Chapter 8: Space

Lesson 8.1 The solar system

1 Mercury

2 The Sun would look very small and very dim (and just like a typical star looks from Earth) since Pluto is very far away from the Sun.

3 Because if they were drawn to the same scale as the orbits then they would be too small to see.

4 Jupiter

5 Pluto is a dwarf planet.

6 It could have a higher density / higher mass

7 They orbit the Earth or enter the atmosphere and burn up.

8 Pluto is very small; it is a very long distance away from the Earth; it is very dim (because Pluto is very far from the Sun).

Lesson 8.2 Orbits of planets, moons and artificial satellites

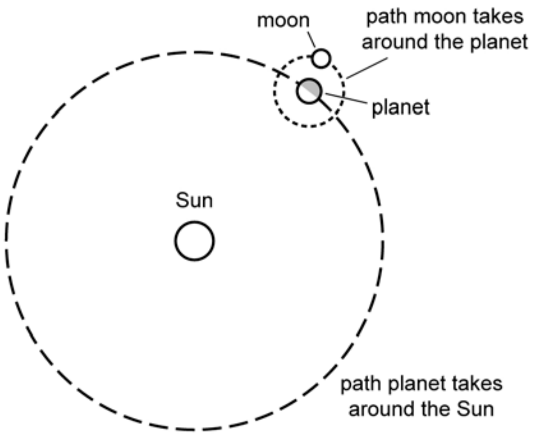
1 The force of gravity.

2 The further the distance, the longer it takes to orbit the Sun.

3 The distance the planet has to travel for a complete orbit around the Sun is larger the further away it is from the Sun – so it takes longer to make a complete orbit. Another reason is that the planets further out travel slower as the Sun's gravity is weaker.

4 The force of gravity.

5 a and b



6 Velocity has a magnitude and a direction. Since the direction is changing the velocity is changing.

7 The radius of its orbit and the speed it is going.

8 The faster the satellite is travelling, the closer it is to the surface of the Earth.

Lesson 8.3 The sun and other stars

1 planet, star, Solar System, galaxy

2 Hydrogen, some helium and a small amount of the heavier elements.

3 The gravitational force.

4 Protostars are formed from clouds of dust and gas which are very spread out. The gravity that makes the clouds to contract is very weak.

5 The gravitational force pulls the cloud of gas and dust inwards. This heats up the centre of the cloud and a protostar is formed. As the temperature increases it eventually becomes so hot that nuclear fusion reactions occur at the centre. The pressure produced from the heat emitted from the fusion reactions balances out the inward force of gravity and the star becomes stable.

6 Hydrogen

7 The nuclei repel each other due to their positive charges. Therefore, the need a lot of energy to overcome the repulsion so they become close enough to fuse.

8 Small nuclei (such as hydrogen) join together to form larger nuclei (such as helium).

9 There is a small amount of helium, but this was the helium that was there originally rather than helium formed from fusion reactions.

10 When something is burned, it is reacting with oxygen chemically. This is not happening in the Sun.

Lesson 8.4 Main sequence of a star

1 It is a star in the stable phase of its life.

2 Stars spend most of their lifetime as main sequence stars; the other stages of their lives are much shorter. Therefore, there is a greater chance that a particular star is currently at its main sequence stage.

3 They are balancing out so that there is no resultant force.

4 The star is stable so its energy output does not vary by a large amount. The force of gravity which is acting to compress the star is matched by the force from the radiation pressure which is acting to expand the star.

5 Our Sun is making lots of Helium gas at the moment.

6 The force of gravity and the force from the nuclear fusion reactions are balancing out so there is no resultant force acting to compress or expand the star.

7a When it is a protostar and at the end of its life when its core contracts.

7b During its main sequence phase.

8a The larger the mass, the higher the surface temperature.

8b If there is a large mass then the force of gravity is very strong. Therefore, the temperature needs to be high so the pressure expanding the star is large enough to balance out the strong force of gravity.

8c Gliese 758 is very close to the mass of the Sun. Therefore, the surface temperature of the Sun would be expected to be slightly higher than 5242 K. So a sensible estimate would be 6000 K (to the nearest 1000 K).

Lesson 8.5 Life cycles of stars

1 The life cycle a star follows depends on its mass.

2 When there is no longer enough hydrogen in its core to fuse into helium.

3 After the Sun's red giant phase, its outer layers expand to form a planetary nebula and its core contracts to form a white dwarf star. The white dwarf cools down over billions of years to become a black dwarf.

4 The gravitational force is very large which means the temperature at their core becomes very high. This means that the nuclear reactions occur at a much faster rate.

5 A red supergiant will eventually explode as a supernova. The core will collapse to form a neutron star or a black hole.

