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

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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.

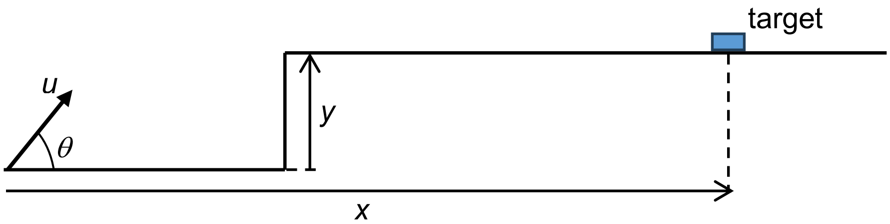


Fig. 1.1

(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]

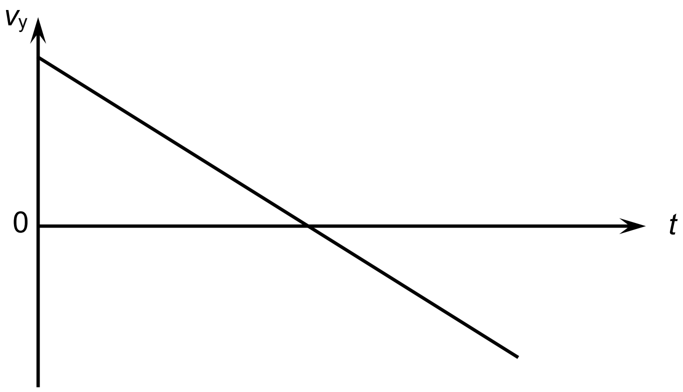


Fig. 1.2

[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.

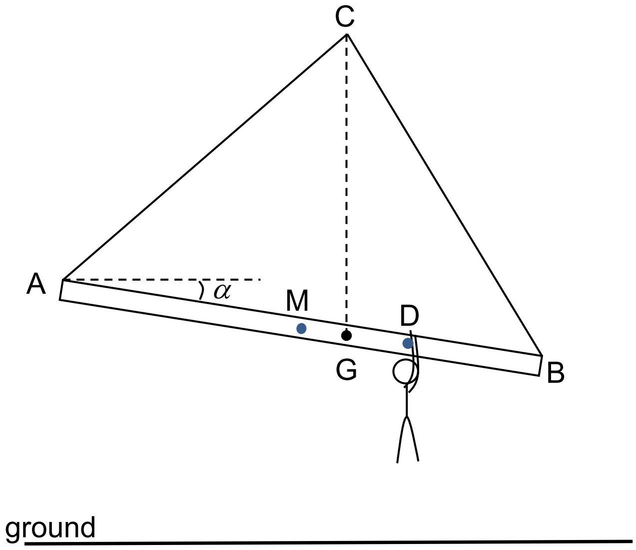


Fig. 2.1

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}.

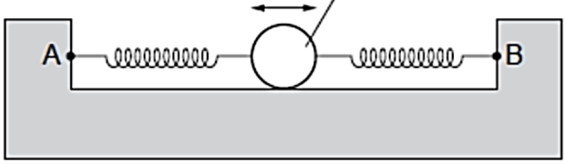


Fig. 4.1

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]

