

NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

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## PHYSICS

**9749/01**

Paper 1 Multiple Choice

**26 September 2017**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

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### READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

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

Write your name, class and tutor's name 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.

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This document consists of **12** printed pages.

**[Turn over**

**Data**

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

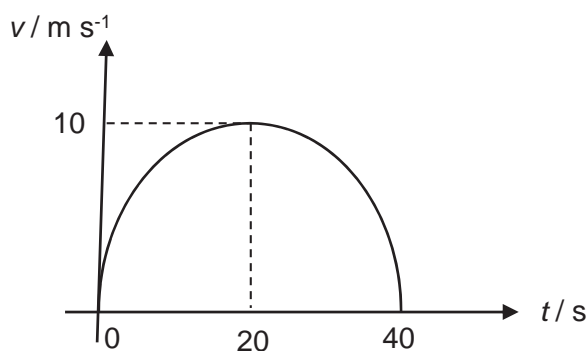
**Formulae**

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

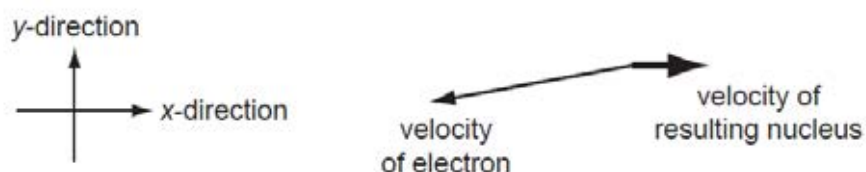
- 1 A body, dropped from the edge of a cliff, is timed to take  $(2.0 \pm 0.1)$  s to fall to the surface of the sea. If the acceleration of free fall is taken to be  $(9.8 \pm 0.2)$  m s<sup>-2</sup>, the calculated height of the cliff above the water surface should be quoted as

- A  $(20 \pm 0.1)$  m                      B  $(20 \pm 0.2)$  m  
 C  $(20 \pm 1)$  m                        D  $(20 \pm 2)$  m

- 2 The velocity-time graph below depicts the motion of an object travelling in a straight line. Which of the following statements is true?



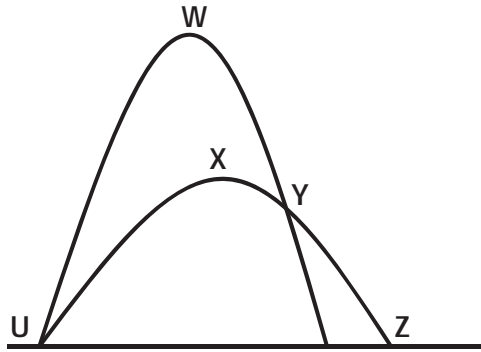
- A During the first 20 s of the motion, the object accelerates and travels a distance of 200 m.  
 B The acceleration of the object increases during the first 20 s to become a maximum when the velocity is 10 m s<sup>-1</sup>.  
 C The acceleration of the object when  $t = 5$  s is equal to its acceleration when  $t = 35$  s.  
 D The object decelerates during the final 20 s of its motion, with the greatest deceleration occurring at  $t = 40$  s.
- 3 A stationary nucleus undergoes beta-decay. The diagram below shows the velocities of the resulting nucleus and the emitted electron.



How does the diagram support the idea that a unseen third particle is also emitted?

- A If there were only two particles involved, their velocities should be equal and opposite.  
 B It is clear that linear momentum is not conserved in the x-direction.  
 C Something must carry away the extra energy.  
 D The linear momentum of the original nucleus has no y-component.

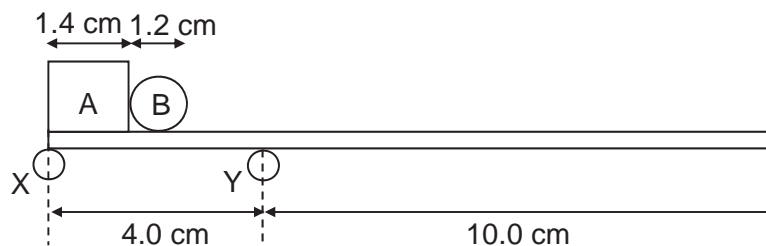
- 4 The paths of two identical projectiles, fired with the same initial speed but with different launch angles, are shown below. Which of the following statements is true?



- A The kinetic energies of both projectiles are the same at Y if there is no air resistance.
- B The potential energy of the projectile at W is lower than the potential energy of the projectile at X.
- C The kinetic energy of the projectile at W and the kinetic energy of the projectile at X are both zero.
- D The kinetic energy of the projectile at W is higher than the kinetic energy of the projectile at X.
- 5 A tractor of mass 1000 kg pulls a trailer of mass 1000 kg via a tow-bar. The total resistance to motion has a constant value of 4000 N. One quarter of this resistance acts on the trailer. At first the acceleration of the tractor and trailer is  $2.0 \text{ m s}^{-2}$  but eventually they move at a constant speed of  $6.0 \text{ m s}^{-1}$ .

What is the force exerted on the tractor by the tow-bar when the acceleration of the tractor and trailer is  $2.0 \text{ m s}^{-2}$ ?

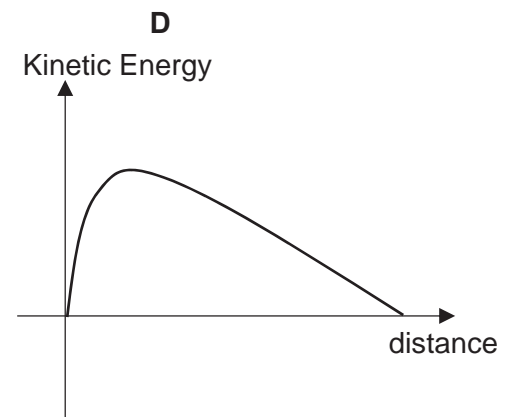
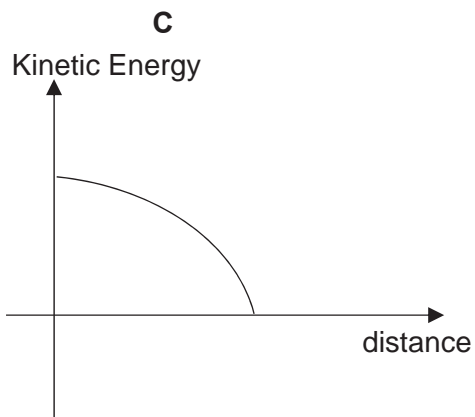
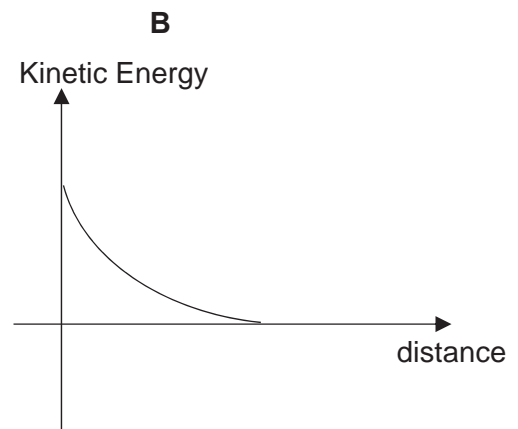
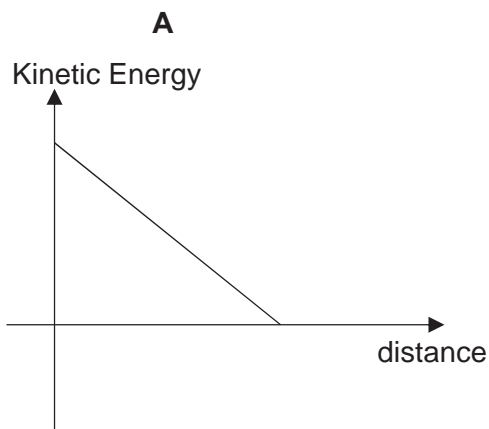
- A 1000 N      B 3000 N      C 5000 N      D 8000 N
- 6 A beam of negligible mass is supported by two rods X and Y. Block A of mass 200 g and ball B of mass 100 g rest on the beam as shown. Both A and B have uniform density.



