Unit 7: Principles and Applications of Physics II

Delivery guidance

This unit explores the main concepts that form the foundations of our understanding of thermodynamics. This is an important unit for learners as it is linked with two vast areas of physics: material stress and strain, and radiation. A sound understanding of these areas will be essential for learners going into a range of industrial and energy sectors.

Approaching the unit

This unit is integral to all aspects of work in material and energy production industries.

A range of delivery methods can be used to engage all types of learner and learning style, for example:

- practical work on power, work done and efficiency
- opportunities to practice calculations and use formulae
- tutor-led presentations to introduce topics and ensure understanding
- visits from or to companies involved in industry testing of materials/fluids for domestic and industrial applications and/or uses of radioactivity
- small group work to research topics, followed by presentation of facts to the rest of the class
- simulations and computer modelling.

Videos, documentaries, newspaper articles and scientific articles can be used to stimulate debate and contribute to knowledge and understanding of the unit.

Approaching the unit

Learning aim A focuses on thermal physics, materials and fluids. Learners must develop an understanding of the units used to measure power (watts, kilowatts, megawatts, gigawatts), temperature (°C and K) and pressure (Pa and Nm−2). Learners must be able to use three formulae to calculate work: work done as energy transferred, work done as force × distance moved in direction of force, work done by a gas as pressure × change in volume of gas. They must also become confident in calculating efficiency. Learners will gain knowledge of heat energy, its transfer and importance in domestic and industrial systems. They will learn about the properties and uses of different materials and their behaviour under conditions of stress and strain, as well as behaviour of fluids in motion.

Learning aim B investigates the properties and uses of radioactivity. It covers atoms and atomic structure. Learners will develop an understanding of ionising radiation, radioactive decay and half-life, and the principles of nuclear fission. They will learn about applications of radiation in medical, industrial and military capacities. They will also consider health hazards linked with radioactivity.

Assessment model

Learning aim	Key content areas	Recommended 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.

Assessment guidance

This is an internally assessed unit. There are no practically assessed criteria, but practical work could allow learners to acquire the knowledge and understanding required to produce evidence for assessment that outlines, describes, explains, analyses and evaluates thermal physics, materials, fluids and properties and uses of radioactivity.

Give learners assignment briefs as early as possible so they can see how they will be assessed.

There is a maximum of two summative assignments for the unit, one for each learning aim. A holistic approach to the pass, merit and distinction criteria is required.

Learners must give independent, valid and authentic evidence to meet the assessment criteria. Secondary sources must be referenced, and learners are expected to produce a bibliography.

The report should be written up to a high standard. Use examples of other scientific reports to show learners the common themes and have them recognise these. consider diagrams and the correct manner in which to use them within scientific reports. The centre may have its own ideal format for giving a presentation which learners should adhere to if you so choose or another system may be employed.

Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 7: Principles and Applications of Physics II

Introduction

This unit delivers a knowledge of materials and their make-up alongside thermal physics and fluids. It also covers radioactivity and atomic structure, the associated energy production and its uses. A range of laboratory resources will be required for practical work, including wires made of various metals, retort stands, clamps, weights, pullies, Geiger counters, and sources of radiation. Appropriate health and safety regulations and risk assessments must be in place and met.

Learning aim A Understand thermal physics, materials and fluids

- Begin by introducing learners to the learning environment, detailing the centre's health and safety features, fire escapes, procedures, laboratory PPE and any other relevant housekeeping requirements.
- Introduce the unit by asking learners to list everything they expect to learn during its delivery. These lists can be used to assess learners' attitudes, opinions and current level of knowledge. A visual, auditory, read/write and kinaesthetic (VARK) test would help you to understand learners' learning styles.

A1

- Introduce this aim by writing the words 'power' and 'watt' on the board. Ask learners to discuss what they think is the difference between these words, then ask them to write a definition for each word.
- Give a presentation on power and watts, defining each term. Learners should record these definitions in a glossary of terms, which they will build on throughout the delivery of the unit so they can quickly check words when necessary.
- Ask learners to work in small groups to describe how they think temperature is measured (what the measurements actually measure, rather than the names of the units). Ask learners to share their ideas with the class and build on this to explain how temperature is measured, detailing Celsius and Kelvin scales.
- In groups, ask learners to consider what they think pressure is and how it is measured. Give a presentation on Pascals and N m^{-2}.
- Demonstrate how a Newton is measured using a pendulum. By adding differing weights to the pendulum and swinging them against a 1 kg weight, try to knock the 1 kg weight 1 metre in 1 second. Discuss the limitations of this demonstration due to air resistance, temperature and friction acting on the 1 kg weight.
- Ask learners to research the term 'work' (this could be a homework exercise or a class activity). Ask learners to share their ideas with the class.
- Give a presentation on 'work'. Then ask learners to work in small groups to devise an experiment they could carry out to calculate the work done by an object. Provide equipment

