H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/02**

Paper 2 Structured Questions

23 August 2022
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name 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 a 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.
Answers **all** questions.

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

For Examiner's Use	
1	/ 10
2	/ 10
3	/ 10
4	/ 8
5	/ 8
6	/ 14
7	/ 20
Total (80)	

This document contains **22** printed pages and **2** blank pages.

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	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
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 constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
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	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
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 spaces provided.

1 As a ship is approaching the dock at 45.0 cm s^{-1}, an important piece of landing equipment needs to be thrown to it before it can dock. This equipment is thrown at 15.0 m s^{-1} at 60.0° above the horizontal from the top of a tower at the edge of the water, 8.75 m above the ship's deck as shown in Fig. 1.1.

For this equipment to land at the front of the ship's deck, the distance from the dock to the ship when the equipment is thrown should be *D* as shown in Fig.1.1

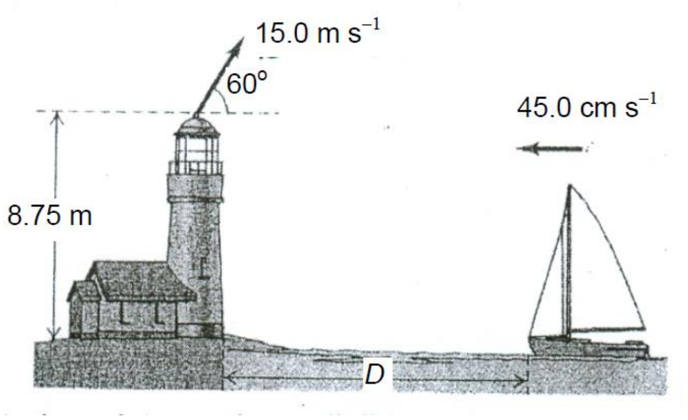

Fig 1.1

(a) Assuming that air resistance is negligible.

(i) Show that the time of flight of the equipment is 3.21 s.

[1]

(ii) Hence, determine the value of *D*.

D = ………………………………………………… m [3]

(b) If air resistance is not negligible, comment on whether *D* should be longer or shorter.

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

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

(c) Sketch and label clearly on the same axes in Fig 1.2, a graph to show the variation with time of flight t of the vertical component of velocity V_y of the equipment during its flight if

(i) air resistance is negligible,

(ii) air resistance is not negligible.

For both graphs, take upwards direction as positive.

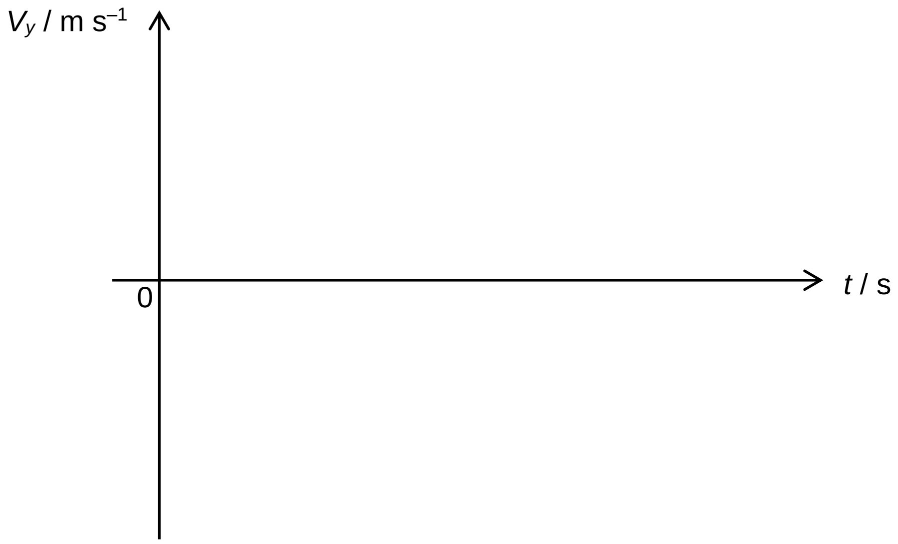

Fig 1.2

[4]

[Total: 10]

2 Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 2.1.

