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Scheme of Work

GCSE (9-1) Astronomy

Pearson Edexcel Level 1/Level 2 GCSE (9-1) in Astronomy (1AS0)

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Week 1	Topic 1 Planet Earth 1.1 The Earth's structure			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

1.1
1.2
1.3 a-d
	• Starter: Teacher shows images of the Earth showing its many diverse surface features and asks the class to share what they know about its shape, size and internal structure.
	• Pupils study the shape and mean diameter of the Earth (13 000 km).
	• Pupils study the Earth's interior, its main divisions and their properties (approximate size, state of matter, temperature etc.):
	  ○ crust
	  ○ mantle
	  ○ outer core
	  ○ inner core.
		• Find useful information in chapter 1 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 3 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
			2a
			2b	

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Week 2	Topic 1 Planet Earth 1.2 Latitude and longitude			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

1.4
1.5 a-h
	• Teacher demonstrates latitude and longitude on a globe of the Earth.
	
	• Pupils use globes, maps and/or an atlas to study latitude and longitude.
	
	• Pupils learn that in addition to being simply lines on a map, latitude and longitude are actually angles.
	
	• Pupils study the main divisions of the Earth's surface that they will later use as astronomical reference points, including:
	
	  ○ Equator
	  ○ Tropic of Cancer
	  ○ Tropic of Capricorn
	  ○ Arctic Circle
	  ○ Antarctic Circle
	  ○ Prime Meridian
	  ○ North Pole
	  ○ South Pole.
	
	• Pupils complete worksheet locating major cities on Earth from their latitude and longitudes and *vice versa*.
	
	• Plenary: Pupils consolidate their knowledge and understanding of latitude and longitude with the aid of flashcards or other short worksheet.
		• Find useful information in chapter 1 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Model globes and atlases are available from many retail outlets or borrowed from the Geography department.
			5a
			5d	

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Week 3	Topic 1 Planet Earth 1.3 The Earth's atmosphere			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

1.6
6.6
	• Teacher uses *Stellarium* software to demonstrate effects of the Earth's atmosphere on astronomical observations, including:
	  ○ sky colour (daytime and sunset/rise)
	  ○ skyglow (light pollution).
	• Pupils study the major sources and causes of light pollution.
	• Pupils study the locations and purposes of Dark Sky Parks.
	• Pupils study seeing conditions and the reasons why stars 'twinkle'.
		• *Stellarium* can be downloaded free-of-charge from: http://www.stellarium.org/en_GB
		• Find useful information in chapter 1 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 3 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
		• Information on The Commission for Dark Skies can be found at: http://www.britastro.org/dark-skies/
		• Information on Dark Sky Parks in the UK can be found at: http://www.darkskydiscovery.org.uk/dark-sky-discovery-sites/map.html
				• **Observational tasks A5 and B5:** Study the astronomical effects of light pollution by observing the faintest stars that are visible either with the naked eye (A5) or on photographs (B5).

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Week 4	Topic 6 Celestial observation 6.1 The night sky			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

6.1 a-l
5.7
	• Teacher demonstrates planetarium software such as *Stellarium* to the class, pointing out the types of objects found in the night sky (suggest 'slow' speed so that pupils can see the apparent east-west movement of the sky), including:
	  ○ the Sun
	  ○ the Moon
	  ○ stars
	  ○ star clusters
	  ○ nebulae
	  ○ galaxies
	  ○ planets.
	• Pupils study further objects in the night sky:
	  ○ meteors
	  ○ aurorae
	  ○ supernovae
	  ○ artificial satellites
	  ○ aircraft.
	• Pupils study the causes of meteors and showers, and complete worksheet showing part of the night sky and meteor trails; pupils extend the trails to determine the location of the radiant point.
		• Find useful information in chapter 2 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• http://spaceweather.com/ has up-to-date information on the visibility of meteor showers and aurorae.
		• *Stellarium* can be downloaded free-of-charge from: http://www.stellarium.org/en_GB/
		• *Philip's Star Chart* can be purchased from many retail outlets or online.
				• **Observational tasks A2 and B2**: Find the radiant point of a meteor shower using naked-eye drawings (A2) or photographs (B2).
				• Observe the night sky and identify celestial objects such as planets, double stars (e.g. in the handle of the Plough), nebulae (e.g. Orion Nebula), clusters (e.g. the Pleiades), aircraft and artificial satellites.

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Week 5	Topic 6 Celestial observation 6.2 Stars and constellations			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
6.2 a-g 6.3 6.4	• Pupils use *Stellarium* or other resources such as star charts in recent *BBC Sky at Night* or *Astronomy Now* magazines to study constellations and asterisms, including: ○ Cassiopeia ○ Cygnus ○ Orion ○ The Plough ○ Southern Cross (NB southern hemisphere) ○ Summer Triangle ○ Square of Pegasus. • Pupils study how pointers in some asterisms can be used to locate: ○ Arcturus and Polaris from The Plough ○ Sirius, Aldebaran and the Pleiades from Orion's Belt ○ Fomalhaut and the Andromeda galaxy from the Square of Pegasus. • Pupils study constellations, asterisms and star names among different cultures.	• Find useful information in chapter 2 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • *Astronomy Now* and *BBC Sky at Night* monthly magazines are available at retail outlets or on subscription.		• Observe the night sky and identify: Cassiopeia, Cygnus, Orion, The Plough, Southern Cross (from the southern hemisphere), Summer Triangle and Square of Pegasus. • Observe the night sky and use pointers to locate Arcturus and Polaris, Sirius, Aldebaran and the Pleiades, and Fomalhaut and the Andromeda galaxy.

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Week 6	Topic 6 Celestial observation 6.3 The celestial sphere			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

6.7 a-c
6.8
	• Starter: Teacher recaps latitude and longitude on Earth (using short true/false worksheet) and asks the class to think about whether a similar system for stars might be useful. Discussion.
	
	• Pupils study the terms:
	  ○ celestial sphere
	  ○ celestial poles
	  ○ celestial equator.
	
	• Pupils study the equatorial coordinate system involving right ascension and declination.
	
	• Pupils are given names of common bright stars and practise finding their RA and dec with the aid of star charts etc.
	
	• Conversely, pupils practise identifying stars on star charts etc. given their RA and dec coordinates.
		• Find useful information in chapter 2 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK).
		
		• *Philip's Star Chart* can be purchased from many retail outlets or online.
		
		• *Astronomy Now* and *BBC Sky at Night* monthly magazines are available at retail outlets or on subscription.
			5a
			5b
			5c	

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Week 7	Topic 6 Celestial observation 6.4 Coordinate systems			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
6.9 6.10	• Starter: Teacher-led discussion about the need for a coordinate system based on the observer's location. • Teacher demonstrates the horizontal coordinate system (altitude and azimuth) using *Stellarium* or similar planetarium software. • Pupils use clinometers and compasses to estimate the altitude and azimuth of objects in or around the school grounds. • Pupils study how an observer's latitude links the equatorial and horizontal coordinates for an object on the observer's meridian. • Pupils practise this link by completing worksheets relating latitude, declination and altitude.	• Find useful information in chapter 2 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Information regarding the visibility of the ISS from a given location can be obtained from: https://spotthestation.nasa.gov/ • Simple clinometers can be made with protractors and drinking straws. This YouTube video shows how: https://www.youtube.com/watch?v=gWMgf0XpGF4 • An excellent article on horizontal coordinates can be found at: http://www.astronomynotes.com/nakedeye/s6.htm	1a 4a 5a 5b 5c	• Observe the International Space Station (ISS): use internet data to discover the rising and setting times and azimuths, maximum altitude etc. and use these to predict the passage of the ISS and assess the accuracy of these predictions. • Observe bright stars with the naked eye and estimate their altitudes and azimuths; use a clinometer and magnetic compass to assess the accuracy of the estimates.

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Week 8	Topic 6 Celestial observation 6.5 Diurnal motion			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

6.11
6.12 a-b
6.13 a-e
6.14
	• Starter: Teacher demonstrates diurnal motion using *Stellarium* or similar planetarium software set onto 'slow' rotation speed. Class discussion as to whether it is the sky rotating or the Earth.
	
