Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME: Solved Paper

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6250050850

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 2021**

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 **28** pages. Any blank pages are indicated.

DC (LK/SW) 197654/3

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	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the 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	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
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.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

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

The force is proportional to the product of their masses & inversley proportional from their square of their seperation from their centre of mass. [2]

(b) Planets have been observed orbiting a star in another solar system. Measurements are made of the orbital radius r and the time period T of each of these planets.

The variation with R^3 of T^2 is shown in Fig. 1.1.

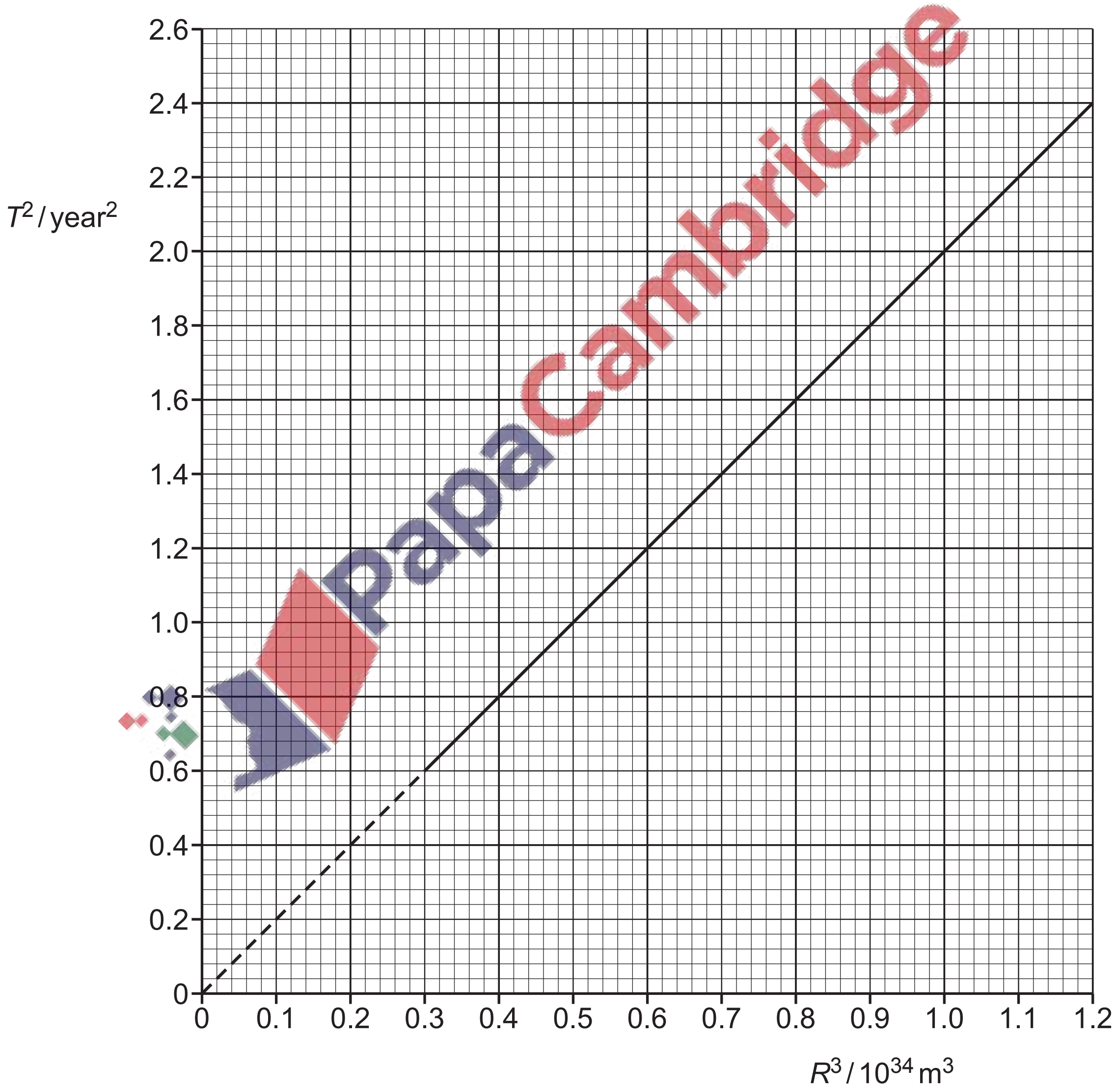


Fig. 1.1

The relationship between T and R is given by

$$T^2 = \frac{4\pi^2 R^3}{GM}$$

where G is the gravitational constant and M is the mass of the star.

Determine the mass M.

$2.4 \times (363 \times 24 \times 3600) = \frac{4\pi^2 \times (1.2 \times 10^{34})}{6.67 \times 10^{-11} \times M}$

$M = \frac{4\pi^2 \times (1.2 \times 10^{34})}{(6.67 \times 10^{-11}) \times 2.4 \times (365 \times 24 \times 3600)}$

$= 9.38 \times 10^{37}$

M = ...9.4×10^{37}...... kg [3]

(c) A rock of mass m is also in orbit around the star in **(b)**. The radius of the orbit is r.

(i) Explain why the gravitational potential energy of the rock is negative.

The work done in bringing the stone from infinity to the orbit against the rock's gravity is the reason for the GPE of the rock to be negative as it shows it's attractive nature. [3]

(ii) Show that the kinetic energy E_k of the rock is given by

$$E_k = \frac{GMm}{2r}.$$

$F_c = F_G$

$\frac{mv^2}{r} = \frac{GMm}{r^2}$

$\frac{1}{2} \times \frac{mv^2}{r} = \frac{1}{2} \times \frac{GMm}{r^2}$

$E_K = \frac{GMm}{2r}$

[2]

(iii) Use the expression in **(c)(ii)** to derive an expression for the total energy of the rock.

$T_E = GPE + KE$

$-\frac{GMm}{r} + \frac{GMm}{2r} = GMm\left[\frac{1}{2r} - \frac{1}{r}\right]$ [2]

$= -\frac{GMm}{2r}$

[Total: 12]

2 A fixed mass of an ideal gas is at a temperature of 21 °C. The pressure of the gas is 2.3×10^5 Pa and its volume is $3.5 \times 10^{-3}\,m^3$.

(a) **(i)** Calculate the number *N* of molecules in the gas.

