Unit 44: Astronomy

Unit code: F/502/5614

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to enable learners to study the fundamental principles of astronomy. It also allows access to more in-depth study of astronomical concepts and aims to develop learners' investigative skills.

Unit introduction

Understanding the nature of the Universe and our place within it has long been of interest to humans. It is important for learners to appreciate that the study of astronomy will lead to more questions than solutions and that this subject will give them with many fascinating facts and theories and an insight into human innovation and adaptability.

Space science has numerous associated industries:

- materials and manufacturing
- mechanical and electrical engineering
- computers, communication, design
- chemical research and engineering
- education and practical research
- aeronautics and aerospace.

This unit aims to develop knowledge and understanding of the key areas in astronomy and space flight and of the links between these exciting topics and related industries. Learners will be able to apply skills learned to other areas of study and to workplace practices.

Learners will study the Solar System and will gain an appreciation of the advances made in space flight. Different scientific disciplines will be encountered at various stages as the unit unfolds, so developing analytical, investigative and research skills. Knowledge of key Solar System objects will lead to accurate night sky positioning and star mapping with ample opportunity for both short and long duration practical observation.

Learners will be introduced to the many factors associated with space flight and will be given an insight into the practicalities and problems in propelling an object beyond the Earth's atmosphere and sustaining an orbit. The realities of interplanetary missions will come into focus and should help to identify the difficulties of making progress when faced with such extreme environments.

Concepts introduced in astrophysics and cosmology will serve to focus learners' attention on areas which still pose many unanswered questions. Learners will develop an understanding of how physical laws are slowly opening doors to our understanding of complex deep space phenomena and gain an appreciation of the limitations which exist.

Learning outcomes

On completion of this unit a learner should:

1 Know the components within our Solar System

2 Be able to observe astronomical objects

3 Know the factors involved in space flight

4 Understand concepts in astrophysics and cosmology.

Unit content

1 Know the components within our Solar System

The Sun as a typical star: structure (corona, photosphere, convective zone, radiation zone, core); nuclear fusion, mass-energy conversion E=mc2 and proton-proton chain; features (prominences, flares, solar wind, solar spectrum, Sunspots and cycles); physical parameters (diameter, average distance, rotation, mass, surface and core temperatures)

The Earth-Moon system: internal structure of the Earth (crust, mantle, core, atmospheric composition); rotations; orbital characteristics; Van-Allen belts; lunar features (surface detail, impact craters, phases, eclipses, composition, orbital characteristics, rotation, gravitational effects)

Inner and outer planets: rocky and gaseous differentiation, main features of planets (Kepler's laws, orbital plane and periods, distances, masses, diameters, ring systems, surface features)

Planetary moons, the asteroid belt, comets and meteors: numbers of moons orbiting the planets; characteristic features of sample moons (surface, diameters, masses); asteroid belt position; features of largest asteroids, eg NEAR Shoemaker to Eros; Kuiper belt and short period comets; long period comets and compositions; meteor showers; meteor composition (stony, stony-iron, iron)

2 Be able to observe astronomical objects

Earth-based observational instruments: reflector telescopes (ray diagrams, focal point of concave mirror); merits of reflector/refractor design; aspects of image clarity (spherical and chromatic aberration, resolving power); charge coupled devices (CCD's); radio telescope design

Space observatories: microwave (Wilkinson Microwave Anisotropy Probe (WMAP)); infrared (Spitzer, James Webb Space Telescope (JWST)); visible (Hubble Space Telescope (HST)); ultraviolet (HST); x-ray (Chandra, XMM-Newton); gamma ray (Integral, Fermi Gamma Ray Telescope); solar (Solar and Heliospheric Observatory (SOHO), Hinode)

Night sky mapping and observation: constellations; apparent motion of the planets and Earth's moon; identifying stars; observational techniques; celestial coordinates (Right Ascension (RA) and declination (dec), altitude and azimuth, zenith, celestial equator, the ecliptic); the Pole Star; the Milky Way; identification of primary star catalogue objects, eg bright naked eye objects; sporadic or shower meteors; Galilean moons of Jupiter; phases of Venus; angles of Saturn's rings

Day time observation: motion of Sun and Moon; principle of the sundial; sunspot activity by projection; eclipses and transits

3 Know the factors involved in space flight

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)

Space flight practicalities: spacesuit design features; costs; distance and time; communications; effects on humans (radiation exposure, micro-gravity environment, psychological)