	• Pupils study (in relation to astronomical observations):
	  ○ cardinal points
	  ○ culmination
	  ○ meridian
	  ○ zenith
	  ○ circumpolarity.
	
	• Pupils study local sidereal time.
	
	• Pupils study the link between local sidereal time and hour angle.
	
	• Pupils use software or star charts to determine:
	  ○ the best time to observe a particular celestial object
	  ○ the best celestial objects to observe at a particular time.
		• Find useful information in chapter 2 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK).
		
		• *Stellarium* can be downloaded free-of-charge from: http://www.stellarium.org/en_GB/
			1a
			4a
			5a
			5b
			5c
				• Observe the diurnal motion of stars as they culminate in the night sky; use right ascension data to predict the times at which nearby eastward stars will culminate.

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Week 9	Topic 6 Celestial observation 6.6 Circumpolar stars			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

6.15
6.16
6.17
6.18
	• Teacher demonstrates the link between the altitude of Polaris and an observer's latitude (this assumes the declination of Polaris is +90°).
	
	• Teacher asks the class to consider the factors that might determine whether or not a star will rise and set (whether or not it will be circumpolar).
	
	• Pupils study the apparent motion of circumpolar stars, including:
	  ○ upper transit (culmination)
	  ○ lower transit.
	
	• Pupils practise numerical questions involving circumpolar stars.
	
	• Pupils study how information on rising and setting times of stars can be used to predict their approximate positions in the sky.
		• Find useful information in chapter 2 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK).
			1c
			4a
			5a
			5b
			5c
				• Determine (approximate) latitude by making a series of measurements of the elevation of Polaris using a clinometer and taking the mean of the measurements.

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Week 10	Topic 6 Celestial observation 6.7 Practical observing			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

6.5
6.19
6.20 a-d
	• Starter: Teacher asks pupils to write down a list of resources that could be used to identify objects in the night sky. Class discussion.
	
	• Pupils study resources and discuss good/bad features of each one, including:
	  ○ star charts
	  ○ planispheres
	  ○ computer software
	  ○ apps such as *Sky Map* or *Google Sky*.
	
	• Pupils study naked-eye techniques, including:
	  ○ dark adaptation
	  ○ averted vision.
	
	• Pupils study the factors that affect visibility, including:
	  ○ rising and setting times
	  ○ seeing conditions
	  ○ weather conditions
	  ○ landscape.
	
	• In groups, pupils plan a naked-eye observing session (see Related practical activities).
		• Find useful information in chapter 2 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK).
				• In groups, pupils plan a naked-eye observing session using a variety of resources, selecting the best celestial objects to observe for a given date and time.

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Week 11	Topic 2 The lunar disc 2.1 Surface features of the Moon			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

2.1
2.2
2.3 a-e
2.4 a-e
2.5 a-g
	• Starter: Teacher displays a lunar chart showing the near side and major features. Discussion about the differences with respect to Earth.
	
	• Pupils study the shape and mean diameter (3500 km) of the Moon.
	
	• Pupils study the appearance, structure and origin of lunar features, including:
	  ○ maria
	  ○ terrae
	  ○ craters
	  ○ mountains
	  ○ valleys.
	
	• Pupils suggest features that are not strictly visible with the naked eye but that could be clearly resolved using binoculars or a small telescope.
	
	• Pupils identify and study:
	  ○ Sea of Tranquillity
	  ○ Ocean of Storms
	  ○ Sea of Crises
	  ○ Tycho crater
	  ○ Copernicus crater
	  ○ Kepler crater
	  ○ Apennine mountain range.
		• Find useful information in chapter 3 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 3 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
		
		• An interactive Moon map can be found at: http://www.scientificpsychic.com/etc/moonmap/moon-map.html
		
		• Charts of the Moon can be obtained from specialist retail outlets.
			1a
			1b
			2f
				• **Observational tasks A1 and B1**: Demonstrate the changing appearance of lunar features by using a series of naked-eye drawings (A1) or telescopic drawings or photographs (B1).
				
				• Observe the Moon with binoculars or a telescope to locate the Seas of Tranquillity and Crises, Ocean of Storms, Tycho, Copernicus and Kepler craters and the Apennine mountain range.

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Week 12	Topic 2 The lunar disc 2.2 The Moon's orbit			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
2.6 2.7 2.8	• Starter: Teacher asks the pupils to write down how long it takes the Moon to orbit the Earth once. Expected answers: 1 month; 28 days. • Pupils study this more precisely: both the rotation and revolution (orbital) periods of the Moon are 27.3 days. • Pupils study how this synchronous nature of the Moon's orbit has developed. • Pupils study the causes of lunar libration and its effects on the visibility of the lunar disc. • Extension work: Teacher might show NASA video clip - see Exemplar resources - and ask the pupils to think about where the Moon would be placed in the sky (e.g. close to the western horizon) at its different phases; this could lead to a discussion about different types of libration.	• Find useful information in chapter 3 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 3 of *The Planets* by Aderin-Pocock, M. *et al* (DK). • An excellent video showing the lunar phase cycle and how the Moon 'wobbles' can be seen in this short NASA clip: https://www.youtube.com/watch?v=3f_21N3wcX8	1a	

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Week 13	Topic 9 Exploring the Moon 9.1 Exploration of the Moon			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

9.1
9.2
9.3
9.4
11.30
	• Starter: teacher reminds pupils of the Earth's internal structure and asks whether they think the Moon might have similar layers.
	• Pupils study the internal divisions of the Moon and compare them with Earth.
	• Pupils study the Moon's far side and write down major differences from the near side.
	• Pupils study how information about the Moon's far side has been gathered; in particular they might study:
	  ○ The Soviet Union's *Luna 3* space probe (unmanned)
	  ○ The manned *Apollo* missions
	  ○ More recent unmanned space probes e.g. NASA's *Lunar Reconnaissance Orbiter*.
	• Pupils research and make presentations of the *Apollo* programme to land astronauts on the Moon and return them safely to Earth.
		• Find useful information in chapter 4 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 3 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
		• STFC offer a loan scheme in which schools can borrow samples of lunar rocks and meteorites free of charge. http://www.stfc.ac.uk/public-engagement/borrow-the-moon/
		• An article on the achievements of *Luna 3* can be found at: http://www.wired.com/2011/10/1007luna-3-photos-dark-side-moon/		

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Week 14	Topic 9 Exploring the Moon 9.2 Origin of the Moon			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

9.5	• Pupils undertake research to discover the likely origin of the Moon (Giant Impact Hypothesis).
	• Pupils research alternative theories, including:
	  ○ Capture Theory
	  ○ Co-accretion Theory.
		• Find useful information in chapter 4 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• An excellent feature (with plenty of good science) by the US Planetary Science Institute on the origin of the Moon (and alternative theories) can be found at: https://www.psi.edu/epo/moon/moon.html		

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Week 15	Topic 11 Exploring the Solar System 11.1 Planets and dwarf planets			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

11.1 a-c
11.6 a-f
	• Starter: Pupils are asked to write down the names of all the planets and dwarf planets that they know. Discussion of difference between planets and dwarf planets.
	
	• Pupils study the location of planets and dwarf planets.
	
	• Pupils study the principal characteristics of the planets (as given in the Data Sheet in the specification). The astronomical unit could be introduced here. Characteristics include:
	  ○ relative size
	  ○ relative mass
	  ○ surface temperature
	  ○ atmospheric conditions
	  ○ presence of satellites
	  ○ presence of ring systems.
	
	• Pupils study the location and nature of other bodies in the Solar System (SSSOs – Small Solar System Objects) such as asteroids, meteoroids and comets.
	