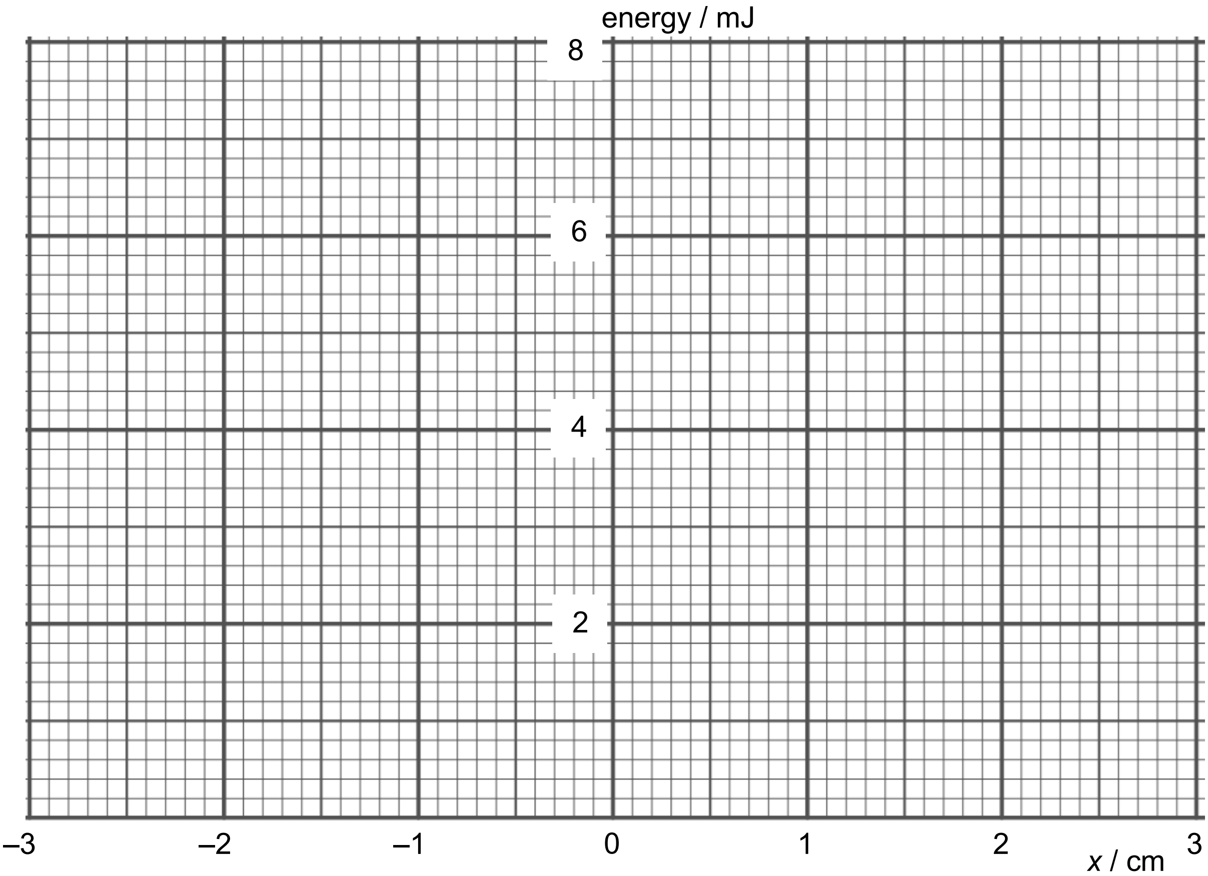


Fig. 4.2

(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.

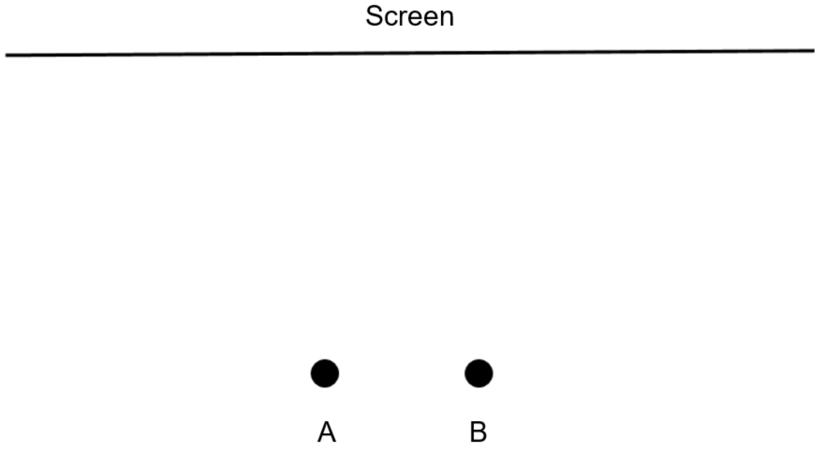


Fig. 5.1

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.

