RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 2
PAPER 2

13 SEPTEMBER 2023

2 HOURS

CANDIDATE NAME	

CENTRE NUMBER	S					**INDEX NUMBER**					

CLASS	2	2	J		

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected where appropriate.

Candidates answer on the Question Paper.
No Additional Materials are required.

*Answer **all** questions.*

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINERS' USE	
Paper 2	
1	/ 8
2	/ 8
3	/ 9
4	/ 8
5	/ 12
6	/ 8
7	/ 9
8	/ 6
9	/12
Deduction	
Paper 2	**/ 80**

This document consists of **25** printed pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 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	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	T / K = T / °C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
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,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A ball of mass 58 g collides horizontally with a wall. Fig. 1.1 shows the variation of magnitude of force on the ball F with time.

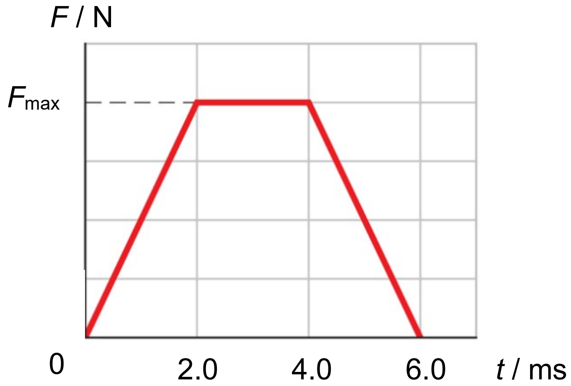

Fig. 1.1

The initial velocity of the ball is 34 m s^{-1} perpendicular to the wall. The ball rebounded with the same speed and also perpendicular to the wall.

(a) Explain what is impulse on the wall.

....

....

.... [1]

(b) Calculate the change in momentum of the ball. Take initial direction of the ball to be positive.

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

(c) Hence, use Fig. 1.1 to find F_{max} on the ball.

F_{max} = …………………. N [2]

(d) On Fig. 1.2 complete the sketch of the variation of velocity of the ball with time.

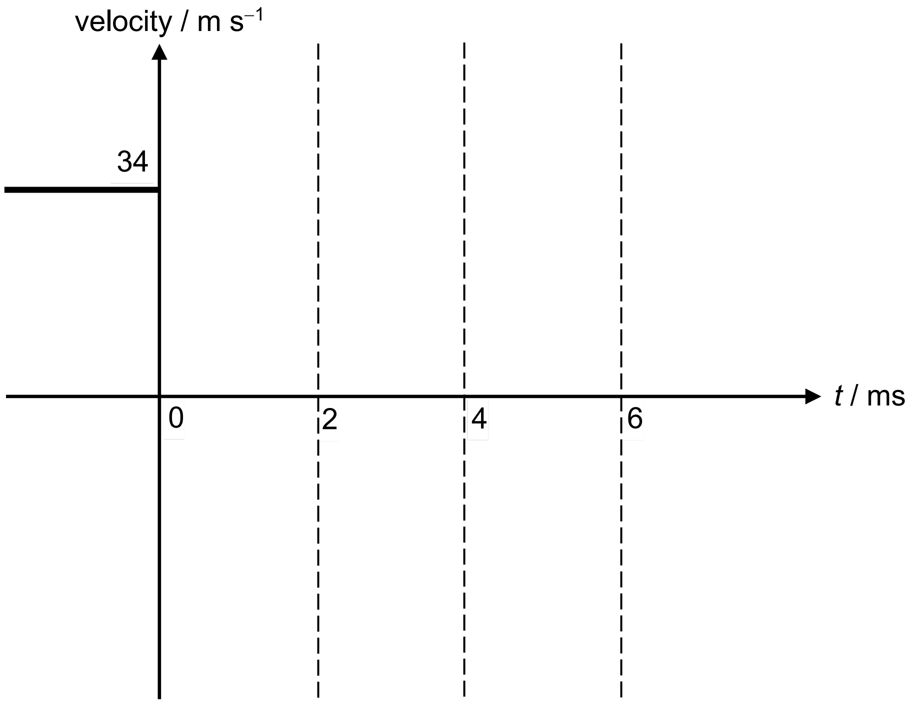

Fig. 1.2

[3]

2 **(a)** A cube of volume V contains N molecules of an ideal gas. Each molecule has a component c_x of velocity normal to one side S of the cube as shown in Fig. 2.1.

