Cambridge Assessment International Education

24/7

CONFIDENTIAL

Cambridge International AS & A Level

CANDIDATE NAME: Sohaib Sarosh Shamsi

CENTRE NUMBER: P6011

CANDIDATE NUMBER: 0170

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 [ ].

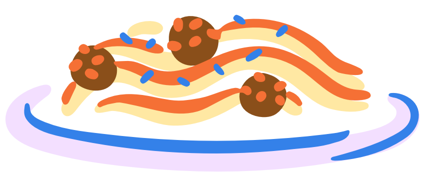
This document has **28** pages. Any blank pages are indicated.

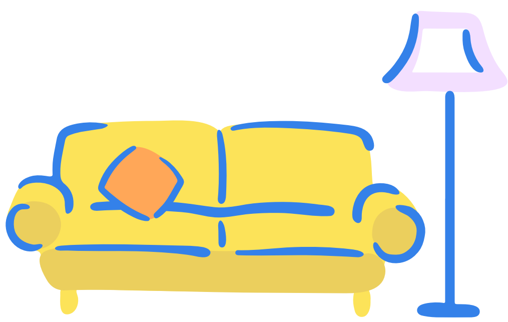
DC (LK/SW) 197654/3

[Turn over

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.

Gravitational force between two point masses is directly propotional to product of masses and inversely propotional to the square of their separation. [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.

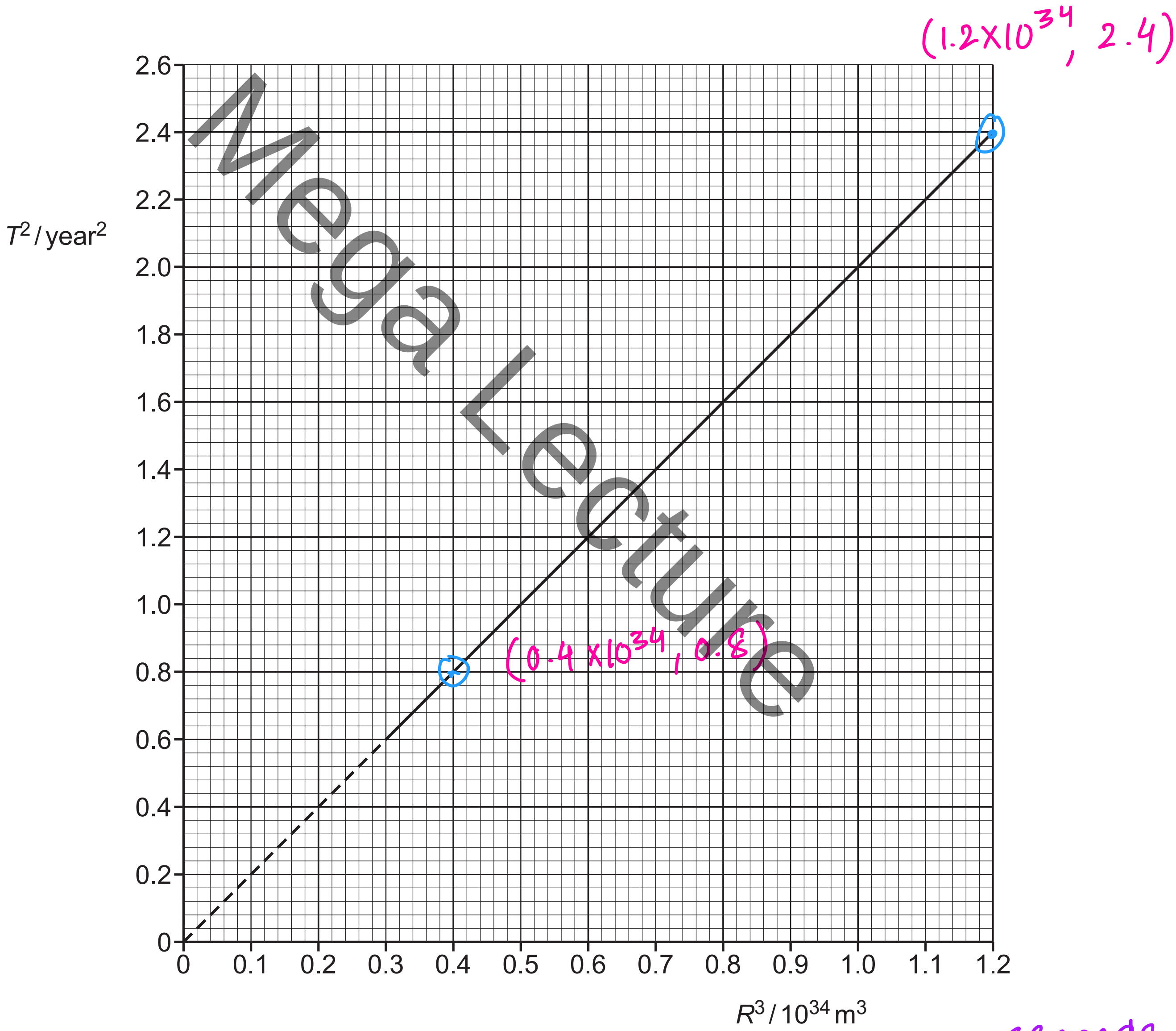


Fig. 1.1

seconds

$m = \frac{\Delta y}{\Delta x} = \frac{1.6 \text{ years}^2}{8 \times 10^{33} \text{ m}^3}$

proof : F_c

$$\frac{GMm}{R^2} = mR\left(\frac{4\pi^2}{T^2}\right)$$

The relationship between T and R is given by

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

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

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

Determine the mass M.

