H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

CENTRE NUMBER S

INDEX NUMBER

PHYSICS

9749/01

Paper 1 Multiple Choice

24 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **13** 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	$T / \text{K} = T / {^\circ}\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal 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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 A single sheet of aluminium foil is folded twice to produce a stack of four sheets. The total thickness of the stack of sheets is measured to be (0.80 ± 0.02) mm. This measurement is made using a digital calliper with zero error of (–0.20 ± 0.02) mm.

What is the percentage uncertainty in the calculated thickness of a single sheet?

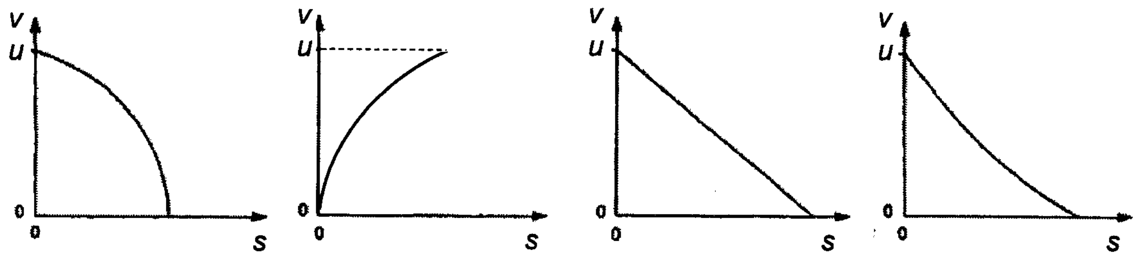
A 1.0% **B** 2.0% **C** 4.0% **D** 6.7%

2 A voltmeter connected across a resistor in a circuit gives readings which have high precision but low accuracy.

Which of the following best describes the likely error in readings taken with this voltmeter?

	random error	systematic error
A	high	high
B	high	low
C	low	high
D	low	low

3 A stone falls vertically and strikes soft ground with speed *u*. The stone experiences constant deceleration until it comes to rest. Which graph shows the variation of speed *v* with distance *s* below the ground surface?



A **B** **C** **D**

4 A particle X with kinetic energy E_k collides with a stationary particle Y. Both particles have the same mass.

After colliding, X and Y travel together as a single particle.

How much kinetic energy is lost in the collision?

A zero **B** $\frac{E_k}{4}$ **C** $\frac{E_k}{2}$ **D** $\frac{3E_k}{4}$

5 A sphere of mass 3.0 kg travelling due North at 2.0 m s^{-1} collides with another sphere of mass 4.0 kg travelling due East at 2.0 m s^{-1}.

The magnitude of their resultant momentum after the collision will be

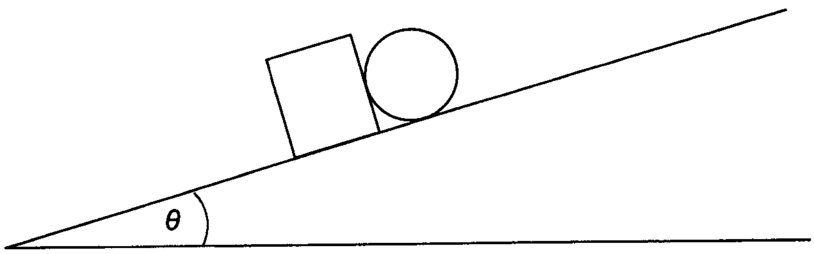
A 2.0 kg ms^{-1}.

B 10 kg m s^{-1}.

C 14 kg m s^{-1}.

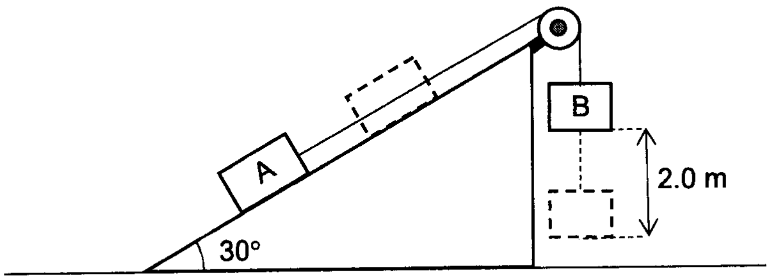
D dependent on whether the the collision is elastic or inelastic.

6 A block and a sphere of equal mass *m* are placed on an inclined plane. If the maximum frictional force that can exist between the block and the plane is equal to the weight of the block, and there is no frictional force between the sphere and the plane, what is the maximum angle θ at which the plane can be inclined before the block starts to slip?



A 30° **B** 45° **C** 60° **D** 73°

7 Blocks A and B, of masses 4.0 kg and 6.0 kg respectively, are connected by a light cord passing over a light, frictionless pulley. Block A is held at rest on a rough slope inclined at 30° to the horizontal as shown.



When A and B are released, block A experiences a constant frictional force of 3.0 N.

What is the total kinetic energy of A and B when B has travelled 2.0 m downwards?

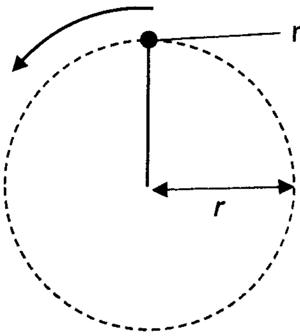
A 39 J **B** 72 J **C** 78 J **D** 118 J

8 A wire is stretched elastically by a force of 200 N, causing an extension of 2.00 mm. The force is gradually increased to 250 N, and the wire remains within its elastic limit.

What is the work done in stretching the wire from 200 N to 250 N?

A 0.113 J **B** 0.225 J **C** 113 J **D** 225 J

9 A small mass is attached to a light string and rotates in a vertical circle of radius r.



Taking g to be acceleration of free fall, what is the centripetal acceleration of the mass when it is at the lowest point of motion if the speed of the mass at the highest point just allow the mass to complete the circular motion?

A g **B** $2g$ **C** $4g$ **D** $5g$

10 Two satellites P and Q orbit the Earth due to the gravitational field of the Earth. P and Q are at distances R and $3R$ from the Earth's surface respectively, where R is the radius of the earth. The speed of P is v.

What is the speed of Q?

A $\sqrt{\frac{1}{3}}\,v$ **B** $\sqrt{\frac{1}{2}}\,v$ **C** $\sqrt{2}\,v$ **D** $\sqrt{3}\,v$

11 Mars has a diameter that is approximately 0.5 times the diameter of the Earth, and the mass of Mars is 0.1 times the mass of the Earth.

Given that the gravitational potential at the Earth's surface is -63 MJ kg^{-1}.

What is an approximate value for the gravitational potential at the surface of Mars?

A -13 MJ kg^{-1} **B** -25 MJ kg^{-1} **C** -95 MJ kg^{-1} **D** -320 MJ kg^{-1}

12 Container X contains neon and container Y contains argon. The two containers are identical, and the two gases are at the same temperature. The pressure in X is twice that in Y.

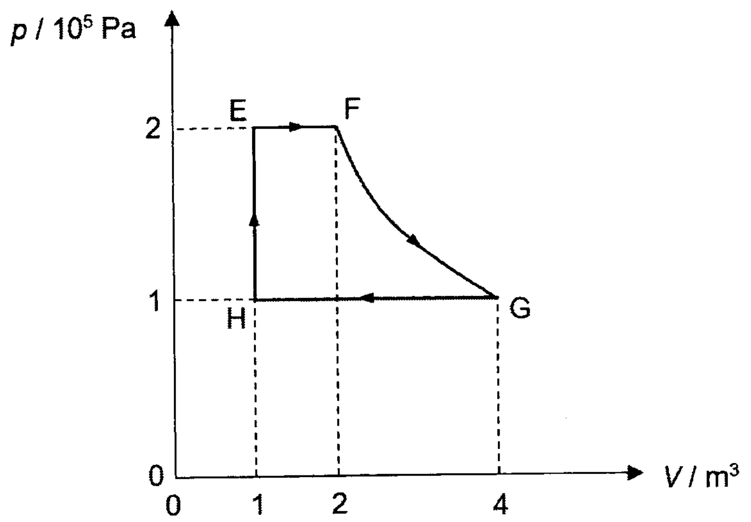
What is the ratio of the mean kinetic energy of a neon molecule to the mean kinetic energy of an argon molecule?
[The relative atomic masses of neon and argon are 20 and 40 respectively.]

A 0.5 **B** 1 **C** 2 **D** 4

13 The density of helium at 150 kPa is 0.178 kg m^{-3}. What is the root-mean-square speed of its particles?

A 130 m s^{-1} **B** 232 m s^{-1} **C** 1300 m s^{-1} **D** 1600 m s^{-1}

14 An ideal gas goes through the thermodynamic cycle EFGHE as shown.



Which of the following statements is correct?

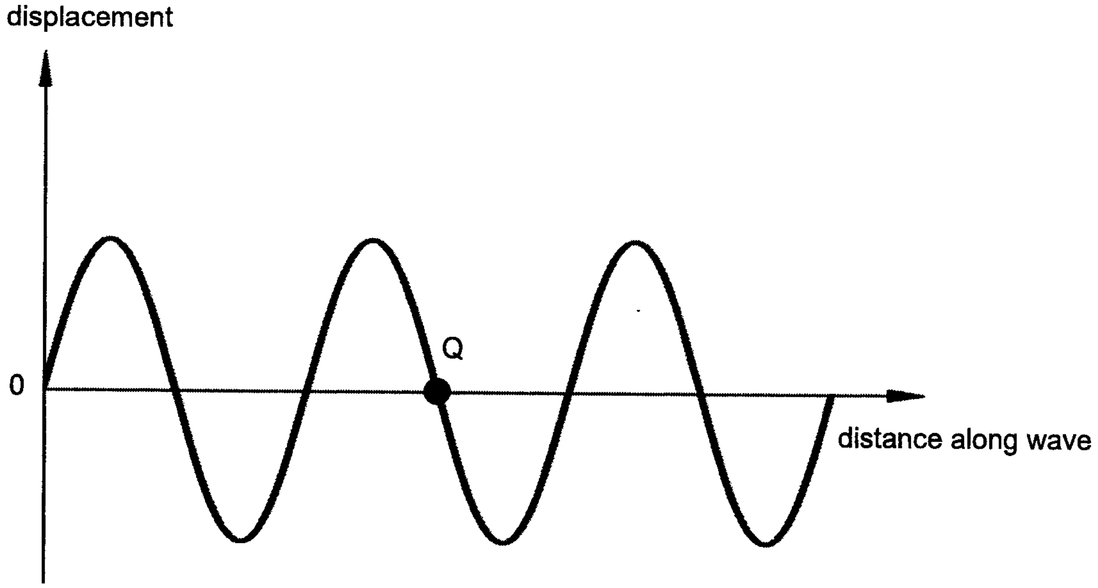
A After completing one cycle, there is net heat lost by the gas.

B During process FG, there is no change in the internal energy of the gas.

C During process HE, the gas loses heat.

D The work done by the gas during process EF is equal in magnitude to the work done on the gas during process GH.

