H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

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

PHYSICS

9749/01

Paper 1 Multiple Choice

20 September 2022

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 **16** 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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

BP~83

1 Which of the following is not a reasonable estimate?

A Sound of frequency in the order of 10^9 Hz is audible to human beings.

B Light of wavelength in the order of 10^{-7} m is visible to human beings.

C The volume of an average-sized orange is in the order of 10^{-4} m^3.

D The speed of beta particles emitted from a nucleus is in the order of 10^7 m s^{-1}.

Ans: A

Options B and D are typical values that candidates should be familiar with. Using $V = \frac{4}{3}\pi r^3$,

Option C works out for an orange having radius of about 5 cm. The frequency of sound (or even ultrasound) cannot hit GHz range.

2 The kinetic energy E_K of a rotating solid sphere is given by the following expression

$$E_K = \frac{2\pi^2 I}{T^2}$$

where I is the moment of inertia and T is the period of rotation of the solid sphere.

What is the unit for the moment of inertia I, expressed in SI base units?

A kg m^2 s^{-1}

B kg m^2

C J s^2

D N m s^2

Ans: B

$$E_K = \frac{2\pi^2 I}{T^2}$$

$$I = \frac{E_K T^2}{2\pi^2}$$

unit for I = (unit for E_K)(unit for T)^2

= {unit for (mv^2)}(unit for T)^2

= (kg)(m^2 s^{-2})(s^2)

= kg m^2

3 A ruler is supported horizontally by two pivots as shown.

The vertical displacement y at the centre of the ruler can be used to measure the mass loaded on it and is given by the equation

$$y = \frac{kML^3}{wt^3}$$

where

k is a constant,
L is the distance between the pivots,
M is the mass loaded onto the ruler,
t is the thickness of the ruler and
w is the width of the ruler.

When a particular M is loaded onto the ruler, the following results are obtained:

$y = (0.25 \pm 0.01)$ mm
$L = (80.0 \pm 0.2)$ cm
$t = (6.0 \pm 0.1)$ mm
$w = (23.0 \pm 0.5)$ mm

Which measurement contributes the most to the uncertainty of M?

A y **B** L **C** t **D** w

Ans: C

Make M subject of formula:

$$M = \frac{ywt^3}{kL^3}$$

$$\frac{\Delta M}{M} = \frac{\Delta y}{y} + \frac{\Delta w}{w} + 3\frac{\Delta t}{t} + 3\frac{\Delta L}{L}$$

$$\frac{\Delta y}{y} = \frac{0.01}{0.25} = 0.040$$

$$\frac{\Delta w}{w} = \frac{0.5}{23.0} = 0.022$$

$$3\frac{\Delta t}{t} = 3\frac{0.1}{6.0} = 0.050$$

$$3\frac{\Delta L}{L} = 3\frac{0.2}{80.0} = 0.0075$$

4 The speed of an aeroplane in still air is 200 km h^{-1}. The wind pushes it from the west at a speed of 85.0 km h^{-1}.

In which direction must the pilot steer in order to fly due north?

A 23.0° east of north

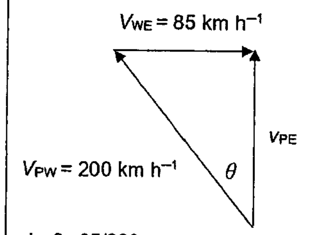
B 23.0° west of north

C 25.2° east of north

D 25.2° west of north

Ans: D

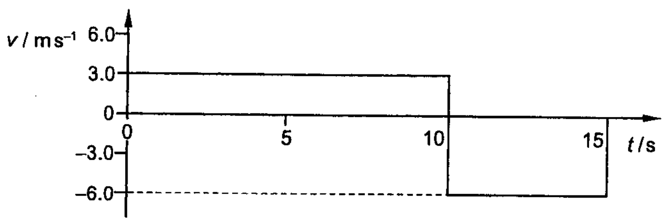
$v_{PE} = v_{PW} + v_{WE}$ where v_{PE} is velocity of plane relative to Earth
v_{PW} is velocity of plane relative to Wind
v_{WE} is velocity of wind relative to Earth



sin θ =85/200
θ = 25.2° west of north

5 A radio-controlled toy car travels along a straight line for a time of 15 s.

The variation with time *t* of the velocity *v* of the car is shown below.



What is the average velocity of the toy car for the 15 s journey?

A −1.5 m s^{-1} **B** 0.0 m s^{-1} **C** 4.0 m s^{-1} **D** 4.5 m s^{-1}

Area under the graph = Δs = zero
v_{ave} = Δs/t = 0

Answer: B

6 A tennis ball is thrown horizontally in air from the top of a tall building. The effect of air resistance is not negligible.

Which of the following correctly describes the subsequent change in the horizontal and vertical components of the ball's velocity?

	horizontal component of velocity	vertical component of velocity
A	constant	constant
B	constant	increases at a constant rate
C	decreases to zero	increases at a constant rate
D	decreases to zero	increases to a maximum value

Since the building is tall, the time of flight is long enough for the vertical component of velocity to reach a maximum value.

Answer: D

7 A rock of mass 2*m* in deep space, initially travelling at velocity *v*, explodes into two parts of equal mass, one of which becomes stationary immediately after the explosion.

What is the kinetic energy of the moving part after the explosion?

A $\frac{1}{2}mv^2$ **B** mv^2 **C** $\frac{3}{2}mv^2$ **D** $2mv^2$

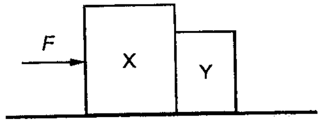
By COM, momentum after explosion = 2mv, which is only carried by moving part.

So KE of moving part = $(2mv)^2/(2m) = 2mv^2$

Answer: D

BP-85

8 A single horizontal force F is applied to a block X which is in contact with a separate block Y, as shown.



The blocks remain in contact as they accelerate along a horizontal frictionless surface. X has a greater mass than Y.

Which statement is correct?

A The acceleration of X is equal to force F divided by the mass of X.

B The force that X exerts on Y is equal to F.

C The force that X exerts on Y is less than F.

D The force that X exerts on Y is less than the force that Y exerts on X.

Answer: C

A: wrong. Acceleration of X = $(F - F_{by\ Y\ on\ X})$ divided by mass of X

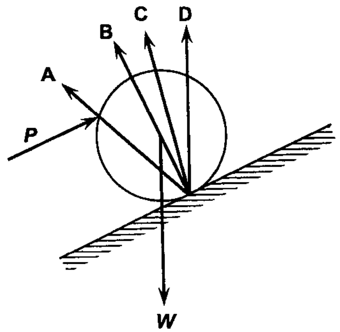
B: wrong. $F_{by\ X\ on\ Y}$ is equal in magnitude with $F_{by\ Y\ on\ X}$. If $F_{by\ Y\ on\ X} = F$, net force on X = 0 and X will not accelerate.

C: correct. $F_{by\ X\ on\ Y}$ is equal in magnitude with $F_{by\ Y\ on\ X}$. If $F_{by\ Y\ on\ X}$ is less than F, net force on X acts in the direction of F and X will accelerate.

D: wrong. By N3L, $F_{by\ X\ on\ Y}$ is equal in magnitude with $F_{by\ Y\ on\ X}$.

9 A full barrel of weight W is being rolled up a ramp. The force P is required to hold the barrel at rest on the ramp. Friction between the barrel and the ramp stops the barrel from slipping.

Which arrow shows the resultant force that the ramp exerts on the barrel?

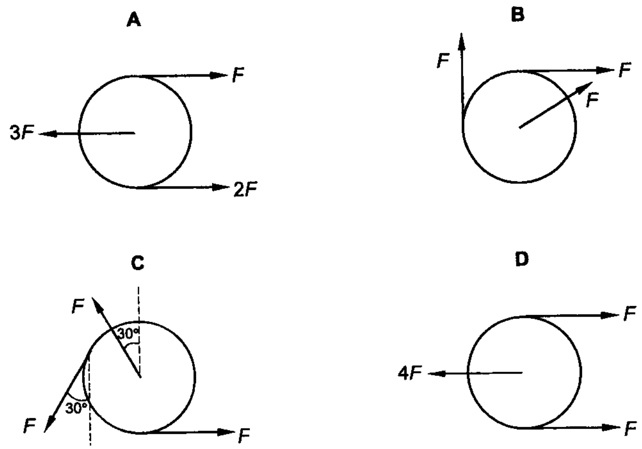


The line of action of the 3 forces need to intersect at a common point for rotational equilibrium.

Answer: C

10 An isolated disc is subjected to three forces, each given in terms of units of magnitude F.

In which situation will the disc experience both a resultant force and a resultant torque?

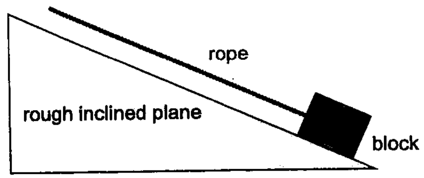


Check for ΣFx ≠ 0 OR ΣFy ≠ 0 for non-zero resultant force .

Check for resultant moment about centre of disc is non-zero.

Answer: B

11 A block is being pulled up a rough inclined plane using a rope at a constant speed.



Which of the following statements is correct?

A The weight of the block does no work because the block is not moving in the direction of its weight.

B The work done by the force of the rope is equal to the work done against the frictional force from the plane because there is no gain in kinetic energy.

C The normal reaction force from the plane does positive work because it has an upward component and the block is moving upwards.

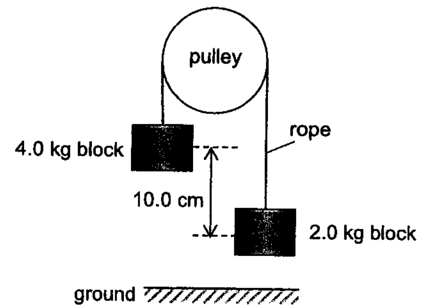
D The negative work done by the weight of the block is equal to the gain in gravitational potential energy of the block.

Ans: D

A force does no work when it is perpendicular to the direction of motion. (A & C)

Net work done on the block is positive because there is gain in GPE of the block. (B)

12 The figure below shows a light inextensible rope that passes over a light smooth pulley with two blocks of masses 4.0 kg and 2.0 kg attached to its two ends. The two blocks are initially at rest with the 4.0 kg block 10.0 cm above the 2.0 kg block.



What is the speed of the blocks when they are at the same height above the ground?

A 0.57 m s^{-1} **B** 0.81 m s^{-1} **C** 0.99 m s^{-1} **D** 1.4 m s^{-1}

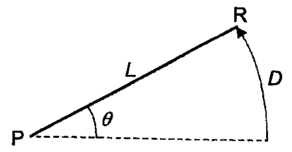
Ans: A

Loss in GPE = 4.0 × 9.8 × (5.0×10^{-2}) – 2.0 × 9.8 × (5.0×10^{-2}) = 0.98 J

Gain in KE = ½ × (2.0 + 4.0) × v^2 = 0.33 J

→ v = 0.57 m s^{-1}

13 A rod PR of length L is turned about the point P through an angle θ.



The end R of the rod moves through a distance D. Both D and L are measured in metres.

What is the angle θ, expressed in radians?

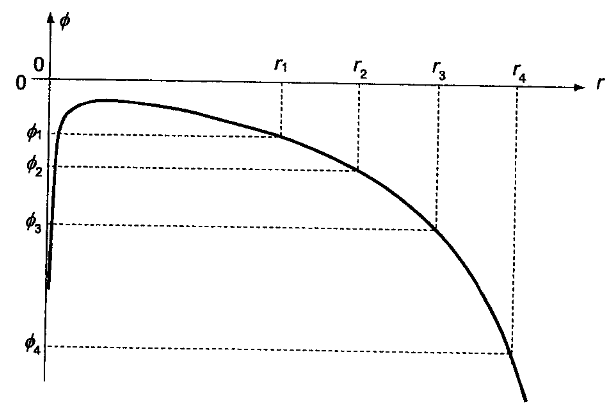
A L/D **B** D/L **C** DL **D** $1/(DL)$

Answer: B

D = Lθ

θ = (D / L) rad

14 The gravitational potential ϕ along the line joining the centres of a planet and its moon varies with the distance r from the centre of the moon as shown.



Which of the following expressions gives a value that is closest to that of the gravitational force acting on a 1 kg mass at a distance of r_2?

A $\dfrac{\phi_1 - \phi_2}{r_2 - r_1}$

B $-\dfrac{\phi_2}{r_2}$

C $\dfrac{\phi_1 - \phi_3}{r_3 - r_1}$

BP~87

D $\dfrac{\phi_1 - \phi_4}{r_4 - r_1}$

Ans: C

$F = -\dfrac{dE_p}{dr} = -m\dfrac{d\phi}{dr} \approx -1 \times \dfrac{\Delta\phi}{\Delta r}$

Option A: Underestimated the gradient.

Option B: Incorrectly used $g = \dfrac{\phi}{r}$ .which is applicable only for a radial field. Here the g-field is the vector sum of the g-field due to the moon and the g-field due to the planet. The net field is not radial.

Option D: Overestimated the gradient.

15 Earth has a mass M and radius R. X is a point $5R$ from the center of the Earth.

An object of mass m falls freely from rest at X and hits the surface of the Earth.

Which of the following statements is false?

A The change in gravitational potential is $\dfrac{4}{5}\dfrac{GM}{R}$.

B The work done by the gravitational field is $\dfrac{4}{5}\dfrac{GMm}{R}$.

C The speed of impact is $\sqrt{\dfrac{8}{5}\dfrac{GM}{R}}$.

D The change in the magnitude of gravitational field strength is $\dfrac{24}{25}\dfrac{GM}{R^2}$.

Ans: A

Option A is an incorrect statement because as the object is falling, it should lose gravitational potential and hence the change should take on a negative value.

Change in gravitational potential = $\phi_{final} - \phi_{initial}$

$$= -\frac{GM}{R} - \left(-\frac{GM}{5R}\right)$$
$$= -\frac{4GM}{5R}$$

Option B is correct statement because the direction of gravitational force and displacement of object is the same. Hence work done by gravitational field is positive. The amount of work done by gravitational field will be the same as the amount of GPE loss in the fall.

Option C is correct statement because

Loss in GPE = Gain in KE

$GPE_{initial} - GPE_{final} = KE_{final} - KE_{initial}$

$-\dfrac{GMm}{5R} - \left(-\dfrac{GMm}{R}\right) = \dfrac{1}{2}mv^2$

$\dfrac{4GMm}{5R} = \dfrac{1}{2}mv^2$

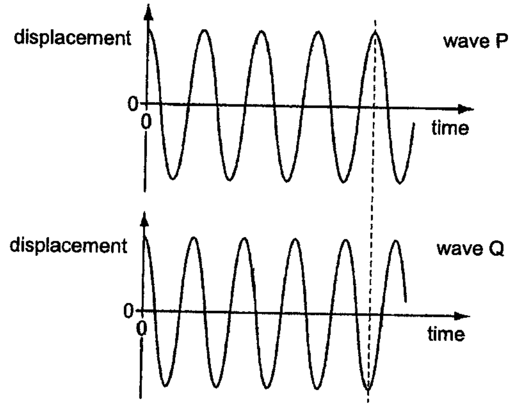
$v = \sqrt{\dfrac{8GM}{5R}}$

Option D is correct

Change in gravitational field strength = $g_{final} - g_{initial}$

$$= \frac{GM}{R^2} - \left(\frac{GM}{(5R)^2}\right)$$
$$= \frac{24GM}{25R^2}$$

16 The diagram shows the displacement-time graphs of two sound waves P and Q at a point in space. The graphs have the same scales for the time axes.



The frequency of Q is 125 Hz. The waves are in phase at time = 0.

At what time are the waves next in phase?

A 32 ms **B** 36 ms **C** 64 ms **D** 72 ms

Ans: D

From graphs shown,

P and Q are initially in phase at t = 0, and become out of phase next at t = $4.5T_Q$, where T_Q is the period of wave Q.

$T_Q = 1/f_Q = 1/125$ s

Hence the next time the waves become in phase must be for another duration of 4.5 T_Q,

i.e. they are next in phase at time

t = 4.5 T_Q + 4.5 T_Q = 9 T_Q = 0.072 s

17 Which of the following correctly states the changes, if any, in the potential energy and kinetic energy of the molecules of a solid as it melts?

	potential energy	kinetic energy
A	decreases	increases
B	increases	remains the same
C	remains the same	decreases
D	remains the same	remains the same

temperature is constant when the solid melts

Answer: B

18 The frequency of a wave is 600 Hz and its speed is 330 m s^{-1}.

What is the phase difference between the oscillation of two points on the wave that are 0.275 m apart?

