Class	Index Number	Name
23S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2024
Preliminary Examination

PHYSICS, Higher 2 **9749/02**

Paper 2 Structured Questions **28th August 2024**
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group in the spaces at the top of this page.
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.
Answer **all** questions.

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

For Examiner's Use	
1	/ 8
2	/ 10
3	/ 5
4	/ 6
5	/ 7
6	/11
7	/ 11
8	/ 22
Total	/ 80

This document consists of **22** printed pages including this page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = u t + \frac{1}{2} a t^2$
	$v^2 = u^2 + 2 a s$
work done on/by a gas	$W = p \Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\varphi = -\frac{Gm}{r}$
temperature	T / K $= T$ / °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 molecule	$E = \frac{3}{2} kT$
displacement of particle in s.h.m.	$x = x_o \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$v = \pm \omega \sqrt{x_0^2 - x^2}$
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	$x = x_o \sin \omega t$
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	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_o \exp(-\lambda t)$

decay constant $\lambda = \dfrac{\ln 2}{t_{1/2}}$

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

1 A car has a total mass of 1100 kg and an initial speed 18.0 m s^{-1}. A set of traffic lights turn red when the driver is some distance from them. The driver applies a braking force on the car. Fig. 1.1 is the graph of braking force against time for the car approaching the traffic lights.

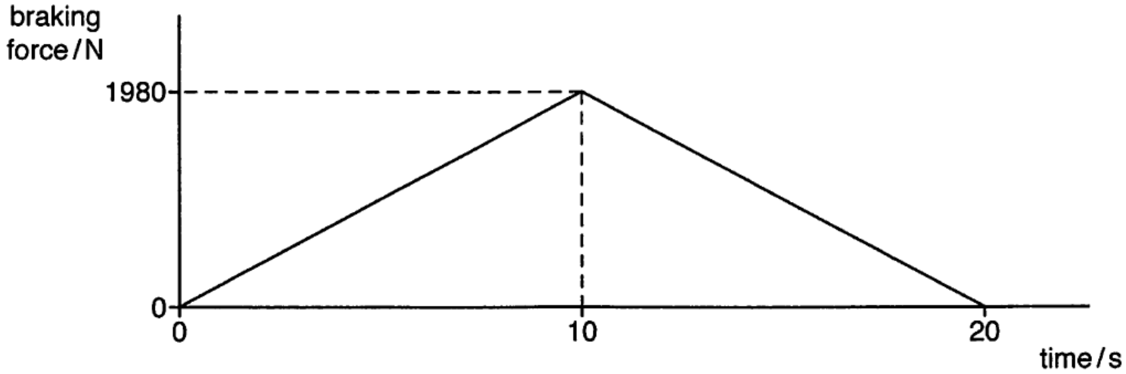


Fig. 1.1

(a) **(i)** Calculate the speed of the car at 10 s.

speed = …………………………….. m s^{-1} [2]

(ii) State an assumption made in your calculations above.

……………………………………………………………………………………………

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

(b) On Fig. 1.2, sketch a graph to show how the speed of the car changes from the instant the braking force is applied till the force becomes zero. [3]