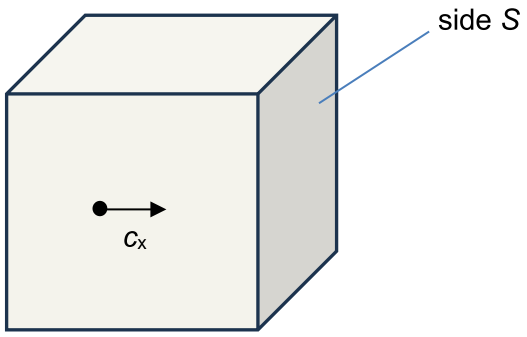

Fig. 2.1

The pressure due to one molecule with the component c_x of velocity is given by the expression

$$\frac{m}{V}c_x^2$$

where m is the mass of one molecule.

Explain how the expression leads to the relation

$$pV = \frac{1}{3}Nm < c^2 >$$

where p is the pressure due to N molecules.

……………………..……………………………………………………………………………

……………………..……………………………………………………………………………

…………..………………………………………………………………………………… [3]

(b) Three moles of an ideal gas are in a rigid cubical box with sides of length 0.200 m.

(i) Calculate the force that the gas exerts on one side of the box when the gas temperature is 20.0 °C.

force = ………………….. N [3]

(ii) Kinetic theory of gases assumes that the intermolecular forces between the gas particles are negligible.

Suggest and explain how your answer in **(b)(i)** may change if there are intermolecular forces between particles.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

3 One end of a light spring is fixed to a support. A mass is attached to the other end of the spring. The arrangement is shown in Fig. 3.1.

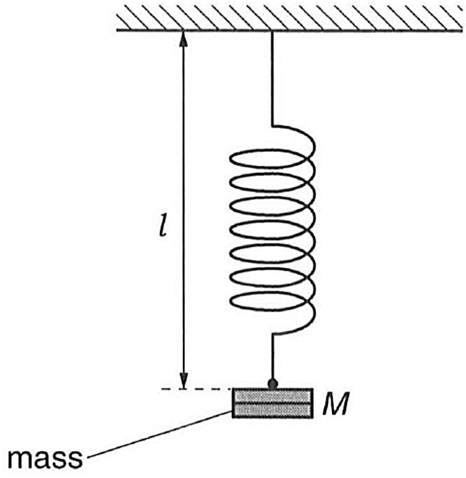

Fig. 3.1

This arrangement is used to determine the length l of the spring when mass M is attached to the spring. The procedure is repeated for different values of M. The variation of mass M with length l is shown in Fig. 3.2.

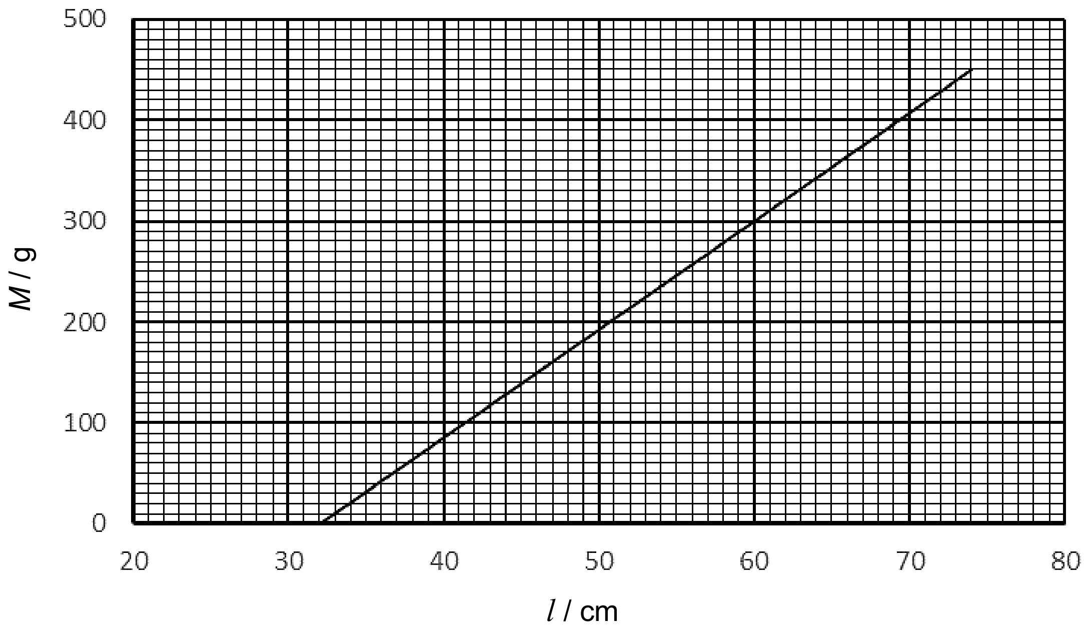

Fig. 3.2

The spring constant k of the spring is given to be 10.5 N m^{-1}.

