, such as the Pacific Ocean, or a tiny, isolated rock pool (tide pool) on the shore. You will learn about the delicate balance of ecosystems and how even small disturbances can cause major harm and long-term damage, as well as how human activities can cause change and damage.

The understanding and knowledge of factors that can relate to plants, animals and microorganisms is an essential requirement for those wishing to pursue a science related occupation. This unit will help provide access to higher education to allow you to pursue on to science related careers.

Learning aims

In this unit, you will:

A Understand the characteristics and interactions of ecosystems

B Understand energy flow and biogeochemical cycling in ecosystems

C Be able to measure populations and species diversity in ecosystems

D Understand the effects of disruption to ecosystems.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Understand the characteristics and interactions of ecosystems	**A1** Terms and concepts used to describe ecosystems **A2** Characteristics of ecosystems **A3** Biotic relationships within ecosystems	A portfolio of evidence, referencing specific, named ecosystems and their characteristics, it may include maps, survey data, diagrams and flow charts.
B Understand energy flow and biogeochemical cycling in ecosystems	**B1** Trophic structures of ecosystems **B2** Energy flow in ecosystems **B3** Chemicals are cycled between organisms and the Earth	
C Be able to measure populations and species diversity in ecosystems	**C1** Estimating plant populations **C2** Estimating animal populations **C3** Estimating species diversity	A report using primary data and other research methods to analyse a named species of plant and a named species of animal, including an evaluation of the impact of a major manmade disturbance on these populations.
D Understand the effects of disruption to ecosystems	**D1** Natural disturbances **D2** Human interactions with ecosystems **D3** Consequences of disturbances	

Content

Learning aim A: Understand the characteristics and interactions of ecosystems

A1 Terms and concepts used to describe ecosystems

- Biome, habitat, microhabitats, niche, population, community, biomass.
- Carrying capacity, biotic potential, environmental resistance, population growth (lag phase, exponential growth, stationary phase, death phase), law of tolerance.
- Producer, consumer, trophic levels, keystone species.
- Succession, zonation.
- Soil composition and soil profiles: mineral particles, pore space, air capacity, soil air, soil moisture, organic matter, pH, temperature, microflora, fauna, distribution of soil organisms, decomposition, food webs in soil.

A2 Characteristics of ecosystems

- Distribution of ecosystems:
    - abiotic factors affecting distribution: global (e.g. climate), regional (e.g. altitude), local (e.g. soil pH) and micro (e.g. shade)
    - biotic factors affecting distribution, plants, animals, humans, and their modifying influence.
- Types of ecosystems:
    - aquatic (freshwater, marine), desert, forest (temperate, tropical, taiga), grassland (savannah), tundra
    - terrestrial ecosystems classified by temperature, rainfall and flora.
- Influencing factors that characterise ecosystems:
    - altitude, latitude, prevailing winds, rainfall, proximity to sea, temperature, aspect, soil type, fauna and flora.

A3 Biotic relationships within ecosystems

- Interspecific interactions:
    - predation; competition; mutualism; herbivory; parasitism, commensalism, symbiosis
    - harmful or negative relationships result in evolutionary pressure to adapt
    - competitive exclusion principle, resource partitioning, fundamental niche, realised niche.
- Animal requirements: food/water, territory (shelter), reproduction, protection, migration can result in interspecific and/or intraspecific competition.

Learning aim B: Understand energy flow and biogeochemical cycling in ecosystems

B1 Trophic structures of ecosystems

- Autotrophic, heterotrophic, gross primary productivity, net primary productivity, secondary productivity, detritivores, decomposers.
- Food chains, food webs.

B2 Energy flow in ecosystems

- Energy conversion: transfer of energy into, through and out of ecosystem.
- Importance of respiration and photosynthesis.
- Pyramids of energy, biomass, numbers: construction, interpretation of data, comparisons.
- Energy budget calculations.
- Population dynamics:
  - fecundity
  - natality
  - mortality
  - immigration
  - emigration
  - basic breeding strategies (r and K)
  - concepts of carrying capacity, density dependent population control, Boom and bust cycling, life tables and survivorship
  - predator/prey relationships
  - age classes.

B3 Chemicals are cycled between organisms and the Earth

- Carbon cycle: requirement for carbon, photosynthesis, respiration, greenhouse gas effect.
- Nitrogen cycle: requirement for nitrogen, reservoirs, bacteria and nitrogen fixation.
- Water cycle: requirement for water, climate, weather, rainfall.
- Oxygen, phosphorus: requirement for oxygen and phosphorous, weathering of rocks, photosynthesis.

Learning aim C: Be able to measure populations and species diversity in ecosystems

C1 Estimating plant populations

- Planning a survey:
  - survey techniques
  - area to be surveyed
  - equipment
  - personal protective equipment (PPE) and health and safety considerations
  - random, systematic, stratified
  - accuracy and precision
  - data analysis, statistics
  - recording and reporting of data.
- Mapping and classification, Phase 1 survey methodology, habitat maps, target notes, statistics.
- Area estimation by the line-intercept method, transect sampling.
- Quadrat sampling.

C2 Estimating animal populations

- Planning: equipment, scheduling, methodology.
- Legislation, health and safety, licensing of live capture programmes.
- Complete counts, incomplete counts, indirect counts.
- Transects, quadrant, kicking methods, tracks and signs, tracking tunnels.
- Mark and recapture: Lincoln–Petersen index – number of animals in first capture (n) over the number in the population (N) is proportional to the number marked in the second capture (k) over the number recaptured (K) $N = \frac{Kn}{k}$
  - data manipulation, calculations, reporting
  - choice of mark, release (location, timing).

C3 Estimating species diversity

- Species diversity: species richness, relative abundance, evenness.
- Estimation of biomass.

Learning aim D: Understand the effects of disruption to ecosystems

D1 Natural disturbances

- Damage to biological communities:
  - droughts
  - fire
  - flood
  - overgrazing
  - storms.
- Frequency, severity.
- Ecological succession: colonisation.
- Primary succession, secondary succession.
- Invasive species.

D2 Human interactions with ecosystems

- Local, regional, global.
- Burning of fossil fuels.
- Deforestation and other habitat destruction.
- Hunting and intensive agriculture, over-fishing.
- Plastics and other pollution.
- Pet trade and traditional medicines.

D3 Consequences of disturbances

- Local, regional, global.
- Global warming/climate change.
- Bioaccumulation.
- Eutrophication.
- Pollution.
- Species become threatened, endangered, extirpated or extinct.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the characteristics and interactions of ecosystems		**AB.D1** Analyse how the dependencies and interactions of an ecosystem contribute to evolution. **AB.D2** Evaluate boom or bust population dynamics data for a named wildlife population, suggesting reasons for this pattern and impacts on the energy budget.
A.P1 Explain why and how characteristics of ecosystems vary with their distribution around the globe. **A.P2** Explain inter- and intra-specific interactions within ecosystems.	**A.M1** Analyse the relationships of named species within an ecosystem.	
Learning aim B: Understand energy flow and biogeochemical cycling in ecosystems		
B.P3 Explain how energy flows through an ecosystem. **B.P4** Explain the recycling of water and minerals in an ecosystem.	**B.M2** Explain the energy budget of a named ecosystem.	
Learning aim C: Be able to measure populations and species diversity in ecosystems		**CD.D3** Evaluate the impact of a specific human activity in a named ecosystem.
C.P5 Carry out a population survey of a named plant species. **C.P6** Carry out a population survey of a named animal species.	**C.M3** Evaluate the species diversity and relative abundance in a specific community, using survey data.	
Learning aim D: Understand the effects of disruption to ecosystems		
D.P7 Explain the fragility of ecosystems and their susceptibility and response to disturbance.	**D.M4** Analyse the effect of a specific natural disaster on a named species.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, B.P4, A.M1, B.M2, AB.D1, AB.D2)

Learning aims: C and D (C.P5, C.P6, D.P6, C.M3, D.M4, CD.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to habitats which contain plants and animals, which may include countryside, hedges, parks, farmland, appropriate private land, disused land. Risk assessments must be carried out for any visits and any interactions with animals and harmful plants. Emphasis must be placed on the necessity for animal welfare during any activities with animals.

Learners should have access to good quality, scientific and ethical television programmes which focus on nature and wildlife.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will **analyse** how the interactions, competition and dependencies between the organisms in a named ecosystem can create pressure which can lead to evolutionary change. Examples of the potential for this to occur should be given, preferably from the ecosystem being studied, supplemented, if necessary, with examples from other ecosystems.

Learners should source secondary data to show 'boom or bust' population dynamics for a named wildlife population. Learners will analyse the data patterns and provide conclusions, supported reasons and judgements evaluating how changing population dynamics impact on the energy budget.

For Merit standard, learners will briefly describe an ecosystem in order to **analyse** the relationships, of named species within that ecosystem. Food chains, food webs, pyramids of energy, biomass, numbers will be constructed and interpreted. Population dynamics (increase/decrease and reasons) will also need to be analysed and used to **explain** the energy budget in the chosen ecosystem.

For Pass standard, learners will correctly use a variety of technical terms to explain why and how characteristics of ecosystems (aquatic, desert, forest, grassland and tundra) vary around the globe. The impact of abiotic factors (e.g. latitude, altitude, climate, soil, pH, amount of light) on the ecosystems must be considered and explained.

The impact of biotic factors and interspecific and intraspecific interactions, competition and the struggle for life (predation, feeding relationships and competition for food/water territory, protection, reproduction must be explained.

Learners will choose an ecosystem and **explain** how water, carbon, nitrogen and oxygen are recycled within it. Trophic levels and how these allow energy to flow through the ecosystem must be **explained**. Energy production, consumption and conservation and the importance of respiration and photosynthesis must be included.

