



Cambridge International AS & A Level

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PHYSICS**9702/41**

Paper 4 A Level Structured Questions

October/November 2025**2 hours**

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [].

This document has **24** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





gravitational potential

$$\phi = -\frac{GM}{r}$$

gravitational potential energy

$$E_P = -\frac{GMm}{r}$$

pressure of an ideal gas

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

simple harmonic motion

$$a = -\omega^2 x$$

velocity of particle in s.h.m.

$$v = v_0 \cos \omega t$$

$$v = \pm \omega \sqrt{(x_0^2 - x^2)}$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

electrical potential energy

$$E_P = \frac{Qq}{4\pi\epsilon_0 r}$$

capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel

$$C = C_1 + C_2 + \dots$$

discharge of a capacitor

$$x = x_0 e^{-\frac{t}{RC}}$$

Hall voltage

$$V_H = \frac{BI}{ntq}$$

alternating current/voltage

$$x = x_0 \sin \omega t$$

radioactive decay

$$x = x_0 e^{-\lambda t}$$

decay constant

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

intensity reflection coefficient

$$\frac{I_R}{I_0} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$$

Stefan-Boltzmann law

$$L = 4\pi\sigma r^2 T^4$$

Doppler redshift

$$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$



- 1 (a) In terms of velocity and acceleration, describe uniform circular motion of an object.

.....

.....

..... [2]

- (b) Fig. 1.1 shows the view from above of a polystyrene ball undergoing horizontal circular motion of radius R .

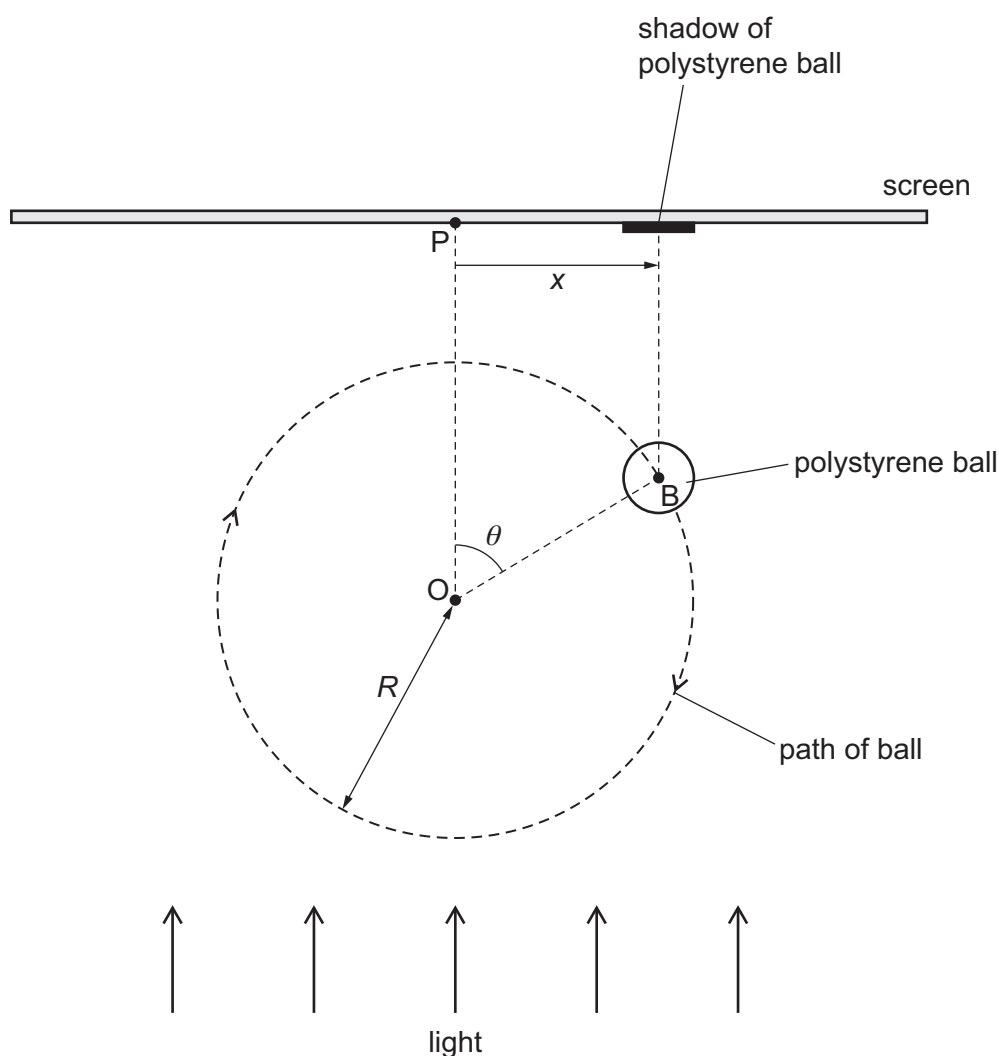


Fig. 1.1

The ball is illuminated by parallel light so that a shadow of the ball forms on a screen placed on the opposite side of the ball from the light source.

The line joining points O and P is perpendicular to the screen.

The angular speed of the circular motion is ω .



- (i) State an expression, in terms of R and ω , for the speed v of the ball.

$$v = \dots\dots\dots [1]$$

- (ii) Determine an expression, in terms of v and ω , for the centripetal acceleration of the ball.

$$\text{centripetal acceleration} = \dots\dots\dots [2]$$

- (c) The ball in (b) is in the position shown in Fig. 1.1, such that line OB is at an angle θ to the line OP.

- (i) Determine an expression, in terms of R and θ , for the displacement x of the shadow from P.

$$x = \dots\dots\dots [1]$$

- (ii) The value of θ is zero at time $t = 0$.

State an expression for θ in terms of ω and t .

$$\theta = \dots\dots\dots [1]$$

- (iii) Use your answers in (c)(i) and (c)(ii) to show that x is given by

$$x = R \sin \omega t.$$

[1]

- (iv) Explain, with reference to the equation in (c)(iii), why the motion of the shadow of the ball on the screen may be modelled as simple harmonic.

.....
 [1]



- (d) The circular motion of the ball in Fig. 1.1 has a diameter of 0.46 m and an angular speed of 1.9 rad s^{-1} .

For the simple harmonic motion of the shadow of the ball in Fig. 1.1, calculate:

- (i) the amplitude

amplitude = ... m [1]

- (ii) the period

period = ... s [2]

- (iii) the maximum acceleration.

maximum acceleration = ... m s^{-2} [2]

- (e) On Fig. 1.1, draw, and label with the letter A, the position of the shadow on the screen when the shadow has its maximum positive acceleration. [1]

[Total: 15]



- 2 (a) State **two** ways in which the first law of thermodynamics describes that the internal energy of a system may be changed.

1

.....

2

.....

[2]

- (b) (i) Use the first law of thermodynamics to explain why a bicycle pump gets hot when it is used to pump up a tyre quickly.

.....

.....

.....

.....

..... [3]

- (ii) With reference to molecular energies, explain why the temperature of water remains at 100 °C when it vaporises in a kettle, even though it is being heated.

.....

.....

.....

.....

..... [3]

[Total: 8]



- 3 (a) Define gravitational field at a point.

.....
 [1]

- (b) Fig. 3.1 shows an isolated point mass of mass M .

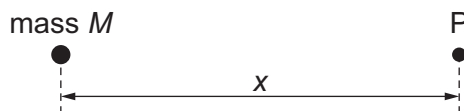


Fig. 3.1

Point P is at distance x from the point mass.

- (i) By considering the force exerted by the point mass on a test mass of mass m placed at P, derive an equation for the gravitational field strength g at P, in terms of M and x . Identify any other symbols you use.

[2]

- (ii) On Fig. 3.1, draw an arrow to indicate the direction of the gravitational field at P. [1]

- (iii) Point Q is at distance $\frac{x}{2}$ from the point mass, on the opposite side of the mass from P, as shown in Fig. 3.2.



Fig. 3.2

Compare the gravitational field at Q with that at P.

.....

 [2]



- (c) Two identical isolated uniform spheres X and Y each have radius R . The centres of the spheres are separated by distance L , as shown in Fig. 3.3.

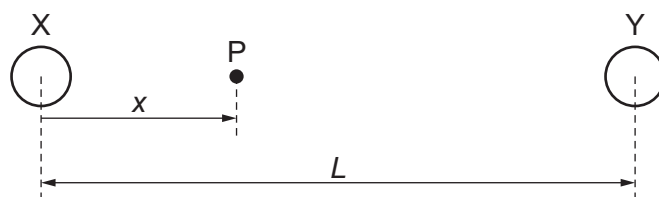


Fig. 3.3

Point P lies on the line joining the centres of X and Y, and is at a variable displacement x from the centre of sphere X.

The gravitational field strength at the surface of each sphere is g_0 .

On Fig. 3.4, sketch the variation with x of the gravitational field g at point P between $x = R$ and $x = L - R$.

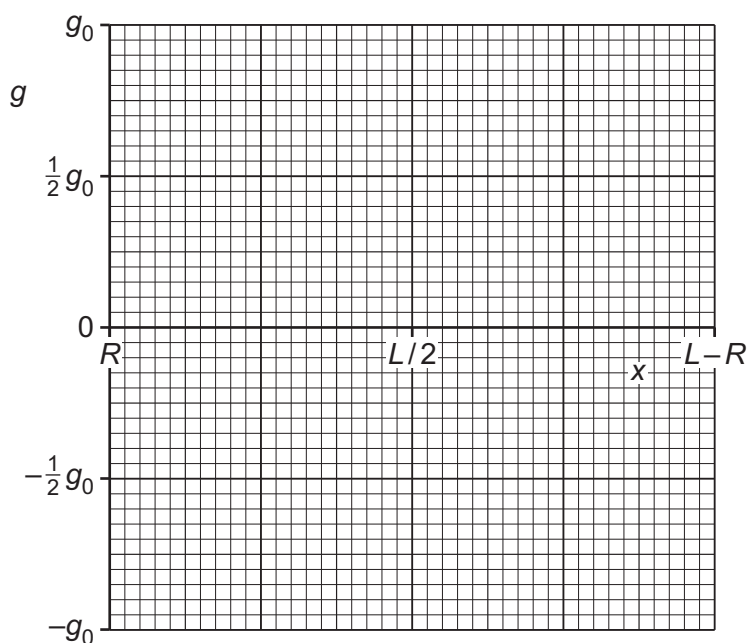


Fig. 3.4

[3]

[Total: 9]



4 (a) State the value of absolute zero on:

(i) the Celsius temperature scale

temperature = ... °C [1]

(ii) the thermodynamic temperature scale. Give a unit with your answer.

temperature = ... unit [1]

(b) A sample contains a fixed amount of gas. The gas has pressure p , volume V and thermodynamic temperature T .

Fig. 4.1 shows the variation of pV with kT for the sample, where k is the Boltzmann constant.

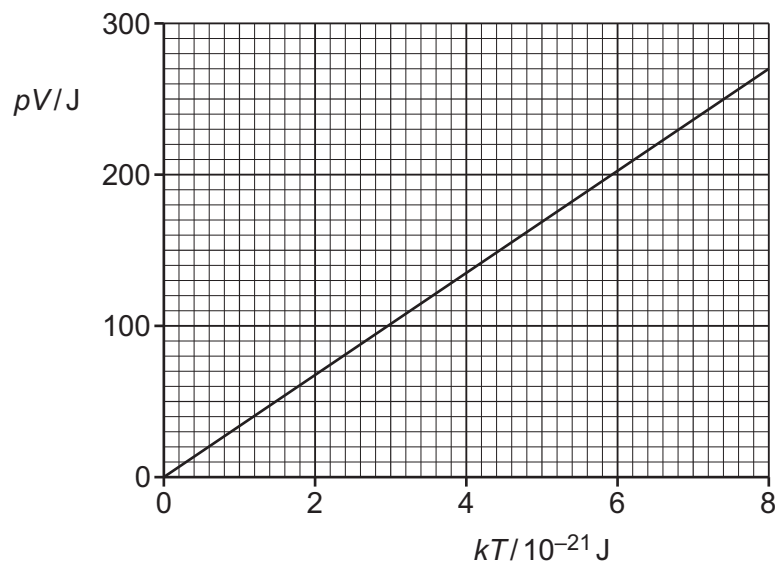


Fig. 4.1

(i) State what is indicated about the nature of the gas from the variation shown in Fig. 4.1.

..... [1]

(ii) Determine the number N of molecules of the gas in the sample.

$N =$ [2]



(iii) Use your answer in (b)(ii) to determine the amount n of gas in the sample.

$$n = \dots\dots\dots \text{mol} \quad [1]$$

- (c) The root-mean-square (r.m.s.) speed of the molecules of the gas is 1900 ms^{-1} when pV is equal to 270 J .

Determine the mass, in u , of one molecule of the gas, where u is the unified atomic mass unit.

$$\text{mass} = \dots\dots\dots u \quad [4]$$

[Total: 10]



- 5 (a) Define electric potential at a point.

.....

.....

..... [2]

- (b) A hydrogen atom may be considered to consist of a proton and an electron separated by a distance of 120 pm, as shown in Fig. 5.1.

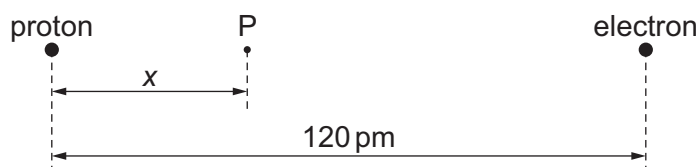


Fig. 5.1

The two particles may be considered as point charges.