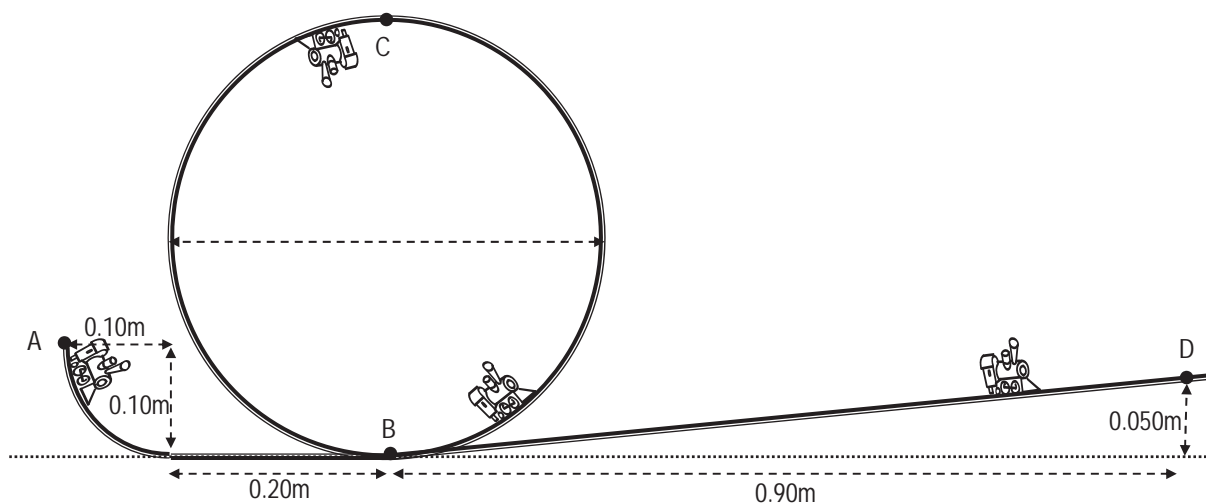
If ball B were to start rolling to the right, what is the distance it would have moved before the beam just loses contact with rod X? Assume that there is negligible friction.

- A 6.6 cm      B 8.0 cm      C 8.6 cm      D 9.4 cm

- 7 A submarine descends vertically at a constant velocity. The three forces acting on the submarine are viscous drag, upthrust and weight. Which of the following relationships between the magnitudes of these three forces is correct?
- A weight < drag
  - B weight = drag
  - C weight < upthrust
  - D weight > upthrust
- 8 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 distance travelled by the block after its point of projection?



- 9 A toy train of mass  $m$  passes point **A** of the track with velocity  $v$ . What is the minimum value of  $v$  such that the train will travel up the loop of radius  $0.20\text{ m}$  via points **B**, then **C** and eventually reach point **D**? You may ignore resistive forces in your calculation.



- A**  $1.0\text{ m s}^{-1}$       **B**  $1.4\text{ m s}^{-1}$       **C**  $2.4\text{ m s}^{-1}$       **D**  $2.8\text{ m s}^{-1}$

- 10 What is the speed of a geostationary satellite that is orbiting Earth? The mass of Earth is taken to be  $6.0 \times 10^{24}\text{ kg}$ .

- A**  $3.08 \times 10^3\text{ m s}^{-1}$     **B**  $4.71 \times 10^4\text{ m s}^{-1}$     **C**  $1.80 \times 10^5\text{ m s}^{-1}$     **D**  $4.23 \times 10^7\text{ m s}^{-1}$

- 11 A ball which is thrown upward near the surface of Earth with velocity  $v$  will come to rest five seconds later. If the ball were to be thrown upward with the same velocity  $v$  on Planet X, it would still be moving upward at  $31\text{ m s}^{-1}$  after five seconds.

What is the ratio  $\frac{\text{gravitational field strength near surface of Planet X}}{\text{gravitational field strength near surface of Earth}}$ ?

- A** 0.16      **B** 0.37      **C** 0.53      **D** 0.63

- 12 Which of the following statements is *not true* for an oscillating body when light damping is present?

- A** The damping force is always in the opposite direction to the velocity of the body.  
**B** The damping force is always in the opposite direction to the acceleration of the body.  
**C** The presence of light damping changes the period of oscillation.  
**D** The presence of light damping changes the maximum potential energy of the body.

- 13 A fixed mass of ideal gas in a thermally insulated container is compressed. After compression, the temperature of the gas would have
- A fallen, since more molecules bombard the container so they must be moving slower.
  - B fallen, since the molecules collide more frequently with each other so their average speed is slower.
  - C remained constant if the compression is very slow.
  - D risen, since doing work on the gas increases the kinetic energy of the gas molecules.

- 14 Two vessels X and Y, of volumes  $V_X$  and  $V_Y$  respectively, are kept at temperatures  $T_X$  and  $T_Y$ . They are filled with the same ideal gas and are connected via a narrow tube.

What is the ratio  $\frac{\text{number of molecules in X}}{\text{number of molecules in Y}}$ ?

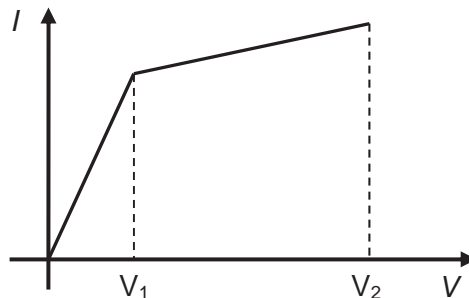
- A  $\frac{T_X V_X}{T_Y V_Y}$       B  $\frac{T_X V_Y}{T_Y V_X}$       C  $\frac{T_Y V_Y}{T_X V_X}$       D  $\frac{T_Y V_X}{T_X V_Y}$

- 15 A potential difference is applied between the electrodes of a gas discharge tube of area  $1.3 \times 10^{-3} \text{ m}^2$  so that the gas is ionised into positively charged particles and electrons.

The gas carries a current of 12.2 mA and the number of electrons passing any point in the gas per unit time is  $2.54 \times 10^{16} \text{ s}^{-1}$ . Given that the charge on each positively charged particle is  $3.20 \times 10^{-19} \text{ C}$  and the number of the positively charged particles per unit volume is  $1.0 \times 10^{19} \text{ m}^{-3}$ , what is the drift velocity of these positively charged particles in the gas?

- A  $0.98 \text{ m s}^{-1}$       B  $1.96 \text{ m s}^{-1}$       C  $3.91 \text{ m s}^{-1}$       D  $7.82 \text{ m s}^{-1}$

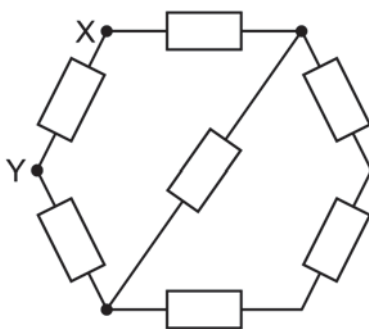
- 16 The graph below shows the variation of current  $I$  through an electrical component with the potential difference  $V$  across the component.



The resistance of the component is

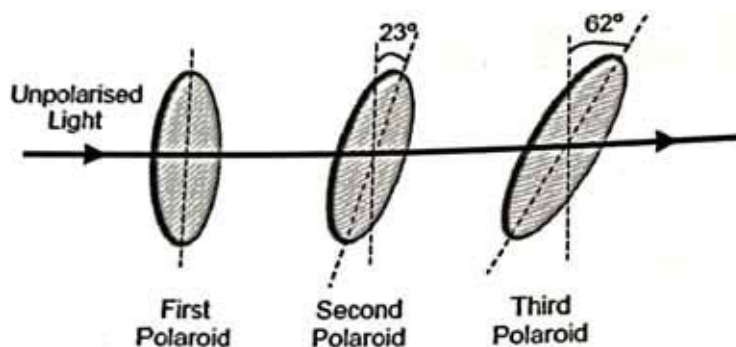
- A constant from 0 to  $V_1$ , then increases to another constant from  $V_1$  to  $V_2$ .
- B constant from 0 to  $V_1$ , then decreases to another constant from  $V_1$  to  $V_2$ .
- C constant from 0 to  $V_1$ , then decreases continuously from  $V_1$  to  $V_2$ .
- D constant from 0 to  $V_1$ , then increases continuously from  $V_1$  to  $V_2$ .

- 17 The diagram shows a network of 7 resistors, each with resistance  $R$ .



What is the resistance between points X and Y?

- A  $\frac{2}{3}R$       B  $\frac{3}{5}R$       C  $\frac{7}{11}R$       D  $\frac{11}{15}R$
- 18 In a transverse progressive wave with a period of 0.060 s, the least distance between two adjacent points which have a phase difference of  $90^\circ$  is 0.20 m. What is the time taken for the wave to travel a distance of 4.00 m?
- A 0.30 s      B 0.60 s      C 1.20 s      D 1.50 s
- 19 Light is polarised when it passes through a sheet material known as a polaroid. Three polaroids are stacked, with the polarising axis of the second and third polaroids at  $23^\circ$  and  $62^\circ$  respectively to that of the first polaroid, as shown in the diagram below.



When unpolarised light of amplitude  $A_0$  is incident on the stack of polaroids, its amplitude after passing through the first polaroid is  $A_1$ , and becomes  $A_2$  after it passes through the second polaroid, and subsequently  $A_3$  after it passes through the third polaroid. What is the value of  $\frac{A_3}{A_1}$ ?

- A 0.25      B 0.31      C 0.43      D 0.72



- 20 A space shuttle orbits at a height of 330 km above the surface of the Earth. It carries two panels separated by a distance of 24 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.

