Unit 16: Astronomy and Space Science

Level: 3

Unit type: Internal

Guided learning hours: 60

Unit in brief

This unit covers the fundamental principles and present day understanding of developments in astronomy.

Unit introduction

During study of this unit, you will explore the main concepts which have formed the foundations of astronomy for hundreds of years. This unit aims to develop your knowledge and understanding of the key areas in astronomy and space flight and of the links between these exciting topics and related industries.

You will be able to apply skills learned to other areas of study and to workplace practices. The unit will focus on the study of the Solar System and you will gain an appreciation of the advances made in space flight and their applications on Earth. You will appreciate the different scientific disciplines which will be encountered at various stages as the unit unfolds. Skills in analysis, investigation and research will be enhanced. 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. You will be introduced to the many factors associated with space flight and will be given an insight into the practicalities and problems associated with propelling an object beyond the Earth’s atmosphere and sustaining an orbit.

The realities of interplanetary missions will be explored in light of current governmental and commercial plans for further development and you will develop an understanding of how physical laws are linked to complex deep space exploration missions. You will discuss the 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.

Study of this unit will allow progression to further education in related science, and possible introduction to the expanding space science working industry, involving astronomical data analysis, research and development.

Learning aims

In this unit you will:

**A** Examine 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 | Recommended assessment approach |
| **A** Examine the fundamental aspects of the Solar System | A1 Essential features and characteristics of the sun  A2 Main features, characteristics and relationship factors of the Earth and Moon  A3 Characteristic features of the inner and outer planets  A4 Characteristic features of other solar system objects | Scientific report and diagrams including use of terms and numerical values  Presentation style document outlining the main features and numerical values associated with Earth and Moon  Diagrammatic display and text information for all planets  Descriptions of smaller components with 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 and characteristics  B3 Mapping and observation of the night sky  B4 Daytime observation | Descriptions of important telescopes, optical and radio. Geographical positions.  Report on specific types of telescopes using the range of wavelengths in the e/m spectrum. 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 aspects  C2 Practicalities and physics of spaceflight  C3 Future of spaceflight and exploration  C4 Earth-based applications of space technology | Report on space craft materials using links to specified named vehicles. Conditions faced and required to overcome for space flight. Maths associated with speed, gravitational forces, re-entry conditions.  Case study: power-point space craft designs, Moon missions, Mars missions probes and space stations, international plans  Report on space spin-offs developed from the space industry and examples of research activities undertaken by Astronauts in space. |
| **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 evolution of the Universe and astronomical dimensions | Information poster outlining birth and death of stars of all categories. Includes stages and principle factors.  Report or display format of star characteristics linked to star formation and death. Detailed H/R diagram aspects.  Trigonometric parallax principles of distance measurement  Presentation of origin and end of universe – current theories outlined and evidence explained. |

Content

Learning aim A: Examine the fundamental aspects of the solar system

**A1 The Sun**

* structure to include corona, photosphere, convective zone, radiation zone, core
* nuclear fusion, mass-energy conversion E=mc2 and proton-proton chain
* features to include prominences, flares, solar wind, solar spectrum, sunspots and cycles
* physical parameters to include diameter, average distance, rotation, mass, surface and core temperatures
* analysis of spectrum range from telescope observation

**A2 The Earth-Moon system**

* internal structure of the Earth to include crust, mantle, core, atmospheric composition
* rotations and orbital characteristics
* Van-Allen belts
* lunar features to include surface detail, impact craters, phases, eclipses, composition, orbital characteristics, rotation, gravitational effects

**A3 Inner and outer planets**

* rocky and gaseous differentiation
* main features of planets
* Kepler’s laws – inverse square relation of distance with gravitational attraction
* orbital plane and periods, distances, masses, diameters, ring systems, surface features

**A4 Planetary moons, the asteroid belt, comets and meteors**

* numbers of moons orbiting the planets
* characteristic features of sample moons to include 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 period comets
* long period comets and compositions
* meteor showers
* meteor composition to include stony, stony-iron, iron

Learning aim B: Undertake measurement and observation of astronomical objects

**B1 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

**B2 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)

**B3 Night sky mapping and observations**

* 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

**B4 Day time observation**

* motion of 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 Space flight practicalities**

* 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 = /2gr
* use of ‘gravity assist’ eg. Voyager 1 and 2 case study

