Module overview

The approach

This module is equivalent in extent to three of the earlier modules P1–P3 or P4–P6.

There are three broad aims:

- to extend the coverage of key themes in modern physics (optics, digital imaging, behaviour of gases, fundamental particles)
- to explore selected ideas about science further in physics contexts (explanations in terms of models, the international community of astronomers)
- to illustrate modern applications of physics (designing, siting and remotely operating new telescopes, astrophysics)

In this way the module features key characteristics of the *Science*, *Additional Science*, and *Additional Applied Science* courses in *Twenty First Century Science*.

The topics

The Textbook presents the content of the specification in four topics:

- *Observatories and telescopes* highlights the use of the full electromagnetic spectrum to understand the cosmic landscape, and then describes refractors and reflectors and how they work.
- *Mapping the heavens* discusses observations of celestial objects: motions of stars, planets, and the Moon; measuring distances to stars and galaxies using both parallax and variable stars called Cepheids; star temperatures; the expansion of the Universe and the Hubble constant.
- *Inside stars* explores classical physics that helps explain how stars work: Fraunhofer lines and the composition of stars; evidence for the nuclear structure of atoms, and particles more fundamental than protons and neutrons; the kinetic theory of gases; the Kelvin scale of temperature and the gas laws
- *The life of stars:* starting with classification of stars using the Hertzsprung–Russell diagram, the final topic shows how the internal structure of main-sequence stars is modelled, and then describes protostars and how stars of different masses die.

The 'physics in action' examples in the Textbook are not examinable but show how physics ideas are put to work in the twenty-first century. Activities related to these are referenced in the scheme of work, and are available from

www.twentyfirstcenturyscience.org

Practical work

This includes building telescopes, understanding the action of lenses and mirrors, and a variety of classroom experiments that help develop understanding of physics concepts. The homework suggested in several lessons involves students observing the night sky, because personal experience is so valuable.

ICT resources

Electronic resources for this module include

- PowerPoint presentations on the Milky Way, lenses, diffraction, ray diagrams, image processing, stars and the seasons, variable stars, the Hubble constant, and the *Hubble Space Telescope*
- Do not forget relevant presentations from earlier modules:
  IP1.17 *The Sun and other stars*
  IP1.18 *Journeys through space*
  IP1.20 *Galaxies*
  IP2.2 *The space rainbow*
  IP6.3 *Light effects* (showing diffraction)
- There are three robotic telescope projects in the UK. See

  www.twentyfirstcenturyscience.org/furtherguidance

Skills assessment

Some of the 'physics in action' examples and related activities can be used as a practice (or assessed) case study – see notes in the scheme of work.

Health and safety

Health and safety advice (if any) is included in the guidance notes for each activity.

Advance preparation

Keep up with developments in astronomy and astrophysics: access to the PPARC magazine *Frontiers* is free (**www.pparc.ac.uk/frontiers**). Also, **www.universetoday.com/** allows you to download for free a very fine and very full sky-watching guide (click on the 'Skywatching' link).

Module maps

Topic 1 Observatories and telescopes

GCSE Science	Module story	Science ideas and explanations	*GCSE Additional Science*
The electromagnetic spectrum is introduced in P2 *Radiation and life*, as a range of photon energies.	**What is a telescope?**	Range of electromagnetic radiation detected by astronomers. Examples of some major observatories, ways that astronomers work with local and remote telescopes.	In P6 *Wave model of radiation,* electromagnetic radiation is described as a spectrum of frequencies (or wavelengths).
	Images, focal length, and power	A language for describing images. Link between power of a converging lens and the curvature of its surfaces, as well as its focal length.	
	Making a telescope	Objective and eyepiece lenses. **Magnification**. Big apertures gather more light. Some advantages of reflecting telescopes. Ray diagram for a converging lens: distant point source off-axis, distant extended source.	
	Resolving power	**Importance of large aperture in terms of wave diffraction and resolving power.**	Diffraction is introduced in P6 *Wave model of radiation.*
The filtering effect of the Earth's atmosphere is introduced in P2 *Radiation and life.*	**Windows in the atmosphere**	Advantages and disadvantages of using telescopes outside the Earth's atmosphere. OPTIONAL lesson.	P6 *Wave model of radiation* looks more closely at differential absorption across the electromagnetic spectrum by the Earth's atmosphere.
	Electronic imaging and digital processing	This is an OPTIONAL lesson, about a key development in modern astronomy. **Not** required by the OCR specification.	