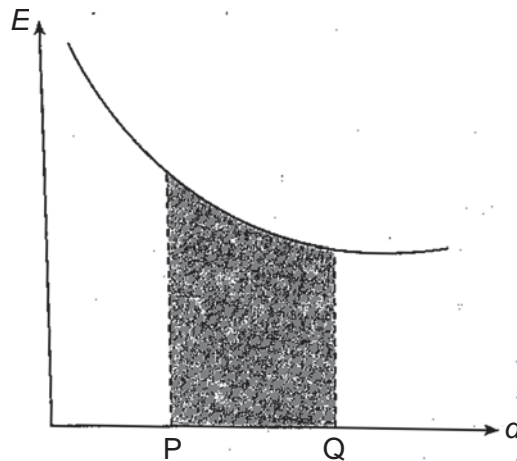
The observer views the panels with a telescope that has an aperture diameter of 85 mm. Assume that the panels act as point sources of light for the observer. Which of the following is correct?

	Will the two images seen by the observer be resolved?	Angular separation of two sources as measured from aperture / rad
<b>A</b>	Yes	$5.9 \times 10^{-6}$
<b>B</b>	Yes	$7.3 \times 10^{-5}$
<b>C</b>	No	$5.9 \times 10^{-6}$
<b>D</b>	No	$7.3 \times 10^{-5}$

- 21 A single slit that is 1.0 mm wide is illuminated by light which has a wavelength of 450 nm. What is the width of the central maximum in the diffraction pattern produced on a screen 5.0 m away?

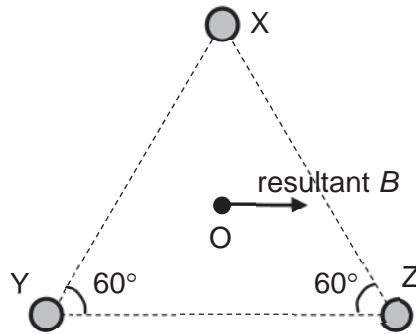
**A** 1.1 mm      **B** 2.2 mm      **C** 4.5 mm      **D** 7.2 mm

- 22 The graph below shows the variation of the electric field strength  $E$  with distance  $d$  along a straight line in an electric field. What does the shaded area under the curve between P and Q represent?



- A** The work done by the electric field to move a charge from P to Q.  
**B** The total charge that moves between P and Q.  
**C** The power dissipated when moving a unit charge from P to Q.  
**D** The potential difference between P and Q.

- 23 Three parallel conductors, all carrying currents of the same magnitude, pass vertically through the three corners X, Y and Z of a horizontal equilateral triangle as shown in the diagram below. A resultant magnetic flux density  $B$  acts at the centre O of the triangle, in the direction as shown below. What must be the directions of the currents in X, Y and Z?

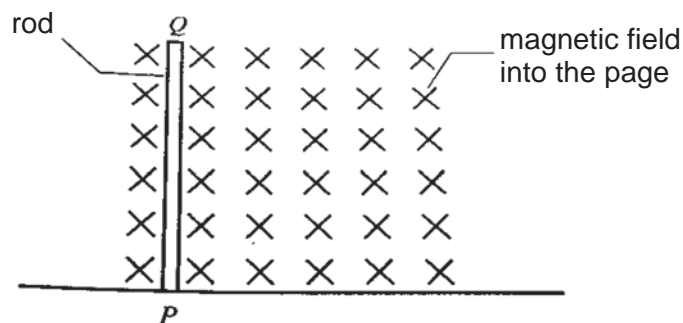


	Into the page	Out of the page
<b>A</b>	X	Y and Z
<b>B</b>	Z	X and Y
<b>C</b>	Y and Z	X
<b>D</b>	X, Y and Z	None

- 24 An electron moves along the axis of a solenoid carrying current. Which of the following is a correct statement about the electromagnetic force acting on the electron?

- A** No force acts.  
**B** The force acts in the direction of motion.  
**C** The force acts against the direction of motion.  
**D** The force acts radially outward towards the solenoid.

- 25 A vertical rod PQ is hinged to a flat surface at the end P and placed in a uniform magnetic field that acts into the page, as shown in the diagram. When the rod is lightly pushed to the right at the end Q, it swings downwards while still hinged at P.



Just before the end Q hits the flat surface, which of the following statements is correct?

- A** Q is at a higher electrical potential than P.  
**B** An upward magnetic force acts on the rod.  
**C** An induced current flows to Q from P  
**D** The rod rotates clockwise with a constant angular speed.

- 26 A steady current  $I$  dissipates a certain power in a variable resistor, set at  $12\ \Omega$ . To dissipate the same power when a sinusoidal alternating current is used, the resistor has to be set at  $3\ \Omega$ . What is the r.m.s. value of the alternating current?

A  $\frac{1}{\sqrt{2}}I$       B  $I$       C  $\sqrt{2}I$       D  $2I$

- 27 The four energy levels of the hydrogen atom and their corresponding energy values are

Level	Energy / eV
P	-13.60
Q	-3.40
R	-1.50
S	-0.85

A spectral line of 488 nm could result from an electron transition between levels

A Q and P      B R and P      C R and Q      D S and Q

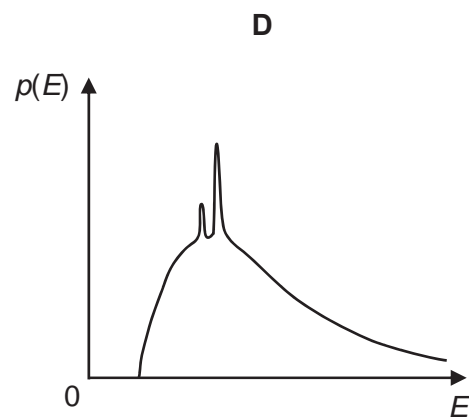
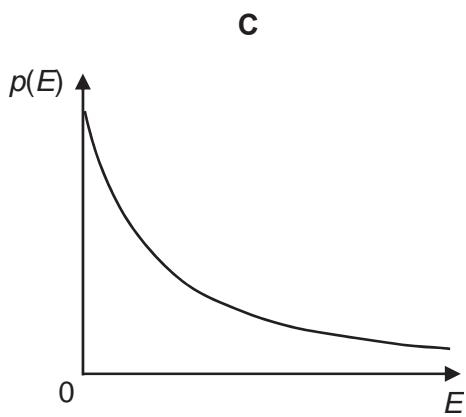
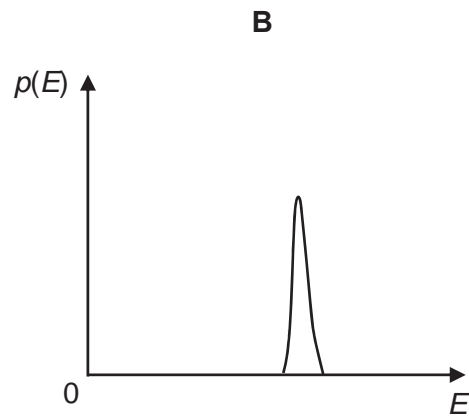
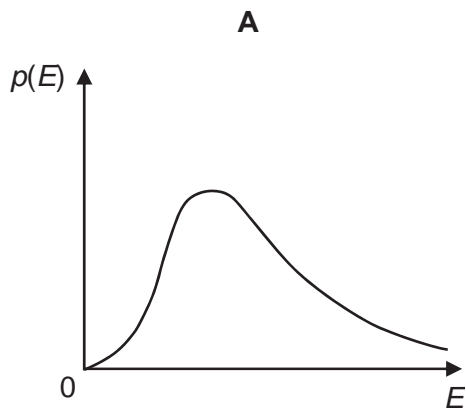
- 28 What is the wavelength of a beam of electrons accelerated through a potential difference of 5200 V?

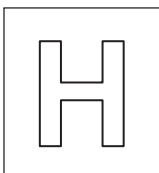
A  $1.7 \times 10^{-11}\ \text{m}$       B  $2.4 \times 10^{-10}\ \text{m}$       C  $1.4 \times 10^{-7}\ \text{m}$       D  $2.8 \times 10^{-6}\ \text{m}$

- 29 The deviation of alpha particles by thin metal foils through angles ranging from  $0^\circ$  to  $180^\circ$  can be explained by

- A random motion of alpha particles.  
 B diffraction of the alpha particles through the metal due to the wave properties of the alpha particles.  
 C scattering by small but heavy regions of positive charges.  
 D scattering by the free electrons in the metal foils.

- 30 Which of the following graphs could represent  $p(E)$ , the distribution of the energies  $E$  of alpha particles that are emitted from a given source?





NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

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## PHYSICS

**9749/02**

Paper 2 Structured Questions

**18 September 2017**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required

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### READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
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<b>Total</b>	

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This document consists of **19** printed pages.