From graph : c = 0

(1) $\text{gradient} = \frac{4\pi^2}{GM}$

(2) $\frac{1.6\ \text{years}^2}{8\times10^{33}\ \text{m}^3} = \frac{4\pi^2}{GM}$

(3) $\frac{1.6\times(365\times24\times3600)^2}{8\times10^{33}} = \frac{4\pi^2}{6.67\times10^{-11}M}$

$M = 2.9757\times10^{30}$

M = 3.0×10^{30} 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.

At infinity, GPE is zero.
Since G Field is always attractive, work is done by the field when a rock is brought from infinity to orbit, GPE decreases from 0 [3]

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

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

$F_c = F_g$

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

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

[2]

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

$E_T = E_K + E_P$

$$E_T = \frac{GMm}{2r} + \left(-\frac{GMm}{r}\right)$$

[2]

[Total: 12]

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

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.

$$PV = NKT$$

$$2.3 \times 10^5 \times 3.5 \times 10^{-3} = N \times 1.38 \times 10^{-23} (21 + 273)$$

$$N = 2.0 \times 10^{23}$$

N = 2.0×10^{23} [2]

(ii) The mass of one molecule of the gas is 40 u. → 1.66×10^{-27}

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

$$\tfrac{1}{2} m \langle c^2 \rangle = \tfrac{3}{2} KT$$

$$\langle c^2 \rangle = \frac{3KT}{m}$$

$$\langle c^2 \rangle = \frac{3 \times 1.38 \times 10^{-23} \times (21 + 273)}{40 \times 1.66 \times 10^{-27}}$$

$$\sqrt{\langle c^2 \rangle} = \sqrt{183307.2}$$

↑ crms

r.m.s. speed = 428 $m\,s^{-1}$ [2]

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

Calculate the value of the ratio

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

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

$c_{rms} = \sqrt{\frac{3kT}{m}}$

$c_{rms} \propto \sqrt{T}$

$c_{rms1} \div c_{rms2}$

$\sqrt{\frac{3kT_{new}}{m}} \times \sqrt{\frac{m}{3kT_{OG}}}$

$\frac{\sqrt{T_{new}}}{\sqrt{T_{OG}}} = \frac{\sqrt{(21+273+84)}}{\sqrt{(21+273)}} = \frac{\sqrt{378}}{\sqrt{294}} = 1.1$

ratio = 1.1 [2]

[Total: 6]

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

particles in a solid are closely packed in a lattice structure and vibrates about fixed position. Strong IMF compared to liquids or gas. [2]

(b) The specific latent heat of vaporisation is much greater than the specific latent heat of fusion for the same substance.
Explain this, in terms of the spacing of molecules.

During boiling, the increase in molecular spacing is much greater than melting. ∴ more energy required. [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.