such as pulleys, scales, springs, weights and wires. This is a simple experiment, but it can be made to fit the space available, from pushing a toy car across a table to pushing a real car across a car park. Demonstrate to learners how to complete the necessary calculations to find the work done. Observe other forces acting on the experiment which could affect the results. Consider how and if these forces can be removed. Emphasise the importance of reviewing limitations in any experiment.

- Introduce the subject of efficiency by asking learners to work in small groups to explain or define what 'efficiency' means. Ask learners to share their ideas with the class.
- Lead a practical session that demonstrates efficiency and teaches learners how to calculate efficiency. For example, observe the basic movement of an object up a ramp and then alter the movement by limiting the barriers to efficiency (perhaps by adding a lubricant or by changing the angle of the ramp).
- Compare this with an experiment which demonstrates the efficiency of an engine and its products of 'waste energy' such as excess heat. Consider how the engine can be made more efficient.
- Talk to learners about maximum theoretical efficiency. Show videos which explain developments in this area and give examples of the most efficient systems we have managed to produce.
- Ask learners to research systems that claim to be the most efficient of their kind in terms of minimum loss of energy. Learners should share their findings with the group.
- Lead a practical session to teach learners about work done by a gas in the form of pressure. You could do this using a pump, a pressure meter and a tyre and blowing air into the tyre. You could also use a video or diagram to show the change in volume of the gas. Summarise the practical session by posing questions to the entire class and then selecting learners at random to answer.
- Give a presentation on the law of conservation of energy. Explain the concept of a perpetual motion machine and why it cannot possibly exist, referring to the law of conversation of energy and thermodynamics.
- Explain the ideal gas equation and the associated calculations using pressure, volume and temperature. Set up a demonstration which shows the first law of thermodynamics.
- Discuss the idealised engine cycle and its association with thermodynamics. Build on this to discuss isothermal and adiabatic processes. Use a plenary quiz to check learners' understanding.
- Introduce changes of state of substances used in domestic and industrial processes by writing three words on the board: 'ice', 'water' and 'steam'. Ask learners to write down the six words that describe the changes of state between ice, water and steam. This is likely to challenge learners, so give a presentation on material states and their changes, paying particular attention to gas-to-solid (deposition) and vice versa (sublimation).
- Use diagrams to show the density and structure of atoms within materials in these different states. Explain how changes of state are used in domestic and industrial processes, for example, within a refrigerator, the 'smoke' created by dry ice, or an engine.
- Demonstrate latent heat to learners by setting up a beaker of water. Monitor its slow evaporation through the coming weeks. Demonstrate the latent heat of fusion by melting ice with and without a heat source and comparing the weight of ice melted from both.

- Learners should perform calculations to find the specific latent heat of fusion of ice. You could generate the data required using a heating element in ice connected to a voltmeter and bench power supply and recording the temperature. Learners measure the time taken for the ice to melt and find the total energy used to melt the ice from power = current × voltage.
- Produce a worksheet to test learners' understanding of thermal energy and their ability to work out the energy required to melt/freeze given amounts of ice/water.

A2

- Introduce this learning aim by discussing stress, strain and elasticity with learners. Ask learners to define each term.
- Give a presentation on elasticity, stress–strain curves, elastic limit, strength, yield point, creep, fatigue, ductility, brittleness, malleability and elastic hysteresis, and how these ideas are relevant in domestic and industrial applications. Apply these terms to different materials so learners understand how to use this information in different industries.
- Arrange a site visit to a manufacturer where the stress and strain of materials are measured as part of the process of testing products. Give learners time to talk to representatives about routes into employment.
- Teach learners how to calculate compressive and tensile stresses and strains acting on a material. Give learners a worksheet detailing the stresses and strains of different materials and ask them to work out Young's modulus for each material; support learners as necessary. Discuss factors that may change the Young's modulus of a material, such as different levels of purity.
- Give a presentation on the difference in density of atoms in solids, gases and liquids. Set up an experiment which shows tensile compressive stress and strain.
- Explain the application of Young's modulus and how to work this out. Then discuss Hooke's law in relation to the stretching and compression of a wire or a spring's elastic strain.
- Introduce fluid flow patterns by putting learners in groups and asking them to explain every way in which a liquid can move or interact with anything else.
- Demonstrate fluid flow patterns and how streamlining can prevent turbulent flow. Show fluids with different viscosities, explaining that flow per second is constant within a pipe or stream tube; make connections with Newtonian fluid flow.
- Show learners how flow and turbulence are affected by pressure. Use a venturi meter to show Bernoulli's principle and demonstrate a Tesla valve and how it works in relation to turbulence.
- Introduce the assignment for learning aim A and answer any questions about it. Give learners time to:
    - plan their report and
    - review any work they have carried out already to fulfil the requirements of the assignment
    - carry out experimental work and research
    - begin writing up their experiments, describing, explaining and analysing their