(a) A mass of 450 g is attached to the spring and is held at rest with length l of 50.0 cm. The mass is then released and the mass oscillates freely. The angular frequency of the spring-mass system is given by the formula

$$\omega = \sqrt{\frac{k}{m}}$$

(i) Calculate the frequency of the system.

frequency = ……………..……..……..Hz [2]

(ii) Using energy considerations, calculate the speed of the mass during its oscillation when the spring is extended to a length l of 80.0 cm.

speed = ……………..……..…….. m s^{-1} [4]

(b) **(i)** On Fig. 3.3, sketch the displacement-time curve for the system depicted in **(a)**.

Label this curve **W**.

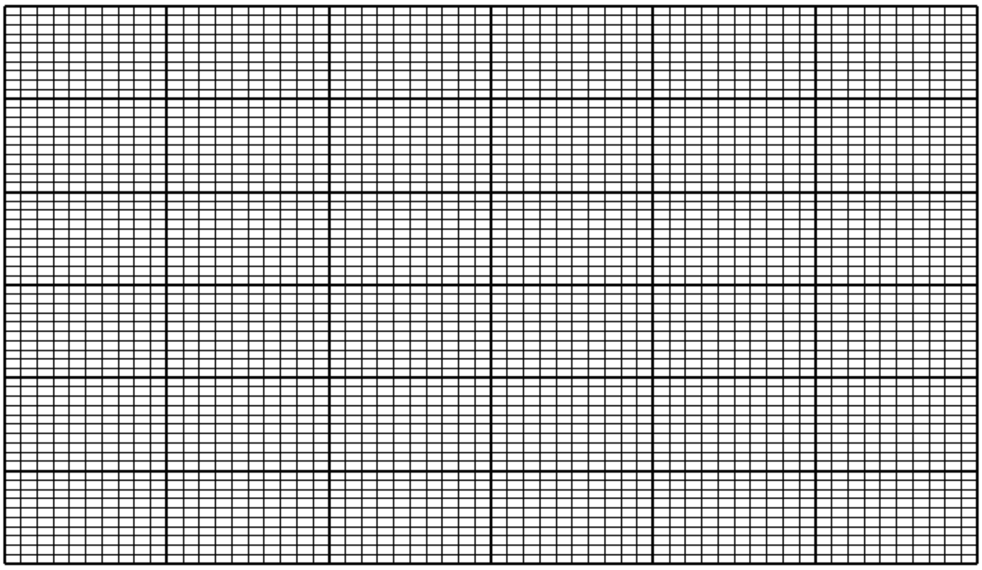

Fig. 3.3

(ii) A student affixed a piece of light cardboard beneath the mass, that extended beyond the perimeter of the mass.

Assuming that the spring constant *k* is unchanged, on the same axes in Fig. 3.3, sketch the displacement-time curve for the mass with cardboard.

Label this curve **X**.

[3]

4 **(a)** State what is meant by *interference*.

....

.... [1]

(b) **(i)** A beam of white light is shone normally onto a diffraction grating with 300 lines per millimetre. The light source consists of wavelength between 400 nm to 700 nm.

Determine the highest order of the full spectrum that can be produced.

highest order = ……………………. [2]

(ii) Determine whether the first and the second spectra overlap. Show your calculations clearly.

………………………………………………………………………………

…………………………………………………………………………… [3]

(c) At the edge of the central maximum bright fringe, it is observed that there are coloured fringes. Explain this phenomenon.

....

....

....

.... [2]

5 **(a)** A resistor of resistance R consists of a thin layer of copper deposited uniformly on the surface of an iron wire of radius of 0.60 mm and length 3.0 m as shown in Fig. 5.1. The thickness of the copper is 1.78×10^{-5} m.