A 0 **B** $\frac{\pi}{4}$ rad **C** $\frac{\pi}{2}$ rad **D** π rad

Apply to the formula (x/λ) × 2π.

Answer: D

19 A point source emits 50.0 W of sound energy in all directions. A small microphone of area 0.85 cm^2 detects the sound at 4.0 m from the source.

What is the power received by the microphone?

A 1.6×10^{-5} W

B 2.1×10^{-5} W

C 2.1×10^{-1} W

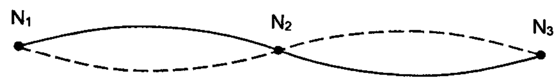
D 2.5×10^{-1} W

Intensity = power emitted /area spread = $50 / 4\pi r^2$

Power received = intensity × microphone area = 2.1×10^{-5} W

Answer: B

20 The diagram shows a standing wave on a string. The standing wave has three nodes N_1, N_2 and N_3.



Which statement is correct?

A All points on the string vibrate in phase.

B All points on the string vibrate with the same amplitude.

C Points equidistant from N_2 vibrate with the same frequency and in phase.

D Points equidistant from N_2 vibrate with the same frequency and the same amplitude.

Ans: D

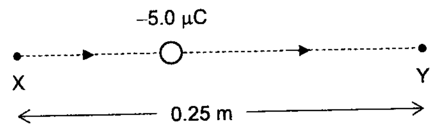
All points between N_1 and N_2 vibrate in phase, and are all in antiphase with points between N_2 and N_3.

All points between a node and an anti-node vibrate with different amplitudes

N All points vibrate with same frequency. Points to the left of a node vibrate in antiphase with the points to the right of a node.

BP~89

21 A particle of charge −5.0 μC is projected from X towards Y with kinetic energy 250 μJ. When the partice is at Y which is 0.25 m away from X, its kinetic energy decreased to 150 μJ.



Which of the following statements may not be correct?

A X is at a higher electric potential than Y.

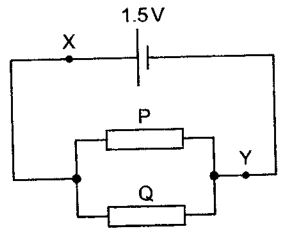
B The potential difference between X and Y is 20 V.

C The electric field between X and Y is of uniform strength 80 N m^{-1}.

D The electric field between X and Y is directed towards Y.

Ans: C
The field between X and Y need not be uniform. (C)
Since particle lost KE, it gained EPE + particle is negatively charged
→ X is at a higher potential than Y (A)
ΔV = ΔW / q = (250 – 150) / 5.0 = 20 V (B)
→ Field is directed from X to Y (D)

22 The diagram shows an electrical circuit consisting of a 1.5 V cell of negligible internal resistance and two resistors P and Q.



Which statement about this circuit is correct?

A The cell converts 1.5 J of electrical energy to chemical energy for each coulomb of charge passing through it.

B The energy dissipated per unit charge passing through P and Q is the same.

C The potential difference across P and the potential difference across Q add up to 1.5 V.

D The rate of flow of charge at point X is greater than the rate of flow of charge at Y.

Answer: B
Option A is incorrect because the energy conversion inside the cell is from chemical energy

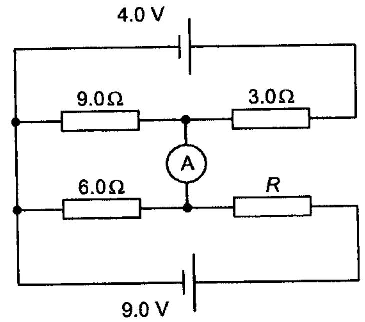
to electrical energy, and not the other way around.

Option B is correct because P and Q are connected in parallel, thus they have the same potential difference across them. By definition, the work done converting electrical energy to thermal energy per unit charge in each resistor is the same as well.

Option C is incorrect because P and Q are connected in parallel, thus they have the same potential difference across them, which is 1.5 V across each resistor.

Option D is incorrect, because the rate of flow of charge (current) at X is the same as that at Y.

23 In the circuit shown, the cells have negligible internal resistance and the reading on the ammeter is zero.



What is the resistance of R?

A 2.0 Ω **B** 6.0 Ω **C** 12 Ω **D** 18 Ω

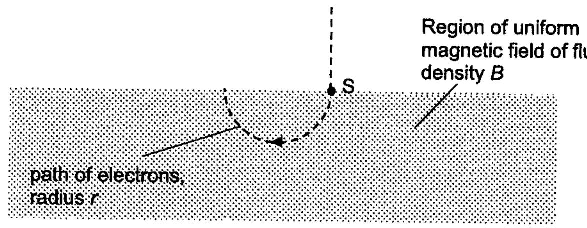
Answer: C
The ammeter reads zero which means the potentials at the two ends of the ammeter are the same. This means that the potential difference across the 9.0 Ω resistor is the same as that across the 6.0 Ω resistor.

$$\frac{V_{9.0\Omega}}{4.0} = \frac{9.0}{9.0+3.0}$$
$$V_{9.0\Omega} = 3.0 \text{ V}$$

$$\frac{V_{6.0\Omega}}{9.0} = \frac{6.0}{6.0+R}$$
$$\frac{3.0}{9.0} = \frac{6.0}{6.0+R}$$
$$V_{9.0\Omega} = 3.0 \text{ V}$$
$$R = 12\ \Omega$$

24 Electrons, each of mass m and charge q, are accelerated from rest in a vacuum through a potential difference V.

The accelerated electrons are then projected at point S into a region of uniform magnetic field of flux density B, as shown. The electrons move in a circular path of radius r.



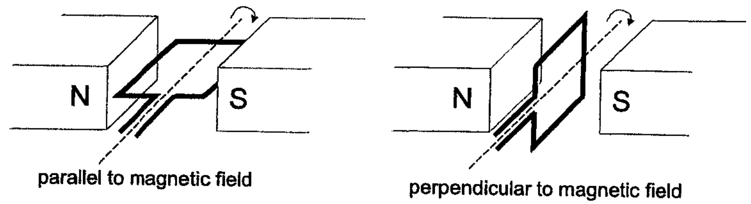
Which of the following expressions represents the specific charge $\frac{q}{m}$ of the electrons?

A $\frac{V}{2B^2r}$ **B** $\frac{2V}{B^2r}$ **C** $\frac{V}{2B^2r^2}$ **D** $\frac{2V}{B^2r^2}$

Ans: D

$$qV=\frac{1}{2}mv^2$$
$$v=\sqrt{\frac{2qV}{m}}$$
$$Bqv=\frac{mv^2}{r}$$
$$Bq\sqrt{\frac{2qV}{m}}=\frac{m\left(\frac{2qV}{m}\right)}{r}$$
$$\sqrt{\frac{2qV}{m}}=\frac{m\left(\frac{2V}{m}\right)}{Br}=\frac{2V}{Br}$$
$$\frac{2qV}{m}=\frac{4V^2}{B^2r^2}$$
$$\frac{q}{m}=\frac{2V}{B^2r^2}$$

25 A rectangular coil made of 100 turns of wire with cross sectional area 30 cm^2 is placed within a uniform magnetic field of 0.80 T. The coil is rotated with an angular velocity of 100 rad s^{-1}. At different stages of its rotation, the cross sectional area of the coil can be parallel or perpendicular to the magnetic field, as shown.



What is the maximum e.m.f. induced and the corresponding orientation of the coil?

	maximum e.m.f. / V	orientation of coil
A	0.24	parallel to magnetic field
B	0.24	perpendicular to magnetic field
C	24	parallel to magnetic field
D	24	perpendicular to magnetic field

Ans: C

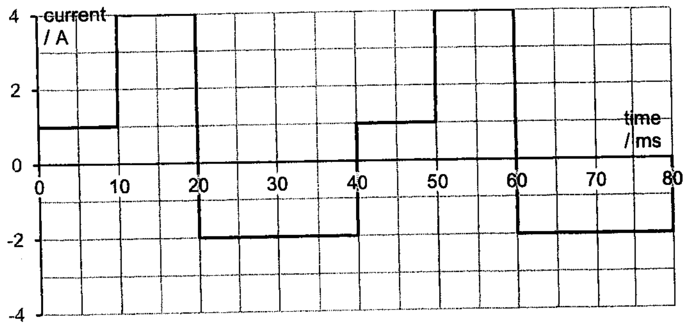
$$\phi = NBA\sin\omega t$$
$$\varepsilon = \frac{d\phi}{dt} = \omega NBA\cos\omega t$$
$$\varepsilon_{max} = \omega NBA = (100)(100)(0.80)(30\times(10^{-2})^2)$$
$$= 24\text{ V}$$

Maximum rate of change of flux linkage occurs when ϕ=0. I.e. at the instant of rotation where the coil is parallel to the magnetic field.

Distractors: forget to multiply by ω.

BP~91

26 The graph below shows how the current in a coil varies with time.



What is the value of a steady current that will dissipate heat in the coil at the same average rate as the current above?

A 1.5 A **B** 2.3 A **C** 2.5 A **D** 2.6 A

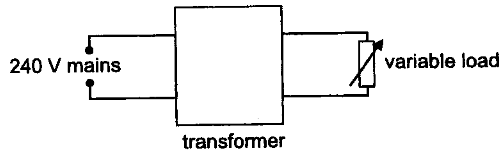
Ans: C

Area under current^2 graph = $(2\times1^2 + 2\times4^2 + 4\times2^2) \times 5 = 250$

Mean current^2 = 380 / 40 = 6.25 A^2

RMS current = $\sqrt{6.25}$ = 2.5 A

27 An ideal transformer steps down the 240 V sinusoidal voltage from the mains to 12 V, which is then applied to a variable load.



What is the change in the current supplied by the mains when the resistance of the load is increased from 20 Ω to 50 Ω?

A Decrease from 30 mA to 12 mA.

B Increase from 12 mA to 30 mA.

C Decrease from 12 mA to 4.8 mA.

D Increase from 0.24 A to 0.60 A.

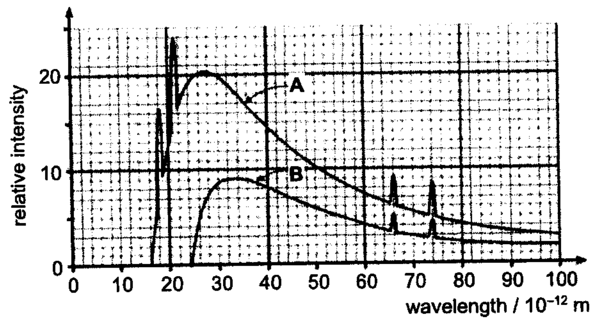
Ans: A

$I_P / I_s = n_S / n_P = V_S / V_P = 12 / 240 = 0.050$

At 20 Ω, I_S = 12 / 20 = 0.60 A → I_P = 0.60 × 0.050 = 0.030 A

At 50 Ω, I_S = 12 / 50 = 0.24 A → I_P = 0.24 × 0.050 = 0.012 A

28 The diagram shows two spectra of X-rays from an X-ray tube.



Which of the following statements is true?

A The accelerating potential to produce spectrum B is lower than that to produce spectrum A.

B A different target metal is used to produce spectra A and B as shown from the existence of additional peaks in spectrum A.

C With the same accelerating potential, the temperature of cathode used to produce spectrum A is higher than that to produce spectrum B as shown from the higher intensity of X-ray photons in spectrum A.

D The temperature of cathode used to produce spectrum A is higher than that to produce spectrum B as shown from the existence of additional peaks in spectrum A.

Ans: A

A: Lower accelerating p.d. for B, smaller loss in EPE and smaller gain in KE, smaller E of most energetic X-ray photon produced, larger cut-off wavelength. At the same time, fewer X-ray photons produced, hence intensity is lowered.

B: Additional peaks are observed in A because the cut-off wavelength for A is shorter. Same target metal used.

C: Higher temperature of cathode leads to more X-ray photons produced, hence intensity is higher. But it does not explain why the cut-off wavelength for A is shorter.

D: Higher temperature of cathode leads to more X-ray photons produced, hence intensity is higher. But it does not explain why additional peaks for A are observed.

29 Which of the following radioactive samples has the greatest activity?

	nuclide	amount / mole	half-life / day
A	$^{225}_{89}Ac$	0.003	10
B	$^{228}_{90}Th$	0.1	400
C	$^{228}_{88}Ra$	0.6	2100
D	$^{241}_{94}Pu$	1.0	4800

Answer: A

$A = \lambda N = \dfrac{\ln 2}{T_{½}} N$ where N is the number of molecules in the sample

So N = n N_A

And the A of each can be compared by finding the nuclide with the greatest ratio of $\dfrac{n}{T_{½}}$

Option A: $\dfrac{n}{T_{½}} = \dfrac{0.003}{10} = 0.0003$

Option B: $\dfrac{n}{T_{½}} = \dfrac{0.1}{400} = 0.00025$

Option C: $\dfrac{n}{T_{½}} = \dfrac{0.6}{2100} = 0.00029$

Option D: $\dfrac{n}{T_{½}} = \dfrac{1.0}{4800} = 0.00020$

30 A radioactive source is placed 1 cm from a Geiger-Muller tube, and various absorbers are placed between them, one at a time. For each absorber, a one-minute count is taken of the total number of decays, and this is repeated several times. The table shows the results of the experiment.

absorber	average number of decays detected in one minute
none	1043
0.1 mm paper	1040
1 mm aluminium	497
1 cm lead	6

The average background count per minute is 5.

What nuclear radiation do the results suggest the source was emitting?

A alpha and beta only

B beta only

C beta and gamma only

D alpha, beta and gamma

Answer: B

Type of decay	alpha	beta	gamma
Penetration power	3 cm of air A sheet of paper	3 m of air A sheet of aluminum of a few mm thickness	Lead, concrete or steel of >10 cm thickness

Because most particles can pass through paper, they are not alpha particles.
Some of them are absorbed by the aluminium, and stopped by 4 cm lead; they must be beta particles.

End of Paper

BP~93

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS | TUTOR'S NAME

CENTRE NUMBER S | INDEX NUMBER

PHYSICS

9749/02

Paper 2 Structured Questions

13 September 2022

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and tutor's name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, 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.

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

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

This document consists of **22** printed pages.

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

1 **(a)** A ball leaves the edge of a table with a horizontal velocity v, as shown in Fig. 1.1.

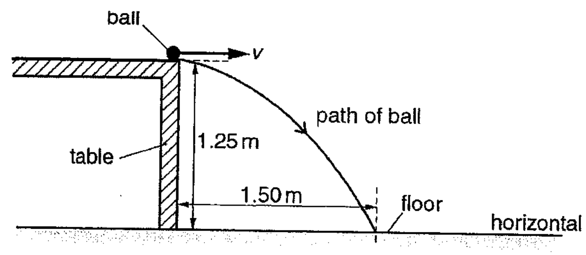


Fig. 1.1

The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

Calculate, for the ball,

(i) the horizontal velocity v as it leaves the table,

$u_x = v$, $u_y = 0$

$s_x = u_x t = vt$ **[1]**

$s_y = 0 + \frac{1}{2}at^2 \Rightarrow 1.25 = 0 + \frac{1}{2}(9.81)t^2$ **[1]**

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

(ii) the velocity just before it hits the floor.

$v = \sqrt{(v_y)^2 + (v_x)^2}$ [1]

$v_y = u_y + at = 0 + (9.81)(0.505) = 4.95$ m s^{-1}[1]

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

BP~95

(b) A second ball leaves the edge of the table with a horizontal velocity $2v$.

(i) State and explain whether the time taken to hit the floor is the same or different compared to the first ball.

Since both ball initial velocity for the vertical component is zero, the height is the same and same acceleration of free fall, the time taken is the same.

[2]

(ii) Describe the variation of the vertical component of velocity if air resistance is not negligible.

The vertical component of velocity is increasing at a decreasing rate.

[2]

[Total: 8]

2 (a) State Newton's Second Law of motion.

The rate of change in the momentum of a body is proportional to the resultant external force that acts on it, and the change in momentum is in the direction of the force.

[1]

(b) A jet of water hits a vertical wall at right angles, as shown in Fig. 2.1. The jet of water has density ρ, cross-sectional area A, and hits the vertical wall with impact velocity u. The water then runs down the wall after impact with the wall.