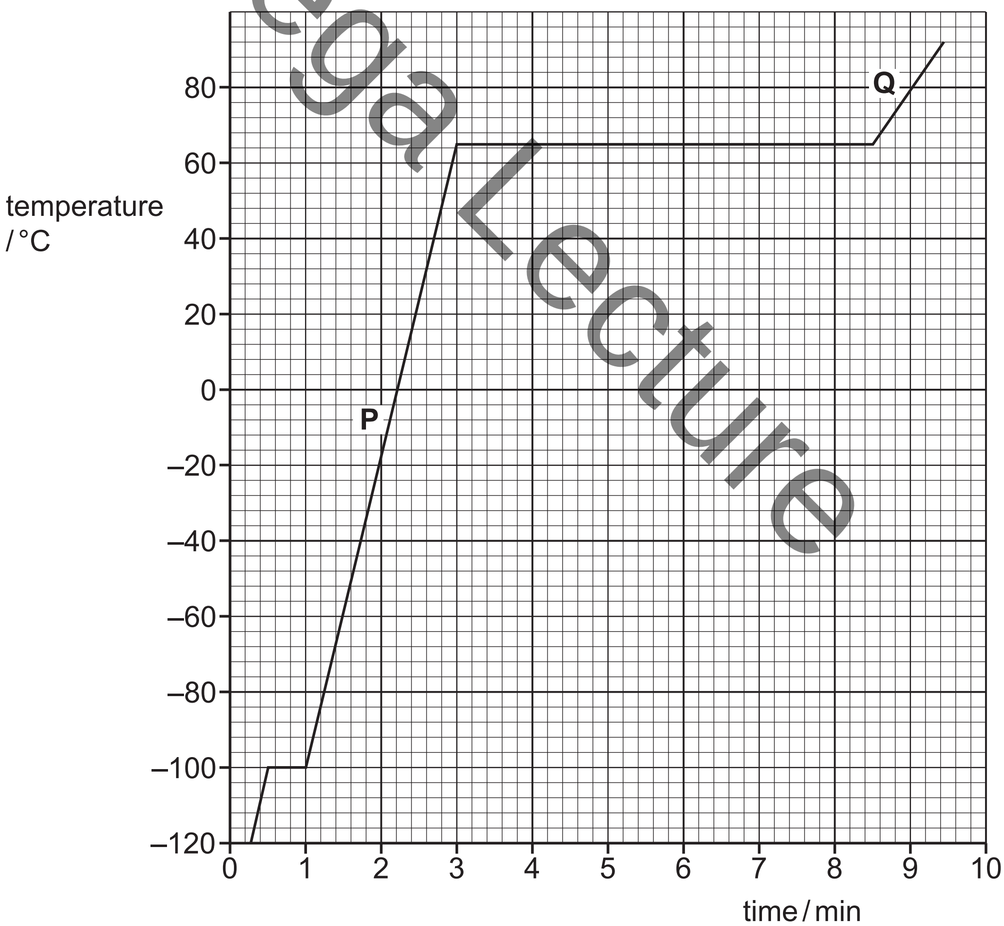


Fig. 3.1

(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.

$8.5 - 3 = 5.5$

$150 \times 5.5 \times 60 = 0.045 \times L$

$L = 1.1 \times 10^6\ J\,kg^{-1}$

L = ...1.1×10^3... $kJ\,kg^{-1}$ [3]

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

In Q → less m → less ΔT per minute
so greater c. Gaseous phase has greater 'c'. [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.

a and x have opposite directions

.... [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.

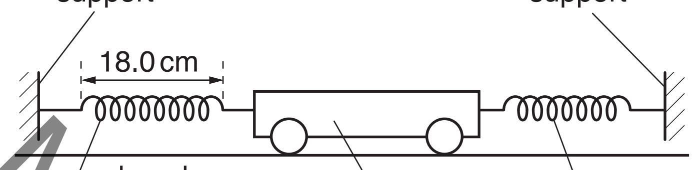


Fig. 4.1

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.

compression + tension.

$F_R = 2kx$

$= 2(8)(4.8 \times 10^{-2})$

$= 0.77$

[2]

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

Calculate the maximum acceleration a of the trolley.

$a = F/m$

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

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

$a = -\omega^2 x$

$\uparrow$

$\frac{2\pi}{T}$

T = ... 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.

NO effect ∴ T depends on k and m.
which remains same.

.... [2]

[Total: 9]

$a = \frac{k}{m} x$

$a = -\omega^2 x$

$\frac{2\pi}{T} = \sqrt{\frac{k}{m}}$

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

Displacement of the carrier wave is made to vary in sychrony with the displacement of the circle. Freq remain constant. [2]

(ii) State **two** advantages of AM transmissions when compared with frequency modulation (FM) transmissions. Used to walkie-talkie

1. Cheaper, simple circuits

2. Longer range of transmission.

– Better quality + can carry more info. [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.

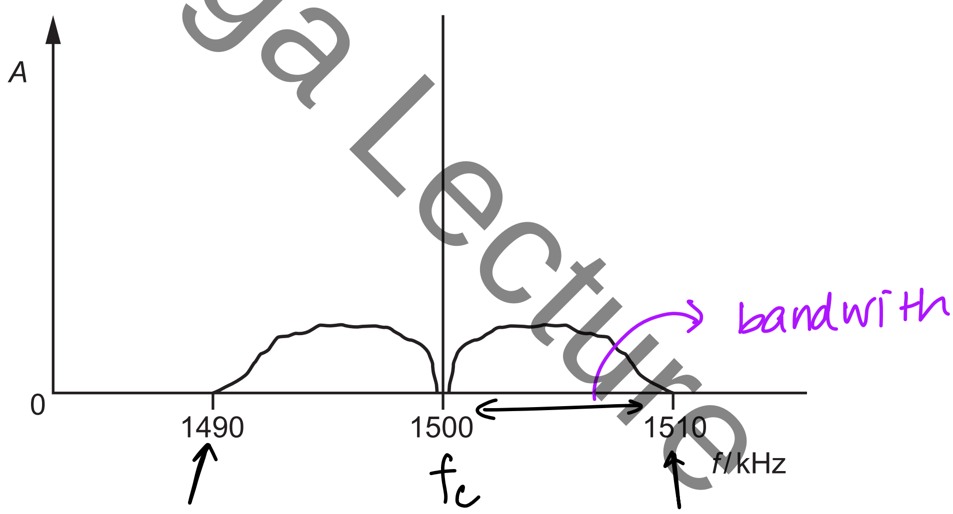


Fig. 5.1

For this transmission, determine:

(i) the wavelength of the carrier wave

$v = f\lambda$

$3 \times 10^8 = \lambda \times 1500 \times 10^3$

$\lambda = 200$

wavelength = 200 m [1]

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

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.

L H

1510 1530

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

[Total: 7]

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

both field lines are radial and obey the inverse square relationship wrt distance from pt charge/mass.

[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.