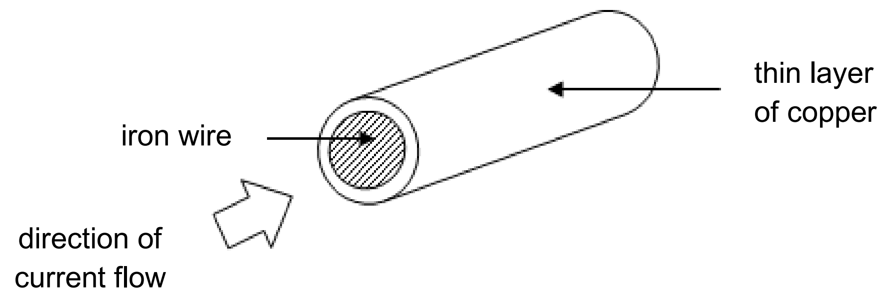

Fig. 5.1

(i) The resistivity of iron and copper are $8.90 \times 10^{-8}\ \Omega$ m and $1.60 \times 10^{-8}\ \Omega$ m respectively.

If the resistance of iron wire is 0.236 Ω, show that R is 0.18 Ω.

[2]

(ii) Explain how R changes after the current passes through it for a period of time.

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………………………….. [2]

(b) A 50 Hz 240 V alternating sinusoidal voltage is applied across the primary coil of a **step-down** transformer as shown in Fig. 5.2. A diode acting as a rectifier is placed in series with the resistor in **(a)** and the secondary coil.

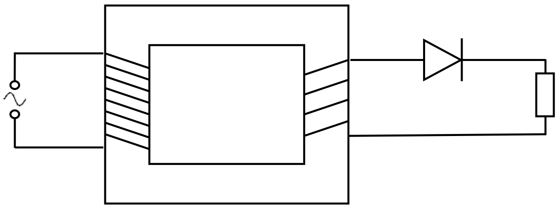

Fig. 5.2

The ratio $\dfrac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$ is 10.

(i) Determine the maximum output voltage from the transformer.

maximum output voltage = …………………….. V [2]

(ii) On Fig. 5.3, sketch the variation with time the output power of the resistor. Label your graph clearly.

output power / W

Fig. 5.3

[2]

(iii) Hence, or otherwise, calculate the mean power generated by the resistor. Show your working clearly.

mean power = ……………………. W [3]

(c) In a new electrical circuit as shown in Fig. 5.4, a direct current voltage of 24 V is connected across the resistor in **(a)**. A diode is placed in series with the resistor.

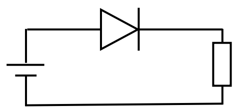

Fig. 5.4

Explain if there is any change to the mean power generated by the resistor as compared to your answer in **(b)(iii)**.

....

.... [1]

6 **(a)** Define *electric field strength*.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………… [2]

(b) Two plane parallel conducting plates 1.50 cm apart are held horizontal, one above the other, in air. The upper plate is maintained at a positive potential of 1500 V while the lower plate is earthed, as shown in Fig. 6.1.

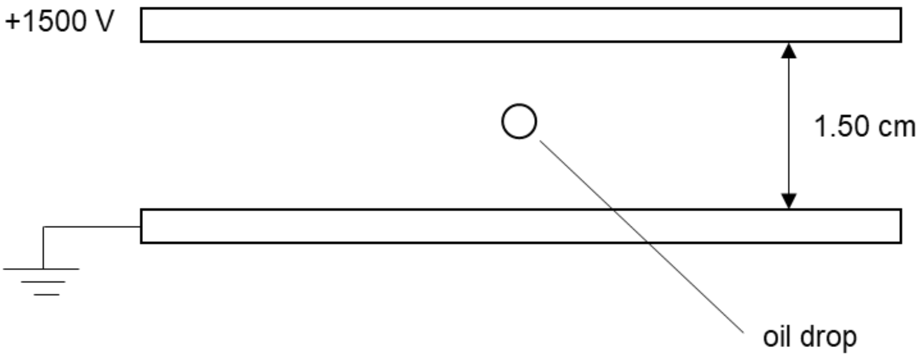

Fig. 6.1

(i) Calculate the number of electrons which must be attached to a small oil drop of mass of 4.90×10^{-12} g stationary in the air between the plates. Assume that the density of air is negligible in comparison with that of oil.

number of electrons = ………………….. [3]

(ii) The potential of the upper plate is suddenly changed to −1500 V.

Determine the initial magnitude and direction of acceleration of the charged drop. Explain your answer.

magnitude of acceleration = ………………….. m s^{-2}

direction of acceleration = …………………..

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………… [3]

7 **(a)** State the *laws of electromagnetic induction*.