Point P lies on the line joining the electron and the proton and is at a variable distance x from the proton.

- (i) Show that the electric potential V at point P when $x = 10$ pm is equal to 130 V.

[2]

- (ii) Calculate, to two significant figures, V when $x = 30$ pm.

$V = \dots\dots\dots V$ [2]

- (iii) On Fig. 5.1, draw a cross (x) at one position, other than infinity, where the electric potential is zero. [1]



(iv) On Fig. 5.2, sketch the variation of V with x between $x = 10\text{ pm}$ and $x = 110\text{ pm}$.

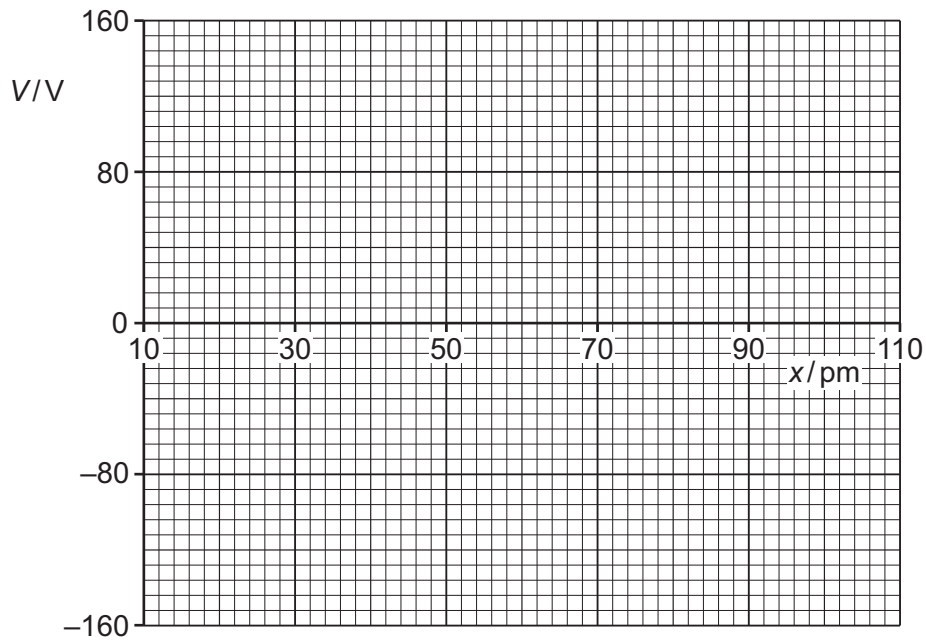


Fig. 5.2

[3]

[Total: 10]



- 6 (a) Two parallel plate capacitors C_1 and C_2 are connected to a supply that has a potential difference (p.d.) V_S . The capacitors may be connected in series or in parallel.

The supply provides charge Q_S and the plates of the two capacitors acquire charges Q_1 and Q_2 respectively. The p.d.s across the plates of the capacitors are V_1 and V_2 respectively.

Complete Table 6.1 to indicate how Q_S , Q_1 and Q_2 relate to each other, and how V_S , V_1 and V_2 relate to each other, for series and parallel connections of the capacitors to the supply.

Table 6.1

	relationship between charges	relationship between p.d.s
series		
parallel		

[4]

- (b) An isolated capacitor of capacitance $470\ \mu\text{F}$ stores 19 mJ of energy.

- (i) Calculate the p.d. across the capacitor.

p.d. = ...V [2]

- (ii) Calculate the charge on the capacitor.

charge = ... C [2]





- (iii) The capacitor is now connected in parallel with a capacitor of capacitance $180\mu\text{F}$ that is initially uncharged.

Determine the total energy, in mJ, now stored in the two capacitors.

energy = ... mJ [3]

[Total: 11]



- 7 (a) State Faraday's law of electromagnetic induction.

.....

.....

..... [2]

- (b) An aircraft is flying horizontally at constant speed v through the Earth's magnetic field, as shown in Fig. 7.1.

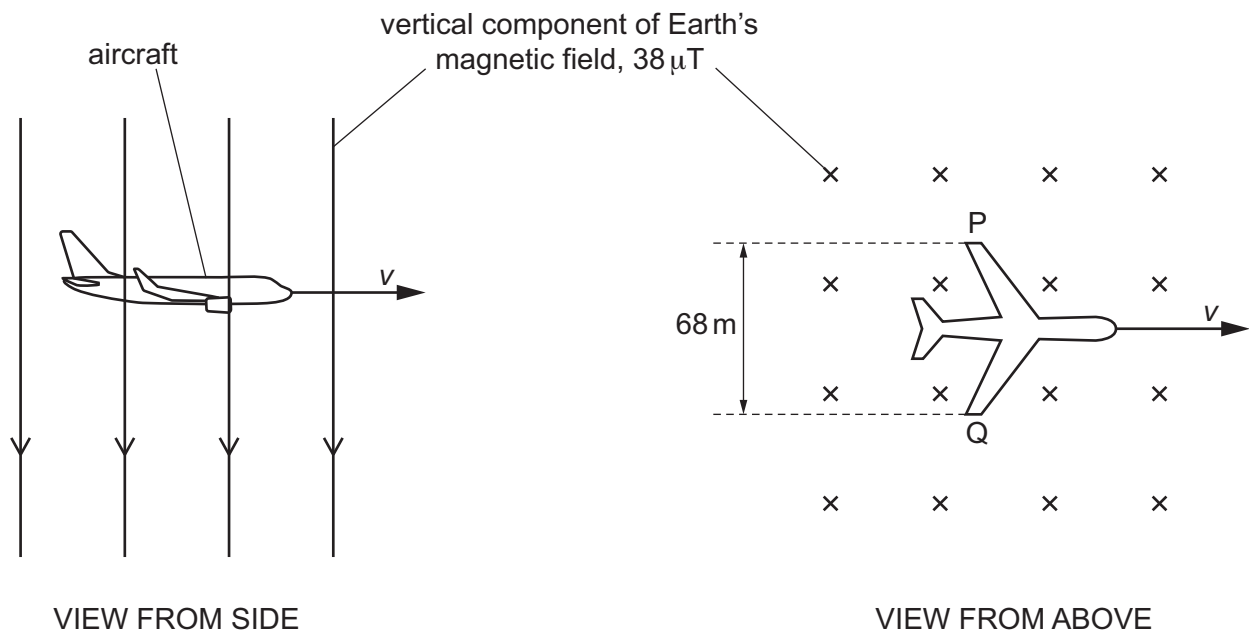


Fig. 7.1

At the location of the aircraft, the vertical component of the Earth's magnetic field is $38\mu\text{T}$ towards the ground.

The distance between the wingtips P and Q of the aircraft is 68 m.

As the aircraft moves through the magnetic field, an electromotive force (e.m.f.) of 0.54 V is induced between the wingtips P and Q.

- (i) Calculate the magnetic flux cut by the wings of the aircraft in a time of 15 s. Give a unit with your answer.

magnetic flux = ... unit [2]



- (ii) Determine the area of flux cut by the wings in a time of 15 s.

area = ...m² [2]

- (iii) Use your answer in (b)(ii) to determine the speed v of the aircraft.

v = ...ms⁻¹ [2]

- (iv) Use Lenz's law of electromagnetic induction to explain which of the wingtips P and Q is at the higher induced potential.

.....

.....

.....

.....

..... [3]

[Total: 11]



- 8 (a) State what is meant by a photon.

.....

.....

..... [2]

- (b) A stationary nucleus of uranium-238 ($^{238}_{92}\text{U}$) undergoes alpha decay to produce a nucleus of thorium-234 ($^{234}_{90}\text{Th}$). The kinetic energy of the emitted alpha particle is 4.200 MeV. A gamma-ray photon is also emitted during the decay.

Assume that the rebound kinetic energy of the thorium nucleus is negligible.

Table 8.1 shows the masses of the nuclides involved in the decay reaction. The mass of the uranium-238 nuclide is missing.

Table 8.1

nuclide	nuclide mass/u
$^4_2\alpha$	4.000 407
$^{234}_{90}\text{Th}$	233.915 174
$^{238}_{92}\text{U}$	

The total energy released in the decay of the nucleus of uranium-238 is 4.274 MeV.

- (i) Calculate the mass, in u, of the uranium-238 nuclide. Give your answer to five decimal places.

mass = ... u [3]



- (ii) Determine a value for the wavelength of the gamma radiation emitted during the decay of the uranium-238 nucleus.

wavelength = ... m [3]

- (iii) In practice, the rebound kinetic energy of the thorium nucleus is **not** negligible.

Explain, without further calculation, how your answer in **(b)(ii)** compares with the true wavelength of gamma radiation emitted during the decay of the uranium-238 nucleus.

.....

 [1]

- (c) Gamma radiation emitted during the decay of a sample of uranium-238 has a single wavelength.

Nuclei of cobalt-60 ($^{60}_{27}\text{Co}$) decay by beta emission, and also emit gamma radiation in the process.

Suggest why there is **not** a single wavelength for the gamma radiation emitted during the decay of a sample of cobalt-60.

.....

 [2]

[Total: 11]



9 (a) State Wien's displacement law.

.....

.....

..... [2]

(b) Fig. 9.1 shows the variation with d^{-2} of the radiant flux intensity F observed from a star X, where d is the distance of the observer from the star. Fig. 9.2 shows the variation with wavelength λ of the rates of emission P of radiation by star X and the Sun.

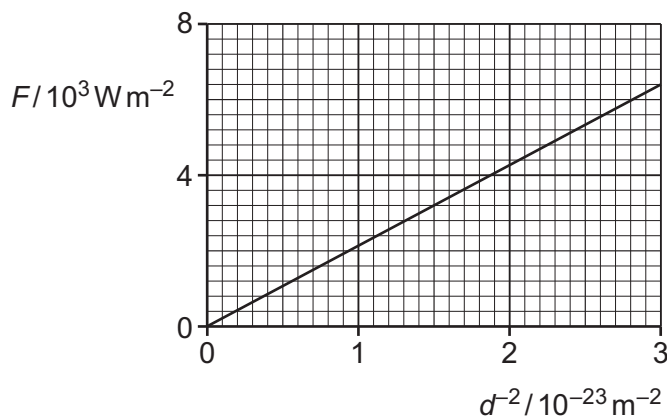


Fig. 9.1

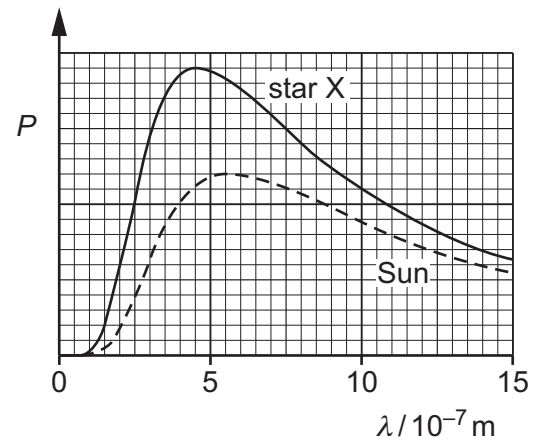


Fig. 9.2

The surface temperature of the Sun is 5770 K.

State **three** conclusions about star X that can be drawn from this data. The conclusions may be qualitative or quantitative. Use the space for any working.

1

.....

2

.....

3

.....



(c) Star X is in a galaxy that is moving away from the Earth.

Suggest, with a reason, how the line for star X in Fig. 9.2 would appear differently if it had been obtained from data measured on the Earth.

.....

.....

..... [2]

[Total: 7]



10 (a) Define specific acoustic impedance.

.....

 [2]

(b) Explain how ultrasound waves are detected by a piezoelectric crystal.

.....

 [2]

(c) Table 10.1 shows the specific acoustic impedance Z for body tissue, water and steel.

Table 10.1

material	$Z/\text{kg m}^{-2} \text{ s}^{-1}$
body tissue	1.38×10^6
water	1.48×10^6
steel	4.04×10^7

(i) Calculate the intensity reflection coefficient for ultrasound incident on a water–steel boundary.

intensity reflection coefficient = ... [2]

(ii) Explain, without calculation, what is likely to happen when ultrasound is incident on a body tissue–water boundary.

.....

 [2]

[Total: 8]







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9702/42

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2 hours

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simple harmonic motion

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velocity of particle in s.h.m.

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$$v = \pm \omega \sqrt{(x_0^2 - x^2)}$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

electrical potential energy

$$E_P = \frac{Qq}{4\pi\epsilon_0 r}$$

capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

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Stefan-Boltzmann law

$$L = 4\pi\sigma r^2 T^4$$

Doppler redshift

$$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$



- 1 The Earth may be considered as a uniform sphere of radius $6.37 \times 10^6 \text{ m}$.

Cambridge is at a point on the Earth's surface that has a latitude of 52.2° north of the Equator, as shown in Fig. 1.1.