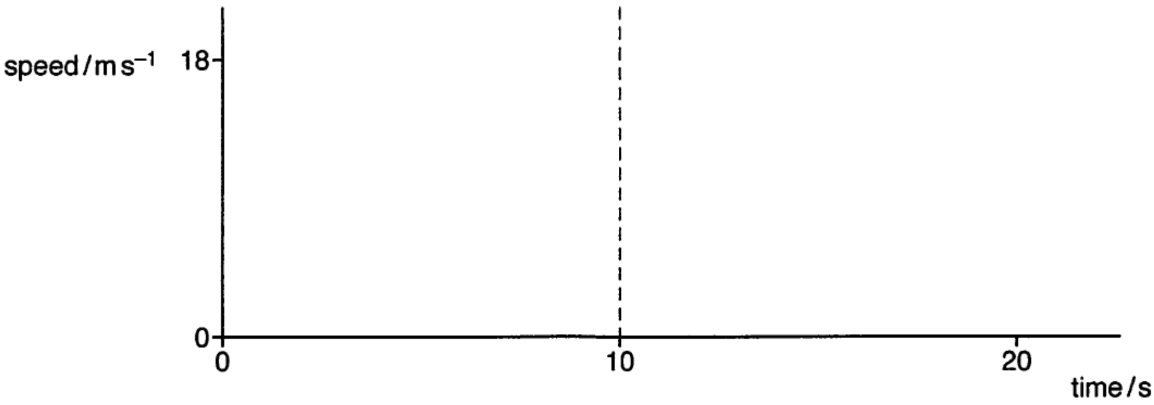


Fig. 1.2

(c) On Fig. 1.3, sketch a graph to show how the distance travelled by the car from the instant the braking force is applied till the force becomes zero. [2]

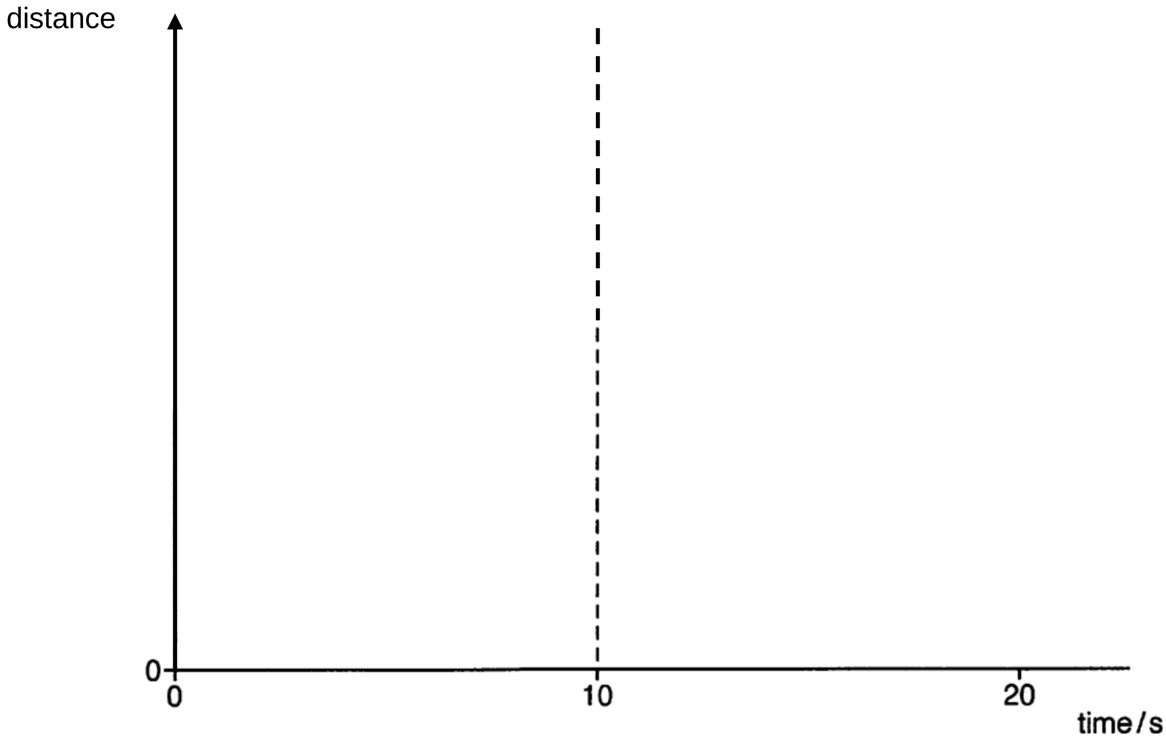


Fig 1.3

2 **(a)** State the principle of conservation of momentum.

………

………

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

(b) A firework is initially stationary. It explodes into three fragments A, B and C that move in a horizontal plane, as shown in the view from above in Fig. 2.1.

