RAFFLES INSTITUTION
2022 Preliminary Examination

PHYSICS
Higher 2

9749/01

Paper 1 Multiple Choice Questions

26 September 2022
1 hour

Additional Materials: OMR Form

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your index number, name and class on the OMR Form in the spaces provided. Shade the appropriate boxes.

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 OMR Form.

Read the instructions on the OMR Form 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 appropriate scientific calculator is expected, where necessary.

This document consists of **16** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin\omega t$
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	=	$R_1 + R_2 + \dots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \dots$
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	λ	=	$\ln 2/t_{1/2}$

1 A student makes measurements from which he calculates the speed of sound in air as 335.61 m s^{-1}. He estimates the percentage uncertainty in the speed of sound to be $\pm$ 4.5%.

How should the student record the speed of sound, considering the uncertainty?

A 330 m s^{-1} **B** 335.6 m s^{-1} **C** 336 m s^{-1} **D** 340 m s^{-1}

2 The Stefan-Boltzmann law for the rate of thermal energy emitted per unit surface area of a body is given by

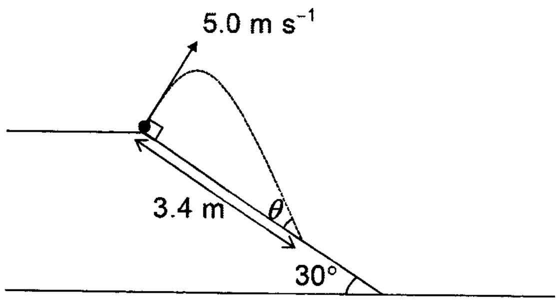
$$\frac{P}{A} = e\sigma T^4,$$

where P is the rate of thermal energy emitted, A is the surface area, T is the thermodynamic temperature and e, a dimensionless constant, is the emissivity of the body and σ is the Stefan-Boltzmann constant.

Which is the S.I. base unit for σ?

A kg s^{-3} K^{-4} **B** kg s^{-1} K^4 **C** W m^{-2} K^{-4} **D** W m^{-2} °C^{-4}

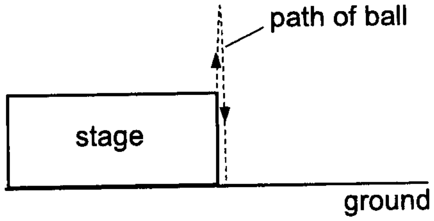
3 A stone is projected perpendicularly to a slope with a velocity of 5.0 m s^{-1} and lands 3.4 m down the slope. The slope is inclined at an angle of 30° to the horizontal. Air resistance is negligible.



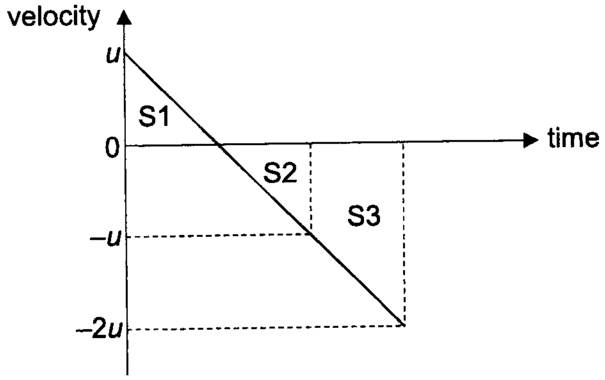
What is the angle θ that the velocity of the stone makes with the slope as it lands?

A 27° **B** 32° **C** 41° **D** 71°

4 A ball is thrown vertically upwards from the edge of a stage with speed u and hits the ground at the foot of the stage with speed $2u$. The time taken for the ball to reach its maximum height is t.

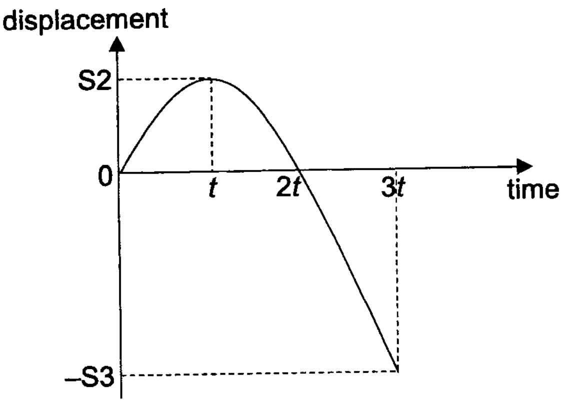


The graph shows how the velocity of the ball varies from the time it is thrown to the time it hits the ground. The areas under different sections of the graph are labelled S1, S2 and S3.

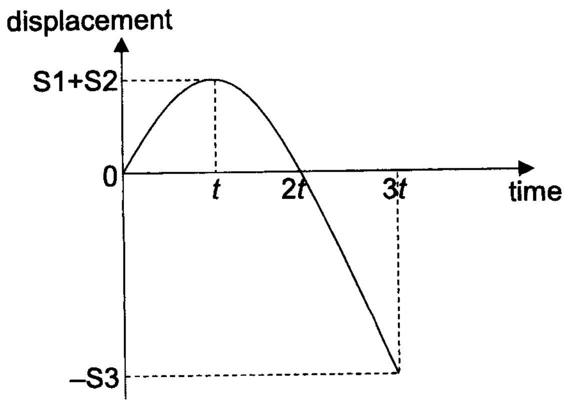


Which graph shows the variation of the displacement of the ball with time?

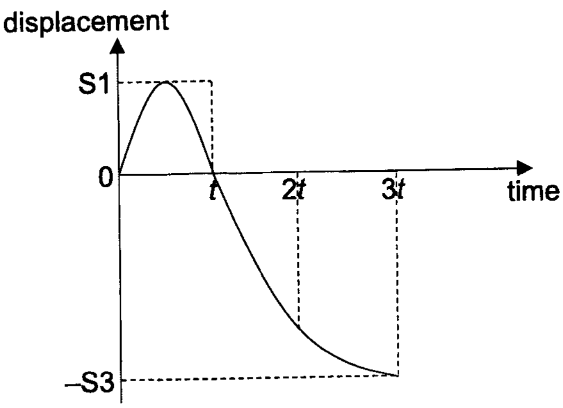
A



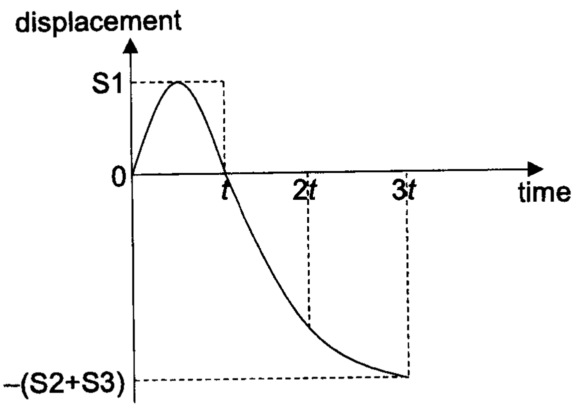
B



C

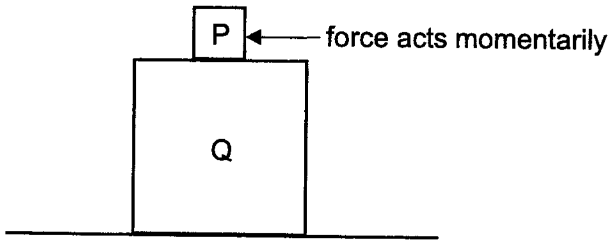


D



5 Block P is resting on a more massive block Q, which is resting on a smooth ground. The surfaces of blocks P and Q that are in contact with each other are rough.

A sudden force acts momentarily on block P to start it sliding to the left.



Which statement about the subsequent motions of the blocks is correct?

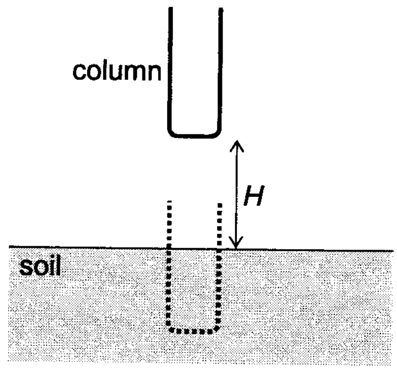
A Block P accelerates as it moves to the left, while block Q remains at rest.

B Block P and block Q accelerate as they move to the left, where the acceleration of block Q is smaller in magnitude compared to the acceleration of block P.

C Block P decelerates and block Q accelerates as they move to the left, where the acceleration of block Q is smaller in magnitude compared to the deceleration of block P.

D Block P decelerates and block Q accelerates as they move to the left, where the magnitudes of the acceleration of block Q and the deceleration of block P are the same.

6 A column of mass M is dropped from height H above the surface of the soil and comes to a stop after travelling for a duration t in the soil.



What is the average resistive force that acts on the column due to the soil?

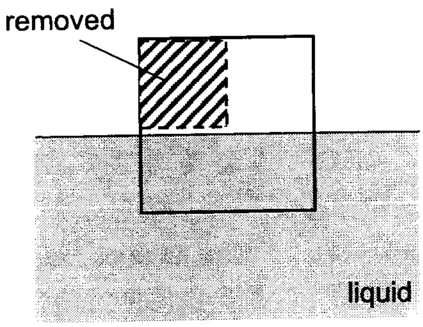
A $Mg\left(1+\sqrt{\frac{2H}{gt^2}}\right)$

B $Mg\sqrt{\frac{2H}{gt^2}}$

C Mg

D $Mg\left(1-\sqrt{\frac{2H}{gt^2}}\right)$

7 A uniform cube is floating in a liquid. A quarter of the cube is then removed.

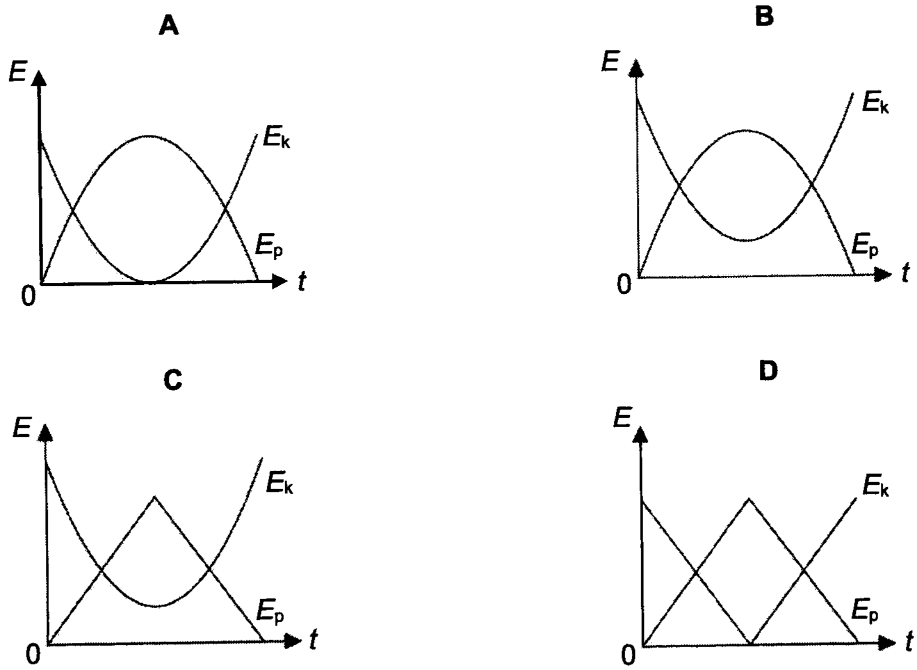


What is the resultant force and resultant moment on the remaining portion of the cube immediately after the quarter of the cube is removed?

	resultant force	resultant moment
A	zero	anticlockwise
B	upwards	clockwise
C	zero	clockwise
D	upwards	anticlockwise

8 A ball is projected with an initial velocity at an angle above a horizonal ground and falls back to the ground in a parabolic path.

Which graph shows the variation with time t of the gravitational potential energy E_p and the kinetic energy E_k of the ball?



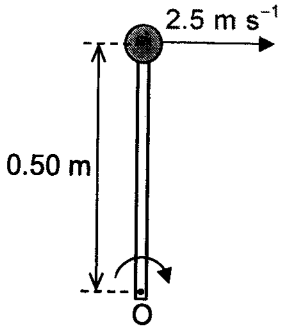
9 Two bodies A and B of masses *m* and 2*m* respectively are initially at rest on a smooth horizontal surface.

A constant force acts on body A for twice the duration that it acts on body B.

What is the ratio $\frac{\text{gain in kinetic energy of body A}}{\text{gain in kinetic energy of body B}}$?

A 1 **B** 2 **C** 4 **D** 8

10 A sphere of mass 0.40 kg is attached to a light, rigid rod of length 0.50 m that is hinged at point O. The sphere is projected with a horizontal speed of 2.5 m s^{-1} when it is vertically above point O and rotates freely about point O.



What is the magnitude of the force exerted on the sphere by the rod at the instant when the sphere is vertically below point O?

A 3.9 N **B** 8.9 N **C** 17 N **D** 25 N

11 A satellite in orbit experiences atmospheric drag and spirals towards Earth.

Which of the following describes the period and speed of the satellite during this motion?

	orbital period	orbital speed
A	increases	decreases
B	decreases	increases
C	increases	increases
D	decreases	decreases

12 A low-Earth-orbit satellite orbits near the surface of the Earth at a speed of 7.90 km s^{-1}.

The radius of the Earth is 4 times that of the Moon, and the density of the Earth is 1.25 times that of the Moon.

What is the speed of a low-Moon-orbit satellite that orbits near the surface of the Moon?

A 1.77 km s^{-1} **B** 2.21 km s^{-1} **C** 3.53 km s^{-1} **D** 14.1 km s^{-1}

13 An ideal gas has a volume of 3.7 m^3 and contains 1.5 kg of neon-20 atoms. Its temperature is 25 °C.

What is the pressure of the gas?

A 4.2 Pa **B** 50 Pa **C** 4.2 kPa **D** 50 kPa

14 When water is boiled at atmospheric pressure, the steam produced behaves like an ideal gas. A water molecule has a mass of 18*u*.

What is the root-mean-square speed of the water molecule in the steam?