Learning aims C and D

For Distinction standard, learners will **evaluate** the impact of a specific human activity on a named ecosystem. This could be in relation to the ecosystem they investigated but is more likely to require research into a different ecosystem and associated human activity. Local road or house building, hunting, culling and use of chemicals in agriculture, are some examples that learners could research and evaluate. Learners will need to analyse secondary and or primary data, identify patterns and trends and draw insightful conclusions about the effects of disruption on the chosen ecosystem. Strategies to minimise disruption to the ecosystem should be identified and evaluated.

For Merit standard, learners will present and analyse the data they have collected from their survey of a chosen ecosystem. They will comment on the considerations that were given to collecting reliable and accurate data when they were planning and carrying out their survey. Data must be **analysed** using relevant calculations and appropriate statistical techniques to identify patterns, trends and draw meaningful conclusions about the relative abundance of the targeted species in their ecosystem.

The effect of a named natural disaster on a **named species** must be **analysed**. Learners will need to access secondary data for their analysis and to support more generalised comments they may provide in their analysis. Secondary sources must be referenced.

For Pass standard, learners will identify a local ecosystem that will enable them to **carry out** a survey to measure population and species diversity. They can have support in choosing a suitable location and in producing a plan for the investigation. Health and safety considerations will need to be checked and monitored by the tutor.

Learners must **carry out** a population survey and collect data on a **named plant** and a **named animal** species. They will need to identify data to be collected and select appropriate survey methods and equipment. Different learners should collect different data and use different species. Learner evidence that a survey has been carried out must be provided.

Learners will **explain** how the fragility of ecosystems in general and of a named ecosystem makes them susceptible to disruption from natural and human activities, examples could be building work, pollution, agriculture, droughts, fire, flood, overgrazing, storms.

Links to other units

This unit links to:

- Unit 1: Principles and Applications of Biology I
- Unit 5: Principles and Applications of Biology II
- Unit 8: Contemporary Issues in Science
- Unit 10: Climate Change
- Unit 15: Diseases and Infections
- Unit 24: Pollution and Waste Management
- Unit 25: Water Quality
- Unit 26: Animal Conservation.

Employer involvement

This unit would benefit from employer involvement in the form of:

- employers visiting and speaking to learners
- learners visiting companies and organisations that specialise in conservation, carrying out surveys and climate change
- work placements.

Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop a number of transferrable employability skills, including:

- analytical and observation skills
- formal written communication
- self-management and planning skills
- the ability to work in a scientific environment
- the ability to carry out independent research.

Unit 28: Sustainable Energy

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

This unit covers the issues surrounding the global use of fossil fuels and the need to find alternative, clean and sustainable energy sources.

Unit introduction

In this unit, you will study the issues surrounding environmental pollution and global warming that are linked to the use of non-renewable fossil fuels (i.e. coal, gas and crude oil). You will explore the concerns of the scientific community relating to linking ecologically disruptive increases in the Earth's temperature and a rise in sea levels and pollution, to excessive use of fossil fuels and the associated emission of greenhouse gases.

You will investigate potential solutions to the global energy crisis and you will research the production and use of renewable energy derived from different sources, including solar, hydroelectric, wind and geothermal. You will also investigate the social, environmental and financial implications of increasing the use of sustainable energy sources to decrease reliance on fossil fuels.

The skills you learn in this unit can be applied to other areas of study and to workplace practices. You can progress to further education for science-related courses, and to the expanding science industry, involving renewable energy, research and development.

Learning aims

In this unit, you will:

A Explore the environmental impact of continued use of fossil fuels

B Explore the generation of electricity from alternative fuel sources

C Compare the social, environmental and financial benefits and advantages of increasing the use of renewable energy with the disadvantages.

Summary of unit

Learning aim	Key content areas	Assessment approach
A Explore the environmental impact of continued use of fossil fuels	**A1** Uses of coal and the by-products of coal, crude oil and natural gas **A2** Environmental impact of fossil-fuel use	A report detailing the sources and environmental impact of the continued use of fossil fuels, to include: • amplified greenhouse effect through increased atmospheric concentration of carbon dioxide • release of nitrogen oxides, sulphur dioxide • emissions of soot and other particulates • land degradation • water pollution and generation of waste water • fracking.
B Explore the generation of electricity from alternative fuel sources	**B1** Renewable energy **B2** Nuclear energy **B3** Efficiency of energy production	A portfolio of evidence that explores alternative energy sources, to include: • how photovoltaic panels convert the sun's energy into electricity • how wind energy is produced • how waves and tides are utilised to produce energy • capture and uses of geothermal energy • production of nuclear energy • efficiency of energy sources.

Learning aim	Key content areas	Assessment approach
C Compare the social, environmental and financial benefits and advantages of the use of renewable energy with the disadvantages	**C1** Advantages of generating electricity from renewable resources **C2** Disadvantages of generating electricity from renewable sources	A report that explores, evaluates and compares the advantages and disadvantages of increasing use of renewable energy sources. The report will include: • the social, environmental and financial benefits of using solar, wind, hydroelectric, biomass and geothermal sources • the social, environmental and financial disadvantages of using solar, wind, hydroelectric, biomass and geothermal sources.

Content

Learning aim A: Explore the environmental impact of continued use of fossil fuels

A1 Uses of coal and the by-products of coal, crude oil and natural gas

- Uses of coal:
  - steam coal (thermal coal) in power generation
  - coking coal (metallurgical coal) in steel production
  - carbon fibre – e.g. manufacture of bicycles, tennis rackets
  - activated carbon – water filters, kidney dialysis machines, air purification.
- Use of by-products of coal (coal tar):
  - creosote oil
  - naphthalene
  - phenol
  - Benzene
  - ammonia gas (ammonia salts, nitric acid, fertilisers)
  - soaps, dyes, nylon
  - aspirin
  - coal combustion products (CCPs) – e.g. fly ash in cement making.
- Crude oil as a fuel and as a base for other products:
  - fuels – gasoline, diesel, kerosene
  - tar, asphalt, paraffin wax
  - fertilisers, perfume, insecticides
  - plastics – PVC, textiles.
- Natural gas:
  - generation of electricity
  - cooking and heating
  - vehicle fuel
  - as a feedstock for products such as fertilisers and pharmaceutical products.

A2 Environmental impact of fossil-fuel use

Global warming, the 'greenhouse effect':

- emission of heat-trapping gases – carbon dioxide (CO2), methane (CH4), water vapour (H2O)
- rise in global temperatures
- rise in sea levels
- risks of drought, heat waves, intensified storms
- ecological disruption
- chlorofluorocarbons (CFCs).

Toxic air pollutants:

- mercury – linked to damage to human body systems and water pollution
- sulphur dioxide – linked to asthma, bronchitis, acid rain, smog, damage to crops and ecosystems, acidification of lakes and streams
- nitrous oxides – linked to smog, lung irritation
- lead – accumulation in the body and consequent damage to body systems, decreased growth and reproductive rates in plants and animals, and neurological effects in vertebrates
- arsenic – linked to contamination of air, water and soil
- volatile organic compounds (VOCs) – linked to the formation of ground-level ozone
- particulates (soot) – linked to lung disease.

Extraction of oil and shale gas by hydraulic fracturing (fracking):

- risk of earthquakes
- leakage of fracking fluids into local aquifers
- substantial use of water.

Learning aim B: Explore the generation of electricity from alternative fuel sources

B1 Renewable energy

- Solar energy.
- Wind energy – turbines, wind farms, offshore wind farms.
- Geothermal energy.
- Hydroelectric energy – e.g. dams.
- Biomass energy.
- Tidal and wave energy

B2 Nuclear energy

- Use of uranium.
- Nuclear fission and chain reaction.
- Boiling-water reactors.
- Pressurised water reactors.
- Gas-cooled reactors.

B3 Efficiency of energy production

Levelized cost of energy (LCOE):

- value of electrical energy generated
- costs incurred – construction, operation and maintenance of power-generating plant
- technology – design of more efficient systems used to capture energy
- cost of fuel
- cost of dealing with environmental damage.

Learning aim C: Compare the social, environmental and financial benefits and advantages of the use of renewable energy with the disadvantages

C1 Advantages of generating energy from renewable resources

- Advantages of biofuels (e.g. wood, animal dung, ethanol), sustainable crops and forests.
- Advantages of solar energy.
- Advantages of wind energy (horizontal or vertical axis turbines).
- Advantages of hydroelectric energy (impoundment (dam), diversion, and pumped storage).
- Advantages of tidal and wave energy.
- Creating jobs and income for rural communities.
- Free resources (wind, water, sun).
- Non-polluting, clean generation.

C2 Disadvantages of generating energy from renewable resources

- Initial investment costs.
- Operating costs.
- Inconsistent, unreliable supply (clouds, wind, sun).
- Efficiency per square metre of land use.
- Use of large areas of land to install wind turbines or dams.
- Environmental impact of dams (creation of artificial reservoirs, change in habitat for aquatic plants and animals, blocking fish migration, alteration of sediment transport, changes to riparian zones).
- Use of large areas of land to grow biofuel crops.
- Use of pesticides to protect biofuel crops.
- Noise pollution (wind turbines).
- Visual impact.
- Harm to wildlife.
- Use of large quantities of freshwater (geothermal)
- Ease of storage (biomass).
- Destabilisation of marine systems.
- Hot-spots from solar farms.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Explore the environmental impact of continued use of fossil fuels		**A.D1** Evaluate the impact of fossil fuels on human health and the environment.
A.P1 Describe the sources and uses of oil, coal and natural gas. **A.P2** Describe how the use of fossil fuels impacts human health and the environment.	**A.M1** Explain how the use of fossil fuels affects human health and the environment.	
Learning aim B: Explore the generation of electricity from alternative fuel sources		**B.D2** Evaluate the factors that affect the efficiency of methods used to generate energy.
B.P3 Describe the technologies used to generate renewable energy. **B.P4** Describe the advantages and disadvantages of using nuclear fuels.	**B.M2** Explain and compare the efficiency of different renewable energy sources.	
Learning aim C: Compare the social, environmental and financial benefits and advantages of the use of renewable energy with the disadvantages		**C.D3** Evaluate the benefits and detrimental effects of increased use of solar, wind, hydroelectric, biomass, and geothermal power.
C.P5 Describe the social, environmental and financial advantages of increasing use of renewable energy. **C.P6** Describe the disadvantages of increasing use of renewable energy.	**C.M3** Compare the social, environmental and financial advantages and disadvantages of using nuclear energy and biofuels as energy sources.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.M2, B.D2)

Learning aim: C (C.P5, C.P6, C.M3, C.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to books, relevant DVDs, scientific magazines, journals and the internet.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will **evaluate** the links between the extraction and uses of fossil fuels and the impact on the global environment, societies and human health. Learners will use referenced data to inform a discussion of how atmospheric concentrations of carbon dioxide and methane have risen, and how this has contributed to the anthropogenic greenhouse effect, global climate change and rising sea levels. They will consider the ways in which sea-level rise and increased intensity of storms threaten coastal areas and wildlife habitats. The links between the release of toxic pollutants from burning fossil fuels and the resultant damage to ecosystems, for example acid rain, and human health, for example the release of particulates into the air and lung disease, will be explained in detail, using at least three examples of specific toxic pollutants.

