



**HWA CHONG INSTITUTION**  
**JC2 Preliminary Examination**  
**Higher 2**

**CANDIDATE  
NAME**

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**CT GROUP**

**23S**

**CENTRE  
NUMBER**

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**INDEX  
NUMBER**

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**PHYSICS**

**9749/01**

**Paper 1 Multiple Choice**

**17 September 2024**

**1 hour**

Additional Materials: Optical Mark Sheet

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**INSTRUCTIONS TO CANDIDATES**

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, CT, NRIC or FIN number on the optical mark sheet (OMS). Shade your NRIC or FIN in the spaces provided.

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 OMS.

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.

Data	Formulae
speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$	uniformly accelerated motion $s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	work done on / by a gas $W = p \Delta V$
permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\approx (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$	hydrostatic pressure $p = \rho gh$
elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$	gravitational potential $\phi = -\frac{Gm}{r}$
the Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$	temperature $T/\text{K} = T/^\circ\text{C} + 273.15$
unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$	pressure of an ideal gas $P = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
rest mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$	mean kinetic energy of a molecule of an ideal gas $E = \frac{3}{2} kT$
rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$	displacement of particle in s.h.m. $x = x_0 \sin \omega t$
molar gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	velocity of particle in s.h.m. $v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
the Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	electric current $I = Anvq$
the Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	resistors in series $R = R_1 + R_2 + \dots$
gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	resistors in parallel $1/R = 1/R_1 + 1/R_2 + \dots$
acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$	electric potential $V = \frac{Q}{4\pi\epsilon_0 r}$
	alternating current / voltage $x = x_0 \sin \omega t$
	magnetic flux density due to a long straight wire $B = \frac{\mu_0 I}{2\pi d}$
	magnetic flux density due to a flat circular coil $B = \frac{\mu_0 NI}{2r}$
	magnetic flux density due to a long solenoid $B = \mu_0 nI$
	radioactive decay $x = x_0 \exp(-\lambda t)$
	decay constant $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

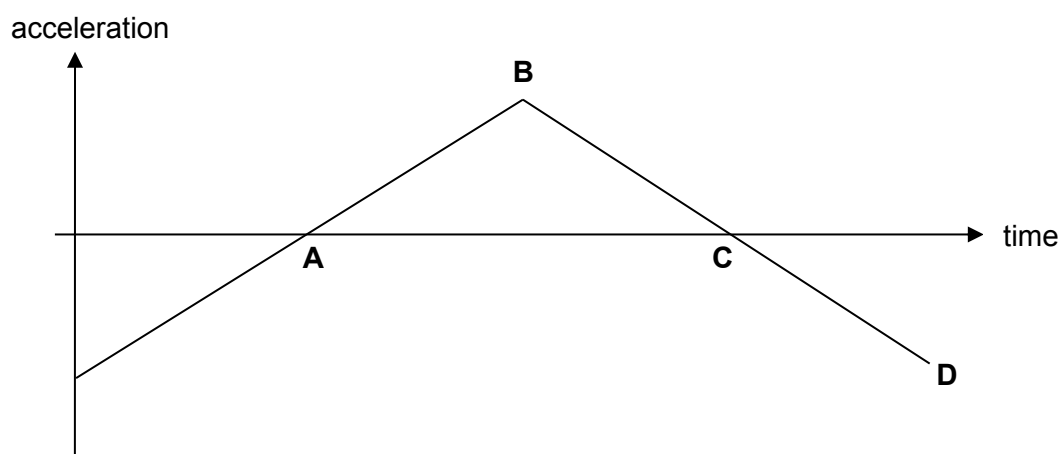
- 1 A thermometer can be read to an accuracy of  $\pm 0.5\text{ }^{\circ}\text{C}$ . This thermometer is used to measure a temperature rise from  $20\text{ }^{\circ}\text{C}$  to  $80\text{ }^{\circ}\text{C}$ .

What is the percentage uncertainty in the measurement of the temperature rise?

- A** 0.5 %                      **B** 0.8 %                      **C** 1.3 %                      **D** 1.7%

- 2 The acceleration–time graph of an object moving along a straight line is shown below. The object was initially at rest.

At which point on the graph is the object farthest from the starting point?



- 3 An elevator is moving downwards with a downward acceleration of  $5.8\text{ m s}^{-2}$ . A ball, held  $2.0\text{ m}$  above the floor of the elevator and at rest with respect to the elevator, is released.

How long does it take for the ball to reach the floor of the elevator?

- A** 0.51 s                      **B** 0.64 s                      **C** 0.83 s                      **D** 1.0 s

- 4 A man walking inside a shallow swimming pool managed to accelerate himself forward with a constant horizontal acceleration,  $a$ . Given the following information, which equation describes the horizontal motion of the man?

Mass of man:  $m$

Upthrust:  $U$

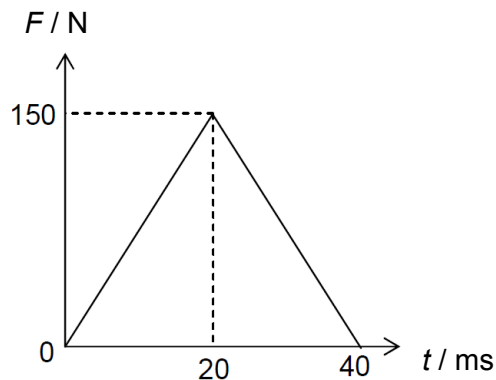
Drag force of water:  $f_D$

Frictional force from the floor of the pool:  $f$

Acceleration due to gravity:  $g$

- |          |                         |          |                    |
|----------|-------------------------|----------|--------------------|
| <b>A</b> | $f - f_D = ma$          | <b>B</b> | $mg - U = ma$      |
| <b>C</b> | $f_D - f + mg - U = ma$ | <b>D</b> | $f - f_D + U = ma$ |

- 5 The graph shows the force delivered to an incoming ball by a tennis player. After the impact, the 60 g ball leaves the racket with a speed of  $30 \text{ m s}^{-1}$ .



What was the magnitude of the momentum, in  $\text{N s}$ , of the tennis ball before the player hit it?

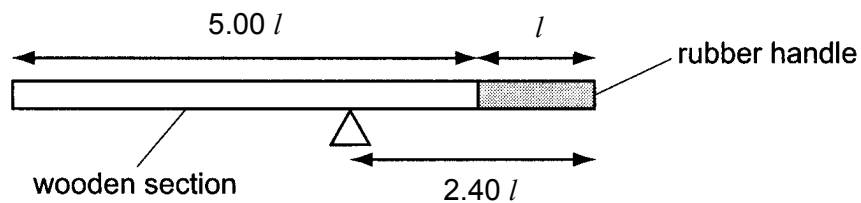
- |          |     |          |     |          |     |          |    |
|----------|-----|----------|-----|----------|-----|----------|----|
| <b>A</b> | 1.2 | <b>B</b> | 1.8 | <b>C</b> | 4.8 | <b>D</b> | 20 |
|----------|-----|----------|-----|----------|-----|----------|----|

- 6 A thruster is used to launch a 500 kg rocket vertically upward from rest. This thruster ejects exhaust at a speed of  $1000 \text{ m s}^{-1}$ .

What should be the minimum rate, in  $\text{kg s}^{-1}$ , at which the exhaust leaves the thruster at the instant of launch?

- A 0.5                      B 2.0                      C 4.9                      D 20

- 7 A uniform rod has a wooden section and a solid rubber handle, as shown.

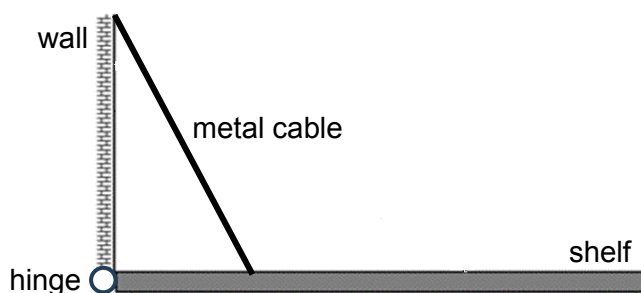


The length of the handle is  $l$  and the length of the wooden section is  $5.00 l$ . The rod balances a distance  $2.40 l$  from the rubber end.

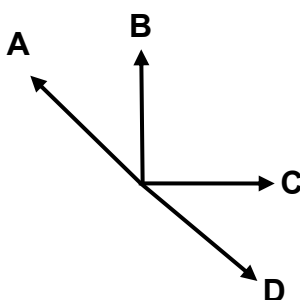
What is the ratio  $\frac{\text{density of rubber}}{\text{density of wood}}$  ?

- A 5.42                      B 5.00                      C 2.89                      D 0.345

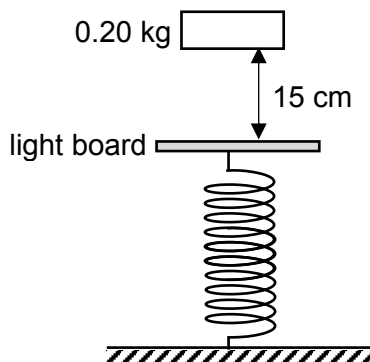
- 8 A shelf made of uniform material is held horizontally against a wall by a metal cable. The forces acting on the shelf are its weight, the force exerted by the metal cable, and the force exerted by the hinge.



Which arrow could represent the direction of the force the hinge exerts on the shelf?



- 9 A block of mass  $0.20\text{ kg}$  is dropped from a height of  $15\text{ cm}$  above a light spring of spring constant  $85\text{ N m}^{-1}$ , as shown below. The block lands on a light board and compresses the spring.



Determine the maximum compression of the spring.

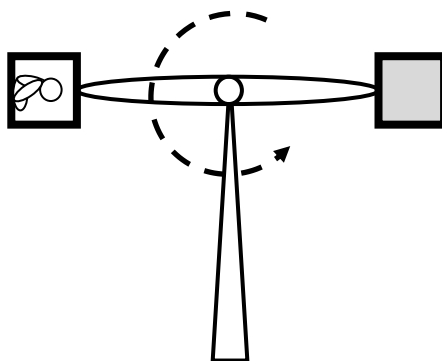
- A     $2.3\text{ cm}$                       B     $4.6\text{ cm}$                       C     $8.3\text{ cm}$                       D     $11\text{ cm}$

- 10** A speed boat with two engines, each of power  $32 \text{ kW}$ , can travel at a maximum speed of  $14 \text{ m s}^{-1}$ . The total drag force on the boat is directly proportional to the speed of the boat.

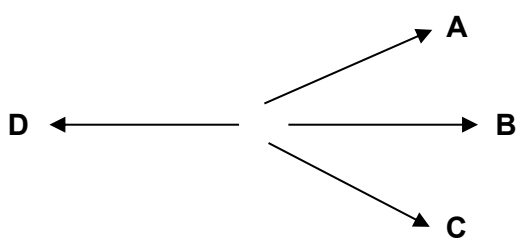
What is the maximum speed of the boat when only one engine is working?

- A**  $3.5 \text{ m s}^{-1}$       **B**  $7.0 \text{ m s}^{-1}$       **C**  $9.9 \text{ m s}^{-1}$       **D**  $11 \text{ m s}^{-1}$

- 11** In an amusement park ride, a person sits in a cage which moves in a vertical circle at a constant speed. The person stays stationary with respect to the cage.

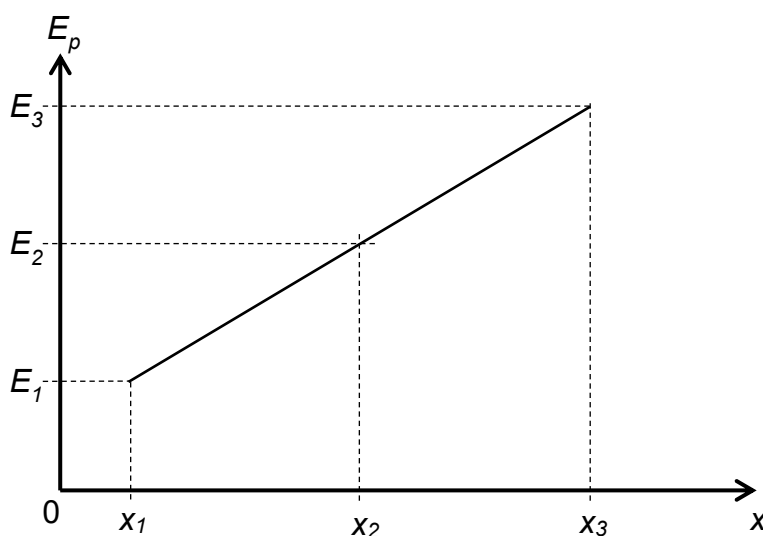


At the instant shown, what is the direction of the force exerted by the cage on the person?



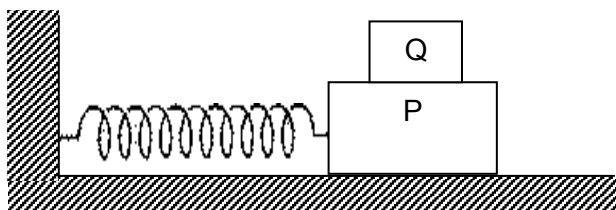
- 12 An object of mass  $m$  is moving radially away from Earth of mass  $M$ .

For a small distance  $x$  above the surface of the Earth, the variation with  $x$  of the stone's gravitational potential energy  $E_p$  is shown. At a point a distance  $x_2$  from the surface of the Earth, the potential energy of the stone is  $E_2$ .



What is the magnitude of the force acting on the stone?

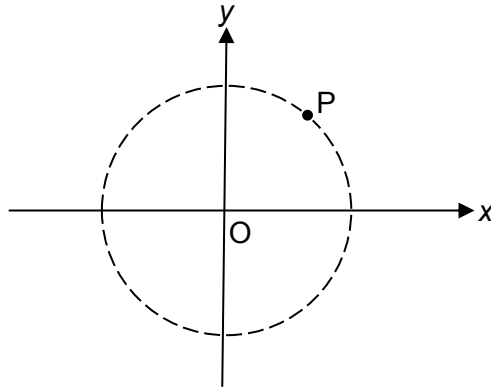
- A  $\frac{GMm}{(x_2)^2}$       B  $\frac{E_2}{x_2}$       C  $\frac{E_3 - E_1}{x_3 - x_1}$       D  $\frac{(x_1 + x_2) \times (E_2 + E_1)}{4}$
- 13 A system consisting of a large block P with a smaller block Q resting on it, oscillates on a frictionless surface with a frequency of 1.5 Hz. The maximum static friction *between* the two blocks is 5.0 N.



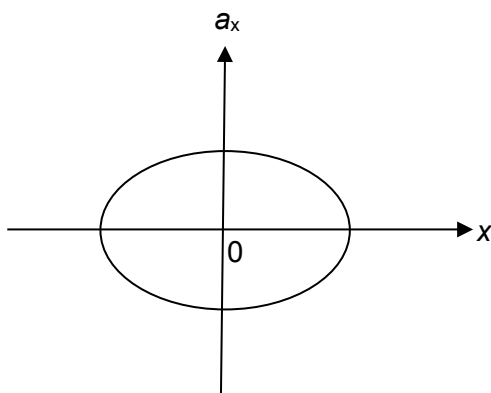
If the mass of P is 2.0 kg and the mass of Q is 0.20 kg, what is the maximum amplitude of oscillation of the system in order that block Q does not slip?

- A 0.026 m      B 0.028 m      C 0.056 m      D 0.28 m

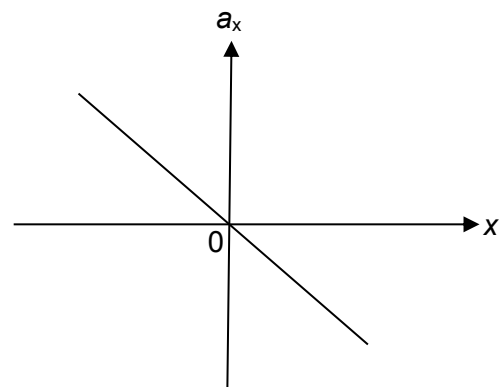
- 14 A particle P performs uniform circular motion about the origin O in the x-y plane as shown below.



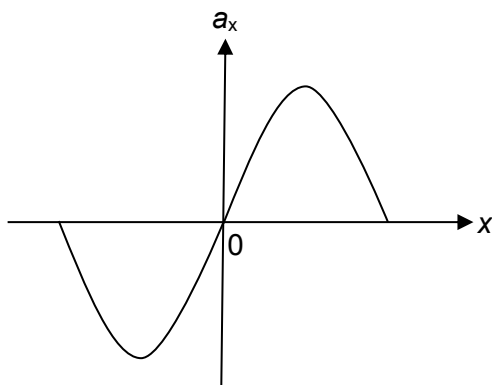
Which of the following graphs shows the relationship between the x-component of the acceleration  $a_x$  and the displacement in the x-direction?



