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Cambridge Assessment International Education

Cambridge International AS & A Level

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CENTRE NUMBER

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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.

DC (KAS) 357183

Data

acceleration of free fall	$g = 9.81\ \mathrm{m\,s^{-2}}$
speed of light in free space	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
unified atomic mass unit	$1\ \mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
molar gas constant	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ $\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}}\right)$
Planck constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$

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	$f_o = \dfrac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

gravitational potential	$\phi = -\dfrac{GM}{r}$
gravitational potential energy	$E_P = -\dfrac{GMm}{r}$
pressure of an ideal gas	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
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	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
electrical potential energy	$E_P = \dfrac{Qq}{4\pi\varepsilon_0 r}$
capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
discharge of a capacitor	$x = x_0 e^{-\frac{t}{RC}}$
Hall voltage	$V_H = \dfrac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 e^{-\lambda t}$
decay constant	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$
intensity reflection coefficient	$\dfrac{I_R}{I_0} = \dfrac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$
Stefan–Boltzmann law	$L = 4\pi\sigma r^2 T^4$
Doppler redshift	$\dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$

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 $3.99 \times 10^{14}\,\mathrm{m^3\,s^{-2}}$.

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

R = ... 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 = ... [1]

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

E_2 = ... [1]

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

E_3 = ... [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 1.6×10^5 Pa has a density of $1.9\,\mathrm{kg\,m^{-3}}$.

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

[3]

(ii) One molecule of the gas has a mass of 4.7×10^{-26} 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.

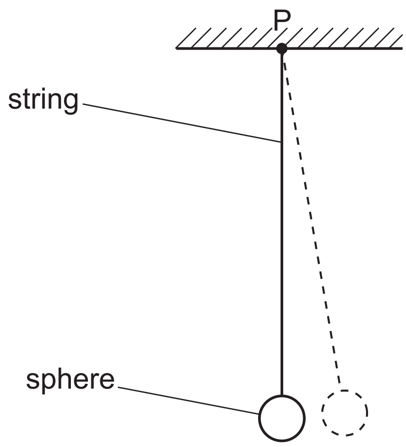

Fig. 4.1

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.

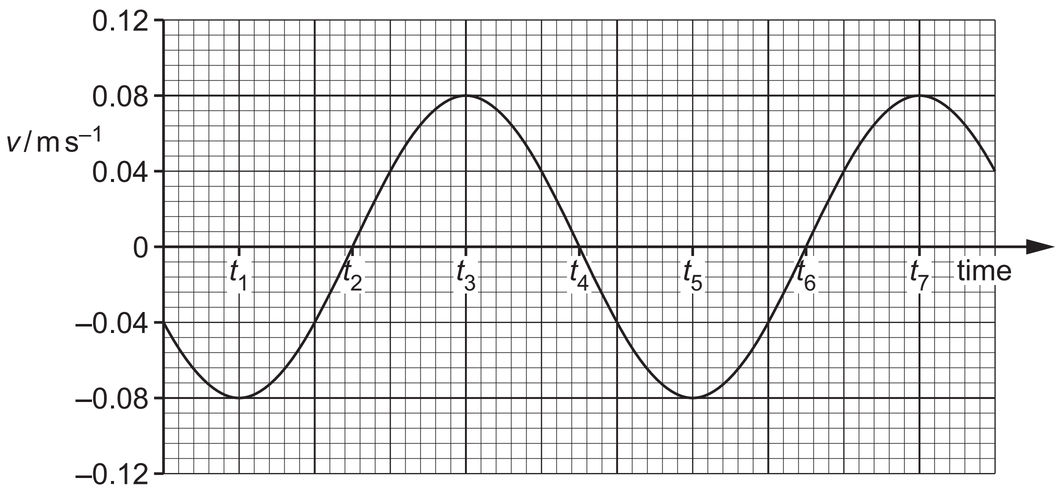

Fig. 4.2

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

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

electric field strength = ... $\mathrm{N\,C^{-1}}$ [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.

