TAMPINES MERIDIAN JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME ( )

CIVICS GROUP

H2 PHYSICS 9749/03

Paper 3 Longer Structured Questions **21 September 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

For Examiner's Use		Percentage
Subtotal P1		/ 15
Subtotal P2		/ 30
Paper 3		
1	/ 8	
2	/ 16	
3	/ 9	
4	/ 15	
5	/ 12	
6	/ 20	
7	/ 20	
Deduction		
Subtotal P3		/ 35
Subtotal P4		/ 20
Grand total		/ 100

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ 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	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
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	=	$v_o \cos \omega t$
		=	$\pm\, \omega\sqrt{x_o^{\,2} - x^2}$
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	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A toy car collides into a fixed wall and rebounds with the same speed as shown in Fig. 1.1.

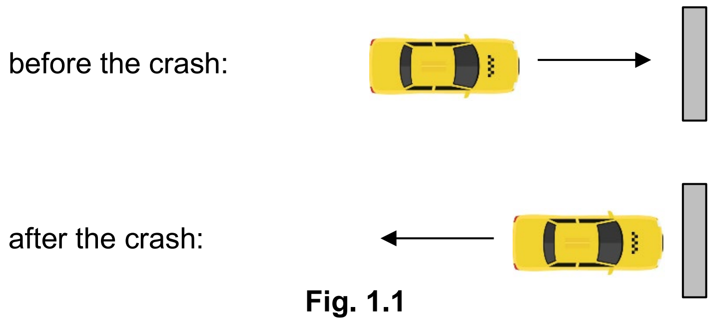

Fig. 1.1

(a) **(i)** State the type of collision that occurred between the car and the wall.

.... [1]

(ii) During the collision the momentum of the car changes. State and explain whether momentum is conserved in this collision.

....

....

.... [2]

(b) Fig. 1.2 shows the variation with time of the magnitude of force acting on the toy car due to the wall during the collision. Take rightwards as positive.

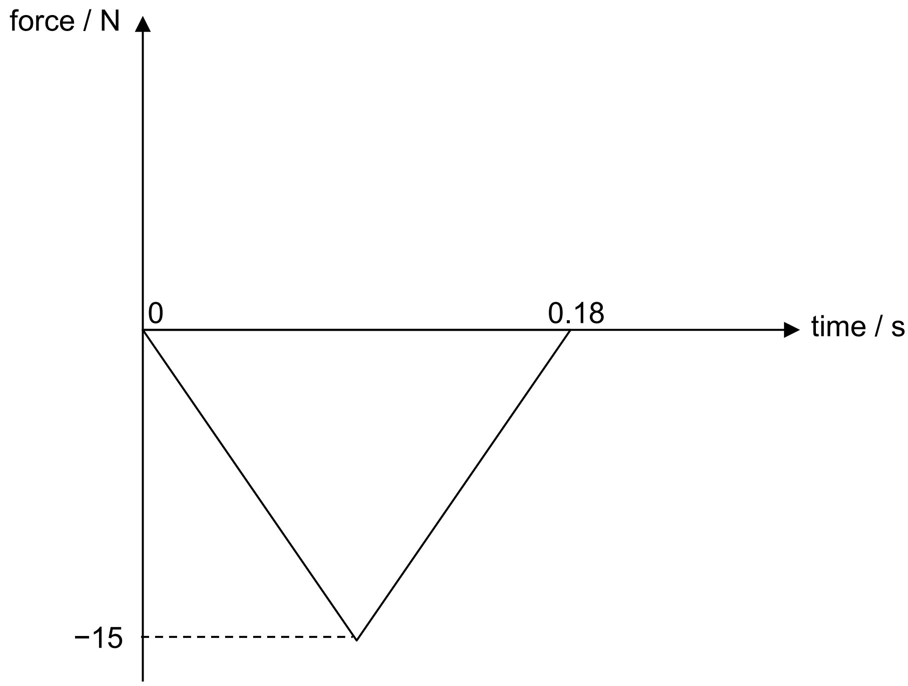

Fig. 1.2

(i) Determine the magnitude of the initial momentum of the car.

initial momentum = ………………………. kg m s^{-1} [2]

(ii) The mass of the toy car is 0.65 kg. Determine the magnitude of average acceleration of the toy car during the collision.

average acceleration = ………………………. m s^{-2} [2]

(iii) A rubber bumper is now secured to the front of the toy car. The toy car undergoes a similar collision with the wall.

On Fig. 1.2, sketch a new graph showing the variation with time of the force acting on the toy car.

[1]

2 **(a)** State what is meant by a *field of force*.

....

.... [1]

(b) State one similarity and one difference between gravitational field and electric field.

Similarity: ....

....

Difference: ....

.... [2]

(c) Fig. 2.1 shows the variation of the gravitational potential ϕ between the Moon and the Earth with distance from the centre of the Moon.

