

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

Solution

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 15 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 $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
 $(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$
- 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
 - $s = ut + \frac{1}{2}at^2$
 - $v^2 = u^2 + 2as$
 - $W = p\Delta V$
 - $p = \rho gh$
 - $\phi = -Gm/r$
 - $T/K = T/^\circ\text{C} + 273.15$
 - $p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
 - $E = \frac{3}{2}kT$
 - $x = x_0 \sin \omega t$
 - $v = v_0 \cos \omega t$
 - $= \pm \omega \sqrt{x_0^2 - x^2}$
 - $I = Anvq$
 - $R = R_1 + R_2 + \dots$
 - $1/R = 1/R_1 + 1/R_2 + \dots$
 - $V = \frac{Q}{4\pi\epsilon_0 r}$
 - $x = x_0 \sin \omega t$
 - $B = \frac{\mu_0 I}{2\pi d}$
 - $B = \frac{\mu_0 NI}{2r}$
 - $B = \mu_0 nI$
 - $x = x_0 \exp(-\lambda t)$
 - $\lambda = \frac{\ln 2}{t_{1/2}}$
- work done on / by a gas
- hydrostatic pressure
- gravitational potential
- temperature
- pressure of an ideal gas
- mean translational kinetic energy of an ideal molecule
- displacement of particle in s.h.m.
- velocity of particle in s.h.m.
- electric current
- resistors in series
- resistors in parallel
- electric potential
- alternating current/voltage
- magnetic flux density due to a long straight wire
- magnetic flux density due to a flat circular coil
- magnetic flux density due to a long solenoid
- radioactive decay
- decay constant

3

- 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%

Ans: C

$$4t = (1.00 \pm 0.04) \text{ mm}$$

$$t = (0.25 \pm 0.01) \text{ mm}$$

$$\frac{\Delta t}{t} \times 100\% = \frac{0.01}{0.25} \times 100\% = 4.0\%$$

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

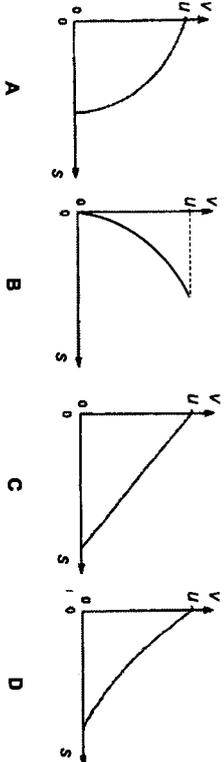
Which of the following best describes the likely error in readings taken with this voltmeter?

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

Ans: C

4

- 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?



Ans: A

Take downward as positive.

Below ground surface, acceleration is upward, which is thus negative.

Let this acceleration be $-a$.

$$v^2 = u^2 + 2as$$

$$v = \sqrt{u^2 + 2as}$$

$$v = \sqrt{u^2 - 2as}$$

Using GC, the graph will give be similar to option A.

- 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 $\frac{3E_k}{4}$

Ans: C

$$E_k = \frac{1}{2}mv^2$$

By principle of conservation of momentum,

$$mv + 0 = 2mv' \rightarrow v' = \frac{v}{2}$$

loss in KE = $KE_i - KE_f$

$$= \frac{1}{2}mv^2 - \frac{1}{2}(2m)\left(\frac{v}{2}\right)^2 = \frac{1}{2}mv^2 - m\left(\frac{v^2}{4}\right) = \frac{1}{4}mv^2 = \frac{E_k}{4}$$

5

- 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} .

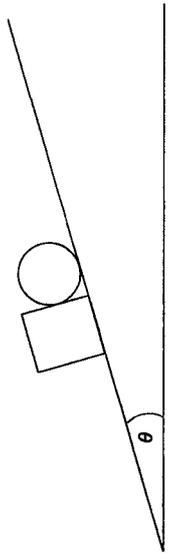
The magnitude of their resultant momentum after the collision will be

- A 2.0 kg ms^{-1} .
- B 10 kg m s^{-1} .
- C 14 kg m s^{-1} .
- D dependent on whether the collision is elastic or inelastic.

Ans: B
 Using vector addition, resultant initial momentum = 10 kg m s^{-1}
 Since the final momentum = initial momentum (PCOM),
 Magnitude of resultant momentum after collision is 10 kg m s^{-1}

6

- 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°

Ans: A

Considering the net force on the block along the inclined plane,

$$W_{\text{block}} + F_{\text{by sphere on block}} - F_{\text{friction by plane on block}} = 0$$

$$mg \sin \theta + mg \sin \theta - f = 0$$

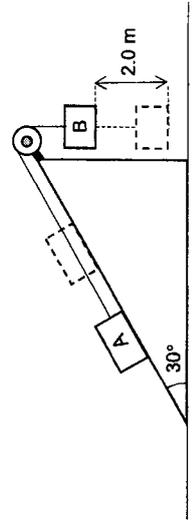
Since the frictional force is f , when the block just starts to slip, $f = mg$.

$$2mg \sin \theta - mg = 0$$

$$\sin \theta = 0.5$$

$$\theta = 30^\circ$$

- 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

Ans: B
 Loss in GPE of B = Gain in GPE of A + Gain in KE of A and B + Work done agst friction
 $6.0(9.81)(2.0) = 4.0(9.81)(2.0 \sin 30) + KE_{A+B} + 3.0(2.0)$
 $KE_{A+B} = 72 \text{ J}$

7

- 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

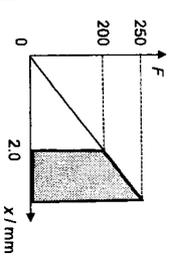
Ans: A

$$F = kx$$

$$k = \frac{200}{0.002} = 100\,000 \text{ N m}^{-1}$$

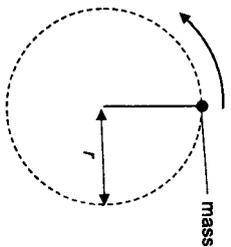
Area under graph for additional extension

$$\begin{aligned} \text{work done} &= \frac{1}{2} (200 + 250) \left(\frac{250}{100000} - 0.002 \right) \\ &= 0.113 \text{ J} \end{aligned}$$



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

8



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 $5g$

Ans: D

At the top of circle,

$$T + mg = 0 + mg = \frac{mv_{\text{top}}^2}{r}$$

$$v_{\text{top}}^2 = rg$$

By conservation of energy,

$$\frac{1}{2} mv_{\text{top}}^2 + mg(2r) = \frac{1}{2} mv_{\text{bottom}}^2$$

$$\frac{1}{2} (rg) + g(2r) = \frac{1}{2} v_{\text{bottom}}^2$$

$$v_{\text{bottom}}^2 = 5rg$$

$$a_c = \frac{v_{\text{bottom}}^2}{r} = 5g$$

- 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 $\sqrt{3}v$

Ans: B

Gravitational force provides for centripetal force.

$$F_G = F_c$$

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{GM}{r}}$$

$$v_P = \sqrt{\frac{GM}{2R}}$$

$$v_Q = \sqrt{\frac{GM}{4R}} = \left(\frac{1}{\sqrt{2}}\right) \sqrt{\frac{GM}{2R}} = \frac{1}{\sqrt{2}}v$$

Take note that the satellites are R and $3R$ from the surface of Earth, not the centre of the Earth.

- 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}

Ans: A

The gravitational potential at the surface of a planet is directly proportional to the planet's mass, and inversely proportional to its radius (or diameter).

$$\phi = -\frac{GM}{r}$$

$$\phi_{\text{Earth}} = -\frac{GM_{\text{Earth}}}{r_{\text{Earth}}}$$

$$\phi_{\text{Mars}} = -\frac{G(0.1M_{\text{Earth}})}{(0.5r_{\text{Earth}})} = \frac{1}{5}(-63) = 12.6 \text{ MJ kg}^{-1}$$

Hence, the potential at Mars' surface is approximately -13 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

Ans: B

$$\frac{E_{k,x}}{E_{k,y}} = \frac{\frac{3}{2}kT_x}{\frac{3}{2}kT_y} = \frac{T_x}{T_y} = 1$$

- 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}

Ans: D

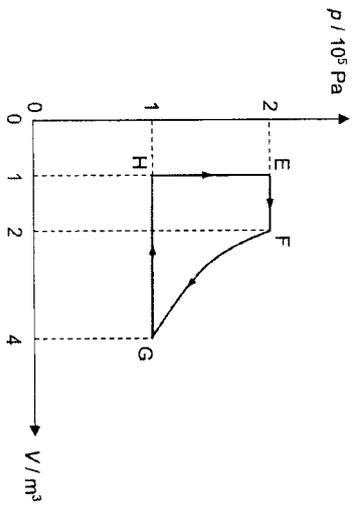
From the kinetic theory of gases,

$$p = \frac{1}{3}Nm\langle c^2 \rangle$$

$$p = \frac{1}{3}\rho\langle c^2 \rangle$$

$$c_{r.m.s.} = \sqrt{\frac{3p}{\rho}} = \sqrt{\frac{3(150 \times 10^3)}{0.178}} = 1600 \text{ m s}^{-1}$$

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

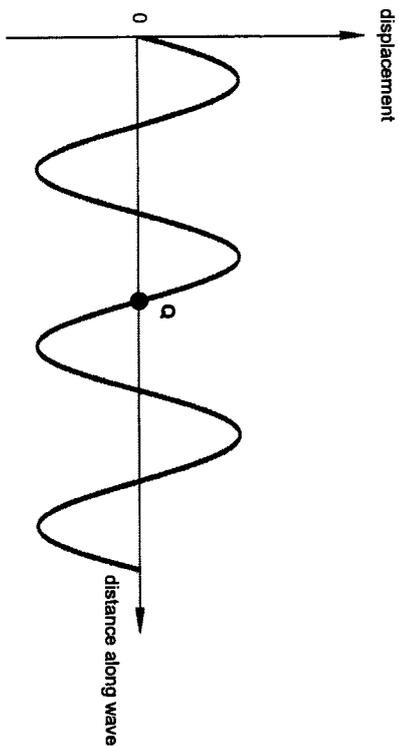


Which of the following statements is correct?