For Merit standard, learners must provide a detailed **explanation** of the adverse effects of global use of coal, oil and natural gas on the environment. They will consider how the use of fossil fuels is linked to the 'greenhouse effect', climate change, acid rain, crop damage, air and water pollution, and land damage. Learners will **explain** how the release of toxic pollutants as a result of burning fossil fuels is linked to harmful effects on public health. Learners will give **explanations** that link three specific pollutants to the effects they have on human body systems.

For Pass standard, learners must **describe** the sources and uses of oil, coal and natural gas from beneath the Earth's surface and ocean beds. Brief descriptions of methods used for surface and underground mining for coal, offshore and onshore drilling for oil and natural gas, and hydraulic fracturing to obtain shale gas, will be included. Learners will then **describe**, with given examples, of how fossil fuels are used in industry and the impact the use of coal, oil and natural gas has on the environment and human health.

Learning aim B

For Distinction standard, learners must **evaluate** the factors that affect the economic and operational efficiency of renewable energy sources, for example capital cost of building generators, operating costs, cost of fuels, energy output, cost of environmental damage. They will discuss the effects of external factors on efficiency, for example advancement in wind turbine technology, leading to the development of curved blade tips designed to capture more wind energy versus the intermittent nature of wind.

For Merit standard, learners will **explain** the meaning of 'efficiency' when applied to the generation of electricity. They will explain how the efficiency of different renewable energy sources is calculated using levelised cost of electricity (LCOE) and **compare** the efficiencies of renewable energy sources to fossil fuels and nuclear power.

For Pass standard, learners must **describe** methods of generating electricity from renewable fuel sources. The descriptions will include technologies used to generate electricity using solar, wind, water and biomass as fuels. Learners may include labelled diagrams that they have produced themselves to illustrate their descriptions. Learners must also **describe** the advantages and disadvantages of nuclear energy in terms of sustainability, cost, risks to the environment and disposal of radioactive waste.

Learning aim C

For Distinction standard, learners must produce a detailed **evaluation** of the advantages and disadvantages of using renewable resources for energy supply. The evidence produced must include use of solar, wind, hydroelectric, biomass and geothermal sources. They will discuss factors such as sustainability, cost of maintenance and environmental impact. They will compare the benefits of using renewable resources with the disadvantages, such as the reliability of production (dependency on weather conditions), land use and impact on communities, habitats and wildlife. Learners will use their research and balance the advantages and disadvantages of using renewable energy sources to reach a conclusion, identifying the most effective renewable energy resource. Learners will justify their conclusion by giving the reasons for it.

For Merit standard, learners must examine the advantages and disadvantages of generating electricity using biofuels, **compared** with generating electricity from nuclear fuels. They will compare the environmental, societal and financial impact of each energy source. The evidence produced must cover factors such as initial investment costs, land use, air, water and thermal pollution, potential harm to environments, storage of fuels, disposal of waste products and electricity supply in relation to demand and public perception.

For Pass standard, learners will **describe** the social, environmental and financial advantages and disadvantages of increasing the use of renewable energy resources. Their descriptions will focus on a minimum of two sources of renewable energy listed in the unit content for assessment criterion C.

Links to other units

This unit links to:

- Unit 17: Electrical Circuits and their Applications
- Unit 23: Materials Science
- Unit 25: Water Quality.

Employer involvement

Centres may involve employers in the delivery of this unit. There may be local opportunities for learners to visit power-generation plants. Centres could invite employees from energy industries to talk to learners.

Opportunities to develop transferable employability skills

- Formal written communication.
- Interpretation of data.
- Ability to carry out independent research.

4 Planning your programme

How do I choose the right BTEC International Level 3 qualification for my learners?

BTEC International Level 3 qualifications come in a range of sizes, each with a specific purpose. You will need to recruit learners very carefully to ensure that they start on the right size of qualification to fit into their study programme and that they take the right pathways or optional units to allow them to progress to the next stage.

Some learners may want to take a number of complementary qualifications or keep their progression options open. These learners may be suited to taking a BTEC International Level 3 Certificate or Subsidiary Diploma. Learners who then decide to continue with a fuller vocational programme can transfer to a BTEC International Level 3 Diploma or Extended Diploma.

Some learners are sure of the sector in which they wish to work and are aiming for progression into that sector via higher education. These learners should be directed to the two-year BTEC International Level 3 Extended Diploma as the most suitable qualification.

Is there a learner entry requirement?

As a centre, it is your responsibility to ensure that the learners you recruit have a reasonable expectation of success on the programme. There are no formal entry requirements but we expect learners to have qualifications at or equivalent to Level 2.

Learners are most likely to succeed if they have:

- five International GCSEs at good grades and/or
- BTEC qualification(s) at Level 2
- other appropriate qualifications or achievement at year 11 or age 16 in core subjects.

Learners may demonstrate the ability to succeed in various ways. For example, they may have relevant work experience or specific aptitude shown through diagnostic tests or non-educational experience.

If learners are studying in English we recommend that they have attained at least Level B2 in the Common European Framework of Reference for Languages. Please see resources available from Pearson at www.pearson.com/english

What is involved in becoming an approved centre?

All centres must be approved before they can offer these qualifications – so that they are ready to assess learners and so that we can provide the support that is needed. Further information is given in *Section 8 Quality assurance*.

What level of sector knowledge is needed to teach these qualifications?

We do not set any requirements for teachers but recommend that centres assess the overall skills and knowledge of the teaching team to ensure that they are relevant and up to date. This will give learners a rich programme to prepare them for employment in the sector.

What resources are required to deliver these qualifications?

As part of your centre approval, you will need to show that the necessary material resources and work spaces are available to deliver BTEC International Level 3 qualifications. For some units, specific resources are required.

How can Pearson Progress help with planning for these qualifications?

Pearson Progress is a digital support system that supports the delivery, assessment and quality assurance of BTECs in centres. It supports teachers with activities such as course creation, creating and verifying assignments and creating assessment plans and recording assessment decisions.

For further information, see *Section 10 Resources and support*.

Which modes of delivery can be used for these qualifications?

You are free to deliver BTEC International Level 3 qualifications using any form of delivery that meets the needs of your learners. We recommend making use of a wide variety of modes, including direct instruction in classrooms or work environments, investigative and practical work, group and peer work, private study and e-learning.

What are the recommendations for employer involvement?

BTEC International Level 3 qualifications are vocational qualifications and, as an approved centre, you are encouraged to work with employers on design, delivery and assessment to ensure that it is engaging and relevant, and that it equips learners for progression. There are suggestions in many of the units about how employers could become involved in delivery and/or assessment but these are not intended to be exhaustive and there will be other possibilities at local level.

What support is available?

We provide a wealth of support materials, including curriculum plans, delivery guides, sample Pearson Set Assignments, authorised assignment briefs and examples of marked learner work.

You will be allocated a Standards Verifier early on in the planning stage to support you with planning your assessments. There will be extensive training programmes as well as support from our Subject Advisor team.

For further details see *Section 10 Resources and support*.

Meeting local needs

Centres should note that the qualifications set out in this specification have been developed in consultation with centres and employers for the relevant sector. Centres should make maximum use of the choice available to them within the optional units to meet the needs of their learners, and local skills and training needs.

In certain circumstances, units in this specification might not allow centres to meet a local need. In this situation, Pearson will allow centres to either make use of units from other BTEC specifications in this suite, or commission new units to meet the need. Centre developed units will need to be quality assured by Pearson at a cost. Centres are required to ensure that the coherence and purpose of the qualification is retained and to ensure that the vocational focus is not diluted.

The proportion of imported, or locally developed units that can be used are as follows. These units cannot be used at the expense of the mandatory units in any qualification.

Qualification	Meeting local needs allowance	Unit equivalence
Certificate (180 GLH)	No MLN allowed	0 units
Subsidiary Diploma (360 GLH)	60 GLH MLN allowed	1 * 60 GLH unit
Foundation Diploma (540 GLH)	120 GLH MLN allowed	e.g. 2 * 60 GLH units
Diploma (720 GLH)	180 GLH MLN allowed	e.g. 3 * 60 GLH units
Extended Diploma (1080 GLH)	240 GLH MLN allowed	e.g. 4 * 60 GLH units

How will my learners become more employable through these qualifications?

BTEC International Level 3 qualifications are mapped to relevant occupational standards, please see *Appendix 1*: *Links to industry standards*.

Employability skills, such as teamworking and entrepreneurialism, and practical, hands-on skills have been built into the design of the learning aims and content. This gives you the opportunity to use relevant contexts, scenarios and materials to enable learners to develop a portfolio of evidence that demonstrates the breadth of their skills and knowledge in a way that equips them for employment.