	• Pupils complete worksheets on relative and actual sizes of planets (using the Earth's diameter as a reference), and converting distances in AU into kilometres, paying attention to appropriate numbers of significant figures.
		• Find useful information in chapter 5 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapters 3 and 4 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
			2a
			2c
			4b	

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Week 16	Topic 11 Exploring the Solar System 11.2 Comets			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

11.2
11.3
11.4
11.5
11.13
	• Starter: Teacher asks pupils to write down facts they know about comets. Discussion.
	• Pupils study the structure of comets, including:
	  ○ nucleus
	  ○ coma
	  ○ tails.
	• Pupils study the difference in orbits between short- and long-period comets.
	• Pupils study the likely origins of short- and long-period comets.
	• Pupils study the location and nature of the Kuiper Belt, Oort Cloud and heliosphere.
	• Pupils study the main theories of the origin of water on Earth.
		• Find useful information in chapter 5 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 5 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
		• The latest information on *Rosetta* and the analysis of data returned from the *Philae* lander can be found at: http://rosetta.esa.int/
		• An informative *National Geographic* article on asteroids and comets can be found at: http://science.nationalgeographic.com/science/space/solar-system/asteroids-comets-article/		

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Week 17	Topic 11 Exploring the Solar System 11.3 Meteoroids and meteorites			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
11.10	• Pupils study samples of meteorites and their likely origins. • Pupils study meteoroids and distinguish between them and meteorites. • Revision: Pupils could take the opportunity to explain how meteoroids produce meteors.	• Find useful information in chapter 5 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • STFC offer a loan scheme in which schools can borrow samples of lunar rocks and meteorites free of charge. http://www.stfc.ac.uk/public-engagement/borrow-the-moon/ • Further information about meteorites, including a list of reliable sources from which meteorites can be purchased, can be found at: http://www.meteorite.com/		

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Week 18	Topic 11 Exploring the Solar System 11.4 The size of the Solar System			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
11.8 11.9 11.11 11.12	• Starter: Short worksheet on distances within the Solar System, converting AU to kilometres (and *vice versa*) and using an appropriate number of significant figures. • Pupils study the astronomical unit and other units of distance used by astronomers: light year (l.y.) and parsec (pc). • Pupils study the orbital motion of the planets around the Sun in the same sense and in roughly the same plane, close to the plane of the Earth's orbit (the ecliptic). • Pupils study transits of Venus and how Edmond Halley's proposal allowed the value of the astronomical unit and thus the absolute size of the Solar System to be determined.	• Find useful information in chapter 5 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • An informative article of the transits of Venus and the ingenious idea of Edmond Halley can be found at: http://www.skyandtelescope.com/astronomy-news/observing-news/transits-of-venus-in-history-1631-1716/	2c 5a 5b	

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Week 19	Topic 11 Exploring the Solar System 11.5 Optical telescopes 1			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
11.14 11.15 11.16 11.17 11.18 a-d	• Starter: Teacher demonstrates the basic optical components in refracting and reflecting telescopes. The teacher asks the class to suggest why astronomers use telescopes. Responses might include magnification, and the teacher might explain why this is not the prime consideration. • Pupils study the limitations of the human eye. • Pupils study the optical elements of refracting and reflecting telescopes in further detail, and study the basic designs of: ○ Keplerian refracting telescope ○ Galilean refracting telescope ○ Newtonian reflecting telescope ○ Cassegrain reflecting telescope.	• Find useful information in chapter 5 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK). • STFC publish a free A2-sized poster *Big Telescopes*; further information at www.stfc.ac.uk/bigtelescopes		

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Week 20	Topic 11 Exploring the Solar System 11.6 Optical telescopes 2			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

11.19
11.20
11.21
11.22
11.23
11.25 a-d
13.34 a-g
	• Pupils study the 'light grasp' of a telescope and how it relates to the telescope's aperture (diameter of the objective element).
	
	• Pupils study the field of view of a telescope, measured in degrees or arcmin.
	
	• Pupils study the resolution of a telescope and that it is:
	  ○ proportional to the diameter of the objective element
	  ○ reduced by observing at a longer wavelength (IR and radio).
	
	• Pupils study and practise using the formula for the magnification of a telescope.
	
	• Pupils study the advantages of reflecting telescopes over refracting telescopes, in terms of:
	  ○ chromatic aberration
	  ○ very long focal lengths
	  ○ large aperture objectives
	  ○ use of multiple mirrors.
	
	• Pupils study how viewing celestial objects with a telescope alters their appearance.
	
	• Extension: Pupils could research key features and costs of telescopes (on, say, a budget of £1500), recommending a particular telescope to the class.
		• Find useful information in chapter 5 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• STFC publish a free A2-sized poster *Big Telescopes*; further information at www.stfc.ac.uk/bigtelescopes
		
		• Information on robotic telescopes that are available for use by schools can be obtained at: www.schoolsobservatory.org.uk www.faulkes-telescope.com www.telescope.org.
		
		• The monthly magazines *Astronomy Now* and *BBC Sky at Night* often contain telescope advertisements.
			1c
			1e
			3a
			3b
			3c
			3d
			5a
			5b
			5c
				• Plan an observing session using one of the robotic telescopes available to schools. The plan could include: date, times, objects to be viewed, exposure times etc.

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Week 21	Topic 11 Exploring the Solar System 11.7 Space probes			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

11.26 a-d
11.27 a-d
11.28
11.29
	• Starter: Teacher asks pupils to write down the names of 10 different space missions. Discussion.
	
	• Pupils study the major types of space probe, comparing the advantages and disadvantages of each type:
	  ○ fly-by (including *New Horizons*)
	  ○ orbiter (including *Juno*, *Dawn*)
	  ○ impactor (including *Deep Impact*)
	  ○ lander (including *Philae*).
	
	• Pupils research one example of each type of space probe and its major discoveries.
	
	• Pupils study the concept of the Earth's escape velocity and that the energy requirements can only be met using rockets.
	
	• Plenary: general discussion on the advantages and disadvantages of direct observation through the use of manned space missions.
		• Find useful information in chapter 5 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapters 3 and 4 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
		
		• Both the ESA and NASA websites are full of information on space probes: http://www.esa.int/ESA/Our_Missions and http://www.jpl.nasa.gov/missions/		

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Week 22	Topic 5 Solar System observation 5.1 Observing the planets			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
5.3 5.4 5.5 5.8 a-e	• Starter: Teacher asks the pupils to think about the apparent motion of the planets in the night sky - are they 'fixed' or do they 'wander'? Class discussion about the reasons for this and why the orbital motion of planets confines them to a narrow Zodiacal Band. • Pupils collect positional data for a superior planet over several months and plot its position on a prepared start chart; pupils study how the gradual west-east motion is interrupted by stationary points and retrograde motion. • Pupils study the reasons for the apparent retrograde motion of the planets. • Pupils discuss what the apparent motion of an inferior planet might be; pupils study key terms associated with planetary orbits: ○ conjunction (superior and inferior) ○ opposition ○ elongation ○ transit (across the solar disc) ○ occultation.	• Find useful information in chapter 6 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK). • An informative, well-illustrated account of the retrograde motion of planets can be found at: http://www.polaris.iastate.edu/EveningStar/Unit1/unit1_sub3.htm	2c 4a 5a	• Observe the position of a superior planet (e.g. Mars or Jupiter) over a period of several months; plot its position on a star chart to demonstrate the planet's retrograde motion.