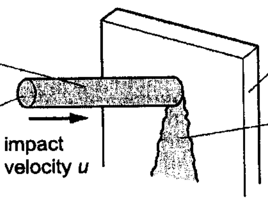


Fig. 2.1

(i) Using Newton's Law of motion, show that the magnitude of the average force exerted on the water by the wall is

$$F = \rho A u^2 .$$

From Newton's Second Law,

Force on water, F = rate of change of momentum of water

$$\text{Average } F = \frac{\Delta p}{\Delta t}$$

$$= \frac{M(0-u)}{\Delta t}$$

$$= -\left(\rho \times \frac{V}{\Delta t}\right)u = -\left(\rho \times \frac{Al}{\Delta t}\right)u = -\rho(Au)u$$

$$= -\rho A u^2$$

Hence, magnitude of F = $\rho A u^2$

Equation for N2L [1]

Sub in final velocity = 0 [1]

Sub in (M/t) = ρAu [1]

[3]

(ii) The density of water ρ is 1000 kg m^{-3}. Given that the jet of water in **(b)** has cross-sectional area A of 1.5 cm^2 and impact velocity u of 5.0 m s^{-1},

1. Calculate the magnitude of the average force exerted on the wall by the water. Explain your answer.

Force by wall on water = ρAu^2 = (1000)(1.5 x 10^{-4})(5.0^2) = 3.75 = 3.8 N [1]

By Newton's 3rd Law, magnitude of force by water on wall is equal to that by wall on water [1]

Hence magnitude of average force by water on wall = 3.8 N

magnitude of average force = ... N [2]

2. On Fig 2.2, sketch a graph to show the variation of pressure p on the wall with impact velocity u. [1]

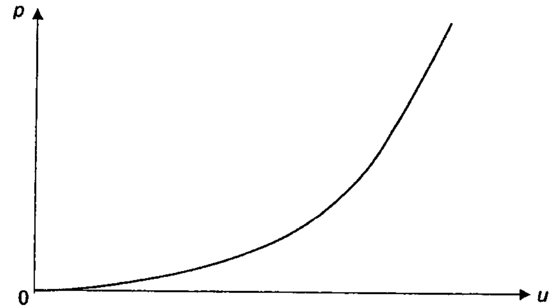


Fig. 2.2

3. Suggest the change, if any, to pressure P if the cross-sectional area A of the water jet is doubled.

No change.
(Since Pressure = Force/Area = F/A = $(\rho Au^2)/A = \rho u^2$, pressure is independent of A)

[Total: 8]

3 A ball of mass M of 750 g is held on a smooth horizontal surface between two identical springs at their natural lengths as shown in Fig. 3.1.

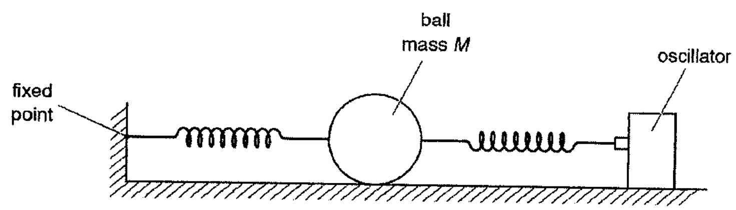


Fig. 3.1

One spring is attached to a fixed point while the other spring is attached to a mechanical oscillator. At t = 0 the ball is displaced to its amplitude position. The variation with time t of the displacement L of the ball is shown in Fig. 3.2.

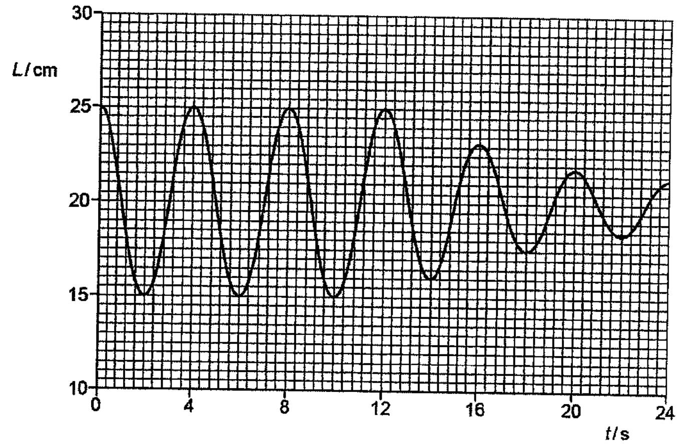


Fig. 3.2

(a) For the first 12 s of the oscillations,

(i) state one time at which the ball is moving with maximum speed,

Equilibrium: 1.0 s, 3.0 s, 5.0 s, 7.0 s, 9.0 s, 11.0 s.

time = ... s [1]

(ii) state one time at which the springs have maximum elastic potential energy,

Max displacement: 0.0 s, 2.0 s, 4.0 s, 6.0 s, 8.0 s, 12.0 s.

time = ... s [1]

(iii) calculate the angular frequency ω of the ball,

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{4.0}$$
$$= 1.57 \text{ rad s}^{-1}$$

ω = ... rad s^{-1} [1]

BP~97

(iv) calculate the maximum acceleration of the ball.

$a_{max} = \omega^2 x_o$
$= (1.57)^2 (0.05)$
$= 0.123 \text{ m s}^{-2}$

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

(b) Some salt is sprinkled on the horizontal surface at t = 12.0 s.

Calculate the loss in total energy of the oscillations during the first 24 s of the oscillations.

Show your working clearly.

At t = 0 s, x_o = 0.05 m

Total $E = \frac{1}{2}mv_{max}^2 = \frac{1}{2}m\omega^2 x_o^2$
$= \frac{1}{2}(0.750)(1.5708)^2(0.05)^2$
$= 2.3132 \times 10^{-3}$ J

At t = 24 s, x_o = 0.0125 m

Total $E = \frac{1}{2}mv_{max}^2 = \frac{1}{2}m\omega^2 x_o^2$
$= \frac{1}{2}(0.750)(1.5708)^2(0.0125)^2$
$= 1.4457 \times 10^{-4}$ J

Loss in Total E = 2.17×10^{-3} J

[3]

[Total: 8]

4 Microwaves of the same wavelength and amplitude are emitted in phase from two point sources X and Y, as shown in Fig. 4.1.

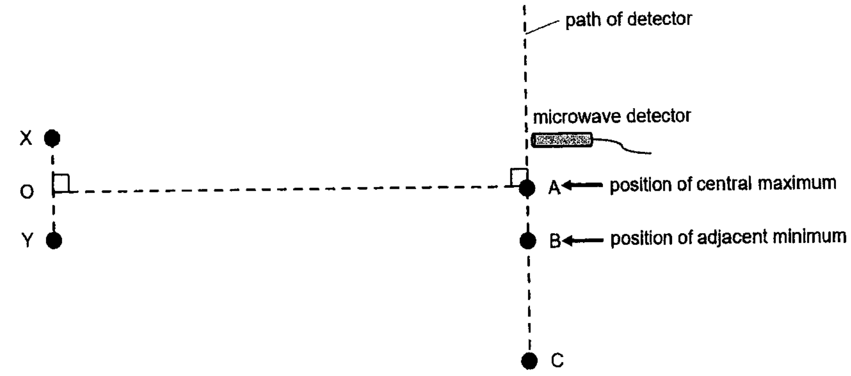


Fig. 4.1 (not to scale)

(a) State and explain along which of the lines XY and OA do the microwaves superpose to produce a stationary wave.

XY. [A1]

Only along XY the microwaves travel in a direction **opposite** to one another. [M1]

Do not accept: "Different direction"

(b) A microwave detector is moved along a line from A to C. The microwave detector gives a maximum intensity reading at A and the first minimum reading at B. The microwaves have a wavelength of 4.0 cm.

For the waves arriving at B, determine the path difference.

B is at position of 1st minima. Hence path difference is 0.5λ.

Path difference = 0.020 m [A1]

path difference = ... m [1]

(c) Describe the effect, if any, on the intensity of the microwave detected at A and B when the following changes are made, separately to the sources X and Y:

(i) when the amplitude of both source X and Y is doubled.

Resultant amplitude is doubled. Intensity is proportional to $(\text{amplitude})^2$. [B1]

Maximum intensity increased by a factor of 4 [B1]

....[2]

(ii) the amplitude of one of the sources is halved.

Resultant amplitude at maxima is 1.5 x_0 and minima at 0.5 x_0. [B1]

Maximum intensity at A becomes 0.5625 or (9/16) times of initial intensity and minimum intensity at B becomes 0.0625 or (1/16) of the initial intensity at A. [B1]

....

....[2]

(iii) the sources are now anti-phase.

the maximum becomes a minimum **and** the minimum becomes a maximum [B1]

the intensity at A and B will swap (B1)

[Total: 8]

5 Fig. 5.1 shows the electric field in the region between two points P and Q. The electric potential at P and at Q are +400 V and –400 V respectively.

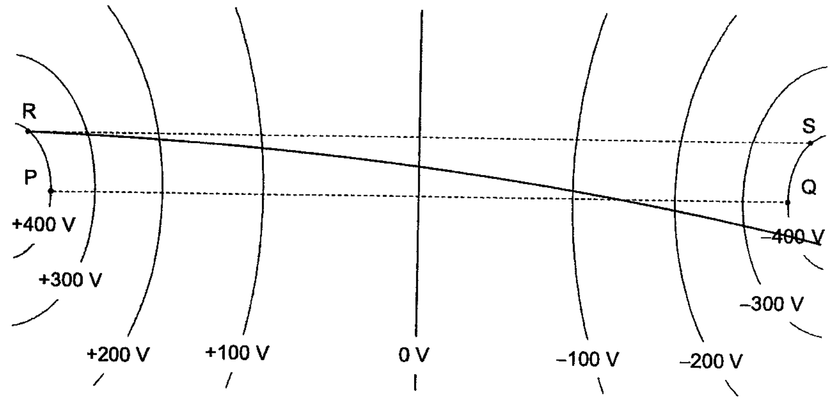


Fig. 5.1

(a) Define *electric potential* at a point.

Electric potential at a point is the work done by external agent per unit positive charge on a small test charge to bring it from infinity to that point, (without change in its kinetic energy.)

....[2]

(b) Describe how the direction and magnitude of the electric field strength varies along the line PQ.

From P to Q, the direction of the field is always towards Q, and the magnitude will decrease to a minimum and then increase.

....[2]

(c) An electron is projected from P towards Q with a speed of 2.2×10^7 m s^{-1}. Calculate its speed when it reaches Q.

Loss in KE = Gain in EPE

$\frac{1}{2} m_e (u^2 - v^2) = q \Delta V \rightarrow \frac{1}{2} \times 9.1\times10^{-31} \times ((2.2\times10^7)^2 - v^2) = 1.6\times10^{-19} \times 800$

$v = 1.4\times10^7$ m s^{-1}

speed = ... m s^{-1} [3]

BP~99

(d) Another electron is projected from R towards S. Explain why this electron will not move in the path RS.

The direction of the electric field is not along the line RS, thus the electron will accelerate in a direction different from its velocity and move in a curved path. [1]

(e) Sketch a possible path taken by the electron in **(d)**. [1]

[Total: 9]

6 **(a)** A cell of e.m.f. 1.5V and internal resistance 0.25 Ω is connected in series with a resistor R, as shown in Fig. 6.1.

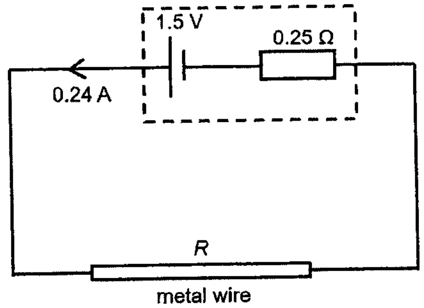


Fig. 6.1

The resistor R is made of metal wire.

A current of 0.24 A passes through R for a time of 5.0 minutes.

Calculate

(i) the charge that passes through the cell,

Q = I t = 0.24 × 5.0 × 60 = 72 C

charge = ... C [1]

(ii) the total energy transferred by the cell,

W = Q V = 72 (1.5) = 108 J

Or

W = I E t = (0.24)(1.5) (5×60) = 108 J

energy = ... J [2]

(iii) the energy transferred in the resistor R,

By conservation of energy,

Energy transferred in R = Total energy – Energy dissipated in 0.25 Ω

= 108 − $I^2 r t$

= 108 − $(0.24)^2$ (0.25)(5.0×60)

= 104 J

[2]

(iv) the resistance of R.

E= I^2 R t 104 = $(0.24)^2$ (R)(5.0×60) R = 6.0 Ω	E = I (R+r) 1.5 = 0.24 (R + 0.25) R = 6.0 Ω

resistance = ... Ω [2]

(b) Two cells identical to the one in **(a)** are now connected in series with a fixed resistor of resistance 2000 Ω and a thermistor, as shown in Fig. 6.2.

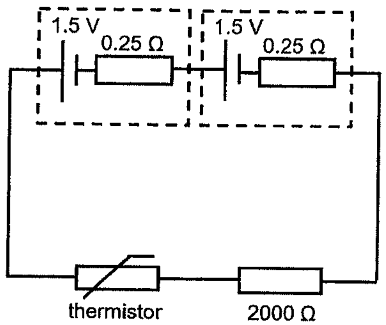


Fig. 6.2

The thermistor has resistance 4000 Ω at 0 °Cand 1800 Ω at 20 °C.

(i) Explain why, in this circuit, the internal resistance of the cells may be considered to be negligible.

The combined resistance of the fixed resistor and thermistor at 20 °C is between 3800Ω and 6000Ω,

while the combined resistance of the internal resistance of the cells is 0.50Ω×2.

Since the external resistance (5800Ω) is much greater than the internal resistance of the cells (0.50Ω), the internal resistance of the cells can be neglected, whereas the external resistance in fig 7.1 is 6.0Ω.

[1]

(ii) In one particular application of the circuit of Fig. 6.2, it is desired that the potential difference across the **fixed** resistor should range from 1.2 V at 0 °C to 2.4 V at 20 °C.

Determine whether it is possible to achieve this range of potential differences.

In order to get that range R would need to be changed to another resistor.

Let the resistor of the fixed resistor be R.

At 0°C, R needs to be 1.2 V

$$\frac{V_R}{E}=\frac{R}{R+4000}$$
$$\frac{1.2}{3.0}=\frac{R}{R+4000}$$
$$R=2700\ \Omega$$

Checking whether 2700 Ω will give 2.4 V at 20°C,

$$\frac{V_R}{E}=\frac{R}{R+4000}$$
$$\frac{V_R}{3.0}=\frac{2700}{2700+1800}$$
$$V_R=1.8\text{ V}$$

Since the same fixed resistor does not give the required range, it is not possible to achieve this range of potential differences.

[3]

11]

BP-101

7 **(a)** Distinguish between the appearance of emission and absorption line spectra.

Emission spectrum consists of coloured lines on a dark background while absorption spectrum consists of dark lines on a coloured spectrum.

.... [2]

(b) The lowest six discrete energy levels for a hydrogen atom are shown in Fig. 7.1, where the ground state is –13.6 eV.

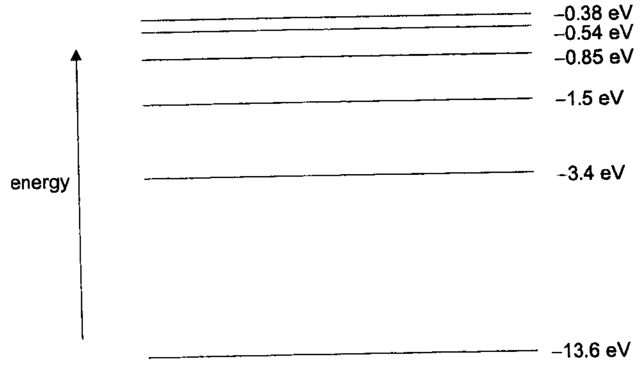


Fig. 7.1 (not to scale)

(i) The spectrum produced by hydrogen is a line spectrum. Use Fig. 7.1 to explain why the spectrum is a line spectrum rather than a continuous spectrum.

Fig. 7.1 shows that the energy levels of electrons within the atom are discrete. Hence the energies of the photons emitted when the electrons de-excite from higher to lower energy levels are discrete as well. Light of a single wavelength and frequency is produced, corresponding to each line on the line spectrum.

.... [2]

(ii) Describe one way by which an electron in gaseous hydrogen can be raised from a ground state to the –0.54 eV energy level.

Electrons can be excited through collision with other particles that possess at least 13.06 eV of energy. OR

Electrons can be excited through absorption of photons with exactly 13.06 eV of energy.

[1]

(iii) State the total number of different wavelengths that may be emitted as the electron de-excites from the –0.54 eV energy level.