- 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.

Ans: B
 A is wrong. Net work done on gas is negative, in other words, there is a net work done by gas. As the change in internal energy is zero for one complete cycle, net work done by gas is equal to net heat gained by gas.
 C is wrong. As work done on gas is zero, an increase in internal energy means that there is heat gained by gas.
 D is wrong. Areas under the graph for EF and GH are different.
 B is correct as FG is an isothermal process whereby temperature remains constant (since PV is unchanged)

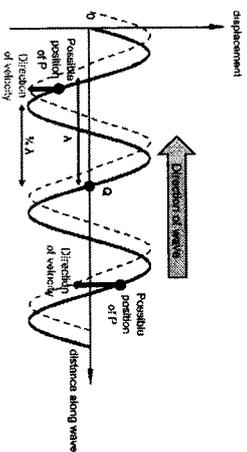
15 This diagram shows the displacement-distance graph of a transverse wave at time, $t = 0$. Taking upwards as positive, point Q is a point on the wave and is travelling downwards at $t = 0$. Another point P is $\frac{7}{8}$ of a wavelength from point Q.



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

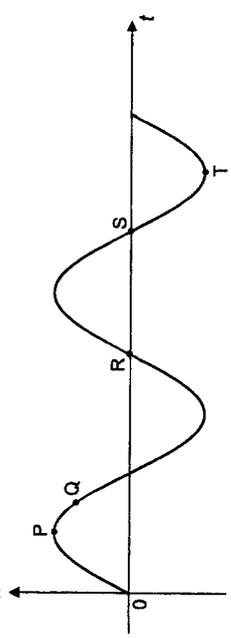
	displacement	direction of velocity
A	positive	positive
B	positive	0
C	0	negative
D	negative	negative

Ans: D
 Since the point Q is travelling downwards at $t = 0$, it implies that the transverse wave is travelling towards the left.



Since P is $\frac{7}{8}$ of a wavelength away from Q, there are 2 possible positions it can be at as shown above. Some time later, the wave profile will be as shown by the dotted line. In order for this to happen, if P is on the left side of Q, it must move downwards and have a negative displacement from equilibrium at $t = 0$. On the other hand, if P is on the right side of Q, it must move downwards and have a positive displacement from equilibrium at $t = 0$.

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.

Ans: A

A-phase difference is $\frac{\Delta t}{T} \times 2\pi = \frac{\left(\frac{T}{4}\right)}{T} \times 2\pi = \frac{\pi}{2}$

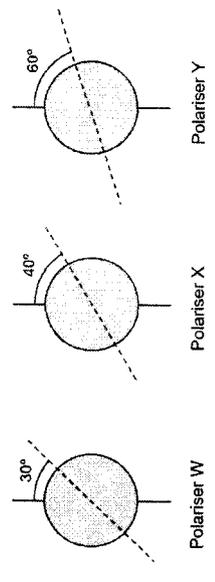
B- at T acceleration is maximum (max. displacement)

C-maximum PE at T (x_{max}), lesser PE at Q

D-maximum KE at R (equilibrium position), lesser KE at Q

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 $0.64 I_0$

Ans: C

Using Malus' law, the intensity of transmitted light (I) through polarisers is proportional to $I_0 \cos^2 \theta$, where I_0 is the intensity of transmitted through the first polariser, θ is the angle between two polarisers.

Unpolarized light loses exactly half of its intensity after it passes through polariser W no matter what the direction of polarising for polariser X is: $0.50 I_0$.

The angle between polariser W and X is 10° , the transmitted intensity after X would be $0.50 I_0 \times \cos^2(40^\circ - 30^\circ) = 0.48 I_0$.

The angle between polariser X and Y is 20° , the transmitted intensity after Y would be $0.48 I_0 \times \cos^2(60^\circ - 40^\circ) = 0.43 I_0$.

15

- 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

Ans: C

Since the situation is a one end open, one end closed pipe of length L ,

Fundamental harmonic: $\lambda = 4L \rightarrow f = 80\text{Hz}$

1/4 wave



1st Overtone: $\lambda = (4/3)L \rightarrow f = 3 \times 80\text{Hz} = 240\text{ Hz}$

3/4 waves



2nd Overtone: $\lambda = (4/5)L \rightarrow f = 5 \times 80\text{Hz} = 400\text{ Hz}$

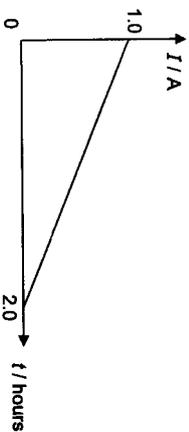
5/4 waves



We can see that subsequent overtones are just odd-integer multiples of the fundamental frequency, in other words: $f, 3f, 5f, 7f, 9f, \dots, (2n+1)f$ are all possible solutions.

16

- 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.



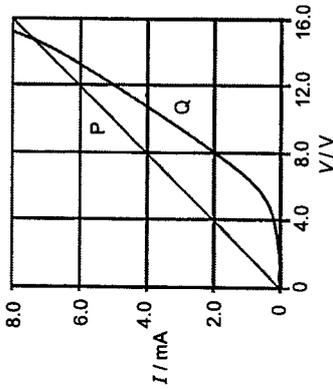
- What is the energy transferred to the battery during the time of 2.0 hours shown in the graph?
- A 360 J B 720 J C 22 000 J D 43 000 J

Ans: C

$$Q = \text{Area under graph} = \frac{1}{2}(1.0)(2.0 \times 3600) = 3600\text{ C}$$

$$\text{Energy transferred i.e. work done on charge} = QV = 3600(6.0) = 21600\text{ J}$$

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



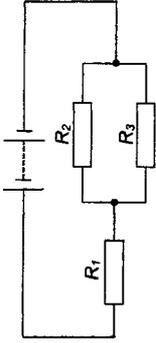
Which of the following statements is correct?

- 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.

Ans: C

- Option A: Q is a semi-conductor diode, not filament
- Option B: Resistance of Q becomes smaller than P beyond $V \approx 14$ V.
- Option C: V_Q is twice V_P at 2.0 mA. Since $P = IV$, P_Q is twice P_P .
- Option D: At intersection, resistance of both are equal since V and I are the same.

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



What is the ratio of power dissipated in R_1 to power dissipated in R_2 ?

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

Ans: C

Total resistance of R_2 and $R_3 = \left(\frac{1}{R} + \frac{1}{R}\right)^{-1} = \left(\frac{2}{R}\right)^{-1} = \frac{1}{2}R$

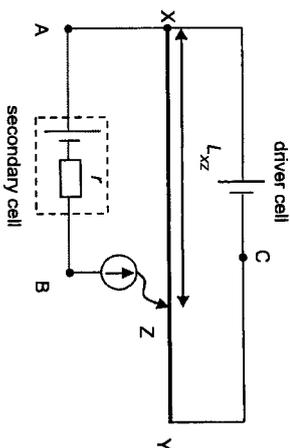
$$I = \frac{E}{R_{total}} = \frac{E}{R + \frac{1}{2}R}$$

p.d. across R_1 , $V_1 = \frac{E}{R + \frac{1}{2}R} \cdot R = \frac{2E}{3}$

p.d. across R_2 , $V_2 = E - \frac{2E}{3} = \frac{1E}{3}$

$$\frac{P_1}{P_2} = \frac{\frac{V_1^2}{R}}{\frac{V_2^2}{R}} = \frac{2^2}{1^2} = 4$$

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.

Ans: D

Option A: this decreases V_{xy} . L_{xz} has to increase in order for V_{yz} to still be equal to e.m.f. of secondary cell.

Option B: this means L_{xz} has to increase to increase V_{yz} to match e.m.f. of secondary cell.

Option C: this causes the same effect as in option A.

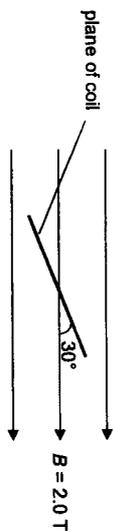
Option D: at balance length, the current is through secondary cell is zero, thus V_{AB} will still be equal to the e.m.f. of the secondary cell. Thus L_{xz} does not change.

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.

Ans: B
Electric potential decreases along the direction of electric field strength.

