H2

MINISTRY OF EDUCATION, SINGAPORE
in collaboration with
CAMBRIDGE INTERNATIONAL EDUCATION
General Certificate of Education Advanced Level

CANDIDATE NAME	

CENTRE NUMBER	S					INDEX NUMBER					

0123456789

PHYSICS **9478/03**

Paper 3 Longer Structured Questions **For examination from 2026**

SPECIMEN PAPER **2 hours**

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Section A: answer **all** questions.
- Section B: answer **one** question.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and index 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. Do **not** use correction fluid or tape.
- Do **not** write on any bar codes.
- You may use an approved calculator.

INFORMATION

- The total mark for this paper is 75.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **24** pages.

Singapore Examinations and Assessment Board

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}}\right)$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_\mathrm{e} = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_\mathrm{p} = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro constant	$N_\mathrm{A} = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
pressure	$p = \frac{F}{A}$
gravitational potential	$\phi = -\frac{GM}{r}$
temperature	$T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas particle	$E = \frac{3}{2}kT$

displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t = \pm \omega \sqrt{(x_0^2 - x^2)}$
electric current	$I = nAvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$
capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy in a capacitor	$U = \dfrac{1}{2}QV = \dfrac{1}{2}\dfrac{Q^2}{C} = \dfrac{1}{2}CV^2$
charging a capacitor	$Q = Q_0\left[1 - e^{-\frac{t}{\tau}}\right]$
discharging a capacitor	$Q = Q_0\, e^{-\frac{t}{\tau}}$
RC time constant	$\tau = RC$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
energy states for quantum particle in a box	$E_n = \dfrac{h^2}{8mL^2}n^2$
radioactive decay	$x = x_0 e^{-\lambda t}$
radioactive decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in this Section in the spaces provided.

1 A car has a mass of 1250 kg.

The variation with speed v of the driving force F_D on the car is shown in Figure 1.1. The variation with speed v of the resistive force F_R opposing the motion of the car is shown on the same axes.

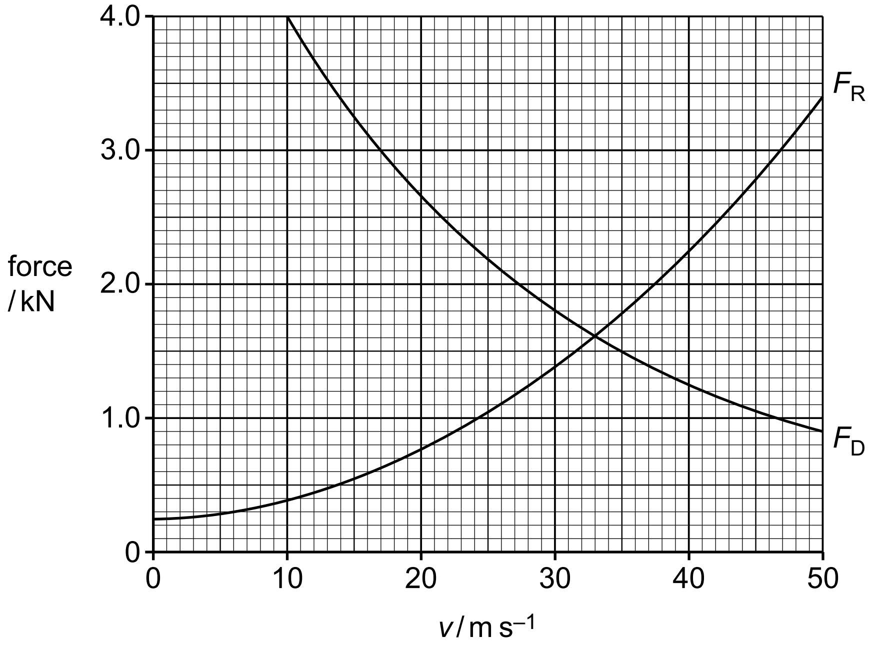

Figure 1.1

The resistive force F_R, in newtons, acting on the car at speed v is given by the equation:

$$F_R = A + 1.25v^2$$

where A is a constant and v is measured in m s^{-1}.