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………………………………………………………… [2]

(b) The diameter of the cross-section of a long solenoid with 15 turns is 3.2 cm, as shown in Fig. 7.1.

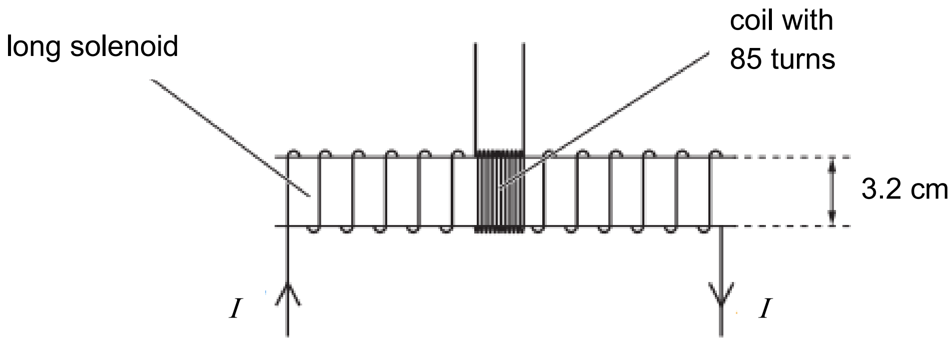

Fig. 7.1

A coil with 85 turns of wire, is wound tightly around the centre region of the solenoid. The magnetic flux density B, in tesla, at the centre of the solenoid is given by the expression

$$B = \pi \times 10^{-3} \times I$$

where I is the current in the solenoid in ampere.

(i) Calculate, for a current I of 2.8 A in the solenoid, the magnetic flux linkage of the coil.

magnetic flux linkage = …………………. Wb [2]

(ii) The current I in the solenoid in **(b)(i)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in the coil.

e.m.f. induced = ………………….. mV [2]

(iii) The current I in the solenoid in **(b)(i)** is now varied with time t as shown in Fig. 7.2.

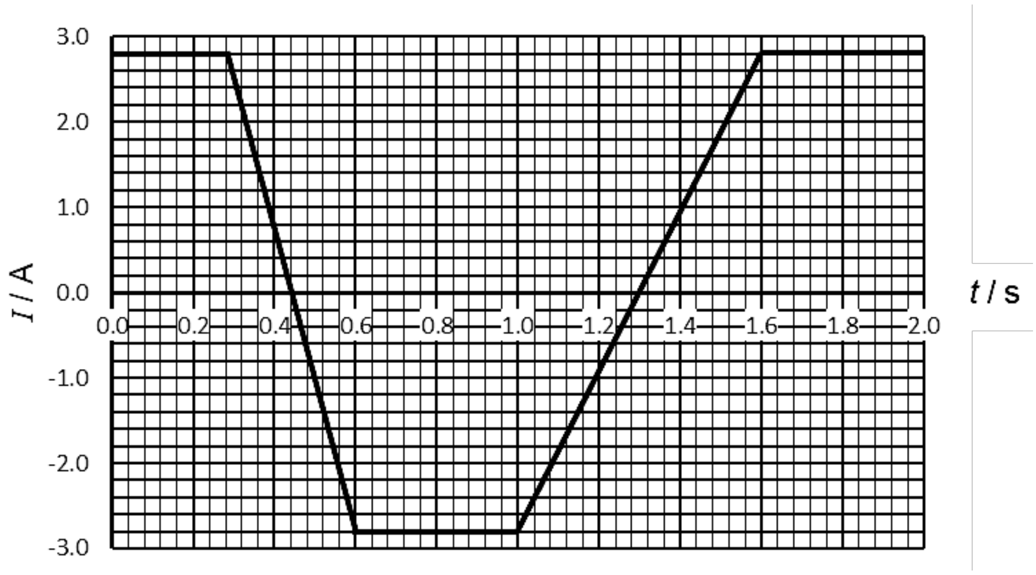

Fig. 7.2

Use your answer to **(b)(ii)** to show, on Fig. 7.3, the variation with time t of the e.m.f. E induced in the coil.