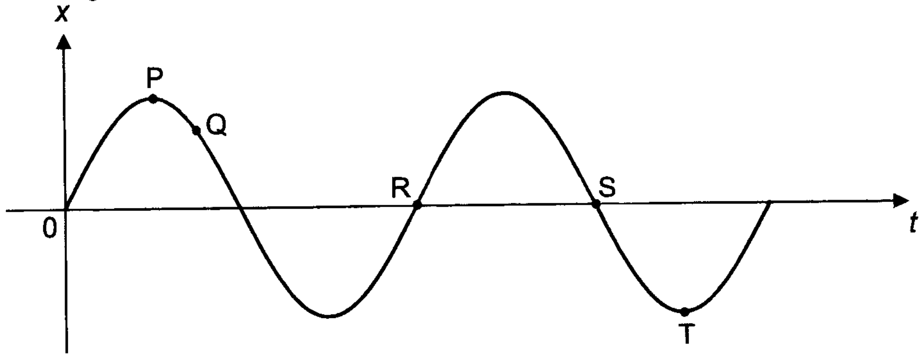
15 This diagram shows the displacement-distance graph of a transverse wave at time, $t = 0$. Taking upwards as positive, point Q is a point on the wave and is travelling downwards at $t = 0$. Another point P is $\frac{7}{8}$ of a wavelength from point Q.



Which of the following descriptions shows a possible displacement and direction of velocity of point P?

	displacement	direction of velocity
A	positive	positive
B	positive	0
C	0	negative
D	negative	negative

16 The graph below shows the variation with time t of the displacement x of a simple harmonic oscillator oscillating horizontally.



Which statement is correct?

A The phase difference between P and S is $\frac{\pi}{2}$ rad.

B The acceleration at T is zero.

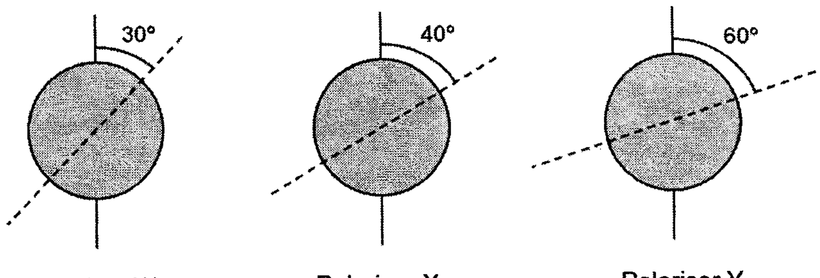
C The potential energy of the oscillator is larger at Q compared to T.

D The kinetic energy of the oscillator is larger at Q compared to R.

17 The diagram below shows three polarisers W, X and Y.

A beam of unpolarised light of intensity I_0 is incident normally onto the surface of polariser W, which then passes through polariser X and eventually emerges from polariser Y.

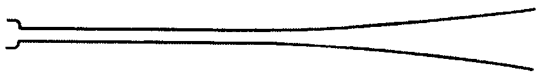
The axis of polarisation of each polariser is indicated by a dashed line.



What is the intensity of the light that emerges from polariser Y?

A $0.11\,I_0$ **B** $0.32\,I_0$ **C** $0.43\,I_0$ **D** $0.64\,I_0$

18 A musical instrument is made using a long tube with a mouthpiece at one end. The other end is open and flared, as shown.



A musician maintains stationary sound waves with a node at the mouthpiece and an antinode at the other end. The fundamental frequency of sound that the instrument can produce is 80 Hz.

Which different frequencies of sound can be produced by the instrument?

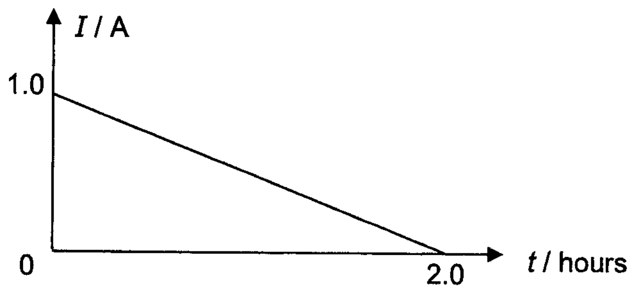
A 160 Hz, 240 Hz, 320 Hz

B 160 Hz, 320 Hz, 640 Hz

C 240 Hz, 400 Hz, 720 Hz

D 240 Hz, 320 Hz, 480 Hz

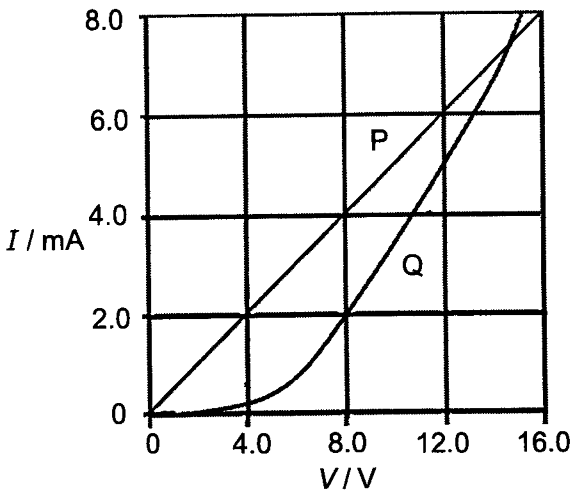
19 A portable fan battery is charged by connecting it to a constant potential difference of 6.0 V. The variation with time t of the current I through the battery is as shown.



What is the energy transferred to the battery during the time of 2.0 hours shown in the graph?

A 360 J **B** 720 J **C** 22 000 J **D** 43 000 J

20 The I-V characteristics of two electrical components P and Q are shown below.



Which of the following statements is correct?

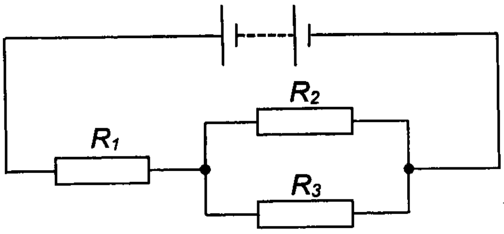
A P is an ohmic conductor and Q is a filament.

B Resistance of Q is always larger than resistance of P.

C At 2.0 mA, the power dissipated through Q is twice that of P.

D At the point where the two lines intersect the resistance of Q is approximately twice that of P.

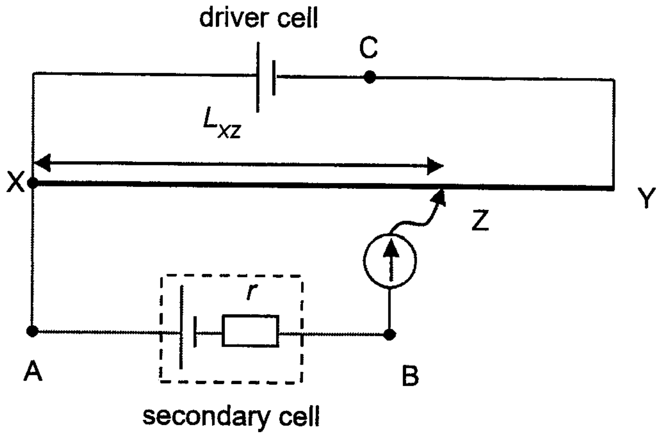
21 The diagram shows a network of three identical resistors connected to a battery of negligible internal resistance.



What is the ratio of $\dfrac{\text{power dissipated in } R_1}{\text{power dissipated in } R_2}$?

A 1 **B** 2 **C** 4 **D** 9

22 A typical potentiometer circuit is shown.



Which of the following does **not** increase the balance length L_{XZ}?

A decreasing the e.m.f. of the driver cell.

B increasing the e.m.f. of the secondary cell.

C adding a fixed resistor in series with the driver cell at point C.

D decreasing the internal resistance of the secondary cell.

23 In the direction opposite of an electric field line, which of the following must be true?

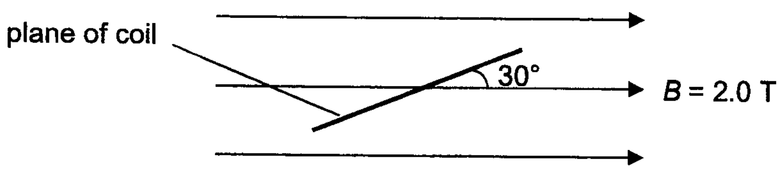
A The potential must decrease.

B The potential must increase.

C The electric field strength must decrease.

D The electric field strength must increase.

24 A square coil of 10 turns with sides of 5.0 cm is placed so that the plane of the coil makes an angle of 30° with the direction of a uniform magnetic field B of flux density 2.0 T. A current of 15 A is passed through the coil.



What is the magnitude of the torque acting on the square coil?

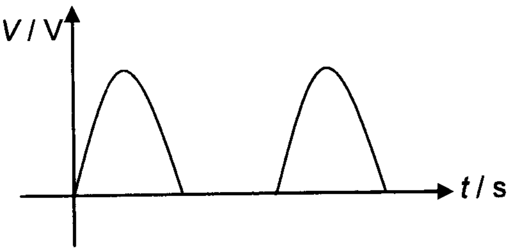
A 0.19 N m **B** 0.33 N m **C** 0.38 N m **D** 0.65 N m

25 A flat circular coil of 120 turns, each of area 0.070 m^2, is placed with its axis parallel to a uniform magnetic field. The flux density of the field is changed steadily from 80 mT to 20 mT over a period of 4.0 s.

What is the e.m.f. induced in the coil during this time?

A 0 mV **B** 1.1 mV **C** 130 mV **D** 500 mV

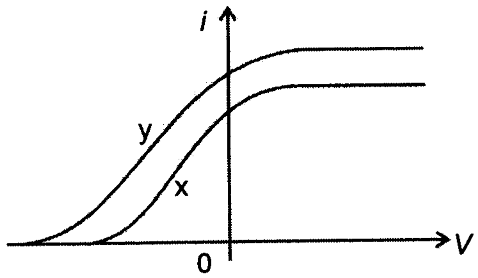
26 The figure belows shows a varying voltage.



The r.m.s. value of this rectified voltage is 100 V. The peak voltage is

A 50 V **B** 71 V **C** 141 V **D** 200 V

27 The figure shows the variation of the photoelectric current *i* with voltage *V* between the electrodes in a photocell for two different radiations, x and y.



The intensity and the frequency of radiation x are I_x and f_x while the intensity and the frequency of radiation y are I_y and f_y. Which of the following shows the relationship between the intensities and frequencies of x and y?

A $I_x > I_y$, $f_x > f_y$ **B** $I_x > I_y$, $f_x < f_y$

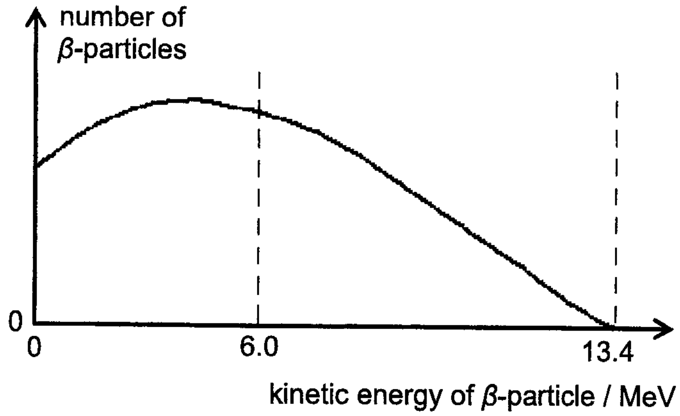
C $I_x < I_y$, $f_x > f_y$ **D** $I_x < I_y$, $f_x < f_y$

28 An electron of mass *m* and charge *e* is accelerated from rest through an electric field of potential difference *V*.