(a) The car accelerates from rest along a straight horizontal road until it reaches its maximum possible speed.

Use Figure 1.1 to determine:

(i) the value of the constant A

A = ... kN [1]

(ii) the maximum speed of the car. Explain your answer.

maximum speed = ... m s^{-1}

explanation ....

....

[2]

(iii) the total power output of the car at the maximum speed

power = ... W [2]

(iv) the acceleration of the car when it is travelling at 20 m s^{-1}.

acceleration = ... m s^{-2} [3]

(b) The car now travels in a straight line down a constant slope at an angle of 4.7° to the horizontal.

Determine the new maximum possible speed of the car.

maximum speed = ... m s^{-1} [3]

[Total: 11]

2 The mass M of a spherical planet may be assumed to be a point mass at the centre of the planet. The planet has no atmosphere and is isolated in space.

(a) By considering energy transfers, show that the escape velocity v of the planet is given by:

$$v = \sqrt{\frac{2GM}{R}}$$

where G is the gravitational constant and R is the radius of the planet.

Explain your working.

[3]

(b) The mass M of the planet is 6.0×10^{24} kg and the escape velocity v is $11\ \text{km s}^{-1}$.

Calculate the average density of the material from which the planet is made.

density = ... kg m^{-3} [3]

(c) Two stones, A and B, are launched from a point just above the planet's surface, each with speed $v = 11\,\text{km s}^{-1}$.

Stone A is launched vertically upwards, and stone B is launched horizontally.

State **one** similarity and **one** difference in the subsequent motion of the stones.

similarity ....

....

difference ....

....

[2]

[Total: 8]

3 **(a)** A cube of volume V contains N particles of an ideal gas. Each particle has a component c_x of velocity normal to side S of the cube, as illustrated in Figure 3.1.

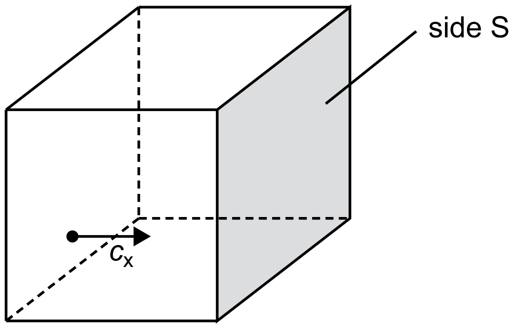

Figure 3.1

The pressure p of the gas due to component c_x of velocity is given by the relation:

$$pV = Nm\langle c_x^2\rangle$$

where m is the mass of a particle.

Explain how this relation leads to:

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

where $\langle c^2\rangle$ is the mean square speed of the particles.

[3]

(b) Neon gas behaves as an ideal gas.

A mass of 20.2 g of neon gas occupies a volume of $2.24 \times 10^4\,\text{cm}^3$ at a pressure of $1.01 \times 10^5\,\text{Pa}$ and a temperature of 273 K.

Deduce the root-mean-square (r.m.s.) speed of neon atoms at a temperature of:

(i) 273 K

r.m.s. speed = ... m s^{-1} [3]

(ii) 27.0 °C.

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

[Total: 8]

4 **(a)** Define capacitance.

....

.... [1]

(b) A capacitor is connected in a circuit used for a flash camera as shown in Figure 4.1.