5 Assessment structure

Introduction

BTEC International Level 3 qualifications are assessed using a combination of *internal assessments*, which are set and marked by teachers, and *Pearson Set Assignments*, which are set by Pearson and marked by teachers.

- Mandatory units have a combination of internal and Pearson Set Assignments.
- All optional units are internally assessed.

In developing an overall plan for delivery and assessment for the programme, you will need to consider the order in which you deliver units, whether delivery is over short- or long periods and when assessment can take place. Some units are defined as synoptic units (see *Section 2 Structure*). Normally, a synoptic assessment is one that a learner would take later in a programme and in which they will be expected to apply learning from a range of units. You must plan the assignments so that learners can demonstrate learning from across their programme.

We have addressed the need to ensure that the time allocated to final assessment of units is reasonable so that there is sufficient time for teaching and learning, formative assessment and development of transferable skills.

In administering an internal assignment or a Pearson Set Assignment, the centre needs to be aware of the specific procedures and policies that apply, for example to registration, entries and results. An overview, with signposting to relevant documents, is given in *Section 7 Administrative arrangements*.

Internal assessment

Our approach to internal assessment for these qualifications will be broadly familiar to experienced centres. It offers flexibility in how and when you assess learners, provided that you meet assessment and quality assurance requirements. You will need to take account of the requirements of the unit format, which we explain in *Section 3 Units*, and the requirements for delivering assessment given in *Section 6 Internal assessment*.

Pearson Set Assignment units

A summary of the set assignments for this qualification is given in *Section 2 Structure*. You should check this information carefully, together with the details of the unit being assessed, so that you can timetable learning and assessment periods appropriately.

Learners must take the authorised Pearson Set Assignment for the set assignment unit. Teachers are not permitted to create their own assessments for set assignment units. Some assignments may need to be taken in controlled conditions. These are described in each unit.

Please see *Section 6* for resubmission and retaking regulations.

6 Internal assessment

This section gives an overview of the key features of internal assessment and how you, as an approved centre, can offer it effectively. The full requirements and operational information are given in the *BTEC International Quality Assurance Handbook*. All members of the assessment team need to refer to this document.

For BTEC International Level 3 qualifications, it is important that you can meet the expectations of stakeholders and the needs of learners by providing a programme that is practical and applied. Centres can tailor programmes to meet local needs and use links with local employers and the wider vocational sector.

When internal assessment is operated effectively, it is challenging, engaging, practical and up to date. It must also be fair to all learners and meet international standards.

All units in these qualifications are internally assessed but Pearson sets assignments for some units.

Principles of internal assessment (applies to all units)

Assessment through assignments

For all units, the format of assessment is an assignment taken after the content of the unit, or part of the unit if several assignments are used, has been delivered. An assignment may take a variety of forms, including practical and written types. An assignment is a distinct activity, completed independently by learners, that is separate from teaching, practice, exploration and other activities that learners complete with direction from teachers.

An assignment is issued to learners as an assignment brief with a defined start date, a completion date and clear requirements for the evidence that they need to provide. There may be specific observed practical components during the assignment period. Assignments can be divided into tasks and may require several forms of evidence. A valid assignment will enable a clear and formal assessment outcome, based on the assessment criteria. For most units, teachers will set the assignments. For Pearson Set Assignment units, Pearson will set the assignment.

Assessment decisions through applying unit-based criteria

Assessment decisions for BTEC International Level 3 qualifications are based on the specific criteria given in each unit and set at each grade level. To ensure that standards are consistent in the qualification and across the suite as a whole, the criteria for each unit have been defined according to a framework. The way in which individual units are written provides a balance of assessment of understanding, practical skills and vocational attributes appropriate to the purpose of qualifications.

The assessment criteria for a unit are hierarchical and holistic. For example, if an M criterion requires the learner to show 'analysis' and the related P criterion requires the learner to 'explain', then to satisfy the M criterion, a learner will need to cover both 'explain' and 'analyse'. The unit assessment grid shows the relationships between the criteria so that assessors can apply all the criteria to the learner's evidence at the same time. In *Appendix 3: Glossary of terms used*, we have set out a definition of terms that assessors need to understand.

Assessors must show how they have reached their decisions using the criteria in the assessment records. When a learner has completed all the assessment for a unit, then the assessment team will give a grade for the unit. This is given according to the highest level for which the learner is judged to have met all the criteria. Therefore:

- to achieve a Distinction, a learner must have satisfied all the Distinction criteria (and therefore the Pass and Merit criteria); these define outstanding performance across the unit as a whole
- to achieve a Merit, a learner must have satisfied all the Merit criteria (and therefore the Pass criteria) through high performance in each learning aim
- to achieve a Pass, a learner must have satisfied all the Pass criteria for the learning aims, showing coverage of the unit content and therefore attainment at Level 3 of the qualification.

The award of a Pass is a defined level of performance and cannot be given solely on the basis of a learner completing assignments. Learners who do not satisfy the Pass criteria should be reported as Unclassified.

The assessment team

It is important that there is an effective team for internal assessment. There are three key roles involved in implementing assessment processes in your centre, each with different interrelated responsibilities; the roles are listed below. There is detailed information in the *BTEC International Quality Assurance Handbook*.

- The Lead Internal Verifier (the Lead IV) has overall responsibility for the programme, its assessment and internal verification, record keeping and liaison with the Standards Verifier, ensuring our requirements are met. The Lead IV registers with Pearson annually. The Lead IV acts as an assessor, standardises and supports the rest of the assessment team, making sure that they have the information they need about our assessment requirements and organises training, making use of our standardisation, guidance and support materials.
- Internal Verifiers (IVs) oversee all assessment activities in consultation with the Lead IV. They check that assignments and assessment decisions are valid and that they meet our requirements. IVs will be standardised by working with the Lead IV. Normally, IVs are also assessors but they do not verify their own assessments.
- Assessors set or use assignments to assess learners. Before making any assessment decisions, assessors participate in standardisation activities led by the Lead IV. They work with the Lead IV and IVs to ensure that the assessment is planned and carried out in line with our requirements.

Effective organisation

Internal assessment needs to be well organised so that the progress of learners can be tracked and so that we can monitor that assessment is being carried out. We support you through, for example, providing training materials and sample documentation. Our online Pearson Progress service can help support you in planning and record keeping. Further information on using Pearson Progress can be found in *Section 10 Resources and support*, and on our website.

It is particularly important that you manage the overall assignment programme and deadlines to make sure that learners are able to complete assignments on time.

Learner preparation

To ensure that you provide effective assessment for your learners, you need to make sure that they understand their responsibilities for assessment and the centre's arrangements.

From induction onwards, you will want to ensure that learners are motivated to work consistently and independently to achieve the requirements of the qualifications. Learners need to understand how assignments are used, the importance of meeting assignment deadlines and that all the work submitted for assessment must be their own.

You will need to give learners a guide that explains how assignments are used for assessment, how assignments relate to the teaching programme and how learners should use and reference source materials, including what would constitute plagiarism. The guide should also set out your approach to operating assessment, such as how learners must submit work and request extensions.

Making valid assessment decisions

Authenticity of learner work

Once an assessment has begun, learners must not be given feedback on progress towards fulfilling the targeted criteria.

An assessor must assess only learner work that is authentic, i.e. learners' own independent work. Learners must authenticate the evidence that they provide for assessment through signing a declaration stating that it is their own work.

Assessors must ensure that evidence is authentic to a learner through setting valid assignments and supervising them during the assessment period. Assessors must take care not to provide direct input, instructions or specific feedback that may compromise authenticity.

Assessors must complete a declaration that:

- to the best of their knowledge the evidence submitted for this assignment is the learner's own
- the learner has clearly referenced any sources used in the work
- they understand that false declaration is a form of malpractice.

Centres can use Pearson templates or their own templates to document authentication.

During assessment, an assessor may suspect that some or all of the evidence from a learner is not authentic. The assessor must then take appropriate action using the centre's policies for malpractice. Further information is given in *Section 7 Administrative arrangements*.

Making assessment decisions using criteria

Assessors make judgements using the criteria. The evidence from a learner can be judged using all the relevant criteria at the same time. The assessor needs to make a judgement against each criterion that evidence is present and sufficiently comprehensive. For example, the inclusion of a concluding section may be insufficient to satisfy a criterion requiring 'evaluation'.

Assessors should use the following information and support in reaching assessment decisions:

- the *Essential information for assessment decisions* section in each unit gives examples and definitions related to terms used in the criteria
- the explanation of key terms in *Appendix 3: Glossary of terms used*
- examples of assessed work provided by Pearson
- your Lead IV and assessment team's collective experience, supported by the standardisation materials we provide.

Pass and Merit criteria relate to individual learning aims. The Distinction criteria as a whole relate to outstanding evidence across the unit. Therefore, criteria may relate to more than one learning aim (for example A.D1) or to several learning aims (for example DE.D3). Distinction criteria make sure that learners have shown that they can perform consistently at an outstanding level across the unit and/or that they are able to draw learning together across learning aims.

Issuing assessment decisions and feedback

Once the assessment team has completed the assessment process for an assignment, the outcome is a formal assessment decision. This is recorded formally and reported to learners.

The information given to the learner:

- must show the formal decision and how it has been reached, indicating how or where criteria have been met
- may show why attainment against criteria has not been demonstrated
- must not provide feedback on how to improve evidence
- must be validated by an IV before it is given to the learner.

Planning and record keeping

For internal processes to be effective, an assessment team needs to be well organised and keep effective records. The centre will work closely with us so that we can ensure that standards are being satisfied and achieved. This process gives stakeholders confidence in the assessment approach.