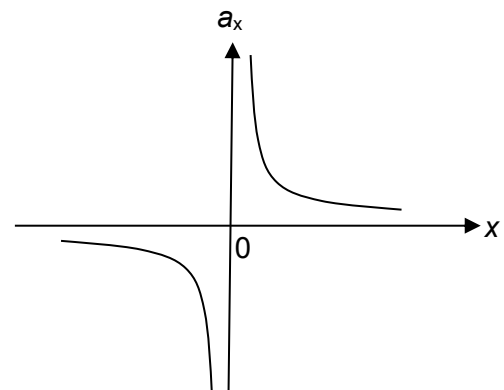
A



B

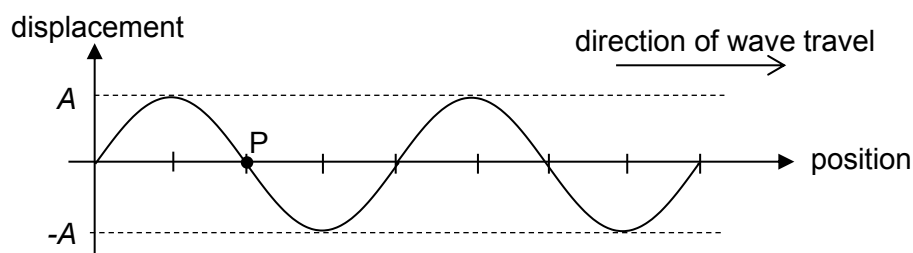


C



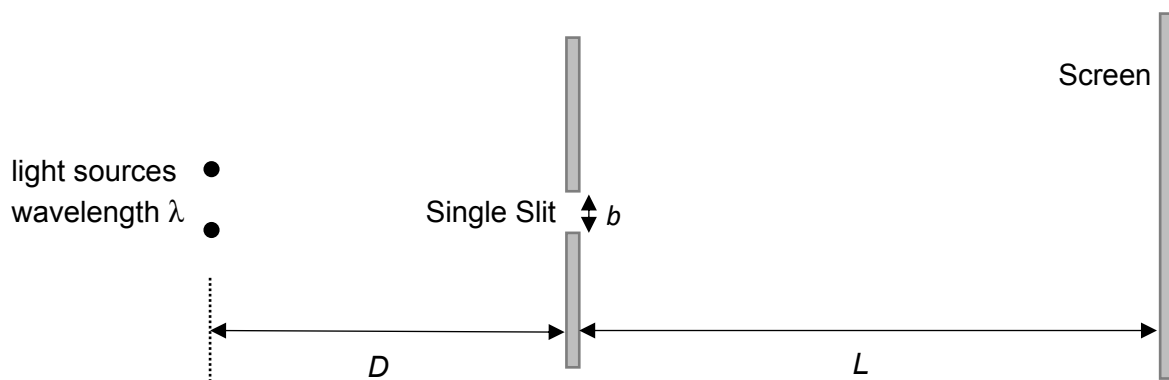
D

- 15 The displacement-position graph of a progressive wave is shown below. Particle P is a point along the wave.



Which of the following statements is **true** about particle P at the instant shown in the graph?

- A It is moving towards the negative direction.
  - B It has zero velocity.
  - C It has an amplitude of  $A$ .
  - D It is experiencing the largest acceleration.
- 16 Two monochromatic light sources of wavelength  $\lambda$  are separated by a fixed distance. Light from the sources pass through a single slit of width  $b$  at a distance of  $D$ . The image of the light sources is projected on a screen at a distance  $L$  from the single slit.



One is just able to distinguish that there are two light sources from the image captured on the screen.

For the image captured on screen, which of the following changes will make it easier to distinguish that there are two light sources?

- A  $\lambda$  is increased.
- B  $D$  is reduced.
- C  $b$  is decreased.
- D  $L$  is increased.

- 17 White light (400 - 700 nm) is directed perpendicularly towards a diffraction grating. The diffraction grating has 300 lines per mm and the resulting image is projected on a screen.

What is the highest order of diffraction whereby a complete spectrum (red to violet) which does not overlap with the next order is clearly visible?

- A 1<sup>st</sup> order      B 2<sup>nd</sup> order      C 3<sup>rd</sup> order      D 4<sup>th</sup> order

- 18 In deriving the equation  $p = \frac{1}{3}\rho\langle c^2 \rangle$  using the kinetic theory of gases, which of the following is **not** a valid assumption?

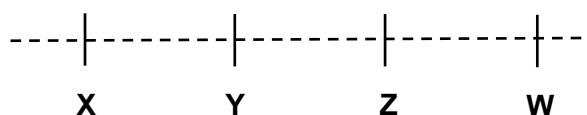
- A The volume of the molecules is negligible compared with the volume of the gas.  
 B The duration of a collision is negligible compared with the time between collisions.  
 C The molecules experience negligible change of momentum on collision with the walls of the container.  
 D Collisions with the walls of the container and with other molecules cause no change in the average kinetic energy of the molecules.

- 19  $N$  molecules of a monatomic ideal gas are contained in a rigid box at pressure  $p$  and temperature  $T$ . An additional  $N$  molecules of the same gas are added to the box in such a way that the internal energy is kept constant at its original value.

Which of the following indicates the values of the temperature and pressure of the gas after the addition?

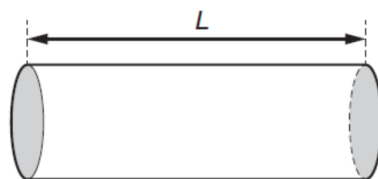
	<u>temperature</u>	<u>pressure</u>
A	$\frac{1}{2}T$	$p$
B	$\frac{1}{2}T$	$\frac{1}{2}p$
C	$T$	$2p$
D	$T$	$p$

- 20 X, Y, Z and W are four points on a straight line as shown below. The points are equally spaced apart.



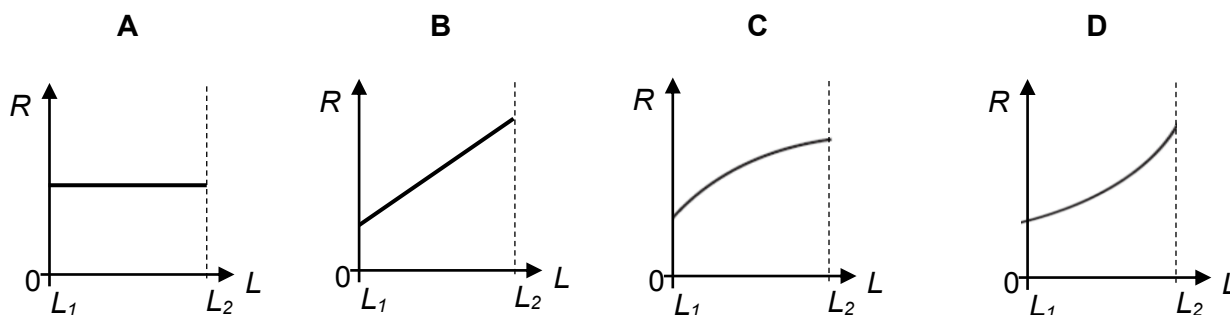
A point charge  $+Q$  is fixed at X. When another point charge  $-Q$  is moved from Y to Z, which of the following statements is **false**?

- A The electric potential energy of the system of charges will increase.
  - B The magnitude of the electric field strength at point W will increase.
  - C The electric potential at point W will increase.
  - D The electric potential at point Y will become zero.
- 21 A piece of conducting modelling clay of constant resistivity is formed into a cylindrical shape. The resistance  $R$  between its flat ends (shaded) is measured.

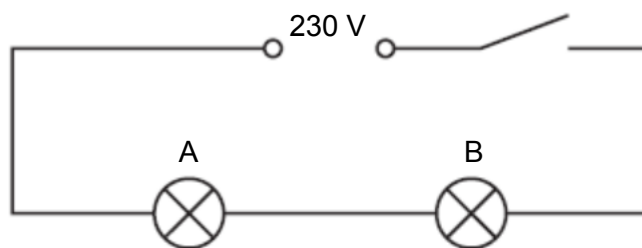


The same volume of modelling clay is re-formed into cylinders of different lengths  $L$  in the range of  $L_1$  to  $L_2$  and the resistance  $R$  between the flat ends is measured for each value of  $L$ .

Which graph best shows the variation of  $R$  with  $L$ ?



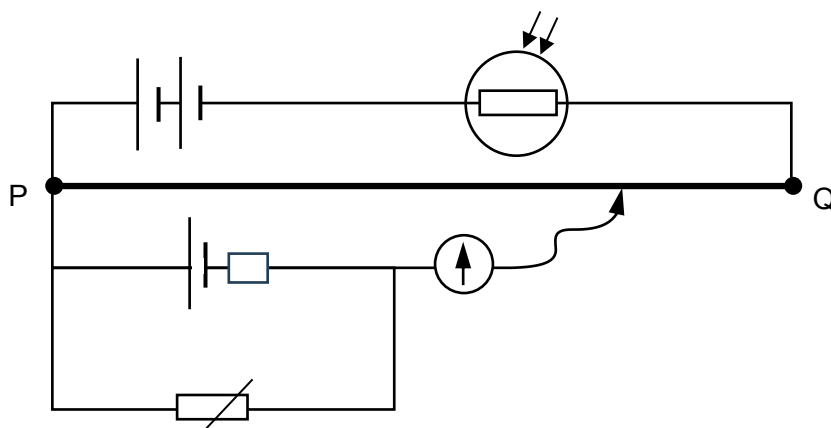
- 22 In the circuit shown, lamp A is rated 230 V, 10 W and lamp B is rated 230 V, 40 W. The two lamps are connected in series to a 230 V power supply.



Assume that the resistance of each lamp remains constant at all temperatures.

Which statement most accurately describes what happens when the switch is closed?

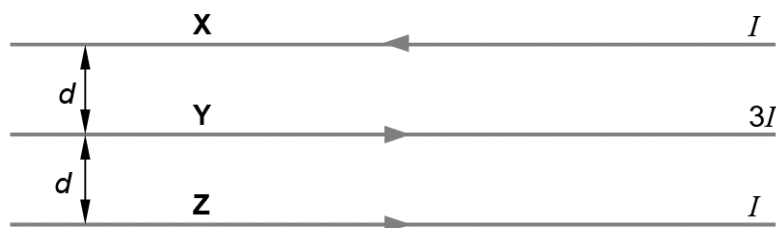
- A Lamp A emits twice as much power as lamp B.  
 B Lamp A emits four times as much power as lamp B.  
 C Lamp B emits twice as much power as lamp A.  
 D Lamp B emits four times as much power as lamp A.
- 23 A NTC thermistor and a light-dependent resistor are connected in a potentiometer circuit. PQ is a resistance wire.



Which combination of temperature and lighting condition maximises the balance length?

	<u>temperature</u>	<u>lighting</u>
A	low	dark
B	low	bright
C	high	dark
D	high	bright

- 24 The diagram below shows three long, parallel, straight wires X, Y and Z placed in the same plane in a vacuum. Wires X and Z each carries a current of  $I$ , and wire Y carries a current of  $3I$ . Wire Y is halfway between wire X and wire Z.

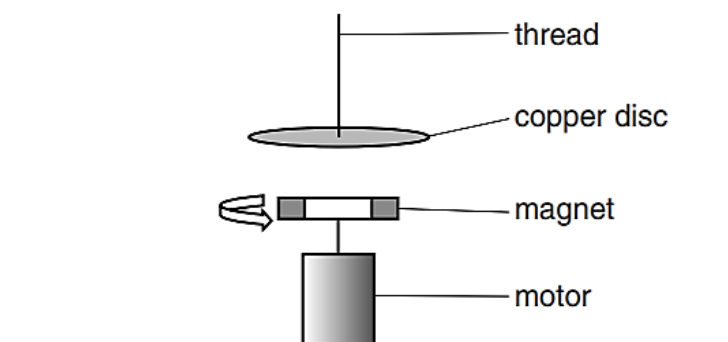


The magnitude of the force per unit length acting between X and Z is  $F$ .

What is the direction and magnitude of the net force per unit length acting on Z?

	<u>Direction</u>	<u>Magnitude</u>
A	Towards Y	$F$
B	Towards Y	$5F$
C	Away from Y	$5F$
D	Away from Y	$7F$

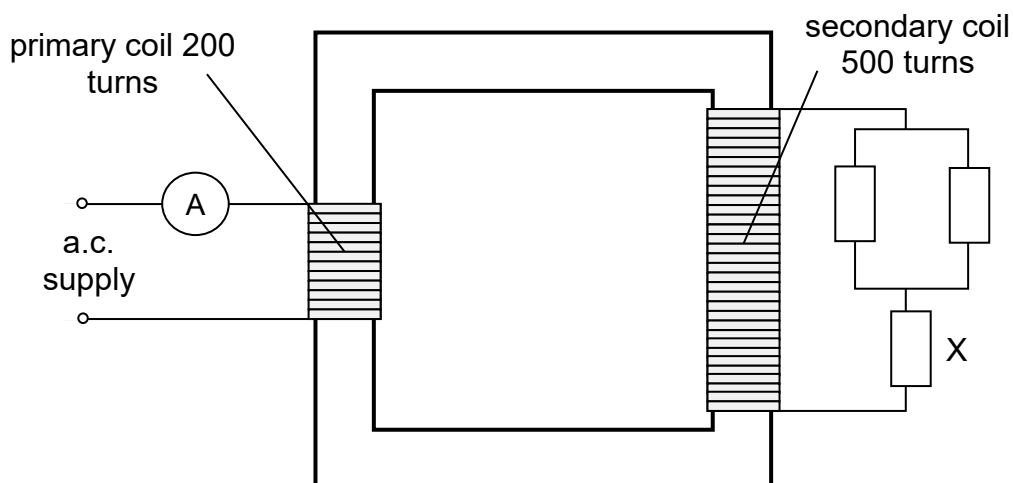
- 25 A magnet is attached to a motor and rotates below a freely-suspended copper disc as shown below.



Which of the following statements is correct?

- A The disc remains stationary as copper is not magnetic.
- B The disc rotates in the same direction as the magnet as copper is magnetic.
- C The disc rotates in the same direction as the magnet as eddy currents are induced in the disc.
- D The disc rotates in the opposite direction as the magnet as eddy currents are induced in the disc.

- 26 A 100% efficient transformer is connected to a sinusoidal a.c. supply as shown below. The secondary coil is connected to 3 identical resistors, each of resistance  $1000\ \Omega$ . The potential difference across resistor X is 80 V.



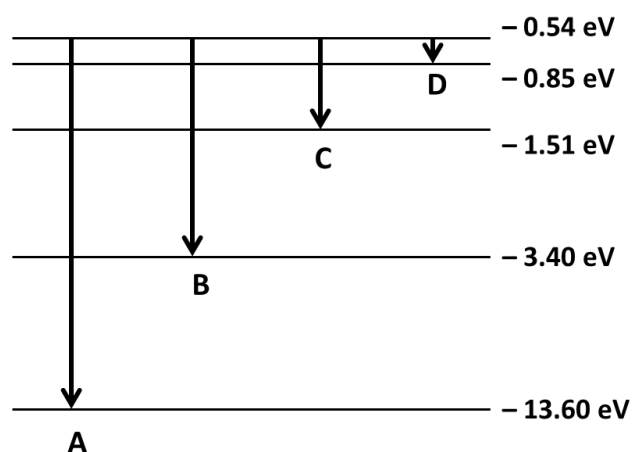
What is the reading on the ammeter?

- A 0.080 A      B 0.20 A      C 0.40 A      D 2.3 A
- 27 Which of the following statements is **true** when the photoelectric effect occurs?
- A The maximum speed of emitted electron is proportional to the intensity of the incident light.
  - B The maximum energy of the emitted electrons increases with the wavelength of the incident light.
  - C The number of electrons emitted per unit time is proportional to the intensity of the incident light.
  - D The wavelength of the incident light must be greater than a certain threshold value.

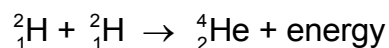
- 28 The energy level diagram represents the five lowest energy levels of hydrogen.

A spectral line of wavelength 435 nm corresponds to one of the lines in the spectrum of hydrogen.

Which of the transitions gives this particular spectral line?



- 29 Two deuterium nuclei undergo a fusion reaction to form a helium nucleus as represented by



The binding energy per nucleon of helium is 2.54 MeV.

The minimum amount of energy released in this reaction is 3.26 MeV.

What is the binding energy per nucleon of deuterium?

- A 1.45 MeV      B 1.73 MeV      C 3.36 MeV      D 3.45 MeV
- 30 A detector detects an average count-rate of 600 counts  $\text{min}^{-1}$ . Two half-lives later, the count-rate drops to 180 counts  $\text{min}^{-1}$ .

Determine the average background count-rate, in counts  $\text{min}^{-1}$ .