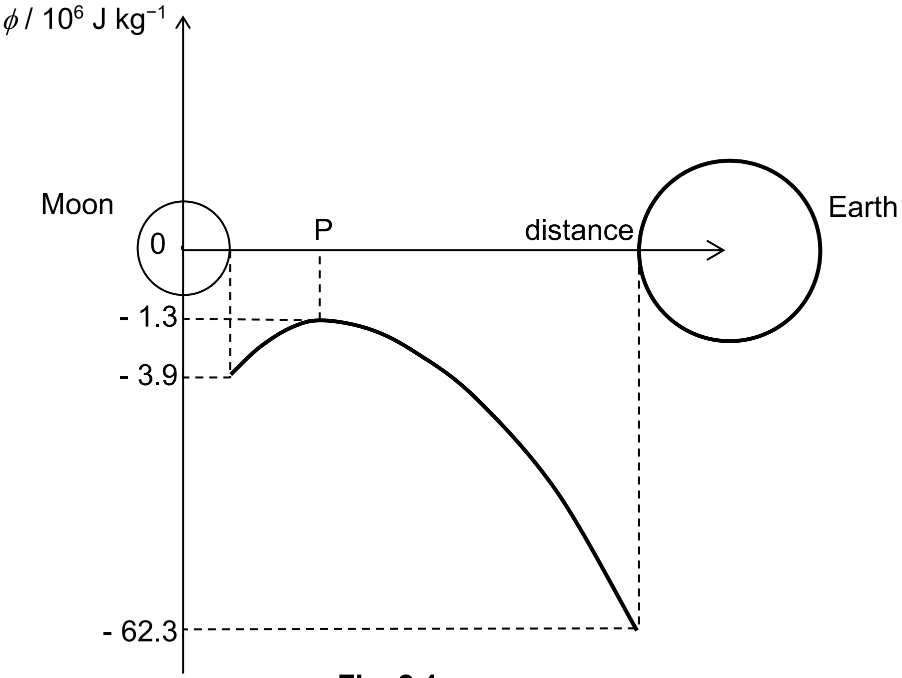

Fig. 2.1

(i) Point P is a point along the line between the centres of the Moon and the Earth. Explain why point P is closer to the Moon than to the Earth.

....

....

....

.... [2]

(ii) The distance between the centres of the Earth and the Moon is 3.80×10^{8} m.

Fig. 2.2 shows the values of the radius R and mass M of the Earth and Moon.

	R / m	M / kg
Earth	6.37×10^{6}	5.98×10^{24}
Moon	1.74×10^{6}	7.35×10^{22}

Fig. 2.2

Show that the distance from the centre of the Moon to point P is 3.79×10^{7} m.

[2]

(iii) NASA intends to project a space probe from the Earth to the Moon.

Determine the minimum projection speed.

Explain your answer.

speed = ……………………… m s^{-1}

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………… [3]

(d) Two small spherical charged particles P and Q are fixed in their positions at 5.0 cm apart in a vacuum. An electron is moved along the line joining the two charges as shown in Fig. 2.3.

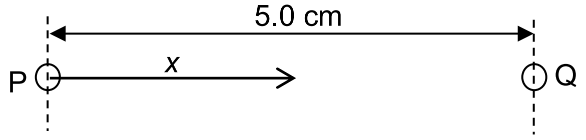

Fig. 2.3

The variation with the displacement x of electron from P of the electric potential energy E_p of the electron is shown in Fig. 2.4.

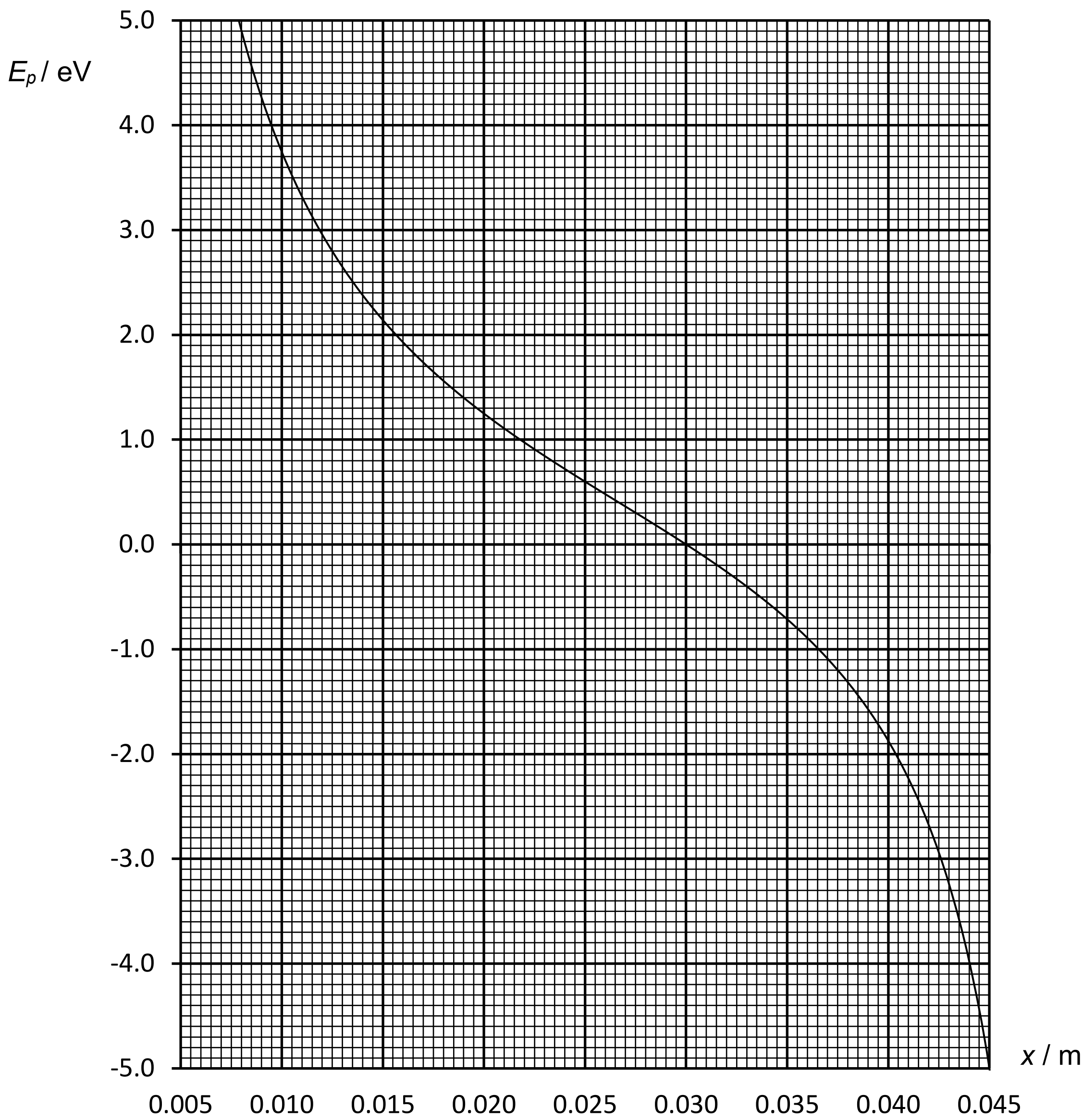

Fig. 2.4

(i) State and explain which charge P or Q is negatively charged.