6 The outer layers ejected by the star as a supernova will eventually contract to form new stars.

7 We understand how stars work and the laws of physics that they follow. Therefore, we can calculate how they will evolve in the future. There are also many stars at different stages of their lives so we can compare similar stars that are at different ages. Therefore, we can see what the younger stars will be like when they are older.

Lesson 8.6 How the elements are formed

1 The early Universe was like the core of a star, so fusion reactions happened in the Universe itself, fusing hydrogen into helium.

2 It formed stars from the early clouds of gas.

3a At the centre of the star.

3b The temperature is not hot enough for fusion to take place in the other parts of the Sun.

4 It expands to become a red giant or a red supergiant. The helium at the core of the star starts fusing into heavier elements.

5 Lighter nuclei fuse together to form heavier nuclei and so a new element. As a heavier element is formed eventually it fuses to form an even heavier element and so a series of elements are created.

6 Fusing nuclei together to form heavier elements gives out energy until you get to iron. Energy is needed when elements are formed that are heavier than iron. This makes the star cool down and the fusion reactions quickly stop.

7 You need a lot of energy to form the heavier elements, which is only present during a supernova.

8 Elements heavier than iron were formed when a previous star (or stars) exploded as a supernova. These elements were dispersed into space and became part of the cloud of dust and gas that eventually formed the protostar that became the Sun.

Lesson 8.7 Red-shift

1 The light emitted from an object has its wavelengths stretched.

2 It tells us the galaxies are moving away from us.

3 Hubble discovered that the speed that a galaxy is moving away from us is directly proportional to its distance away.

4 This suggests that our Universe is expanding.

5 Observations allow us to test that the Universe behaves in a way that we would expect according to current theories. If the observations do not agree with the theory, then we need to develop the theory or produce an alternative theory that fits in with all of the observations. Therefore, theories develop over time as more observations are made.

6 The Big Bang theory describes the Universe as starting at a very small, very dense and very hot point. It then started to expand at the Big Bang and it has been expanding ever since.

7 It is impossible to tell because all the galaxies would be moving away from us *wherever* we are in the Universe.

8 They found that the mass of the universe was much heavier than the combined mass of all of the objects that they knew about. This suggests that there must be a lot of other matter out there (called dark matter).

Lesson 8.8 Key Concept: Gravity: the force that binds the Universe

1 All of them. Anything that has a mass can exert a force of gravity.

2 Gravity forms galaxies, stars and planets.

3 Our weight is the force of gravity on us, so the stronger the force of gravity the more our weight.

4a Weight = mass × g = 1000 × 9.81 = 9810 N

4b $a = F / m$ = 9810 / 1000 = 9.81 m/s^2

4c Yes – all objects will fall to the ground with an acceleration = g (assuming that there is no air resistance).

Lesson 8.9 Maths skills: Using scale and standard form

1 A scale of 0.06 mm of A4 paper to 1 million km works:

Place the paper in landscape.

Draw a dot for the Sun on the left hand edge.

Distance from the Sun on the A4 sheet:

Planet	Actual Distance (million km)	Distance on A4 paper (mm)
Mercury	57	3.4
Venus	108	6.5
Earth	150	9.0
Mars	228	14
Jupiter	778	47
Saturn	1429	86
Uranus	2870	172
Neptune	4500	270

2 Distance from Sun to Neptune = 4.5×10^9 km

Distance from Sun to Alpha Centauri = 4.1×10^{12} km

Diameter of Milky Way galaxy = 1×10^{18} km

3a Distance = speed × time = 3.0×10^8 m/s × (365 × 24 × 60 × 60) s = 9.5×10^{15} m

3b Diameter of Milky Way = 1×10^{18} km = 1×10^{21} m.

Distance in light years = $1 \times 10^{21} / 9.5 \times 10^{15}$ = 1.1×10^5 light years (to 2 significant figures).

4 170×10^{-9} m = 1.7×10^{-7} m

5a $1 / 1 \times 10^{-45} = 1 \times 10^{45}$ times bigger.

5b $1 \times 10^{39} / 1 = 1 \times 10^{39}$ times bigger.

5c The proton expands to be 1×10^{45} times bigger which means that the person would expand to be 1×10^{45} m^3. This is $1 \times 10^{45} / 1 \times 10^{39}$ = 1 million times the size of the solar system!

End of Chapter Questions

1 The Sun [1 mark]

2 The force of gravity. [1 mark]

3 C A galaxy [1 mark]

4 (nuclear) fusion [1 mark]

5 It will become a red giant [1 mark] and then a white dwarf [1 mark]

6 Its speed needs to be faster. [1 mark]

7 Kepler 33-b (as it takes the shortest time to orbit) [1 mark]

8 Blue-shift occurs when objects move towards us [1 mark]. Most of the galaxies are moving away from us [1 mark].

(In fact there are a few very close galaxies that do show blue shift as they are moving towards us due to gravitational attraction.)