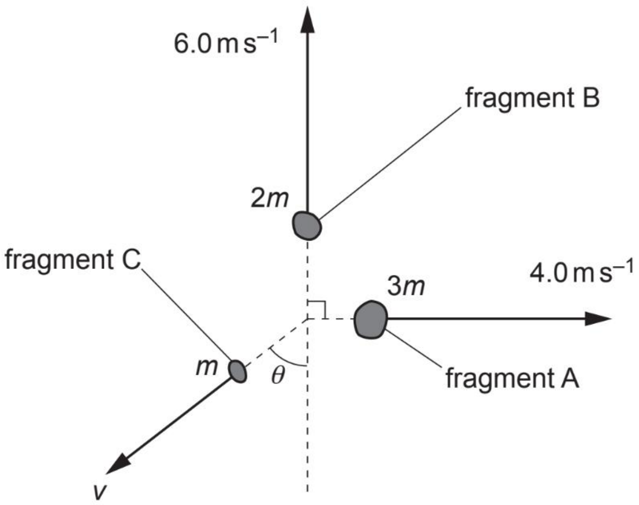


Fig. 2.1

Fragment A has a mass of 3*m* and moves away from the explosion at a speed of 4.0 m s^{-1}.

Fragment B has a mass of 2*m* and moves away from the explosion at a speed of 6.0 m s^{-1} at right angles to the direction of A.

Fragment C has a mass of *m* and moves away from the explosion at a speed *v* and at an angle *θ* as shown in Fig. 2.1.

Calculate:

(i) the angle *θ*,

θ = ………………………….. ° [3]

(ii) the speed v.

v = ………………………….. m s^{-1} [2]

(c) The firework in **(b)** contains a chemical that has mass 5.0 g and has chemical energy per unit mass 700 J kg^{-1}. When the firework explodes, all the chemical energy is transferred to the kinetic energy of fragments A, B and C.

Calculate the mass m.

m = ………………………….. kg [3]

3 A sphere of radius 2.1 mm falls with terminal velocity through a liquid, as shown in Fig. 3.1.

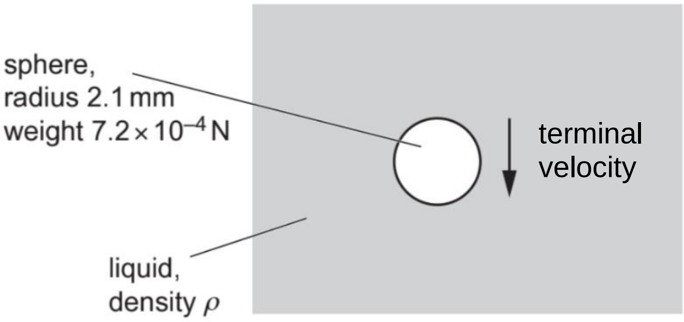


Fig. 3.1

Three forces act on the moving sphere. The weight, W, of the sphere is 7.2×10^{-4} N and the upthrust, U, acting, on it is 4.8×10^{-4} N. The viscous force, F_V, acting on the sphere is given by

$$F_V = krv$$

where r is the radius of the sphere, v is its velocity and k is a constant. The value of k is 17 kg m^{-1} s^{-1}.

(a) Calculate the density ρ of the liquid.

ρ = ... kg m^{-3} [2]

(b) **(i)** On the sphere in Fig. 3.1, draw three arrows to show the weight, the upthrust and the viscous force. Label these arrows W, U and F_V respectively. [1]

(ii) Determine the magnitude of the terminal velocity of the sphere.

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

4 **(a)** The planet Mars has a mass of 6.4 x 10^{23} kg and a diameter of 6.8 x 10^{3} km. A rock, initially at rest a long distance from Mars, travels towards its surface.

Assuming that Mars is isolated in space, show that the speed of the rock as it reaches the surface of Mars is 5.0 x 10^{3} m s^{-1}.

[2]

(b) **(i)** Helium-4 may be assumed to be an ideal gas.