What is the frequency of a photon whose wavelength is equal to the de Broglie wavelength of this electron?

A $\dfrac{c\sqrt{2meV}}{h}$ **B** $\dfrac{h}{\sqrt{2meV}}$ **C** $\dfrac{hc}{eV}$ **D** $\dfrac{eV}{h}$

29 The beta spectrum for ^{12}B decay is as shown below.



The kinetic energy of an emitted β-particle is 6.0 MeV. What is the approximate energy of the associated neutrino?

A 4.0 MeV **B** 6.0 MeV **C** 7.4 MeV **D** 13.4 MeV

30 A radioactive source in the laboratory has a half-life of 10 days. The count rate was measured to be 100 Bq initially. 20 days later, the count rate was found to be 34 Bq. What is the count rate in the laboratory without the source?

A 9 **B** 12 **C** 17 **D** 22

End of Paper

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CLASS		TUTOR'S NAME	
CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS 9749/02

Paper 2 Structured Questions

15 September 2025

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number 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, 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.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 7
2	/ 7
3	/ 11
4	/ 11
5	/ 8
6	/ 7
7	/ 9
8	/ 20
Total	/ 80

This document consists of **24** printed pages.

Data

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pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal 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.	$v = v_0 \cos \omega t$
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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 The rate of heat flow through a rod due to conduction is given by Fourier's Law:

$$\frac{Q}{t} = \frac{CA(\Delta T)}{L}$$

where *A* is the cross-sectional area of the material,

L is the length of the material,

ΔT is the temperature difference across the length of the material, and

C is a constant.

(a) Determine the SI base units of *C*.

SI base units = ... [2]

(b) An experiment is conducted to determine the value of *C*. Using copper rod of diameter 0.80 cm but different length, and two ends of the rod are maintained at pure ice point and steam point, the rate of flow of thermal energy was measured using a heat flux sensor. A graph of how $\frac{Q}{t}$ varies with $\frac{1}{L}$ is plotted, as shown in Fig. 1.1.

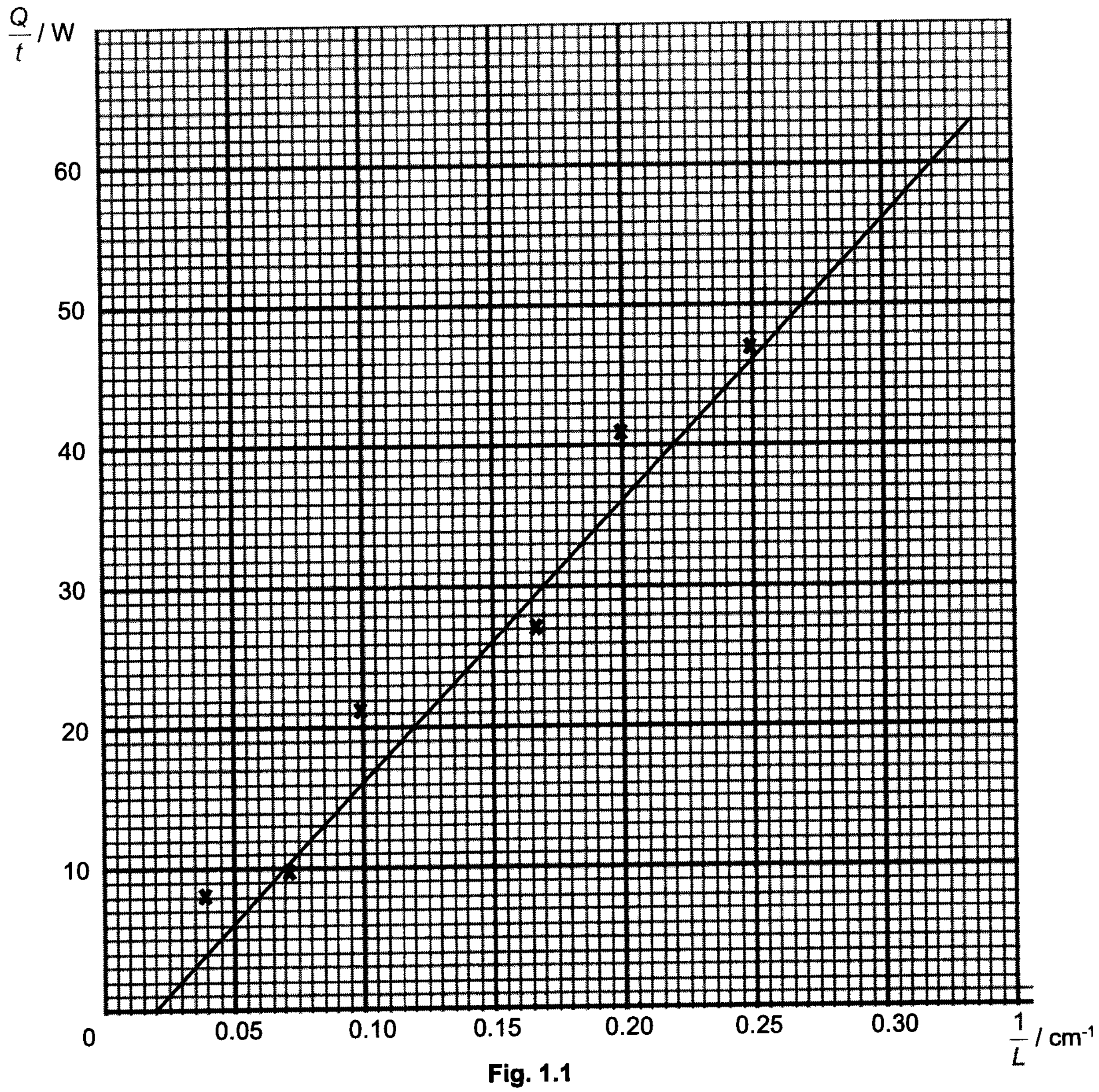

Fig. 1.1

(i) State the feature of the graph that indicates the presence of systematic error in the experiment.

....

....[1]

(ii) Calculate the value of *C*, in SI units, from Fig. 1.1.

value of *C* = ... SI base units [3]

(iii) With reference to Fig. 1.1 and **(b)(i)**, state and explain whether the accuracy of *C* is affected by the presence of systematic error in the experiment.

....

....

....

....[1]

[Total: 7]

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

....

....

....

....[1]

(b) Fig. 2.1 shows a metal bullet of mass 2.0 g fired horizontally into a block of wood of mass 600 g. The block is suspended from strings so that it is free to move in the vertical plane. The bullet hits and becomes embedded in the block. The block and bullet rise together through a vertical distance of 8.6 cm.

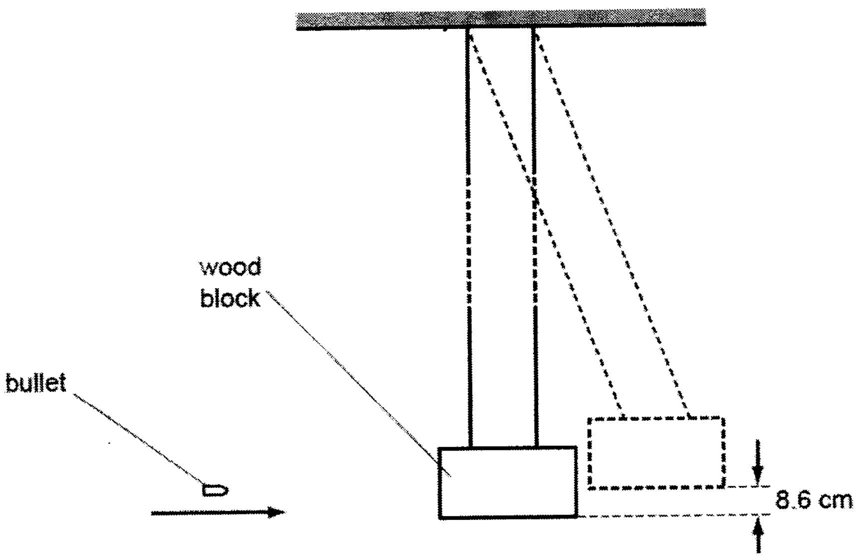

Fig. 2.1

(i) Show that the speed of the block and bullet as they just move off together is 1.3 m s^{-1}.

[2]

(ii) Using **(a)** and **(b)(i)**, determine the speed of the bullet before the impact with the block.

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

(iii) A rubber bullet of the same mass hits the block with the same speed calculated in **(ii)** and rebounds in the opposite direction. State and explain whether the block will reach a maximum height of greater or less than 8.6 cm.

....

....

....

....[2]

[Total : 7]

3 A steel sphere of mass 0.30 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 3.1.

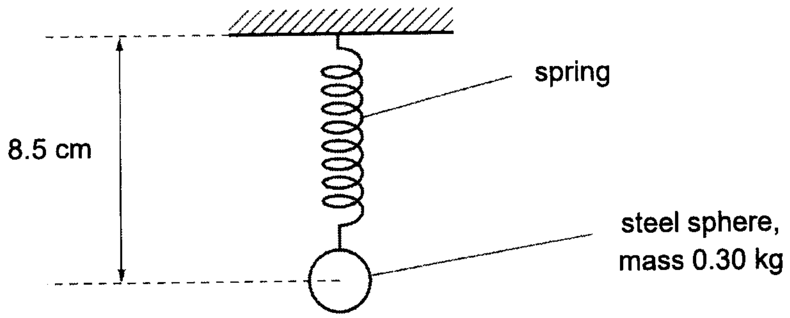

Fig. 3.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 3.2.

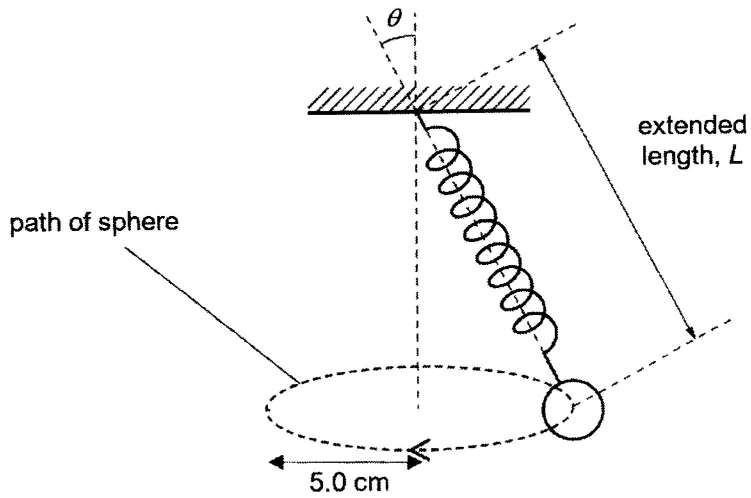

Fig. 3.2

The spring stretches to a new extended length L, and the radius of the circular motion is 5.0 cm. The angle between the linear axis of the spring and the vertical is θ. The period of the circular motion is 0.60 s.

(a) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 3.2 is greater than in Fig. 3.1.

....

....

....

....

....[3]

(b) **(i)** Calculate the centripetal acceleration of the sphere.

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

(ii) Show that the angle θ is 29°.

[2]

(iii) Calculate the tension in the spring in Fig. 3.2.

tension in spring = ... N [2]

(iv) Calculate the spring constant of the spring.

spring constant = ... N m^{-1} [3]

[Total: 11]

4 Fig. 4.1 shows a fixed mass of ideal gas in a cylinder of pressure 2.1×10^5 Pa, volume 4.0×10^{-4} m^3 and temperature 27 °C.