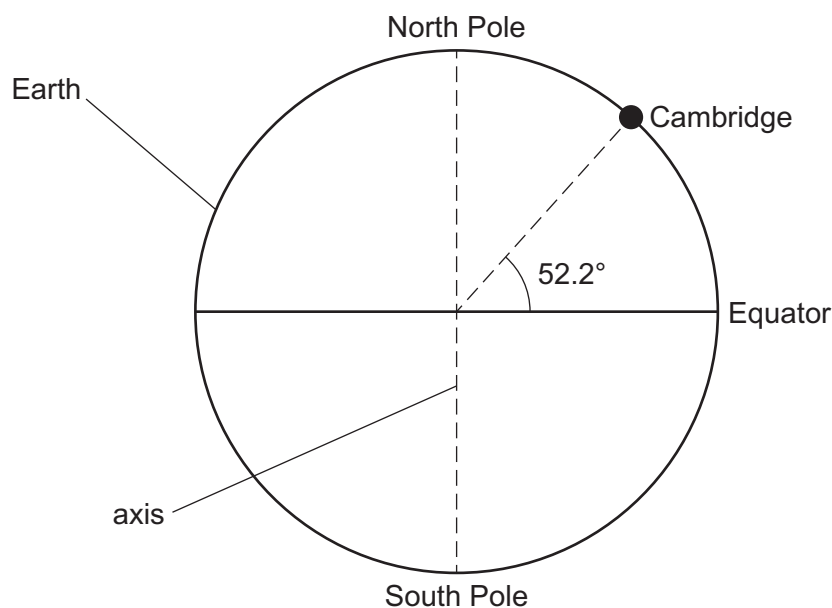


Fig. 1.1

As the Earth spins on its axis, Cambridge moves in a circle that is parallel to the Equator but with a smaller radius.

- (a) (i) Show that the radius of the circle around which Cambridge moves is $3.90 \times 10^6 \text{ m}$.

[1]

- (ii) Calculate the speed at which Cambridge moves around the circle.

speed = ... ms^{-1} [3]



(b) A student of mass 58.6 kg stands on horizontal ground in Cambridge.

- (i) Determine the magnitude of the resultant force that acts to cause the circular motion of the student.

resultant force = ... N [2]

- (ii) On Fig. 1.2, draw an arrow to show the direction of the resultant force that acts on the student.

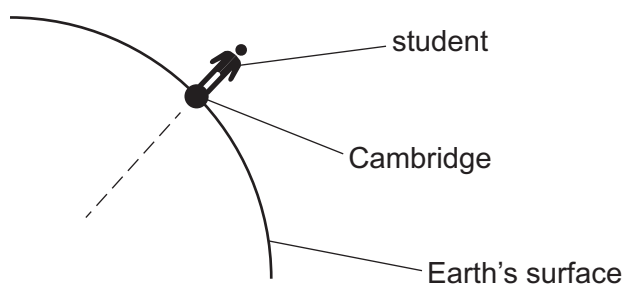


Fig. 1.2 (not to scale)

[1]

- (iii) On Fig. 1.3, draw labelled arrows from the student to show the directions of the forces that act on the student to cause the resultant force in (b)(ii).

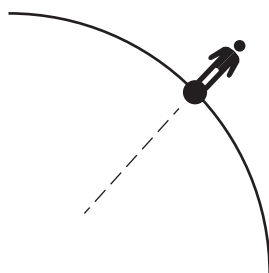


Fig. 1.3 (not to scale)

[2]

[Total: 9]



- 2 (a) State Newton's law of gravitation.

.....

 [2]

- (b) One of the basic assumptions of the kinetic theory of gases is that there are no forces exerted between the molecules of the gas except during collisions.

State **two** other basic assumptions of the kinetic theory of gases.

1

 2
 [2]

- (c) Hydrogen gas consists of molecules that each have a mass of 3.34×10^{-27} kg. Hydrogen may be considered to be an ideal gas.

A spherical balloon contains 0.0160 mol of hydrogen gas at a temperature of 282 K. At this temperature, the volume of gas in the balloon is $1.87 \times 10^{-4} \text{ m}^3$.

- (i) Determine the pressure of the gas.

pressure = ... Pa [2]

- (ii) Estimate the average separation of the hydrogen molecules in the gas.

average separation = ... m [2]



- (d) (i) Use your answer in (c)(ii) to calculate the average gravitational force between adjacent molecules in hydrogen gas.

average force = ... N [2]

- (ii) By considering the weight of a molecule, suggest with a reason whether your answer in (d)(i) is consistent with the assumption of the kinetic theory of gases that there are no forces exerted between molecules.

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

[Total: 11]



- 3 (a) State what is meant by two objects being in thermal equilibrium.

.....

.....

..... [2]

- (b) Fig. 3.1 shows a type of thermometer called a constant volume gas thermometer.

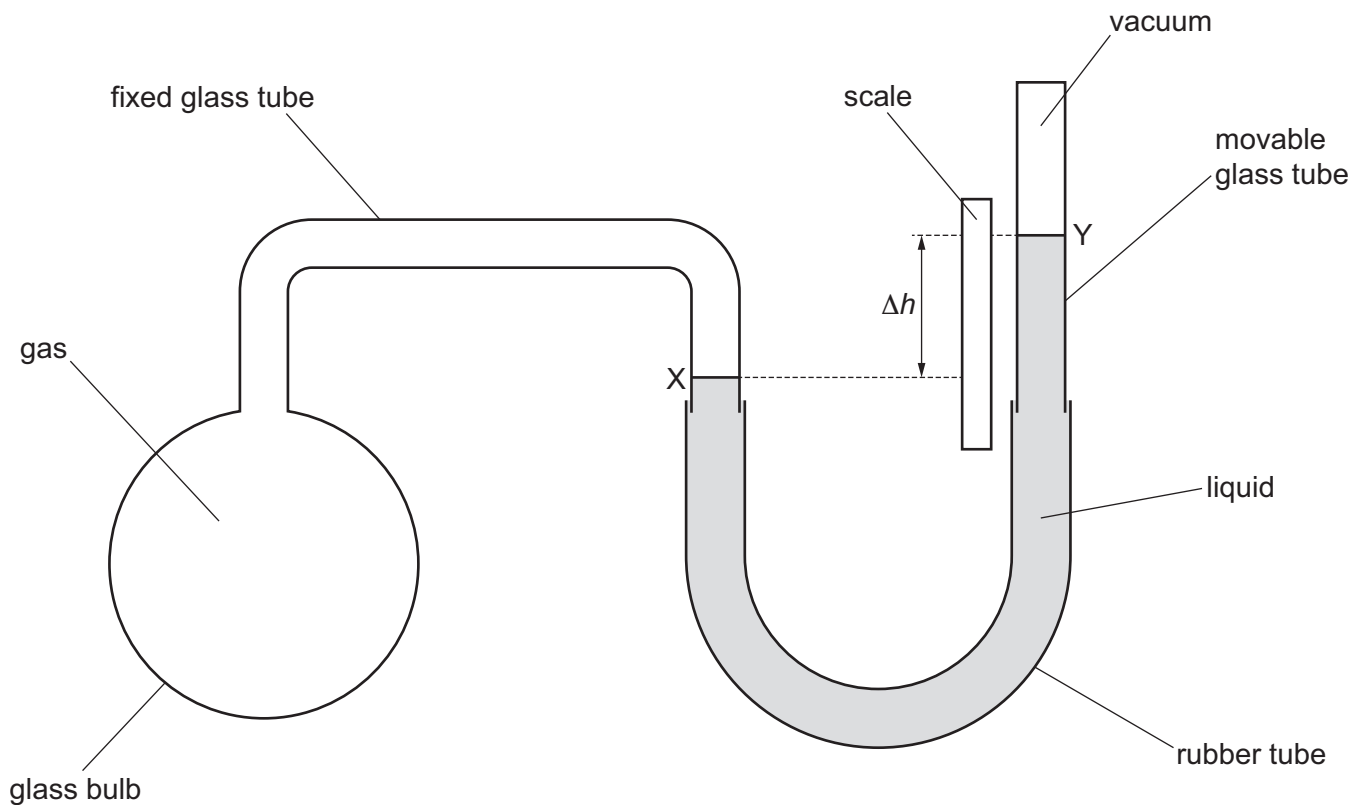


Fig. 3.1 (not to scale)

The thermometer is used to determine the thermodynamic temperature T of the gas in the glass bulb.

The glass bulb is immersed in the environment for which the temperature is to be measured. The height of the movable glass tube is then adjusted so that the level of the liquid on the left-hand side aligns with the reference line X marked on the fixed glass tube. The reference line Y is marked on the side of the movable glass tube. The level of the liquid at Y is higher than at X as a result of the pressure of the gas in the glass bulb.

The difference in height Δh between the liquid levels at X and Y is then measured using the scale. The thermodynamic temperature T of the gas is directly proportional to the pressure of the gas. This pressure is directly proportional to Δh .



- (i) The value of Δh can be used to calculate the pressure of the gas. In order to do this, the gravitational field strength is used, along with a property of the liquid.

State the property of the liquid that is used to calculate the pressure.

..... [1]

- (ii) Before the measurement of Δh can be made, the glass bulb needs to reach thermal equilibrium with the environment for which the temperature is to be measured.

State **two** disadvantages of using a constant volume gas thermometer to measure temperature.

1

.....

2

.....

[2]

- (iii) Suggest **one** situation in which a constant volume gas thermometer would be an appropriate type of thermometer to choose for measuring temperature.

.....

.....

..... [1]

- (iv) Level X aligns with 2.31 cm on the scale. At 0°C , level Y aligns with 8.69 cm.

At temperature θ , level Y aligns with 7.83 cm on the scale.

Determine a value for θ in $^\circ\text{C}$.

$\theta =$ $^\circ\text{C}$ [3]

[Total: 9]



- 4 A cylinder contains a fixed mass of an ideal gas at pressure $2Y$ and volume $6X$.

The gas undergoes a sequence of changes from its initial state A, through states B, C and D, then finally back to its initial state A, as shown in Fig. 4.1.

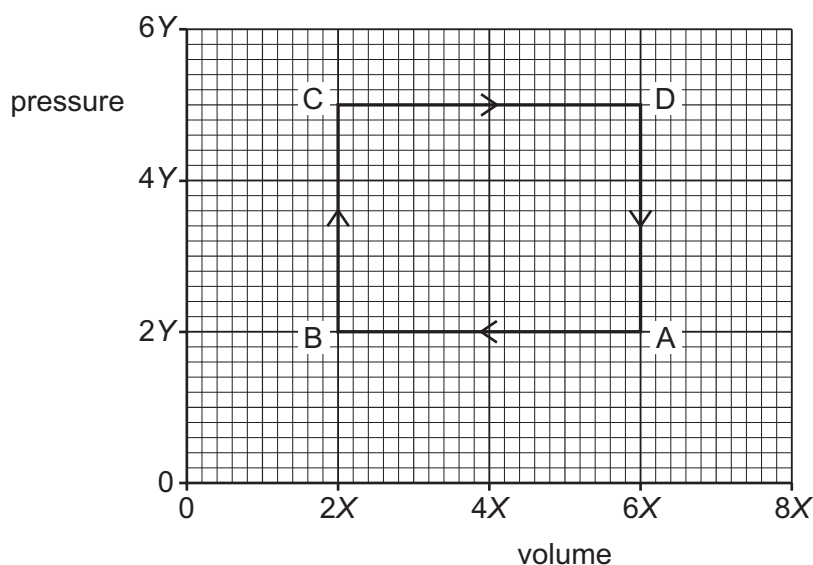


Fig. 4.1

Fig. 4.2 shows the variation with time of the internal energy of the gas.

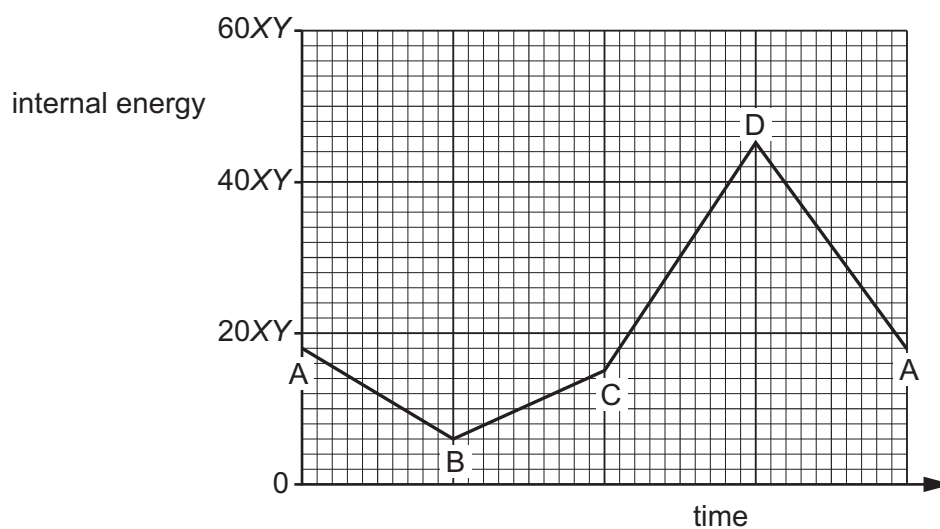


Fig. 4.2

- (a) State the first law of thermodynamics.

.....

.....

..... [2]



- (b) (i) Use Fig. 4.1 and Fig. 4.2 to determine the general expression for the internal energy U of the gas when it has pressure p and volume V .

$$U = \dots\dots\dots [1]$$

- (ii) An ideal gas at thermodynamic temperature T contains N molecules.