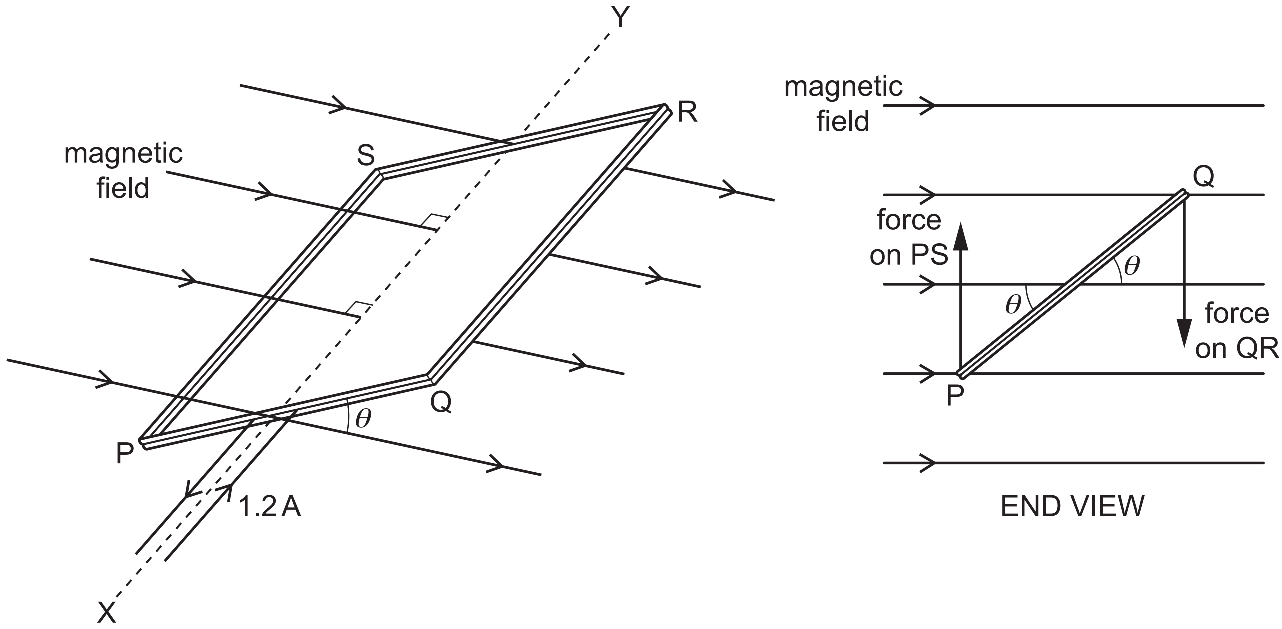

Fig. 6.1 (not to scale)

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 5.2×10^{-3} 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.

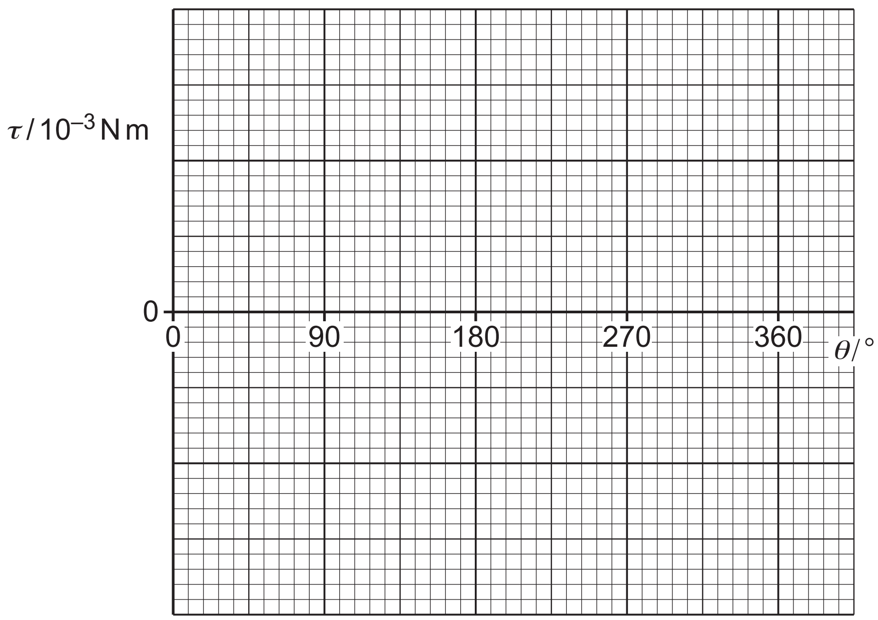

Fig. 6.2

[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.

