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PHYSICS

9702/41

Paper 4 A Level Structured Questions

May/June 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) Define gravitational potential at a point.

.....

.....

..... [2]

- (b) Mars is a planet that may be considered to be an isolated uniform sphere of radius 3.4×10^6 m.

A satellite of mass 122 kg is in orbit around Mars at a constant height of 1.7×10^6 m above the surface of the planet.

The height of the orbit is increased to 6.8×10^6 m above the surface. This increases the gravitational potential energy of the satellite by 5.1×10^8 J.

- (i) Show that the mass of Mars is 6.4×10^{23} kg.

[3]

- (ii) Calculate the gravitational potential ϕ at the surface of Mars. Give a unit with your answer.

$\phi =$ unit [2]



(c) The satellite in (b) is moved to an orbit in which the satellite remains at the same point above the surface of Mars.

(i) The orbit has a period of 25 hours.

State what can be deduced from this about the rotation of Mars on its axis.

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

(ii) State **one** other feature of this orbit.

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

[Total: 9]



- 2 A helium atom may be modelled as a nucleus surrounded by two electrons in diametrically opposite circular orbits, each of radius 170 pm, as shown in Fig. 2.1.

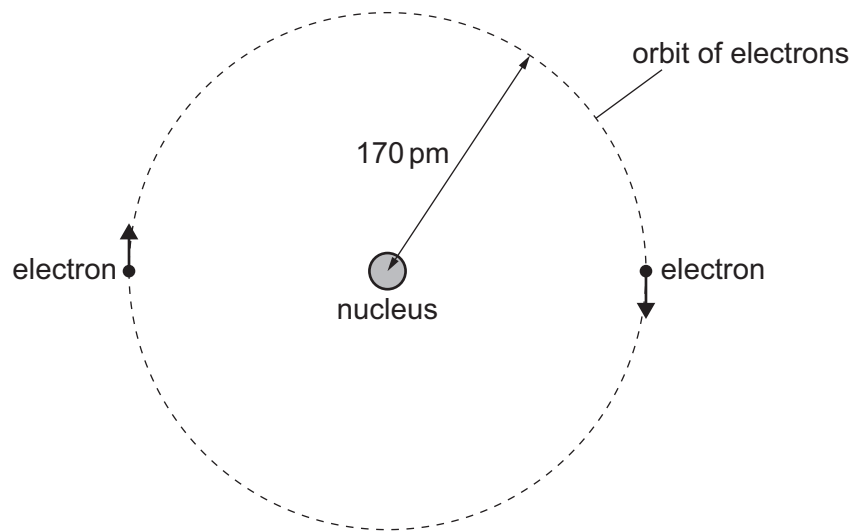


Fig. 2.1

- (a) State Coulomb's law.

.....

 [2]

- (b) (i) State the charge on the nucleus, in terms of the elementary charge e .

charge = ... e [1]

- (ii) Show that the electric force between the nucleus and one of the electrons is $1.6 \times 10^{-8} \text{ N}$.

[1]



(c) Assume that the force in (b)(ii) is the only force on the electrons.

(i) Calculate the speed of the orbiting electrons.

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

(ii) Calculate the period of the orbit of the electrons.

period = ... s [2]

(d) In practice, the orbit of each electron is affected by the presence of the other electron.

(i) For the position of one of the electrons, determine the ratio

$$\frac{\text{electric field strength due to the other electron}}{\text{electric field strength due to the nucleus}}.$$

ratio = ... [2]

(ii) Use your answer in (d)(i) to suggest and explain how the orbit of the electron is affected by the presence of the other electron.

.....
 [1]

[Total: 11]



- 3 (a) Define specific latent heat.

.....

 [2]

- (b) Explain why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

.....

 [3]

- (c) An ice cube of mass 37.0g at temperature 0.0°C is placed in a beaker containing water of mass 208g at temperature 26.4°C.

When all the ice has melted, and all the water in the beaker has reached thermal equilibrium, the final temperature of all the water is 10.3°C.

The specific heat capacity of water is $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$.

The beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

Determine a value, to three significant figures, for the specific latent heat of fusion of water.

specific latent heat of fusion = ... J g^{-1} [4]

[Total: 9]



4 (a) (i) State what is meant by the internal energy of a system.

.....

.....

..... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

.....

.....

.....

..... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U .

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W , T and U , the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]



- 5 A cuboidal block floats in a liquid with its base horizontal, as shown in Fig. 5.1.

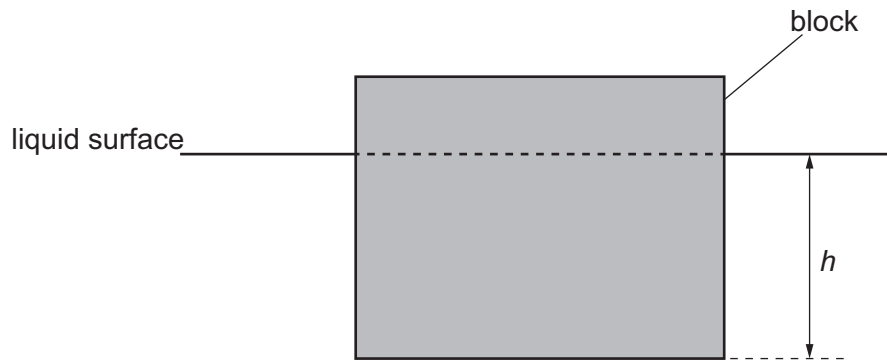


Fig. 5.1

The base of the block is at a depth h below the surface of the liquid.

The block is displaced downwards by a small distance and then released so that it oscillates.

Fig. 5.2 shows the variation with h of the acceleration a of the block.

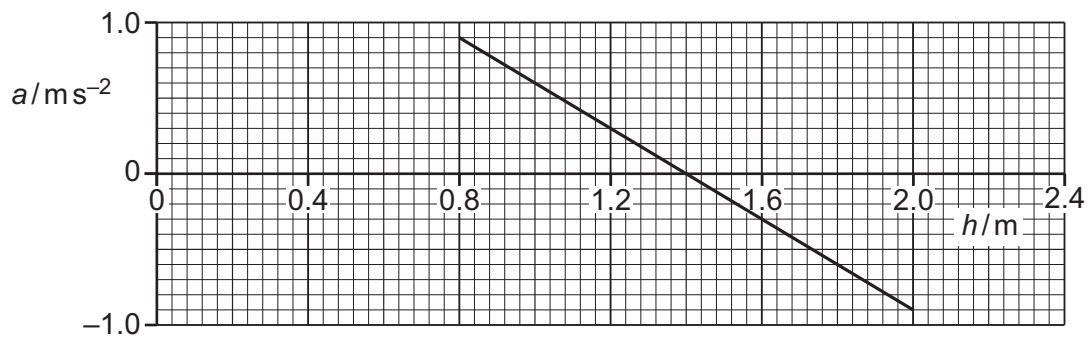


Fig. 5.2

Fig. 5.3 shows the variation with h of the kinetic energy E_K of the block.

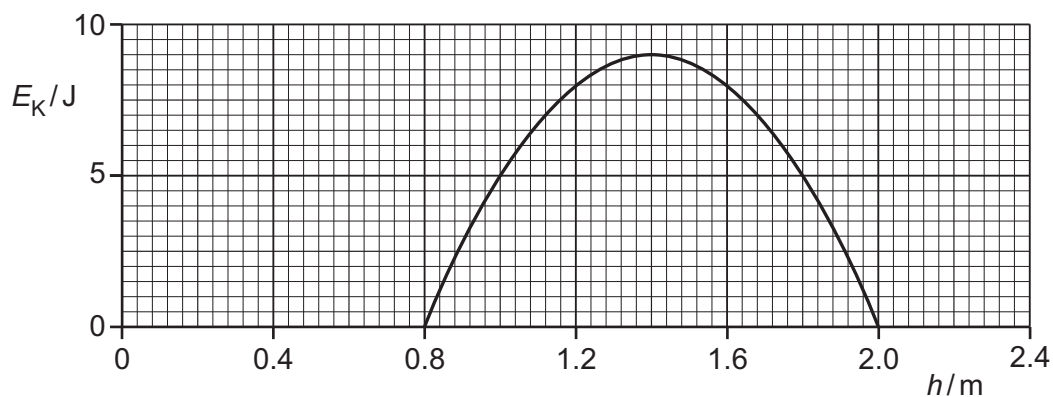


Fig. 5.3



- (a) (i) Determine the amplitude of the oscillations.

amplitude = ... m [1]

- (ii) State what the line in Fig. 5.2 shows about the nature of the oscillations.

..... [1]

- (b) State **three** other quantitative conclusions that can be drawn from Fig. 5.2 and Fig. 5.3 about the block and its oscillations. Use the space for any working.

1

.....

2

.....

3

.....

[3]

- (c) On Fig. 5.4, sketch the variation with h of the potential energy E_p of the oscillations.

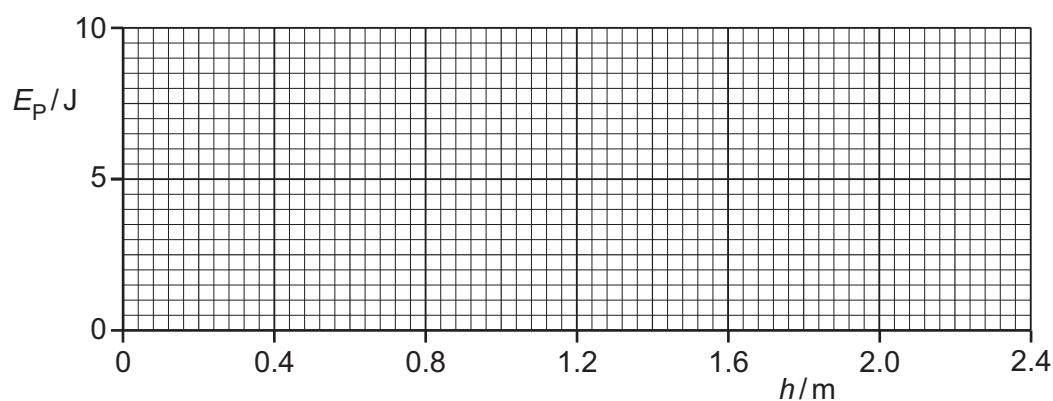


Fig. 5.4

[3]

[Total: 8]



- 6 Fig. 6.1 shows a circuit that rectifies an alternating input voltage V_{IN} and produces an output voltage V_{OUT} across a resistor R .

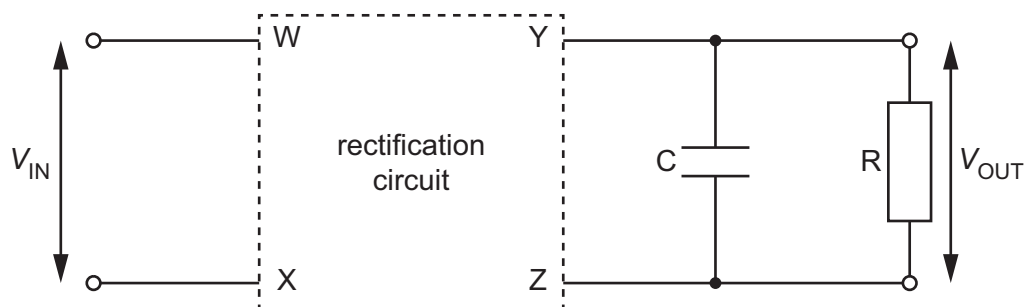


Fig. 6.1

The four terminals of the rectification circuit are labelled W, X, Y and Z.
A capacitor C is connected in parallel with resistor R .

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

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

- (ii) State the purpose of capacitor C .

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

- (b) Fig. 6.2 shows the variations with time t of the potential differences (p.d.s) V_{IN} and V_{OUT} .