$PV = nRT$

$2.3 \times 10^5 \times 3.5 \times 10^{-3} = n \times 8.31 \times (21 + 273)$

$n = 0.32949$

$n = \frac{N}{N_A}$

$N = 0.32949 \times 6.02 \times 10^{23}$

$= 1.98 \times 10^{23}$

N = 2.0×10^{23} .... [2]

(ii) The mass of one molecule of the gas is 40 u.

Determine the root-mean-square (r.m.s.) speed of the gas molecules.

$PV = \frac{1}{3} N \langle c^2 \rangle m$

$m = 40u$

$= 40 \times 1.66 \times 10^{-27}$

$\langle c^2 \rangle = \frac{3PV}{Nm}$

$\langle c \rangle = \sqrt{\frac{3PV}{Nm}} = 426.49$

r.m.s. speed = 430 .... $m\,s^{-1}$ [2]

(b) The temperature of the gas is increased by 84 °C.

Calculate the value of the ratio

$$\frac{\text{new r.m.s. speed of molecules}}{\text{original r.m.s. speed of molecules}}.$$

initial temp: 21°C
final temp: 105° C

$<c^2> \propto \sqrt{T}$

$\frac{\text{new}_{crms}}{\text{old}_{crms}} = \frac{483.537}{426.44} = 1.1338 \approx 1.13$

$\frac{crms_1}{crms_2} = \frac{\sqrt{T_1}}{\sqrt{T_2}}$

$\frac{426.44}{x_2} = \frac{\sqrt{21+273}}{\sqrt{105+273}}$

$x_2 = 483.537$

ratio = 1.13 [2]

[Total: 6]

3 **(a)** Using a simple kinetic model of matter, describe the structure of a solid.

Particles of Solids form a lattice, and vibrate on their own fixed position such that the vibration speed is proportional to the temprature.

[2]

(b) The specific latent heat of vaporisation is much greater than the specific latent heat of fusion for the same substance. liquid → gas solid → liquid

Explain this, in terms of the spacing of molecules.

As space between the bonds of liquids & gases are greater hence more energy is needed so latent heat of vaporisation is more. In latent heat of fusion bonds are only weakend.

[1]

(c) A heater supplies energy at a constant rate to 0.045 kg of a substance. The variation with time of the temperature of the substance is shown in Fig. 3.1. The substance is perfectly insulated from its surroundings.

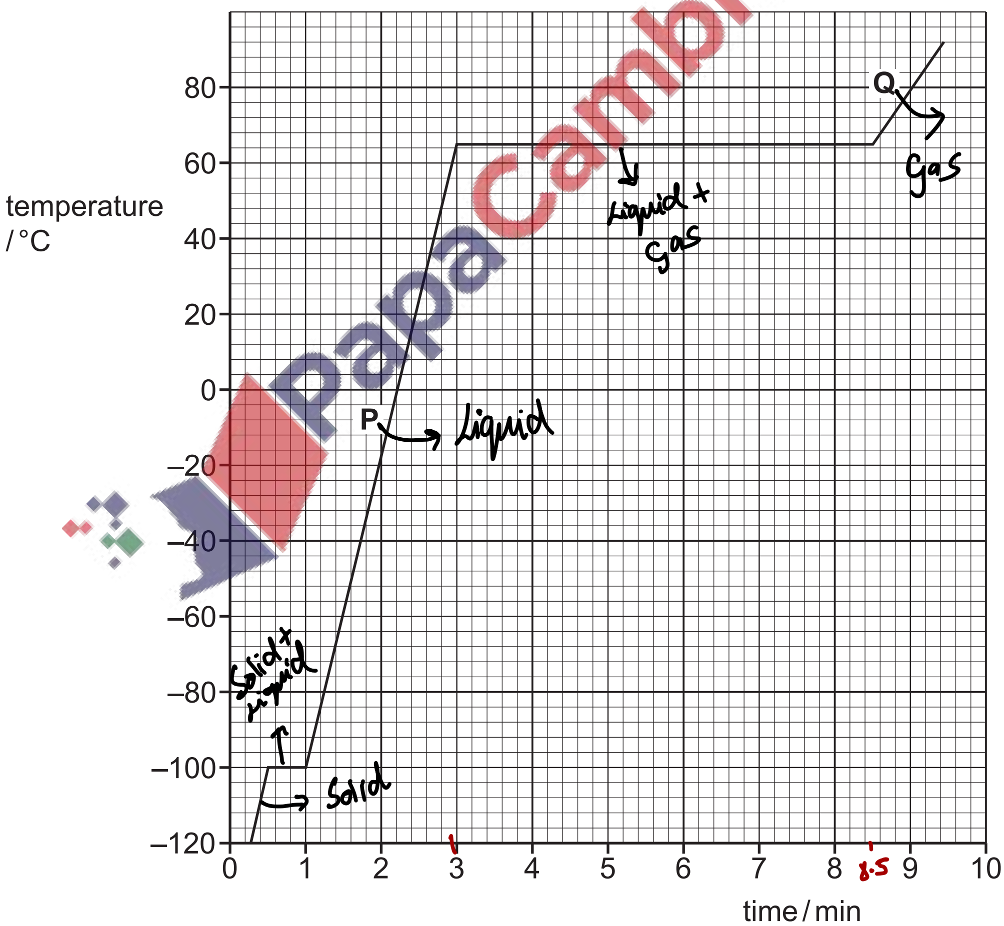


Fig. 3.1

(i) Determine the temperature at which the substance melts.

temperature = ...−100...... °C [1]

(ii) The power of the heater is 150 W.
Use data from Fig. 3.1 to calculate, in $kJ\,kg^{-1}$, the specific latent heat of vaporisation L of the substance.

m = 0·045 Kg

Time = 8·5 − 3 = 5·5 min × 60 = 330 sec

E = mL $5.0 \times 10^4 = 0.045 \times L$

E = PT 1.1×10^6 J = L

= 150 × 330

= 5.0×10^4 $L = 1.1 \times 10^3$

L = ...1100...... $kJ\,kg^{-1}$ [3]

(iii) Suggest what can be deduced from the fact that section **Q** on the graph is less steep than section **P**.

Energy supplied in P is less than that supplied in Q. [1]

[Total: 8]

4 **(a)** The defining equation of simple harmonic motion is

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

State the significance of the minus (–) sign in the equation.

Acceleration is in the opposite direction to it's displacemont from it's mean position. [1]

(b) A trolley rests on a bench. Two identical stretched springs are attached to the trolley as shown in Fig. 4.1. The other end of each spring is attached to a fixed support.