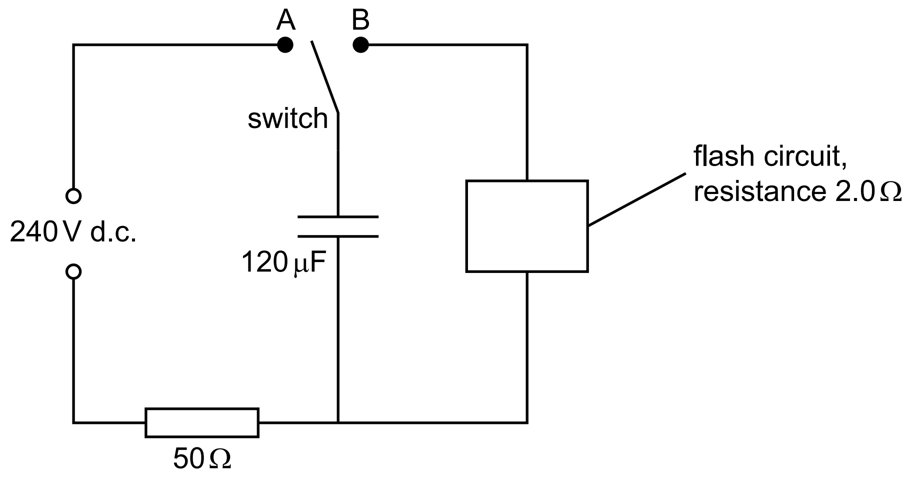

Figure 4.1

(i) When the switch is connected to terminal A, the capacitor charges.

The switch automatically connects to terminal B when the charge in the capacitor reaches 95% of its maximum possible charge at this voltage.

Calculate the time taken for the capacitor to reach 95% of its maximum charge.

time taken = ... s [3]

(ii) The capacitor now discharges through the flash circuit.

Calculate the maximum amount of energy that the capacitor can deliver to the flash circuit.

energy = ... J [3]

[Total: 7]

5 Light of wavelength 590 nm passes through a rectangular slit of width 0.20 mm. The light is observed on a screen placed 0.75 m from the slit, as illustrated in Figure 5.1.

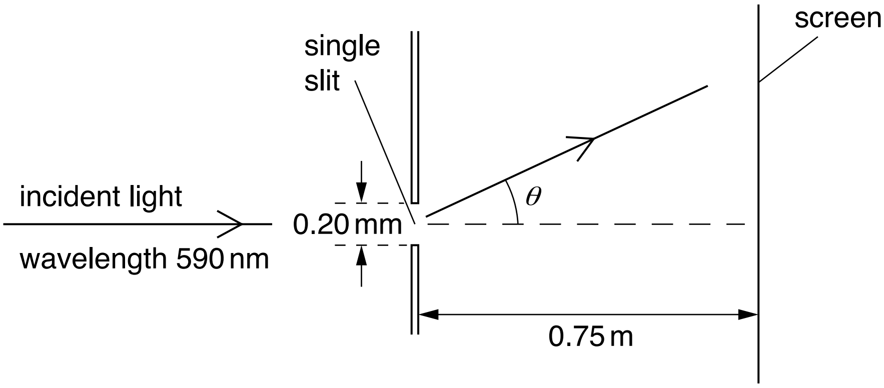

Figure 5.1

Light passing through the slit is diffracted through an angle θ.

The variation of the intensity I of the light with the angle θ of diffraction is shown in Figure 5.2.

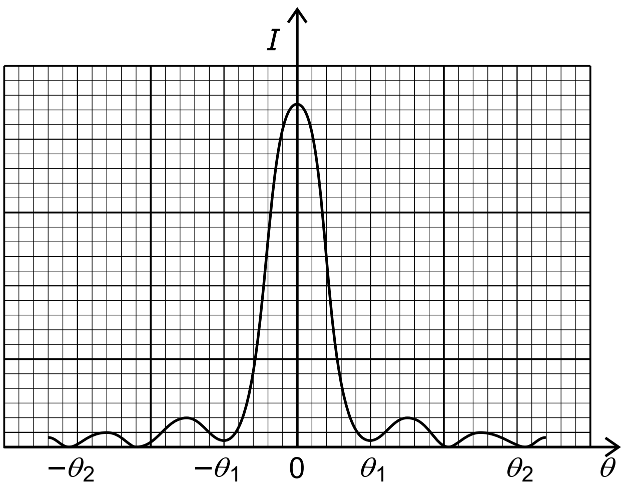

Figure 5.2

(a) By reference to Figure 5.2, determine the magnitude of:

(i) the angle θ_1

θ_1 = ... rad [2]

(ii) the angle θ_2.

θ_2 = ... rad [1]

(b) Calculate the width, in mm, of the central maximum of the diffraction pattern.

width = ... mm [2]

(c) Determine the angle between two beams of light, each of wavelength 590 nm, incident on the slit such that their diffraction patterns are just resolved.