**[Turn over**

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the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

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

- 1 (a) State how force is related to linear momentum.

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

- (b) In a laboratory experiment a small metal cylinder containing liquid carbon dioxide is attached to a trolley as shown in Fig 1.1. The trolley is initially at rest. When the cylinder is punctured, carbon dioxide gas rushes out and the trolley accelerates.

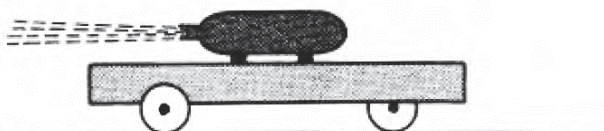


Fig. 1.1

- (i) Using Newton's laws of motion, explain the origin of the force that is accelerating the trolley.

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

- (ii) The trolley and cylinder have a mass of 0.68 kg and they reach a maximum speed of  $2.7 \text{ m s}^{-1}$ . The total mass of carbon dioxide initially in the cylinder is 12 g.

1. Write an equation relating the initial and final velocities of the trolley-cylinder system in terms of the average acceleration  $a$  of the trolley-cylinder system, and the time  $t$  taken for this system to achieve maximum speed.

..... [1]

2. Write an equation relating the average ejection speed  $v_g$  of the carbon dioxide gas, the average accelerating force  $F$  exerted on the gas and the time  $t$  taken for all the gas to be ejected.

..... [1]

3. Hence calculate the average ejection speed of the carbon dioxide gas.

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

- (iii) The cylinder is then removed from the trolley, and the trolley is given a push so that it collides head-on with a second stationary trolley which is identical to the first one.

Describe the subsequent motion of the trolleys if they make

1. an elastic collision,

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

2. a completely inelastic collision.

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

- 2 (a) (i) Define *gravitational potential* at a point in a gravitational field.

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

- (ii) Explain why gravitational potential is always negative.

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



- (b) Fig. 2.1 shows the variation of gravitational potential between the surface of Moon and the surface of Earth along the line joining their centres.

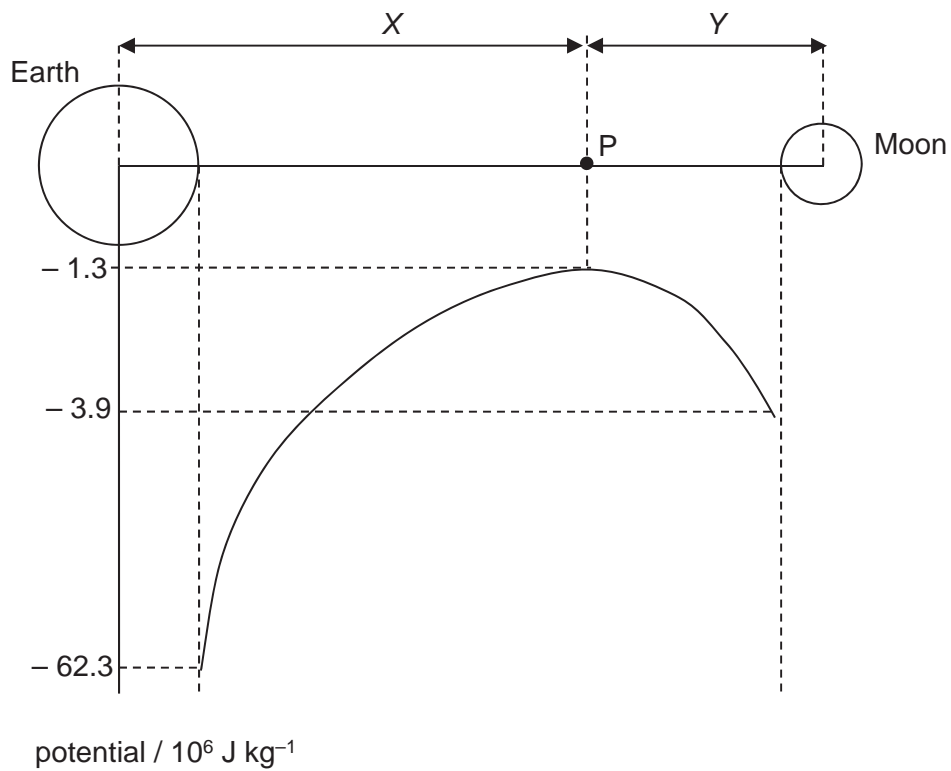


Fig. 2.1

Explain why the gradient of the graph near the surface of Earth and that near the surface of Moon have opposite signs.

.....

.....

.....

..... [2]

- (c) Two moons A and B move in circular orbits about a planet, as illustrated in Fig. 2.2.

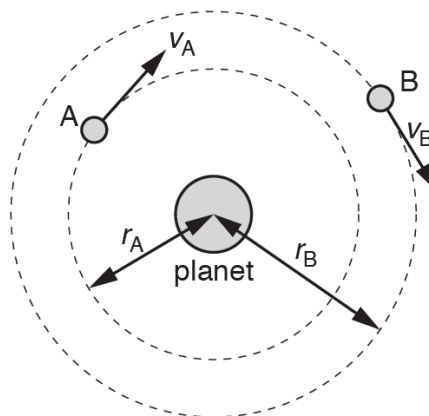


Fig. 2.2

Moon A has an orbital radius  $r_A$  of  $1.3 \times 10^8$  m, linear speed  $v_A$  and orbital period  $T_A$ .  
Moon B has an orbital radius  $r_B$  of  $2.2 \times 10^{10}$  m, linear speed  $v_B$  and orbital period  $T_B$ .

(i) Determine the ratio

1.  $\frac{v_A}{v_B}$ , and

ratio = ..... [3]

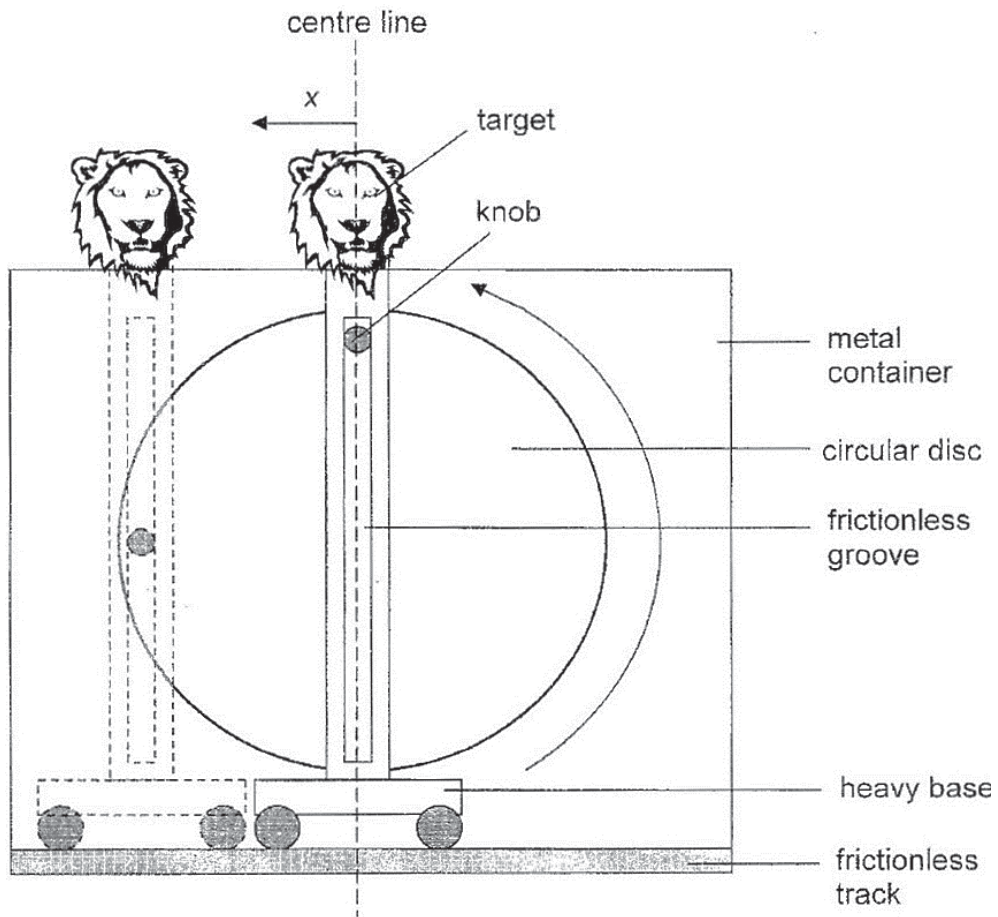
2.  $\frac{T_A}{T_B}$ .

ratio = ..... [1]

(ii) The planet spins about its own axis with angular speed  $1.7 \times 10^{-4}$  rad s<sup>-1</sup>. Moon A is always above the same point on the planet's surface. Determine the orbital period  $T_B$  of moon B.

