P8H Space Physics: Higher Tier Practice

AQA 8463 · Calculator allowed · about 95 minutes

Total Marks

Name: ________________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 A weather satellite moves at a constant speed around the Earth in a circular orbit.

(a) State whether the satellite's velocity is constant, and explain your answer. **(2)**

(b) Explain why the satellite is accelerating, even though its speed does not change. **(1)**

(Total for Question 1 is 3 marks)

---

2 The Earth orbits the Sun because of the gravitational force between them.

(a) State the direction of the gravitational force acting on the Earth at any point in its orbit, relative to the Sun. **(1)**

(b) Explain how this gravitational force is able to keep the Earth moving in a circular orbit, rather than travelling off in a straight line. **(2)**

(Total for Question 2 is 3 marks)

3 A communications satellite orbits the Earth in a circular orbit of radius 4.22×10^7 m. It takes 24.0 hours to complete one full orbit. Use the equation: orbital speed = (2 x π x orbital radius) / time period. Use π = 3.14.

(a) Convert the time period of 24.0 hours into seconds. **(2)**

(b) Calculate the orbital speed of the satellite, in m/s. Give your answer to 3 significant figures. **(2)**

....

(Total for Question 3 is 4 marks)

---

4 Two satellites, X and Y, orbit the Earth. Satellite X has a small orbital radius, close to the Earth's surface. Satellite Y has a much larger orbital radius, far from the Earth's surface.

(a) State and explain which satellite, X or Y, has the greater orbital speed. **(2)**

(b) State and explain which satellite, X or Y, has the longer orbital time period. **(2)**

(Total for Question 4 is 4 marks)

5 Stars form from clouds of dust and gas, and their eventual fate depends on their mass. Consider a star with roughly the same mass as the Sun, and a much more massive star.

(a) Describe the life cycle of a star with roughly the same mass as the Sun, from the main sequence stage onwards. **(3)**

(b) Describe how the life cycle of a much more massive star differs after the main sequence stage. **(3)**

(Total for Question 5 is 6 marks)

---

6 When astronomers analyse the light from a distant galaxy, they compare the wavelengths of specific spectral lines in that light with the wavelengths of the same spectral lines measured from a source at rest, such as a laboratory light source on Earth.

(a) State what is observed about the wavelength of light from most distant galaxies, compared with the same light from a source at rest. **(1)**

(b) Explain what this observation, called red-shift, tells scientists about the motion of most distant galaxies relative to the Earth. **(1)**

(Total for Question 6 is 2 marks)

7 The table shows the observed red-shift of light from four galaxies, and their approximate distance from Earth.

Galaxy -- Distance from Earth (million light years) -- Observed red-shift
P -- 100 -- small
Q -- 400 -- moderate
R -- 900 -- large
S -- 1600 -- very large

(a) Describe the relationship between a galaxy's distance from Earth and the size of its observed red-shift, as shown by the data. **(1)**

(b) Explain what this relationship shows about how the speed at which galaxies are moving away from Earth depends on their distance. **(1)**

(c) Explain how this relationship between distance and speed supports the theory that the universe is expanding. **(2)**

(Total for Question 7 is 4 marks)

---

8 Astronomers measure the distance to a nearby star, Proxima Centauri, as 4.24 light years. Light travels at a speed of 3.00×10^8 m/s. One year is approximately 3.15×10^7 s.

(a) Calculate the distance to Proxima Centauri in metres. Give your answer in standard form, to 3 significant figures. **(2)**

....

(b) A radio signal sent from Earth would take the same time to reach Proxima Centauri as light does. Calculate this time, in years, giving a reason without further calculation. **(1)**

....

(Total for Question 8 is 3 marks)

9 In the 1960s, scientists Arno Penzias and Robert Wilson detected faint microwave radiation coming from every direction in space, with a very similar intensity wherever they pointed their detector.

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

(b) Explain how the existence of this radiation, detected uniformly from every direction, provides evidence for the Big Bang theory of the origin of the universe. **(2)**

(Total for Question 9 is 3 marks)

---

10 The Moon orbits the Earth in a roughly circular orbit of radius 3.84 x 10^5 km, taking 27.3 days to complete one orbit. Use the equation: orbital speed = (2 x π x orbital radius) / time period. Use π = 3.14.

(a) Convert the orbital radius into metres, and the time period into seconds. Give both answers in standard form. **(2)**

(b) Calculate the orbital speed of the Moon, in m/s, to 3 significant figures. **(2)**

....

(Total for Question 10 is 4 marks)

---

11 Satellites are placed in orbits of very different radii, depending on their purpose. A weather-monitoring satellite is often placed in a low orbit, close to the Earth's surface. A communications satellite is often placed in a much higher, geostationary orbit, where its orbital period matches the Earth's rotation period of 24 hours, so it stays above the same point on the Earth's surface.

