P8 Space Physics

AQA 8463 · Calculator allowed · about 80 minutes

Total Marks

Name: ________________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 The solar system contains the Sun and many objects that orbit it.

(a) State what force keeps the planets in orbit around the Sun. **(1)**

(b) Define the term satellite. **(1)**

(c) State the difference between a natural satellite and an artificial satellite, giving one example of each. **(2)**

(Total for Question 1 is 4 marks)

2 The Sun is currently a stable, average-mass star.

(a) State the term used to describe a star, like the Sun, during the long stable period of its life cycle. **(1)**

(b) State the name of the cloud of dust and gas from which a star forms. **(1)**

(c) Name the force that causes the dust and gas in a nebula to be pulled together to form a protostar. **(1)**

(Total for Question 2 is 3 marks)

3 The life cycle of a star with a similar mass to the Sun passes through several distinct stages.

(a) Put the following four stages in the correct order, starting with the earliest: main sequence star, protostar, red giant, white dwarf. **(3)**

(b) State what a white dwarf eventually becomes, once it has cooled completely and stopped glowing. **(1)**

(c) State the process that keeps a star stable and glowing during the main sequence stage. **(1)**

(Total for Question 3 is 5 marks)

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4 A star that is much more massive than the Sun follows a different life cycle after leaving the main sequence.

(a) Name the stage a very massive star enters after leaving the main sequence. **(1)**

(b) Name the explosive event that ends the life of a red super giant. **(1)**

(c) State the two possible objects that can be left behind after a supernova, and state what determines which one forms. **(2)**

(Total for Question 4 is 4 marks)

5 Elements are created within stars during their life cycles.

(a) State the process by which elements up to the mass of iron are formed within a star. **(1)**

(b) Explain how elements heavier than iron are formed, and how they are then spread throughout the universe. **(2)**

(Total for Question 5 is 3 marks)

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6 A planet orbits the Sun in a stable, roughly circular orbit at a constant orbital radius.

Figure (to be drawn): *A planet moving in a circular orbit around the Sun, with an arrow showing its velocity at a tangent to the orbit and a second arrow showing the gravitational force directed towards the Sun at the centre.*

(a) Name the force that provides the centripetal force needed to keep the planet in its circular orbit. **(1)**

(b) Explain why a planet moving at constant speed in a circular orbit is still accelerating. **(2)**

(Total for Question 6 is 3 marks)

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7 Satellites can orbit the Earth at different orbital radii.

(a) State how the orbital speed needed to maintain a stable circular orbit changes as the orbital radius increases. **(1)**

(b) Explain why a satellite in a larger orbit needs a slower orbital speed to remain in a stable orbit, in terms of the gravitational force. **(2)**

(Total for Question 7 is 3 marks)

8 Artificial satellites can be placed in different types of orbit, depending on their purpose.

(a) State one everyday use of a satellite in a geostationary orbit. **(1)**

(b) State one everyday use of a satellite in a low polar orbit. **(1)**

(Total for Question 8 is 2 marks)

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9 A geostationary satellite stays above the same point on the Earth's surface at all times.

(a) State the orbital period of a geostationary satellite. **(1)**

(b) Explain why this orbital period allows the satellite to stay above the same point on the Earth's surface. **(1)**

(Total for Question 9 is 2 marks)

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10 A satellite orbits the Earth at an orbital radius of 6.6×10^6 m, completing one orbit every 5400 s. Use the Physics Equations Sheet. Use the equation: orbital speed = (2 x π x orbital radius) / time period.

(a) Calculate the orbital speed of the satellite. **(2)**

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(b) A second satellite orbits at a much larger radius than the first, with a longer time period. State and explain how the orbital speed of the second satellite would compare with the first. **(2)**

(Total for Question 10 is 4 marks)

11 Higher Tier only. A satellite is designed to orbit the Earth at an orbital speed of 3900 m/s, at an orbital radius of 2.0×10^7 m. Use the Physics Equations Sheet. Use the equation: orbital speed = (2 x π x orbital radius) / time period.

(a) Rearrange the equation to make time period the subject. **(1)**

(b) Calculate the time period of the satellite's orbit, in seconds. **(3)**

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(Total for Question 11 is 4 marks)

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12 Satellite A orbits the Earth at a low altitude, with an orbital period of 90 minutes. Satellite B orbits much further from the Earth, at geostationary altitude, with an orbital period of 24 hours.