Calculate the temperature of helium-4 gas at which the r.m.s. speed of its atoms is equal to the speed of the rock in **(a).**

[2]

(ii) Suggest, with a reason, whether helium-4 is found on the surface of Mars.

....

....

....

.... [2]

5 **(a)** A progressive wave transfers energy. A stationary wave does not transfer energy. State two other differences between progressive waves and stationary waves.

1. ……………………………………………………………………………………………...…………

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

2. ……………………………………………………………………………………………...……….

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

[2]

(b) A stationary wave is formed on a stretched string between two fixed points A and B. The variation of displacement *y* of the particles of the string with distance *x* along the string for the wave at time *t* = 0 is shown in Fig. 5.1.

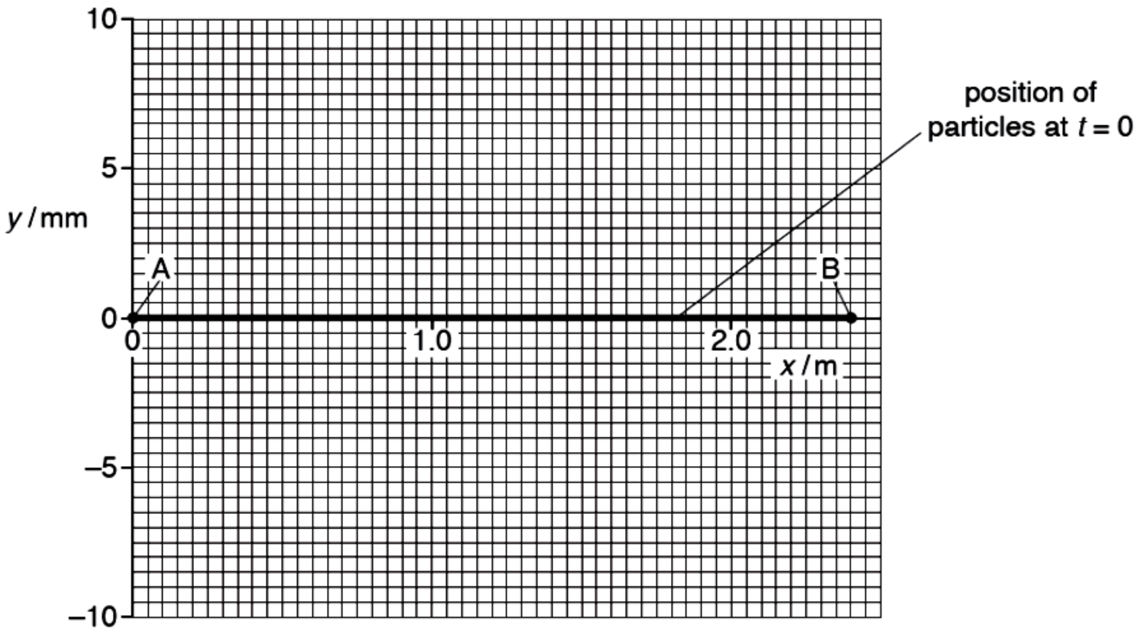


Fig. 5.1

The wave has a period of 20 ms and a wavelength of 1.2 m. The maximum amplitude of the particles of the string is 5.0 mm.

(i) On Fig. 5.1, draw a line to represent the position of the string at *t* = 5.0 ms. [2]

(ii) State the phase difference between the particles of the string at x = 0.40 m and at *x* = 0.80 m.

phase difference = ………………………. unit …………………… [1]

(iii) State and explain qualitatively the change in kinetic energy of a particle at an antinode between t = 0 and t = 5.0 ms.

....

....

....

.... [2]

6 **(a)** An electrician is connecting two identical electric cookers to a supply. One of the cookers is connected to the supply using wire X, and the other cooker is connected using wire Y. The same current flows in each wire when the cookers are switched on.