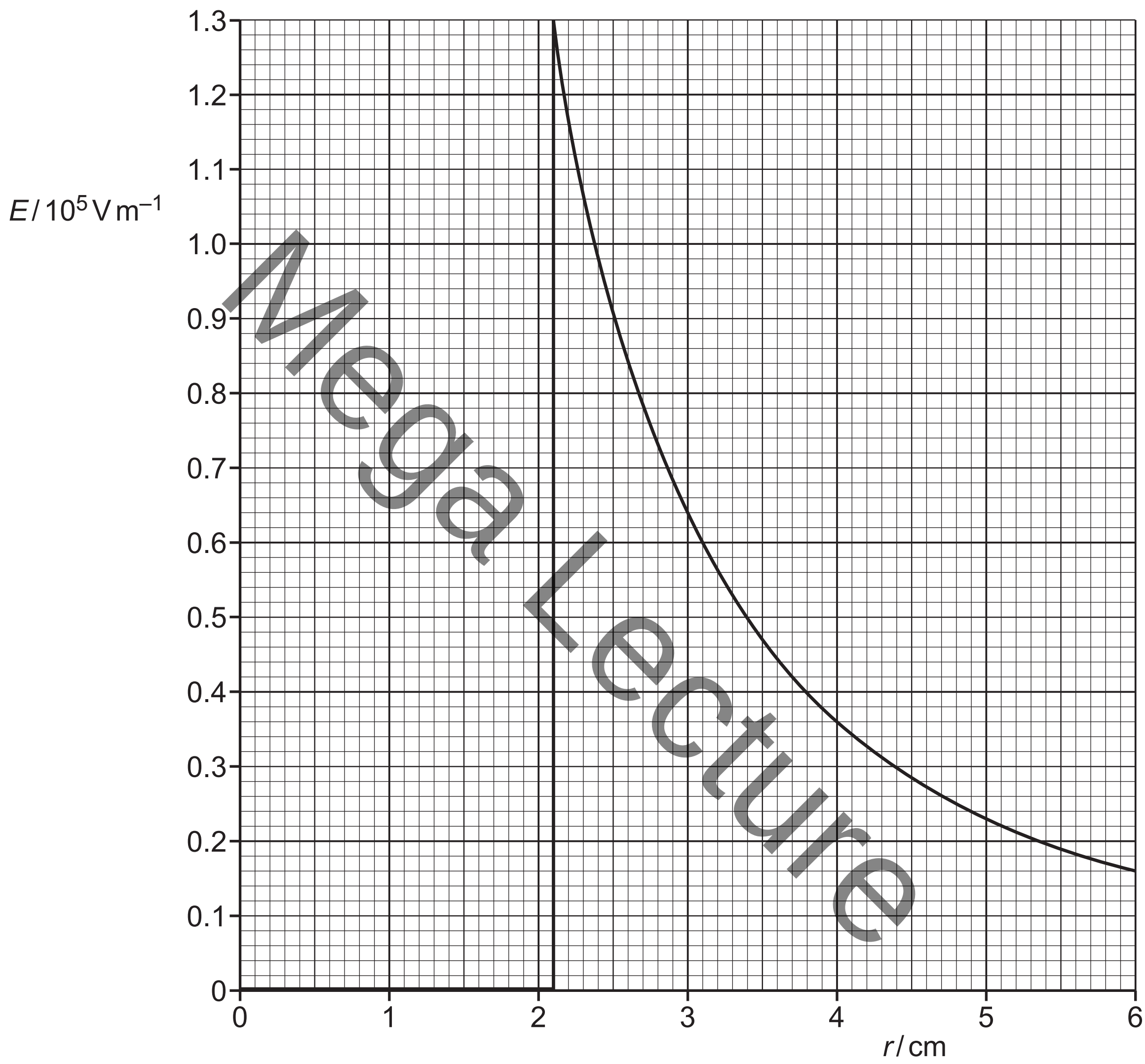


Fig. 6.1

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.

$$1.3\times10^{5} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{(2.1\times10^{-2})^2}$$

charge = 6.4×10^{-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)**.

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

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

capacitance = 2.3×10^{-12} F [3]

[Total: 7]

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

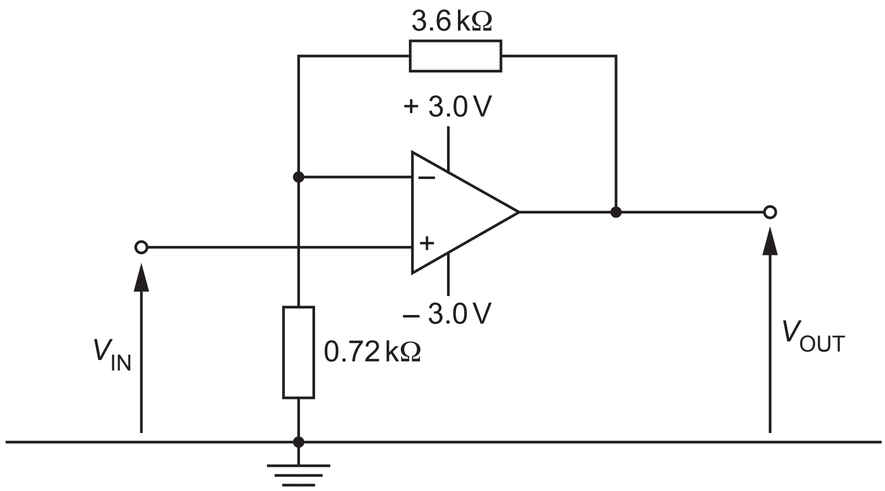


Fig. 7.1

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

Non inverting amplifier.