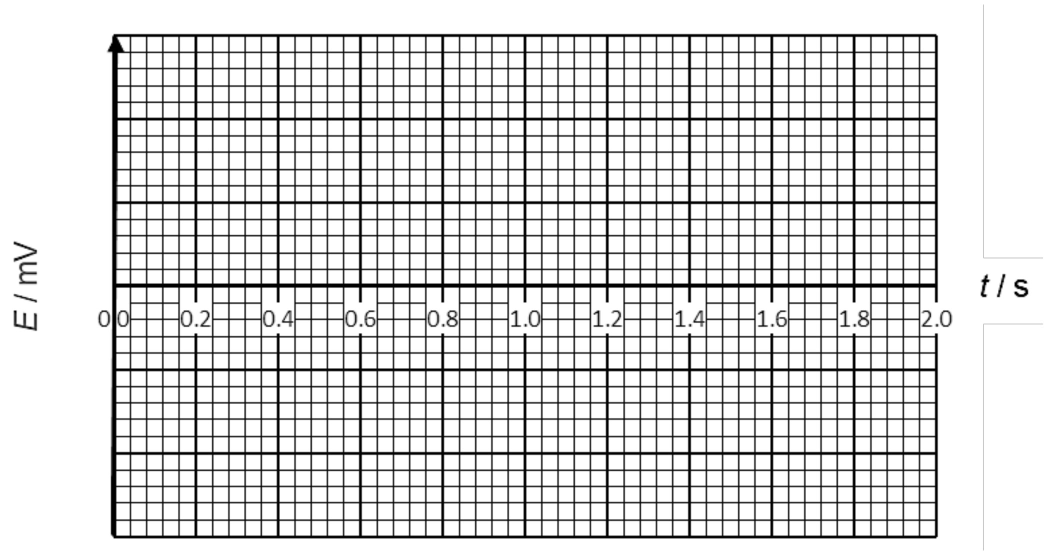

Fig. 7.3

[3]

8 The spectrum of sunlight has dark lines. These dark lines are due to the absorption of photons of certain wavelengths by the cooler gases in the atmosphere of the Sun.

Fig. 8.1 shows some of the energy levels of an isolated atom of helium.

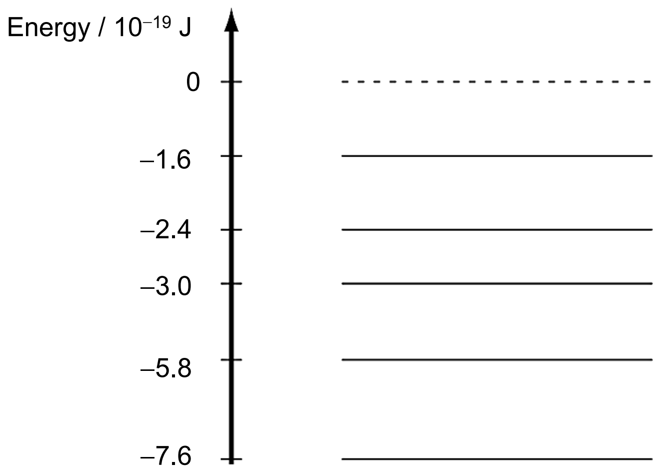

Fig. 8.1

(a) Explain the significance of the energy levels having negative values.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………………………………………………………………………………………… [1]

(b) **(i)** One particular dark spectral line has a wavelength of 590 nm.

Calculate the energy of a photon with this wavelength.

energy = ………………….. J [2]

(ii) Hence, with reference to a possible transition in Fig. 8.1, explain how there could be presence of helium in the atmosphere of the Sun.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………… [2]

(c) All the light absorbed by the atoms in the Sun's atmosphere is re-emitted.

Suggest why a dark spectral line of wavelength of 590 nm is still observed from the Earth.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………… [1]

9 Dangers associated with exposure to radiation have been recognised for many years. As a result of these hazards, measures have been adopted to reduce exposure to radiation to as low a level as possible. One such measure is to shield individuals from radioactive source using radiation absorbing materials.

Experiments have been carried out to investigate the effectiveness of materials as absorbers of γ-ray photons. One possible experiment is illustrated in Fig. 9.1.