**C3 Spaceflight future**

* International Space Station (ISS) and its decommission
* proposed inter-planetary manned missions eg. ‘Inspiration Mars’, Mars landing, Orion
* Inter-planetary un-manned missions eg. James Webb Telescope, SOLO, Juno, Mars Exploration Rovers
* international missions eg. Russia, China, Japan, ESA
* space tourism, eg Spaceship 1, Genesis 1 space hotel, water purification, food, near zero gravity conditions for long duration, astronaut relationships, time and psychological aspects, problems of space debris

**C4 Applications**

* materials and manufacturing
* Health & Medicine, Transport, Public Safety, Industry, Computer technology, Consumers, Environmental and Agriculture
* orbital types including Geostationary (Parking) orbit for TV and communications eg. GPS, meteorology, Earth resources
* experiments carried out by Astronauts in space

Learning aim D: Understand the fundamental concepts outlined in astrophysics and cosmology

**D1 Birth of stars**

* giant molecular clouds, gravity, collapse, fragmentation (Jean’s mass)
* internal temperature rise, initial nuclear reactions (lithium, deuterium)
* pressure balance (equilibrium)
* proto star
* slower evolution to main sequence

**D2 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 star, pulsars
* black holes, event horizon, Schwarzschild radius, singularity
* stellar spectral energy distribution, temperature

**D3 Properties of stars**

* physical and chemical characteristics, mass, luminosity, apparent magnitude, absolute magnitude, m-M = 5 log d/10, black body radiation, star classification based on spectral analysis (O,B,A,F,G,K,M), absorption lines, Hertzsprung-Russell (HR) diagram

**D4 Astronomical dimensions, Universe origin and evolution**

* units, Astronomical Unit, light year, parsec
* methods of measuring distance, parallax, Cepheid variables, brightness variation, eclipsing binaries
* redshift and absorption of wavelengths
* galaxies to include formation, classification (spiral, barred-spiral and elliptical)
* quasars
* the big bang
* Hubble’s law, the Universe and its composition – dark matter, dark energy, matter, projected time-line (big-bang to photon age), critical density, the fate of the Universe
* Olber’s Paradox

Assessment criteria

|  |  |  |
| --- | --- | --- |
| Pass | Merit | Distinction |
| Learning aim A: Examine the fundamental aspects of the Solar System | | **A.D1** Analyse the importance of the Sun in its Solar System |
| **A.P1** Describe the main features of the Sun, Earth, Moon and Solar System | **A.M1** Explain the effects of the interaction between the Sun, Earth and Moon and other solar system objects |
| Learning aim B: Undertake measurement and observation of astronomical objects | | **B.D2** Evaluate the findings and validity of practical astronomical observations |
| **B.P2** Describe the types of telescopes used for astronomical observation  **B.P3** Confirm the relative positions of night time astronomical objects  **B.P4** Confirm the relevant positions and features of daytime astronomical objects | **B.M2** Explain the findings of practical astronomical observations |
| Learning aim C: Investigate the essential factors involved in space flight | | **C.D3** Evaluate the future of space flight and space exploration and research |
| **C.P5** Explain the main factors associated with achieving space flight for manned and un-manned exploration | **C.M3** Assess the main factors and benefits associated with achieving space flight for manned and un-manned exploration |
| Learning aim D: Understand the fundamental concepts outlined in astrophysics and cosmology | |
| **D.P6** Review the current knowledge and theories of star life cycles  **D.P7** Describe the evidence linked to theories of the evolution of the Universe | **D.M4** Explain the processes of star formation 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 with suitable forms of evidence. Further information on setting assignments is given on our website. Section 6 gives information on setting assignments.

The maximum number of summative assignment for this unit is 2 and the relationship of the learning aims and criteria is:

List structure and give criteria

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

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

Learning Aims: C and D (C.P5,C.M3, C.D3, D.P6, D.P7, D.M4, D.M5)

Further information for teachers and assessors

Resource requirements

For this unit learners must have access to:

• 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.

Essential information for assessment decisions

Learning aims A

**For the distinction standard**, learners should explain, in detail, the natural forces allowing the Sun to remain in equilibrium and the eventual outcome when these forces change, in terms of its expected life cycle and ultimate effects on the Solar System. Learners should explain the process of nuclear fusion and detail the magnetic forces and features on the surface of the Sun and their associated effects. The composition of the Sun should be explained with suitable illustrations, identifying the gases involved and the layered structure (D1).