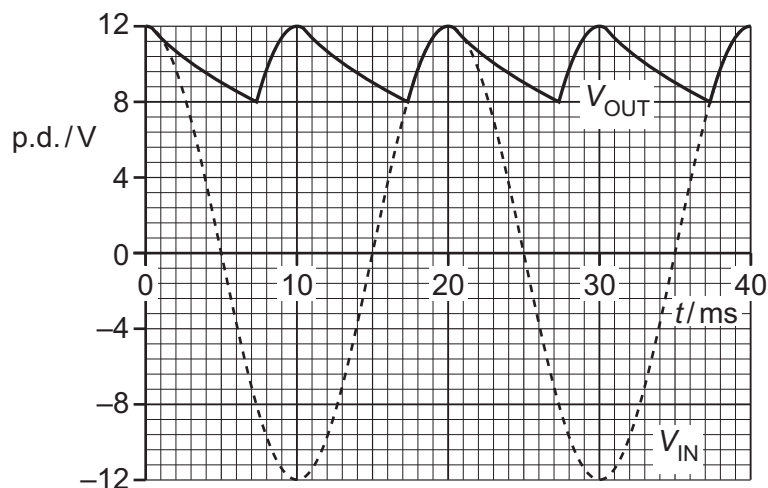


Fig. 6.2



- (i) The variation of V_{IN} with t can be represented by

$$V_{\text{IN}} = A \cos Bt$$

where A and B are constants.

Determine the values of A and B . Give a unit with your answer for A .

$$A = \dots\dots\dots \text{unit} \dots\dots\dots$$

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

- (ii) Determine the type of rectification produced by the circuit in Fig. 6.1.

..... [1]

- (iii) On Fig. 6.3, draw the circuit diagram for the components inside the rectification circuit.

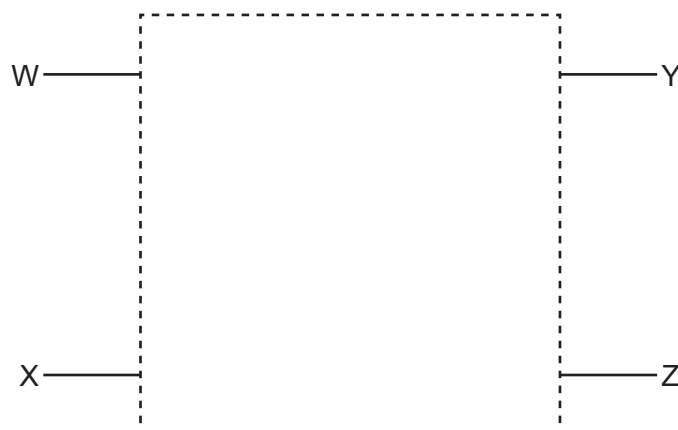


Fig. 6.3

[2]

- (iv) Determine a value for the time constant for the discharge of the capacitor C through the resistor R in Fig. 6.1.

time constant = ... s [3]



- (c) The capacitor C has a capacitance of $570\ \mu\text{F}$.

Use your answer in (b)(iv) to determine the resistance of resistor R.

resistance = ... Ω [2]

[Total: 12]

- 7 (a) Define magnetic flux density.

.....

 [2]

- (b) A particle of mass m and charge $+Q$ moves at speed v into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

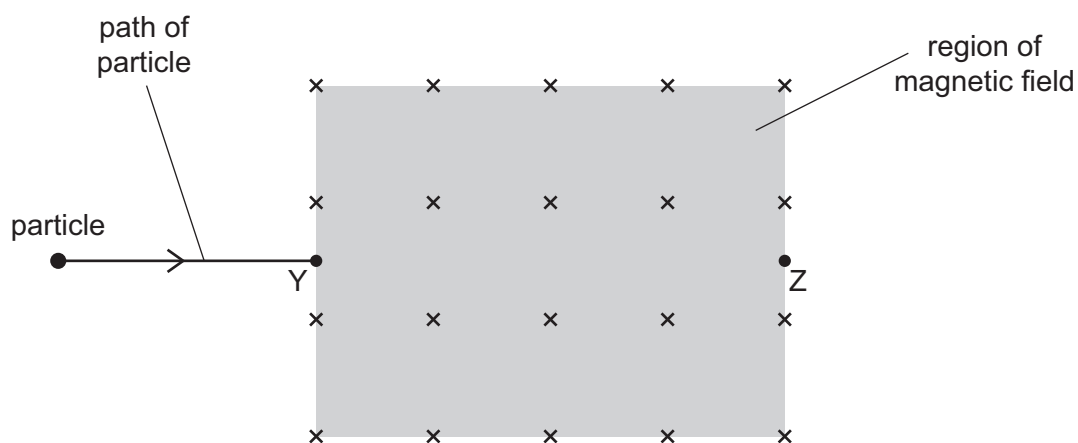


Fig. 7.1

The uniform magnetic field is into the page and has flux density B . The particle enters the region of the field at point Y.



- (i) State an expression, in terms of some or all of m , Q , B and v , for the magnetic force F that acts on the particle when it is at point Y.

$$F = \dots\dots\dots [1]$$

- (ii) On Fig. 7.1, draw an arrow at point Y to indicate the direction of the force in **(b)(i)**. [1]
- (iii) On Fig. 7.1, draw a line to show a possible path for the particle through the region of the magnetic field. [1]
- (c) (i) Explain how an electric field can be used with the magnetic field to ensure that the particle in **(b)** now passes through point Z.

.....

.....

.....

.....

..... [3]

- (ii) Derive an expression for v in terms of B and the electric field strength E .

$$v = \dots\dots\dots [2]$$

[Total: 10]



- 8 (a) State what is meant by the de Broglie wavelength.

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

- (b) Calculate the de Broglie wavelength of an electron moving at a speed of $4.9 \times 10^7 \text{ m s}^{-1}$.

wavelength = ... m [2]

- (c) State **one** similarity and **one** difference between an electron and a positron.

similarity:
.....
difference:
..... [2]

- (d) An electron moving at a speed of $4.9 \times 10^7 \text{ m s}^{-1}$ collides with a positron that is travelling at the same speed in the opposite direction. As a result of the collision, two gamma-ray photons are produced.

- (i) State the name of this type of reaction.

..... [1]

- (ii) State what happens to the electron and to the positron.

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



- (iii) Explain why two gamma-ray photons are produced, rather than just one.

.....
 [1]

- (iv) Show that the kinetic energy of the electron before the collision is $1.1 \times 10^{-15} \text{ J}$.

[1]

- (v) Use the information in (d)(iv) to determine, to three significant figures, the wavelength associated with the gamma radiation emitted in the collision.

wavelength = ... m [3]

[Total: 13]



- 9 (a) Define activity of a radioactive sample.

.....
 [1]

- (b) Explain why the variation with time of the activity of a radioactive sample is exponential in nature.

.....

 [3]

- (c) A sample contains a single radioactive isotope that decays to form a stable isotope.

The sample has an activity of 180 Bq at time $t = 0$.

At a time 8.4 minutes later, the activity is 120 Bq.

- (i) Determine the decay constant, in min^{-1} , of the radioactive isotope.

decay constant = ... min^{-1} [2]

- (ii) Use your answer in (c)(i) to determine the half-life, in min, of the radioactive isotope.

half-life = ... min [1]



- (iii) On Fig. 9.1, sketch the variation of the activity A of the sample with t for values of t between $t = 0$ and $t = 24$ min.

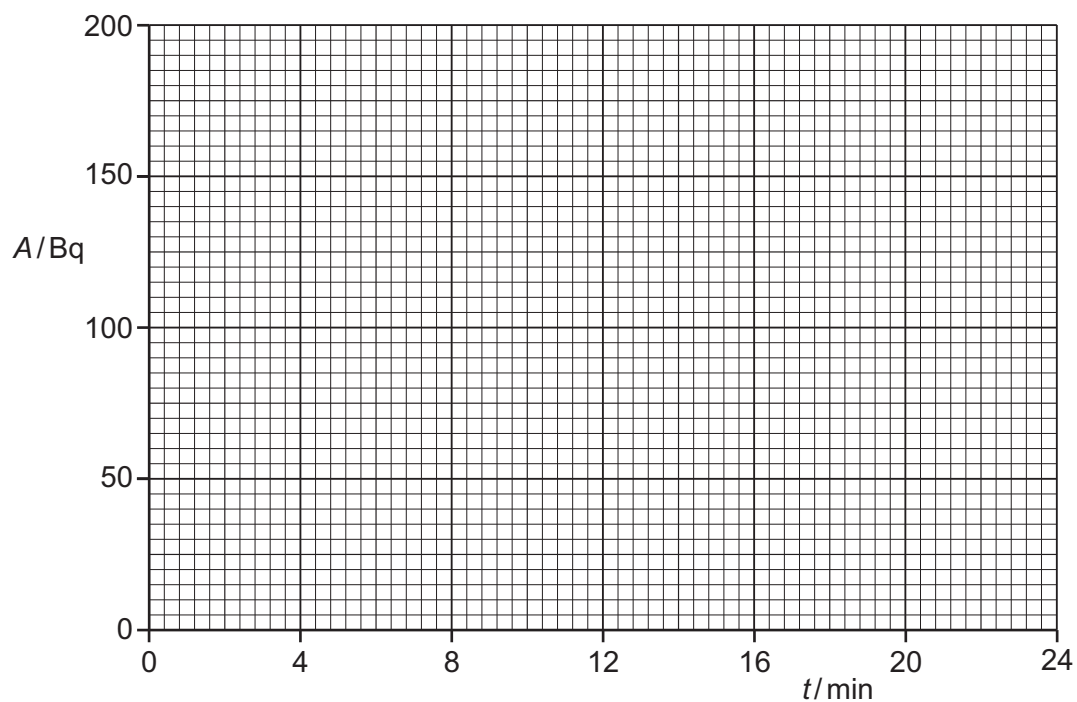


Fig. 9.1

[3]

[Total: 10]





10 (a) State Hubble's law.

.....

.....

..... [2]

(b) A star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of $4.62 \times 10^{-7} \text{ m}$.

Observations of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of $4.91 \times 10^{-7} \text{ m}$.

(i) Explain why the observed wavelength and the emitted wavelength have different values.

.....

.....

..... [2]

(ii) Calculate the speed of the star relative to the Earth.

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

(iii) The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

Explain how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

.....

.....

..... [2]





(c) A value for the Hubble constant is $2.3 \times 10^{-18} \text{ s}^{-1}$.

Use your answer in (b)(ii) to determine the distance of the star in (b) from the Earth.

distance = ...m [2]

[Total: 10]









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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 (a) Define the radian.

.....
 [1]

- (b) The rear wheel and the pedals of a bicycle are connected by a chain that passes around two cogs (toothed wheels), as shown in Fig. 1.1.

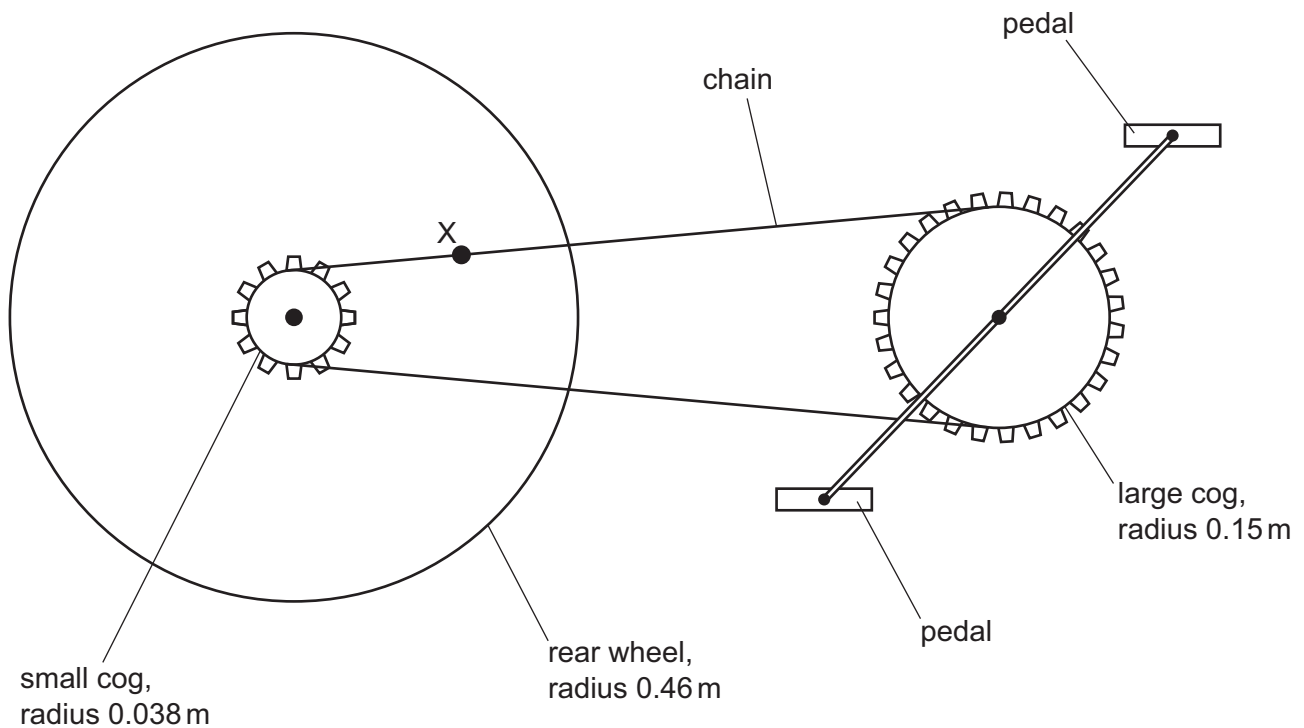


Fig. 1.1 (not to scale)

The small cog has a radius of 0.038 m and is fixed to the rear wheel so that it rotates with it. The large cog has a radius of 0.15 m and is fixed to the pedals so that it rotates with them. The rear wheel has a radius of 0.46 m.