Escaping the Earth and other planetary bodies: gravitation; escape velocity; use of 'gravity assist'

Applications: materials and manufacturing; computer programs; satellite search and rescue systems; intensive care monitors; micro-electromechanical systems; TV, communications, meteorology, Earth resources

Spaceflight future: International Space Station (ISS); proposed inter-planetary manned and unmanned missions; space tourism, eg Spaceship 1, Genesis 1 space hotel

4 Understand concepts in astrophysics and cosmology

Birth of stars: giant molecular clouds, gravity, collapse, fragmentation (Jean's mass); internal temperature rise, initial nuclear reactions (lithium, deuterium); pressure balance (equilibrium); protostar; slower evolution to main sequence

Properties of stars: physical and chemical characteristics, mass, luminosity, apparent magnitude, absolute magnitude, $m\text{-}M = 5 \log d/10$, black body radiation, spectral classes, absorption lines, Hertzsprung-Russell (HR) diagram

Death of stars: mass relation to life cycle; core collapse; red giants; white dwarfs; electron-degenerate matter, Chandrasekhar limit; supernovae; neutron star, pulsars; black holes, event horizon, Schwarzschild radius, singularity; stellar spectral energy distribution, temperature

Astronomical dimensions: units, Astronomical Unit, light year, parsec; methods of measuring distance, parallax, Cepheid variables, brightness variation, eclipsing binaries; redshift, Doppler effect

Universe origin and evolution: galaxies (formation, classification, dark matter); quasars; the big bang; Hubble's law, the age of the Universe; critical density, dark energy, the fate of the Universe

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 outline the main features of the Sun, Earth and Moon [IE1,2; CT2]	**M1** describe the main features associated with the Solar System	**D1** explain the forces affecting, and the processes taking place in the Sun
P2 outline the characteristic features of other Solar System objects [IE1,2; CT2]		
P3 describe Earth-based observational instruments and space observatories [CT2]	**M2** analyse the results of the observations, producing viable conclusions	**D2** evaluate the observations made, suggesting improvements to methods used
P4 carry out practical investigations, over a suitable time period, on night time and day time astronomical objects [RL2,3; TW1,2; SM3,4]		
P5 describe the factors involved with space flight [IE1,2]	**M3** explain the implications of space flight for manned and unmanned missions	**D3** evaluate the benefits of space flight and space research
P6 explain the stages and processes involved in the life cycle of a star [IE1,2]	**M4** discuss the variations of star types which occur	**D4** evaluate the methods used to determine the characteristics of stars and to determine distance of astronomical objects.
P7 illustrate how distance can be measured in astronomy [TW1,2; SM3,4]	**M5** explain the different methods of determining distance to astronomical objects.	
P8 discuss the theories for the origin and fate of the Universe. [EP6]		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key			
	IE – independent enquirers CT – creative thinkers	RL – reflective learners TW – team workers	SM – self-managers EP – effective participators

Essential guidance for tutors

Delivery

The learning outcomes in this unit should be delivered through a programme of tuition, facilitated learning and practical investigative work. Tutors need to address health and safety issues for observations of solar activity and independent night-time activities.

For learning outcome 1, tutors should provide a comprehensive overview of the most up-to-date knowledge of our Solar System and the components within it. The internal structure of the Sun, Earth and Moon will serve to highlight the variation in terms of 'activity' which prevail in these objects and demonstrates the differences between stars, planets and moons. The Sun's effect on all objects in the Solar System, and those objects which have extremely long orbital periods (eg comets), should be emphasised to illustrate the extent of the Sun's gravitational field and the limits of the Solar System. The definition in this unit of 'other Solar System' objects and features refers mainly to everything apart from the Sun, Earth and Moon. The amount of information for these is now vast and tutors may wish to deliver just the essential aspects and simply allow learners to develop a detailed case study of one feature from the list provided.

It is important for learners to fully appreciate the health and safety aspects of astronomical observations and all other practical activities which will be carried out in learning outcome 2. Experimental work on telescope construction will concentrate on reflectors and refractors and associated ray diagrams. The physics for this section can be quite involved but the emphasis should be placed firmly on practical investigation. Observations using wavelengths other than the visible range can be delivered using a list of Earth-based radio and satellite telescopes and text or internet images produced. Actual astronomical observations and mapping are fundamental to the completion of this unit and to the development of important transferable skills. Solar observations must be carried out using the projection method and should be supervised. Parental contact should be made to ensure that out-of-hours observations by learners are safely conducted. Tutors must provide adequate guidance to ensure that learners can identify regions of the sky quickly and to minimise the time spent on observations.