A 330 m s^{-1} **B** 370 m s^{-1} **C** 640 m s^{-1} **D** 720 m s^{-1}

15 A piece of metal of mass *m*, specific heat capacity *c* and temperature 20 °C is placed into a liquid of temperature 100 °C. The liquid, which is in a well-insulated container, has mass 3*m* and specific heat capacity 2.5*c*.

What is the temperature of the liquid when thermal equilibrium is reached?

A 56 °C **B** 60 °C **C** 64 °C **D** 91 °C

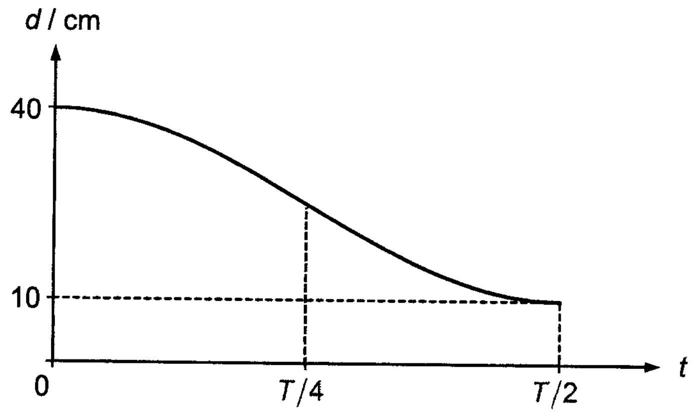
16 A particle oscillates in simple harmonic motion with amplitude x_0 and total energy *E*.

What is the potential energy of the particle at a displacement of $\frac{1}{3}x_0$ from the equilibrium?

A $\frac{1}{9}E$ **B** $\frac{1}{3}E$ **C** $\frac{2}{3}E$ **D** $\frac{8}{9}E$

17 A mass is attached to a spring that is suspended from a ceiling. The mass is displaced vertically downwards from its equilibrium position and released such that it performs simple harmonic motion with period T.

The graph shows the variation with time t of the vertical distance d of the mass from the ceiling.



Which of the following statements is not correct?

A The speed is maximum at $T/4$.

B The amplitude of oscillation is 30 cm.

C The restoring force on the mass is zero at $d = 25$ cm.

D The magnitude of the acceleration of the mass increases from $T/4$ to $T/2$.

18 Three polarisers are held in line one after the other such that the transmission axis of the last polariser is perpendicular to that of the first.

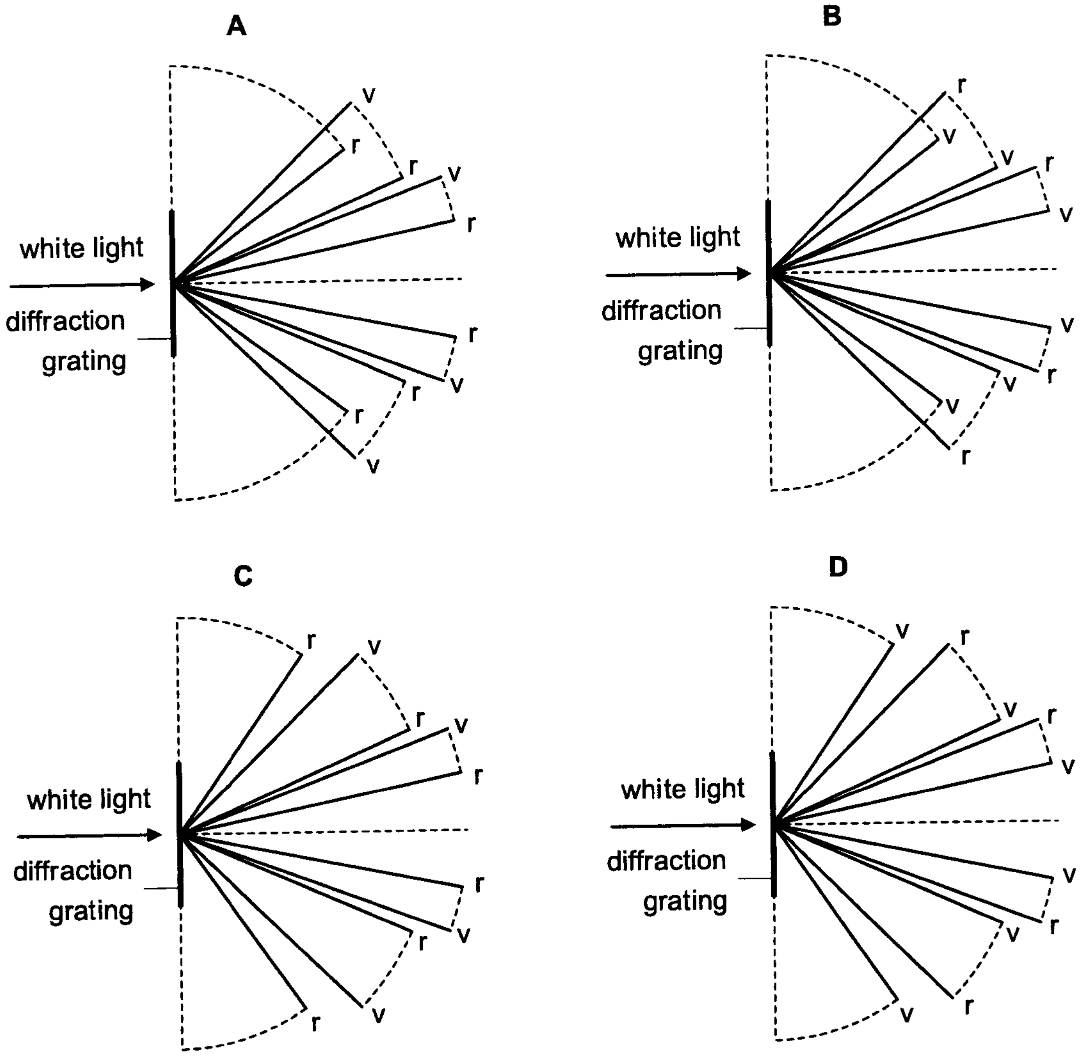
Unpolarised light of intensity 40 W m^{-2} is incident normally on the first polariser. The intensity of the emergent light after passing through all three polarisers is 2.5 W m^{-2}.

What is the angle between the transmission axes of the first and the second polariser?
(Hint: $\sin 2\theta = 2\sin\theta\cos\theta$)

A 7.2° **B** 15.0° **C** 22.5° **D** 53.5°

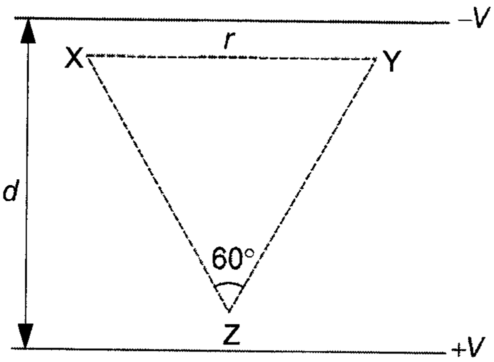
19 White light, which consists of light of wavelengths 400 nm to 700 nm, is incident on a diffraction grating.

Which of the following shows the diffracted spectra where v is for violet and r is for red?



20 Two large horizontal metal plates are distance d apart. The upper and lower plates are at potentials $-V$ and $+V$ respectively.

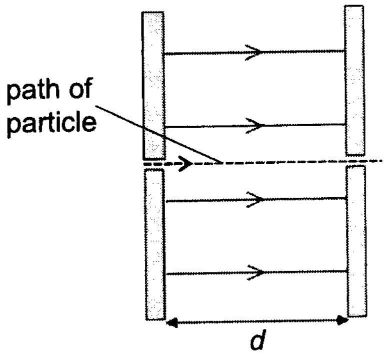
X, Y and Z are points between the metal plates such that they form an equilateral triangle with sides of length r. Side XY is parallel to the plates.



Which of the following shows the work done against the electric force in moving an electron at constant speed from X to Y, Y to Z and Z to X?

	X to Y	Y to Z	Z to X
A	$+\left(\frac{2V}{d}\right)er$	$+\left(\frac{2V}{d}\right)er\cos 60°$	$-\left(\frac{2V}{d}\right)er\cos 60°$
B	0	$-\left(\frac{2V}{d}\right)er\sin 60°$	$+\left(\frac{2V}{d}\right)er\sin 60°$
C	0	$+\left(\frac{2V}{d}\right)er\sin 60°$	$-\left(\frac{2V}{d}\right)er\sin 60°$
D	0	$-\left(\frac{2V}{d}\right)er\cos 60°$	$+\left(\frac{2V}{d}\right)er\cos 60°$

21 A particle of mass m and charge q is accelerated from rest in a uniform electric field between two parallel plates. After travelling a distance d between the plates, it leaves the field with a final speed v.



The electric field strength and the distance between the plates are doubled. A second particle of mass $3m$ and charge $3q$ is accelerated from rest between the plates.

What is the final speed of the second particle when it leaves the field?

A v **B** $2v$ **C** $3.5v$ **D** $4v$

22 Two resistors of resistances R_1 and R_2 are connected in parallel to a battery.

The combined resistance R_T of the two resistors is given by

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}.$$

Which concept is used in the derivation of this formula?

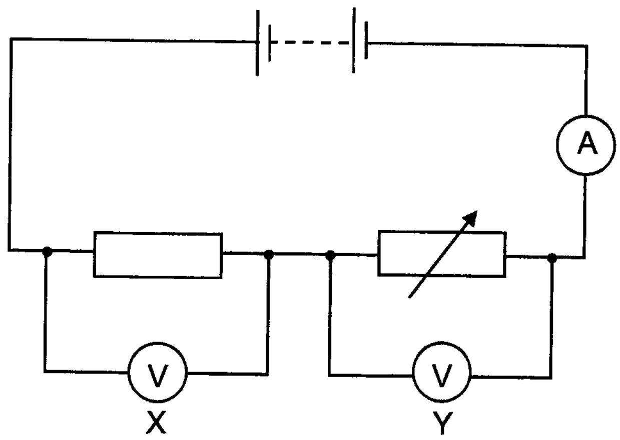
A There is no power loss in the battery.

B The current through each resistor is the same.

C The potential difference across each resistor is the same.

D The ratio of the currents through the resistors is equal to the ratio of their resistances.

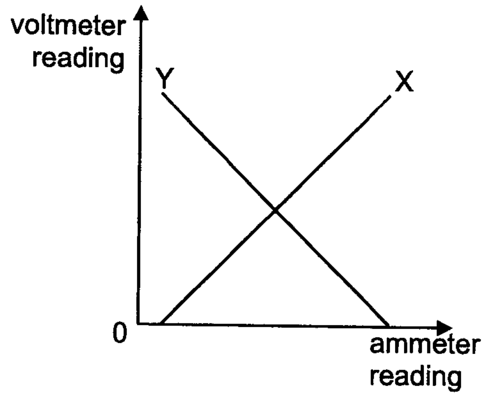
23 A battery is connected in series with an ammeter, a fixed resistor and a variable resistor. Voltmeters X and Y are connected across the fixed resistor and the variable resistor respectively.



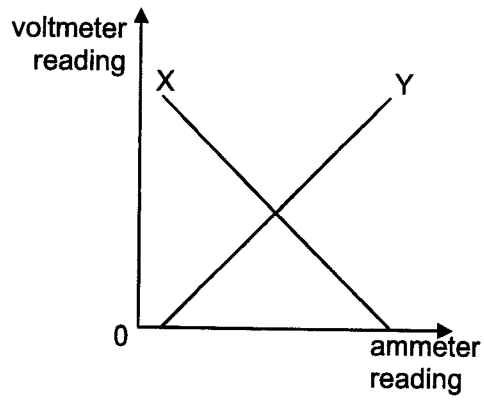
The resistance of the variable resistor is reduced from its maximum resistance to 0 Ω.

Which graph shows the variation of the voltmeter readings with the ammeter reading?

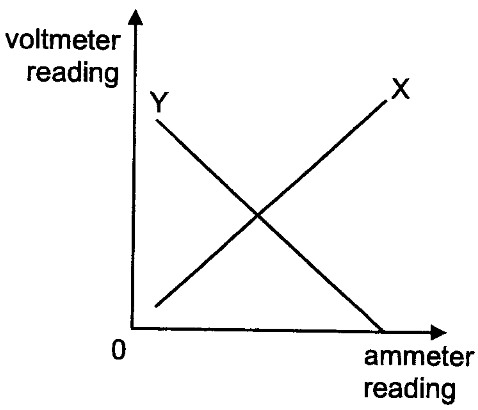
A



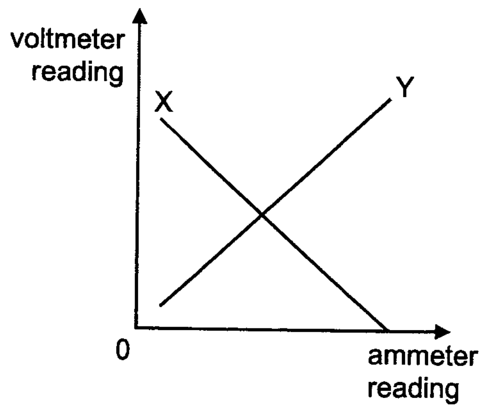
B



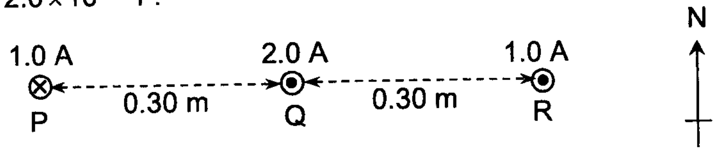
C



D



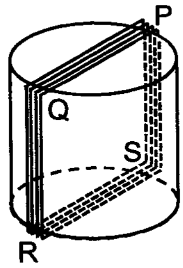
24 Three long vertical wires P, Q and R are carrying currents 1.0 A, 2.0 A and 1.0 A, respectively. The diagram shows the top view of the wires with the directions of their currents and the distances between them. The component of the Earth's magnetic field that is parallel to the Earth's surface is 2.0×10^{-5} T.