The bicycle is being pedalled so that it moves in a straight line at a constant speed of 17 m s^{-1} .

- (i) Calculate the angular speed of the rear wheel.

angular speed = ... rad s^{-1} [2]



- (ii) Calculate the period of rotation of the small cog.

period = ... s [2]

- (iii) Show that the distance moved by point X on the chain during one full rotation of the small cog is 0.24 m.

[1]

- (iv) Use the information in (b)(iii) to determine the angle through which the large cog rotates during one full rotation of the small cog.

angle = ... rad [2]

- (c) The chain of the bicycle in (b) is moved onto a smaller cog fixed to the rear wheel. The speed of the bicycle does not change.

Explain, without calculation, the effect of this change on the angular speed of the pedals.

.....

 [2]

[Total: 10]



- 2 (a) (i) State what is represented by a gravitational field line.

.....

.....

..... [2]

- (ii) The Earth may be considered as a uniform sphere, as shown in Fig. 2.1.

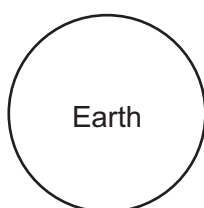


Fig. 2.1

On Fig. 2.1, draw field lines to represent the Earth's gravitational field outside the Earth. [2]

- (b) The Earth's magnetic field may be considered as being due to the Earth acting as a long solenoid, as shown in Fig. 2.2.

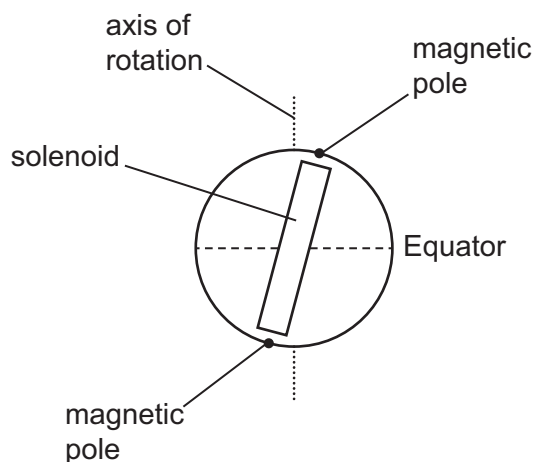


Fig. 2.2

The magnetic poles do not align with the geographic poles, which are on the axis of rotation.



Fig. 2.3 is a copy of Fig. 2.2 without the labels but with two magnetic field lines shown.

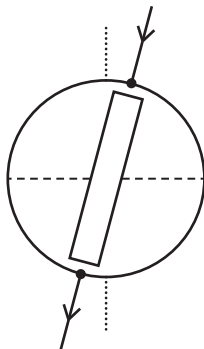


Fig. 2.3

- (i) On Fig. 2.3, label the magnetic poles with the letters N and S to indicate which one is the magnetic N pole and which one is the magnetic S pole. [1]
- (ii) On Fig. 2.3, draw field lines to represent the Earth's magnetic field outside the Earth. [2]
- (c) An observer moves around the surface of the Earth.

- (i) Use your answer in (a)(ii) to explain why the observed gravitational field of the Earth does not vary around the surface.

.....

.....

..... [2]

- (ii) With reference to your answer in (b)(ii), describe how the observed magnetic field of the Earth varies around the surface.

.....

.....

.....

.....

..... [3]

[Total: 12]



- 3 (a) Define specific heat capacity.

.....

.....

..... [2]

- (b) A block of aluminium has a volume of $3.612 \times 10^{-3} \text{ m}^3$ at a temperature of 0°C .

Aluminium has a density of $2.700 \times 10^3 \text{ kg m}^{-3}$ at 0°C .

It has a density of $2.620 \times 10^3 \text{ kg m}^{-3}$ at 500°C .

The block is heated so that its temperature increases from 0°C to 500°C at an atmospheric pressure of $1.01 \times 10^5 \text{ Pa}$.

The increase in internal energy of the block is 4.38 MJ .

- (i) Calculate the mass of the block.

mass = ... kg [2]

- (ii) Show that the volume of the block at a temperature of 500°C is $3.722 \times 10^{-3} \text{ m}^3$.

[1]

- (iii) Use the information in (b)(ii) to determine the magnitude of the work done on the block when its temperature is raised from 0°C to 500°C .

work done = ... J [2]



(iv) Explain whether the work done on the block is positive or negative.

.....

.....

..... [2]

(v) Use the first law of thermodynamics to determine, to three significant figures, a value for the specific heat capacity of aluminium. Explain your reasoning. Give a unit with your answer.

specific heat capacity = ... unit [3]

(c) Without further calculation, suggest with a reason how doubling the pressure in (b) is likely to affect the answer in (b)(v).

.....

.....

..... [1]

[Total: 13]



- 4 (a) The equation of state for an ideal gas may be written as

$$pVA = NBT$$

where p is the pressure of the gas, V is the volume of the gas, A is the Avogadro constant, B is another constant and N is the number of molecules of the gas.

- (i) State the meaning, in the equation, of the symbol T .

..... [1]

- (ii) Identify the constant B .

..... [1]

- (b) The product pV for an ideal gas is also given by

$$pV = \frac{1}{3} Nm \langle c^2 \rangle.$$

- (i) State the meanings, in this equation, of the symbols m and $\langle c^2 \rangle$.

m :

$\langle c^2 \rangle$: [2]

- (ii) Use the equations in (a) and (b) to derive an expression, in terms of A , B and T , for the mean kinetic energy E_K of a molecule of the gas.

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



- (c) On Fig. 4.1, sketch the variation with T of the root-mean-square (r.m.s.) speed of the molecules of an ideal gas.

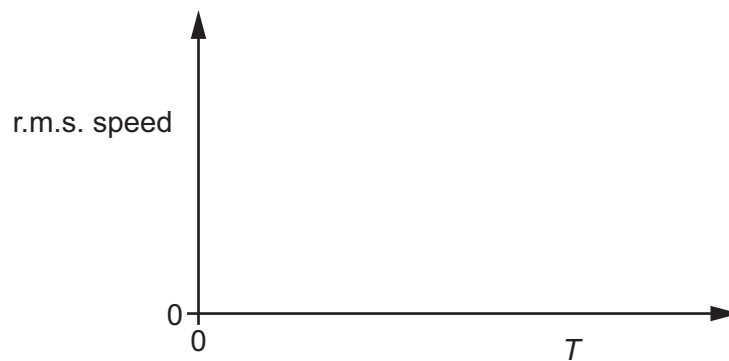


Fig. 4.1

[2]

[Total: 8]



- 5 (a) State what is meant by simple harmonic motion.

.....

 [2]

- (b) A block is suspended by a spring. The block oscillates vertically with simple harmonic motion.

The velocity v of the block varies with time t according to

$$v = 0.56 \cos 16t$$

where v is in m s^{-1} and t is in s.

- (i) Calculate the period of the oscillation.

period = ... s [1]

- (ii) Determine the amplitude x_0 of the oscillation.

$x_0 =$ m [2]

- (iii) Use your answer in (b)(ii) to determine the equation for v in terms of the displacement x of the block, where v is in m s^{-1} and x is in m.

$v =$ [1]



(iv) On Fig. 5.1, sketch the variation of v with x .

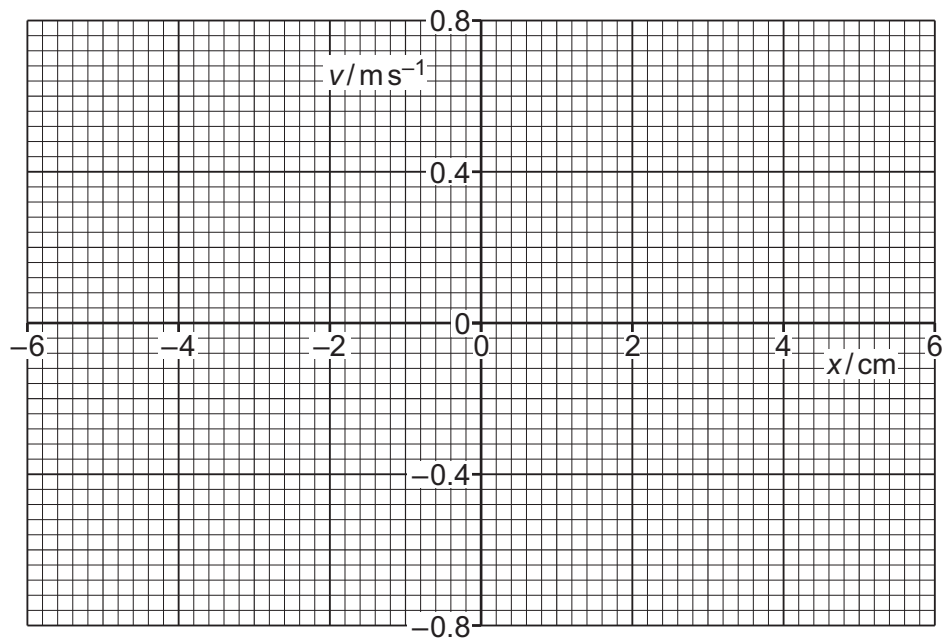


Fig. 5.1

[3]

[Total: 9]



- 6 Two parallel metal plates X and Y are separated by a distance of 0.041 m, as shown in Fig. 6.1.

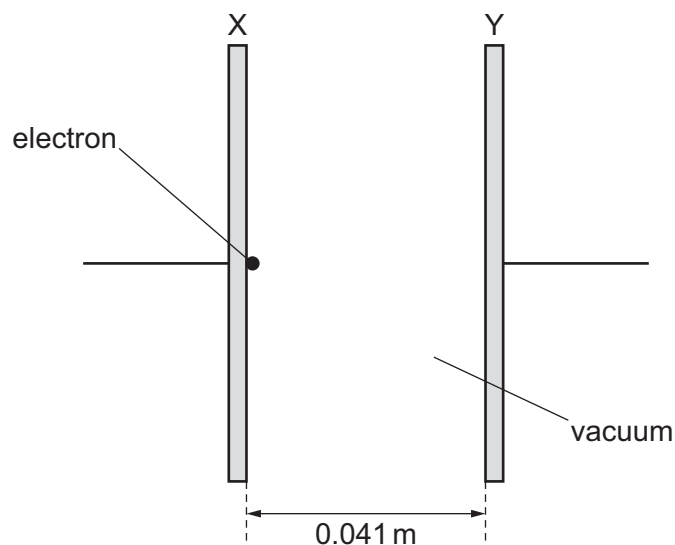


Fig. 6.1

There is a vacuum between the plates. An electron is at rest at the centre of plate X.

A potential difference (p.d.) of 58 kV is applied across the plates. This causes the electron to accelerate towards plate Y.

- (a) On Fig. 6.1, use the symbols + and – to indicate which of plates X and Y is the positive plate and which is the negative plate. [1]
- (b) (i) Calculate the electric field strength E between the plates. Give a unit with your answer.

$$E = \dots\dots\dots \text{unit} \dots\dots\dots [2]$$

- (ii) Determine the acceleration of the electron.

$$\text{acceleration} = \dots\dots\dots \text{ms}^{-2} [2]$$



- (c) Many electrons are now accelerated from rest from plate X to plate Y in Fig. 6.1. When the electrons hit plate Y, the absorption of their kinetic energies results in the emission of electromagnetic waves.

(i) Show that the minimum wavelength of these electromagnetic waves is 21 pm.