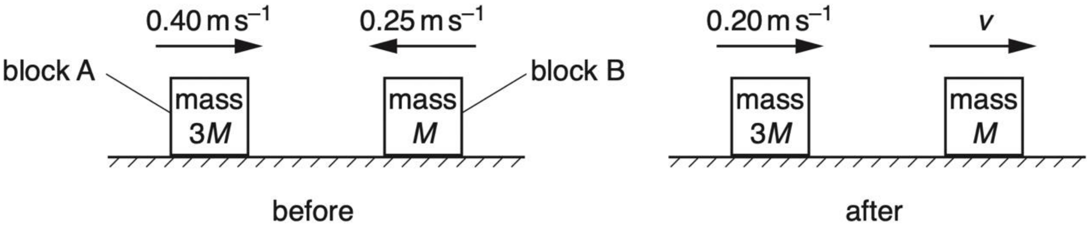

Fig. 2.1

Block A has mass $3M$ and block B has mass M.
Before the collision, block A moves to the right with speed $0.40\ \text{m s}^{-1}$ and block B moves to the left with speed $0.25\ \text{m s}^{-1}$.
After the collision, block A moves to the right with speed $0.20\ \text{m s}^{-1}$ and block B moves to the right with speed v.

(a) **(i)** Use Newton's laws of motion to explain why the change in momentum of each block is equal in magnitude and opposite in direction.

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.... [4]

(ii) Hence, explain whether it is possible for both blocks to be at rest simultaneously during the collision.

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....

....

.... [2]

(b) **(i)** Determine speed v.

v = …………………………………………….. m s^{-1} [2]

(ii) Deduce whether the collision is elastic or inelastic.

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

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[Total: 10]

3 Fig. 3.1 shows the front view of a container ship.

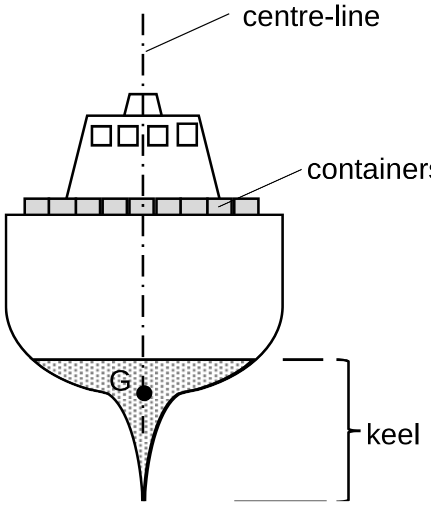

Fig. 3.1

The line of symmetry of the ship is known as the centre-line.

An important part of the ship is the ballast keel, a vertical downward extension of the ship's hull, that is loaded to keep the centre of gravity G of the boat low as shown in Fig. 3.1.

When the ship floats in the sea, the upthrust of the ship is equal in magnitude but opposite in direction to the weight of the ship.

(a) Explain

(i) what is meant by the *centre of gravity* of the ship,

....

....

.... [2]

(ii) the origin of the upthrust acting on the ship.

....

.... [1]

(b) The ship has a mass of 2.20×10^8 kg and the density of seawater is 1030 kg m^{-3}.

Calculate the volume of seawater displaced by the ship.

volume = ... m^3 [2]

(c) A ship will roll on its sides due to the wind and the water waves. Fig 3.2 shows ship on its side at a particular instant.

