H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/01**

Paper 1 Multiple Choice

18 September 2024
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THE INSTRUCTION FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

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.

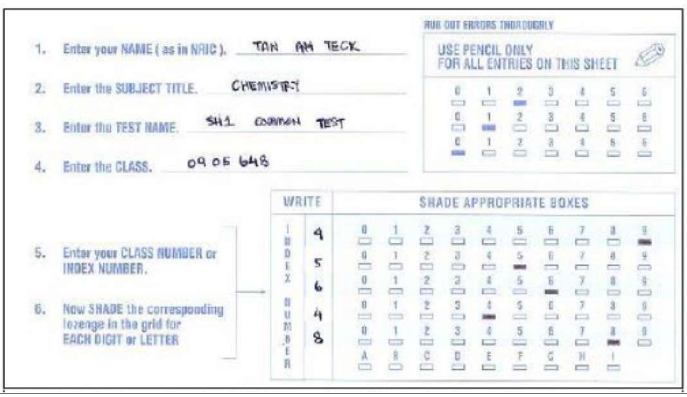
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

The OAS index number is in a 5-digit format.

The 5-digit format is as follows: **2nd digit** and the **last four digits** of the Reg Number.

e.g. 2**00**5**011** becomes **05011**

INSTRUCTIONS ON SHADING OF REGISTRATION NUMBER



This document contains **15** printed pages and **1** blank pages.

[Turn over

Data

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

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	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 What is the number of heartbeats of a person at rest in one hour, to the nearest order of magnitude?

A 10^1 **B** 10^2 **C** 10^3 **D** 10^5

2 Which experimental technique reduces the systematic error of the quantity being investigated?

A measuring the diameter of a wire repeatedly and calculating the average

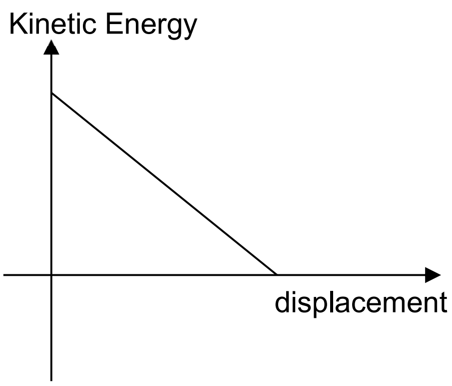
B measuring several internodal distances on a standing wave to find the mean internodal distance

C adjusting an analogue ammeter to remove its zero error before measuring a current

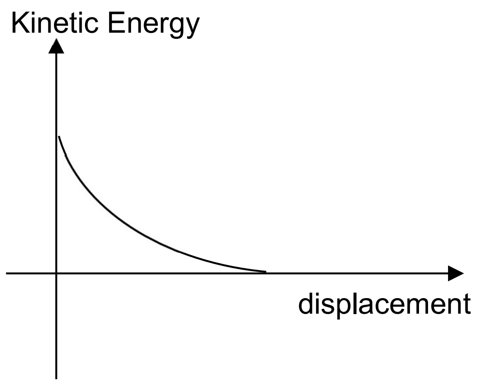
D timing a large number of oscillations to find a period

3 A block is projected at a certain speed up a frictionless slope. Which of the following graphs correctly shows the relationship between the kinetic energy of the block and the displacement of the block along the slope after its point of projection?

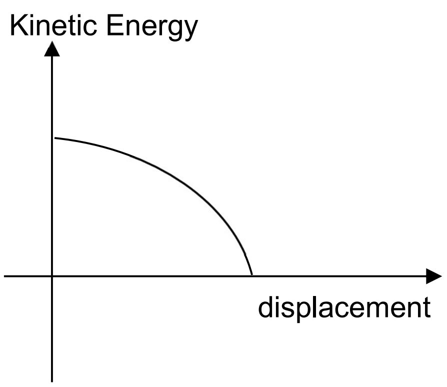
A



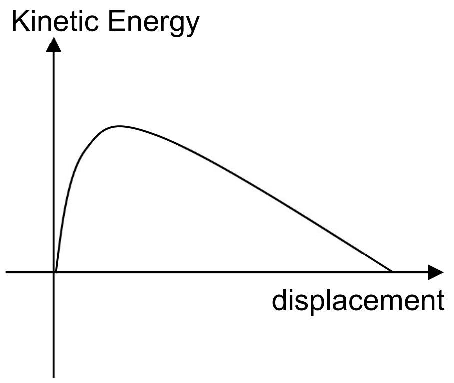
B



C



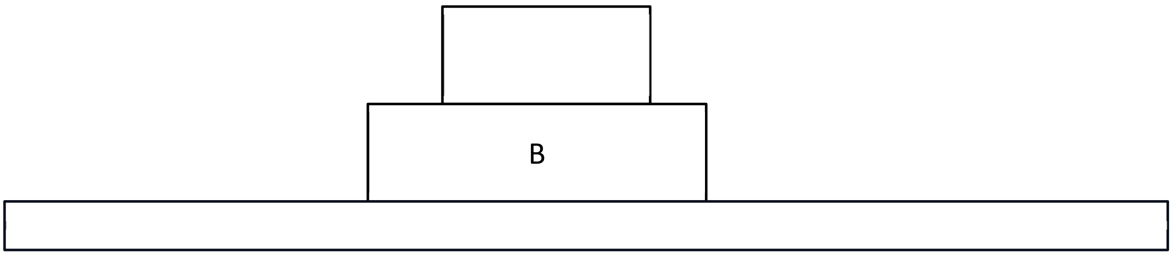
D



4 Drops of water falls from the roof of a building 9.0 m high at regular intervals of time. The first drop reaches the ground at the instant the fourth drop starts its fall. What is the distance between the second and third drops from the roof?

A 1.0 m **B** 3.0 m **C** 4.0 m **D** 5.0 m

5 Two objects are being pulled along a smooth floor by a 70 N force as shown. Object A has a mass of 20 kg and object B has a mass of 6.0 kg. The masses do not slide against each other.



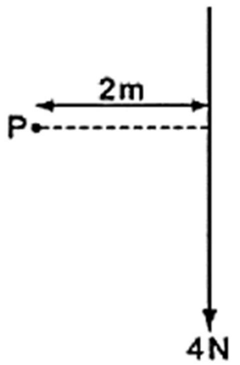
A
B
70 N

Which line of the table correctly states the magnitude and direction of friction on A by B?

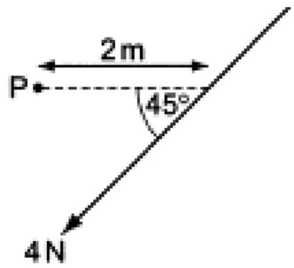
	magnitude	direction
A	16 N	to the left
B	16 N	to the right
C	54 N	to the left
D	54 N	to the right

6 In which diagram is the moment of force about point P greatest?

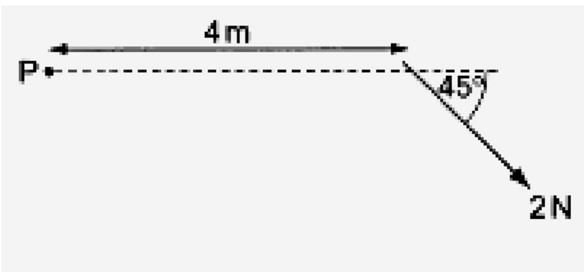
A



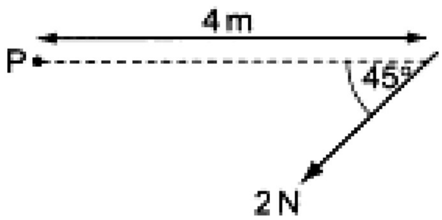
B



C



D



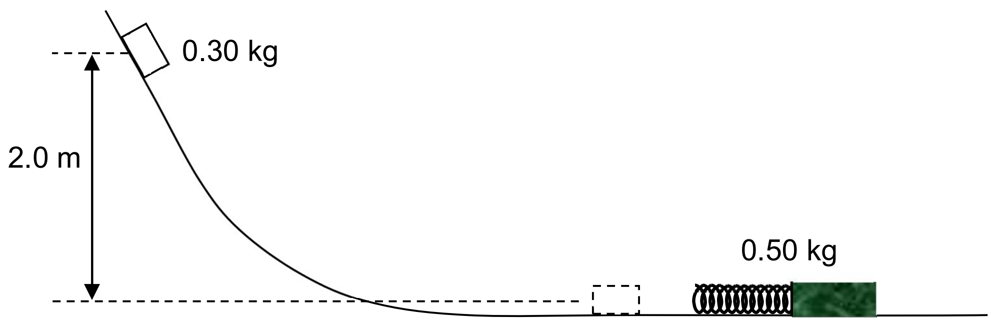
[Turn over

7 Before two moving bodies collide, they have kinetic energy and momentum.

Which row correctly states whether the total kinetic energy and the total momentum are conserved or not after the collision?

	total kinetic energy	total momentum
A	always conserved	always conserved
B	always conserved	may change
C	may change	always conserved
D	may change	may change

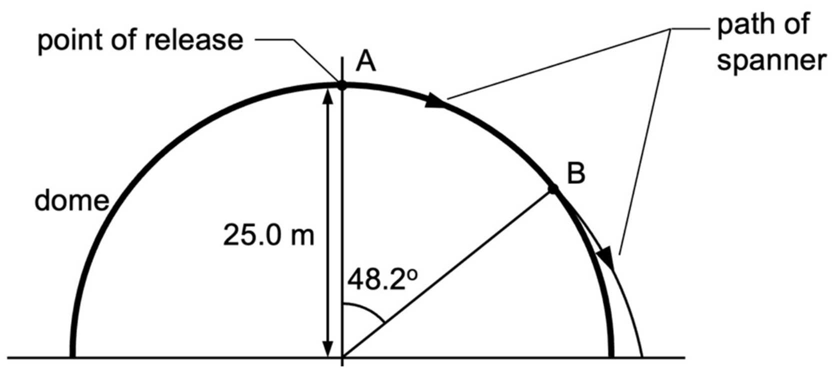
8 A mass of 0.30 kg slides from rest at height 2.0 m down a smooth curved surface which becomes horizontal at zero height. Another mass with a spring attached has a total mass of 0.50 kg and it is at rest on the level part of the surface. During collision, the maximum compression of the spring is 0.20 m.



What is the spring constant?

A 184 N m^{-1} **B** 196 N m^{-1} **C** 253 N m^{-1} **D** 294 N m^{-1}

9 A workman on the roof of a hemispherical sports dome of radius 25.0 m lets go of a spanner very close to the highest point A as shown.



The surface of the roof is very smooth and the spanner starts to slide from rest down the dome. The spanner loses contact with the surface at point B.

What is the centripetal acceleration of the spanner at point B?

A 4.91 m s^{-2} **B** 6.54 m s^{-2} **C** 7.31 m s^{-2} **D** 9.81 m s^{-2}

10 Which of the following statements about geostationary orbits is **false**?

A A geostationary orbit must be directly above the equator.

B All satellites in a geostationary orbit must have the same mass.

C The period of a geostationary orbit must be 24 hours.

D There is only one possible radius for a geostationary orbit.

11 Which of the following is a property of a uniform gravitational field?

A It acts equally in all directions

B Its field strength is the same at all points within it.

C It produces zero force on a stationary test mass placed in it.

D The gravitational potential has the same value at all points within it.

12 Three particles have speeds of 2u, 10u and 11u. Which one of the following statements is correct?

A The r.m.s. speed exceeds the mean speed by about 1u.

B The mean speed exceeds the r.m.s. by about 1u.

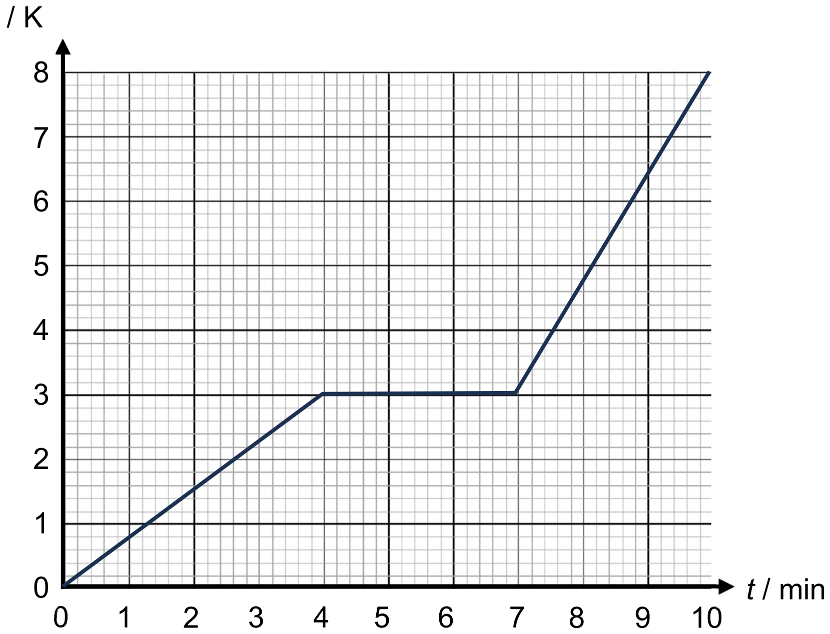
C The r.m.s. speed exceeds the mean speed by more than 2u.

D The mean speed exceeds the r.m.s. speed by more than 2u.

13 A gas cylinder is fitted with a safety valve which releases a gas when the pressure inside the cylinder reaches 2.0×10^6 Pa. Given that the maximum mass of this gas the cylinder can hold at 10°C is 15 kg, what would be the maximum mass at 30°C?

A 5.0 kg **B** 14 kg **C** 15 kg **D** 16 kg

14 The graph shows the variation with time t of temperature change Δ(for 1 kg of a substance, initially solid at room temperature. The substance receives heat at a uniform rate of 2000 J min^{-1}.



What can be deduced from this graph?

A The specific heat capacity of the substance is greater when liquid than when solid.

B The specific latent heat of fusion of the substance is 6000 J kg^{-1}.

C The substance melts at a temperature of 3 K.

D After 10 min, the substance is all gaseous.

15 A student is investigating the specifications of a camera shutter. He used a camera to photograph a simple pendulum bob that is moving in front of a horizontal scale. The extreme positions of the bob were at 600 mm and 700 mm marks.

The photograph showed that the bob moved from the 640 mm mark to the 675 mm mark when the shutter was opened. If the period of the pendulum was 2.0 s, what is the time that the shutter has remained opened?

A 0.13 s **B** 0.23 s **C** 0.40 s **D** 0.44 s

16 Two particles P and Q are in a sinusoidal wave of amplitude A. The distance of particle P from its equilibrium is A while the distance of particle Q from its equilibrium is $\frac{1}{3}A$.

What can be the phase angle between the two particles P and Q?

A 19° **B** 45° **C** 60° **D** 71°

17 The intensity of a wave depends on the amplitude. The intensity is also proportional to the square of the frequency.

A wave has frequency 5.0 Hz, amplitude 2.4 cm and intensity I.

