Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6396939581

PHYSICS **9702/43**

Paper 4 A Level Structured Questions **May/June 2023**

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	$g = 9.81\ \mathrm{m\,s^{-2}}$
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	$m_\mathrm{p} = 1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	$m_\mathrm{e} = 9.11 \times 10^{-31}\ \mathrm{kg}$
Avogadro constant	$N_\mathrm{A} = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
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	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$ $(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
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	$f_\mathrm{o} = \dfrac{f_\mathrm{s} v}{v \pm v_\mathrm{s}}$
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) (i) Define gravitational field.

....

.... [1]

(ii) Define electric field.

....

.... [1]

(iii) State **one** similarity and **one** difference between the gravitational potential due to a point mass and the electric potential due to a point charge.

similarity: ....

....

difference: ....

....
[2]

(b) An isolated uniform conducting sphere has mass M and charge Q.
The gravitational field strength at the surface of the sphere is g.
The electric field strength at the surface of the sphere is E.

(i) Show that

$$\frac{M}{Q} = \alpha \frac{g}{E}$$

where α is a constant.

[3]

(ii) Show that the numerical value of α is $1.35 \times 10^{20}\,\mathrm{kg^2\,C^{-2}}$.

[1]

(c) Assume that the Earth is a uniform conducting sphere of mass 5.98×10^{24} kg.
The surface of the Earth carries a charge of -4.80×10^{5} C that is evenly distributed.

(i) Use the information in **(b)** to determine the electric field strength at the surface of the Earth. Give a unit with your answer.

electric field strength = ... unit .... [2]

(ii) State how the direction of the electric field at the surface of the Earth compares with the direction of the gravitational field.

.... [1]

[Total: 11]

2 A steel sphere of mass 0.29 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 2.1.

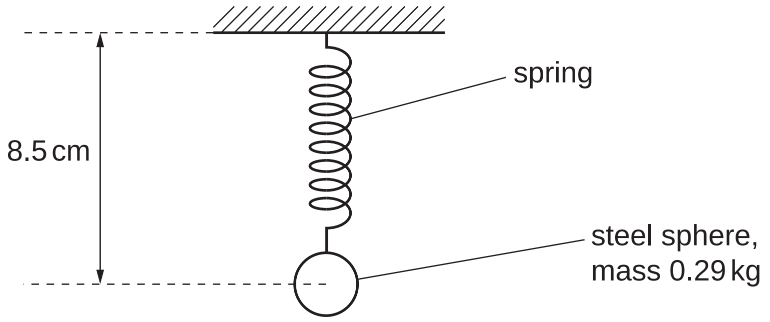

Fig. 2.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 2.2.

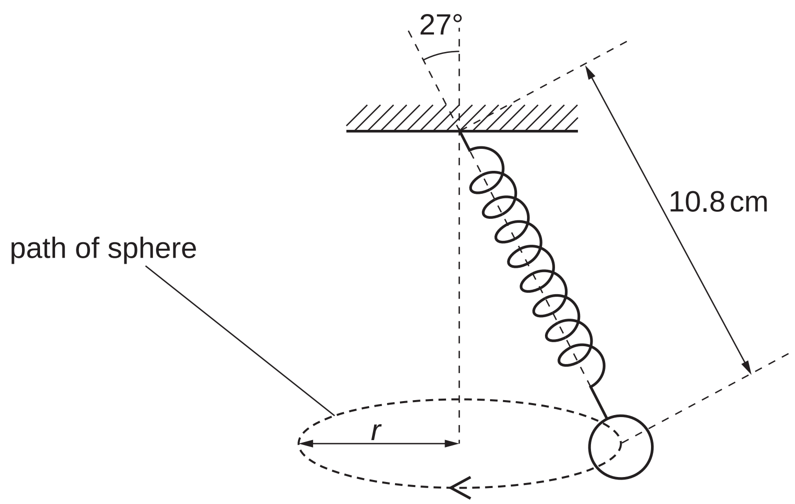

Fig. 2.2

The distance from the centre of the sphere to the top of the spring is now 10.8 cm.

(a) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 2.2 is greater than in Fig. 2.1.

....

....

....

....

.... [3]

(b) The angle between the linear axis of the spring and the vertical is 27°.