Explain your working.

angle = ... rad [2]

[Total: 7]

6 **(a)** Explain the use of a uniform electric field and a uniform magnetic field for the selection of the velocity of a charged particle. You may draw a diagram if you wish.

....

....

....

.... [3]

(b) Ions, all of the same element, are travelling in a vacuum with a speed of 9.6×10^4 m s^{-1}. The ions are incident normally on a uniform magnetic field of magnetic flux density 320 mT. The ions follow semicircular paths A and B before reaching a sensor, as shown in Figure 6.1.

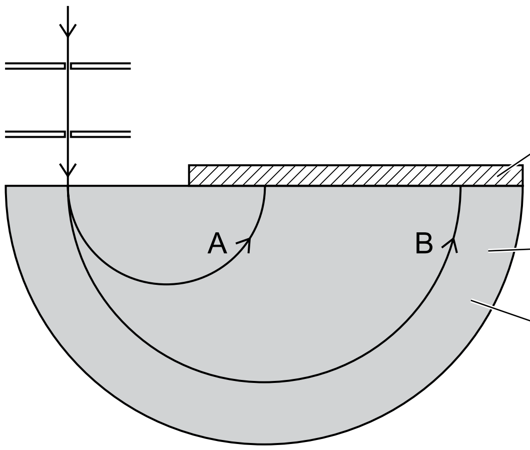

Figure 6.1

Data for the diameters of the paths are shown in Table 6.1.

Table 6.1

path	diameter / cm
A	6.2
B	12.4

The ions in path B each have charge $+1.6 \times 10^{-19}$ C.

(i) Determine the mass of the ions in path B.

mass = ... kg [3]

(ii) Suggest and explain reasons for the difference in radii of the paths A and B of the ions.

....

....

....

.... [3]

[Total: 9]

7 Light of wavelength 430 nm is incident normally on a surface, as illustrated in Figure 7.1.

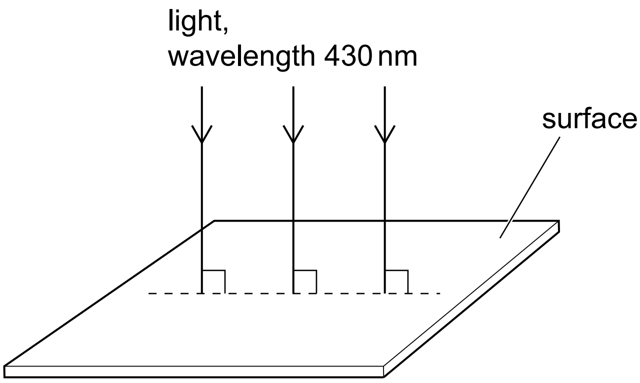

Figure 7.1

The power of the light is 3.2 mW. The light is completely absorbed by the surface.

(a) Calculate the number of photons incident on the surface in 1.00 s.

number = ... [3]

(b) Use your answer in **7(a)** to determine the total momentum of the photons arriving on the surface in 1.00 s.

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

[Total: 5]

Turn over

Section B

Answer **one** question in this section in the spaces provided.

8 **(a)** State what is meant by simple harmonic motion.

....

....

.... [2]

(b) A spring hangs vertically from an oscillator. A copper plate is attached to the free end of the spring, as illustrated in Figure 8.1.

