Original Questions

Book 6

Chapter Exercise

Multiple-choice Questions

1. If a model of the universe is geocentric, it **must**

(1) assume the Earth to be the centre of the universe.
(2) use epicycles to explain the retrograde motion of planets.
(3) place the Earth slightly off centre from the circular orbits of the planets.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

2. Which of the following is NOT suggested by the Copernican model?

A. Planets move in circular orbits around the Sun.
B. The Sun is at the centre of the universe.
C. Mars undergoes retrograde motion in the sky because the Earth overtakes Mars in its orbit.
D. All planets have a complete cycle of phases as seen from the Earth.

3. Which of the following is NOT an astronomical discovery made by Galileo?

(1) Venus and Mercury are only visible shortly before sunrise or shortly after sunset.
(2) The Milky Way is made up of numerous stars.
(3) Mars has ice caps at both of its poles.

A. (2) only
B. (3) only
C. (1) and (2) only
D. (1) and (3) only

4. Venus is 0.7 AU from the Sun. Which of the following is NOT a possible distance between Venus and the Earth, according to the Copernican model?

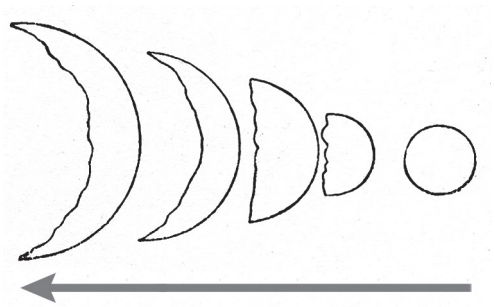
A. 0.2 AU
B. 0.7 AU
C. 1 AU
D. 1.6 AU

5. **HKDSE 2013** Which of the following statements about Ptolemy's geocentric model and Copernican's heliocentric model of the universe is/are correct?

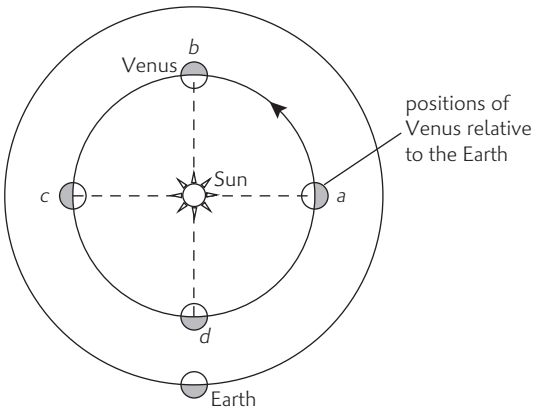
(1) Orbits are circular in both models.
(2) The Earth is at the centre of the Moon's orbit in both models.
(3) Retrograde motion can be explained in both models.

A. (l) only
B. (3) only
C. (1) and (2) only
D. (1), (2) and (3)

6. **HKDSE 2014** The following diagram is Galileo's drawing in 1610 showing the phases of Venus.



Which of the following parts of the orbit of Venus represent the above change of phases from right to left?



A. $a \rightarrow b \rightarrow c$
B. $b \rightarrow c \rightarrow d$
C. $c \rightarrow d \rightarrow a$
D. $d \rightarrow a \rightarrow b$

Structured Questions

7. Ptolemaic model had been relied upon for a long time in the history of astronomy.

(a) (i) How does the Ptolemaic model explain the retrograde motion of Mars? (1 mark)

(ii) Mercury is always close to the Sun when viewed from the Earth. How does the Ptolemaic model explain this phenomenon? Illustrate your answer with a diagram. (2 marks)

(b) Later, Galileo discovered Venus's phase changes.

(i) Can this be explained by the Ptolemaic model? If yes, how? If no, why not? (2 marks)

(ii) Galileo also made another discovery that was contrary to the common belief at that time. What is it? (1 mark)

8. The Ptolemaic and Copernican models are two different models of the universe.

(a) State the essential difference between the two models. (1 mark)

(b) In a single night, the stars move across the sky but their relative positions remain unchanged. Describe how the Ptolemaic model accounts for this observation. (2 marks)

(c) The two models were later superseded by other models after Tycho and Kepler's time.

(i) Outline the contributions made by Tycho and Kepler to the understanding of planetary motion. (2 marks)

(ii) How do the first two Kepler's laws overturn the basic beliefs at Kepler's time? (2 marks)

9. **IB Higher level Nov 2000** The figures at the bottom represent two different models of the universe.

(a) Which figure represents Copernicus's model of the universe and which Aristotle's model of the universe? (1 mark)

On any one particular night, the stars' and planets' observed **general** motion appears to be a rotation about the Earth. If observed on more than one night, the planets also show retrograde motions.

Both models can explain this observed **general** motion of the stars and the planets. Only the model in Fig. b can explain the *observed retrograde motions of the planets* without further modifications.

(b) Explain what is meant by the '*observed retrograde motions of the planets*'. (2 marks)

(c) The following questions are about the model in Fig. a.

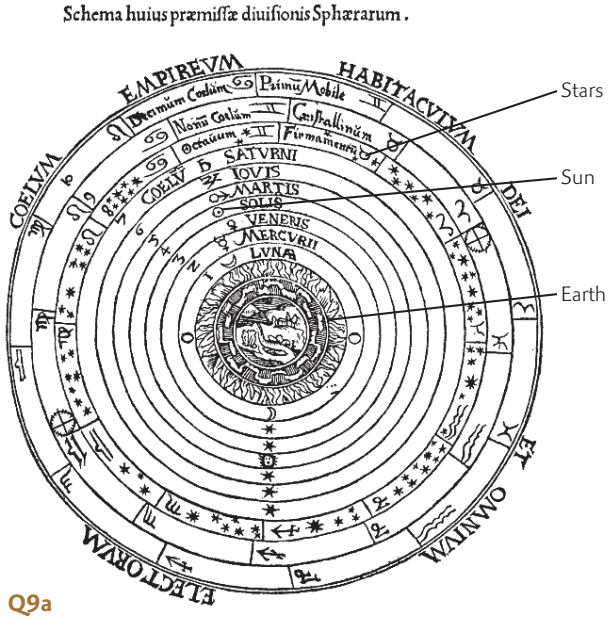
(i) How does it account for the observed *general* motion of the stars **and** the planets? (2 marks)

(ii) Explain what modifications are required for this basic model to be able to explain retrograde motion. (2 marks)

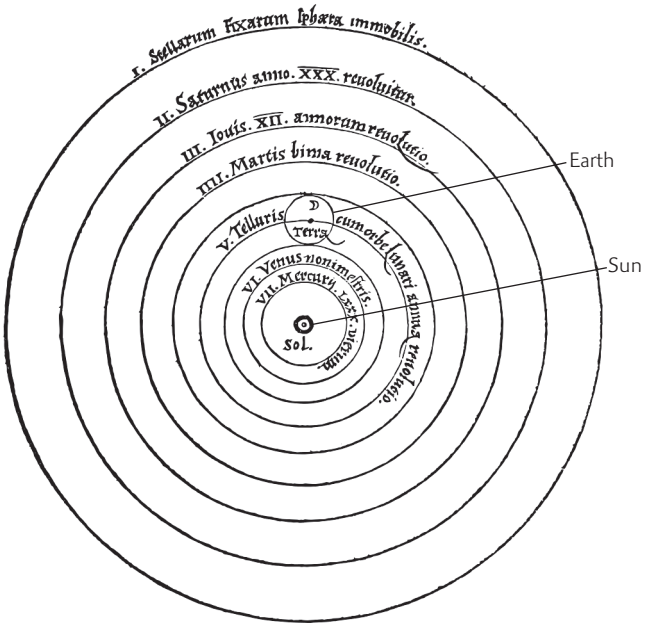
(d) The following questions are about the model in Fig. b.