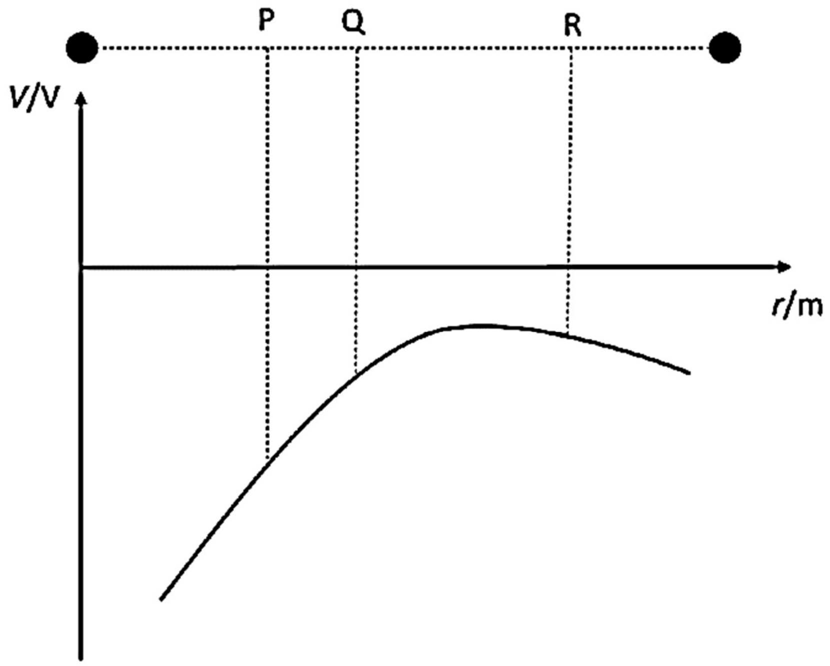
What is the intensity of a similar wave of frequency 15.0 Hz and amplitude 1.2 cm?

A $\frac{4}{9}I$ **B** $\frac{2}{3}I$ **C** $\frac{9}{4}I$ **D** 36 I

18 Light of wavelength λ is incident normally on a diffraction grating of slit separation 4λ. What is the angle between the second order maximum and third order maximum?

A 14.5° **B** 18.6° **C** 48.6° **D** 71.4°

19 Two charges are placed in free space. The variation of the electric potential *V,* with the distance *r* from the left charge along the line joining the centres of the charges is shown below.



Which of the following statements is true?

A Any charge placed at point P will experience a resultant force towards the left.

B The electric field strength at point Q is larger than the electric field strength at P.

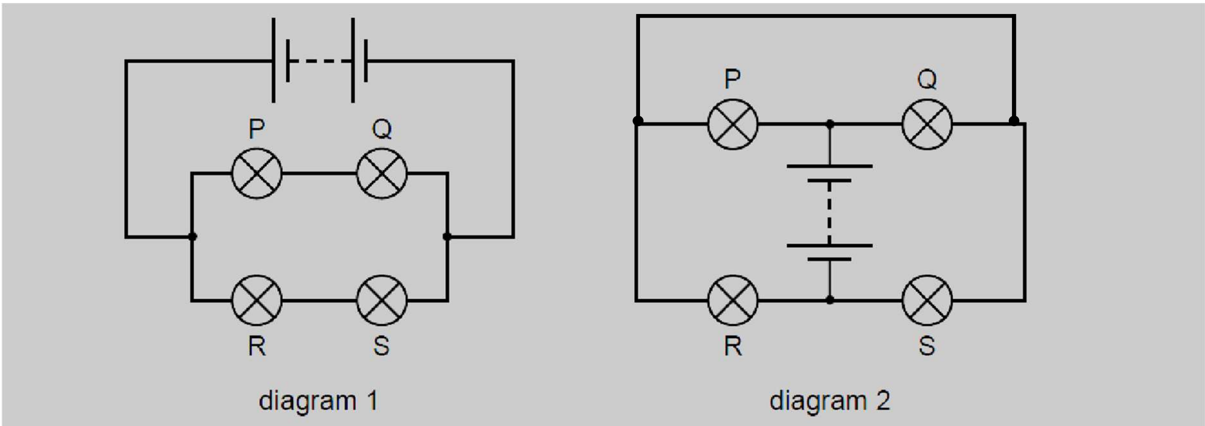
C Net positive work needs to be done by an external agent to move a negative charge from point R to point P.

D A positive charge at P has more electric potential energy as compared to an identical positive charge placed at R.

20 Two parallel plates are connected to a high potential difference of 4.5 kV. The separation of the plates is 1.5 mm. The maximum acceleration of an electron between the plates is

A 1.0×10^{9} m s^{-2} **B** 1.2×10^{12} m s^{-2} **C** 1.6×10^{15} m s^{-2} **D** 5.3×10^{17} m s^{-2}

21 When four identical lamps P, Q, R and S are connected as shown in diagram 1, they have normal brightness.



The four lamps and the battery are then connected as shown in diagram 2. Which statement is correct?

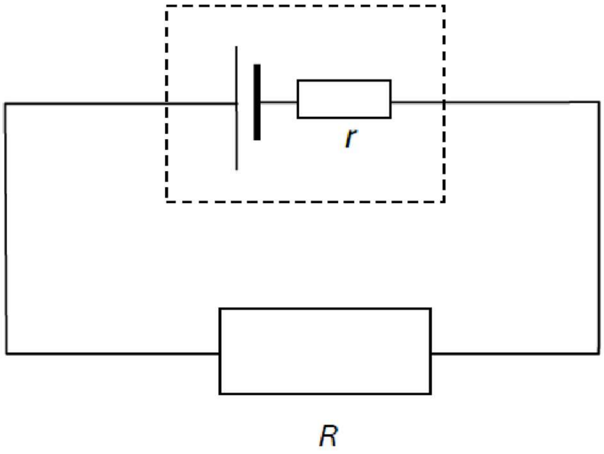
A The lamps P and Q in diagram 2 do not light up.

B The lamps P and Q are brighter while R and S are less bright than normal.

C All lamps have normal brightness.

D All lamps are brighter than normal.

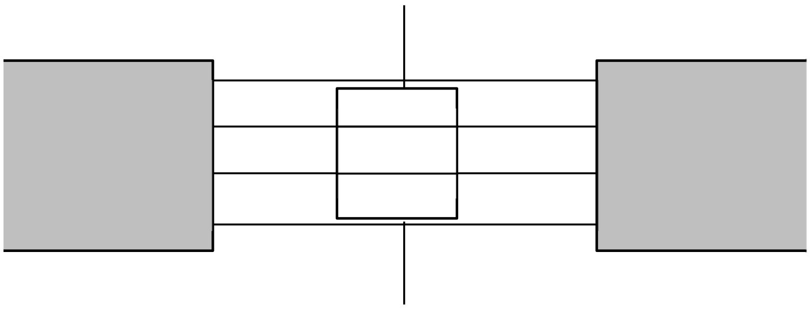
22 A battery with internal resistance *r* is connected to a resistor *R* as shown in the figure below. A constant current passes through *R*. When a charge of 20.0 C passes through the circuit, the heat dissipated in *r* is 10.0 J and the heat dissipated in *R* is 50.0 J.



What is the e.m.f. of the battery and the potential differences across *r* and *R*?

	e.m.f. of the battery	potential difference across r	potential difference across R
A	6.00 V	1.00 V	5.00 V
B	6.00 V	5.00 V	1.00 V
C	3.00 V	2.50 V	0.50 V
D	3.00 V	0.50 V	2.50 V

23 In an electric motor, a rectangular coil WXYZ carrying current has 20 turns and is in a uniform magnetic field of flux density 0.80 T.



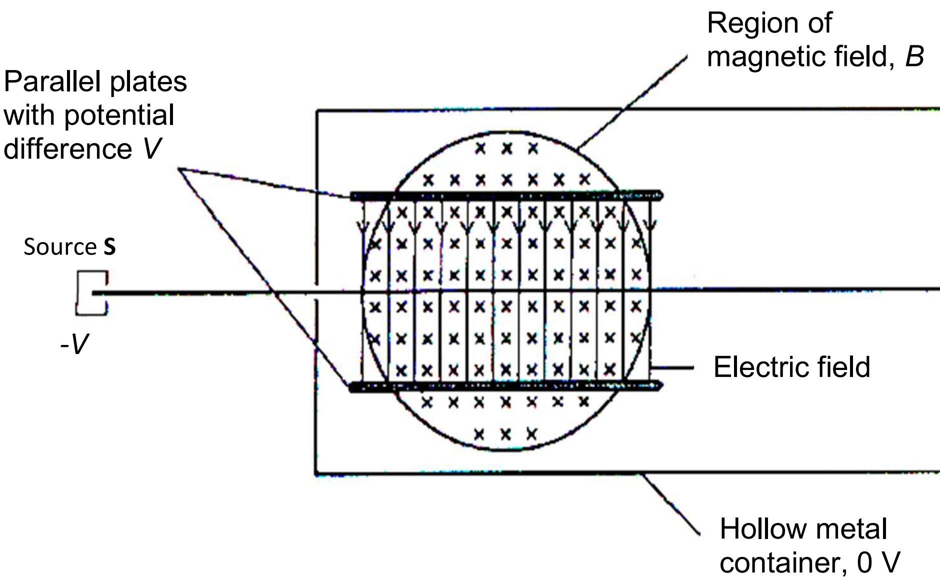
Z Y
W X
N S

The lengths of sides XY and ZW are 0.17 m and of sides WX and YZ are 0.11 m. The maximum torque provided by the motor is 1.35 N m.

What is the current in the rectangular coil?

A 4.5 A **B** 9.0 A **C** 45 A **D** 90 A

24 A part of a mass spectrometer is shown in the figure below. Negative ions are generated at the source **S** with negligible speed, which is at a potential of $-V$ with respect to the hollow metal container. Inside the container, there are parallel plates separated by distance d and a uniform magnetic field B is applied to the region between the parallel plates.

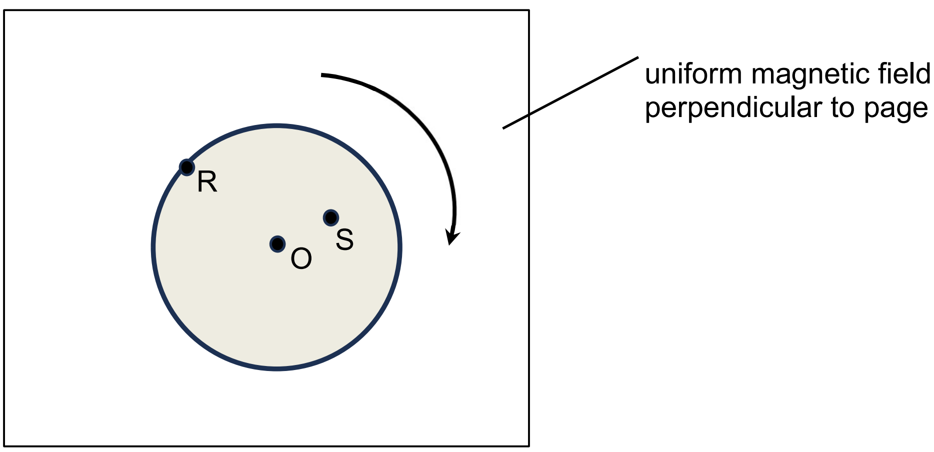


If the potential difference between the parallel plates is V, what is the charge to mass ratio of the ions that can pass through the fields undeviated?

A $\dfrac{V}{2B^2d^2}$ **B** $\dfrac{2V}{B^2d^2}$ **C** $\dfrac{2B^2d^2}{V}$ **D** $\dfrac{B^2d^2}{2V}$

25 The figure below shows a copper disc rotating at constant angular speed about its centre O in a uniform magnetic field acting perpendicular to the page. Point R is at a distance r from the centre O. The induced e.m.f. between O and R is E.

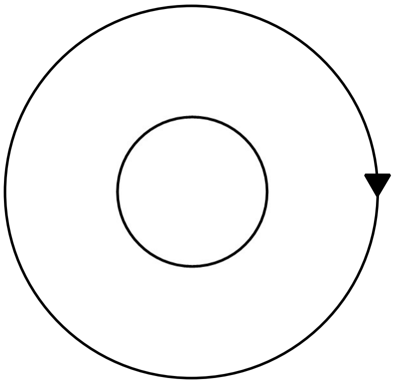
Point S is at a distance $\frac{r}{2}$ from O.



What is the induced e.m.f. between R and S?

A $E/4$ **B** $E/2$ **C** $3E/4$ **D** E

26 Fig. (a) shows two concentric circular conductors lying in the same plane. The current in the outer loop is clockwise and changes with time as shown in Fig. (b).



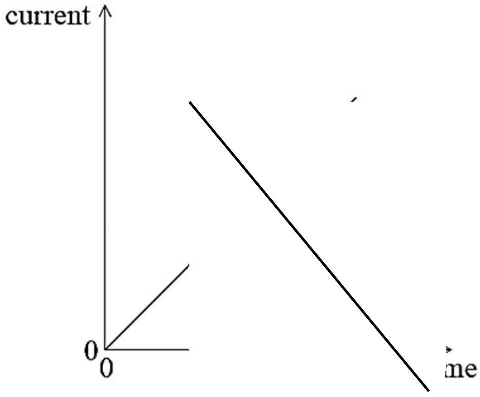


Fig. (a)

Fig. (b)

inner loop

outer loop

current

time

The induced current in the inner loop is

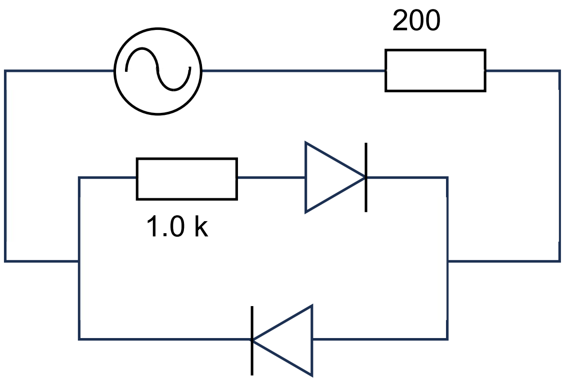
A constant in the clockwise direction.

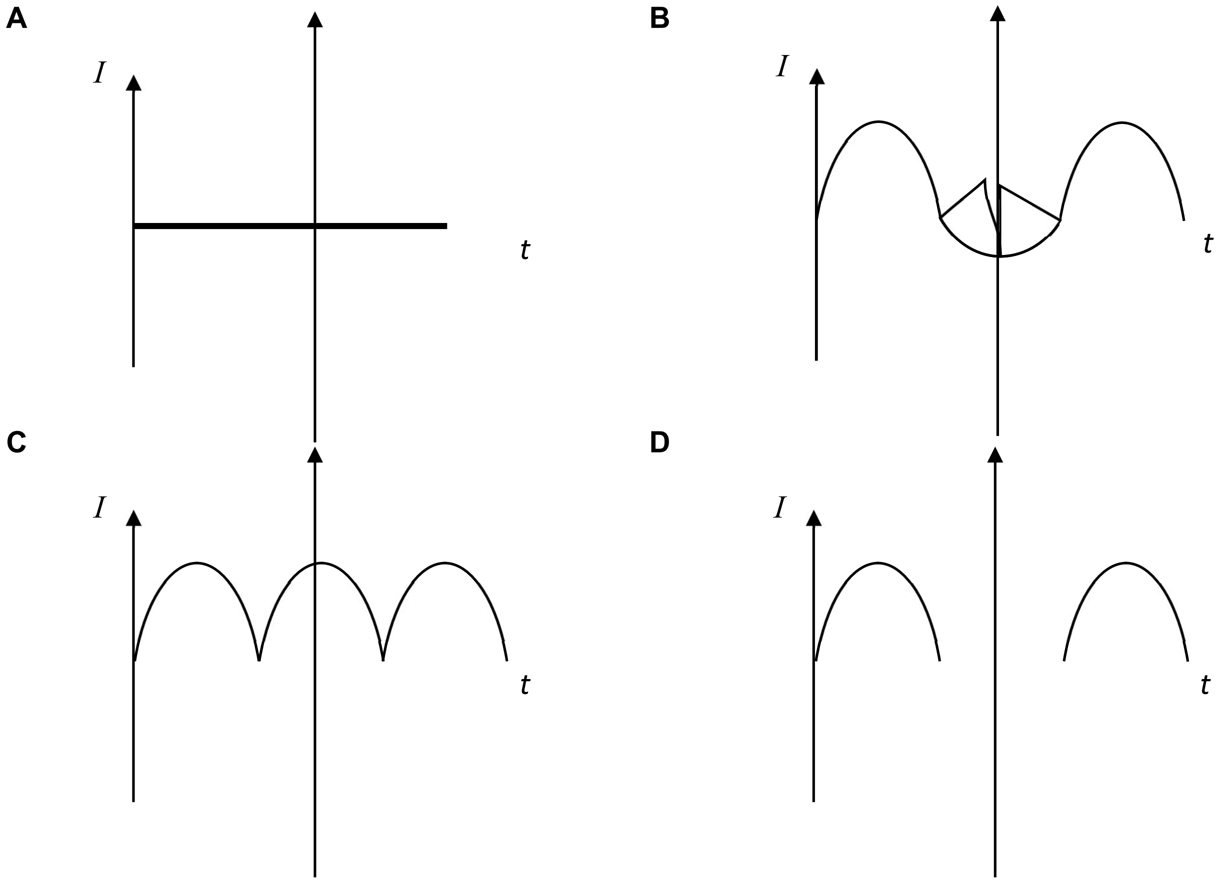
B increasing linearly with time in the clockwise direction.