[3]

- (ii) State the region of the electromagnetic spectrum that contains these waves.

..... [1]

- (iii) Explain how these electromagnetic waves may be used to form images of internal body structures.

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

[Total: 11]



- 7 Fig. 7.1 shows a circuit containing a capacitor of capacitance C and a resistor of resistance R .

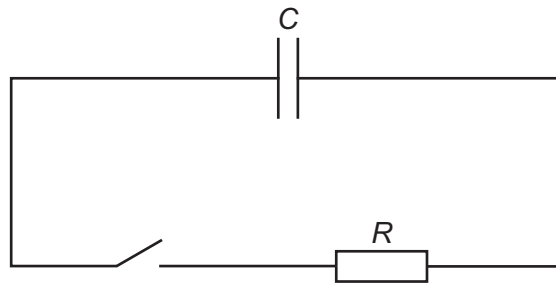


Fig. 7.1

Initially, the switch is open and the potential difference (p.d.) across the capacitor is 12 V.

The switch is closed at time $t = 0$ and the capacitor discharges through the resistor.

Fig. 7.2 shows the variation of the charge Q on the capacitor with the p.d. V_C across the capacitor as the capacitor discharges. Fig. 7.3 shows the variation of the current I in the resistor with the p.d. V_R across the resistor as the capacitor discharges.

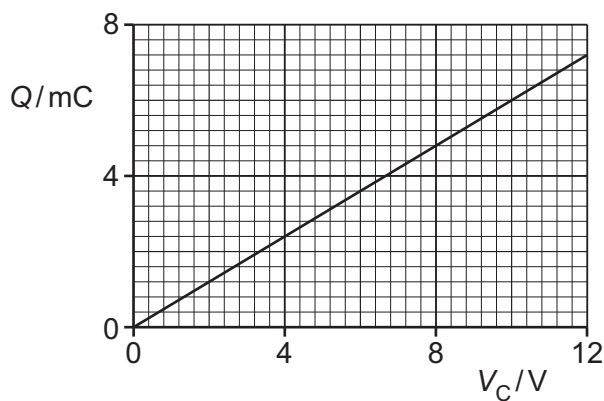


Fig. 7.2

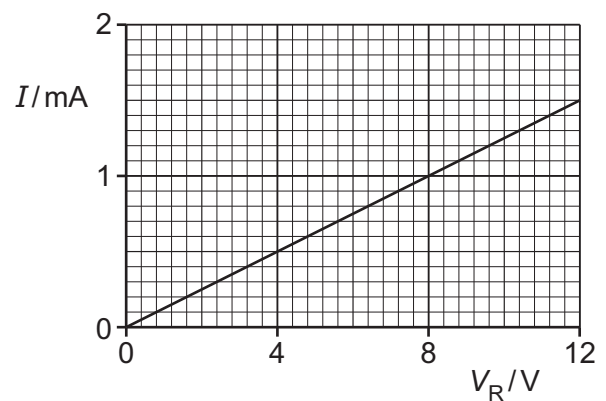


Fig. 7.3

- (a) State the relationship between V_C and V_R .

..... [1]

- (b) Determine:

- (i) the capacitance C , in μF

$C = \dots\dots\dots \mu\text{F}$ [2]





(ii) the resistance R , in $\text{k}\Omega$

$R = \dots\dots\dots \text{k}\Omega$ [2]

(iii) the time constant τ of the circuit.

$\tau = \dots\dots\dots \text{s}$ [2]

(c) Use Fig. 7.2, Fig. 7.3 and your answer in (a) to explain why the variation of Q with t is exponential in nature.

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

[Total: 10]



- 8 Fig. 8.1 shows a circuit that produces rectification of an alternating input voltage.

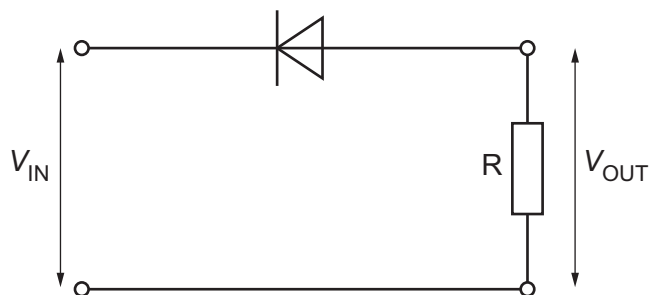


Fig. 8.1

The input voltage V_{IN} is sinusoidal. The rectified output voltage V_{OUT} is applied across resistor R .

The variation of V_{IN} with time t has amplitude V_0 and period T , as shown in Fig. 8.2.

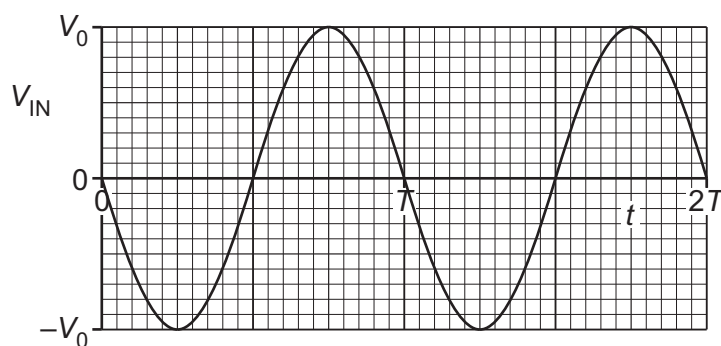


Fig. 8.2

The root-mean-square (r.m.s.) value of V_{IN} is 6.0 V.

- (a) (i) State the type of rectification produced by the circuit of Fig. 8.1.

..... [1]

- (ii) Calculate V_0 .

$V_0 =$ V [1]



(b) Resistor R has resistance $45\ \Omega$.

Assume that there is no p.d. across the diode when it is conducting.

(i) Determine the peak power P_0 in the resistor.

$$P_0 = \dots\dots\dots \text{ W [2]}$$

(ii) On Fig. 8.3, sketch the variation of the power P in the resistor with t between $t = 0$ and $t = 2T$.

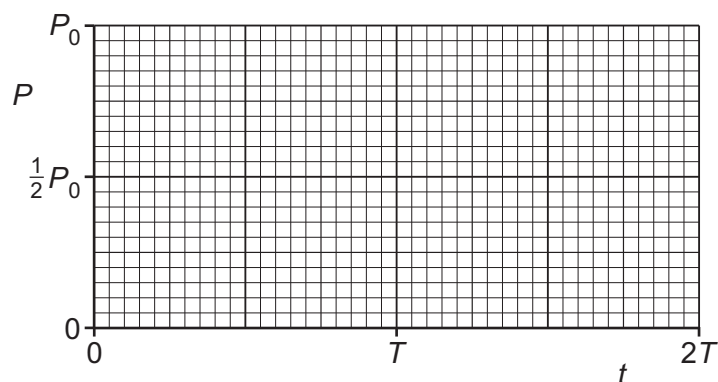


Fig. 8.3

[3]

(iii) Use the answer in (b)(ii) to explain why the mean power in the resistor is $\frac{1}{4}P_0$.

.....

 [2]

(iv) Use the information in (b)(iii) to determine the r.m.s. value of V_{OUT} .

$$\text{r.m.s. voltage} = \dots\dots\dots \text{ V [1]}$$

[Total: 10]



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

.....

.....

..... [2]

- (b) The photoelectric effect is investigated in two stages using the circuit shown in Fig. 9.1.

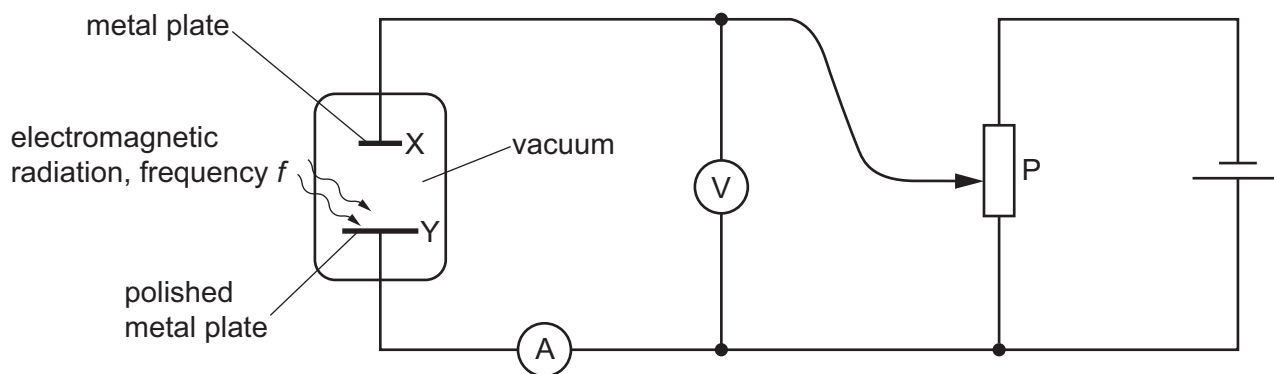


Fig. 9.1

The polished metal plate Y is illuminated with electromagnetic radiation of frequency f and constant power.

In stage 1 of the investigation, frequency f is set to a constant value of 2.5×10^{15} Hz. The current I in the ammeter is varied by adjusting the potentiometer P. Fig. 9.2 shows the variation of I with the voltmeter reading V . There is a value V_S of V at which the current just falls to zero.

In stage 2 of the investigation, stage 1 is repeated for different values of frequency. As frequency f is varied, the voltmeter reading V_S at which the current just falls to zero is measured. Fig. 9.3 shows the variation of V_S with f .

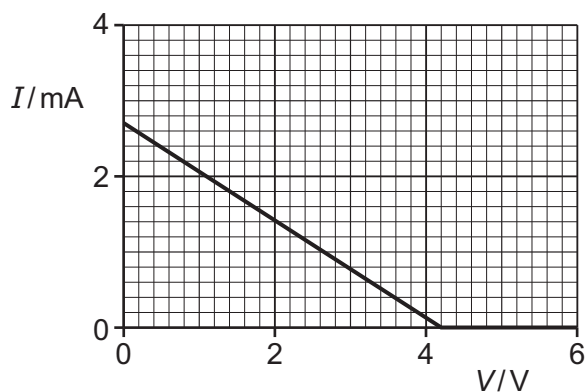


Fig. 9.2

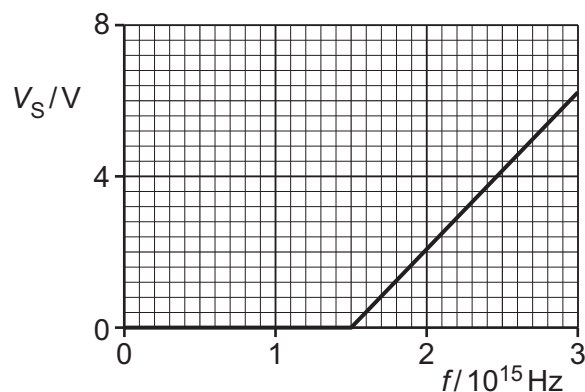


Fig. 9.3



- (i) Explain, with reference to photons, why V_S depends on the frequency of the incident electromagnetic radiation.

.....

.....

.....

.....

.....

..... [3]

- (ii) State **three** quantitative conclusions that can be drawn from the results in Fig. 9.2 and Fig. 9.3. Use the space for any working.

1

.....

2

.....

3

..... [3]

[Total: 8]



- 10 (a) Radioactive decay is a spontaneous process.

State the meaning, in this context, of the term spontaneous.

.....
 [1]

- (b) Two radioactive isotopes X and Y each decay to form a stable isotope.
 A sample initially contains only atoms of isotope X. At this time, its activity is $4A$.
 Another sample initially contains only atoms of Y. At this time, its activity is A .

Fig. 10.1 shows the variation of the activity of each sample with time t between $t = 0$ and $t = 6T$.