Table 6.1 contains information on the two electrical wires X and Y.

wire	cross-sectional area	total length of wire	Resistivity of wire material
X	A	L	ρ
Y	1.50 A	1.50 L	1.58 ρ

Table 6.1

(i) Calculate the ratio

$$\frac{\text{rate at which electrical energy is converted into thermal energy in wire X}}{\text{rate at which electrical energy is converted into thermal energy in wire Y}}$$

ratio = …………………… [2]

(ii) Suggest with a reason which wire is more suitable for connection to the cooker.

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(iii) In practice, each connecting wire consists of a cable made up of five thin wires which are electrically isolated from each other. Fig. 6.1 shows a cross section of the cable.

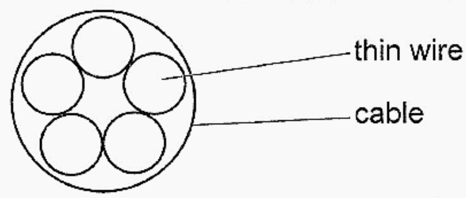


Fig. 6.1

1. The resistance of one of the cables is measured as 0.0458 ∧. Calculate the resistance of a single thin wire.

resistance = ... Ω [2]

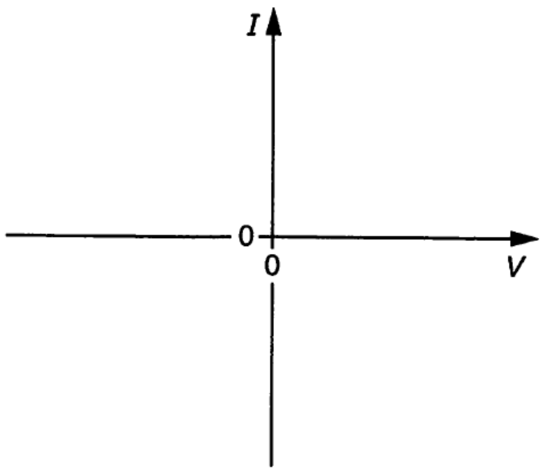
2. Suggest why, for a cooker, a cable made of several thin wires is used rather than a single thick wire with the same resistance.

....

....

.... [1]

(b) **(i)** Sketch, on Fig. 6.2, the I-V characteristic graph for a filament lamp.



[1]

Fig. 6.2

(ii) Explain, in terms of particles, why the I-V characteristic graph for a filament lamp has this shape.

....

....

....

....

.... [3]

(iii) Discuss whether the resistance of the filament lamp can be deduced from:

$$\frac{1}{gradient\ of\ I - V\ characteristic}$$

....

....

.... [1]

7 **(a)** **(i)** State what is meant by nuclear fusion.

....

....

.... [1]

(ii) On Fig. 7.1, sketch the variation of binding energy per nucleon with nucleon number A for values of A between 1 and 250. Label the value of A where binding energy per nucleon is the highest.

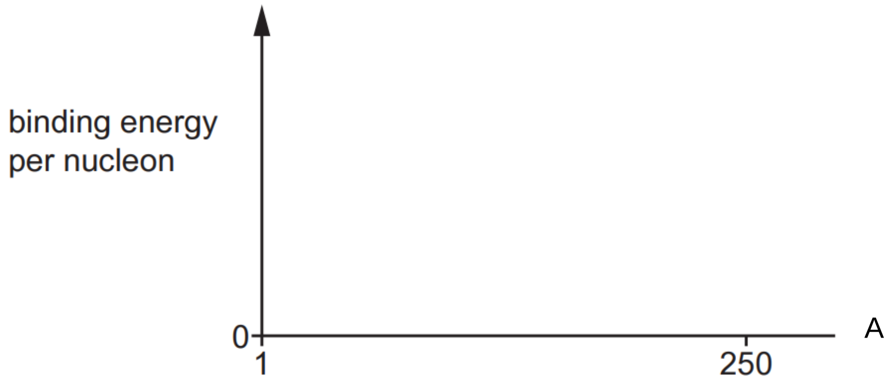


Fig. 7.1

[1]

(iii) On your line in Fig. 7.1, label:

1. a point X that could represent a nucleus that undergoes alpha-decay. [1]

2. a point Y that could represent a nucleus that undergoes nuclear fusion. [1]

(iv) A nucleus Z undergoes nuclear fission to form strontium-93 ($3893Sr$) and xenon-139 ($54139Xe$) according to

$$01n + \mathrm{Z} \rightarrow 3893Sr + 54139Xe + 201n.$$

Table 7.1 shows the binding energies of the strontium-93 and xenon-139 nuclei.