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Week 23	Topic 5 Solar System observation 5.2 The apparent motion of the Sun			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
5.2 5.6	• Starter: Teacher asks pupils to consider the apparent motion of the Sun during the course of one year. How might this be represented on the celestial sphere? Discussion. • Pupils study the meaning(s) of the term ecliptic. • Pupils use positional data for the Sun for a period of one year to plot its position of a prepared chart. • Pupils locate the First Point of Aries and the First Point of Libra and study their astronomical and terrestrial significances. • Plenary: Pupils complete worksheet on the apparent motion of the Sun, seasons, equinoxes and solstices.	• Find useful information in chapter 6 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK). • An informative article and chart from which teachers could obtain RA and dec positions for the Sun during one year can be found at: http://www.physicalgeography.net/fundamentals/6h.html		

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Week 24	Topic 7 Early models of the Solar System 7.1 Solar and lunar cycles			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

7.1 a-d
7.2
	• Pupils research how detailed observations of lunar and solar cycles by ancient civilisations around the world gave rise to:
	  ○ agricultural systems
	  ○ religious systems
	  ○ time and calendar systems
	  ○ alignment of ancient monuments.
	• Pupils study why precession of the Earth's axis has caused the current celestial alignment of ancient monuments to differ from their original celestial alignment.
		• Find useful information in chapter 7 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 3 of *The Universe* by Rees, M. *et al* (DK).
		• An excellent article on precession can be found at: http://www.astronomynotes.com/nakedeye/s6.htm		

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Week 25	Topic 7 Early models of the Solar System 7.2 Models of the Solar System			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
7.3 7.4 8.1 8.2 11.24 7.5	• Pupils study early geocentric (Earth-centred) models of the Solar System, including the need for epicycles (as described by Ptolemy) to account for the retrograde motion of the planets. • Pupils study the detailed observational work of Tycho Brahe and how this contributed to the transition from a geocentric to a heliocentric (Sun-centred) model. • Pupils study the contribution of the mathematical modelling of Copernicus and Kepler in the transition from a geocentric to a heliocentric model. • Pupils study the early telescopic observations made by Galileo and how these contributed to establishing a heliocentric model of the Solar System. • Revision: Pupils complete worksheets on sizes and distances within the Solar System (including conversion of km into AU and *vice versa*, order-of-magnitude calculations and the use of an appropriate number of significant figures).	• Find useful information in chapter 7 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Information on the life, times and achievements of Tycho Brahe can be found at: http://www.tychobrahe.com/en/ • Information on the life, times and achievements of Nicolaus Copernicus can be found at: http://www.bbc.co.uk/history/historic_figures/copernicus.shtml • Information on the life, times and achievements of Johannes Kepler can be found at: http://kepler.nasa.gov/Mission/JohannesKepler/ • Information on the life, times and achievements of Galileo can be found at: http://solar-center.stanford.edu/galileo/	2c 2f	

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Week 26	Topic 8 Planetary motion and gravity 8.1 Orbits and Kepler's first and second laws			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

8.3
8.4
8.5
	• Starter: Teacher demonstrates 'Newton's cannon' thought experiment, explaining the role of gravity in creating stable orbits.
	• Pupils study Kepler's first law of planetary motion, drawing ellipses with the aid of string and drawing pins on an A3 sheet of card or paper.
	• Pupils study the terminology for minimum and maximum distances from the primary:
	  ○ aphelion and perihelion for solar orbits
	  ○ apogee and perigee for Earth orbits.
	• Pupils study Kepler's second law and use it to explain the change of speed in the secondary body during one orbit.
	• Plenary: Pupils complete worksheets on Kepler's first and second laws.
		• Find useful information in chapter 8 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 1 of *The Universe* by Rees, M. *et al* (DK).
		• An interactive 'Newton's cannon' animation can be found at: http://waowen.screaming.net/revision/force&motion/ncananim.htm
		• Information on the life, times and achievements of Johannes Kepler can be found at: http://kepler.nasa.gov/Mission/JohannesKepler/
			4a
			5a	

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Week 27	Topic 8 Planetary motion and gravity 8.2 Kepler's third law			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

8.6
8.7
	• Starter: Quick quiz on Kepler's first and second laws and associated terminology.
	• Pupils study Kepler's third law of planetary motion.
	• Pupils practise questions using the appropriate formulae for:
	  ○ planetary orbits around the Sun
	  ○ orbits of moons around planets
	  ○ orbits of artificial satellites around Earth.
	• Pupils study Kepler's third law in more detail, in particular that 'the constant' relates to the inverse of the mass of the primary body.
	• Pupils practise challenging calculations involving the mass of the primary body, orbital periods and mean orbit radii.
		• Find useful information in chapter 8 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• The Data Sheet at the rear of the specification gives data on orbital periods and mean distances from planets to the Sun.
		• A wealth of information about Earth-orbiting satellites, with some data that teachers could use in worksheets, can be found at: http://earthobservatory.nasa.gov/Features/OrbitsCatalog/
			1c
			1e
			3b
			3c
			3d
			4b	

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Week 28	Topic 8 Planetary motion and gravity 8.3 Gravitation			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

8.8
8.9
	• Pupils study Newton's law of universal gravitation, understanding that the gravitational force between two bodies:
	  ○ is proportional to the product of their masses
	  ○ is inversely proportional to the square of their separation.
	• Pupils study how Newton's law of universal gravitation can be used to explain Kepler's laws.
		• Find useful information in chapter 8 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 1 of *The Universe* by Rees, M. *et al* (DK).
		• *The Physics Classroom* website gives a good account of the inverse-square nature of gravitational forces: http://www.physicsclassroom.com/class/circles/Lesson-3/Newton-s-Law-of-Universal-Gravitation
			1c
			1e	

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Week 29	Topic 10 Solar astronomy 10.1 Observing the Sun			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
5.1 10.1 a-b 10.6 10.7 10.8	• Starter: Pupils are asked to write down reasons why it might be dangerous to look at the Sun directly; discussion. • Teacher demonstrates how a simple pinhole camera and telescopic or binocular projection allows safe solar viewing. • Pupils study the structure, origin and evolution of sunspots. • Pupils use data on the number of sunspots against year to determine the length of the solar cycle. • Pupils obtain (see **observational tasks A6 and B6**) sunspot data to determine the mean solar rotation period.	• Find useful information in chapter 9 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 2 of *The Planets* by Aderin-Pocock, M. *et al* (DK). • STFC publish a free A2-sized poster *The Sun*: http://www.stfc.ac.uk/public-engagement/for-schools/ • NASA produce a pdf on how to observe the Sun safely; this can be downloaded from: http://pwg.gsfc.nasa.gov/istp/outreach/sunobserve1.pdf • Try also *Sky at Night* magazine's: http://www.skyatnightmagazine.com/feature/how-guide/how-observe-sun-safely • Current *SOHO* images of the Sun, with sunspot data can be obtained at: http://sohowww.nascom.nasa.gov/sunspots/ • Data for the solar cycle can be obtained at: http://solarscience.msfc.nasa.gov/SunspotCycle.shtml	1c 2b 4a 5a 5b	• **Observational tasks A6 and B6:** Estimate the rotation period of the Sun by observing sunspots with the aid of a series of pinhole camera (A6) or telescopic (B6) projections. • Observe the Sun safely using telescopic projection with a light-baffle or using an H-alpha filter.

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Week 30	Topic 10 Solar astronomy 10.2 The Sun's interior			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
10.2 a-d 10.3 10.4	• Starter: Pupils are asked to think about the Earth and Moon having internal structures - might the Sun also have internal divisions? • Pupils study the Sun's core, radiative zone, convective zone and photosphere. • Wacky fact: The Sun loses 4 million tonnes of mass every second. • Pupils explore the thermonuclear fusion reactions in the Sun's core and produce posters showing the proton-proton cycle either in terms of particles or using chemical notation.	• Find useful information in chapter 9 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 2 of *The Planets* by Aderin-Pocock, M. *et al* (DK). • http://www.suntrek.org/ is an excellent website full of resources for schools.		

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Week 31	Topic 10 Solar astronomy 10.3 The Sun's atmosphere			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
10.5	• Pupils research the internet to discover the temperature and relative densities of the Sun's chromosphere and corona. • Discussion on why the Sun's corona might be so hot (2 million K).	• Find useful information in chapter 9 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 2 of *The Planets* by Aderin-Pocock, M. *et al* (DK). • For further information about the Sun and its interactions with Earth, visit http://www.suntrek.org/.		

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Week 32	Topic 10 Solar astronomy 10.4 The solar wind			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

10.10
10.11 a-d
10.12
	• Starter: Pupils are asked to think and write down the different ways in which they think the Sun affects the Earth. Obvious responses might include heat, light, energy etc.
	
	• Teacher leads discussion towards the emission of charged particles from the Sun - the solar wind.
	
	• Pupils study the nature, composition and origin of the solar wind.
	
	• Pupils study the principal effects of the solar wind:
	  ○ aurorae
	  ○ cometary tails
	  ○ geomagnetic storms
	  ○ effects on satellites, aircraft travel and manned spaceflight missions.
	