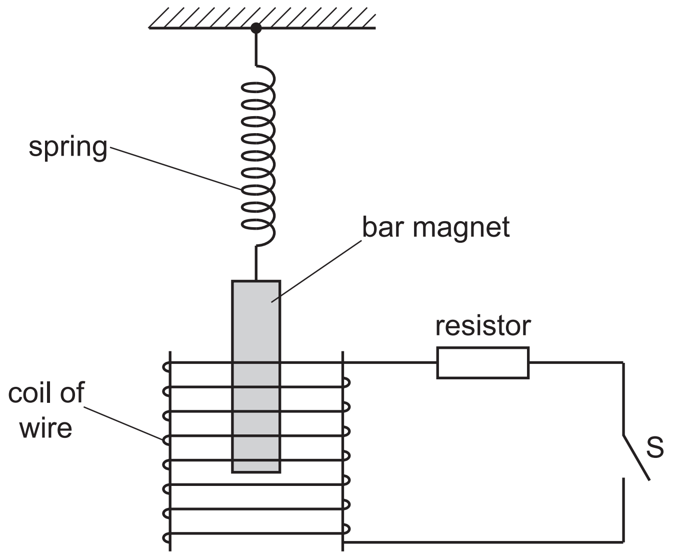

Fig. 7.1

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.

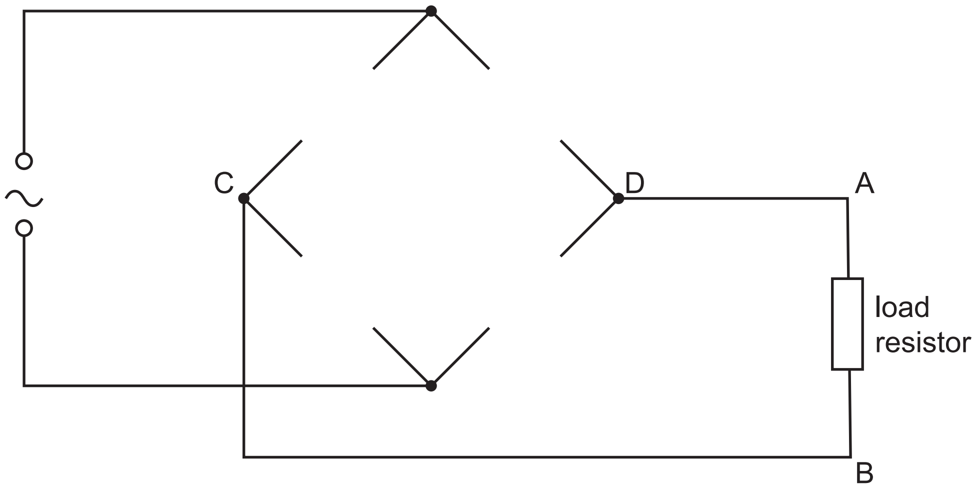

Fig. 8.1

(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.

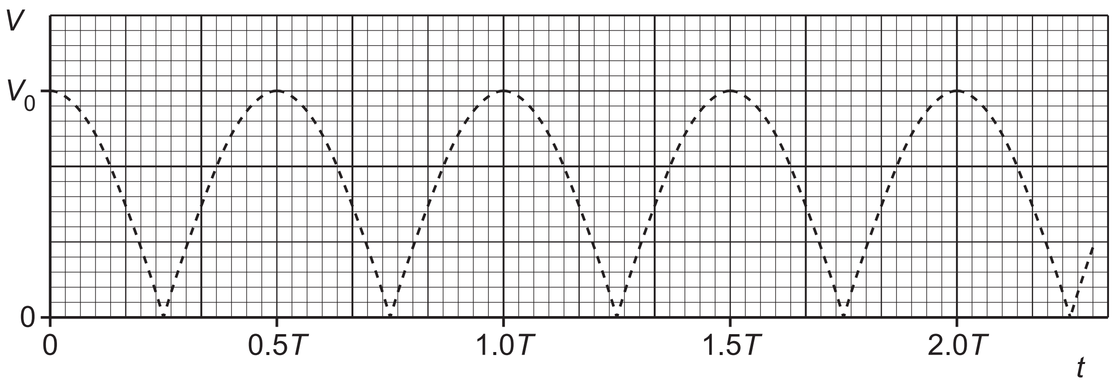

Fig. 8.2

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.

