

4.8

Space physics

Exam-style questions — answers and mark schemes

100 questions • 235 marks

Written in the style of AQA papers, including the required practicals, maths and working scientifically.

How to use this booklet

Each answer gives the creditworthy points; one mark per point unless stated.

Alternative correct wording is credited — these are marking points, not model answers.

Calculations: the equation and the substitution each earn a mark, so a wrong final answer can still score. Error carried forward applies where stated.

Examiner notes flag the mistakes that actually lose marks in real examinations.

Command words used

State, Give, Name, Write down — a short factual answer, no explanation needed

Describe — say what happens, in order, without needing a reason

Explain — give a reason; 'because', 'so' or 'therefore' should appear

Calculate — show your working and give a unit

Determine — use data given, often from a graph or table

Estimate — an approximate value from reasonable assumptions

Suggest — apply what you know to an unfamiliar situation

Compare — say how things are similar and different, in the same sentence

Evaluate — give both sides, then a conclusion

Design, Plan — set out a method others could follow

Questions are labelled beside the marks where they are Higher Tier only, Separate Physics only, or Working scientifically — the apparatus, variables, accuracy, evaluation and maths skills that carry around a third of the marks in every AQA paper.

4.8.1 The solar system and the life cycle of a star

1

Our solar system formed from a cloud of dust and gas.

- a Name the bodies that make up the solar system. Separate Physics only [3]

The Sun at the centre (1); eight planets and dwarf planets such as Pluto (1); moons orbiting planets, and asteroids and comets (1)

- b Define a natural satellite and give an example. Separate Physics only [2]

A natural body that orbits a planet (1); for example the Moon orbiting the Earth (1)

- c Name the galaxy that contains our solar system. Separate Physics only [1]

The Milky Way (1)

- d Explain how the Sun was formed. Separate Physics only [3]

Gravity pulled together a cloud of dust and gas called a nebula (1); as the material fell inwards the temperature and pressure rose (1); until hydrogen nuclei began to fuse into helium, forming a star (1)

- e Explain why a protostar becomes hotter as it forms. Separate Physics only [2]

The particles lose gravitational potential energy as they fall inwards (1); and gain kinetic energy, so the temperature rises (1)

2

A main sequence star is stable for billions of years.

- a Explain why a main sequence star is stable. Separate Physics only [3]

Fusion in the core releases energy, creating an outward pressure (1); gravity pulls the material of the star inwards (1); the two effects balance, so the star stays the same size (1)

- b State the process that releases energy in a star, and name the elements involved. Separate Physics only [2]

Nuclear fusion (1); hydrogen nuclei fuse to form helium (1)

- c Describe the life cycle of a star of about the same mass as the Sun, from nebula onwards. Separate Physics only [4]

Nebula (1); protostar, then main sequence star once fusion begins (1); red giant when the hydrogen in the core runs out (1); then the outer layers are shed and a white dwarf remains (1)

Examiner note: Examiners report that simply naming the stages is not enough when the question asks for a description of what happens.

- d Describe how the life cycle differs for a star much more massive than the Sun. Separate Physics only [4]

It becomes a red supergiant rather than a red giant (1); then explodes as a supernova (1); leaving a neutron star (1); or, if the original star was massive enough, a black hole (1)

- e Explain why a star expands to become a red giant. Separate Physics only [3]

The hydrogen in the core runs out, so fusion of hydrogen stops there (1); the outward pressure falls and the core contracts, becoming hotter (1); heavier elements then fuse and the outer layers expand and cool, so the star looks red (1)

3

All the elements heavier than hydrogen were made in stars.

- a** Explain how elements up to iron are produced. Separate Physics only [2]

By nuclear fusion in stars (1); light nuclei fuse into progressively heavier nuclei, up to iron (1)

- b** Explain how elements heavier than iron are produced and distributed. Separate Physics only [3]

They are produced in the explosion of a supernova (1); which releases enough energy to fuse nuclei heavier than iron (1); and distributes all the elements into space, where they may form new planets (1)

- c** Explain what the presence of heavy elements on Earth tells us about the solar system. Separate Physics only [2]

The solar system formed from material that had been through at least one earlier generation of stars (1); including at least one supernova (1)

4.8.1 Orbital motion

4

A satellite orbits the Earth at a constant speed.