	• Pupils study the shape and location of the Earth's magnetosphere and Van Allen Belts.
		• Find useful information in chapter 9 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Information on the solar wind and Sun-Earth interactions can be found at: http://spaceweather.com/ and http://www.suntrek.org/
		
		• Further information on the Earth's magnetosphere can be obtained at:
		
		http://www.swpc.noaa.gov/phenomena/earths-magnetosphere		

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Week 33	Topic 3 The Earth-Sun-Moon system 3.1 Eclipses			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

3.8
3.9
3.10
	• Starter: Pupils are shown video clips of lunar and solar eclipses. General discussion about what is being observed and why eclipses occur.
	
	• Pupils study the appearance of the Sun during partial, annular and total solar eclipses, including the terms:
	  ○ first umbral contact
	  ○ second umbral contact
	  ○ third umbral contact
	  ○ fourth umbral contact.
	
	• Pupils study the appearance of the Moon during partial and total lunar eclipses, including the terms:
	  ○ first umbral contact
	  ○ second umbral contact
	  ○ third umbral contact
	  ○ fourth umbral contact.
	
	• Pupils draw diagrams to understand the causes of lunar and solar eclipses.
	
	• Extension: Pupils might consider the possibility of observing total solar eclipses from other planets or their moons in the Solar System.
		• Find useful information in chapter 10 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 3 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
		
		• There are many movie clips on the internet that show the passage of lunar and solar eclipses; here is one: https://www.youtube.com/watch?v=KWvPQBTvtfc
		
		• An informative glossary on solar eclipse terminology can be found at: http://cs.astronomy.com/asy/b/astronomy/archive/2014/08/14/a-solar-eclipse-glossary.aspx
		
		• Information on upcoming lunar eclipses can be found here: http://www.moongiant.com/Lunar_Eclipse_Calendar.php
				• Observe a total lunar eclipse, noting the times of first, second, third and fourth umbral contact.
				
				• Observe a partial solar eclipse and make a series of drawings or take a series of photographs showing its progress.

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Week 34	Topic 3 The Earth-Sun-Moon system 3.2 Tides and precession			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

3.5
3.6
3.7
	• Starter: Teacher asks the class to consider how the Moon and Sun might combine to affect Earth. Discussion about tides and precession of the Earth's axis. Teacher reminds pupils about the inverse-square nature of gravitation.
	
	• Pupils study tides, including the relative effects of the Sun and Moon in producing:
	  ○ high tides
	  ○ low tides
	  ○ spring tides
	  ○ neap tides.
	
	• Pupils study precession of the Earth's axis and in particular how it affects the locations of the Sun, Moon and stars when observed from Earth.
	
	• Pupils study archaeoastronomy and why the rate of precession of the Earth's axis is relatively slow.
	
	• Pupils complete worksheets containing data-related questions on the precession of the Earth's axis.
		• Find useful information in chapter 10 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• An excellent article on precession can be found at: http://www.astronomynotes.com/nakedeye/s6.htm
			1a
			5a
			5b
			5d	

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Week 35	Topic 3 The Earth-Sun-Moon system 3.3 The Earth, Sun and Moon			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
3.1 3.2 3.3	• Starter: Pupils write down the approximate relative sizes of the Earth, Sun and Moon. Discussion about why the Sun and Moon have the same apparent diameter (30 arcmin) when observed from Earth. • Pupils complete worksheets on the relative sizes of, and distances between, the Earth, Sun and Moon. • Pupils complete worksheets on actual sizes of the Earth, Sun and Moon, using the mean diameter of the Sun as 1.4×10^6 km. Calculations involve using standard form numbers and expressing answers using an appropriate number of significant figures.	• Find useful information in chapter 10 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • An interesting feature on the angular sizes of the Moon and Sun can be found at: http://earthsky.org/space/coincidence-that-sun-and-moon-seem-same-size	1b 1c 2f	

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Week 36	Topic 3 The Earth-Sun-Moon system 3.4 Diameters and distances			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

3.3 a-e	• Starter: Teacher asks pupils to consider how diameters and distances within the Earth-Moon-Sun system might have been established. Discussion.
	
	• Pupils study the observations and calculations of the ancient Greeks Eratosthenes and Aristarchus in determining the:
	  ○ circumference and hence diameter of the Earth
	  ○ diameter of the Moon
	  ○ distance to the Moon
	  ○ distance to the Sun
	  ○ diameter of the Sun.
	
	• Pupils complete worksheets involving calculations on the relative and absolute sizes of, and distances to, the Moon and Sun.
		• Find useful information in chapter 10 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• An illustrated summary of the contributions by Eratosthenes and Aristarchus can be found at: https://sites.ualberta.ca/~pogosyan/teaching/ASTRO_122/lect11/lecture11.html
		
		• Carl Sagan gives a clear explanation of how Eratosthenes determined the circumference of the Earth in this YouTube clip: https://www.youtube.com/watch?v=G8cbIWMv0rI
			1b
			1c
			3a
			5a
			5b
			5c
				• **Observational task A4:** Estimate a celestial property using drawings of a celestial event (e.g. observe an eclipse to estimate the relative sizes of the Earth and Moon).
				
				• **Observational task B4:** Measure a celestial property using telescopic drawings, measurements or photographs of a celestial event (e.g. observe a Jovian satellite to determine its orbital period).

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Week 37	Topic 4 Time and the Earth-Moon-Sun cycles 4.1 Sidereal and synodic time			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
4.1 4.11 4.12 4.13 4.14 13.19	• Starter: Teacher recaps the length of a sidereal day and how it differs from a solar day. Discussion as to the reason for this. • Pupils revise the variation in the annual motion of the Sun in one year and the astronomical significance of the equinoxes and solstices. • Pupils study why the times of sunrise and sunset vary through the year and are different for different (latitude) locations. • Pupils use star trail photographs and time exposure information to determine the length of a sidereal day. Pupils suggest how accurate and precise values can be obtained. • Pupils study the relationship between sidereal time and synodic (solar) time.	• Find useful information in chapter 11 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Data on times of sunrise and sunset for different locations can be found at: http://www.sunrisesunset.com/	1c 4a 5a 5b 5c	• **Observational task B12:** Calculate the length of the sidereal day using long-exposure photographs of the area around the celestial pole.

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Week 38	Topic 4 Time and the Earth-Moon-Sun cycles 4.2 Lunar phases			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
4.9 4.10	• Starter: Teacher gives groups of students 12 images of lunar phases on postcard-sized cards and asks them to arrange them in time sequence, starting at the 'new' phase. • Pupils study the difference between sidereal months (27.3 days) and synodic months (29.5 days), explaining why there is a 2.2-day difference. • Pupils complete worksheets on lunar phases, sidereal months and synodic months.	• Find useful information in chapter 11 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • An interactive lunar phase calendar can be found at: http://www.moonconnection.com/moon_phases_calendar.phtml		

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Week 39	Topic 4 Time and the Earth-Moon-Sun cycles 4.3 The Equation of Time			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

4.2
4.3
4.4
4.5
4.6
	• Pupils study Apparent Solar Time (AST) and how it is determined by the Sun.
	• Pupils study how the Mean Sun determines Mean Solar Time (MST) and Local Mean Time (LMT).
	• Pupils research the Equation Of Time (EOT) and how it is used to convert between AST and MST; pupils study how and why the EOT varies throughout the year.
	• Pupils study sources of information for the EOT on a particular date, including:
	  ○ analemma
	  ○ table
	  ○ graphical chart.
	• Pupils complete worksheet with questions involving the EOT.
		• Find useful information in chapter 11 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Information regarding the EOT can be found at: http://www.timeanddate.com/astronomy/equation-of-time.html
		• Teachers and pupils might like to visit the National Maritime Museum and Royal Observatory (and other attractions) in Greenwich, London; their website is: http://www.rmg.co.uk/
			3b
			3c
			3d
			4a	

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Week 40	Topic 4 Time and the Earth-Moon-Sun cycles 4.4 Sundials and shadow sticks			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
4.7 4.8	• Practical activity: In groups, pupils set up vertical shadow sticks and use a series of shadows either side of local noon to determine the time (GMT) of local noon. • Pupils study the structure and use of sundials.	• Find useful information in chapter 11 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • A wealth of information on sundials can be found at: http://www.sundials.co.uk/	1a 3b 4a 4b	• **Observational task A10:** Assess the accuracy of a sundial by completing a log of sundial and clock times. • Use a sundial and a clock (watch) to determine the Equation Of Time on a series of dates. • Use a shadow stick to determine the time of local noon using shadows.