(i) Show that the radius r of the circle is 4.9 cm.

[1]

(ii) Show that the tension in the spring is 3.2 N.

[2]

(iii) The spring obeys Hooke's law.

Calculate the spring constant, in $N\,cm^{-1}$, of the spring.

spring constant = ... $N\,cm^{-1}$ [2]

(c) **(i)** Use the information in **(b)** to determine the centripetal acceleration of the sphere.

centripetal acceleration = ... $m\,s^{-2}$ [2]

(ii) Calculate the period of the circular motion of the sphere.

period = ... s [2]

[Total: 12]

3 **(a)** State the reason why two objects that are at the same temperature are described as being in thermal equilibrium.

....

.... [1]

(b) Fig. 3.1 shows the variations with temperature of the densities of mercury and of water between 0 °C and 100 °C.

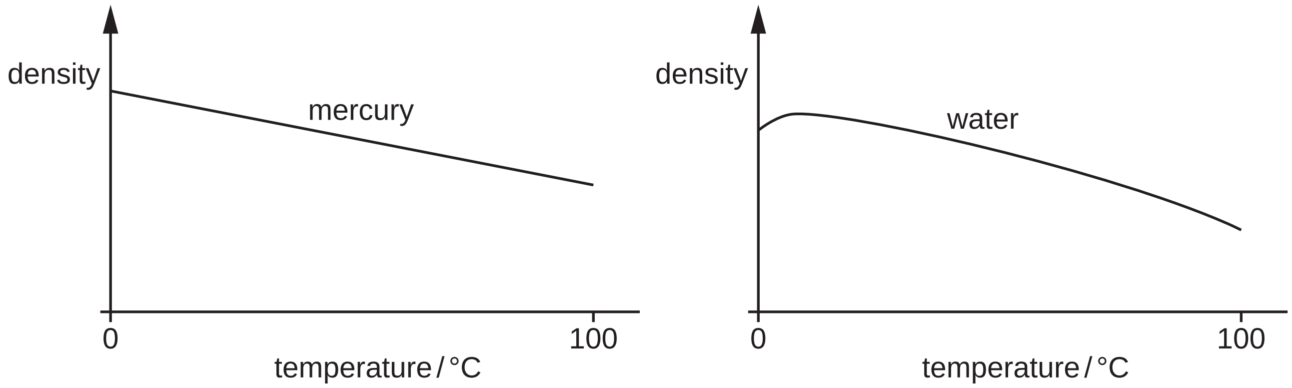

Fig. 3.1

Temperature may be measured using the variation with temperature of the density of a liquid.

Suggest why, for measuring temperature over this temperature range:

(i) mercury is a suitable liquid

....

.... [1]

(ii) water is not a suitable liquid.

....

....

.... [2]

(c) A beaker contains a liquid of mass 120 g. The liquid is supplied with thermal energy at a rate of 810 W. The beaker has a mass of 42 g and a specific heat capacity of 0.84 $\mathrm{J\,g^{-1}\,K^{-1}}$. The beaker and the liquid are in thermal equilibrium with each other at all times and are insulated from the surroundings.

Fig. 3.2 shows the variation with time *t* of the temperature of the liquid.

