**mock papers 1**

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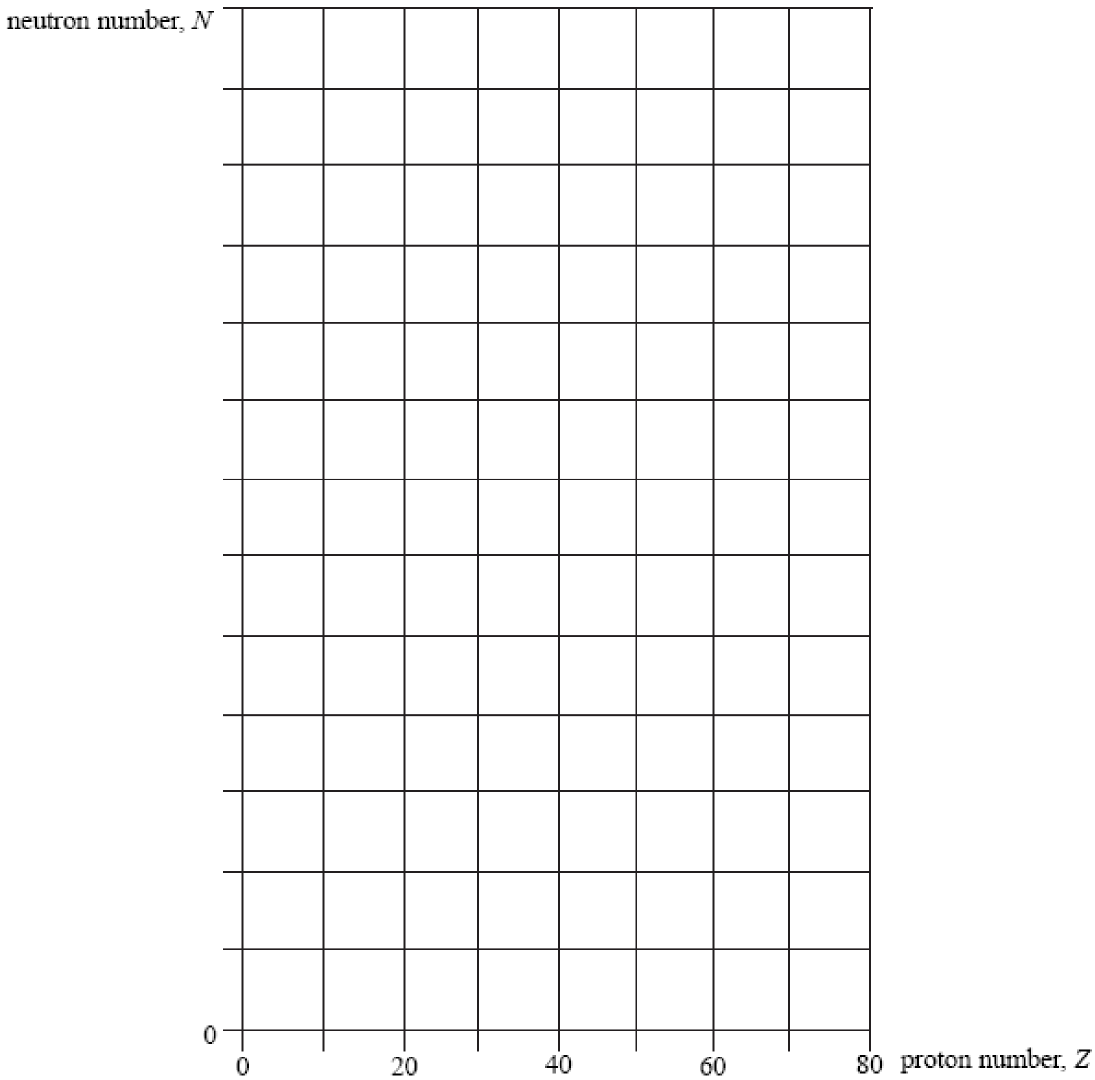
**1** (a) Sketch, using the axes provided, a graph of neutron number, *N*, against proton number, *Z*, for stable nuclei over the range *Z* = 0 to *Z* = 80. Show suitable numerical values on the *N* axis.




*(2 marks)*

(b) On the graph indicate, for each of the following, a possible position of a nuclide that might decay by

(i) α emission, labelling the position with **W**,

(ii) $\beta^-$ emission, labelling the position with **X**,

(iii) $\beta^+$ emission, labelling the position with **Y**.

*(3 marks)*

(c) Used fuel rods from a nuclear reactor emit $\beta^-$ particles from radioactive isotopes that were not present before the fuel rod was inserted in the reactor. Explain why $\beta^-$ emitting isotopes are produced when the fuel roads are in the reactor.

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*(3 marks)*

(d) A nuclear power station is a reliable source of electricity that does not produce greenhouse gases but it does produce radioactive waste. Discuss the relative importance of these features in deciding whether or not new nuclear power stations are needed.

The quality of your written answer will be assessed in this question.

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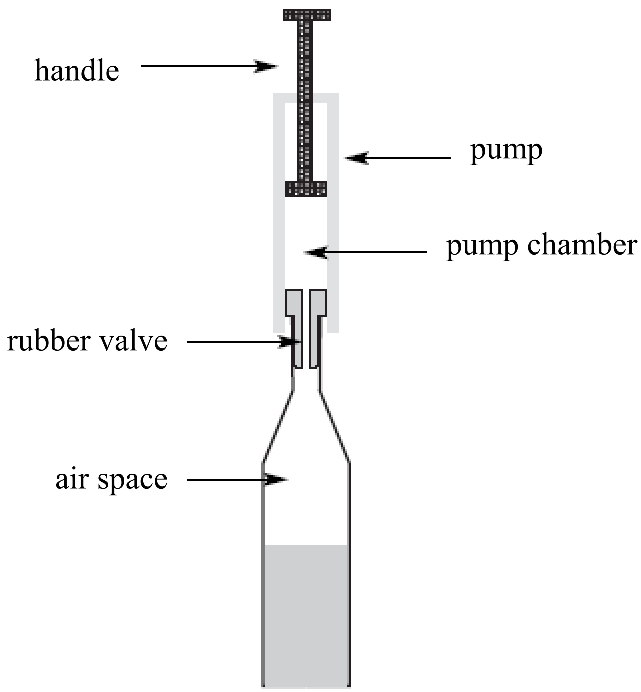
*(6 marks)*

**Total 14 marks**

**2** Some liquids in open bottles deteriorate exposure to air. **Figure 1** shows one device used to reduce this deterioration. It consists of a rubber valve that is inserted into the neck of the bottle together with a pump that is used to remove some of the air in the bottle through this rubber valve. On an up-stroke of the pump, air enters the pump chamber from the bottle. On the down-stroke, the rubber valve closes and the air in the chamber is expelled to the atmosphere through another valve (not shown) in the handle.