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

(ii) Use Fig. 2.4 to estimate the magnitude of the force acting on the electron when it is at the point x = 3.0 cm.

force = ………………………… N [3]

(iii) On Fig. 2.4, sketch a new graph if the magnitude of charge Q is increased.

[1]

3 Fig. 3.1 shows a trolley of mass 0.50 kg resting on a smooth horizontal surface. The trolley is attached to two identical springs, both of which are initially at their natural lengths.

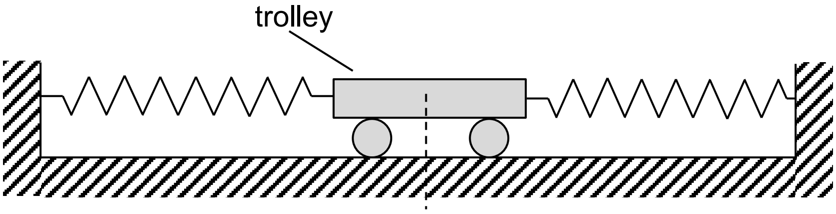

Fig. 3.1

(a) The trolley is displaced to the right along the axis of the springs and then released. The trolley undergoes simple harmonic motion.

Fig. 3.2 shows the variation with time t of velocity v of the trolley.

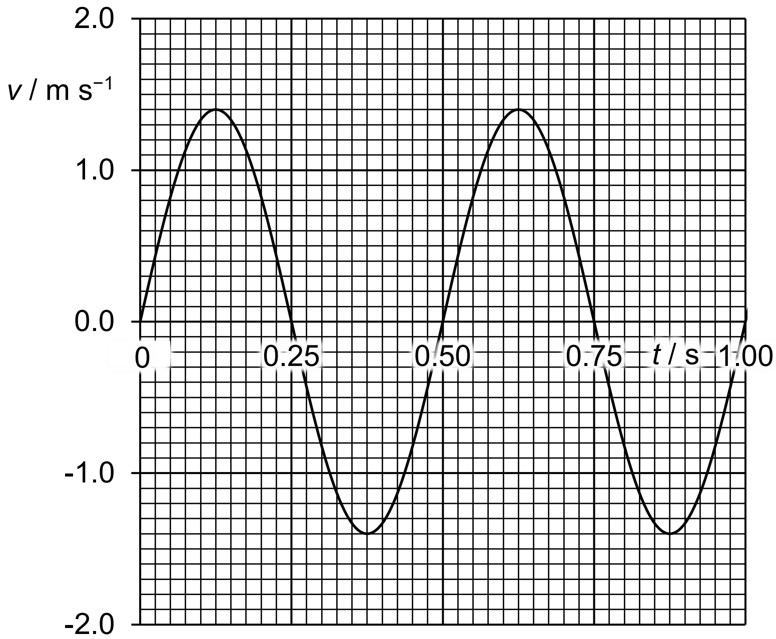

Fig. 3.2

(i) Determine the kinetic energy of the oscillating trolley when it is at the equilibrium position.

kinetic energy = ………………… J [2]

(ii) Determine the amplitude of the oscillation.

amplitude = ………………… m [2]

(b) A wooden board is attached vertically to the top of the trolley as shown in Fig. 3.3. The modified trolley is displaced to the right and then released.

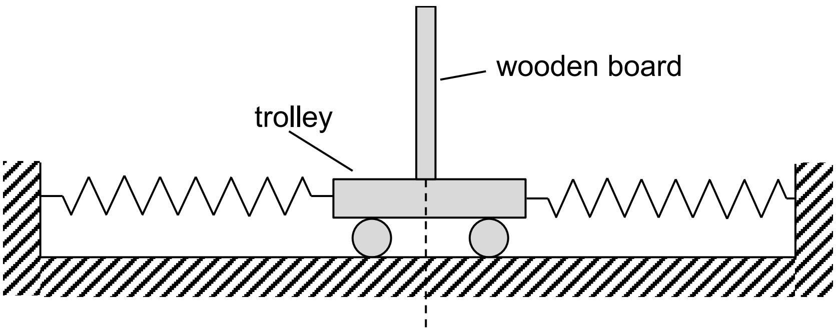

Fig. 3.3

Fig. 3.4 shows the variation with time t of velocity v of the modified trolley.