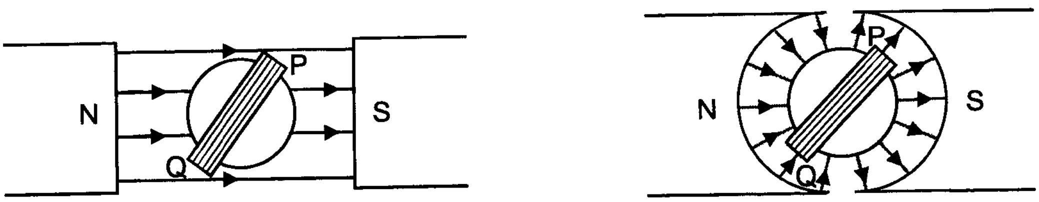
What is the magnitude and direction of the force per unit length acting on wire Q?

	magnitude	direction
A	1.3×10^{-6} N m^{-1}	East
B	2.7×10^{-6} N m^{-1}	East
C	1.9×10^{-5} N m^{-1}	West
D	3.7×10^{-5} N m^{-1}	West

25 A long copper wire is wound round an iron cylinder to form a rectangular coil PQRS. A current flows through the coil.



The cylinder and the coil are placed in turn within magnetic fields X and Y and are free to rotate.



top view of coil in field X

top view of coil in field Y

Which of the following statements is not correct?

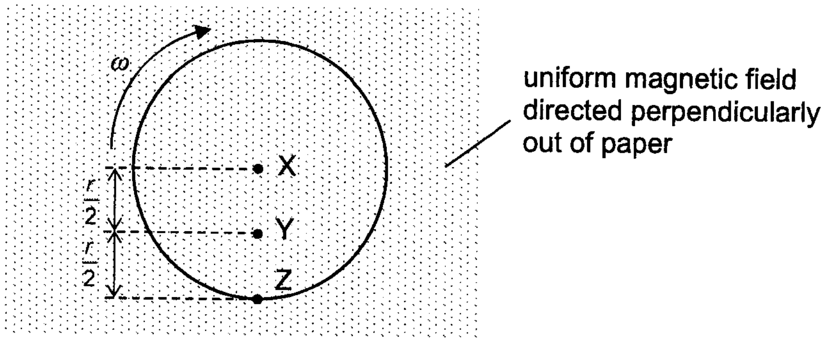
A The torque on the coil in each field varies sinusoidally as it rotates.

B The angular velocity of the coil in each field is not constant.

C Increasing the area of the coil will increase the torque on the coil in each field.

D The magnitude of the force on the side QR of the coil in each field remains constant as the coil rotates.

26 A metal disc of radius r rotates about its centre X at a constant angular speed ω in a uniform magnetic field. Point Z is on the rim of the disc and point Y is a distance $\frac{r}{2}$ from point X.



The potential difference between X and Z is V.

What is the potential difference between X and Y?

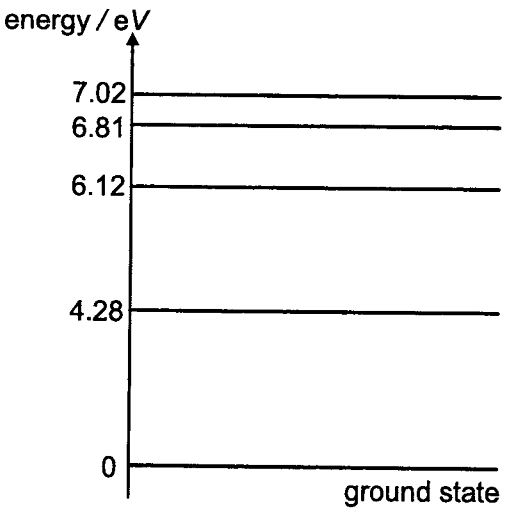
A 0 **B** $\frac{1}{4}V$ **C** $\frac{1}{2}V$ **D** $\frac{3}{4}V$

27 The primary coil of a transformer is connected to a 120 V r.m.s. sinusoidal a.c. supply. The secondary coil has 250 turns and a peak output of 8.0 V.

What is the number of turns on the primary coil?

A 2650 **B** 3750 **C** 5300 **D** 7500

28 The diagram shows the first five energy levels of an atom.



How many transitions between these energy levels result in the emission of visible light?

A 1 **B** 2 **C** 3 **D** 4

29 Electrons that are accelerated from rest through a potential difference of 30 kV are made to collide with a metal target to produce X-rays.

What is the shortest wavelength of the X-rays produced?

A 6.6×10^{-30} m **B** 2.8×10^{-21} m **C** 7.1×10^{-12} m **D** 4.1×10^{-11} m

30 A radioactive source has a half-life of 20 hours. At the start of an experiment, a Geiger counter records an average count-rate of 20 s^{-1} in the absence of the source. When the source is placed in front of the Geiger counter, the average count-rate recorded is 100 s^{-1}.

What is the average count-rate recorded by the Geiger counter after 60 hours?

A 10 s^{-1} **B** 13 s^{-1} **C** 30 s^{-1} **D** 47 s^{-1}

End of Paper 1

Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2022 Preliminary Examination

PHYSICS
Higher 2

9749/02

Paper 2 Structured Questions

12 September 2022
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use pencil for any diagrams or 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	/ 9
2	/ 5
3	/ 8
4	/ 10
5	/ 7
6	/ 12
7	/ 7
8	/ 22
Deduction	
Total	/ 80

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

Data

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permittivity of free space	ε_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
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temperature	T/K	$= T/°C + 273.15$
pressure of an ideal gas	p	$= \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	$= \frac{3}{2}kT$
displacement of particle in s.h.m.	x	$= x_0 \sin \omega t$
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	$= R_1 + R_2 + \dots$
resistors in parallel	$1/R$	$= 1/R_1 + 1/R_2 + \dots$
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	λ	$= \ln 2 / t_{1/2}$

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

1 Particle A of mass $9m$ and particle B of mass m travel towards each other along a smooth horizontal surface in a straight line and collide head-on. The initial speed of particle A before the collision is u.

In Fig. 1.1, the variation with time t of momentum p is shown from $t = 0$ to $t = 3T$ for particle A and from $t = 0$ to $t = T$ for particle B.

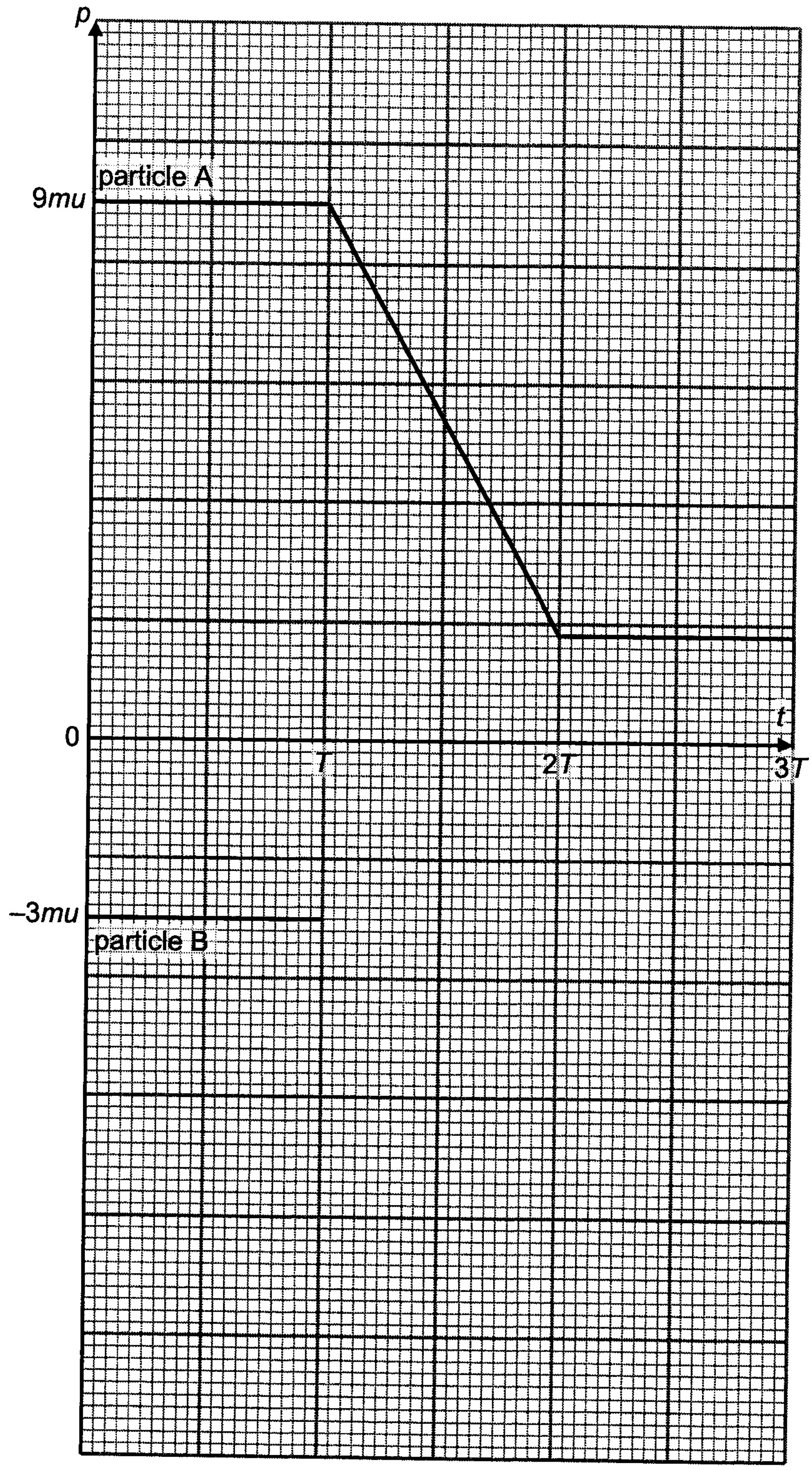

Fig. 1.1

(a) **(i)** On Fig. 1.1, draw the variation with t of p from $t = T$ to $t = 3T$ for particle B. [1]

(ii) Explain how the principle of conservation of momentum is used to complete the graph in **(a)(i)**.

....

....

....

.... [2]

(b) Explain, with appropriate working, whether the collision between particles A and B is elastic.

....

.... [3]

(c) Using Fig. 1.1, explain how the graphs are consistent with Newton's third law of motion during the collision.

....

....

....

....

....

.... [3]

2 A uniform square box with sides 0.80 m and mass 2.0 kg is at rest on the ground. One end of a light rope is attached to the box and the other end is attached to the wheel of a motor. The motor applies a constant clockwise torque of 5.0 N m on the wheel of radius 0.20 m.

At the instant shown in Fig. 2.1, the rope is taut and it makes an angle of $\theta = 20°$ with the vertical side of the box. The system remains in equilibrium.

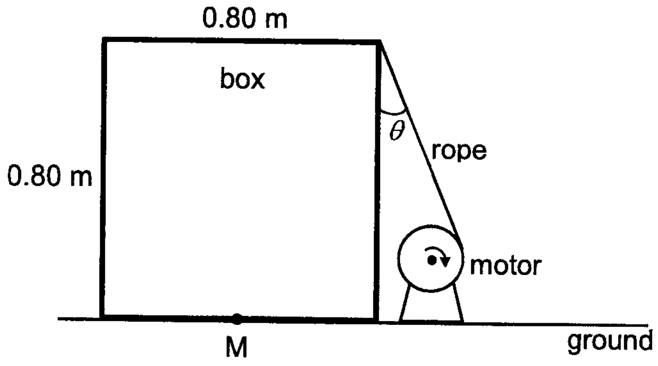

Fig. 2.1

(a) Calculate the tension in the rope.

tension = ... N [1]

(b) Point M is the mid-point at the base of the box as shown in Fig. 2.1.

By taking moments about point M, determine the horizontal distance *d* between M and the point at which the contact force by the ground acts on the box.

d = ... m [3]

(c) The motor is shifted to the right such that θ increases. The torque applied by the motor remains constant.

Without any further calculations, explain why there is a maximum value of θ for which equilibrium can be maintained.

....

....

.... [1]

3 A bob of mass 1.5 kg is attached to a string of negligible mass and of length 25.0 cm. The other end of the string is fixed to point X of an inverted "L" structure of arm length d. The structure is fixed to the centre of a rotating disc of radius 8.0 cm.

When the disc rotates with an angular velocity ω, the string makes at an angle θ to the vertical as shown in Fig. 3.1.

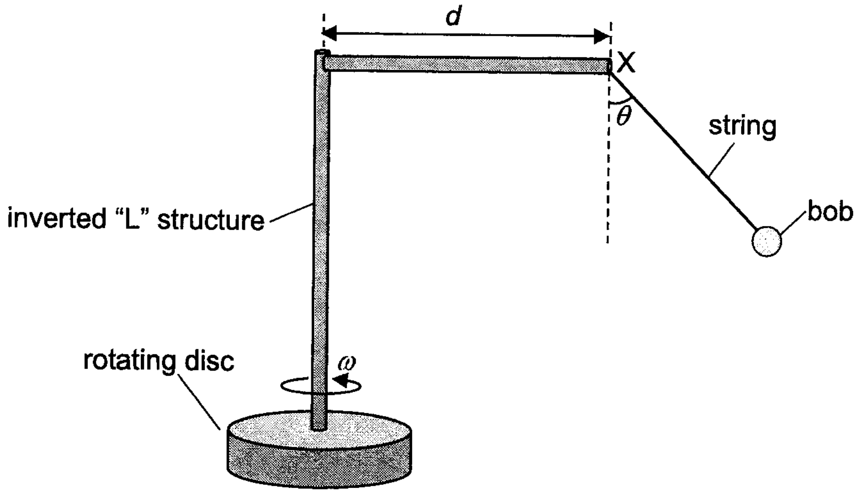

Fig. 3.1

(a) A point on the circumference of the rotating disc has a speed of 24.0 cm s^{-1}.

Determine ω.

ω = ... rad s^{-1} [1]

(b) **(i)** Determine the tension in the string for $\theta = 30°$.

tension = ... N [2]

(ii) Calculate *d*.

$d =$ .... m [3]

(c) A student states that as the angular velocity of the disc increases, θ increases but θ will always be smaller than $90°$.

Comment on the validity of the statement made by the student.

....

....

....

.... [2]

4 (a) Explain why gravitational potential is always negative whereas electric potential can have positive and negative values, given that both potentials are zero at infinity.

....

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....

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....

....

.... [3]

(b) Fig. 4.1 shows how the gravitational potential ϕ from the surface of a planet varies with distance r from the centre of the planet.