The programme must have an assessment plan validated by the Lead IV, produced as a spreadsheet. When producing a plan, the assessment team needs to consider:

- the time required for training and standardisation of the assessment team
- the time available to undertake teaching and carry out assessment, taking account of when learners may complete assessments and when quality assurance will take place
- the completion dates for different assignments and the name of each Assessor
- who is acting as the Internal Verifier for each assignment and the date by which the assignment needs to be internally verified

- setting an approach to sampling assessor decisions though internal verification that covers all assignments, assessors and a range of assessment decisions
- how to manage the assessment and verification of learners' work so that they can be given formal decisions promptly
- how resubmission opportunities can be scheduled.

The Lead IV will also maintain records of assessment undertaken. The key records are:

- internal verification of assignment briefs
- learner authentication declarations
- assessor decisions on assignments, with feedback given to learners
- internal verification of assessment decisions
- assessment tracking for the unit.

There are examples of records and further information in the *BTEC International Quality Assurance Handbook*.

Setting effective assignments (applies to all units without Pearson set assignments)

Setting the number and structure of assignments

This section does not apply to set assignment units. In setting your assignments, you need to work with the structure of assignments shown in the *Essential information for assignments* section of a unit. This shows the structure of the learning aims and criteria that you must follow and the recommended number of assignments that you should use. For these units we provide sample authorised assignment briefs and we give you suggestions on how to create suitable assignments. You can find these materials on our website. In designing your own assignment briefs, you should bear in mind the following points.

- The number of assignments for a unit must not exceed the number shown in *Essential information for assignments*. However, you may choose to combine assignments, for example to create a single assignment for the whole unit.
- You may also choose to combine all or parts of different units into single assignments, provided that all units and all their associated learning aims are fully addressed in the programme overall. If you choose to take this approach, you need to make sure that learners are fully prepared so that they can provide all the required evidence for assessment and that you are able to track achievement in the records.
- A learning aim must always be assessed as a whole and must not be split into two or more tasks.
- The assignment must be targeted to the learning aims but the learning aims and their associated criteria are not tasks in themselves. Criteria are expressed in terms of the outcome shown in the evidence.
- For units containing synoptic assessment, the planned assignments must allow learners to select and apply their learning, using appropriate self-management of tasks.
- You do not have to follow the order of the learning aims of a unit in setting assignments but later learning aims often require learners to apply the content of earlier learning aims and they may require learners to draw their learning together.

- Assignments must be structured to allow learners to demonstrate the full range of achievement at all grade levels. Learners need to be treated fairly by being given the opportunity to achieve a higher grade if they have the ability.
- As assignments provide a final assessment, they will draw on the specified range of teaching content for the learning aims. The specified content is compulsory. The evidence for assessment need not cover every aspect of the teaching content as learners will normally be given particular examples, case studies or contexts in their assignments. For example, if a learner is carrying out one practical performance, or an investigation of one organisation, then they will address all the relevant range of content that applies in that instance.

Providing an assignment brief

A good assignment brief is one that, through providing challenging and realistic tasks, motivates learners to provide appropriate evidence of what they have learned.

An assignment brief should have:

- a vocational scenario, this could be a simple situation or a full, detailed set of vocational requirements that motivates the learner to apply their learning through the assignment
- clear instructions to the learner about what they are required to do, normally set out through a series of tasks
- an audience or purpose for which the evidence is being provided
- an explanation of how the assignment relates to the unit(s) being assessed.

Forms of evidence

BTECs have always allowed for a variety of forms of evidence to be used – provided that they are suited to the type of learning aim being assessed. For many units, the practical demonstration of skills is necessary and, for others, learners will need to carry out their own research and analysis. The units give you information on what would be suitable forms of evidence to give learners the opportunity to apply a range of employability or transferable skills. Centres may choose to use different suitable forms of evidence to those proposed. Overall, learners should be assessed using varied forms of evidence.

Full definitions of types of assessment are given in *Appendix 3: Glossary of terms used*. These are some of the main types of assessment:

- written reports
- projects
- time-constrained practical assessments with observation records and supporting evidence
- recordings of performance
- sketchbooks, working logbooks, reflective journals
- presentations with assessor questioning.

The form(s) of evidence selected must:

- allow the learner to provide all the evidence required for the learning aim(s) and the associated assessment criteria at all grade levels
- allow the learner to produce evidence that is their own independent work
- allow a verifier to independently reassess the learner to check the assessor's decisions.

For example, when you are using performance evidence, you need to think about how supporting evidence can be captured through recordings, photographs or task sheets.

Centres need to take particular care that learners are enabled to produce independent work. For example, if learners are asked to use real examples, then best practice would be to encourage them to use their own or to give the group a number of examples that can be used in varied combinations.

Late completion, resubmission and retakes (applies to all units including Pearson set assignment units)

Dealing with late completion of assignments for internally-assessed units

Learners must have a clear understanding of the centre policy on completing assignments by the deadlines that you give them. Learners may be given authorised extensions for legitimate reasons, such as illness at the time of submission, in line with your centre policies.

For assessment to be fair, it is important that learners are all assessed in the same way and that some learners are not advantaged by having additional time or the opportunity to learn from others. Therefore, learners who do not complete assignments by your planned deadline or by the authorised extension deadline may not have the opportunity to subsequently resubmit.

If you accept a late completion by a learner, then the assignment should be assessed normally when it is submitted, using the relevant assessment criteria.

Resubmission of improved evidence for internally-assessed units

An assignment provides the final assessment for the relevant learning aims and is normally a final assessment decision, except where the Lead IV approves one opportunity to resubmit improved evidence based on the completed assignment brief.

The Lead IV has the responsibility to make sure that resubmission is operated fairly. This means:

- checking that a learner can be reasonably expected to perform better through a second submission, for example that the learner has not performed as expected
- making sure that giving a further opportunity can be done in such a way that it does not give an unfair advantage over other learners, for example through the opportunity to take account of feedback given to other learners
- checking that the assessor considers that the learner will be able to provide improved evidence without further guidance and that the original evidence submitted has been authenticated by both the learner and assessor and remains valid.

Once an assessment decision has been given to the learner, the resubmission opportunity must have a deadline within 15 working days after the timely issue of assessment feedback to learners, which is within term time in the same academic year.

A resubmission opportunity must not be provided where learners:

- have not completed the assignment by the deadline without the centre's agreement
- have submitted work that is not authentic.

We recognise that there are circumstances where the resubmission period may fall outside of the 15-day limit owing to a lack of resources being available, for example where learners may need to access a performance space or have access to specialist equipment. Where it is practical to do so, for example evaluations, presentations, extended writing, resubmission must remain within the normal 15-day period.

Retake of internal assessment

A learner who has not achieved the level of performance required to pass the relevant learning aims after resubmission of an assignment may be offered a single retake opportunity using a new assignment. The retake may be achieved at a Pass only.

The Lead Internal Verifier must authorise a retake of an assignment only in exceptional circumstances where they believe it is necessary, appropriate and fair to do so. The retake is not timebound and the assignment can be attempted by the learner on a date agreed between the Lead IV and assessor within the same academic year.

For further information on offering a retake opportunity, you should refer to the *BTEC Centre Guide to Internal Assessment*. Information on writing assignments for retakes is given on our website (www.btec.co.uk/keydocuments).

7 Administrative arrangements

Introduction

This section focuses on the administrative requirements for delivering a BTEC qualification. It is of particular value to Quality Nominees, Lead IVs, Programme Leaders and Examinations Officers.

Learner registration and entry

Shortly after learners start the programme of learning, you need to make sure that they are registered for the qualification and that appropriate arrangements are made for internal assessment. You need to refer to the *International Information Manual* for information on making registrations for the qualification and entries for external assessments.

Learners can be formally assessed only for a qualification on which they are registered. If learners' intended qualifications change, for example if a learner decides to choose a different pathway specialism, then the centre must transfer the learner appropriately.

Access to assessment

Assessments need to be administered carefully to ensure that all learners are treated fairly, and that results and certification are issued on time to allow learners to progress to their chosen progression opportunities.

Our equality policy requires that all learners should have equal opportunity to access our qualifications and assessments, and that our qualifications are awarded in a way that is fair to every learner. We are committed to making sure that:

- learners with a protected characteristic are not, when they are undertaking one of our qualifications, disadvantaged in comparison to learners who do not share that characteristic
- all learners achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

Further information on access arrangements can be found in the Joint Council for Qualifications (JCQ) document *Access Arrangements, Reasonable Adjustments and Special Consideration for General and Vocational Qualifications*.

Administrative arrangements for assessment

Records

You are required to retain records of assessment for each learner. Records should include assessments taken, decisions reached and any adjustments or appeals. Further information can be found in the *International Information Manual*. We may ask to audit your records, so they must be retained as specified.

Reasonable adjustments to assessment

To ensure that learners have fair access to demonstrate the requirements of the assessments, a reasonable adjustment is one that is made before a learner takes an assessment. You are able to make adjustments to internal assessments to take account of the needs of individual learners. In most cases, this can be achieved through a defined time extension or by adjusting the format of evidence. We can advise you if you are uncertain as to whether an adjustment is fair and reasonable. You need to plan for time to make adjustments if necessary.

Further details on how to make adjustments for learners with protected characteristics are given on our website, in the document *Guidance for reasonable adjustments and special consideration in vocational internally assessed units*.

Special consideration

Special consideration is given after an assessment has taken place for learners who have been affected by adverse circumstances, such as illness. You must operate special consideration in line with our policy (see above). You can give special consideration related to the period of time given for evidence to be provided or for the format of the assessment if it is equally valid. You may not substitute alternative forms of evidence to that required in a unit or omit the application of any assessment criteria to judge attainment. Pearson can consider applications for special consideration if they are in line with the policy.

Appeals against assessment

Your centre must have a policy for dealing with appeals from learners. These appeals may relate to assessment decisions being incorrect or assessment not being conducted fairly. The first step in such a policy could be a consideration of the evidence by a Lead IV or other member of the programme team. The assessment plan should allow time for potential appeals after assessment decisions have been given to learners. If there is an appeal by a learner, you must document the appeal and its resolution. Learners have a final right of appeal to Pearson but only if the procedures that you have put in place have not been followed. Further details are given in the document *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy*.