C decreasing linearly with time in the clockwise direction.

D increasing linearly with time in the anticlockwise direction.

27 Which of the following graphs best represents the variation with time t of the current I through the 200 Ω resistor in the circuit below?





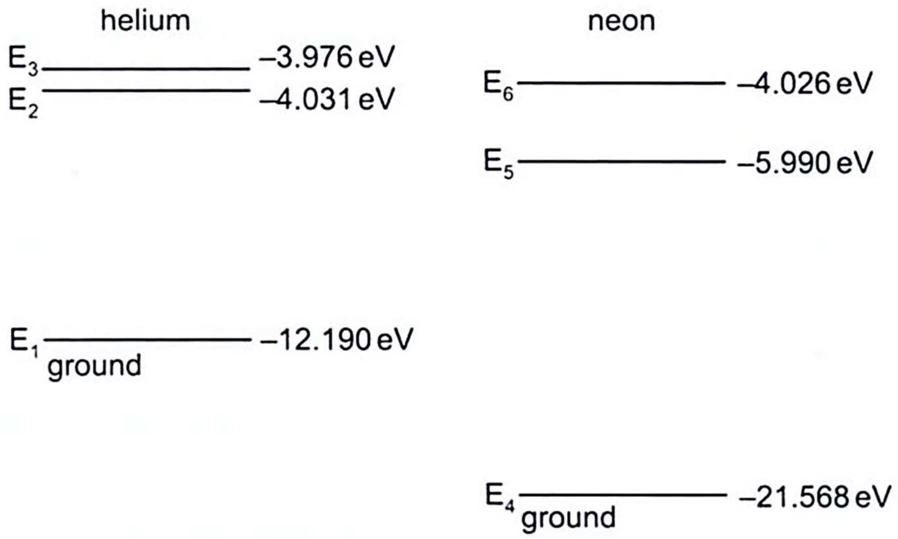
28 Two beams P and Q of light of the same wavelength is incident on the same metal surface causing photoelectrons to be emitted.

The photoelectric current produced by P is four times that produced by Q.

Which of the following gives the ratio $\dfrac{amplitude\ of\ wave\ P}{amplitude\ of\ wave\ Q}$?

A 0.25 **B** 0.50 **C** 2.0 **D** 4.0

29 The diagram shows some of the energy levels of helium and neon. The elements are the major constituents in a laser that emits red light.



Which transition between the labelled levels gives rise to the emission of the laser light?

A E_3 to E_2 **B** E_6 to E_5 **C** E_2 to E_1 **D** E_5 to E_4

30 Thorium $90232Th$ decays through a series of transformations. The particles emitted in successive transformations are

α **β** **β** **γ** **α**

The resulting nuclide may be represented by

A $82230Pb$ **B** $88226Ra$ **C** $86224Rn$ **D** $88224Ra$

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H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS **9749/02**

Paper 2 Structured Questions

27 August 2024
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and 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 or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answers **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	/ 9
3	/ 4
4	/ 6
5	/ 11
6	/ 10
7	/ 10
8	/ 22
Total (80)	

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temperature	$T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \dfrac{3}{2}kT$
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	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin\omega t$
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magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

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

1 An object is launched at a speed of 30 m s^{-1} with an angle of 60° from the ground as shown in Fig. 1.1. Ignore air resistance.

60º
30 m s^{-1}

Fig 1.1

(a) Show that the time taken for the object to reach its maximum height is 2.6 s.

[1]

(b) Sketch the variation with time t of the vertical component of the velocity v_y on Fig. 1.2, from the time it leaves the ground to the time it returns to the ground. [2]

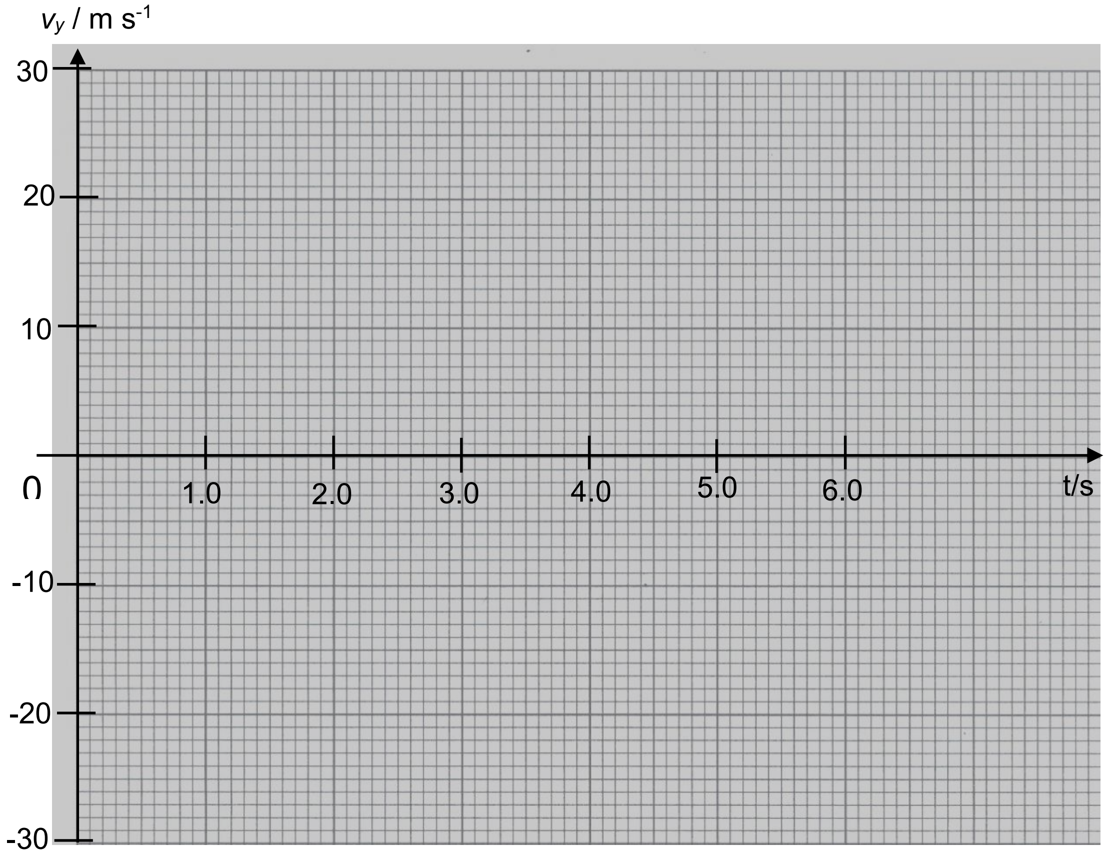


Fig. 1.2

(c) Sketch on Fig. 1.3,

(i) the variation of the horizontal component of the velocity v_x with time of the object for the duration of time in flight.
Label this line **A**. [1]

(ii) the variation of the horizontal component of the velocity v_x with time of the object for the duration of time in flight if air resistance is not negligible.
Label this line **B**. [2]

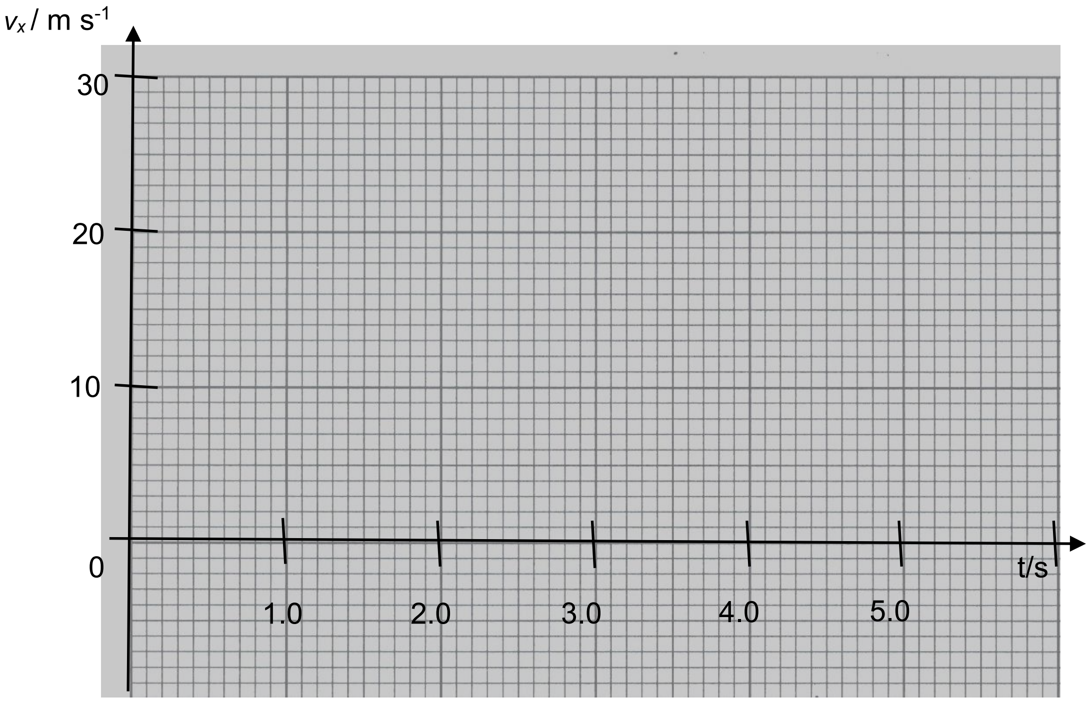


Fig. 1.3

(d) A second object is launched at the same instant with the same speed but at an angle of 30° above the ground. Air resistance is negligible.

Determine the vertical displacement between the two objects at 2.6 s.

vertical displacement = …………………………………… m [2]

[Total: 8 marks]

2 **(a)** State the relation between force and momentum.

.... [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 2.1

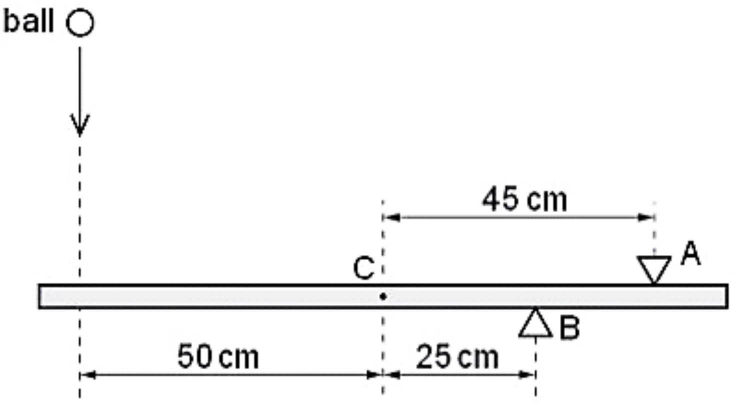


Fig. 2.1

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 2.1.

The variation with time *t* of the velocity *v* of the ball before, during and after hitting the bar is shown in Fig. 2.2.

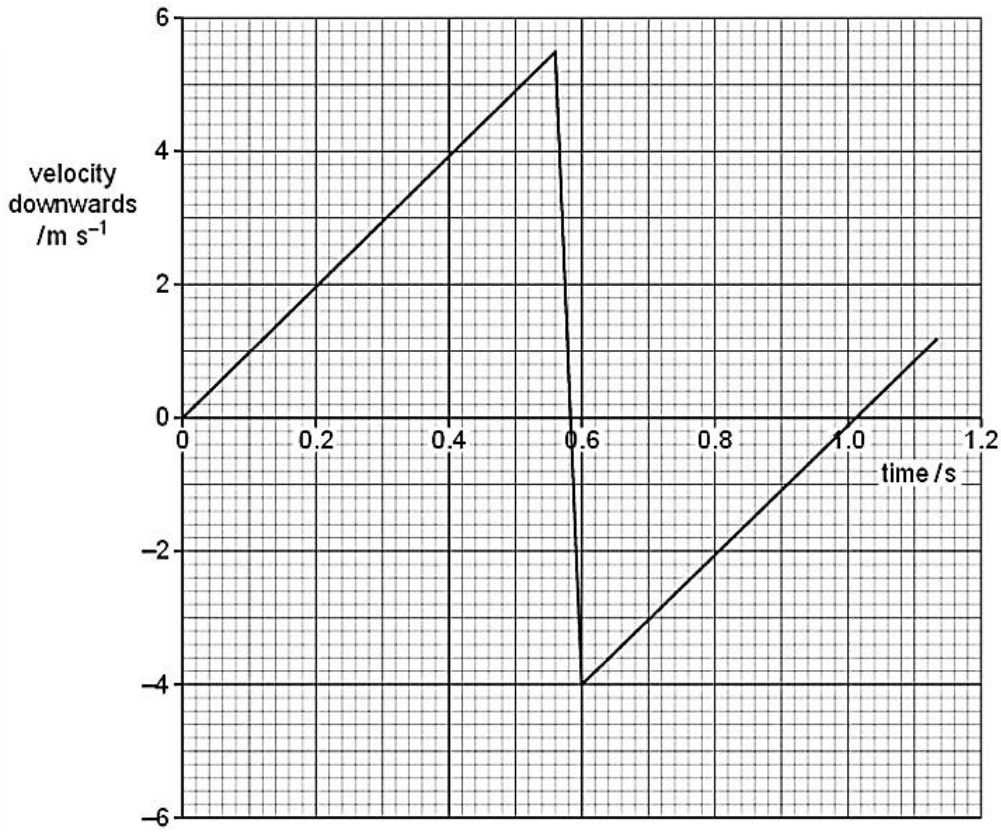


Fig. 2.2

For the time that the ball is in contact with the bar, use Fig. 2.2 to

(i) determine the resultant force acting on the ball,

resultant force = ... N [2]

(ii) show that the force exerted by the ball on the bar is 35 N.

[1]

(c) For the time that the ball is in contact with the bar, use data from Fig. 2.1. and (b)(ii) to calculate the force exerted on the bar by

(i) the support A,

force = ... N [3]

(ii) the support B,

force = ... N [2]

[Total: 9 marks]

3 **(a)** Fig 3.1 below shows a closed symmetrical jar with dimensions as shown. It contains a liquid of mass 3.0 kg and density 900 kg m^{-3}. The liquid exerts a pressure on the base of the jar.