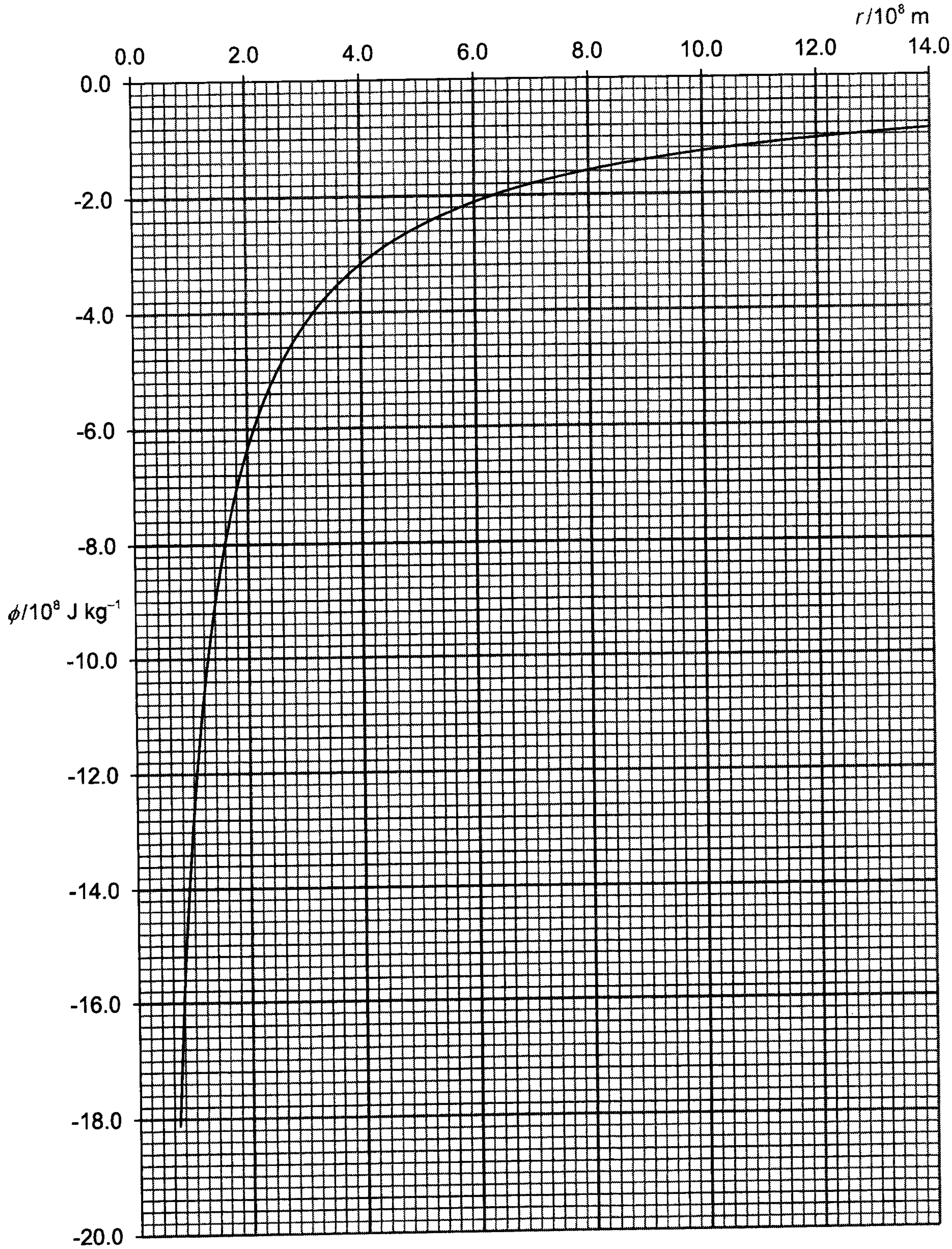

Fig. 4.1

(i) A moon orbits the planet. The mass of the moon is 1.48×10^{23} kg and its orbital radius is 1.07×10^{6} km.

Using Fig 4.1, calculate

1. the orbital speed of the moon,

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

2. the total energy of the moon.

total energy = ... J [2]

(ii) A rock is projected vertically upwards with a speed of 45 km s^{-1} from the surface of the planet. The resistive forces on the rock by the planet's atmosphere are negligible.

Using Fig 4.1,

1. show, with clear working, that the rock will not escape the planet,

[2]

2. determine the maximum distance of the rock from the surface of the planet.

distance = ... m [1]

5 A transverse wave on a rope is travelling to the right. Fig. 5.1 shows the waveform at a particular time. Particles Q, R, S, T, U and V are labelled.

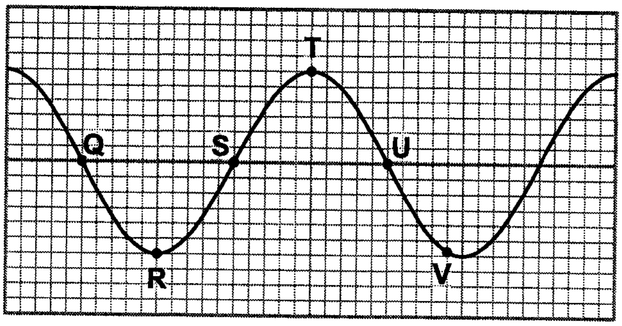

Fig. 5.1

(a) On Fig. 5.1, indicate using arrows the directions in which the particles Q, S and U are moving.

[2]

(b) State the motion of particles R and T at this instant shown.

.... [1]

(c) On Fig. 5.1, mark two particles on the waveform, other than Q, R, S, T and U, that are

(i) in phase with each other (mark with 'X'),

(ii) in antiphase with each other (mark with '+'). [2]

(d) Particle V leads particle U by a phase of ϕ.

Calculate ϕ. Explain your working.

ϕ = ... rad [2]

6 Fig 6.1 shows a miniature E10 filament light bulb with a rating of 6.0 V, 3.0 W.

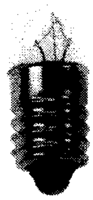

Fig. 6.1

(a) **(i)** Calculate the resistance of the bulb.

resistance = ... Ω [1]

(ii) The filament of the bulb is made of tungsten wire of length 2.0 cm and diameter 78 μm.

Calculate the resistivity of the tungsten filament.

resistivity = ... Ω m [2]

(iii) The resistivity of tungsten from a table of constants is stated to be 5.6×10^{-8} Ω m.

Explain, in microscopic terms, the difference between this value and your answer in **(a)(ii)**.

....

....

....

....

.... [2]

(b) Six identical E10 light bulbs are connected to a 6.0 V d.c. supply of negligible internal resistance in the arrangement shown in Fig. 6.2.

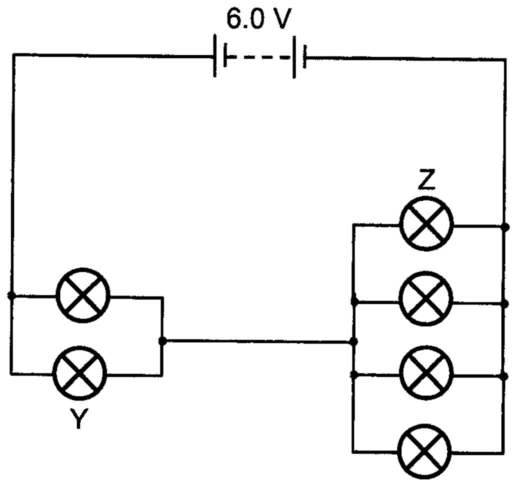

Fig. 6.2

Assume that the resistance of each bulb is as calculated in **(a)(i)**.

(i) Determine the amount of charge that passes through bulb Y in 2 minutes.

charge = ... C [2]

(ii) Explain how the mean drift velocity of the electrons in the filament of bulb Y compare with that of the electrons in the filament of bulb Z.

....

....

....

....

.... [2]

(c) The six E10 light bulbs are now connected to an alternating power supply with frequency 50 Hz and r.m.s. voltage 6.0 V. An ideal diode is connected in parallel to bulb Z as shown in Fig. 6.3.

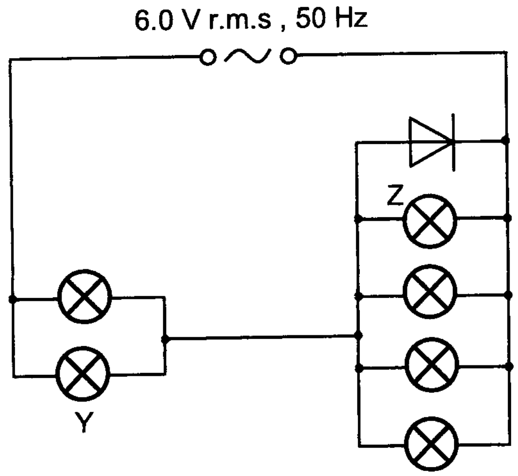

Fig. 6.3

On Fig. 6.4, sketch the variation with time t of the power P dissipated in bulb Y from $t = 0$ s to $t = 0.04$ s.

Include appropriate values for power on the vertical axis.

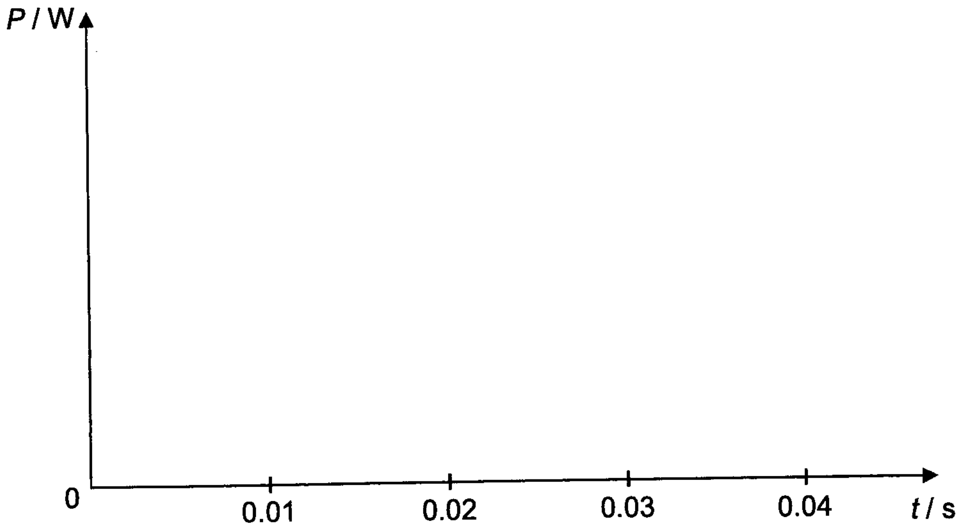

Fig. 6.4

[3]

7 A medical treatment makes use of a sample of americium-240 that emits alpha particles to kill cancer cells. In one such treatment, a total energy of 1140 J is applied to a tumour of mass 0.500 kg. At the start of the treatment, the mass of the americium-240 sample is 2.00×10^{-9} kg.

Americium-240 has a half-life of 50.2 hours, and it decays by emitting an alpha particle of kinetic energy 5.71 MeV.

(a) Determine

(i) the initial activity of the americium-240 sample,

activity = ... Bq [2]

(ii) the number of decays required for the treatment,

number of decays = ... [2]

(iii) the duration of the treatment.

duration = ... h [2]

(b) A student states that "radioactive materials with a long half-life have low activity".

Explain whether the statement is correct.

....

.... [1]

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

Despite the increasing popularity of laser printers, inkjet printers remain a common choice for many people who are looking to print documents and photos from their computers due to their relatively low cost, smaller size and ability to print photos with better quality than laser printers.

In inkjet printers, tiny droplets of ink are ejected and directly applied onto the paper, which then form the text or image. Traditionally, there are two main technologies used for droplet ejection in inkjet printers: continuous inkjet (CIJ) and drop-on-demand (DOD).

In CIJ printers, a vibrating nozzle ejects a stream of regularly spaced ink droplets at a high velocity towards a pair of charging electrodes that deposits electrons on the droplets, giving the appropriate amount of charge to each droplet. The charged droplets then enter a region of uniform electric field between two deflection plates, which causes the droplets to deflect by different amounts corresponding to the amount of charge deposited on them. These droplets finally land on the piece of paper to form the desired image. This process in a CIJ printer is shown in Fig. 8.1.

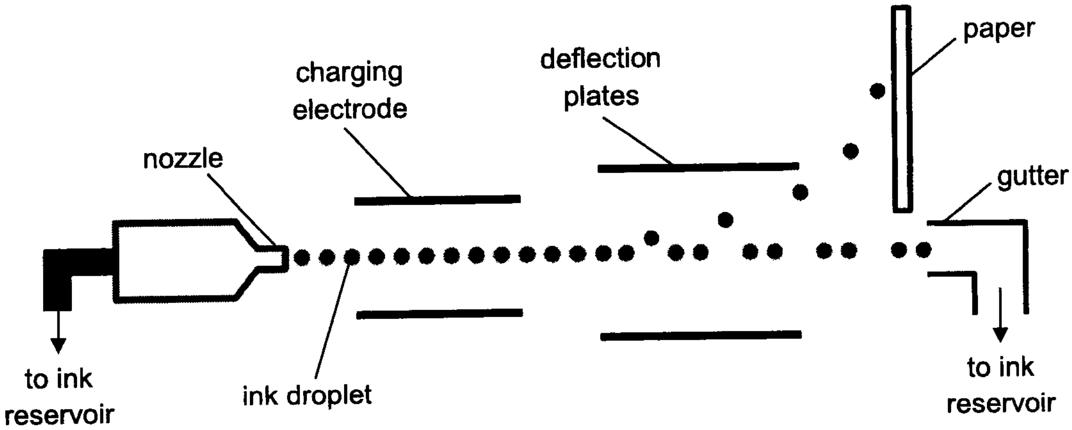

Fig. 8.1

Not every ink droplet that passes through the charging electrodes will get charged – instead, charged droplets will usually be separated by one or more uncharged "guard droplets". These uncharged droplets, which will not be deflected by the electric field, will enter a gutter that will divert these unused droplets back into the ink reservoir to be reused.

Typical data for a commercial CIJ printer are given in Table 8.1.