Table. 7.1

nucleus	binding energy / J
$^{93}_{38}\mathrm{Sr}$	1.25×10^{-10}
$^{139}_{54}\mathrm{Xe}$	1.81×10^{-10}

The fission of 1.00 mol of Z releases 1.77×10^{13} J of energy.

Determine the binding energy per nucleon, in MeV, of Z.

binding energy per nucleon = ... MeV [3]

(b) Fluorine-18 ($918F$) is a radioactive nuclide that is used as a tracer in positron emission tomography (PET scanning). Fluorine-18 decays to a nuclide of oxygen and emits 2 gamma-rays. The half-life of fluorine-18 is *T*. A patient is injected with amount of substance *n* of fluorine-18.

(i) Determine an expression for the initial value R_0 of the rate *R* of production of gamma-ray photons by the tracer, in terms of *n, T* and the Avogadro constant N_A. Explain your working.

R_0 = ... [2]

(ii) On Fig. 7.2, sketch the variation with time *t* of *R*.

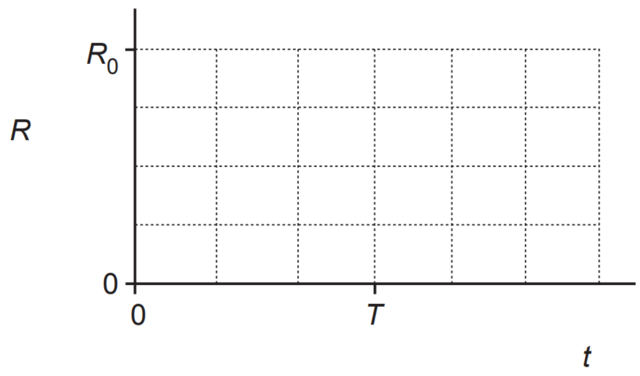


Fig. 7.2

[2]

8 Read the following article and then answer the questions that follow.

Shielding from nuclear radiation

Since the beginning of the industrial age, the burning of fossil fuels such as coal and petroleum has elevated the atmospheric CO_2 concentration to unprecedented levels. As a consequence, the global average surface temperature has increased and the earth has experienced the hottest years ever recorded. If we continue to consume fossil fuels at the same rate, the resulting temperature increase will have dramatic effects on global climate.

One measure to mitigate global warming is the use of renewable energy. Unfortunately, they are heavily dependent on the weather. Even as the technology for utilising renewable energy such as solar and wind improve, there are reliability issues, which present important challenges to be overcome before the world can turn “100 per cent renewables”.

Nuclear fission reactors generate electricity without producing greenhouse emissions. However, these power plants can pose serious safety and security problems due to concerns over radioactivity. 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 sources 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. 8.1.

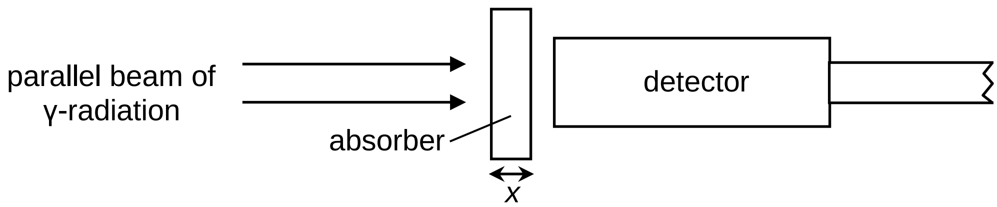


Fig. 8.1

The count-rate C_X of γ-ray photons is measured for various thickness x of the absorber, together with the count-rate C_0 for no absorber. Fig. 8.2 shows the variation with thickness x of the ratio C_X/C_0 for lead.