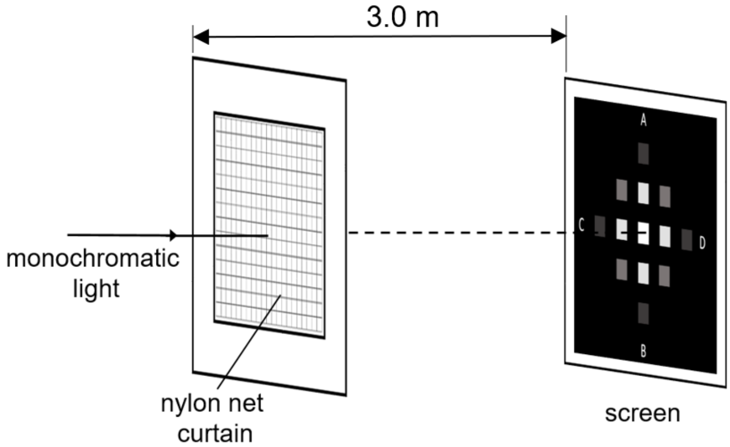


Fig. 5.2

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

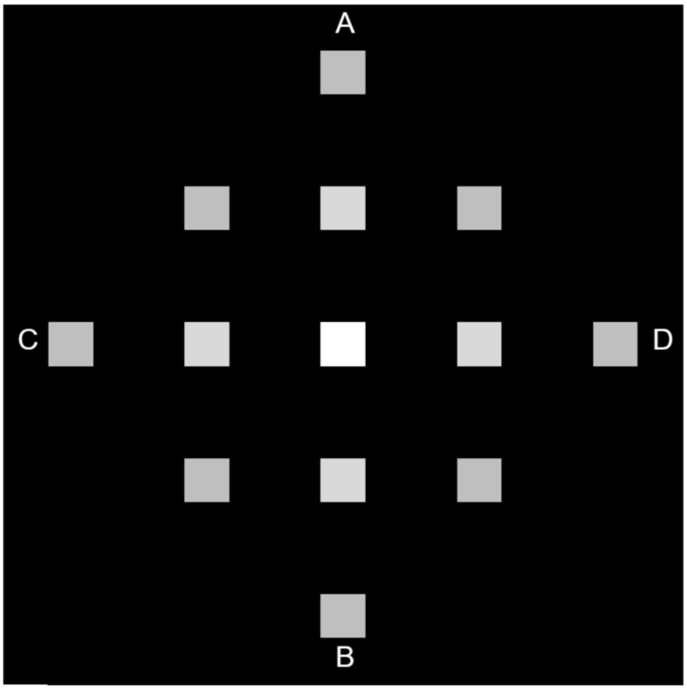


Fig. 5.3

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.

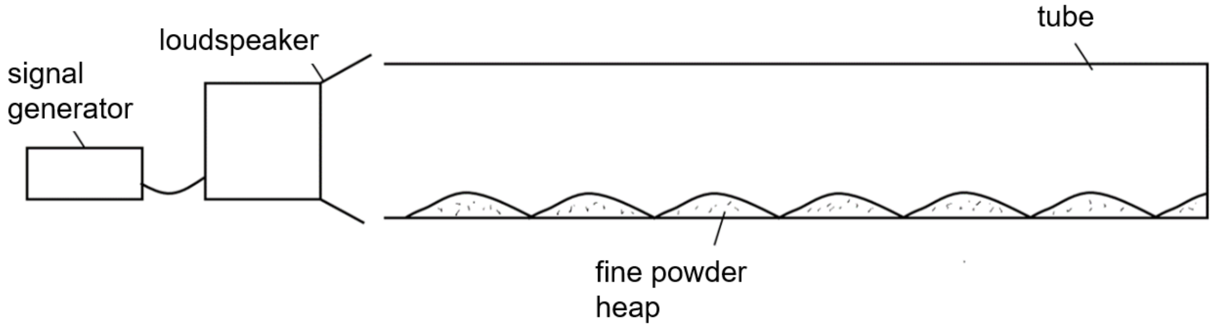


Fig. 5.4

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)

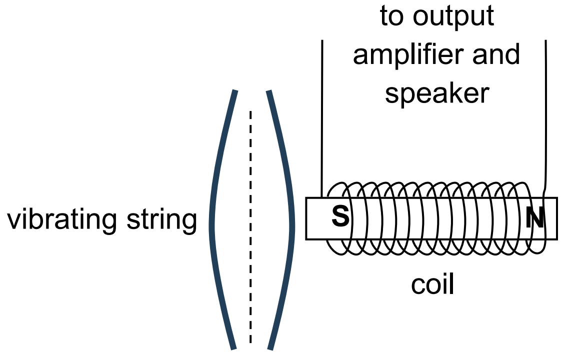


Fig. 6.1

(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.