**Figure 1**




(a) There is $3.5 \times 10^{-4}$ m$^3$ of air space in the bottle and the volume of the pump chamber changes from zero at the beginning of the up-stroke to $6.5 \times 10^{-5}$ m$^3$ at the end of the up-stroke. The initial pressure of the air in the bottle is that of the atmosphere with a value of 99 kPa.

Assuming the process is at constant temperature, calculate the pressure in the bottle after one up-stroke of the pump.

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*(3 marks)*

(b) Calculate the number of molecules of air originally in the air space in the bottle at a temperature of 18 °C.

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*(3 marks)*

(c) Explain how the kinetic theory of an ideal gas predicts the existence of a gas pressure inside the bottle. Go on to explain why this pressure decreases when some of the air is removed from the bottle.

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*(5 marks)*

**Total 11 marks**

**3** In an experiment to measure the temperature of the flame of a Bunsen burner, a lump of copper of mass 0.12 kg is heated in the flame for several minutes. The copper is then transferred quickly to a beaker, of negligible heat capacity, containing 0.45 kg of water, and the temperature rise of the water measured.

Specific heat capacity of water = 4200 J $kg^{-1}$ $K^{-1}$
Specific heat capacity of copper = 390 J $kg^{-1}$ $K^{-1}$

(a) (i) The temperature of the water rises from 15ºC to 35ºC. Calculate the thermal energy gained by the water.

thermal energy gained = ...................................

(ii) Calculate the temperature reached by the copper in the flame. Assume no heat is lost when the copper is transferred.

temperature = ...................................

*(4 marks)*

(b) When the lump of copper entered the water, some of the water was turned to steam.

(i) The specific latent heat of vaporisation of steam is 2.25 MJ $kg^{-1}$. What further measurement would need to be made to calculate the energy used to produce this steam?

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(ii) Without further calculation, describe how this further measurement should be used to obtain a more accurate value of the flame temperature.

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*(3 marks)*

**Total 7 marks**

**4** Potassium-42 decays with a half-life of 12 hours. When potassium-42 decays, it emits $\beta^-$ particles and gamma rays. One freshly prepared source has an activity of $3.0 \times 10^7$ Bq.

(a) To determine the radiation dose absorbed by the scientist working with the source, the number of gamma rays photons incident on each $cm^2$ of the body has to be known.

One in every five of the decaying nuclei produces a gamma ray photon. A scientist is initially working 1.50 m from the fresh source with no shielding. Show that at this time approximately 21 gamma photons per second are incident on each $cm^2$ of the scientist's body.

*(3 marks)*

(b) The scientist returns 6 hours later and works at the same distance from the source.

(i) Calculate the new number of gamma ray photons incident per second on each $cm^2$ of the scientist's body.

number of gamma photons per second per $cm^2$ = ................................

(ii) Explain why it is not necessary to consider the beta particle emissions when determining the radiation dose the scientist receives.

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*(5 marks)*

**Total 8 marks**

Answer **all** the questions.

1 **(a)** State Newton's second and third laws of motion.

*In your answer, you should use appropriate technical terms spelled correctly.*

**(i)** second law

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**(ii)** third law

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**(b)** A golfer uses a golf club to hit a stationary golf ball off the ground. Fig. 1.1 shows how the force $F$ on the golf ball varies with time $t$ when the club is in contact with the ball.

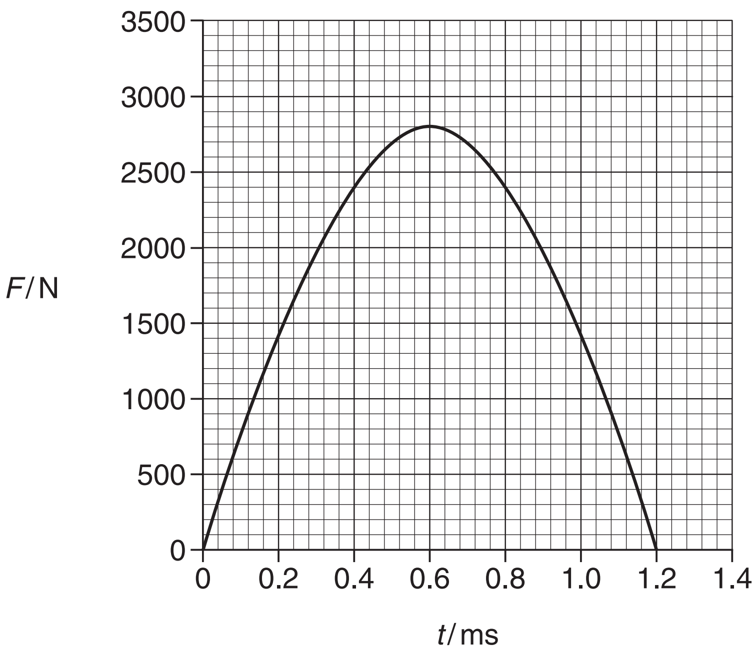


**Fig. 1.1**

**(i)** Estimate the area under the graph.

area = .................................................. N s **[2]**

**(ii)** Name the physical quantity represented by the area under the graph in **(i)**.

*In your answer, you should use appropriate technical terms spelled correctly.*

.................................................................................................................................... **[1]**

**(iii)** Show that the speed of a golf ball, of mass 0.046 kg, as it leaves the golf club is about $50\,m\,s^{-1}$.

speed = ............................................... $m\,s^{-1}$ **[2]**

**(iv)** The ground is level. The ball leaves the ground at a velocity of $50\,m\,s^{-1}$ at an angle of 42° to the horizontal. Determine the horizontal distance travelled by the ball before it hits the ground.

State **one** assumption that you make in your calculations.

distance = ........................................................... m

assumption ...........................................................................................................................