.... [1]

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

$$\text{gain} = 1 + \frac{3.6 \times 10^3}{0.72 \times 10^3}$$

$$= 1 + 5 \Rightarrow 6$$

[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.

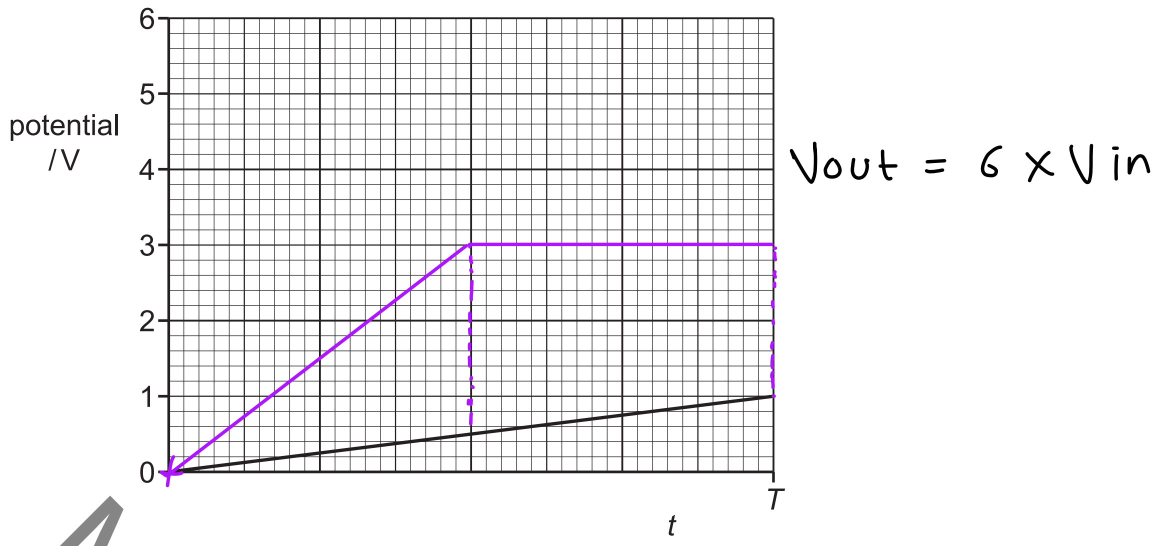


Fig. 7.2

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.

Add thermistor in the place of 7.2kΩ

.... [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.

LED / Relay switch / voltmeter [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.

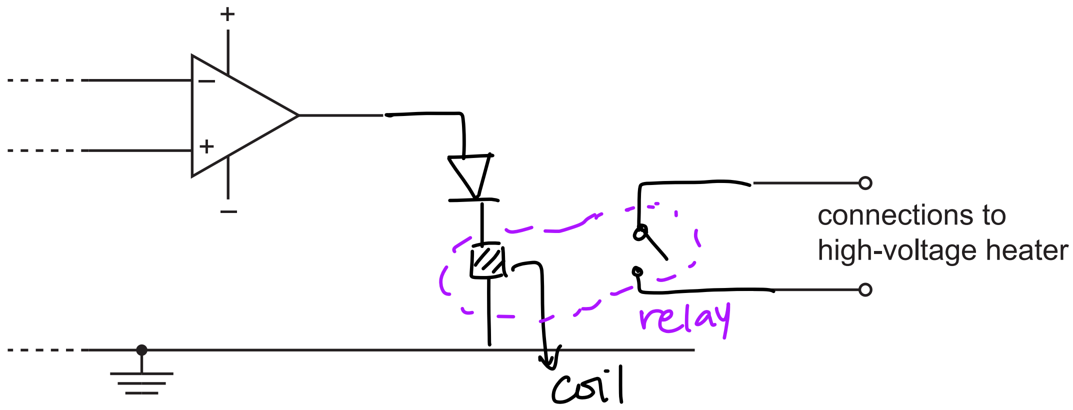


Fig. 7.3

[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.