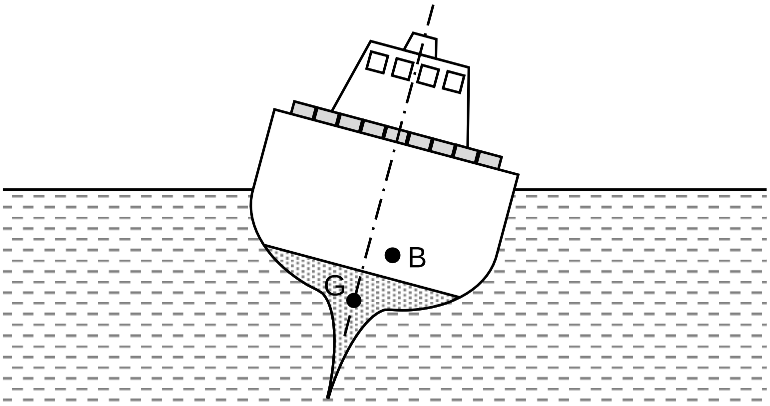

Fig. 3.2

The upthrust acts through the centre of gravity of the displaced fluid, known as the centre of buoyancy B shown in Fig. 3.2.

(i) On Fig. 3.2, mark with arrows labelled *W* for the weight and labelled *U* for the upthrust. [1]

(ii) By reference to the completed diagram of Fig. 3.2, explain why the ship will not overturn.

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

(d) When the ship is fully loaded with containers (you may assume the containers are secured and will not shift), the centre of gravity G will be at a higher position along the centre-line.

Draw relevant forces on Fig. 3.3 to explain the danger of a fully loaded ship rolling to its side.

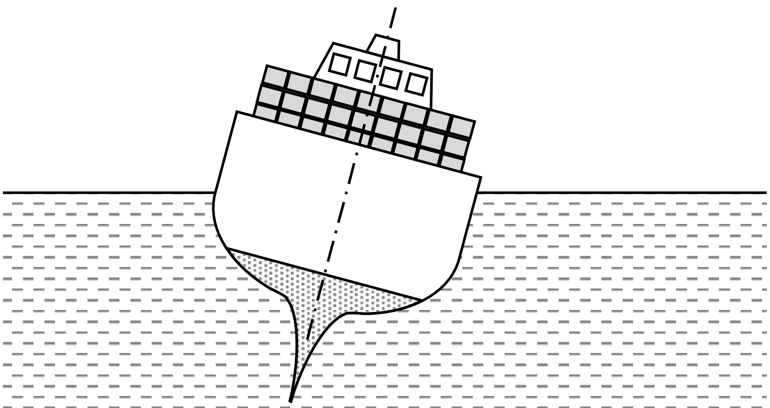


Fig. 3.3

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

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

[Total: 10]

4 **(a)** A resistor "ladder" with 2 stages "R-2R" resistors, with values of R and 2R, are connected to an ideal cell of e.m.f. V as shown in Fig. 4.1.

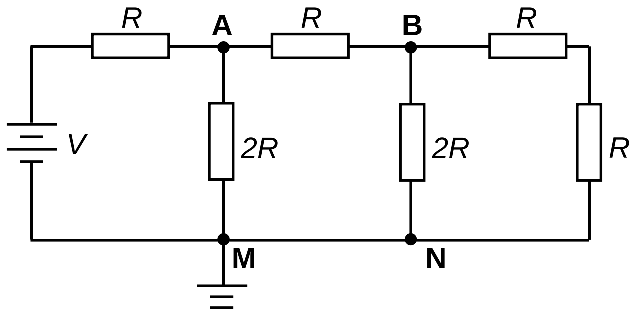


Fig. 4.1

(i) Show that the effective resistance between junction **A** and **M** is R.

[1]

(ii) Determine the potential at junction **A** in terms of V.

potential at **A** in terms of V ………………..……………………………………….. [2]

(iii) Two additional "*R*-2*R*" stages, are added to the resistor "ladder" as shown in Fig 4.2.