5C2 = 10

number = ... [1]

(iv) Electromagnetic radiation is emitted when an electron falls to the ground state from from the –0.54 eV energy level.

Calculate the wavelength of this radiation. Suggest the type of radiation emitted.

$$|E_f - E_i| = \frac{hc}{\lambda}$$

$$|(-13.6+0.54)\times 1.60\times 10^{-19}| = \frac{(6.63\times 10^{-34})(3.00\times 10^{8})}{\lambda}$$

$\lambda = 9.52\times 10^{-8}$ m

ultraviolet

wavelength = ... m

type of radiation = ...

[2]

[Total: 8]

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

Optical Tweezers

In early 1970s, Arthur Ashkin first reported the observation of micron-sized particles being accelerated and trapped in stable optical potential wells by utilising only the radiation pressure caused by continuous laser. This led to the development of a single-beam, gradient force optical trap, commonly known as Optical Tweezers.

Optical tweezers have since been used in fields ranging from fundamental physical sciences to biology, performing single molecule force and motion measurements, and non-invasively manipulating objects such as DNA and live single cells.

Optical tweezers have the ability of applying pico-newton forces to micron-sized particles. In such systems, transparent dielectric particles made of glass or polystyrene are commonly used as they have higher index of refraction than their surrounding medium (typically liquid), thus attracting them toward the region of maximum laser intensity.

An optical trap uses forces exerted by a highly focused monochromatic laser beam in order to trap and manipulate microscopic dielectric objects. The beam is focused through a microscope objective lens in order to produce a narrow beam waist as shown in Fig. 8.1. Dielectric particles suspended in the surrounding liquid medium will be attracted to the centre of the beam waist and towards the optical axis as shown in Fig. 8.2, where it is the region of maximum laser intensity. The laser intensity decreases with distance from the optical axis.

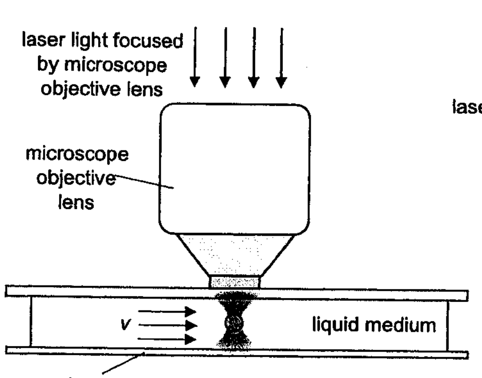


Fig. 8.1

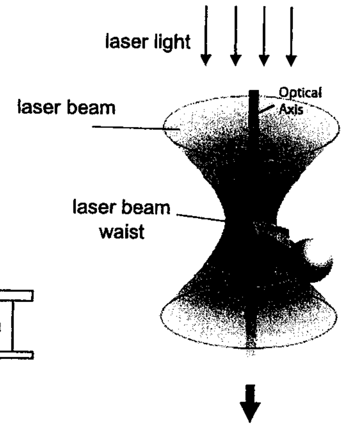


Fig. 8.2

For particles of radius much larger than the wavelength λ of the laser, the Mie scattering approach is utilised. The laser beam is made up of a stream of photons. Some incident photons are reflected by the dielectric sphere, while the rest are refracted through the dielectric sphere. The reflected and refracted processes lead to a change in the momentum of the photons, producing a resultant force on the sphere, which is proportional to the light intensity of the incident laser. With a dielectric sphere of refractive index larger than that of the liquid medium, the refracted light will induce a force in the direction of the intensity gradient, causing the sphere to move towards the centre of the beam waist.

Using the Mie approach, geometric optics is used for the calculation of optical forces. A simplified ray diagram of the refracted laser beam is shown in Fig. 8.3, where two beams G and H pass from a liquid medium through a polystyrene sphere. The sphere experiences a net force towards the centre of the laser waist beam due to both refracted and reflected beams of beams G and H. The sphere will then be stably trapped, with the centre of the sphere aligned with the optical axis.

The force due to the reflected beam may be taken to be negligible, compared to that due to the refracted beam.

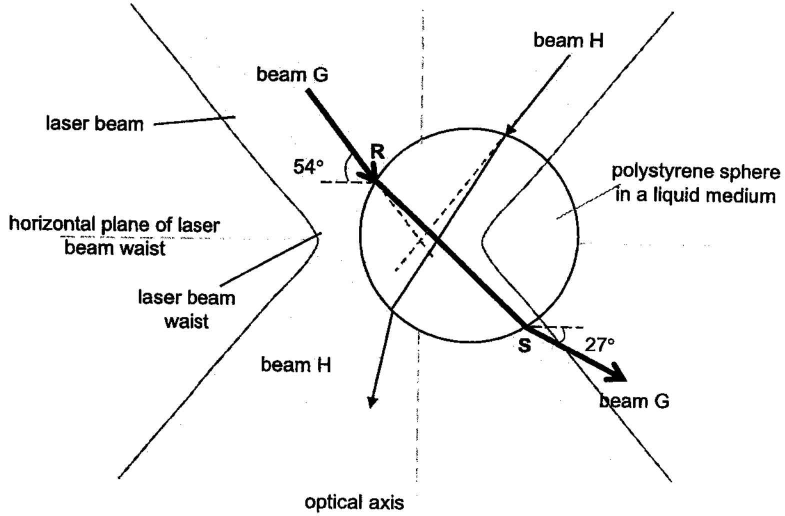


Fig. 8.3 (Reflected beams not drawn)

When the centre of a trapped sphere is displaced by a small displacement Δx from the equilibrium position, there is a restoring force F which obeys Hooke's law where

$$F = k\Delta x$$

and k is the trap stiffness.

The restoring force F can be determined using the Stoke's method, by allowing a fluid of known velocity v to flow past the sphere and measuring the corresponding displacement Δx as shown in Fig. 8.4. The viscous drag F_{drag} acting on the sphere is given by the relationship

$$F_{drag} = 6\pi r\eta v$$

BP~103

where r is the radius of the sphere, η is the fluid viscosity and v is the velocity of fluid flow.

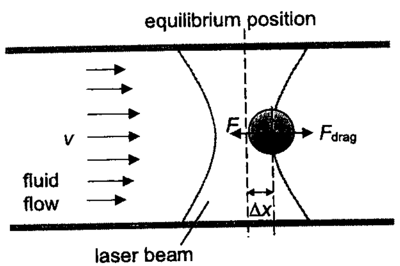


Fig. 8.4

The optical trap can then be calibrated to obtain the trap stiffness k for molecular force measurements.

(a) Suggest why opaque particles are not used for optical tweezer manipulation.

It is because incident light particles will hit the sphere and get reflected, causing a scattering force in the direction of the laser light. Hence no trapping will occur/ no light can be transmitted through the particle and hence no restoring force can be produced. [1]

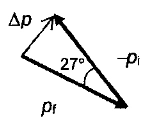
(b) A laser of wavelength 603 nm is used for trapping polystyrene spheres.

With reference to Fig. 8.3, laser beam G with photons of total momentum p_i in unit time is incident on the sphere at R at an angle of 54° to the horizontal, and exits at S with total momentum p_f in unit time at an angle 27° to the horizontal.

(i) For laser beam G, sketch a vector diagram to show the total initial momentum p_i, total final momentum p_f, and total change in momentum Δp of the photons in unit time. Label the vectors clearly.

Correct triangle [B1]

Correct angle [B1]



[2]

(ii) With reference to your answer in **(b)(i)** and using Newton's laws of motion, explain how the refracted laser beam G gives rise to a force acting on the sphere.

There is a change in momentum in unit time of beam G in direction shown in (b)(i). By Newton's second law, there is a force on the laser beam in this same direction as there is a rate of change of momentum. [B1]

By Newton's third law, there is a force equal in magnitude and opposite in direction acting on the sphere. [B1]

[2]

(iii) Calculate the momentum of a single photon.

$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{603 \times 10^{-9}} = 1.1 \times 10^{-27}$ N s

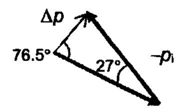
momentum = ... N s [2]

(iv) Using your answer in **(b)(i)**, show that the change in momentum of one photon is 5.14×10^{-28} N s.

$\frac{1.1 \times 10^{-27}}{\sin 76.5°} = \frac{\Delta p}{\sin 27°}$

$\Delta p = 5.1358 \times 10^{-28}$ N s [C1]

$= 5.14$ N s



[1]

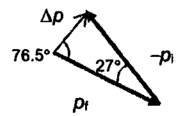
(v) The force on the sphere due to laser beam G is 16 pN.

Hence calculate the number of photons in laser beam G traversing the sphere in unit time.

$F = \frac{N \Delta p}{t}$

$N = \frac{Ft}{\Delta p} = \frac{(16 \times 10^{-12})(1)}{5.3158 \times 10^{-28}}$ [M1]

$= 3.01 \times 10^{16}$ [A1]



number of photons = ... [2]

(vi) Due to laser beams G and H, the sphere experiences a net force of 19 pN towards the centre of the beam waist.

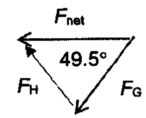
Calculate the magnitude of the force due to beam H.

Calculate angle [C1]

$F_H = \sqrt{F_{net}^2 + F_G^2 - 2(F_{net})(F_G)\cos 49.5°}$

$= \sqrt{19^2 + 16^2 - 2(19)(16)\cos 49.5°}$ [M1]

$= 14.9$ pN [A1]



magnitude of force = ... N [3]

(vii) Suggest why laser beam G produces a larger force on the sphere as compared to laser beam H.

Beam G originates from a region of higher intensity nearer the optical axis, hence there are more photons incident on the sphere as compared to beam H, and hence a larger rate of change of momentum.

....[1]

(c) An optical tweezer system is calibrated using the Stoke's method by trapping a polystyrene sphere of diameter 4.0 μm in liquid as shown in Fig. 8.4. Values for v and Δx are obtained from the experiment and the values are plotted on the graph of Fig. 8.5.

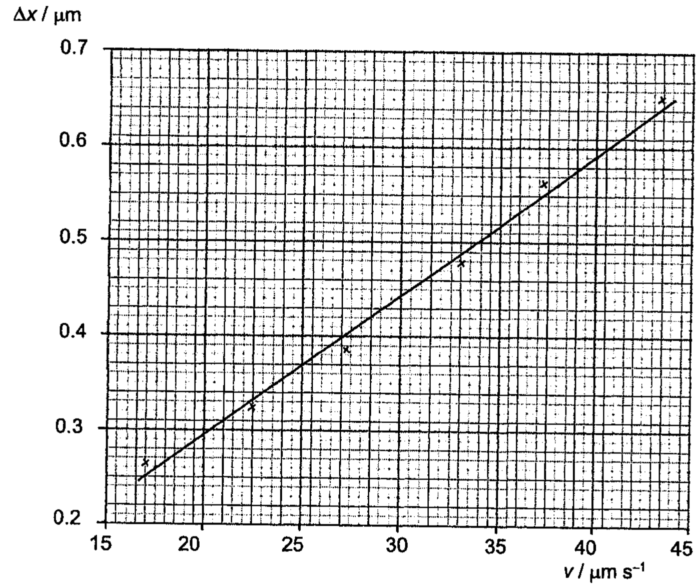


Fig. 8.5

(i) Determine the base units of viscosity η.

$F_{drag} = 6\pi r \eta v$,

Units of η = units of $\frac{F}{rv} = \frac{\text{kg m s}^{-2}}{\text{m m s}^{-1}} = \text{kg m}^{-1}\text{ s}^{-1}$

SI base units = ... [1]

(ii) On Fig. 8.5, draw the line of best fit for all the points. [1]

(iii) Determine the gradient of the line drawn in **(c)(ii)**.

Reading off coordinates from the graph, we have
(17.0, 0.250), (42.0, 0.620)

$\text{Gradient} = \frac{(0.620 - 0.250)\times10^{-6}}{(42.0-17.0)\times10^{-6}}$ [M1]

$= \frac{0.370}{25.0} = 0.0148$ [A1]

gradient = ... [2]

(iv) Hence, determine the trap stiffness k of this optical tweezer system, given that the value of η is 0.890×10^{-3}.

$\text{Gradient} = \frac{6\pi r\eta}{k}$

$0.0148 = \frac{6\pi(2\times10^{-6})(0.890\times10^{-3})}{k}$ [M1]

$k = 2.27\times10^{-6}\text{ N m}^{-1}$ [A1]

k = ... N m⁻¹ [2]

[Total: 20]

End of Paper

BP~105

H

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 2022

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	/ 8
2	/ 12
3	/ 8
4	/ 9
5	/ 6
6	/ 9
7	/ 8
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 × 10^{8} m s^{-1}
permeability of free space	μ_0 = 4π × 10^{-7} H m^{-1}
permittivity of free space	ε_0 = 8.85 × 10^{-12} F m^{-1}
	(1 / (36π)) × 10^{-9} F m^{-1}
elementary charge	e = 1.60 × 10^{-19} C
the Planck constant	h = 6.63 × 10^{-34} J s
unified atomic mass constant	u = 1.66 × 10^{-27} kg
rest mass of electron	m_e = 9.11 × 10^{-31} kg
rest mass of proton	m_p = 1.67 × 10^{-27} kg
molar gas constant	R = 8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A = 6.02 × 10^{23} mol^{-1}
the Boltzmann constant	k = 1.38 × 10^{-23} J K^{-1}
gravitational constant	G = 6.67 × 10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g = 9.81 m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

BP~107

Section A

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

1 Fig. 1.1 shows a man standing on a stationary sailboard floating in the sea. The sailboard consists of a surfing board, mast and sail.

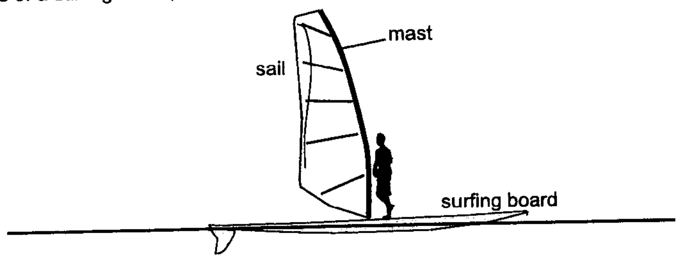


Fig. 1.1

(a) The total mass of the sailboard and the man is 90 kg. Taking the density of seawater to be 1020 kg m^{-3}, calculate the volume of seawater displaced by the sailboard.

$\Sigma F = 0$

$U - mg = 0$

$V\rho g = mg$

$V = \dfrac{90}{(1020)} = 0.088\ \text{m}^3$

volume of seawater displaced = ... m^3 [2]

Comments: A significant number of students did not show evidence of resultant force is zero. Hence presentation of answers is important in this question in general.

(b) The sailboard then cruises at constant speed. Fig. 1.2 shows some of the forces acting on the mast and sail of the sailboard.

The uniform mast has length 4.3 m and the base of the mast is connected to the surfing board by a smooth hinge. The wind exerts a force of 200 N on the sail, perpendicular to the mast at a distance 3.5 m away from the hinge.

The man pulls the sail with a force T at distance 1.5 m away from the hinge and the weight of the mast and sail is 50 N.

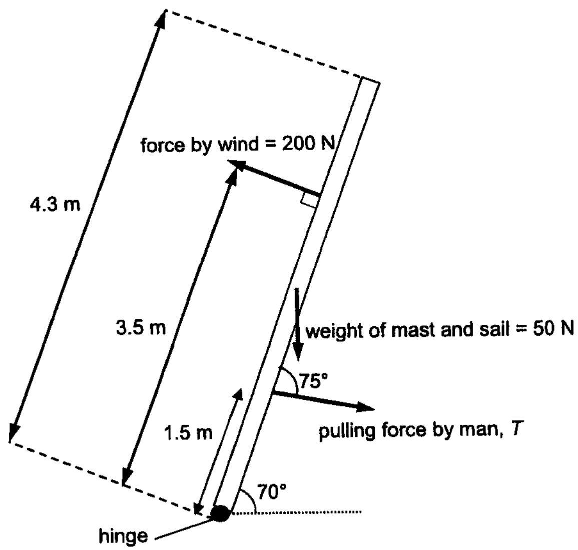


Fig. 1.2

(i) Show that pulling force T by the man is 460 N.

$\sum \tau_{hinge} = 0$

$200(3.5) - (50)(2.15\cos 70°) - T\sin 75°(1.5) = 0$

$T = 460\ \text{N}$

[2]

(ii) Determine the magnitude of the force, R, exerted by the hinge.