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Week 41	Topic 4 Time and the Earth-Moon-Sun cycles 4.5 Longitude and time zones			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

4.15
4.16
4.17
4.18
4.19
4.20
4.21
	• Starter: Teacher asks the class 'It is x o-clock now here in Xxxxxxx. What time is it in America?' Hopefully, pupils respond by giving an earlier time (by 5-8 hours).
	• Pupils study the difference in local time for observers at different longitudes.
	• Pupils study global time zones.
	• Pupils complete worksheets on time zones.
	• Pupils study the Prime Meridian (0° longitude) and learn that at any point of the Prime Meridian, Local Mean Time is defined as Greenwich Mean Time (GMT).
	• Pupils study Universal Time (UT), as used by astronomers, which is the same as GMT.
	• Pupils use shadow stick data (to determine the time of local noon) and the Equation Of Time to calculate their longitude.
	• Pupils study the principles of determining longitude historically, including:
	  ○ the lunar distance (astronomical) method
	  ○ the horological method involving Harrison's marine chronometer.
		• Find useful information in chapter 11 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).	1a
			1c
			3b
			4a
			5a
			5b
				• **Observational task A9:** Determine longitude using a shadow stick by measuring the lengths of shadows around local noon.

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Week 42	Topic 12 Formation of planetary systems 12.1 Interactions			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

12.1 a-e	• Starter: Teacher asks the pupils to write down some of the common properties of planets and moons (reminding the pupils about the role of gravitation in producing regular orbits), leading the discussion into some of the more unusual and unique aspects of the Solar System.
	
	• Pupils research and identify the interactions of multiple bodies producing:
	  ○ gradual shifts in orbit
	  ○ chaotic motion
	  ○ resonances and the significance of Lagrangian Points.
	
	• Pupils research and identify evidence for accidental collisions causing:
	  ○ impact craters
	  ○ changes to orbital motion and planetary orientations.
	
	• Pupils research and identify the effects of the solar wind, including:
	  ○ structure of comets
	  ○ planetary atmospheres
	  ○ the heliosphere.
		• Find useful information in chapter 12 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 1 of *The Planets* by Aderin-Pocock, M. *et al* (DK).		

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Week 43	Topic 12 Formation of planetary systems 12.2 Formation of planets and moons			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

12.2 a-b	• Starter: Recapitulation of evidence found by pupils on Week 42's subject matter.
	
	• Pupils study tidal gravitational forces and the interaction between tidal gravitational forces and elastic forces in determining whether a large body that is too close to its primary (within the Roche Limit)is broken apart.
	
	• Pupils research and identify the operation of the effects of tidal gravitational forces producing:
	
	  ○ ring systems
	  ○ asteroid belts
	  ○ internal heating (e.g. on moons Io and Enceladus).
	
	• Pupils study the interaction between gravitational forces and elastic forces in determining whether a body is spherical or irregular in shape.
		• Find useful information in chapter 12 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 1 of *The Planets* by Aderin-Pocock, M. *et al* (DK).
		
		• An informative summary of the Roche Limit and its effects can be found at: http://www.universetoday.com/56538/roche-limit/
		
		• An interesting account of planetary ring systems and their likely formation can be found at: http://www.universetoday.com/77109/which-planets-have-rings/
		
		• A short YouTube clip covering tidal heating can be found at: https://www.youtube.com/watch?v=U7NIms7Q4C0		

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Week 44	Topic 12 Formation of planetary systems 12.3 Gas giants and planetary atmospheres			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
12.2 12.3	• Starter: Teacher summarises the unusual features of the Solar System studied in the last two sessions (Weeks 42 and 43). • Pupils research the interaction between gravitational and thermal factors in determining the presence of an atmosphere on planets and their moons. • Pupils study the main theories for the formation and location of gas giants in planetary systems.	• Find useful information in chapter 12 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapters 1 and 4 of *The Planets* by Aderin-Pocock, M. *et al* (DK).		

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Week 45	Topic 12 Formation of planetary systems 12.4 Exoplanets			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

12.4	• Starter: Teacher asks pupils to write down possible ways in which they might detect the presence of planets around a nearby star. Discussion.
	• Pupils study methods for discovering systems of exoplanets, including:
	  ○ transit method
	  ○ astrometry
	  ○ radial velocity method.
	• Plenary: Discussion about the limitations of each method of detecting systems of exoplanets.
		• Find useful information in chapter 12 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 4 of *The Universe* by Rees, M. *et al* (DK).
		• Sky & Telescope publish up-to-date news on the discovery of exoplanets online at: http://www.skyandtelescope.com/astronomy-news/exoplanets/		

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Week 46	Topic 12 Formation of planetary systems 12.5 Extra-terrestrial life			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

12.5 a-d
12.6
12.7
12.8
	• Starter: Teacher asks class to write down the essential 'ingredients' for life. Discussion.
	• Pupils research conditions on:
	  ○ Titan
	  ○ Europa
	  ○ Enceladus.
	• Pupils study the possibility of life existing outside the Solar System, taking into account the requirements for life.
	• Pupils study Habitable (Goldilocks) Zones.
	• Pupils research the Drake Equation and list some of its factors.
	• Pupils make reasonable estimates of some of the factors in the Drake Equation.
	• Pupils research methods of searching for extra-terrestrial life, including the search for extra-terrestrial intelligence (SETI).
	• Plenary: Pupils discuss the benefits and dangers of discovering extra-terrestrial life.
		• Find useful information in chapter 12 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Further useful information in chapter 2 of *The Universe* by Rees, M. *et al* (DK).
		• There are some excellent videos, notes and resources in the OU's free online Futurelearn course *Moons*. Sign up at: https://www.futurelearn.com/courses/moons/
		• The SETI Institute's website is: http://www.seti.org/
		• A good example of a 'false' SETI signal is reported at: http://earthsky.org/space/hd-164595-signal-alien-civilization-seti
			2a
			2e	

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Week 47	Topic 13 Exploring starlight 13.1 Magnitudes			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
13.1 14.2 13.2 13.3	• Pupils study the magnitude scale and how apparent magnitude relates to the brightness of a star when viewed in the night sky from Earth. • Pupils complete worksheets on magnitude differences and brightness ratios. • Pupils study the Bayer system using Greek letters to signify the brightest, second brightest etc. stars in a constellation (noting errors). • Pupils study absolute magnitude and the distance modulus equation: $M = m + 5 - 5 \log d$. • Pupils perform and practise calculations using the distance modulus formula to determine *m* or *M*, noting that distance *d* is in parsec (see 13.11). Note that unlike the previous specification, *d* will not necessarily be given as a power of 10.	• Find useful information in chapter 13 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 4 of *The Universe* by Rees, M. *et al* (DK).	1a 1c 1d 2c 3b 3c 3d	• **Observational tasks A3 and B3:** Using reference stars, assess the accuracy of a range of stellar magnitude estimates by naked-eye observations (A3) or photographs. • Observe the brightest stars in a constellation with the naked eye; name them according to the Bayer system (α, β, γ etc.) and compare these with the 'official' names.

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Week 48	Topic 13 Exploring starlight 13.2 Spectroscopy and the H-R diagram			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

13.21
13.4
13.5
13.6
13.7
	• Teacher demonstrates dispersion of white light using a prism and by a diffraction grating.
	
	• Pupils use diffraction gratings to study the emission spectra of excited gases.
	
	• Pupils study how astronomers split up light from stars to form a continuous spectrum with absorption lines.
	
	• Pupils study what information can be gathered from spectral lines, including:
	
	  ○ chemical composition
	  ○ temperature
	  ○ radial velocity
	  ○ stellar classification (OBAFGKM).
	
	• Pupils use data to produce a HR diagram of absolute magnitude against spectral type.
	
	• Pupils study alternative axes (luminosity and temperature) for the HR diagram.
	