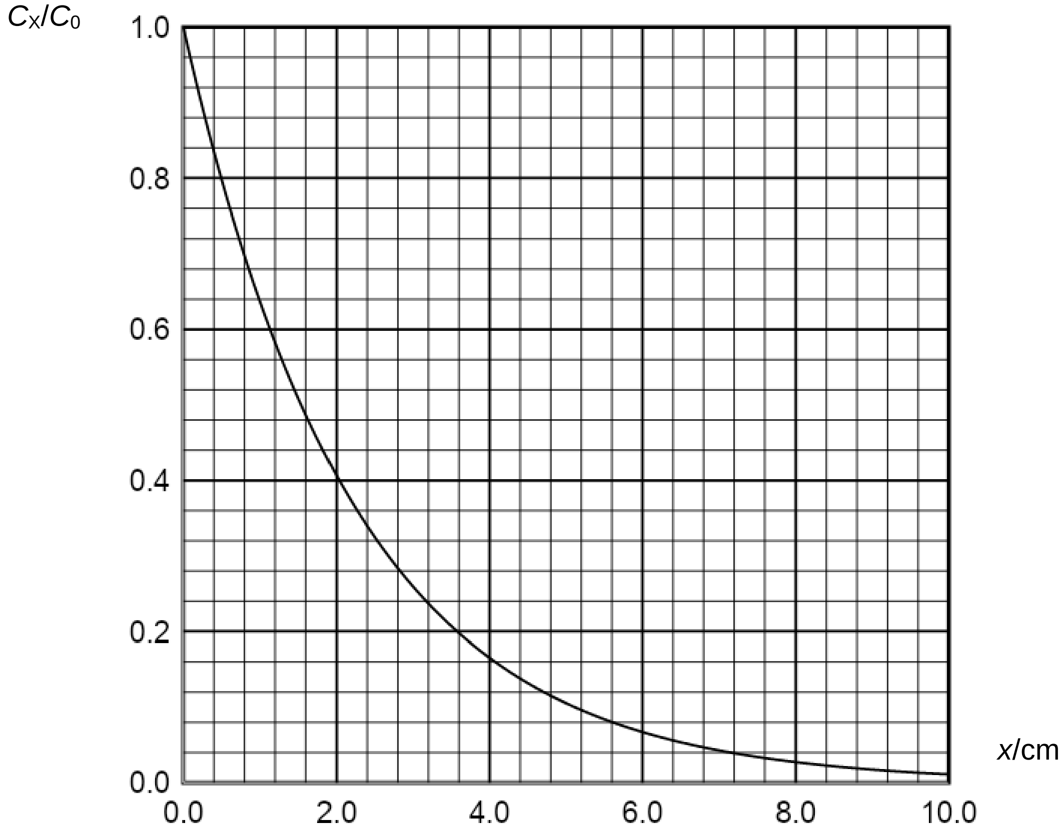


Fig. 8.2

(a) **(i)** By providing examples, suggest possible reliability issues faced by renewable energy sources.

....

....

....

.... [2]

(ii) State what is meant by γ-radiation.

....

.... [2]

(iii) Suggest how exposure to γ-radiation could be dangerous.

....

....

....

.... [2]

(iv) Suggest why it is necessary to have a parallel beam of γ-radiation in this experiment.

....

....

.... [1]

(v) Suggest how Fig. 8.2 shows that complete shielding does not take place.

....

....

.... [1]

(b) Data from Fig. 8.2 are used to obtain values of ln (C_X/C_0). These are used to plot the graph of Fig. 8.3.