Table 8.1

velocity of ink droplets / m s^{-1}	20
frequency of droplet ejection / kHz	110
average diameter of ink droplet / μm	80
density of ink / g cm^{-3}	0.84
p.d. across deflection plates / V	10000

In DOD inkjet printers, ink droplets are ejected from a nozzle one drop at a time. While there are a number of different methods by which the droplets are ejected out individually, a common method used is called the thermal inkjet, or sometimes known as the "bubble jet".

In thermal inkjet printers, the printhead consists of an ink chamber connected to a nozzle from which the ink will be ejected. There is a square-shaped thin-film resistor of sides length 20 μm that acts as a heating element on top of the ink chamber.

A small pulse of current is passed through the thin-film resistor, which quickly heats up and vapourises a thin layer of ink just below the thin-film resistor. This creates a bubble which expands rapidly. The pressure within the ink chamber increases and pushes a tiny drop of ink out of the nozzle onto the paper underneath to form the desired image. This process in a thermal inkjet printer is shown in Fig. 8.2.

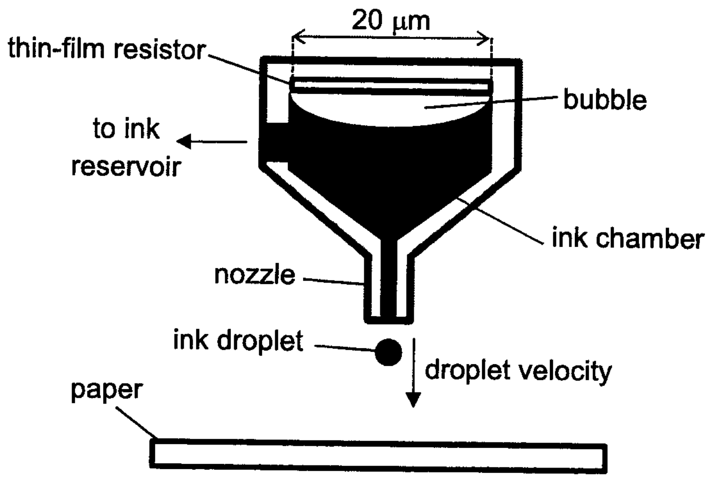

Fig. 8.2

Typical data for a commercial thermal inkjet printer are given in Table 8.2.

Table 8.2

velocity of ink droplets / m s^{-1}	4.5
frequency of droplet ejection / kHz	18
average diameter of ink droplet / μm	10
density of ink / g cm^{-3}	1.17
specific heat capacity of ink / J kg^{-1} K^{-1}	2090
specific latent heat of vaporisation of ink / kJ kg^{-1}	444
boiling point of ink / °C	80
resistance of thin-film resistor / Ω	30

(a) Fig. 8.3 shows a close-up of a series of spherical ink droplets travelling between the charging electrodes in a CIJ printer. Droplets A and B are two adjacent droplets.

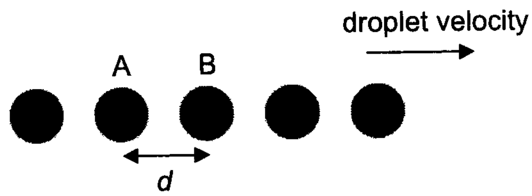

Fig. 8.3

Assume that the velocity of the droplets remains constant over its time of flight through the charging electrodes.

(i) Using the data given, determine

1. the distance d between droplets A and B,

d = ... μm [2]

2. the mass of each droplet.

mass = ... kg [2]

(ii) If droplets A and B are each charged uniformly with -1.0×10^{-13} C,

1. show that the electrostatic force between the droplets is 2.7 nN,

[1]

2. calculate the acceleration experienced by either droplet due to the electrostatic force in **(a)(ii)1.**

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

(iii) Suggest why "guard droplets" are necessary between two charged particles in the stream of ink droplets in a CIJ printer.

....

....

....

.... [2]

(b) Fig. 8.4 shows the deflection plates of the CIJ printer. Droplet A, with a charge of -1.0×10^{-13} C, enters at the midpoint between the plates at 20 m s^{-1} and is to be deflected upwards towards the piece of paper.

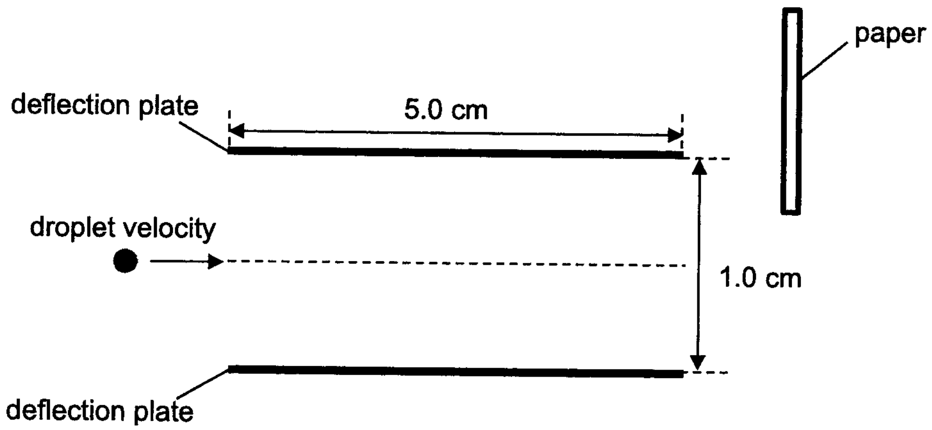

Fig. 8.4 (not to scale)

(i) Draw the electric field lines between the deflection plates on Fig. 8.4. [1]

(ii) Determine the electric field strength between the deflection plates.

electric field strength = ... N C^{-1} [1]

(iii) An engineer suggests using a magnetic field instead of an electric field to deflect droplet A.

1. Describe the direction of the magnetic flux density that is required to deflect droplet A upwards.

.... [1]

2. To deflect droplet A onto the paper, a reasonable radius of curvature for droplet A to undergo in the magnetic field would be 26.0 cm.

By determining the magnitude of the magnetic flux density *B* required to achieve a radius of curvature of 26.0 cm, comment on the feasibility of using a magnetic field in a commercial CIJ printer. Explain your working clearly.

....

....

.... [2]

(c) In a thermal inkjet printer, a constant current of 0.50 A is passed through the thin-film resistor for a short time interval of 0.010 μs. This causes a square layer of ink below the thin-film resistor of thickness x to heat up and vaporise. This is shown in Fig. 8.5.

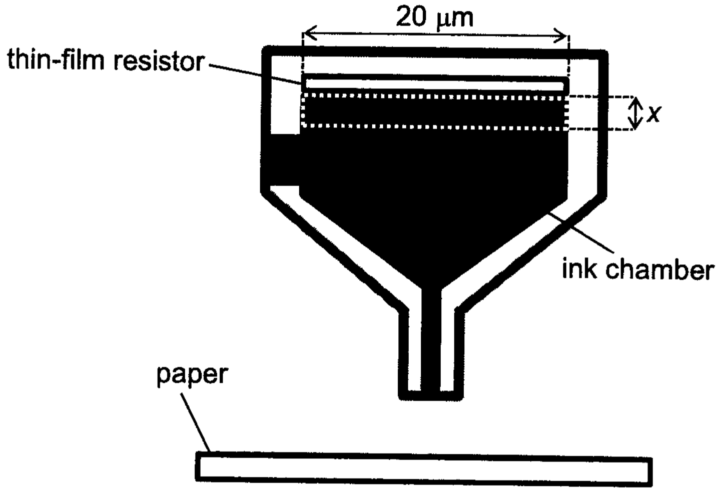

Fig. 8.5

(i) Determine the thermal energy produced by the current passing through the thin-film resistor.

thermal energy = ... J [2]

(ii) The ink in the ink chamber is initially at room temperature of 25°C.

Determine the maximum mass of ink that can be vaporised by the amount of thermal energy in **(c)(i)**.

mass = ... kg [2]

(iii) Hence, determine the maximum thickness x of the layer of ink that can be vaporised.

x = ... μm [2]

(iv) Suggest a possible reason why the actual thickness of the vaporised layer in real thermal inkjet printers is much smaller than that calculated in **(c)(iii)**.

....

.... [1]

(d) State, with reference to the information given, an advantage and a disadvantage of thermal inkjet printing as compared to CIJ printing.

Advantage: ....

....

....

Disadvantage: ....

....

.... [2]

End of Paper 2

Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2022 Preliminary Examination

PHYSICS
Higher 2

9749/03

Paper 3 Longer Structured Questions

21 September 2022
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use pencil for any diagrams or graphs.
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 and **circle the question number** on the cover page.

You are advised to spend one and a half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section A.**

For Examiner's Use		
Section A	1	/ 10
	2	/ 10
	3	/ 10
	4	/ 10
	5	/ 8
	6	/ 12
Section B (circle 1 question)	7	/ 20
	8	/ 20
Deduction		
Total		/ 80

This document consists of **15** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

Section A

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

1 **(a)** The microscopic potential energy of an ideal gas is taken to be zero.
State the assumption of an ideal gas that leads to this result.

....

.... [1]

(b) Fig. 1.1 shows a sealed thermally insulated container with a smooth and light piston that separates two monatomic ideal gases, gas A and gas B. The piston does not allow gas A and gas B to mix but allows heat transfer between them.

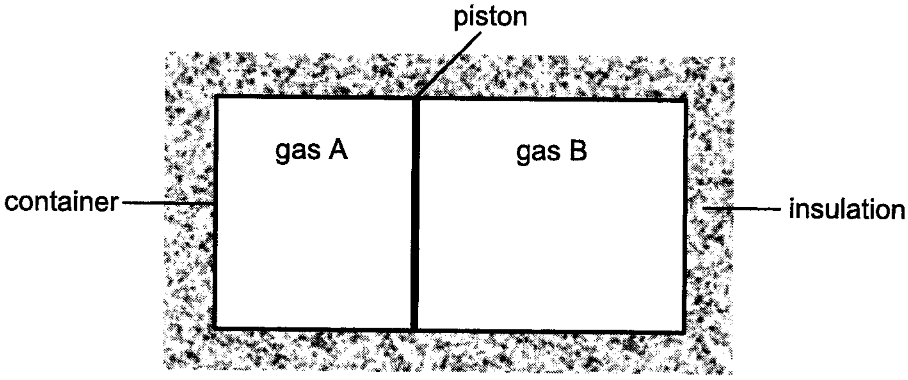

Fig. 1.1

(i) Initially, 1.8 mol of gas A at temperature 400 K and pressure 3.0×10^5 Pa occupies a volume of 2.0×10^{-2} m^3 while gas B at temperature of 300 K and pressure of 2.0×10^5 Pa occupies a volume of 3.0×10^{-2} m^3.

1. Show that the amount of gas B is 2.4 mol.

[1]

2. Determine the total internal energy of gas A and gas B.

total internal energy = ... J [2]

(ii) Due to the difference in pressure of the gases, the piston moves until both gases achieve thermal equilibrium and the piston is in translational equilibrium.

1. Calculate the final temperature of the gases. Explain your working.

temperature = ... K [2]

2. Use the first law of thermodynamics to explain the change in the temperature of gas A as the system achieves equilibrium.

....

....

....

....

....

....

.... [3]

(iii) For the set-up in Fig. 1.1, gas B is now replaced by vacuum. The piston is then removed without any gas escaping or entering the container.

It is found that the final temperature of gas A at equilibrium remains at 400 K, which is the same as its initial temperature.

Explain why there is no change in the temperature of gas A.

....

....

.... [1]

2 A light spring hangs vertically from a fixed point. A load of mass m is attached to the free end of the spring and slowly lowered until equilibrium is reached as shown in Fig. 2.1. The spring has then stretched elastically by a distance of x_0.

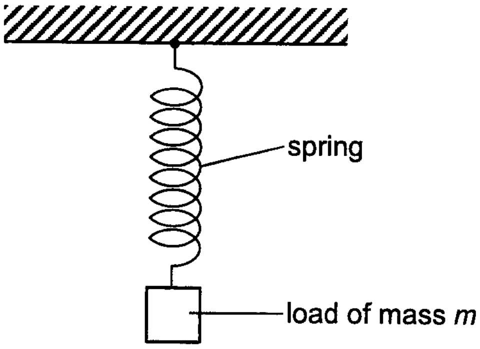

Fig. 2.1

(a) **(i)** Show, for the stretching of the spring, that the decrease in the gravitational potential energy of the mass is twice the increase in the elastic potential energy of the spring.

[2]

(ii) Account for the difference in the decrease in gravitational potential energy and the increase in elastic potential energy.

....

.... [1]

(b) The load on the spring is now made to oscillate vertically in simple harmonic motion with amplitude x_0.

Take the lowest point of the oscillation as the position where the gravitational potential energy of the load is zero.

(i) Determine, in terms of m, x_0 and the acceleration of free fall g, the elastic potential energy of the spring when the load is at the lowest point of the oscillation.

elastic potential energy = ... [2]

(ii) Use your answers in **(a)(i)** and **(b)(i)** to draw, on the axes of Fig. 2.2, the variation with position of

1. the gravitational potential energy (label this line G.P.E.),
2. the elastic potential energy (label this line E.P.E.),
3. the kinetic energy (label this line K.E.),
4. the total energy (label this line T.E.).