(a) State which satellite, A or B, has the smaller orbital radius. **(1)**

(b) Explain how you can tell this from the information given, without using a formula. **(2)**

(Total for Question 12 is 3 marks)

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13 Astronomers observe light from distant galaxies using spectrometers.

(a) State what is observed about the light from most distant galaxies, compared with light from a stationary source on Earth. **(1)**

(b) State the name given to this observed increase in wavelength. **(1)**

(c) State how the amount of red-shift changes with the distance of a galaxy from Earth. **(2)**

(Total for Question 13 is 4 marks)

14 Red-shift is often explained by comparison with the Doppler effect for sound.

(a) State what red-shift tells us about the motion of a distant galaxy relative to the Earth. **(1)**

(b) Almost all distant galaxies show red-shift, and more distant galaxies show greater red-shift. Explain what this suggests about the universe as a whole. **(2)**

(Total for Question 14 is 3 marks)

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15 The observation of red-shift provides evidence for a particular theory of the origin and evolution of the universe.

(a) Name this theory. **(1)**

(b) Describe the main features of this theory, in terms of the initial conditions of the universe and how it has changed since. **(3)**

(Total for Question 15 is 4 marks)

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16 Cosmic microwave background radiation (CMBR) is further evidence supporting the Big Bang theory.

(a) State what CMBR is. **(1)**

(b) Explain how the existence of CMBR supports the Big Bang theory. **(2)**

(Total for Question 16 is 3 marks)

17 The table shows the recession speed (the speed at which a galaxy is moving away from Earth, found from its red-shift) for four galaxies at different distances from Earth.
Distance (millions of light years): 100, 200, 300, 400
Recession speed (km/s): 2200, 4300, 6600, 8700

(a) Describe the relationship shown by the data between a galaxy's distance from Earth and its recession speed. **(2)**

(b) State what this relationship provides evidence for. **(1)**

(Total for Question 17 is 3 marks)

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18 Higher Tier only. A geostationary communications satellite orbits the Earth at an orbital radius of 4.2×10^7 m, with a time period of 86000 s. Use the Physics Equations Sheet. Use the equation: orbital speed = (2 x π x orbital radius) / time period.

(a) Calculate the orbital speed of the satellite. **(3)**

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(b) Compare this orbital speed with the orbital speed calculated in Q10 for a satellite at a smaller orbital radius, and state whether this comparison is consistent with the relationship described in Q7. **(1)**

(Total for Question 18 is 4 marks)

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19 Higher Tier only. A company claims to have proved beyond any doubt that the Big Bang theory is completely correct and that no further research into the origin of the universe is needed.

(Total for Question 19 is 4 marks)

20 Compare the life cycle of a star with a similar mass to the Sun with the life cycle of a star with a much greater mass than the Sun, from the main sequence stage onwards. In your answer, refer to: the stages each type of star passes through after the main sequence; the final object left at the end of each life cycle.

(Total for Question 20 is 6 marks)

Mark scheme · P8 Space Physics

Question 1

- (a) **B1** gravitational force (gravity)
- **(a) Answer: Gravitational force.**
- (b) **B1** an object that orbits a larger object, oe
- **(b) Answer: An object that orbits a larger object.**
- (c) **B1** a natural satellite occurs naturally, e.g. the Moon orbiting the Earth
- (c) **B1** an artificial satellite is human-made, e.g. a communications or weather satellite
- **(c) Answer: A natural satellite (e.g. the Moon) occurs naturally; an artificial satellite (e.g. a communications satellite) is human-made.**

Question 2

- (a) **B1** main sequence (star)
- **(a) Answer: Main sequence star.**
- (b) **B1** nebula
- **(b) Answer: Nebula.**
- (c) **B1** gravity (gravitational force/attraction)
- **(c) Answer: Gravity.**

Question 3

- (a) **B1** protostar placed before main sequence star
- (a) **B1** main sequence star placed before red giant
- (a) **B1** red giant placed before white dwarf
- **(a) Answer: protostar, main sequence star, red giant, white dwarf**
- (b) **B1** black dwarf
- **(b) Answer: Black dwarf.**
- (c) **B1** nuclear fusion of hydrogen (into helium) in the star's core
- **(c) Answer: Nuclear fusion of hydrogen into helium.**