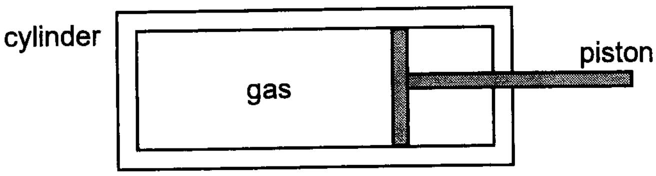

Fig. 4.1

The gas is compressed at constant temperature along process I. Fig. 4.2 shows the variation with volume V of the pressure P of the gas.

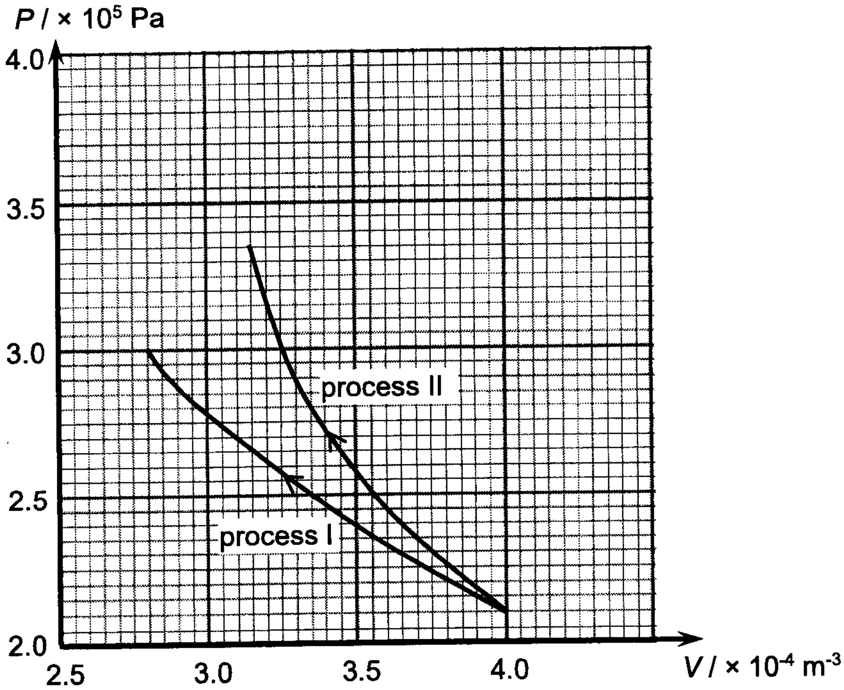

Fig. 4.2

(a) **(i)** With reference to Fig. 4.2, estimate the work done on the gas through process I.

work done = ... J [3]

(ii) State the *first law of thermodynamics*.

....

....[1]

(ii) Determine the heat loss from the gas through process I.

....

....[1]

(b) A second identical cylinder containing the same ideal gas is thermally insulated. The gas is compressed to a new pressure and volume, as shown in process II. The work done on the gas in process I equals to the work done on the gas in process II.

(i) Using the kinetic theory of gases, explain why the pressure in process II increases.

....

....

....

....

....[4]

(ii) Calculate the final temperature of process II.

temperature = ... °C [2]

[Total: 11]

5 **(a)** State one differences between *progressive* waves and *stationary* waves.

....

....

.... [1]

(b) Define *transverse* waves and *longitudinal* waves.

1. Transverse wave: ....

....

.... [1]

2. Longitudinal wave: ....

....

.... [1]

(c) **(i)** Explain why it would not be possible to polarise sound waves.

....

....

....

....

.... [2]

(ii) Unpolarised light of intensity I_0 is incident on two polarising filters P and Q, as shown in Fig. 5.1 below. The transmission axis of filter P is aligned vertically. The intensity of the unpolarised light is halved after passing P.

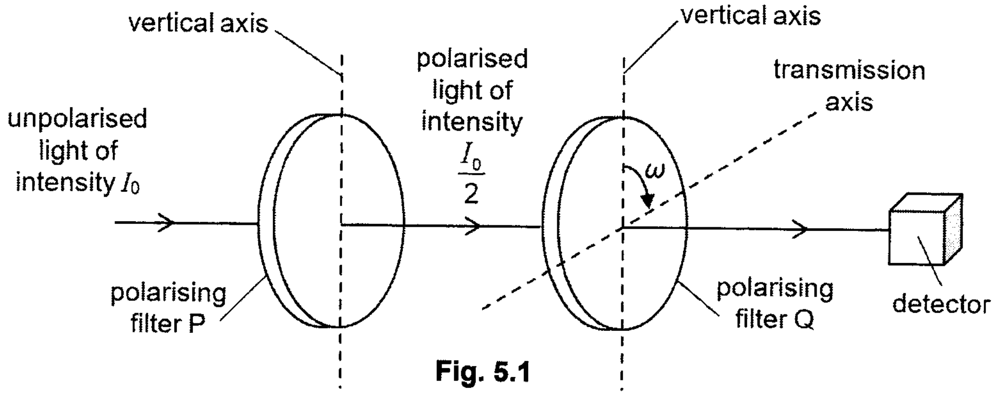

Fig. 5.1

The light is then passed through filter Q, which has the transmission axis initially aligned vertically and spun at a constant angular velocity of 2.0 rad s^{-1}.

Determine the ratio $\frac{\text{intensity reaching detector}}{\text{initial intensity } I_0}$ after 9.0 s.

ratio = ... [3]

[Total: 8]

6 **(a)** A uniform magnetic field has a constant flux density B. A straight wire of fixed length carries a current I at angle θ to the magnetic field, as shown in Fig. 6.1.

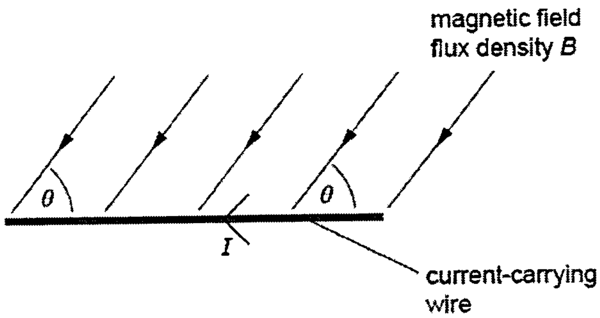

Fig. 6.1

(i) The current in the wire is changed, keeping the angle θ constant.

On Fig. 6.2, sketch the graph to show the variation with the current I of the force F on the wire.

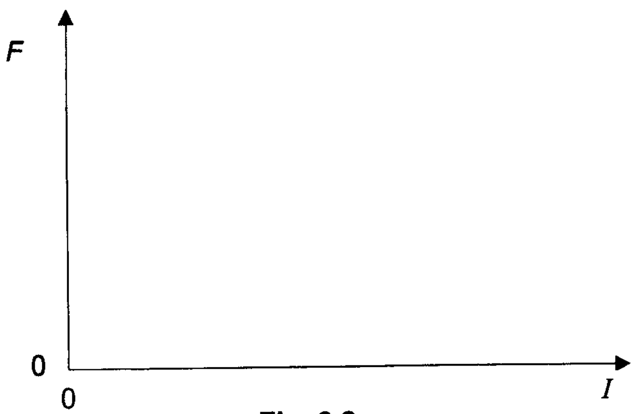

Fig. 6.2

[2]

(ii) The angle θ between the wire and the magnetic field is now varied and the current I is kept constant.

On Fig. 6.3, sketch a graph to show the variation with angle θ of the force F on the wire from θ = 0° to 180°.

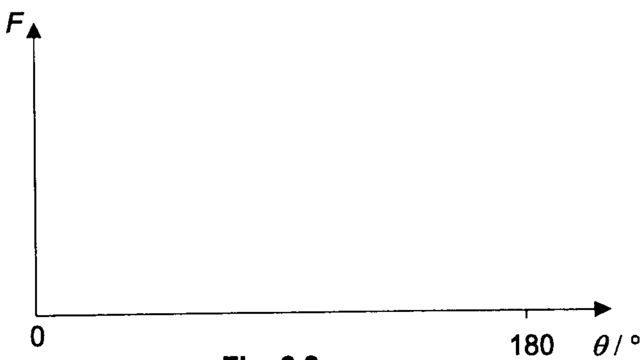

Fig. 6.3

[2]

(b) A uniform magnetic field is directed at right angle to the rectangular surface PQRS of a slice of conducting material, as shown in Fig. 6.4.

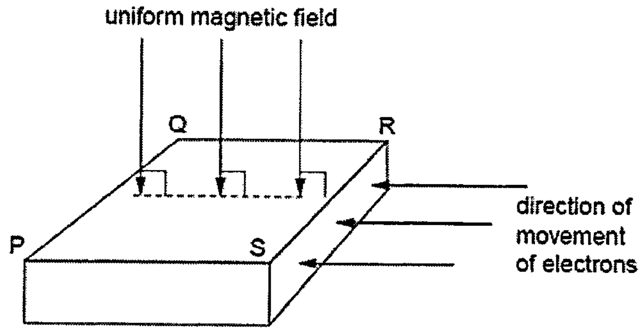

Fig. 6.4

Electrons, moving towards side SR, enters the slice of conducting material. The electrons enter the slice at right angle to side SR.

(i) Explain why the electrons do not travel in straight lines across the slice from side SR to side PQ.

....

....

....[2]

(ii) State the direction of the electric field applied to the slice of conducting material for the electrons to pass through the slice undeviated.

....[1]

[Total: 7]

7 In a nuclear reaction, a stationary fluorine-19 is bombarded with a proton having a kinetic energy of 5.00 MeV. The following reaction may occur.

$${}^{1}_{1}H + {}^{19}_{9}F \rightarrow {}^{16}_{8}O + {}^{4}_{2}He$$

The following data may be used for the calculation.

Rest mass of ${}^{19}_{9}F$	18.998403 *u*
Rest mass of ${}^{1}_{0}n$	1.008665 *u*
Rest mass of ${}^{1}_{1}H$	1.007825 *u*
Rest mass of ${}^{4}_{2}He$	4.003860 *u*

(a) Explain what is meant by

(i) binding energy of a nucleus,

....

....[1]

(ii) mass defect of a nucleus.

....

....[1]

(b) Calculate the binding energy per nucleon, in MeV, for fluorine-19.

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

(c) Use the answer in **(b)** and the following data to determine the total kinetic energy of the products. Assume no photon is emitted in this reaction.

	Binding energy per nucleon/MeV
Oxygen-16	7.72
Helium-4	6.82

total kinetic energy = ... J [2]

(d) Determine the rest mass of ${}^{16}_{8}O$.

rest mass of ${}^{16}_{8}O$ = ... kg [2]

[Total: 9]

8 Read the passage below and answer the questions that follow.

DPM Heng Swee Kiat announced in Budget 2020 that Singapore will be phasing out internal combustion engine vehicles (i.e. vehicles that use petrol or diesel as fuel) in favour of fully electric vehicles (EV) by 2040. The move is part of Singapore's commitment to tackle climate change and build an eco-friendlier city.

To increase the adoption rate of EVs, all HDB car parks in at least eight "EV-Ready Towns" across Singapore will be fitted with EV charging stations, according to Minister for Transport Ong Ye Kung during his Committee of Supply debate for the Singapore Green Plan on March 4, 2021.