- A 15      B 40      C 60      D 120

**END OF PAPER**



CANDIDATE  
NAME

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CT GROUP

23S

CENTRE  
NUMBER

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INDEX  
NUMBER

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## PHYSICS

9749/02

### Paper 2 Structured Questions

10 September 2024

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

### READ THESE INSTRUCTIONS FIRST

Write your Centre Number, index 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 soft 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.

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

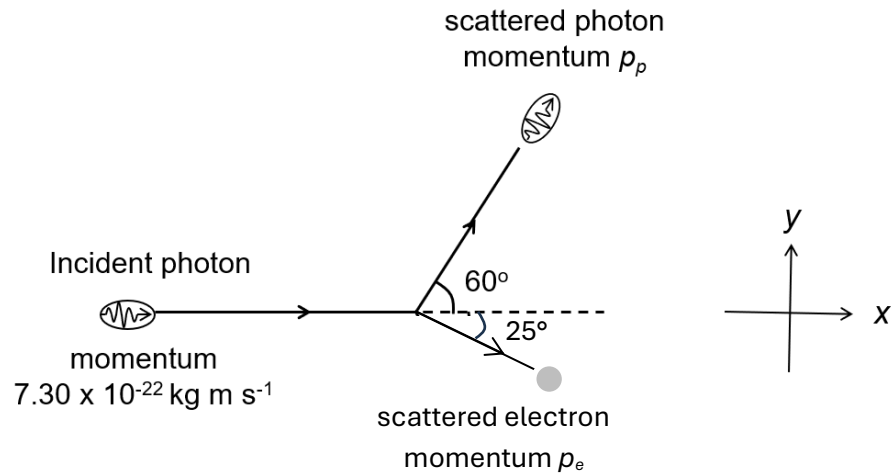
You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Paper 2		
1		6
2		11
3		5
4		8
5		9
6		10
7		9
8		22
Deductions		
Total		80

Data	Formulae
speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$	uniformly accelerated motion $s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	work done on / by a gas $W = p \Delta V$
permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\approx (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$	hydrostatic pressure $p = \rho gh$
elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$	gravitational potential $\phi = -\frac{Gm}{r}$
the Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$	temperature $T/\text{K} = T/^\circ\text{C} + 273.15$
unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$	pressure of an ideal gas $P = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
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rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$	displacement of particle in s.h.m. $x = x_0 \sin \omega t$
molar gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	velocity of particle in s.h.m. $v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
the Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	electric current $I = Anvq$
the Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	resistors in series $R = R_1 + R_2 + \dots$
gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	resistors in parallel $1/R = 1/R_1 + 1/R_2 + \dots$
acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$	electric potential $V = \frac{Q}{4\pi\epsilon_0 r}$
	alternating current / voltage $x = x_0 \sin \omega t$
	magnetic flux density due to a long straight wire $B = \frac{\mu_0 I}{2\pi d}$
	magnetic flux density due to a flat circular coil $B = \frac{\mu_0 NI}{2r}$
	magnetic flux density due to a long solenoid $B = \mu_0 nI$
	radioactive decay $x = x_0 \exp(-\lambda t)$
	decay constant $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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- 1 Fig. 1.1 shows an incident photon of momentum  $7.30 \times 10^{-22} \text{ kg m s}^{-1}$  colliding with a stationary electron.



**Fig. 1.1**

After the collision, the photon is scattered off through an angle of  $60^\circ$  and has a momentum  $p_p$ . The electron gets scattered off at an angle of  $25^\circ$  with a momentum  $p_e$ . Their scattering angles are measured with respect to the path of the incident photon.

- (a) Explain why linear momentum is conserved in this collision for the system of photon and electron.

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

- (b) Consider the photon and electron as a system.

- (i) State the total momentum of the system along the

1. x-direction,

momentum in x-direction = .....  $\text{kg m s}^{-1}$  [1]

2. y-direction.

momentum in y-direction = .....  $\text{kg m s}^{-1}$  [1]

- (ii) Applying the principle of conservation of momentum in both directions, determine the momentum  $p_e$  of the electron after the collision.

momentum  $p_e$  of the electron = ..... kg m s<sup>-1</sup> [3]

[Total: 6]

- 2 (a) State Newton's law of gravitation.

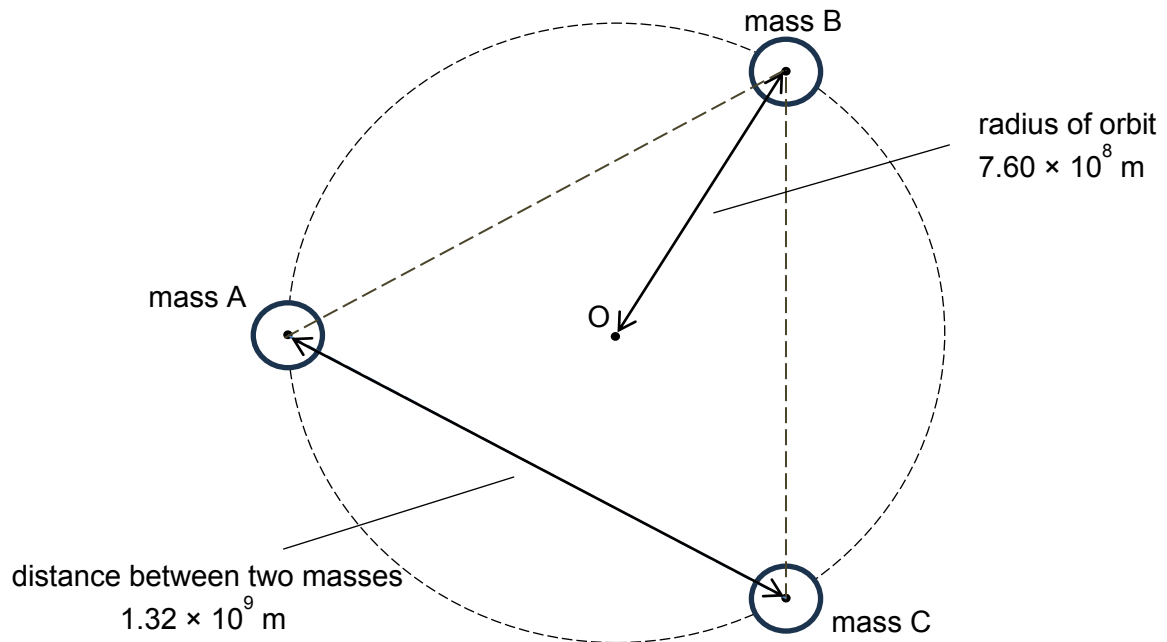
.....

.....

.....[2]

- (b) Fig. 2.1 shows a hypothetical stable three-body system. The system comprises of three identical masses A, B and C orbiting about a common centre of rotation O.

The radius of orbit is  $7.60 \times 10^8 \text{ m}$ .



**Fig 2.1**

The masses are equally distributed along the circular path of orbit, such that the distance between any two masses is always the same.

The distance between the centres of any two masses is  $1.32 \times 10^9 \text{ m}$ . Each mass is  $6.20 \times 10^{24} \text{ kg}$ .

- (i) Show that the resultant force on mass A is  $2.55 \times 10^{21} \text{ N}$ .

[2]

- (ii) Hence, calculate the period of orbit of the three masses about O. Explain your working.

period = ..... s [3]

- (iii) Explain why gravitational potential near this system of three masses is always negative.

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

- (iv) Calculate the gravitational potential energy of this system of three masses.

gravitational potential energy = ..... J [2]

[Total: 11]

- 3 (a) Describe what is meant by a *polarised* wave.

.....

.....

.....

.....[2]

- (b) A narrow beam of light is incident on three ideal polarising filters A, B and C as illustrated in Fig. 3.1.

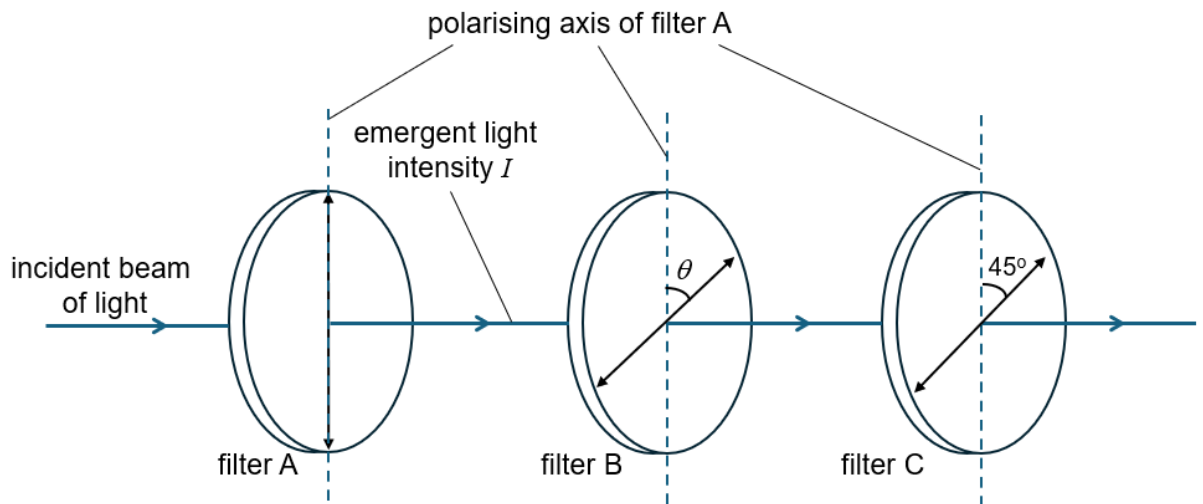


Fig. 3.1

The emergent beam after passing through filter A has an intensity of  $I$ .

Filter C is fixed in position such that its polarising axis is at an angle of  $45^\circ$  from the polarising axis of filter A.

Filter B is allowed to rotate.  $\theta$  is the angle between the polarising axes of filter A and B.

- (i) Polarising filter B is rotated from  $\theta = 0^\circ$  to  $\theta = 180^\circ$ .

Besides  $\theta = 90^\circ$ , there is another angle  $\theta$  where the intensity of light emergent from filter C is zero. State the value of this angle.

$\theta = \dots\dots\dots^\circ$  [1]

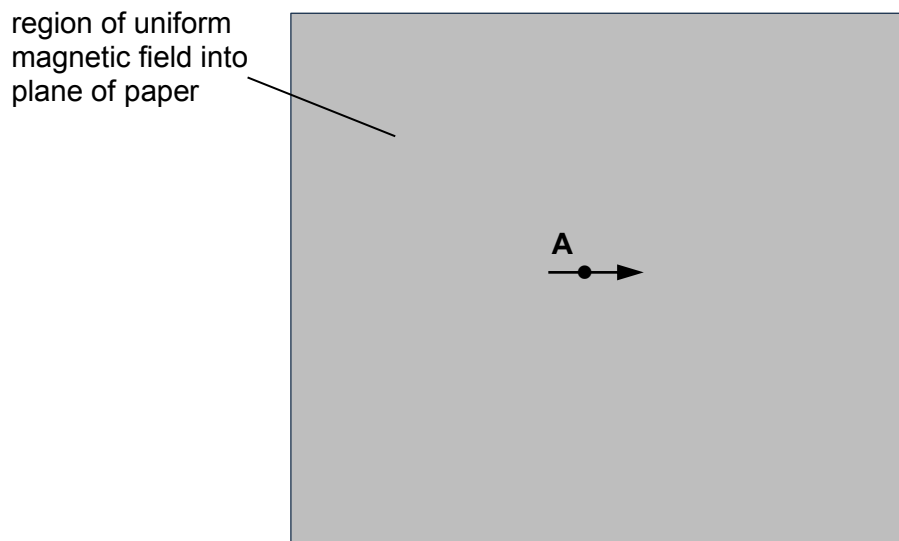
- (ii) Filter B is adjusted such that  $\theta = 60^\circ$ .

Determine the intensity of light, in terms of  $I$ , that emerges from filter C.

intensity = ..... $I$  [2]

[Total: 5]

- 4 An electron is travelling at right angles to a uniform magnetic field of flux density 1.2 mT, as illustrated in Fig. 4.1.



**Fig. 4.1**

The magnetic field is directed into the plane of the paper.

When the electron is at A, its velocity is  $2.8 \times 10^7 \text{ m s}^{-1}$  in the direction shown. This is normal to the magnetic field.

- (a) (i) On Fig. 4.1, sketch the path of the electron, assuming that it does not leave the region of the magnetic field. [1]
- (ii) Show that the radius of the path of the electron is 13 cm.

[2]

- (b) (i) A uniform electric field is applied in the same region so that the electron now moves undeflected through the magnetic field.
1. Draw on Fig. 4.1 the direction of the electric field. Label your arrow **E**.
  2. Determine the magnitude of the electric field strength.

magnitude of electric field strength = .....  $\text{N C}^{-1}$  [3]

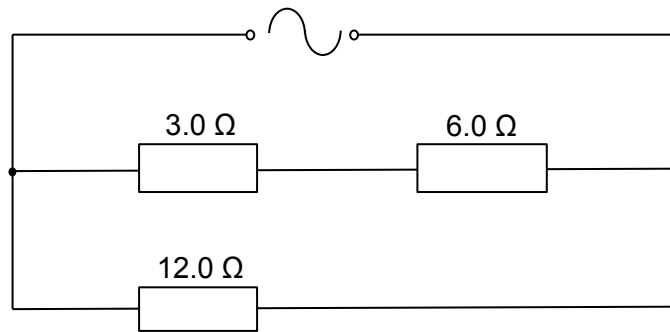
- (ii) If however, the direction of the uniform electric field is in the same direction as the magnetic field, describe the shape of the resultant path of the electron.

You may draw a sketch to illustrate the path if you wish.

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

[Total: 8]

- 5 Fig. 5.1 shows an a.c. power supply connected to three resistors.



**Fig. 5.1**

The variation with time  $t$  of the voltage  $V$  of the power supply is given by the expression:

$$V = 15 \sin 628t$$

- (a) Determine, for the power supply,
- (i) the period  $T$  of the a.c. voltage,

$$T = \dots\dots\dots \text{ s [1]}$$

- (ii) the root-mean-square (r.m.s.) voltage  $V_{rms}$ ,

$$V_{rms} = \dots\dots\dots \text{ V [1]}$$

- (iii) the peak current  $I_0$  from the power supply,

$$I_0 = \dots\dots\dots \text{ A [2]}$$

- (iv) the mean power  $\langle P \rangle$  dissipated in the resistor of resistance  $6.0 \, \Omega$ .

$\langle P \rangle = \dots\dots\dots \text{ W [2]}$

- (b) Use your answers in (a) to sketch, on the axes of Fig 5.2, the variation with time  $t$  of the power  $P$  transferred in the  $6.0 \, \Omega$  resistor, for two complete periods of the alternating potential difference. Label your axes and indicate relevant values.

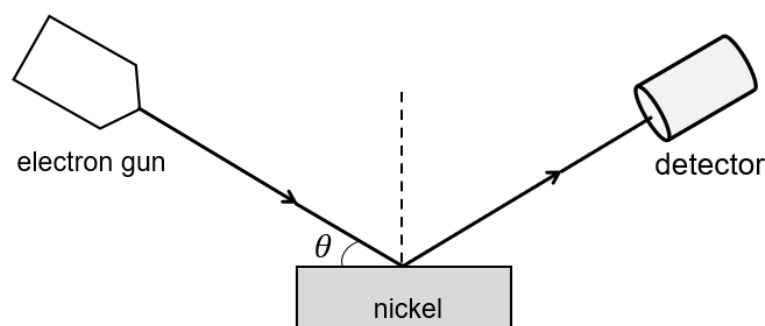


Fig. 5.2

[3]

[Total: 9]

- 6 Fig 6.1 shows the set-up of the Davisson and Germer experiment which was originally designed to measure the energy of electrons scattered from a nickel metal target.



**Fig. 6.1**

Electrons are accelerated from rest through a potential difference of 100 V in the electron gun.

The accelerated beam of electrons, which emerge from the electron gun, is then directed at an angle  $\theta$  with respect to the surface of the nickel target.

Electrons that are scattered from the nickel are collected by a detector which measures the rate  $I$  at which the charges are collected.

- (a) Consider a single electron that is being accelerated inside the electron gun.
- (i) Calculate the final speed attained by the electron before emerging from the gun.

speed = ..... m s<sup>-1</sup> [2]

- (ii) Deduce the corresponding de Broglie wavelength of the electron.

de Broglie wavelength = ..... m [2]

- (b) The nickel metal has a regular crystalline geometry. Two horizontal atomic planes in the nickel metal, separated by distance  $d$ , are shown in Fig 6.2.

The electrons in the electron beam from the electron gun can take different paths to the nickel and then to the detector. Two possible paths, path 1 and path 2, are illustrated. Both paths make the same angle  $\theta$  with respect to the planes.