.................................................................................................................................... **[5]**

**[Total: 12]**

**2** **(a)** Fig. 2.1 shows the London Eye.

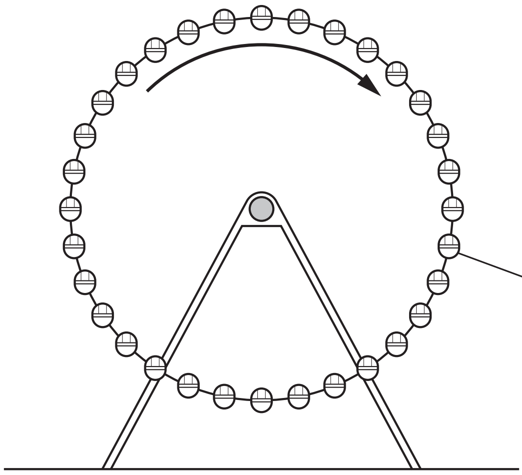


**Fig. 2.1**

It has 32 capsules equally spaced around the edge of a large vertical wheel of radius 60 m. The wheel rotates about a horizontal axis such that each capsule has a constant speed of 0.26 m $s^{-1}$.

**(i)** Calculate the time taken for the wheel to make one complete rotation.

time = ...................................................... s **[1]**

**(ii)** Each capsule has a mass of $9.7 \times 10^3$ kg. Calculate the centripetal force which must act on the capsule to make it rotate with the wheel.

centripetal force = ..................................................... N **[2]**

**(b)** Fig. 2.2 shows the drum of a spin-dryer as it rotates. A dry sock **S** is shown on the inside surface of the side of the rotating drum.

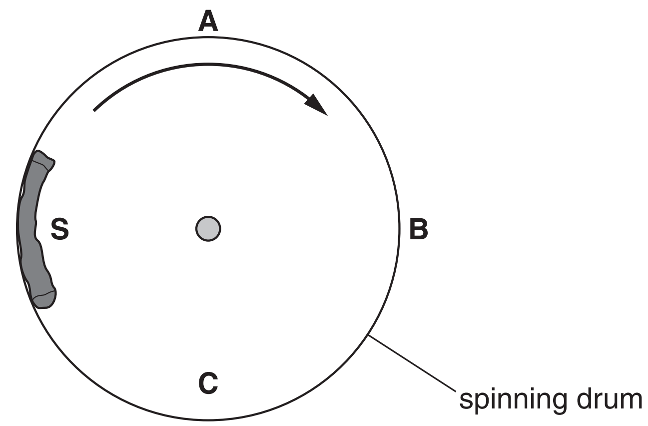


**Fig. 2.2**

**(i)** Draw arrows on Fig. 2.2 to show the direction of the centripetal force acting on **S** when it is at points **A**, **B** and **C**. **[1]**

**(ii)** State and explain at which position, **A**, **B** or **C** the normal contact force between the sock and the drum will be

**1** the greatest

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**2** the least.

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**[Total: 7]**

Turn over

**3** Fig. 3.1 represents the planet Jupiter. The centre of the planet is labelled as **O**.

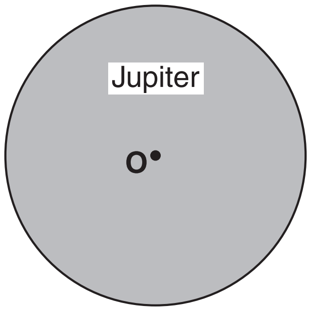


**Fig. 3.1**

**(a)** Draw gravitational field lines on Fig. 3.1 to represent Jupiter's gravitational field. **[2]**

**(b)** Jupiter has a radius of $7.14 \times 10^7$ m and the gravitational field strength at its surface is $24.9\,\mathrm{N\,kg^{-1}}$.

**(i)** Show that the mass of Jupiter is about $2 \times 10^{27}$ kg.

**[3]**

**(ii)** Calculate the average density of Jupiter.

density = ............................................ $\mathrm{kg\,m^{-3}}$ **[2]**

**[Total: 7]**

**4** Fig. 4.1 shows a mass suspended from a spring.

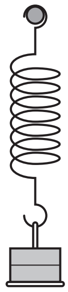

**Fig. 4.1**

**(a)** The mass is in equilibrium. By referring to the forces acting on the mass, explain what is meant by *equilibrium*.

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**(b)** The mass in **(a)** is pulled down a vertical distance of 12 mm from its equilibrium position. It is then released and oscillates with simple harmonic motion.

**(i)** Explain what is meant by *simple harmonic motion*.

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**(ii)** The displacement $x$, in mm, at a time $t$ seconds after release is given by

$$x = 12\cos(7.85\,t).$$

Use this equation to show that the frequency of oscillation is 1.25 Hz.

**[2]**

**(iii)** Calculate the maximum speed $V_{max}$ of the mass.

$V_{max}$ = .............................................. $m\,s^{-1}$ **[2]**

**(c)** Fig. 4.2 shows how the displacement *x* of the mass varies with time *t*.

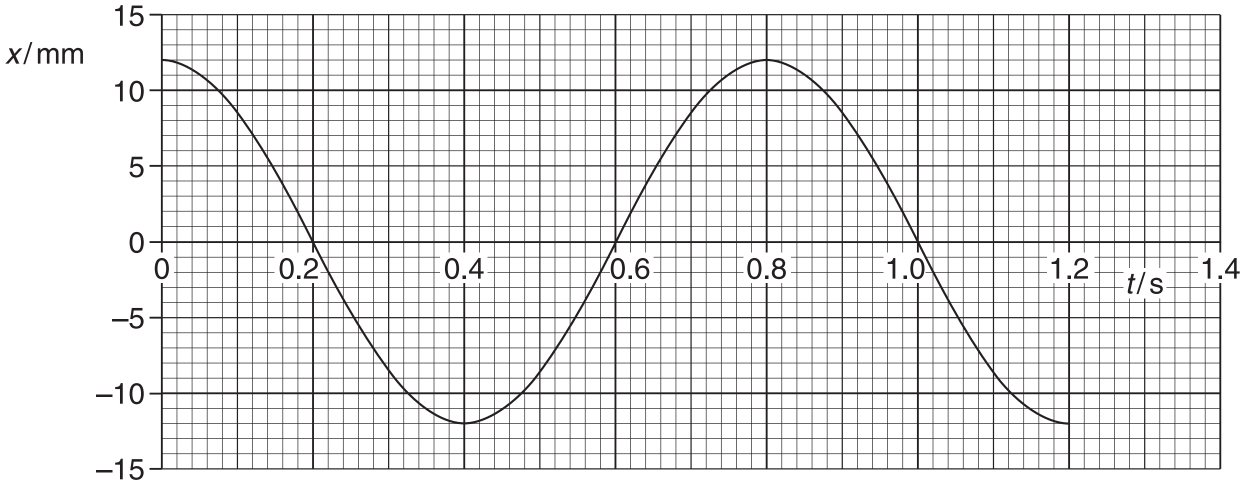


**Fig. 4.2**

Sketch on Fig. 4.3 the graph of velocity against time for the oscillating mass.