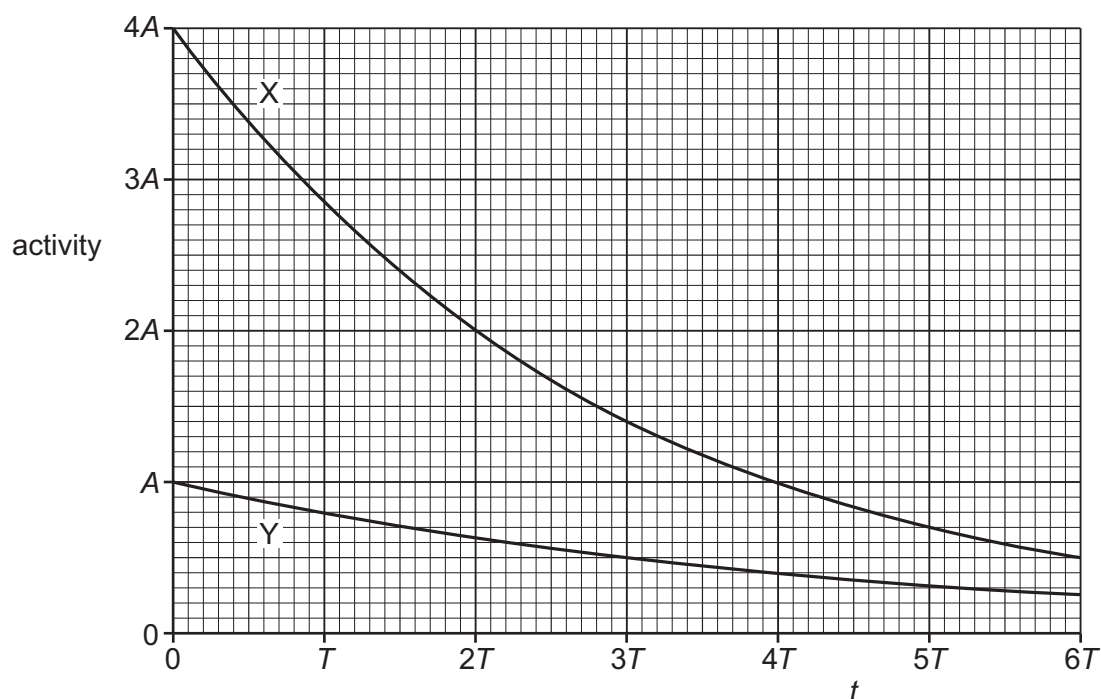


Fig. 10.1

- (i) Complete Table 10.1 to give expressions, in terms of either or both of A and T , for the quantities indicated for each of the samples.

Table 10.1

sample	half-life	decay constant	initial activity	initial number of nuclei
X			$4A$	
Y			A	

[3]



(ii) Determine, in terms of T , the time at which the two samples will have equal activities.

time = ... T [3]

(c) A radiation detector is placed near to one of the samples in (b).

Explain why the count rate measured by the detector is less than the activity of the sample.

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

[Total: 9]





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PHYSICS

9702/43

Paper 4 A Level Structured Questions

May/June 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) Define gravitational potential at a point.

.....

 [2]

- (b) Mars is a planet that may be considered to be an isolated uniform sphere of radius 3.4×10^6 m.

A satellite of mass 122 kg is in orbit around Mars at a constant height of 1.7×10^6 m above the surface of the planet.

The height of the orbit is increased to 6.8×10^6 m above the surface. This increases the gravitational potential energy of the satellite by 5.1×10^8 J.

- (i) Show that the mass of Mars is 6.4×10^{23} kg.

[3]

- (ii) Calculate the gravitational potential ϕ at the surface of Mars. Give a unit with your answer.

$\phi =$ unit [2]



(c) The satellite in (b) is moved to an orbit in which the satellite remains at the same point above the surface of Mars.

(i) The orbit has a period of 25 hours.

State what can be deduced from this about the rotation of Mars on its axis.

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

(ii) State **one** other feature of this orbit.

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

[Total: 9]



- 2 A helium atom may be modelled as a nucleus surrounded by two electrons in diametrically opposite circular orbits, each of radius 170 pm, as shown in Fig. 2.1.

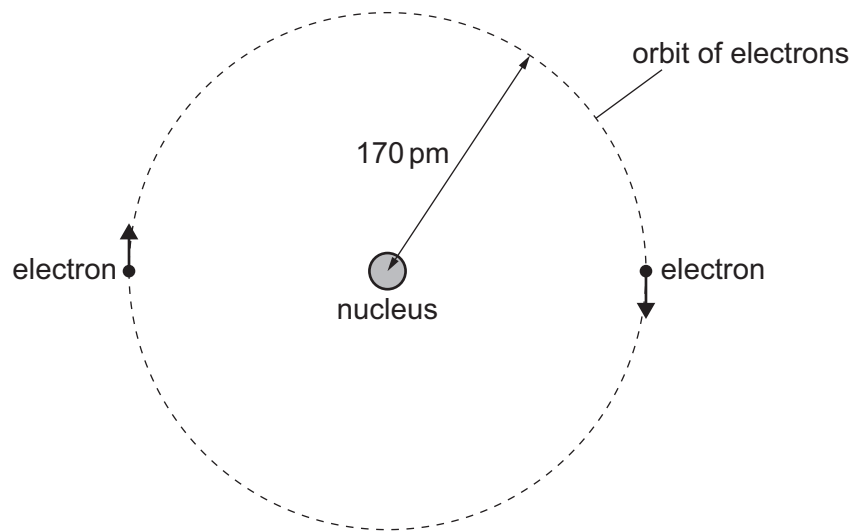


Fig. 2.1

- (a) State Coulomb's law.

.....

 [2]

- (b) (i) State the charge on the nucleus, in terms of the elementary charge e .

charge = ... e [1]

- (ii) Show that the electric force between the nucleus and one of the electrons is $1.6 \times 10^{-8} \text{ N}$.

[1]



(c) Assume that the force in (b)(ii) is the only force on the electrons.

(i) Calculate the speed of the orbiting electrons.

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

(ii) Calculate the period of the orbit of the electrons.

period = ... s [2]

(d) In practice, the orbit of each electron is affected by the presence of the other electron.

(i) For the position of one of the electrons, determine the ratio

$$\frac{\text{electric field strength due to the other electron}}{\text{electric field strength due to the nucleus}}.$$

ratio = ... [2]

(ii) Use your answer in (d)(i) to suggest and explain how the orbit of the electron is affected by the presence of the other electron.

.....
 [1]

[Total: 11]



3 (a) Define specific latent heat.

.....

.....

..... [2]

(b) Explain why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

.....

.....

.....

.....

..... [3]

(c) An ice cube of mass 37.0g at temperature 0.0°C is placed in a beaker containing water of mass 208g at temperature 26.4°C.

When all the ice has melted, and all the water in the beaker has reached thermal equilibrium, the final temperature of all the water is 10.3°C.

The specific heat capacity of water is $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$.

The beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

Determine a value, to three significant figures, for the specific latent heat of fusion of water.

specific latent heat of fusion = ... J g^{-1} [4]

[Total: 9]



4 (a) (i) State what is meant by the internal energy of a system.

.....

.....

..... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

.....

.....

.....

..... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U .

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W , T and U , the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]



- 5 A cuboidal block floats in a liquid with its base horizontal, as shown in Fig. 5.1.

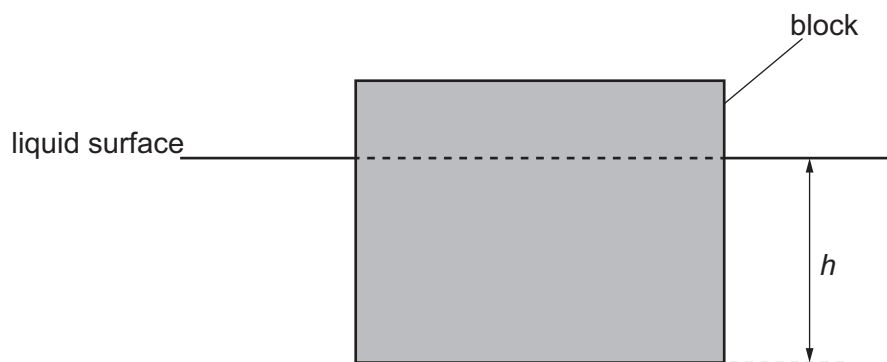


Fig. 5.1

The base of the block is at a depth h below the surface of the liquid.

The block is displaced downwards by a small distance and then released so that it oscillates.

Fig. 5.2 shows the variation with h of the acceleration a of the block.

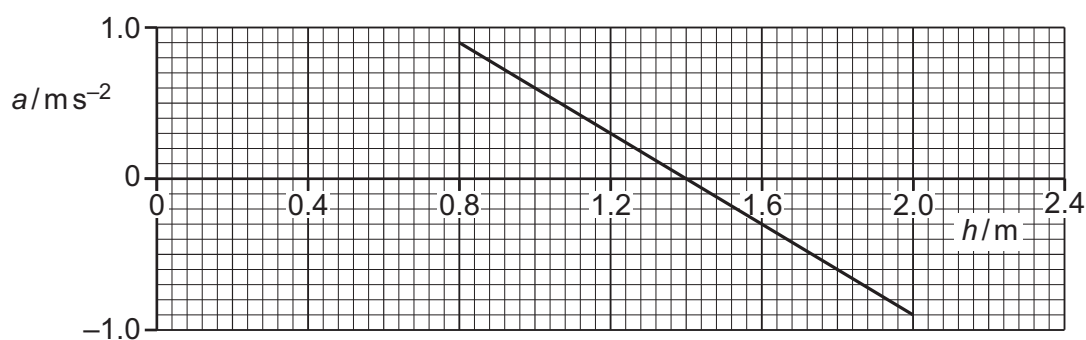


Fig. 5.2

Fig. 5.3 shows the variation with h of the kinetic energy E_K of the block.

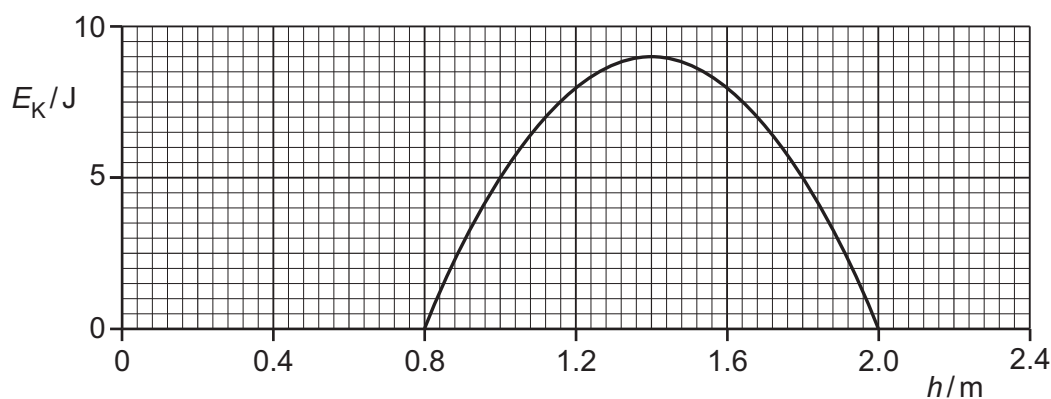


Fig. 5.3



- (a) (i) Determine the amplitude of the oscillations.

amplitude = ... m [1]

- (ii) State what the line in Fig. 5.2 shows about the nature of the oscillations.

..... [1]

- (b) State **three** other quantitative conclusions that can be drawn from Fig. 5.2 and Fig. 5.3 about the block and its oscillations. Use the space for any working.

1

.....

2

.....

3

.....

[3]

- (c) On Fig. 5.4, sketch the variation with h of the potential energy E_p of the oscillations.

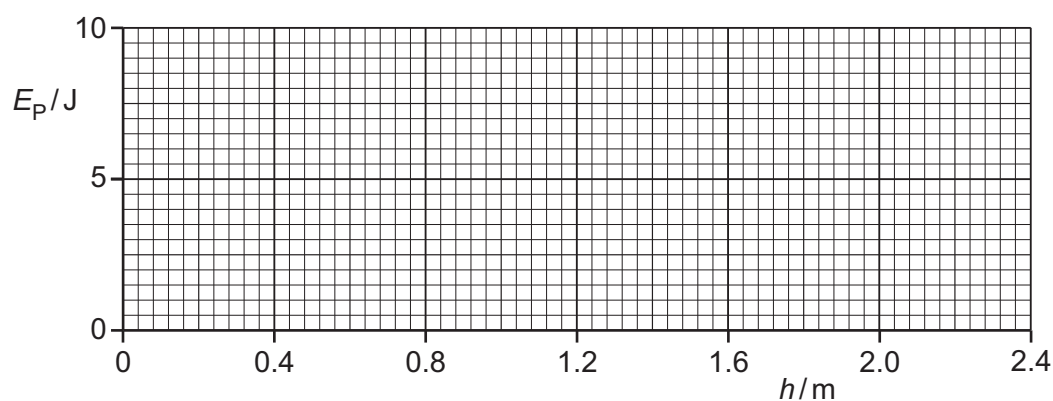


Fig. 5.4

[3]

[Total: 8]



- 6 Fig. 6.1 shows a circuit that rectifies an alternating input voltage V_{IN} and produces an output voltage V_{OUT} across a resistor R .