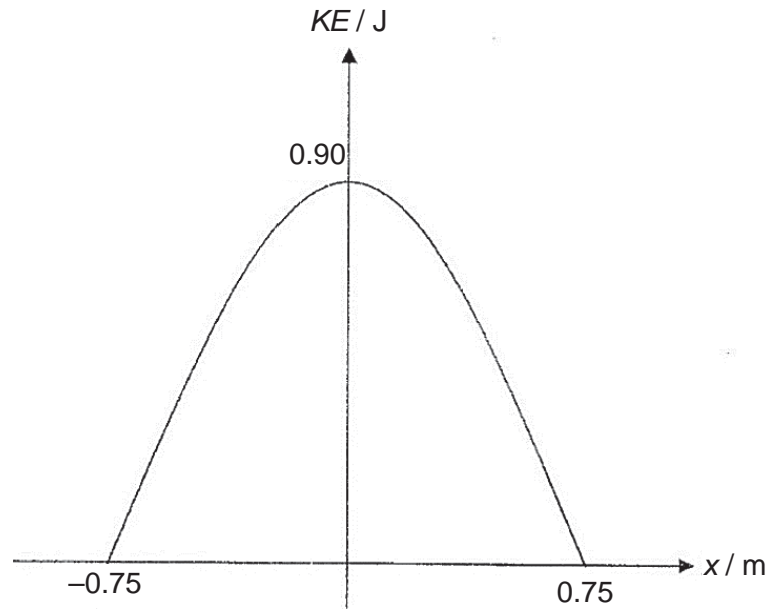
$T_B = \dots\dots\dots$  s [2]

3 At a shooting gallery in a fun fair, a mobile target lion sways horizontally with simple harmonic motion as shown in Fig. 3.1. Hidden in a metal container below the lion target is a motor-driven circular rotating disc with a knob that slides along a frictionless groove attached to the lion. As the disc rotates with constant angular frequency, it pushes the lion target horizontally left and right.

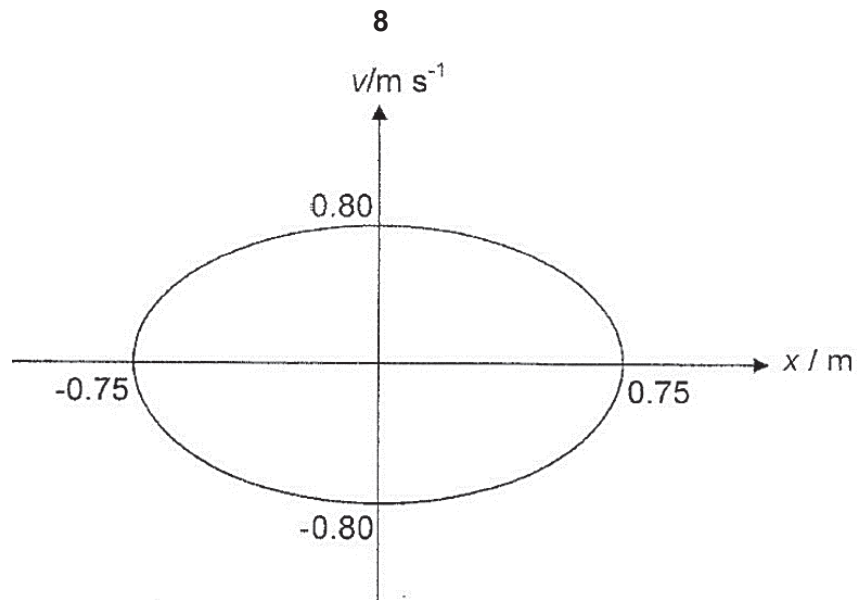


**Fig. 3.1**

Fig. 3.2 shows how the kinetic energy  $KE$  of the lion target varies with its displacement  $x$  from the centre line and Fig. 3.3 shows how its velocity  $v$  varies with its displacement  $x$ .



**Fig. 3.2**



**Fig. 3.3**

**(a)** Deduce, from Fig. 3.2 and Fig. 3.3,

**(i)** the mass of the lion target,

mass = ..... kg [2]

**(ii)** the number of revolutions per second of the circular disc,

number of revolutions per second = ..... s<sup>-1</sup> [2]

**(iii)** the speed of the knob when the displacement of the lion is maximum.

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

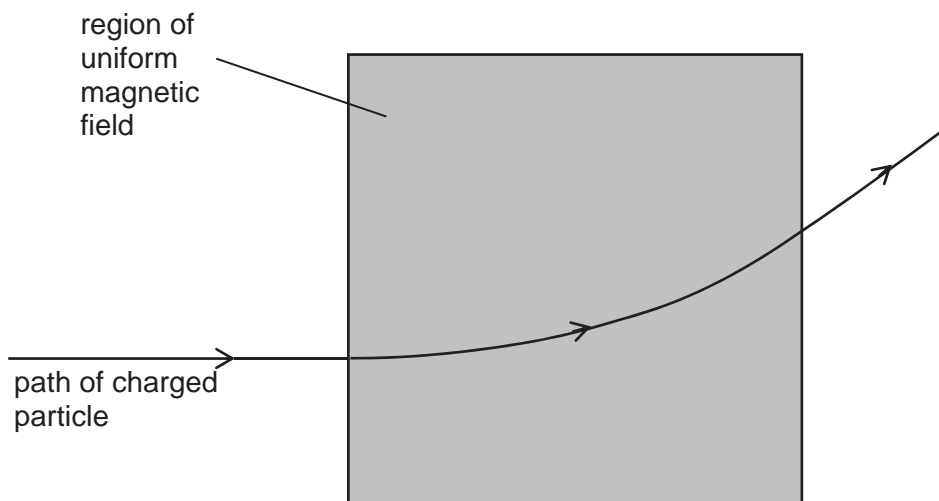
- (b) When the lion target is at its leftmost position, a ball was tossed towards the middle position between the leftmost position and the centre line, with the aim of hitting the lion target. The ball takes 0.74 s to reach that middle position. Determine and explain whether the ball will hit the lion target right at its nose.

.....

.....

..... [2]

- 4 A positively charged particle passes through a region of uniform magnetic field of flux density 0.75 T, as shown in Fig. 4.1.



**Fig. 4.1**

The radius  $r$  of the path of the particle in the magnetic field is 25 cm.

- (a) Define the *tesla*.

.....

.....

..... [2]

- (b) State the direction of the magnetic field.

..... [1]

- (c) (i) The specific charge of a particle is the ratio of its charge to its mass,  $\frac{q}{m}$ . Given that the speed of the particle is  $9.0 \times 10^6 \text{ m s}^{-1}$ , calculate the specific charge of the particle.

specific charge = ..... C kg<sup>-1</sup> [3]

- (ii) Using your answer in (i), suggest the name of a possible charged particle which has entered the uniform magnetic field. Show your working.

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

- (iii) Explain how the path of the charged particle in the uniform magnetic field will be different if it were an electron projected into the field with the same speed as the positively charged particle in (i).

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

- 5 (a) State Faraday's law of electromagnetic induction.

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

- (b) Induction heating is commonly used for heating up electrically conductive materials in a clean, efficient and controlled manner. In industry, induction heating is a simple and reliable method for bottle sealing. It welds a circular piece of aluminium foil across the necks of medicine and drink bottles.

As shown in Fig. 5.1, a bottle is first filled at position 1. A plastic cap, complete with a piece of aluminium foil, is applied to the bottle neck at position 2. The foil is also coated with 'hot-melt glue' before being screwed onto the top of the bottle during manufacture. As the bottle passes under the induction heater (positions 3, 4, 5) on the production line, the foil is rapidly heated. The heat generated melts the glue and seals the foil onto the top of the bottle by position 5. When the cap is removed, the foil remains attached, providing an airtight seal and preventing any tampering or contamination of the bottle contents until the customer pierces the foil.

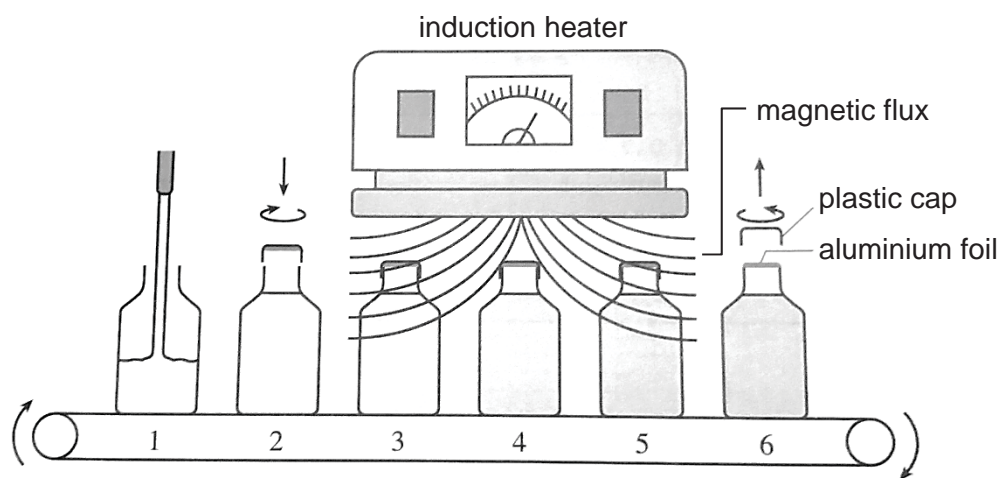


Fig. 5.1

- (i) State one advantage of using induction heating.