Use your answer in (b)(i) and the equation of state for an ideal gas to deduce an expression for U in terms of N and T . Identify any other symbols you use.

$$U = \dots\dots\dots [2]$$

- (c) Determine expressions, in terms of X and Y , for the work W done on the gas during:

- (i) change AB

$$W = \dots\dots\dots [1]$$

- (ii) change CD.

$$W = \dots\dots\dots [1]$$

- (d) Use your answers in (c) and the first law of thermodynamics to determine an expression, in terms of X and Y , for the net thermal energy Q supplied to the gas during one full cycle ABCDA. Explain your reasoning.

$$Q = \dots\dots\dots [3]$$

[Total: 10]



- 5 A steel ball on the end of a thin string oscillates with small oscillations, as shown in Fig. 5.1.

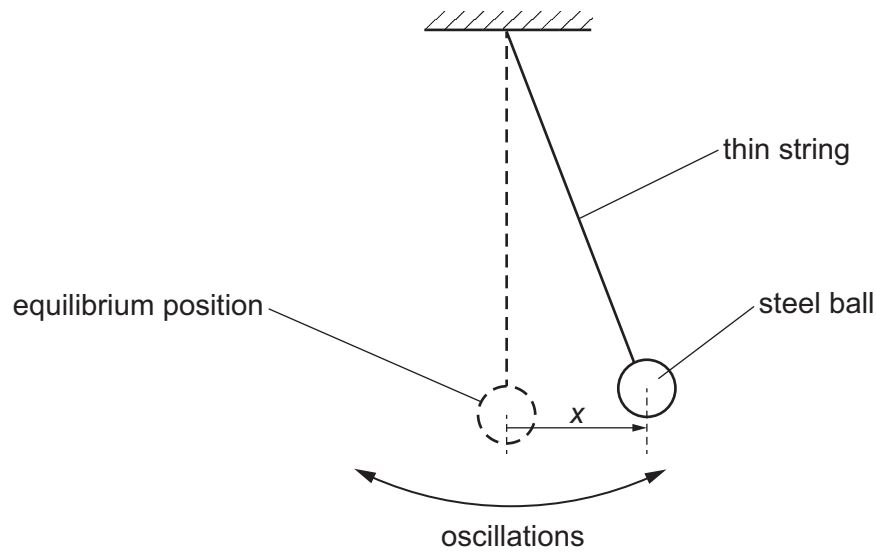


Fig. 5.1 (not to scale)

The displacement of the centre of the ball from its equilibrium position is x .

- (a) Fig. 5.2 shows the variation with x of the acceleration a of the ball.

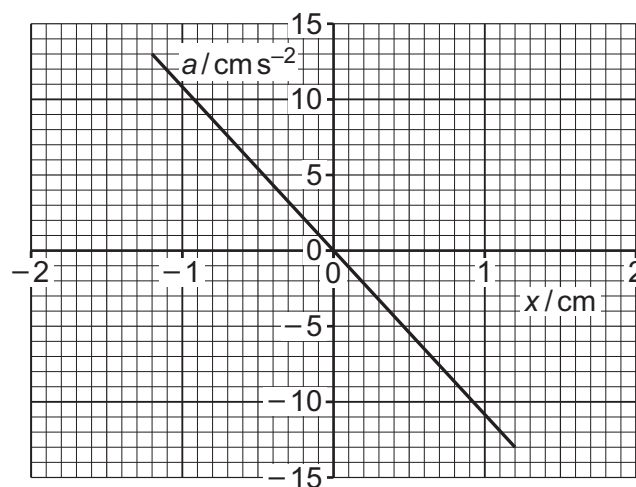


Fig. 5.2

- (i) Explain how Fig. 5.2 shows that the oscillations of the ball are simple harmonic.

.....

.....

..... [2]



- (ii) Determine the period T of the oscillations.

$T = \dots\dots\dots$ s [3]

- (b) At time $t = 0$, when the displacement of the ball has its maximum value, the ball is immersed in a trough containing thick oil so that the ball is just below the surface of the oil. This results in the subsequent motion of the ball being heavily damped.

- (i) State what is meant by damping.

.....

 [2]

- (ii) On Fig. 5.3, sketch a possible variation of the displacement x of the ball with t between $t = 0$ and $t = 2T$.

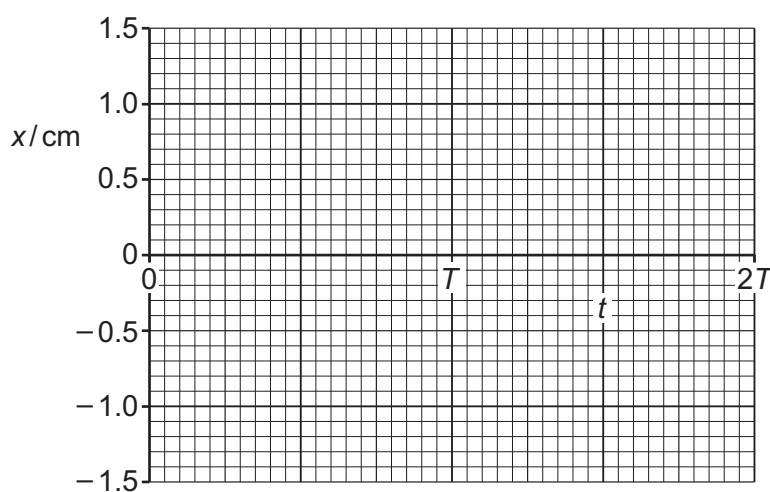


Fig. 5.3

[3]

[Total: 10]



- 6 (a) Define electric field at a point.

.....
 [1]

- (b) An isolated conducting sphere in a vacuum has a capacitance of 69 pF.
 The charge on the sphere is +83 pC.

- (i) On Fig. 6.1, draw field lines to represent the electric field outside the sphere due to the charge on the sphere.

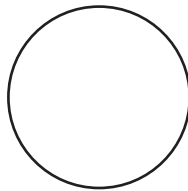


Fig. 6.1

[2]

- (ii) Calculate the electric potential at the surface of the sphere.

electric potential = ... V [2]

- (iii) Determine the radius of the sphere.

radius = ... m [2]



- (iv) Calculate the electric field strength E at the surface of the sphere. Give a unit with your answer.

$E =$ unit [2]

- (c) The sphere in (b) is discharged by connecting it to earth (0 V) through a resistor of resistance $120 \text{ M}\Omega$.

Calculate the time taken for the charge to fall to 26 pC .

time = ... s [2]

[Total: 11]



- 7 An alternating voltage V varies with time t according to

$$V = 18 \cos 40\pi t$$

where V is in V and t is in s.

- (a) For the alternating voltage:

- (i) show that the period is 0.050 s

[1]

- (ii) determine the root-mean-square (r.m.s.) voltage.

r.m.s. voltage = ... V [1]

- (b) On Fig. 7.1, sketch the variation of V with t for values of t from $t = 0$ to $t = 100$ ms.

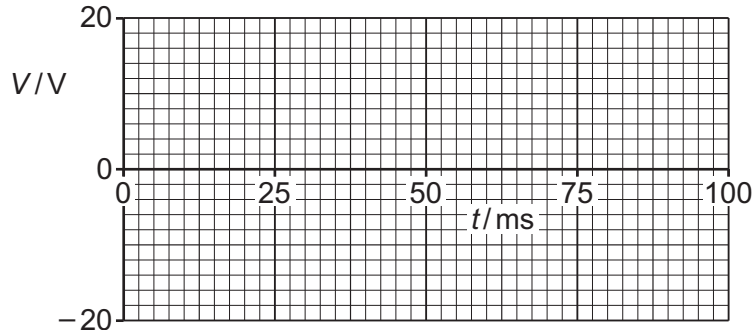


Fig. 7.1

[3]

- (c) The alternating voltage is rectified to produce an output voltage across a load resistor R , as shown in Fig. 7.2.

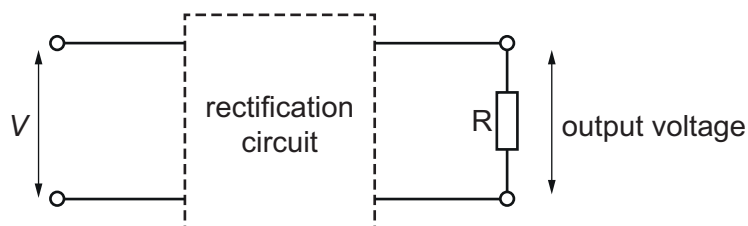


Fig. 7.2



Fig. 7.3 shows the variation with t of the power P in the load resistor.

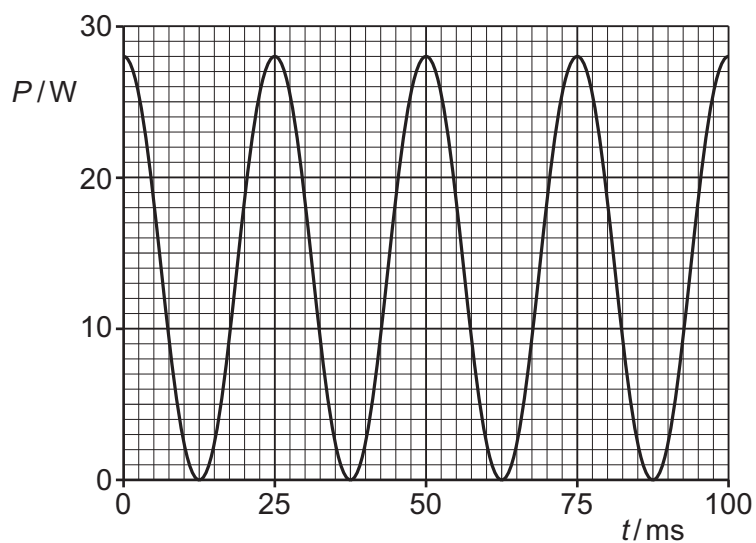


Fig. 7.3

State **three** conclusions that can be drawn from Fig. 7.3. The conclusions may be qualitative or quantitative. Use the space for any working.

1

.....

2

.....

3

.....

[3]

[Total: 8]



- 8 Fig. 8.1 shows the three lowest-frequency lines in the part of the emission spectrum for hydrogen that relates to electron transitions to the ground state (level $n = 1$).

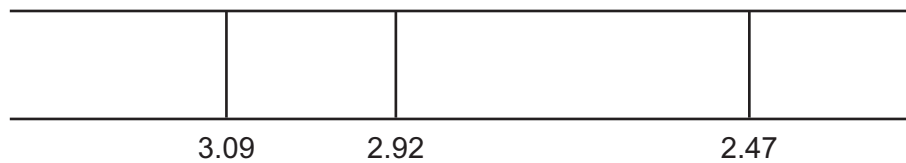


Fig. 8.1 (not to scale)

The numbers represent the frequencies, in 10^{15} Hz, associated with the spectral lines.

- (a) Use the photon model of electromagnetic radiation to explain how the existence of spectral lines in the emission spectrum provides evidence for discrete electron energy levels in the hydrogen atom.

.....

 [3]

- (b) The energy of the ground state (level $n = 1$) in a hydrogen atom is -13.6 eV.

- (i) Calculate the energy, in J, of the ground state.

energy = ... J [1]

- (ii) Show that the energy difference between levels $n = 1$ and $n = 2$ is 10.2 eV.

[2]



- (iii) Complete Table 8.1 to show the energy differences from the ground state, and the energies of the levels up to $n = 4$, in the hydrogen atom. Use the space for any working.

Table 8.1

level	(energy difference from $n = 1$)/eV	energy/eV
$n = 4$		
$n = 3$		
$n = 2$	10.2	
$n = 1$	0.0	-13.6

[4]

[Total: 10]



- 9 (a) State what is meant by the mass defect of a nucleus.

.....

.....

..... [2]

- (b) The nuclear fusion reaction for the formation of helium-4 from deuterium is represented by

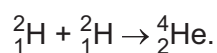


Table 9.1 shows the masses of the nuclides involved in this reaction.

Table 9.1

nuclide	nuclide mass/u
${}^2_1\text{H}$	2.013553
${}^4_2\text{He}$	4.001505

Calculate the energy released in the formation of 1.00 mol of helium-4.

energy = ... J [4]



- (c) The star Sirius has a radius of $1.19 \times 10^9 \text{ m}$ and loses mass due to nuclear fusion at a rate of $1.09 \times 10^{11} \text{ kg s}^{-1}$. Assume that the power of the radiation emitted by the star is equal to the power released by this process.

(i) Determine a value for the luminosity of Sirius. Give a unit with your answer.

luminosity = ... unit [2]

(ii) Use your answer in (c)(i) to determine the surface temperature of Sirius.

surface temperature = ... K [2]

- (d) Explain how cosmologists use standard candles to estimate the distance of a galaxy from the Earth.

.....

 [3]

[Total: 13]



- 10 (a) State what is meant by contrast in an X-ray image.

.....
 [1]

- (b) X-rays of intensity I_0 are incident normally on a structure, as shown in Fig. 10.1.