- a** Name the force that keeps the satellite in orbit and state its direction. Separate Physics only [2]

Gravity, or gravitational attraction (1); acting towards the centre of the Earth, that is towards the centre of the orbit (1)

- b** Explain how an object can travel at a constant speed and still be accelerating. Separate Physics only [3]

Acceleration means a change in velocity (1); velocity is a vector, so it includes direction (1); in a circular orbit the direction is constantly changing, so the velocity changes even though the speed is constant (1)

- c** Explain what happens to the radius of a stable orbit if the orbital speed increases. Separate Physics only [3]

The radius must decrease (1); a faster object needs a larger resultant force to follow a circular path (1); and gravity is only strong enough to provide that force closer to the planet (1)

- d** Explain why the planets closer to the Sun orbit at higher speeds. Separate Physics only [2]

The gravitational force is stronger closer to the Sun (1); so it can provide the larger force needed for a faster orbit (1)

- e** State what would happen to a satellite if the gravitational force suddenly disappeared. Separate Physics only [2]

There would be no resultant force on it (1); so by Newton's first law it would travel in a straight line at a constant velocity, flying off at a tangent (1)

5

The table gives data about three planets in the solar system.

Planet	Mean distance from Sun in million km	Orbital period in Earth years
Earth	150	1.0
Mars	228	1.9
Jupiter	778	11.9

- a** Describe the relationship between distance from the Sun and orbital period.

Working scientifically · Separate Physics [2]

The further a planet is from the Sun, the longer its orbital period (1); the period increases more rapidly than the distance (1)

- b** Explain this relationship in terms of forces.

Separate Physics only [2]

Gravity is weaker further from the Sun (1); so the planet travels more slowly, and it also has a longer path to travel (1)

- c** Calculate how many times further Jupiter is from the Sun than the Earth.

Maths skill [2]

$778 \div 150$ (1); = 5.2 times (1)

- d** Suggest, with a reason, whether a planet twice as far from the Sun as Jupiter would have an orbital period of about 24 years.

Working scientifically · Separate Physics [3]

No (1); the period increases faster than in direct proportion to distance (1); so the period would be considerably more than 24 years (1)

4.8.2 Red-shift and the Big Bang

6

Light from distant galaxies shows red-shift.

- a** State what is meant by red-shift. Separate Physics only [2]

Light from a galaxy moving away is shifted towards the red end of the spectrum (1); meaning a longer observed wavelength and lower frequency (1)

- b** Describe the observed link between a galaxy's distance and its red-shift. Separate Physics only [2]

The more distant the galaxy, the greater the red-shift observed (1); so the faster it is moving away from us (1)

- c** Explain how astronomers detect red-shift in practice. Separate Physics only [3]

They compare the pattern of dark absorption lines in the galaxy's spectrum (1); with the same pattern measured in a laboratory on Earth (1); the lines are shifted towards longer wavelengths, and the size of the shift gives the speed (1)

- d** Explain how red-shift provides evidence that the universe is expanding. Separate Physics only [3]

Red-shift is observed for galaxies in all directions (1); showing that they are all moving away from us (1); which is what would be observed if space itself were expanding and carrying the galaxies apart (1)

- e** Describe the Big Bang theory. Separate Physics only [3]

The universe began from a very small region (1); that was extremely hot and dense (1); and it has been expanding and cooling ever since (1)

- f** Explain why red-shift supports the Big Bang theory. Separate Physics only [2]

If the universe is expanding now, then in the past everything must have been closer together (1); running the expansion backwards leads to a single hot, dense starting point (1)

7

The Andromeda galaxy shows a blue-shift rather than a red-shift.