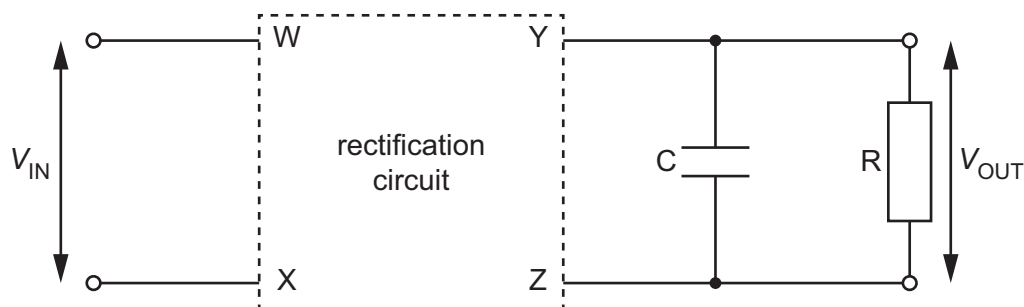


Fig. 6.1

The four terminals of the rectification circuit are labelled W, X, Y and Z.
A capacitor C is connected in parallel with resistor R .

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

.....
 [1]

- (ii) State the purpose of capacitor C .

.....
 [1]

- (b) Fig. 6.2 shows the variations with time t of the potential differences (p.d.s) V_{IN} and V_{OUT} .

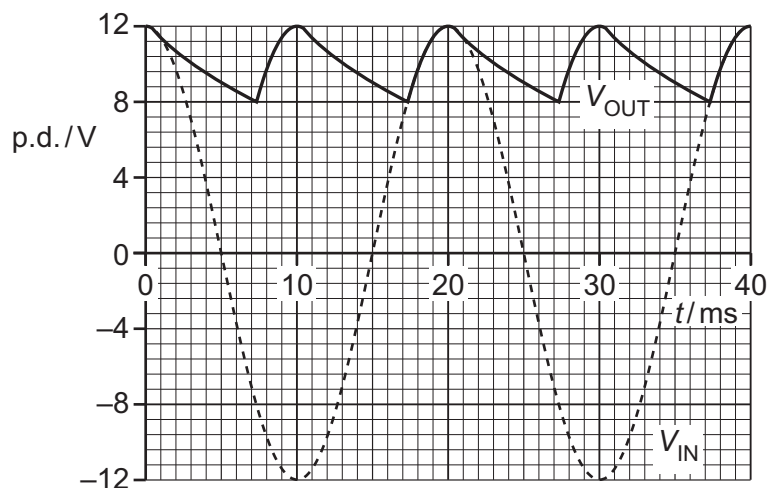


Fig. 6.2



- (i) The variation of V_{IN} with t can be represented by

$$V_{\text{IN}} = A \cos Bt$$

where A and B are constants.

Determine the values of A and B . Give a unit with your answer for A .

$$A = \dots\dots\dots \text{unit} \dots\dots\dots$$

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

- (ii) Determine the type of rectification produced by the circuit in Fig. 6.1.

..... [1]

- (iii) On Fig. 6.3, draw the circuit diagram for the components inside the rectification circuit.

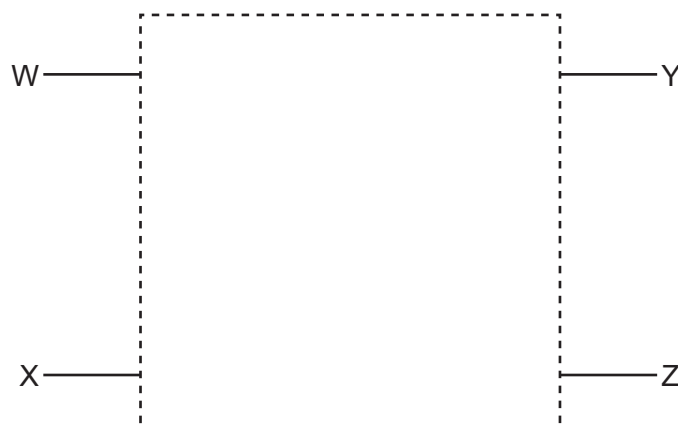


Fig. 6.3

[2]

- (iv) Determine a value for the time constant for the discharge of the capacitor C through the resistor R in Fig. 6.1.

time constant = ... s [3]



- (c) The capacitor C has a capacitance of $570\ \mu\text{F}$.

Use your answer in (b)(iv) to determine the resistance of resistor R.

resistance = ... Ω [2]

[Total: 12]

- 7 (a) Define magnetic flux density.

.....

 [2]

- (b) A particle of mass m and charge $+Q$ moves at speed v into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

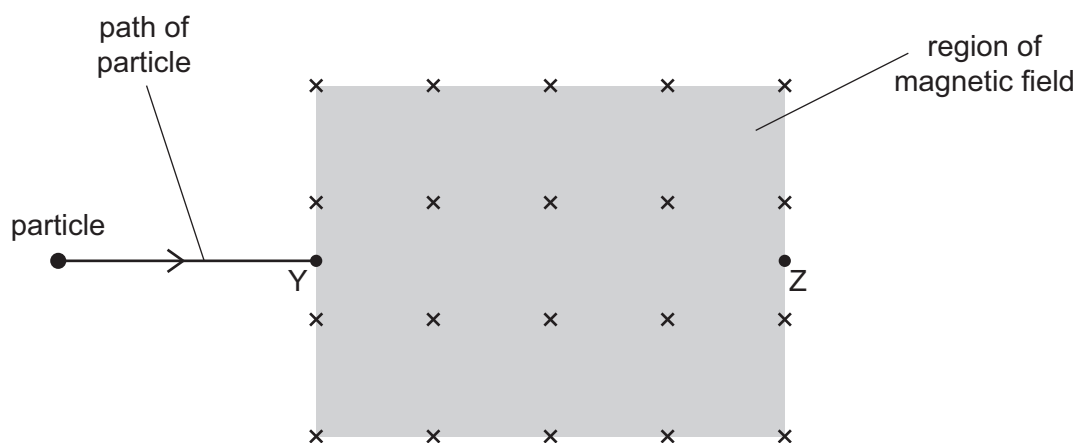


Fig. 7.1

The uniform magnetic field is into the page and has flux density B . The particle enters the region of the field at point Y.



- (i) State an expression, in terms of some or all of m , Q , B and v , for the magnetic force F that acts on the particle when it is at point Y.

$$F = \dots\dots\dots [1]$$

- (ii) On Fig. 7.1, draw an arrow at point Y to indicate the direction of the force in **(b)(i)**. [1]
- (iii) On Fig. 7.1, draw a line to show a possible path for the particle through the region of the magnetic field. [1]
- (c) (i) Explain how an electric field can be used with the magnetic field to ensure that the particle in **(b)** now passes through point Z.

.....

.....

.....

.....

..... [3]

- (ii) Derive an expression for v in terms of B and the electric field strength E .

$$v = \dots\dots\dots [2]$$

[Total: 10]



- 8 (a) State what is meant by the de Broglie wavelength.

.....
 [1]

- (b) Calculate the de Broglie wavelength of an electron moving at a speed of $4.9 \times 10^7 \text{ m s}^{-1}$.

wavelength = ... m [2]

- (c) State **one** similarity and **one** difference between an electron and a positron.

similarity:

 difference:
 [2]

- (d) An electron moving at a speed of $4.9 \times 10^7 \text{ m s}^{-1}$ collides with a positron that is travelling at the same speed in the opposite direction. As a result of the collision, two gamma-ray photons are produced.

- (i) State the name of this type of reaction.

..... [1]

- (ii) State what happens to the electron and to the positron.

.....

 [2]



- (iii) Explain why two gamma-ray photons are produced, rather than just one.

.....

..... [1]

- (iv) Show that the kinetic energy of the electron before the collision is $1.1 \times 10^{-15} \text{ J}$.

[1]

- (v) Use the information in (d)(iv) to determine, to three significant figures, the wavelength associated with the gamma radiation emitted in the collision.

wavelength = ... m [3]

[Total: 13]



- 9 (a) Define activity of a radioactive sample.

.....
 [1]

- (b) Explain why the variation with time of the activity of a radioactive sample is exponential in nature.

.....

 [3]

- (c) A sample contains a single radioactive isotope that decays to form a stable isotope.

The sample has an activity of 180 Bq at time $t = 0$.

At a time 8.4 minutes later, the activity is 120 Bq.

- (i) Determine the decay constant, in min^{-1} , of the radioactive isotope.

decay constant = ... min^{-1} [2]

- (ii) Use your answer in (c)(i) to determine the half-life, in min, of the radioactive isotope.

half-life = ... min [1]



- (iii) On Fig. 9.1, sketch the variation of the activity A of the sample with t for values of t between $t = 0$ and $t = 24$ min.

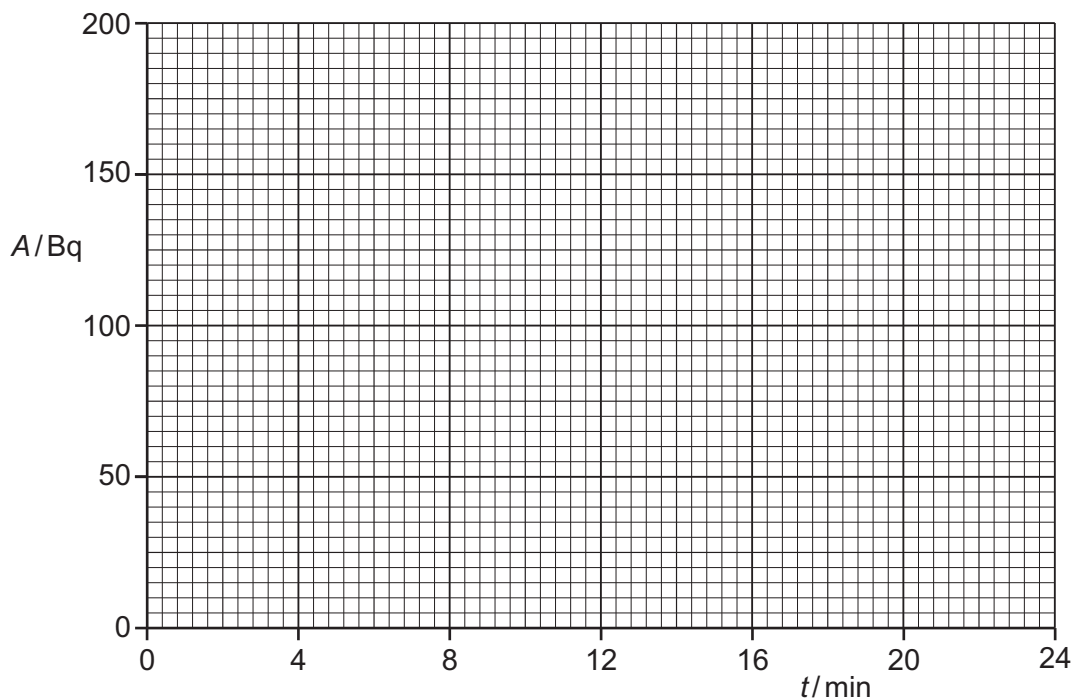


Fig. 9.1

[3]

[Total: 10]





10 (a) State Hubble's law.

.....

.....

..... [2]

(b) A star in a distant galaxy emits radiation that has a maximum intensity of emission at a wavelength of $4.62 \times 10^{-7} \text{ m}$.

Observations of the galaxy made on the Earth detect the maximum intensity of emission from the star at a wavelength of $4.91 \times 10^{-7} \text{ m}$.

(i) Explain why the observed wavelength and the emitted wavelength have different values.

.....

.....

..... [2]

(ii) Calculate the speed of the star relative to the Earth.

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

(iii) The wavelength of maximum intensity of emission is used to determine a value for the surface temperature of the star.

Explain how the temperature determined using the observed wavelength compares with the true value of temperature determined using the emitted wavelength.

.....

.....

..... [2]





(c) A value for the Hubble constant is $2.3 \times 10^{-18} \text{ s}^{-1}$.