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

Ans: D

Total torque,
 $\tau = F \times d$
 $= NBILd$
 $= 10 \times 2.0 \times 15 \times \frac{5.0}{100} \times \frac{5.0}{100} \cos 30^\circ$
 $\approx 0.65 \text{ Nm}$

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

Ans: C

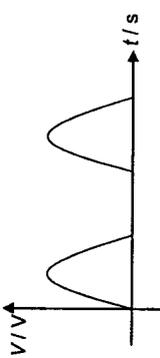
Axis of coil parallel to magnetic field \rightarrow magnetic field lines are normal to the area enclosed by coil

$$E_{\text{mf}} = \frac{d\phi}{dt} = NA \frac{dB}{dt} = 120 \times 0.070 \times \frac{(80 - 20) \times 10^{-3}}{4.0}$$

$$= 0.126 \text{ V} \approx 130 \text{ mV}$$

21

26 The figure belows shows a varying voltage.



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

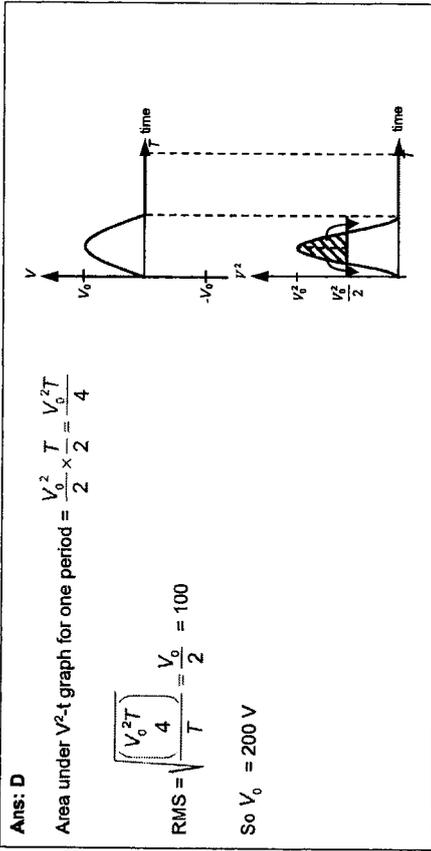
- A 50 V
- B 71 V
- C 141 V
- D 200 V

Ans: D

$$\text{Area under } V^2\text{-}t \text{ graph for one period} = \frac{V_0^2}{2} \times \frac{T}{2} = \frac{V_0^2 T}{4}$$

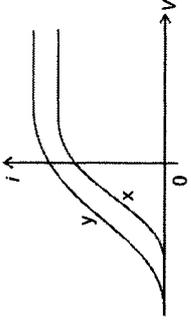
$$\text{RMS} = \sqrt{\frac{V_0^2 T}{4T}} = \frac{V_0}{2} = 100$$

$$\text{So } V_0 = 200 \text{ V}$$



22

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 $I_x < I_y, f_x < f_y$

Ans: D
 $hf = eV_s + \phi$
 $f_x < f_y$ since $V_{sx} < V_{sy}$
 Since $f_x < f_y, I_x < I_y$

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 $\frac{c\sqrt{2meV}}{h}$
- B $\frac{h}{\sqrt{2meV}}$
- C $\frac{hc}{eV}$
- D $\frac{eV}{h}$

Ans: A
 Loss in EPE = Gain in KE

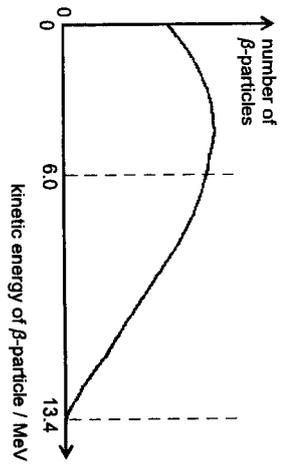
$$eV = \frac{p^2}{2m}$$

$$p = \sqrt{2meV}$$

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$f = \frac{c}{\lambda} = \frac{c\sqrt{2meV}}{h}$$

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

Ans: C

Based on COE and COM, the kinetic energy of the daughter nuclei is negligible hence the total energy released is shared between β particle and neutrino. Since the highest possible KE of β particle is 13.4 MeV, i.e. when neutrino has zero KE, hence the total energy released by the reaction is also 13.4 MeV, and this value is fixed for this particular reaction. Thus, when an emitted β particle has KE of 6.0 MeV, the associated neutrino must have $13.4 - 6.0 = 7.4$ MeV of energy.

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

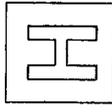
Ans: B

$$(C - C_{\text{background}}) = \frac{1}{4} (C_0 - C_{\text{background}})$$

$$(34 - C_{\text{background}}) = \frac{1}{4} (100 - C_{\text{background}})$$

$$C_{\text{background}} = 12 \text{ days}$$

End of Paper



NANYANG JUNIOR COLLEGE
 JC 2 PRELIMINARY EXAMINATION
 Higher 2

CANDIDATE NAME: Solution

CLASS: TUTORS 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 26 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 $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
- $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
- 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
 - $s = ut + \frac{1}{2}at^2$
 - $v^2 = u^2 + 2as$
 - $W = p\Delta V$
 - $p = \rho gh$
 - $\phi = -Gm/r$
 - $T/K = T/^\circ\text{C} + 273.15$
 - $p = \frac{1}{3} \frac{Nm}{V} < c^2 >$
 - $E = \frac{3}{2}kT$
 - $x = X_0 \sin \omega t$
 - $v = V_0 \cos \omega t$
 - $= \pm \omega \sqrt{X_0^2 - x^2}$
 - $I = Anvq$
 - $R = R_1 + R_2 + \dots$
 - $1/R = 1/R_1 + 1/R_2 + \dots$
 - $V = \frac{Q}{4\pi\epsilon_0 r}$
 - $x = X_0 \sin \omega t$
 - $B = \frac{\mu_0 I}{2\pi d}$
 - $B = \frac{\mu_0 NI}{2r}$
 - $B = \mu_0 n I$
 - $x = X_0 \exp(-\lambda t)$
 - $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$
- work done on / by a gas
- hydrostatic pressure
- gravitational potential
- temperature
- pressure of an ideal gas
- mean translational kinetic energy of an ideal molecule
- displacement of particle in s.h.m.
- velocity of particle in s.h.m.
- electric current
- resistors in series
- resistors in parallel
- electric potential
- alternating current/voltage
- magnetic flux density due to a long straight wire
- magnetic flux density due to a flat circular coil
- magnetic flux density due to a long solenoid
- radioactive decay
- decay constant

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 .

$$[C] = \frac{[Q][L]}{[t][A][\Delta T]}$$

$$= \frac{(\text{kg m}^2 \text{ s}^{-2})(\text{m})}{(\text{s})(\text{m}^2)(\text{K})}$$

$$= \text{kg m s}^{-3} \text{ K}^{-1}$$

[Recall : Q can be considered as energy whose unit can be found from work done]

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.

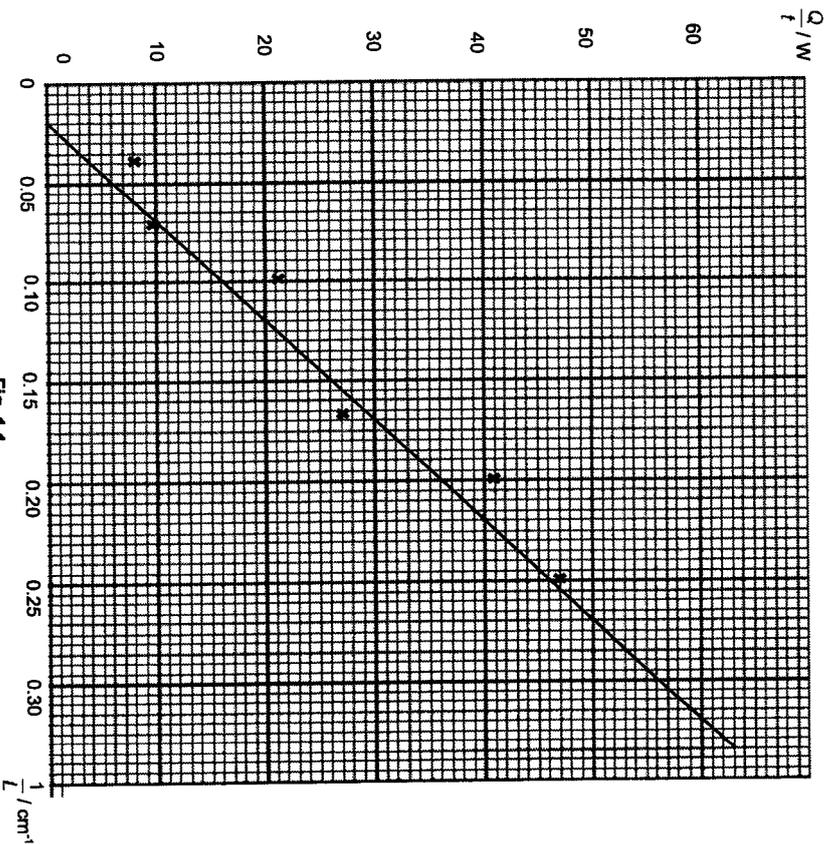


Fig. 1.1

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

The evidence of systematic error is seen by the graph shift by a fixed value to the right and did not pass through the origin. The best fit should pass through the origin if there is no systematic error.

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

When bodies in a system interact, the total momentum remains constant provided no resultant external force acts on the system.

.....[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.