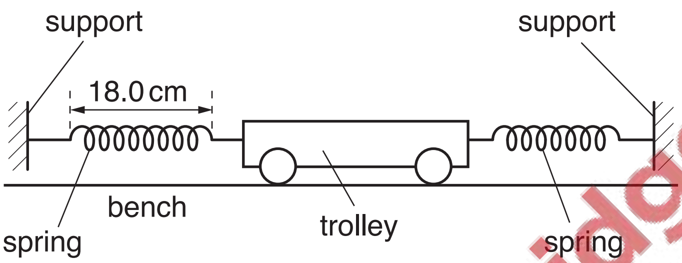


Fig. 4.1

The unstretched length of each spring is 12.0 cm. The spring constant of each spring is 8.0 N m^{-1}. When the trolley is in equilibrium the length of each spring is 18.0 cm.

The trolley is displaced 4.8 cm to one side and then released. Assume that resistive forces on the trolley are negligible.

(i) Show that the resultant force on the trolley at the moment of release is 0.77 N.

$F = Kx$

$F = (8+8) \times \frac{4.8}{100}$

$F = 0.768$

≈ 0.77

$F = Kx + Kx$

$8 \times (18 - 12 + 4.8) +$

$8 \times (18 - 12 - 4.8)$

[2]

(ii) The mass of the trolley is 250 g.

Calculate the maximum acceleration *a* of the trolley.

$F = ma$

$\frac{0.77}{230 \times 10^{-3}}$

$\frac{F}{m} = a$

a = 3.1 m s^{-2} [1]

(iii) Use your answer in **(ii)** to determine the period *T* of the subsequent oscillation.

$a = -\omega^2 x$

$3.08 = -\omega^2 \times \frac{4.8}{100}$

$64.166 = 4\pi^2 f^2$

$64.166 = \frac{4\pi^2}{T^2}$

$T = \left(\frac{4\pi^2}{64.166}\right)^{1/2}$

T = 0.78 s [3]

(iv) The experiment is repeated with an initial displacement of the trolley of 2.4 cm.

State and explain the effect, if any, this change has on the period of the oscillation of the trolley.

$a = \frac{4\pi^2}{T^2} \times x$; $T^2 a = 4\pi^2 x$; $T^2 \propto x$

$x \to 1/2$ ∴ Time period will decrease such the T_2 is $1/\sqrt{2}$ of T_1. [2]

[Total: 9]

$T \propto \sqrt{x}$

$\frac{T_2}{T_1} \propto \sqrt{\frac{x_2}{x_1}}$

$\frac{T_2}{T_1} \propto \sqrt{\frac{2.4}{4.8}}$

$\frac{T_2}{T_1} \propto \sqrt{\frac{1}{2}}$

$T_2 \propto \frac{1}{\sqrt{2}} \times T_1$

5 **(a)** **(i)** State what is meant by the *amplitude modulation* (*AM*) of a radio wave.

The amplitude of the carrier wave varies in synchrony with the displacement of the information signal. [2]

(ii) State **two** advantages of AM transmissions when compared with frequency modulation (FM) transmissions.

1. Much Greater Range

2. Cheaper

[2]

(b) The variation with frequency f of the amplitude A of a transmitted radio wave after amplitude modulation by an audio signal is shown in Fig. 5.1.

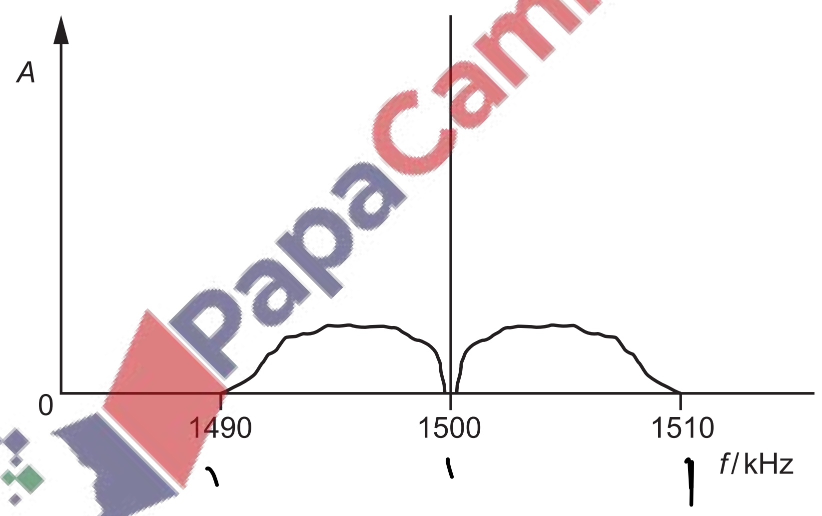


Fig. 5.1

For this transmission, determine:

(i) the wavelength of the carrier wave

$F = \lambda c$

$\frac{1500 \times 10^3}{3 \times 10^8} = \lambda$

wavelength = 0.005 m [1]

(ii) the maximum frequency of the transmitted audio signal.

Bandwith = 2F

20 = 2F

F = 10

frequency = 10 kHz [1]

(c) Another audio signal with the same maximum frequency is transmitted using a different carrier wave frequency. The lowest frequency of this modulated wave is equal to the highest frequency of the modulated wave in **(b)**.

Determine the frequency of this carrier wave.