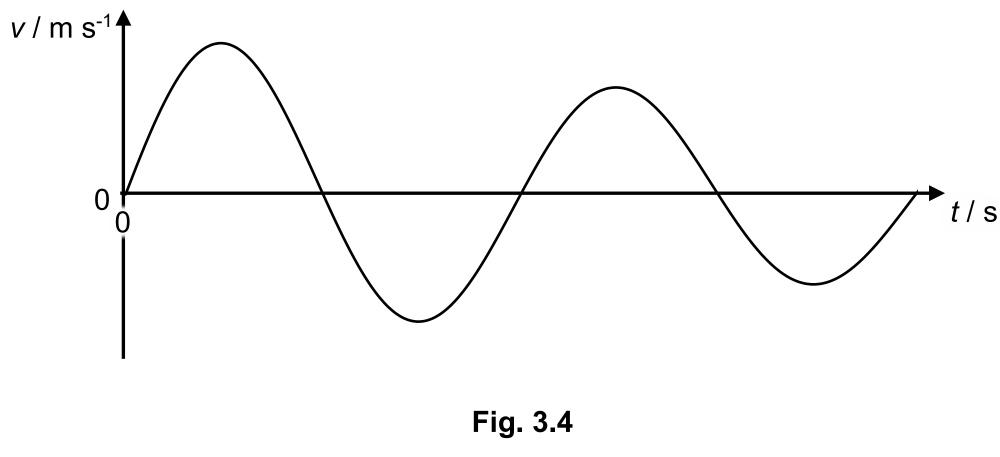

Fig. 3.4

State the type of oscillation illustrated in Fig. 3.4. Suggest what caused it.

………………………………………………………………………………………………

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

(c) An air jet is placed as shown in Fig. 3.5. It emits periodic pulses of air at a frequency f as the modified trolley oscillates.

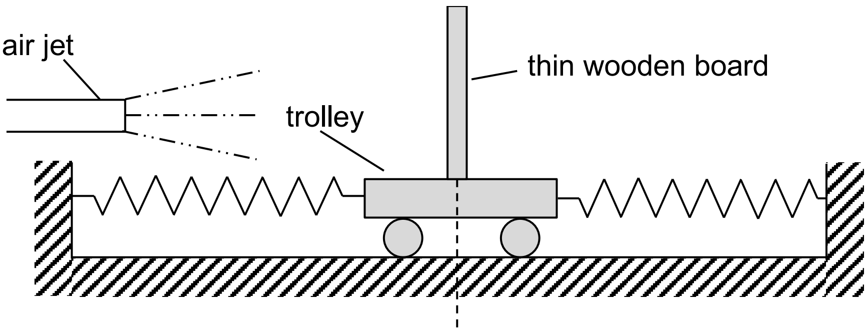

Fig. 3.5

Fig. 3.6 shows the variation with time t of the displacement x of the modified trolley when pulses of air is emitted at 2.0 Hz for some time.

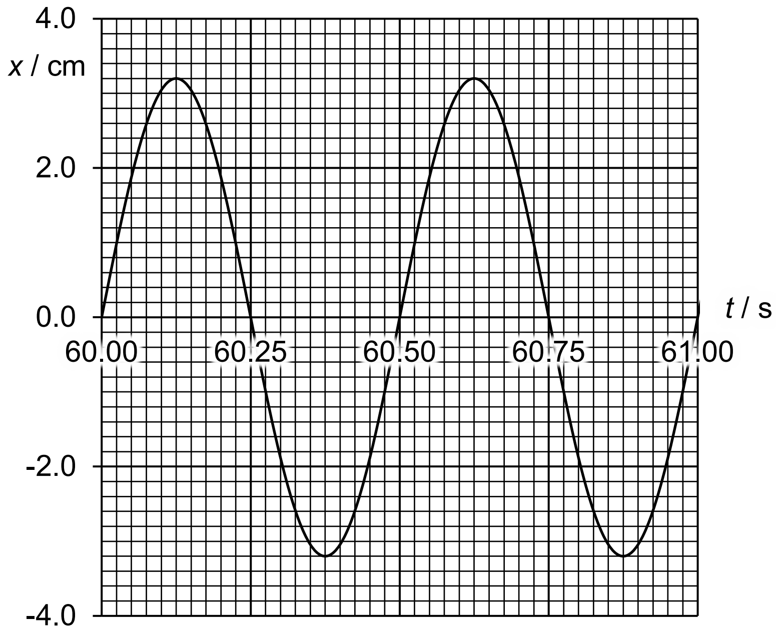

Fig. 3.6

The variation with frequency f of the pulses of air of the amplitude A of the oscillation of the trolley is shown in Fig. 3.7.

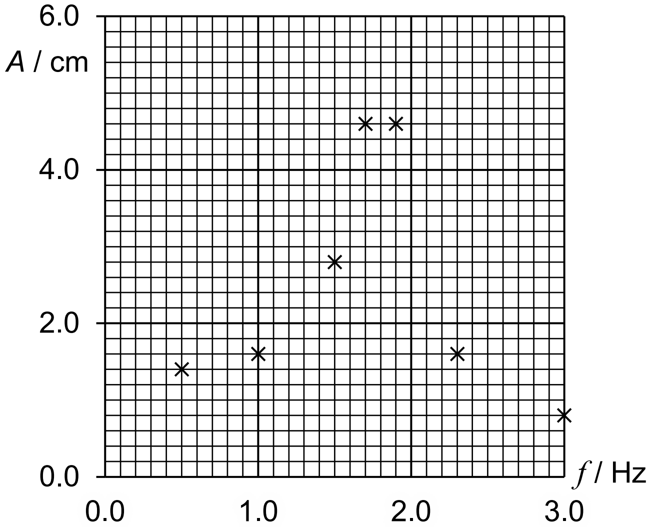

Fig. 3.7

(i) Plot the point in Fig. 3.7 for when f = 2.0 Hz. [1]

(ii) Complete Fig. 3.7 by drawing the curve of best fit. [1]

(iii) Estimate the resonant frequency.

resonant frequency = ………………… Hz [1]

4 **(a)** Light is incident normally on a single slit. A screen is placed 1.8 m away, parallel to the slit, as shown in Fig. 4.1.