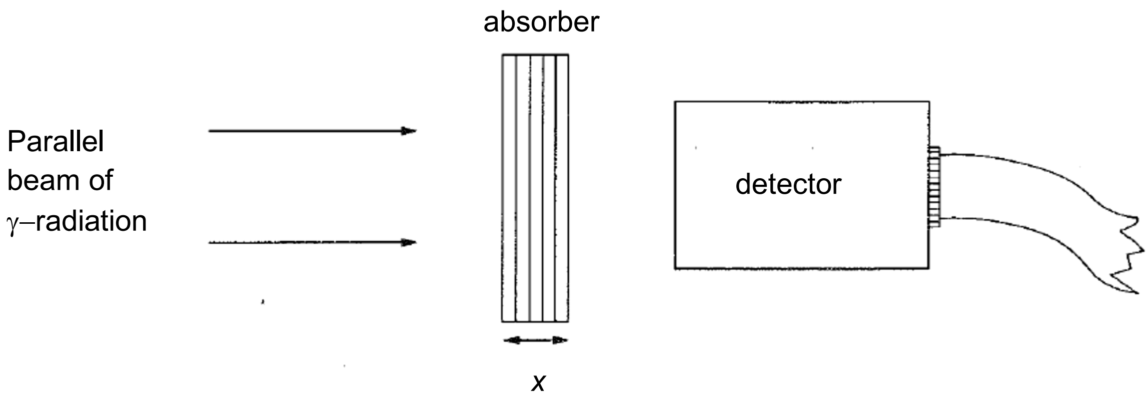

Fig. 9.1

The count-rate C_x of γ-ray photons is measured for various thicknesses x of the absorber, together with the count-rate C_0 for no absorber. Fig. 9.2 shows the variation with thickness x of the ratio C_x/C_0 for lead.

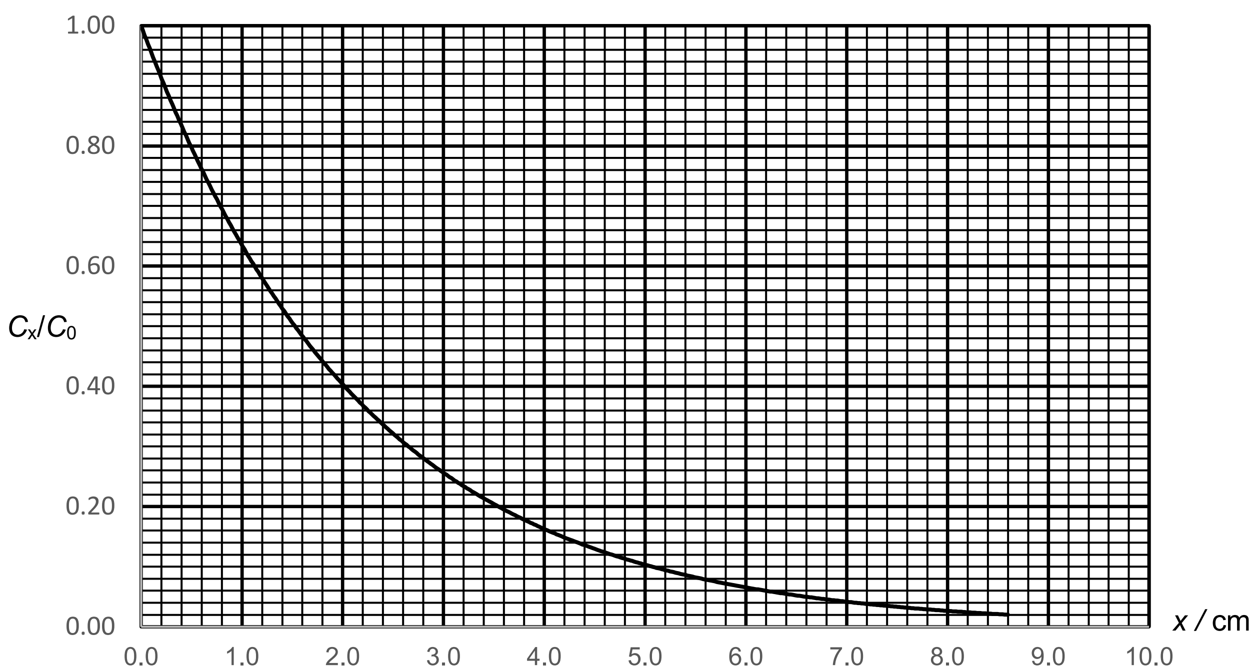

Fig. 9.2

(a) Use Fig. 9.2 to deduce that, theoretically, complete shielding is not possible.

....

.... [1]

(b) Fig. 9.2 indicates that there may be an exponential decrease of the ratio C_x/C_0 with thickness x. In order to test this suggestion, a graph of $\ln(C_x/C_0)$ against x is plotted. This is shown in Fig. 9.3.