Put a suitable scale on the velocity axis. **[3]**

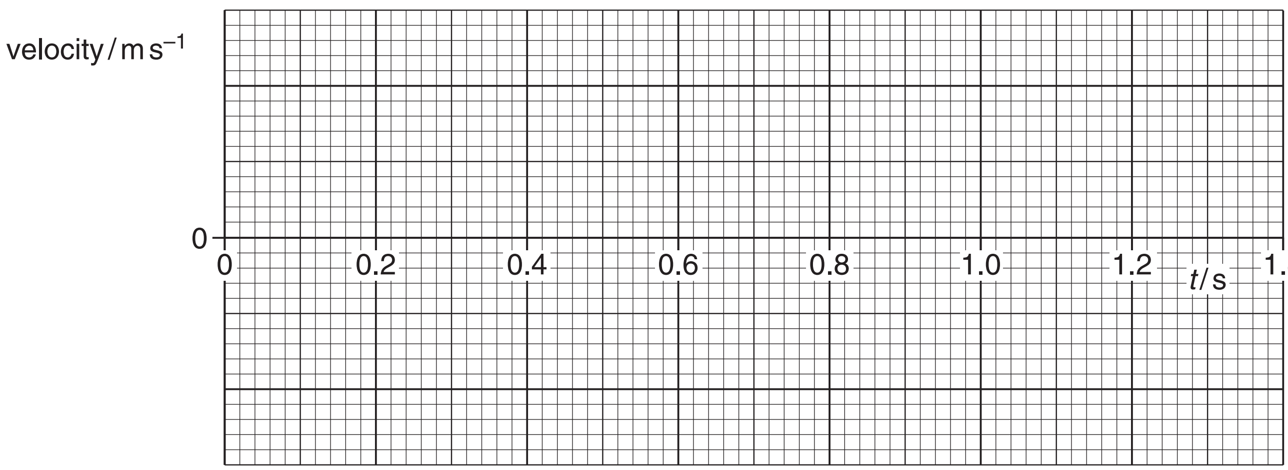


**Fig. 4.3**

**[Total: 11]**

**5** **(a)** The table shows the specific heat capacities $c$ of alcohol and water.

| | $c$ / J kg$^{-1}$ K$^{-1}$ |
|---|---|
| alcohol | 2460 |
| water | 4180 |

**(i)** An alcohol thermometer is placed in 80 g of water at 20 °C. The mass of alcohol in the thermometer is 0.050 g. The water is then heated from 20 °C to 60 °C.

Calculate the ratio

$$\frac{\text{energy required to warm the water from 20 °C to 60 °C}}{\text{energy required to warm the alcohol from 20 °C to 60 °C}}.$$

ratio = ........................................................ **[2]**

**(ii)** State and explain a situation in which the very high value of specific heat capacity for water is useful.

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**(b)** Describe an electrical experiment to determine the specific heat capacity *c* of a liquid.

Include in your answer:

- a labelled diagram of the arrangement
- a list of the measurements to be taken
- an explanation of how the value of *c* would be determined from your results
- possible sources of uncertainty in your measurements and how these could be reduced.

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[Total: 12]

**6** **(a)** The ideal gas equation may be written as

$$pV = nRT.$$

State the meaning of the terms $n$ and $T$.

$n$ ..............................................................................................................................................

$T$ .............................................................................................................................................. **[2]**

**(b)** Fig. 6.1 shows a cylinder that contains a fixed amount of an ideal gas. The cylinder is fitted with a piston that moves freely. The gas is at a temperature of 20 °C and the initial volume is $1.2 \times 10^{-4}\,m^3$. Fig. 6.2 shows the cylinder after the gas has been heated to a temperature of 90 °C under constant pressure.

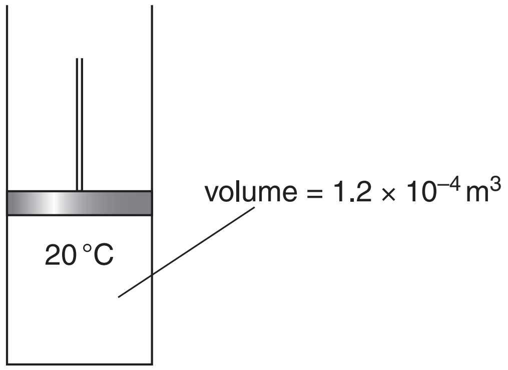


**Fig. 6.1**

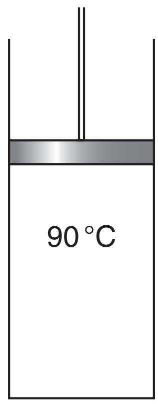


**Fig. 6.2**

**(i)** Explain in terms of the motion of the molecules of the gas why the volume of the gas must increase if the pressure is to remain constant as the gas is heated.

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.............................................................................................................................................. **[4]**

**(ii)** Calculate the volume of the gas at 90 °C.

volume = .................................................. $m^3$ **[2]**

**(c)** The mass of each gas molecule is $4.7 \times 10^{-26}$ kg. Estimate the average speed of the gas molecules at 90 °C.

speed = ................................................ $m\,s^{-1}$ **[3]**

**[Total: 11]**

**END OF QUESTION PAPER**

**mock papers 3**

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**1** A converging lens can be used to produce both a magnified real image and a magnified virtual image of an object.

(a) Draw ray diagrams to show how each image are formed. Label the principal foci of the lens in each case.

*(4 marks)*

(b) Calculate the object distance required to produce a magnified image 0.25 m from a lens of focal length 0.10 m where the image is virtual.