- a** State what a blue-shift indicates. Separate Physics only [1]

The galaxy is moving towards us (1)

- b** Explain why this does not disprove the Big Bang theory. Separate Physics only [3]

Andromeda is a near neighbour of the Milky Way (1); the gravitational attraction between the two galaxies is strong enough to outweigh the general expansion of space (1); the evidence for expansion comes from distant galaxies, which all show red-shift (1)

8

Observations of supernovae since 1998 have led to new ideas about the universe.

- a** State what these observations showed about the expansion of the universe. Separate Physics only [2]

Distant galaxies are receding ever faster (1); so the expansion of the universe is accelerating (1)

- b** Explain why this was unexpected. Separate Physics only [2]

Gravity between galaxies would be expected to slow the expansion down (1); so the expansion should have been decelerating, not accelerating (1)

- c** State what scientists proposed to explain the observations. Separate Physics only [2]

Dark energy, driving the accelerating expansion (1); and dark matter, to explain why galaxies rotate faster than their visible matter allows (1)

- d** Explain why scientists accept ideas such as dark energy even though it has never been detected directly. Working scientifically · Separate Physics [3]

It explains observations that existing theories cannot account for (1); the observations have been repeated and checked by other scientists through peer review (1); but the idea remains provisional and may be replaced if better evidence emerges (1)

Working scientifically

9

An astronomer measures the wavelength of a particular absorption line in light from four galaxies. The laboratory value of the wavelength is 486 nm.

Galaxy	A	B	C	D
Observed wavelength in nm	489	495	502	521

- a** Calculate the shift in wavelength for galaxy D. Maths skill [1]

$$521 - 486 = 35 \text{ nm (1)}$$

- b** State which galaxy is the most distant from Earth, and justify your answer. Working scientifically · Separate Physics [2]

Galaxy D (1); it has the greatest red-shift, and the most distant galaxies recede fastest (1)

- c** Calculate the percentage shift in wavelength for galaxy B. Maths skill [2]

$$(495 - 486) \div 486 \times 100 \text{ (1); } = 1.9\% \text{ (1)}$$

- d** Explain why the laboratory value must be known accurately for this method to work. Working scientifically [2]

The shift is found by comparing the observed and laboratory wavelengths (1); an error in the laboratory value would appear as a false shift and give the wrong speed (1)

- e** Suggest why measurements are repeated for the same galaxy on different nights. Working scientifically [2]

To reduce the effect of random error caused by atmospheric conditions and instrument variation (1); and to check that the result is repeatable (1)

10

A student says: 'The Big Bang theory is just a theory, so it is only a guess.'

- a** Explain why this statement misunderstands what a scientific theory is. Working scientifically [3]

In science a theory is an explanation supported by a large body of evidence (1); not a guess, which would be a hypothesis (1); the Big Bang theory is supported by red-shift observations and by the cosmic microwave background radiation (1)

- b** Explain why scientists may still change or replace the theory in future. Working scientifically [2]

New observations may be made that the theory cannot explain (1); scientific models are always provisional and are revised when better evidence emerges (1)

- c** Explain why peer review matters in astronomy, where experiments cannot be repeated in a laboratory. Working scientifically [3]

Other astronomers check the methods, calculations and interpretations before publication (1); observations can be repeated by different teams using different telescopes (1); which makes errors and false claims much less likely to be accepted (1)

11

A spacecraft is sent to study a comet. The mission costs several billion pounds.

- a** Give one argument in favour of spending money on this mission. Working scientifically [2]

It provides evidence about the formation of the solar system (1); and develops new technology and expertise that has other uses (1)

- b** Give one argument against. Working scientifically [2]

The money could be spent on more immediate problems such as healthcare (1); and the scientific benefits are uncertain in advance (1)

- c** Explain why decisions like this are not purely scientific. Working scientifically [2]

They involve economic, ethical and political judgements as well as scientific ones (1); science can describe the likely benefits and risks, but not decide what society should value (1)

12

The Moon orbits the Earth, and the Earth orbits the Sun.