Learning outcome 3 deals with the practicalities of space flight and includes spacecraft design, useful spin-offs from space research and the future of space travel. This section leaves aside the essential astronomical principles of the unit and introduces the fundamentals of space flight. Learners should develop an understanding of the design aspects of spacecraft and the rockets required to achieve orbit. Tutors can deliver this section by asking 'how can we get into space?', and develop group activities to produce reporting or complete space craft designs. The contextual nature of this topic should enhance the learning experience by illustrating that the progress made in space flight has had real impact in terms of biological, chemical and physical advances. Tutors should ensure sufficient internet access to meet the demands of the research necessary to complete this learning outcome, particularly in relation to materials development and commercial space ventures.

Learning outcome 4 requires learners to demonstrate the principles of distance measurement and to report on the techniques used for deep space objects. Tutors need to explain the various stages in the life of a star and show how these fundamentals help in our understanding of the development and demise of almost all known objects in the Universe. The HR diagram can be detailed at length and related to observed stars, for example, in learning outcome 2. Learners can discuss all the relevant information provided for the origin and fate of the Universe and make an informed decision as to what they believe will be the eventual outcome. This learning outcome is likely to be delivered best by a combination of formal lecture, practical task, computer aided modelling, group discussion, independent research and visits to related educational lectures.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction to unit and programme of assignments.
Outline *Unit content* and investigative procedures.
Theoretical session working towards assignment. • The Sun in cross-section and internal processes, spectral lines. • The Earth and Moon in cross-section and surface features/characteristics. • Case studies eg Cassini to Titan, Eros NEAR Shoemaker landing, van Allen zones. **Assignment 1 – Solar System Objects (P1, P2, M1, D1)**
Investigation: Telescopes and celestial objects. • Determination of focal point of concave mirror. • Making a refractor telescope. • Mapping motion of planets, Jupiter moons, Saturn ring angle. • Sunspot motion across face using projection onto angular sectioned screen. Determine Sun's rotational speed; possible links with weather patterns? **Assignment 2 – Looking Further (P3, P4, M2, D2)**
Theoretical and practical: Problems of space flight, solutions, development. • Fuel systems – advantages/disadvantages. • Physiological effects of spaceflight – poster showing areas affected and solutions. • Report based on useful products currently in use from space research. • Design a re-usable space craft for commercial use. **Assignment 3 – Getting into Space (P5, M3, D3)**
Theoretical and report: Life cycle of stars and possible outcomes, research style project dealing with protostar development through main sequence and eventual outcomes. Variations depending on mass. Key word vocabulary. **Assignment 4 – Recycling Stellar Material (P6, M4, D4)**
Project and practical: Distance measurement and cosmology. Determining object distance using laser and trigonometric methods. **Assignment 5 – How Big Is the Universe? (P7, M5, D4)** Report on methods used for astronomical distances. Review current theories of fate of Universe. Strengths and weaknesses. **Assignment 6 – Beginnings (P8)**
Review of unit and programme of assignments.

Assessment

Suitable evidence can include well-presented posters, presentations, reports, scientific investigations, research work, and observation logbooks.

To meet the requirements of learning outcome 1, P1 learners need to outline the main features of the Sun, Earth and Moon. This should include a brief definition of structure, forces involved, orbital characteristics, rotation, phases, atmospheric compositions and physical data. In addition, learners should outline, by written or diagrammatic form, the other Solar System objects which will include all the known planets, prominent moons, asteroids, comets, meteors and characteristic associated features in order to achieve P2.

M2 grade learners should work with more independence and produce descriptions of the main features within the Solar System. This can include details of planetary axes of rotation; composition of planets, moons, asteroids, comets and meteors; planetary ring system labels; Van Allen radiation zones; surface features etc.

D1 grade learners should explain in depth the natural forces allowing the Sun to remain in equilibrium and the eventual outcome when these forces change. Learners should explain the process of nuclear fusion and detail the magnetic forces on the surface and their associated effects.