Module maps

Topic 2 Mapping the heavens

GCSE Science	Module story	Science ideas and explanations	*GCSE Additional Science*
	The Sun, Moon, and Earth	Orbits of the planets and Moon. How these result in phases of the Moon, eclipses of the Sun and Moon, apparent motion of planets and stars. Difference between solar and sidereal day.	
P1 *The Earth in the Universe* introduces (qualitiatively) parallax and apparent brightness of stars as ways of measuring distances. Also introduces the light-year.	**Measuring distance to stars and galaxies**	Parallax and parsec quantitatively. The distinction between intrinsic brightness (related to star colour and size) and apparent brightness, seen from Earth.	
	Black body radiation	Hot objects (including stars) emit a continuous range of electromagnetic radiation, whose total intensity and peak frequency increase with temperature.	P6 *The Wave model of radiation* touches on this when introducing infrared.
P1 *The Earth in the Universe* introduces the Curtis–Shapley debate, but without reference to the role of Cepheid variables in resolving it. P1 also introduces the Hubble law, qualitatively.	**Cepheid variables and the Hubble constant**	The linear relationship between periodic time and intrinsic brightness for Cepheid variables, and they way this is used to measure distance to galaxies. The Curtis–Shapley debate as an example of how science explanations develop. The Hubble law quantitatively.	

Module maps

Topic 3 Inside stars

GCSE Science	Module story	Science ideas and explanations	*GCSE Additional Science*
P1 *The Earth in the Universe* describes absorption lines in the spectra of stars as a means of knowing what stars are made from, but makes no attempt to explain them.	**Mystery of the Sun** ↓	Various failed attempts to explain the source of the Sun's energy. Fraunhofer lines: emission and absorption spectra explained. Identifying elements.	
P3 *Radioactive materials* introduces atomic and nuclear structure, neutrons, and protons – but not the evidence for them.	**Evidence for a nuclear atom** ↓	Rutherford's alpha scattering experiment.	
P1 *The Earth in the Universe* introduces nuclear fusion.	**Nuclear fusion** ↓	OPTIONAL lesson. Neutrons and protons. The short range of the strong force means high speeds are required to trigger fusion.	
	Kinetic theory of gases	The relationships between pressure, temperature, and volume of an ideal gas. Absolute zero of temperature and the Kelvin scale.	

Module maps

Topic 4 The life of stars

GCSE Science	Module story	Science ideas and explanations	*GCSE Additional Science*
	The Hertzsprung–Russell diagram	Classification of the variety of observed stars and their relative numbers. Idea that stars have a life cycle, related to their mass.	
	↓		
	Main sequence stars	A model of the internal structure of a star. Different modes of thermal transfer from the core, where fusion occurs. Stars change when their supply of hydrogen gets used up.	
	↓		
	Protostars	Theory of star formation: the roles played by gravity, and gas laws in triggering nuclear fusion.	
	↓		
	Dying stars	The effect of mass on terminal stages of a star: from red giant to white dwarf; or from red supergiant to supernova, neutron star, or black hole.	
	↓		
	International collaboration	Locations of major observatories, computer control and data transfer. Benefits of international collaboration. Factors to consider in planning, building, operating, and closing down observatories.	

Further notes

Integrating module P7 with other physics modules

All of the content for P7 is included in its scheme of work, but the following table shows how it is possible to integrate the teaching of some P7 statements as extension material in earlier modules. Taking this approach makes it possible to cover the ground in fewer lessons, especially if students make effective use of private study.

This could help where separate sciences are taught in the time allowed for two GCSEs.

Concepts shown in **bold** indicate the additional content required for P7.

Deeper treatment of . . .	**. . . incorporates P7 lesson**	**concept(s)**
P1 lesson 9 *What are we made of?* P3 lesson 6 *Inside the atom*	20 *Mystery of the Sun* 23 *Nuclear fusion*	spectral lines identify elements, **explanation for Fraunhofer lines** fusion of hydrogen and heavier elements; protons & neutrons; **electrostatic repulsion & strong nuclear force**
P1 lesson 10 *Are we alone?*	13 *Parallax and parsecs* 15 *Star brightness, size, and distance*	distances to stars by parallax, **in parsec** intrinsic v apparent brightness; **star temperature and size affect brightness**
P1 lesson 11 *The great debate*	17 *Cepheid variables* 18 *The Curtis–Shapley debate*	**how cepheid variables are used to measure distances** galaxies beyond the Milky Way
P1 lesson 12 How did the Universe begin?	19 *The Hubble constant*	the expansion of the Universe, **using Hubble constant equation**
P2 lesson 2 Sunlight and life	1 *What is a telescope?*	**variety of telescopes used to form** astronomical images across the whole electromagnetic spectrum
P2 lesson 4 Absorbing electromagnetic radiation P6 lesson 9 Microwaves, radio waves and SETI	8 *Windows in the atmosphere*	**selective** absorption of em radiation by the Earth's atmosphere **and its implications for modern astronomy**
P6 lesson 5 Is light a wave?	6 *Resolving power*	wave diffraction at an aperture. **bigger aperture has greater resolving power (H tier only)**