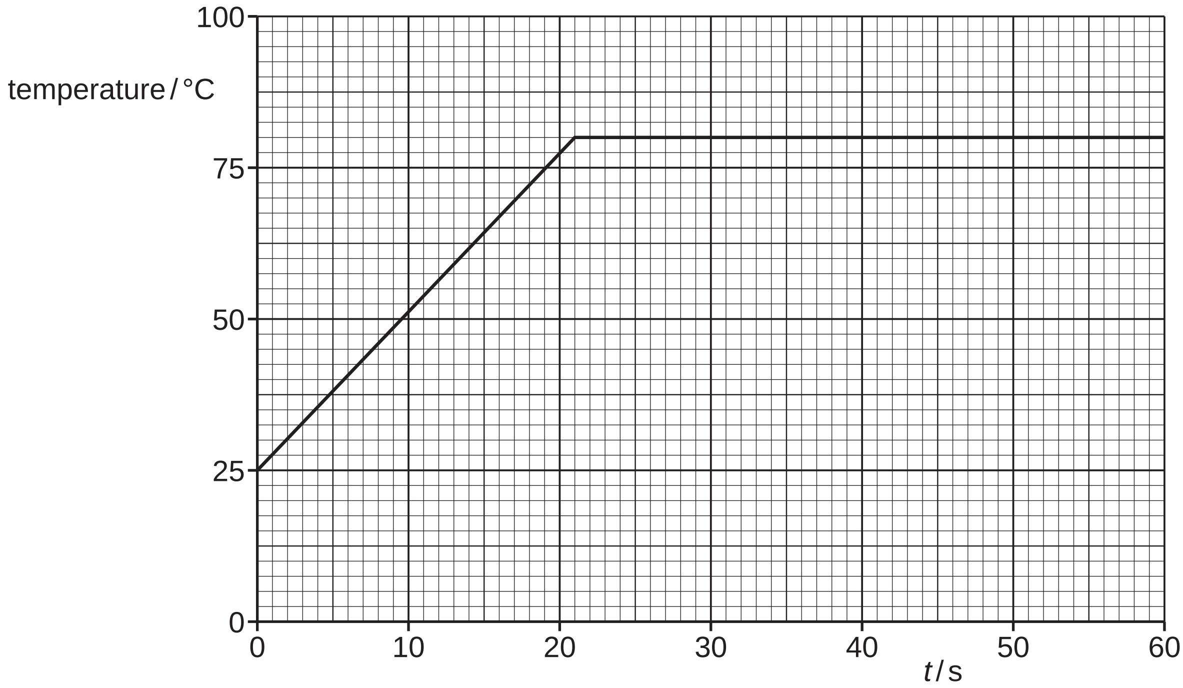

Fig. 3.2

(i) State the boiling temperature, in °C, of the liquid.

temperature = ... °C [1]

(ii) Determine the specific heat capacity, in $J\,g^{-1}\,K^{-1}$, of the liquid.

specific heat capacity = ... $J\,g^{-1}\,K^{-1}$ [4]

(d) The experiment in **(c)** is repeated using water instead of the liquid in **(c)**. The mass of liquid used, the power supplied, and the initial temperature are all unchanged.
The specific heat capacity of water is approximately twice that of the liquid in **(c)**.
The boiling temperature of water is 100 °C.

On Fig. 3.2, sketch the variation with time t of the temperature of the water between $t = 0$ and $t = 60\,s$. Numerical calculations are not required. [2]

[Total: 11]

4 **(a)** State **two** of the basic assumptions of the kinetic theory of gases.

1 ....

....

2 ....

....
[2]

(b) An ideal gas has amount of substance n.
The gas is initially in state X, with pressure $2p$ and volume V.
The gas is cooled at constant volume to state Y, with pressure p.
The gas is then heated at constant pressure to state Z, with volume $2V$.
Finally, the gas returns at constant temperature to state X.

(i) Determine an expression for the temperature T of the gas in state X, in terms of n, p and V.
Identify any other symbols that you use.

[2]

(ii) On Fig. 4.1, sketch the variation with volume of pressure for the gas as the gas undergoes the three changes. The state X is labelled. Label states Y and Z.

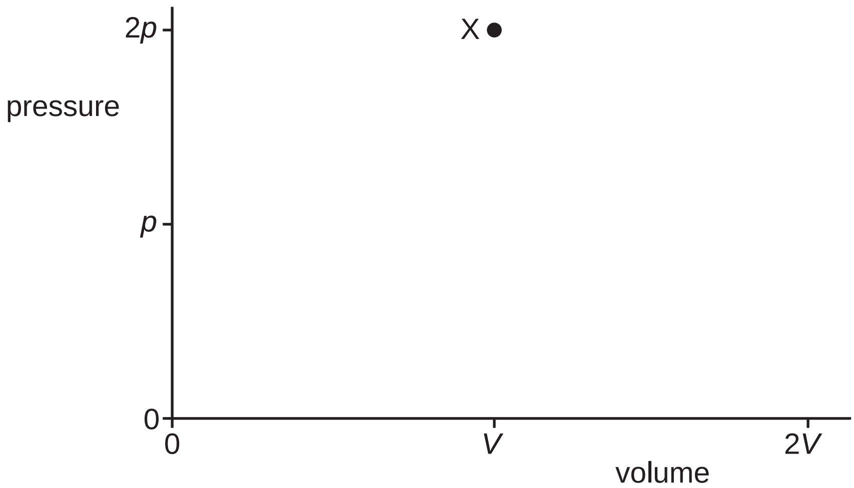

Fig. 4.1

[3]

(iii) During the change of state from Y to Z, the increase in internal energy of the gas is U. During the change of state from Z to X, the work done on the gas is W.