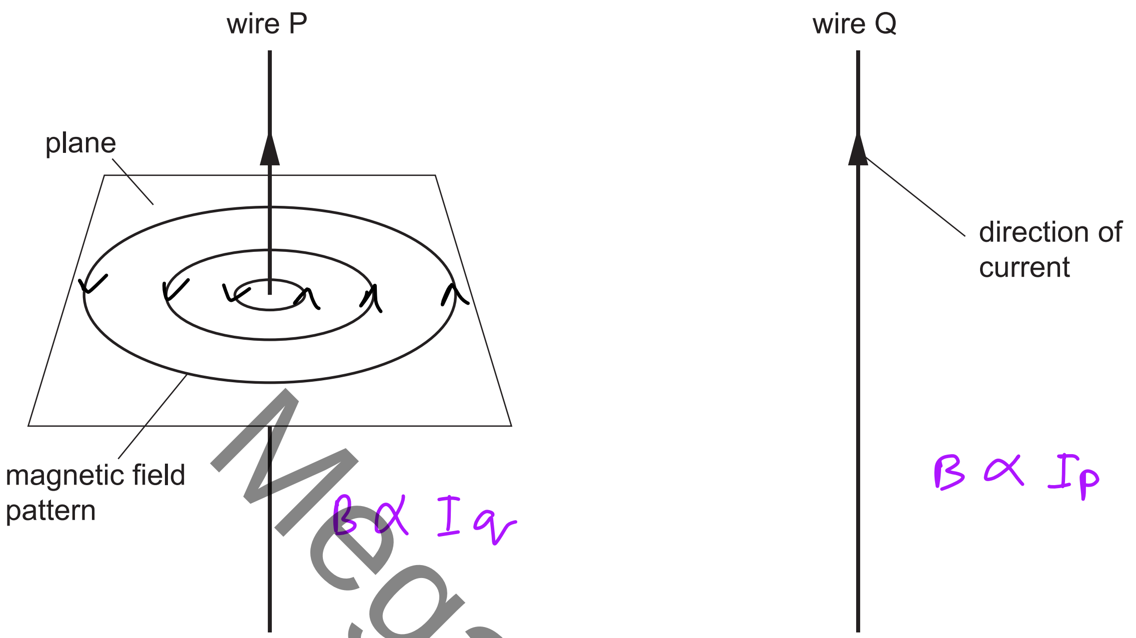


Fig. 8.1

(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 ..... [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 force on both wire are equal.

Force ∝ product of the 2 currents

..... [2]

Equal in magnitude and opposite in direction ; Newton's third law.

$F = \frac{\mu_0 I_P I_Q}{2\pi r}$

(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.

It has the same frequency as the natural frequency for precession of proton known as Larmor freq. proton absorb energy and flip into high energy state [resonate].

[2]

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

The same transducer that emits radio pulses have to detect at the same time, that's why pulses. time interval needed in b/w emmission and detection.

[2]

[Total: 8]

9 (a) Define *magnetic flux linkage*.

$\phi = NBA$

where N is no. of coil, B is magnetic field strenght, A is area where coil is placed perpendicular to the field.

[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.

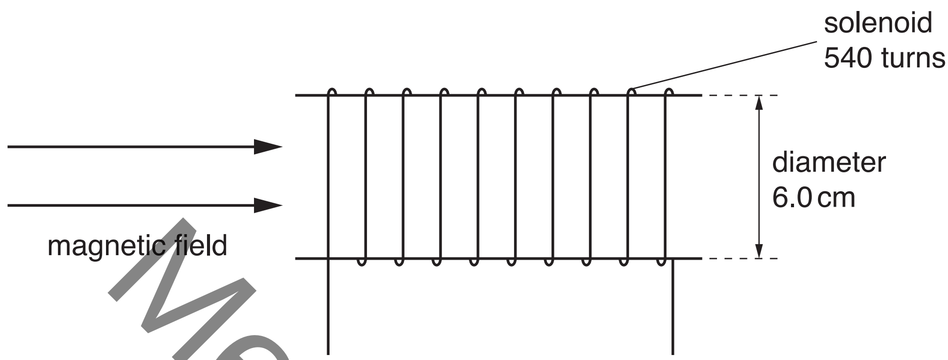


Fig. 9.1

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

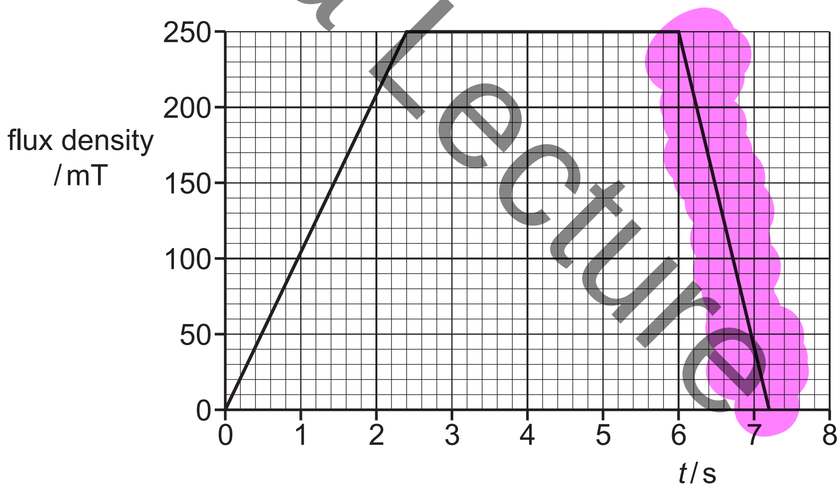


Fig. 9.2

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

$$E = \frac{d\phi}{dt}$$

$$E = NA\left(\frac{\Delta B}{\Delta T}\right)$$

$$\frac{540 \times \pi \times (3\times10^{-2})^2 \times 250\times10^{-3}}{1.2} = 0.32$$

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

(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.