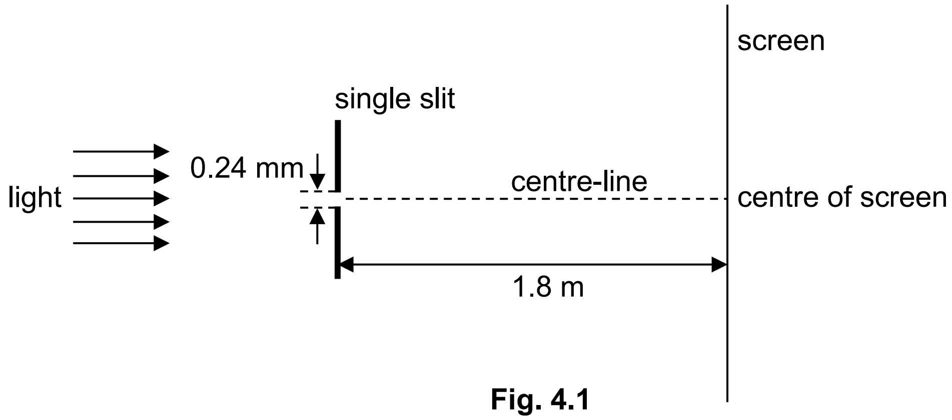

Fig. 4.1

The slit has a width of 0.24 mm. The first minimum occurs at an angle of 0.16° to the centre-line.

(i) Calculate the wavelength of the light incident on the single slit.

wavelength = ………………………… m [1]

(ii) Determine the width of the central maximum on the screen.

width = ………………………… mm [2]

(iii) On Fig. 4.2, sketch the variation of the intensity of light on the screen with distance from the centre of screen, up to and including the second minima.

Label the horizontal axis with appropriate values for the positions of the minimas. [2]

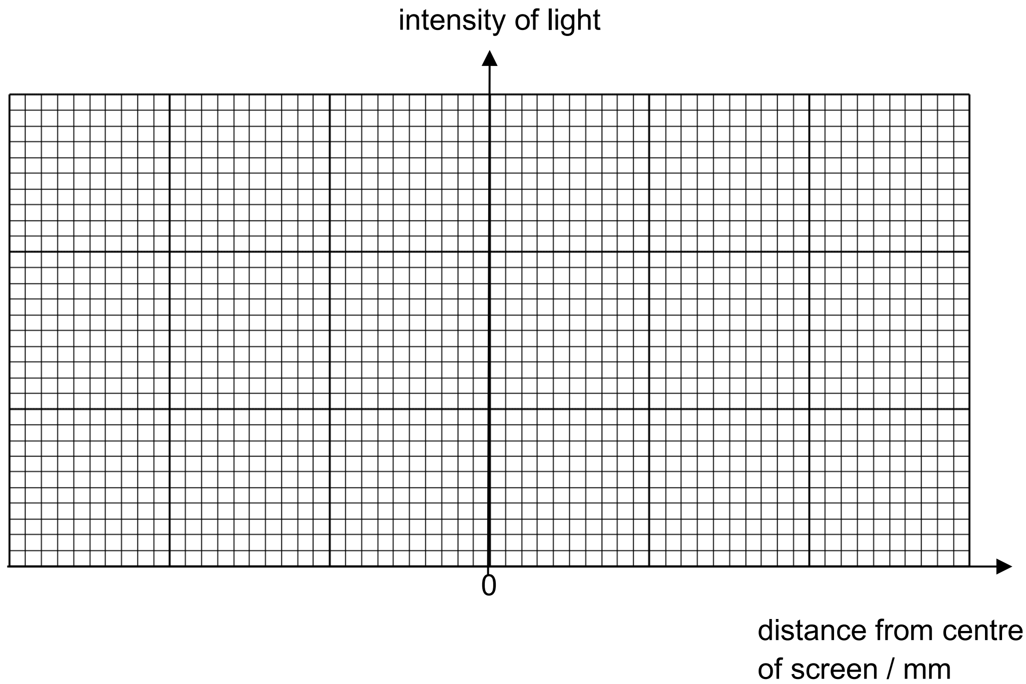

Fig. 4.2

(iv) If the slit width is reduced, describe two changes to the intensity graph sketched in part **a(iii)**.

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

(b) The single slit is now replaced with a double slit as shown in Fig. 4.3.

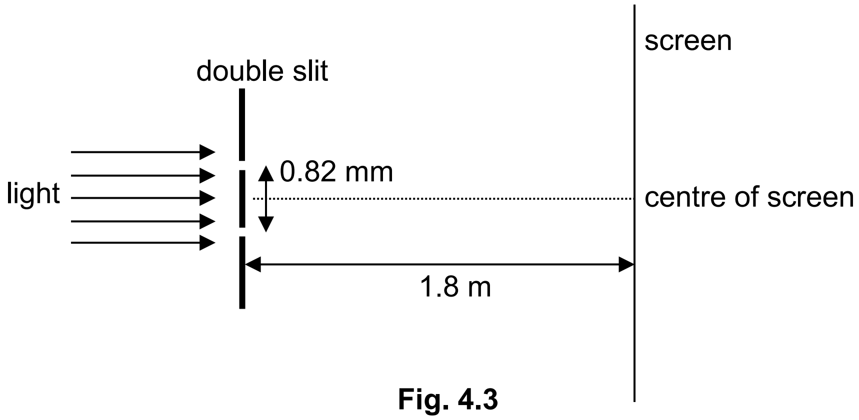

Fig. 4.3

Light of wavelength 638 nm is incident on the double slit. The double slit has a slit separation of 0.82 mm.

The light emerging from both slits can be considered to be coherent sources of light. A series of bright and dark fringes are formed on the screen.

(i) State what is meant by *coherent* sources of light.

………………………………………………………………………………………….