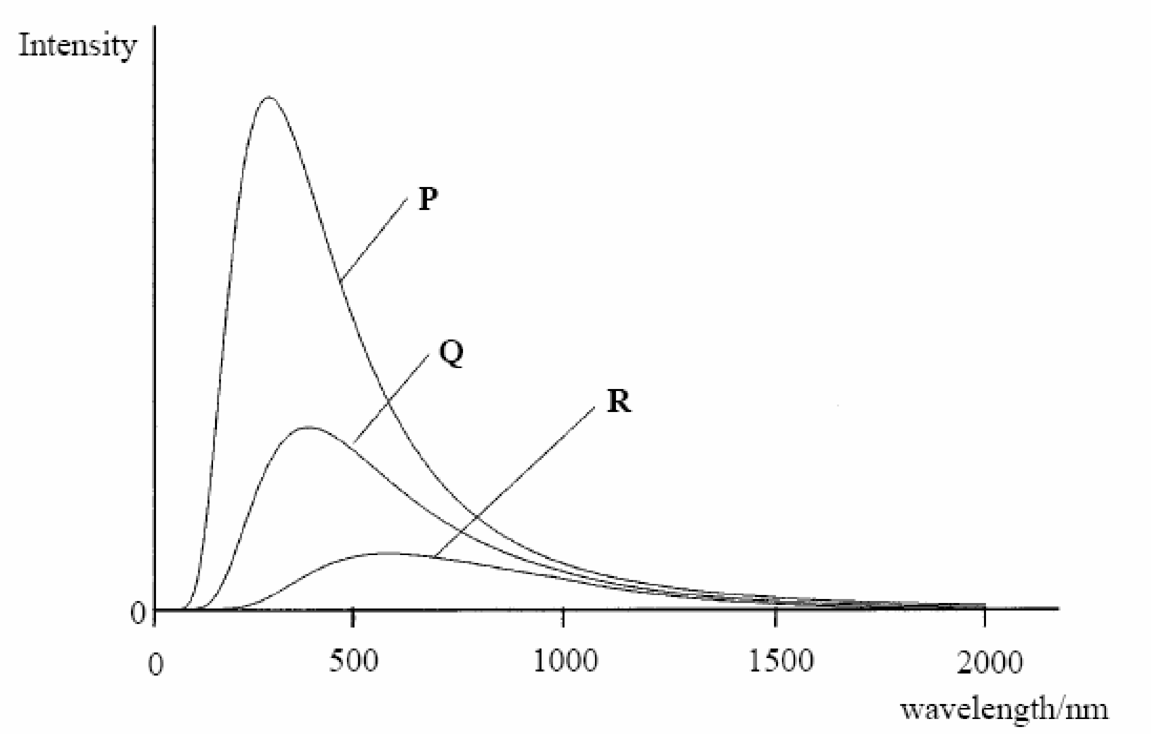
Object distance = ....................................

*(2 marks)*

**Total 6 marks**

**2** **Figure 1** shows the black body radiation curves for three stars, labelled P, Q and R.

**Figure 1**




(a) (i) State and explain, without calculation, which one of these three stars is the hottest.

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(ii) Calculate the black body temperature of the hottest star.

Temperature =....................................

*(3 marks)*

(b) More detailed analysis of the hottest star's spectrum revealed the presence of Hydrogen Balmer absorption lines.

(i) For which two spectral classes are these lines the prominent feature?

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(ii) Describe how these absorption lines are produced in the spectrum of a star.

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*(4 marks)*

**Total 7 marks**

**3** Modern astronomy relies on the analysis of radiation from many different parts of the electromagnetic spectrum. Compare the main features of telescopes used to detect radio waves with those of optical reflecting telescopes. Explain the differences in their resolving and collecting powers.

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*(6 marks)*

**Total 6 marks**

**4** (a) Define the *absolute magnitude* of a star.

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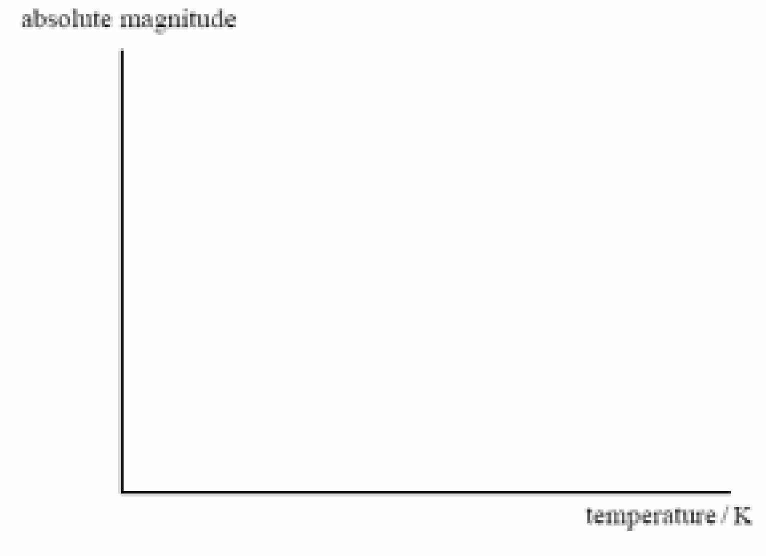
*(1 mark)*

(b) **Figure 2** shows the axes of a Hertzsprung-Russell (H-R) diagram.

**Figure 2**




(i) On each axis indicate a suitable range of values.

(ii) Label with an S the current position of the Sun on the H-R diagram.

(iii) Label the positions of the following stars on the H-R diagram:

(1) star W, which is significantly hotter and brighter than the Sun.

(2) star X, which is significantly cooler and larger than the Sun.

(3) star Y, which is the same size as the Sun, but significantly cooler.

(4) star Z, which is much smaller than the Sun, and has molecular bands as an . important feature in its spectrum.