- a** Explain why the Moon stays in orbit around the Earth rather than flying off into space. Separate Physics only [3]
- The Earth exerts a gravitational force on the Moon (1); this force acts towards the centre of the Earth, at right angles to the Moon's motion (1); so it changes the direction of travel continuously, keeping the Moon in a circular orbit (1)
- b** Explain why an artificial satellite in a low orbit must travel faster than one in a high orbit. Separate Physics only [3]
- Gravity is stronger closer to the Earth (1); so a larger force acts on the satellite (1); which can only be matched by a faster orbital speed at that radius (1)
- c** A geostationary satellite has an orbital period of exactly 24 hours. Explain why this is useful for communications. Separate Physics only [2]
- It stays above the same point on the Earth's surface as the Earth rotates (1); so a receiving dish can be pointed at a fixed position and never needs to be moved (1)
- d** Calculate the orbital period of a satellite in seconds if it completes 16 orbits per day. Maths skill [2]
- 24 hours = 86 400 s (1); $86\,400 \div 16 = 5400$ s (1)

13

A student draws a diagram of the solar system with the planets equally spaced and all the same size.

- a** Give two ways in which the diagram is not an accurate model. Working scientifically [2]
- The planets differ greatly in size, with Jupiter far larger than Earth (1); and the spacing between orbits increases greatly with distance from the Sun (1)
- b** Suggest why scale models of the solar system are rarely drawn accurately. Working scientifically [2]
- The distances are vastly greater than the sizes of the planets (1); so a diagram drawn to scale for distance would show the planets as invisible dots (1)
- c** Explain why scientists still find simplified models useful. Working scientifically [2]
- They show the key relationships clearly, such as the order of the planets (1); provided the limitations of the model are understood (1)

14

The table shows the surface temperature and colour of four stars.

Star	Colour	Surface temperature in K
P	Blue	25 000
Q	White	9000
R	Yellow	5800
S	Red	3200

- a** Describe the relationship between colour and surface temperature.

Working scientifically · Separate Physics

[2]

Blue stars are the hottest and red stars the coolest (1); the temperature decreases from blue through white and yellow to red (1)

- b** Identify which star is most like our Sun, and justify your answer.

Separate Physics only [2]

Star R (1); the Sun is a yellow star with a surface temperature of about 5800 K (1)

- c** Convert the surface temperature of star S into degrees Celsius.

Maths skill [2]

$^{\circ}\text{C} = \text{K} - 273$ (1); $3200 - 273 = 2927^{\circ}\text{C}$ (1)

- d** Explain why a red giant can be cooler than the Sun yet much brighter overall.

Separate Physics only [2]

Its surface is cooler, so each square metre emits less radiation (1); but it is vastly larger, so the total radiation emitted is far greater (1)

15

Explain what is meant by a light year, and why astronomers use it rather than kilometres.

- a** Define a light year.

Separate Physics only [1]

The distance light travels in one year (1)

- b** Light travels at 3.0×10^8 m/s. Calculate the number of metres in a light year.

Maths skill [3]

Seconds in a year = $365 \times 24 \times 3600 = 3.15 \times 10^7$ s (1); distance = $v t = 3.0 \times 10^8 \times 3.15 \times 10^7$ (1); $= 9.5 \times 10^{15}$ m (1)

- c** Explain why this unit is convenient for astronomers.

Working scientifically [2]

Distances between stars are enormous, so values in metres would need very large powers of ten (1); light years give manageable numbers that are easier to compare (1)

- d** Light from a star takes 400 years to reach Earth. Explain what this means about what we see.

Separate Physics only [2]

We see the star as it was 400 years ago (1); it may have changed, or even ceased to exist, since the light left it (1)

- 16** A student states: 'The universe is expanding, so the Earth must be at its centre because all galaxies are moving away from us.'

a Explain why this conclusion is wrong.