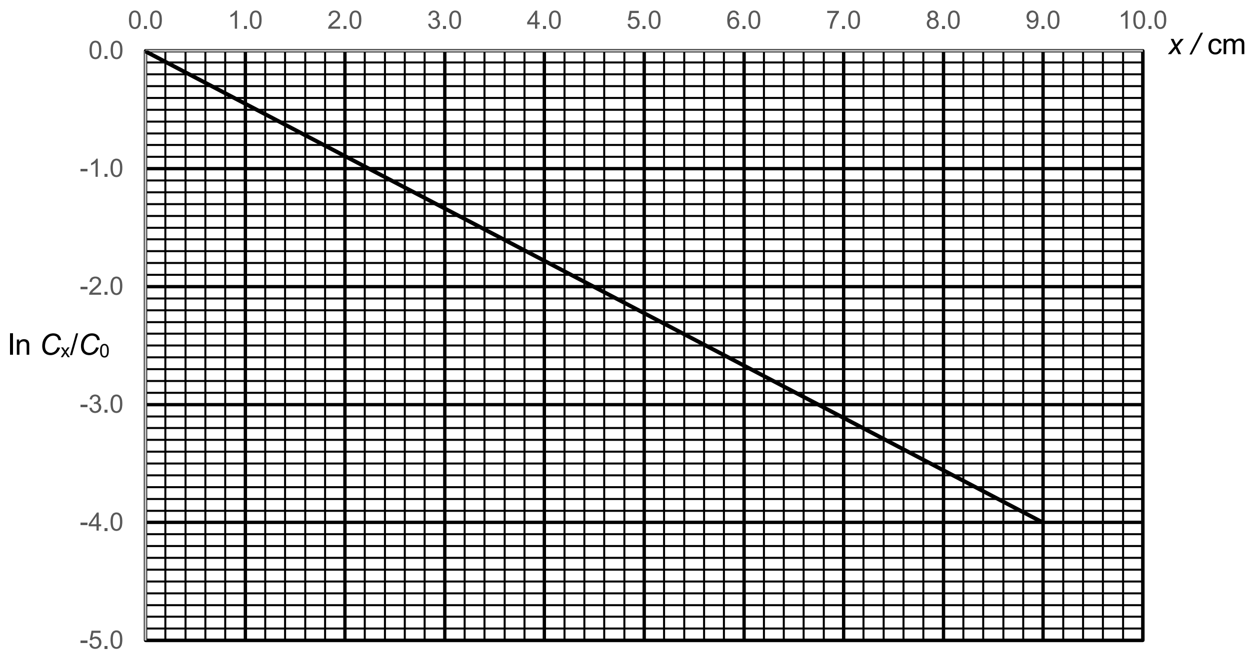

Fig. 9.3

(i) Show that Fig. 9.3 indicates a relationship of the form

$$C_x = C_0 e^{-\mu x}$$

where μ is a constant. Explain your working clearly.

....

....

.... [2]

(ii) The constant μ is known as the linear absorption coefficient. Use Fig. 9.3 to calculate a value of μ for lead.

μ = ………………… cm^{-1} [2]

(c) The linear absorption coefficient μ has been found to depend on photon energy and on the absorbing material itself. For γ-ray photons of one energy, μ is different for different materials.

In order to assess absorption of γ-ray photons in matter such that the material of the absorber does not have to be specified, a quantity known as the mass absorption coefficient μ_m is calculated. μ_m is given by the expression

$$\mu_m = \frac{\mu}{\rho}$$

where ρ is the density of the absorbing material.

Values of μ for 2.75 MeV photons and of ρ for different materials are given in Fig. 9.4.

material	μ / cm^{-1}	ρ / g cm^{-3}	μ_m / …………
aluminium	0.095	2.70	0.035
tin	0.267	7.28	0.037
lead	……………..	11.3	………………..

Fig. 9.4

On Fig. 9.4,

(i) give a unit for μ_m, [1]

(ii) use your answer to **(b)(ii)** to complete the table of values for lead. [1]

(d) Research is currently ongoing for a new building material M which can also be used for shielding. The density of M is 2.4×10^3 kg m^{-3}.

(i) By calculating an average value for μ_m, show that the linear absorption coefficient μ for 2.75 MeV photons in material M is approximately 0.09 cm^{-1}.

[2]

(ii) By reference to Fig. 9.2 and the equation given in **(b)(i)**, calculate the approximate thickness of material M which would provide the same level of shielding, for 2.75 MeV photons, as a thickness of 4.0 cm of lead.

thickness = …………………. cm [3]

END OF PAPER