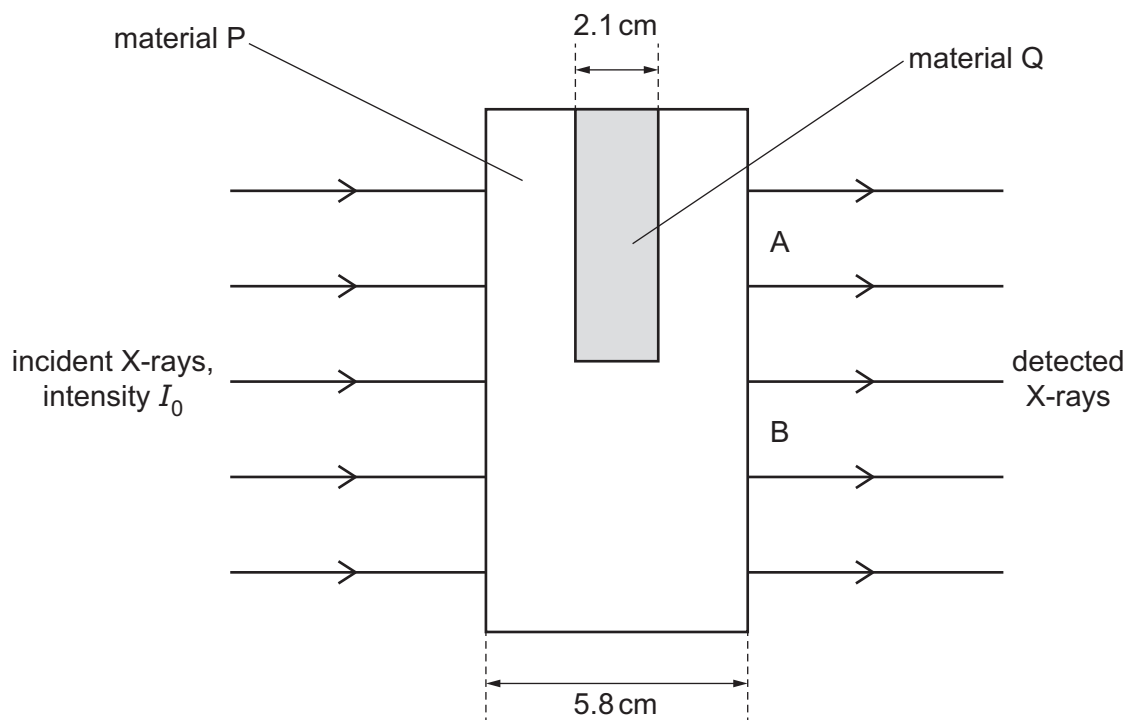


Fig. 10.1

Material P has a linear attenuation coefficient of 0.35 cm^{-1} .

The X-rays emerging from the structure in region A have an intensity of $0.053I_0$.

- (i) Show that the intensity of the X-rays emerging in region B is $0.13I_0$.

[1]





(ii) Determine the linear attenuation coefficient μ of material Q.

$\mu = \dots\dots\dots \text{cm}^{-1}$ [3]

(iii) Use the information in (b)(i) to suggest why the X-rays emerging from the structure form an image that has poor contrast.

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

(c) Explain how X-rays are used in computed tomography (CT) scanning to produce a three-dimensional image of an internal structure.

.....
.....
.....
.....
..... [3]

[Total: 9]





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PHYSICS

9702/43

Paper 4 A Level Structured Questions

October/November 2025

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [].

This document has **24** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





3

gravitational potential

$$\phi = -\frac{GM}{r}$$

gravitational potential energy

$$E_P = -\frac{GMm}{r}$$

pressure of an ideal gas

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

simple harmonic motion

$$a = -\omega^2 x$$

velocity of particle in s.h.m.

$$v = v_0 \cos \omega t$$

$$v = \pm \omega \sqrt{(x_0^2 - x^2)}$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

electrical potential energy

$$E_P = \frac{Qq}{4\pi\epsilon_0 r}$$

capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel

$$C = C_1 + C_2 + \dots$$

discharge of a capacitor

$$x = x_0 e^{-\frac{t}{RC}}$$

Hall voltage

$$V_H = \frac{BI}{ntq}$$

alternating current/voltage

$$x = x_0 \sin \omega t$$

radioactive decay

$$x = x_0 e^{-\lambda t}$$

decay constant

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

intensity reflection coefficient

$$\frac{I_R}{I_0} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$$

Stefan-Boltzmann law

$$L = 4\pi\sigma r^2 T^4$$

Doppler redshift

$$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$



- 1 (a) In terms of velocity and acceleration, describe uniform circular motion of an object.

.....

.....

..... [2]

- (b) Fig. 1.1 shows the view from above of a polystyrene ball undergoing horizontal circular motion of radius R .

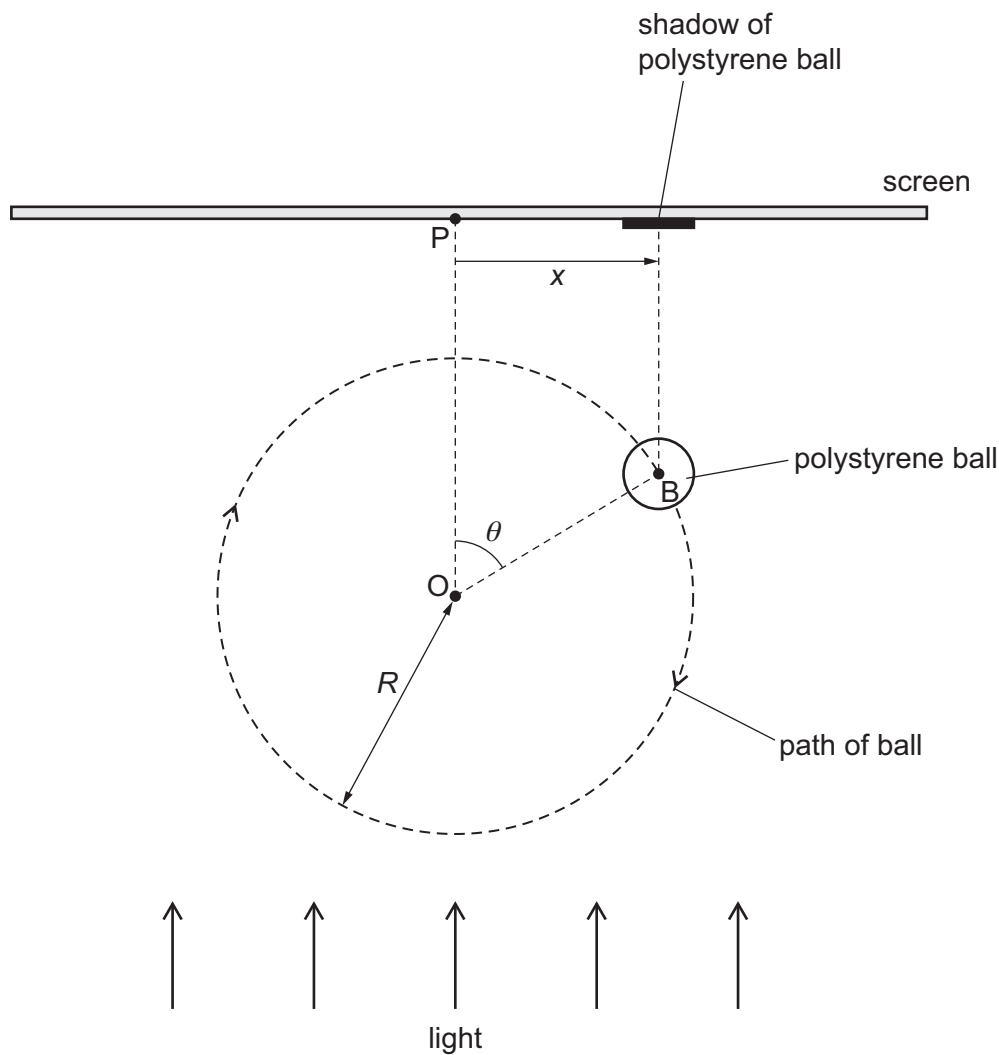


Fig. 1.1

The ball is illuminated by parallel light so that a shadow of the ball forms on a screen placed on the opposite side of the ball from the light source.

The line joining points O and P is perpendicular to the screen.

The angular speed of the circular motion is ω .



- (i) State an expression, in terms of R and ω , for the speed v of the ball.

$$v = \dots\dots\dots [1]$$

- (ii) Determine an expression, in terms of v and ω , for the centripetal acceleration of the ball.

$$\text{centripetal acceleration} = \dots\dots\dots [2]$$

- (c) The ball in (b) is in the position shown in Fig. 1.1, such that line OB is at an angle θ to the line OP.

- (i) Determine an expression, in terms of R and θ , for the displacement x of the shadow from P.

$$x = \dots\dots\dots [1]$$

- (ii) The value of θ is zero at time $t = 0$.

State an expression for θ in terms of ω and t .

$$\theta = \dots\dots\dots [1]$$

- (iii) Use your answers in (c)(i) and (c)(ii) to show that x is given by

$$x = R \sin \omega t.$$

[1]

- (iv) Explain, with reference to the equation in (c)(iii), why the motion of the shadow of the ball on the screen may be modelled as simple harmonic.

.....
 [1]



- (d) The circular motion of the ball in Fig. 1.1 has a diameter of 0.46 m and an angular speed of 1.9 rad s^{-1} .

For the simple harmonic motion of the shadow of the ball in Fig. 1.1, calculate:

- (i) the amplitude

amplitude = ... m [1]

- (ii) the period

period = ... s [2]

- (iii) the maximum acceleration.

maximum acceleration = ... m s^{-2} [2]

- (e) On Fig. 1.1, draw, and label with the letter A, the position of the shadow on the screen when the shadow has its maximum positive acceleration. [1]

[Total: 15]



- 2 (a) State **two** ways in which the first law of thermodynamics describes that the internal energy of a system may be changed.

1

.....

2

.....

[2]

- (b) (i) Use the first law of thermodynamics to explain why a bicycle pump gets hot when it is used to pump up a tyre quickly.

.....

.....

.....

.....

..... [3]

- (ii) With reference to molecular energies, explain why the temperature of water remains at 100 °C when it vaporises in a kettle, even though it is being heated.

.....

.....

.....

.....

..... [3]

[Total: 8]



- 3 (a) Define gravitational field at a point.

.....

..... [1]

- (b) Fig. 3.1 shows an isolated point mass of mass M .

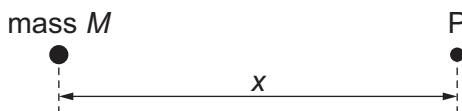


Fig. 3.1

Point P is at distance x from the point mass.

- (i) By considering the force exerted by the point mass on a test mass of mass m placed at P, derive an equation for the gravitational field strength g at P, in terms of M and x . Identify any other symbols you use.

[2]

- (ii) On Fig. 3.1, draw an arrow to indicate the direction of the gravitational field at P. [1]

- (iii) Point Q is at distance $\frac{x}{2}$ from the point mass, on the opposite side of the mass from P, as shown in Fig. 3.2.



Fig. 3.2

Compare the gravitational field at Q with that at P.

.....

.....

..... [2]



- (c) Two identical isolated uniform spheres X and Y each have radius R . The centres of the spheres are separated by distance L , as shown in Fig. 3.3.

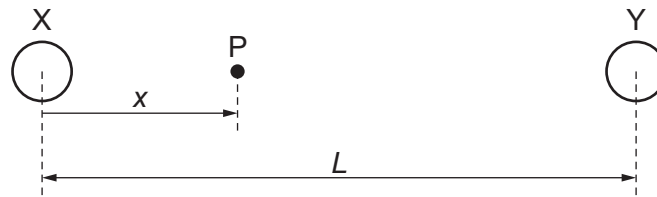


Fig. 3.3

Point P lies on the line joining the centres of X and Y, and is at a variable displacement x from the centre of sphere X.

The gravitational field strength at the surface of each sphere is g_0 .

On Fig. 3.4, sketch the variation with x of the gravitational field g at point P between $x = R$ and $x = L - R$.

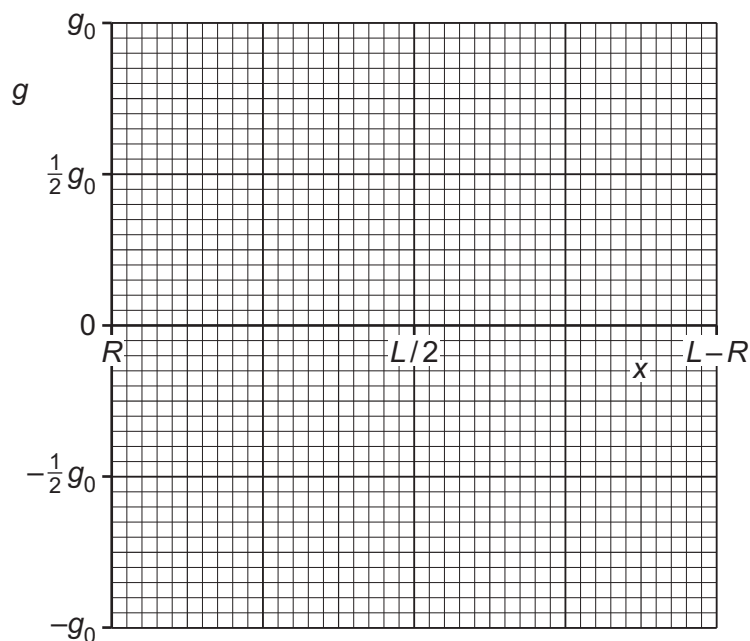


Fig. 3.4

[3]

[Total: 9]



4 (a) State the value of absolute zero on:

(i) the Celsius temperature scale

temperature = ... °C [1]

(ii) the thermodynamic temperature scale. Give a unit with your answer.

temperature = ... unit [1]

(b) A sample contains a fixed amount of gas. The gas has pressure p , volume V and thermodynamic temperature T .