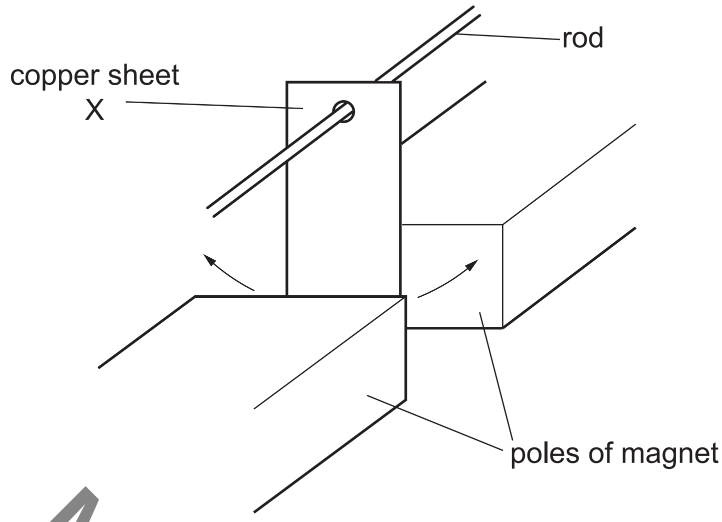


Fig. 9.3

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.

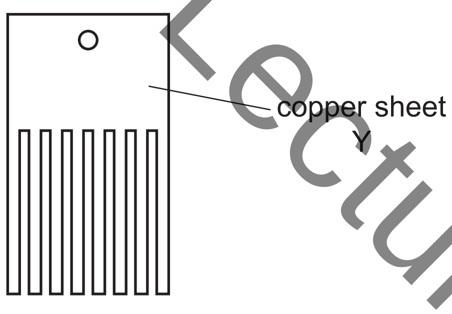


Fig. 9.4

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.

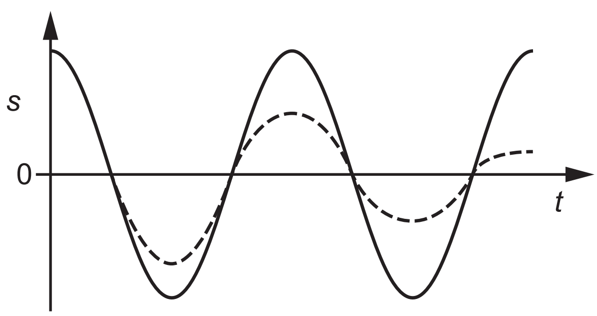


Fig. 9.5

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

Damping ← Light [1]

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

Amp of dotted line ↓
∴ it osscilates b/w poles of magnet ∴
induced current
Eddy current in sheet X > sheet Y because of
larger surface area. ∴ e are unable to cross
b/w insulating gaps so circulates less,
smaller eddy current, less thermal energy
lost → less damping [4]

[Total: 10]

Greater loss of T.E in X
Greater damping

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.

330 / √2 =

r.m.s. p.d. = ...226.......... V [1]

(b) Determine the period T of the output.

100π = ω

100π = 2π / T

T = 0.02 s

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.

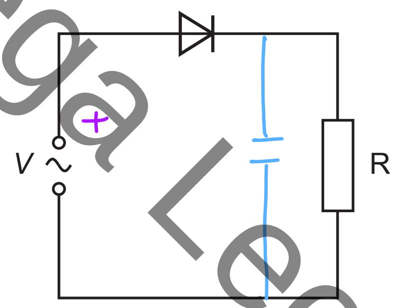


Fig. 10.1

(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.

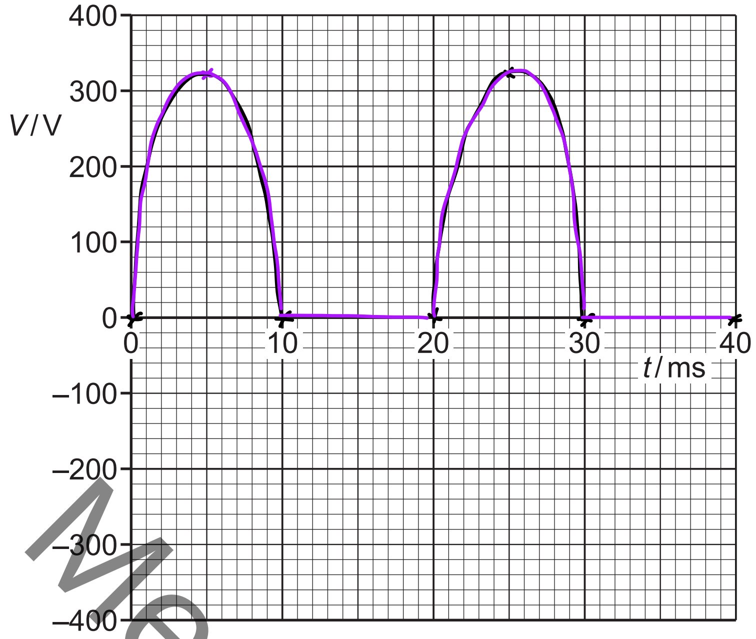


Fig. 10.2

[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.

e hitting the target metal have a range of accelerations (decelerations ⊛)

x ray photons released when the e slow down, have a range of energy value and wavelenght value. K.E of e is converted to E of photon. [3]

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

1 e → photon.
convert
fully stop.