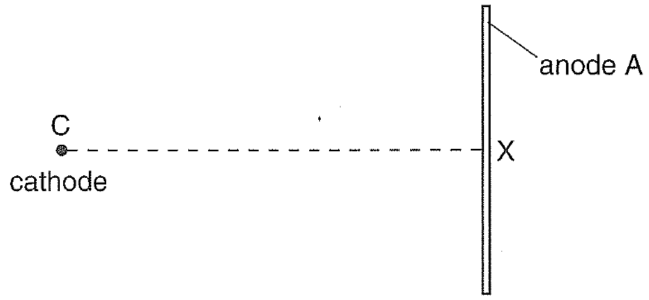
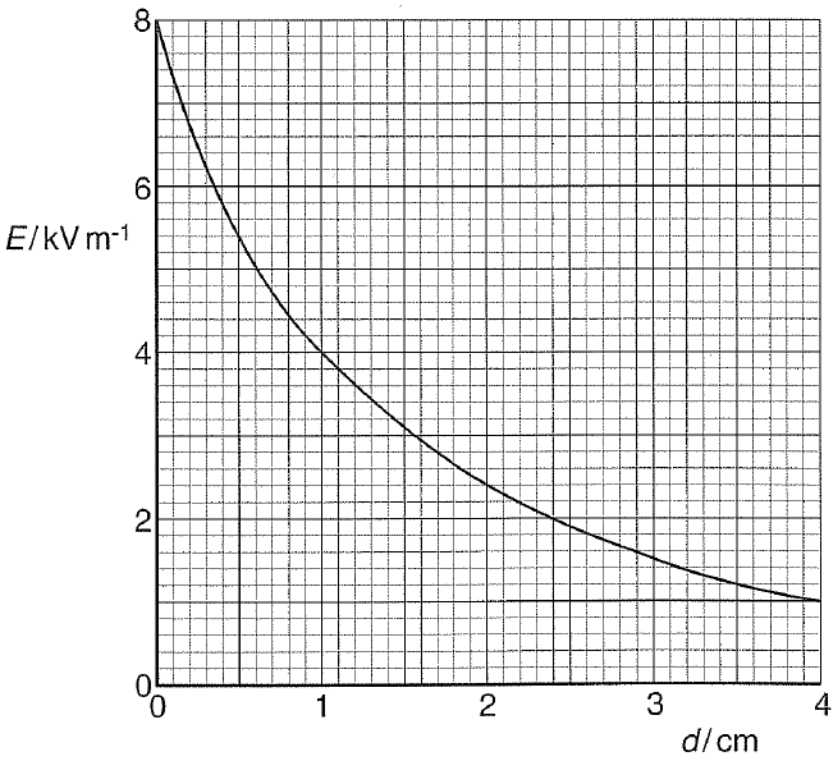


Fig. 7.1

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.

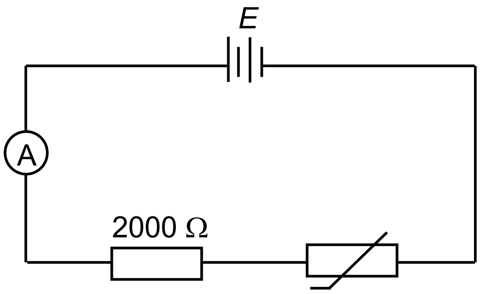


Fig. 8.1

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.

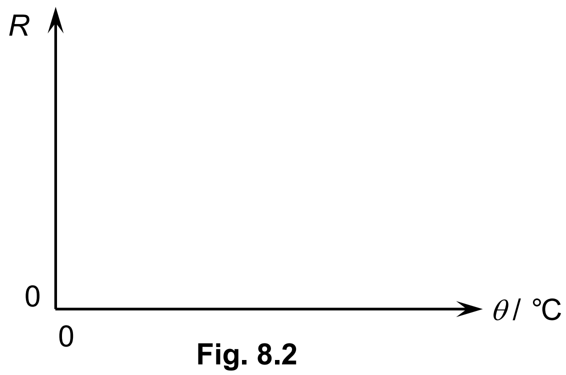


Fig. 8.2

[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.

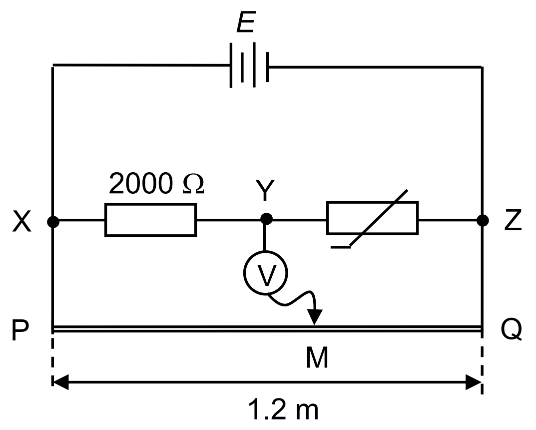


Fig. 8.3

(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 $1.0 \times 10^{-6}\ \Omega$ 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.