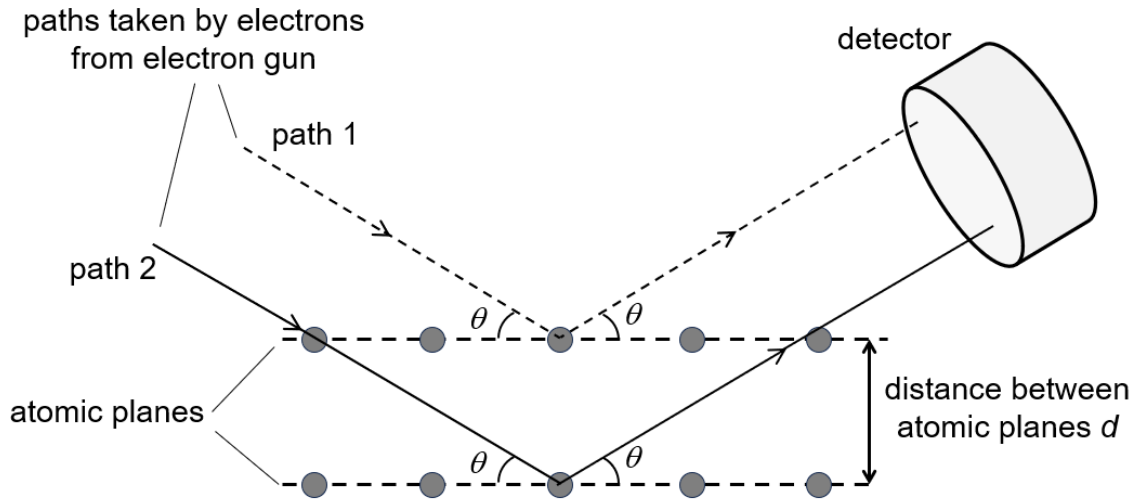


Fig. 6.2 (not to scale)

- (i) Determine an expression, in terms of  $d$  and  $\theta$ , for the path difference between the electrons of path 1 and path 2.

path difference = ..... [1]

- (ii) In a particular experiment, the angle  $\theta$  that the electron beam makes with the atomic planes is kept constant while the accelerating voltage  $V$  of the electron gun is slowly increased.

Fig 6.3 shows the graph of the rate  $I$  at which the charges are detected against the square root of the accelerating voltage  $\sqrt{V}$  for the experiment. The rate of charges detected fluctuates between a series of maximum and minimum values of  $I$  as  $V$  is increased.



**Fig 6.3**

- Describe and explain how the de Broglie wavelength of the electrons emerging from the electron gun changes as the accelerating voltage is increased.

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

- Hence, explain why the graph in Fig. 6.3 shows maximum values of  $I$  being detected at only certain accelerating voltages.

.....  
 .....  
 .....  
 .....  
 .....  
 .....[3]

[Total: 10]



- 7 Potassium-42 is a radioactive isotope of potassium that is artificially produced in the laboratories for use in medical research studies involving potassium metabolism.

The nuclide Potassium-42 ( $^{42}_{19}\text{K}$ ) undergoes radioactive decay to become Calcium-42 ( $^{42}_{20}\text{Ca}$ ), a stable nuclide. A radioactive sample contains  $N_0$  atoms of Potassium-42 at time  $t = 0$ . Fig. 7.1 shows the variation with time  $t$  of the number  $N$  of atoms of Potassium-42.

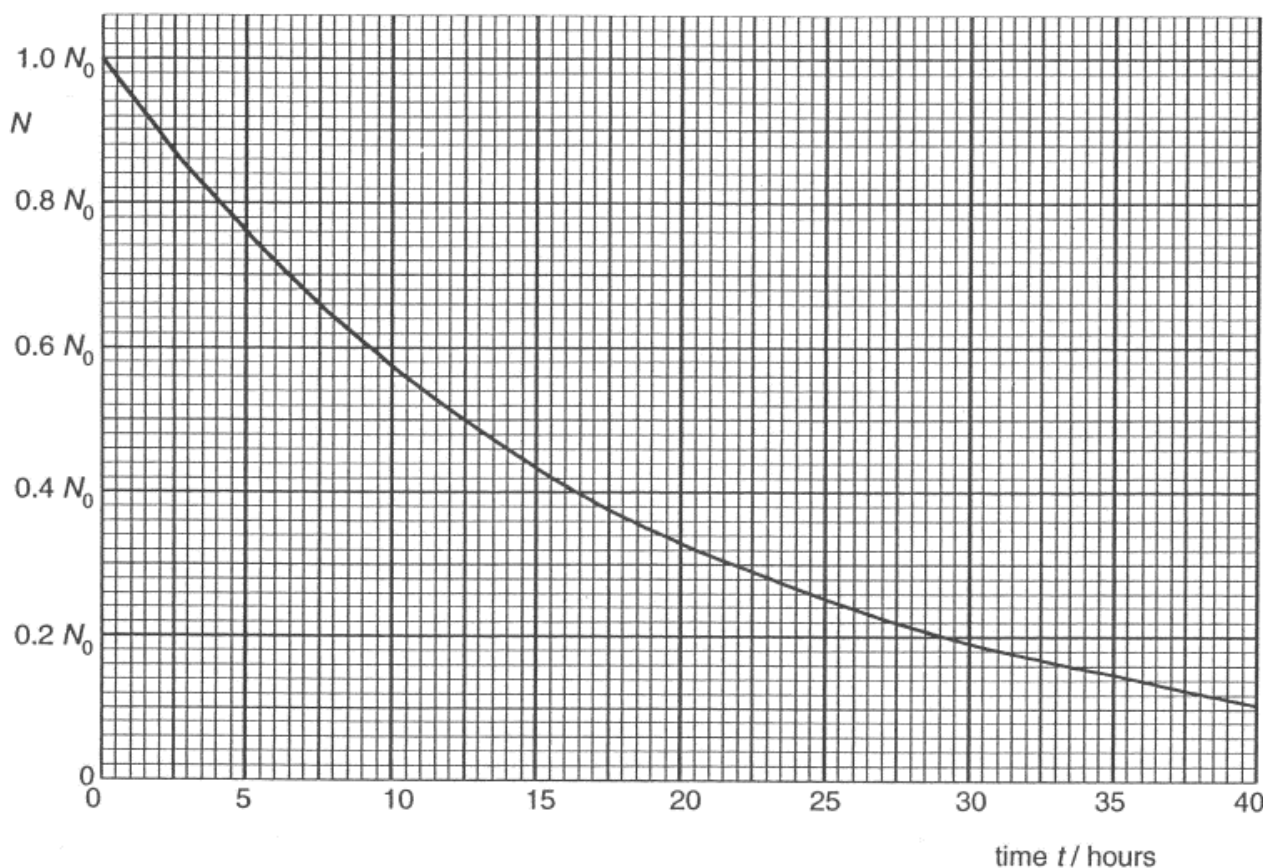


Fig. 7.1

- (a) Define *half-life* of a radioactive sample.

.....[1]

- (b) Explain what is meant by the *activity* of a radioactive sample.

.....[1]

- (c) (i) Use Fig. 7.1 to determine the probability per unit time that Potassium-42 decays.

probability per unit time = .....  $\text{s}^{-1}$  [3]

- (ii) Determine, in terms of  $N_0$ , the activity of Potassium-42 at  $t = 27.5$  hours.

activity = .....  $N_0$  Bq [2]

- (d) Fig. 7.2 shows the variation of the logarithm of the activity  $A$  with time  $t$  for the decay of Potassium-42.

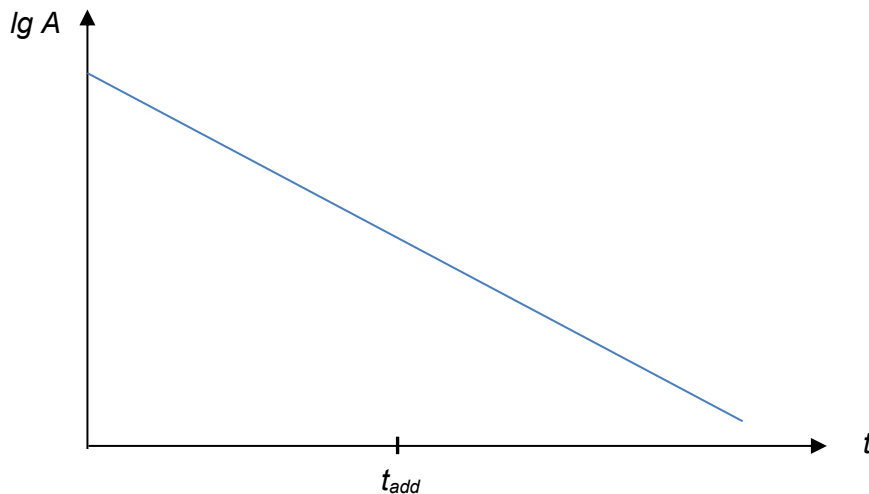


Fig. 7.2

- (i) If more Potassium-42 is added to the sample at time  $t_{\text{add}}$ , sketch on Fig. 7.2 the new variation of the logarithm of  $A$  with time  $t$ . Label this graph **P**.
- (ii) If instead of more Potassium-42, another nuclide of a *very much shorter* half-life were added, sketch also on Fig. 7.2 the new variation of the logarithm of  $A$  with time  $t$ . Label this graph **Q**.

[2]

[Total: 9]

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

In the world of competitive cycling, every detail can make a significant difference in a rider's performance. Athletes compete with one another, trying to be a bit better by improving both their bodies and their equipment. Factors such as strategy, equipment efficiency, and physical conditioning all play crucial roles in determining the outcome of races.

Many different types of bicycles exist, with each possessing its own unique strengths. To gain an edge over the competition, bicycle designers are constantly experimenting with different bicycle designs and shapes.

Fig. 8.1 shows the propulsive power  $P$  required, for 5 different types of bicycles to travel on **flat ground** at different speeds  $v$ .

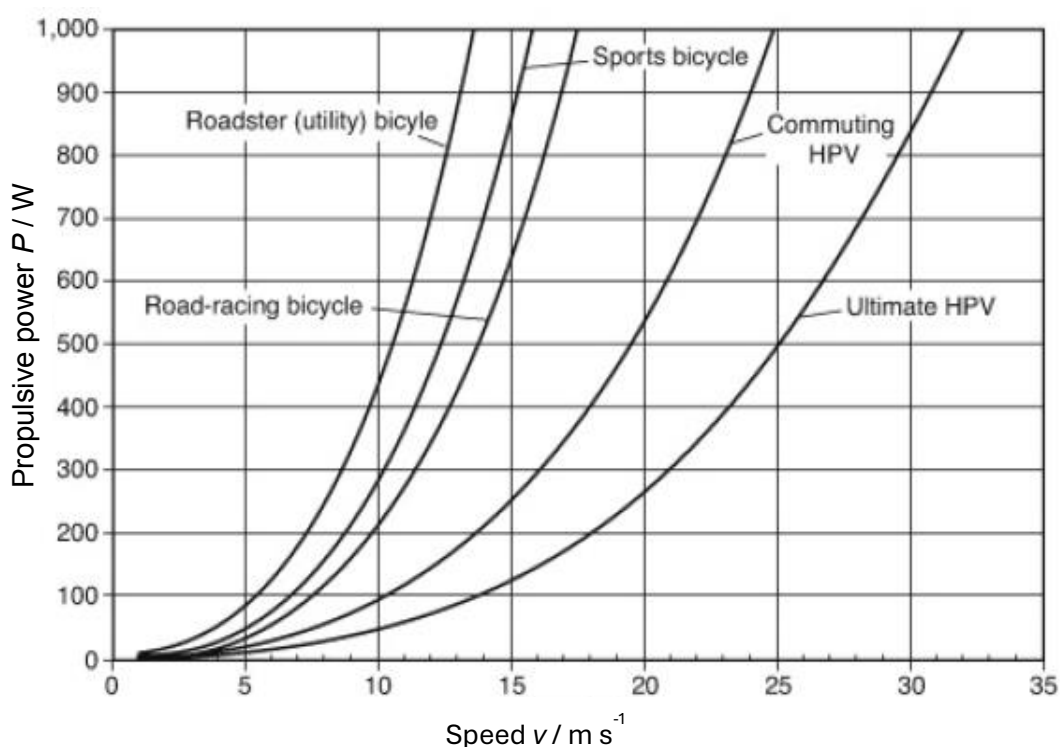


Fig. 8.1

More effort is required to ride fast against the wind or going uphill. A cyclist riding up a slope at a high speed experiences two main forces opposing his motion – slope resistance  $F_{\text{slope}}$  and air resistance  $F_{\text{air}}$ .

Slope resistance  $F_{\text{slope}}$  is related to the steepness of the road. Specifically,  $F_{\text{slope}}$  refers to the component of the rider (and bicycle)'s weight that acts parallel to the slope. The steepness of a road is commonly referred to as the slope, and is usually expressed as a percentage. Slope is calculated as a fraction ("rise over run") in which *rise* is the vertical distance and *run* is the horizontal distance. A notable example of a challenging slope is found in the Dirty Dozen bicycle race in Pittsburgh, Pennsylvania. The Canton Avenue hill section of the race is notorious for being one of the steepest in the world, boasting a distance of just 6.4 m, but with a slope of 37%!

Meanwhile, a rider moving at a greater speed experiences greater air resistance  $F_{\text{air}}$ . For a solo rider, it is suggested that  $F_{\text{air}}$  is related to the speed  $v$  by the equation

$$F_{\text{air}} = \frac{1}{2} \rho C_D A v^2$$

where  $\rho$  is the air density and the product  $C_D A$  is the effective drag area.

For rider safety, the governing body, Union Cycliste Internationale, mandates the use of brakes on bicycles in their events. Brakes can be placed on the front and/or rear wheels of the bicycle, and their effectiveness is limited by the friction  $F$  between the wheel and the road.

Theory suggests that  $F$  is related to the normal contact force acting at that point  $N$  by the equation

$$F = \mu N$$

where  $\mu$  is the coefficient of friction.

Consequently, both the frictional force acting on the front and rear wheels have different braking efficacy and serve different purposes in assisting the rider to brake effectively.

- (a) For a competitive cyclist using an Ultimate HPV bicycle, travelling at constant speed of  $25 \text{ m s}^{-1}$  on flat ground,

- (i) state the propulsive power required.

power = ..... W [1]

- (ii) Hence, determine the propulsive force provided by the rider.

propulsive force = ..... N [2]

- (iii) Calculate the effective drag area,  $C_D A$  of the cyclist. You may assume that the air density is  $1.0 \times 10^{-3} \text{ g cm}^{-3}$ .

effective drag area,  $C_D A$  = .....  $\text{m}^2$  [3]

- (b) The competitive cyclist in (a) takes part in the Dirty Dozen race using the Ultimate HPV bicycle. The combined mass of the cyclist and his bike is 85 kg.
- (i) Calculate the slope resistance  $F_{slope}$  that the cyclist experiences as he rides up the Canton Avenue hill section.

$$F_{slope} = \dots\dots\dots \text{ N [3]}$$

- (ii) The cyclist rides up the Canton Ave hill section at a constant speed.  
Determine

1. the work done against gravity for this section of the race.

$$\text{work done} = \dots\dots\dots \text{ J [2]}$$

2. the new propulsive power required by this cyclist if he wishes to maintain a constant speed of  $25 \text{ m s}^{-1}$  as he climbs the hill.

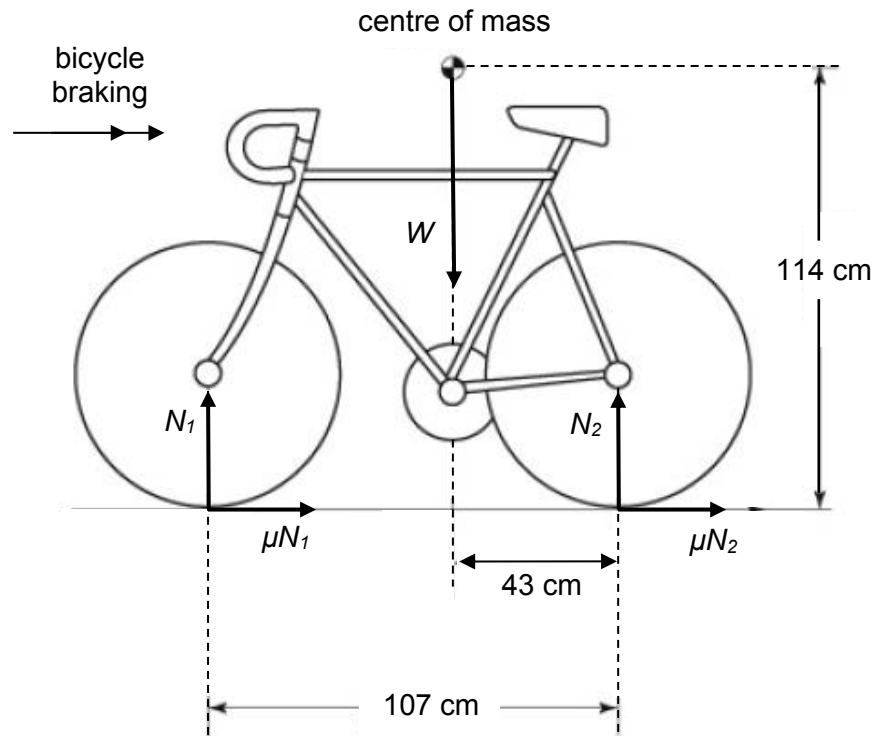
$$\text{new propulsive power} = \dots\dots\dots \text{ W [3]}$$



- (c) Fig. 8.3 shows some of the forces acting on the system of cyclist and bicycle as it *brakes*.