(a) Suggest one advantage of using a low orbit for a weather-monitoring satellite. **(1)**

(b) Suggest one advantage of using a geostationary orbit for a communications satellite. **(1)**

(Total for Question 11 is 2 marks)

12 In the twentieth century, most astronomers believed the universe was static (not expanding or contracting). Explain how the discovery of red-shift in the light from distant galaxies, and the later discovery of the cosmic microwave background radiation, changed scientific understanding of the origin of the universe, leading to the widespread acceptance of the Big Bang theory.

(Total for Question 12 is 6 marks)

Mark scheme · P8H Space Physics: Higher Tier Practice

Question 1

- (a) **B1** the satellite's velocity is not constant (it is changing), oe
- (a) **B1** because velocity is a vector, and although the satellite's speed stays constant, its direction of travel is continuously changing as it moves around the circular orbit, oe
- **(a) Answer: The satellite's velocity is not constant. Although its speed stays the same, velocity is a vector, and its direction of travel is continuously changing as it moves around the circular orbit.**
- (b) **B1** acceleration is defined as a change in velocity; because the satellite's direction (and therefore its velocity) is continuously changing, it is continuously accelerating, even though its speed is constant, oe
- **(b) Answer: Acceleration is a change in velocity. Because the satellite's direction, and therefore its velocity, is continuously changing, it is continuously accelerating, even though its speed stays the same.**

Question 2

- (a) **B1** the force acts towards the centre of the orbit (towards the Sun), oe
- **(a) Answer: The gravitational force acts towards the centre of the orbit, that is, towards the Sun.**
- (b) **B1** the gravitational force provides the centripetal force needed to continuously change the direction of the Earth's velocity, oe
- (b) **B1** this constantly pulls the Earth towards the Sun, curving its path into a (roughly) circular orbit instead of letting it continue in a straight line, oe
- **(b) Answer: The gravitational force provides the centripetal force needed to continuously change the direction of the Earth's velocity. This constant pull towards the Sun curves the Earth's path into an orbit, instead of letting it travel off in a straight line.**

Question 3

- (a) **M1** 24.0 x 3600
- (a) **A1** 86400 s cao
- **(a) Answer: 86400 s**
- (b) **M1** substitutes: speed = (2 x 3.14 x 4.22 x 10^7) / 86400, ft from (a)
- (b) **A1** 3070 m/s or 3.07 x 10^3 m/s cao
- **(b) Answer: 3070 m/s (3.07 x 10^3 m/s)**

Question 4

- (a) **B1** satellite X (the one with the smaller orbital radius)
- (a) **B1** a satellite closer to the Earth experiences a stronger gravitational force, which requires (and provides) a greater orbital speed to maintain a stable circular orbit at that radius, oe
- **(a) Answer: Satellite X, the one with the smaller orbital radius, has the greater orbital speed, because it experiences a stronger gravitational force, which requires a greater speed to maintain a stable orbit at that radius.**
- (b) **B1** satellite Y (the one with the larger orbital radius)
- (b) **B1** satellite Y has both a much longer distance to travel to complete one orbit, and a lower orbital speed, so it takes much longer to complete one full orbit, oe
- **(b) Answer: Satellite Y, the one with the larger orbital radius, has the longer orbital time period, because it has a much greater distance to travel and a lower orbital speed.**

Question 5

- (a) **B1** the star spends most of its life on the main sequence, fusing hydrogen into helium in its core, oe
- (a) **B1** once the hydrogen in the core is used up, the star expands to become a red giant, oe
- (a) **B1** the red giant then sheds its outer layers, forming a planetary nebula, leaving behind a white dwarf, which gradually cools, oe
- **(a) Answer: The star spends most of its life on the main sequence, fusing hydrogen into helium. When the hydrogen in its core runs out, it expands into a red giant, which then sheds its outer layers as a planetary nebula, leaving behind a white dwarf that gradually cools.**
- (b) **B1** the massive star expands to become a red supergiant (rather than a red giant), oe
- (b) **B1** the red supergiant explodes in a supernova, oe
- (b) **B1** the supernova leaves behind either a neutron star or, if the original star was massive enough, a black hole, oe
- **(b) Answer: The much more massive star expands to become a red supergiant, which then explodes as a supernova. This leaves behind either a neutron star or, for the most massive stars, a black hole.**

Question 6

- (a) **B1** the wavelength is increased (shifted towards the red end of the spectrum), oe
- **(a) Answer: The wavelength is increased; it is shifted towards the red end of the spectrum (red-shifted).**
- (b) **B1** it shows that most distant galaxies are moving away from the Earth (and from each other), oe
- **(b) Answer: It shows that most distant galaxies are moving away from the Earth (and from each other).**