(i) How does it account for the observed *general* motion of the stars **and** the planets? (2 marks)

(ii) Explain how this model is able to explain retrograde motion. (2 marks)



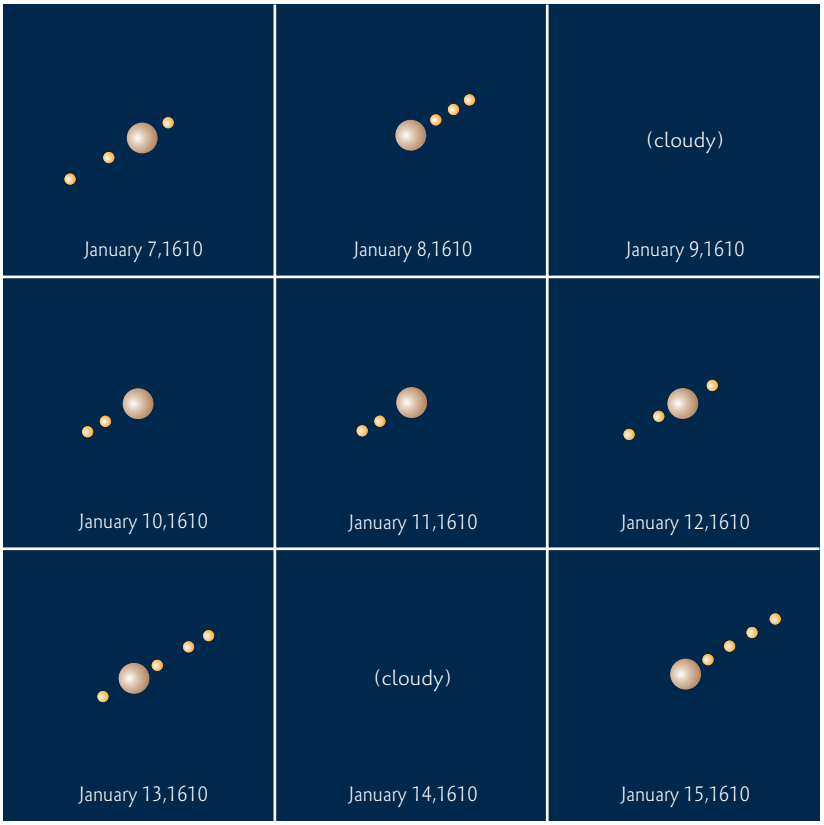
Q9a



Q9b

10. **OCR A-level 2825/01 Jun 2002** Galileo is credited with the first application of the telescope to astronomy.

(a) On January 7 1610, Galileo observed the planet Jupiter and saw tiny spots of light either side of it. On subsequent days the pattern of spots changed as shown.



(i) Explain the existence of the spots of light near Jupiter.

(ii) Explain why there are two spots in some sketches and three or four in others. (2 marks)

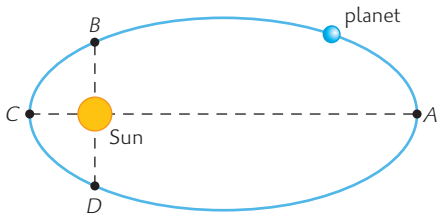
(b) State two other astronomical discoveries made by Galileo. For each one explain how the observation conflicts with previous models of the Universe. (4 marks)

Chapter Exercise

Unless otherwise stated, use the values of the constants provided in the Appendix for calculation.

Multiple-choice Questions

1. A planet moves in an elliptical orbit as shown. *A*, *B*, *C* and *D* are four points on the orbit such that *AC* is perpendicular to *BD*.



Which of the following statements is correct?

(1) The planet moves with a higher speed at *A* than at *B*.

(2) The time for the planet to travel from *A* to *B* is the same as that from *B* to *C*.

(3) The period of the planet is proportional to the cube of *AC*.

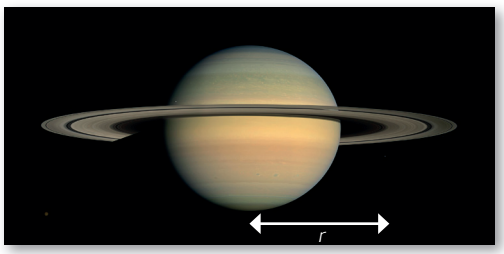
A. (1) only B. (2) only

C. (3) only D. None of the above

2. The ring system of Saturn is made up of a large number of icy lumps orbiting Saturn in nearly circular orbits. How does the orbital speed v of these lumps depend on the distance r from the centre of Saturn?

A. $v \propto r$ B. $v \propto 1/r$

C. $v \propto \sqrt{r}$ D. $v \propto 1/\sqrt{r}$



3. Planet *A* orbits a star of mass *M* and planet *B* orbits a star of mass 2*M*. If the planets are at equal distance from the centres of the corresponding stars, what is the ratio of the orbital period of *A* to that of *B*?

A. 1 : 2 B. $1:\sqrt{2}$ C. 2 : 1 D. $\sqrt{2}:1$

4. Which of the following comets has the longest orbital period?

	comet	perihelion / AU	aphelion / AU
A.	67P/C-G	1.24	5.68
B.	19P/Borrelly	1.35	5.83
C.	9P/Tempel	1.51	4.74
D.	81P/Wild	1.59	5.31

5. Three planets move in elliptical orbits around the Sun. The semi-major axes of their orbits are in the ratio 1 : 2 : 3. What is the ratio of their orbital period?

A. 1 : 2 : 3 B. $1 : 2^2 : 3^2$

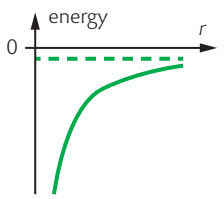
C. $1 : 2^{3/2} : 3^{3/2}$ D. $1 : 2^{2/3} : 3^{2/3}$

6. Two identical satellites *X* and *Y* are placed in two separate circular orbits around the Earth. *X* is at a higher orbit than *Y*. (a) Which satellite has more KE? (b) Which satellite has more gravitational PE (more positive)?