*(7 marks)*

**Total 8 marks**

**5** The red shift of a galaxy's spectrum can be used to determine its velocity, relative to the Earth.

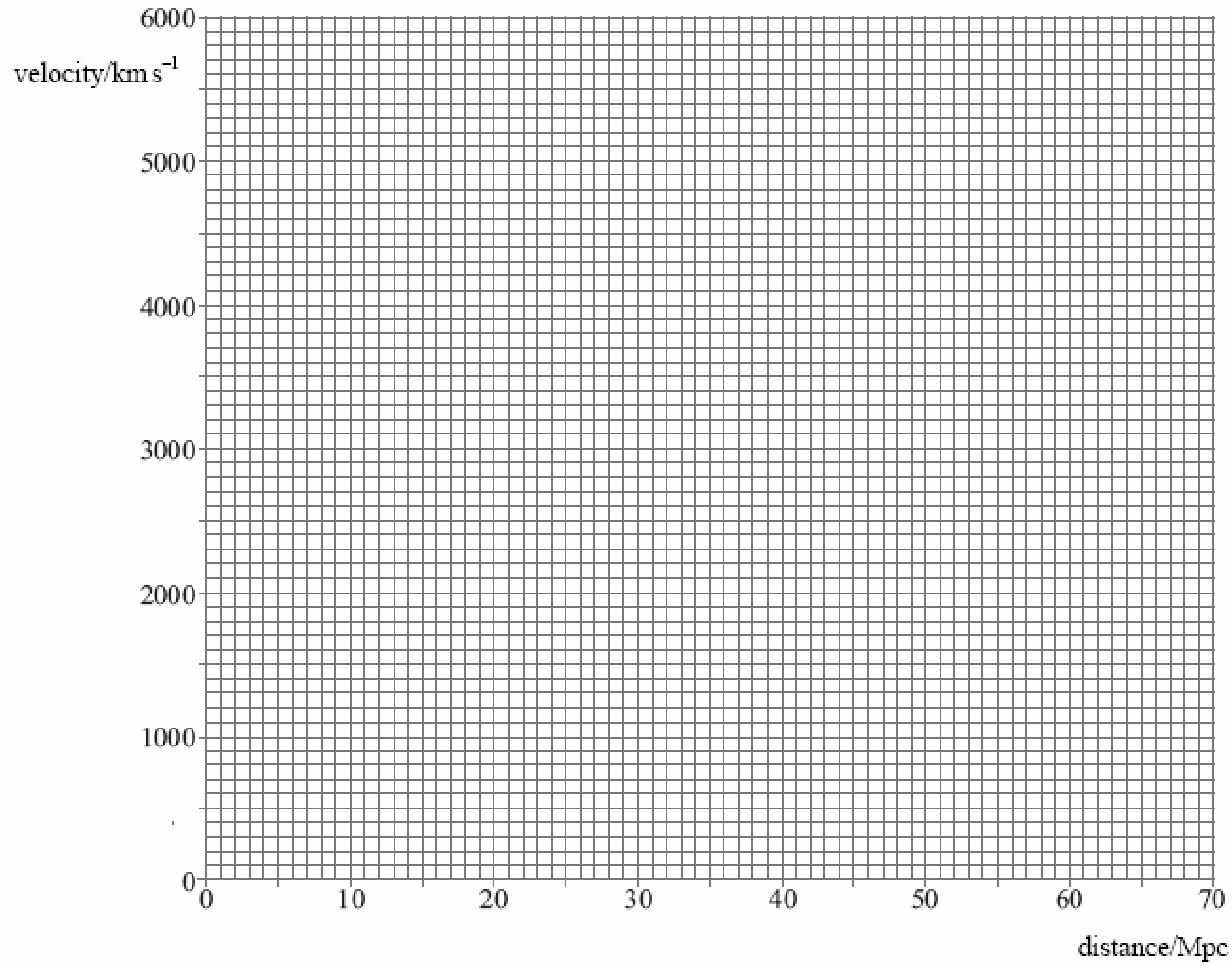
(a) The wavelength of the hydrogen alpha line in the spectrum of the galaxy NGXC 1357 is 660.86 nm. The wavelength of the same line from a laboratory based source is 656.28 nm. Calculate the velocity of galaxy NGC 1357.

Velocity = ....................................

*(2 marks)*

(b) Use the value obtained in (a) to complete the table. Plot a graph of the data in the table and use the graph to determine a value for the Hubble constant.

| galaxy | velocity/km $s^{-1}$ | distance/Mpc |
|---|---|---|
| NGC 1357 | | 28 |
| NGC 1832 | 2000 | 31 |
| NGC 5548 | 5270 | 67 |
| NGC 7469 | 4470 | 65 |




Hubble constant....................................

*(3 marks)*

(c) Analysis of light from supernovae suggests that the expansion of the Universe is accelerating.

(i) Explain how the light from supernovae can be used to determine the distance to galaxies.

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(ii) What is the name given to the energy believed to be responsible for this accelerating expansion?

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*(3 marks)*

**Total 8 marks**

Answer **all** the questions.

**1** **(a)** **(i)** State the principle of *conservation of linear momentum*.

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**(ii)** Explain what is meant by an *inelastic collision*.

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**(iii)** Fig. 1.1 shows the head-on-collision of two blocks on a frictionless surface.

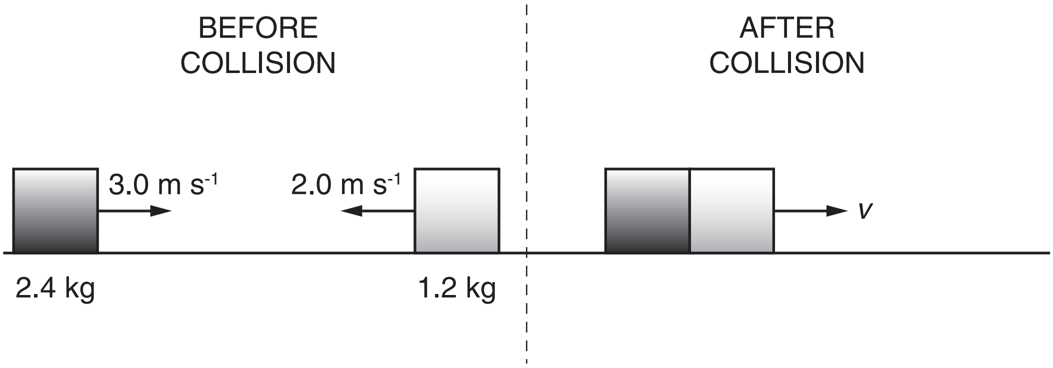


**Fig. 1.1**

Before the collision, the 2.4 kg block is moving to the right with a speed of $3.0\,\mathrm{m\,s^{-1}}$ and the 1.2 kg block is moving to the left at a speed of $2.0\,\mathrm{m\,s^{-1}}$. During the collision the blocks stick together. Immediately after the collision the blocks have a common speed *v*.

**1** Calculate the speed *v*.

$v$ = .............................................. $\mathrm{m\,s^{-1}}$ **[2]**

**2** Show that this collision is inelastic.

**[2]**

**(b)** Fig. 1.2 shows a helicopter viewed from above.

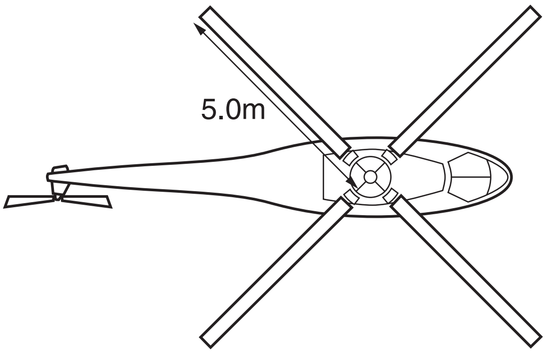


**Fig. 1.2**

The blades of the helicopter rotate in a circle of radius 5.0 m. When the helicopter is hovering, the blades propel air vertically downwards with a constant speed of 12 m s$^{-1}$. Assume that the descending air occupies a uniform cylinder of radius 5.0 m.