Six of the 30 lessons in the P7 scheme of work are shown as OPTIONAL:

P7 lesson	**Why it is optional**
8 *Windows in the atmosphere*	repeats material covered in P2 and P6 (see above)
9 *Images of stars*	at margins of the OCR specification
14 *More parallax and parsecs*	an able group can do this in private study time
18 *The Curtis v Shapley debate*	can be covered in P1 (see above)
19 *The Hubble constant*	can be covered in P1 (see above)
23 *Nuclear fusion*	can be covered in P1 & P3 (see above)

Resource list

Activity	ICT	(type)	Item title (in scheme-of-work order)	Activity sheet (A)	Guidance (G)
	IP7.1	*Presentation*	*Images of the Milky Way*		
AP7.1			Looking out into space	▲	●
AP7.2			A pinhole camera	▲	●
	IP7.2	*Presentation*	*The power of lenses*		
AP7.3			Focal length and power	▲	●
AP7.4			At the optician's	▲	●
AP7.5			Making a telescope	▲	●
AP7.6			Demonstrating light rays		●
AP7.7			Objects and images	▲	●
AP7.8			What affects the spreading?	▲	●
AP7.9			Resolving stars	▲	●
	IP7.3	*Presentation*	*Ray diagrams*		
AP7.10			Drawing ray diagrams	▲	●
AP7.11			An extended source		●
AP7.12			Telescopes and rays	▲	●
AP7.13			Scattering and refracting light		●
AP7.14			Where to put a telescope	▲	●
	IP7.4	*Presentation*	*What is digital image processing*		●
AP7.15			Stacking and multiplying	▲	●
	IP7.5	*Image*	*Image process multiply*		
	IP7.6	*Spreadsheet*	*Stacking*		
AP7.16			Levels and contrast	▲	●
	IP7.7	*Image*	*Levels*		
AP7.17			Solar system – true or false?		●
AP7.18			The Sun and the Earth	▲	●
AP7.19			The Moon		●
AP7.20			The night sky		●
	IP7.8	*Presentation*	*Stars and seasons*		●
	IP7.9	*Presentation*	*The retrograde motion of Mars*		
AP7.21			The retrograde motion of Mars	▲	●
AP7.22			Modelling an eclipse	▲	●
AP7.23			A rare event		●
AP7.24			Parallax and distance	▲	●
AP7.25			Parsecs	▲	●
AP7.26			Parsecs and light-years	▲	●
AP7.27			Far, far away	▲	
AP7.28			Luminosity and size	▲	●
AP7.29			Orion the hunter	▲	●
AP7.30			Radiation and temperature	▲	●
AP7.31			Black body radiation	▲	●
	IP7.10	*Presentation*	*Variable stars*		
AP7.32			Cepheid variable stars	▲	●
	IP7.11	*Spreadsheet*	*Cepheid variable stars*		
AP7.33			The great debate		●
AP7.34			Hubble and Cepheids	▲	●
	IP7.12	*Spreadsheet*	*Hubble data*		
AP7.35			A model to explain Hubble's law	▲	●
	IP7.13	*Presentation*	*What does H_0 tell us?*		
AP7.36			The spectrum of the Sun		●
AP7.37			Does the Sun burn hydrogen?	▲	●
AP7.38			Probing the atom		●
AP7.39			Seeing the invisible		●
AP7.40			How does fusion happen?	▲	●
AP7.41			A fusion reactor in the sky	▲	●
AP7.42			Boyle's law	▲	●
AP7.43			Charles' law	▲	●
AP7.44			Temperature scales	▲	●
AP7.45			Physics in stars – revision		●
AP7.46			The Hertzsprung–Russell diagram		●
AP7.47			Star research		●