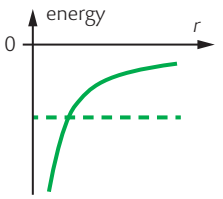
	(a)	(b)
A.	*X*	*X*
B.	*X*	*Y*
C.	*Y*	*X*
D.	*Y*	*Y*

7. The solid lines in the graphs below represent the gravitational PE of satellites moving around the Earth in various circular orbits of radius r. Which of the following (dotted lines) best represents the corresponding mechanical energy?

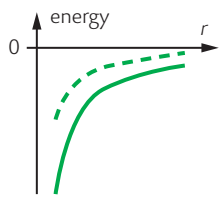
A.



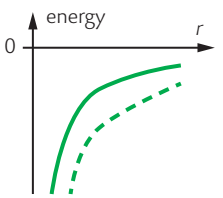
B.



C.



D.



8. The escape speed of the Earth is higher than that of the Moon because

A. the Earth has a larger mass.
B. the Earth has a larger radius.
C. the Earth has an atmosphere.
D. the Moon is orbiting the Earth.

9. An astronaut experiences weightlessness inside an orbiting spacecraft. The astronaut and the spacecraft MUST have the same

(1) acceleration.
(2) speed.
(3) momentum.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

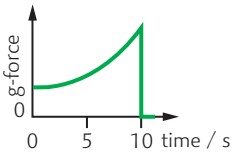
10. An astronaut appears to be weightless inside a spacecraft orbiting around the Earth. Which statement is correct?

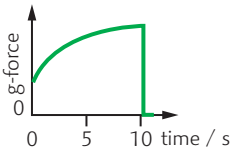
A. The gravitational field strength produced by the Earth at the position of the astronaut is almost zero.
B. The gravitational forces from the Earth and from the Moon cancel each other out.
C. The centripetal force of the spacecraft and the contents inside cancel out the total weight.
D. Both the spacecraft and the astronaut are falling freely towards the Earth.

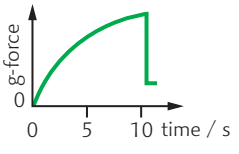
11. **AQA A-level PHYA4 Jan 2011** As a comet orbits the Sun the distance between the comet and the Sun continually changes. As the comet moves towards the Sun this distance reaches a minimum value. Which one of the following statements is INCORRECT as the comet approaches this minimum distance?

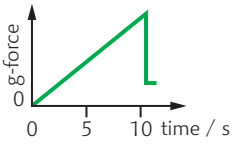
A. The potential energy of the comet increases.
B. The gravitational force acting on the comet increases.
C. The direction of the gravitational force acting on the comet changes.
D. The kinetic energy of the comet increases.

12. **NSW HSC 2011** A rocket is launched. Its engine produces a constant thrust for the first 10 seconds and is then switched off. Which graph best illustrates the *g*-force experienced by an astronaut in the rocket? [Editor's note: *g*-force is a measurement of all kinds of accelerations that cause weight]

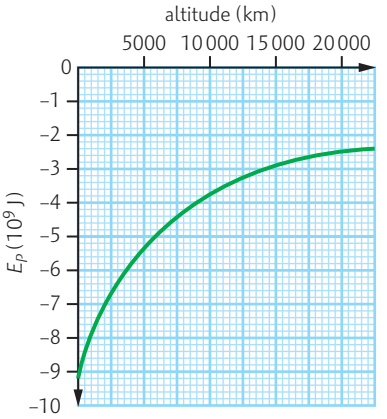
A.


B.


C.


D.


13. **NSW HSC 2012** The graph shows how the gravitational potential energy (E_p) of a satellite changes with its altitude.



What is the change in gravitational potential energy of the satellite when its altitude is reduced from 14 000 km to 4000 km?

A. -8.8×10^9 J
B. -2.8×10^9 J
C. 2.8×10^9 J
D. 8.8×10^9 J

14. **HKDSE 2012** An interplanetary spacecraft is launched from the Earth. The initial speed is $\sqrt{\frac{3GM}{R}}$, where G is the universal gravitational constant, M is the mass of the Earth and R is the radius of the Earth. What is the speed of the spacecraft when it is very far away from the Earth?

A. $\sqrt{\frac{GM}{R}}$
B. $\sqrt{\frac{GM}{2R}}$
C. $\sqrt{\frac{2GM}{R}}$
D. zero

15. **HKDSE 2012** Which statement about the motion of the Earth around the Sun is INCORRECT?

A. The speed of the Earth in its orbit is NOT constant.
B. The Sun is at the centre of the Earth's orbit.
C. The distance from the Sun to the Earth changes periodically.
D. In general, the instantaneous velocity of the Earth is NOT perpendicular to the Sun's gravitational force.

Structured Questions

16. The perihelion and aphelion distances of the asteroid Eros are 1.13 AU and 1.78 AU, respectively. Its mass is 6.69×10^{15} kg.

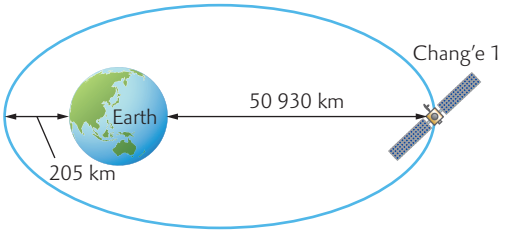
(a) What is the semi-major axis of its orbit? (1 mark)

(b) What is the orbital period of Eros? (2 marks)

(c) What is the change in the (i) gravitational PE and (ii) KE of Eros when it moves from the perihelion to the aphelion? (4 marks)

(d) A student uses an old one pound note as shown and tells his friend that Eros orbits in an ellipse. What is wrong about the diagram for the planetary model in view of Kepler's laws? (1 mark)

17. Before entering a transfer orbit to the Moon, Chang'e 1 moved in an elliptical orbit around the Earth as shown. The closest and the farthest distances of Chang'e 1 from the Earth's surface are 205 km and 50 930 km, respectively.

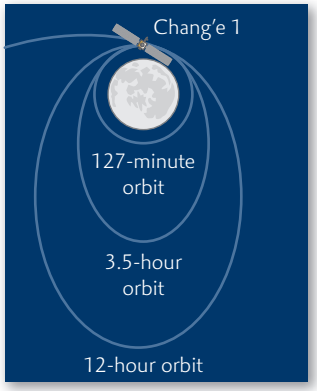


(a) Find the semi-major axis of the orbit. (1 mark)

(b) Find the orbital period. (2 marks)

(c) If the speed of Chang'e 1 is 10 423.9 m s^{-1} when it is closest to the Earth, find its speed when it is farthest from the Earth. (2 marks)

When arriving at the Moon, Chang'e 1 first entered a 12-hour elliptical orbit (i.e. an orbit with a period of 12 hours) as shown. It decelerated during its closest approaches to the Moon, so that the orbit was deformed into a 3.5-hour elliptical orbit and then a 127-minute circular orbit. In the circular orbit, Chang'e 1 was 200 km above the lunar surface. The radius of the Moon is 1740 km.