	• Pupils locate the positions of:
	
	  ○ main sequence stars
	  ○ the Sun
	  ○ red and blue giant stars
	  ○ white dwarfs
	  ○ supergiants.
		• Find useful information in chapter 13 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 4 of *The Universe* by Rees, M. *et al* (DK).
		
		• Sky & Telescope publish an informative article on spectroscopy: http://www.skyandtelescope.com/astronomy-equipment/the-spectral-types-of-stars/		

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Week 49	Topic 13 Exploring starlight 13.3 Stellar distances			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
13.9 13.10 13.11 13.12 13.13	• Starter: Pupils think about the reasons why stars might have different brightnesses in the sky. Discussion leads into thinking about the inverse-square law between distance and brightness/intensity of light. • Pupils study small angles (minutes and seconds of arc) and practise converting between these units. • Teacher reminds pupils about the parsec and its use by astronomers. • Pupils study the heliocentric parallax method of determining distances to relatively nearby stars. • Pupils study how the HR diagram can be used to determine distances to stars.	• Find useful information in chapter 13 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 4 of *The Universe* by Rees, M. *et al* (DK).	1a 1c 1e 2c 2d 4a 5b	

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Week 50	Topic 13 Exploring starlight 13.4 Variable stars			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

13.14
13.15
13.16
13.17
13.18
	• Starter: Teacher asks pupils to consider whether the magnitudes of stars are constant or not. Discussion introduces the concept of variable stars.
	
	• Pupils study the light curves of:
	
	  ○ short/long period variables
	  ○ eclipsing binary star
	  ○ Cepheid variable star
	  ○ novae and supernovae.
	
	• Pupils study eclipsing binary stars and plot a typical light curve from data.
	
	• Pupils explain the cause of variability in an eclipsing binary star and deduce the period from its light curve.
	
	• Pupils study other gravitationally bound stellar systems such as clusters
	
	• Pupils study Cepheid variables and how their period is related to luminosity; pupils go on to study how this allows stellar distances to be determined.
		• Find useful information in chapter 13 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Information on different types of variable star can be found at: http://www.space.com/15396-variable-stars.html
			4a	• **Observational tasks A7 and B7:** Estimate the period of a variable star from a light curve produced by naked-eye estimates of magnitude (A7) or by telescopic or photographic (B7) estimates of magnitude.

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Week 51	Topic 13 Exploring starlight 13.5 Radio telescopes			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

13.22
13.23
13.24
13.25
13.26
13.27
	• Starter: Pupils study a chart showing the relative penetration/absorption of electromagnetic radiation at different wavelengths as it passes through the Earth's atmosphere. Pupils are asked to identify any 'windows' in which the majority of radiation reaches sea-level.
	
	• Pupils study the reasons why only optical and radio telescopes are located at sea-level.
	
	• Pupils study the principles behind the operation of a simple radio telescope.
	
	• Pupils are reminded of the factors affecting the resolution of a telescope (aperture and wavelength), and explain why radio telescopes need extremely large apertures to maintain a useful resolution.
	
	• Pupils study how multiple radio telescopes can operate as an aperture synthesis system.
	
	• Pupils study how radio astronomy has been important in:
	
	  ○ the discovery of quasars
	  ○ the discovery of jets from black holes
	  ○ deducing the structure of the Milky Way
	  ○ discovering protoplanetary discs.
		• Find useful information in chapter 13 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• The free A2-sized poster published by STFC, *Big Telescopes,* contains information about the Square Kilometre Array; further information at: www.skatelescope.org.
		
		• More information on radio telescopes at: http://www.jodrellbank.net/ and https://www.mrao.cam.ac.uk/outreach/
			1c
			4a	

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Week 52	Topic 13 Exploring starlight 13.6 Observing in other wavelength regions			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

13.20
13.28
13.29
13.30
13.31
13.32
13.33
14.11
10.9
	• Pupils study how modern astronomical observations are recorded:
	  ○ digital sensors convert light into electrical signals
	  ○ these are processed and stored as data files.
	• Pupils study the detrimental effect of the Earth's atmosphere on the quality of images obtained from telescopes at sea-level, and the advantages and disadvantages of space telescopes.
	• Pupils study the reasons for siting telescopes that operate outside the radio and optical 'windows' above the Earth's surface.
	• Pupils study infra-red astronomy: pupils study why some IR telescopes can be sited on high locations on the Earth's surface; pupils also study how IR astronomy has been important in the discovery of:
	  ○ protostars
	  ○ dust and molecular clouds
	  ○ hotspots on moons.
	• Pupils study UV, x-ray and gamma ray astronomy: pupils study some of the discoveries made at these wavelengths, including:
	  ○ gamma ray bursts
	  ○ accretion discs around black holes
	  ○ corona and chromosphere structure of young stars.
	• Pupils study the appearance of the Sun when observed in different regions of the electromagnetic spectrum.
		• Find useful information in chapter 13 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Posters and information on many key space observatories can be downloaded from STFC at: http://www.stfc.ac.uk/public-engagement/for-schools/
		• http://mwmw.gsfc.nasa.gov/ shows how astronomers use multiwavelength astronomy to learn more about our Galaxy's structure.		

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Week 53	Topic 14 Stellar evolution 14.1 Nebulae and clusters			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

14.1	• A research lesson in which pupils examine and explore the objects (nebulae, clusters and galaxies) contained in:
	  ○ the Messier Catalogue
	  ○ the New General Catalogue.
	• (The appearance and structure of different types of nebulae will provide a major part of evidence for different stages of the evolution of stars in this module).
		• Find useful information in chapter 14 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		• Posters of objects in the Messier Catalogue are available to purchase at suitable retail outlets: http://messier.seds.org/xtra/poster.html
		• An informative article on Charles Messier and his catalogue can be found at: http://www.universetoday.com/30572/messier-objects/
		• A detailed, but rather lengthy, article on the revises NGC can be found at: http://www.klima-luft.de/steinicke/ngcic/rev2000/Explan.htm
				• **Observational task B11:** Demonstrate the range of objects in the Messier Catalogue using detailed drawings or photographs.

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Week 54	Topic 14 Stellar evolution 14.2 Evolution of solar-mass stars			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
14.3 14.4 14.5 14.9 a-f	• Starter: Teacher asks the pupils to write down what they can remember about energy production in the Sun. • Pupils study the interaction between radiation pressure and gravity in a main sequence star. • Pupils study the changes in radiation pressure and its effects when fusible nuclear fuel is depleted in a solar-mass star. • Pupils study white dwarf stars and the balance between electron pressure and gravity. • Pupils study the principal stages and timescales for solar-mass stars, including: o emission and absorption nebulae o main sequence star o red giant o planetary nebula o white dwarf o black dwarf.	• Find useful information in chapter 14 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 5 of *The Universe* by Rees, M. *et al* (DK).		

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Week 55	Topic 15 Stellar evolution 14.3 Evolution of massive stars			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
14.6 14.7 14.8 14.10	• Pupils study the changes in the radiation pressure-gravity balance at different stages in the evolution of a star with a mass much greater than that of the Sun. • Pupils study neutron stars and the balance between neutron pressure and gravity. • Pupils study what effect the Chandrasekhar Limit has on the final outcome of massive stars. • Pupils research and study the principal stages and timescales of stellar evolution for stars of much larger mass than the Sun, including: o emission and absorption nebulae o main sequence star o red giant o white dwarf (in some cases) o supernova o neutron star o black hole.	• Find useful information in chapter 14 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 5 of *The Universe* by Rees, M. *et al* (DK).	3a	

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Week 56	Topic 14 Stellar evolution 14.4 Evolution on the H-R diagram			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
13.8	• Starter: Teacher displays a version of the H-R diagram without labels and asks pupils to label the axes with different quantities. Discussion about the general features of the H-R diagram. • Pupils study how stages in the life cycles of stars relate to positions on the H-R diagram, in particular for stars with: o a similar mass to that of the Sun o much greater masses than that of the Sun.	• Find useful information in chapter 14 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 5 of *The Universe* by Rees, M. *et al* (DK).		