$f_c = 1300$ Hz

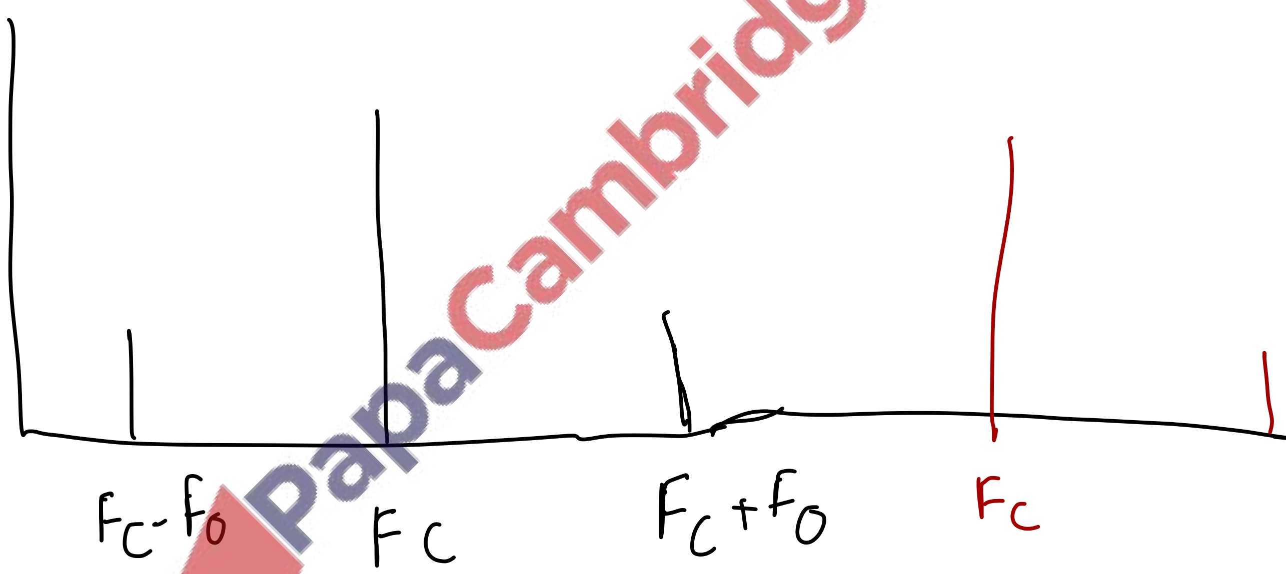
$f_o = 10$ Hz

$1310 = f_c - f_o$

$1520 = f_c$

frequency = ...1520...... kHz [1]

[Total: 7]



highest of old, lowest New

$\therefore f_c = 1310 + 10 = 1520$

fo constant

6 (a) State a similarity between the gravitational field lines around a point mass and the electric field lines around a point charge.

field lines are radial

.... [1]

(b) The variation with radius r of the electric field strength E due to an isolated charged sphere in a vacuum is shown in Fig. 6.1.

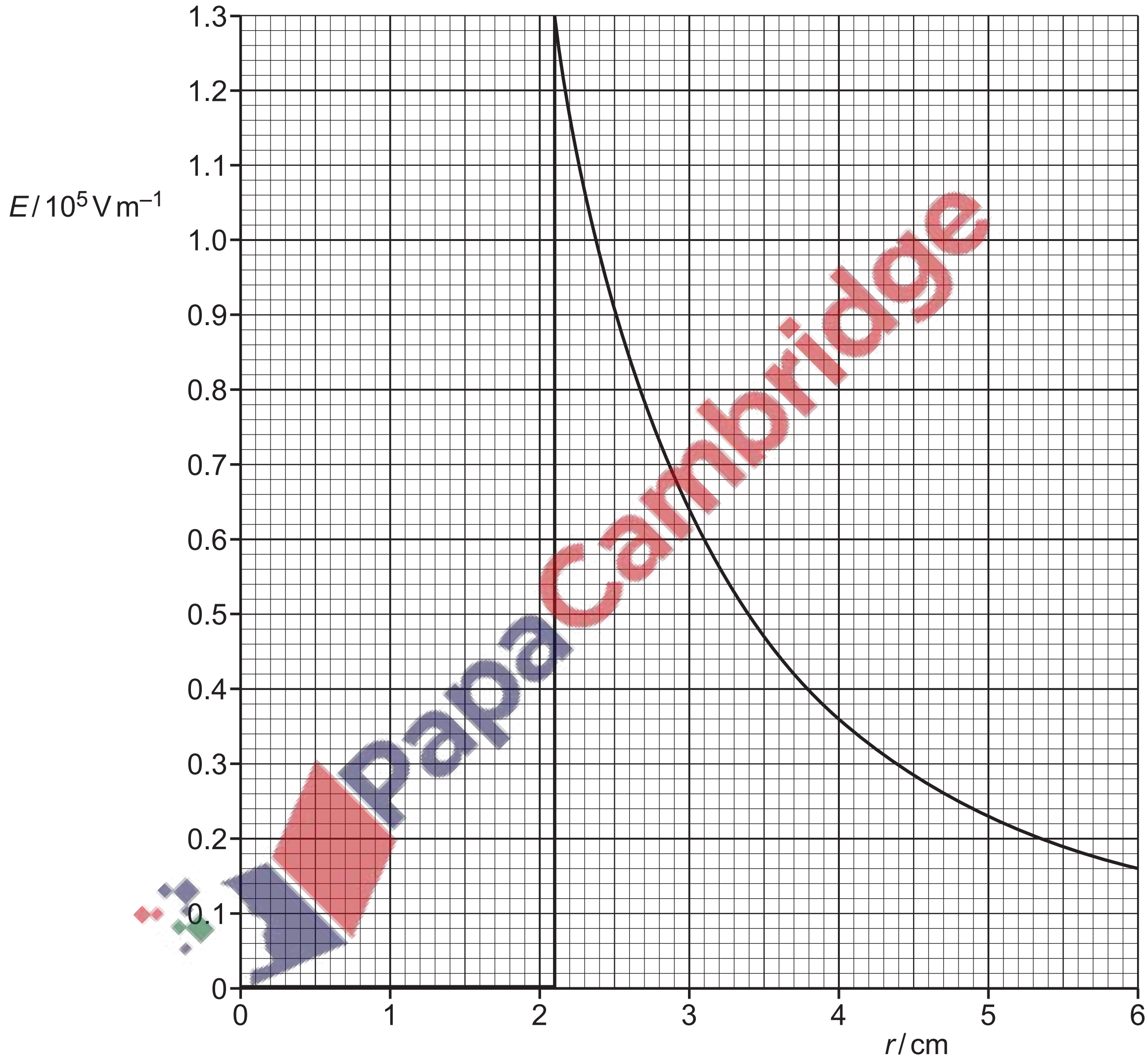


Fig. 6.1

Use data from Fig. 6.1 to:

(i) state the radius of the sphere

radius = 2.1 cm [1]

(ii) calculate the charge on the sphere.

$E = \frac{kQ}{r^2}$

$1.3 \times 10^5 = \frac{9 \times 10^9}{(2.1 \times 10^{-2})^2} \times Q$

$Q = 0.64 \times 10^{-9}$

charge = ... 0.64×10^{-9} .... C [2]

(c) Using the formula for the electric potential due to an isolated point charge, determine the capacitance of the sphere in **(b)**.