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

(ii) Determine the distance of the second dark fringe from the centre of the screen.

distance = ………………………… mm [3]

(iii) The light incident on the screen due to one of the slits has an intensity of I and amplitude of *A*.

Show that the intensity of the central bright fringe is $4I$.

[2]

(iv) A student commented:

"By conservation of energy, the light energy incident on the screen should be the sum of the light energies from each of the slits, hence the intensity of the central bright fringe should be $2I$ instead of $4I$. I conclude that the principle of conservation of energy is violated in this double slit experiment."

Explain why the student's conclusion is wrong.

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……………………………………………………………………………….. [2]

5 **(a)** A main coil is made of a coil of wire wound round the end of a soft iron core, as shown in Fig. 5.1. The main coil is connected to a variable power supply.

The axis of the soft iron core and main coil are both vertical. An aluminium ring is placed over the soft iron core and is free to move along the core.

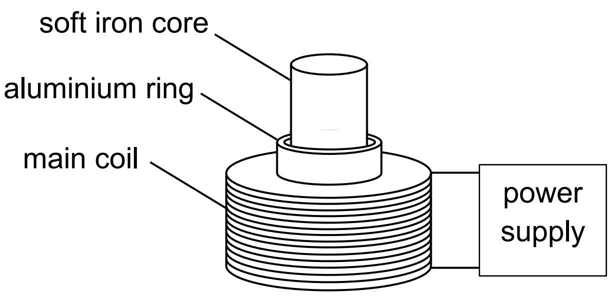

Fig. 5.1

The power supply provides an alternating voltage to the main coil. The variation with time t of the supply voltage V is given by

$$V = 240\sin(377t)$$

where V is measured in volts and t in seconds.

(i) Calculate the frequency of the supply voltage.

frequency = ………………………… Hz [2]

(ii) Determine the root-mean-square value of the supply voltage.

root-mean-square voltage = ………………………… V [2]

(iii) When the power supply is switched on, the aluminium ring is observed to float above the main coil.

Using the laws of electromagnetic induction, explain why the ring floats above the main coil.

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……………………………………………………………………………………….. [4]

(iv) The power supply is switched off. A small slit is then made on the ring, as shown in Fig. 5.2.

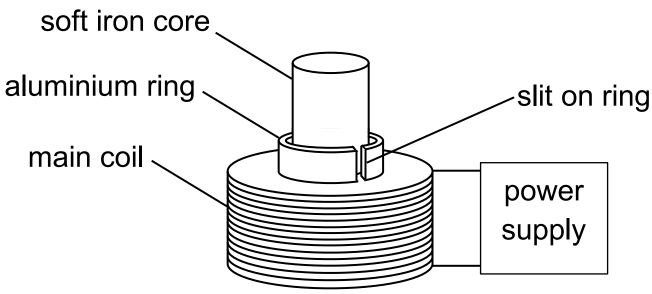

Fig. 5.2

State and explain what will be observed when the power supply is switched on again.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(b) The ring is now removed, and a small coil is placed over the soft iron core, as shown in Fig. 5.3.

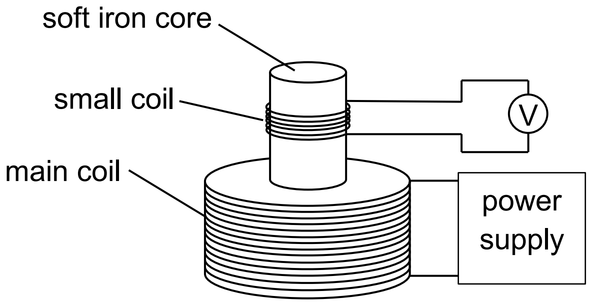

Fig. 5.3

The power supply now provides a varying current to the main coil to create a magnetic field. Fig. 5.4 below shows the variation of the magnetic flux density, B, through the small coil with time, t.