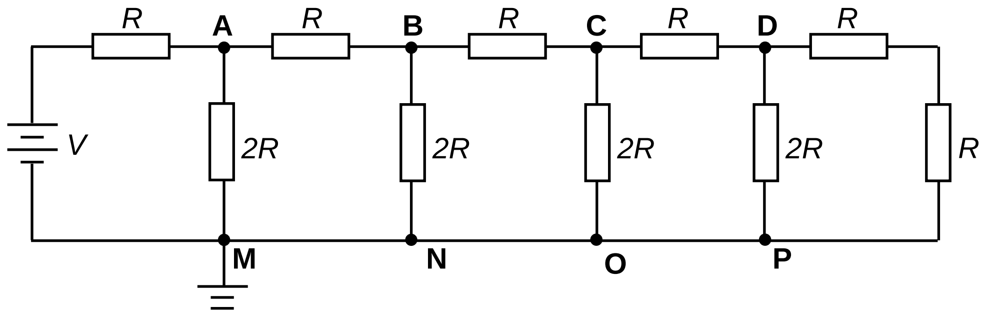


Fig 4.2

Using your answers from **(i)** and **(ii)**, deduce the potential at junction **D**, in Fig. 4.2 in terms of *V*.

potential at **D** in terms of *V* …………….……………………………………….. [2]

(b) The current-potential difference relationship for two electrical components P and Q is shown in Fig. 4.3.

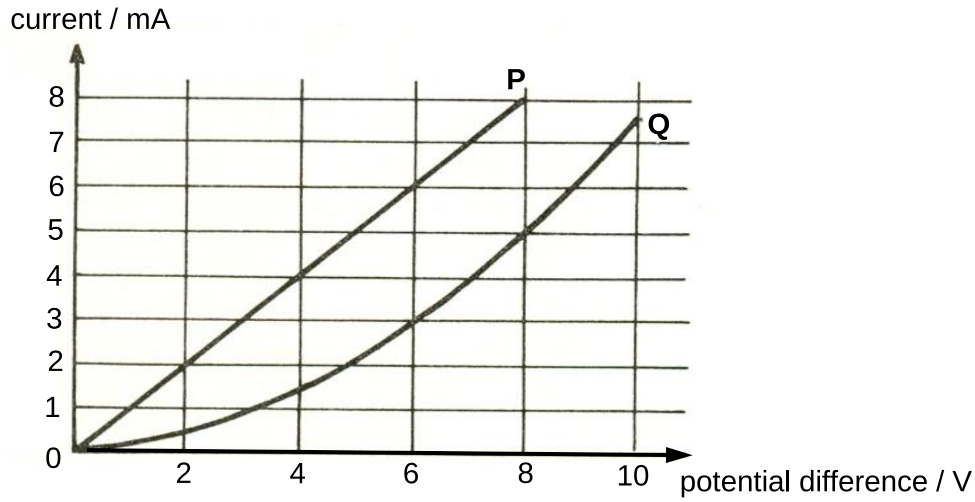
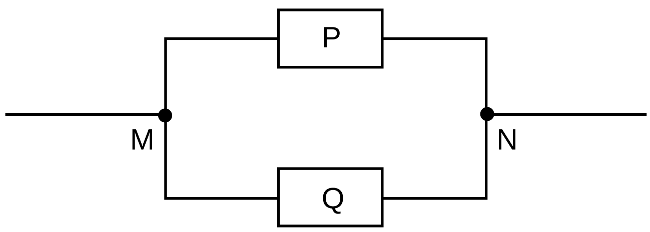


Fig. 4.3

P and Q are connected in parallel. The current flowing through P is 6 mA.



Determine the effective resistance between M and N.

effective resistance = …………………………………………………………….. Ω [3]

[Total: 8]

5 **(a)** Force-fields may be represented using lines that have direction.

State

(i) what is meant by a *field of force,*

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

(ii) how, using lines of force, changes in the strength of a force-field are represented.

…………………………………………………………………………………………………

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

(b) A large horseshoe magnet produces a uniform magnetic field of flux density B between its poles. Outside the region of the poles, the flux density is zero.