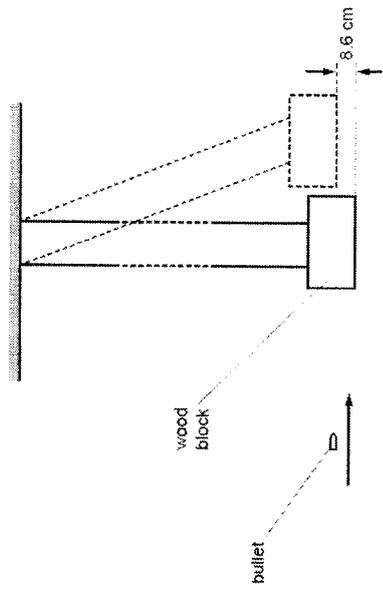


Fig. 2.1

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

Comparing when bullet just become embedded in the block to highest position,
 Gain in GPE = Loss in KE
 $(0.602)(9.81)(0.086) - 0 = KE_i - 0$ [M1]
 $v = \sqrt{\frac{(0.602)(9.81)(0.086) \times 2}{0.602}}$ [M1]
 $= 1.3 \text{ m s}^{-1}$

[2]

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

gradient of graph = $C\Delta T$
 $\text{Gradient} = \frac{56.0 - 10.0}{0.300 - 0.070}$
 $= \frac{46.0}{0.230}$
 $= 200 \text{ W cm}$
 $= 2.00 \text{ W m}$
 $C = \frac{\text{gradient}}{\Delta T}$
 $= \frac{2.00}{\left(\frac{\pi(0.80 \times 10^{-2})^2}{2}\right)(100 - 0)}$
 $= 398 \text{ kg m s}^{-3} \text{ K}^{-1}$

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.

No, the gradient of the straight line is equal to $C\Delta T$ and the gradient is not affected by the presence of systematic error, the accuracy of C is not affected.

.....[1]

[Total : 7]

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

PCOM, $\Sigma p_i = \Sigma p_f$

$$m_{bullet} v_{bullet} + 0 = (m_{bullet} + m_{block}) \times v_{bullet \& block}$$

$$0.002 v_{bullet} = 0.602 \times 1.3 \text{ [M1]}$$

$$v_{bullet} = 391.3 \approx 390 \text{ m s}^{-1} \text{ [A1]}$$

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.

Change in momentum of bullet increase, (by PCOM or N3L) change in momentum of block increases too [B1].

Block will rise up with a greater speed/KE. Hence the maximum height of the block will be greater. [B1]

..... [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.

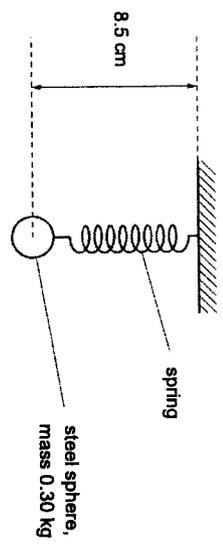


Fig. 3.1

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.

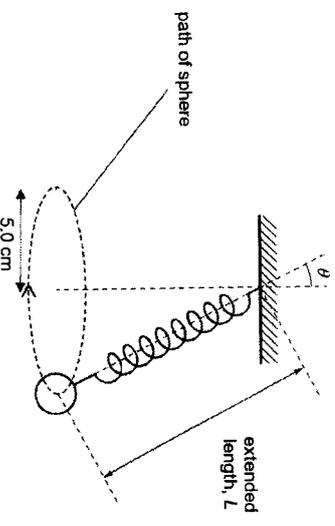


Fig. 3.2

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.

In Fig 3.2, the vertical component of the tension in the spring equal to the weight of the sphere. [B1]

the horizontal component of the tension provides the centripetal force for circular motion. [B1]

Since the vertical and horizontal forces combine to give a greater tension in the spring in Fig. 3.2 compared to the tension in Fig 3.1 that equals to the weight of sphere. [B1] the spring undergoes a greater extension by Hooke's law.

..... [3]

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

$$a_c = r\omega^2 = (0.050)\left(\frac{2\pi}{0.60}\right)^2 = 5.5 \text{ m s}^{-2} \quad \text{[A1]}$$

(ii) Show that the angle θ is 29° .
centripetal acceleration = m s^{-2} [1]

Let T be the tension in the spring

$$T \sin \theta = mr\omega^2 \dots (1) \quad \text{[M1]}$$

$$T \cos \theta = mg \dots (2) \quad \text{[M1]}$$

Taking (1)
(2),

$$\tan \theta = \frac{r\omega^2}{g} = \frac{r\left(\frac{2\pi}{T}\right)^2}{g}$$

$$= \frac{(0.050)\left(\frac{2\pi}{0.60}\right)^2}{9.81} \quad \text{[M1]}$$

$$\theta = 29.202^\circ \approx 29^\circ \quad \text{[A0]} \quad \text{[2]}$$

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

$$T \cos \theta = mg$$

$$T \cos(29.202) = (0.30)(9.81) \quad \text{[C1]}$$

$$T = 3.3715 \approx 3.4 \text{ N} \quad \text{[A1]}$$

tension in spring = N [2]

(iv) Calculate the spring constant of the spring.

$$\sin \theta = \frac{0.05}{L}$$

$$\sin(29.202) = \frac{0.05}{L} \quad \text{[C1]}$$

$$L = 0.10248 \text{ m}$$

$$k = \frac{\Delta F}{\Delta x} = \frac{3.3715 - (0.30)(9.81)}{0.10248 - 0.085} \quad \text{[C1]}$$

$$= 24.5 \text{ N m}^{-1} \quad \text{[A1]}$$

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} m³ and temperature 27 °C.

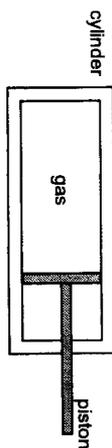


Fig. 4.1

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.

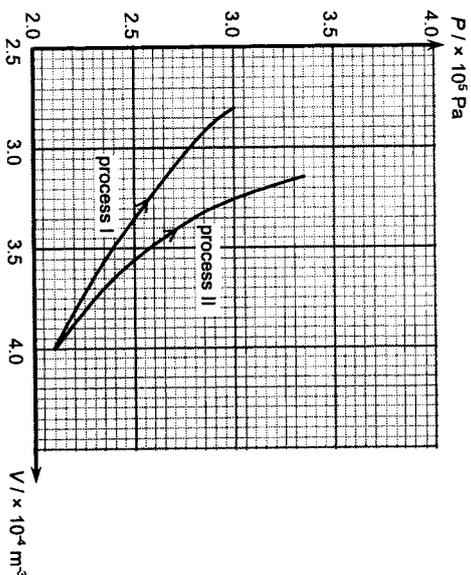


Fig. 4.2

- (a) (i) With reference to Fig. 4.2, estimate the work done on the gas through process I.
 Work done on gas = Area under $P - V$ graph
 $= 0.5(2.90 + 2.10) \times 10^5 \times (4.00 - 2.80) \times 10^{-4}$
 $= 30.0$ J

work done = J [3]

- (ii) State the first law of thermodynamics.

The increase in internal energy is the sum of the heat supplied and the work done on system. [1]

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

30.0 J. Since there is no change in temperature, there is no change in internal energy. Hence heat loss by gas is equal to work done on the gas. [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.

There is no heat loss to surrounding, and the work done on gas results in an increase in internal energy. [B1]

This increase in internal energy is equivalent to the increase in kinetic energy, resulting in an increase in speed / momentum of the gas particles. [B1]

Upon collision with the walls of the cylinder, there is a greater change in momentum. [B1]

There is also higher frequency of collision between particles in the walls of the cylinder. [B1]
 These result in a greater force and hence greater pressure.

- (ii) Calculate the final temperature of process II.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{(2.10)(4.00)}{273.15 + 27} = \frac{(3.35)(3.15)}{T_2}$$

$$T_2 = 377 \text{ K} = 104 \text{ }^\circ\text{C}$$

temperature = °C [2]
 [Total: 11]

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

Progressive waves transfer energy but not stationary waves [B1]
 Particle in a progressive wave have the same amplitude but particles in a stationary wave have different amplitude, ranging from a maximum at antinodes to minimum at nodes. (B1)
 Adjacent particles in a progressive wave are out of phase but adjacent particles between two consecutive nodes in a stationary are in phase. (B1)

(b) Define transverse waves and longitudinal waves.

Particles in a transverse wave oscillate/vibrate normal/perpendicular to the direction of energy transfer of wave [B1]
 Particles in a longitudinal wave oscillate/vibrate parallel to the direction of energy transfer of wave [B1]

..... [1]

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

Sound waves are longitudinal waves. [B1]
 Hence, sound waves in a gas or liquid cannot be polarised because the medium oscillates only along the direction of wave propagation or energy transfer (i.e. a single line), and hence cannot be restricted to a plane normal to the direction of energy transfer. [B1]

..... [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.

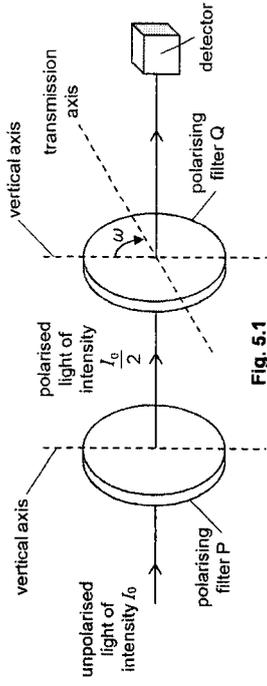


Fig. 5.1

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.

relative angle between P and Q = $\omega t = 2(9) = 18 \text{ rad}$ [C1]

By Malus' law, $\frac{I_0 \cos^2(18 \text{ rad})}{2}$ [B1]

$= \frac{I_0}{2} = 0.2I_0$ [A1]

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.

