Space physics

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Astronomers are studying a young star that has about fifteen times the mass of the Sun.

Describe the life cycle of this star, from its formation to the end of its life.

Separate science only

(6 marks)

Model answer

The star begins in a nebula, which is a huge cloud of dust and gas, mostly hydrogen. Gravity pulls the dust and gas together, forming a protostar. As it collapses it gets hotter, and when the temperature is high enough, hydrogen nuclei start to fuse into helium. The star is now shining.

The star then spends most of its life on the main sequence. Here it is stable because the inward pull of gravity is balanced by the outward force caused by the energy released from fusion. Because the star is so massive, it uses up its hydrogen much faster than the Sun does.

When the hydrogen in its core begins to run out, the star expands into a red supergiant. Fusion continues, making heavier elements up to iron.

Eventually the core collapses and the star explodes as a supernova. The explosion makes elements heavier than iron and spreads all of these elements out into space, where they can form new stars and planets. What is left of the core becomes a very dense neutron star, or, if enough mass remains, a black hole.

Marking points (credit any 6 relevant points, linked in a sensible order)

- The star forms from a nebula, a cloud of dust and gas, mainly hydrogen
- Gravity pulls the dust and gas together to form a protostar
- As it collapses the temperature rises until hydrogen nuclei fuse to form helium, and a star is born
- During its main sequence stage the inward force of gravity is balanced by the outward force from fusion energy, so the star is stable
- When the hydrogen in the core starts to run out, the star swells to become a red supergiant
- In the red supergiant, fusion makes heavier elements, up to iron
- The star then collapses and explodes as a supernova
- The supernova makes elements heavier than iron and spreads all the elements through the universe
- What is left becomes a neutron star, or a black hole if the remaining mass is big enough
- A massive star like this goes through its life much faster than the Sun

How it is marked

- 5-6 marks: describes every stage in the correct order for a massive star, including the balance of forces on the main sequence and supernova, ending as a neutron star or black hole.
- 3-4 marks: describes most stages in order but leaves out a stage, gives little detail of what happens in each stage, or mixes in part of the Sun's life cycle.
- 1-2 marks: names one or two stages, or gives the life cycle of a Sun-sized star instead.

What loses marks

- Giving the Sun's life cycle (red giant, white dwarf) for a massive star
- Saying the star is stable because there are no forces on it
- Putting the stages in the wrong order, such as supernova before red supergiant

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

2 Ethan reads that the Sun, the planets and their moons all formed from the same cloud of material about 4.6 billion years ago, and that the Sun has been shining steadily for most of that time.

Explain how the Sun and the planets formed, and why the Sun has stayed a stable size for billions of years.

Separate science only

(6 marks)

Model answer

The Solar System started as a nebula, a huge cloud of dust and gas. Gravity pulled this material together, and most of it collected at the centre. As it collapsed, the centre became denser and hotter, forming a protostar.

Eventually the temperature and density at the centre were high enough for hydrogen nuclei to fuse into helium. This nuclear fusion released large amounts of energy and the Sun became a star.

Some dust and gas was left over in orbit around the young Sun. Gravity pulled this material together into clumps, which grew bigger as they attracted more material. These clumps became the planets, all orbiting the Sun. Smaller clumps caught around the planets became their moons.

The Sun has stayed a stable size because it is on the main sequence. Gravity pulls all of its material inwards, while the energy released by fusion in the core creates an outward pressure. These two forces are balanced, so the Sun neither collapses nor expands. It will stay like this for as long as it has enough hydrogen left to fuse.

Marking points (credit any 6 relevant points, linked in a sensible order)

- The Solar System formed from a nebula, a cloud of dust and gas
- Gravity pulled the material inwards, and most of it collected at the centre
- The material at the centre became more dense and hotter as it collapsed, forming a protostar
- When it was hot and dense enough, nuclear fusion of hydrogen into helium began and the Sun became a star
- The leftover dust and gas around the young Sun was pulled together by gravity into clumps
- These clumps grew to form the planets, which then orbited the Sun
- Smaller clumps around planets formed moons
- The Sun is on the main sequence: gravity pulls its material inwards
- The energy released by fusion creates an outward force (pressure)
- These forces are balanced, so the Sun stays the same size while it still has hydrogen to fuse

How it is marked

- 5-6 marks: explains the role of gravity at each step from nebula to Sun and planets, the start of fusion, and the balance of inward and outward forces that keeps the Sun stable.
- 3-4 marks: explains that a cloud of gas was pulled together by gravity to form the Sun and planets and refers to fusion, but the balance of forces is missing or unclear.
- 1-2 marks: states that the Sun formed from gas or that it uses fusion, with little explanation.