$\sum Fy = 0$ $\sum Fx = 0$

$200\cos 70° - 50 - 460\sin 5° + Ry = 0$ $Rx - 200\sin 70° + 460\cos 5° = 0$

$Ry = 21.7$ N $Rx = -270$ N

$R = \sqrt{(270)^2 + (21.7)^2} = 271$ N

magnitude of R = ... N [3]

Comments: A significant number of students are able to get full credit for this question even though it is quite mathematically challenging.

(c) The surfing board is designed with the foot straps at the rear part of the board rather than at the centre part of the board, as shown in Fig. 1.3.

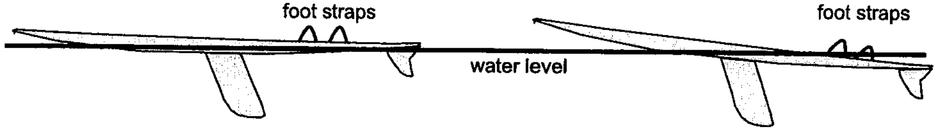


Fig. 1.3

Such a design allows the surfing board to move across the water surface while inclined at an angle to the surface.

Suggest why when the man is moving horizontally with the board at an incline, the volume of seawater displaced by the sailboard is lower than your answer in **(a)**.

As the surfboard move across the water surface inclined at an angle, there will be water continuously changing direction as it come into contact with the surf board. By Newton 2nd law, there is a rate of change in momentum resulting in a force acting iin the downward direction. Hence by Newton's 3rd law, there is upwards force acting acting on the surf board. Hence the upthrust can be smaller causing water displaced to decrease. [1]

[Total: 8]

Comments: This part prove to be challenging for the large majority of students.

2 **(a)** Planets have been observed orbiting a star in another solar system. Measurements are made for the orbital radius r and the time period T of each of these planets.

The variation with r^3 of T^2 is shown in Fig. 2.1.

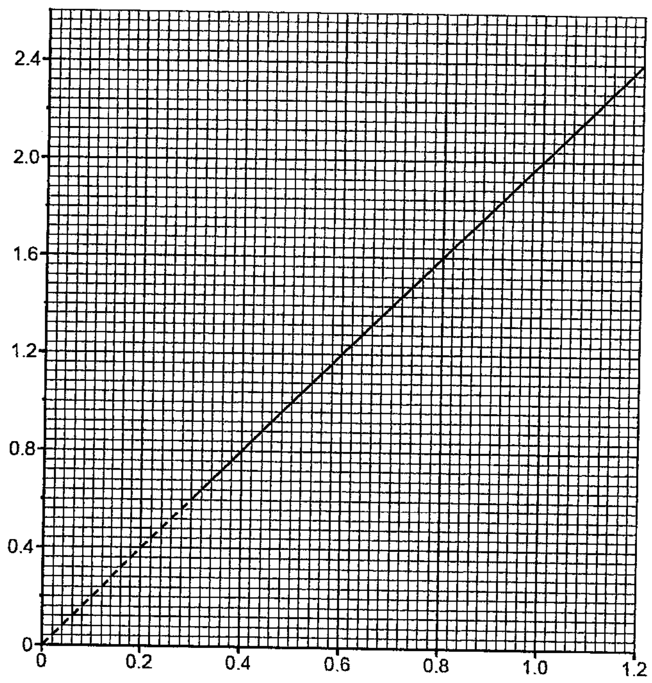


Fig. 2.1

The relationship between T and r is given by

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where G is the gravitational constant and M is the mass of the star.

BP~109

(i) Determine the mass M of the star.

Gradient = $\frac{2.4-0}{(1.2-0)\times10^{34}} = 2.0\times10^{-34}$

$\frac{4\pi^2}{GM} = 2.0\times10^{-34}\times(365\times24\times60\times60)^2$ [1]

M = 2.98 x 10^{30} kg or in 2 sf [1]

M = ... kg [2]

(ii) The radius of the star is 700 000 km. Determine the minimum speed with which gas particles from its surface have to be ejected to just escape from the star's pull of gravity.

By Conservation of Energy,

Initial KE + initial GPE at surface = Final KE + final GPE at infinity

½ mv_{escape}^2 + (-GMm/r) = 0

v_{escape} = $(2GM/r)^{1/2}$ = 7.53 x 10^5 m/s

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

(iii) Hydrogen gas, consisting of hydrogen-2 particles, may be assumed to be an ideal gas. If the surface temperature of the star is 6000 K, determine whether hydrogen gas

(Find speed of hydrogen-2 particles)
½ mv^2 = 3/2 kT
½ (2 x 1.66 x 10^{-27}) v^2 = 3/2 (1.38 x 10^{-23})(6000) [1]
v = 8630 ms^{-1} < v_{esc} = 7.53 x 10^5 m/s^{-1} , particles cannot escape [1]

Or
(Find initial KE required to escape)
KE required = ½ mv_{escape}^2 = ½ (2 x 1.66 x 10^{-27})(7.53 x 10^5)^2 = 9.41 x 10^{-16} J
KE of gas particles = 3/2 (1.38 x 10^{-23}) (6000) = 1.242 x 10^{-19} J [1]
Since KE of particles is less than that required, particles cannot escape. [1]

[2]

(iv) Some gas particles have very large kinetic energy to be able to escape from the star.

Given that the star is rotating about an axis through its poles, suggest why the gas particles at the equator of the star are more likely to escape the surface than those at the poles.

Gas particles at the equator is furthest away from this axis of rotation/largest radius of rotation. [1]
Hence particles at the equator has the largest speed of rotation [1]
and may exceed the minimum speed to escape the star's surface

[2]

(b) A satellite of mass m is also in orbit around the star in (a). The radius of the orbit is r.

(i) Show that the kinetic energy E_k of the satellite is given by

$$E_k = \frac{GMm}{2r}.$$

Gravitational force by star on satellite provides for the centripetal force on the satellite

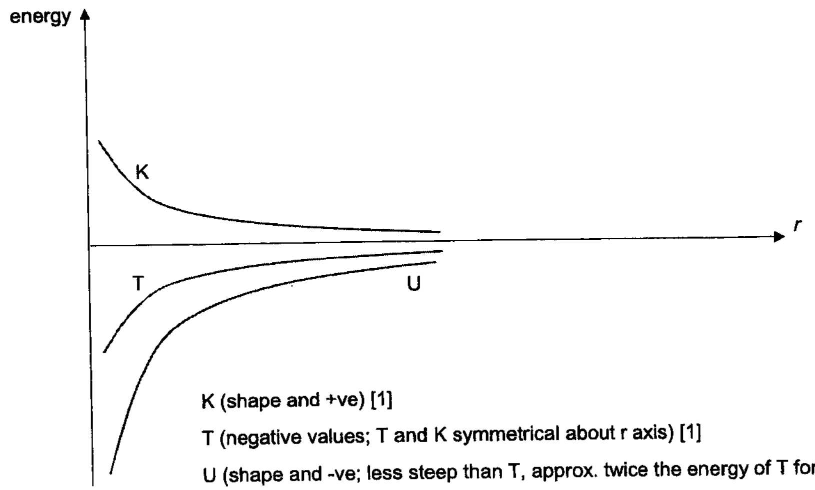
By Newton's 2nd Law,
∑F = ma_c
GMm/r^2 = mv^2/r
½ mv^2 = ½ GMm/r

[1]

(ii) On Fig. 2.2, sketch graphs to show the variation with orbital radius r of the

1. gravitational potential energy of the satellite. Label the graph U.
2. kinetic energy of the satellite. Label the graph K.
3. total energy of the satellite. Label the graph T.

[3]



K (shape and +ve) [1]
T (negative values; T and K symmetrical about r axis) [1]
U (shape and -ve; less steep than T, approx. twice the energy of T for each r) [1]

Fig. 2.2

[Total: 12]

3 A roller coaster ride in an amusement park consists of an unpowered car moving freely along a smooth track. Fig. 3.1 shows the roller coaster car moving with speed v at the top of a vertical loop with radius R. Ignore any resistive forces on the car.

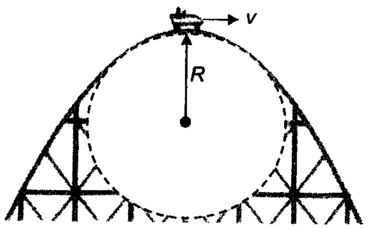


Fig. 3.1

(a) For the car to remain in contact with the track at the top of the loop, show that the maximum speed v_{max} of the car is

$$v_{max} = \sqrt{Rg}.$$

Explain your working.

At top of loop,

$mg - N = mv^2/R$ → $N = mg - mv^2/R$ [1] (using N2L)

For car to remain in contact, $N \geq 0$ [1]

→ $mv^2/R \leq mg$ [1]

So max speed at the top is such that $v_{max}^2/R = g$

[3]

(b) The entire roller coaster ride consists of two of such vertical loops with positions A and B as shown in Fig. 3.3. The two loops have radii R_1 and R_2 respectively.

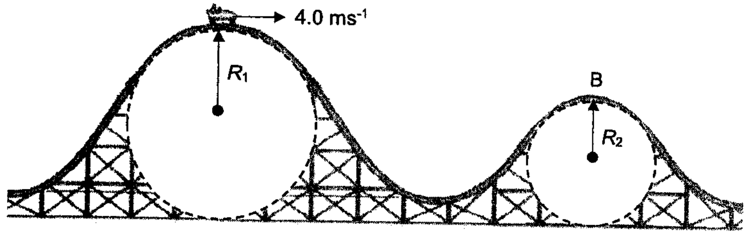


Fig. 3.3

During a test run, the car has a speed of 4.0 m s^{-1} at A where radius of the first loop R_1 is 15 m. Determine the minimum radius R_2 so that the car will remain in contact with the track throughout its journey.

To remain in contact at B,

$v_B = (R_2 g)^{1/2}$ [1]

By COE,

$\frac{1}{2} mv_B^2 = \frac{1}{2} mv_A^2 + mg(2R_1 - 2R_2)$ [1]

$\frac{1}{2} m(R_2 g) = \frac{1}{2} mv_A^2 + mg(2R_1 - 2R_2)$ → $\frac{1}{2} gR_2 + 2gR_2 = \frac{1}{2}(16) + 2g(15)$

→$R_2 = 12$ m [1]

R_2 = ... m [3]

(c) Fig. 3.4 shows the car when it is at position C after it leaves A.

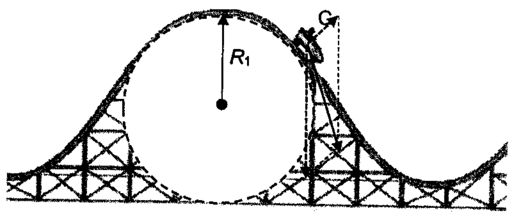


Fig. 3.4

On Fig. 3.4, draw an arrow to show the resultant force on the car at point C. Explain your answer.

The resultant of the weight and normal contact force has a radial component to produce the centripetal acceleration and a tangential component to increase the speed. [1]

Direction of arrow between direction of weight and of tangential velocity [1]

[2]

[Total: 8]

BP~111

BP-112

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

It is a gas that **obeys** the equation of state $PV=nRT$ for **all values** of pressure P, volume V and temperature T for a fixed amount n of gas.

......[1]

(b) A fixed mass of ideal gas has a volume of 210 cm^3 at pressure 3.0 × 10^5 Pa and a temperature of 35 °C.

(i) State and explain the assumption of the kinetic theory that allows a gas to maintain its temperature.

The assumption is all collisions are elastic.

If the collisions are elastic, total kinetic energy of the gas molecules will be constant ~~Hence the average kinetic energy will also be~~ constant resulting in the temperature remains constant. ......[2]

(ii) The volume of the gas is then reduced at constant pressure to 140 cm^3 by a moving piston. Determine the final temperature of the gas.

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

$$\frac{210}{35+273}=\frac{140}{T_2}$$

$$T=205\text{ K}$$

temperature of gas = ... K [2]

(iii) Calculate the average kinetic energy of a gas molecule at this final temperature.

$$E_k=\frac{3}{2}kT=\frac{3}{2}(1.38\times10^{-23})(205)$$

$$=4.24\times10^{-21}\text{ J}$$

average kinetic energy = ... J [2]

(iv) Using the first law of thermodynamics, explain whether heat is supplied to or released by the gas.

Positive work is done on the gas during compression. Since temperature of the gas decreases, its internal energy also decreases. Therefore the change in internal energy is negative. By the first law of thermodynamics, heat transfer will be negative resulting in heat released by the gas.

......[2]

[Total: 9]

5 Source S_1, consisting of parallel light with wavelength 700 nm, is incident on a rectangular slit of width b, as shown in Fig. 5.1.

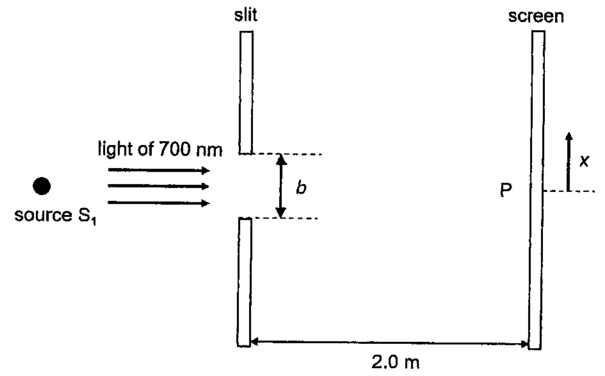


Fig. 5.1 (not to scale)

(a) A central maxima is observed on the screen and its width is found to be 4.0 mm. Calculate the width *b* of the single slit.

Since θ is small, $\theta = \frac{\lambda}{b} = \tan\theta = \frac{x}{D}$

$\frac{700\times10^{-9}}{b} = \frac{0.002}{2.0}$ [C1]

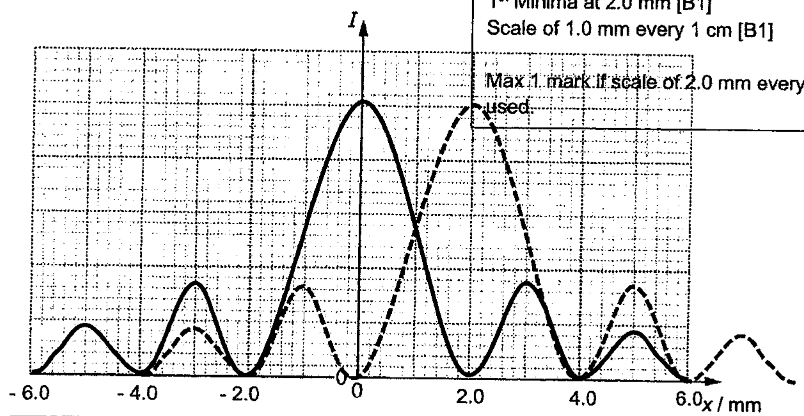
$b = 7.0\times10^{-4}\ m$ [A1]

Comment
Poorly done. A number of candidates do not remember that *x* is half the width of the central maxima.

(b) Fig. 5.2 shows the variation with distance *x* from P of the intensity *I* of the red light on the screen. Label, on Fig. 5.2, the values of the six *x*-intercepts. [2]

1st Minima at 2.0 mm [B1]
Scale of 1.0 mm every 1 cm [B1]

Max 1 mark if scale of 2.0 mm every 1 cm is used.



Comment
Poorly done. Candidates equated slit width with width of central maxima which is conceptually wrong. Uneven scaling of x axis is observed. Many missed this question.

(c) A

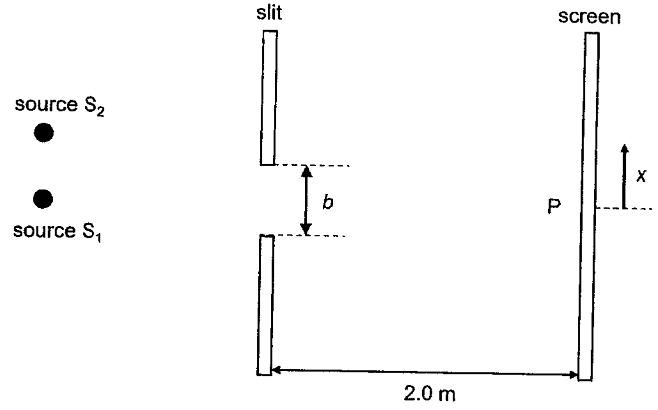


Fig. 5.3 (not to scale)

Sketch, on Fig. 5.2, the variation with distance *x* from P of the intensity *I* of the second source S_2 when Rayleigh criterion is satisfied. [2]

[Total: 9]

Central maxima of new diffraction envelop at first minima of original diffraction envelop [B1]

1st Minima of new diffraction envelop at central maxima AND 2nd minima of original diffraction envelop [B1] – rephrase using terms in Rayleigh's criterion.