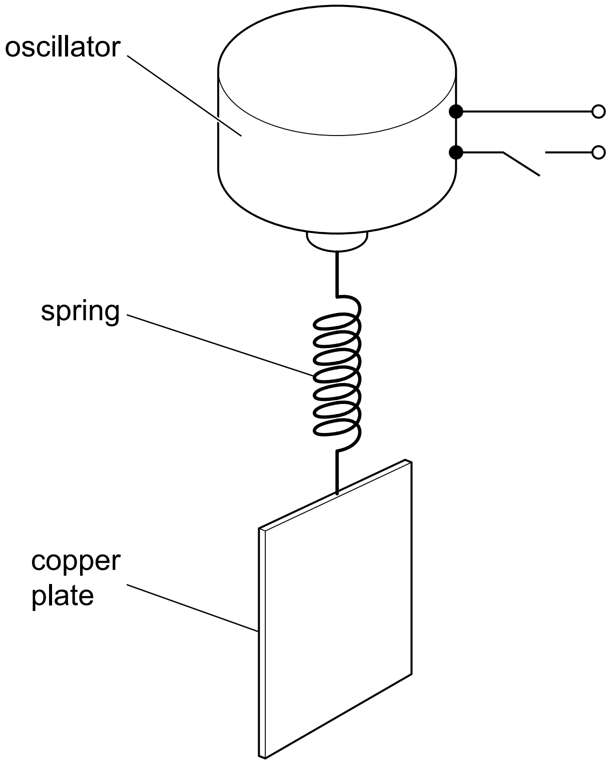

Figure 8.1

The oscillator is switched off.

The copper plate is displaced vertically and then released. The variation with time t of the vertical displacement y of the plate is shown in Figure 8.2.

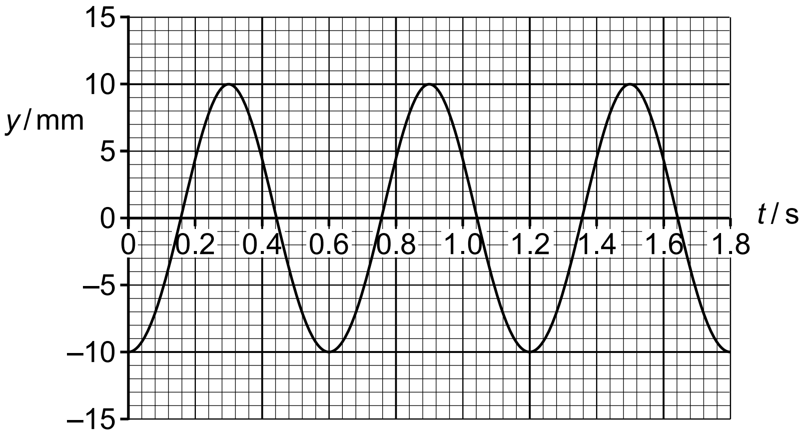

Figure 8.2

The copper plate undergoes simple harmonic motion with frequency *f*.

The mass *m* of the oscillating copper plate is 320 g.

(i) Determine the frequency *f* of oscillation.

f = ... Hz [1]

(ii) Show that the total energy E_T of the oscillations is given by:

$$E_T = 2\pi^2 m f^2 {y_0}^2$$

where y_0 is the amplitude of vibration of the plate.

[2]

(iii) Use the expression in **8(b)(ii)** to calculate the total energy of an oscillation.

energy = ... J [2]

(c) The oscillator is now switched on. The oscillator produces vertical vibrations of constant amplitude but with a frequency that can be varied.

The variation with frequency f of the amplitude y_0 of the oscillations of the plate is shown in Figure 8.3.

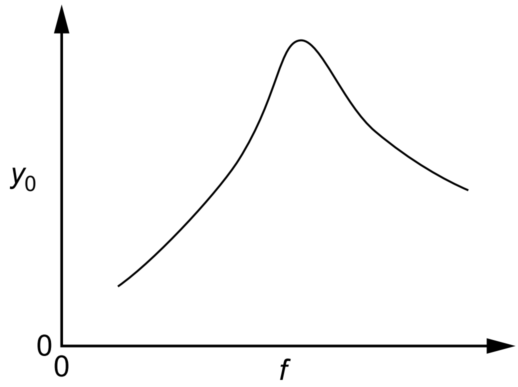

Figure 8.3

(i) State the name of the phenomenon illustrated in Figure 8.3.

.... [1]

(ii) State the frequency at which y_0 is at its maximum.

frequency = ... Hz [1]

(d) One end of a current-carrying coil of wire, wound on a cardboard tube, is placed near to the copper plate, as shown in Figure 8.4.