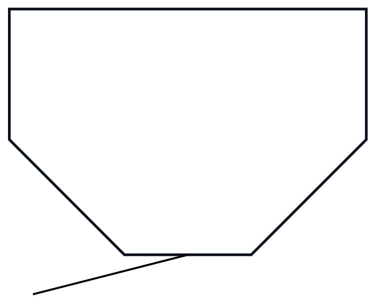
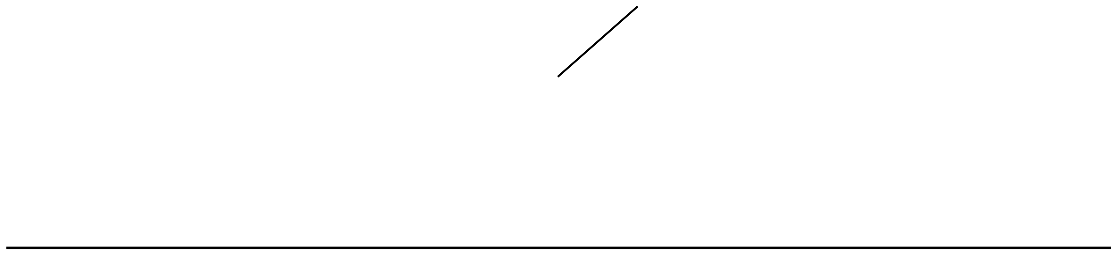


Fig. 3.1
3.0 cm
3.0 cm
Area of base 9.0 cm^2

Determine the pressure exerted by the liquid at the base of the jar.

pressure = ……………………………………. Pa [2]

(b) Fig 3.2 below shows an object that is not in equilibrium partially submerged in water.



water

Object not in equilibrium

Fig 3.2

The density of the object is uniform and is less than the density of water.

By drawing the weight of the object *W* and the upthrust *U* acting on the object on Fig. 3.2, describe briefly what will happen to the object and suggest its approximate position after it comes to equilibrium.

………..

………..

……… [2]

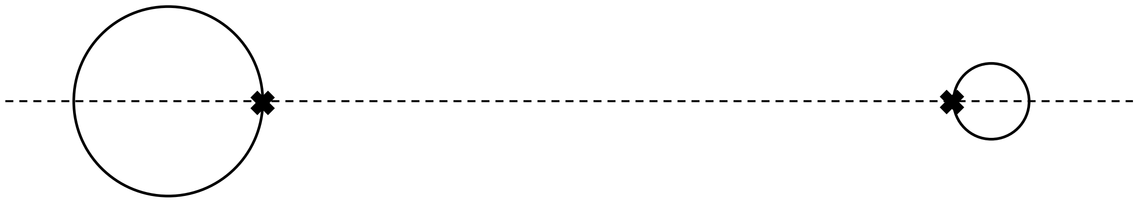
[Total: 4 marks]

4 **(a)** Define gravitational field strength**.**

....

.... [1]

(b) Fig 4.1 shows point A and point B on the surface of the Earth and the Moon respectively, along the line joining their centres.



Earth
Moon
A
B

Fig 4.1 (not to scale)

(i) There exist a point X on the line joining the centres of Earth and Moon where the resultant gravitational field strength is zero. Estimate and label this point X on Fig 4.1. [1]

(ii) The mass of Earth is 5.97×10^{24} kg, the mass of Moon is 7.34×10^{22} kg, the radius of Earth is 6.37×10^{3} km, and the radius of Moon is 1.74×10^{3} km. The centre-to-centre distance between Earth and Moon is 3.84×10^{5} km.

Determine the magnitude of gravitational field strength at A and B respectively.

gravitational field strength at A = ... N kg^{-1}

gravitational field strength at B = ... N kg^{-1}
[3]

[Turn over

(iii) Without further calculations, sketch the variation with distance *d* of gravitational field strength *g*, experienced along the line joining the centre of Earth and Moon between points A and B in Fig. 4.2. [1]

g / N kg^{-1}
d / m
A
B

Fig. 4.2

[Total: 6 marks]

5 Fig. 5.1 shows a horizontal string of length 1.000 m, stretched between a vibrator at A and a pulley at B. The vibrator produces a small oscillation at A and energy is transferred as a wave along the string. P is a point 0.300 m from B. You may consider B to be a fixed point.

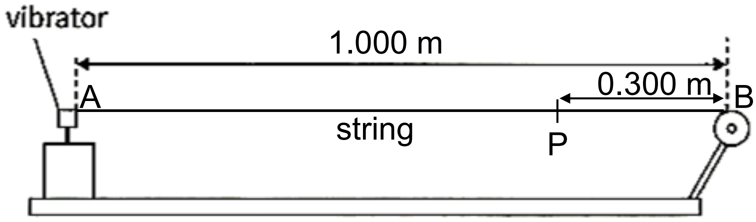


Fig. 5.1

(a) The wave from A, travelling along the string, reaches P along two paths:

Path 1: A to P (the incident wave)
Path 2: A to B to P (the reflected wave)

(i) Show that the path difference between the two waves meeting at P is 0.600 m.

[1]

(ii) The wavelength is 1.000 m. When the wave is reflected at B, an additional phase difference of π rad is added to the reflected wave. Determine the phase difference between the two waves when they superpose at P.

phase difference = …………………………………… rad [2]

(iii) A stationary wave is formed along AB in Fig 5.1. Sketch the stationary waveform along AB below. [2]

A
B

(iv) Point Q is 0.300 m to the right of A. Using your answer in **(a)(iii)**, state the phase relation between the motion of the particles at P and Q.

……………………………………………………………………………………………………
[1]

(b) Fig. 5.2 shows a modified set up where the string at B is now attached to slotted masses to vary the tension in the string. The pulley at B is frictionless.

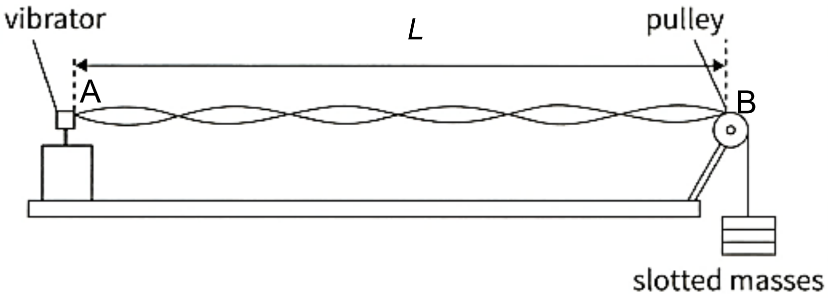


Fig. 5.2

The speed v of the wave travelling along the string is related to the weight mg of the slotted masses and the mass per unit length μ of the string according to the equation:

$$v = \sqrt{\frac{mg}{\mu}}$$

The amplitude of oscillation of the vibrator is small and hence point A is approximately a node.

L is 1.000 m.

(i) Show that for stationary waves to form along the string in Fig. 5.2, the frequency f of oscillation of the vibrator must satisfy the following relation:

$$f = \frac{n}{2}\sqrt{\frac{mg}{\mu}}$$

where n is an integer.

[2]

(ii) The mass per unit length μ of the string is 7.0 x 10^{-3} kg m^{-1} and the frequency of oscillation of the vibrator is f = 25 Hz. Calculate the mass m of the slotted masses needed to produce the stationary wave shown in Fig 5.2.

m = …………………………………… kg [1]

(iii) The mid-point of the string in Fig 5.2 is now fixed so that it will always be a node. The total mass hanging from the pulley at B remained unchanged. The frequency of oscillation of the vibrator is slowly increased from 25 Hz. Determine the next higher frequency that a stationary wave will form along the string.

frequency = …………………………………… Hz [2]

[Total: 11 marks]

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6 **(a)** Fig. 6.1 shows a circuit with a network of resistors.

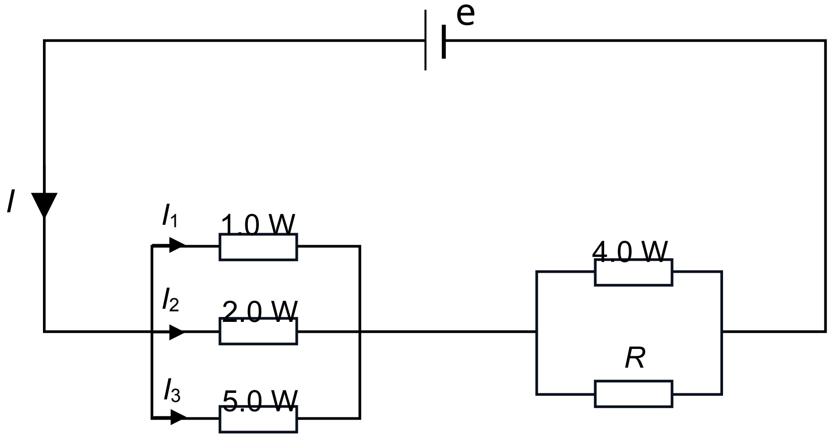

Fig. 6.1

The current from the cell is I.

(i) Determine the ratio of the currents $I_1 : I_2 : I_3$.

$I_1 : I_2 : I_3$ = ……………………………………. [2]

(ii) 1.0×10^{-3} mol of electrons flowed through the 4.0 ∧ resistor in a time interval of 320 s. During this time interval,

1. Show that the total charge that flowed through the 4.0 ∧ resistor is 96 C.

[1]

2. Show that the electrical energy dissipated in the 4.0 ∧ resistor is approximately 115 J.

[2]

3. The current through the 4.0 ∧ resistor is three times the current through resistor *R*. Determine *R*.

R = …………………………………… ∧ [2]

(b) Fig. 6.2 shows a circuit in which a non-ohmic device X is connected in series with a 20 ∧ resistor. The cell has e.m.f. 6.0 V and negligible internal resistance. Fig 6.3 shows the *I*-*V* characteristics of X and the 20 ∧ resistor.

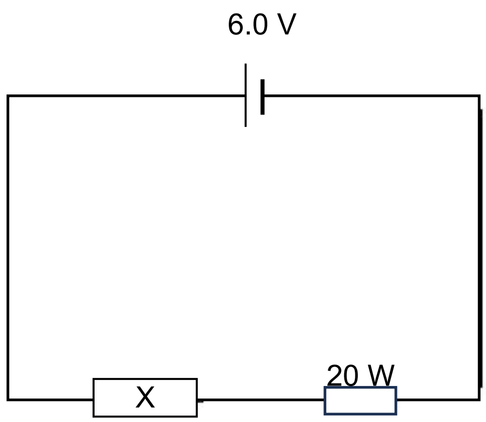

Fig. 6.2

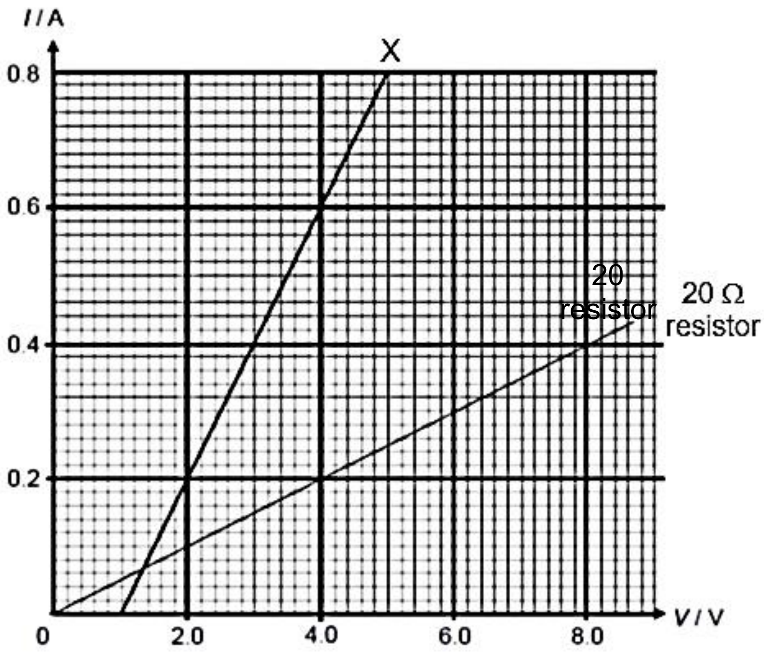

Fig. 6.3 **Fig. 6.3**

(i) Determine the current in the circuit.

current = …………………………………… A [1]

(ii) Device X consists of an ideal diode, a cell with negligible internal resistance and an ohmic resistor, connected in series as shown in Fig. 6.4. Suggest the values of the e.m.f of the cell and resistance of the ohmic resistor that will give the I-V characteristics shown in Fig. 6.3.

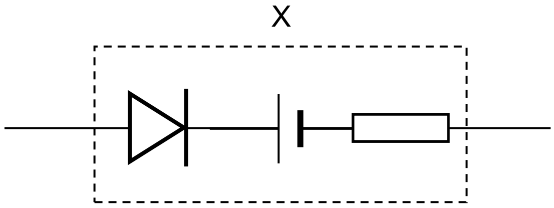

Fig. 6.4

emf of cell = ………….……………… V

resistance of resistor = ………………………….. Ω

[2]

[Total: 10 marks]

[Turn over

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7 **(a)** State the number of protons, neutrons of a single nuclide whose symbol is

612C

number of neutrons = ……………………………………

number of protons = ……………………………………
[1]

(b) Define the terms

(i) decay constant,

……………………………………………………………………………………………….....

………………………………………………………………………………………………… [1]

(ii) half-life.

……………………………………………………………………………………………….....

………………………………………………………………………………………………… [2]

(c) Explain why the random nature of radioactive decay makes it difficult to measure the values of the terms in **(b)** to a high degree of accuracy.

……

……

……

……………………………………………………………………………………………………... [2]

[Turn over

(d) Radiocarbon dating, or carbon-14 dating, is a scientific method that can estimate the age of organic materials. Measurements are made of the activity of a specimen of carbon from pieces of wood found in a fireplace at an archaeological site.

The specimen is found to contain one Carbon-14 atom per 8.6×10^{10} Carbon-12 atoms. In a similar wood specimen from a modern fireplace, the concentration of Carbon-14 atoms is greater at one Carbon-14 atom per 3.3×10^{10} Carbon-12 atoms.

(i) The difference between the concentrations of Carbon-14 to Carbon-12 atoms in the old pieces of wood and modern wood is because Carbon-14 is radioactive and some atoms have decayed over the years.

Show that the ratio of undecayed Carbon-14 atoms N to original amount of Carbon-14 atoms N_0 of the old specimen is 0.384. State any assumption(s) made.

Assumption(s): ……………………………………………………………………………………...

……………………………………………………………………………………………………..…

[2]

(ii) Hence, determine the age of the wood from the ancient fire. The half-life of Carbon-14 is 5700 years.

age of wood = …………………………………… years [2]

[Total: 10 marks]

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

Light emitting diodes, commonly called LEDs, are real unsung heroes in the electronics world. They are found in all kinds of devices such as transmitting information from remote controls, digital display on your appliances and form images on television screen.

In LEDs, electrons in the higher energy conduction band fall into empty orbitals of lower energy to release energy in the form of photons. For a standard silicon diode, the photon's is in the infra-red portion of the electromagnetic spectrum and is invisible to the human eye. Depending on the materials used in LEDs, they can be built to shine in infra-red, ultraviolet, and all the colours of the visible spectrum in between. Fig. 8.1 shows different types of LEDs producing distinct wavelengths of colour made of exotic semiconductor compounds mixed together at different ratios such as Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN).

typical LED characteristics			
semiconductor material	wavelength / nm	perceived colour	forward operating voltage V_F at 20 mA / V
GaAs	850 to 940	Infra-red	1.1
GaAsP	630 to 660	Red	1.8
GaAsP	605 to 620	Amber	2.0
GaAsP:N	585 to 595	Yellow	2.2
SiC	430 to 505	Blue	3.4

Fig. 8.1

When operating in a circuit there is a minimum voltage that must be connected across an LED to make it emit light known as the forward operating voltage V_F. V_F is related to the average wavelength $\langle\lambda\rangle$ of emitted light by the following equation:

$$V_F = k\,\langle\lambda\rangle^n$$

where *k* and *n* are constants.