Conducting set assignments

Centres must make arrangements for the secure delivery of Pearson Set Assignments.

At least one Pearson Set Assignment will be available each year for each unit with an additional one provided for resit. Centres must not select an assignment that learners have attempted already.

Each set assignment has a defined degree of control under which it must take place. We define degrees of control as follows.

Medium control

This is completion of assessment, usually over a longer period of time, which may include a period of controlled conditions. The controlled conditions may allow learners to access resources, prepared notes or the internet to help them complete the assignment.

Low control

These are activities completed without direct supervision. They may include research, preparation of materials and practice.

Each set assignment unit will contain instructions in the *Essential information for assignments* section on how to conduct the assessment of that unit.

Some set assignments will need to be taken with limited controls. Limited controls are described in each unit and may include the following conditions:

- Time: each assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.
- Supervision: you should be confident of the authenticity of learner's work. This may mean that learners be supervised.
- Resources: all learners should have access to the same types of resources to complete the assignment.
- Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

Schools and colleges must be able to confirm that learner evidence is authentic.

Dealing with malpractice in assessment

Malpractice means acts that undermine the integrity and validity of assessment, the certification of qualifications, and/or that may damage the authority of those responsible for delivering the assessment and certification.

Pearson does not tolerate actions (or attempted actions) of malpractice by learners, centre staff or centres in connection with Pearson qualifications. Pearson may impose penalties and/or sanctions on learners, centre staff or centres where incidents (or attempted incidents) of malpractice have been proven.

Malpractice may arise or be suspected in relation to any unit or type of assessment within the qualification. For further details regarding malpractice and advice on preventing malpractice by learners, please see Pearson's *Centre guidance: Dealing with malpractice and maladministration in vocational qualifications*, available on our website.

Centres are required to take steps to prevent malpractice and to investigate instances of suspected malpractice. Learners must be given information that explains what malpractice is for internal assessment and how suspected incidents will be dealt with by the centre. The *Centre Guidance: Dealing with malpractice and maladministration in vocational qualifications* document gives comprehensive information on the actions we expect you to take.

Pearson may conduct investigations if we believe that a centre is failing to conduct internal assessment according to our policies. The above document gives further information and examples, and details the penalties and sanctions that may be imposed.

In the interests of learners and centre staff, centres need to respond effectively and openly to all requests relating to an investigation into an incident of suspected malpractice.

Learner malpractice

Learner malpractice refers to any act by a learner that compromises or which seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

Learner malpractice in examinations **must** be reported to Pearson using a *JCQ Form M1* (available at www.jcq.org.uk/exams-office/malpractice). The form should be emailed to Learnermalpractice@pearson.com. Please provide as much information and supporting documentation as possible. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice constitutes staff or centre malpractice.

Staff/centre malpractice

Staff and centre malpractice includes both deliberate malpractice and maladministration of our qualifications. As with learner malpractice, staff and centre malpractice is any act that compromises or which seeks to compromise the process of assessment, or which undermines the integrity of the qualifications or the validity of results/certificates.

All cases of suspected staff malpractice and maladministration **must** be reported immediately, before any investigation is undertaken by the centre, to Pearson on a *JCQ Form M2(a)* (available at www.jcq.org.uk/exams-office/malpractice).

The form, supporting documentation and as much information as possible should be emailed to pqsmalpractice@pearson.com. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice itself constitutes malpractice.

More-detailed guidance on malpractice can be found in the latest version of the document *JCQ General and vocational qualifications Suspected Malpractice in Examinations and Assessments*, available at www.jcq.org.uk/exams-office/malpractice.

Sanctions and appeals

Where malpractice is proven, we may impose sanctions or penalties.

Where learner malpractice is evidenced, penalties may be imposed, such as:

- disqualification from the qualification
- being barred from registration for Pearson qualifications for a period of time.

If we are concerned about your centre's quality procedures, we may impose sanctions, such as:

- working with you to create an improvement action plan
- requiring staff members to receive further training
- placing temporary blocks on your certificates
- placing temporary blocks on registration of learners
- debarring staff members or the centre from delivering Pearson qualifications
- suspending or withdrawing centre approval status.

The centre will be notified if any of these apply.

Pearson has established procedures for centres that are considering appeals against penalties and sanctions arising from malpractice. Appeals against a decision made by Pearson will normally be accepted only from Heads of Centres (on behalf of learners and/or members of staff) and from individual members (in respect of a decision taken against them personally). Further information on appeals can be found in our document *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy*, which is on our website. In the initial stage of any aspect of malpractice, please notify the Investigations Team by email via pqsmalpractice@pearson.com, who will inform you of the next steps.

Certification and results

Once a learner has completed all the required components for a qualification, the centre can claim certification for the learner, provided that quality assurance has been successfully completed. For the relevant procedures, please refer to our *International Information Manual*. You can use the information provided on qualification grading to check overall qualification grades.

Changes to qualification requests

Where a learner who has taken a qualification wants to resit a unit to improve their qualification grade, you firstly need to decline their overall qualification grade. You may decline the grade before the certificate is issued.

Additional documents to support centre administration

As an approved centre, you must ensure that all staff delivering, assessing and administering the qualifications have access to the following documentation. These documents are reviewed annually and are reissued if updates are required.

- *BTEC International Quality Assurance Handbook*: this sets out how we will carry out quality assurance of standards and how you need to work with us to achieve successful outcomes.
- *International Information Manual*: this gives procedures for registering learners for qualifications, transferring registrations and claiming certificates.
- *Regulatory policies*: our regulatory policies are integral to our approach and explain how we meet internal and regulatory requirements. We review the regulated policies annually to ensure that they remain fit for purpose. Policies related to this qualification include:
    - adjustments for candidates with disabilities and learning difficulties, access arrangements and reasonable adjustments for general and vocational qualifications
    - age of learners
    - centre guidance for dealing with malpractice
    - recognition of prior learning and process.

This list is not exhaustive and a full list of our regulatory policies can be found on our website.

8 Quality assurance

Centre and qualification approval

As part of the approval process, your centre must make sure that the resource requirements listed below are in place before offering the qualification.

- Centres must have appropriate physical resources (for example equipment, IT, learning materials, teaching rooms) to support the delivery and assessment of the qualification.
- Staff involved in the assessment process must have relevant expertise and/or occupational experience.
- There must be systems in place to ensure continuing professional development for staff delivering the qualification.
- Centres must have in place appropriate health and safety policies relating to the use of equipment by learners.
- Centres must deliver the qualification in accordance with current equality and diversity legislation and/or regulations.
- Centres should refer to the *Further information for teachers and assessors* section in individual units to check for any specific resources required.

Continuing quality assurance and standards verification

On an annual basis, we produce the *BTEC International Quality Assurance Handbook*. It contains detailed guidance on the quality processes required to underpin robust assessment and internal verification.

The key principles of quality assurance are that:

- a centre delivering BTEC programmes must be an approved centre, and must have approval for the programmes or groups of programmes that it is delivering
- the centre agrees, as part of gaining approval, to abide by specific terms and conditions around the effective delivery and quality assurance of assessment; the centre must abide by these conditions throughout the period of delivery
- Pearson makes available to approved centres resources and processes that exemplify assessment and appropriate standards. Approved centres must use these to ensure that all staff delivering BTEC qualifications keep up to date with the guidance on assessment
- an approved centre must follow agreed protocols for standardisation of assessors and verifiers, for the planning, monitoring and recording of assessment processes, and for dealing with special circumstances, appeals and malpractice.

The approach of quality-assured assessment is through a partnership between an approved centre and Pearson. We will make sure that each centre follows best practice and employs appropriate technology to support quality-assurance processes, where practicable. We work to support centres and seek to make sure that our quality-assurance processes do not place undue bureaucratic processes on centres. We monitor and support centres in the effective operation of assessment and quality assurance.

The methods we use to do this for BTEC Level 3 include:

- making sure that all centres complete appropriate declarations at the time of approval
- undertaking approval visits to centres
- making sure that centres have effective teams of assessors and verifiers who are trained to undertake assessment
- assessment sampling and verification, through requested samples of assessments, completed assessed learner work and associated documentation
- an overarching review and assessment of a centre's strategy for delivering and quality assuring its BTEC programmes, for example making sure that synoptic units are placed appropriately in the order of delivery of the programme.

Centres that do not fully address and maintain rigorous approaches to delivering, assessing and quality assurance cannot seek certification for individual programmes or for all BTEC Level 3 programmes. An approved centre must make certification claims only when authorised by us and strictly in accordance with requirements for reporting.

Centres that do not comply with remedial action plans may have their approval to deliver qualifications removed.

9 Understanding the qualification grade

Awarding and reporting for the qualification

This section explains the rules that we apply in awarding a qualification and in providing an overall qualification grade for each learner. It shows how all the qualifications in this sector are graded.

Eligibility for an award

In order to be awarded a qualification, a learner must complete all units, achieve a Pass or above in all mandatory units unless otherwise specified. Refer to the structure in *Section 2 Structure*.

To achieve any qualification grade, learners must:

- complete and have an outcome (D, M, P or U) for all units within a valid combination
- achieve the **required units at Pass or above** shown in *Section 2*, abiding by the minimum requirements in the compensation table below
- achieve the **minimum number of points** at a grade threshold.

It is the responsibility of a centre to ensure that a correct unit combination is adhered to. Learners who do not achieve the required minimum grade (P) in units shown in the structure will not achieve a qualification.

Learners who do not achieve sufficient points for a qualification or who do not achieve all the required units may be eligible to achieve a smaller qualification in the same suite, provided they have completed and achieved the correct combination of units and met the appropriate qualification grade points threshold.