Fig. 4.1 shows the variation of pV with kT for the sample, where k is the Boltzmann constant.

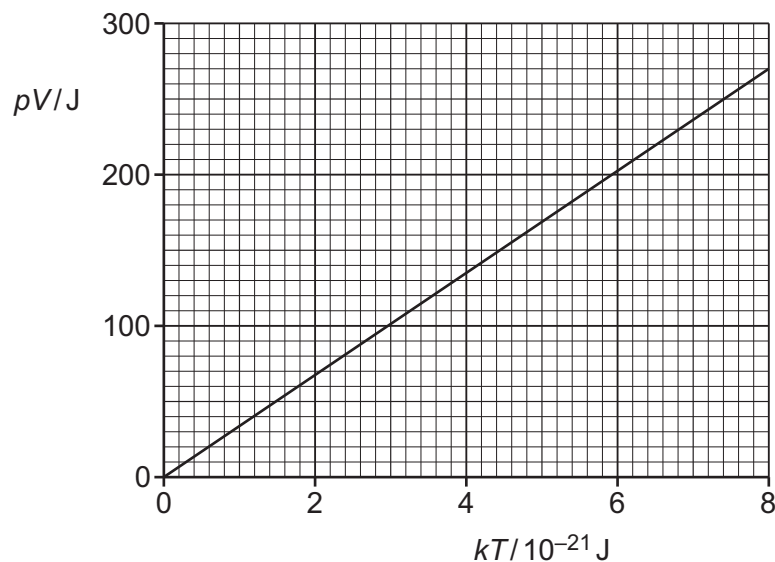


Fig. 4.1

(i) State what is indicated about the nature of the gas from the variation shown in Fig. 4.1.

..... [1]

(ii) Determine the number N of molecules of the gas in the sample.

$N =$ [2]



(iii) Use your answer in (b)(ii) to determine the amount n of gas in the sample.

$$n = \dots\dots\dots \text{mol} \quad [1]$$

- (c) The root-mean-square (r.m.s.) speed of the molecules of the gas is 1900 ms^{-1} when pV is equal to 270 J .

Determine the mass, in u , of one molecule of the gas, where u is the unified atomic mass unit.

$$\text{mass} = \dots\dots\dots u \quad [4]$$

[Total: 10]



- 5 (a) Define electric potential at a point.

.....

.....

..... [2]

- (b) A hydrogen atom may be considered to consist of a proton and an electron separated by a distance of 120 pm, as shown in Fig. 5.1.

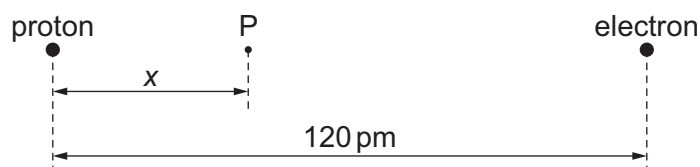


Fig. 5.1

The two particles may be considered as point charges.

Point P lies on the line joining the electron and the proton and is at a variable distance x from the proton.

- (i) Show that the electric potential V at point P when $x = 10$ pm is equal to 130 V.

[2]

- (ii) Calculate, to two significant figures, V when $x = 30$ pm.

$V = \dots\dots\dots V$ [2]

- (iii) On Fig. 5.1, draw a cross (x) at one position, other than infinity, where the electric potential is zero. [1]



(iv) On Fig. 5.2, sketch the variation of V with x between $x = 10\text{ pm}$ and $x = 110\text{ pm}$.

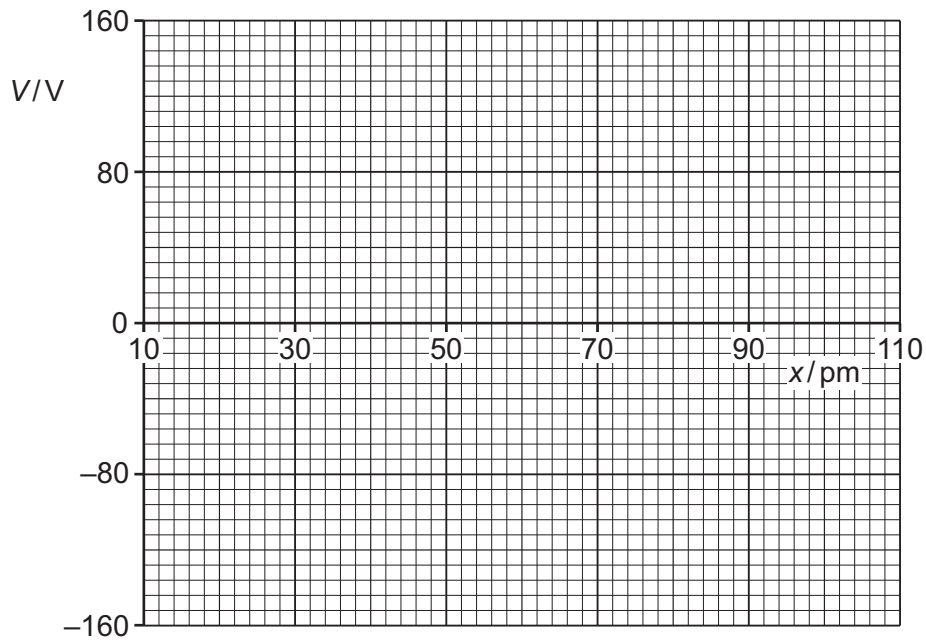


Fig. 5.2

[3]

[Total: 10]



- 6 (a) Two parallel plate capacitors C_1 and C_2 are connected to a supply that has a potential difference (p.d.) V_S . The capacitors may be connected in series or in parallel.

The supply provides charge Q_S and the plates of the two capacitors acquire charges Q_1 and Q_2 respectively. The p.d.s across the plates of the capacitors are V_1 and V_2 respectively.

Complete Table 6.1 to indicate how Q_S , Q_1 and Q_2 relate to each other, and how V_S , V_1 and V_2 relate to each other, for series and parallel connections of the capacitors to the supply.

Table 6.1

	relationship between charges	relationship between p.d.s
series		
parallel		

[4]

- (b) An isolated capacitor of capacitance $470\ \mu\text{F}$ stores 19 mJ of energy.

- (i) Calculate the p.d. across the capacitor.

p.d. = ...V [2]

- (ii) Calculate the charge on the capacitor.

charge = ... C [2]





- (iii) The capacitor is now connected in parallel with a capacitor of capacitance $180\mu\text{F}$ that is initially uncharged.

Determine the total energy, in mJ, now stored in the two capacitors.

energy = ... mJ [3]

[Total: 11]



- 7 (a) State Faraday's law of electromagnetic induction.

.....

.....

..... [2]

- (b) An aircraft is flying horizontally at constant speed v through the Earth's magnetic field, as shown in Fig. 7.1.

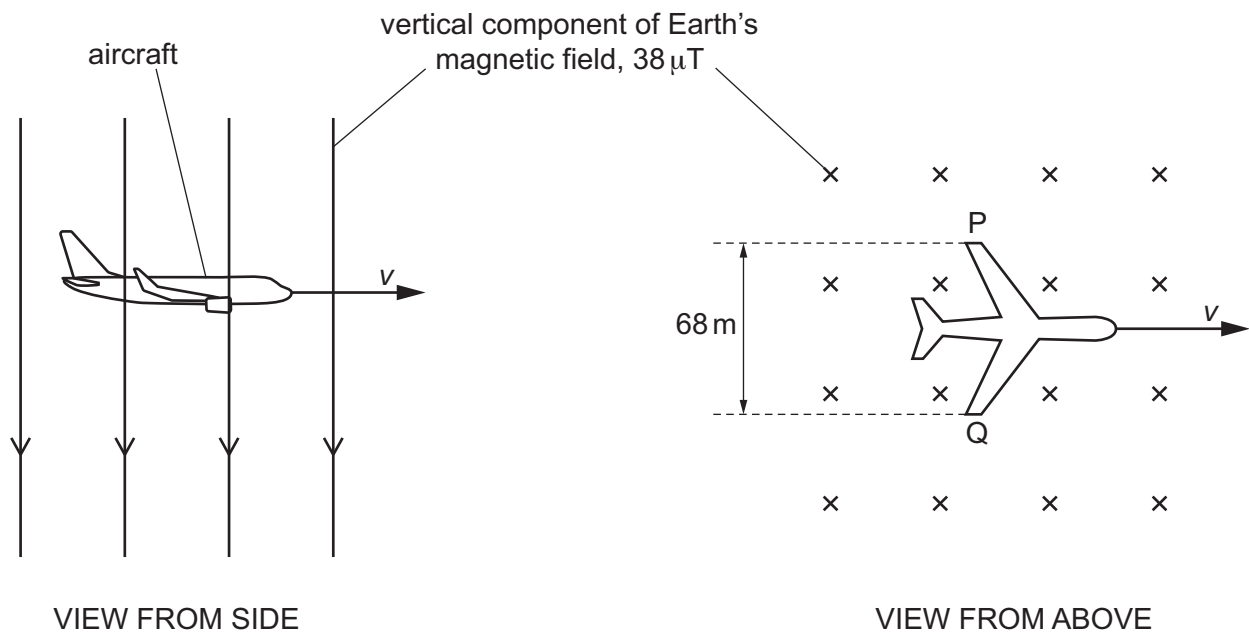


Fig. 7.1

At the location of the aircraft, the vertical component of the Earth's magnetic field is $38\mu\text{T}$ towards the ground.

The distance between the wingtips P and Q of the aircraft is 68 m.

As the aircraft moves through the magnetic field, an electromotive force (e.m.f.) of 0.54 V is induced between the wingtips P and Q.

- (i) Calculate the magnetic flux cut by the wings of the aircraft in a time of 15 s. Give a unit with your answer.

magnetic flux = ... unit [2]





(ii) Determine the area of flux cut by the wings in a time of 15 s.

area = ...m² [2]

(iii) Use your answer in (b)(ii) to determine the speed v of the aircraft.

v = ...ms⁻¹ [2]

(iv) Use Lenz's law of electromagnetic induction to explain which of the wingtips P and Q is at the higher induced potential.

.....
.....
.....
.....
..... [3]

[Total: 11]



- 8 (a) State what is meant by a photon.

.....

.....

..... [2]

- (b) A stationary nucleus of uranium-238 ($^{238}_{92}\text{U}$) undergoes alpha decay to produce a nucleus of thorium-234 ($^{234}_{90}\text{Th}$). The kinetic energy of the emitted alpha particle is 4.200 MeV. A gamma-ray photon is also emitted during the decay.

Assume that the rebound kinetic energy of the thorium nucleus is negligible.

Table 8.1 shows the masses of the nuclides involved in the decay reaction. The mass of the uranium-238 nuclide is missing.

Table 8.1

nuclide	nuclide mass/u
$^4_2\alpha$	4.000 407
$^{234}_{90}\text{Th}$	233.915 174
$^{238}_{92}\text{U}$	

The total energy released in the decay of the nucleus of uranium-238 is 4.274 MeV.

- (i) Calculate the mass, in u, of the uranium-238 nuclide. Give your answer to five decimal places.

mass = ... u [3]



- (ii) Determine a value for the wavelength of the gamma radiation emitted during the decay of the uranium-238 nucleus.

wavelength = ... m [3]

- (iii) In practice, the rebound kinetic energy of the thorium nucleus is **not** negligible.

Explain, without further calculation, how your answer in **(b)(ii)** compares with the true wavelength of gamma radiation emitted during the decay of the uranium-238 nucleus.

.....

 [1]

- (c) Gamma radiation emitted during the decay of a sample of uranium-238 has a single wavelength.

Nuclei of cobalt-60 ($^{60}_{27}\text{Co}$) decay by beta emission, and also emit gamma radiation in the process.

Suggest why there is **not** a single wavelength for the gamma radiation emitted during the decay of a sample of cobalt-60.

.....

 [2]

[Total: 11]



9 (a) State Wien's displacement law.

.....

.....

..... [2]

(b) Fig. 9.1 shows the variation with d^{-2} of the radiant flux intensity F observed from a star X, where d is the distance of the observer from the star. Fig. 9.2 shows the variation with wavelength λ of the rates of emission P of radiation by star X and the Sun.

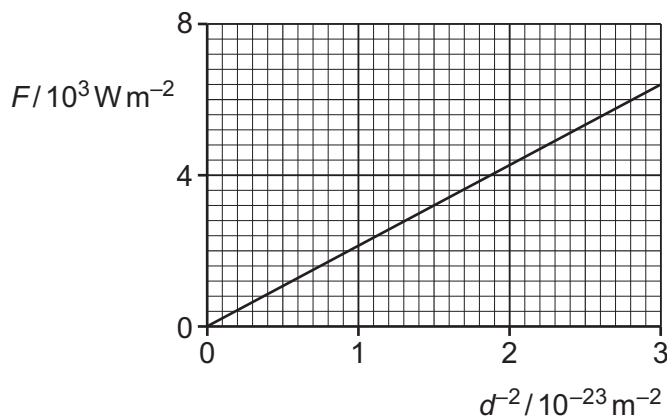


Fig. 9.1

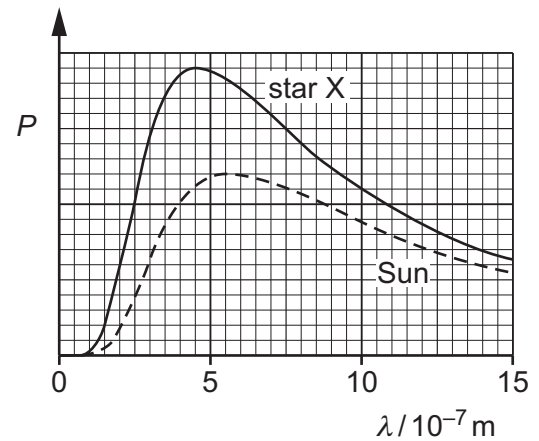


Fig. 9.2

The surface temperature of the Sun is 5770 K.