The combined weight of the cyclist and his bicycle is  $W$ .  $N_1$  and  $N_2$  are the normal contact forces acting on the front and rear wheels, respectively. Consequently, the frictional forces acting on the front and rear wheels are  $\mu N_1$  and  $\mu N_2$ , respectively.

The centre of mass of the system is located 114 cm above the ground. The rear wheel of the bicycle is located at a horizontal distance of 43 cm from the centre of mass, and the horizontal distance between the centres of both wheels is 107 cm.



**Fig. 8.3**

The coefficient of friction  $\mu$  between the ground and the wheels of the bicycle is 0.37.

- (i) Using Newton's second law of motion, determine the magnitude of the cyclist's deceleration.

deceleration = ..... m s<sup>-2</sup> [3]

- (ii) Taking moments about the centre of mass, show that

$$N_1 = 0.80 W.$$

[2]

- (iii) Determine the ratio of the deceleration contributed by the front wheel to that contributed by the back wheel.

ratio = ..... [1]

- (iv) When a cyclist brakes too quickly, his centre of mass will tend to move forward due to inertia.

By considering the torques due to individual forces about the centre of mass, explain why a cyclist will tend to flip forward.

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

[Total: 22]

**END OF PAPER**



**HWA CHONG INSTITUTION**  
**JC2 Preliminary Examination**  
**Higher 2**

**CANDIDATE NAME**

**CT GROUP**

**23S**

**CENTRE NUMBER**

**INDEX NUMBER**

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**PHYSICS**

**9749/03**

**Paper 3 Longer Structured Questions**

**13 September 2024**

Candidates answer on the Question Paper.

**2 hours**

No Additional Materials are required.

---

**INSTRUCTIONS TO CANDIDATES**

Write your **Centre number**, **index number**, **name** and **CT class** clearly on all work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paperclips, highlighters, 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. **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.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Section A		
1		5
2		8
3		8
4		8
5		9
6		8
7		8
8		6
Section B (choose ONE)		
9		20
10		20
Deductions		
Total		80

Data	Formulae
speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$	uniformly accelerated motion $s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	work done on / by a gas $W = p \Delta V$
permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\approx (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$	hydrostatic pressure $p = \rho gh$ gravitational potential $\phi = -\frac{Gm}{r}$
elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$	temperature $T/\text{K} = T/^\circ\text{C} + 273.15$
the Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$	pressure of an ideal gas $p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$	mean translational kinetic energy of an ideal gas molecule $E = \frac{3}{2} kT$
rest mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$	displacement of particle in s.h.m. $x = x_0 \sin \omega t$
rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$	velocity of particle in s.h.m. $v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
molar gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	electric current $I = Anvq$
the Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	resistors in series $R = R_1 + R_2 + \dots$
the Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	resistors in parallel $1/R = 1/R_1 + 1/R_2 + \dots$
gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	electric potential $V = \frac{Q}{4\pi\epsilon_0 r}$
acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$	alternating current / voltage $x = x_0 \sin \omega t$
	magnetic flux density due to a long straight wire $B = \frac{\mu_0 I}{2\pi d}$
	magnetic flux density due to a flat circular coil $B = \frac{\mu_0 NI}{2r}$
	magnetic flux density due to a long solenoid $B = \mu_0 nI$
	radioactive decay $x = x_0 \exp(-\lambda t)$
	decay constant $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

## Section A

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

- 1 (a) Distinguish between random error and systematic error in a set of measurements of a physical quantity.

.....

.....

.....

..... [2]

- (b) The power  $P$  required by a car to overcome the drag force acting on it when it is travelling at a speed  $v$  in turbulent condition is given by the equation

$$P = k\rho A^p v^q$$

where  $A$  is the frontal area of the car and  $\rho$  is the density of the air.

Given that  $k$  is a quantity with no units, determine the values of  $p$  and  $q$ .

$$p = \dots\dots\dots$$

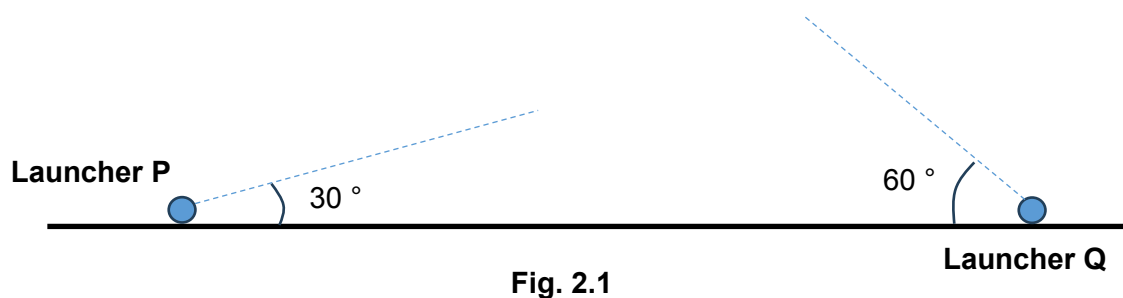
$$q = \dots\dots\dots [3]$$

[Total: 5]

- 2 (a) Define acceleration.

..... [1]

- (b) Two projectile launchers are facing each other on horizontal ground as shown in Fig 2.1. Launcher P fires a projectile at an angle of  $30^\circ$  from the horizontal, at an initial speed of  $210 \text{ m s}^{-1}$ . Air resistance is negligible.



- (i) Determine the maximum height the projectile fired from launcher P reaches.

maximum height = ..... m [2]

- (ii) Determine the time of flight for the projectile to reach this maximum height.

time of flight = ..... s [2]

- (iii) A short time after launcher P fires, launcher Q too fires a projectile at an initial speed of  $210 \text{ m s}^{-1}$  and an angle of  $60^\circ$  from the horizontal.

Both projectiles collide when the projectile from launcher P reaches its maximum height.

1. Show that the projectile from launcher Q has been in flight for 3.4 s when the two projectiles collide.

[1]

2. Fig. 2.2 shows the variation of the vertical velocity with time of the projectile from launcher P from its launch to when it has reached its highest point.

On Fig. 2.2, sketch another graph to show the variation of the vertical velocity with time of the projectile from launcher Q.

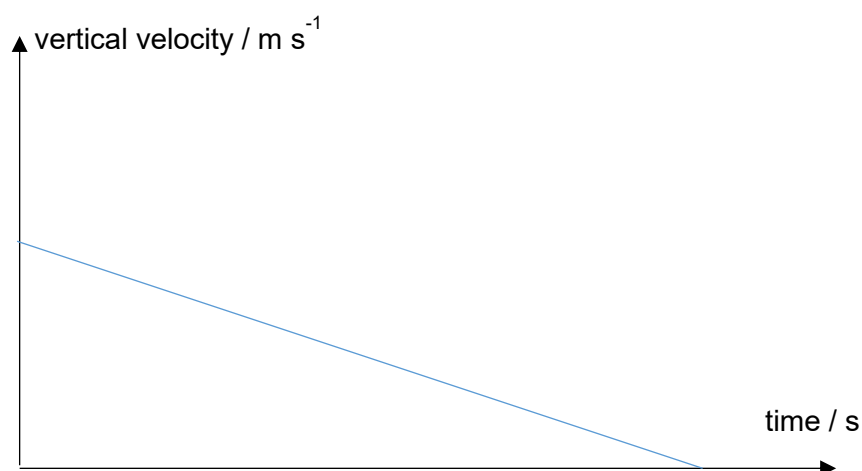


Fig. 2.2

[2]

[Total: 8]

- 3 Fig. 3.1 shows a thick glass cup submerged in water. The glass has a density of  $2200 \text{ kg m}^{-3}$  and displaces  $6.8 \times 10^{-5} \text{ m}^3$  of water when it is submerged as in Fig 3.1. Water has density  $1000 \text{ kg m}^{-3}$ .

The glass cup is held stationary by an external force  $F$ .

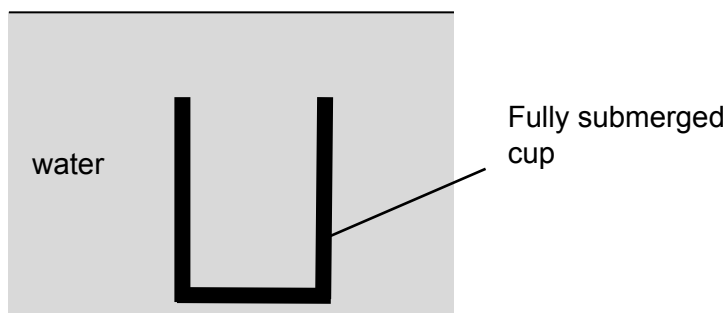


Fig. 3.1

- (a) (i) Explain why the liquid exerts an upthrust on the cup.

.....

.....

..... [2]

- (ii) By considering the forces acting on the cup, show that the external force  $F$  needed to keep the cup stationary is  $0.80 \text{ N}$ .

[2]

- (iii) The cup is pushed further down into the water.  
Explain how the upthrust acting on the cup will change.

.....

..... [1]

- (b) Fig. 3.2 shows the same glass cup now inverted and held right at the surface of the water. When placed this way,  $5.50 \times 10^{-4} \text{ m}^3$  of air is contained within the cup at atmospheric pressure of  $1.0 \times 10^5 \text{ Pa}$ .

The cup is then pushed slowly into the water, trapping and compressing the air within the cup, as shown in Fig. 3.3. The cup is again held stationary by an external force such that the water surface is at a distance  $d$  above the water level in the cup.

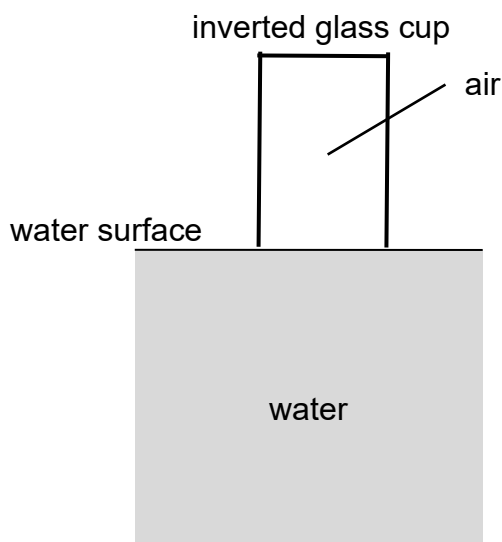


Fig. 3.2

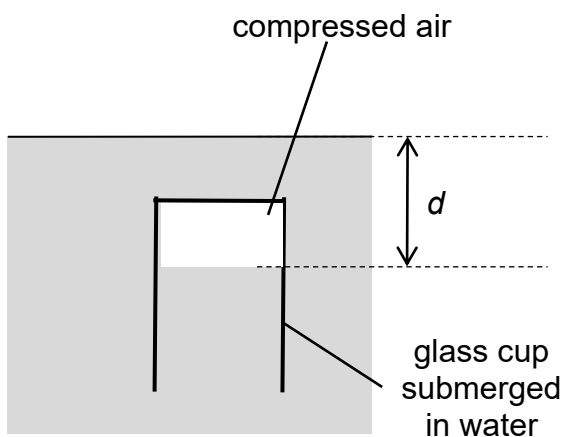


Fig. 3.3

Assuming that air is an ideal gas that is insoluble in water, and that the temperature of the trapped air remains unchanged, calculate the volume of the compressed air within the cup in Fig. 3.3 when  $d = 30.0 \text{ cm}$ .

volume = .....  $\text{m}^3$  [3]

[Total: 8]

- 4 A test-tube with a total mass  $M$  is able to float upright in water of density  $\rho$ , as shown in Fig. 4.1. Ignoring its rounded bottom, the test-tube may be regarded as a cylinder of a cross-sectional area  $A$ .

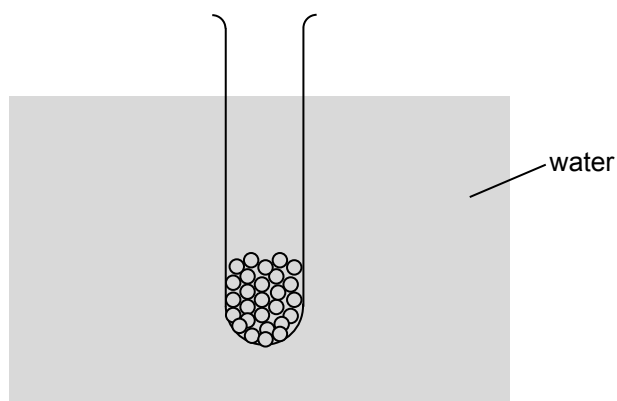


Fig. 4.1

The test-tube is displaced vertically by a small displacement  $y$  and then released.

The acceleration of the test-tube is given by

$$a = -\left(\frac{\rho Ag}{M}\right)y$$

where  $g$  is the acceleration of free fall.

- (a) Define simple harmonic motion.

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

- (b) Given:  $\rho = 1.00 \times 10^3 \text{ kg m}^{-3}$ ,

$$A = 6.0 \times 10^{-4} \text{ m}^2,$$

$$M = 0.037 \text{ kg},$$

show that the period of oscillation of the test-tube is 0.50 s.

[2]

- (c) The test-tube is given a displacement of 1.0 cm and allowed to oscillate. The variation with time  $t$  of the vertical displacement  $y$  of the test-tube is shown in Fig. 4.2.

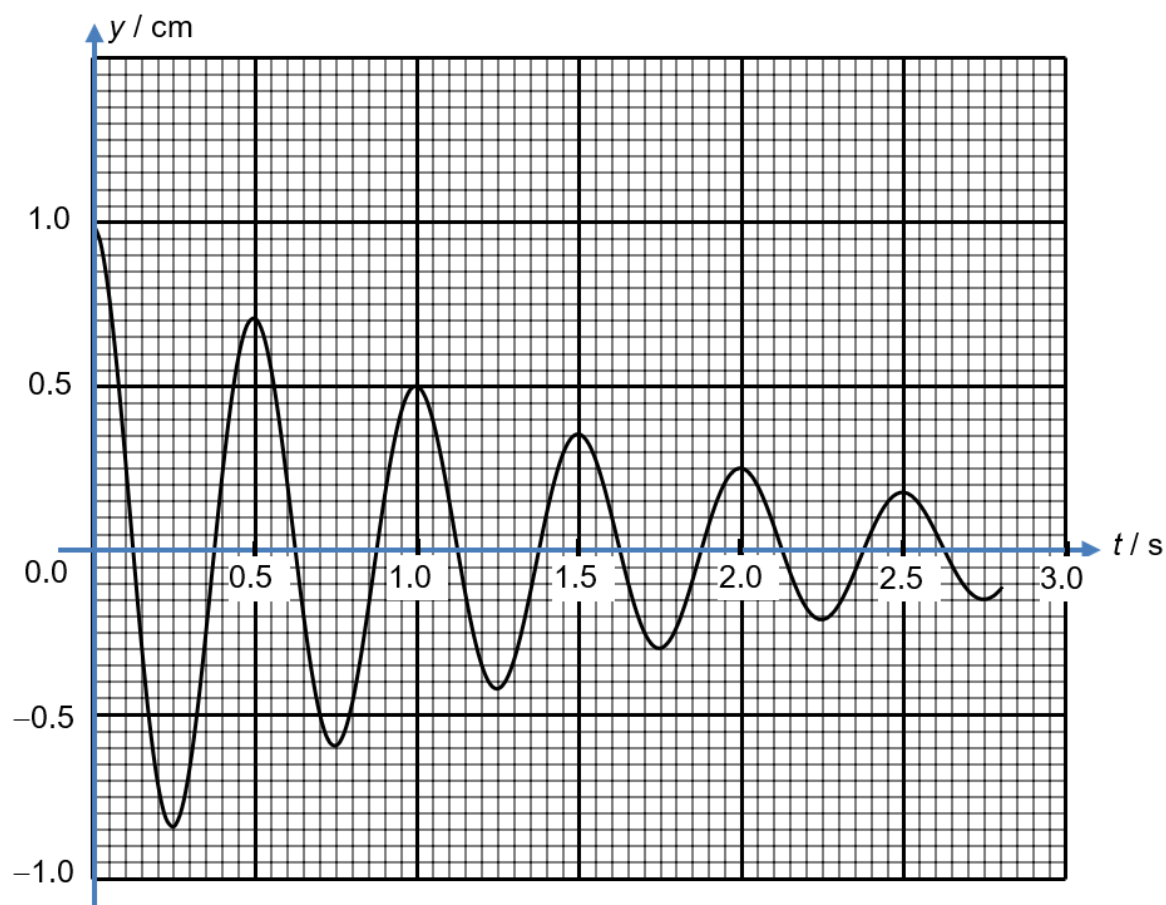


Fig. 4.2

- (i) Estimate the time when the *energy of oscillation* has decreased by 75 % of its original value.

time = ..... s [2]

- (ii) To sustain the oscillations of the test-tube, low-amplitude water waves of frequency 1.0 Hz are generated on the surface of the water. It is observed that the amplitude of the vertical oscillations of this test-tube is rather small while oscillating at 1.0 Hz.