The density of air is 1.3 kg m$^{-3}$.

**(i)** Show that the mass of air propelled downwards in a time of 5.0 seconds is about 6000 kg.

**[2]**

**(ii)** Calculate

**1** the momentum of this mass of descending air

momentum = .......................................... $kg\,m\,s^{-1}$ **[1]**

**2** the force provided by the rotating helicopter blades to propel this air downwards

force = .................................................... N **[2]**

**3** the mass of the hovering helicopter.

mass = .................................................. kg **[1]**

**[Total: 13]**

**2** **(a)** **(i)** State, in terms of force, the conditions necessary for an object to move in a circular path at constant speed.

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**(ii)** Explain why this object is accelerating. State the direction of the acceleration.

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**(b)** A satellite moves in a circular orbit around the Earth at a constant speed of 3700 m $s^{-1}$.

The mass *M* of the Earth is $6.0 \times 10^{24}$ kg.

Calculate the radius of this orbit.

radius = ...................................................... m **[4]**

**(c)** In order to move the satellite in **(b)** into a new smaller orbit, a decelerating force is applied for a brief period of time.

**(i)** Suggest how the decelerating force could be applied.

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.................................................................................................................................... **[1]**

**(ii)** The radius of this new orbit is $2.0 \times 10^{7}$ m. Calculate the speed of the satellite in this orbit.

speed = ................................................ m $s^{-1}$ **[2]**

**[Total: 10]**

**Turn over**

**3** **(a)** **(i)** Define the *kilowatt-hour*.

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**(ii)** A domestic refrigerator works at a mean power of 70 W. Calculate the cost of running this refrigerator for one week at a cost of 12 p per kW h.

cost = £ ........................................................ **[2]**

**(b)** A large jug containing 2.0 kg of milk is placed in a refrigerator. The milk cools from 18 °C to 3.0 °C over a time period of 100 minutes. The specific heat capacity of milk is 3800 $J\,kg^{-1}\,K^{-1}$.

Calculate

**(i)** the thermal energy removed from the milk as it cools from 18 °C to 3 °C

energy removed = ...................................................... J **[2]**

**(ii)** the rate at which thermal energy is removed from the milk.

rate = ................................................ $J\,s^{-1}$ **[1]**

**(c)** Another container full of milk is placed in a freezer and cooled from 18 °C to –18 °C.

Assume that thermal energy is removed at a constant rate and that the freezing-point of milk is 0 °C. The specific heat capacity of milk below 0 °C is significantly less than its value above 0 °C.

On Fig. 3.1 sketch a graph to show the variation with time of the temperature of the milk over the range 18 °C to –18 °C. Numbers are not required on the time axis.


**Fig. 3.1** **[3]**

**[Total: 9]**

4 **(a)** For a body undergoing simple harmonic motion describe the difference between

**(i)** *displacement* and *amplitude*

*In your answer, you should use appropriate technical terms spelled correctly.*

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.................................................................................................................................... **[2]**

**(ii)** *frequency* and *angular frequency*.

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**(b)** A harbour, represented in Fig. 4.1, has vertical sides and a flat bottom. The surface of the water in the harbour is calm.

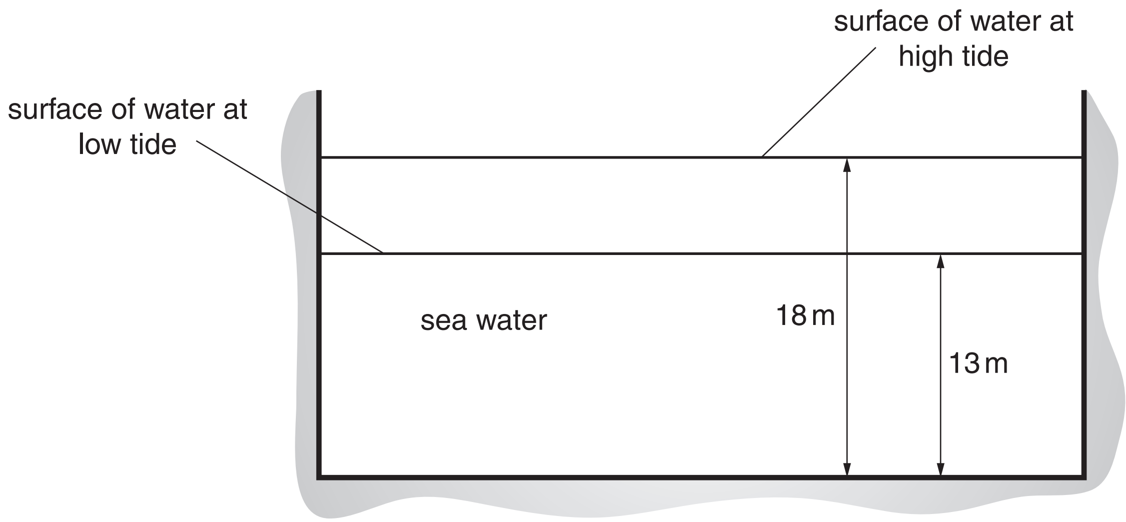


**Fig. 4.1**

The tide causes the surface of the water to perform simple harmonic motion with a period of 12.5 hours. The maximum depth of the water is 18 m and the minimum depth is 13 m.

**(i)** For the oscillation of the water surface, calculate

**1** the amplitude

amplitude = .................................................... m **[1]**

**2** the frequency.

frequency = .................................................. Hz **[2]**

**(ii)** Calculate the maximum vertical speed of the water surface.

maximum speed = ............................................. $m\,s^{-1}$ **[2]**

**(iii)** Write an expression for the depth *d* in metres of water in the harbour in terms of time *t* in seconds.

**[2]**

**[Total: 11]**

**5** **(a)** A student investigates Brownian motion by observing through a microscope smoke particles suspended in air.

**(i)** Describe the behaviour of the smoke particles as observed by the student.

*In your answer, you should use appropriate technical terms spelled correctly.*

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.......................................................................................................................... **[1]**

**(ii)** State how the observations lead to conclusions about the nature and properties of the molecules of a gas.

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**(b)** The molar masses of hydrogen and oxygen are 0.0020 kg mol$^{-1}$ and 0.032 kg mol$^{-1}$ respectively. The mean speed of hydrogen molecules at room temperature is 1800 m s$^{-1}$.

Calculate the mean speed of oxygen molecules at the same temperature.

mean speed = ................................................ m s$^{-1}$ **[3]**

**[Total: 7]**

6 (a) (i) State Boyle's law.