Working scientifically · Separate Physics [3]

Space itself is expanding, so every point moves away from every other point (1); an observer in any galaxy would see all other galaxies receding (1); so the observation gives no evidence that the Earth is at a special position (1)

b Suggest an analogy that illustrates the correct explanation.

Working scientifically [2]

Dots on the surface of a balloon being inflated (1); every dot moves away from every other dot, and no dot is at the centre of the surface (1)

- 17** The Sun will remain on the main sequence for about ten billion years in total, and is currently about 4.6 billion years old.

a Calculate the fraction of its main sequence lifetime that the Sun has completed.

Maths skill [2]

$4.6 \div 10$ (1); = 0.46, or 46% (1)

b Explain what will happen to the Earth when the Sun becomes a red giant.

Separate Physics only [2]

The Sun will expand enormously (1); so the Earth will be scorched or engulfed (1)

c Explain why the Sun will never become a black hole.

Separate Physics only [2]

Only stars much more massive than the Sun end as black holes (1); the Sun is not massive enough, so it will become a white dwarf (1)

- 18** Describe the evidence that supports the Big Bang theory, other than red-shift.

Give your answer.

Separate Physics only [3]

Cosmic microwave background radiation is detected from all directions in space (1); it is the leftover radiation from the hot early universe, stretched to microwave wavelengths by the expansion (1); the observed abundance of light elements such as helium also matches the theory's predictions (1)

- 19** Two students argue about whether a comet is a satellite of the Sun.

a Explain whether a comet can be described as orbiting the Sun.

Separate Physics only [2]

Yes (1); it is held in a path around the Sun by gravitational attraction, although the orbit is a long ellipse rather than nearly circular (1)

b Explain why a comet travels fastest when it is closest to the Sun.

Separate Physics only [3]

Gravity is much stronger close to the Sun (1); so the comet accelerates as it approaches (1); and slows again as it moves away into the weaker field (1)

c State one difference between the orbit of a comet and that of a planet.

Separate Physics only [1]

A comet's orbit is a long, highly elliptical path, whereas a planet's is nearly circular (1)

20

An astronomer measures the brightness of a distant supernova to estimate its distance.

- a** Explain why repeated independent measurements by different teams are important.

Working scientifically [3]

Astronomical measurements are difficult and subject to error from the atmosphere and the instruments (1); independent repeats check that the result is reproducible (1); which makes the conclusion about the expansion of the universe far more trustworthy (1)

- b** Explain why a conclusion based on a single supernova would be unreliable.

Working scientifically [2]

One measurement could be affected by random error or by unusual local conditions (1); a large sample is needed before a general conclusion about the universe can be drawn (1)

21

The diagram data below compares the Sun with a red supergiant and a white dwarf.

Star type	Radius compared with the Sun	Surface temperature in K
Red supergiant	500	3500
Sun	1	5800
White dwarf	0.01	10 000

- a** Identify the hottest star and the largest star.

Separate Physics only [2]

Hottest: the white dwarf (1); largest: the red supergiant (1)

- b** Explain why a white dwarf is very hot but hard to see.

Separate Physics only [2]

Its surface is very hot, so each square metre emits a great deal of radiation (1); but it is tiny, about the size of the Earth, so the total emitted is small (1)

- c** Describe what will eventually happen to a white dwarf.

Separate Physics only [2]

There is no fusion taking place in it (1); so it gradually cools and fades over billions of years (1)

- d** A red supergiant has a radius 500 times that of the Sun. Calculate how many times greater its surface area is.

Maths skill [2]

Surface area depends on the square of the radius (1); $500^2 = 250\,000$ times greater (1)

22

Explain the sequence of stages that follow the main sequence for a star much more massive than the Sun, and state what determines which remnant is left.

Give your answer.