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

- (ii) Using laws of electromagnetic induction where appropriate, explain how the glue is melted.

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

(iii) The amount of heat produced in the aluminum foil can be estimated using a small coil placed underneath the induction heater. The coil has a cross-sectional area of  $2.40 \text{ cm}^2$  and contains 150 turns of wire. The resistance of the coil is  $6.8 \times 10^{-3} \Omega$ . Given that the magnetic flux density increased from zero to 500 mT in 0.30 s,

1. calculate the maximum magnetic flux linkage through the coil, and

maximum magnetic flux linkage = ..... Wb [2]

2. determine the power dissipated by the coil.

power dissipated = ..... W [2]

(iv) Explain if this method can be used to fix a plastic seal around the bottle instead.

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

6 (a) Describe three observations of the photoelectric effect that provide evidence for the particulate nature of electromagnetic radiation.

1 .....  
.....  
2 .....  
.....  
3 .....  
..... [3]



- (b) Light of wavelength  $\lambda$  is incident on a metal surface having a work function energy  $\phi$ . Photoelectrons of maximum kinetic energy  $E_{\text{MAX}}$  are emitted from the surface.

The variation with  $1/\lambda$  of  $E_{\text{MAX}}$  is shown in Fig. 6.1.

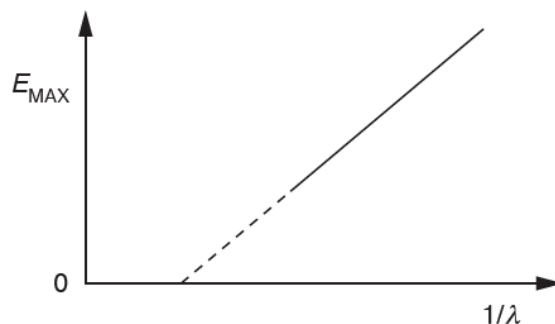


Fig. 6.1

- (i) Explain why the gradient of the line in Fig. 6.1 does not depend on the type of the metal surface.

.....

.....

..... [2]

- (ii) The work function energy of sodium is 2.28 eV. Determine the minimum wavelength  $\lambda_0$  at which  $E_{\text{MAX}}$  is zero.

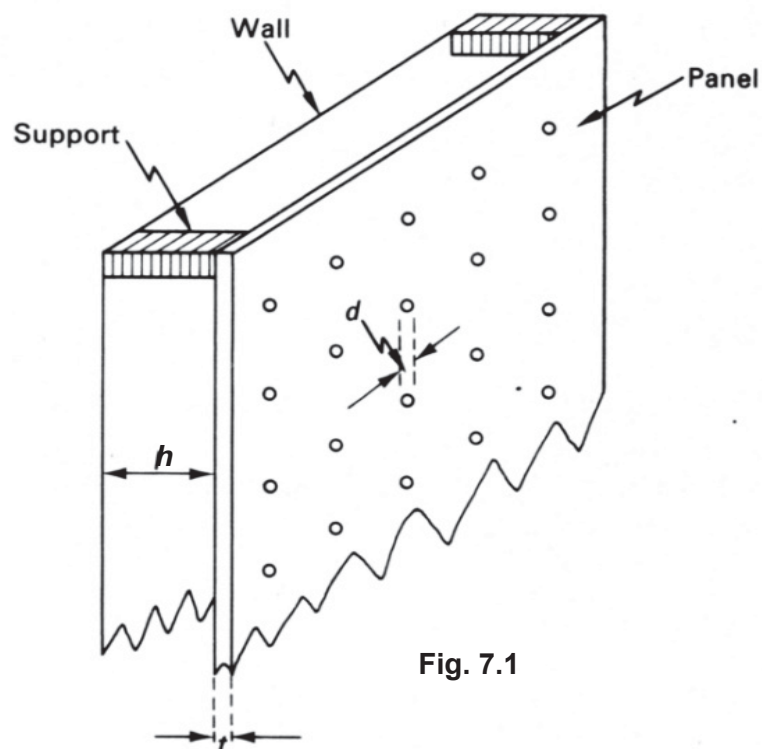
minimum wavelength = ..... m [2]

- (c) An electron gun is used to shoot a beam of electrons towards a screen, at a speed of  $6.00 \times 10^6 \text{ m s}^{-1}$ , through a slit of width 2.00 mm. Determine the distance between the slit of the gun and the screen, in order to see the beam of electrons spread by 1.00 cm on the screen because of the uncertainty principle.

distance = ..... m [3]

- 7 The walls of music halls are acoustically covered with a sound-absorbing panel that is able to absorb certain sound frequencies more than others.

One particular design is to use the resonance of a perforated panel as shown in Fig. 7.1.



It is found that this panel resonates at a particular frequency and hence can absorb sounds of that frequency more than others. A suggested formula for this resonant frequency  $f$  is given as:

$$f = k \sqrt{\frac{x}{h(t + 0.8d)}} \quad \text{--- Equation 7.1}$$

where  $k = 5000 \text{ mm s}^{-1}$ ,  
 $h =$  depth of airspace with unit mm,  
 $t =$  thickness of panel with unit mm,  
 $d =$  hole diameter with unit mm, and  
 $x =$  percentage of panel surface area occupied by holes (e.g.  $x = 10 \%$ )

Using identical hardboard panels having holes of the same diameter of 10 mm, the resonant frequencies  $f$  for different  $x$  values are measured, keeping  $h$  and  $t$  constant. The results are shown in Fig. 7.2:

$x / \%$	2	4	6	8	10	12
$f / \text{Hz}$	530	750	920	1070	1190	1300

**Fig. 7.2**

- (a) Using the results from Fig. 7.2, state and explain whether the formula for  $f$  given in Equation 7.1 is correct.

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

- (b) Determine suitable values for  $h$  and  $t$  when  $x = 10 \%$ , such that the results from Fig. 7.2 satisfy the given formula for  $f$  in Equation 7.1.

$h =$  ..... mm

$t =$  ..... mm [2]

- (c) Using a panel with  $x$  fixed at 10 % and  $d$  fixed at 5 mm, the engineer decides to investigate the effect of filling the air space with 2 different absorbers. He obtains the absorption characteristics shown in Fig. 7.3.

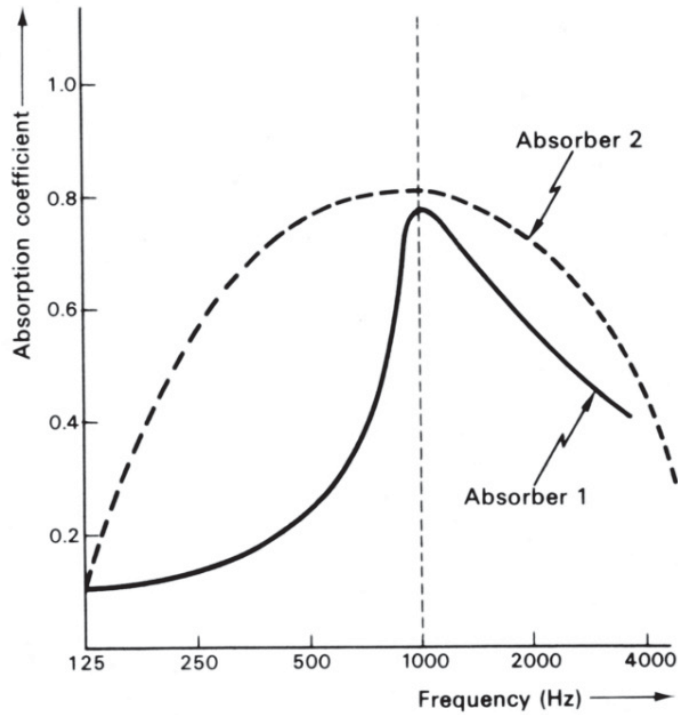


Fig. 7.3

Absorption coefficient is an indication of how much sound waves can be absorbed i.e. the higher the absorption coefficient, the stronger the absorption.

- (i) Using your knowledge on resonance, state one effect that absorbers have on the resonant frequency when they are inserted into the air space.