(d) Find

(i) the mass of the Moon, (2 marks)

(ii) the speed of Chang'e 1 in the circular orbit. (2 marks)

(e) The mechanical energy of Chang'e 1 was NOT conserved. Why? (1 mark)

(f) Without calculation, briefly explain in which orbit Chang'e 1 had the least mechanical energy. (2 marks)

18. A spherical asteroid has a mass of 1.47×10^{16} kg and a radius of 10 km.

(a) Find the acceleration due to gravity of the asteroid on its surface. (2 marks)

(b) What is the weight of a 100 kg block on the surface of the asteroid? (2 marks)

(c) A ball is thrown vertically upwards at a speed of 20 m s^{-1}. Briefly explain whether the ball can escape from the asteroid. (3 marks)

(d) Find the speed of a rock which moves in a circular orbit very near the surface of the asteroid. (2 marks)

19. An artificial satellite moves around the Earth in a circular low-Earth orbit with an orbital speed v.

(a) Show that its mechanical energy E is given by

$$E = -\frac{GMm}{2r}$$

where M and m are the masses of the Earth and the satellite, respectively. (3 marks)

(b) The satellite is affected by the air resistance of the upper atmosphere such that it shifts slowly to an orbit closer to the Earth. Explain any change in the following physical quantities:

(i) the mechanical energy E of the satellite, and (2 marks)

(ii) the orbital speed v of the satellite. (2 marks)

20. A spacecraft of mass 1600 kg moves around the Earth in a circular orbit at an altitude of 2000 km.

(a) Find the orbital speed u of the spacecraft. (2 marks)

(b) Find the gravitational potential energy and mechanical energy of the spacecraft. (4 marks)

(c) By turning on the rocket thrusters, the spacecraft increases its speed v suddenly. Find the minimum value of v so that the spacecraft can escape from the Earth forever. (2 marks)

(d) Is the speed you find in (c) the same as the escape speed of the Earth? Explain. (2 marks)

21. **OCR A-level 2863 Jan 2008** This question is about the escape velocity from the Earth and the atmosphere of the Earth.

The gravitational potential energy of a mass m on the surface of a planet of mass M is given by the equation

$$\text{gravitational potential energy} = -\frac{GMm}{r}$$

where r is the radius of the planet and G is the gravitational constant.

(a) (i) Explain why the minimum kinetic energy required for a body of mass m to escape from the surface of a planet and not fall back is equal to $+GMm/r$. (1 mark)

(ii) Suggest why this gives the minimum energy required. (1 mark)

(iii) Hence show that the minimum velocity v_{esc} required to escape from the planet is given by $v_{esc} = \sqrt{\frac{2GM}{r}}$. (2 marks)

(iv) Use the equation for gravitational field strength g at the surface of the planet to show that $v_{esc} = \sqrt{2gr}$. (2 marks)

(v) Calculate v_{esc} for the Earth. Given: $r = 6.4 \times 10^6$ m and $g = 9.8$ N kg^{-1}. (1 mark)

(b) A particle in the atmosphere of the Earth has a kinetic energy of about 4×10^{-21} J when the temperature of the atmosphere is 300 K.

(i) Calculate the velocity of a nitrogen molecule with energy 4×10^{-21} J. Given: mass of nitrogen molecule = 5×10^{-26} kg. (2 marks)

(ii) Use your answer to (i) to explain why the Earth retains nitrogen in its atmosphere. (1 mark)

22. **OCR A-level 2863 Jun 2010** This question is about a method of measuring the mass of the planet Saturn.

Saturn has a system of rings that orbit the planet. The rings are composed of pieces of ice and rock which orbit the planet.

(a) Consider a piece of rock of mass 2500 kg in a ring at a distance of 1.8×10^8 m from the centre of Saturn. The rock takes 21 hours to orbit the planet.

(i) Show that the speed of the rock is about 1.5×10^4 m s^{-1}. (2 marks)

(ii) Show that the magnitude of the centripetal force on the rock is about 3100 N. Write down the equation you use to calculate your result. (2 marks)

(iii) The centripetal force is the force on the rock due to the gravitational attraction of Saturn. Show that the mass of Saturn is about 6×10^{26} kg. Write down the equation you use in your calculation. Given: $G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}. (2 marks)

(b) (i) Calculate the potential energy of the rock due to the gravitational field of Saturn. (2 marks)

(ii) Calculate the kinetic energy of the rock due to its speed in orbit. (1 mark)

(iii) Use your results to answers (i) and (ii) to explain why the rock will not fly out of the ring unless it gains energy from collisions with other rocks in the ring. [1 mark for the quality of written communication] (2 marks)

23. **Edexcel A-level Jan 2013** Communication satellites were first proposed in 1945 by the science fiction author Arthur C. Clarke. In an article published in the magazine *Wireless World* he asked whether rocket stations could give worldwide radio coverage.

In the article Clarke states:

"There are an infinite number of possible stable orbits, circular and elliptical, in which a rocket would remain if the initial conditions were correct. A velocity of 8 km s^{-1} applies only to the closest possible orbit, one just outside the atmosphere, and the period of revolution would be about 90 minutes. As the radius of the orbit increases the velocity decreases, since gravity is diminishing and less centrifugal force is needed to balance it."

with permission of Electronics World
www.electronicsworld.co.uk

(a) State what is meant in the article by the phrase "gravity is diminishing", and criticize the statement that "less centrifugal force is needed to balance (the satellite)". (3 marks)

(b) (i) By deriving an appropriate equation, show that the orbital speed of the satellite decreases as the radius of orbit increases. (3 marks)

(ii) By deriving an appropriate equation, show that the orbital period of a satellite increases as the orbital speed decreases. (2 marks)

(c) The period T of a satellite in a circular orbit is given by the equation

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$

where r is the radius of orbit and M is the mass of the Earth.

Calculate the period of a satellite in an orbit 4.0×10^5 m above the surface of the Earth.

mass of the Earth = 5.98×10^{24} kg

radius of the Earth = 6.36×10^6 m (2 marks)

(d) After a time the radius of the satellite's orbit will start to decrease due to the resistive forces acting on the satellite from the atmosphere. As this happens the satellite speeds up.

Describe the energy changes occurring as the radius of the orbit decreases. (2 marks)

24. **HKDSE 2013** Given: $GM = 4.0 \times 10^{14}$ N m^2 kg^{-1}, where G is the universal gravitational constant and M is the mass of the Earth.

Mean radius of the Earth = 6400 km.

Radius of the geostationary orbit is about 42 400 km, i.e. 36 000 km above Earth's surface.

The following describes a way to launch a satellite into the geostationary orbit:

- The satellite is first launched by a rocket to a circular near-Earth orbit (1) at 300 km above the Earth's surface.
- At A, the satellite's engine is fired for a short period of time to give it a boost needed to enter the elliptical transfer orbit (2), with AB as the ellipse's major axis.
- At B, the satellite's engine is fired again briefly to boost it into the geostationary orbit (3).