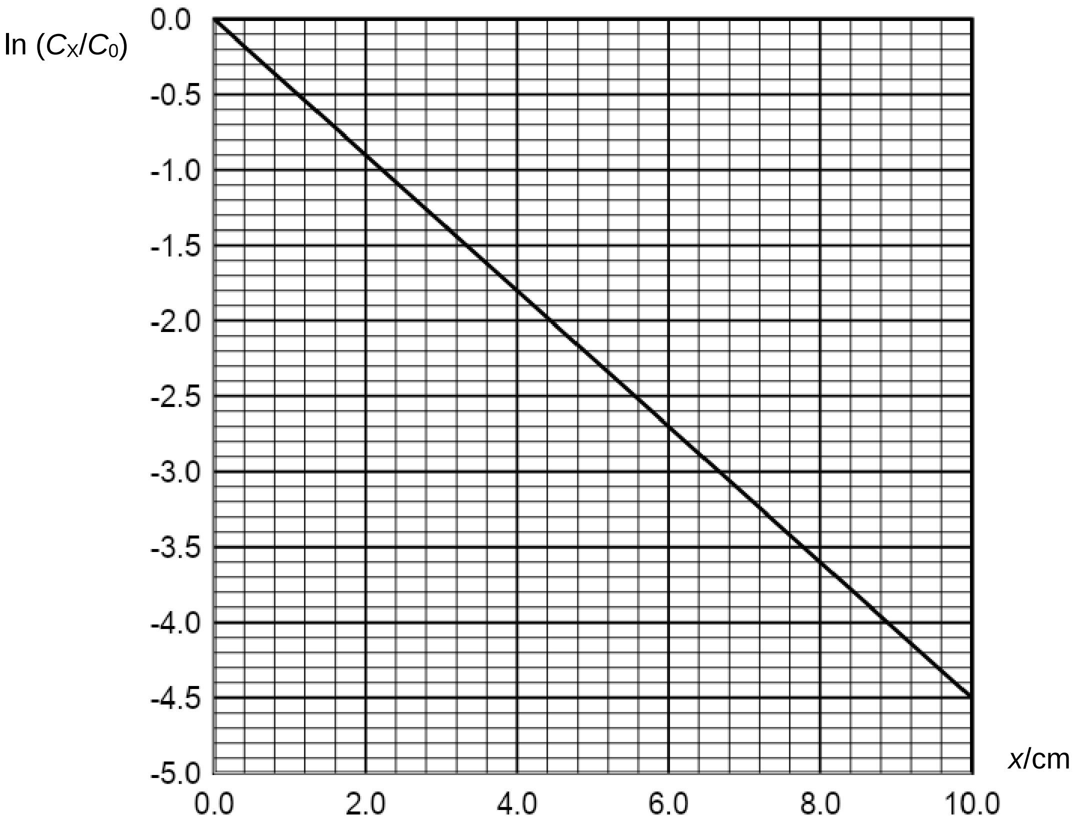


Fig. 8.3

(i) It is proposed that the count-rate C_X changes with the thickness x of the absorber according to an expression of the form

$$C_X = C_0\, e^{-\mu x},$$

where μ is a constant.

Explain why the graph of Fig. 8.3 supports this proposal.

[3]

(ii) The constant μ is known as the linear absorption coefficient. Use Fig. 8.3 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. 8.4.

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. 8.4

On Fig. 8.4,

(i) give an appropriate unit for μ_m, [1]

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

(d) Concrete is a common building material which is sometimes used for shielding. The density of concrete is 2.4×10^3 kg m^{-3}.

(i) Use the information given in Fig. 8.4 to calculate an average value for μ_m and hence show that the linear absorption coefficient μ for 2.75 MeV photons in concrete is approximately 0.09 cm^{-1}.

[3]

(ii) Calculate the approximate thickness of concrete which would provide the same level of shielding, for 2.75 MeV photons, as a thickness of 4.0 cm of lead.

thickness of concrete = ……………………………cm [2]

(iii) Suggest two reasons why concrete may be used, in preference to lead, where radioactive sources of high activity are to be shielded.

1. ....

....

2. ....

....[2]

[End of Paper]