.......................................................................................................................................

............................................................................................................................... [2]

(ii) For a gas which obeys Boyle's law, sketch

1 on Fig. 6.1 a graph of pressure $p$ against volume $V$

2 on Fig. 6.2 a graph of $p$ against $1/V$. [3]

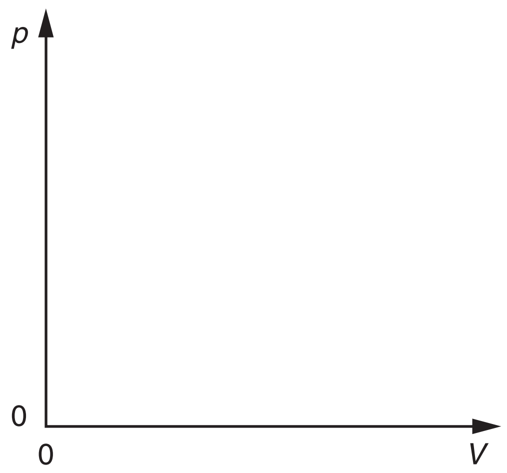


**Fig. 6.1**

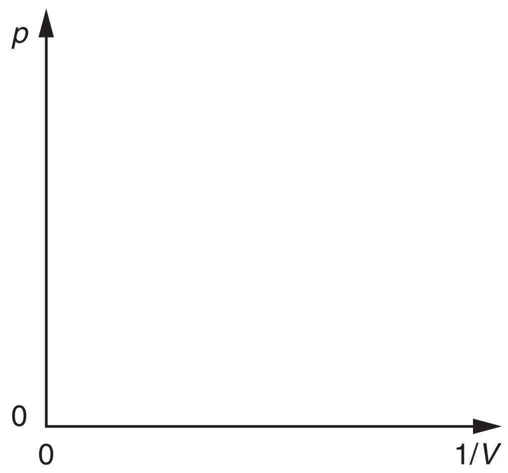


**Fig. 6.2**

**Question 6 continues over the page.**

**Turn over**

**(b)** A cylinder of fixed volume 0.040 $m^3$ is filled with nitrogen gas at a pressure of $5.0 \times 10^5$ Pa and temperature 15 °C. The molar mass of nitrogen is 0.028 kg $mol^{-1}$.

**(i)** Calculate the number of moles of nitrogen in the cylinder.

number of moles = ........................................................ **[2]**

**(ii)** After a period of 100 days the pressure has fallen to $4.5 \times 10^5$ Pa, at the same temperature, because of leakage. Calculate the mass of nitrogen that has escaped.

mass = ..................................................... kg **[3]**

**[Total: 10]**

**END OF QUESTION PAPER**

**mock papers 5**



**1 (a)** Draw a ray diagram for an astronomical refracting telescope in normal adjustment. Your diagram should show the paths of **three** non-axial rays through both lenses. Label the principal foci of the two lenses.

*(3 marks)*

**1 (b)** An early form of this telescope was built by Johannes Hevelius. It was 3.7 m long and had an angular magnification of 50. Hevelius used it to help produce one of the earliest maps of the Moon's surface.

**1 (b) (i)** Calculate the focal lengths of the objective lens and eyepiece lens in an astronomical telescope of length 3.7 m and angular magnification 50.

focal length of objective lens = ...................................... m

focal length of eyepiece lens = ...................................... m

*(2 marks)*

**1 (b) (ii)** The Triesnecker Crater on the Moon has a diameter of 23 km. Calculate the angle subtended by the image of this crater when viewed through a telescope of angular magnification 50 on the Earth.

distance from Earth to Moon = $3.8 \times 10^5$ km

angle = ...................................... rad

*(2 marks)*

**1 (c)** Early refracting telescopes suffered significantly from chromatic aberration. Draw a diagram to show how a single converging lens produces chromatic aberration.

*(2 marks)*

9

**Turn over for the next question**

**2** Sirius is a binary system consisting of two stars, Sirius A and Sirius B, the properties of which are summarised below.

| | **Sirius A** | **Sirius B** |
|---|---|---|
| absolute magnitude | 1.4 | 11.2 |
| apparent magnitude | –1.4 | 8.4 |
| diameter / $10^3$ km | 2400 | 12 |
| black-body temperature / K | 10 000 | 25 000 |

**2 (a)** Calculate the distance to Sirius, giving an appropriate unit.

distance = ....................................
*(3 marks)*

**2 (b) (i)** Calculate the ratio

$$\frac{\text{power output of Sirius A}}{\text{power output of Sirius B}}$$

ratio = ....................................
*(2 marks)*

**2 (b) (ii)** Show that data in the table suggests that one star is about 8000 times brighter than the other.

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*(2 marks)*

**2 (b) (iii)** With reference to the spectra of the two stars, explain why the value in part **b (ii)** is much greater than the answer to part **b (i)**.

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*(3 marks)*

10

**Turn over for the next question**

**3** The Chandra X-ray Observatory was launched into orbit in 1999. It is used to observe hot and turbulent regions of space.

**3 (a)** Explain why X-ray telescopes need to be in orbit.

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*(1 mark)*

**3 (b)** In 2000, the Chandra telescope was used to observe a *black hole* in Ursa Major.

**3 (b) (i)** Explain what is meant by a black hole.

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*(1 mark)*

**3 (b) (ii)** The black hole is believed to have a mass 7 times that of the Sun. Calculate the radius of its event horizon.

mass of the Sun = $2.0 \times 10^{30}$ kg

radius = ..................................... m

*(2 marks)*

**3 (c)** Chandra makes use of a charge coupled device (CCD) to detect the X-ray photons. Describe the processes involved in the detection of photons by a CCD.

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*(3 marks)*

7

**4 (a)** In 1997 a type 1a *supernova* was observed which contributed to the controversial conclusion that the expansion of the Universe is accelerating.

Explain why observations of supernovae led to the conclusion that the Universe is expanding at an accelerating rate and discuss why this conclusion is controversial.

The quality of your written communication will be assessed in this question.

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*(6 marks)*

**Question 4 continues on the next page**

**4 (b)** Measurements of the shift in the 21 cm H1 line in the spectrum of galaxy M84 suggests that it is receding at a velocity of $900\,\text{km}\,\text{s}^{-1}$.

**4 (b) (i)** Calculate the value of the red shift, $z$, for this galaxy.

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$z$ = ........................................

*(1 mark)*

**4 (b) (ii)** Calculate the distance to this galaxy.

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distance = ..................................... Mpc

*(2 marks)*

9

**END OF QUESTIONS**