Learning outcome 2 assesses the ability of learners to carry out practical investigation. P3 and P4 grade learners should 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. Ray diagrams should be produced. Learners must also produce a log demonstrating observations of some aspects of the night sky and of the Sun. These activities should be carried out over a suitable time period and night sky observations should be set against their constellation position where appropriate. To achieve P3 learners must describe instruments used in space observations. Pass grade learners should show some degree of accurate star mapping. To achieve M2 learners need to analyse the results from their observations and draw suitable conclusions. Observation of the night sky and solar activity should show accuracy and precision and it is suggested that these objects are taken from those provided in the *Unit content* section which require the use of a telescope.

For D2, observations must be evaluated and improvements suggested. Errors must be identified and comments made. Data collected should be represented in a suitable format and all observations set against an accurately illustrated star map.

For learning outcome 3, P5 grade learners must produce a comprehensive list of the various factors which need to be considered to achieve space flight. The list should include, for example; materials, fuels, escape velocity, hazards, costs, communication and effects on humans. A brief description of each must be included.

M3 grade learners must explain the effects of space flight on the human body in detail 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. Evidence can take the form of a large poster or booklet with clear labelling of the specific areas of the body that are affected.

To achieve D3 learners, in addition, should produce a well worded report depicting examples of the products used in everyday life which have been developed as a direct result of space flight and research. It should be sufficient to outline at least two products from each category listed in the Unit content. Work should be largely independent and research evidence must be included as references and bibliography

For learning outcome 4, P6 grade learners must develop a clear document or sketch which illustrates the various stages of a star's life and the different outcomes which can result from mass variations. Brief notes should accompany each stage. Learners must include brief comments outlining the principles of distance measurement used by astronomers for P7. Part of this criterion may be achieved using a practical method or essential diagrams.

M4 grade learners should describe in some detail the variations of star types which occur, with some reference to the HR diagram. Spectral classes and the relationship with mass should be included and also examples, by name, of star types depicted. Explanations of the methods used to measure astronomical distances must show the limitations of trigonometric parallax to relatively short distances for M5. Learners should explain the principles behind Cepheid variables and eclipsing binaries and must also be able to appreciate the significance of the shift of wavelength from galaxies to indicate acceleration towards or away from our view point.

D4 grade learners must use the HR diagram extensively and relate the position of star types to its known characteristics. Exactly how astronomers are able to differentiate between stars should be evaluated by referring to luminosity, apparent and absolute magnitude, black body radiation, Wien's Law and absorption lines. Star spectral classes should be defined. Cosmological theories of present day need to be listed, explained and analysed. Learners should summarise relevant material and explain the concepts in a coherent report or argument. The essential physical laws which help to explain some key aspects should be used effectively.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, M1, D1	Solar System Objects	Technical journalist for scientific magazine.	Report including: • internal structure • main features • orbits and rotation • phases.
P3, P4, M2, D2	Looking Further	Observatory maintenance technician.	Practical sketches showing results of experimental work and ray diagrams. Observation log: • star maps • object locations • coordinates • sketches • time scales.
P5, M3, D3	Getting into Space	Manufacturing industry – testing materials and systems.	Information leaflet providing list of factors, materials, human effects, escape velocity, fuels.
P6, M4, D4	Recycling Stellar Material	Recruited to textbook publishing company.	Diagram designed to illustrate life cycle and variations.
P7, M5, D4	How Big Is the Universe?	IT technician developing computer modelling systems.	Report outlining distance definitions, example practical results, list of other methods.
P8	Beginnings	Science journalist	Article looking at the theory of how the universe originated and the scientific evidence for this.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Applied Science sector suite. This unit has particular links with the units shown below in the BTEC Applied Science suite of qualifications:

Level 2	Level 3
Energy and Our Universe	Fundamentals of Science
Exploring our Universe	Scientific Investigation
	Using Mathematical Tools for Science
	Informatics for Science

Essential resources

Learners must have access to suitable text material, equipment and the internet. Science departments delivering this unit should ensure that the following items are available:

- updated textbooks, scientific magazines and astronomical journals
- computer facilities, internet access, relevant CD ROMs, simulation models
- portable telescopes (min. 50 mm refr./100 mm refl.) binoculars (10 x 50 mm) and projection attachments
- optical physics equipment; lenses (converging and diverging), mirrors (concave spherical and parabolic if possible), suitable light sources.

Employer engagement and vocational contexts

There are now many industrial and manufacturing industries using modern methods of technology and materials science in their processes which have links with space research.