$C = 4\pi\varepsilon_0 r = 4\pi \times \varepsilon_0 \times (2.1 \times 10^{-2})^2$

$= 4\pi\varepsilon_0 \times (2.1 \times 10^{-2})$

$= 2.34 \times 10^{-12}$

capacitance = ... 2.3×10^{-12} .... F [3]

[Total: 7]

$C = Q/V$

$V = \frac{kQ}{r} = \frac{Q}{r \times 4\pi\varepsilon_0}$

$C = \frac{Q}{\frac{Q}{r \times 4\pi\varepsilon_0}} = 4\pi\varepsilon_0 r$

7 **(a)** Fig. 7.1 shows the circuit diagram containing an operational amplifier (op-amp).

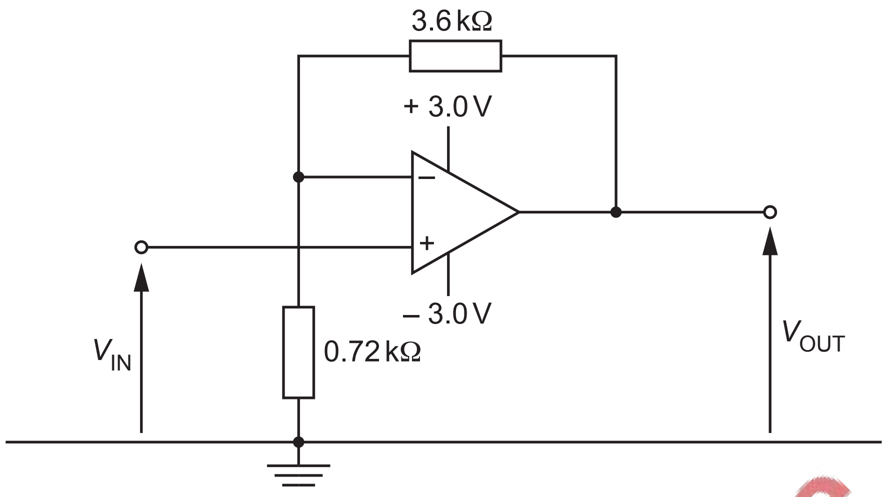


Fig. 7.1

(i) State the name of this type of amplifier.

Non - Inverting Amplifier .... [1]

(ii) Show that the gain of the amplifier is 6.0.

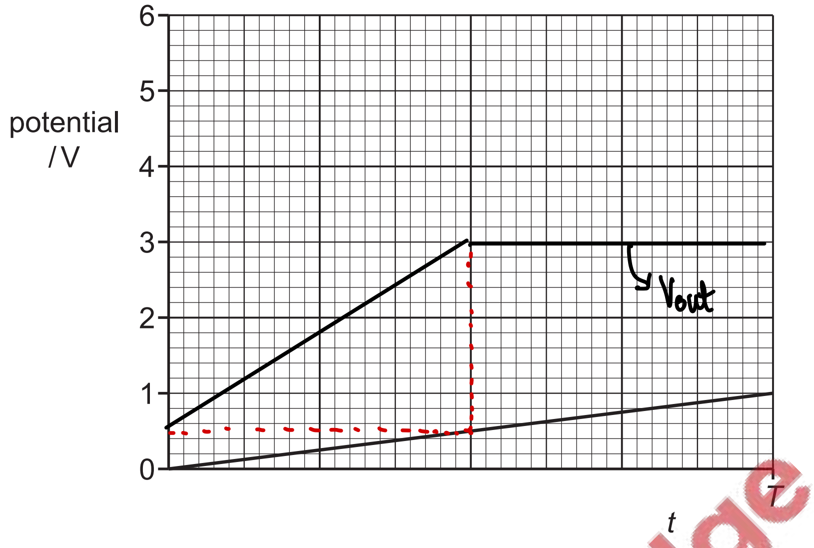
gain = $1 + \frac{R_f}{R}$

$= 1 + \frac{3.6}{0.72}$

$= 6$

[1]

(iii) At time $t = 0$ the input potential V_{IN} is zero. V_{IN} then gradually increases with time t as shown in Fig. 7.2.



Saturation = ±3

V_{out} = Gain x V_{IN}

Fig. 7.2

On Fig. 7.2 sketch a line to show the variation with time t of the output potential V_{OUT} from time $t = 0$ to time $t = T$. [2]

(iv) State how the circuit of Fig. 7.1 may be changed so that the gain of the amplifier is dependent on light intensity.

Replace the 0·72 KΩ Resistor with a light dependant Resistor. [1]

(b) An op-amp is to be used to switch on a high-voltage heater.

(i) State the name of the component used as the output device of the op-amp.

Relay [1]

(ii) Complete Fig. 7.3 using the device named in **(i)** and a diode so that the heater may be switched on when the output of the op-amp is positive.

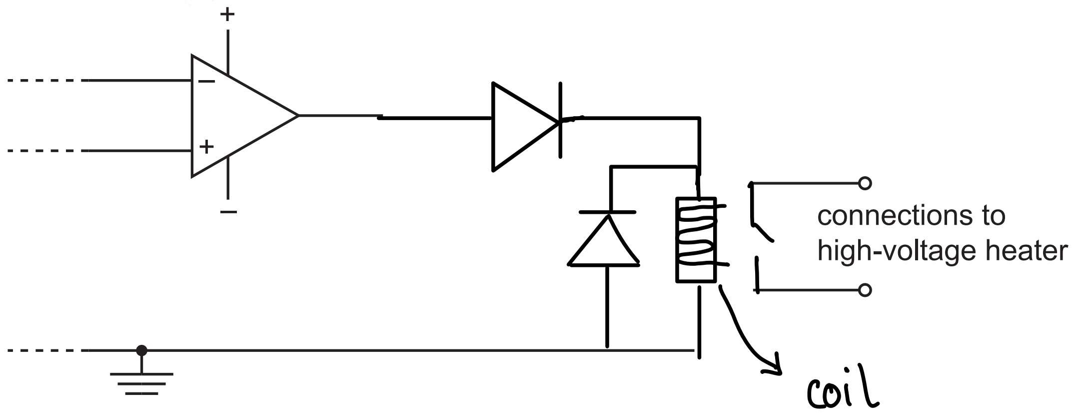


Fig. 7.3

[3]

[Total: 9]

8 **(a)** Two long straight wires P and Q are parallel to each other, as shown in Fig. 8.1. There is a current in each wire in the direction shown.

The pattern of the magnetic field lines in a plane normal to wire P due to the current in the wire is also shown.