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

- (ii) State and explain which of the two absorbers would be preferred in a room in which

1. absorption over a wide frequency range is required,  
 .....  
 ..... [1]

2. sounds below 500 Hz need amplification.  
 .....  
 ..... [1]

- 8 In 2012 skydiver Felix Baumgartner jumped out of a helium-filled balloon from a height of 39 km above sea level. His free fall of over 36 km lasted 4 minutes and 20 seconds. In this free fall, he became the first person whose speed exceeded the speed of sound  $330 \text{ m s}^{-1}$ , without the use of an aeroplane or rocket.

During the fall, Felix Baumgartner opened his parachute at about 1500 m above sea level, when his speed is  $192 \text{ km hr}^{-1}$ , and he landed safely 15 minutes later. All height and speeds were recorded by GPS.

Some data on the air atmosphere and helium is collected and given in Fig. 8.1.

	sea level	39 km above sea level
Temperature of atmosphere / °C	15	-25
Atmospheric pressure / Pa	101 000	318
Air density	-	0.00447
Helium density / $\text{kg m}^{-3}$	-	0.00065

Fig. 8.1

- (a) Using data given in Fig. 8.1, determine the minimum volume of helium required in the balloon at sea level, for a skydiver in the helium-filled balloon to reach a height of 39 km above sea level at constant speed. Assume that the total mass of the skydiver and the helium-filled balloon is 3140 kg, and that helium behaves as an ideal gas.

volume required at sea level = .....  $\text{m}^3$  [3]

Two main forces acting on the skydiver of mass  $m$  are his weight and air resistance. The air resistance  $F$  can be written as follows

$$F = \frac{1}{2} C_D A \rho v^2$$

where  $\rho$  is the density of air,  $A$  is effective cross-sectional area and  $C_D$  is the drag coefficient.

- (b) (i) Show that the terminal speed  $v_T$  that can be achieved by the skydiver as he falls is given by

$$v_T = \sqrt{\frac{2mg}{C_D A \rho}}$$

[1]

(ii) Explain why the skydiver's terminal speed will not be constant as he falls.

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

(c) The acceleration  $a$  of the sky diver when he is falling at a speed  $v$  is given by

$$a = g \left( \frac{v^2}{v_T^2} - 1 \right) \quad \text{--- Equation 8.1}$$

The variation of the skydiver's speed with time as he falls is shown in Fig 8.2. The terminal speed  $v_T$  based on the expression given in (b)(i) is also plotted in Fig. 8.2 (denoted by the dashed line).

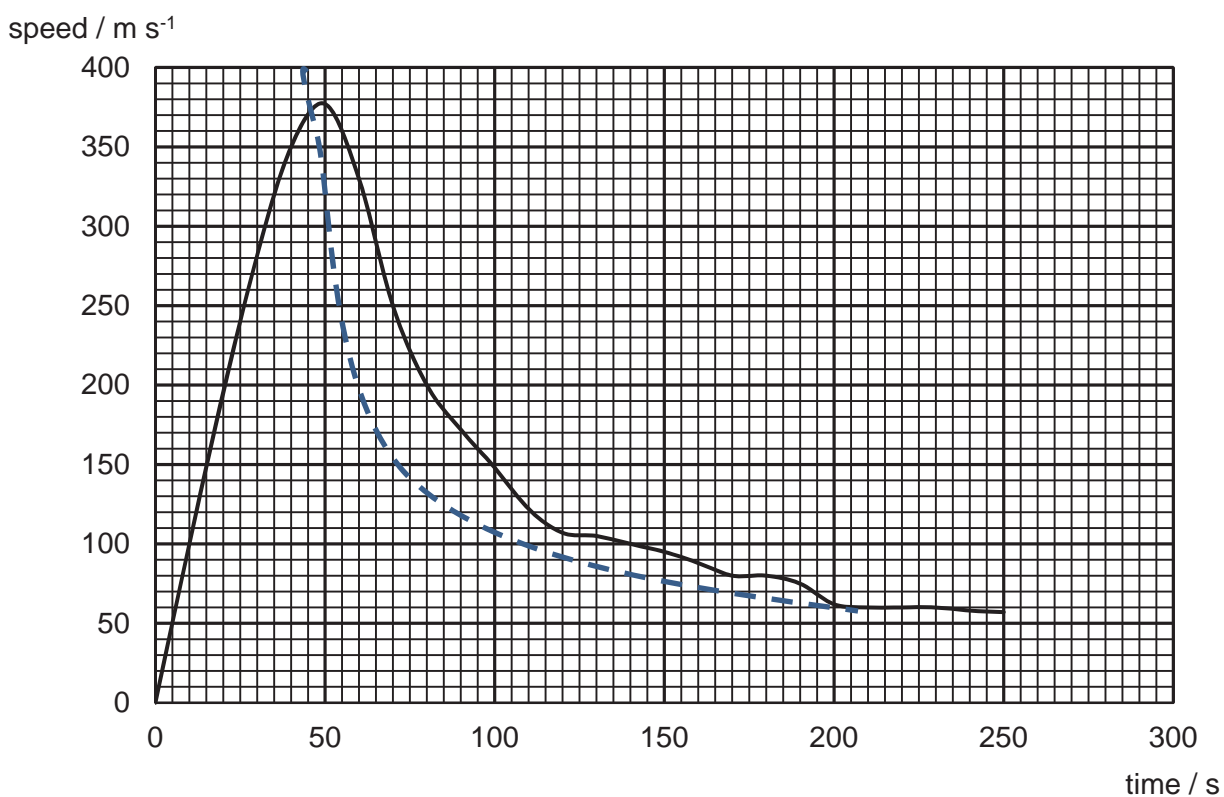


Fig. 8.2

(i) Deduce from Fig 8.2 the duration of time when the skydiver exceeds the speed of sound during his fall.

duration = ..... s [1]

- (ii) Use Fig 8.2 to determine the total distance fallen when the sky diver reaches his maximum speed.

total distance fallen = ..... m [2]

- (iii) Using Fig. 8.2 and Equation 8.1, describe and explain the variation in the speed of the skydiver from time = 50 s to 250 s.

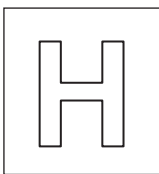
.....  
 .....  
 .....  
 ..... [2]

- (d) (i) Suggest why a helium-filled balloon is used to bring the skydiver to a height of 39 km above sea level, instead of using an aircraft.

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

- (ii) Suggest a major health hazard to the skydiver at such a high attitude, even with the use of oxygen supply.

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



NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

CANDIDATE  
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TUTOR'S  
NAME

## PHYSICS

**9749/03**

Paper 3 Longer Structured Questions

**21 September 2017**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required

### READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.

#### Section A

Answer **all** questions.

#### Section B

Answer any **one** question.

You are advised to spend about one and a half hours on Section A, and about thirty minutes on Section B.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8	
9	
Total	

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

[Turn over



**Data**

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

**Formulae**

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

## Section A

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

- 1 A hot air balloon P is moving vertically upward at a uniform speed when weather condition turns windy. A constant breeze blows horizontally across the sky at a speed  $4.0 \text{ m s}^{-1}$ , which causes the hot air balloon to travel with a resultant velocity  $11 \text{ m s}^{-1}$  at an angle  $\theta$  to the horizontal, as shown in Fig. 1.1 below.

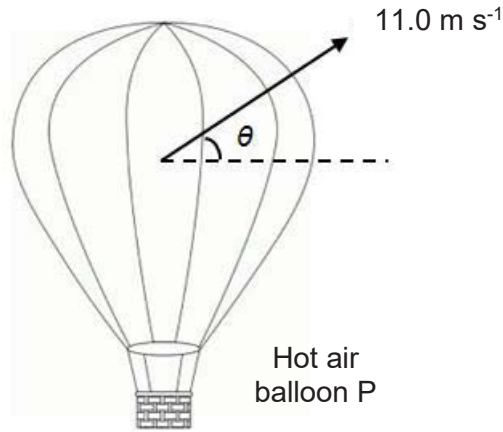


Fig. 1.1

A sandbag is released from the balloon P. Ignore the effects of air resistance. Assuming that the sandbag has yet to land on the ground after 2.3 s, and that the velocity of balloon P is not affected by the release of the sandbag,

- (a) determine the horizontal distance of the sandbag from balloon P after 2.3 s, and

horizontal distance = ..... m [1]

- (b) show that the vertical distance of the sandbag from balloon P after 2.3 s is 26 m. [2]

(c) There is a second hot air balloon Q which is at a stationary position below the first hot air balloon P. At the instant when the released sandbag passes in front of this second air hot balloon Q at 2.3 s, the person inside balloon Q throws another sandbag at this first sandbag that was released from P. The second sandbag is thrown from Q at an angle of  $45^\circ$  below the horizontal.

(i) Determine the speed at which the second sandbag is thrown from Q if both sandbags reach the ground at the same time.

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

(ii) The person inside Q wants the sandbag that was thrown out from Q in (i) to reach the ground within a shorter time. Therefore he throws out another sandbag from Q with the same speed and angle of projection as the sandbag which he threw out in (i) but this time, he uses a heavier sandbag. Comment on whether he will succeed.