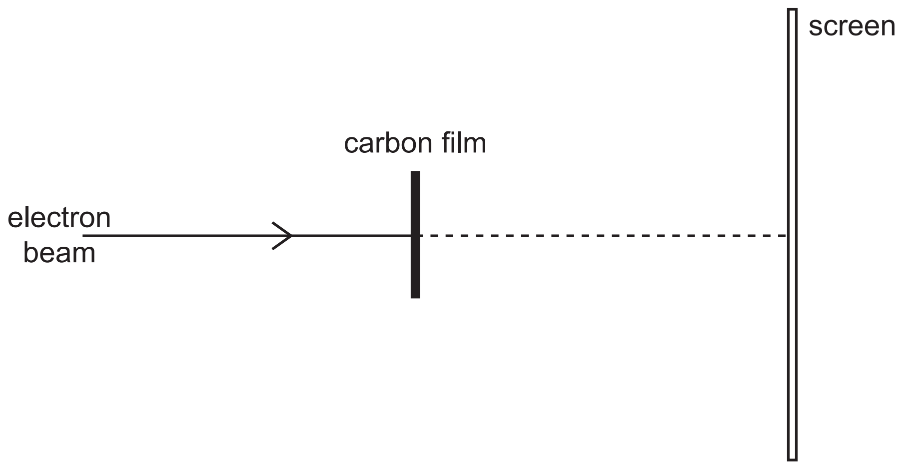

Fig. 9.1

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

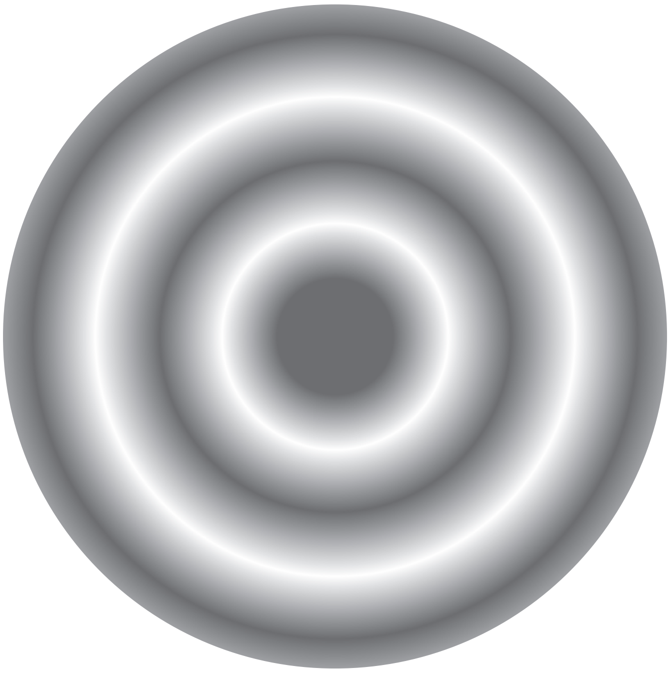

Fig. 9.2 (not to scale)

(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.

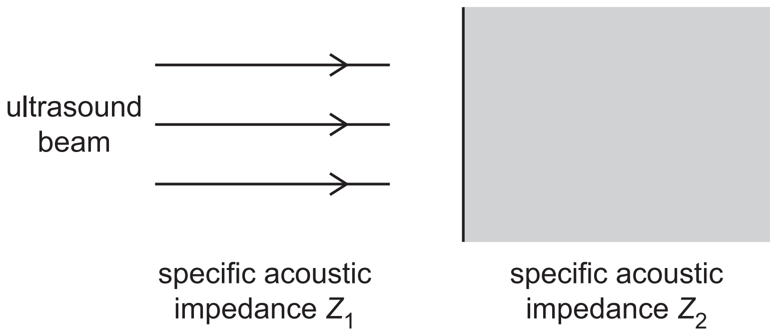

Fig. 10.1

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 $0.62\,I_0$.

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

μ = ... unit .... [2]

[Total: 9]

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11 The deuterium nucleus ($^{2}_{1}H$) has a mass defect of 0.002 388 u. The helium-4 nucleus ($^{4}_{2}He$) 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

$$3\,^{2}_{1}H \longrightarrow \,^{4}_{2}He + \,^{1}_{1}p + \,^{1}_{0}n.$$

(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 7.34×10^{11} 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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