findings.

Learning aim B: Investigate the properties and uses of radioactivity

B1

- Introduce learning aim B by revising the structure of an atom. You could ask learners what they think of when they imagine an atom. Lead a group discussion about their initial thoughts regarding atoms and ask them to produce diagrams of what they think an atom looks like.
- Show some examples of atoms on the board or as part of a PowerPoint presentation, without labelling them. Ask learners to point out the differences between them and to label them differences using the correct terms.
- Give a presentation on the components of an atom and label the diagrams as new subjects are introduced. Ask learners to produce their own diagrams of different atoms. Define the term relative atomic mass and explain the difference in the shells of different atoms.
- Give a presentation on the experiments carried out by Rutherford, Geiger and Marsden. Include shooting alpha particles at gold sheets and how their deflection demonstrates atomic structure as it is still recognised today. Your presentation could include video clips and diagrams to explain the experiments. Explain the history of thoughts on the structure of atoms that have been used to formulate the model we use today.
- Introduce the periodic table of the elements. Give each learner a copy of the periodic table to keep for future reference and ask them what they already know about it, in terms of the symbols and numbers on it.
- Give a presentation about atomic number and atomic mass and how they are worked out, to build on learners' background knowledge. Use diagrams to illustrate your points.
- Give learners a worksheet with diagrams of atoms and ask learners to work out their atomic structures, mass and numbers, and to identify the elements. Learners should use the periodic table to help them.
- Give a presentation about isotopes. Show learners how to write isotope symbols. Explain the circumstances necessary for different isotopes of elements to be formed, both in nature and in the lab. Discuss the applications of isotopes in industry and in domestic situations.
- Give a presentation on nuclear force and electric force. Explain how the stability of a nucleus depends on protons and neutrons within the atom. Use diagrams to show what happens when atoms become ions or molecules with covalent bonds and how this links with atomic stability. (Refer back to the presentation about the periodic table and the location of elements within the table; explain how this corresponds with their behaviour in terms of forming ions or molecules.) Discuss how to balance equations. Give learners examples of unbalanced equations and ask them to balance them.

B2

- Introduce this learning aim by giving a presentation on radiation. Make links with electric force and nuclear forces in atomic nuclei.
- Explain radioactive decay, half-lives and how they are calculated. You could use computer modelling or a coin-tossing exercise to demonstrate the randomness of a half-life. Discuss Marie Curie and her original findings in the field of radioactivity, as well as the history of other notable radiation scientists. Show learners a Geiger counter and demonstrate how it

works.

- Give a presentation on ionising radiation, explaining that alpha radiation is most likely to cause ionisation of an atom, followed by beta radiation and then gamma radiation. Use diagrams and videos to demonstrate what happens when an atom is ionised by a radioactive particle, paying particular attention to the transformation of the nucleus in relation to alpha and beta decay principles.
- Explain how a magnetic field acts on atoms and how electrons create their own magnetic fields under different circumstances. Ask learners to produce diagrams showing how radiation affects atoms and what happens during ionisation. They could use these diagrams to produce a poster, to be displayed in the learning environment. Test learners' understanding using a quiz.
- Give a presentation on nuclear fission. Describe how nuclear fission is carried out in a controlled manner to produce energy. Explain what happens at an atomic level, using diagrams and videos to show how neutrons interact with the atomic nuclei. Review the lighter elements and release of energy in chain reactions.
- Discuss nuclear energy, considering positives and negatives, strengths and weaknesses, as well as the long-term effects on us and our environment. Using samples, videos and diagrams, show learners how a Geiger–Müller tube works to detect different sources of ionising radiation.
- Discuss the use of a scintillation counter, its applications and history. Ask learners to produce a poster or an instruction guide explaining how a Geiger counter works.
- Following your centre's guidelines with regards to radioactive sources, and after a health and safety briefing, demonstrate how to use a Geiger counter with different sources of radiation to assess what the different sources are.
- Ask a guest speaker from an industry that uses radiation to give a talk on the health hazards of working in their industry. Video conferencing could be used to make this more accessible for learners. The speaker should consider PPE, signs of ill health and safety features in place in their workplace.
- Give a presentation on background radiation, considering different sources. Include naturally occurring radon gas in the south west of England, cosmic rays, medical products and nuclear power production. Illustrate cosmic radiation by leaving a Geiger counter on, measuring background radiation during the lesson.
- Use documentaries and historical news reports to illustrate nuclear power station accidents, such as those at Chernobyl and Fukushima.