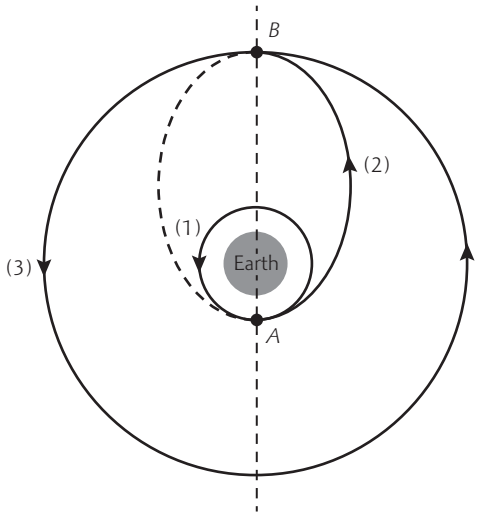


diagram NOT drawn to scale

Assume that the three orbits are coplanar such that the elliptical orbit touches the two circular orbits at A and B respectively. During the period when the satellite travels from A to B along the transfer orbit, its engine is shut.

(a) Communications satellites are usually launched into the geostationary orbit. State and explain the advantage of such an arrangement. (2 marks)

(b) Find the speed of the satellite in the near-Earth orbit (1). (2 marks)

(c) (i) Show that for a satellite of mass m moving in a circular orbit of radius r around the Earth, its total mechanical energy is $-\frac{GMm}{2r}$, where M is the mass of the Earth. Take the gravitational potential energy of the satellite at infinity to be zero. (2 marks)

(ii) Use the result in (c)(i) to calculate the energy required to transfer a satellite of mass m = 2000 kg from the near-Earth orbit (1) through A to the geostationary orbit (3) through B. (2 marks)

(iii) How long does it take for the satellite to travel from A to B along the transfer orbit (2)? (2 marks)

Chapter Exercise

Unless otherwise specified, take

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

$L_\odot = 3.85 \times 10^{26}$ W

$R_\odot = 6.96 \times 10^{8}$ m

$T_\odot = 5780$ K

$M_\odot = 1.99 \times 10^{30}$ kg

1 pc = 206 264.8 AU = 3.26 ly

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

Multiple-choice Questions

1. Which of the following statements is/are correct?

(1) The larger the distance between two observation positions, the larger the parallax of the observed body.

(2) The closer the distance to an object, the smaller the parallax of the object.

(3) The smaller the parallax of the object, the fainter the object.

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

2. The apparent magnitude and absolute magnitude of four stars are shown below:

star	apparent magnitude	absolute magnitude
P	3	–4
Q	6	0.5
R	0	2
S	–1.5	2

Which star is the closest to us?

A. *P* B. *Q*

C. *R* D. *S*

3. Which of the following properties of a star can be found by analysing its spectrum alone?

(1) Surface temperature

(2) Luminosity

(3) Radius

A. (1) only B. (3) only

C. (1) and (2) only D. (2) and (3) only

4. Which of the following can be obtained by analysing the spectrum of a star?

(1) Chemical composition of the star

(2) Surface temperature of the star

(3) Mass of the star

A. (1) only B. (2) only

C. (1) and (2) only D. (2) and (3) only

5. Which of the following stars has the highest luminosity?

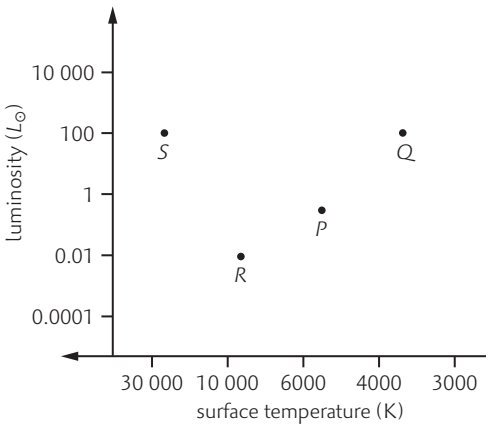
A. A star with a surface temperature 2700 K and radius $4R_\odot$

B. A star with a surface temperature 6500 K and radius $0.8R_\odot$

C. A star with a surface temperature 11 500 K and radius $0.01R_\odot$

D. The Sun

6. Four stars are shown in the H–R diagram as shown.



Which of the following statements MUST be correct?

(1) Star *P* is bigger than star *R*.

(2) Star *Q* is smaller than star *S*.

(3) Star *R* is the smallest.

A. (1) only B. (2) only

C. (1) and (3) only D. (2) and (3) only

7. Which of the following stars has the largest red shift in its spectrum?

A. A star moves away along the line of sight at 35 km s^{-1}

B. A star moves away at 58 km s^{-1} making an angle of 30° to the line of sight

C. A star moves at 100 km s^{-1} perpendicular to the line of sight

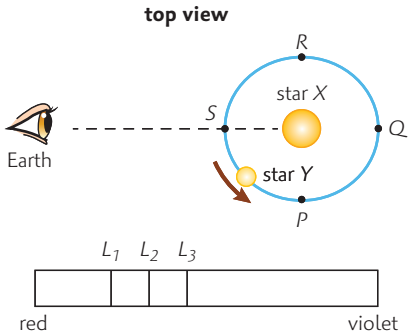
D. A star moves towards us along the line of sight at 65 km s^{-1}

8. Which of the following Doppler shifts in spectral lines are possibly measured from the same star?

(1) $\lambda = 588.997$ nm, $\Delta\lambda = -0.194$ nm
(2) $\lambda = 656.28$ nm, $\Delta\lambda = 0.216$ nm
(3) $\lambda = 656.28$ nm, $\Delta\lambda = -0.216$ nm

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. All of them come from different stars.

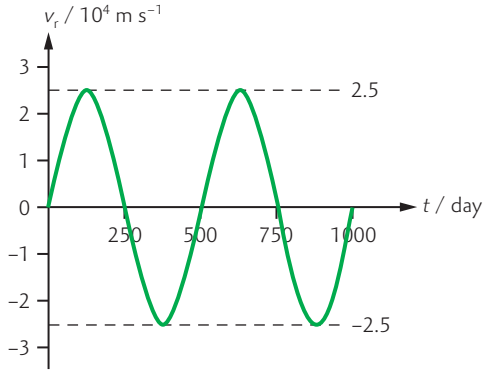
9. Star *Y* orbits around star *X* in a circular orbit. An observer on the Earth viewing a spectral line from *Y* found that its wavelength varies between the limits L_1 and L_3. L_2 is the wavelength of that line observed in the laboratory.



Which wavelengths correspond to positions *P* and *R*?

	P	*R*
A.	L_1	L_1
B.	L_1	L_3
C.	L_2	L_2
D.	L_3	L_1

10. A low-mass star moves around a massive star in a circular orbit. The orbital plane is along the line of sight. The radial velocity curve of the low-mass star is as shown.

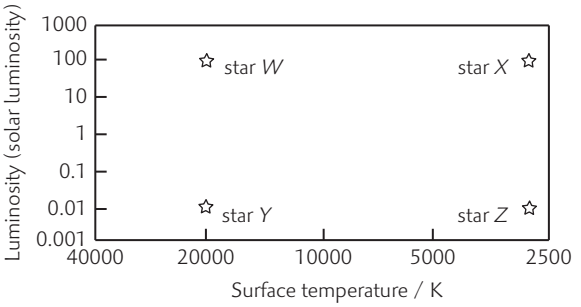


Which of the following statements is/are correct?