What loses marks

- Saying the planets broke off the Sun
- Describing fusion as burning or as splitting atoms
- Not naming the two forces that are balanced on the main sequence

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

3 **Higher tier | Separate science only**

A weather satellite moves in a circular orbit around the Earth at a constant speed. Engineers later move it to a lower circular orbit, closer to the Earth.

Explain how the satellite can be accelerating even though its speed is constant, and explain why it must travel faster in the lower orbit to stay in a stable orbit. (6 marks)

Model answer

The main force on the satellite is the Earth's gravity, which always pulls it towards the centre of the Earth. In a circular orbit this force acts at right angles to the direction the satellite is moving. Because of this, the force does not speed the satellite up or slow it down. Instead, it continually changes the satellite's direction.

Velocity is a vector, so it has both a size and a direction. Even though the speed stays the same, the direction is always changing, so the velocity is always changing. A change in velocity is an acceleration, so the satellite is accelerating towards the centre of the Earth all the time.

In the lower orbit the satellite is closer to the Earth, so the gravitational force on it is stronger. This bigger force changes its direction more quickly. To stay at that radius instead of falling inwards, the satellite must move faster. If it went too slowly it would spiral down towards the Earth, and if it went too fast it would move out to a bigger orbit. So the smaller the orbit, the faster the satellite must travel for the orbit to be stable.

Marking points (credit any 6 relevant points, linked in a sensible order)

- The only significant force on the satellite is the Earth's gravity, which acts towards the centre of the Earth
- In a circular orbit this force is at right angles to the direction the satellite is moving
- The force changes the direction of the satellite but not its speed
- Velocity is a vector, with size and direction, so changing direction means the velocity changes
- A changing velocity is an acceleration, so the satellite is accelerating towards the centre of the Earth
- In the lower orbit the satellite is closer to the Earth, so the gravitational force on it is stronger
- A stronger force produces a greater change in direction (greater acceleration)
- To stay in a stable orbit at that radius without falling inwards, the satellite must move faster
- If it moved too slowly it would spiral inwards; too fast and it would move out to a larger orbit
- So a smaller orbit radius needs a higher speed for a stable orbit

How it is marked

- 5-6 marks: explains that gravity at right angles to the motion changes direction and therefore velocity, so there is acceleration, and links the stronger gravity in a lower orbit to the need for a higher speed.
- 3-4 marks: explains either the acceleration with a changing direction or why the lower orbit needs a higher speed clearly, with the other part only partly explained.
- 1-2 marks: states that gravity keeps the satellite in orbit or that closer orbits are faster, without an explanation.

What loses marks

- Saying that constant speed means no acceleration
- Saying there is no gravity in space or that the satellite is weightless because there is no force
- Saying the satellite needs a forward engine force to keep moving

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

4 A student researched the light from five distant galaxies. Red-shift tells you how much the wavelength of a galaxy's light has increased compared with the same light from a source on Earth.

Galaxy	Distance in millions of light years	Red-shift (increase in wavelength as a fraction)
P	100	0.007
Q	250	0.018
R	400	0.029
S	600	0.043
T	800	0.058

Use the data to describe the pattern, and explain how this kind of observation supports the Big Bang theory.

Separate science only

(6 marks)

Model answer

All five galaxies show red-shift, meaning the wavelength of their light is longer than the same light from a source on Earth. This shows that every galaxy is moving away from us.

The data show that the further away a galaxy is, the bigger its red-shift. Galaxy P, at 100 million light years, has the smallest red-shift of 0.007, while galaxy T, at 800 million light years, has the largest of 0.058. The red-shift is roughly proportional to the distance: doubling the distance from 400 to 800 million light years roughly doubles the red-shift from 0.029 to 0.058.

A bigger red-shift means a galaxy is moving away faster, so more distant galaxies are moving away faster than nearer ones. This is what we would see if the whole universe is expanding, with space itself stretching.