The magnet is placed on a top-pan balance and a stiff wire XY is situated between its poles as shown in Fig. 5.1.

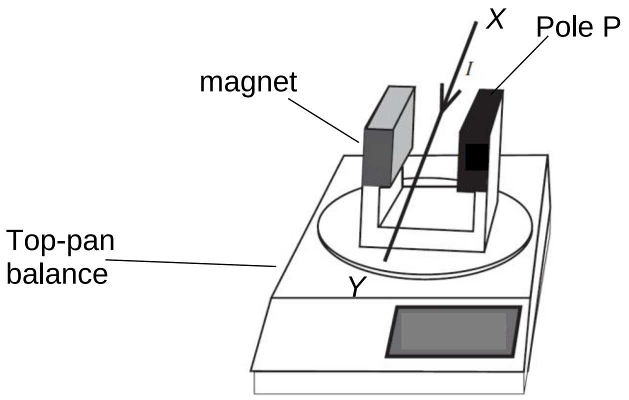


Fig. 5.1

The wire XY is horizontal and normal to the magnetic field.

A direct current is now passed through the wires in the direction from X to Y.
The reading on the top-pan balance increased.

State and explain the polarity of the pole P of the magnet.

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…………………………………………………………………………………………………

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…………………………………………………………………………………………………

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

(c) A charged particle of mass *m* and charge +*q* travelling with velocity *v* in a vacuum. It enters a region of uniform magnetic field of flux density *B* as shown in Fig. 5.2.

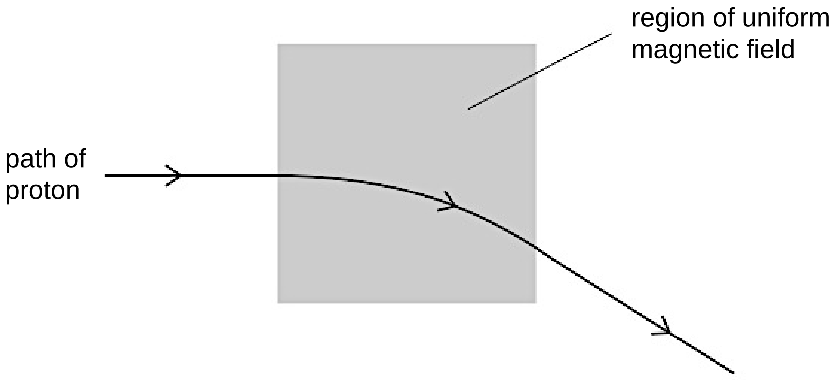

Fig. 5.2

A thin metal foil is placed in the magnetic field in **(c).**
A second charged particle enters the region of the magnetic field. It loses kinetic energy as it passes through the foil.

The particle follows the path as shown in Fig. 5.3.

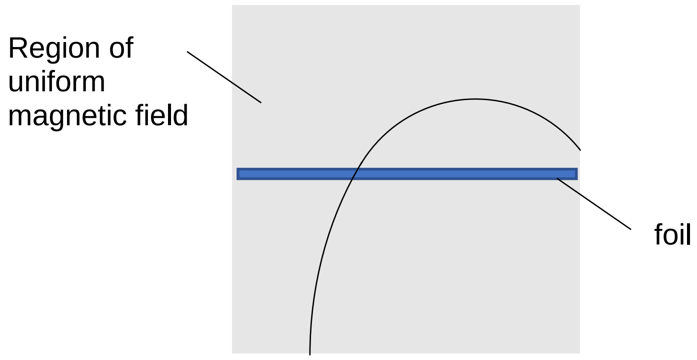

Fig. 5.3

(i) On Fig. 5.3, mark with an arrow the direction of travel of particle. [1]

(ii) The path of the particle has different radii on each side of the foil.
The radii are 7.4 cm and 5.7 cm.