An LED is damaged when the p.d. across it is too high. A protective resistor is connected in series with the LED to prevent this. The normal operating current through an LED is 20 mA.

Bare, uncoated semiconductors has a very high refractive index relative to air, which prevents the passage of photons at sharp angles relative to the air-contacting surface of the semiconductor. Uncoated LED semiconductor chip will emit light only perpendicular to the semiconductor's surface, and a few degrees to the side, in a cone shape illustrated in Fig. 8.2. The angle of the cone is determined by the maximum angle of incidence known as the *critical angle*. When this angle is exceeded, photons no longer penetrate the semiconductor, but are instead, reflected internally inside the semiconductor crystal as if it were a mirror.

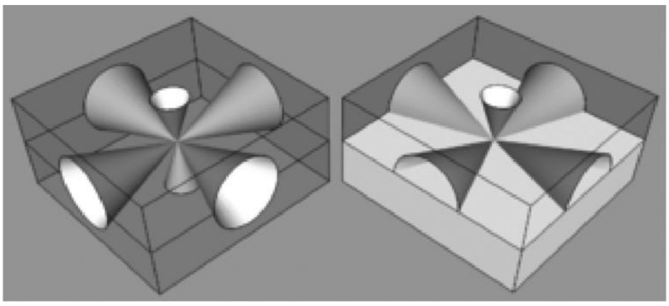

Fig. 8.2

LEDs are specially constructed to release a large number of photons outwards. Additionally, they are housed in a plastic bulb that concentrates the light in a particular direction. As shown in Fig. 8.3, most of the light from the diode bounces off the sides of the bulb, travelling on through the rounded end.

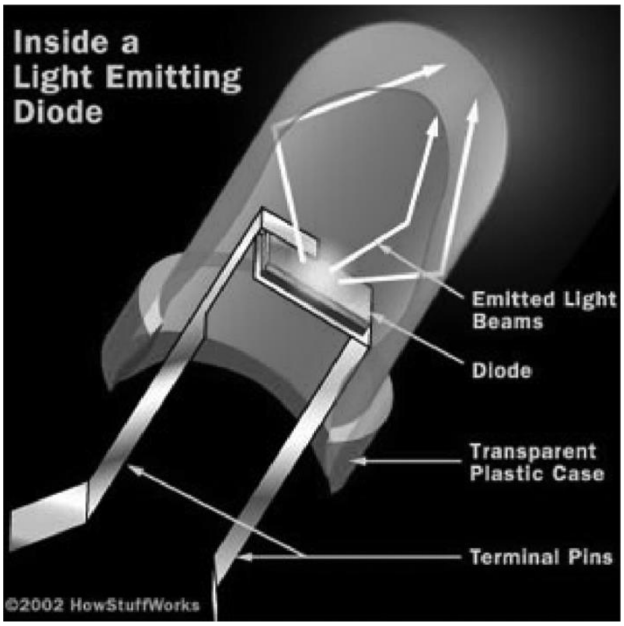

Fig. 8.3

LEDs have several advantages over conventional incandescent lamps. They don't have a filament that will burn out and their small plastic bulb makes them a lot more durable, so LEDs can have lifetimes of 50 000 hours or more. They also fit easily into modern electronic circuits. The main advantage is their efficiency. In conventional incandescent bulbs, the light-production process involves generating a lot of heat so a huge portion of the electrical energy isn't going toward producing visible light. LEDs generate very little heat, relatively speaking, so a much higher percentage of the electrical power goes directly to generating light.

The luminous flux of a device is the total amount of light produced per second and the SI unit of luminous flux is the lumen (symbol: lm). The efficacy of the device is the ratio of its luminous flux to the electrical power supplied and this is measured in lumens per watt (lm W^{-1}). The luminous efficacy of a device is a measurement related to its efficiency. The key advantages of LED-based lighting sources is high luminous efficacy.

Until quite recently, LEDs were too expensive to use for most lighting applications because they're built around advanced semiconductor material. However, the price of semiconductor devices has plummeted since the year 2000, making LEDs a more cost-effective lighting option for a wide range of situations. While they may be more expensive than incandescent lights up front, their lower cost in the long run can make them a better buy.

(a) The photons from a standard silicon diode are invisible to the human eye.

Suggest how other LEDs are able to emit light in the visible light spectrum.

………

………

………

……… [2]

(b) Use information in Fig. 8.1.

(i) Determine the lowest energy of the photons emitted by a nitrogen doped Gallium Arsenide Phosphide (GaAsP:N) LED,

energy = …………………………………… eV [3]

(ii) The minimum voltage that must be connected across an LED to make it emit light is called the forward operating voltage V_F.

Explain

1. why no light is emitted by an LED when the voltage supplied is less than V_F,

……………………………………………………………………………………………

…………………………………………………………………………………………….. [1]

2. why the value of V_F for an LED that emits blue light is greater than that for a LED that emits red light.

……………………………………………………………………………………………

…………………………………………………………………………………………….. [1]

[Turn over

(c) Data relating average wavelength $\langle\lambda\rangle$ of the light photons emitted by an LED and the forward operating voltage V_F of the five semiconductor materials in Fig. 8.1 are listed in Fig. 8.4.

semiconductor material	$\langle\lambda\rangle$ / nm	V_F / V	lg ($\langle\lambda\rangle$ / nm)	lg (V_F / V)
GaAs	895	1.1	2.952	0.041
GaAsP	645	1.8	2.810	0.255
GaAsP	613	2.0	2.787	0.301
GaAsP:N	590	2.2	2.771	0.342
SiC	468	3.4	2.670	0.531

Fig. 8.4

The variation of lg (V_F / V) with lg ($\langle\lambda\rangle$ / nm) is shown in Fig. 8.5.

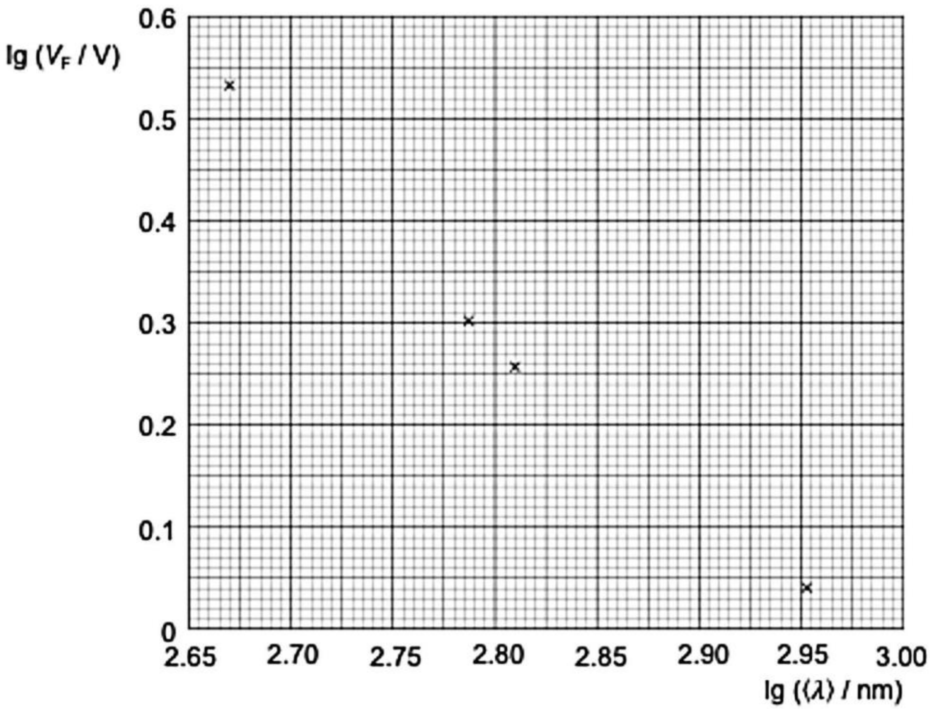

Fig. 8.5

(i) Plot the point for GaAsP:N on Fig. 8.5. [1]

(ii) Complete Fig. 8.5 by drawing the line of best fit. [1]

(iii) Determine the value of *n* from your line.

n = ……………………………………….. [2]

(d) An unknown LED emits photons of average wavelength 520 nm.

(i) Determine V_F across this LED.

V_F = …………………………………….. V [2]

(ii) The LED is connected to a power supply of e.m.f. 4.5 V with negligible internal resistance and operates under normal conditions.

Calculate the resistance of the series resistor required for safe operation of the LED.

resistance = …………………………………….. Ω [2]

(e) The light produced by an uncoated LED is produced in the silicon layer. The refractive index of silicon is 4.24 and air is 1.00.

(i) Show that the speed of light in silicon is 7.08×10^{7} m s^{-1}.

[1]

(ii) Determine the critical angle for light passing from silicon into air.

critical angle = ……………………………………… ° [2]

(iii) Explain why encapsulating a semiconductor chip in a suitable material increases the efficiency of the LED.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

…………………………………………………………………………………………………… [2]

(f) A incandescent lamp produces an illumination of 840 lumens for a 60 W power consumption. An LED lamp produces an illumination of 900 lumens for a 9 W power consumption.

Determine the ratio

$$\frac{efficiency\ of\ LED}{efficiency\ of\ incandescent\ lamp}.$$

ratio = ……………………………………….. [2]

[Total: 22]

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H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/03**

Paper 3 Structured Questions

13 Sep 2024
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and 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 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
Answers **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

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

For Examiner's Use	
Section A	
1	**/ 9**
2	**/ 7**
3	**/ 10**
4	**/ 13**
5	**/ 8**
6	**/ 6**
7	**/ 7**
Section B	
8	**/ 20**
9	**/ 20**

Total (80)	

This document contains **29** printed pages and **3** blank pages.

Data

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

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	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \dfrac{3}{2}kT$
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	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** Use Newton's laws of motion to explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle.

....

....

....

....

....

.... [3]

(b) Fig. 1.1 shows the construction of a simple accelerometer that is used to measure the centripetal acceleration of a car turning into a corner.

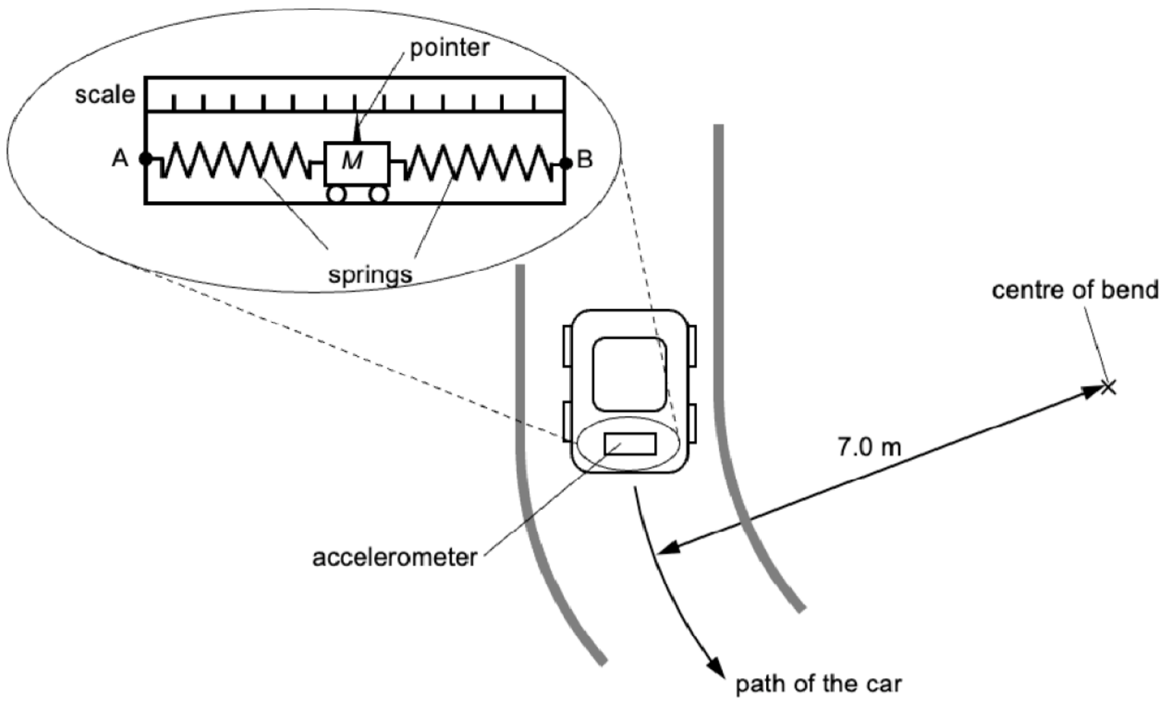

Fig. 1.1 (not to scale)

The two ends A and B of the accelerometer are fixed to the car. A mass M is connected to two identical springs and it moves between A and B with negligible friction. A pointer attached to M indicates the acceleration of the car.

The car enters the corner at a speed of 25 km h^{-1}. The radius of the path of the car is 7.0 m.

(i) Determine the centripetal acceleration of the car.

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

(ii) The mass *M* between the springs in the accelerometer is 0.50 kg. A test shows that a force of 1.0 N moves the pointer by 5.0 mm from its equilibrium position.

Determine the displacement of the pointer from the equilibrium position when the car is turning into the corner.

displacement = …………………….……………….. mm [2]

(iii) End B is nearer to the centre of the bend compared to A. Explain, in terms of forces exerted by the springs, whether the pointer of the accelerometer moves towards end A or B.

……………………………………………………………………………………………...…..

……………………………………………………………………………………………...…..

…………………………………………………………………………………………….…..

…………………………………………………………………………………………….. [2]

[Total: 9]

2 **(a)** Define gravitational potential at a point.

....

....

.... [1]

(b) A satellite of mass m is in a circular orbit of radius r_1 around the Earth. It is transferred to a new circular orbit of radius r_2 as shown in Fig. 2.1 by firing its thrusters.

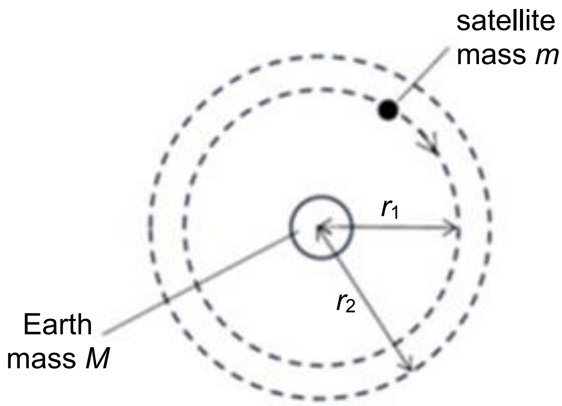

Fig. 2.1

The mass of the Earth is M and the gravitational constant is G.

(i) Show that the increase in potential energy ⊗E_P of the satellite is given by

$$\Delta E_P = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right).$$

[1]

(ii) The speed of the satellite at r_2 is smaller than at r_1. A student claims that by conservation of energy, the decrease in kinetic energy of the satellite is equal to the increase in gravitational potential energy. Explain why the student is not correct.

…………………………………………………………………………………………………..

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…………………………………………………………………………………………………. [2]

(c) A rock of mass m_r, initially at rest at infinity, falls towards the satellite orbiting at a radius of r_2. The gravitational force between the rock and the satellite is negligible. Determine the speed v of the rock as it hits the satellite in terms of G, M, m, m_r, r_1 and r_2. [3]

[Total: 7]

3 **(a)** According to the kinetic theory of gases, the average random translational kinetic energy E_K of an ideal gas particle is given by:

$$E_K = \frac{3}{2}kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature of the gas.