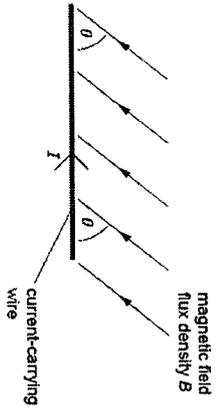


Fig. 6.1

- (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.

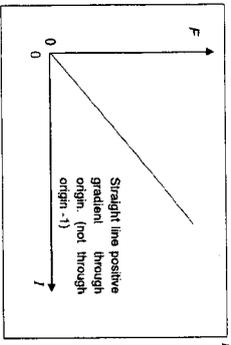


Fig. 6.2

[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 $\theta = 0^\circ$ to 180° .

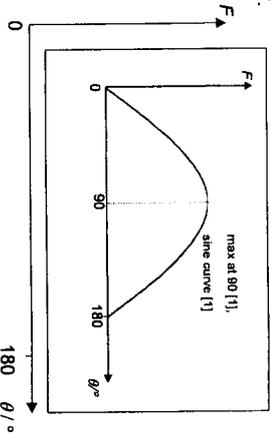


Fig. 6.3

[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.

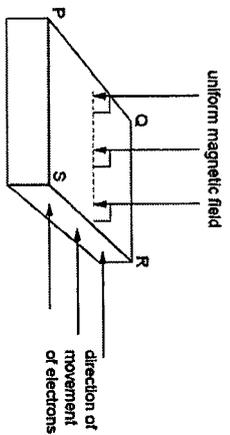


Fig. 6.4

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.

There is a magnetic force on the electrons due to the magnetic field and this force is normal to both the magnetic field and direction of electron motion. Hence the electrons will experience an acceleration perpendicular to its motion, causing the direction of velocity to change and they will not travel in a straight line.

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

From S to R or from P to Q

[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.



The following data may be used for the calculation.

Rest mass of ${}^{19}_9\text{F}$	18.998403 u
Rest mass of ${}^1_1\text{H}$	1.008665 u
Rest mass of ${}^{18}_8\text{O}$	1.007825 u
Rest mass of ${}^4_2\text{He}$	4.003860 u

(a) Explain what is meant by

(i) binding energy of a nucleus,

It is defined as the energy needed just to separate completely to infinite the nucleons in the nucleus.

Or

It is also defined as energy released when a nucleus is formed from infinite by putting all its constituent nucleons together

(ii) mass defect of a nucleus.

Mass defect is defined as the difference between the total mass of the nucleons of the atom taken separately and the mass of the nucleus.

.....[1]

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

$$\begin{aligned} \text{Mass defect} &= (\sum m_p + \sum m_n) - m_{\text{nucleus}} \\ &= (9(1.007825\text{u}) + (19-9)(1.008665\text{u}) - 18.998403\text{u}) \\ &= 0.158672 \text{ u} \\ &= 2.633955 \times 10^{-28} \text{ kg [1]} \end{aligned}$$

$$\begin{aligned} \text{Binding energy per nucleon} &= \frac{\text{mass defect} \times c^2}{19} \\ &= \frac{(2.633955 \times 10^{-28}) \times (3.0 \times 10^8)^2}{19} \\ &= 1.247663 \times 10^{12} \text{ J [1]} \\ &= 7.80 \text{ MeV [1]} \end{aligned}$$

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

$$\begin{aligned} \text{Total energy} &= (\text{total BE})_{\text{products}} - (\text{total BE})_{\text{reactants}} + \text{input energy} \\ &= [(7.72)(16) + (6.82)(4)] - (7.80)(19) + 5.00 \\ &= 7.60 \text{ MeV} \\ &= 1.22 \times 10^{12} \text{ J} \end{aligned}$$

total kinetic energy = J [2]

(d) Determine the rest mass of ${}^{16}_8\text{O}$.

By conservation of energy,

$$(\sum M)_{\text{reactants}} \times c^2 + KE_{\text{reactants}} = (\sum M)_{\text{products}} \times c^2 + KE_{\text{products}}$$

$$\Rightarrow [(18.998403 \text{ u}) + (1.007825\text{u})] c^2 + (5.00 \times 10^6)(1.60 \times 10^{-19})$$

$$= (4.003860 \text{ u})(c^2) + M_{\text{O}}c^2 + 1.22 \times 10^{12} \text{ J}$$

$$\text{Rest mass} = 2.655926 \times 10^{-26} \text{ kg} = 2.66 \times 10^{-26} \text{ kg}$$

Alternatively,

Binding energy of Oxygen = mass defect $\cdot c^2$.

$$(7.72)(16) \times 1.60 \times 10^{-19} \times 10^6 = (\text{mass of 8 protons} + 8 \text{ neutrons} - \text{rest mass of oxygen})(3.0 \times 10^8)^2$$

$$\text{rest mass of oxygen} = 8 \times (1.007825 + 1.008665)(1.66 \times 10^{-27}) - 2.195911 \times 10^{-28}$$

$$= 2.655940 \times 10^{-26} \text{ kg} = 2.66 \times 10^{-26} \text{ kg}$$

[Total : 9]

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

DPM Heng Swee Keat 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.

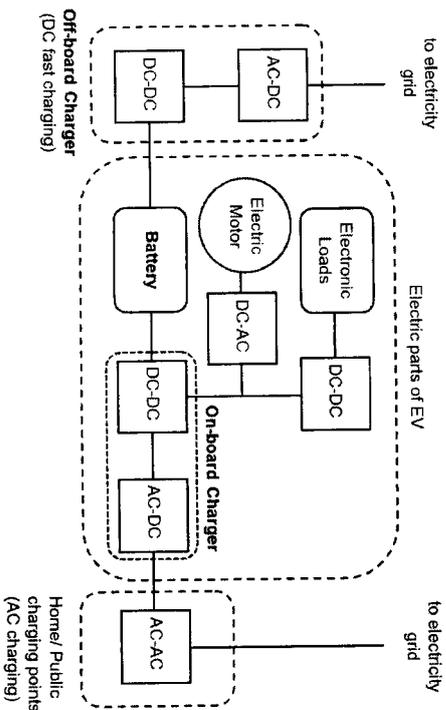


Fig. 8.1

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.

$P_s = I_s V_s$	[C-1]
$8.0 \times 10^3 = I_s (250)$	[A-1]
$I_s = 32 \text{ A}$	

current in the secondary coil = A [2]

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

$P_p = P_s$	
$I_p V_p = P_s$	[C-1]
$I_p (21 \times 10^3) = 8.0 \times 10^3$	[A-1]
$I_p = 0.38 \text{ A}$	

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.

$\frac{N_p}{N_s} = \frac{V_p}{V_s}$	[C-1]
$\frac{N_p}{N_s} = \frac{21 \times 10^3}{250}$	[A-1]
$\text{ratio} = \dots\dots\dots$	[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 value of ½-wave rectified voltage	[B-1]
= Peak value of unrectified secondary voltage	[A-1]
$= \sqrt{2} V_s = \sqrt{2} (250) = 354 \text{ V}$	

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.

$$\begin{aligned}
 Pt &= E \\
 (8000)t &= (0.80)(27000 \times 3600) \quad [C1] \\
 t &= 9720s \\
 &= 2.7 \text{ hr} \quad [A1]
 \end{aligned}$$

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.

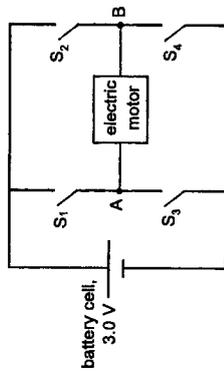


Fig. 8.2

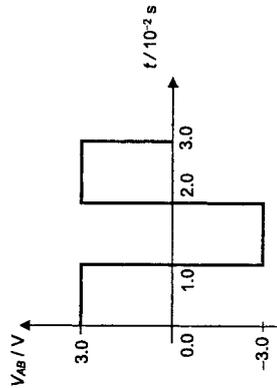


Fig. 8.3

- 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.

- First $\frac{1}{2}$ cycle, S_1 and S_4 closed, S_2 and S_3 open, $V_{AB} = +3.0 \text{ V}$. [B1]
 Next $\frac{1}{2}$ cycle, S_2 and S_3 closed, S_1 and S_4 open, $V_{AB} = -3.0 \text{ V}$. [B1]
 Full cycle repeated 50 times a second to give a period of 0.020 s. [B1]

(ii)

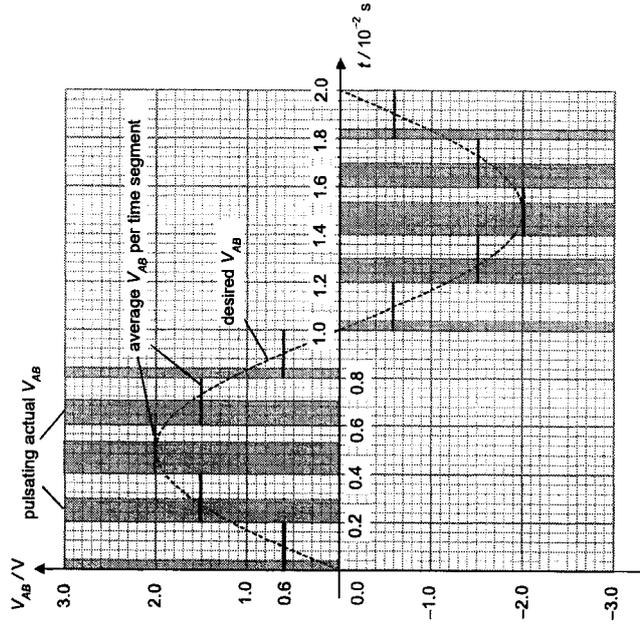


Fig. 8.4

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.