Determine the ratio

$$\frac{\text{final momentum of particle}}{\text{initial momentum of particle}}$$

for the particle as it passes through the foil.

ratio = …………………………………………………….. [2]

[Total: 8]

6 **(a)** Radon-220 ($^{220}_{86}Rn$), at rest, decays spontaneously to form polonium (Po). During this decay, an α- particle of kinetic energy 6.29 MeV and a γ- ray photon of energy 0.55 MeV are emitted.

(i) Write down the nuclear equation to represent the decay of a Radon-220 nucleus.

[2]

(ii) Calculate in joules the energy of 1.0 MeV.

energy = ………………………………………………….. J [1]

(iii) Calculate, for this decay,

1. the mass equivalence of the energy released during the decay, and

mass = …………………….……………………….. kg [2]

2. the wavelength of the emitted γ-ray photon.

wavelength = ……………………..……………………….. m [2]

(b) Measurements are made of the activity of a specimen of carbon from pieces of wood found in a fireplace at an archaeological site. The specimen is found to contain one Carbon-14 (C-14) atom per 8.6×10^{10} Carbon-12 (C-12) atoms. In a modern firewood, the concentration of C-14 atoms is one C-14 atom per 3.3×10^{10} C-12 atoms. The difference between these two figures is because C-14 is radioactive and some atoms have decayed over the years.

(i) The half-life of C-14 is 5700 years. C-12 is stable.
Calculate the age of the wood from the ancient fire.

age of the wood = …………………………………………….. years [3]

(ii) The technique of dating described above is difficult to carry out accurately. This difficulty can be minimised by using all the C-14 atoms rather than just those which happen to undergo radioactive decay when the dating is being carried out. Carbon atoms from the wood can be ionised by removing one electron from each atom. They are then formed into a beam which is passed through a magnetic field as shown in Fig. 7.1.

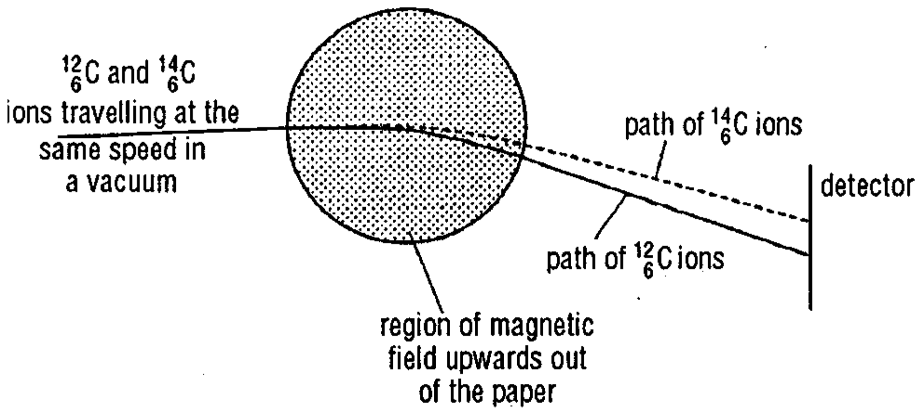

Fig. 7.1

1. Explain why the paths of the two types of ions are different.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

2. Suggest why this method of measuring the ratio of C-14 to C-12 atoms is more reliable.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

[Total: 14]

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7 In the first half of the last century, numerous experiments were conducted to investigate the absorption and scattering of X-rays by matter.

It was discovered that when a monochromatic beam of X-rays is incident on a light element such as carbon, the scattered X-rays have wavelengths dependent on the angle of scattering.

Compton (1923) assumed that the scattering process could be treated as an elastic collision between an X-ray photon and a 'free' electron, and that energy and momentum would be conserved.

(a) Explain what is meant by a *photon*.

....

....

.... [2]

(b) The elastic collision between a photon and a stationary electron may be represented as in Fig. 7.1.