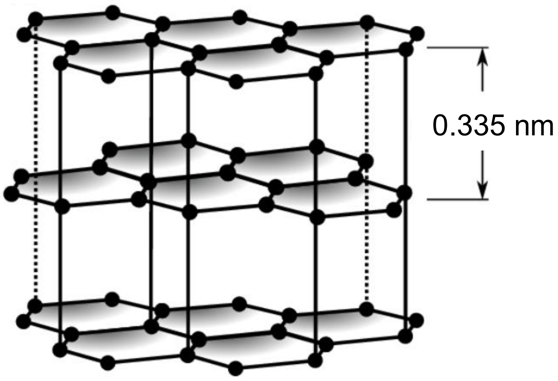


Fig. 9.1

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.

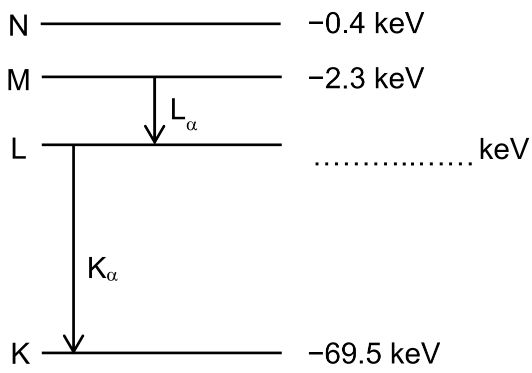


Fig. 9.2 (not to scale)

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.

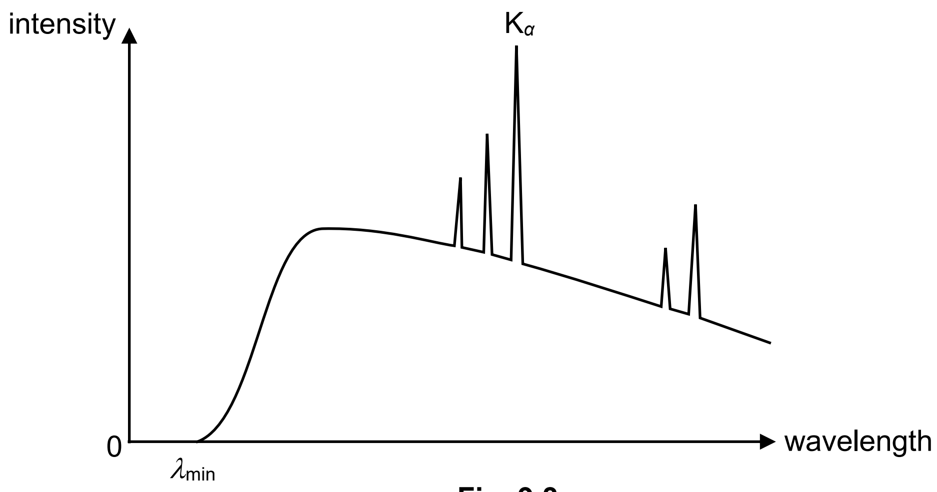


Fig. 9.3

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.

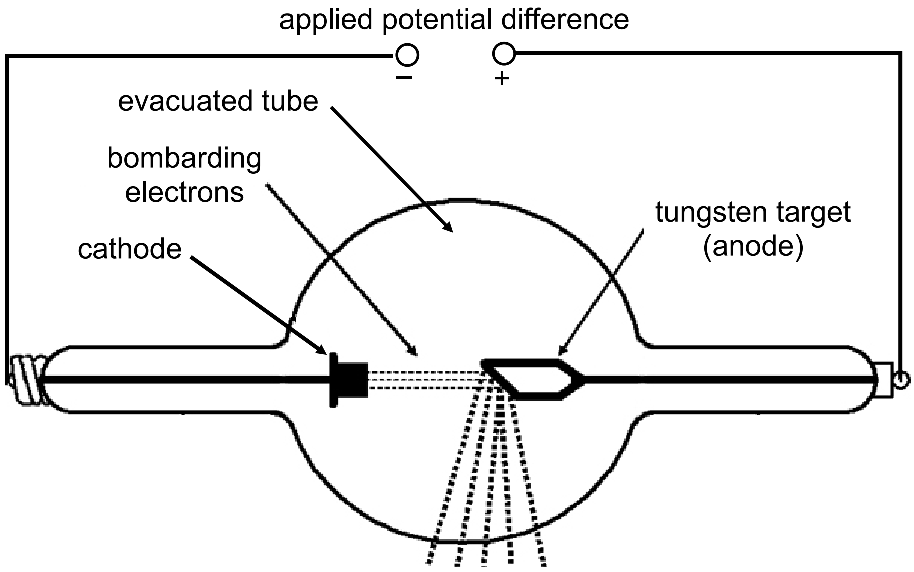


Fig. 9.4

(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