  Discuss the causes and effects of these incidents, and the current efforts being made to control the aftermath. Review what went wrong to cause the accidents and what measures have been put in place to avoid such disasters happening again. Learners should produce a piece of work summarising the effects of nuclear power station accidents. This could be presented as a warning for somebody who is about to start working in a nuclear power station.
- Review learners' understanding so far. You could do this using a class discussion, asking learners to identify the areas of the unit with which they feel confident and those they feel they need to work on.

B3

- Introduce uranium-235 by describing its discovery and its history in science. Explain how uranium-235 is split through fission and how the resulting chain reaction releases energy to drive turbines in nuclear power stations. Ask learners to produce a diagram of the processes involved in using uranium-235 to create energy. They should consider how energy is converted during these processes.
- Put learners into groups and ask them to produce a SWOT (strengths, weaknesses, opportunities, threats analysis or PESTLE (political, economical, social, technological, legislative and environmental) analysis of nuclear energy and our reliance on it.
- Introduce radiocarbon dating by giving learners samples of rocks and asking them to guess how old they are. It is unlikely they will be able to do this accurately (although some may be able to make geologically supported guesses based on rock make-up). Then explain how radiocarbon dating works and discuss its uses and limitations.
- Introduce radioisotope dating and explain that this can be used where radiocarbon dating fails.
- Ask a visiting speaker to give a talk on X-rays and gamma radiography. Encourage learners to talk to the speaker about the industry in which they work and the route they took to get a job in that area. This will develop learners' social skills and build links with industry.
- Give a presentation on the uses of radioactive tracers in medicine. Show examples of X-rays and compare them with images produced using radioactive tracers such as barium.
- Lead a class discussion to asses learners' knowledge of nuclear weaponry.
- Give a presentation on the production of plutonium for nuclear weapons. Describe the differences between gun-type nuclear bombs and implosion-type bombs. Detail the implications of nuclear war and the long-term effects, both locally and nationally, of nuclear weapons. Explain the UN rulings on nuclear weapon ownership by different countries.
- Discuss the second assignment, hand out the assignment brief and answer any questions.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- Unit 3: Principles and Applications of Physics I
- Unit 22: Medical Physics Applications
- Unit 23: Materials Science
- Unit 28: Sustainable Energy

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International Level 3 in Applied Science. Check the Pearson website at http://qualifications.pearson.com/endorsed-resources for more information as titles achieve endorsement.

Textbooks

- Mannie Shuler, J., *Understanding Radiation Science: Basic Nuclear and Health Physics*, Universal Publishers, 2006, ISBN 978-1-581-12907-6 – Provides a basic understanding of radiation science.
- Chadwick, K., *Understanding Radiation Biology: From DNA Damage to Cancer and Radiation Risk*, CRC Press, 1st edition, 2019, ISBN 978-0-367-25376-9 – Provides a qualitative and quantitative exploration of the action of radiation on living matter.

Journals

- *Journal of Nuclear Medicine and Radiation Therapy*
- *Practical Radiation Oncology*
- *Nuclear Engineering and Design*

Videos

- HBO's 'Chernobyl' – A dramatisation of the events of the Chernobyl nuclear power plant disaster.

You may wish to search YouTube for the following titles:

- Nuclear Energy Explained: How does it work? (three parts)
- Elasticity & Hooke's Law – Intro to Young's Modulus, Stress & Strain, Elastic & Proportional Limit

Websites

- United Nations – This website contains some interesting information about nuclear weapons and nuclear energy. Searching the UN site for 'nuclear'.
- World Nuclear Association – This website has information about nuclear energy.
- BSI (British Standards Institution) – This website has some useful information about testing the tensile strength of metallic materials. Go to the UK part of the BSI website, then searching for 'standard for testing tensile strength of metallic materials'.

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling students to access them through the school/college intranet.