Visits can be arranged to: National Space Centre at Leicester (www.spacecentre.co.uk); museums; planetariums and science centres; materials manufacturers; National Maritime Museum (www.nmm.ac.uk); Royal Observatory, Edinburgh. The Rutherford Appleton Laboratory in Oxfordshire provides a lot of information on space research and leads the field in infrared observational equipment which will be used in the HST successor telescope (www.sstd.rl.ac.uk).

In addition, many universities have well-equipped laboratories for space studies which include telescope facilities. The National Schools Observatory (www.schoolsobservatory.org.uk) allows links with remote telescopes online.

Indicative reading for learners

Textbooks

Breithaupt J – *Understanding Physics* (Stanley Thornes, 1995) ISBN 9780748715794

Couper H – *Universe* (Cassell Illustrated, 2006) ISBN 9781844034376

Ellse M and Honeywill C – *Electricity and Thermal Physics* (Nelson Thornes, 2004) ISBN 9780748776634

Ellse M and Honeywill C – *Waves and our Universe* (Nelson Thornes, 2001) ISBN 9780174482994

Kerrod R and Scott C – *Hubble the Mirror on the Universe* (David & Charles, 2008) ISBN 9780715329238

Kitchin C R – *Solar Observing Techniques* (Springer Verlag, 2001) ISBN 9781852330354

Moore P – *Philip's Astronomy Encyclopaedia* (Philips, 2002) ISBN 9780540078639

Pople S – *Advanced Physics* (Oxford University Press, 1996) ISBN 9780199146413

Tirion W – *The Cambridge Star Atlas* (Cambridge University Press, 2001) ISBN 9780521800846

Journal

Journal of the British Astronomical Association

Websites

fermi.gsfc.nasa.gov	Fermi Gamma Ray Space Telescope
hubblesite.org	Hubble News
map.gsfc.nasa.gov	Wilkinson Microwave Anisotropy Probe
sohowww.nascom.nasa.gov/home.html	Solar and Heliospheric Observatory
solarb.msfc.nasa.gov	National Aeronautics and Space Administration
webbtelescope.org/webb_telescope	The James Webb Space Telescope
www.answers.com/topic/spacecraft	Definition of spacecraft
www.astronomy.ohio-state.edu	Department of Astronomy Ohio State Universty
www.britastro.org	British Astronomical Association
www.esa.int	European Space Agency
www.jpl.nasa.gov	NASA Jet Propulsion Laboratory
www.space.com	Space News
www.spacefuture.com	Space Future Journal
www.spitzer.caltech.edu/spitzer/index.shtml	Spitzer Space Telescope
www.thespacereview.com	Essays and Commentary on Space

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	[IE1,2] when conducting research, for example, into the features of the Solar System
Creative thinkers	[CT2] asking questions when carrying out research into, for example, the lifecycle of stars
Reflective learners	[RL3,4] carrying out accurate and precise observations and using results to inform changes to practice
Team workers	[TW1,2] working in a team, using practical techniques to establish short distance measurement of objects
Self-managers	[SM3,4] carrying out independent practical observations and measurements
Effective participators	[EP6] advocating views that may differ from own when discussing the origins of the universe.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	[IE3,4,6] making valid comments on the origins and fate of the Universe from current theories
Creative thinkers	[CT3,5] linking the methods of observation to the physics underpinning the methods
Team workers	[TW3,5] using research techniques in groups to explain the Earth-Moon characteristics
Self-managers	[SM1,2] using mathematical notes to explain the means of distance measurement.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using ICT facilities to conduct research; for simulation; remote telescopes; to present results from observations
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	using ICT to plan observations and evaluating the effectiveness of programmes used
Manage information storage to enable efficient retrieval	effectively store and manage research and observation information
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	using a variety of ICT resources (search engines; online journals) to research a topics, such as, features of the Solar System and lifecycle of stars
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	evaluating the suitability of information before using it in assignments
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	enter and format a variety of information on astronomical distances for an assignment
Present information in ways that are fit for purpose and audience	using the correct format, ie scientific report, essay or article, depending on its purpose
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	understand the complexity of measuring astronomical distances
Select and apply a range of skills to find solutions	apply the correct mathematical method to measure astronomical distance
Use appropriate checking procedures and evaluate their effectiveness at each stage	ensuring calculations are checked
Draw conclusions and provide mathematical justifications	draw conclusions from observations and measurements

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	taking part in discussions on complex issues of cosmology
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching information for assignments and to support tutorial sessions; understand texts and use them to form arguments in discussions and assignments
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	completing investigative reports and articles.