Use your answer in (b)(ii) to determine the distance of the star in (b) from the Earth.

distance = ...m [2]

[Total: 10]









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PHYSICS

9702/44

Paper 4 A Level Structured Questions

May/June 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) Define gravitational field.

.....
 [1]

- (b) The gravitational field strength g at a distance x from the centre of a uniform spherical planet of mass M is given by the expression

$$g = \frac{GM}{x^2}$$

where G is the gravitational constant and distance x is greater than the radius of the planet.

- (i) Describe the pattern of the field lines outside the planet that represent the gravitational field due to the planet.

.....

 [2]

- (ii) Explain why, for small changes in vertical height near the surface of the planet, g may be assumed to be constant.

.....

 [2]

- (c) Assume that the Earth is a uniform sphere. For the Earth, the product GM is equal to $3.99 \times 10^{14} \text{ m}^3 \text{ s}^{-2}$.

- (i) Determine a value, to three significant figures, for the radius R of the Earth.

$R = \dots\dots\dots \text{ m}$ [2]



(ii) Calculate the gravitational potential at the Earth's surface. Give a unit with your answer.

gravitational potential = ... unit [2]

(d) Explain why the gravitational potential energy of two point masses is always negative.

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

[Total: 11]



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

.....

.....

..... [2]

- (b) A mass X of ice at 0°C is placed in a beaker containing a mass M of water at Celsius temperature t . The beaker is perfectly insulated and has negligible heat capacity. After some time, the ice that was added reaches thermal equilibrium with the original water in the beaker.

The specific latent heat of fusion of water is L . The specific heat capacity of water is c .
The final Celsius temperature of the system is θ .

Give expressions, in terms of some or all of X , M , t , θ , L and c , for the thermal energy:

- (i) E_1 , gained by the ice as it melts to become water at 0°C

$$E_1 = \dots\dots\dots [1]$$

- (ii) E_2 , lost by the water as its Celsius temperature decreases from t to θ

$$E_2 = \dots\dots\dots [1]$$

- (iii) E_3 , gained by the melted ice as its Celsius temperature increases from 0°C to θ .

$$E_3 = \dots\dots\dots [1]$$

- (c) Use your answers in (b) to show that the final Celsius temperature θ of the system is given by

$$\theta = \frac{Mct - XL}{c(M + X)}.$$

[2]

[Total: 7]



- 3 (a) State what is meant by an ideal gas.

.....

 [2]

- (b) An ideal gas at a pressure of $1.6 \times 10^5 \text{ Pa}$ has a density of 1.9 kg m^{-3} .

- (i) Show that the root-mean-square (r.m.s.) speed of molecules of this gas is approximately 500 m s^{-1} .

[3]

- (ii) One molecule of the gas has a mass of $4.7 \times 10^{-26} \text{ kg}$.

Determine the thermodynamic temperature of the gas.

temperature = ... K [2]

- (c) Calculate the internal energy U of 6.0 mol of the gas in (b). Explain your reasoning.

$U =$ J [3]

[Total: 10]



- 4 (a) State what is meant by simple harmonic motion.

.....

.....

..... [2]

- (b) A small sphere is suspended from a fixed point P by a string of negligible mass, as shown in Fig. 4.1.

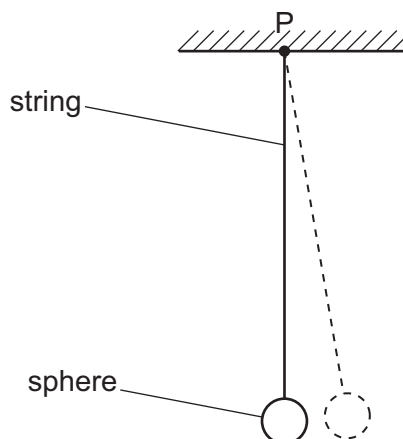


Fig. 4.1

The sphere is given a small horizontal displacement and is then released.

The variation with time of the horizontal velocity v of the sphere is shown in Fig. 4.2.

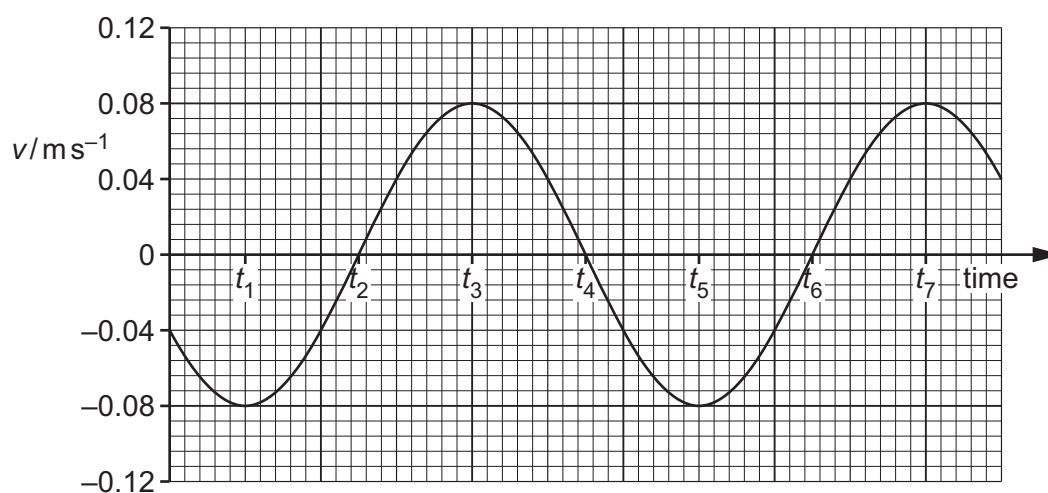


Fig. 4.2



- (i) State two times at which the sphere is passing in the same direction through the equilibrium position.

time and time [1]

- (ii) The time interval between t_1 and t_6 is 2.2 s.

Calculate the frequency of oscillation of the sphere.

frequency = ... Hz [2]

- (c) The sphere in (b) is undergoing simple harmonic motion.

Use your answer in (b)(ii) and data from Fig. 4.2 to determine the maximum displacement of the sphere from its equilibrium position.

maximum displacement = ... m [3]

[Total: 8]



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

.....

.....

..... [2]

- (b) An isolated solid metal sphere of radius r is given a positive charge.

The potential at the surface of the sphere is $9.0 \times 10^4 \text{ V}$. At a distance of $3r$ from the centre of the sphere, the electric field strength is $2.0 \times 10^5 \text{ N C}^{-1}$.

- (i) Determine the electric field strength at the surface of the sphere.

electric field strength = ... N C^{-1} [2]

- (ii) Show that the radius of the sphere is 5.0 cm.

[2]

- (iii) Calculate the charge on the sphere.

charge = ... C [2]



(iv) Use your answer in (b)(iii) to determine the capacitance of the sphere.

capacitance = ... F [2]

[Total: 10]



- 6 A rectangular coil PQRS of wire is free to rotate about its axis XY, as shown in Fig. 6.1.

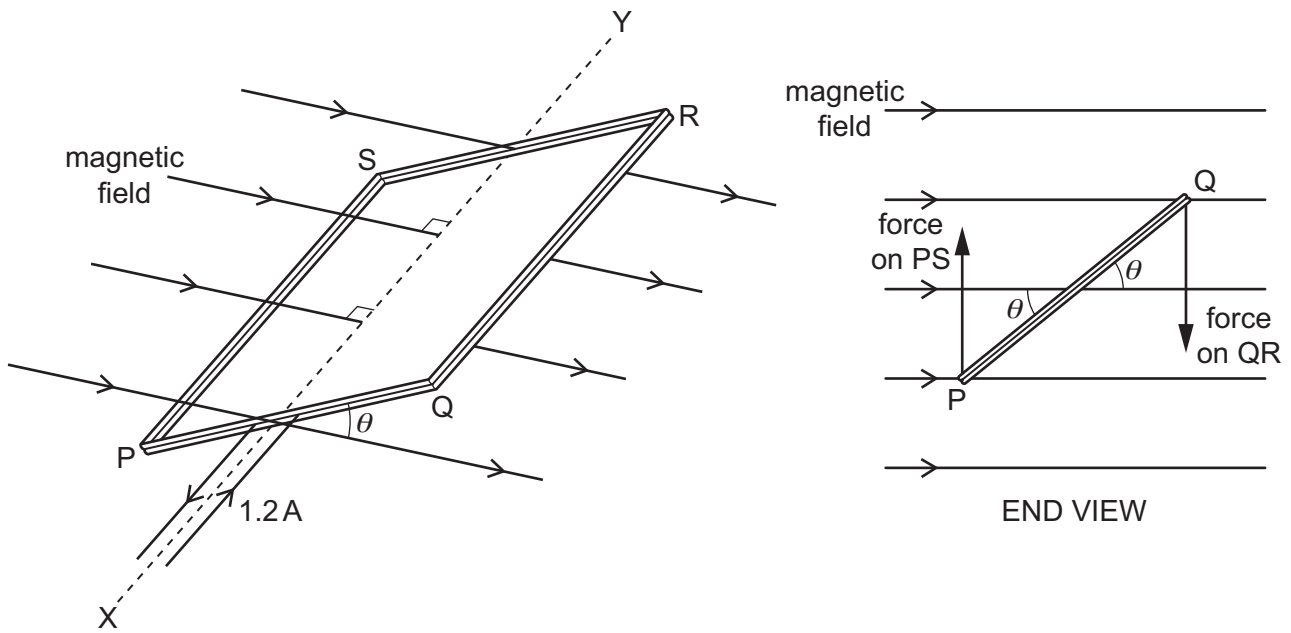


Fig. 6.1 (not to scale)

The coil has length QR of 5.4 cm, width PQ of 2.5 cm and has 190 turns of wire.
 The plane of the coil is at an angle θ to a uniform magnetic field of flux density $5.2 \times 10^{-3} \text{ T}$.
 The axis XY of the coil is normal to the field.
 The current in the coil is 1.2 A.

- (a) (i) Calculate the magnitude of the force on side QR of the coil.

force = ... N [3]



(ii) Use your answer in (a)(i) to show that the torque τ on the coil is given by

$$\tau = 1.6 \times 10^{-3} \cos \theta \text{ N m.}$$

[2]

(iii) Using the expression in (a)(ii) sketch, on the axes of Fig. 6.2, a graph to show the variation of the torque τ with angle θ for values of θ between 0 and 360°. Label the τ axis with an appropriate scale.

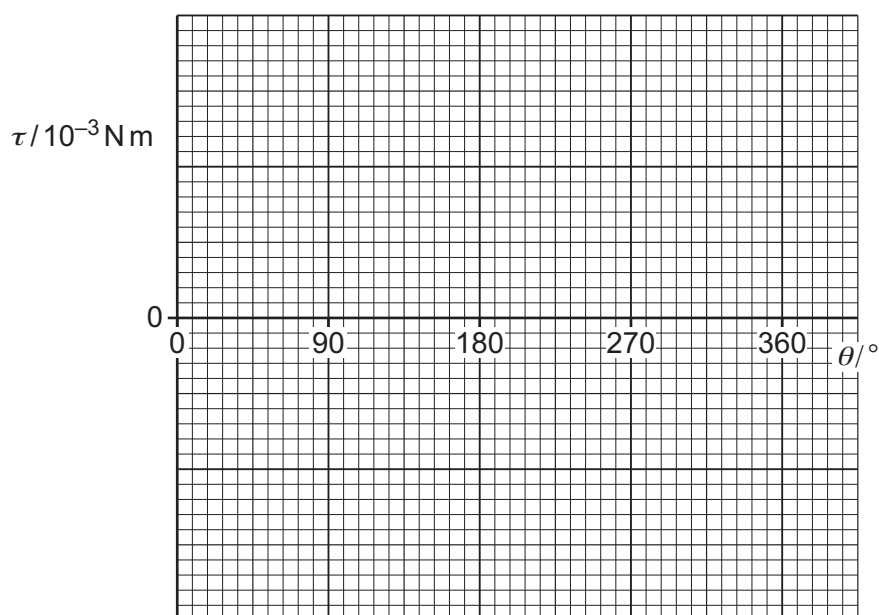


Fig. 6.2

[3]

(b) The coil is now replaced by an identical coil wound on a ferrous core.

Suggest, with a reason, how the torque on this coil compares with the torque on the original coil.

.....