The battery of an EV can be charged through either conductive or inductive methods. Conductive charging involves wired connection to the electricity supply grid. Inductive charging refers to wireless charging systems (WCS). WCS can function in both stationary and dynamic modes. This means that they can be utilized when the car is parked or stopped, such as in car parks, garages, or at traffic signals, or they can be utilized while the vehicle is in motion.

Battery chargers can be implemented inside (on-board) or outside (off-board) the vehicle. Fig 8.1 shows the typical architecture of an EV charging system, where both the on-board charger and the off-board charger are represented.

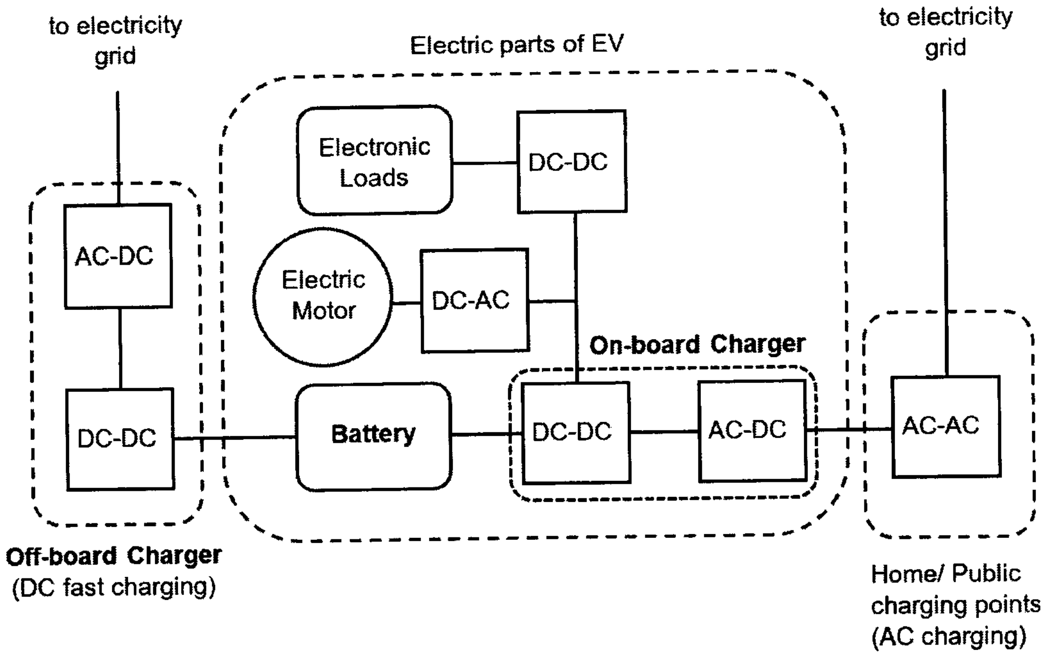

Fig. 8.1

On-board battery chargers are limited by size, weight and volume. On-board chargers are typically composed of two stages: a front-end AC-DC (a.c. to d.c.) stage and a back-end DC-DC (d.c. to d.c.) stage. The front-end conversion can be performed by a full-bridge diode rectifier circuit.

Off-board charging systems, with higher power ratings, are installed outside the vehicle. It is usually made up of two stages: a grid-facing AC-DC converter followed by a DC-DC converter providing an interface to the EV battery.

The batteries installed on EVs are not all the same. The battery capacity is the quantity that measures how much electricity can be stored. Charging power is the quantity that measures the amount of effective energy per unit time that is transferred from the charging station to the battery of the car. Ideally it could be equal to the power of the charging station but in reality, it is almost always limited by a series of factors including charging station power, maximum charging power of the machine, maximum current of the charging cable and grid energy availability.

(a) The alternating voltage from the power sub-station has to be stepped down from 21 kV to 250 V with a transformer before connecting to a domestic EV charger with a rated output of 8.0 kW.

(i) Calculate the current in the secondary coil of the transformer.

current in the secondary coil = ... A [2]

(ii) Assuming the transformer is ideal, calculate the current in the primary coil of the transformer.

current in the primary coil = ... A [2]

(iii) Determine the ratio of the number of turns in the primary coil to the number of turns in the secondary coil in the transformer.

ratio = ... [2]

(iv) If the output voltage from the charger is half-wave rectified to give a d.c. voltage, determine the peak value of this rectified voltage. Explain your working clearly.

peak rectified voltage = ... V [2]

(v) The charger is used to charge an EV installed with a 27 kWh battery. Calculate the duration, in hours, required for the battery to be 80% charged.

time = ... hr [2]

(b) The current from the battery must first be converted from a d.c. to an a.c before it can power the electric motor. This is achieved using a circuit known as an *Inverter*. Fig. 8.2 shows a schematic of a simple inverter.

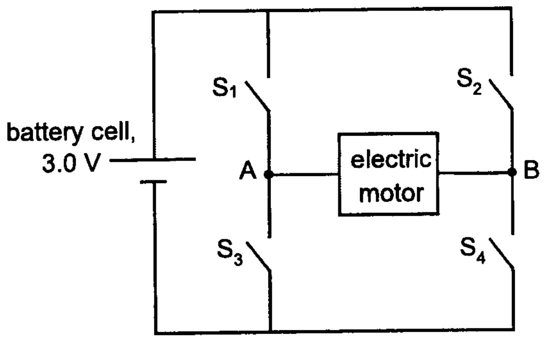

Fig. 8.2

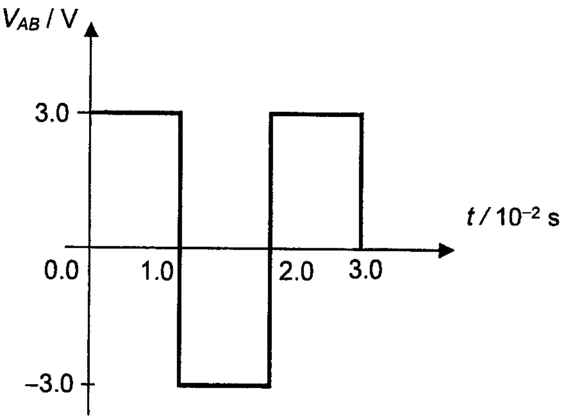

Fig. 8.3

Fig. 8.3 shows the output voltage V_{AB} across points A and B, connected to the motor in the circuit.

(i) The 4 switches S_1, S_2, S_3 and S_4 in Fig. 8.2 are electronically controlled to operate in pairs, so that at any one instant, 2 of switches will be closed while the other 2 will be open.

State and explain how the switches can be paired and operated to produce the output voltage V_{AB} in Fig. 8.3.

....

....

....

....

....

....

....[3]

(ii)

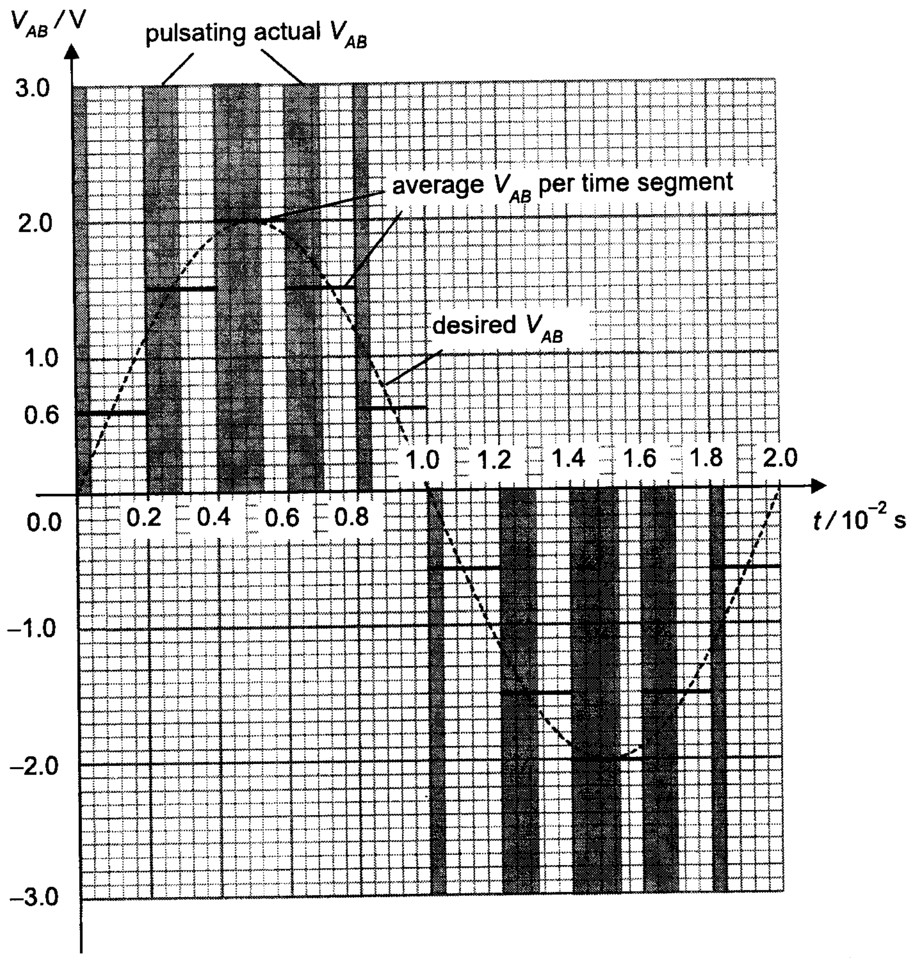

Fig. 8.4

To produce an output waveform that resembles a sinusoidal waveform, the opening and closing of the switches are specially programmed. While one pair of switches is open, the other pair of switches does not just stay closed for the duration of the half-cycle. Instead, they are made to rapidly open and close multiple times in a pulsating pattern. Each pulse varies in width, as shown in Fig. 8.4. This is known as *Pulse Width Modulation*.

The cycle is broken up into multiple smaller segments. By rapidly pulsating the switches the average voltage per segment can be controlled to increase or decrease from one time segment to the next.

The resultant output experienced by the motor can thus be made to approximate a sine wave. The more segments there are, the closer the output mimics a smooth wave.

1. Using information from Fig. 8.4, show that the average output voltage V_{AB} for the time segment $0.00 \leq t \leq 0.20 \times 10^{-2}$ s is 0.60 V.

[1]

2. Explain how the magnitude and the frequency of the average output voltage V_{AB} can be changed.

....

....

....

....

....[2]

(c) Inductive charging, or wireless charging, consists of a transfer of energy from the charging station to the vehicle without using a cable.

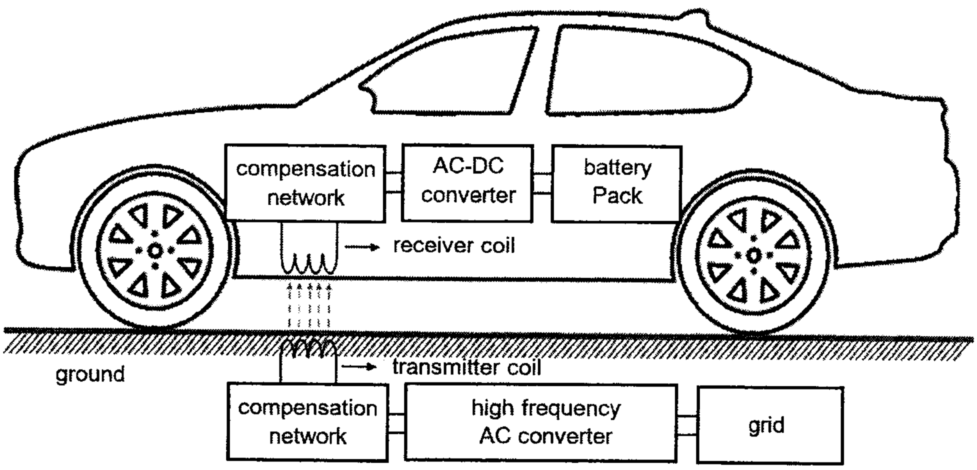

Fig. 8.5

Fig. 8.5 shows two conductive coils, one placed under the car body and the other installed at the ground level of the charging station.