Complete Table 4.1 to indicate, for each of the three changes of state, the increase in internal energy of the gas, the thermal energy transferred to the gas and the work done on the gas, in terms of p, V, U and W.

Table 4.1

change	increase in internal energy of gas	thermal energy transferred to gas	work done on gas
X to Y			
Y to Z	$+U$		
Z to X			$+W$

[5]

[Total: 12]

5 Part of an electric circuit is shown in Fig. 5.1.

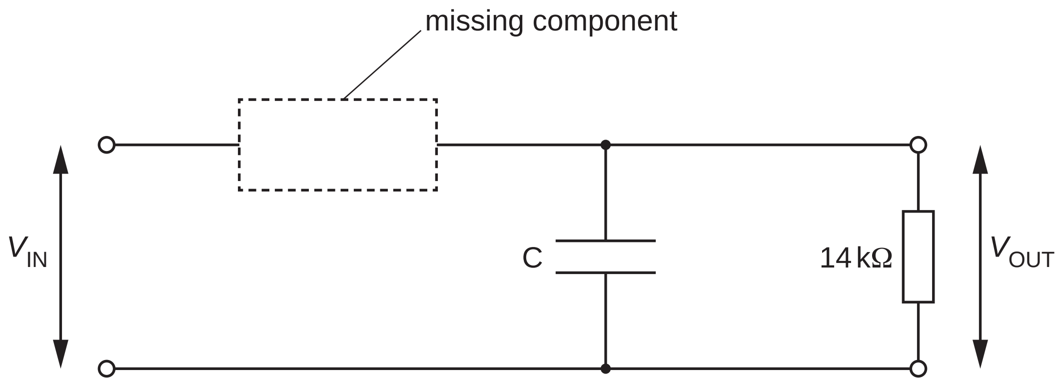

Fig. 5.1

The circuit is used to produce half-wave rectification of an alternating voltage of potential difference (p.d.) V_{IN}.

The output p.d. across the 14 kΩ resistor is V_{OUT}.

(a) **(i)** A component is missing from the circuit of Fig. 5.1.

Complete the circuit diagram in Fig. 5.1 by adding the circuit symbol for the missing component, correctly connected. [1]

(ii) A capacitor C is shown in the circuit of Fig. 5.1.

State the effect on V_{OUT} of including the capacitor in the circuit.

.... [1]

(b) Fig. 5.2 shows the variation with time t of V_{IN}.

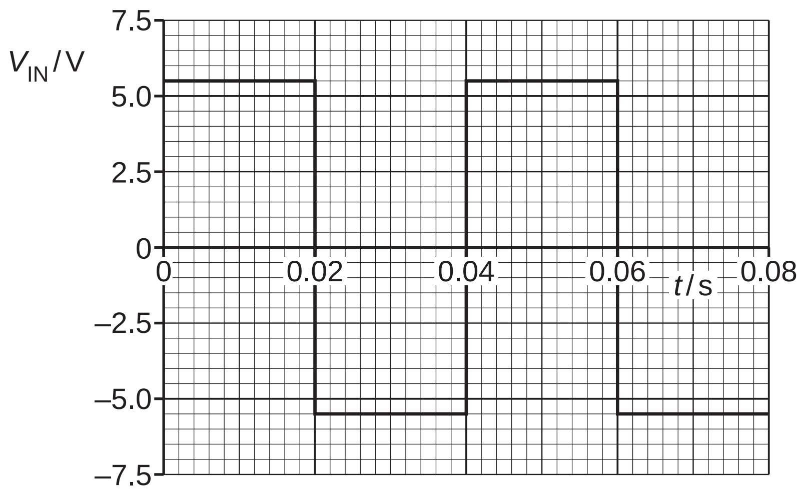

Fig. 5.2

Fig. 5.3 shows the variation with t of V_{OUT}.