Comment
Very poorly done. Candidates did not read question and drew on Fig. 5.3 instead. Curve was drawn without regards to Rayleigh Criterion. Awkwardly shaped graphs and unsymmetrical graphs are observed. Many missed this question.

6 **(a)** Define *magnetic flux.*

Comment
Very poorly done. Confusion between magnetic flux density, magnetic flux and magnetic flux linkage is common. Magnetic field is insufficient as it describe a region and not quantify the strength.

The magnetic flux through a plane surface is the product of the component of the magnetic flux density normal to the surface and the area of the surface.

BP~113

....[2]

(b) A uniform conducting bar XY is pulled horizontally across long parallel frictionless conducting guide rails by a light inextensible string. The string passes over a frictionless pulley and is attached to a hanging block. The guide rails are placed in a vertical magnetic field of uniform magnetic flux density as shown in Fig. 6.1.

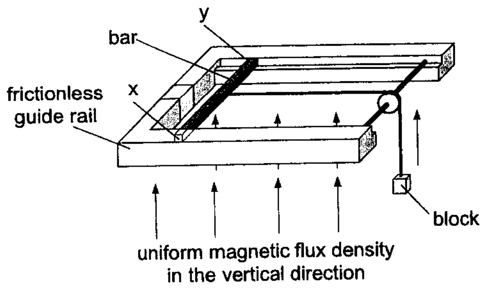


Fig. 6.1

The block is released from rest at time $t = 0$ s, and the bar starts to move.

(i) An e.m.f. is induced in the bar. State which end X or Y of the bar is at a higher potential.

End X of the rod is at a higher potential. ....[1]

> Comment
> Mainly guess work.

(ii) Use Faraday's law and Lenz's law to explain the subsequent motion of the bar.

When the bar accelerates, the velocity increases and there is a change (increase) in magnetic flux linkage through the area enclosed by the rod and the conducting rails because the area is changing (increasing) OR cutting of flux/cutting of magnetic field lines. [B1]

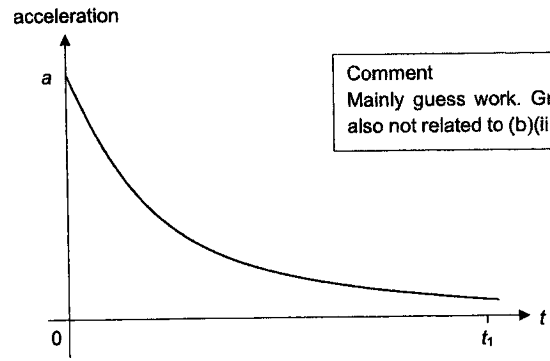
By Faradays law, there is an e.m.f induced and by Lenz's law, a current is induced in a clockwise direction viewed from above to oppose the change in the magnetic flux linkage. [B1]

Hence by Fleming's left hand rule, a magnetic force is experienced by the bar towards the left, hence decreasing its acceleration/decreasing the net force acting on it. [B1]

Hence the speed of the bar increases at a decreasing rate. [B1]

> Comment
> Very poorly done. Majority failed to support change in flux linkage due to change in area of loop. Magnetic flux linkage is a scalar there should not be direction associated with it which is seen in many answers. Faraday's Law and Lenz Law are just stated without linking it to context of question. Faraday's Law do not account for induced current. Lenz Law (in this context) only used to oppose increase in magnetic flux linkage, it is incorrect to say that magnetic flux linkage is reduced. It should account for induced e.m.f. only. Many answers failed to describe direction of induced current adequately. Common misconception that reduction in net force result in deceleration when in fact it only leads to smaller acceleration. Many failed to describe motion of bar adequately to score.

On Fig. 6.2, sketch a graph to show the variation with time t of the acceleration of the rod from $t = 0$ to time $t = t_1$. Label clearly the acceleration at $t = 0$ as a.



> Comment
> Mainly guess work. Graph plotted are also not related to (b)(ii) when it should.

[B1] Shape of curve.
[B1] Start from a positive value, labelled a.

[2]

[Total: 6]

7 (a) A beam of electrons is accelerated through a potential difference of 130 V and is then incident on a thin silicon crystal.

(i) State what is meant by *de Broglie wavelength*.

A particle/electron has a wavelength (associated with it) which is dependent on its momentum.

....

....[1]

(ii) Show that the de Broglie wavelength of the electrons is 1.08×10^{-10} m.

By conservation of energy, Loss in Electric PE = Gain in KE

$$q\Delta V = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

$$(1.60\times10^{-19})(130) = \frac{p^2}{2(9.11\times10^{-31})}$$

$$p = 6.1561\times10^{-24}$$

$$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{6.1561\times10^{-24}} = 1.08\times10^{-10}\text{ m}$$

[3]

(b) A fluorescent screen is positioned 12 cm away from the silicon crystal as shown in Fig. 7.1. The separation of silicon atoms in a silicon crystal is 0.235 nm.

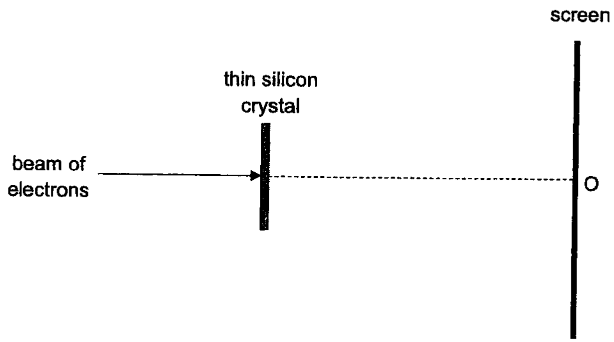


Fig. 7.1

(i) Explain why electron diffraction will be observed on the fluorescent screen.

The separation of the silicon atoms is in the same order of magnitude as the de Broglie wavelength of the electrons. Hence effect of diffraction is appreciable/significant.........[1]

(ii) Electrons are observed in the straight-through direction at position O as shown in Fig. 7.1 and Fig. 7.2. Assume that the silicon crystal acts as a diffraction grating.

Draw to scale, on Fig. 7.2, the resulting diffraction pattern for the 1st order maxima. Show your working.

For electron diffraction,

$$d\sin\theta = n\lambda$$

$$(0.235\times10^{-9})(\sin\theta) = 1(1.08\times10^{-10})$$

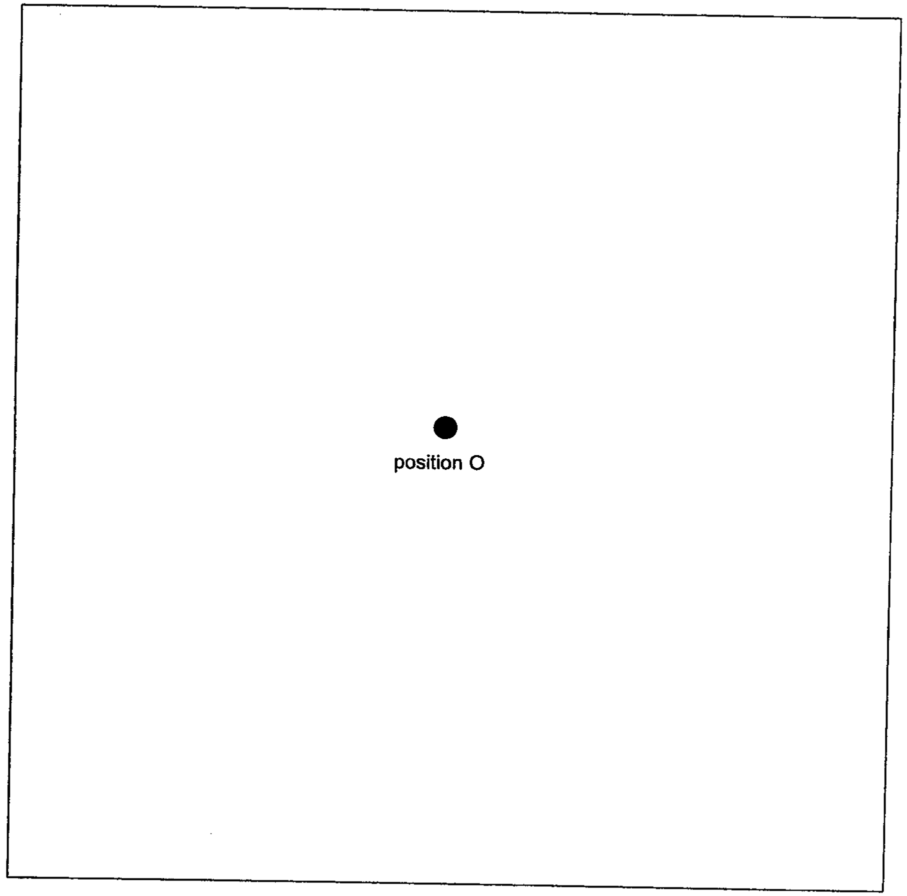


Fig. 7.2

[3]

[Total: 8]

Section B

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

8 Fig. 8.1 shows a thin iron strip of length 8.0 cm, width 2.0 cm and thickness 2.0 mm. As iron is a conductor of electricity, it contains free electrons, one of which is shown in Fig. 8.1.

BP-115

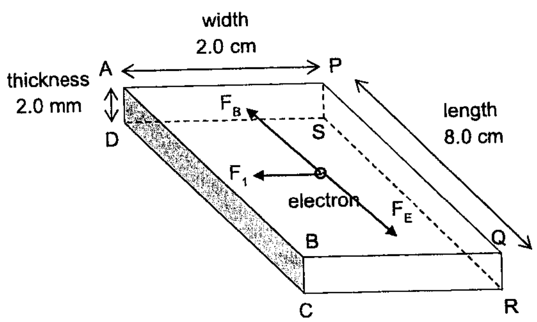


Fig. 8.1

(a) A small potential difference is applied to the iron strip such that face ABCD is at a potential 12 mV higher than face PQRS.

(i) Draw, on Fig. 8.1, an arrow to show the direction of the force on the free electron. Label as F_1. [1]

(ii) Calculate the magnitude of the force in **(a)(i)**.

$E = V / d = 12\times10^{-3} / 0.020 = 0.60$ N C^{-1}

$F = q E = 1.6\times10^{-19} \times 0.60 = 9.6\times10^{-20}$ N

force = ... N [2]

(iii) Determine the change in the electric potential energy of the electron when it moves across the entire width of the strip.

Loss in EPE = $q V = 1.6\times10^{-19} \times 12\times10^{-3} = 1.9\times10^{-21}$ J

change in electric potential energy = ... J [2]

(b) Iron has a resistivity of 9.7×10^{-8} Ω m and an electron density of 8.8×10^{28} m^{-3}.

(i) Calculate the current in the iron strip when there is a potential difference of 12 mV across faces ABCD and PQRS.

$R = \rho L / A = 9.7\times10^{-8} \times 0.020 / (0.080 \times 0.0020) = 1.21\times10^{-5}$ Ω

$I = V / R = 12\times10^{-3} / 1.21\times10^{-5} = 990$ A

current = ... A [3]

(ii) Hence, show that the drift velocity of the electrons is 4.4×10^{-4} m s^{-1}.

$I = n A v e$

$990 = 8.8\times10^{28} \times (0.080 \times 0.0020) \times v \times 1.6\times10^{-19}$

$v = 4.39\times10^{-4}$ m s^{-1}

[1]

(c) A magnetic field of flux density 20 mT is now applied in the downward direction into face ABQP.

(i) Explain what is meant by a magnitude of *20 mT*.

A force per unit length of 20 mN m^{-1} is exerted by the magnetic field on a long conductor carrying 1 A of current placed perpendicular to the magnetic field.

.... [1]

(ii) Draw, on Fig. 8.1, an arrow to show the direction of the force exerted by the magnetic field on the electron. Label as F_2. [1]

(iii) Calculate the magnitude of the force in **(c)(ii)**.

$F = B q v = 20\times10^{-3} \times 1.6\times10^{-19} \times 4.4\times10^{-4} = 1.41\times10^{-24}$ N

force = ... N [2]

(iii) Explain why a potential difference develops across faces APSD and BQRC.

The magnetic force on electrons is parallel to PQ, causing them to drift in the direction of the force. Due to the resulting difference in number density of electrons across the two ends, an electric field is set up across the two faces. [1]

(iv) Draw, on Fig. 8.1, an arrow to show the direction of the force due to the potential difference in **(c)(iii)** on the electron. Label as F_3. [1]

(v) The potential difference in **(c)(iii)** eventually reaches a steady value. State the magnitude of the resultant force on the electron that acts along the length of the strip.

resultant force = zero N [1]

(vi) Hence calculate the value of the potential difference in **(c)(iii)**.

$F_E = F_B$

$1.6\times10^{-19} \times V / 0.080 = 1.41\times10^{-24}$ N

$V = 7.04\times10^{-7}$ V

potential difference = ... V [2]

(vii) Briefly explain how this iron strip can be used to determine the direction of a different magnetic field in another region.

Change orientation of strip until p.d. across APSD and BQRC is maximum. (The magnetic field is normal to the face APQB.)

If APSD is at higher potential, the magnetic field is directed towards APQB. If APSD is at lower potential, the magnetic field is directed towards DSRC. [2]

[Total: 20]

9 (a) Radioactive decay is a random and spontaneous process.

Explain what is meant by

(i) a *random* process,

It is a process in which it cannot be predicted which nuclide will decay at a particular instant or when any particular nuclide will decay. [1]

(ii) a *spontaneous* process.

It is a process which it is not triggered or affected by external factors such as temperature and pressure. [1]

(b) An unstable nucleus of mass number A undergoes α-decay, as illustrated in Fig. 9.1.

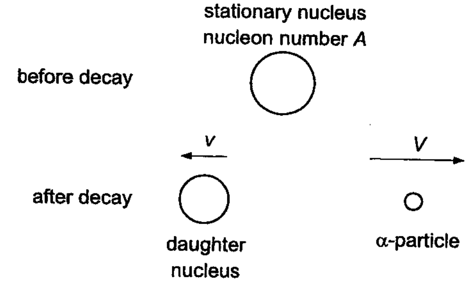


Fig. 9.1

The nucleus is stationary before the decay.

After the decay, the initial speed of the α-particle is V and that of the daughter nucleus is v.

(i) Derive an equation, in terms of A, v and V, to represent conservation of linear momentum for this decay.

....[1]

$\Sigma p_{initial} = \Sigma p_{final}$

$0 = 4V + (A-4)\,v$

$\frac{V}{v} = \frac{A-4}{4}$ [1]

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(ii) Show that the ratio

$$\frac{\text{initial kinetic energy of } \alpha-\text{particle}}{\text{initial kinetic energy of daughter nucleus}}$$

is equal to (¼ A – 1).

$$\frac{\text{initial KE of } \alpha\text{-particle}}{\text{initial KE of daughter nucleus}} = \frac{\frac{1}{2}(4)v^2}{\frac{1}{2}(A-4)V^2}$$ [1] ratio

$$= \frac{4}{A-4}\left(\frac{v}{V}\right)^2$$

$$= \frac{4}{A-4}\left(\frac{A-4}{4}\right)^2$$

$$= \frac{A-4}{4}$$ [1] subst

$$= \frac{1}{4}A-1$$

[2]

(c) Data for the α-decay of bismuth-212 ($^{212}_{83}Bi$) to form thallium-208 ($^{208}_{81}Tl$) are given in Fig. 9.2.

nucleus	mass of nucleus / u
bismuth-212	211.9459
thallium-208	207.9374
helium-4	4.0015

Fig. 9.2

(i) Use the data of Fig. 9.2 to calculate, to two places of decimals, the energy released during the decay.

total rest mass of reactants = 211.9459 u [1] mass diff/u

total rest mass = 207.9374 u + 4.0015 u [1] to kg

mass difference = 0.007 u [1] to J

energy released/J = $0.007\times(1.66\times10^{-27})\times(3.0\times10^{8})^2$ [1] to MeV

energy released/MeV = $0.007\times(1.66\times10^{-27})\times(3.0\times10^{8})^2/(1.6\times10^{-19}) = 6.54$

energy = ... MeV [4]

(ii) Use your answer in **(c)(i)** to show that, based on the expression in **(b)(ii)**, the energy of the α-particle is 6.42 MeV.

$$\frac{\text{initial KE of α-particle}}{\text{initial KE of Tl}} = \frac{1}{4}(212)-1$$

$$\frac{\text{initial KE of α-particle}}{\text{total initial KE- initial KE of α-particle}} = 53$$

initial KE of α-particle = 53 (total initial KE- initial KE of α-particle)

= 53 (6.54- initial KE of α-particle)

= 6.42 MeV

[2]

(d) In practice, the α-particle is found to have an energy of 6.10 MeV, rather than 6.42 MeV, as calculated in **(c)(ii)**.