Separate Physics only [4]

The star becomes a red supergiant when the hydrogen in the core runs out (1); it then explodes as a supernova (1); leaving a very dense neutron star (1); or a black hole if the original star was massive enough — the mass of the star determines which (1)

23

A student is asked to describe the difference between the solar system, a galaxy and the universe.

a Give the difference.

Separate Physics only [3]

The solar system is the Sun with the planets, moons, asteroids and comets that orbit it (1); a galaxy is a collection of billions of stars held together by gravity, such as the Milky Way (1); the universe is everything that exists, containing billions of galaxies (1)

b State how many galaxies are thought to exist, to an order of magnitude.

Separate Physics only [1]

Of the order of 10^{11} , that is billions (1)

24

Explain why astronomers cannot carry out experiments on stars, and describe how they gather evidence instead.

Give your answer.

Working scientifically · Separate Physics
[4]

Stars are far too distant and far too hot to experiment on directly (1); astronomers gather evidence by observing the radiation that reaches Earth (1); analysing the spectrum gives the temperature, composition and speed of a star (1); and observations are combined with models and compared with other stars at different stages to build up a picture of a star's life cycle (1)

25

Before the Big Bang theory was widely accepted, some scientists supported the steady state theory, in which the universe has always existed and matter is continuously created.

a Explain why the discovery of cosmic microwave background radiation supported the Big Bang theory rather than the steady state theory.

Separate Physics only [3]

The Big Bang theory predicted leftover radiation from the hot early universe (1); the cosmic microwave background was then detected coming from every direction (1); the steady state theory made no such prediction and could not explain it (1)

b Explain why both theories were able to explain red-shift.

Working scientifically · Separate Physics
[2]

Both theories describe an expanding universe (1); so both predict that distant galaxies move away from us (1)

c Explain what this example shows about how scientific theories are tested.

Working scientifically [3]

A theory must make predictions that can be tested by observation (1); when observations match one theory and not another, the better supported theory is accepted (1); theories are therefore provisional and change as evidence accumulates (1)

26

A satellite travels in a circular orbit of radius 7.0×10^6 m and completes one orbit in 5800 s.

- a Calculate the circumference of the orbit.

Maths skill [2]

$$C = 2\pi r \text{ (1); } = 2 \times \pi \times 7.0 \times 10^6 = 4.4 \times 10^7 \text{ m (1)}$$

- b Calculate the orbital speed of the satellite.

Maths skill [2]

$$v = \text{distance} \div \text{time} = 4.4 \times 10^7 \div 5800 \text{ (1); } = 7600 \text{ m/s (1)}$$

- c Explain why the satellite's velocity is constantly changing even though its speed is constant.

Separate Physics only [2]

The direction of travel changes continuously around the orbit (1); velocity is a vector, so a change in direction is a change in velocity (1)

- d State the direction of the resultant force on the satellite.

Separate Physics only [1]

Towards the centre of the Earth (1)

27

A student researches the ages of objects in the universe and records the values below.

Object	Age in billions of years
The universe	13.8
The Milky Way	13.6
The Sun	4.6
The Earth	4.5

- a Calculate how long after the Big Bang the Sun formed.

Maths skill [1]

$$13.8 - 4.6 = 9.2 \text{ billion years (1)}$$

- b Calculate the age of the Sun as a percentage of the age of the universe.

Maths skill [2]

$$(4.6 \div 13.8) \times 100 \text{ (1); } = 33\% \text{ (1)}$$

- c Suggest why the Earth and the Sun formed at almost the same time.

Separate Physics only [2]

They formed from the same cloud of dust and gas (1); the Sun formed at the centre and the planets from the material left orbiting around it (1)

- d Explain why these ages are given to only two or three significant figures.

Working scientifically [2]

They are estimates based on measurements with significant uncertainty (1); quoting more figures would imply a precision the evidence does not support (1)

28

Explain why the life cycle of a star cannot be observed directly from beginning to end, and describe how astronomers have worked it out.

Give your answer.