If the universe is expanding now, it must have been much smaller in the past. This supports the Big Bang theory, which says the universe began from a very small region that was extremely hot and dense. Five galaxies is a small sample, but observations of many more galaxies show the same pattern.

Marking points (credit any 6 relevant points, linked in a sensible order)

- All five galaxies show red-shift: the wavelength of their light is longer than expected
- Red-shift shows that the galaxies are moving away from us
- The further away the galaxy, the bigger the red-shift: T at 800 million light years has the largest (0.058), P at 100 has the smallest (0.007)
- The red-shift is roughly proportional to distance: doubling the distance from 400 to 800 roughly doubles the red-shift from 0.029 to 0.058
- A bigger red-shift means a galaxy is moving away faster
- So more distant galaxies are moving away faster than nearer ones
- This is what you would expect if the whole universe is expanding
- If the universe is expanding, it must once have been much smaller
- The Big Bang theory says the universe began from a very small, extremely hot and dense region
- Five galaxies is a small sample, but many more observations show the same pattern

How it is marked

- 5-6 marks: describes the pattern with figures, including proportionality, explains that red-shift means moving away faster, and links this to an expanding universe that began very small, hot and dense.
- 3-4 marks: describes the pattern using some data and links red-shift to galaxies moving away, but the link to an expanding universe or the Big Bang is incomplete.
- 1-2 marks: states that further galaxies have more red-shift or that the universe started with a Big Bang, with no clear link between them.

What loses marks

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.

- Saying red-shift means the galaxies are getting hotter or redder in colour
- Saying galaxies are moving towards us
- Describing the pattern without quoting any data

5 Jupiter orbits the Sun. Io is one of Jupiter's moons. A space probe has also been placed in orbit around Jupiter to take photographs.

Compare the orbits of Jupiter, Io and the space probe. In your answer refer to what each one orbits, the force involved and whether each is natural or artificial.

Separate science only (6 marks)

Model answer

Jupiter, Io and the space probe all move in orbits that are roughly circular, and in each case the force keeping them in orbit is gravity. The gravitational force acts towards the centre of the body they are orbiting.

Jupiter is a planet, so it orbits a star, the Sun, and it is the Sun's gravity that keeps it in orbit. Io and the probe are different because they both orbit a planet, Jupiter, so Jupiter's gravity keeps them both moving in a curved path.

Io is a moon, which is a natural satellite. The probe is an artificial satellite, because it was built and launched by people. Unlike Io and Jupiter, the probe can have its orbit changed by firing its engines.

Jupiter's orbit is far bigger than the orbits of Io or the probe, so Jupiter takes much longer to go round once. In all three orbits the speed can stay constant, but the direction keeps changing, so the velocity keeps changing.

Marking points (credit any 6 relevant points, linked in a sensible order)

- All three move in orbits that are close to circular
- In each case the force keeping the object in orbit is gravity
- The gravitational force acts towards the centre of the object being orbited
- Jupiter is a planet: it orbits a star, the Sun
- Io is a moon: it is a natural satellite that orbits a planet, Jupiter
- The space probe is an artificial satellite: it was made and launched by people and orbits Jupiter
- Io and the probe both orbit Jupiter, so Jupiter's gravity keeps both in orbit
- Jupiter's orbit is much larger than Io's or the probe's, and Jupiter takes much longer to complete one orbit
- In each orbit the speed can be constant but the velocity keeps changing because the direction changes
- The probe's orbit could be changed by firing its engines, but Io's and Jupiter's orbits cannot be controlled

How it is marked

- 5-6 marks: makes several point-by-point comparisons covering what each orbits, gravity as the force for all three, natural versus artificial, and a difference in orbit size, time or control.
- 3-4 marks: correctly identifies Jupiter as a planet orbiting the Sun and Io as a natural satellite, with some comparison, but leaves out the force or the probe as an artificial satellite.
- 1-2 marks: gives simple facts about one or two of the objects with little comparison.

What loses marks

- Calling Io a planet or the probe a natural satellite
- Naming a different force, such as magnetism, as the force that keeps them in orbit
- Listing facts about each object without making comparisons

Free for classroom and home use: print, photocopy and share. Not for resale or re-hosting.