Suggest

(i) an explanation for the difference in energy,

The energy released in a nuclear reaction are in the form of the kinetic energy of the product particles or energy of an emitted γ photon. Since KE of the product particles is smaller than the total energy lost in the reaction, this implies there is an emission of γ -photon(s).

....

....[1]

(ii) why it is likely that the thallium nucleus and the α-particle do not move off in opposite directions.

Since there is emission of gamma photon(s), the total momentum of zero would include the momentum of the gamma photon(s) as well as the momentum of the thallium nucleus and that of the α-particle . The thallium nucleus and particles need not move off directly in opposite, they could move in other directions such that the vector sum of momentum of the thallium nucleus, α- particle and gamma photon(s) is zero.

....

....

....

....[2]

(e) Some data for the half-lives and decay constants of bismuth-212 and thallium-208 are given in Fig. 9.3.

nucleus	half-life / s	decay constant / s^{-1}
bismuth-212	....	1.9×10^{-4}
thallium-208	190	3.7×10^{-3}

Fig. 9.3

(i) Define *half-life*.

......The half life t1/2 of a quantity is defined as the time taken for the quantity to... decrease to half of its initial value. ......[1]

(ii) Complete Fig. 9.3 by calculating the half-life of bismuth-212.

$T_{1/2}$ of bismuth 212 = 0.693/ □ = 0.693/ 1.93 x 10^{-4}

[1]

(iii) Initially, a radioactive source contains *N* nuclei of bismuth-212.

After two hours, it is found that the number of bismuth-212 nuclei has reduced to approximately ¼ *N*. However, although bismuth-212 decays to form thallium-208, the number of thallium nuclei is much less than ¾ *N*.

Suggest an explanation for these observations.

Based on the data given, the half life for bismuth 212 is 3700 s while the hale life for thallium 208 is only 190 s. Hence half life for bismuth 212 is significantly larger than half life for thallium 208.

~~Hence in the first 190 s of decay, the number of bismuth 212 will remains~~ approximately the same while the number of thallium 208 will have reduced by half.

After two hours, bismuth -212 would have gone through about 2 half lives, ~~hence the number of bismuth 212 is about N/4. But thallium 208 is not a~~ ......[4] stable nucleus, hence the number of thallium after two hours must be less than 3/4N. [Total: 20]

Since thallium 208 only have a half life of 190 s, after 2 hours, the number of thallium would have reduced greatly and hence much less than 3/4N.

End of Paper

BP~119

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

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

PHYSICS

9749/04

Paper 4 Practical

15 August 2022

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name, class, tutor's name, 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.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details on the practical shift and laboratory, where appropriate, in the boxes provided.

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.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
Total	**/ 55**

This document consists of **17** printed pages.

1 Many electrical components have to function properly in conditions of extreme temperature and moisture content. In this experiment you will maintain a diode at 5 °C and investigate how the current in it varies as the potential difference across it is changed

(a) Set up the circuit shown in Fig. 1.1. The resistor R is to prevent current overload in the diode.

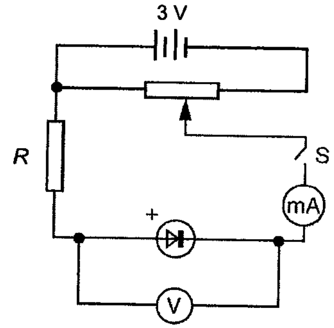


Fig. 1.1

(b) Put 50 ml of water into the beaker. Place the diode in the water.

Close Switch S.

Add a quantity of ice to the water in the beaker. Stir the ice/water mixture gently using the thermometer until the temperature is at, or close to, 5 °C.

(i) Record the temperature of the ice/water mixture. You are to maintain this temperature to be within 2 °C of your recorded temperature for the rest of the experiment.

temperature of ice/water mixture = 2.0 °C [1]

- Temperature recorded to 1 d.p. in degree celsius

(ii) Adjust the slider of the rheostat until the potential difference V across the diode is 0.70 V. Measure and record the current I.

I = 9.2 mA [1]

- current less than 25 mA

BP~121

BP~122

(c) Vary V and repeat **(b)(ii)**.
Present your results clearly.

V /V	I / mA	ln (I / mA)
0.70	9.2	2.22
0.75	18.8	2.934
0.77	25.0	3.219
0.81	41.9	3.735
0.85	69.6	4.243
0.90	130.3	4.8698

Marking points:
- 6 sets of data points [1]
- Column headings: Each column heading must contain a quantity and a unit where appropriate. [1]
- V recorded to 2 d.p. and I recorded to one d.p. in mA [1]
- Significant figures: d.p. of ln (I) follows s.f. and calculated correctly. [1]
- Plotting of points: All observations must be plotted on the grid and Points must be plotted to an accuracy of half a small square.[1]
- Line of best fit: There must be an even distribution of points either side of the line along the full length. Allow one anomalous point only if clearly indicated (i.e. circled or labelled) by the candidate. [1]

(d) (i) The current I in the diode and potential difference V across it are related by the expression

$$I = I_0 e^{qV}$$

where q and I_0 are constants.

Plot a suitable graph to determine the values of q and I_0.

$\ln I = \ln I_o + qV$

Plot $\ln I$ against V where gradient is q, and y-intercept is $\ln I_o$

$$\text{Gradient} = \frac{(5.50 - 2.50)}{(0.940 - 0.720)} = \frac{3.00}{0.270} = 13.6$$

Using (0.940, 5.50)

$$Y = (\text{gradient})X + (\text{y - intercept})$$
$$5.50 = (13.6 \times 0.940) + \text{y - intercept}$$
$$5.50 = 12.8 + \text{y - intercept}$$

y-intercept = –7.3

q = gradient = 13.6 V^{-1}

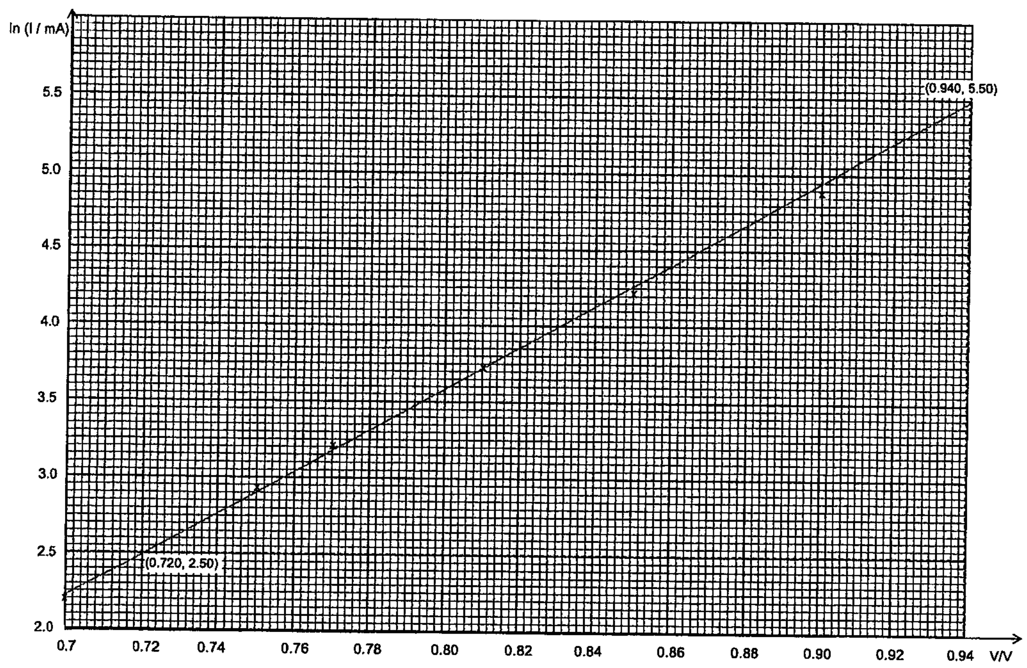
$\ln I_o$ = y-intercept = – 7.3
$I_o = e^{-7.3} = 7 \times 10^{-4}$ mA

Linearization [1]
Calculation of gradient [1]
Calculation of y-intercept [1]
q calculated correctly with sf and units [1]
I_o calculated correctly with sf and units [1]

q = ...

I_0 = ...

[5]



(d) **(ii)** Theory suggests that

$$q = \frac{a}{kT}$$

where k is the Boltzmann constant of 1.38×10^{-23} J K^{-1}, a is a constant, T is the temperature of diode in kelvin where $T\,/\,\text{K} = T\,/\,°\text{C} + 273.15$.

Calculate a, giving an appropriate unit.

$a = qkT = 13.6 \times 1.38 \times 10^{-23} \times (5.0 + 273.15)$

$= 5.22 \times 10^{-20}$ C

[1] Substitution of values

[1] I calculated correctly, with sf and units

a = ... [2]

(e) Calculate the current in the diode if it were placed in boiling water with a potential difference of 0.60 V applied across it.

$$I = I_o e^{\frac{aV}{kT}}$$

$$= (7 \times 10^{-4})\, e^{\frac{(5.22\times10^{-20})(0.60)}{(1.38\times10^{-23})(273.15+100)}}$$

$= 0.307$ mA

[1] I calculated with correct substitution of values and units

I = ... [1]

(f) The experiment is repeated where the value a is halved.

Sketch a line on your graph grid on page to show the expected result.

Label this line F.

[1]

Gradient = q, and q is proportional to a

So when a is halved, gradient is halved.

(g) A manufacturer wishes to put this diode in their product where the operating temperature is between room temperature and 300 °C.

The expression in **(d)** is only valid for temperatures less than a critical value.

Plan an investigation to determine the critical temperature of the diode.

Your account should include:

- your experimental procedure
- control of variables
- how you would determine the critical temperature.

Basic setup:

- Circuit similar to earlier part, with correct adaptations.
- Diode submerged in **oil bath with heater, beaker of oil in electric mantle, oven/sand bath in heater** to get temperature range stated (room to 300°C). *Use of ice and cool water penalised here.* Required temperature is room to 300°C
- Use of thermocouple or any suitable thermometer to measure the temperature.

[1]

No marks for procedure identical to earlier part (no value add).

Experimental procedure:

- Vary **setting in heater/electric mantle/power supply** to change the temperature of oil bath, heat source (needs to be mentioned.)
- *Instructions to decrease temperature penalised here.* Temperature of oil bath has to be increasing, not decreasing. The diode may fail and malfunction beyond the critical temperature.
- There must be some indication that the temp is to be kept const during the measurement process if heating is done using a heater or Bunsen flame.

[1]

Control of variables:

- **Keep voltage constant** using a rheostat /variable power supply and a voltmeter across the supply to **monitor** it.

[1]

Determination of critical temperature:

- $q = \frac{a}{kT}$ where $I = I_o e^{qV} \Rightarrow \ln I = \ln I_o + qV \Rightarrow q = \frac{\ln I - \ln I_o}{V}$,

  So that $\frac{a}{kT} = \frac{\ln I - \ln I_o}{V}$
- **Plot a graph of ln *I* vs 1/*T*.**
- The critical temperature is determined by **looking for the value of 1/*T* which the graph start to deviate from the best fit line. (It is NOT the anomalous point). The critical temperature is the reciprocal of that value.**

[1]

....

<u>Notes on the rationale of the answer.</u>

- The mini-planning question is at the end of an experiment. The mini-planning experiment would usually be similar to the original experiment. However some of the apparatus may need to be changed or modified to address the aim of the new investigation.
- The aim for this mini-planning experiment is to fine the critical value of T beyond which $q = \frac{a}{kT}$ no longer applies. q is not a measurable value, but q comes from $I = I_o e^{qV} \Rightarrow$

  $\ln I = \ln I_o + qV \Rightarrow q = \frac{\ln I - \ln I_o}{V}$, which consists of the measureable values I_o and V.

  Putting all the information together, $\frac{a}{kT} = \frac{\ln I - \ln I_o}{V}$. The new experiment would have

  T, I and V as the variables. It is easier to keep V constant, and to vary T and read I.
- Another approach is similar to the original experiment, at each constant temperature The current I in the diode and potential difference V across it are related by the expression and since $\ln I = \ln I_o + qV \Rightarrow$ plot a graph of ln I vs V to get the gradient q. However, it must be made clear that there must be different experiments and different graphs for different T to get different values of q. After that, another graph of q vs $1/T$ must be constructed to look for the critical temperature.

<u>Notes on Practical Procedures</u>

- **The diode CANNOT BE PLACED DIRECTLY IN A FLAME** and **IT CANNOT BE PLACED DIRECTLY ON A HOT PLATE.** The temperature will be too high and may cause the diode to melt. In addition the temperature of a flame or a hot plate cannot be controlled.
- Keeping the rheostat slider in the same position will not ensure that that V is a constant. The cell's emf may decrease with time, and so will V. The slider should be readjusted if the value of V on the voltmeter is said to change.
- Oil and sand baths or electric mantles are better because they allow the temperature to remain constant while the reading is taken. Heating methods like beakers of water over Bunsen burners cause the temperature to keep increasing.
- A microwave oven works on different principles as a conventional oven. It causes oscillations of water molecules, so IS NOT SUITABLE for heating experiments.
- Do not use Chemistry terms in a Physics paper. A significant number of students referred to a 'product' when there is NO product in the experiment. A product is the result of a chemical reaction.

2 In this experiment, you will investigate the oscillations of a pendulum.

(a) Set up the apparatus as shown in Fig. 2.1.

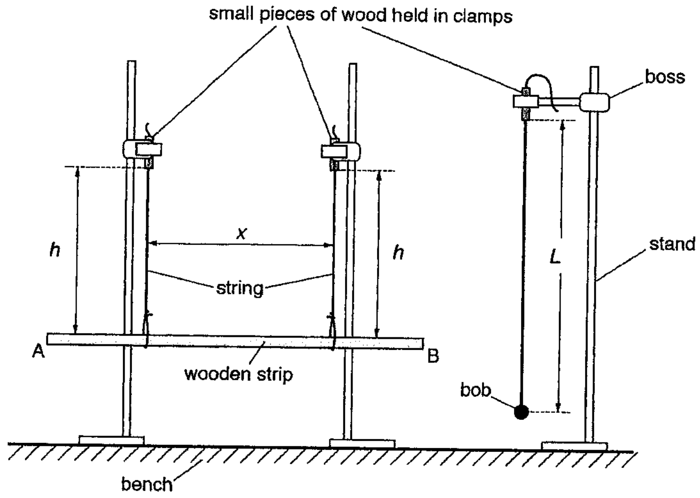


Fig. 2.1

The distance between the strings supporting the wooden strip is x.

The distances between the top of the strip and the bottom of the small pieces of wood should be equal. These distances are both h.

The distance between the centre of the bob and the bottom of the small pieces of wood is L.

Adjust the position of the strings so that $x \approx 25$ cm, $h \approx 25$ cm and $L \approx 45$ cm.

The strings should be vertical, the strip should be parallel to the bench and the strip should be supported centrally by the strings.

(i) Measure and record x and h.

Generally well done. With a few still not sure of precision of measurement

Raw values to 1mm.

Values between 23 – 27 cm.

x = 25.0 cm

h = 25.0 cm [2]

(ii) Estimate the percentage uncertainty in your value of x.

0.2 / 25.0 = 0.80 %

Absolute uncertainty ≥2mm and <10mm

Percentage uncertainty calculated correctly and expressed in 1-2 sf.

Generally well done. Do remember uncertainty is recorded to 1 sf and % uncertainty can be up to maximum of 2 sf

percentage uncertainty = 0.80 % [1]

(b) (i) Pull the bob and end B of the strip towards you through a short distance.

Release the bob and the strip together so that they oscillate.

Adjust L until the periods of the oscillations of the bob and of the strip are the same.

Measure and record L.

L between 20 – 40 cm.

L = 30.5 cm [1]

(ii) Estimate the percentage uncertainty in your value of L.

0.5 / 30.5 = 0.80 %

Absolute uncertainty ≥5mm and <20mm

Percentage uncertainty calculated correctly and expressed in 1-2 sf.

Poorly done. Quite a number of candidates underestimated the uncertainty of L.

percentage uncertainty = 1.6 % [1]

(iii) Calculate the value of Lx^2 with appropriate units.

$0.305 \times 0.250^2 = 0.0191$

Value calculated correctly expressed in correct units.