$q\Delta V = \frac{hc}{\lambda}$

$1.6 \times 10^{-19} \times 15 \times 10^{3} = \frac{hc}{\lambda}$

$\lambda = 8.29 \times 10^{-11}$

wavelength = 8.29×10^{-11} m [3]

(b) A beam of X-rays has an initial intensity I_o. 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_o).

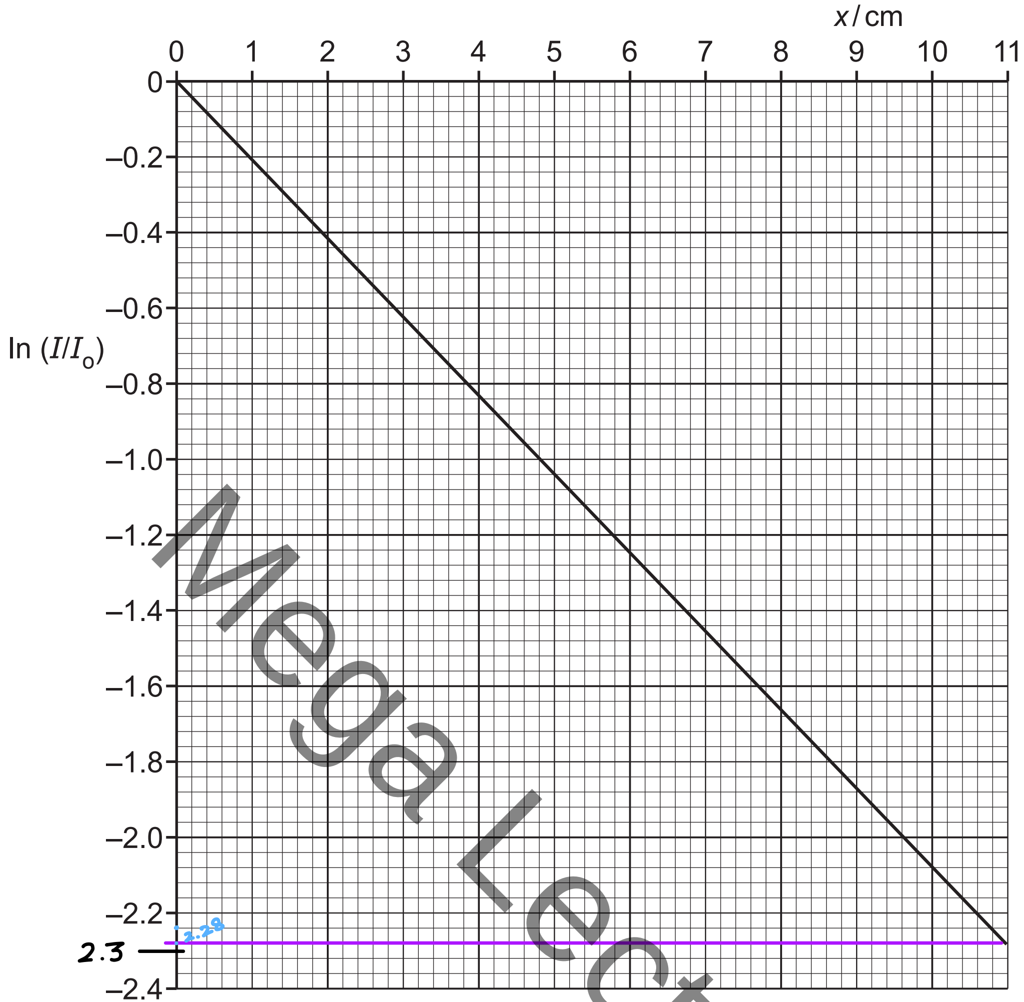


Fig. 11.1

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

$\ln\left(\frac{I}{I_o}\right) = -\mu x$ $\mu = 0.21$

$m = -\mu$

$-\frac{2.28}{11} = -\mu$

μ = ... 0.21 .... 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.

$0.05\, I_o = I_o\, e^{-\mu x}$

$\ln 0.05 = -0.21x$

$x = 14.5$

thickness = ... 14.5 .... cm [2]

[Total: 10]

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

State what is meant by:

1. *spontaneous decay* without any change in condition
independent of any external or environment factor.

2. *random decay.* in no specific order.
cannot be predicted / each nucleus / same probability. [2]

(b) Strontium-90 ($^{90}_{38}Sr$) is an unstable nuclide. → 5.2×10^6 Bq

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. $N = \frac{1.0 \times 10^{-9} \times 10^3}{90} \times 6.02 \times 10^{23}$

$A = \lambda N$

$N = 6.69 \times 10^{15}$

$5.2 \times 10^6 = \lambda (6.69 \times 10^{15})$

$\lambda = 7.77 \times 10^{-10}$

λ = ... 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.

The product formed is also unstable; adds to the activity. [1]

or background radiation.

[Total: 6]

BLANK PAGE