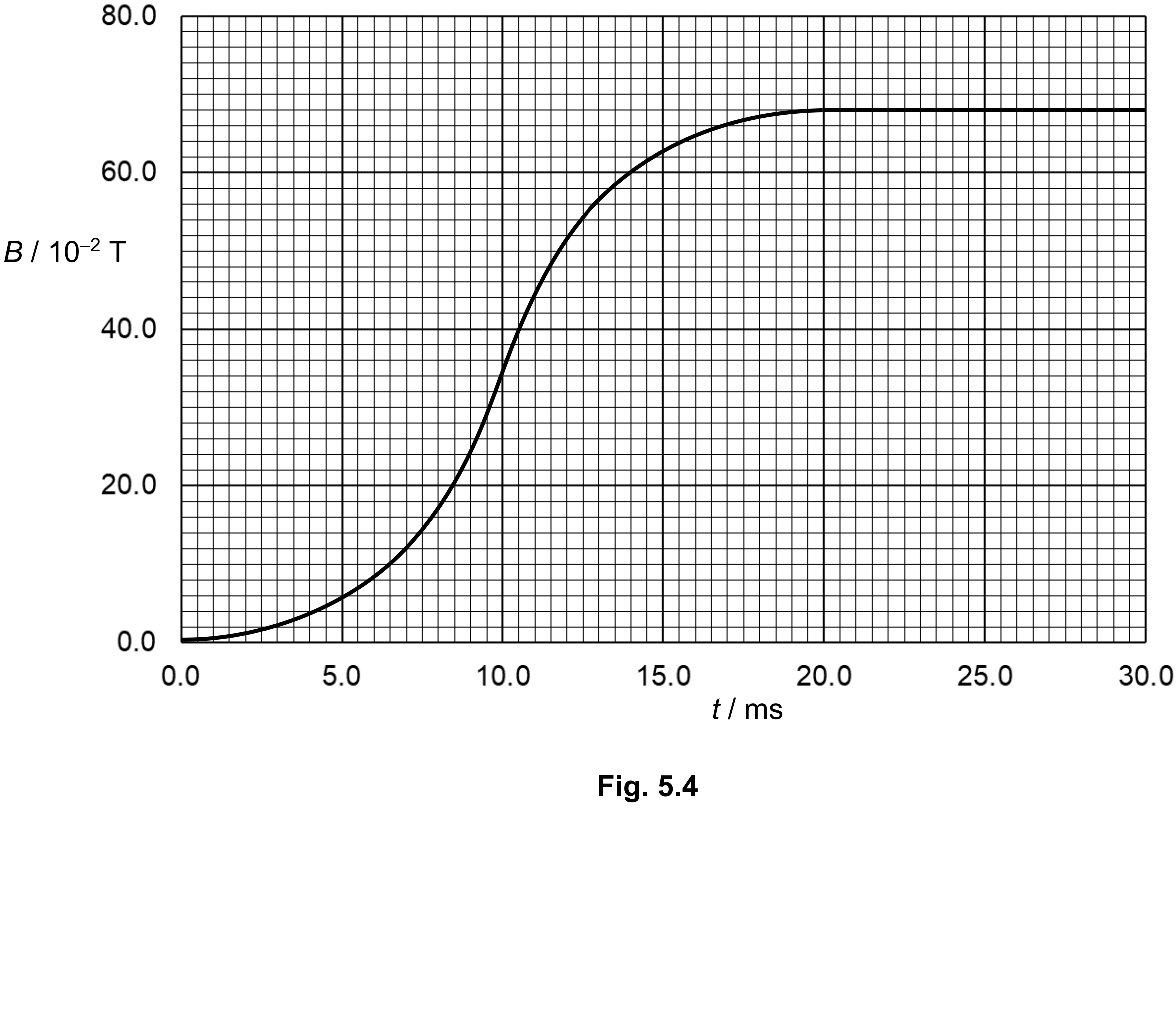

Fig. 5.4

The small coil has 80 turns, and a cross-sectional area of 4.2×10^{-5} m^2.

Using Fig. 5.4, estimate the magnitude of the maximum e.m.f. induced in the small coil.

maximum e.m.f. = ………………………… V [2]

Section B

Answer **one** question from this Section in the spaces provided.

6 **(a)** **(i)** Energy is supplied to water that is boiling.

State and explain, in terms of molecular behaviour, the change (if any) in its internal energy.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [3]

(ii) Steam at 100 °C is used to warm 200 g of water in a 100 g closed insulated glass container from 20 °C to 50 °C.

The specific heat capacity of glass is 8.4×10^{2} J kg^{-1} K^{-1}.
The specific heat capacity of water is 4.2×10^{3} J kg^{-1} K^{-1}.
The specific latent heat of vaporisation of steam is 2.3×10^{6} J kg^{-1}.

Calculate the mass of steam required.

mass of steam = ……………………… kg [3]

(iii) Referring to data in **(a)(ii)**, state and explain which is more likely to cause a more serious burn, 1 kg of 100 °C liquid water or 1 kg of 100 °C steam.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

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……………………………………………………………………………………… [2]

(b) Fig. 6.1 shows a cylinder with a piston connected to it.

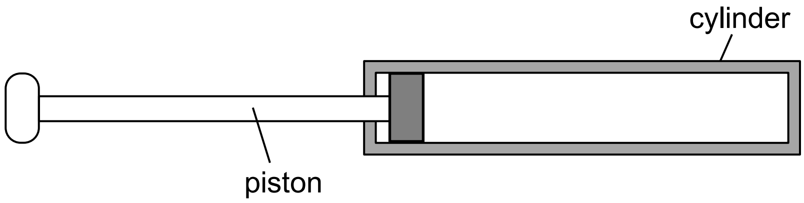

Fig. 6.1

The gas in the cylinder is compressed quickly by a piston resulting in an increase in temperature. The gas in the cylinder can be assumed to be ideal.

(i) Explain what is meant by an *ideal gas*.

……………………………………………………………………………………………..

……………………………………………………………………………………… [2]

(ii) Use the kinetic theory of gases to explain why the temperature of the gas increases.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………… [2]

(iii) Before compression, the gas in the cylinder is at a pressure of 1.1×10^5 Pa and a temperature of 28 °C. The volume of the gas in the cylinder is 6.2×10^{-4} m^3.

1. Calculate the number of moles of gas in the cylinder.

number of moles = ……………………… mol [2]

2. The work done to *quickly* compress the gas is 15 J.

Calculate the increase in the internal energy, ΔU, of the gas in the cylinder.

ΔU = ……………………… J [2]

3. Calculate the change in average kinetic energy, ΔE_K, of a gas molecule due to the compression.

ΔE_K = ……………………… J [2]

(c) The gas is now *slowly* being compressed by the same amount. This is to ensure that the process took place at a constant temperature.

State and explain how the final pressure of the gas compares to final pressure of the gas in **(b)**.

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

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

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

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

7 **(a)** Fig. 7.1 shows a high voltage supply set up to produce energetic electrons with kinetic energies of 3.50 eV in a discharge tube. These electrons bombard the cool sodium gas in the discharge tube, giving rise to a spectrum of transmitted light. The light passes through a diffraction grating to reach a detector.