(1) The orbital period of the low-mass star is 500 days.
(2) The distance between the stars is 1.72×10^{11} m.
(3) The mass of the low-mass star is 1.61×10^{30} kg.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

(For questions 11 and 12) The figure below shows some information of stars *W*, *X*, *Y* and *Z*.



11. **HKDSE 2012** Which of the following statements is/are correct?

(1) For star *X*, the intensity of red light is higher than any other colour light.
(2) For star *W*, the intensity of blue light is higher than any other colour light.
(3) Intensity ratio of red light to other colours of light is larger in star *Z* than that in star *Y*.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

12. **HKDSE 2012** The absorption spectrum of star *X* contains hydrogen absorption lines. What can be concluded from this?

(1) Star *X* is mainly composed of hydrogen.
(2) There is hydrogen gas in the outer atmosphere of star *X*.
(3) The abundance of hydrogen in star *X* is less than that in a similar star of the same temperature.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

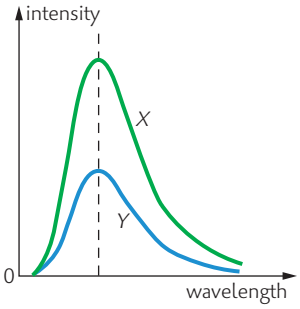
13. **HKDSE 2013** Stars *P* and *Q* have the same luminosity. Star *P* is 25 times brighter than Star *Q*. We can deduce that

A. *P*'s distance is 5 times that of *Q*.
B. *Q*'s distance is 5 times that of *P*.
C. *P*'s distance is 25 times that of *Q*.
D. *Q*'s distance is 25 times that of *P*.

14. **HKDSE 2014** The violet line (410 nm) of the hydrogen spectrum from a distant celestial body is blue shifted and its wavelength appears 50 nm shorter when observed. What is the observed wavelength of the red line (656 nm) from the same source?

A. 576 nm
B. 606 nm
C. 706 nm
D. 736 nm

(For questions 15 and 16) The diagram shows the spectra of radiation from stars *X* and *Y* with their peaks lying at the same wavelength. [Editor's note: measured at the star surface]



15. **HKDSE 2014** Which statement is correct?

A. Surface temperature of *X* > Surface temperature of *Y*
B. Surface temperature of *X* < Surface temperature of *Y*
C. Surface temperature of *X* = Surface temperature of *Y*
D. The information is NOT sufficient to make a comparison of the surface temperature of *X* and *Y*.

16. **HKDSE 2014** Which statement is correct?

A. Star *X* is smaller than star *Y*.
B. Star *X* is bigger than star *Y*.
C. Star *X* and star *Y* are of the same size.
D. The information is NOT sufficient to make a comparison of the size of stars *X* and *Y*.

Structured Questions

17. Pleiades (M45, also called the Seven Sisters) (昴宿星團／七姊妹星團) is a prominent open star cluster in the constellation of Taurus (金牛座). The parallax of the stars in the cluster is 0.007 41″.

(a) Find the distance to Pleiades in light years. (2 marks)

(b) If the angular size of the cluster is about 2.1°, estimate the actual size of the cluster in light years. (2 marks)

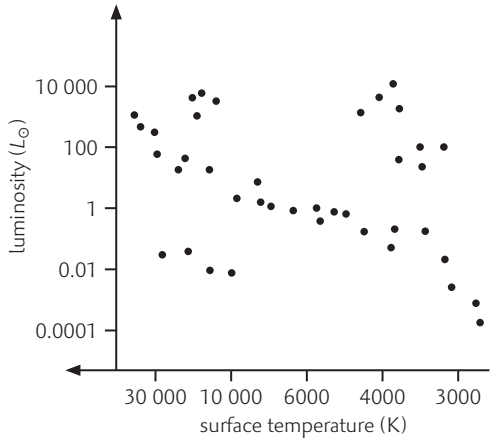
(c) The major members of the cluster are class B main-sequence stars. How do the luminosities, radii and surface temperatures of these stars compare to that of the Sun? (3 marks)

(d) The brightest star in the cluster, Alcyone, has a luminosity of 1400 times that of the Sun and a surface temperature of about 13 000 K. Find its radius in terms of the solar radius. (2 marks)

18. Some properties of the stars *W*, *X*, *Y* and *Z* are shown.

star	luminosity / $L_\odot$	surface temperature / K	apparent magnitude
W	0.1	4000	12.6
X	1	6000	13.1
Y	1000	3000	18.7
Z	0.001	7500	10

(a) Sketch the positions of the stars on the H–R diagram. What kinds of stars are they? (4 marks)



(b) Which star is the farthest from us? Which star is the nearest? Explain your answer. (4 marks)

(c) Find the radius of star *X* in terms of the solar radius. (2 marks)

19. Arcturus (大角星) is a star 36.7 ly from us. Its luminosity is about $170L_\odot$.

(a) Suggest TWO factors that affect the luminosity of a star. (2 marks)

(b) What is the intensity of radiation that the Earth receives from the star? (2 marks)

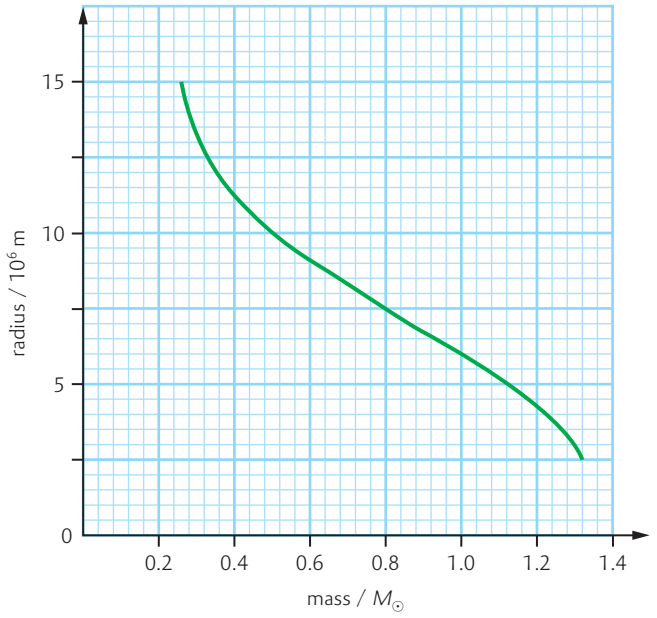
(c) The absolute magnitude M of a star is related to its apparent magnitude m and its distance d (in parsecs) by the following equation:

$$M = m - 5\log\left(\frac{d}{10}\right)$$

(i) Show that this formula is consistent with the definition that the absolute magnitude of a star is the magnitude that the star would have if it were 10 pc from the Earth. (1 mark)

(ii) Arcturus has an apparent magnitude of −0.04. Find its absolute magnitude. (2 marks)

20. White dwarfs are dead stars of very high density. The graph shows the relation between the mass and the radius of white dwarfs.