Working scientifically · Separate Physics
[4]

A star's life lasts billions of years, far longer than human history (1); so no single star can be watched through its whole life (1); astronomers observe very large numbers of stars at different stages at the same time (1); and arrange them into a sequence using their mass, colour, temperature and composition, supported by models (1)

29

State what is meant by a dwarf planet, and explain why Pluto is no longer classified as a planet.

a Give your answer.

Separate Physics only [3]

A dwarf planet orbits the Sun and is large enough to be roughly spherical (1); but it has not cleared other objects out of its orbital path (1); Pluto shares its region with many other objects in the Kuiper belt, so it was reclassified (1)

b Explain what this reclassification shows about scientific definitions.

Working scientifically [2]

Definitions are agreed by the scientific community and can change (1); as new evidence, such as the discovery of other similar objects, makes the old definition unhelpful (1)

30

A student lists the stages in the life cycle of a star in the wrong order: red giant, nebula, white dwarf, main sequence star, protostar.

a Write the stages in the correct order.

Separate Physics only [2]

Nebula, protostar, main sequence star, red giant, white dwarf (2, or 1 for three or four in the correct order)

b State the stage at which fusion first begins.

Separate Physics only [1]

When the protostar becomes a main sequence star (1)

31

Explain why the Sun appears far brighter than any other star, even though many stars are much larger and hotter.

Give your answer.

Separate Physics only [2]

The Sun is vastly closer to the Earth than any other star (1); the intensity of radiation received decreases rapidly with distance (1)

32

A student suggests that the universe must have an edge because it began from a single point.

a Explain why scientists do not describe the universe as having an edge.

Working scientifically · Separate Physics
[2]

The expansion is of space itself rather than of matter moving outwards into something (1); so there is no boundary or outside region to expand into (1)

b Explain why questions like this are difficult to answer with evidence.

Working scientifically [2]

We can only observe the part of the universe from which light has had time to reach us (1); so there is no direct observational evidence about anything beyond it (1)

Extended response

33

Two stars form at the same time from the same nebula. One has a mass similar to the Sun; the other is twenty times more massive.

Describe and compare the life cycles of the two stars, explaining the part played by gravity and fusion at each stage.

[6]

Level 3 (5–6 marks): both life cycles described in full with the roles of gravity and fusion. Level 2 (3–4 marks): both partly described, or one fully. Level 1 (1–2 marks): stages named only.

Indicative content: both begin as a nebula, where gravity pulls dust and gas together, raising the temperature until fusion begins and a protostar becomes a main sequence star; both are then stable because the outward pressure from fusion balances the inward pull of gravity; the more massive star burns its hydrogen far more quickly, so its main sequence life is much shorter; when the hydrogen in the core runs out the Sun-like star becomes a red giant, then sheds its outer layers to leave a white dwarf that slowly cools; the massive star becomes a red supergiant and then explodes as a supernova, distributing heavy elements into space; its remnant becomes a neutron star, or a black hole if it is massive enough; elements up to iron are made by fusion, and heavier elements in the supernova.

34

Explain how observations of light from distant galaxies have shaped our understanding of the origin of the universe.

Your answer should refer to red-shift, the Big Bang theory and the limits of current understanding.

[6]

Level 3 (5–6 marks): a coherent account linking the observations to the theory and acknowledging its limits. Level 2 (3–4 marks): several correct points. Level 1 (1–2 marks): isolated statements.

Indicative content: absorption lines in light from distant galaxies are shifted towards longer wavelengths compared with laboratory measurements; this red-shift shows the galaxies are moving away from us; the more distant the galaxy, the greater the red-shift and so the faster it recedes; this is observed in every direction, indicating that space itself is expanding; extrapolating backwards suggests the universe began from a very small, hot, dense region, which is the Big Bang theory; observations of supernovae since 1998 show the expansion is accelerating, which was not predicted; dark energy and dark matter have been proposed to explain this but have not been directly detected; much about the universe remains unexplained, so the theory may be revised as further evidence is gathered and peer reviewed.