(i) Using the above expression, show that the root-mean-square speed $c_{r.m.s.}$ of the gas particles is given by:

$$c_{r.m.s.} = \sqrt{\frac{3RT}{M}}$$

where R is the molar gas constant and M is the molar mass.

[2]

(ii) A sealed canister contains 0.200 mol of oxygen (molar mass = 32 g). An identical canister contains 0.300 mol of nitrogen (molar mass = 28 g) at the same temperature.

Assuming ideal gas behaviour, determine the ratio

$$\frac{c_{r.m.s.} \text{ of oxygen molecules}}{c_{r.m.s.} \text{ of nitrogen molecules}}$$

ratio = ………………. [1]

(b) The root-mean-square speed of particles at the centre of the Sun is 4.85×10^5 m s^{-1} and the density of the particles in that region is 1.50×10^5 kg m^{-3}.

(i) Assuming that the particles behaved like ideal gas, calculate the pressure in that region.

pressure = ……………. Pa [2]

(ii) The actual pressure at the centre of the Sun is much higher than the value calculated above. This shows that some of the assumptions used in the kinetic theory of gases cannot be applied to the particles in that region of the Sun.

State one assumption that is no longer applicable and explain how it leads to the actual pressure being higher than the one calculated above.

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…………………………………………………………………………………………. [2]

(c) A fixed mass of ideal gas is made to undergo the processes shown in Fig 3.1 starting from state A.

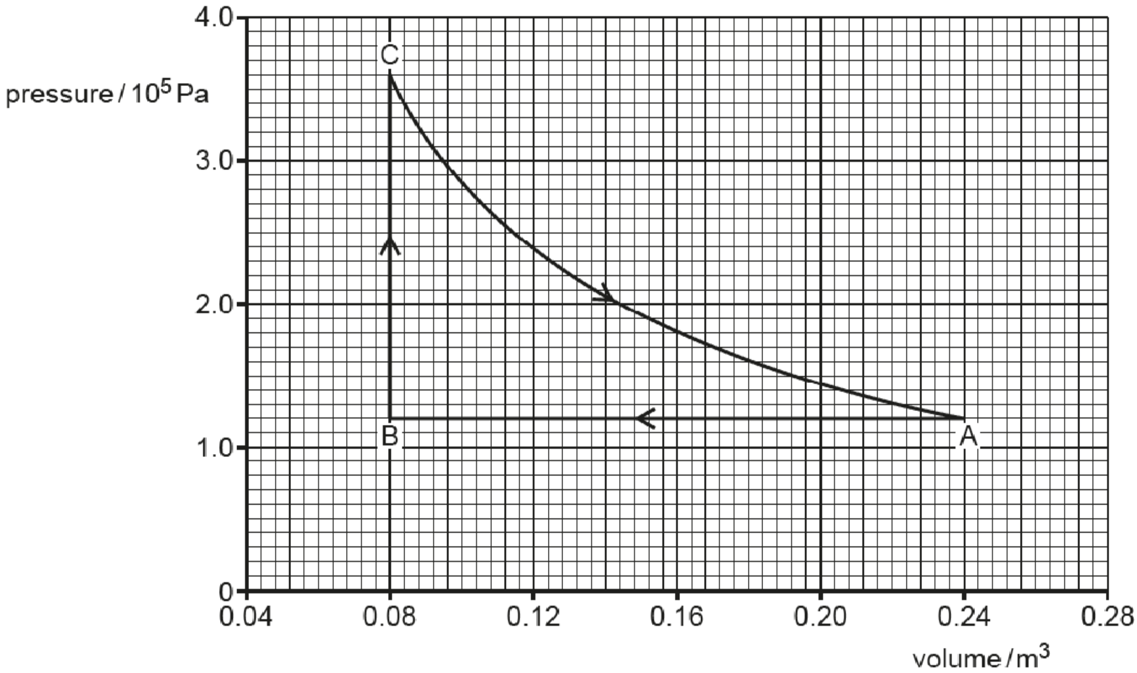

Fig. 3.1

Complete the table below for each of the processes shown in Fig. 3.1.

Process	w / kJ	q / kJ	⊗U / kJ
A to B		67.2	
B to C	0		
C to A	31.6	31.6	0

[3]

[Total: 10]

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4 A test-tube of cross-sectional area A is loaded with lead shots. It rests in equilibrium in a beaker of water of density ρ as shown in Fig. 4.1, with a length L submerged in the water.

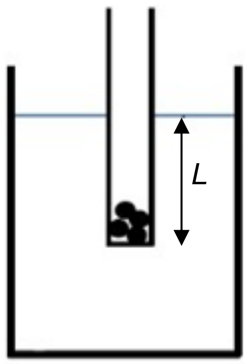

Fig. 4.1

(a) **(i)** On Fig. 4.1, draw and label the forces acting on the loaded test-tube. [2]

(ii) Derive an expression for the mass of the loaded test tube in terms of ρ, A, and L. [2]

(b) The loaded test-tube is displaced downward and released, which causes it to bob up and down in simple harmonic motion. At a particular instant in time, the loaded test-tube is at a distance x below the equilibrium position, as shown in Fig. 4.2.

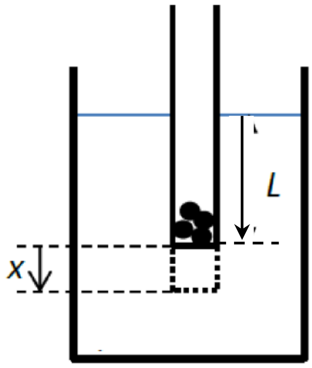

Fig. 4.2

(i) Ignoring resistive forces, show that the resultant force F acting on the loaded test-tube at this instant is given by:

$$F = -\rho Axg$$

where g is the acceleration of free fall.

[2]

(ii) Hence or otherwise, show that the angular frequency 7of oscillation of the loaded test-tube is given by:

$$\omega = \sqrt{\frac{g}{L}}$$

[3]

(iii) Given that the mass of the loaded test-tube is 50 g, L is 12.5 cm and the amplitude of oscillation is 1.5 cm.

Calculate the total energy of oscillation.

Total energy = ………………… J [2]

(iv) The loaded test-tube is at the lowest position at $t = 0$. The period of oscillation is T.

On Fig. 4.3, sketch a clearly labelled graph showing the variation with time of the kinetic energy of the loaded test-tube for two complete oscillations. Ignore resistive forces.

Indicate the maximum kinetic energy of the loaded test-tube along the vertical axis.

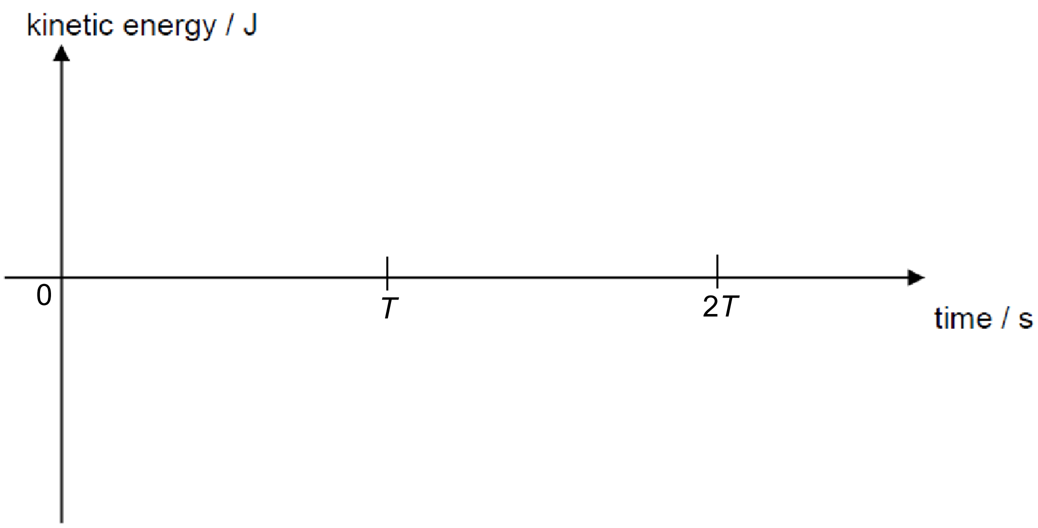

Fig. 4.3

[2]

[Total: 13]

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5 **(a)** Coherent light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 5.1.

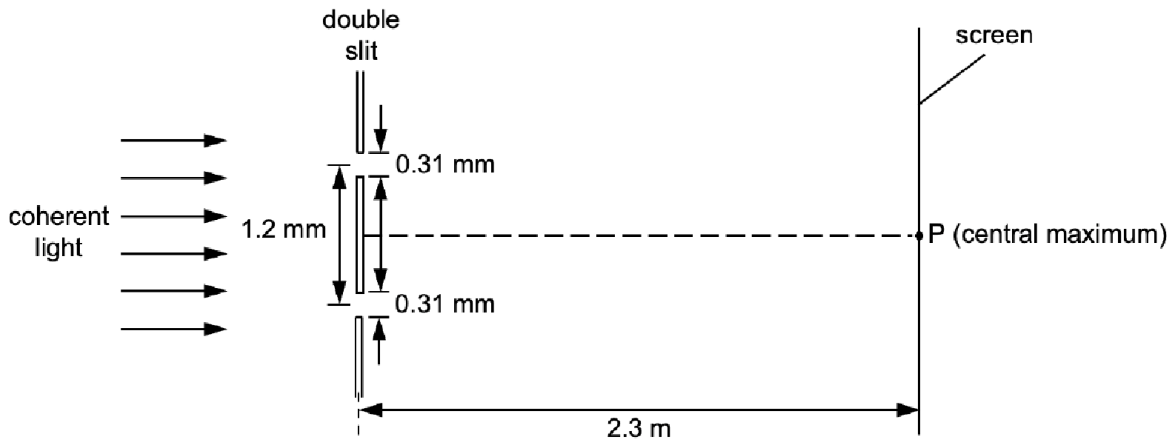

Fig. 5.1 (not to scale)

The separation of the slits is 1.2 mm and the width of each slit is 0.31 mm.

P is equidistant from the slits.

Fig. 5.2 shows the interference fringes observed near point P on a screen placed parallel to the plane of the double slit and 2.3 m from it. The central maximum is at P.

central maximum bright fringes

third order first order first order third order

second order second order

Fig. 5.2

(i) Explain why bright fringes are produced.

....

....

....

....

……………………………………………………………………………………………… [2]

(ii) Determine the separation of the bright fringes.

separation = …………………………………….. mm [2]

(b) The double slit in **(a)** is replaced by a single slit of width 0.31 mm, as shown in Fig. 5.3.

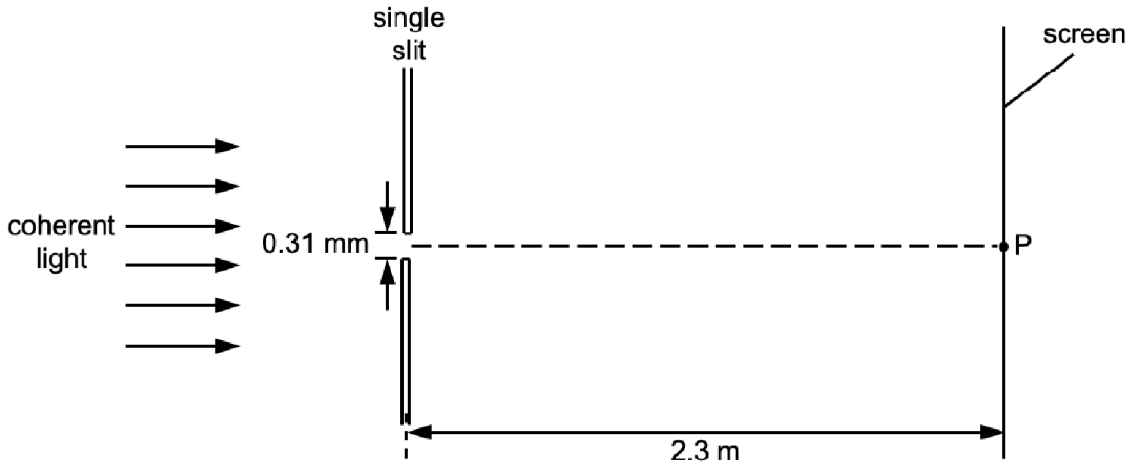

Fig. 5.3 (not to scale)

The centre of the interference pattern formed on the screen is at P.

Show that the width of the central fringe observed on the screen is 8.8 mm.

[2]

(c) The fourth order bright fringes in Fig. 5.2 are "missing".

Explain the reason for the missing fringes.

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [2]

[Turn over

[Total: 8]

6 A positive point charge +Q is positioned at a fixed point X and an identical positive point charge is positioned at a fixed point Y, as shown in Fig. 6.1.

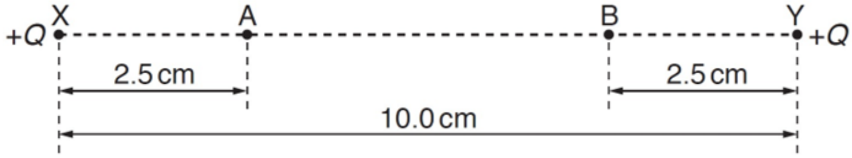

Fig. 6.1

The charges are separated in a vacuum by a distance of 10.0 cm.

Points A and B are on the line XY. Point A is a distance of 2.5 cm from X and point B is a distance of 2.5 cm from Y. The electric field strength at point A is 4.1×10^{-5} V m^{-1}.

(a) Calculate charge +Q.

+Q = ... C [2]

(b) On Fig. 6.2, sketch the variation with distance d of the electric field strength E from A to B, along the line AB.

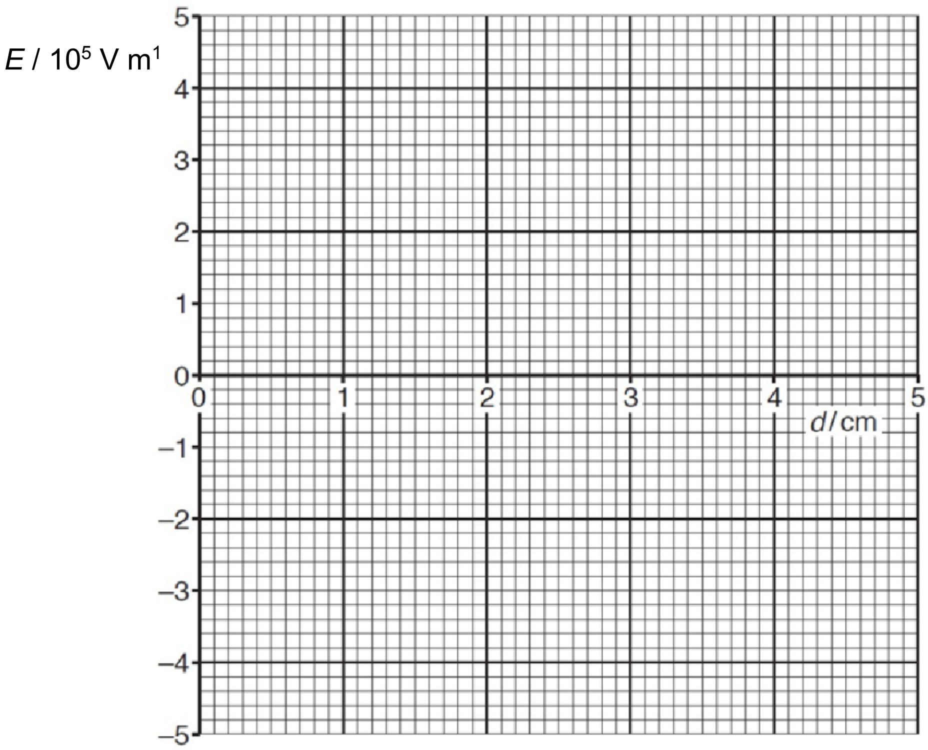

Fig 6.2

[2]

(c) A small positive charge is released at rest at d = 1.0 cm.