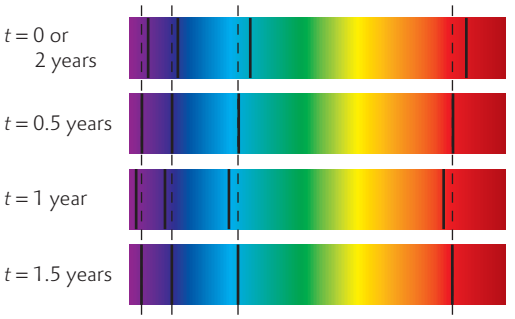
(a) From the graph, deduce whether white dwarfs of larger mass have higher or lower density. Explain briefly. (2 marks)

(b) A white dwarf of 1 solar mass has a luminosity of $0.01L_\odot$. Estimate the surface temperature of the white dwarf. (2 marks)

(c) Theoretically, when a white dwarf radiates for a very long time, its surface temperature and luminosity will decrease. If the luminosity of the white dwarf in (b) decreases to $0.001L_\odot$, what would its surface temperature be? (2 marks)

(d) Estimate the gravitational field strength on the surface of the white dwarf. If a person has mass of 70 kg, what is his weight on the surface of the star? (2 marks)

21. The lines in the spectrum of a small star show a periodic Doppler shift as shown. The dotted lines represent the positions of the spectral lines found in laboratories. The maximum fractional shift of a line is $\Delta\lambda / \lambda = 2.00 \times 10^{-4}$.



(a) Describe and explain the orbital motion of the star with the aid of a diagram. (4 marks)

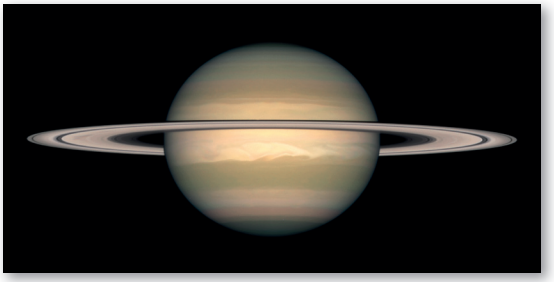
(b) What is its orbital speed? (1 mark)

(c) Sketch the radial velocity curve of the star. Mark the positions on the curve which correspond to the spectra shown. (3 marks)

(d) The spectrum only shows one set of spectral lines. This implies that the star orbits a massive unseen celestial body. Estimate the mass of the body. (2 marks)

(e) In theory, a black hole should have mass over $3M_\odot$. Do you think the unseen body is a possible black hole candidate? Explain your answers. (2 marks)

22. The ring system of Saturn is made of numerous lumps of ice. Assume the rings are circular and lie on a plane along the line of sight.



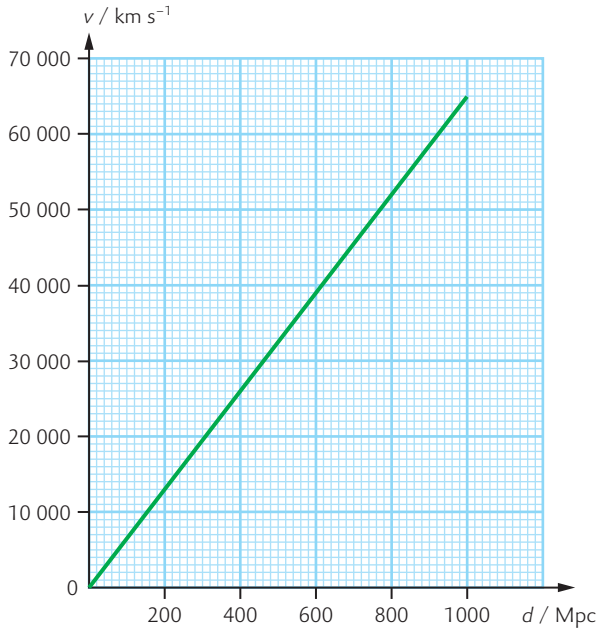
(a) An astronomer suggests that one can measure the rotational speeds of the lumps of ice at various distances from the centre of Saturn by making use of the Doppler effect. Explain how this can be done. (2 marks)

(b) If the plane of the rings is tilted at 20° to the line of sight, how would this affect the measurement of the rotational speed? Why? (2 marks)

(c) How does the rotational speed depend on the distance from the centre of Saturn? Explain briefly. (2 marks)

(d) At a distance of 10^5 km from the centre of Saturn, a fractional Doppler shift of $\Delta\lambda / \lambda = 6.49 \times 10^{-5}$ is observed (assume that the shift due to the motion of Saturn has been eliminated). Find the mass of Saturn. (2 marks)

23. A graph of the recession velocities of several galaxies against their distances from us is shown below.

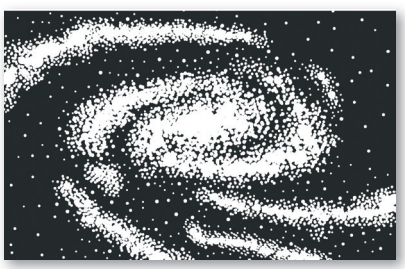


(a) How is the recession velocity related to the distance to the galaxy? (1 mark)

(b) What does the relation in (a) imply about the universe? (2 marks)

(c) Find the Hubble constant from the graph. (1 mark)

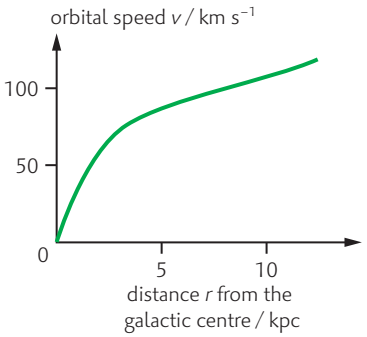
(d) A spiral galaxy is shown. An astronomer measures the spectra of the stars and gas in the spiral arm at various distances from the centre of a spiral galaxy. He finds that all the spectra are red shifted. But the spectra on the right of the centre of the galaxy are red shifted more than those on the left.



(i) Give a reason that is related to the large spatial scale of the universe to explain why all the measured spectra are red shifted. (2 marks)

(ii) Why are the spectra on the right red shifted more than those on the left? What does this tell us about the rotation of the galaxy? (3 marks)

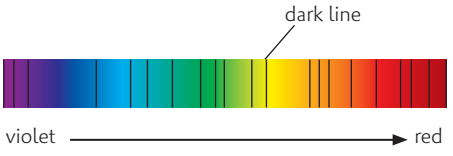
(iii) After eliminating the red shift due to the overall motion of the galaxy, the astronomer obtains a rotation curve of the galaxy.



Suggest a reason why the orbital speeds of the stars increase with their distances from the galactic centre. (1 mark)

24. **OCR A-level 2825/01 Jan 2006**

(a) A part of the Sun's spectrum is shown. It is crossed by a number of dark lines.