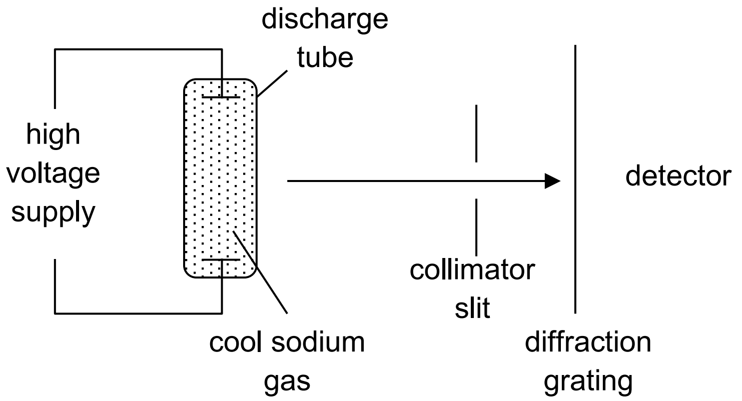

Fig. 7.1

Some electron energy levels in a sodium atom are illustrated in Fig. 7.2. The energy level n = 1 represents the ground state.

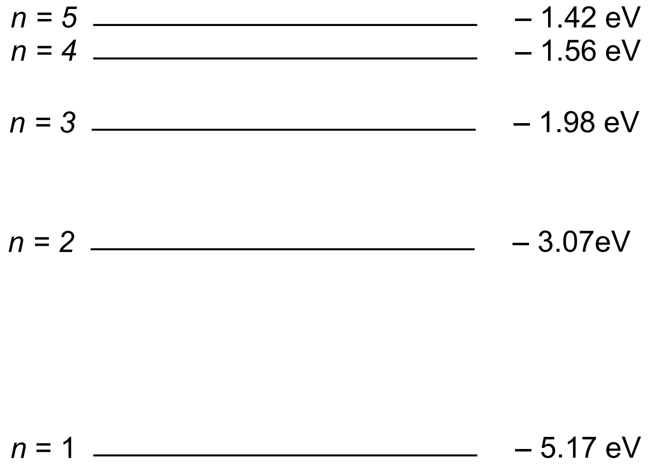

Fig. 7.2

(i) Deduce the maximum number of spectral lines that could be detected.

number of spectral lines = ……………… [1]

(ii) Calculate the frequency of the photon emitted when an electron in energy level n = 2 transits to the ground state.

frequency = ……………… Hz [2]

(iii) A cool gas X is placed between the discharge tube and the collimator slit as shown in Fig. 7.3.

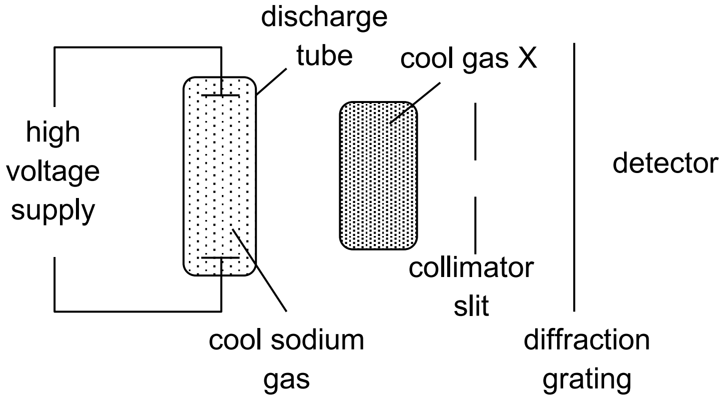

Fig. 7.3

Fig. 7.4 shows the electron energy levels in an atom of X.

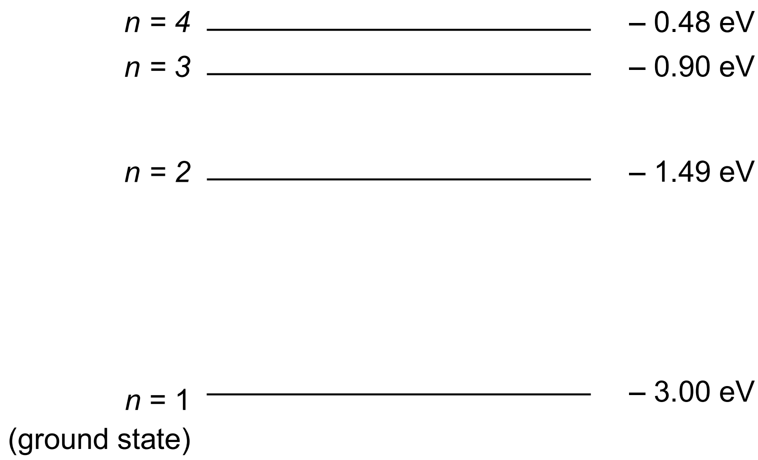

Fig. 7.4

Photons emitted from the sodium gas due to the transitions in **a(ii)** are absorbed by X.

State if the following transitions can occur due to this absorption.
Explain your answer.

1. from ground state to n = 2: ……………………………………………………

2. from ground state to n = 3: ……………………………………………………

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………… [3]

(iv) When the radiation from a nucleus is examined, it is found that it too has a line emission spectrum. These lines correspond to radiation with frequencies in the gamma range.

Deduce two conclusions that can be made from this observation.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

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

(b) Yttrium-90 is a radioactive isotope often used in cancer treatment. As it undergoes β-decay, it emits high-energy electrons.

(i) When a sample of Yttrium-90 isotope is placed in a lead container, X-ray radiation with a range of energies is detected from the container walls.

Explain the phenomenon.

…………………………………………………………………………………………..

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

(ii) Determine the momentum of an X-ray photons with an energy of 100 keV.

momentum = ……………… kg m s^{-1} [3]

(iii) The rate of X-ray photons, with energy of 100 keV, incident on a surface is 1.6×10^{5} s^{-1}.

Assuming that all these photons are absorbed by the surface, calculate the force on the surface.

force = ……………… N [2]

(c) State an experiment and explain how it shows that electromagnetic radiation has a particulate nature.

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