Using your graph in **(b)**, explain why the charge oscillates about a fixed point along the line AB.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

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…………………………………………………………………………………………………...

………………………………………………………………………………………………….. [2]

[Total: 6]

7 A d.c. converter converts direct steady voltage V into an alternating voltage of root-mean-square value V_{rms}. The output voltage V_{rms} from the d.c. converter is equal to V.

Fig. 7.1 shows a steady d.c. supply of 2.4 V connected to the d.c. converter. The output from the d.c. converter is connected to a transformer to step up the voltage so that it can power a camera flash lamp.

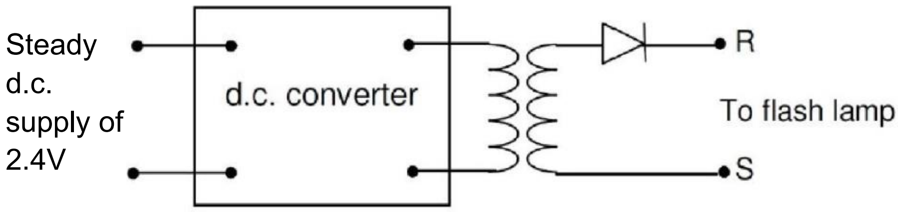

Fig. 7.1

(a) The ratio of the number of turns in the primary coil to the secondary coil is 1:50, calculate the maximum output voltage of the transformer.

maximum output voltage = ………………………………….. V [2]

(b) Fig 7.2 shows the variation with time of the output voltage across RS.

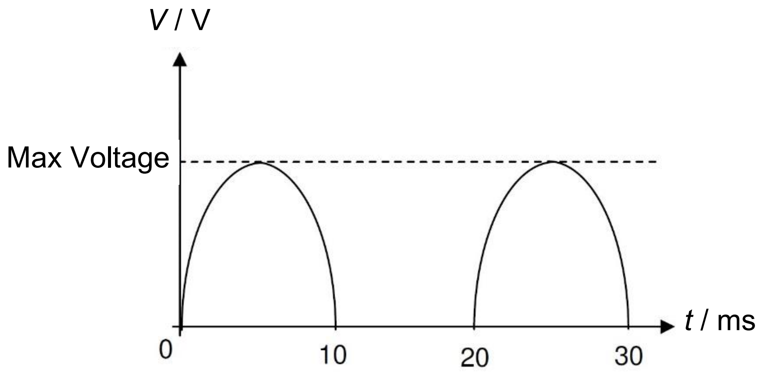

Fig. 7.2

The resistance of the flash lamp is 47 ∧. Calculate the average power supplied to the flash lamp.

average power = ………………………………….. W [2]

(c) The diode in Fig. 7.1. is replaced with a network of diodes to produce the output voltage across RS as shown in Fig. 7.3.

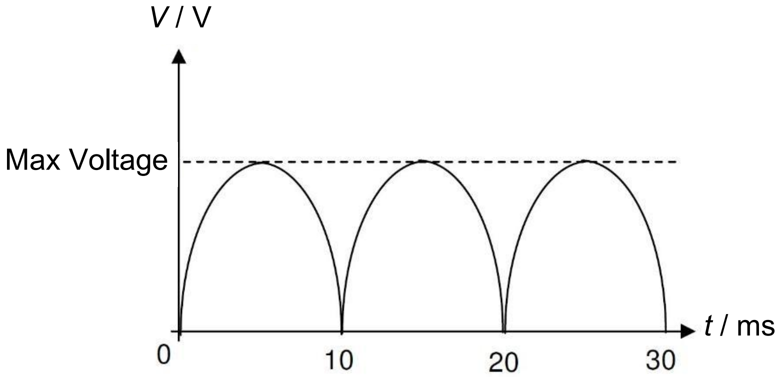

Fig. 7.3

Determine the new average power supplied to the same flash lamp.

power = …………………………………..W [1]

(d) Explain whether Fig. 7.3 represents an alternating voltage or a direct voltage.

……………………………………………………………………………………………………

…………………………………………………………………………………………….. [1]

(e) Explain why is it necessary to have a d.c. converter.

....

.... [1]

[Total: 7]

Section B

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

8 **(a)** Fig. 8.1 (top view) shows a metal ring of mass m and radius r, falling from rest within a horizontal radial magnetic field.

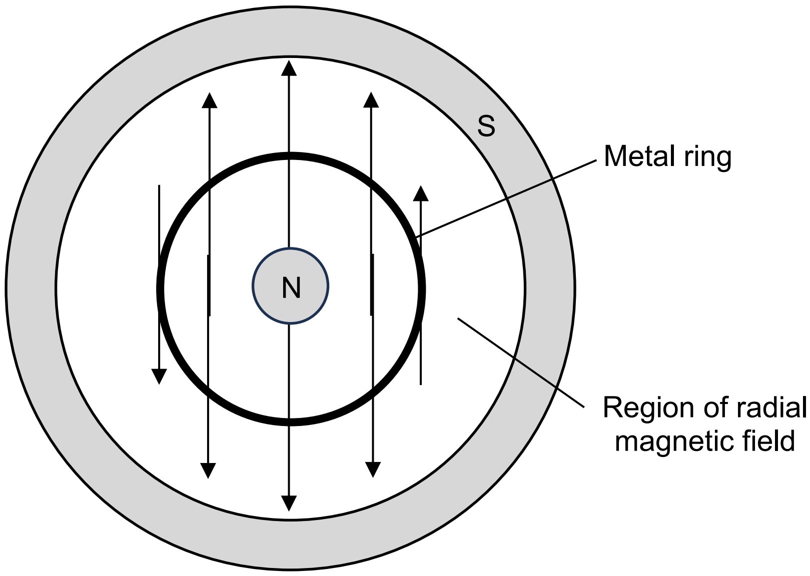

Fig. 8.1 (top view)

The centre of the ring coincides with the centre of the radial magnetic field.

The ring has a resistance R and the average magnetic flux density at the ring's position is B.

At time t, the ring has speed v and acceleration a.

(i) Show that the magnetic flux cut by the ring from time t to t+⊗t, where ⊗t is a short time interval is given by:

$$\Delta\Phi = 2\pi rBv\Delta t$$

[1]

(ii) Show that the current I induced in the ring is given by:

$$I = \frac{2\pi rBv}{R}$$

[2]

(iii) Air resistance is negligible. Show that the acceleration *a* of the ring is given by:

$$a = g - \frac{(2\pi rB)^2 v}{mR}$$

where *g* is the acceleration of free fall.

[2]

(iii) The average magnetic flux density *B* at the ring's position is 0.800 T. The ring has a resistance $R = 2.30 \text{ x } 10^{-4}$ ∧, radius $r = 3.00$ cm and mass $m = 0.0235$ kg.

Determine the maximum speed of the ring.

maximum speed = ……………… m s^{-1} [3]

(iv) On Fig. 8.2a and Fig 8.2b below, sketch the variation with time t of

1. the velocity v of the ring. [2]
2. the acceleration a of the ring. [1]

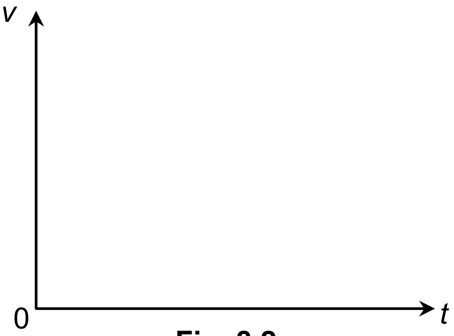

Fig. 8.2a

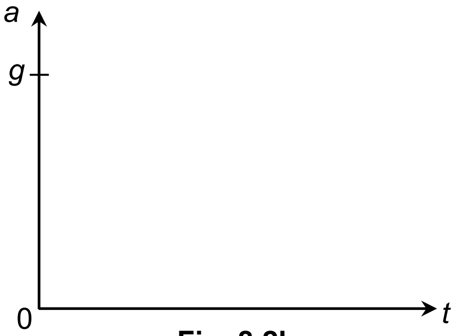

Fig. 8.2b

(b) Fig. 8.3 shows the ring in **(a)**, with one quadrant removed and placed in a uniform magnetic field of flux density 0.500 T.

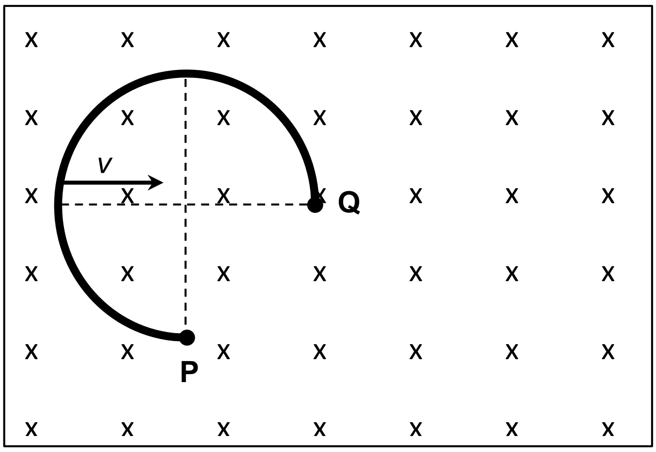

Fig. 8.3

The three-quarter ring is moved at a constant speed of 3.00 cm s^{-1} towards the right.

(i) Determine the e.m.f. induced across the two free ends P and Q.

e.m.f. = ………………… V [2]

(ii) State which end (P or Q) is at a higher potential.

higher potential at ………… [1]

(c) Fig. 8.4 shows three long straight current-carrying conductors placed parallel to one another.

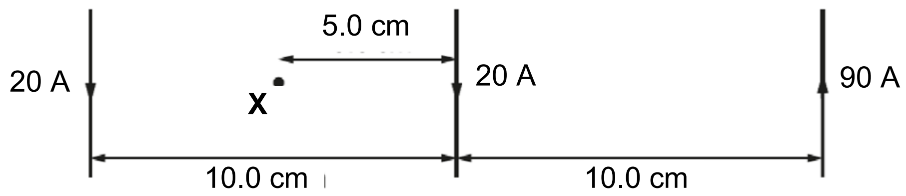

Fig. 8.4

(i) Determine the resultant magnetic flux density at X.

Flux density at X = ………………………………… T [2]

Direction = ………………………………….. [1]

(ii) The distance measured from the left-most conductor is *d*.

Curve A in Fig. 8.5 shows the variation with *d* of the magnetic flux density *B* due to the left-most conductor for the range 2.0 cm δ *d* δ 8.0 cm.

Curve C shows the magnetic flux density due to the current in the right-most conductor.

Positive values of *B* represent magnetic flux density pointing out of the page.

On the same figure, sketch the variation with *d* of

1. the magnetic flux density due to the current in the middle conductor.
Label the curve B and

2. the resultant magnetic flux density due to the current in all three conductors.
Label the curve R.

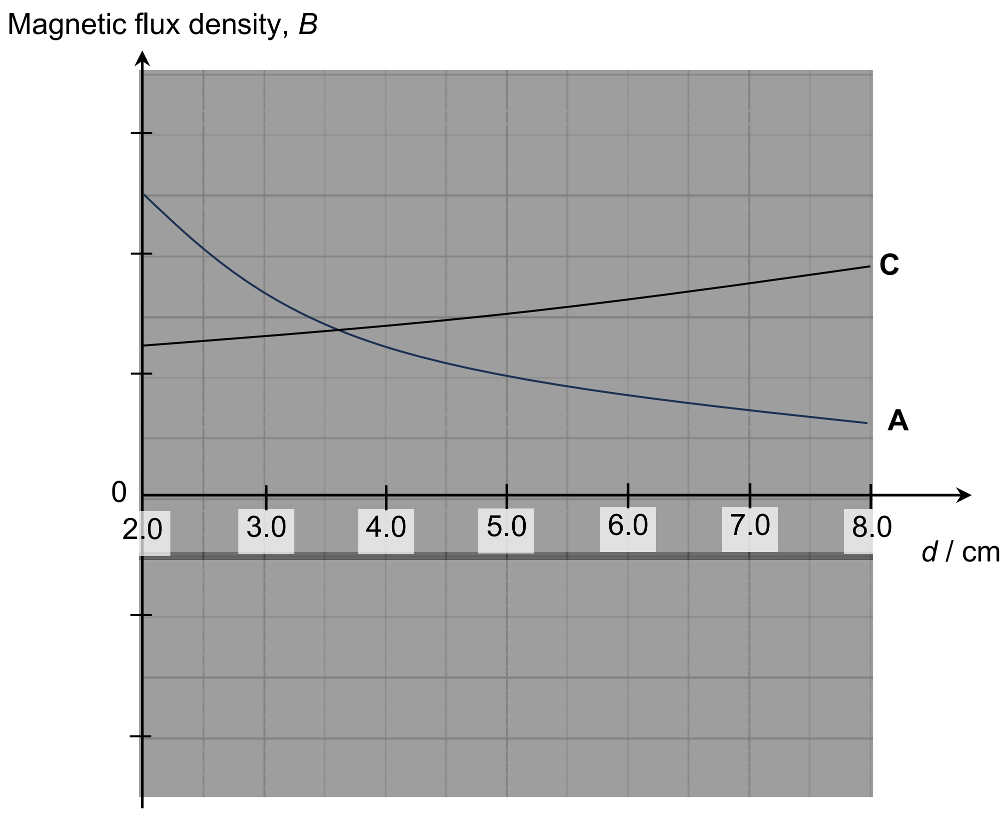

Fig. 8.5

[3]

[Total: 20]

9 **(a)** Some data for the work function energy Φ and the threshold frequency f_0 of some metal surfaces are given in Fig. 9.1.

metal	Φ / 10^{-19} J	f_0 / 10^{14} Hz
sodium	3.8	5.8
zinc	5.8	8.8
platinum	9.0	

Fig. 9.1

(i) State what is meant by the *threshold frequency*.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………… [2]

(ii) Calculate the threshold frequency for platinum.

threshold frequency = ……………………………………… Hz [2]

(iii) Electromagnetic radiation having a continuous spectrum of wavelengths between 300 nm and 600 nm is incident, in turn, on each of the metals listed in Fig. 9.1. Determine which metals, if any, will give rise to the emission of electrons.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

.... [2]

(iv) Some data for the variation with frequency f of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface are shown in Fig. 9.2.

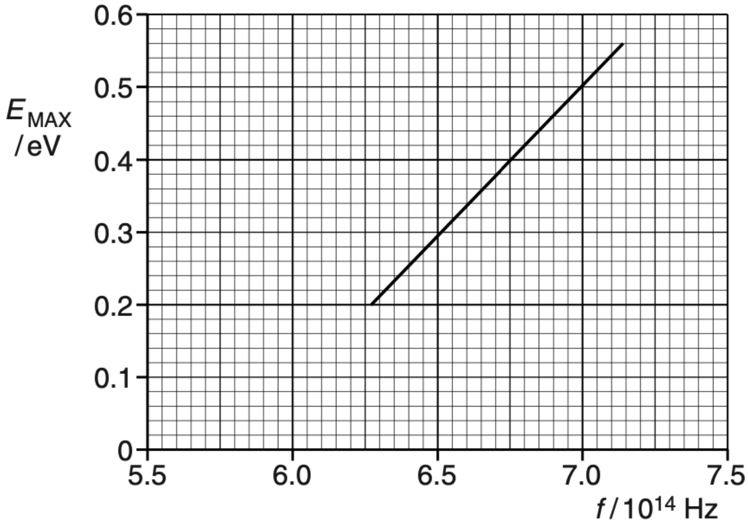

Fig. 9.2

1. Explain why emitted electrons may have kinetic energy less than the maximum at any particular frequency.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………….. [2]

2. Determine which metal listed in Fig. 9.1 is used to collect the data in Fig. 9.2.

metal is ……………………………………………….. [2]

(b) The first theory of the atom to meet with any success was put forward by Niels Bohr in 1913.