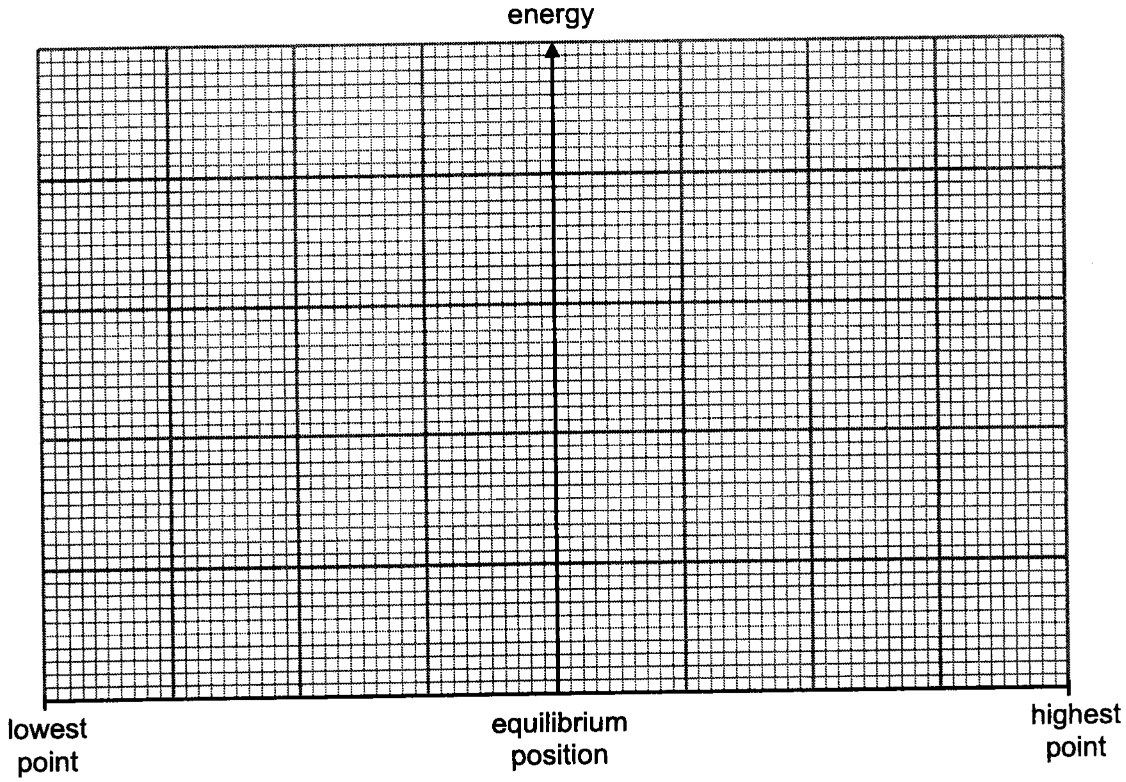

Fig. 2.2

[5]

3 Two identical metal spheres A and B, each with radius R and carrying charge $+Q$, are isolated in space with their centres a distance $2d$ apart as shown in Fig 3.1. Assume charges remain uniformly distributed on the surfaces of the spheres.

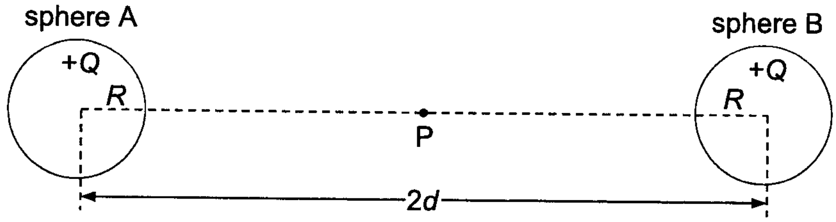

Fig. 3.1

Distance x is measured from the centre of sphere A along the line joining the centres of the two spheres.

Point P is the mid-point between the two metal spheres.

(a) **(i)** On Fig. 3.2, sketch the variation with distance x from $x = 0$ to $x = 2d$ of the electric potential V between the two spheres.

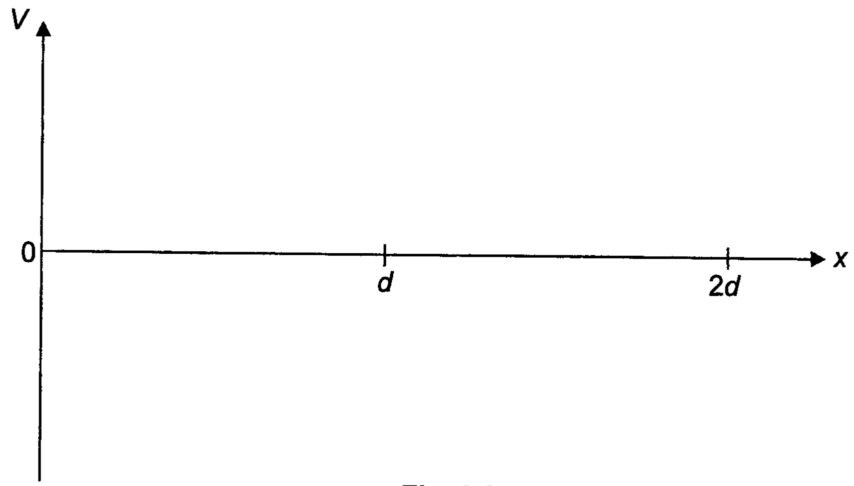

Fig. 3.2

[2]

(ii) On Fig. 3.3, sketch the variation with distance x from $x = 0$ to $x = 2d$ of the electric field strength E between the two spheres.

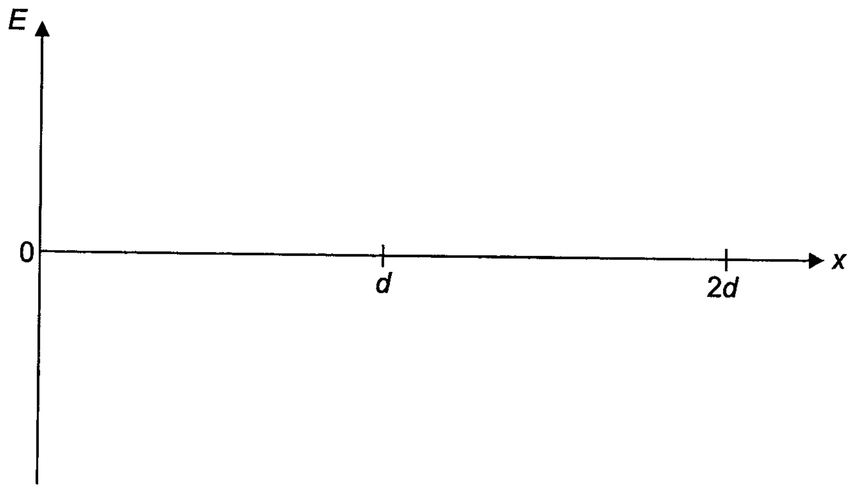

Fig. 3.3

[2]

(b) **(i)** An electron is placed at point P. State and explain the resultant force acting on the electron.

....

....

.... [1]

(ii) The electron is then displaced slightly upwards, perpendicular to the line joining the centres of the two spheres by a distance y from point P.

1. On Fig 3.4, draw and label with F_A and F_B, the force that sphere A and sphere B acts on the electron respectively.

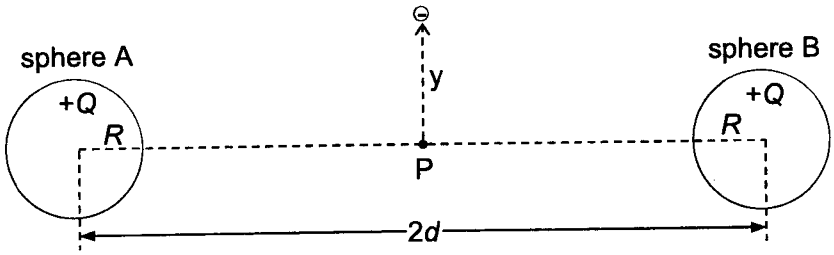

Fig. 3.4

[1]

2. Derive an expression, in terms of Q, d, y, elementary charge e and the permittivity of free space ε_0, for the resultant force F_R acting vertically on the electron when the displacement of the electron from its equilibrium position is y.

Explain your working.

[2]

3. For very small displacements, it can be shown from the expression derived in **(b)(ii)2.** that the acceleration a of the electron at displacement y is given by

$$a = -\frac{Qe}{2\pi\varepsilon_0 m_e d^3} y$$

where m_e is the mass of the electron.

Describe and explain the subsequent motion of the electron after it is released.

....

....

....

....

....

.... [2]

4 Fig. 4.1 shows an electron with constant speed v moving in a region of uniform magnetic field of flux density 2.8×10^{-5} T. The direction of the magnetic field is perpendicular to the plane of to the paper. The electron follows a clockwise circular path in the plane of the paper.

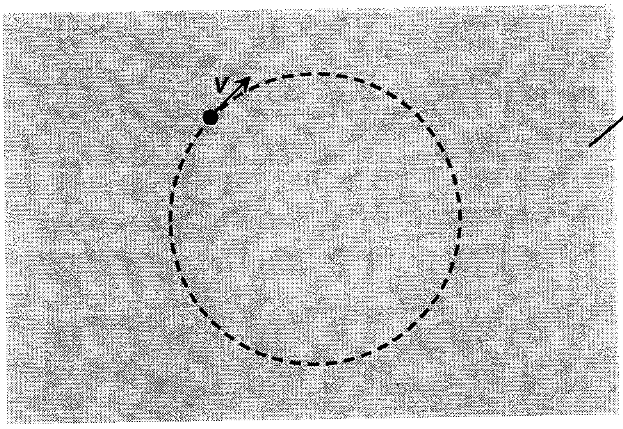

Fig. 4.1

(a) **(i)** Explain why the path of the electron in the magnetic field is circular.

....

....

....

....

....

.... [2]

(ii) Determine the frequency of revolution f of the electron.

f = ... Hz [2]

(b) A second electron, with twice the kinetic energy of the first electron in **(a)**, is injected in the same direction into the same magnetic field. The second electron also follows a circular path in the magnetic field.

Comparing the circular motion of the first and second electron, state and explain whether there are differences in each of the following quantities:

(i) radius of circular path,

....

....

....

.... [2]

(ii) period of revolution,

....

....

.... [1]

(iii) work done on the electron in one revolution.

....

....

.... [1]

(c) A uniform electric field is now applied together with the magnetic field. The direction of the electric field is in the same direction as the magnetic field in Fig. 4.1.

Describe and explain the subsequent motion of the electron.

....

....

....

....

.... [2]

5 Fig. 5.1 shows two uniform magnetic fields P and Q next to each other. The fields do not affect each other.

Field P, with magnetic flux density 0.1 T, is pointing into the page. Field Q, of magnetic flux density 0.2 T, is pointing out of the page. The length of each magnetic field is 3.0 cm.

A small square coil with sides of length 1.0 cm moves at a constant velocity of 1.0 cm s^{-1} across the two fields, entering through field P and finally exiting through field Q.

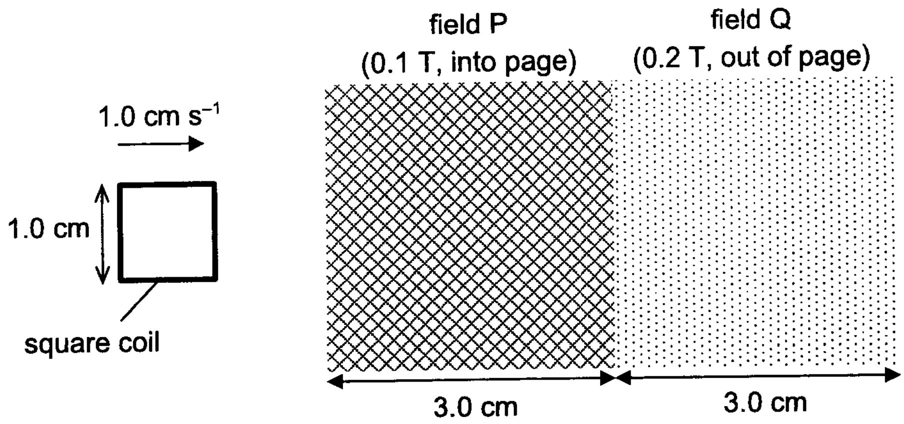

Fig. 5.1

(a) On Fig. 5.2, draw the variation with time t of the magnetic flux Φ through the square coil from the moment the coil enters field P ($t = 0$) to the moment it completely exits field Q.

Include appropriate values on the axes.

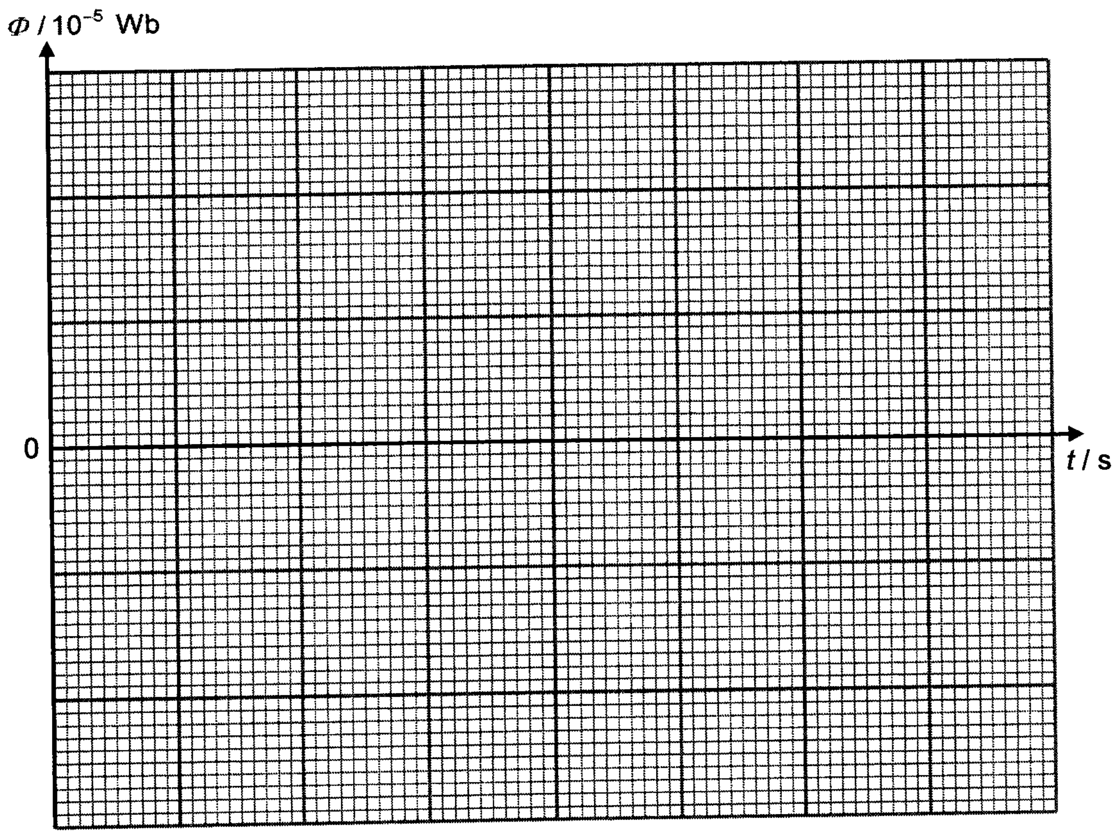

Fig. 5.2

[3]

(b) Using the laws of electromagnetic induction, explain why work needs to be done by an external force on the square coil to move it through the magnetic fields at a constant velocity.