Using information from earlier in the question, explain this observation.

.....

.....

.....

..... [2]

[Total: 8]



- 5 A mass of 0.37 kg of water at 100 °C is provided with the thermal energy needed to vaporise all the water at atmospheric pressure. The specific latent heat of vaporisation of water at atmospheric pressure of  $1.0 \times 10^5$  Pa is  $2.3 \times 10^6$  J kg<sup>-1</sup>.

(a) (i) Calculate the thermal energy  $Q$  supplied to the water.

$Q = \dots\dots\dots$ J [1]

(ii) The mass of 1.0 mol of water is 18 g.

Show that the volume of water vapour produced is 0.64 m<sup>3</sup>. Assume that water vapour can be considered to behave as an ideal gas.

[3]

- (iii) The initial volume of the liquid water is negligible compared with the volume of water vapour produced.

Determine the work done by the water in expanding against the atmosphere when it vaporises.

work done = ..... J [1]

- (iv) Determine the increase in the internal energy of the water when it vaporises at 100 °C.

increase in internal energy = .....J [2]

- (b) State and explain what happens to the internal energy of the water during the phase change process.

.....

.....

.....

.....

..... [2]

[Total: 9]

- 6 (a) The variation with potential difference  $V$  of the current  $I$  in a semiconductor diode is shown in Fig. 6.1.

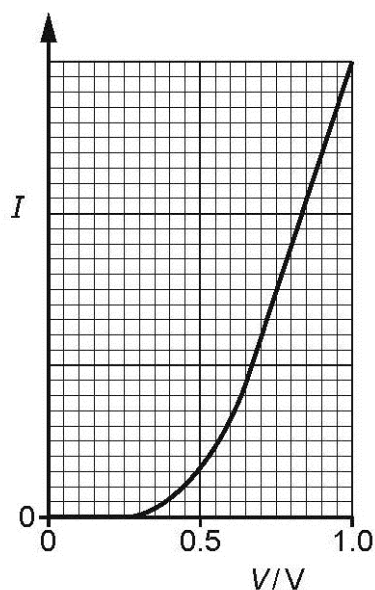


Fig. 6.1

Use Fig. 6.1 to describe qualitatively,

- (i) the resistance of the diode in the range  $V = 0$  to  $V = 0.25$  V.

..... [1]

- (ii) the variation, if any, in the resistance of the diode as  $V$  changes from  $V = 0.75$  V to  $V = 1.0$  V.

..... [1]

- (b) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected to a uniform resistance wire XY, a galvanometer, a light-dependent resistor (LDR) and a fixed resistor of  $1200\ \Omega$ , as shown in Fig. 6.2.

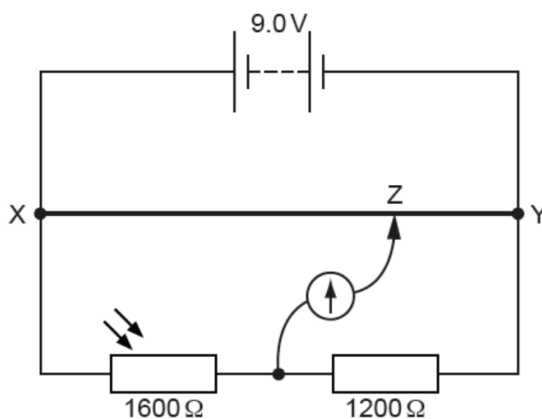


Fig. 6.2

The length of the wire XY is 1.2 m. The movable connection Z is positioned on the wire XY so that the galvanometer gives a zero reading.

- (i) Calculate the length XZ along the resistance wire when the LDR has a resistance of  $1600\ \Omega$ .

length XZ = ..... m [2]

- (ii) The intensity of the light illuminating the LDR is now increased.

State and explain whether there is a decrease, increase or no change to:

1. the length XZ so that the galvanometer reads zero.

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

2. the total power supplied by the battery.

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

[Total: 8]

- 7 The plan view of a train braking system is illustrated in Fig 7.1. The train carriage is mounted on a rectangular metal frame ABCD of length  $L$  and width  $w$ . The effective resistance of the frame is  $R$ .

The train carriage is initially moving at a constant speed along the rails.

A uniform magnetic field  $B$  is directed perpendicularly into the ground over a rectangular region of length  $L$ . Line P denotes the start of this region while line Q denotes the end of the region.

After passing through the magnetic field, the train speed is expected to be reduced to a very low value after which brakes can be applied to stop it completely. Air resistance and friction may be neglected.

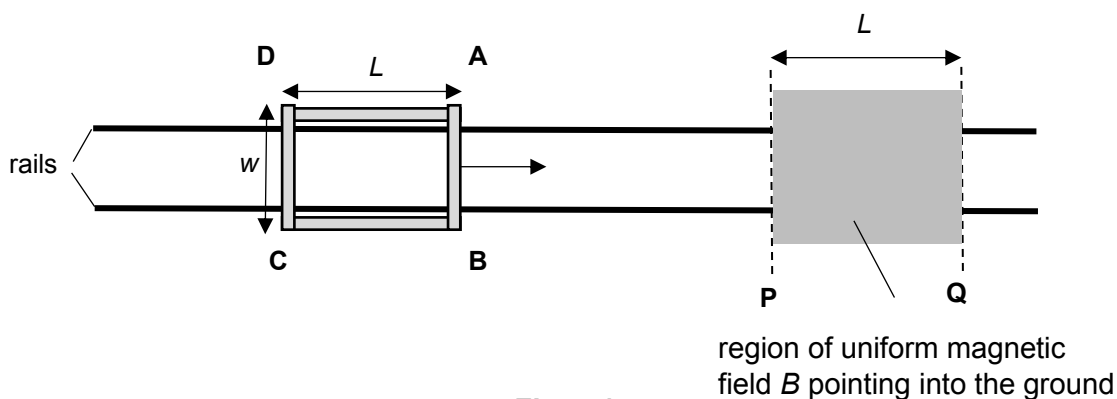


Fig. 7.1

- (a) Show that as the frame enters the region of magnetic field, the e.m.f. induced in it,  $E$ , is given by  $E = Bwv$  where  $v$  is the speed of the train carriage. Explain your working clearly.

[2]

- (b) (i) Explain why the train carriage slows down as AB moves through the magnetic field from P to Q.

.....

.....

.....

.....

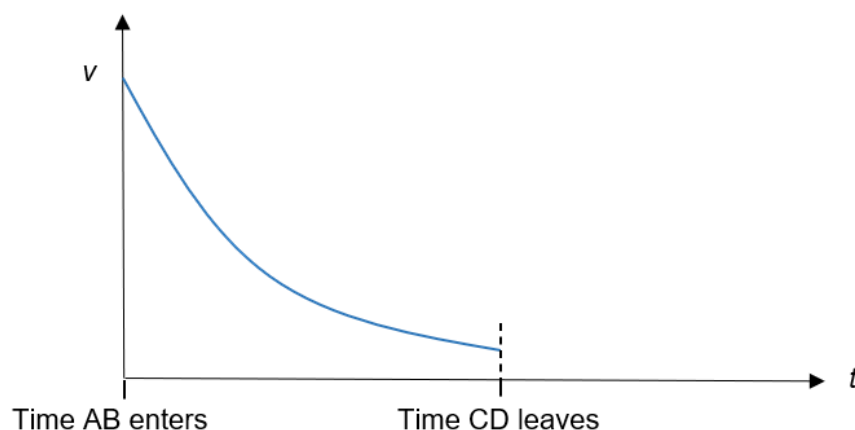
.....

.....

.....

[3]

- (ii) The graph in Fig 7.2 shows the velocity of the train carriage as it moves through the magnetic field, from the instant AB crosses line P to the instant CD crosses line Q.



**Fig. 7.2**

The length of the magnetic field is now reduced by *moving Q closer to P* so that the distance PQ is now smaller than  $L$ .

Sketch on Fig 7.2 the new variation of the velocity of the train carriage with time as it passes through the magnetic field from the instant AB crosses line P to the instant CD crosses line Q.

[3]

[Total: 8]

- 8 (a) In Rutherford's  $\alpha$ -particle scattering experiment,  $\alpha$ -particles from a radioactive source were directed towards a sheet of gold foil in a vacuum chamber as shown in Fig. 8.1.

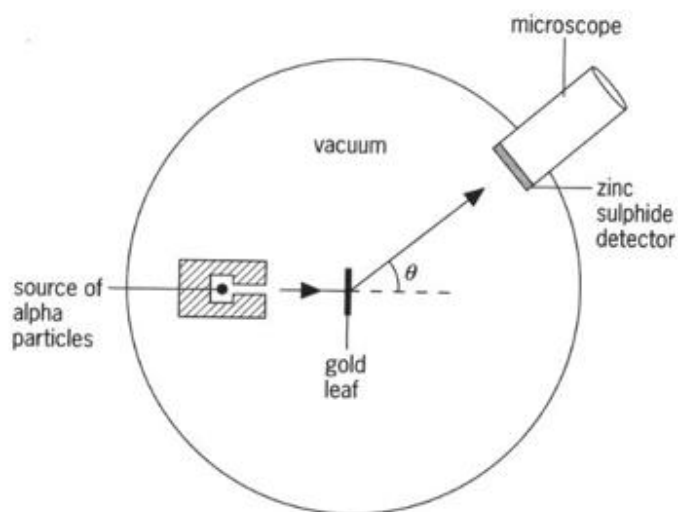


Fig. 8.1

- (i) Explain why it is necessary for the radioactive source to be placed in vacuum.

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

- (ii) State the experimental observation obtained from Rutherford's experiment which suggested that

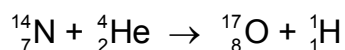
1. the nucleus is small,

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

2. the nucleus is massive and charged.

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

- (b) A common nuclear reaction that can be induced in a laboratory is represented by the following equation:



In this reaction, stationary nitrogen nuclei were bombarded with helium nuclei, forming oxygen and hydrogen.

The total rest masses of the reactant and the product nuclei are as follows:

$${}^{14}_7\text{N} + {}^4_2\text{He} = 18.00568 \text{ u}$$

$${}^{17}_8\text{O} + {}^1_1\text{H} = 18.00696 \text{ u}$$

- (i) Deduce that the change in rest-mass energy in this reaction is  $1.9 \times 10^{-13} \text{ J}$ .

[1]

- (ii) With reference to energy, suggest how it is possible for this reaction to occur.

.....

.....

[1]

- (iii) In reality, more than  $1.9 \times 10^{-13} \text{ J}$  of energy is required for the reaction to occur.

Suggest why this might be so.

.....

.....

[1]

[Total: 6]

## Section B

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

- 9 (a) State the principle of superposition for waves.

.....

.....

..... [2]

- (b) Two identical radio wave point sources A and B placed 12.0 m apart emit waves which are in phase. An interference pattern is detected along the line AB. Point M is the mid-point between A and B.



Fig. 9.1

Fig. 9.2 shows the variation with time  $t$  of the displacement  $x$  of the signal picked up by a detector placed at M.

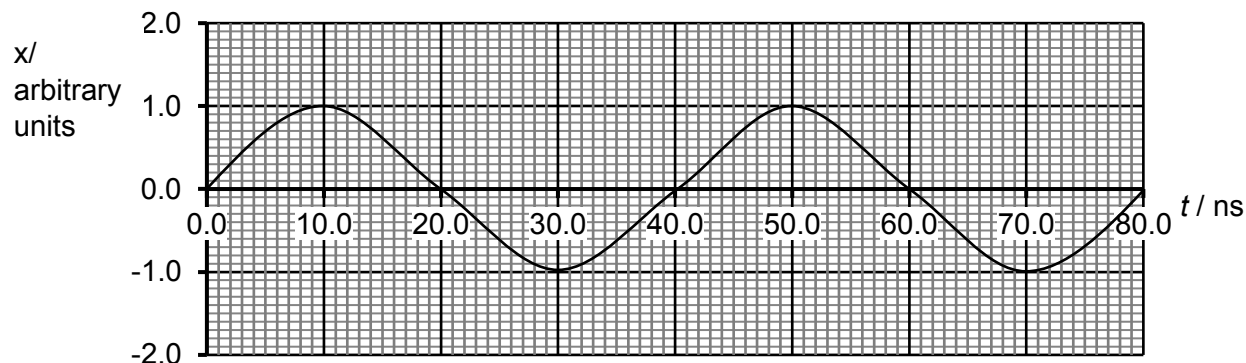


Fig. 9.2

Using the above information,

- (i) show that the frequency  $f$  of the waves from source A and B is 25.0 MHz.

[1]

- (ii) Draw in Fig. 9.2 the displacement of the wave which will be detected at point M if source A is switched off while source B remains on.  
Label this graph as Y.

Explain your answer.

.....

.....

.....

.....

..... [3]

- (iii) With both wave sources A and B switched on, the detector is moved toward the right from M. The first minimum is detected at point N.  
Show that MN is 3.00 m.

[2]

- (iv) When the point sources are operated *separately*, the intensity detected at point M is  $I$ .

Show that

1. the intensity of the wave from source A arriving at point N,  $I_A$  is  $0.444 I$ .
2. the intensity of the wave from source B arriving at point N,  $I_B$  is  $4.00 I$ .

[3]

- (v) Using the result from (b)(iv), calculate the amplitude of the signal detected at N when both sources are switched on.

amplitude = ..... arbitrary units [3]

- (c) A typical Young's double-slit experiment involves a coherent source of monochromatic light of wavelength  $\lambda$  which is directed at the double slits. The slit separation is  $a$  and each slit has a width of  $b$ .

A screen is set up at a distance of  $D$  away from the double slits as shown in Fig. 9.3. The expected interference pattern to be observed on the screen is regularly spaced bright and dark fringes. The fringe separation is  $x$ .

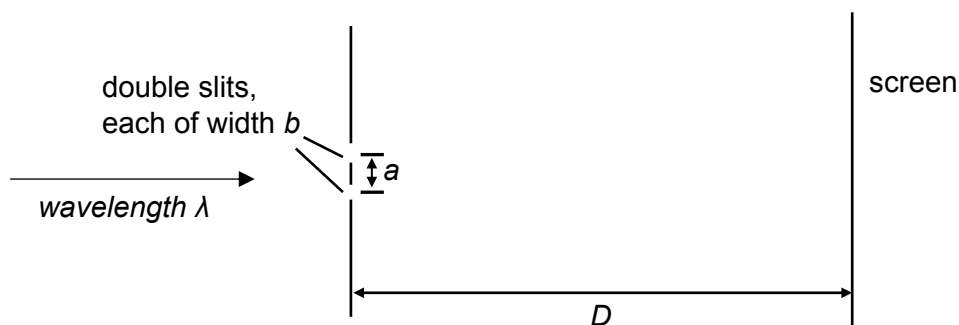


Fig. 9.3

- (i) Using the variables defined above, state the two necessary inequality conditions for the set-up such that the detected fringes are regularly spaced.