(i) Use Faraday's law to explain how the battery in the EV is charged.

....

....

....

....

....[2]

(ii) Wireless charging is rarely used due to the high inefficiencies involved. Charging cables allow for a near 100% energy transfer from the source to the battery, but a wireless charger can have efficiencies as low as 60%.

Suggest two reasons why the energy transfer process might be inefficient.

1. ....

....

.... [1]

2. ....

....

.... [1]

[Total: 20]

End of Paper

H

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JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CLASS		TUTOR'S NAME	
CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS **9749/03**

Paper 3 Longer Structured Questions

19 September 2025

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number 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, 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.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/ 6
2	/ 8
3	/ 12
4	/ 10
5	/ 9
6	/ 8
7	/ 7
Section B	
8	/ 20
9	/ 20
Total	/ 80

This document consists of **23** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
	$(1 / (36\pi)) \times 10^{-9}\ \text{F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$

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	$p = \frac{1}{3}\frac{Nm}{V} \langle c^2 \rangle$
mean translational kinetic energy of an ideal 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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A projectile is fired from ground level with initial velocity u at an angle θ to the horizontal as shown in Fig. 1.1. The projectile strikes a target which is at a horizontal displacement x from the point of projection and a vertical height y above ground level.

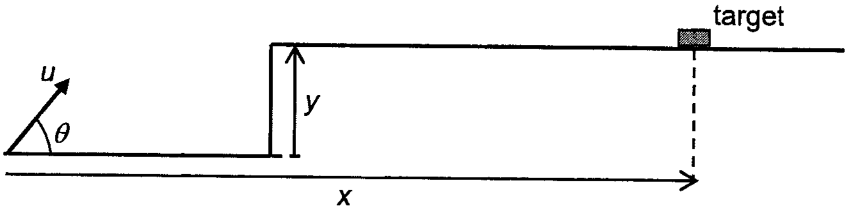


Fig. 1.1

(a) Neglecting the effect of air resistance, show that the vertical height y is given by the expression

$$y = x\tan\theta - 4.91\left(\frac{x}{u\cos\theta}\right)^2$$

[3]

(b) Given that the angle θ is 60°, the horizontal displacement x is 115 m and the vertical height y is 23 m, calculate the speed u.

u = ... m s^{-1} [1]

(c) Fig. 1.2 shows the variation with time t of the vertical velocity v_y of the projectile when air resistance is negligible. On the same axes, sketch a graph to show the variation with time t of the vertical velocity v_y of the projectile when air resistance is not negligible. [2]

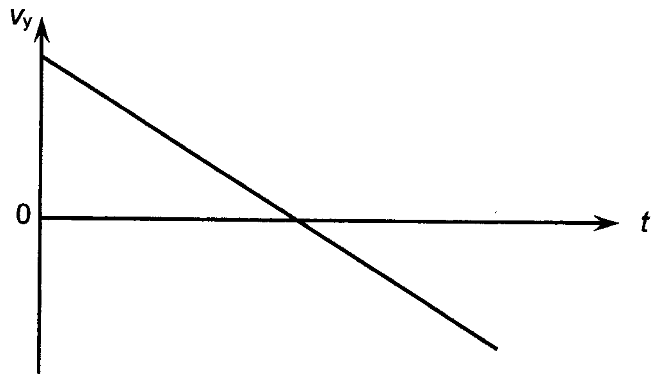


Fig. 1.2

[Total: 6]

2 **(a)** State the **two** conditions necessary for a body to be in equilibrium.

1. ....

....

2. ....

.... [2]

(b) Fig. 2.1 shows a uniform beam AB of length 6.0 m and weight 2700 N suspended by two ropes AC and BC, each of length 6.0 m. The tensions in ropes AC and BC are T_1 and T_2 respectively.

A worker of weight 900 N is holding onto the beam at point D, where AD = 4.0 m and DB = 2.0 m.

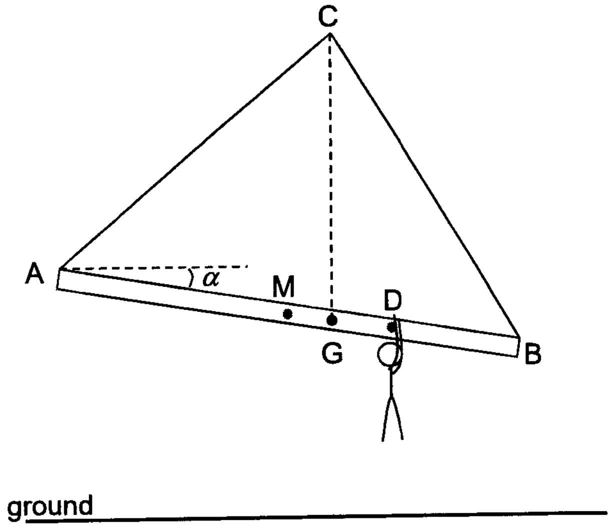


Fig. 2.1

The beam makes an angle α to the horizontal. The point M is the mid-point of the beam and the point G on the beam is the position of the centre of gravity of the beam and the worker.

(i) Explain in terms of forces acting on the beam, why the point G must lie directly below C.

....

....

....

....

....[2]

(ii) Calculate the distances MG and DG.

distance MG = ... m

distance DG = ... m

[2]

(iii) If the angle α is 2.8°, determine the magnitude of the tension T_2.

tension T_2 = ... N [2]

[Total: 8]

3 **(a)** Explain why gravitational potential is a negative value for an isolated mass.

....

....

....

....

....

....[3]

(b) A satellite can orbit the Earth along an east-to-west direction (known as a retrograde orbit) as well as along the west-to-east direction (known as a prograde orbit).

(i) A satellite is launched in the west-to-east direction from a launch pad on the Equator to the geostationary orbit.

Explain why this launch direction is preferred.

....

....

....

....[2]

(ii) The Earth may be considered to be a uniform sphere of radius 6400 km with its mass of 6.0×10^{24} kg concentrated at its centre.

Show that the geostationary satellite is 3.59×10^{7} m above the Earth's surface.

[2]

(iii) A satellite of mass 1000 kg is in geostationary orbit. Find its total energy.

total energy = ... J [2]

(iv) Atmospheric drag is very low but nonetheless present at the height where geostationary satellites orbit.

Explain, in terms of energy, the impact of atmospheric drag on the subsequent trajectory of geostationary satellites.

....

....

....

....

....

....[3]

[Total: 12]

4 Fig. 4.1 shows a ball of mass 37 g on a smooth surface. It is held between two fixed points A and B by two identical stretched helical springs, of spring constant 3.5 N m^{-1}.

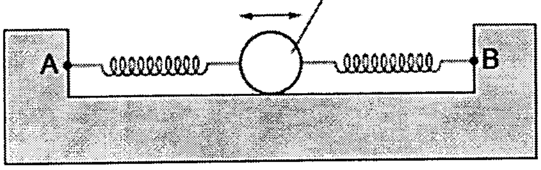


Fig. 4.1

The extension of each spring is 3.2 cm when the ball is at the equilibrium position. The ball oscillates along the line AB with simple harmonic motion of frequency 2.19 Hz and amplitude 3.0 cm.

(a) **(i)** State the extension of the springs when the ball is at the amplitude position closest to point B.

extension of spring A = ... cm

extension of spring B = ... cm

[1]

(ii) Show that the total energy of the system is 6.7×10^{-3} J.

[2]

(b) On the axes of Fig. 4.2 and using your answers to **(a)**, sketch a graph to show the variation with displacement *x* of

(i) the total energy of the system (label this line T), [1]

(ii) the kinetic energy of the ball (label this line K), [2]

(iii) the potential energy stored in the springs (label this line P). [2]

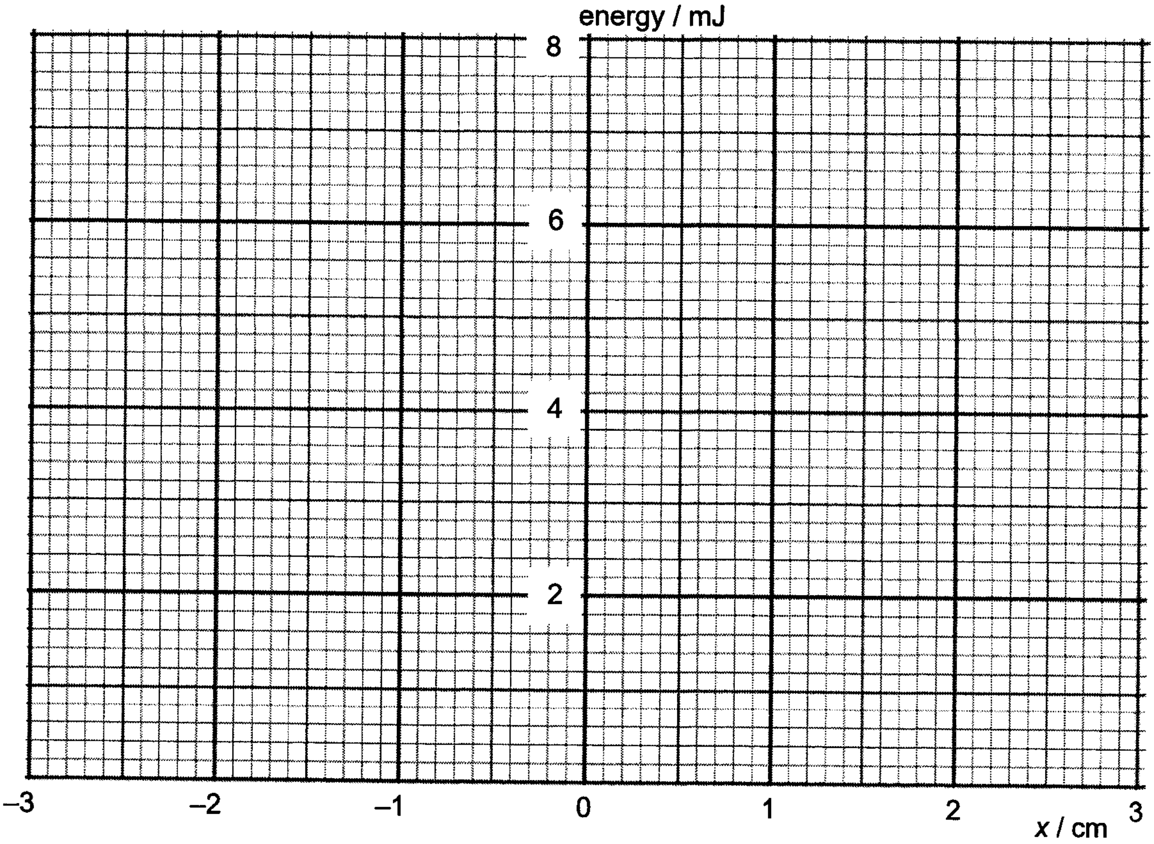


Fig. 4.2

(c) The ball in Fig. 4.1 is replaced with a heavier ball of the same size. State and explain the change, if any, to the maximum speed of the ball during the oscillation, if the amplitude remains unchanged.