**For the merit standard***,* 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 on chosen planets and moons etc. (M1). Learners will also provide detailed explanations of star evolution (M5) and describe in some detail the variations of star types which occur, with reference to the HR diagram. Spectral classes and the relationship with mass should be included and also examples, by name, of star types depicted. Learners would provide further expansion on the work given for P7 to explain the variation in star evolution as a result of mass of initial material ie stars of mass equal to the Sun and those of mass greater than the Sun. For M6, explanations of the methods used to measure astronomical distances must show the limitations of trigonometric parallax to relatively short distances. 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. Learners will also need to include sufficient explanation of Hubble’s Law, the reasons which provide the current age of the Universe and possible fate of the Universe based on density. A clear explanation of Olber’s Paradox will need to be given.

**For the pass standard**, 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, atmospheric compositions and physical data. The relationship of the Earth with the Moon and the Sun should be briefly described by including diagrammatic representation of the particular aspects which 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 (P1). 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 other associated features such as the Kuiper Belt and Oort Cloud objects in order to achieve P2. For P7, 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 variations in the mass of the material which comprises the star. Brief notes should accompany each stage. Learners should 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. The essential physical laws which help to explain some key aspects should be included.

**Learning aims B**

**For the distinction standard***,* observations must be evaluated and improvements suggested. Errors in observations must be identified and relevant comments made relating to visual aspects, inaccuracies of measurement and suitability of equipment for purpose. Data collected should be represented in a suitable format and all observations set against an

accurately illustrated star map. The validity of observations can be determined by comparison with known astronomical data, eg size of sunspots, position of the solar plane, diagram of surface of the moon etc.

**For the merit standard***,* learners will work with more independence and produce explanations of their results from observations and draw suitable conclusions. Observation of the night sky and solar activity should show accuracy and precision, in terms of diameters represented of the Sun, for example and correct positioning of night sky objects against background field stars identified by Right Ascension and Declination. It is suggested that suitable objects are taken from those provided in the *Unit content* section which require the use of a telescope or binoculars, using projection methods for the Sun.

**For the 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 power-point presentation highlighting and naming the telescopes which use different parts of the electro-magnetic spectrum. For light, both refractor and reflector telescopes must be included. A detailed description of operation is not expected although the general mode of operation and principles must be outlined. For criteria P4 and P5, log books and other suitable forms of presentation detailing observational records must be kept to evidence practical observations taken over a length of time using suitable equipment. 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. Accurate ray diagrams must 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. For P4, the observations must be set onto an independently constructed map of a suitable portion of the night sky which has been observed. Paths of objects should be shown against labelled constellations and stars and distances should be accurately measured. Day time observations must 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 (CARE!). If the qualification is delivered during times of solar or lunar eclipse, a valuable opportunity will exist for observation.

Learning aims C and D

**For the distinction standard***,* learners will produce a comprehensive report demonstrating their knowledge and understanding of the history of space flight and the difficulties involved. Learners should include a discussion which identifies a good selection of planned missions, manned and un-manned, proposed by various countries and organisations. The work can be presented as a journalistic appraisal and must provide clear descriptions of the proposals and evaluate the developments of each space programme in terms of costs, difficulties which will be faced, benefits and other implication.

**For the merit standard***,* learners should produce a well worded report depicting examples of the products used in everyday life which have been discovered or developed as a direct result of space flight and research from the full list of areas in the unit content. The report should outline at least five products from materials and manufacturing and learners should 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 which includes a description and indication of its relevance to society in general. Work should be largely independent and research evidence must be included with correct referencing and bibliography. 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. All effects on humans listed in the unit contents must be mentioned. Evidence can take the form of a large poster or booklet with clear labelling of the specific areas of the body that are affected.

Work for this criterion must also focus on the physical aspect of achieving and sustaining space flight for a vehicle. Learners should provide explanations which 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 are to be included. Some acknowledgement of the dangers involved could be provided by reference to well-known accidents such as; Salyut 1, Apollo1, Challenger and Columbia Space Shuttles.

**For the pass standard***,* 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 will be sufficient and the effects on humans can be completed by developing a case study which identifies the issues that NASA faced in their preparations for Astronaut training during the Apollo missions.

Links to other units

Unit 1: Principles and Applications of Science I

Unit 2: Practical Scientific Procedures and Techniques

Unit 4: Laboratory Practical Techniques

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.