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

$$\langle V \rangle = \frac{(3.00)(0.04 \times 10^{-2})}{0.20 \times 10^{-2}} \quad [M1]$$

$$= 0.60 \text{ V}$$

[1]

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

To change the magnitude of V_{av} , control how long a duration of time the paired switches are open/closed in each time segment. [B-1]

To change the frequency of V_{av} , control the frequency of alternating between each paired switches in their pulsating or open states. [B-1]

[2]

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

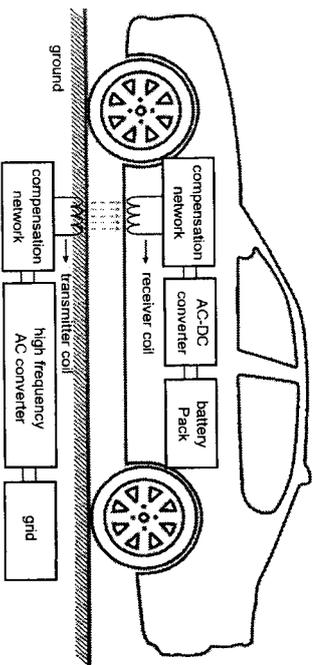


Fig. 8.5

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.

- Use Faraday's law to explain how the battery in the EV is charged.

High frequency a.c. in transmitter coil sets up an alternating current and hence a changing magnetic field/magnetic flux density in the receiver coil. [B-1]

By Faraday's law, an induced e.m.f. is set up in the receiver coil. Since the receiver coil is a closed loop, current will be induced in the coil. The flow of induced current in the charger circuit charges the battery. [B-1]

[2]

- 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%.

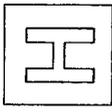
Suggest two reasons why the energy transfer process might be inefficient.

- receiver coil and transmitter coil not close to each other, and may not be perfectly aligned, this resulted in the lost of some flux linkage between the coils [B-1]
- loss of energy via heating of metal parts in car due to eddy currents [B-1]

[1]

[Total: 20]

End of Paper



NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

Solution

CANDIDATE NAME: _____

CLASS: _____ TUTOR'S NAME: _____

CENTRE NUMBER: S [] [] [] [] INDEX NUMBER: [] [] [] []

PHYSICS
Paper 3 Longer Structured Questions **9749/03**
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 24 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 $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
- 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
 - $s = ut + \frac{1}{2}at^2$
 - $v^2 = u^2 + 2as$
 - $W = p\Delta V$
 - $p = \rho gh$
 - $\phi = -Gm/r$
 - $T/K = T/^\circ\text{C} + 273.15$
 - $p = \frac{1}{3} \frac{Nm}{V} < c^2 >$
- work done on / by a gas
- hydrostatic pressure
- gravitational potential
- temperature
- pressure of an ideal gas
- mean translational kinetic energy of an ideal molecule
- displacement of particle in s.h.m.
- velocity of particle in s.h.m.
- electric current
- resistors in series
- resistors in parallel
- electric potential
- alternating current/voltage
- magnetic flux density due to a long straight wire
- magnetic flux density due to a flat circular coil
- magnetic flux density due to a long solenoid
- radioactive decay
- decay constant

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.

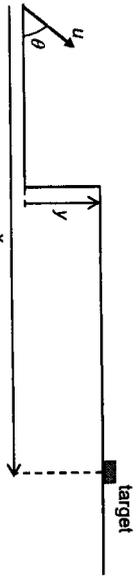


Fig. 1.1

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

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

$$y = u \sin \theta \times \frac{x}{u \cos \theta} - 4.91 \left(\frac{x}{u \cos \theta} \right)^2 \quad (M1)$$

$$y = x \tan \theta - 4.91 \left(\frac{x}{u \cos \theta} \right)^2 \quad (M0)$$

$$s_x = u_x t$$

$$x = (u \cos \theta) t$$

$$t = \frac{x}{u \cos \theta} \quad (M1)$$

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

$$y = (u \sin \theta) t + \frac{1}{2} (-9.81) t^2 \quad (C1)$$

[3]

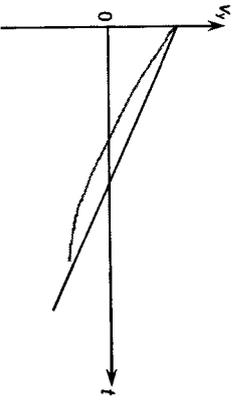
- (b) Given that the angle θ is 60° , the horizontal displacement x is 115 m and the vertical height y is 23 m, calculate the speed u .

$$23 = 115 \tan 60 - 4.91 \left(\frac{115}{u \cos 60} \right)^2$$

$$u = 38 \text{ m s}^{-1}$$

$$u = \dots \text{ m s}^{-1} \quad [1]$$

- (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]



- The curve must decrease at a decreasing rate throughout, with following details:
1. Positive area larger than negative area
 2. a larger initial gradient
 3. a smaller t -intercept
 4. at $v_y = 0$, gradient parallel

Fig. 1.2

[Total: 6]

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

1. The net force is zero. [B1]
2. The net torque is zero. / The net moment about any point is zero. [B1]

[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.

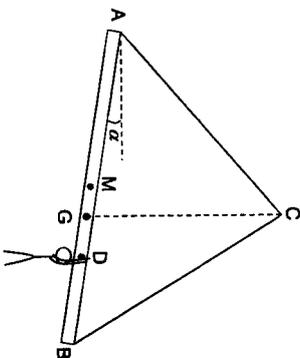


Fig. 2.1

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

The combined weight of the beam and the worker can be considered to be acting at G. Considering moments about C, moments due to T_1 and T_2 about C is zero as their lines of action pass through C. Hence for the resultant moments about C to be zero, the line of action of the combined weight of the beam and worker must pass through C as well so that the moment of the combined weight about C is zero. Hence the vertical line through G must pass through C. [2]

(ii) Calculate the distances MG and DG.

Considering moments due to the weight of beam, W_b , and that of the worker, W_w , about C,

Let distance MG be x and distance DG be y

$$W_b \cdot x = W_w \cdot y$$

$$(2700) x = (900) y$$

$$y = 3x$$

$$MD = AD - AM = 4.0 - 3.0 = 1.0 \text{ m}$$

$$MD = MG + GD = x + 3x = 1.0 \text{ m}, 4x = 1.0 \text{ m}, x = 0.25 \text{ m}.$$

$$MG = 0.25 \text{ m}$$

$$DG = 0.75 \text{ m}$$

distance MG = m

distance DG = m [2]

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

For horizontal equilibrium,

$$T_1 \cos(60.0^\circ - 2.8^\circ) = T_2 \cos(60.0^\circ + 2.8^\circ)$$

$$T_1 = \left(\frac{\cos 62.8^\circ}{\cos 57.2^\circ} \right) T_2 \dots (1)$$

$$T_1 = 0.8438 T_2 \dots (1)$$

For vertical equilibrium,

$$T_1 \sin 57.2^\circ + T_2 \sin 62.8^\circ = 2700 + 900 \dots (2)$$

Substituting equation (1) into equation (2) and solving for T_2 ,

$$T_2 = 2250 \text{ N (3 s.f.)}$$

tension $T_2 = \dots \dots \dots \text{ N [2]}$

[Total: 8]

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

Gravitational potential at infinity is defined to be zero [B1]

Since, gravitational forces are attractive, [B1]

the force exerted by external agent to bring the test mass from infinity to that point (without a change in KE) is opposite in direction to the test mass's displacement. The work done by the external agent is negative and by definition of gravitational potential it will take on a negative value. [B1]

..... [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.

same direction as Earth's rotation about its own axis so satellite begins launch with some speed in correct direction [B1]

satellite already has some kinetic energy so less fuel needed to raise the gravitational potential energy [B1]

..... [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. gravitational force provides centripetal force [M1]

$$\frac{GMm}{r^2} = mr\omega^2$$

$$GM = r^3\omega^2$$

$$r = \sqrt[3]{\frac{GM}{\omega^2}} = \sqrt[3]{\frac{GM}{\left(\frac{2\pi}{T}\right)^2}}$$

$$= \sqrt[3]{\frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{(24 \times 60 \times 60)^2}}$$

$$[= 4.23 \times 10^7 \text{ m } (4.2298 \times 10^7 \text{ m})] \text{ [M1]}$$

$$h = r - R_E = r - 6400 \times 10^3 = 3.59 \times 10^7 \text{ m} \text{ [A0]}$$

[2]

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

$$\begin{aligned}
 E_{\text{total}} &= E_k + E_p \\
 &= \frac{1}{2}mv^2 + \left(-\frac{GMm}{r}\right) = \frac{1}{2}r\left(\frac{mv^2}{r}\right) + \left(-\frac{GMm}{r}\right) \\
 &= \frac{1}{2}r\left(\frac{GMm}{r^2}\right) + \left(-\frac{GMm}{r}\right) = \left(\frac{GMm}{2r}\right) + \left(-\frac{GMm}{r}\right) \quad [M1] \\
 &= -\frac{GMm}{2r} \\
 &= \frac{-(6.67 \times 10^{-11})(6.0 \times 10^{24})(1000)}{2(4.2298 \times 10^7)} \\
 &= -4.73 \times 10^9 \text{ J} \quad [A1]
 \end{aligned}$$

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.