....

....

....[2]

[Total: 10]

5 **(a)** Two light sources that produce light with the same wavelength are placed at position A and B respectively as shown in Fig. 5.1.

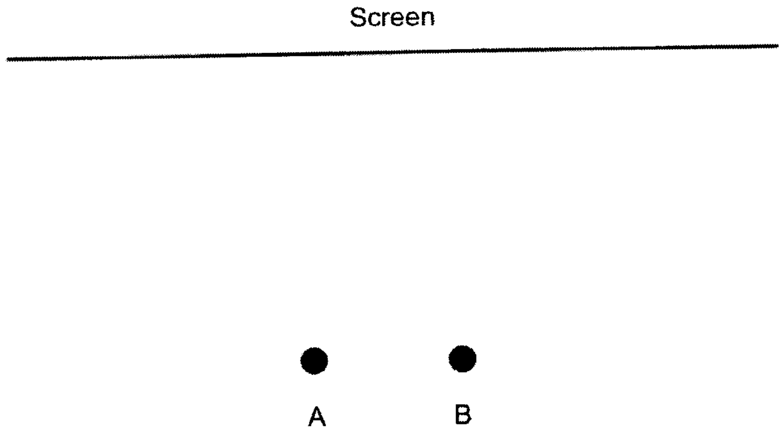


Fig. 5.1

The light from the light sources meet on the screen and a steady interference pattern is formed on the screen.

State two other conditions required for the interference pattern to be observable.

1. ....

....[1]

2. ....

....[1]

(b) When a distant streetlight, which is behaving as a point source of light of wavelength 4.5×10^{-7} m, is viewed through a nylon net curtain, the diffraction pattern of the light projected on a screen is shown in Fig. 5.2. The screen is 3.0 m away from the nylon net curtain.

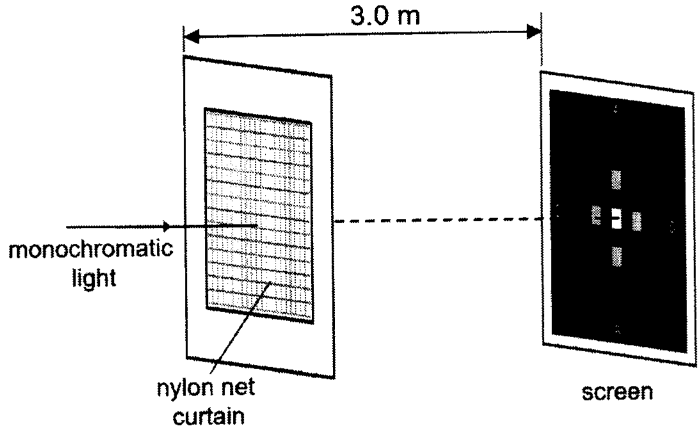


Fig. 5.2

The full-scale diagram of the diffraction pattern is shown in Fig. 5.3.

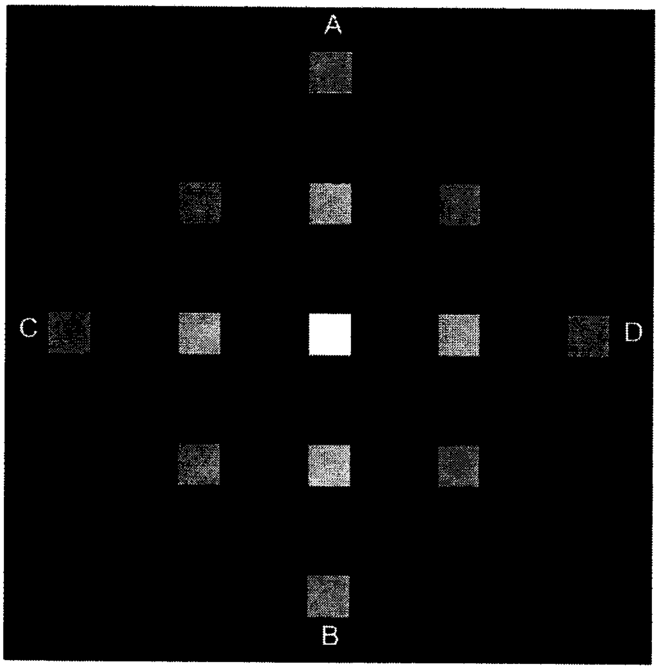


Fig. 5.3

The main feature of this pattern is two lines (AB and CD) of bright images.

(i) Calculate the angle, in radians, between the orders of the diffracted light.

angle = ... rad [2]

(ii) Using your answer to **(b)(i)**, determine the number of nylon threads per millimetre of the mesh.

number = ... mm^{-1} [2]

(c) A long horizontal tube, containing fine powder, is closed at one end. A loudspeaker, connected to a signal generator, is positioned at the other end as shown in Fig. 5.4.

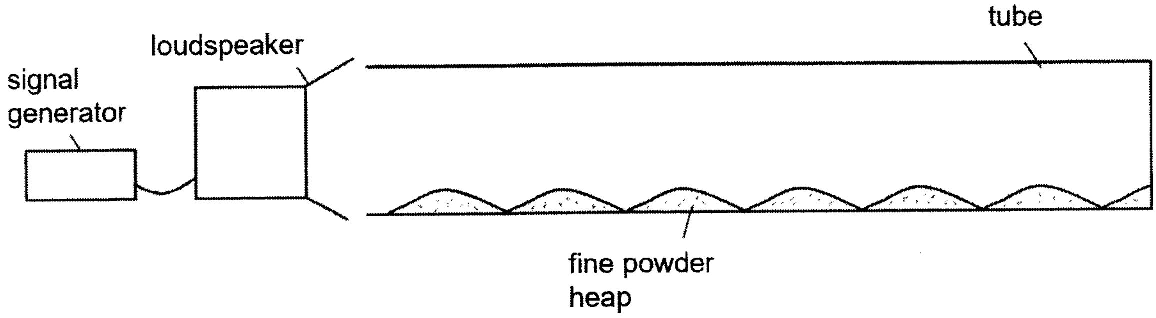


Fig. 5.4

At a particular frequency, a stationary wave is set up inside the tube and the powder forms heaps as shown. The speed of sound is 330 m s^{-1}.

(i) On Fig. 5.4, mark out 2 points where displacement nodes are and label them as N. [1]

(ii) Determine the distance between adjacent heaps if the signal generator is producing a signal with frequency of 3.5 kHz.

spacing = ... m [2]

[Total: 9]

6 An electric guitar uses electromagnetic pickups to detect the vibration of its strings, which are made from steel. Each pickup consists of a coil of wire wrapped around a permanent magnet as shown in Fig. 6.1. When the string vibrates near the pickup, an alternating electromotive force (e.m.f.) is induced in the coil (which is channelled to an output amplifier and speaker)

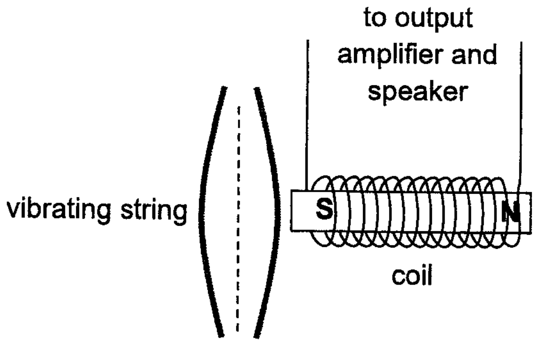


Fig. 6.1

(a) Explain how the vibration of the steel string leads to the generation of an alternating e.m.f. in the coil of the pickup.

....

....

....

....

....

....[4]

(b) A guitarist plucks a string more strongly, causing it to vibrate with the same frequency but larger amplitude. Explain how this affects the e.m.f. induced in the coil.

....

....

....[2]

(c) A guitar string vibrates in a magnetic field, where the field strength at the coil fluctuates between maximum and minimum with a difference of field strength of 5.0×10^{-2} T at a frequency of 880 Hz. The coil has a cross-sectional area of 1.0×10^{-6} m^2. It is desired that the average e.m.f. of the pickup coil is about 0.20 V.

Estimate the number of turns the coil must have.

number of turns = ... [2]

[Total: 8]

7 **(a)** Define *electric field strength* at a point.

....

....[1]

(b) Electrons are emitted from a cathode C and are accelerated towards an anode A, as illustrated in Fig. 7.1.

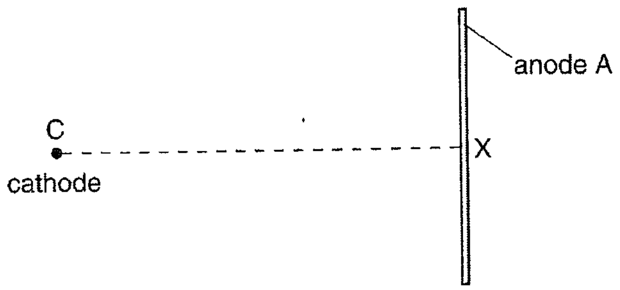
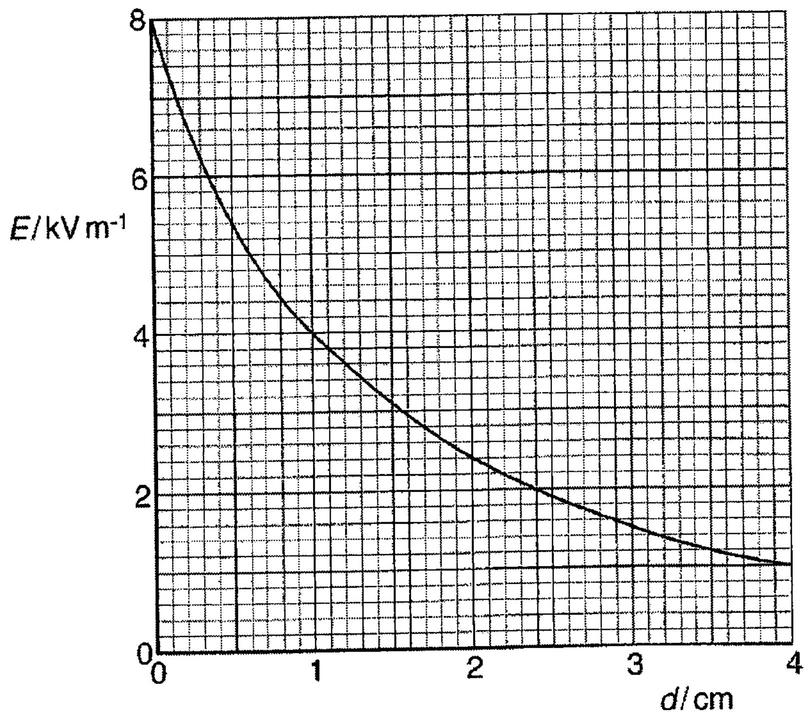


Fig. 7.1

The anode is earthed. CX is a line drawn from C normal to the anode A. The distance CX is 4.0 cm.

The variation with distance *d* from C along CX of the magnitude of the electric field strength *E* is shown in Fig. 7.2.