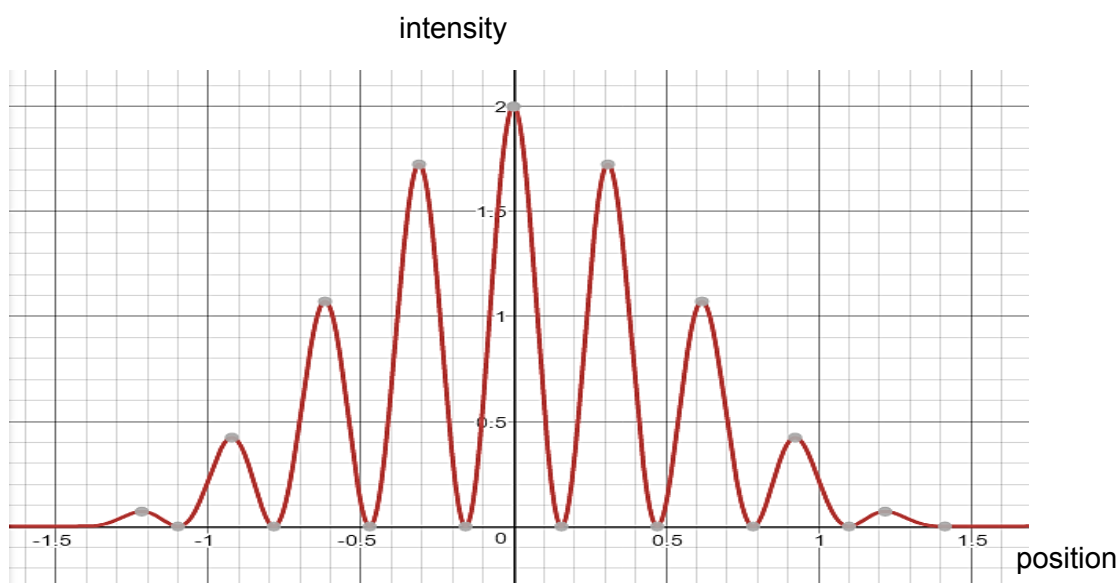
1. ....

2. .... [2]

- (ii) Write down the expression for the fringe separation  $x$  using some of the variables defined above.

..... [1]

- (iii) Fig. 9.4 shows the variation of the intensity of light on a screen at positions around the zeroth order maxima for a particular experiment. The units are arbitrary.



**Fig. 9.4**

1. Suggest why there is no 5<sup>th</sup> order maxima detected.

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

2. Sketch in Fig. 9.4 the new pattern that will be detected when the slit width  $b$  is reduced. [2]

[Total: 20]



- 10 (a) Define electric field strength.

.....

..... [1]

- (b) Fig. 10.1 shows two very small charged spheres S and T. Their centres are separated by a horizontal distance of 30.0 cm. Sphere S carries a charge of  $-2.4 \mu\text{C}$ , while sphere T carries a charge of  $1.2 \mu\text{C}$ .



Fig. 10.1

- (i) On Fig. 10.1, draw field lines to show the electric field pattern between the two spheres. [3]
- (ii) 1. Given that the mass of sphere T is 0.036 kg, calculate the angle the string makes with the vertical.

angle = .....° [3]

2. Determine the magnitude of the acceleration of the sphere the moment the string is cut.

acceleration = .....  $\text{m s}^{-2}$  [3]

- (iii) Fig. 10.2 shows how the electric field strength varies in a portion of the space between the spheres.  $x = 0$  represents the centre of sphere S.

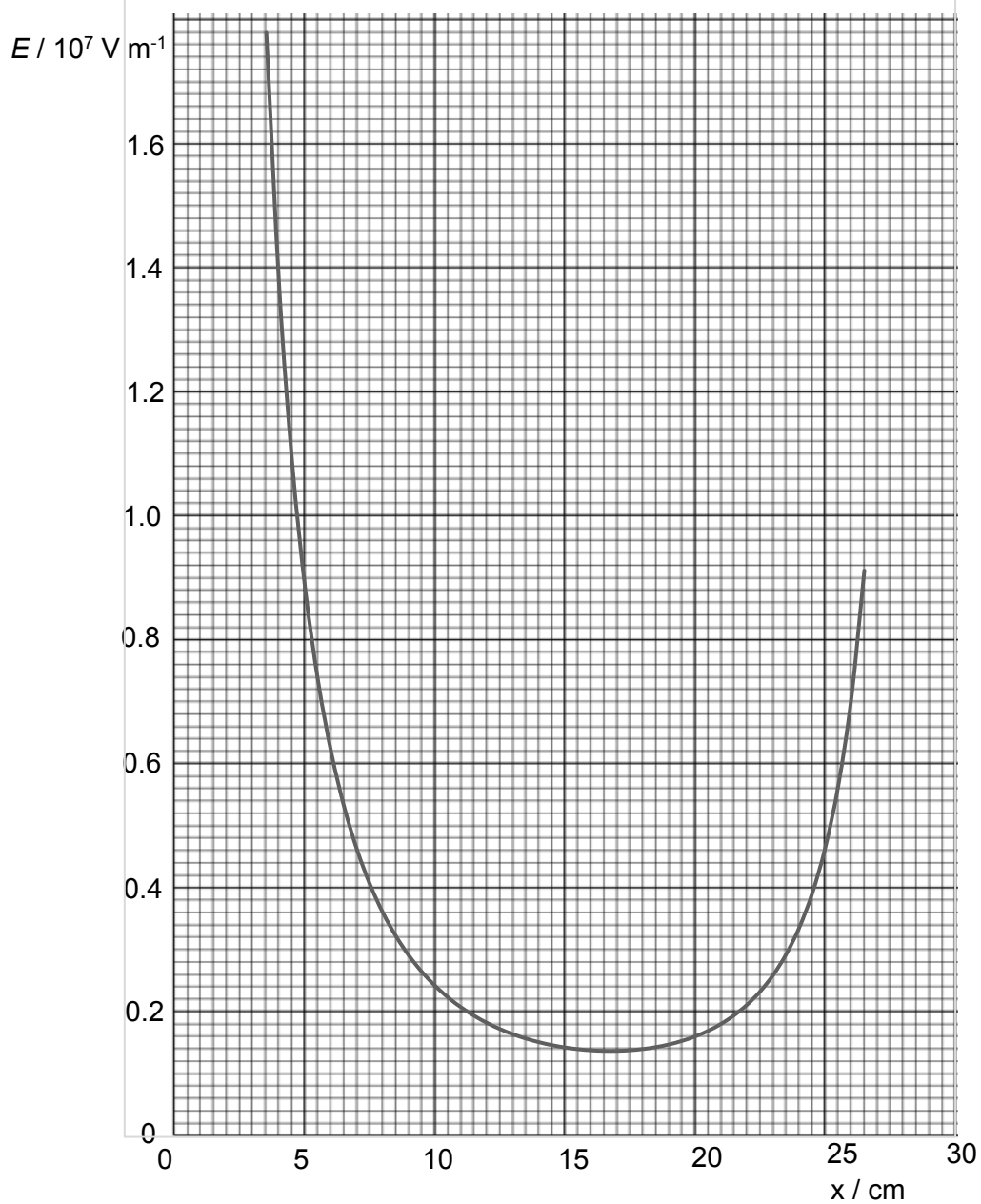


Fig. 10.2

If a helium nucleus is released from rest at  $x = 25$  cm, determine its kinetic energy when it reaches  $x = 15$  cm.

kinetic energy = ..... J [4]

- (c) A uniform electric field is set up between two parallel plates of length 90 mm and spaced 20 mm apart. A potential difference of 150 V is applied between the plates.

A singly-charged lithium ion ( ${}^7\text{Li}^+$ ) of mass 6.941u is projected horizontally into the electric field with a speed of  $3.0 \times 10^5 \text{ m s}^{-1}$ .

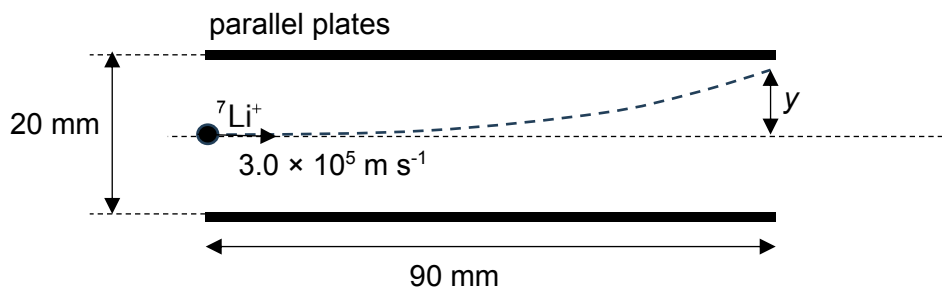


Fig. 10.3

- (i) Show quantitatively that the weight of the lithium ion is negligible compared to the electric force it experiences.

[3]

- (ii) Calculate the deflection  $y$  of the lithium ion as it exits the plates.

$y = \dots\dots\dots$  mm [3]  
[Total: 20]

**End of Paper**



CANDIDATE  
NAME

CT GROUP

23S

TUTOR  
NAME

## PHYSICS

### Paper 4 Practical

9749/04

22 August 2024

2 hours 30 mins

Candidates answer on the Question Paper.

No Additional Materials are required.

### INSTRUCTIONS TO CANDIDATES

Write your name, CT group and tutor's name in the boxes 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.

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

At the end of the examination, submit sets A, B and C separately. The number of marks is given in brackets [ ] at the end of each question or part question.

Shift

Laboratory

#### For Examiner's Use

1 / 12

2 / 9

3 / 22

4 / 12

Total / 55

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- 1 In this experiment, you will investigate the period of torsional oscillations of a suspended disc with loaded mass.

(a) Set up the apparatus as shown in Fig. 1.1.

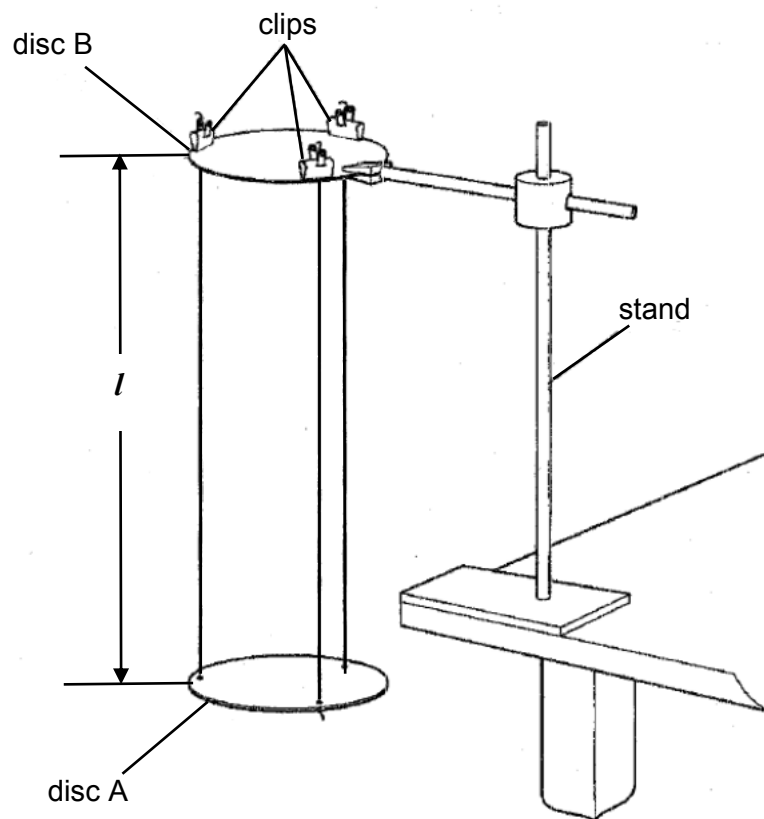


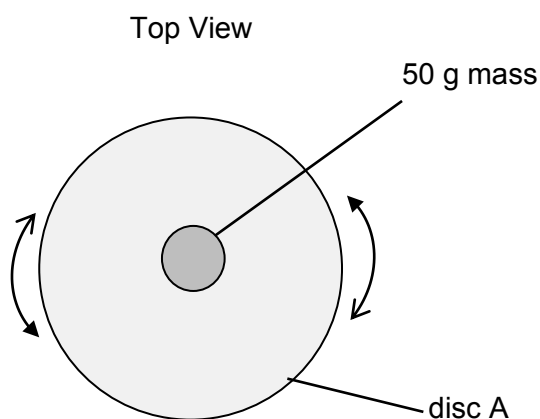
Fig. 1.1

Disc A and disc B have three small holes spaced at regular intervals near the edge. Pieces of string have been threaded through the holes.

Clamp disc B horizontally using two small blocks of wood. Use the clips on disc B to adjust the length  $l$  of each string until  $l$  is about 100 cm.

Place a 50 g mass in the centre of disc A.

- (b) (i) Gently rotate disc A through a small angular displacement and release it so that the disc performs torsional oscillations of period  $T$  in a horizontal plane as shown in Fig. 1.2.



Determine and record  $T$ .

$T = \dots\dots\dots$  [2]

- (ii) Repeat (b)(i) for different values of mass  $m$ , by stacking the slotted masses on top of each other, until you have five sets of readings of  $T$  and  $m$ .

Present your results clearly.

[4]

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- (c) It is suggested that  $T$  and  $m$  are related by the expression:

$$T = km^n$$

where  $k$  and  $n$  are constants.

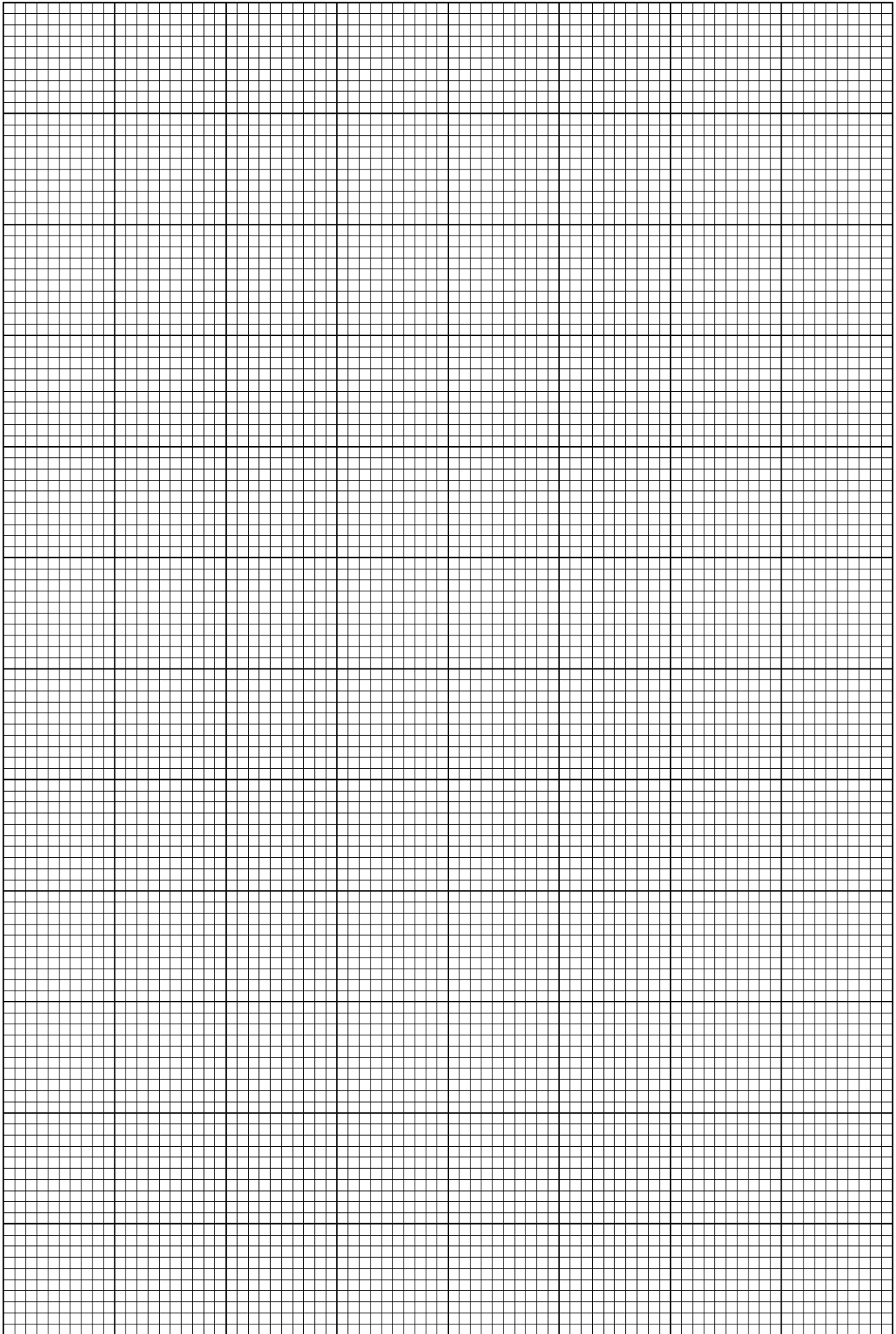
Plot a suitable graph to determine the values of  $k$  and  $n$ .

$k = \dots\dots\dots$

$n = \dots\dots\dots$

[6]

[Total: 12]



2 In this experiment, you will investigate the energy stored in a stretched rubber band.

- (a) (i) Place the rubber band on the bench so that it is taut without being stretched, as shown in Fig. 2.1.

The length of the rubber band is  $L_0$ .