....

....

....

....

....

....

....

.... [3]

(c) Determine the magnitude of the maximum e.m.f. induced in the square coil.

e.m.f. = ... V [2]

6 **(a)** With reference to the photoelectric effect, explain why the existence of a threshold frequency provides evidence for the particulate nature of electromagnetic radiation.

....

....

....

....

....

....

....

.... [3]

(b) Light of frequency f and wavelength λ is incident on a metal surface with work function energy Φ. Electrons are emitted from the surface with maximum kinetic energy E_{max}.

The variation of $E_{max}\lambda$ with λ from 100 nm to 1000 nm is shown in Fig. 6.1.

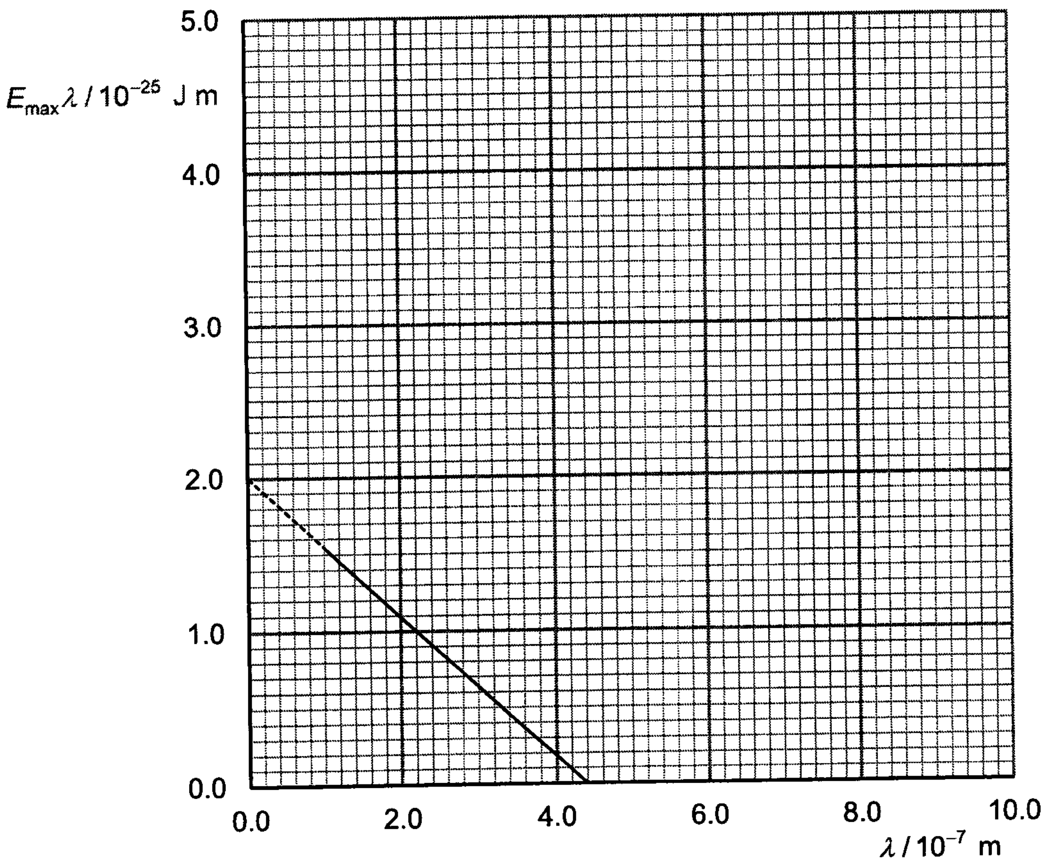

Fig. 6.1

(i) Use Fig. 6.1 to determine Φ. Explain your working.

Φ = ... J [2]

(ii) For $\lambda = 2.0 \times 10^{-7}$ m, use Fig. 6.1 to determine

1. the stopping potential,

stopping potential = ... V [3]

2. the de Broglie wavelength of the electron with maximum kinetic energy.

wavelength = ... m [2]

(c) The metal is now replaced with another metal with twice the work function energy.

On Fig. 6.1, draw a line to show the variation of $E_{max}\lambda$ with λ for this new metal.

[2]

End of Paper 3 Section A

Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2022 Preliminary Examination

PHYSICS
Higher 2

9749/03

Paper 3 Longer Structured Questions

21 September 2022
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use pencil for any diagrams or graphs.
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 and **circle the question number** on the cover page.

You are advised to spend one and half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section B.**

For Examiner's Use		
Section B (circle 1 question)	7	/ 20
	8	/ 20
Deduction		

This document consists of **8** printed pages.

Section B

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

7 **(a)** Fig. 7.1 shows a stretched string connected to an oscillator at one end and a load over a smooth pulley at the other end. The length of the string between the oscillator and the pulley is L.

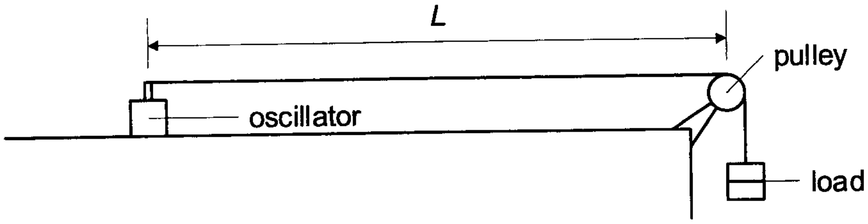

Fig. 7.1

(i) Explain why observable stationary waves are seen on the string when the oscillator is vibrating vertically at certain discrete frequencies.

....

....

....

....

....

....

.... [3]

(ii) Show that the discrete frequencies in **(a)(i)** are integer multiples of $\frac{v}{2L}$ where v is the speed of the wave on the string.

[1]

(iii) When the frequency of the oscillator is 40.0 Hz, a stationary wave with 5 nodes is seen for $L = 0.600$ m.

Calculate v.

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

(iv) The speed v of the wave on the string is related to the tension T in the string by

$$v = k\sqrt{T}$$

where k is a constant.

Determine the new frequency of the oscillator such that a stationary wave with 5 nodes is still seen on the string if the tension is decreased by 2%.

new frequency = ... Hz [2]

(b) (i) Fig. 7.2 shows a point source positioned a distance D from a single slit of width 0.30 mm. The point source emits monochromatic light of wavelength 600 nm.

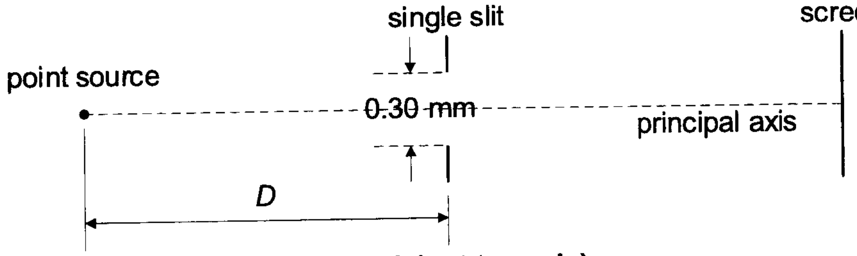

Fig. 7.2 (not to scale)

1. Show that the angle of the first minimum of the diffraction pattern from the principal axis is 2.0×10^{-3} rad.

[1]

2. Sketch on Fig. 7.3, the diffraction pattern of the light after passing through the single slit. The maximum intensity of the central bright fringe is I_0.

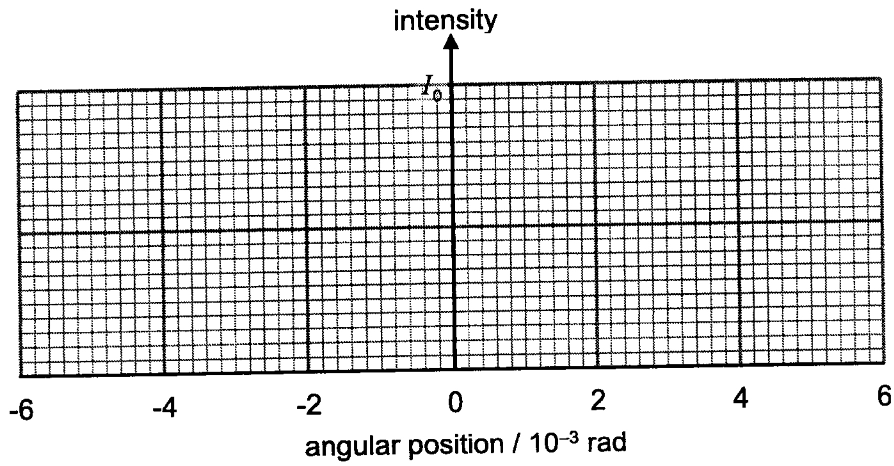

Fig. 7.3

[2]

3. A second identical point source is placed 0.50 m beside the original point source at the same distance D from the single slit.

Determine D where the two point sources are just resolved.

D = ... m [2]

(ii) The second point source is now removed. An opaque film with a width of 0.10 mm is positioned at the centre of the single slit such that a double slit is formed as shown Fig. 7.4.

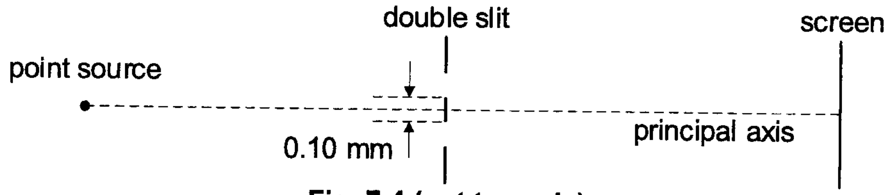

Fig. 7.4 (not to scale)

1. Determine the separation between the two slits.

separation = ... mm [1]

2. Besides a change in intensity, state, with numerical values, the other changes to the diffraction pattern observed in Fig. 7.3.

....

....

....

....

.... [3]

3. Determine, in terms of I_0, the maximum intensity of the pattern after the film is applied.

maximum intensity = ... [3]

8 A uranium-238 (U) nucleus, originally at rest in a cloud chamber, undergoes spontaneous decay by emitting an α-particle to form a thorium (Th) nucleus.

(a) State what is meant by the number *238*.

....

.... [1]

(b) Complete the nuclear equation below for the decay.

$$^{238}_{\square}\text{U} \rightarrow {}^{\square}_{90}\text{Th} + {}^{4}_{\square}\text{He}$$

[2]

(c) The α-particle travels 40.0 mm in the cloud chamber to produce a track of ion-pairs which causes the α-particle's path to be visible due to condensation taking place on the ions produced.

On average, an α-particle produces 5.90×10^3 ion-pairs per mm of track in the cloud chamber and the energy required to produce an ion-pair is 2.70×10^{-18} J.

(i) Show that the kinetic energy of the α-particle is 6.37×10^{-13} J.

[1]

(ii) Determine the momentum of the thorium nucleus.

momentum = ... N s [2]

(iii) Determine the total kinetic energy of the α-particle and the thorium nucleus.

total kinetic energy = ... MeV [3]

(iv) State an assumption you made in your calculations in **(c)(ii)** and **(c)(iii)**.

....

.... [1]

(d) Fig. 8.1 shows the variation with nucleon number A of the nuclear binding energy per nucleon B_E.

The nuclear binding energy per nucleon of uranium-238 nucleus is 7.57 MeV and that of the α-particle is 7.08 MeV.

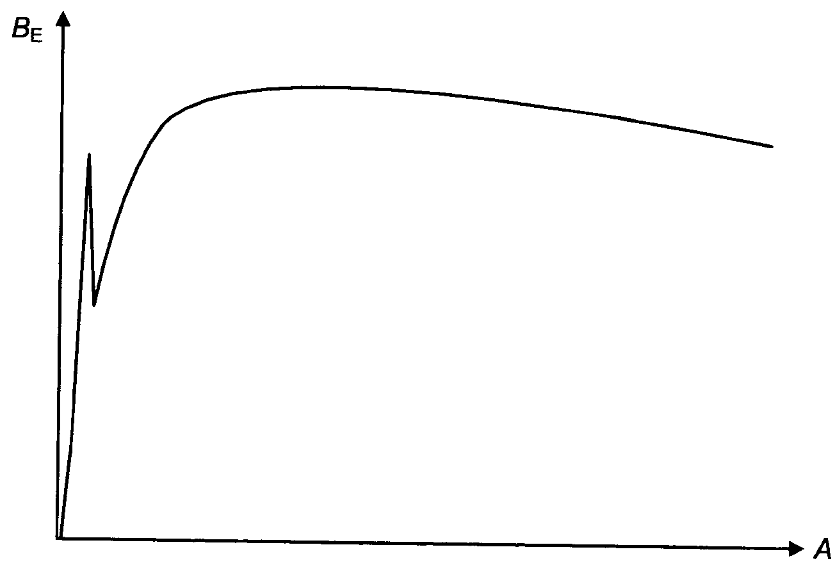

Fig. 8.1

(i) Explain the term *nuclear binding energy*.

....

....

.... [1]

(ii) State the nuclide with the highest B_E and its B_E to 2 significant figures.

nuclide : ....

B_E : .... MeV [2]

(iii) Determine the nuclear binding energy per nucleon of the thorium nucleus.

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

(iv) On the curve in Fig. 8.1, mark the approximate positions of the nuclei of

1. uranium-238 (label the position U),
2. thorium (label the position Th),
3. α-particle (label the position α). [2]

(v) Nuclear fusion is a nuclear reaction that releases energy.

1. Explain the term *nuclear fusion*.

....

.... [1]

2. One such type of nuclear fusion reaction is $A + B \rightarrow C$.

On Fig. 8.1, mark the approximate positions of the nuclei of A, B and C. [1]

End of Paper 3 Section B

Centre Number	Class Index Number	Name	Class
S3016			

RAFFLES INSTITUTION

2022 Preliminary Examination

PHYSICS **Higher 2** Paper 4 Practical	**9749/04** **15 August 2022** **2 hours 30 minutes**

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces provided at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Candidates answer on the Question Paper.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and maximum of one hour for Question 3. You are advised to spend approximately 30 minutes for Question 4.