Compensation table

Qualification	Compensation rule	Unit equivalence
Certificate (180 GLH)	No compensation allowed	0 units
Subsidiary Diploma (360 GLH)	Mandatory must be passed, 60 GLH only at U grade permitted from optional	1 × 60 GLH unit
Foundation Diploma (540 GLH)	Mandatory must be passed, 120 GLH only at U grade permitted from optional	e.g. 2 × 60 GLH units OR 1 × 120 GLH unit
Diploma (720 GLH)	Mandatory must be passed, 180 GLH only at U grade permitted from optional	e.g. 3 × 60 GLH units OR 1 × 60 GLH and 1 × 120 GLH unit
Extended Diploma (1080 GLH)	Mandatory must be passed, 180 GLH only at U grade permitted from optional	e.g. 3 × 60 GLH units OR 1 × 60 GLH and 1 × 120 GLH unit

Calculation of the qualification grade

The final grade awarded for a qualification represents an aggregation of a learner's performance across the qualification. As the qualification grade is an aggregate of the total performance, there is some element of compensation in that a higher performance in some units may be balanced by a lower outcome in others.

In the event that a learner achieves more than the required number of optional units, the mandatory units, along with the optional units with the highest grades, will be used to calculate the overall result, subject to the eligibility requirements for that particular qualification title.

BTEC International Level 3 qualifications are awarded at the grade ranges shown in the table below.

Qualification	Available grade range
Certificate, Subsidiary Diploma, Foundation Diploma	P to D*
Diploma	PP to D*D*
Extended Diploma	PPP to D*D*D*

The *Calculation of qualification grade* table, given later in this section, shows the minimum thresholds for calculating these grades. The table will be kept under review over the lifetime of the qualification. In the event of any change, centres will be informed before the start of teaching for the relevant cohort and an updated table will be issued on our website.

Learners who do not meet the minimum requirements for a qualification grade to be awarded will be recorded as Unclassified (U) and will not be certificated. They may receive a Notification of Performance for individual units. The *International Information Manual* gives full information.

Points available for units

The table below shows the number of **points** available for internal units. For each internal unit, points are allocated depending on the grade awarded.

	Unit size	
	60 GLH	**120GLH**
U	0	0
Pass	6	12
Merit	10	20
Distinction	16	32

Claiming the qualification grade

Subject to eligibility, Pearson will automatically calculate the qualification grade for your learners when the internal unit grades are submitted and the qualification claim is made. Learners will be awarded qualification grades for achieving the sufficient number of points within the ranges shown in the relevant *Calculation of qualification grade* table for the cohort.

Calculation of qualification grade

Applicable for registration from 1 April 2020.

Certificate		Subsidiary Diploma		Foundation Diploma		Diploma		Extended Diploma	
180 GLH		**360 GLH**		**540 GLH**		**720 GLH**		**1080 GLH**	
Grade	**Points threshold**	**Grade**	**Points threshold**	**Grade**	**Points threshold**	**Grade**	**Points threshold**	**Grade**	**Points threshold**
U	0	U	0	U	0	U	0	U	0
Pass	18	P	36	P	54	PP	72	PPP	108
						MP	88	MPP	124
								MMP	140
Merit	26	M	52	M	78	MM	104	MMM	156
						DM	124	DMM	176
								DDM	196
Distinction	42	D	74	D	108	DD	144	DDD	216
						D*D	162	D*DD	234
								D*D*D	252
Distinction*	48	D*	90	D*	138	D*D*	180	D*D*D*	270

This table is subject to review over the lifetime of the qualification. The most up-to-date version will be issued via our website.

Examples of grade calculations based on table applicable to registrations from April 2020

Example 1: Achievement of a Certificate with a P grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Merit	10
Unit 3	60	Int Set	Pass	6
Totals	**180**		**P**	**22**

The learner has sufficient points for a P grade.

Example 2: Achievement of a Certificate with an M grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Merit	10
Unit 2	60	Int Set	Distinction	16
Unit 3	60	Int Set	Pass	6
Totals	**180**		**M**	**32**

The learner has sufficient points for an M grade.

Example 3: An Unclassified result for a Certificate

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	U	0
Unit 2	60	Int Set	Distinction	16
Unit 3	60	Int Set	Pass	6
Totals	**180**		**U**	**22**

The learner has a U in Unit 1.

The learner has sufficient points for a P grade but has not met the minimum requirement for a grade in Unit 1.

Examples of grade calculations based on table applicable to registrations from April 2020

Example 1: Achievement of a Subsidiary Diploma with a P grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Merit	10
Unit 3	60	Int Set	Merit	10
Unit 9	60	Int	Unclassified	0
Unit 12	60	Int	Pass	6
Unit 22	60	Int	Pass	6
Totals	**360**		**P**	**38**

The learner has achieved P or higher in Units 1, 2 and 3.

The learner has sufficient points for a P grade.

Example 2: Achievement of a Subsidiary Diploma with an M grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Merit	10
Unit 3	60	Int Set	Distinction	16
Unit 11	60	Int	Distinction	16
Unit 19	60	Int	Pass	6
Unit 25	60	Int	Merit	10
Totals	**360**		**M**	**64**

The learner has sufficient points for an M grade.

Example 3: An Unclassified Result for a Subsidiary Diploma

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Merit	10
Unit 2	60	Int Set	Unclassified	0
Unit 3	60	Int Set	Distinction	16
Unit 15	60	Int	Merit	10
Unit 17	60	Int	Distinction	16
Unit 23	60	Int	Merit	10
Totals	**360**		**U**	**62**

The learner has a U in Unit 2.

The learner has sufficient points for an M grade but has not met the minimum requirement for a P or higher in Units 1, 2 and 3.

Examples of grade calculations based on table applicable to registrations from April 2020

Example 1: Achievement of a Foundation Diploma with a P grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Pass	6
Unit 3	60	Int Set	Pass	6
Unit 4	120	Int	Pass	12
Unit 5	60	Int	Distinction	16
Unit 6	60	Int	Pass	6
Unit 7	60	Int	Unclassified	0
Unit 16	60	Int	Merit	10
Totals	**540**		**P**	**62**

The learner has achieved P or higher in Units 1 to 3.

The learner has sufficient points for a P grade.

Example 2: Achievement of a Foundation Diploma with an M grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Pass	6
Unit 3	60	Int Set	Pass	6
Unit 4	120	Int	Merit	20
Unit 5	60	Int	Distinction	16
Unit 6	60	Int	Distinction	16
Unit 7	60	Int	Merit	10
Unit 12	60	Int	Merit	10
Totals	**540**		**M**	**90**

The learner has sufficient points for an M grade.

Example 3: An Unclassified result for a Foundation Diploma

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Merit	10
Unit 3	60	Int Set	U	0
Unit 4	120	Int	Pass	12
Unit 5	60	Int	Distinction	16
Unit 6	60	Int	Distinction	16
Unit 7	60	Int	Distinction	16
Unit 12	60	Int	Pass	6
Totals	**540**		**U**	**82**

The learner has a U in Unit 3.

The learner has sufficient points for an M grade but has not met the minimum requirement for P or higher in Unit 3.

Examples of grade calculations based on table applicable to registrations from April 2020

Example 1: Achievement of a Diploma with a PP grade (Applied Science)

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Pass	6
Unit 3	60	Int Set	Pass	6
Unit 4	120	Int	Pass	12
Unit 5	60	Int	Pass	6
Unit 6	60	Int	Pass	6
Unit 7	60	Int	Merit	10
Unit 9	60	Int	Pass	6
Unit 11	60	Int	U	0
Unit 13	60	Int	Merit	10
Unit 16	60	Int	Distinction	16
Totals	**720**		**PP**	**84**

The learner has achieved P or higher in Units 1 to 7.

The learner has sufficient points for a PP grade.

Example 2: An Unclassified result for a Diploma in Applied Science

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	U	0
Unit 3	60	Int Set	Pass	6
Unit 4	120	Int	Pass	12
Unit 5	60	Int	Pass	6
Unit 6	60	Int	Pass	6
Unit 7	60	Int	U	0
Unit 11	60	Int	Pass	6
Unit 13	60	Int	Merit	10
Unit 16	60	Int	Distinction	16
Unit 19	60	Int	Pass	6
Totals	**720**		**U**	**74**

The learner has a U in Units 2 and 7.

Examples of grade calculations based on table applicable to registrations from April 2020

Example 1: Achievement of an Extended Diploma for Applied Science with a PPP grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Pass	6
Unit 3	60	Int Set	Pass	6
Unit 4	120	Int Set	Pass	12
Unit 5	60	Int	Pass	6
Unit 6	60	Int	Pass	6
Unit 7	60	Int	Pass	6
Unit 8	120	Int	Pass	12
Unit 11	60	Int	Merit	10
Unit 13	60	Int	Pass	6
Unit 14	60	Int	Pass	6
Unit 17	60	Int	Pass	6
Unit 18	60	Int	Pass	6
Unit 21	60	Int	Pass	6
Unit 24	60	Int	Pass	6
Unit 27	60	Int	Distinction	16
Totals	**1080**		**PPP**	**122**

The learner has achieved P or higher in Units 1 to 8.

The learner has sufficient points for a PPP grade.

Example 2: Achievement of an Extended Diploma for Applied Science with a DDM grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int Set	Distinction	16
Unit 3	60	Int Set	Distinction	16
Unit 4	120	Int Set	Merit	20
Unit 5	60	Int	Pass	6
Unit 6	60	Int	Distinction	16
Unit 7	60	Int	Distinction	16
Unit 8	120	Int	Merit	20
Unit 11	60	Int	Merit	10
Unit 12	60	Int	Merit	10
Unit 13	60	Int	Merit	10
Unit 17	60	Int	Merit	10
Unit 18	60	Int	Merit	10
Unit 21	60	Int	Merit	10
Unit 24	60	Int	Merit	10
Unit 27	60	Int	Distinction	16
Totals	**1080**		**DDM**	**202**

The learner has sufficient points for a DDM grade.