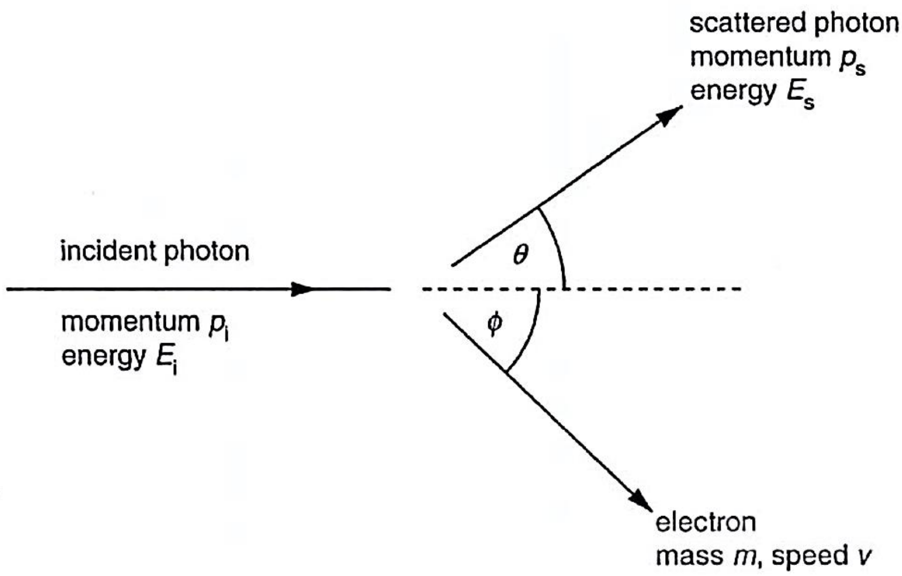

Fig. 7.1

The incident photon has momentum p_i and energy E_i. The photon is scattered through an angle θ and, after scattering has momentum p_s and energy E_s. The electron of mass m, which was originally stationary, moves off with speed v at an angle ϕ to the original direction of the incident photon.

(i) Write down equations, in terms of p_i, p_s, E_i, E_s, m, v, θ and ϕ, that represent, for this interaction,

1. conservation of energy,

.... [1]

2. conservation of momentum along the direction of the incident photon.

.... [1]

(ii) Suggest, with a reason, whether the scattered photon will have a wavelength that is greater or less than that of the incident photon.

....

....

....

.... [3]

(c) In an experiment to provide evidence to justify Compton's theory, measurements were made of the wavelength λ_i of the incident photon, the wavelength λ_s of the scattered photon and the angle θ of scattering. Some data from this experiment are given in Fig. 7.2.

λ_i / 10^{-12} m	λ_s /10^{-12} m	θ / °
191.92	193.27	57
153.30	154.65	57
965.04	966.84	75

Fig. 7.2

Use the data in Fig. 7.2 to show that, when a photon is scattered, the change in wavelength produced is independent of the wavelength of the incident photon.

....

....

.... [2]

(d) In this experiment, the uncertainty in the measurement of θ is $\pm 5°$.
Determine the value of $\cos\theta$, with its uncertainty, for the angle $\theta = 75° \pm 5°$.

$\cos\theta$ = …………………………... ± ………………………… [3]

(e) Compton's theory suggests that the change in wavelength $\Delta\lambda$ is related to the angle θ of the scattering by this expression

$$\Delta\lambda = k(1 - \cos\theta)$$

where k is a constant.

Experimental data for the variation with $\cos\theta$ of $\Delta\lambda$ are shown in Fig. 7.3.