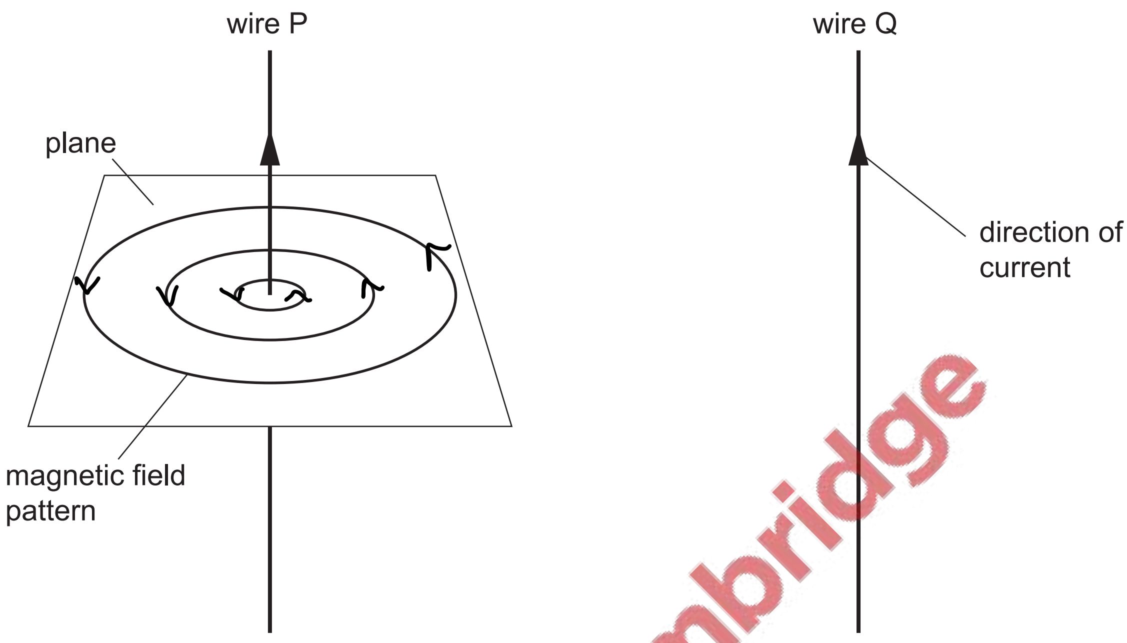


Fig. 8.1

(i) Draw arrows on the magnetic field lines in Fig. 8.1 around wire P to show the direction of the field. [1]

(ii) Determine the direction of the force on wire Q due to the magnetic field from wire P.

towards P (Left side) [1]

(iii) The current in wire Q is less than the current in wire P.

State and explain whether the magnitude of the force on wire P is less than, equal to, or greater than the magnitude of the force on wire Q.

Equal to as the product of the currents is the same & Newtons third law of motion states that there will be equal & opposite magnitude of forces. [2]

$$F = \frac{\mu_0 I_1 I_2 L}{2\pi x}$$

(b) Nuclear magnetic resonance imaging (NMRI) is used to obtain diagnostic information about internal structures in the human body.

Radio waves are produced and directed towards the body. The radio waves affect the protons within the body.

(i) Explain why radio waves are used.

inoder for Reseonance to occur larmur frequency should be in range of applied frequency hence Radio waves are used. [2]

(ii) Explain why the radio waves are applied in pulses.

So the transmited & recived waves can be detected. [2]

[Total: 8]

9 (a) Define *magnetic flux linkage*.

Rate of change of magnetic flux per unit area. (Number of field lines passing per unit area in the coil)

[2]

(b) A solenoid of diameter 6.0 cm and 540 turns is placed in a uniform magnetic field as shown in Fig. 9.1.

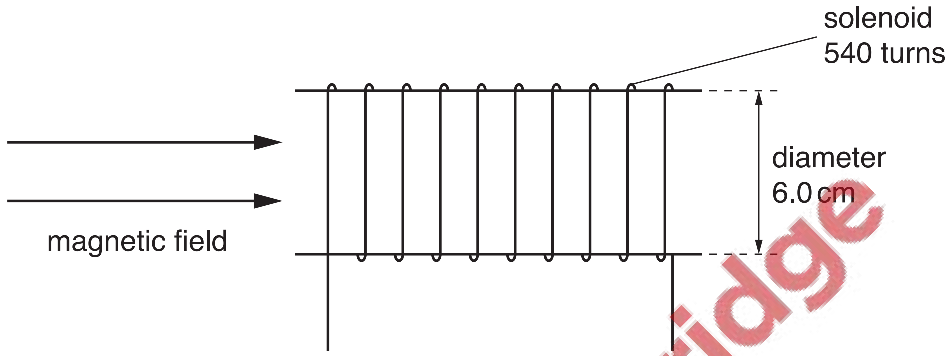


Fig. 9.1

The variation with time t of the magnetic flux density is shown in Fig. 9.2.

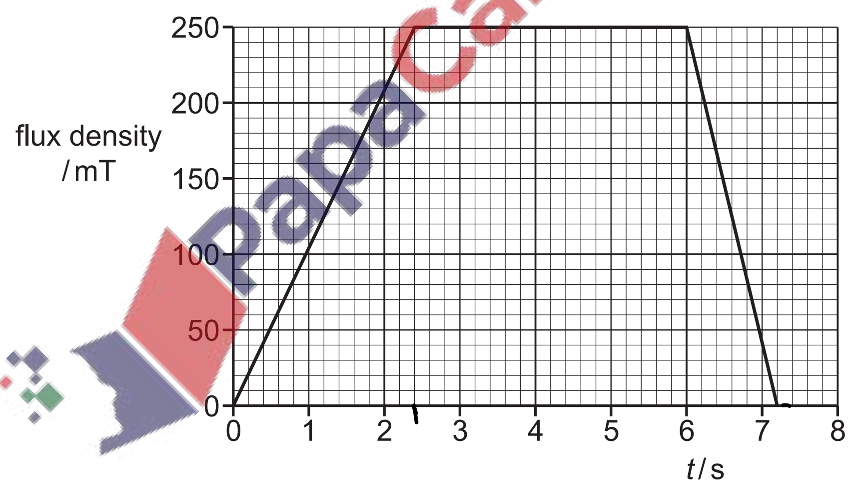


Fig. 9.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

$\phi = BAN \quad Emf = -\frac{d\phi}{dt}$

$EMF = -\frac{\Delta BAN}{\Delta t}$

e.m.f. = 0.32 V [3]

$\frac{\Delta B}{\Delta t} = m$

(7.2, 0)
(6, 250)

$m_{MAX} = \frac{250 \times 10^{-3}}{6 - 7.2} = -208.33 \times 10^{-3}$

$EMF = -(-208.33 \times 10^{-3}) \times \pi \times (3 \times 10^{-2})^2 \times 540 = 318.086 \times 10^{-3}\ V$

(c) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 9.3.