Work done against drag so total energy decreases [B1]

GPE decrease so satellite lowers in height [B1]

KE increase so linear speed increase } [B1]

satellite spirals towards Earth with increasing speed [B1]

.....

.....

..... [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} .

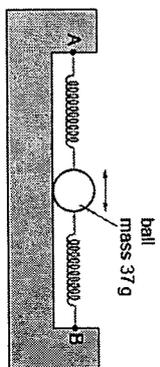


Fig. 4.1

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 in spring B = $3.2 - 3.0 = 0.2 \text{ cm}$

Extension in spring A = $3.2 + 3.0 = 6.2 \text{ cm}$

extension of spring A = cm

extension of spring B = cm [1]

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

$$\begin{aligned}
 \text{Total energy of the system} &= \text{maximum PE at the amplitude position [B1]} \\
 &= \frac{1}{2}kx_A^2 + \frac{1}{2}kx_B^2 \\
 &= \frac{1}{2}(3.5)(0.062)^2 + \frac{1}{2}(3.5)(0.002)^2 \quad [B1] \\
 &= 6.734 \times 10^{-3} \text{ J} \approx 6.7 \times 10^{-3} \text{ J}
 \end{aligned}$$

[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]

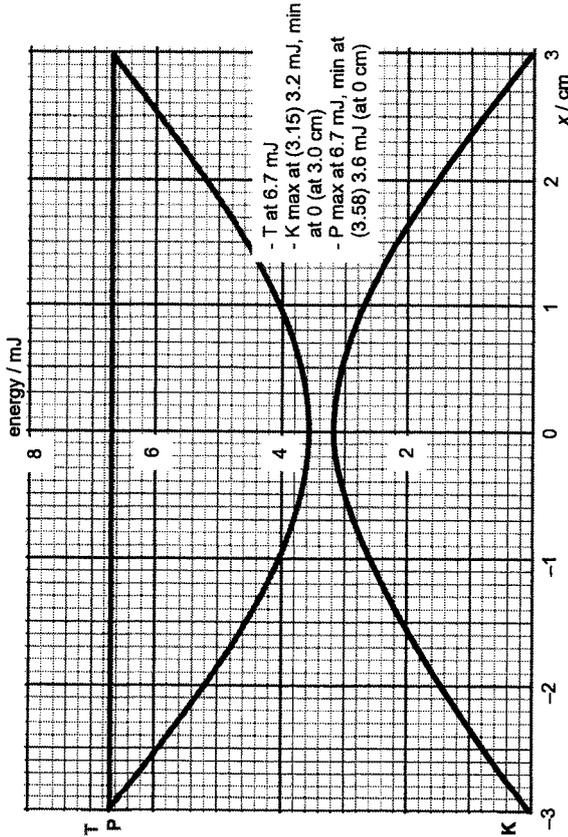


Fig. 4.2

(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.

The maximum energy of the oscillation remains constant [B.1], hence considering energy conservation, the maximum KE (at equilibrium position) remains unchanged. However, with a larger mass, the maximum speed is therefore reduced [B1].

[2]

[Total: 10]
 [Turn over

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.

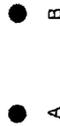


Fig. 5.1

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. Any two of the following:
 - Polarised along the same plane or not polarized [B1]
 - Roughly same amplitude/intensity. [B1]
 - Light source must be coherent [B1]
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.

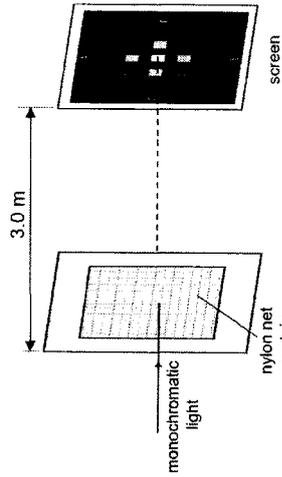


Fig. 5.2

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

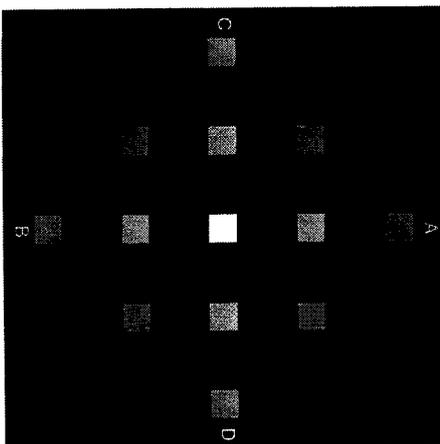


Fig. 5.3

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.

Distance between orders = 1.8 cm [C1]

$$\tan \theta = \frac{0.018}{3.0}$$

$\theta = 0.0060$ rad [A1]

angle = rad [2]

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

$d \sin \theta = n \lambda$

$d \sin (0.0060) = 1 (4.5 \times 10^{-7})$ [C1]

$d = 7.5 \times 10^{-5}$ m

number per mm = $\frac{1}{7.5 \times 10^{-5}} \times 10^{-3} = 13$ [A1]

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.

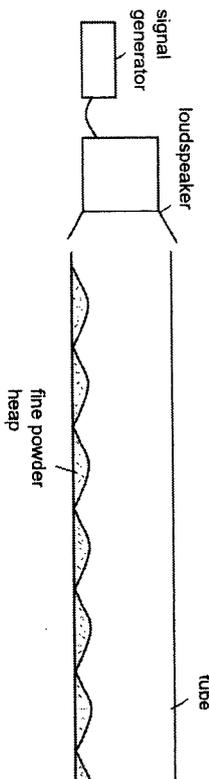


Fig. 5.4

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]

Any 2 points directly above the heap. [B1]

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

$v = f \lambda$

$\lambda = \frac{330}{3.5 \times 10^3} = 0.09429$ m [M1]

Distance between adjacent heaps is 0.5λ

$0.5 \times 0.09429 = 0.047$ m [A1]

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)

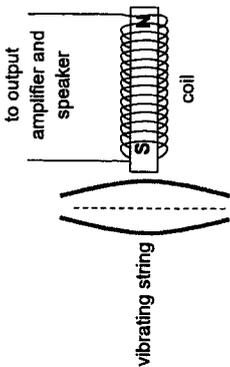


Fig. 6.1

- (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.

The steel string is made of magnetic material, and so it causes changes in the magnetic field from the permanent magnet that the coil is situated in. As the string vibrates, the magnetic field near the (pickup) coil changes over time. [B1] A changing (periodically increasing and decreasing) magnetic flux linkage through the coil [B1] induces an electromotive force in the coil proportional to the rate of change of magnetic flux [B1]. Because the vibration is periodic, the magnetic flux linkage also changes periodically and thus the e.m.f. induced is alternating [B1]

- (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.

Larger amplitude of vibration with the same frequency causes greater change in magnetic field around the magnet and coil, so there will be a greater change in magnetic flux linkage in coil in the same period, hence greater magnitude of induced voltage.

- (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} m². 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.

$$|E| = \frac{d\Phi}{dt} = NA \frac{dB}{dt} \quad \frac{\Delta B}{\Delta t} = \frac{\Delta B_{\text{max/min}}}{T/2} = 2(\Delta B)f$$

$$N = \frac{|E|}{A \left(\frac{\Delta B}{\Delta t} \right)} = \frac{0.20}{(1.0 \times 10^{-6})(5.0 \times 10^{-2})(2 \times 880)} \text{ [M1]}$$

$$= 2272 \text{ turns} \approx 2 \times 10^3 \text{ [A1]} \quad \text{number of turns} = \dots \dots \dots [2]$$

[Total: 8]
[Turn over]

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

The electric field strength at a point is defined as the electric force exerted per unit positive charge acting on a test charge placed at that point.

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

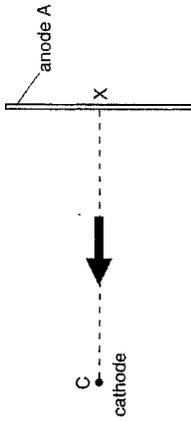
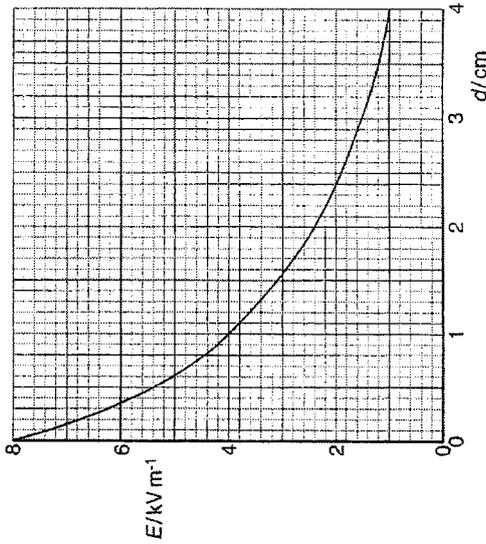


Fig. 7.1

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.