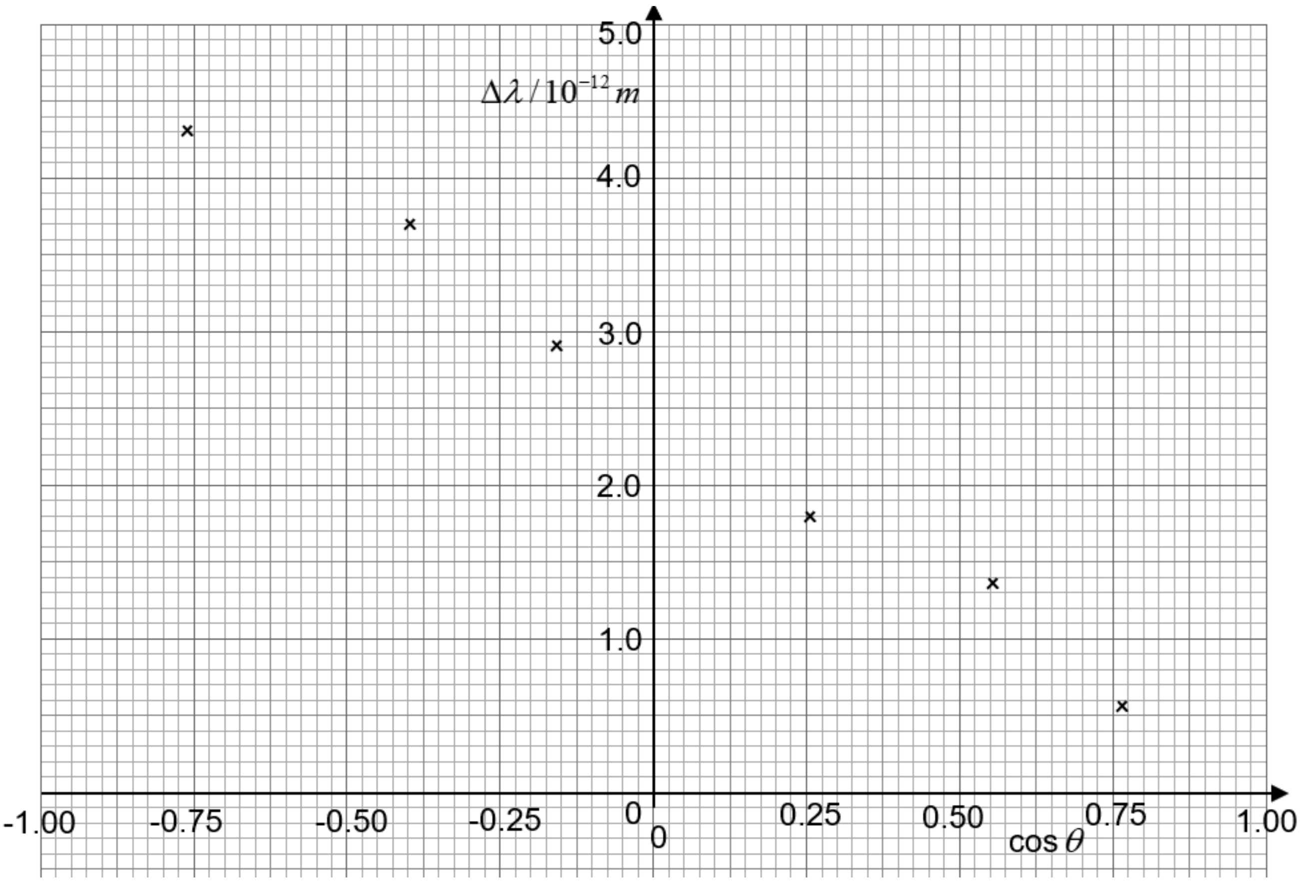

Fig. 7.3

(i) On Fig. 7.3, draw the best-fit line for the points. [1]

(ii) State and explain two different ways by which the constant *k* may be determined from the graph of Fig. 7.3.

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

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

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

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

(iii) Determine the constant *k,* with its unit.

k = ……………………………………………………… [2]

(f) For a carbon atom, the binding energy of an electron is of the order of a few electronvolts.

Compton's theory assumes that the electrons are not bound in the atoms but are free.

Suggest whether, for 30 keV photons, this assumption is justified.

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[Total: 20]

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