State **three** conclusions about star X that can be drawn from this data. The conclusions may be qualitative or quantitative. Use the space for any working.

1

.....

2

.....

3

.....



(c) Star X is in a galaxy that is moving away from the Earth.

Suggest, with a reason, how the line for star X in Fig. 9.2 would appear differently if it had been obtained from data measured on the Earth.

.....

.....

..... [2]

[Total: 7]



10 (a) Define specific acoustic impedance.

.....

.....

..... [2]

(b) Explain how ultrasound waves are detected by a piezoelectric crystal.

.....

.....

..... [2]

(c) Table 10.1 shows the specific acoustic impedance Z for body tissue, water and steel.

Table 10.1

material	$Z/\text{kg m}^{-2} \text{ s}^{-1}$
body tissue	1.38×10^6
water	1.48×10^6
steel	4.04×10^7

(i) Calculate the intensity reflection coefficient for ultrasound incident on a water–steel boundary.

intensity reflection coefficient = ... [2]

(ii) Explain, without calculation, what is likely to happen when ultrasound is incident on a body tissue–water boundary.

.....

.....

..... [2]

[Total: 8]







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PHYSICS

9702/44

Paper 4 A Level Structured Questions

October/November 2025

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [].

This document has **24** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





gravitational potential

$$\phi = -\frac{GM}{r}$$

gravitational potential energy

$$E_P = -\frac{GMm}{r}$$

pressure of an ideal gas

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

simple harmonic motion

$$a = -\omega^2 x$$

velocity of particle in s.h.m.

$$v = v_0 \cos \omega t$$

$$v = \pm \omega \sqrt{(x_0^2 - x^2)}$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

electrical potential energy

$$E_P = \frac{Qq}{4\pi\epsilon_0 r}$$

capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel

$$C = C_1 + C_2 + \dots$$

discharge of a capacitor

$$x = x_0 e^{-\frac{t}{RC}}$$

Hall voltage

$$V_H = \frac{BI}{ntq}$$

alternating current/voltage

$$x = x_0 \sin \omega t$$

radioactive decay

$$x = x_0 e^{-\lambda t}$$

decay constant

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

intensity reflection coefficient

$$\frac{I_R}{I_0} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$$

Stefan-Boltzmann law

$$L = 4\pi\sigma r^2 T^4$$

Doppler redshift

$$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$



- 1 (a) State Newton's law of gravitation.

.....

.....

..... [2]

- (b) A binary star consists of star A, of mass $4.0 \times 10^{30} \text{ kg}$, and star B, of mass $2.0 \times 10^{30} \text{ kg}$, separated by a distance of $3.3 \times 10^{12} \text{ m}$. The stars are both in circular orbit around their common centre of gravity X, as shown in Fig. 1.1.

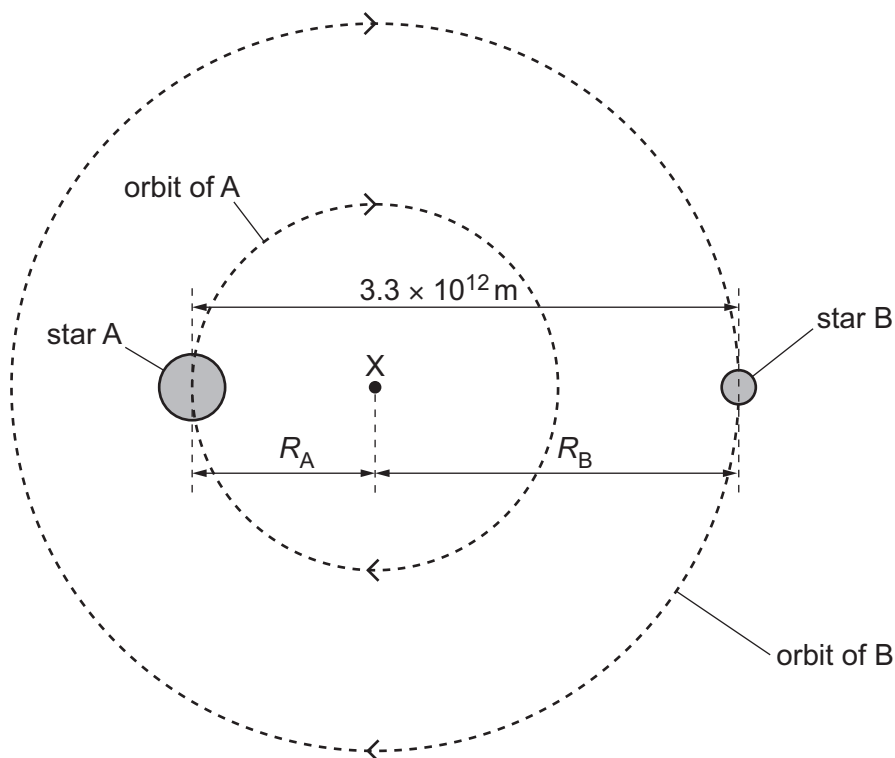


Fig. 1.1

The radius R_B of the orbit of star B is double the radius R_A of the orbit of star A.

- (i) Use Newton's law of gravitation to calculate the magnitude of the gravitational force exerted by each star on the other.

force = ... N [2]



(ii) Calculate the centripetal acceleration of star A.

acceleration = ... ms^{-2} [1]

(iii) Use your answer in (b)(ii) to determine the period of the orbit of star A.

period = ... s [3]

(iv) By placing a tick (✓) in each row, complete Table 1.1 to show how the quantities indicated for star B compare with the same quantities for star A.

Table 1.1

	B less than A	B equal to A	B greater than A
centripetal acceleration			
linear speed			
period			

[3]

[Total: 11]



- 2 (a) The equation of state for an ideal gas may be expressed as

$$pV = NkT.$$

- (i) State the meaning of each of the symbols in this equation.

p :

V :

N :

k :

T : [3]

- (ii) Using the equation of state, derive an expression for the average translational kinetic energy E_K of a particle in the gas in terms of some or all of N , k and T .

$$E_K = ... [2]$$



- (b) A molecule of hydrogen gas consists of two hydrogen atoms, each of nucleon number 1.
A molecule of oxygen gas consists of two oxygen atoms, each of nucleon number 16.

Assume that hydrogen and oxygen both behave as ideal gases.

A sample of hydrogen gas is at the same temperature as a sample of oxygen gas.

For the two samples, determine the ratio

$$\frac{\text{root-mean-square (r.m.s.) speed of hydrogen molecules}}{\text{root-mean-square (r.m.s.) speed of oxygen molecules}}.$$

ratio = ... [2]

[Total: 7]



- 3 (a) With reference to molecular kinetic energy and molecular potential energy, explain what is meant by the internal energy of an ideal gas.

.....

 [2]

- (b) A sample of an ideal gas is initially in state A, at a pressure of $2.0 \times 10^5 \text{ Pa}$ and with a volume of 0.016 m^3 , as shown in Fig. 3.1.

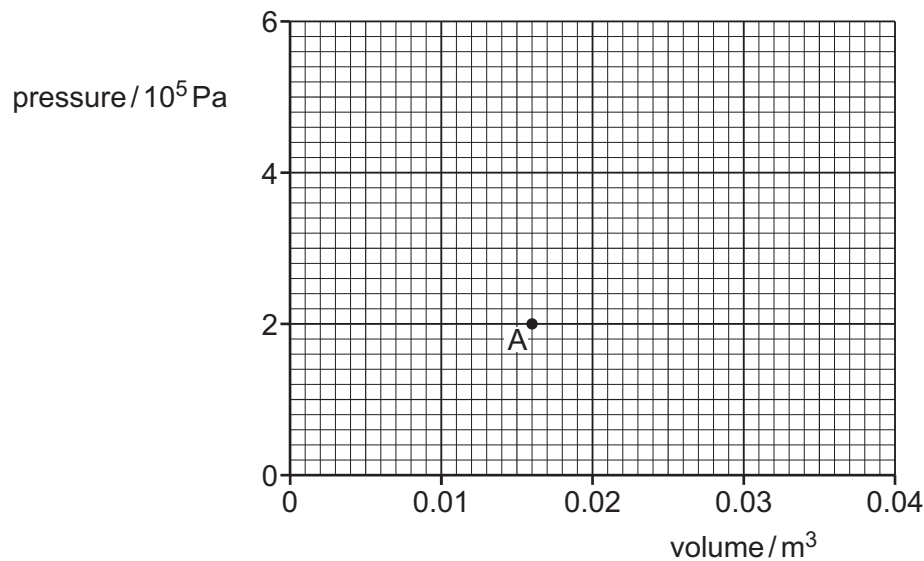


Fig. 3.1

In state A, the temperature of the gas is 400 K.

The gas undergoes two successive changes X and Y.

In change X, it is heated at constant volume to a pressure of $4.0 \times 10^5 \text{ Pa}$. At the end of change X, the gas is in state B.

In change Y, it is then allowed to expand at constant temperature back to its original pressure. At the end of change Y, the gas is in state C.



- (i) Determine the internal energy of the gas in state A.

internal energy = ... J [2]

- (ii) Determine the temperature of the gas in state B.

temperature = ... K [1]

- (iii) Determine the volume of the gas in state C.

volume = ... m³ [1]

- (iv) On Fig. 3.1, draw two lines, one to represent change X and one to represent change Y.
Label your lines X and Y respectively. [3]

[Total: 9]



- 4 (a) State what is meant by the frequency of the oscillations of an oscillating object.

.....
 [1]

- (b) An object is oscillating.

Fig. 4.1 shows the variation of the acceleration a of the object with its displacement x from the equilibrium position.

Fig. 4.2 shows the variation of the kinetic energy E_K of the object with time t .

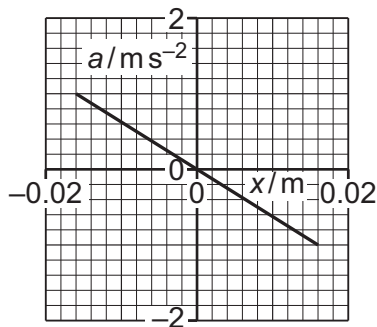


Fig. 4.1

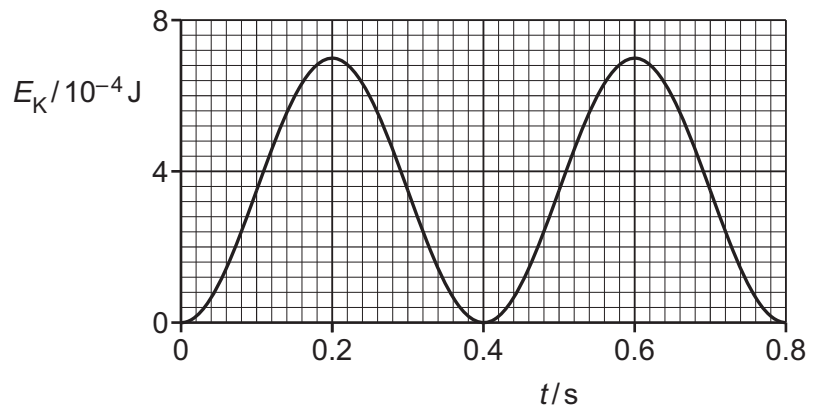


Fig. 4.2

- (i) Explain how Fig. 4.2 shows that the period of the oscillations is 0.80 s.

.....

 [1]

- (ii) Calculate the angular frequency ω of the oscillations.

$\omega = \dots\dots\dots \text{rad s}^{-1}$ [2]



- (iii) Apart from the period, frequency and angular frequency of the oscillations, determine **three** other conclusions about the object and its oscillations that may be drawn from Fig. 4.1 and Fig. 4.2. The conclusions may be qualitative or quantitative. Use the space below for any working.

1

.....

2

.....

3

.....

[3]

- (iv) Describe the interchange between kinetic energy and potential energy during the oscillations. Numerical values are **not** required.

.....

.....

.....

.....

..... [3]

[Total: 10]



- 5 (a) Explain why the electric potential near an isolated proton is positive.

.....

.....

.....

.....

..... [3]

- (b) An isolated metal sphere is positively charged and has radius R , as shown in Fig. 5.1.

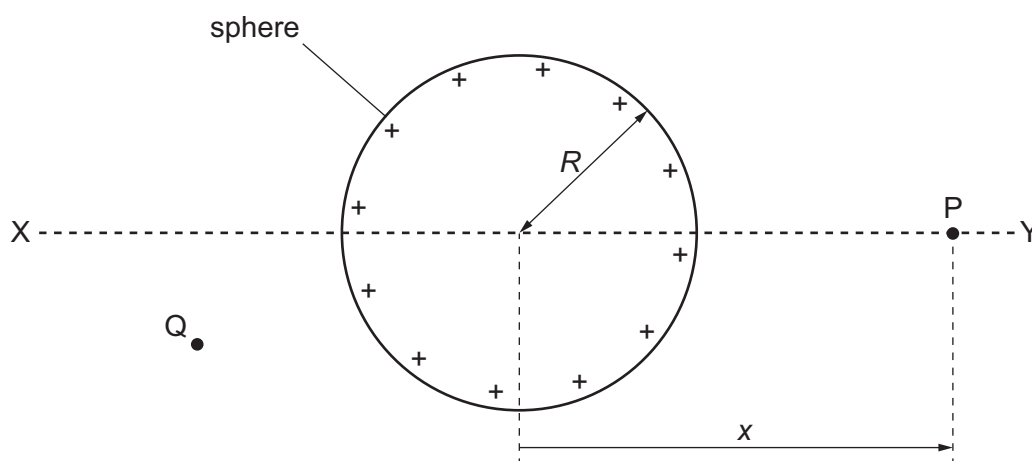


Fig. 5.1

Line XY passes through the centre of the sphere.