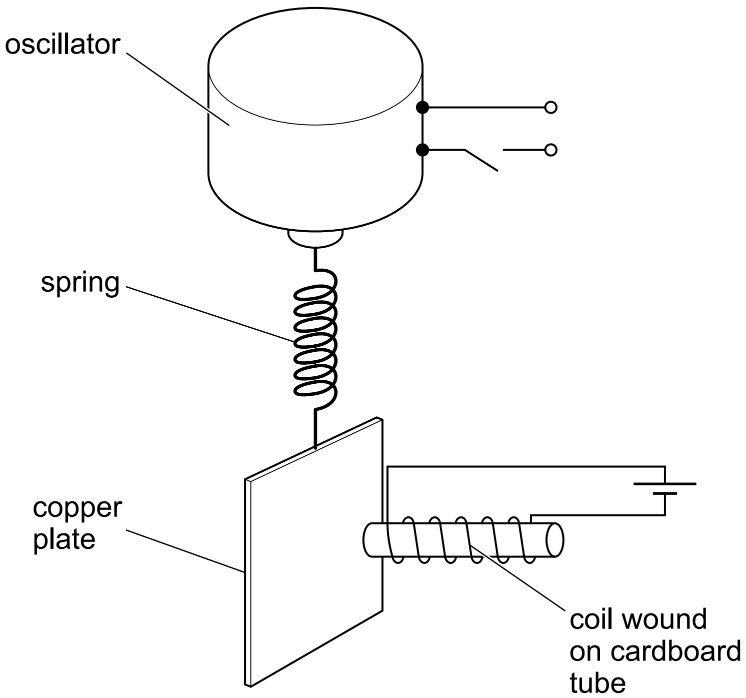

Figure 8.4

When the frequency of the oscillator is varied, the vibrations of the copper plate are seen to be lightly damped.

(i) On Figure 8.3, draw a line to show the variation with frequency of the amplitude of these damped oscillations for the range of frequencies shown. [2]

(ii) State Faraday's law of electromagnetic induction.

....

....

.... [2]

(iii) Use Faraday's law and energy conservation to explain why the oscillations are damped.

....

....

....

....

....

.... [4]

(e) State and explain the effect on the oscillations in **8(d)** of inserting an iron core into the coil.

....

....

....

.... [3]

[Total: 20]

9 **(a)** The radioactive decay of the isotope strontium-90 is both spontaneous and random.

Explain what is meant by:

(i) spontaneous decay

....

.... [1]

(ii) random decay.

....

....

.... [2]

(b) A sample contains N nuclei of strontium-90 at time t. As a result of radioactive decay, a short while later at time $(t + \Delta t)$, the sample contains $(N - \Delta N)$ nuclei of strontium-90.

Give expressions, in terms of N, ΔN and Δt, for:

(i) the activity of the sample

.... [1]

(ii) the probability of decay of a strontium nucleus in time Δt

.... [1]

(iii) the decay constant λ for strontium-90.

.... [1]

(c) Strontium-90 ($^{90}_{30}Sr$) undergoes β-decay to form yttrium (Y).

(i) The emitted β-particles have a range of energies up to a maximum of 0.55 MeV.

Use conservation laws to explain why this range of energies leads to the suggestion that another particle is emitted by the decaying strontium-90 nucleus together with the β-particle.

....

....

....

....

....

.... [4]

(ii) Complete the nuclear equation for the decay of strontium-90 to form yttrium.

$$^{90}_{30}Sr \rightarrow \quad Y +$$

[2]

(d) Some tumours can be treated by implanting a radioactive source in the middle of the tumour.

The ionising radiation emitted by the source destroys the tumour without affecting the surrounding healthy tissue.

Actinium-225 ($^{225}_{89}Ac$) is a radioisotope with a half-life of 10 days. It decays to the stable isotope bismuth-209 ($^{209}_{83}Bi$) in a short span of time. The decay process results in the release of four α-particles for each actinium-225 nucleus.

(i) Explain why the properties of actinium-225 make it a suitable radioisotope for implantation.

....

....

....

.... [3]

(ii) A sample of pure actinium-225 of mass 0.55 μg is implanted into a tumour. Assume that the kinetic energy of each α-particle released in the decay process is 5.8 MeV.

(A) Determine the number of actinium-225 nuclei in the sample.

number = ... [1]

(B) Calculate the energy absorbed by the tumour due to the α-particles released in the first 24 hours after implantation.

energy = ... J [4]

[Total: 20]