 [2]

[Total: 10]



- 7 A bar magnet is suspended from a spring. One pole of the magnet oscillates freely in a coil of wire, as shown in Fig. 7.1.

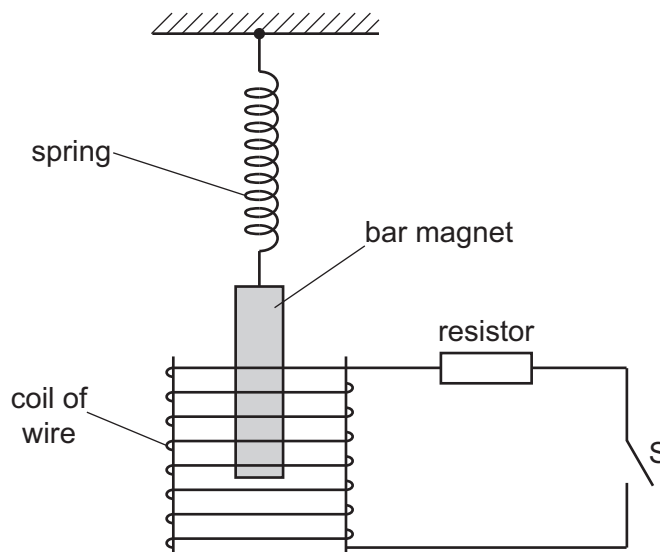


Fig. 7.1

The switch S is initially open.

- (a) The switch S is now closed. As a result, the oscillations of the magnet are lightly damped.

- (i) State what is meant by damping.

.....

 [2]

- (ii) Describe what is observed to indicate that the damping is light.

.....
 [1]

- (iii) By reference to electromagnetic induction and to conservation of energy, explain why the oscillations are damped.

.....

 [3]





(b) The procedure in (a) is repeated after replacing the resistor with one of greater resistance.

Suggest, with a reason, the effect of this change on the oscillations.

.....

.....

..... [2]

[Total: 8]



- 8 An incomplete circuit diagram of a bridge rectifier is shown in Fig. 8.1.

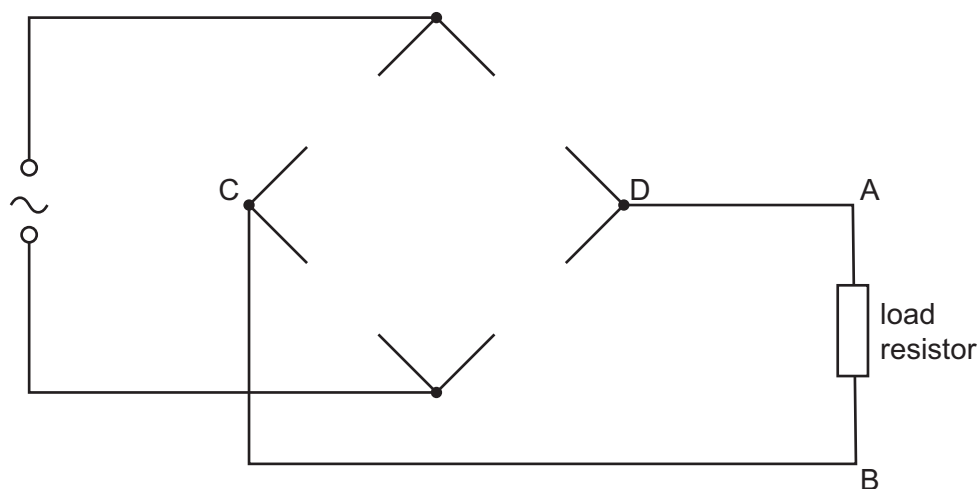


Fig. 8.1

- (a) Complete Fig. 8.1 for the bridge rectifier such that the point A is at a positive potential with respect to point B. [2]
- (b) The variation with time t of the potential difference (p.d.) V across the load resistor is shown in Fig. 8.2.

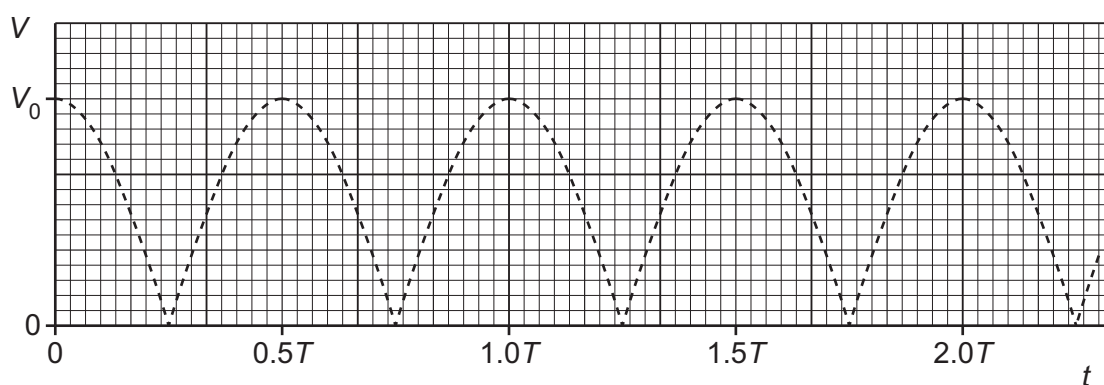


Fig. 8.2

A capacitor is now connected between points C and D of the bridge rectifier. This results in smoothing of the p.d. across the load resistor. The difference between the maximum and minimum values of the smoothed p.d. is 33% of the peak p.d. V_0 .

- (i) On Fig. 8.2, draw a line to show the variation of the potential difference V across the load resistor with time t . Your line should extend from $t = 0.5T$ to $t = 2.0T$. [3]



- (ii) Use your line in (b)(i) to determine, in terms of T , the time constant of the smoothing circuit.

time constant = ... T [3]

- (iii) The resistance of the load resistor is now increased. The capacitance of the capacitor is unchanged.

State and explain the effect of this change on the smoothed output p.d.

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

[Total: 10]



- 9 (a) (i) Describe what is meant by wave–particle duality.

.....

 [2]

- (ii) State the relationship between the de Broglie wavelength λ of a particle and its momentum p . State the meaning of any other symbols that you use.

.....
 [2]

- (b) A narrow beam of electrons, all with the same speed, is incident normally on a carbon film. The electrons then move on to a fluorescent screen, as illustrated in Fig. 9.1.

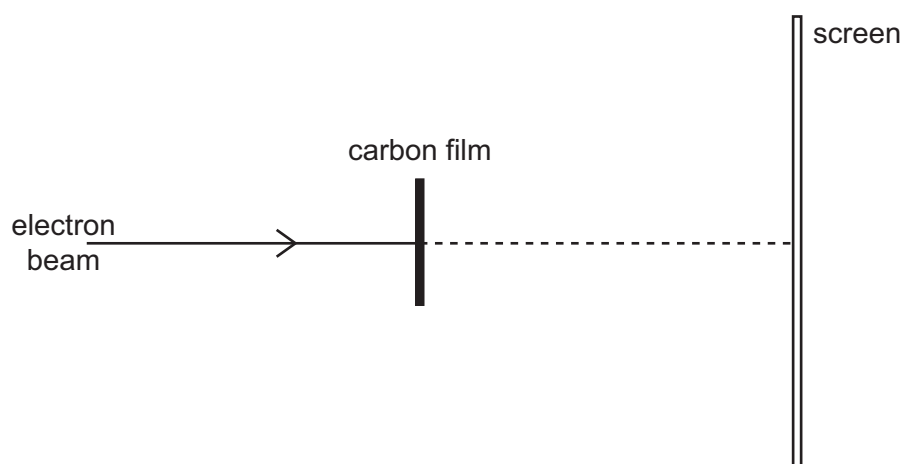


Fig. 9.1

The apparatus is in a vacuum.

The pattern produced on the screen is shown in Fig. 9.2.



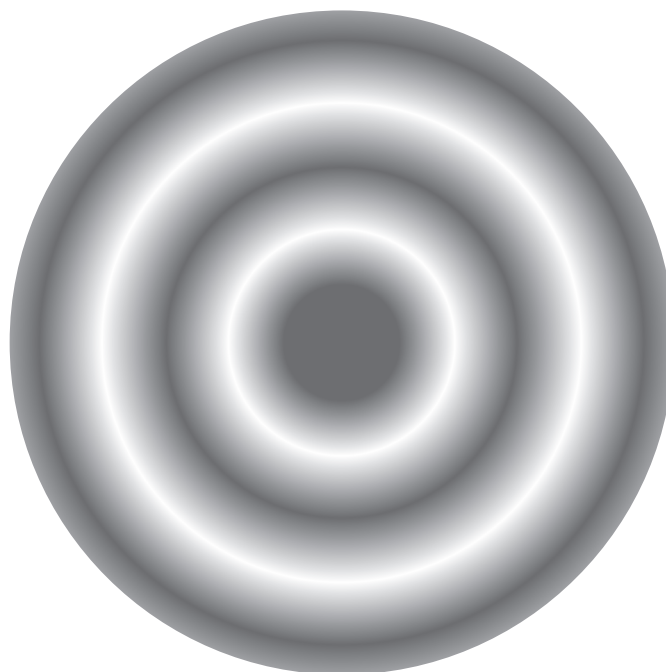


Fig. 9.2 (not to scale)

- (i) Explain why the pattern in Fig. 9.2 provides experimental evidence to indicate a wave nature for the electrons.

.....

.....

..... [2]

- (ii) The speed of the electrons is increased.

Suggest, with a reason, how this change affects the pattern observed on the screen.

.....

.....

..... [2]

[Total: 8]



- 10 (a) Describe how the piezoelectric crystal in a transducer generates ultrasound waves for use in medical diagnosis.

.....

.....

.....

.....

..... [3]

- (b) A parallel ultrasound beam is incident on the boundary between two media, as illustrated in Fig. 10.1.

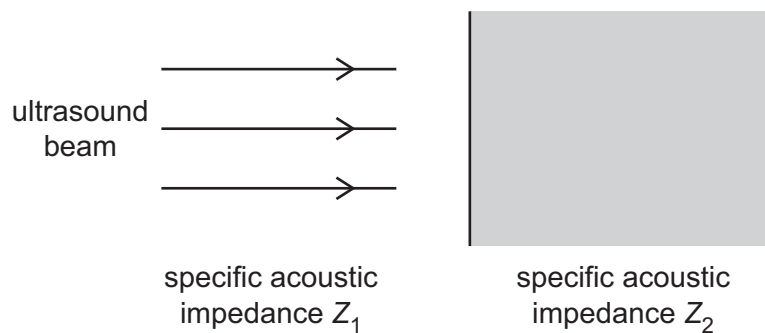


Fig. 10.1

The media have specific acoustic impedances Z_1 and Z_2 .

At the boundary, a fraction α of the incident intensity of the ultrasound beam is reflected. The remainder is transmitted.

- (i) State what is meant by specific acoustic impedance.

.....

.....

..... [2]

- (ii) Describe how α depends on the relative values of Z_1 and Z_2 .

.....

.....

.....

..... [2]



- (c) A parallel ultrasound beam of intensity I_0 enters a region of soft tissue. After passing a distance of 2.1 cm through this tissue, the intensity of the ultrasound is $0.62I_0$.

Calculate the linear attenuation coefficient μ of ultrasound in the soft tissue. Give a unit with your answer.

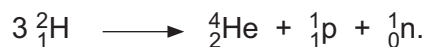
$\mu = \dots\dots\dots$ unit $\dots\dots\dots$ [2]

[Total: 9]





- 11 The deuterium nucleus (${}^2_1\text{H}$) has a mass defect of 0.002 388 u. The helium-4 nucleus (${}^4_2\text{He}$) has a mass defect of 0.030 377 u. Helium-4 is formed from deuterium in a nuclear reaction that can be represented by the equation



- (a) (i) State the name of this type of nuclear reaction.

..... [1]

- (ii) Show that the energy released when one nucleus of helium-4 is formed from deuterium is 3.47×10^{-12} J.

[3]

- (b) A star has a radius of 6.96×10^8 m. Helium-4 is produced in this star, from deuterium, at a mass rate of $7.34 \times 10^{11} \text{ kg s}^{-1}$. All the energy released from this process is radiated away from the star. All the energy that is radiated from the star is released by this process.

- (i) Calculate the luminosity of the star.

luminosity = ... W [3]

- (ii) Use your answer in (b)(i) to determine the surface temperature of the star.

temperature = ... K [2]

[Total: 9]





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