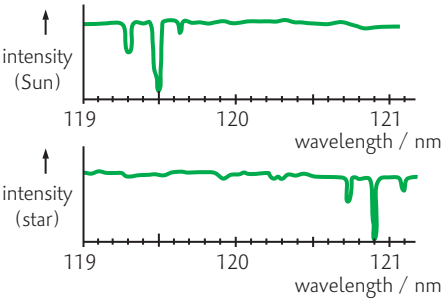


Q24a

(i) Explain how the dark lines are formed. (2 marks)

(ii) How may the spectrum be used to identify the constituents of a star? (1 mark)

(b) The graph below shows the variation of intensity with wavelength for part of the Sun's spectrum and for the same part of the spectrum from a distant star.



Q24b

(i) Explain how the star's motion causes corresponding minima of intensity to occur at different wavelengths. (2 marks)

(ii) Use the graphs in Fig. b to calculate the velocity of the star. (4 marks)

25. OCR A-level 2825/01 Jan 2008

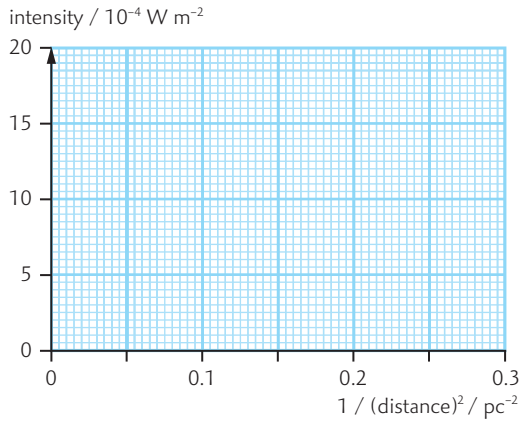
(a) What is meant by the *apparent magnitude* of a star? (2 marks)

(b) The table shows the intensity I of radiation received and the distance d of four stars from Earth. The value of $1 / d^2$ is given for two of the stars.

Star	I / 10^{-4} W m^{-2}	d / pc	$\frac{1}{d^2}$ / pc^{-2}
W	16.1	2.1	0.23
X	7.9	3.0	0.11
Y	4.9	3.8	
Z	3.4	4.6	

(i) Complete the last column of the table. (1 mark)

(ii) Plot a graph of I versus $1 / d^2$ using the axes in the figure and draw the best straight line through the points. (2 marks)



(iii) Assuming a relationship of $I = k / d^2$, use your graph to calculate a value for the constant k. Give a suitable unit with your answer. (3 marks)

(c) (i) Use the equation for intensity in (b)(iii) and your value for k to write down an expression for log (I) in terms of d. (2 marks)

(ii) The apparent magnitude m is given by the expression $m = -2.5 \log(I) + a$ where a is a constant. Show by substitution of log(I) that the apparent magnitude may be expressed as $m = 5 \log(d) + b$ where b is another constant. (2 marks)

(d) Calculate the absolute magnitude of star W if its apparent magnitude is 3.0. (2 marks)

26. HKDSE 2012

(a) Let R_S, T_S and L_S be the radius, surface temperature and luminosity of the Sun and R, T and L be the radius, surface temperature and luminosity of another star.

(i) Show that $R = \left(\frac{T_S}{T}\right)^2 \left(\frac{L}{L_S}\right)^{\frac{1}{2}} R_S$. (2 marks)

(ii) Betelgeuse is a star with surface temperature 3650 K and luminosity 126 000 times that of the Sun. Find the radius of Betelgeuse in terms of R_S. Take the surface temperature of the Sun to be 5780 K. (2 marks)

(b) (i) An estimate of the distance to Betelgeuse is 197 pc which corresponds to the luminosity given in (a)(ii). A measurement of this distance made in 2008 was 197 ± 45 pc. Without calculating the actual value, explain how the radius of Betelgeuse found in (a)(ii) would change if the upper limit of this distance measurement were used. Betelgeuse at this distance can be treated as a point source emitting light evenly in all directions. (2 marks)

(ii) Suggest a reason why it is difficult to measure accurately the distance to Betelgeuse by the method of parallax. (1 mark)

(c) In 2011, some media reports suggested that when Betelgeuse undergoes a supernova explosion (i.e. the death of a star), it will appear as the "second sun" in the sky for a few weeks. Referring to the information given below, explain whether this is true or not by comparing the brightness of Betelgeuse in supernova explosion with that of the Sun.

A star of similar mass as that of Betelgeuse gives off a luminosity of about 10^9 times that of the Sun for a certain period of time when the star undergoes a supernova explosion. About 1% of the power of explosion appears in the form of visible light. Take the distance of Betelgeuse to be 200 pc. (3 marks)

27. HKDSE 2014

(a) A star of radius R and surface temperature T_s (in K) emits radiation in all directions. A planet of radius r orbits the star at a distance d, which is much larger than both R and r. Assume that both the star and the planet behave like black bodies.

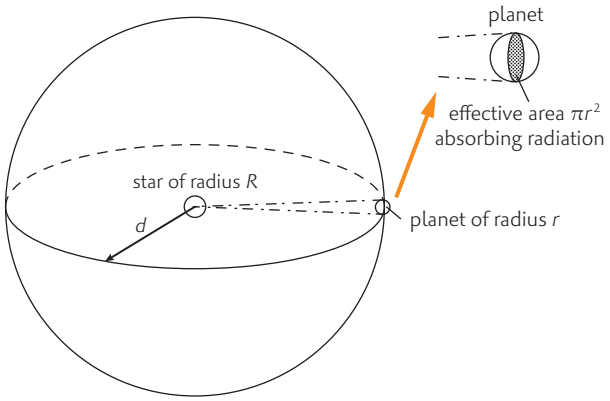


Diagram NOT drawn to scale

(i) Taking the effective area that the planet absorbs radiation emitted from the star as πr^2, show that the power absorbed by the planet is $\pi\sigma\left(\frac{rR}{D}\right)^2 T_s^4$ where σ is the Stefan constant. Assume that the planet is a perfect absorber of radiation. (2 marks)

(ii) If the planet only absorbed energy, its temperature would rise indefinitely. However, this would not happen because the planet also radiates energy as it absorbs energy so that an equilibrium state is maintained. Show that the equilibrium surface temperature of the planet is given by $T_p = \sqrt{\frac{R}{2d}}\,T_s$. (2 marks)

(b) A planet called Kepler-22b was discovered orbiting a Sun-like star with orbital radius 0.84 AU (1 AU = 1.50×10^{11} m). The star has a radius of 6.82×10^8 m and its surface temperature is 5518 K.

(i) Estimate the equilibrium surface temperature of Kepler-22b using the results of (a). (2 marks)

(ii) Liquid water is believed to be essential for life to exist on a planet. Based on the information found in (b)(i), explain whether Kepler-22b would be a favourable planet for life to exist or not. (2 marks)

(iii) If Kepler-22b orbits a class K star instead of a Sun-like star (which is a class G star) with the same orbital radius, would its equilibrium surface temperature increase, decrease or remain unchanged? State your reason. Given: the sequence of spectral classes is O B A F G K M. (2 marks)