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Week 57	Topic 15 Our place in the Galaxy 15.1 The Milky Way			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
6.21 15.1 15.2 15.3	• Starter: Teacher displays an image of the Milky Way taken from Earth. Pupils write down what the image shows. • Pupils study and compare the appearance of the Milky Way from Earth as seen with the naked eye, binoculars and a small telescope, understanding that they are viewing some of the spiral arms 'from the inside'. • Pupils study the contents of the Milky Way and the location of the Sun, dust, sites of star formation and globular clusters. • Teacher-led discussion/revision on radio astronomy; pupils study how 21-cm radio waves are used by radio astronomers to determine the structure and rotation of our Galaxy. • Extension work**: Observational tasks A8 or B8** (needs photographs) allow pupils to compare the densities of stars in and out of the plane of the Milky Way.	• Find useful information in chapter 15 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 5 of *The Universe* by Rees, M. *et al* (DK). • http://mwmw.gsfc.nasa.gov/ shows how astronomers use multiwavelength astronomy to learn more about our Galaxy's structure. • http://news.nationalgeographic.com/2016/06/milky-way-space-science/ is a fine example of an image of the Milky Way that could be used in the lesson starter.		• **Observational tasks A8 and B8:** Compare stellar densities in and outside the plane of the Milky Way using naked-eye estimates of numbers (A8) or telescopic measurements (B8). • Observe the Milky Way with the naked eye, binoculars and a small telescope on the same night; compare its appearance under the different optical instruments.

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Week 58	Topic 15 Our place in the Galaxy 15.2 Groupings of galaxies			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
15.4 15.5 a-b 15.13	• Pupils study groupings of galaxies from small scale (the Local Group) to large scale (clusters and superclusters). • Pupils suggest and then research the reasons why galaxies are grouped in such ways.	• Find useful information in chapter 15 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 6 of *The Universe* by Rees, M. *et al* (DK). • An atlas listing galaxies in the Local Group can be found here: http://www.atlasoftheuniverse.com/galaxies.html • A rather 'wordy', but informative set of notes on clusters and superclusters can be found at: http://www.astronomynotes.com/galaxy/s9.htm		

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Week 59	Topic 15 Our place in the Galaxy 15.3 Classification of galaxies			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
15.6 a-d 15.7 15.8	• Teacher introduces Hubble's 'Tuning Fork' diagram and introduces galactic types: ○ spiral ○ barred spiral ○ elliptical ○ irregular. • Pupils use the internet to 'find' images of all the above types of galaxy; if printing is possible, some could produce 'Tuning Fork' posters using their own images. • Pupils discover that our own galaxy is a barred spiral (SBb).	• Find useful information in chapter 15 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 6 of *The Universe* by Rees, M. *et al* (DK). • Pupils can practise classifying distant galaxies with the Galaxy Zoo project that is part of the Zooniverse public research platform: https://www.zooniverse.org/projects • There are plenty of 'Tuning Fork' diagrams at: http://www.astronomynotes.com/galaxy/s9.htm		

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Week 60	Topic 15 Our place in the Galaxy 15.4 Active galaxies			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

15.9
15.10
15.11 a-c
15.12
15.14
	• Starter: Teacher suggests to the class that galaxies emit more than just 'starlight'. Teacher asks for evidence for this suggestion to be true. Discussion could involve observations of our galaxy at radio wavelengths, multiwavelength observations of the Sun etc.
	
	• Pupils research active galaxies, including:
	  ○ Seyfert galaxies
	  ○ Quasars
	  ○ Blazars (BL Lacerta objects).
	
	• Pupils study the classic 'model' of an Active Galactic Nucleus (AGN), including a super-massive black hole and 'jets'.
	
	• Pupils research and study theories of formation and evolution of galaxies.
		• Find useful information in chapter 15 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 6 of *The Universe* by Rees, M. *et al* (DK).
		
		• Information and 'models' of AGNs (with helpful links to terminology) can be found at: http://astronomy.swin.edu.au/cosmos/A/Active+Galactic+Nuclei		

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Week 61	Topic 16 Cosmology 16.1 Redshift			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
16.1 16.2 16.3 16.4	• Starter: Teacher demonstrates the Doppler Principle with sound waves and light waves. • Pupils study the redshift of galaxies outside the Local Group in which spectral lines are shifted to longer wavelengths. • Pupils study the cause of redshift in galaxies. • Pupils obtain data on the wavelengths of common spectral lines observed by astronomers from: ○ a light source at rest ○ a distant galaxy …and use these to calculate the radial velocity of the galaxy. • Pupils practise using the formula relating redshift to redial velocity of the galaxy. • Pupils study the evidence to confirm the discovery of an expanding Universe.	• Find useful information in chapter 16 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 2 of *The Universe* by Rees, M. *et al* (DK). • This short YouTube clip illustrates the Doppler Principle using sound waves from a passing fire engine: https://www.youtube.com/watch?v=imoxDcn2Sgo • This animation explains the Doppler Principle using light: https://www.youtube.com/watch?v=vDvIhiCnatE	1a 1b 2a 2c 3a 3b 3c 3d 4a	

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Week 62	Topic 16 Cosmology 16.2 Hubble's law			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
16.5 16.6	• Starter: Pupils are shown a set of data obtained by Hubble and asked to suggest if there might be a connection between redshift and distance. • Pupils are introduced to the unit of distance used in Cosmology - the megaparsec, where 1 Mpc = 10^6 pc. • Pupils use data to plot a graph of radial velocity against distance for distant galaxies. • Pupils study Hubble's law and deduce the value of the Hubble constant from the gradient of their *v*–*d* graph. • Pupils study how the value of the Hubble constant can be used to estimate the size and age of the Universe.	• Find useful information in chapter 16 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore). • Further useful information in chapter 2 of *The Universe* by Rees, M. *et al* (DK). • Information on Hubble's law and redshift data can be found at: http://starchild.gsfc.nasa.gov/docs/StarChild/questions/redshift.html	1a 1b 1c 2c 3a 3b 3c 3d 4a 4b 4c	

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Week 63	Topic 16 Cosmology 16.3 The Big Bang			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**

16.7
16.8 a-c
16.9
16.12
	• Starter: Teacher asks the class to consider different models or theories for the beginning of the Universe. Responses are sure to include the 'Big Bang', and the class are asked to consider the evidence for this. Again, it is reasonable to assume that 'the expansion of the Universe' will be suggested as supporting this model; however, the teacher points out that the observed expansion also supports other models.
	
	• Pupils study alternative models of the beginning of the Universe, including the Steady State theory.
	
	• Pupils study the major evidence in support of the Big Bang theory, including:
	  ○ cosmic microwave background (CMB) radiation
	  ○ quasars
	  ○ Hubble Deep Field Image.
	
	• Pupils study the significance of fluctuations in the CMB radiation for theories of the evolution of the Universe, including discoveries from:
	  ○ Wilkinson Microwave Anisotropy Probe (WMAP)
	  ○ the Planck mission.
	
	• Pupils study the different future evolutionary paths predicted by current models of the Universe.
		• Find useful information in chapter 16 of *GCSE Astronomy – A Guide for Pupils and Teachers* (5th ed.) by Marshall, N. (Mickledore).
		
		• Further useful information in chapter 2 of *The Universe* by Rees, M. *et al* (DK).
		
		• Further information on the Big Bang (with links to related websites) can be found at: http://www.space.com/25126-big-bang-theory.html
		
		• Sources of evidence to support the Big Bang theory can be obtained at: http://www.astronomynotes.com/cosmolgy/s7.htm
		
		• An interesting tour of the Hubble Deep Field can be found at: http://hubblesite.org/hubble_discoveries/hubble_deep_field/		

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Week 64	Topic 16 Cosmology 16.4 Dark matter and dark energy			
Specification points	**Exemplar activities**	**Exemplar resources**	**Maths skills**	**Related practical activities**
16.10 16.11	• Pupils undertake research and write a short report or magazine article intended for general readership on: ○ the possible nature of dark matter and dark energy ○ the cosmological significance of dark matter and dark energy ○ the difficulties involved in the detection of dark matter and dark energy.	• Find useful information in chapter 16 of *GCSE Astronomy – A Guide for Pupils and* Teachers (5th ed.) by Marshall, N. (Mickledore).		

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