Point P lies on line XY at a variable displacement x from the centre of the sphere.

Point Q is at a fixed position that is not on line XY.

The electric field strength at the surface of the sphere is E_0 .

- (i) On Fig. 5.1, draw an arrow at point Q to show the direction of the electric field at that point. [1]



- (ii) On Fig. 5.2, sketch the variation of the electric field E at point P with x for values of x between $x = -3R$ and $x = 3R$. Do **not** include the region inside the sphere between $x = -R$ and $x = R$.

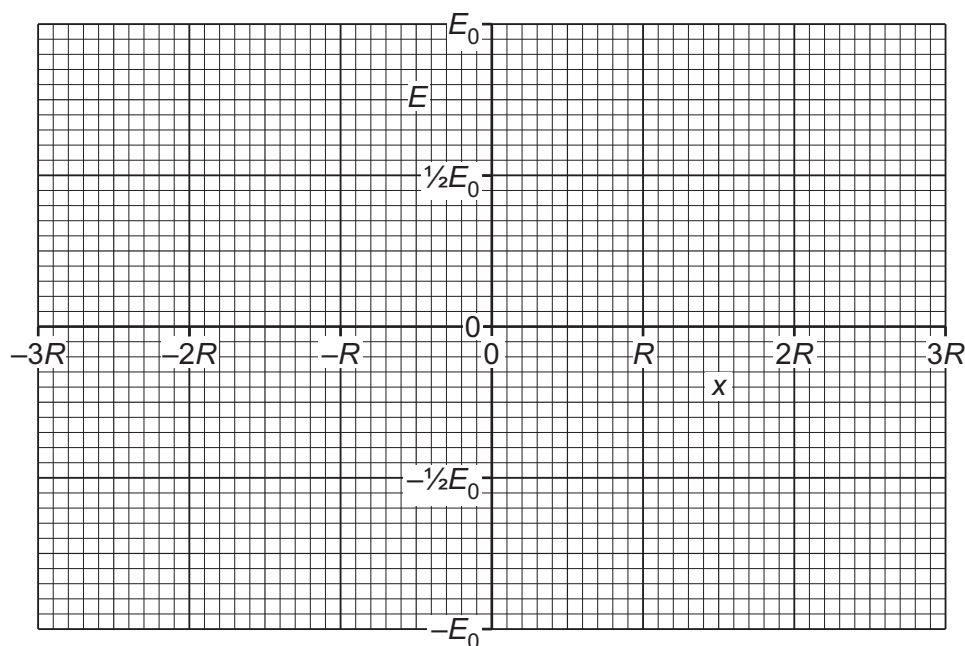


Fig. 5.2

[3]

- (c) The proton and the electron in a hydrogen atom are separated by a distance of 5.3×10^{-11} m.

Calculate the electric potential energy of the proton and the electron.

electric potential energy = ... J [2]

[Total: 9]





- 6 Fig. 6.1 shows part of a bridge rectifier circuit that can be used for rectification of an alternating input voltage V_{IN} .

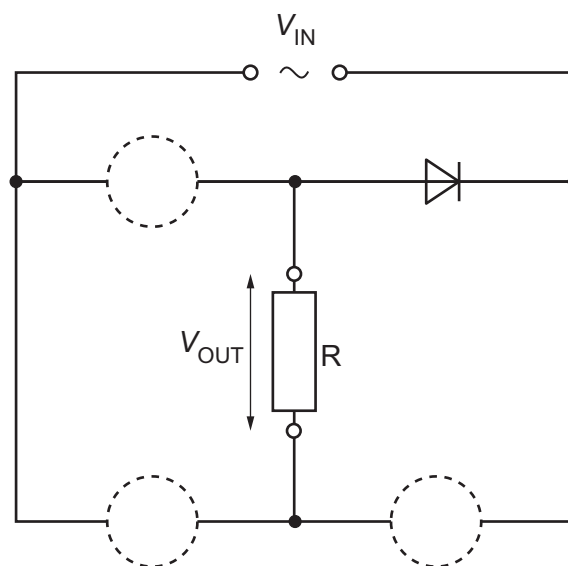


Fig. 6.1

The circuit contains four diodes, one of which is shown.
The rectified output voltage V_{OUT} is applied across load resistor R .

- (a) (i) State what is meant by rectification.

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

- (ii) State the name of the type of rectification produced by a bridge rectifier circuit.

..... [1]

- (iii) Complete the circuit in Fig. 6.1 by drawing the three missing diodes inside the dashed circles. [2]



- (b) The input voltage varies with time t according to the equation

$$V_{\text{IN}} = 34 \sin 18t$$

where V_{IN} is in V and t is in s.

- (i) Show that the period of the input voltage is 0.35 s.

[2]

- (ii) Calculate the root-mean-square (r.m.s.) input voltage.

r.m.s. voltage = ... V [1]

- (iii) On Fig. 6.2, sketch the variation of V_{OUT} with t from $t = 0$ to $t = 0.35$ s.

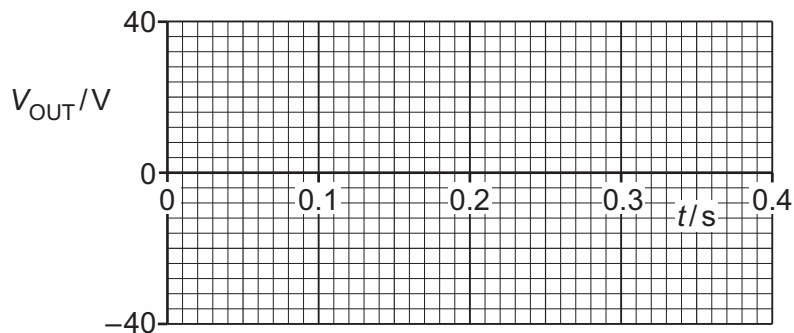


Fig. 6.2

[3]



(c) Resistor R has a resistance of $56\text{ k}\Omega$. A capacitor of capacitance $12\text{ }\mu\text{F}$ is connected into the circuit of Fig. 6.1 in order to smooth the output voltage.

(i) On Fig. 6.1, draw the capacitor correctly connected into the circuit. [1]

(ii) Calculate the time constant of the smoothing circuit.

time constant = ... s [2]

(iii) During each discharge cycle, the time for which the capacitor is discharging is 0.14 s .

Determine the minimum value of the smoothed output voltage.

minimum voltage = ... V [2]

[Total: 15]



- 7 (a) State Lenz's law of electromagnetic induction.

.....

.....

..... [2]

- (b) A helicopter hovering in stationary equilibrium has four rotors, each of length 12 m, as shown in the view from above in Fig. 7.1.

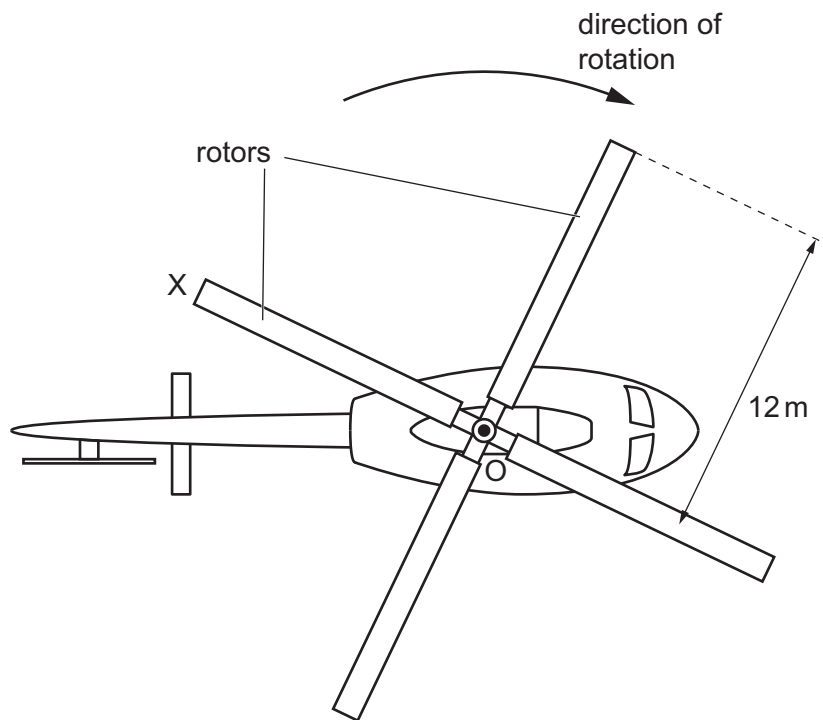


Fig. 7.1

The vertical component of the Earth's magnetic field at the helicopter is downwards with a flux density of 0.047 mT.

The rotors each rotate in a horizontal plane in the direction shown with a frequency of 85 Hz.

- (i) Calculate the magnetic flux Φ cut by rotor OX during one complete rotation. Give a unit with your answer.

$\Phi =$ unit [3]



- (ii) Determine the magnitude of the electromotive force (e.m.f.) induced across the length of rotor OX.

e.m.f. = ... V [2]

- (iii) Use Lenz's law to explain whether end O or end X of the rotor is at the higher potential.

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

[Total: 9]



- 8 Oxygen-15 ($^{15}_8\text{O}$) is radioactive and has a half-life of 2.04 minutes.

The decay of oxygen-15 produces positrons. For this reason, oxygen-15 is sometimes used as a tracer in positron emission tomography (PET scanning).

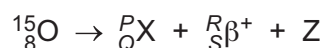
- (a) State what is meant by a tracer.

.....

.....

..... [2]

- (b) The equation for the decay of oxygen-15 is



where X is the nucleus formed during the decay and Z is another particle.

- (i) State the values of the integers P , Q , R and S .

$P =$ $R =$

$Q =$ $S =$ [2]

- (ii) State the name of particle Z.

..... [1]

- (c) (i) Define the activity of a sample.

.....

..... [1]

- (ii) Calculate the decay constant of oxygen-15. Give a unit with your answer.

decay constant = ... unit [2]



- (iii) Determine the rate at which positrons are produced in a sample of oxygen-15 that has a mass of 2.85×10^{-6} kg.

rate = ... s^{-1} [4]

- (d) The particles that are emitted from the body and detected outside it during PET scanning are not positrons but another type of particle.

- (i) State the name of the particles that are detected.

..... [1]

- (ii) Explain how these particles are formed inside the body.

.....

.....

.....

..... [2]

[Total: 15]



- 9 (a) State what is meant by the photoelectric effect.

.....

.....

..... [2]

- (b) The photoelectric effect is investigated using two clean metal plates. One plate is made from metal X and the other is made from metal Y.

Metal X has work function energy Φ . Metal Y has work function energy 2Φ .

Metal X has threshold frequency F .

State expressions, in terms of either or both of Φ and F , for

- (i) the threshold frequency of metal Y

threshold frequency = ... [1]

- (ii) the Planck constant.

Planck constant = ... [1]

- (c) The maximum kinetic energy E_K of photoelectrons is determined for each of the plates in (b) for different frequencies f of incident radiation.

On Fig. 9.1, sketch the variation of E_K with f for each plate. Label your lines X and Y to identify which line relates to which plate.

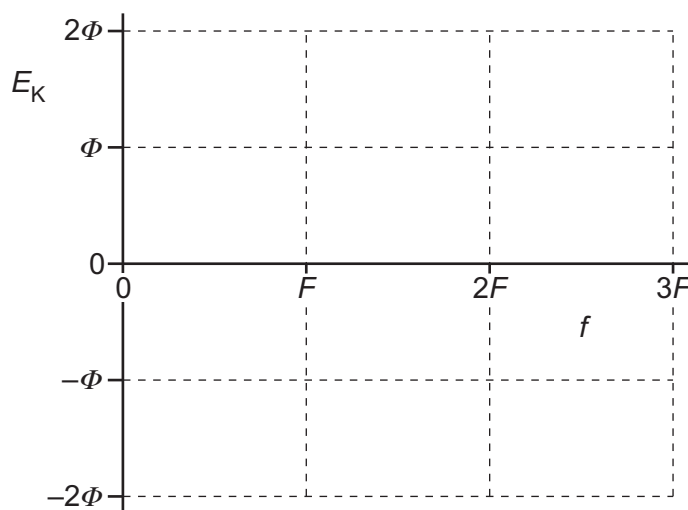


Fig. 9.1

[4]

[Total: 8]





10 (a) State what is meant by redshift.

.....

.....

..... [2]

(b) Explain how observations of redshift lead to the idea that the universe is expanding.

.....

.....

..... [2]

(c) Explain how Hubble's law leads to the Big Bang theory of the origin of the universe.

.....

.....

.....

.....

..... [3]

[Total: 7]





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