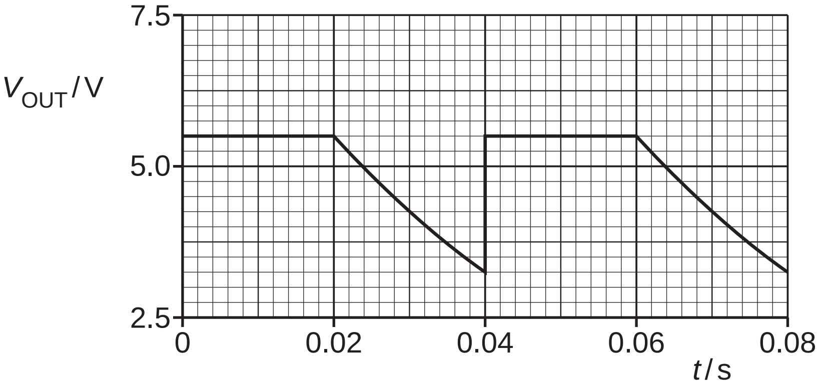

Fig. 5.3

(i) Determine the frequency of V_{IN}.

frequency = ... Hz [1]

(ii) Show that the time constant τ for the discharge of the capacitor through the resistor is 0.038 s.

[2]

(iii) Calculate the capacitance of C. Give a unit with your answer.

capacitance = ... unit .... [2]

(c) The circuit of Fig. 5.1 is modified so that it produces full-wave rectification of an input voltage.

Suggest, with a reason, how V_{OUT} now varies with time when V_{IN} is as shown in Fig. 5.2.

....

....

.... [2]

[Total: 9]

6 **(a)** State what is meant by a magnetic field.

....

....

.... [2]

(b) A long, straight wire P carries a current into the page, as shown in Fig. 6.1.

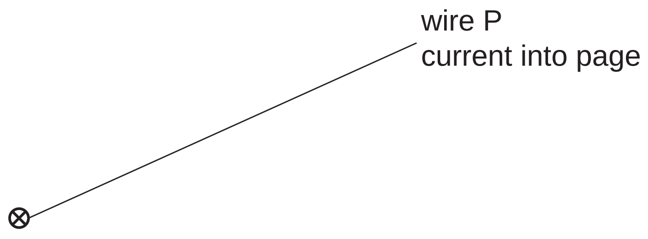

Fig. 6.1

On Fig. 6.1, draw four field lines to represent the magnetic field around wire P due to the current in the wire. [3]

(c) A second long, straight wire Q, carrying a current of 5.0 A out of the page, is placed parallel to wire P, as shown in Fig. 6.2.

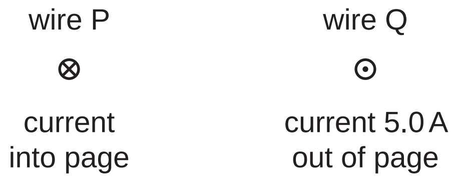

Fig. 6.2

The flux density of the magnetic field at wire Q due to the current in wire P is 2.6 mT.

(i) Calculate the magnetic force per unit length exerted on wire Q by wire P.

force per unit length = ... $N m^{-1}$ [2]

(ii) State the direction of the force exerted on wire Q by wire P.

.... [1]

(iii) The flux density of the magnetic field at wire P due to the current in wire Q is 1.5 mT.

Determine the magnitude of the current in wire P. Explain your reasoning.

current = ... A [2]

[Total: 10]

7 **(a)** State what is meant by the de Broglie wavelength.

....

.... [1]

(b) Fig. 7.1 shows a glass tube in which electrons are accelerated through a high p.d. to form a beam that is incident on a thin graphite crystal.