Simple but poorly done. Quite a number of candidates gave the wrong units and made power of ten errors.

Lx^2 = 0.0191 m^3 [1]

(iv) Justify the number of significant figures that you have given for your value of Lx^2.

Since Lx^2 is calculated using the multiplication/the product of L and x. The calculated value is given to the least number of sf of L and x which are 3 sf respectively.
[1]

Poorly done. A huge proportion of candidates just mentioned that least SF is to be used without explaining why explicitly enough.

BP~125

BP-126

(c) Change x to approximately 30 cm while making sure h remains as the value stated in **(a)(i)**.

The strings should be vertical, the strip should be parallel to the bench and the strip should be supported centrally by the strings.

Measure and record x.

x = 30.0 cm

Repeat **(b)(i)** and **(b)(iii)**.

$0.218 \times 0.300^2 = 0.196$

Second values of x, L and Lx^2.
Second value of L is lower than first.

Generally well done. Most conducted experiment correctly to get reasonable figures.

L = 21.8 cm

Lx^2 = 0.0196 m^3

[2]

(d) It is suggested that L is inversely proportional to x^2.

Explain whether your results support the suggested relationship.

If L is inversely proportional to x^2, $L\,x^2$ should be constant.

% difference in two values of $L\,x^2$= (0.0196 – 0.0191) / 0.0191 = 2.6%

% uncertainty due to L and x = 1.6 + 2 × 0.8 = 3.2 %

Comparison of % difference in two values of Lx^2 with the % uncertainty in L and x (both or the larger of the two).
Conclusion is suitable and consistent with the above comparison.

Since the percentage difference in two values of $L\,x^2$ is less than the percentage uncertainty due to L and x, the difference can be attributed to experimental error, and my results support the suggested relationship.

Generally well done. Those who failed to score here did not use percentage difference to support their justifications.

(e) Using the available apparatus, investigate how a greater value of h affects the value of $L\,x^2$. Show your results and conclusion clearly.

When h = 30.2 cm and x = 30.0 cm, L = 28.0 cm.

$L\,x^2 = 0.280 \times 0.300^2 = 0.0252$ m^3

Third value of L obtained for same x and greater h.
Third value of L shows L is positively related with h.
Conclusion is consistent with results and adequately explained.

The value of $L\,x^2$ is significantly greater and the difference is much larger than the percentage uncertainty due to experimental error.

My results show that a greater value of h results in a greater value of $L\,x^2$.

[3]

[Total: 14]

Poorly done by majority candidates. Majority of the candidates did not use percentage difference to support their answers. Presentation of working is poor and disorganised. Summarizing the data in the form of a table is recommended if you are collecting a lot of data. Quite a number of candidates spend too much time collecting additional 6 set of data which is unnecessary (it is a 3 marks question). 1 or 2 more set to make comparison is sufficient. Last but not least, it is very very disappointing to see a number of candidates did not read the question at all and assume that this is a miniplanning question when it is not.

3 In this experiment, you will determine the weight of a metre rule.

(a) Attach the spring to the clamp. Suspend the mass hanger from the spring as shown in Fig. 3.1.

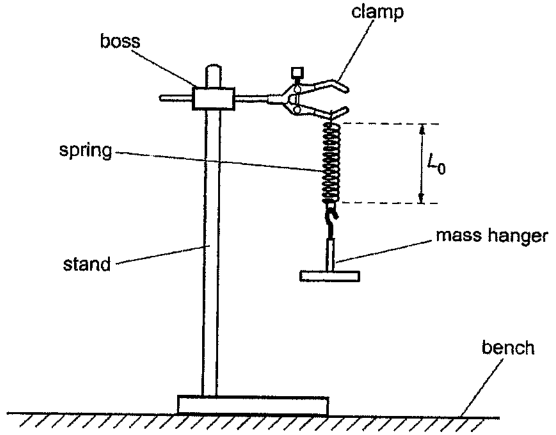


Fig. 3.1

> A number of students did not measure the full length of the sping (<3 cm). This resulted in very inaccurate values of k subsequently.

The length of the coiled section of the spring is L_0. Measure and record L_0.

L_0 = 5.1 cm

(b) (i) Add an additional mass of 100 g to the mass hanger. The new length of the coiled section of the spring is L_1. Measure and record L_1.

L_1 = 9.8 cm [1]

(ii) Remove the 100 g mass.

(iii) The spring constant k is given by the equation

$$k = \frac{F}{(L_1 - L_0)}$$

where F is 0.981 N.
Calculate k.

$$k = \frac{0.981}{(9.8 - 5.1)} = 0.21\ \text{Ncm}^{-1} = 21\ \text{Nm}^{-1}$$

k = 0.21 N cm^{-1} [1]

(c) (i) Set up the apparatus as shown in Fig. 3.2.

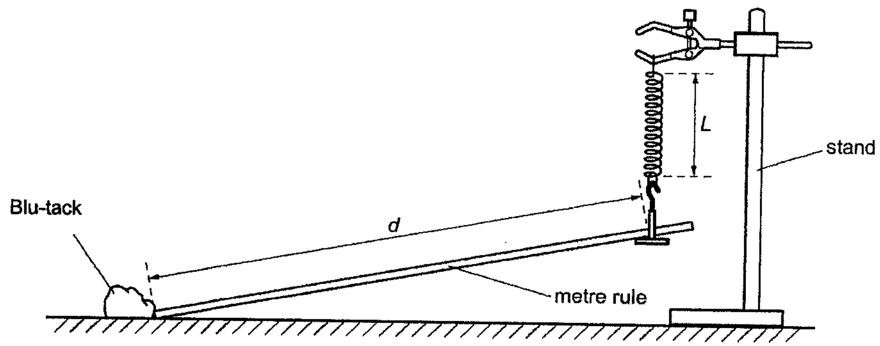


Fig. 3.2

Support the rule on the mass hanger. You may need to use some of the blu-tack to stop the rule from slipping off the mass hanger.

The distance between the lower end of the rule and the mass hanger is d, as shown in Fig. 3.2. The length of the coiled section of the spring is L.

Adjust the apparatus so that d is approximately 90 cm and the spring is vertical.

> A number of students simply recorded d as 90 cm as stated in the question. They are required to measure d to 1dp as with all lengths measured using a ruler.
>
> d need not be exactly 90.0 cm, but it should be within ±1 cm.

d = 90.0 cm

L = 7.4 cm

(iii) Using your answer to **(a)**, calculate $(L - L_0)$.

7.4 – 5.1 = 2.3 cm

$(L - L_0)$ = 2.3 cm [1]

(iv) Repeat **(c)(ii)** and **(c)(iii)** with a distance d of approximately 60 cm.

8.5 – 5.1 = 3.4 cm

d = 60.0 cm

L = 8.5 cm

$(L - L_0)$ = 3.4 cm

[2]

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(d) It is suggested that the relationship between $(L - L_0)$ and d is

$$C = d(L - L_0)$$

where C is a constant.

Use your values from **(c)** to determine two values of C.

$C_1 = (90.0)(2.3) = 207 = 210\ cm^2$
$C_2 = (60.0)(3.4) = 204 = 200\ cm^2$

The most common mistake in this part is leaving out units or having wrong units.

first value of C = 210 cm^2

second value of C = 200 cm^2 [1]

(e) The constant C is given by

$$C = \frac{Wd_0}{2k}$$

where d_0 is the length and W is the weight of the metre rule.

Use your second value of C to determine W.

$$W = \frac{2kC}{d_0} = \frac{2(0.21)(200)}{100.0} = 0.84\ N$$

The most common mistake in this part is using d as d_0.

A few students used the unit kg for weight.

Some others got the wrong value because of the inconsistency in the use of m and cm.

W = 0.84 N [1]

(f) If you were to repeat this experiment with different distances d, describe the graph you will plot to determine W.

Plot a graph of L vs $1/d$ to obtain a best fit line with gradient $m = Wd_0/(2k)$ and y-intercept L_0. W can be calculated by $m \times 2k / d_0$

[1]

Most students lost marks here. Many suggested plotting a graph using W as a variable, even though the objective is to determine W.

Most correct answers suggested plotting $L - L_0$ vs $1/d$. This is not recommend as y and x should not contain constants as far as possible, and in this case L_0 can easily be isolated as the y-intercept.

[Total: 8 marks]

4 When an elastic cord of circular cross-section is stretched between two points A and B and is made to vibrate, stationary waves can be set up on the cord. A possible shape (mode of vibration) for the stationary waves is shown in Fig. 4.1.

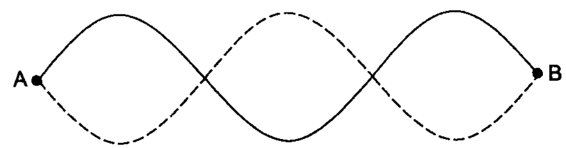

Fig. 4.1

The frequency of vibration of the elastic cord in this mode of vibration depends on the tension in the cord and the mass per unit length of the cord.

It is suggested that the relation between the frequency f of this mode of vibration of the cord, tension T in the cord and mass per unit length μ of the cord is

$$f = kT^p \mu^q$$

where k, p and q are constants.

Design an experiment to determine the values of k, p and q.

You are provided with cords of different thickness. You may also use any of the other equipment usually found in a physics laboratory.

Draw a diagram to show the arrangement of your apparatus. You should play particular attention to:

(a) the equipment you would use

(b) the procedure to be followed,

(c) the method by which the mass per unit length μ of the cord is determined,

(d) the control of variables,

(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

Suggested Solutions

Experimental Setup

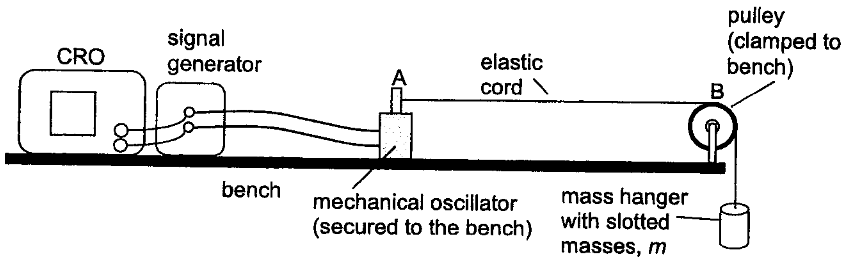

Fig. 1

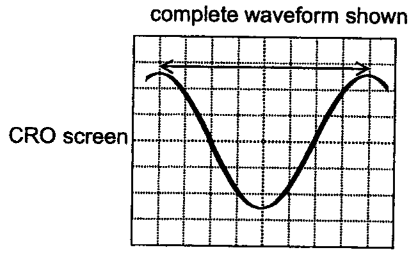

Fig. 2

Experiment 1: To test the relationship between f and T, keeping μ constant

Independent variable: Tension in the cord, T.

Dependent variable: Frequency of standing wave in cord, f

Control variables: Mass per unit length of cord μ, length of the cord AB, mode of vibration or standing waveform in cord as shown in Fig. 4.1

Procedure

1) Measure mass of mass hanger and slotted mass using an electronic mass balance and record as m.
2) Calculate tension T in cord using T = mg, where g is gravitational acceleration. Record T.

3) Set up the apparatus as shown in Fig. 1.
4) Adjust the frequency of the signal generator until a standing wave with 3 distinct loops is shown in Fig. 4.1 is formed.
5) Record the frequency f on the signal generator.
   OR
   Measure and record the frequency f of the wave as shown on the CRO display.
   OR
   Starting with the highest frequency, the frequency of strobing (flashing) is gradually reduced until the cord appears stationary. This means that frequency of strobing is equal to the frequency of the vibration of cord. Record the frequency f on stroboscope.

6) Repeat steps (1) to (5) to obtain 8 sets of values of f and T for increasing T while keeping μ constant. This can be achieved by adding slotted masses to the mass hanger to increase m and hence T.
7) Keep μ constant by using the same elastic cord.

Experiment 2: To test the relationship between f and μ, keeping T constant.

Independent variable: Mass per unit length of cord, μ.

Dependent variable: Frequency of standing wave in cord, f

Control variables: Tension in the cord T, length of the cord AB, mode of vibration or standing waveform in cord as shown in Fig. 4.1

Procedure

8) Measure mass of the cord using an electronic mass balance, and record as M.
9) Measure length of the same cord using metre rule and record as L.
10) Calculate mass per unit length of the cord using $\mu = \frac{m}{L}$. Record μ.

11) Repeat steps (3) to (5) and (8) to (10) to obtain 8 sets of values of f and μ for increasing μ while keeping T constant. This can be achieved by using elastic cords of different μ.
12) Keep tension T in the cord constant by hanging the same mass m to the end of the cord.

13) For both experiments, keep distance AB between the oscillator and the pulley constant by securing them to the bench with clamps. Measure AB using a ruler.

Graphical Analysis

From $f = kT^p\mu^q$,

Experiment 1:

$\Rightarrow \lg f = \lg(k\mu^q) + p\lg T$, where μ is constant.

Plot graph of lg f against lg T, where p is the gradient and $\lg(k\mu^q)$ is the y-intercept.

If the graph is a straight line with y-intercept, the relationship is valid.

p is determined from the gradient of the graph.

Determine k_1 using $k_1 = \dfrac{10^{y\ intercept}}{\mu^q}$.

Experiment 2:

$\Rightarrow \lg f = \lg(kT^p) + q\lg\mu$, where T is constant.

Plot graph of lg f against lg μ, where q is the gradient and $\lg(kT^p)$ is the y-intercept.

If the graph is a straight line with y-intercept, the relationship is valid.

q is determined from the gradient of the graph.

Determine k_2 using $k_2 = \dfrac{10^{y\ intercept}}{T^p}$.

Hence find average value of k using $\langle k \rangle = \dfrac{k_1 + k_2}{2}$.

Additional Details

1. Conduct preliminary experiments to find a suitable range for T and μ that will lead to measurable values of f.
2. Conduct preliminary experiments to find a suitable range for T and μ that will lead to a significant change in values of f.
3. Connect a CRO in parallel to the signal generator. Using the grid on the screen, measure the maximum horixonal distance occupied by a complete waveform. Multiply this distance by the scale indicated on the time-base to obtain period T. Calculate frequency f using $1/T$.
4. Check that the length AB of cord and masses used are able to produce the same mode of vibration in all the wires.

Safety Precautions

1. Wear protective eyewear/goggles to prevent injuries to the eyes in case the wire snaps.

2. Place sand tray or cushions under the masses OR Wear protective footwear to prevent injuries to the feet in case the masses fall.
3. Wear tinted glasses or sunglasses OR do not stare directly at the stroboscope for prolonged period of time.

Suggested Mark Scheme

Diagram of a workable arrangement of apparatus 1. Supports for the wire and pulley need to be firmly clamped to the bench (or written). 2. Oscillator connected to the wire and wire under tension from hanging masses. 3. Signal generator connected to mechanical oscillator (and CRO optional). }	[max 1] 1
Basic procedure 1. Adjust the frequency of the signal generator until a standing wave is set up on the wire. Same mode of vibration (third harmonic)	[max 1] 1
Method of measurement of independent and dependent variable 1. Determination of frequency f a. Read off the c.r.o. display or signal generator **OR** b. Set a stroboscope to its highest frequency c. Lower the frequency until the wire looks stationary 2. Determination of mass per unit length μ of the wire a. Measure mass m using electronic balance and length L using metre rule b. $\mu = \dfrac{m}{L}$ 3. Determination of tension T in cord a. Measure mass hanger and slotted masses, m using electronic balance. b. $T = mg$	[max 3] 1 1 1 1
Graphical Analysis Plot graph of lg f against lg μ, where q is the gradient and $\lg(kT^p)$ the y-intercept. Plot graph of lg f against lg T, where p is the gradient and $\lg(k\mu^q)$ the y-intercept = C. Determine k using $k = \dfrac{10^C}{\mu^q}$.	[max 3] 1 1 1
Additional Details 1. Conduct preliminary experiments to find a suitable range for T and μ that will lead to measurable and distinguishable readings in f, with the required mode of vibration. 2. Check that the length AB of cord and masses used are able to produce the same mode of vibration in all the wires. 3. Determine $\langle k \rangle = \dfrac{k_1 + k_2}{2}$ from experiment 1 and 2. 4. For both experiments, keep distance AB between the oscillator and the pulley constant by securing them to the bench with clamps. Measure AB using a ruler.	[max 3] 1 1 1 1
Safety precautions 1. Wear goggles in case the wire snaps. 2. Wear protective footwear in case of falling masses.	[max 1] 1 1

[Total: 12 marks]

End of Paper

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