10 Resources and support

Our aim is to give you a wealth of resources and support to enable you to deliver BTEC International Level 3 qualifications with confidence. You will find a list of resources to support teaching and learning, and professional development on our website.

Support for setting up your course and preparing to teach

Specification

The specification (for teaching from April 2020) gives you details of the administration of the qualifications and information on the units for the qualifications.

Pearson Progress

Pearson Progress is a digital support system that helps you to manage the assessment and quality assurance of the Pearson BTEC International Level 3 Applied Science qualifications. It supports delivery, assessment and quality assurance of BTECs in centres and supports teachers and students as follows:

- course creation
- creating and verifying assignments
- creating assessment plans and recording assessment decisions
- upload of assignment evidence
- tracking progress of every learner

The system is accessible for teachers and learners so that both teachers and learners can track their progress.

Support for teaching and learning

Pearson Learning Services provide a range of engaging resources to enable you to start teaching BTEC International Level 3 qualifications. These may include the following free materials:

- delivery guides, which give you important advice on how to choose the right course for your learners and how to ensure you are fully prepared to deliver the course. They explain the key features of the BTEC International Level 3 Applied Science qualifications, for example employer involvement and employability skills. They also cover guidance on assessment and quality assurance
- sample schemes of work for each mandatory unit as well as a selection of optional units. These are available in Word™ format for ease of customisation
- slide presentations for use in your teaching to outline the key concepts of a unit
- delivery plans that help you structure delivery of a qualification.

We also provide paid-for resources and courseware which may include:

- teacher resource packs developed by Pearson including materials and activities to fully support your teaching of units
- student study texts across a range of mandatory and optional units to support your students throughout their programme of study.

Support for assessment

Sample assessment materials for internally-assessed units

For internal units assessed with a Pearson Set Assignment we will provide a sample assignment as an example of the form of assessment for the unit. For the remaining internally set units, we allow you to set your own assignments, according to your learners' preferences and to link with your local employment profile.

We provide a service in the form of Authorised Assignment Briefs and sample Pearson Set Assignments, which are approved by Pearson Standards Verifiers. They are available via our website.

Pearson English

Pearson provides a full range of support for English learning including diagnostics, qualifications and learning resources. Please see www.pearson.com/english

Training and support from Pearson

People to talk to

There are many people available to support you and give you advice and guidance on delivery of your BTEC International Level 3 qualifications. They include the following.

- Subject Advisors – available for all sectors. They understand all Pearson qualifications in their sector and can answer sector-specific queries on planning, teaching, learning and assessment.
- Standards Verifiers – they can support you with preparing your assignments, ensuring that your assessment plan is set up correctly, and support you in preparing learner work and providing quality assurance through sampling.
- Regional teams – they are regionally based and have a full overview of the BTEC qualifications and of the support and resources that Pearson provides. Regions often run network events.
- Customer Services – the 'Support for You' section of our website gives the different ways in which you can contact us for general queries. For specific queries, our service operators can direct you to the relevant person or department.

Training and professional development

Pearson provides a range of training and professional development events to support the introduction, delivery, assessment and administration of BTEC International Level 3 qualifications. These sector-specific events, developed and delivered by specialists, are available both face to face and online.

'Getting Ready to Teach'

These events are designed to get teachers ready for delivery of the BTEC International Level 3 qualifications. They include an overview of qualification structures, planning and preparation for internal and external assessment, and quality assurance.

Teaching and learning

Beyond the 'Getting Ready to Teach' professional development events, there are opportunities for teachers to attend sector- and role-specific events. These events are designed to connect practice to theory; they provide teacher support and networking opportunities with delivery, learning and assessment methodology.

Details of our training and professional development programme can be found on our website.

Appendix 1: Links to industry standards

BTEC International Level 3 qualifications have been developed in consultation with industry and appropriate sector bodies to ensure that content and the approach to assessment align closely to the needs of employers. Where they exist, and are appropriate, National Occupational Standards (NOS) and professional body standards have been used to establish unit content.

Appendix 2: Transferable employability skills

The need for transferable skills

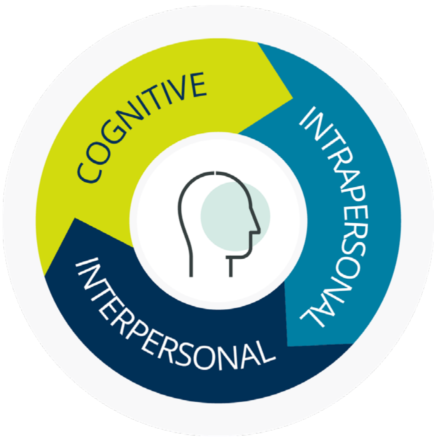
In recent years, higher-education institutions and employers have consistently flagged the need for learners to develop a range of transferable skills to enable them to respond with confidence to the demands of undergraduate study and the world of work.

The Organisation for Economic Co-operation and Development (OECD) defines skills, or competencies, as 'the bundle of knowledge, attributes and capacities that can be learned and that enable individuals to successfully and consistently perform an activity or task and can be built upon and extended through learning.' [1]

To support the design of our qualifications, the Pearson Research Team selected and evaluated seven global 21st-century skills frameworks. Following on from this process, we identified the National Research Council's (NRC) framework [2] as the most evidence-based and robust skills framework, and have used this as a basis for our adapted skills framework.

The framework includes cognitive, intrapersonal skills and interpersonal skills.

The NRC framework is included alongside literacy and numeracy skills.



The skills have been interpreted for this specification to ensure that they are appropriate for the subject. All of the skills listed are evident or accessible in the teaching, learning and/or assessment of the qualifications. Some skills are directly assessed. Pearson materials will support you in identifying these skills and in developing these skills in learners.

The table overleaf sets out the framework and gives an indication of the skills that can be found in Applied Science, it indicates the interpretation of the skills in this area. A full interpretation of each skill, with mapping to show opportunities for learner development, is given on the subject pages of our website: qualifications.pearson.com

---

[1] OECD – *Better Skills, Better Jobs, Better Lives* (OECD Publishing, 2012)

[2] Koenig, J. A. (2011) *Assessing 21st Century Skills: Summary of a Workshop* (National Academies Press, 2011)

Cognitive skills	Cognitive processes and strategies	Critical thinking Problem solving Analysis Reasoning/argumentation Interpretation Decision making Adaptive learning Executive function
	Creativity	Creativity Innovation
Intrapersonal skills	Intellectual openness	Adaptability Personal and social responsibility Continuous learning Intellectual interest and curiosity
	Work ethic/ conscientiousness	Initiative Self-direction Responsibility Perseverance Productivity Self-regulation (metacognition, forethought, reflection) Ethics Integrity
	Positive core self-evaluation	Self-monitoring/ self-evaluation/ self-reinforcement
Interpersonal skills	Teamwork and collaboration	Communication Collaboration Teamwork Cooperation Empathy/perspective taking Negotiation
	Leadership	Responsibility Assertive communication Self-presentation

Developing the ability to make a persuasive case in the fields of applied science and new technologies, supporting one or more arguments, including the ability to create a balanced and evaluated argument.

Taking responsibility for finding and correcting anomalies in regimes.

Appendix 3: Glossary of terms used

This is a summary of the key terms used to define the requirements in the units.

Term	Definition
Examine	Knowledge with application where learners are expected to select and apply knowledge to less familiar contexts.
Explore	Skills and/or knowledge involving practical testing or trialling.
Review	Process for learning (knowledge or skills).
Undertake	Skills, often referring to given processes or techniques.
Understand	For defined knowledge in familiar contexts.
Analyse	Learners present the outcome of methodical and detailed examination either: • breaking down a theme, topic or situation in order to interpret and study the interrelationships between the parts and/or • of information or data to interpret and study key trends and interrelationships. Analysis can be through performance, practice, written or, less commonly, verbal presentation
Apply	Application of skills, knowledge and understanding to or within context/situation.
Assess	Learners present a careful consideration of varied factors or events that apply to a specific situation or, to identify those which are the most important or relevant and arrive at a conclusion.
Calculate	Learners manipulate quantitative data to help analyse and compare findings.
Compare	Learners identify the main factors relating to two or more items/situations or aspects of a subject that is extended to explain the similarities, differences, advantages and disadvantages.

Term	Definition
Conduct/use (of)/carry out	This is used to show depth of knowledge through selection and isolation of characteristics.
Construct	Related to use and demonstration of practical equipment/techniques/ procedures.
Describe	Learners' work gives a clear, objective account in their own words showing recall and, in some cases application, of the relevant features and information about a subject.
Determine	Use of this verb normally requires breadth of content coverage.
Discuss	Learners consider different aspects of: • a theme or topic; • how they interrelate; and • the extent to which they are important. A conclusion is not required.
Evaluate	Learners' work draws on varied information, themes or concepts to consider aspects such as: • strengths or weaknesses • advantages or disadvantages • alternative actions • relevance or significance. Learners' inquiries should lead to a supported judgement showing relationship to its context. This will often be in a conclusion.
Explain	Learners' work shows clear details and gives reasons and/or evidence to support an opinion, view or argument. It could show how conclusions are drawn (arrived at). Learners are able to show that they comprehend the origins, functions and objectives of a subject, and its suitability for purpose.
Illustrate	Learners include examples, images or diagrams to show what is meant in a specific context.
Investigate	Knowledge based on personal research and development.

Term	Definition
Justify	Learners give reasons or evidence to: • support an opinion • prove something right or reasonable.
Predict (make predictions)	Learners can synthesise predictions using applications of relevant knowledge and understanding in a given context.
Prepare	Used with a standard to demonstrate competence in preparation of testing materials, for example, organic and inorganic substances/solutions.

For information about Pearson Qualifications, including Pearson Edexcel BTEC qualifications visit qualifications.pearson.com

Pearson Education Limited. Registered in England and Wales No. 872828
Registered Office: 80 Strand, London WC2R 0RL.

VAT Reg No GB 278 537121

Pearson
BTEC

Publication code:
VQ000528