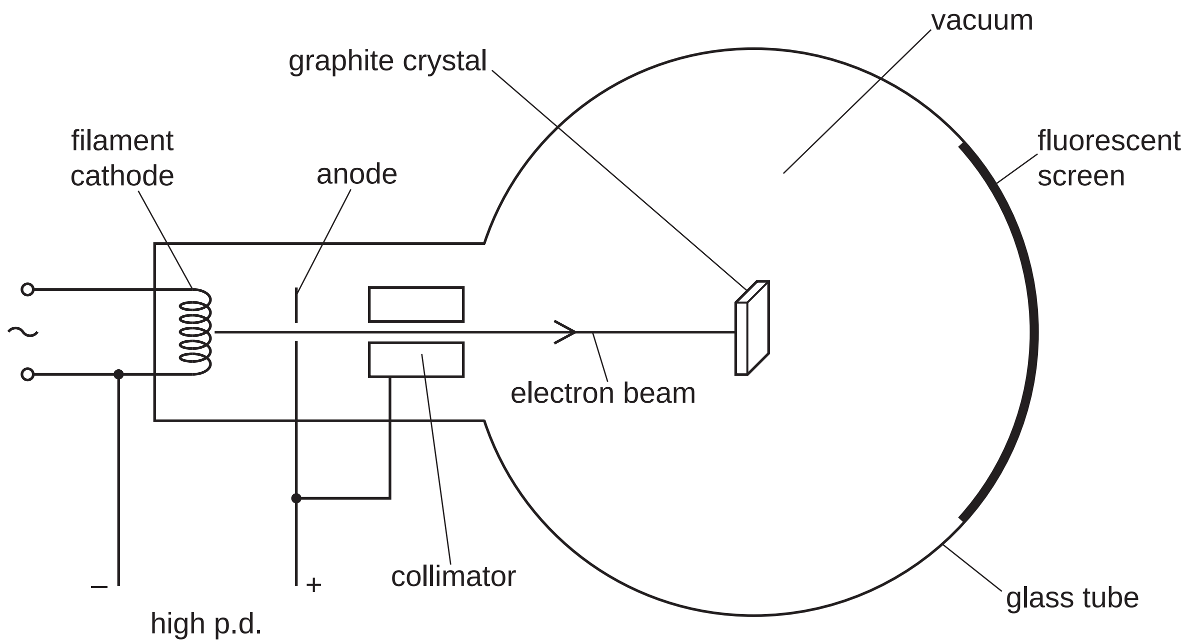

Fig. 7.1 (not to scale)

After passing through the graphite crystal, the electrons reach the fluorescent screen. The screen glows where the electrons strike it.

Fig. 7.2 shows the fluorescent screen viewed end-on, from the right-hand side of Fig. 7.1.

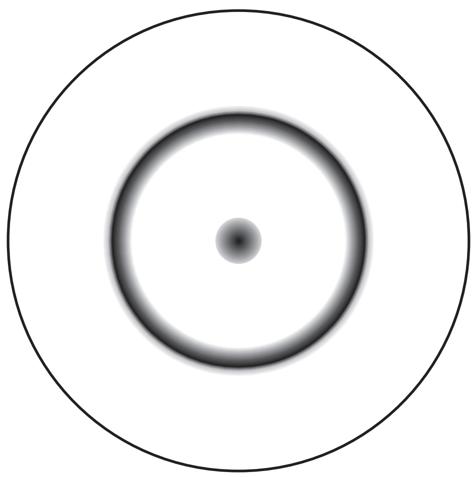

Fig. 7.2

(i) State the name of the phenomenon demonstrated by the pattern shown in Fig. 7.2.

.... [1]

(ii) Explain what can be concluded from the pattern in Fig. 7.2 about the nature of electrons.

....

....

.... [2]

(c) The electrons in **(b)** are now accelerated through a greater potential difference between the cathode and the anode.

(i) On Fig. 7.3, sketch the pattern that is now seen on the fluorescent screen in Fig. 7.1.

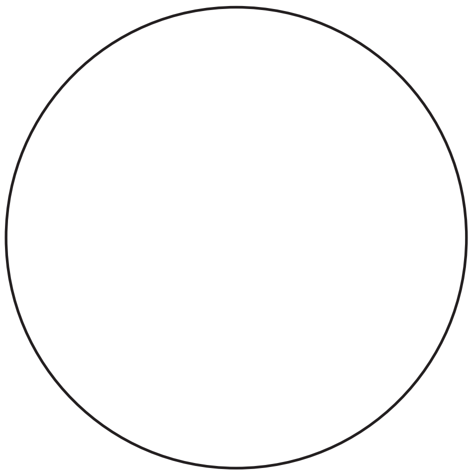

Fig. 7.3

[2]

(ii) Explain, with reference to de Broglie wavelength, the change in the pattern on the fluorescent screen.