Question 4

- (a) **B1** red super giant (red supergiant)
- **(a) Answer: Red super giant.**
- (b) **B1** supernova
- **(b) Answer: Supernova.**
- (c) **B1** neutron star or black hole named
- (c) **B1** a black hole only forms if the remaining core/original star is massive enough, oe
- **(c) Answer: A neutron star or a black hole; a black hole only forms if the original star was massive enough.**

Question 5

- (a) **B1** nuclear fusion
- **(a) Answer: Nuclear fusion.**
- (b) **B1** elements heavier than iron are formed during a supernova explosion
- (b) **B1** the explosion distributes/spreads these elements throughout the universe, oe
- **(b) Answer: Elements heavier than iron form during a supernova explosion, which then distributes them throughout the universe.**

Question 6

- (a) **B1** the gravitational force (of attraction) between the Sun and the planet
- **(a) Answer: Gravitational force between the Sun and the planet.**
- (b) **B1** velocity is a vector, so although the planet's speed is constant, its direction of motion is constantly changing
- (b) **B1** a change in velocity means the planet is accelerating (the acceleration is directed towards the centre of the orbit), oe
- **(b) Answer: Speed is constant but direction keeps changing, so velocity changes, meaning the planet is accelerating towards the centre of its orbit.**

Question 7

- (a) **B1** the orbital speed needed decreases (satellites in larger/higher orbits travel more slowly)
- **(a) Answer: The orbital speed needed decreases.**
- (b) **B1** the gravitational force is weaker at a greater distance from the Earth
- (b) **B1** a weaker force provides less centripetal force, so a slower orbital speed is needed to keep the satellite moving in a stable circular path at that radius, oe
- **(b) Answer: Gravity is weaker at a larger radius, so it can only provide the centripetal force needed for a slower orbital speed.**

Question 8

- (a) **B1** any sensible use, e.g. satellite television/communications broadcasting, or monitoring weather over a fixed region
- **(a) Answer: E.g. satellite television broadcasting.**
- (b) **B1** any sensible use, e.g. Earth observation/environmental monitoring, weather imaging, satellite navigation
- **(b) Answer: E.g. Earth observation/environmental monitoring.**

Question 9

- (a) **B1** 24 hours (1 day)
- **(a) Answer: 24 hours.**
- (b) **B1** its orbital period matches the time the Earth takes to rotate once, so the satellite stays above the same point as the Earth turns beneath it, oe
- **(b) Answer: Its orbital period matches the Earth's rotation, so it stays above the same point.**

Question 10

- (a) **M1** substitution: $v = (2 \times \pi \times 6.6 \times 10^6) / 5400$, oe
- (a) **A1** v = 7680 m/s (3 s.f.), cao (accept awrt 7680 m/s)
- **(a) Answer: v = 7680 m/s**
- (b) **B1** the second satellite's orbital speed would be lower/slower
- (b) **B1** because gravitational force is weaker at a larger orbital radius, so a lower orbital speed is needed to maintain a stable orbit, oe
- **(b) Answer: The second satellite's orbital speed would be lower, because gravity is weaker at the larger radius.**

Question 11

- (a) **B1** time period = (2 x π x orbital radius) / orbital speed
- **(a) Answer: T = (2 x π x r) / v**
- (b) **M1** substitution: $T = (2 \times \pi \times 2.0 \times 10^7) / 3900$, oe
- (b) **M1** correct evaluation of the numerator: $2 \times \pi \times 2.0 \times 10^7 = 1.257 \times 10^8$
- (b) **A1** T = 32200 s (3 s.f.), cao (accept awrt 32200 s)
- **(b) Answer: T = 32200 s (about 8.9 hours)**

Question 12

- (a) **B1** satellite A
- **(a) Answer: Satellite A.**
- (b) **B1** satellites orbiting at a smaller radius experience a stronger gravitational force, travel faster and complete an orbit in less time
- (b) **B1** satellite A has a much shorter orbital period than satellite B, so it must be orbiting at a smaller radius, oe

Question 13

- (a) **B1** the wavelength of the light is increased (longer), oe
- **(a) Answer: The wavelength is increased.**
- (b) **B1** red-shift
- **(b) Answer: Red-shift.**
- (c) **B1** the further away a galaxy is
- (c) **B1** the greater its observed red-shift (the faster it appears to be moving away)
- **(c) Answer: The further away a galaxy is, the greater its red-shift.**