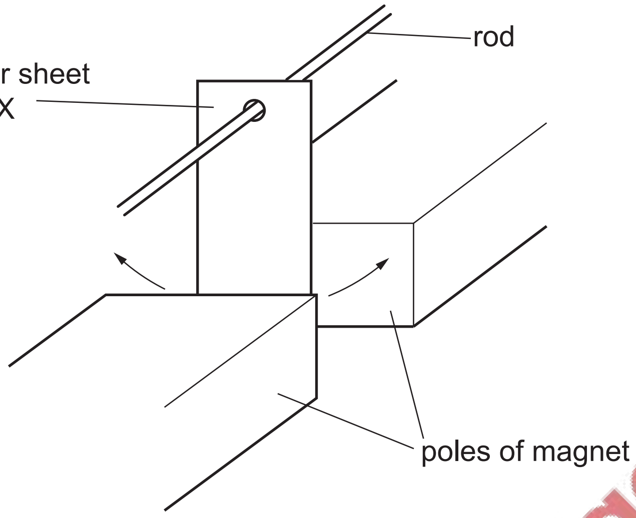


Fig. 9.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig. 9.4.

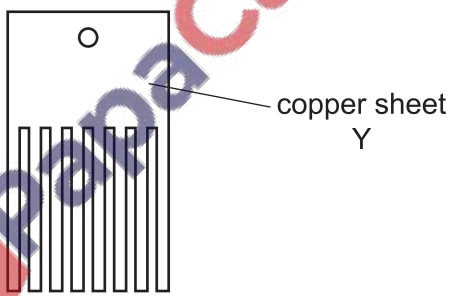


Fig. 9.4

The motion sensor is again used to record the displacement.

The graph in Fig. 9.5 shows the variation with time *t* of the displacement *s* of each copper sheet.

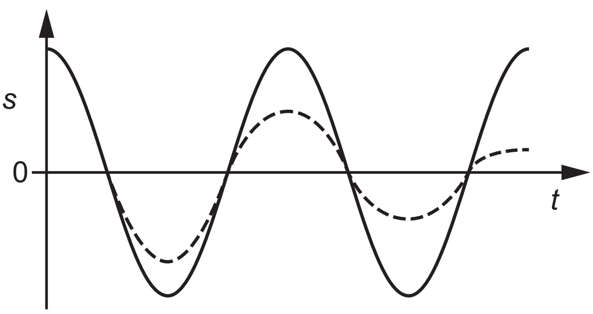


Fig. 9.5

(i) State the name of the phenomenon illustrated by the gradual reduction in the amplitude of the dashed line.

Damping [1]

(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

The dashed line is represented by sheet X, as it does not have any breaking in between therefore as per faraday's law, E.M.F & Eddy currents will be induced as the sheet changes magnetic flux. This current will cause energy loss due to heating thus these oscillations are dampened. [4]

[Total: 10]

10 The output potential difference (p.d.) of an alternating power supply is represented by

$$V = 320\sin(100\pi t)$$

where V is the p.d. in volts and t is the time in seconds.

(a) Determine the root-mean-square (r.m.s.) p.d. of the power supply.

$V = V_0 \sin \omega t$

r.m.s. p.d. = $320/\sqrt{2}$ .... V [1]

(b) Determine the period T of the output.

$\omega = \frac{2\pi}{T}$ $\quad 100\pi = \frac{2\pi}{T}$ $\quad T = 1/50$

$T = 2\pi/100\pi$

T = 0.02 .... s [2]

(c) The power supply is connected to resistor R and a diode in the circuit shown in Fig. 10.1.

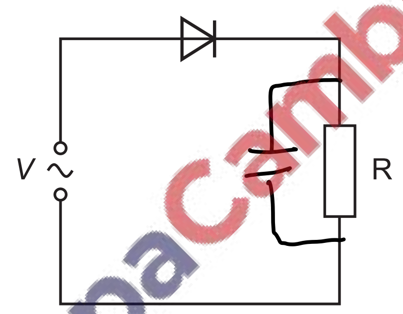


Fig. 10.1

(i) State the name of the type of rectification produced by the diode in Fig. 10.1.

half wave rectification .... [1]

(ii) On Fig. 10.2 sketch the variation with time t of the p.d. V_R across R from time t = 0 to time t = 40 ms.

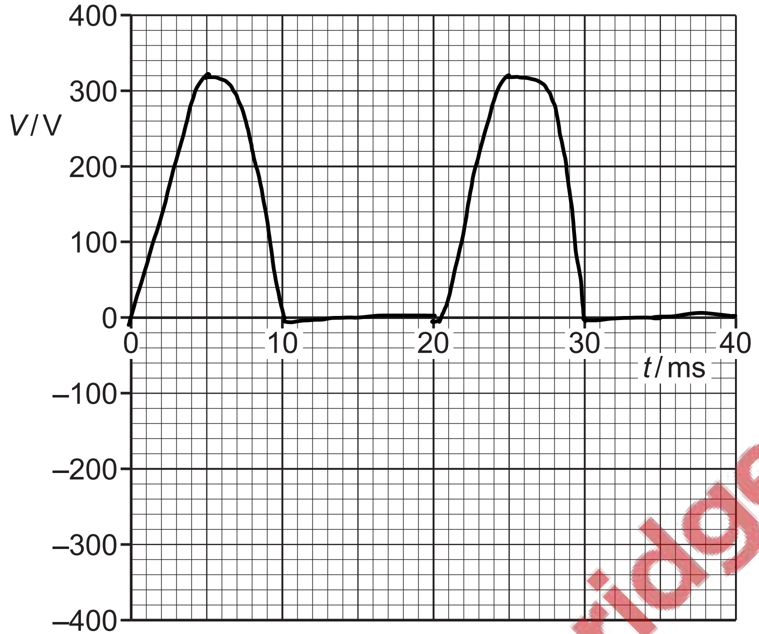


Fig. 10.2

[3]

(iii) On Fig. 10.1, draw the symbol for a component that may be connected to produce smoothing of V_R.