Question 7

- (a) **B1** the further away a galaxy is from Earth, the greater (larger) its observed red-shift, oe
- **(a) Answer: The further away a galaxy is, the greater its observed red-shift.**
- (b) **B1** the further away a galaxy is, the faster it is moving away from the Earth (its red-shift, and therefore its speed of recession, increases with distance), oe
- **(b) Answer: The further away a galaxy is, the faster it is moving away from the Earth; red-shift, and therefore recession speed, increases with distance.**
- (c) **B1** if every galaxy is moving away from every other galaxy, with more distant galaxies moving away faster, this is consistent with the space between all galaxies stretching (expanding) uniformly, oe
- (c) **B1** rather than, for example, all the galaxies simply moving away from one single fixed point in space, oe
- **(c) Answer: If every galaxy is moving away from every other galaxy, with more distant ones moving away faster, this is consistent with the space between all galaxies stretching uniformly, that is, the universe expanding, rather than the galaxies simply moving away from one fixed point.**

Question 8

- (a) **M1** substitutes: distance = speed x time = $(3.00 \times 10^8) \times (4.24 \times 3.15 \times 10^7)$
- (a) **A1** 4.01×10^{16} m cao
- **(a) Answer: 4.01×10^{16} m**
- (b) **B1** 4.24 years, because radio waves are electromagnetic waves and travel at the same speed as light, oe
- **(b) Answer: 4.24 years, because radio waves are electromagnetic waves and travel at the same speed as light.**

Question 9

- (a) **B1** cosmic microwave background radiation (CMBR / CMB)
- **(a) Answer: Cosmic microwave background radiation (CMBR).**
- (b) **B1** the Big Bang theory predicts that the universe began in an extremely hot, dense state, oe
- (b) **B1** as the universe has since expanded and cooled, the radiation released in this early hot state would have stretched to much longer (microwave) wavelengths, and would now be detected uniformly from all directions, which matches what is observed, oe
- **(b) Answer: The Big Bang theory predicts that the universe began in an extremely hot, dense state. As the universe expanded and cooled, radiation from this early state would stretch to much longer, microwave wavelengths and be detected uniformly from every direction, which matches the observed cosmic microwave background radiation.**

Question 10

- (a) **B1** radius = 3.84×10^8 m
- (a) **B1** time period = 27.3 x 24 x 3600 = 2.36×10^6 s (awrt)
- **(a) Answer: Radius = 3.84×10^8 m; time period = 2.36×10^6 s.**
- (b) **M1** substitutes: speed = $(2 \times 3.14 \times 3.84 \times 10^8) / (2.36 \times 10^6)$, ft from (a)
- (b) **A1** 1020 m/s or 1.02×10^3 m/s cao
- **(b) Answer: 1020 m/s (1.02×10^3 m/s)**

Question 11

- (a) **B1** e.g. it is much closer to the Earth's surface, so it can capture more detailed (higher-resolution) images of weather systems, oe
- **(a) Answer: A low orbit is much closer to the Earth's surface, allowing the satellite to capture more detailed, higher-resolution images.**
- (b) **B1** e.g. because it stays above the same point on the Earth, a receiving dish on the ground can be fixed in one direction and does not need to track/move to follow the satellite, oe
- **(b) Answer: Because the satellite stays above the same point on the Earth, a ground-based receiving dish can be fixed in one direction and does not need to track the satellite.**

Question 12

- **Level 3** (5-6): A clear, well-structured explanation that correctly links red-shift observations to an expanding universe, links the cosmic microwave background radiation to a hot, dense early universe, and explains how together these two independent pieces of evidence led scientists to accept the Big Bang theory over a static-universe model.
- **Level 2** (3-4): A partially developed explanation. At least one piece of evidence (red-shift or CMB radiation) is explained accurately and linked to the Big Bang theory, but the second piece of evidence is missing, only briefly stated, or not clearly linked.
- **Level 1** (1-2): Simple, largely unlinked statements about red-shift and/or the CMB radiation, with little or no explanation of how they support the Big Bang theory.
- **Indicative content:**
  - Observations showed that light from almost all distant galaxies is red-shifted, meaning its wavelength has increased.
  - This red-shift shows that almost all distant galaxies are moving away from the Earth, and the further away a galaxy is, the faster it is moving away.
  - This pattern is best explained by the space between galaxies stretching (the universe expanding) uniformly, rather than a static universe, which was the earlier, widely held view.
  - If the universe has been expanding, then running the expansion backwards in time implies that the universe must once have been much smaller, hotter and denser, an idea supporting the Big Bang theory.
  - The cosmic microwave background radiation is a faint microwave signal detected uniformly from every direction in space.
  - It is interpreted as radiation left over from the very hot, dense early universe, that has been stretched to much longer (microwave) wavelengths as the universe expanded and cooled over billions of years.
  - Because the CMB radiation is independent evidence from red-shift, but points to the same conclusion (an expanding universe that began in a hot, dense state), its discovery greatly strengthened scientific confidence in the Big Bang theory and led most astronomers to abandon the static-universe model.