....

....

....

....

.... [3]

[Total: 9]

8 **(a)** Table 8.1 shows some data relating to the properties of air, gel and body tissue. The data are given to three significant figures.

Table 8.1

material	density / $kg\,m^{-3}$	speed of sound / $m\,s^{-1}$	specific acoustic impedance / $kg\,m^{-2}\,s^{-1}$
air		340	440
gel	1200	1400	
tissue	1090		1.68×10^6

(i) Show that the specific acoustic impedance of gel is $1.68 \times 10^6\,kg\,m^{-2}\,s^{-1}$.

[1]

(ii) Complete Table 8.1 by calculating the missing values to three significant figures. Use the space below for any working that you need.

[2]

(b) Use the information in **(a)** to calculate the intensity reflection coefficient for:

(i) an air–tissue boundary

intensity reflection coefficient = ... [2]

(ii) a gel–tissue boundary.

intensity reflection coefficient = ... [1]

(c) Use your answers in **(b)** to explain why gel is applied to the skin during ultrasound scanning.

....

....

.... [2]

[Total: 8]

9 Carbon-11 is radioactive and decays by β^+ emission to form boron-11. Carbon-11 has a half-life of 20 minutes. Boron-11 is stable.

(a) Define half-life.

....

.... [1]

(b) A sample contains N_0 nuclei of carbon-11 and no other nuclei at time $t = 0$.

On Fig. 9.1, sketch the variation with t of the number of nuclei of **boron-11** in the sample.

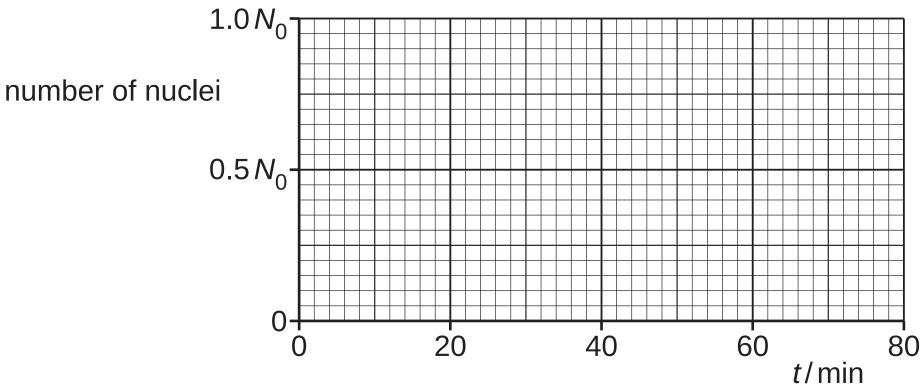

Fig. 9.1

[3]

(c) (i) Explain, with reference to the random nature of radioactive decay, why the activity of the carbon-11 sample in **(b)** decreases with time.

....

....

.... [2]

(ii) State, with reasons, whether a radiation detector placed near to the sample of carbon-11 indicates a measured count rate from the sample that is less than, the same as or greater than the activity of the sample.

....

....

....

....

.... [3]

[Total: 9]

10 **(a)** State Hubble's law. Identify any symbols that you use.

....

....

....

.... [2]

(b) A star of luminosity 3.8×10^{31} W is a distance of 1.8×10^{24} m from the Earth.

Calculate the radiant flux intensity at the Earth of the radiation emitted by the star.

radiant flux intensity = ... $\mathrm{W\,m^{-2}}$ [2]

(c) The star in **(b)** is in a distant galaxy. A spectral line in the light from this galaxy is known to have a wavelength of 486 nm. This spectral line in the light from the galaxy observed on the Earth has a wavelength of 492 nm.

(i) Explain why the wavelength observed on the Earth is different from the wavelength that the galaxy is known to have emitted.

....

....

.... [2]

(ii) Determine a value for the Hubble constant H_0.

H_0 = ... $\mathrm{s^{-1}}$ [3]

[Total: 9]

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