(i) On Fig. 7.1, mark with an arrow the direction of the electric field along CX. [1]

(ii) Use Fig. 7.2 to determine the force *F* on an electron at a point mid-way between C and X.

F = ... N [2]

(c) **(i)** A student assumes that the force *F* on the electron remains constant as the electron moves from C to X.

Use the value of *F* calculated in **(b)(ii)** to estimate, on the basis of this assumption, the potential difference between C and X.

potential difference = ... V [2]

(ii) Suggest, with a reason, whether the magnitude of the potential difference calculated in **(i)** will be an over-estimate or an under-estimate of the actual potential difference.

....

....[1]

[Total: 7]

Section B

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

8 **(a)** By reference to energy transfers, distinguish between electromotive force (e.m.f.) and potential difference (p.d.).

....

....

....

....[2]

(b) A circuit is set up as shown in Fig. 8.1.

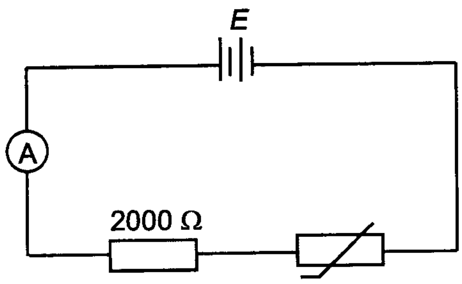


Fig. 8.1

The source of negligible internal resistance is found to provide 2.4×10^5 J of electrical energy to the 2000 Ω resistor and thermistor when a charge of 2.2×10^4 C passes through the ammeter. At room temperature, the thermistor has a resistance of 1800 Ω.

(i) Sketch on Fig. 8.2 the variation with temperature θ of resistance R in a thermistor.

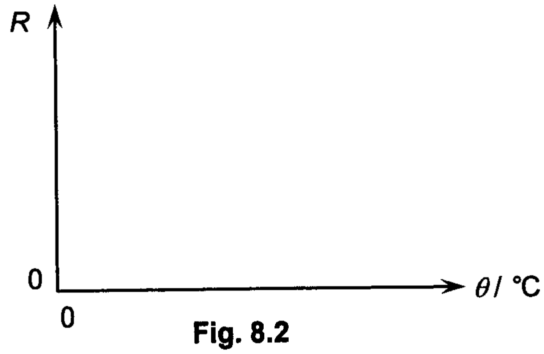


Fig. 8.2

[1]

(ii) For the thermistor at room temperature,

1. show that the e.m.f. of the source is 11 V.

[1]

2. determine the time taken for the charge of 2.2×10^4 C to pass through the ammeter.

time = ... s [2]

3. determine the ratio

$$\frac{\text{power dissipated in thermistor}}{\text{total power supplied by the cell}}$$

ratio = ... [2]

(c) A uniform resistance wire PQ of length 1.2 m is subsequently connected across the resistor and thermistor, as shown in Fig. 8.3. An ideal voltmeter is connected between point Y and a moveable contact M on the wire.

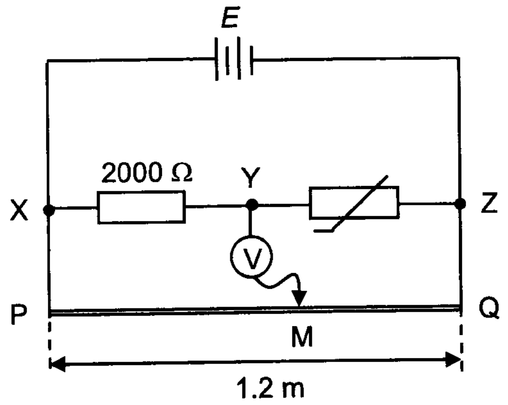


Fig. 8.3

(i) At room temperature, the contact M is moved along PQ until the voltmeter shows zero reading.

Calculate the length of wire between M and Q

length of wire = ... m [2]

(ii) State and explain the effect, if any, on the length of the wire between M and Q for the voltmeter to remain at zero deflection if each of the following changes takes place independently.

1. The thermistor is warmed slightly.

....

....

....[2]

2. A uniform wire of the same material but with a larger cross sectional area is used for PQ.

....

....

....[2]

(d) The heating element of an electric heater is made of nichrome wire. Nichrome has a resistivity of 1.0×10^{-6} Ω m at the operating temperature of the heater. The heater is rated at 240 V, 1200 W.

(i) Determine the resistance of the nichrome wire when the heater is operating normally.

resistance = ... Ω [2]

(ii) Calculate the length of nichrome wire of diameter 0.40 mm required for the heater.

length of wire = ... m [2]

(iii) The potential difference across the heater is then reduced to 180 V. Assuming the resistance of the nichrome wire remains constant, state and explain how this change affects the time taken to dissipate the same amount of thermal energy.

....

....

....

....[2]

[Total: 20]

9 **(a)** An electron is travelling in a vacuum towards an electrode with kinetic energy of 8.55×10^{-19} J.

Calculate the stopping potential V_s required to stop the electron.

V_s = ... V [2]

(b) **(i)** The electron in **(a)** is emitted from a material whose work function is 2.80 eV. Calculate the wavelength of the radiation responsible for causing the emission of the electron.

wavelength = ... m [2]

(ii) Suggest the type of radiation which has the wavelength in **(b)(i)**.

type of radiation = ... [1]

(c) **(i)** Calculate the de Broglie wavelength of an electron travelling with speed 1.85×10^{7} m s^{-1}.

wavelength = ... m [2]

(ii) Graphite, with its layered structure as shown in Fig. 9.1, acts as a natural diffraction grating when used in electron diffraction experiments. The distance between each layer of graphite is 0.335 nm.

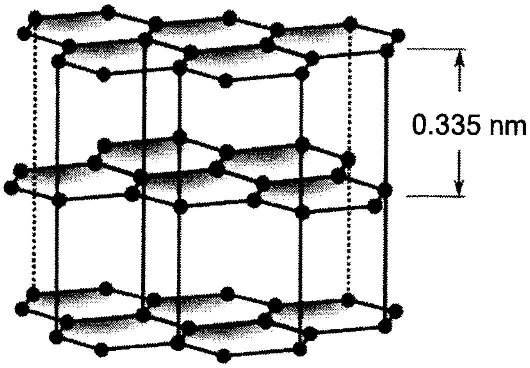


Fig. 9.1

Explain whether electrons having the speed of 1.85×10^7 m s^{-1} can be used to demonstrate electron diffraction.

....

....

....[2]

(d) Tungsten, a transition metal, is commonly used as a target metal to produce X-rays. The energy levels of the K- to M-shells for tungsten are shown in Fig. 9.2 below.

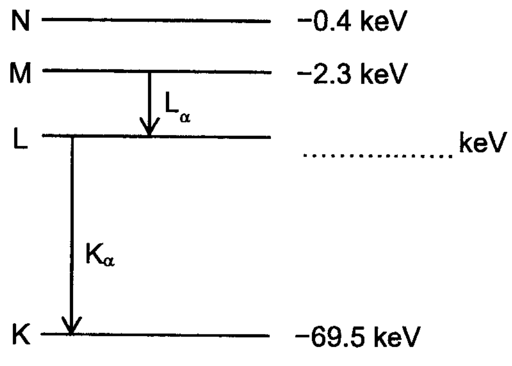


Fig. 9.2 (not to scale)

The wavelength of the photon produced by the K_α transition is 21.2 pm.

(i) Complete Fig. 9.2 by filling in the energy level of the L-shell for tungsten. Show your working clearly.

[3]

(ii) The intensity of various photon wavelengths from electron bombardment of a tungsten target metal is shown in Fig. 9.3. The peak representing K_α transition is labelled.

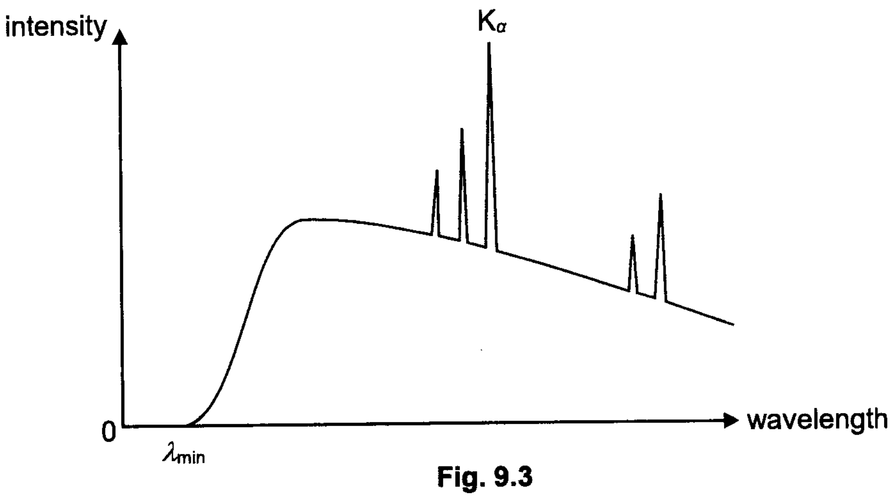


Fig. 9.3

1. On Fig. 9.3, label the peak for L_α transitions. [1]

2. Explain the existence of a minimum wavelength λ_{min}.

....

....

....

....[2]

(iii) With reference to Fig. 9.2, state the minimum energy of the bombarding electrons to produce the characteristic X-rays lines shown in Fig. 9.3.

minimum energy = ... keV [1]

(iv) Explain your answer in **(d)(iii)**.

....

....

....[1]

(e) Fig. 9.4 below shows a typical setup for producing such X-ray beams.

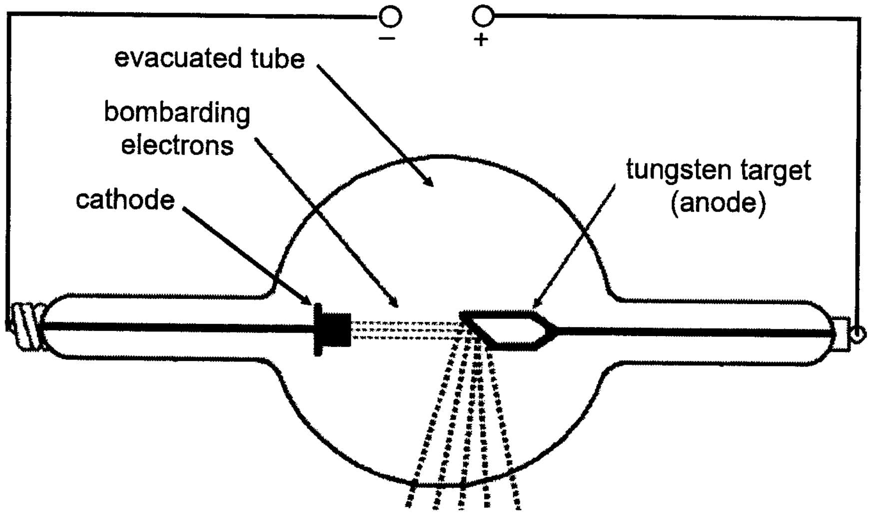


Fig. 9.4

(i) For safety reasons, the wavelength of radiation used for medical X-rays should not be shorter than 50 pm.

Suggest why the wavelength of X-rays radiation should not be shorter than 50 pm.

....

....

....[1]

(ii) Determine the minimum applied potential difference for medical X-rays.

minimum potential difference = ... V [2]

[Total: 20]

End of Paper