[1]

[Total: 8]

11 **(a)** Electrons are accelerated through a potential difference of 15 kV. The electrons collide with a metal target and a spectrum of X-rays is produced.

(i) Explain why a continuous spectrum of energies of X-ray photons is produced.

The electrons experience a range of decelerations and each deceleration. Each deceleration produces X-ray photons thus a continous spectrum of X-ray photons is produced.

.... [3]

(ii) Calculate the wavelength of the highest energy X-ray photon produced.

$E = \frac{hc}{\lambda}$ $E = Vq$

$Vq = \frac{hc}{\lambda}$ $\frac{13000 \times 1.6 \times 10^{-19}}{h \times 3 \times 10^{8}} = \frac{1}{\lambda}$

$\lambda = \frac{h \times 3 \times 10^{8}}{13000 \times 1.6 \times 10^{-19}}$

wavelength = 8.28×10^{-11} m [3]

(b) A beam of X-rays has an initial intensity I_0. The beam is directed into some body tissue. After passing through a thickness *x* of tissue the intensity is I. The graph in Fig. 11.1 shows the variation with *x* of ln (I/I_0).

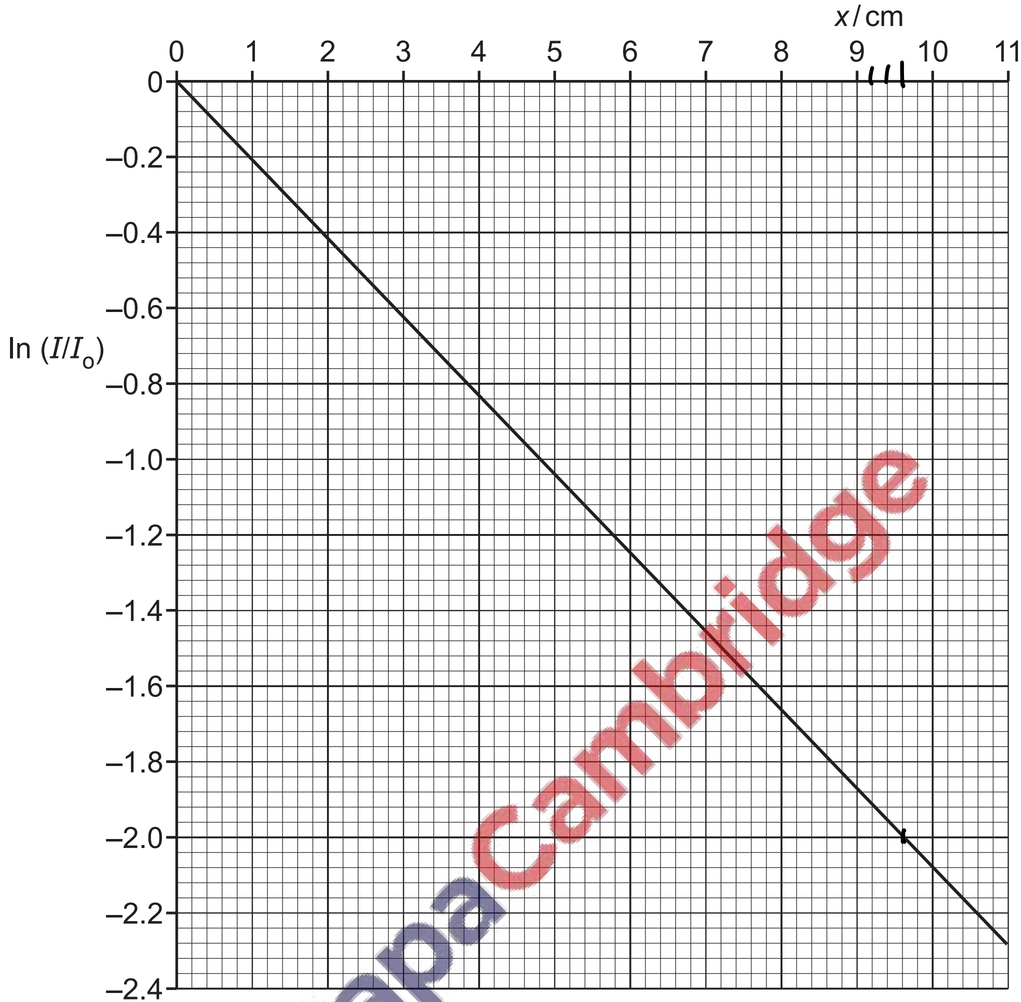


Fig. 11.1

(1, −0.2)
(9.6, −2)

(i) Determine the linear attenuation (absorption) coefficient μ for this beam of X-rays in the tissue.

$I = I_0 e^{-\mu x}$

$\frac{I}{I_0} = e^{-\mu x}$

$\ln\left(\frac{I}{I_0}\right) = -\mu x$

$m = -\mu$

$m = -0.2558$

$\mu = 0.26$

μ = ...0.26...... cm^{-1} [2]

(ii) Determine the thickness of tissue that the X-ray beam must pass through so that the intensity of the beam is reduced to 5.0% of its initial value.

$I = I_0 e^{-\mu x}$

$\frac{I}{I_0} = 5\% = 0.05$

$0.005 = e^{-\mu x}$

$0.005 = e^{-0.2558 \times x}$

$x = 2.071$

thickness = ...2.1...... cm [2]

[Total: 10]

12 **(a)** Radioactive decay is both spontaneous and random.

State what is meant by:

1. *spontaneous decay* when it occurs on its own without being affected by external factors
2. *random decay*. The rate at which decay happens can't be predicted.

[2]

(b) Strontium-90 ($^{90}_{38}Sr$) is an unstable nuclide.

The activity of a sample of 1.0×10^{-9} kg of strontium-90 is 5.2 MBq.

(i) Determine the decay constant λ of strontium-90.

$n = \frac{1.0 \times 10^{-9}}{90}$

$N_A = \frac{1 \times 10^{-9}}{90} \times 6.02 \times 10^{23}$

$N_n = 6.69 \times 10^{12}$

$A = \lambda N$

$\lambda = \frac{A}{N}$

$= \frac{5.2 \times 10^{6}}{6.689 \times 10^{12}}$

$= 7.8 \times 10^{-7}$

λ = 7.8×10^{-7} s^{-1} [3]

(ii) The activity of the sample after a time of 1.0 half lives is found to be greater than the expected 2.6 MBq.

Suggest a possible reason for this.

Because of Background Radiation.

[1]

[Total: 6]