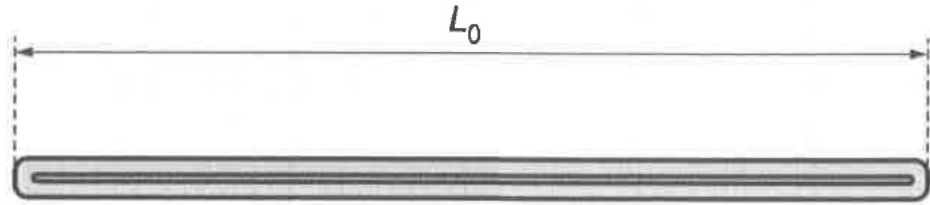


Fig. 2.1

Measure and record  $L_0$  for your rubber band.

$L_0 =$  ..... [1]

- (ii) Use the dimensions given on the card to calculate the volume  $V$  of the rubber band.

$V =$  ..... [1]

- (b) (i) Set up the apparatus as shown in Fig. 2.2 with the mass hanger suspended from the rubber band.

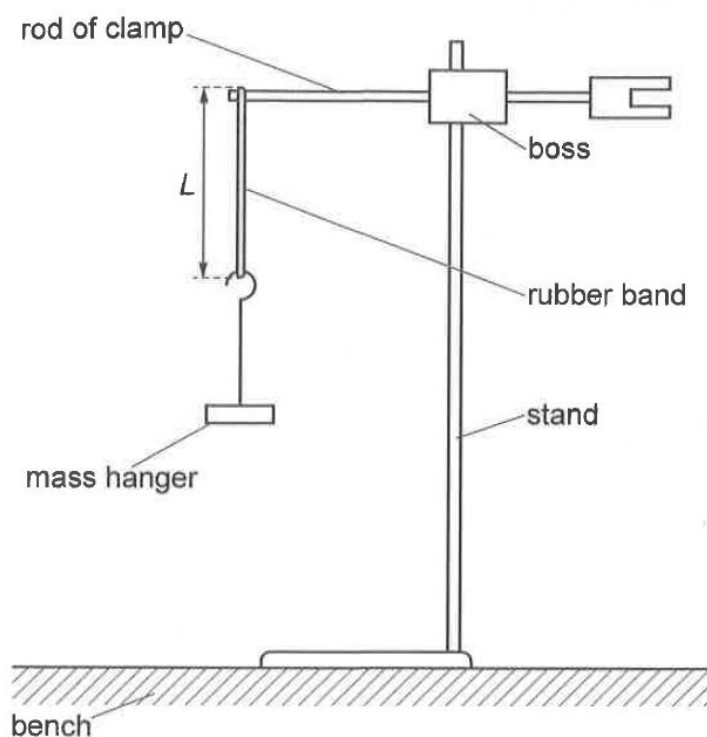


Fig. 2.2

The extended length of the rubber band is  $L$ .

Calculate the extension  $e$  of the rubber band where:

$$e = L - L_0.$$

Record your answer in metres.

$e = \dots\dots\dots$  m

The force  $F$  acting on the rubber band is given by:

$$F = mg$$

Where  $m$  is the mass, in kg, suspended from the rubber band and  $g = 9.81 \text{ N kg}^{-1}$ .

Calculate and record  $F$ .

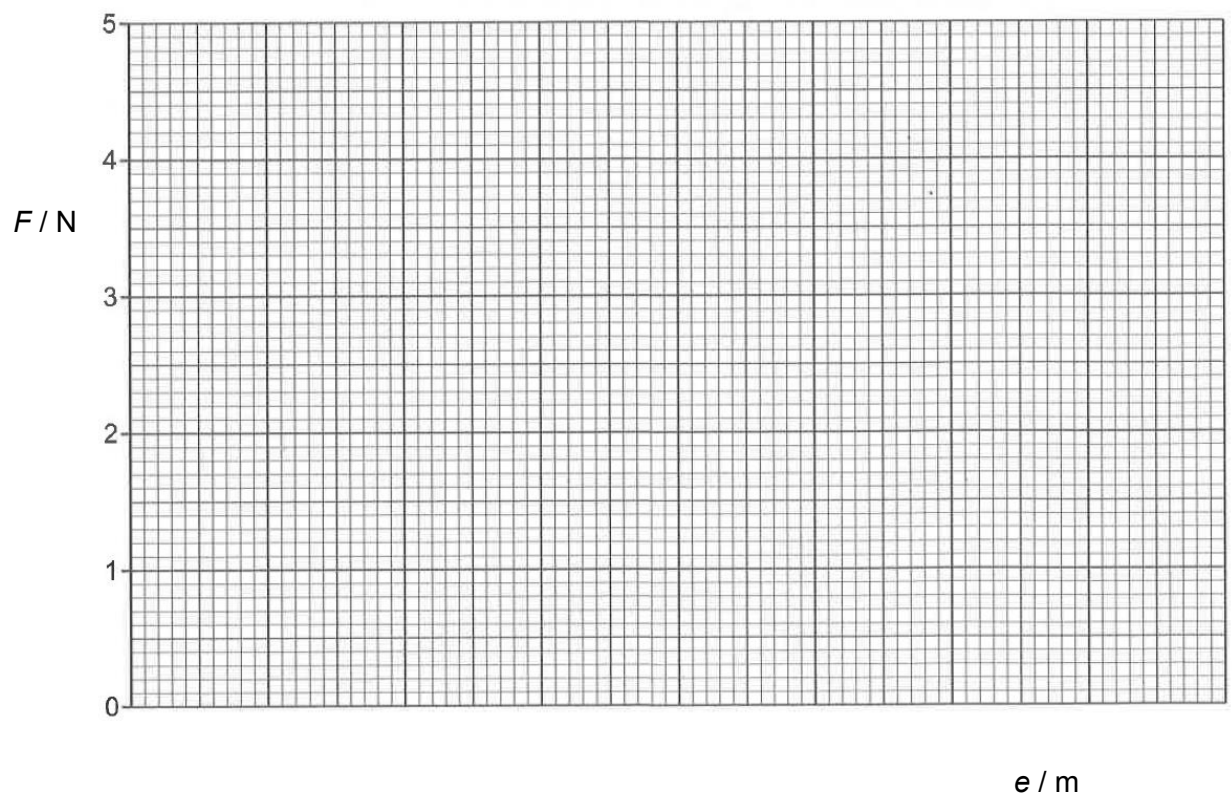
$F = \dots\dots\dots$  N  
[1]

(ii) Vary  $m$  and repeat (b)(i).

Present your results clearly.

[3]

(iii) Plot your results on the grid below.



[1]

- (iv) The area under the graph represents the approximate energy stored by the rubber band.  
Estimate this energy when its extended length  $L = 2L_0$ .

energy stored = ..... J [1]

- (v) Calculate the energy stored per unit volume, in  $\text{J m}^{-3}$ , in the rubber band when its extended length  $L = 2L_0$ .

energy stored per unit volume = .....  $\text{J m}^{-3}$  [1]

[Total: 9]

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**HWA CHONG INSTITUTION**  
**C2 Preliminary Examination**  
**Higher 2**

**B**

<b>CANDIDATE NAME</b>	<input type="text"/>	<b>CT GROUP</b>	<input type="text" value="23S"/>
<b>TUTOR NAME</b>	<input type="text"/>	<b>SCORE</b>	<input type="text"/>

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## **PHYSICS**

### **Paper 4 Practical**

Candidates answer on the Question Paper.

No Additional Materials are required.

---

- 3 This experiment investigates the properties of a coil of wire.
- (a) You have been provided with two cardboard tubes with wire wrapped around them. The diameter of the tube labelled Y is  $D_Y$ , as shown in Fig. 3.1. The diameter of the wire is  $d_Y$ .

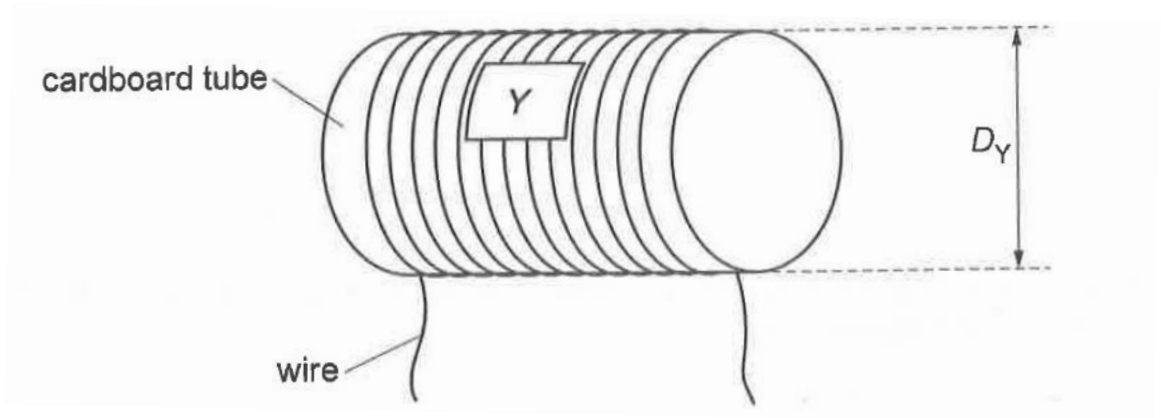


Fig. 3.1

Measure and record  $D_Y$  and  $d_Y$ .

$D_Y = \dots\dots\dots$  cm

$d_Y = \dots\dots\dots$  mm  
[2]

- (b) (i) The total length of wire is  $L_Y$ .  
Estimate and record your value for  $L_Y$ .  
Show your working.

$L_Y = \dots\dots\dots$  cm [2]

- (ii) Estimate the percentage uncertainty in your value of  $L_Y$ .

percentage uncertainty in  $L_Y = \dots\dots\dots$  [1]

- (c) Connect the circuit shown in Fig. 3.2 where resistor  $R$  has a resistance  $R$  of  $15\ \Omega$ .

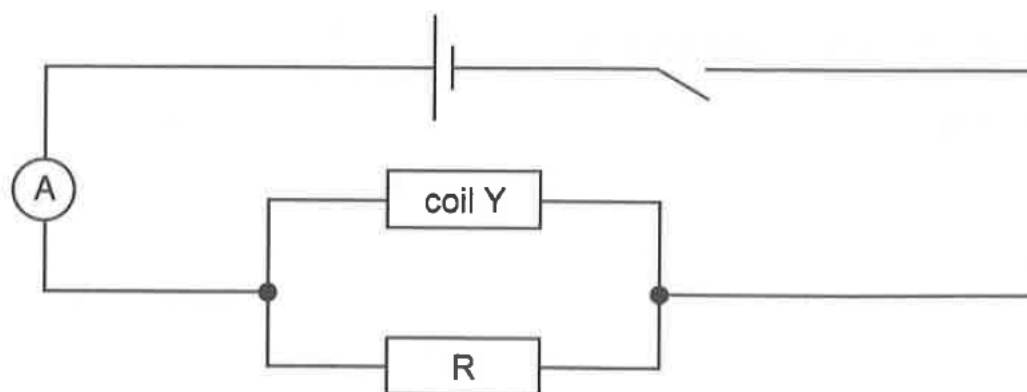


Fig. 3.2

Close the switch.

Note and record  $R$  and the ammeter reading  $I$ .

$R = \dots\dots\dots \Omega$

$I = \dots\dots\dots \text{A}$

[1]

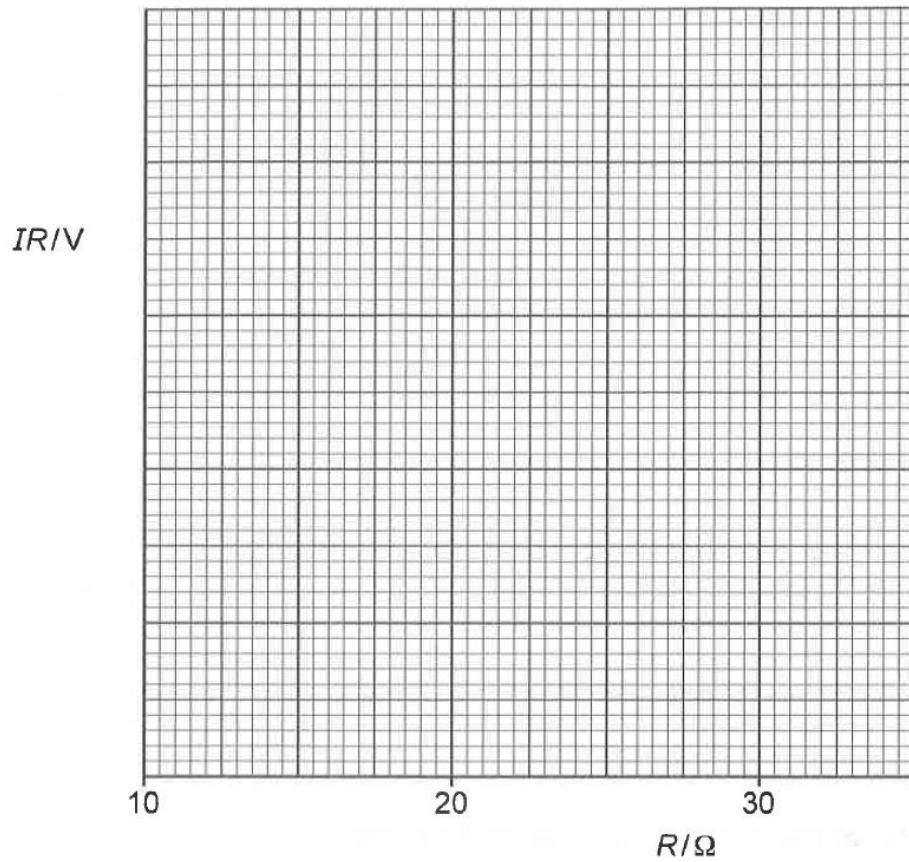
Open the switch.

- (d) Vary  $R$  and repeat (c).

Present your results clearly.

[3]

- (e) Plot your results on Fig. 3.3 and label this line Y.



**Fig. 3.3**

$I$  and  $R$  are related by the expression:

$$IR = GR + H$$

where  $G$  and  $H$  are constants.

The resistance  $X_Y$  of coil Y is given by:

$$X_Y = \frac{H}{G}.$$

Use your graph to determine  $X_Y$ .

$X_Y = \dots\dots\dots \Omega$   
[3]

(f) The diameter of the tube labelled Z is  $D_Z$ . The diameter of the wire is  $d_Z$ .

(i) Measure and record  $D_Z$  and  $d_Z$ .

$D_Z = \dots\dots\dots$  cm

$d_Z = \dots\dots\dots$  mm

The length of wire wrapped around Z is  $L_Z$ , where:

$$L_Z = \frac{3L_Y}{4}.$$

Calculate  $L_Z$ .

$L_Z = \dots\dots\dots$  cm  
[1]

(ii) The resistance of coil Z is  $X_Z$ .

Repeat (c), (d) and (e) to find  $X_Z$ .

Plot your results on Fig. 3.3 and label this line Z.

$X_Z = \dots\dots\dots$   $\Omega$   
[2]

(iii) Use a digital multimeter to measure  $X_Z$ .

Describe any difference between your two values for  $X_Z$  and suggest a reason for this difference.

difference .....

reason .....

.....  
[1]

- (g) It is suggested that the resistance of a wire,  $X$ , is given by the relationship:

$$X = \frac{kL}{d^2}$$

Where  $L$  is the length of the wire,  $d$  is the diameter of the wire and  $k$  is a constant.

- (i) Use your values from (a), (b)(i), (e), (f)(i) and f(ii) to determine 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 value in (b)(ii).

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

- (h) (i) When there is a current  $I$  in one of the coils, the magnetic flux density  $B$  at each end of the tube along its axis is given by:

$$B = CnI$$

Where  $C$  is a constant and  $n$  is the number of turns of wire per unit length on the tube.

Without taking further readings, explain whether tube Y or tube Z has a greater magnetic flux density at its ends when the voltage supply is connected directly across the coil.

.....

.....

.....

.....

..... [1]

- (ii) Describe, using a diagram, how you could check your conclusion in (h)(i) using a small compass.

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..... [3]

[Total: 22]



**HWA CHONG INSTITUTION**  
**C2 Preliminary Examination**  
**Higher 2**

**C**

**CANDIDATE  
NAME**

**CT GROUP**

**23S**

**TUTOR  
NAME**

**SCORE**

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## **PHYSICS**

### **Paper 4 Practical**

Candidates answer on the Question Paper.

No Additional Materials are required.

---

- 4 A student is investigating how the boiling point of a salt solution varies with pressure and the density of the salt solution.

It is suggested that the relationship between the Celsius temperature  $\theta$  at which the water of the solution starts to boil, the air pressure  $P$  and the density  $\sigma$  of the salt solution is

$$\theta = k\sigma^x P^y$$

where  $k$ ,  $x$  and  $y$  are constants.

Design a laboratory experiment to determine the values of  $x$  and  $y$ .

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

- (a) the equipment you would use
- (b) the procedure to be followed
- (c) the control of variables
- (d) any precautions that should be taken to improve the accuracy of the experiment.

**Diagram**

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[Total: 12]