A hydrogen atom consists of a proton, of charge +*e*, and an electron, of charge –*e*. The electron of mass *m* orbits the proton at constant speed *v*. The whole system looks like the Earth orbiting around the Sun.

(i) For the electron in orbit at a distance *r* from the proton, show that

1. its kinetic energy E_K is given by:

$$E_K = \frac{e^2}{8\pi\varepsilon_0 r}$$

[2]

2. its total energy E_T is given by:

$$E_T = -\frac{e^2}{8\pi\varepsilon_0 r}$$

[1]

(ii) Show that the de Broglie wavelength of the orbiting electron is given by:

$$\lambda = \frac{h}{e}\sqrt{\frac{4\pi\varepsilon_0 r}{m}}$$

[1]

(iii) The electron wave in **(b)(ii)** forms a circular standing wave such that only an integer multiples *n* of wavelength λ could fit exactly within the orbit of radius r_n, as shown in Fig. 9.3.

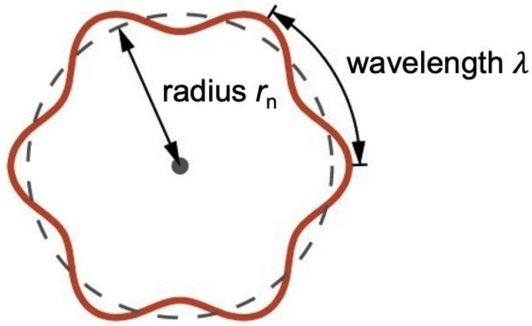

Fig. 9.3

Applying the condition in Fig. 9.3, it can be shown that the orbital radii in Bohr's atom is given by:

$$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2}$$

Show that the total energy of the electron can be expressed as:

$$E_n = -\frac{k}{n^2}$$

where *k* is a constant.

Determine the value of *k*, in J.

k = ... J [3]

(iv) The expression you have derived in **(b)(iii)** is the discrete energy levels in the hydrogen atom. Transition of the electron from higher energy levels (n > 2) to the energy level n = 2 gives rise to the Balmer series line spectra.

Show that the Balmer series line spectra correspond to visible light between 350 nm and 700 nm.

[3]

[Total: 20]

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H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/04**

Paper 4 Practical

26 Aug 2024
2 hours 30 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and 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 an HB pencil for any diagrams, graphs or rough workings.
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 of 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	
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Total	

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1 In this experiment, you will determine the internal resistance of cell P.

(a) You have been provided with two metre rules A and B, each with a wire attached.

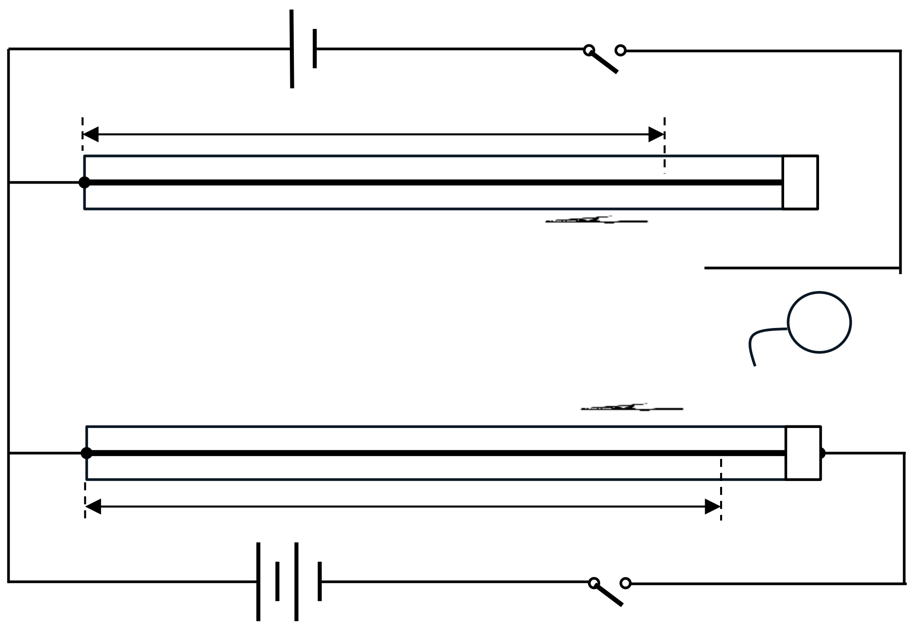
Take measurements to determine the resistance per unit length of each of the wires.

The resistance per unit length of the wire attached to rule A is R_A.
The resistance per unit length of the wire attached to rule B is R_B.

R_A = ...

R_B = ...
[1]

(b) Setup the circuit as shown in Fig. 1.1.



x

y

P

Q

K_1

K_2

A

A

B

Fig. 1.1

(i) Set x to 50 cm.

Close switch K_1 and K_2.

Adjust y until the ammeter reading is zero.

Measure and record x and y.

x = ...

y = ...
[2]

(ii) Open switch K_1 and K_2.

(c) Vary x and adjust y each time so that the ammeter reading is zero.
x must be more than 20 cm.

Present your results clearly.

[4]

(d) y and x are related by the expression:

$$\frac{1}{y} = a\frac{1}{x} + b$$

where a and b are constants.

Plot a suitable graph to determine a and b.

a = ...

b = ...
[7]

(e) Theory suggests that the internal resistance *r* of cell P is

$$r = \frac{a}{b} R_A$$

Determine *r*.

r = ……………………………………………….. [1]

[Total: 15]

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2 In this experiment, you will determine the spring constant of a spring.

(a) Measure and record the length L_0 of the unstretched spring, as shown in Fig. 2.1.

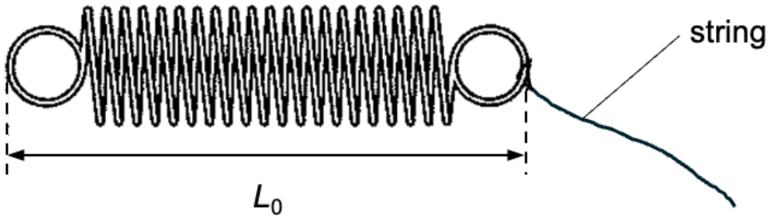
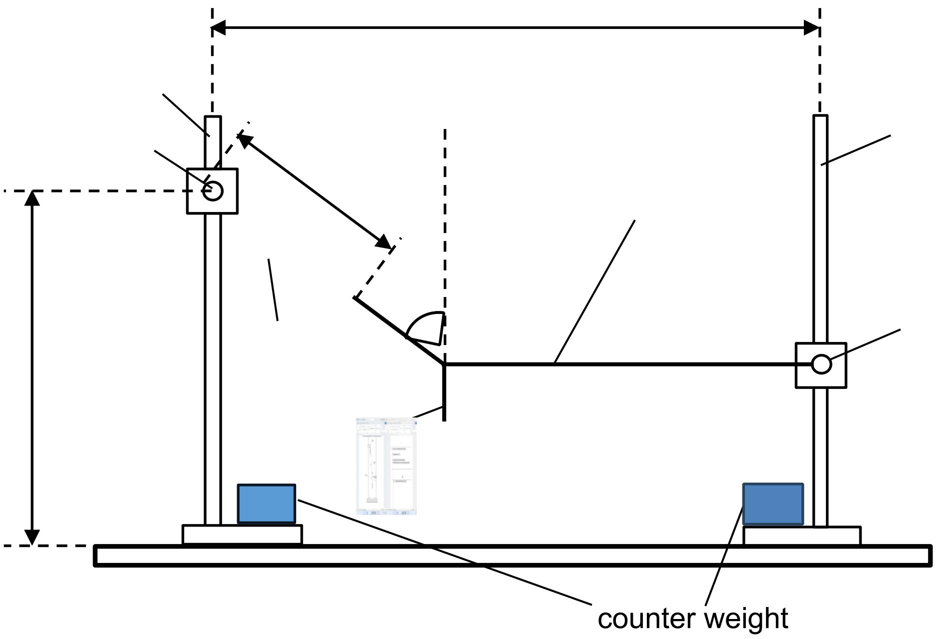


Fig. 2.1

L_0 = ………………………………………………… cm

(b) Set up the apparatus as shown in Fig. 2.2.



rod of clamp

rod of clamp

m

retort stand

retort stand

red string

white string

P

Q

spring

θ

≈ 90 cm

≈ 75 cm

L

Fig. 2.2

Hang a mass m of 150 g from the red string.
The distance between the two retort stands is about 90 cm.
The end of the spring on the retort stand is about 75 cm from the bench.

Adjust the height of Q and/or slide the red string along the white string so that the section PQ is parallel to the bench.

(i) Record the value of mass *m.*

m = ... g

(ii) Measure and record the length L of the spring and the angle θ.

L = ... cm

θ = ...

[2]

(c) Theory suggests that

$$\cos \cos \theta = \frac{mg}{ke}$$

where k is the spring constant of the spring, e is the extension of the spring and $g = 9.81\ \text{m s}^{-2}$.

Determine k.

k = ... N m^{-1} [2]

(d) If you were to repeat this experiment using other masses, describe how you will conduct the experiment and the graph that you would plot to determine k.

....

....

....

....

....

....

....

....

.... [3]

[Total: 7]

3 In this experiment, you will investigate the movement of a loaded wire.

(a) **(i)** Take the **shorter** of the two wires.

(ii) Measure and record the diameter *d* of the wire.

d = ... [2]

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

percentage uncertainty of *d* = ... [1]

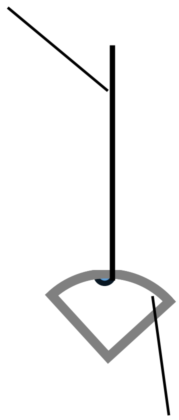
(iv) Calculate the cross-sectional area *A* of the wire using

$$A = \frac{\pi d^2}{4}$$

A = ... [1]

(b) **(i)** Secure the hook of the mass hanger to one end of the wire by wrapping the wire around the hook and vertical wire several times as shown in Fig. 3.1.

Leave at least 25 cm of excess wire.

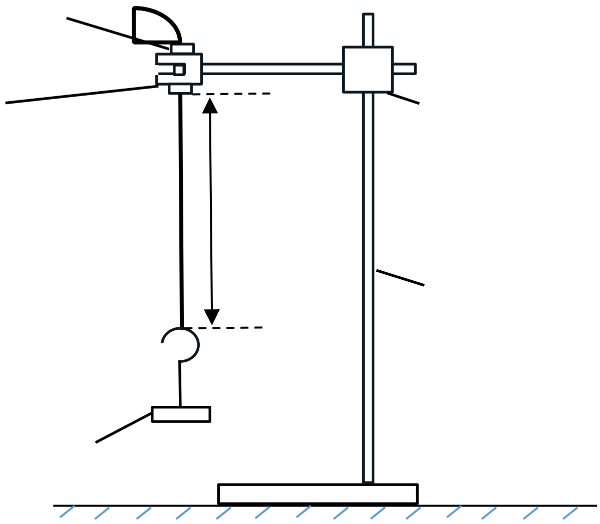


vertical wire

hook of mass hanger

Fig. 3.1

(ii) Set up the apparatus as shown in Fig. 3.2.
The total mass hanging from the end of the wire is 100 g.
The length *L* should be approximately 15 cm.



bench

vertical wire

mass

boss

clamp

split cork

stand

L

Fig. 3.2

(iii) Measure and record L.

L = ...

(iv) Twist the mass through approximately 180°.

Release the mass. The mass will oscillate as shown in Fig. 3.3.

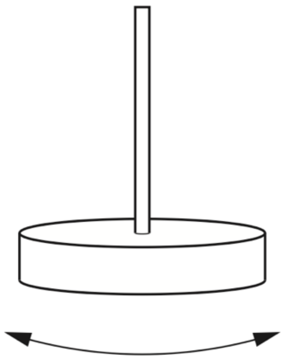


Fig. 3.3

Take measurements to determine the period T of the oscillations.

T = ... [2]

(v) Estimate the percentage uncertainty in your value of T.

percentage uncertainty of T = ... [1]

(c) **(i)** Take the **longer** wire. Repeat **(a)(ii)** and **(a)(iv)**.

d = ...

A = ...
[2]

(ii) Secure the hook of the mass hanger to one end of the wire as shown in Fig. 3.1 and leaving about 60 cm of excess wire.

The total mass hanging from the end of the wire is 100 g.

Repeat **(b)(iii)** and **(b)(iv)** for a value of *L* of approximately 50 cm.

L = ...

T = ………………………………………… [1]

DO NOT dismantle the apparatus.

(d) It is suggested that the relationship between *T, L* and *A* is

$$T = k\frac{\sqrt{L}}{A}$$

where *k* is a constant.

(i) Using your data, calculate two values of *k*.

first value of *k* = …………………………………………

second value of *k* = ………………………………………… [1]

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

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

…………………………………………………………………………………………………… [2]

(e) The oscillations in **(b)** and **(c)** is known as torsional oscillations. Another way to set the wire and mass system into oscillations is to allow it to swing from side-to-side, as shown in Fig. 3.4.

Fig. 3.4

(i) Set the **longer** wire in **(c)** into the swinging oscillations shown in Fig. 3.4.
Take measurements to determine the period T_S of the swinging oscillations.

T_S = …………………………………………

(ii) The torsional oscillations of the wire is dependent on the mass *m* of the load hung from the end of the wire.

Vary *m* and find values of *T* of the **torsional oscillations of the shorter wire** at the length *L* you used in **(b)(iii)**. Present your results clearly.

Use your results to estimate a value of *m* that allows the period *T* to be equal to T_S.

m = ...
[3]

(f) It is suggested that the period of the torsional oscillations of the wire is directly proportional to the radius r of the mass hung from the end of the wire.

Explain how you would investigate this relationship.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show direct proportionality
- why you might have difficulties using mass with very small radii and very large radii.

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.... [5]

[Total: 21]

4 A student is investigating how the intensity of the reflection of sound from a wooden panel depends on the thickness of foam attached to the panel and the frequency of the sound, as shown in Fig. 4.1.

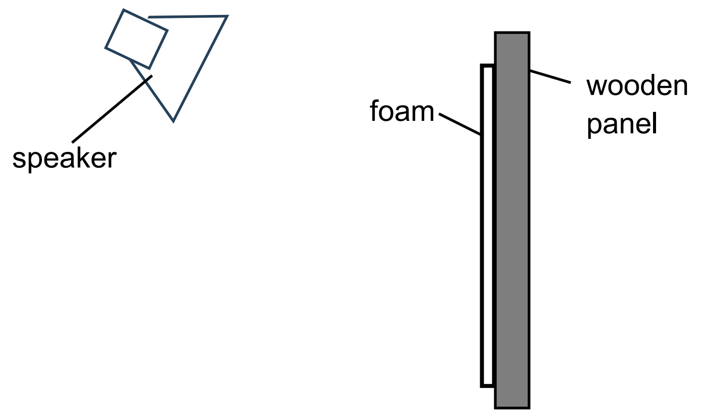

Fig 4.1 (Top View)

It is suggested that the intensity I of the reflected sound is related to the thickness t of the foam and frequency f of the sound by the relationship

$$I = At^x f^y$$

where A, x and y are constants.

You are provided with identical pieces of foam.

Design an experiment to determine the values of x and y.

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 interference is reduced,
(d) the control of variables,
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

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