Question 14

- (a) **B1** the galaxy is moving away from the Earth (receding)
- **(a) Answer: The galaxy is moving away from the Earth.**
- (b) **B1** galaxies are moving apart from each other/from us in every direction
- (b) **B1** this suggests that the whole universe is expanding, oe
- **(b) Answer: It suggests that the whole universe is expanding.**

Question 15

- (a) **B1** the Big Bang theory (model)
- **(a) Answer: The Big Bang theory.**
- (b) **B1** the universe began from a very small region/point that was extremely hot and dense
- (b) **B1** the universe has been expanding ever since (and is still expanding today)
- (b) **B1** the universe has been cooling as it has expanded, oe
- **(b) Answer: The universe began from a very small, extremely hot, dense region, and has been expanding and cooling ever since.**

Question 16

- (a) **B1** electromagnetic radiation (in the microwave part of the spectrum) that fills all of space/the universe
- **(a) Answer: Electromagnetic (microwave) radiation filling all of space.**
- (b) **B1** CMBR is believed to be radiation created shortly after the very early, hot, dense universe
- (b) **B1** as the universe has expanded and cooled, this radiation has been stretched to the microwave wavelengths observed today, and its presence throughout the universe is explained by the theory, oe
- **(b) Answer: CMBR is radiation from the very early universe, stretched to microwave wavelengths as the universe has expanded, matching what the Big Bang theory predicts.**

Question 17

- (a) **B1** as distance increases, recession speed increases
- (a) **B1** the relationship is approximately directly proportional, e.g. doubling the distance from 100 to 200 approximately doubles the speed from 2200 to 4300, oe
- **(a) Answer: Recession speed increases with distance, and the relationship is approximately directly proportional.**
- (b) **B1** that the universe is expanding (uniformly in all directions), oe
- **(b) Answer: That the universe is expanding.**

Question 18

- (a) **M1** substitution: $v = (2 \times \pi \times 4.2 \times 10^7) / 86000$, oe
- (a) **M1** correct evaluation of the numerator: $2 \times \pi \times 4.2 \times 10^7 = 2.639 \times 10^8$
- (a) **A1** v = 3070 m/s (3 s.f.), cao (accept awrt 3070 m/s)
- **(a) Answer: v = 3070 m/s**
- (b) **B1** yes, it is consistent - this satellite, at the larger orbital radius, has a lower orbital speed (about 3070 m/s) than the satellite in Q10 (about 7680 m/s) at the smaller radius, which agrees with Q7
- **(b) Answer: Yes, consistent: the larger-radius satellite here has a lower orbital speed than the smaller-radius satellite in Q10.**

Question 19

- **B1** the Big Bang theory currently explains both major pieces of observational evidence: red-shift (galaxies moving apart) and cosmic microwave background radiation (CMBR)
- **B1** no alternative model currently explains both observations as well
- **B1** however, scientists continue to gather new data (e.g. from more distant galaxies, more precise CMBR measurements) to test the model further
- **B1** scientific models are always provisional/tentative and are revised or replaced if new evidence is found that they cannot explain, so the claim that no further research is needed is not justified, oe
- **Answer: The claim is not justified. The Big Bang theory is currently the best-supported model, but scientific theories remain provisional and are always tested against new evidence.**

Question 20

- **Level 0** (0): No relevant content.
- **Level 1** (1-2): Isolated statement(s) are made about one or both life cycles, with little or no comparison.
- **Level 2** (3-4): Relevant points are made about both life cycles, showing some comparison, but the description may be incomplete or the two life cycles not clearly linked.
- **Level 3** (5-6): A clear, detailed and accurately sequenced comparison of both life cycles is given, correctly identifying the final objects formed, with correct scientific terminology throughout.
- **Indicative content:**
  - Both types of star begin on the main sequence, a long stable period fuelled by nuclear fusion of hydrogen into helium.
  - A Sun-sized star leaves the main sequence and expands into a red giant.
  - The red giant loses its outer layers, leaving behind a white dwarf, which cools over a very long time to eventually become a black dwarf.
  - A much more massive star leaves the main sequence and expands into a red super giant.
  - The red super giant explodes as a supernova.
  - After a supernova, the remaining core collapses to leave either a neutron star, or, if the original star was massive enough, a black hole.
  - Massive stars have much shorter overall lifetimes than Sun-sized stars, because they use up their fuel more quickly.
  - Elements heavier than iron are only formed during a supernova explosion, not during the life cycle of a Sun-sized star.