9 Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune [1 mark]

10 B Main sequence [1 mark]

11 A cloud of dust and gas starts to contract due to gravity [1 mark]. This makes the centre of the cloud heat up [1 mark].

12a Jupiter [1 mark] it has a mass that is much bigger than any other planet [1 mark]

12b Mass of the object = W / g = 111 / 3.7 = 30 kg [1 mark]

So weight of object on Earth = $m \times g$ = 30 × 9.8 = 294 N [1 mark]

13 The satellite must always be above the same point on the Earth's surface [1 mark]. So it must take 24 hours to make a complete orbit [1 mark].

14 The wavelength of light becomes longer when the galaxy/star/light source is moving away from us. [1 mark]

15 Any one of: spying, weather forecasting, communications (e.g. TV), gathering scientific data, telescopes, navigation (e.g. GPS/satnav) [1 mark]

16 The star expands [1 mark] and cools down [1 mark].

17 Level 3: A detailed description is made. All the future stages of the stars are identified and linked to the relevant stars with justification. A comparison of the relative timescales is also made, with justification. (5-6 marks)

Level 2: All future stages of the stars are identified and linked to relevant stars with some description of what the stages are. (3-4 marks)

Level 1: Some future stages of the stars are listed and an attempt is made to link them to the correct stars. (1-2 marks)

Indicative content

The future stages

- Proxima Centauri and Tau Ceti will become red giants and then white dwarves
- Zeta Ophioci will become a red supergiant, explode as a supernova ejecting its outer layers, and its core will become a neutron star or a black hole.

Further detail about the stages

- The star enters the red giant/supergiant stage when it runs out of hydrogen at its core
- During the red giant/supergiant stage it starts fusing helium into heavier elements
- The supergiant stage goes through several stages, forming increasingly heavier elements at its core
- The supergiant explodes in a supernova when it starts trying to form elements heavier than iron
- During the white dwarf stage, no fusion happens but the star gradually cools down
- A neutron star is a very small and dense sphere of neutrons
- A black hole is where the gravity is so strong that not even light can escape.

Justification of the stages

- Proxima Centauri and Tau Ceti are less massive than the Sun and are likely to evolve in the same way that the Sun does
- Zeta Ophioci is much more massive than the Sun and so is likely to evolve in the same way as massive stars do.

Relative timescales

- The more massive the star, the quicker it passes through the stages
- Therefore, although Proxima Centauri is likely to pass through the same stages as Tau Ceti, Tau Ceti is likely to evolve to the red giant stage much sooner
- Zeta Ophioci is likely to evolve much quicker still because it is much more massive.

18 Nuclei are fusing together to form heavier nuclei [1 mark]. The pressure from the fusion reactions that tries to expand the star balances out the force of gravity trying to compress the star and so the star remains stable / in equilibrium [1 mark].

19 The star has formed the heaviest element that can be formed inside the core of a star (iron) [1 mark]. Therefore, the star will eventually explode as a supernova [1 mark] (and its core will become a neutron star or a black hole).

20 Level 3: A detailed account of the Big Bang theory is made and the evidence from the data shown is linked to the formulation of the theory. The data is evaluated and its strengths and weaknesses in support of the Big Bang theory are discussed successfully. (5-6 marks)

Level 2: An account of the Big Bang theory is made but it isn't successfully linked to the data shown in the graph. There is some comment about the quality of the data shown in the graph. (3-4 marks)

Level 1: The Big Bang theory is outlined and there is a comment about the quality of the data. However there is no attempt to link the data presented in the graph to the theory. (1-2 marks)

Indicative content

The Big Bang Theory

- The Universe started as a very small size
- It exploded during the Big Bang and has been expanding ever since
- The evidence Hubble used for this is from the red shift of the galaxies
- The red shift shows that the galaxies are moving away from us
- The graph shows that the further away the galaxy the greater the red shift and the faster it is moving
- This suggests that the Universe is expanding
- Which suggests that it was smaller in the past.

The data

- There is only a small number of galaxies plotted out of billions so the data might not represent the overall effect (there is a very small sample size)
- There is a lot of scatter on the graph and some galaxies that are further away are moving more slowly than nearer galaxies
- There is a general trend that suggests that galaxies further away move faster (as the line of best fit has a positive gradient)
- It is very difficult to measure the data and so there is a lot of experimental error in the results
- Lots more data needs to be gathered from other galaxies and readings need to be repeated by other people to see if Hubble is right.

Other relevant detail

- There is other evidence besides the redshift of galaxies that supports the Big Bang theory (such as cosmic microwave background radiation)
- Modern measurements suggest that the Big Bang model needs modifying to account for dark matter and dark energy