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 of the practical shift and laboratory 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	/ 10
2	/ 12
3	/ 22
4	/ 11
Total	/ 55

This document consists of **18** printed pages and **2** blank pages.

1 In this experiment, you will investigate the effect of friction on a simple pulley system.

(a) You are provided with a spring of unstretched length L_0, as shown in Fig. 1.1.

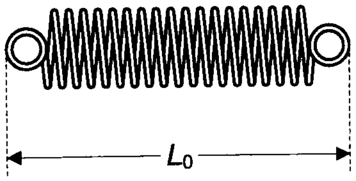

Fig. 1.1

Measure and record L_0.

L_0 = ... [1]

(b) Set up the apparatus as shown in Fig. 1.2.

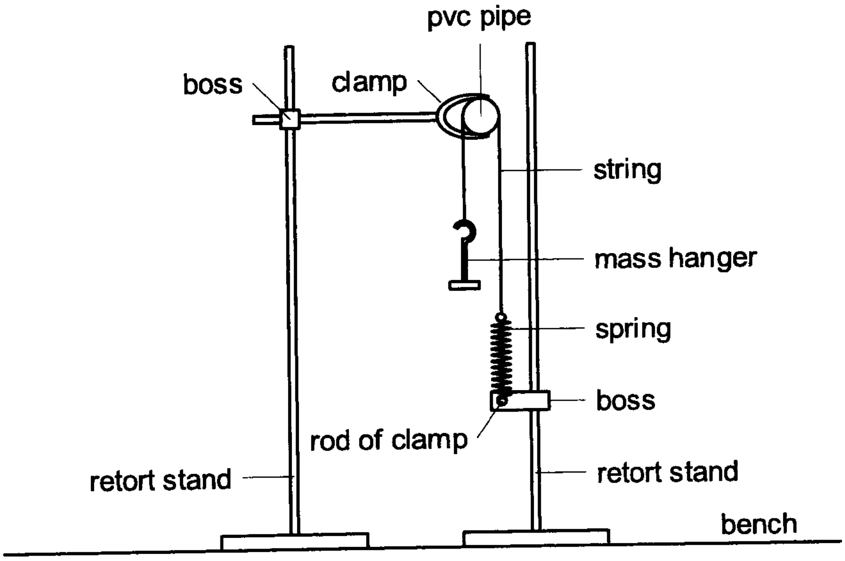

Fig. 1.2

Ensure that the pipe remains horizontal at all times, and that the strings on each side of the pipe are vertical and parallel with each other.

The spring should only stretch minimally at this instant.

(i) Place a 50 g slotted mass onto the mass hanger and **slowly** lower the mass hanger, allowing the spring to extend to a new equilibrium length L_1,

Measure and record L_1.

L_1 = ... [1]

(ii) Calculate the extension x_1 of the spring from its unstretched length, where

$$x_1 = L_1 - L_0$$

x_1 = ... [1]

(iii) Pull the mass hanger downwards by about 10 cm, causing the spring to extend further. Hold the hanger while allowing it to **slowly** rise upwards until the spring retracts to another equilibrium length L_2, where L_2 is larger than L_1.

Measure and record L_2.

L_2 = ...

(iv) Calculate the new extension x_2 of the spring from its unstretched length, where

$$x_2 = L_2 - L_0$$

x_2 = ... [1]

(c) Theory suggests that x_1 and x_2 are related by the expression

$$\ln\frac{x_2}{x_1} = 2\beta\theta$$

where β is a constant and θ is the angle of contact (expressed in radians) between the string and the pipe, as shown in Fig. 1.3.

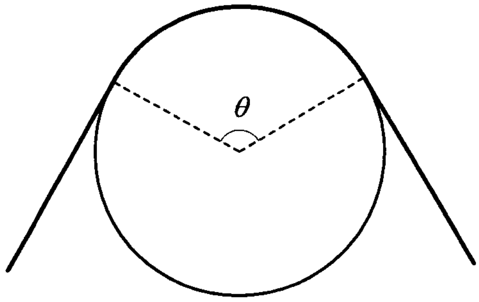

Fig. 1.3

(i) State the value of θ for the set-up in Fig. 1.2.

θ = ... [1]

(ii) Determine a value for β.

β = ... [1]

(iii) The experiment is repeated with different numbers of slotted masses to obtain more values of x_1 and x_2.

State how a straight line graph can be plotted and used to determine the value of β, assuming the theory is correct.

....

....

....

.... [2]

(iv) State the value of β if the pipe is frictionless. Explain your answer.

....

....

....

.... [2]

[Total: 10]

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2 In this experiment, you will investigate an electrical circuit.

(a) Component Z in the circuit shown in Fig. 2.1 is a combination of three resistors: X, X and Y. The values of the resistance of X and Y are 2.2 Ω and 3.3 Ω respectively.

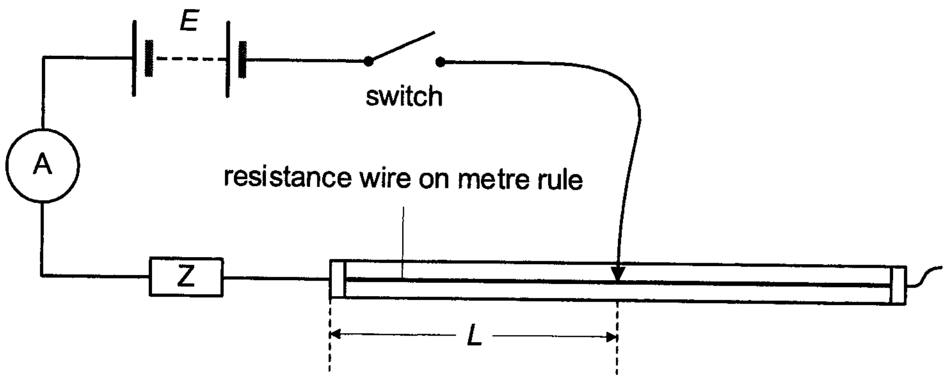

Fig. 2.1

Set up the circuit in Fig. 2.1 such that Z is a combination of X, X and Y connected in series. Draw this series combination.

Calculate the effective resistance R_Z of Z.

R_Z = ... [1]

Close the switch.

Adjust length L to obtain an ammeter reading I of approximately 0.10 A.

Measure and record I and L.

I = ...

L = ... [1]

Open the switch.

(b) Vary R_Z using different combinations of **ALL** the resistors X, X and Y and repeat **(a)**, keeping I constant throughout.

Present your results clearly. Include drawings of the different combinations of X, X and Y.

[3]

(c) R_z and L are related by the expression

$$E = IR_z + kIL$$

where E is the electromotive force of the cell and k is a constant.

Plot a suitable graph to determine a value for k.

k = ... [5]

(d) It is given that

$$k = \frac{\rho}{A}$$

where ρ and A are the resistivity and the cross-sectional area of the resistance wire respectively.

By making appropriate measurements, determine the value of ρ.

ρ = ... [1]

(e) The experiment is repeated using a resistance wire of the same material but with a smaller diameter.

Sketch a line on your graph grid on Page 8 to show the expected result.

Label this line W. [1]

[Total: 12]

3 In this experiment, you will investigate the behaviour of an oscillating system.

You have been provided with a set of acrylic discs and three long strings.

(a) **(i)** Fig. 3.1 shows disc B of diameter *D*. On the disc are three small holes at equal distance *r* from the centre of the disc.

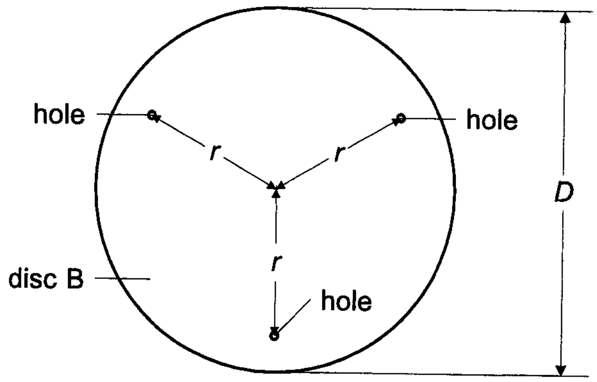

Fig. 3.1

Measure the diameter *D* of disc B using a pair of vernier callipers.

D = ... [1]

(ii) Measure the distance *r* of the holes from the centre of the acrylic disc.

Explain how *r* is measured.

r = ... [1]

....

.... [1]

(iii) Estimate the percentage uncertainty in your value of *r*.

percentage uncertainty in *r* = ... [1]

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

Clamp the top disc between two wooden blocks.

Thread the strings through the holes on both discs and secure the strings to the discs with adhesive tape only.

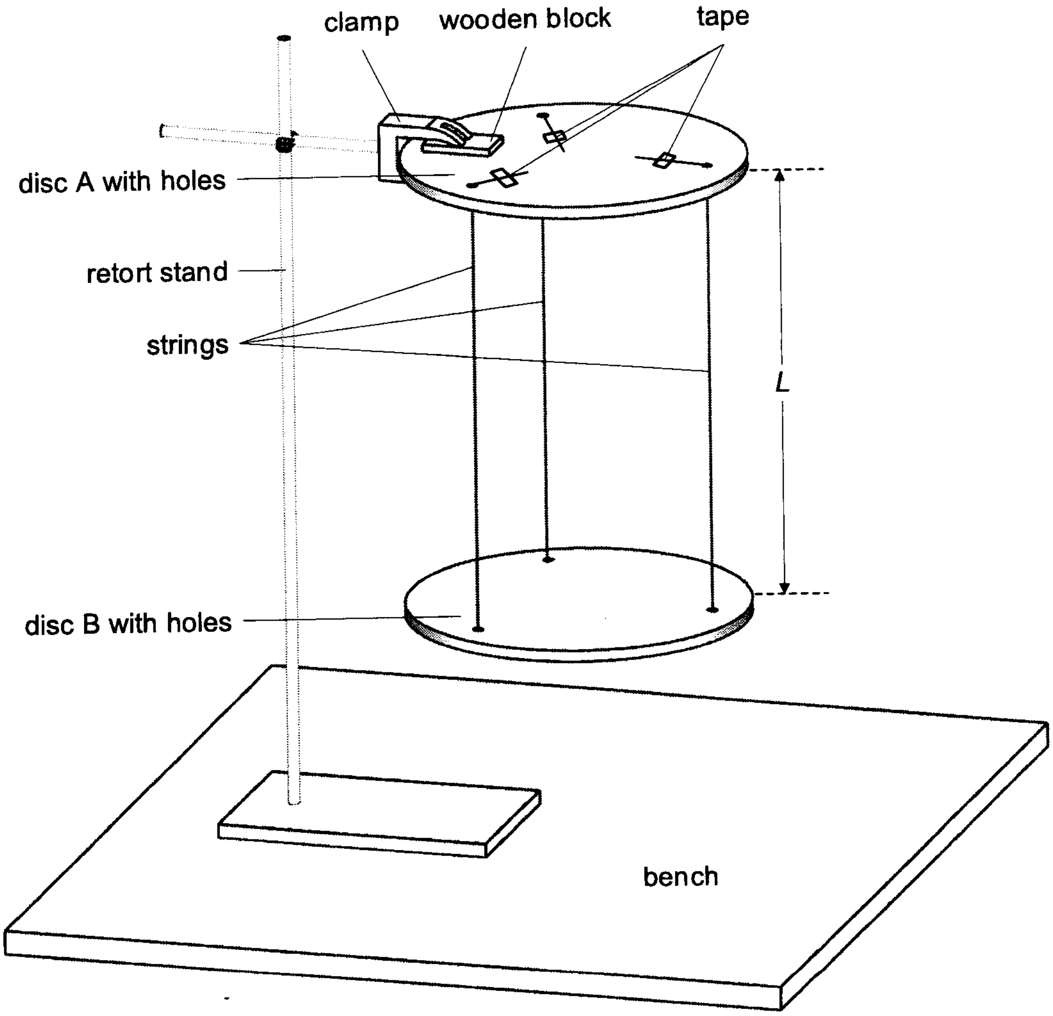

Fig. 3.2

The distance between the bottom face of disc A and the top face of disc B is L.

Adjust the lengths of the strings until L is approximately 30 cm.

Both discs should be horizontal.

Measure and record L.

L = ... [1]

(i) Rotate disc B so that it oscillates about a vertical axis through its centre.
Determine the period T_R of these oscillations.

T_R = ... [1]

(ii) Displace disc B to the left and release such that it oscillates in a vertical plane.
Determine the period T_S of these oscillations.

T_S = ... [1]

(c) Increase L to approximately 50 cm. Repeat **(b)(i)** and **(b)(ii)**.

L = ...

T_R = ...

T_S = ... [2]

(d) It is suggested that

$$T_R = k\frac{\sqrt{L}}{r}$$

where k is a constant.

(i) Use your values from **(a)(ii)**, **(b)** and **(c)** to determine two values of k.

first value of k = ...

second value of k = ... [2]

(ii) Justify the number of significant figures given in your values of k.

....

....

....

.... [1]

(iii) State whether or not the results of your experiment support the suggested relationship. Justify your conclusion by referring to your values in **(a)(iii)**.

....

....

.... [1]

(e) The period T_S of the oscillations in a vertical plane varies linearly with $\sqrt{L}$.

Use your results in **(b)** and **(c)** to estimate a value of L where $T_R = T_S$.

L = ... [4]

(f) The behaviour of the oscillating system in **(b)(i)** also depends on r, the distance of the strings from the centre of the disc according to the expression in **(d)**.

Explain how you would investigate this relationship.

Your account should include:

- your experimental procedure
- how the holes in both discs are accurately located
- control of variables
- how you would use your results to show that T is inversely proportional to r.

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[5]

....

[Total: 22]

4 When two ends of a copper rod of length L have a temperature difference of ΔT, the temperature gradient $\frac{\Delta T}{L}$ along the rod is related to the rate of heat transfer P through the rod and the cross-sectional area A of the rod by

$$\left(\frac{\Delta T}{L}\right) = kP^m A^n ,$$

where k, m and n are constants.

Design an experiment to determine the values m and n.

You are provided with an electrical heating coil, ice cubes and cylindrical copper rods of different dimensions.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to

(a) the equipment you would use

(b) the procedure to be followed

(c) how you would determine the rate of heat transfer

(d) the control of variables

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

Diagram

[11]

[Total: 11]

End of Paper

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