At $d = 2 \text{ cm}$, $E = 2.4 \text{ kV m}^{-1}$ [C1]

$F = qE$

$= (1.60 \times 10^{-19})(2.4 \times 10^3)$

$= 3.84 \times 10^{-16} \text{ N}$ [A1]

$F = \dots\dots\dots \text{ N [2]}$

(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.

Work done on charge $= Fd$

$q\Delta V = Fd$

$\Delta V = \frac{Fd}{q}$

$= \frac{(3.84 \times 10^{-16})(4.0 \times 10^{-2})}{1.60 \times 10^{-19}}$ [M1: must use (b)(ii) answer]

$= 96 \text{ V}$ [A1] potential difference = $\dots\dots\dots \text{ V [2]}$

(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.

Under-estimate because (by observation) the area under graph is $\dots\dots\dots$

greater than 96 V or answer in (c)(i). $\dots\dots\dots$ [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.).
 p.d. refers to the electrical energy per unit charge converted to other forms of energy [B1] whereas e.m.f. refers to the electrical energy per unit charge converted from other forms of energy. [B1]

$\dots\dots\dots$ [2]

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

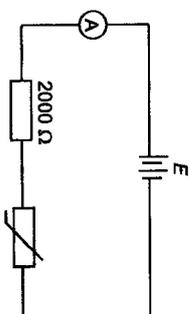


Fig. 8.1

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

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

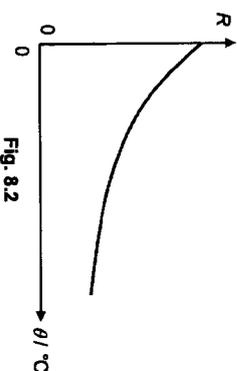


Fig. 8.2

Correctly drawn curve (straight lines not accepted) cuts R-axis at 0°C .

[1]

(ii) For the thermistor at room temperature,

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

$$E = \frac{W}{Q} = \frac{2.4 \times 10^5}{2.2 \times 10^4} \text{ [M1]} \\ = 11 \text{ V [A0]}$$

- determine the time taken for the charge of $2.2 \times 10^4 \text{ C}$ to pass through the ammeter. [1]

$$Q = It = \left(\frac{E}{R}\right)t \\ t = \frac{QR}{E} = \frac{(2.2 \times 10^4)(2000 + 1800)}{11} \text{ [C1]} \\ = 7.6 \times 10^6 \text{ s [A1]}$$

- determine the ratio

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

$$\frac{P_{\text{therm}}}{P_{\text{total}}} = \frac{I^2 R_{\text{therm}}}{I^2 (R_{\text{therm}} + R_{2000})} \text{ [C1]} \\ = \frac{1800}{1800 + 2000} \\ = 0.47 \text{ [A1]}$$

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.

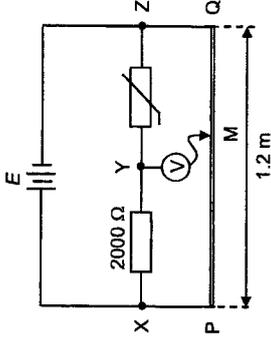


Fig. 8.3

- 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

$$V_{YQ} = V_{YZ} \text{ when voltmeter has zero reading} \\ \frac{L}{1.2} = \frac{1800}{2000 + 1800} \text{ [C1]} \\ L = 0.57 \text{ m [A1]}$$

length of wire = m [2]

- 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.

- The thermistor is warmed slightly.

With a rise in temperature, resistance of thermistor decreases. The ratio of p.d. across thermistor to the fixed resistor decreases. [M1] thus ratio of length MQ to PQ decreases too. Length MQ decreases. [A1]

..... [2]

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

Since the total potential difference and total length remains the same, the potential gradient remains the same. [M1] Therefore length MQ remains the same. [A1]

..... [2]

- (d) The heating element of an electric heater is made of nichrome wire. Nichrome has a resistivity of $1.0 \times 10^{-6} \Omega \cdot \text{m}$ 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.

$$P = \frac{V^2}{R} \quad [C1]$$

$$R = \frac{240^2}{1200} \quad [C1]$$

$$= 48 \Omega \quad [A1]$$

resistance = Ω [2]

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

$$R = \frac{\rho L}{A}$$

$$L = \frac{(48)(\pi(\frac{0.40 \times 10^{-3}}{2})^2)}{1.0 \times 10^{-6}} \quad [C1]$$

$$= 6.0 \text{ m} \quad [A1]$$

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.

Since $P = \frac{V^2}{R}$, a decrease in potential difference will result in a decrease in power. [M1] Hence, the time taken to dissipate the same amount of heat would increase. [A1]

[Total: 20]

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

Calculate the stopping potential V_s required to stop the electron.

Loss in KE = Gain in EPE

$$8.55 \times 10^{-19} - 0 = e(V_s - 0) \quad [C1]$$

$$V_s = \frac{8.55 \times 10^{-19}}{1.60 \times 10^{-19}} = 5.344 \text{ V} = 5.34 \text{ V} \quad [A1]$$

$V_s =$ 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.

$$\frac{hc}{\lambda} = \phi + KE_{\text{max}}$$

$$\frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{\lambda} = (2.80 \times 1.60 \times 10^{-19}) + 8.55 \times 10^{-19} \quad [C1]$$

$$\lambda = 1.53 \times 10^{-7} \text{ m} \quad [A1]$$

wavelength = m [2]

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

type of radiation = ultraviolet [1]

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

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\lambda = \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31})(1.85 \times 10^7)} \quad [C1]$$

$$= 3.93 \times 10^{-11} \text{ m} \quad [A1]$$

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.

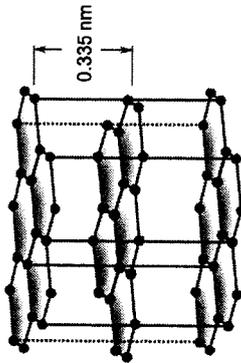


Fig. 9.1

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

The atomic lattice spacing (distance between layers of $3.35 \times 10^{-10} \text{ m}$) is much larger than the de Broglie's wavelength (of $3.93 \times 10^{-11} \text{ m}$), hence there is negligible/little spreading of electrons. It is not suitable 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.

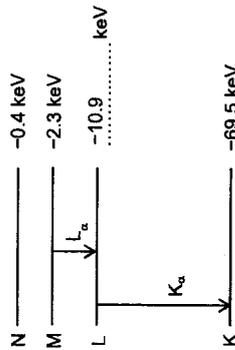


Fig. 9.2 (not to scale)

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.

$$E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}) (3.00 \times 10^8)}{21.2 \times 10^{-12}} \quad [C1]$$

$$= 9.382 \times 10^{-15} \text{ J} = 58.64 \text{ keV} \quad [A1]$$

$$E_2 = -69.5 + 58.64 = -10.9 \text{ keV} \quad [A1]$$

(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.

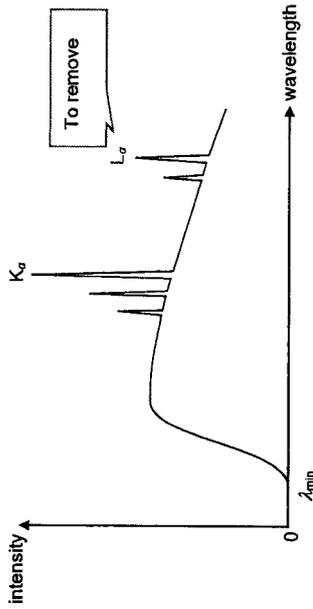


Fig. 9.3

- On Fig. 9.3, label the peak for L_{α} transitions. [1]
- Explain the existence of a minimum wavelength λ_{min} .

The minimum wavelength corresponds to the most energetic X-ray photon produced. This happens when a bombarding electron is completely stopped by the target metal and loses all its KE in a single interaction.

[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 = 69.5 keV [1]

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

The bombarding electrons must have sufficient energy to knock out / remove K-shell electron so that orbital electrons from higher level can de-excite to emit photons resulting in characteristic x-ray lines.

[1]

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

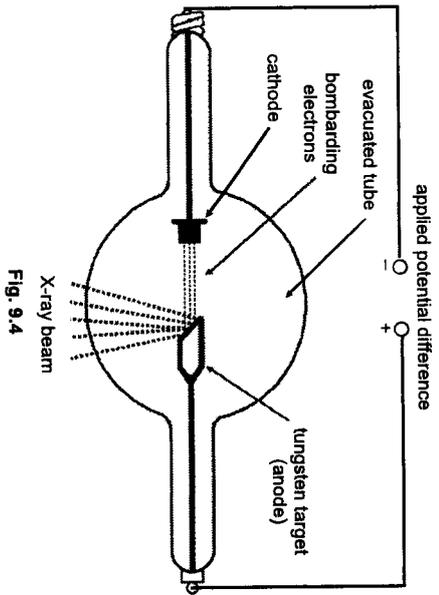


Fig. 9.4

(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.

.....
 A shorter wavelength in X-rays translates to higher energy photons, which can be harmful as they can damage living tissue and increase the risk of cancer.
 [1]

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

Loss in energy of electron = Maximum photon energy

$$q\Delta V = hc / \lambda$$

$$\Delta V = \frac{hc}{2q} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{(2)(1.60 \times 10^{-19} \text{ C})}$$

$$= 24862.5 \text{ V} = 2.5 \times 10^4 \text{ V} \quad [1]$$

..... V [2]

[Total: 20]

End of Paper