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

2 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 2.1.

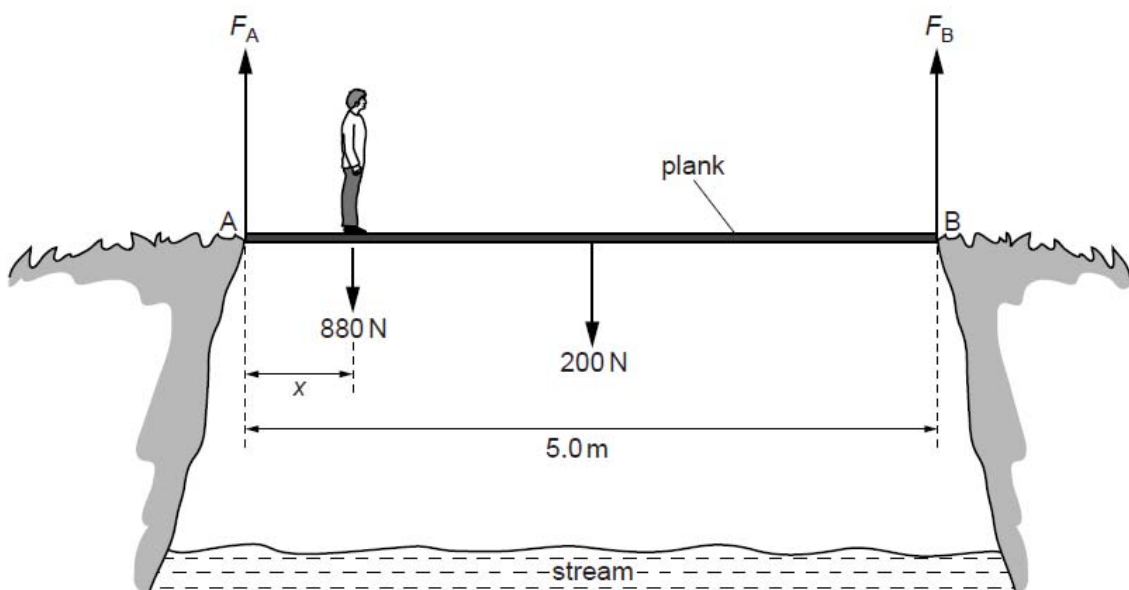


Fig. 2.1

A man of weight 880 N stands at a distance  $x$  from end A. The ground exerts a vertical force  $F_A$  on the plank at end A and a vertical force  $F_B$  on the plank at end B. As the man moves along the plank, the plank is always in equilibrium.

(a) (i) Define *moment of a force*.

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

(ii) Explain why the sum of the forces  $F_A$  and  $F_B$  is constant no matter where the man stands on the plank.

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

(iii) The man stands at a distance  $x = 0.50$  m from end A. Determine the magnitude of  $F_B$ .

$F_B =$  ..... N [2]

(b) The variation with distance  $x$  of the magnitude of force  $F_A$  is shown in Fig. 2.2.

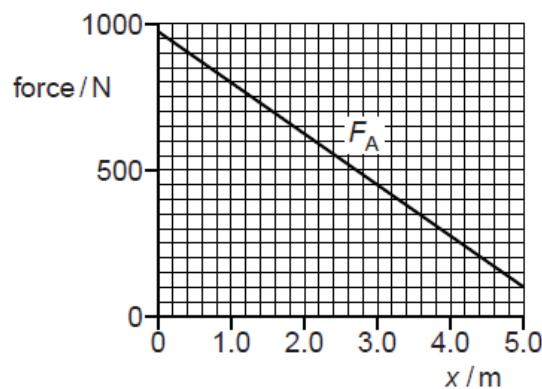


Fig. 2.2

On Fig. 2.2, sketch a graph to show the variation with  $x$  of the magnitude of force  $F_B$ . [2]

- 3 A student attempts to set up a “Rube Goldberg Machine”, which is a contraption consisting of a series of devices that perform simple tasks which are linked together to produce a domino effect, where the activation of one device triggers the next device in the sequence.

A part of the contraption is shown in Fig 3.1. It consists of a small block of mass 40 g, initially at rest, which slides down a rough slope from X to P. When the block reaches point P, it attains a speed of  $0.35 \text{ m s}^{-1}$ .

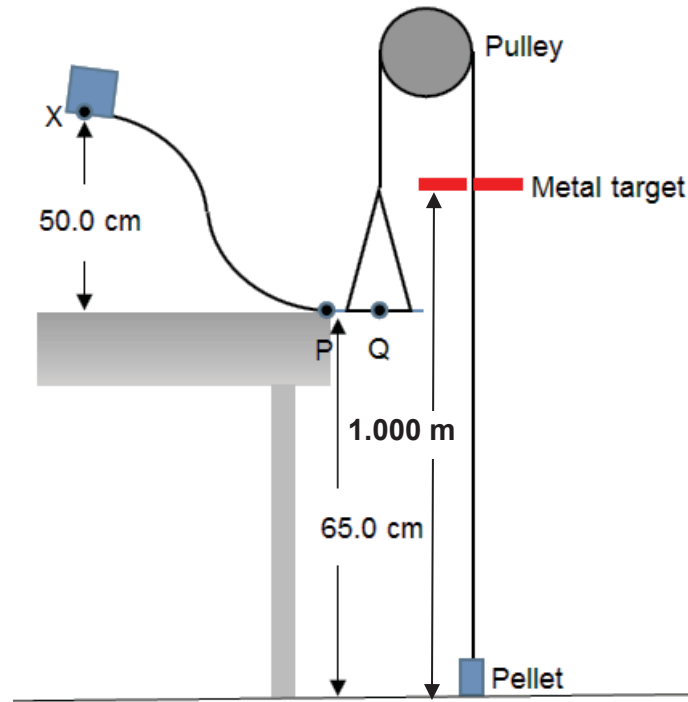


Fig. 3.1

- (a) Determine the work done against friction when the block slides from X to P.

work done = ..... J [2]

(b) At P, the block continues to slide forward a little and comes to a complete stop at point Q on a movable platform connected to a pulley. Its weight causes the pulley to turn and the block eventually hits the ground 65.0 cm below, lifting a small 15 g rectangular pellet from the ground in the process.

(i) Determine the speed of the pellet just as the 40 g block hits the ground.

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

(ii) The contraption is designed such that when the pellet hits a metal target during its upward motion, it will make a loud sound. The target is placed 1.000 m above the ground. State and explain whether the pellet will hit the target, showing your working clearly.

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

(iii) State an assumption you have made in your calculation in (ii).

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

- 4 A turntable is rotating at a constant speed of 15 revolutions per minute. A small five-cent coin of mass 1.56 g is placed at the rim of the turntable and it moves with the turntable without slipping.

(a) Show the angular velocity of the rotating coin is  $1.57 \text{ rad s}^{-1}$ . [1]

(b) Given that the kinetic energy of the coin is  $2.5 \times 10^{-5} \text{ J}$ , determine the radius of the turntable.

radius = ..... m [2]

(c) If the maximum friction between the coin and the turntable is 0.012 N, calculate the maximum number of complete revolutions that the turntable can make per minute, such that the coin can still remain on the turntable.

maximum number of revolutions per minute = .....  $\text{min}^{-1}$  [3]

(d) If the rotational speed of the turntable continues to increase, the coin is observed to slip off the turntable and fall to the ground. Describe the path of the coin after it leaves the turntable until it reaches the ground.

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

- 5 (a) In order to determine the internal resistance of a 12.00 V battery, a student sets up the circuit shown in Fig. 5.1. The rheostat CD has a maximum resistance of 1000  $\Omega$ .

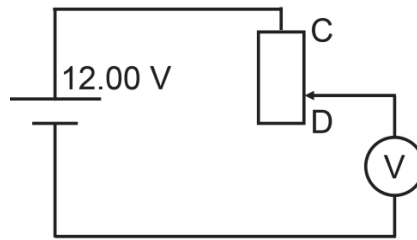


Fig. 5.1

When the sliding contact of the rheostat is placed at C, the voltmeter reading is 11.99 V. When the sliding contact moves from C to D, the voltmeter reading drops from 11.99 V to 11.00 V.

- (i) State the potential difference across the internal resistance of the battery when the sliding contact of the rheostat is placed at C.

potential difference = ..... V [1]

- (ii) Explain why the presence of internal resistance in the battery reduces its output power.

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

- (iii) Determine the internal resistance  $r$  of the battery and internal resistance  $R$  of the voltmeter.

$r =$  .....  $\Omega$

$R =$  .....  $\Omega$  [4]



- (b) In another circuit shown in Fig. 5.2, a uniform wire AB of length 80.0 cm and resistance  $1.5 \Omega$  is connected in series with a resistor of  $5.0 \Omega$  and a cell of e.m.f. 9.0 V with internal resistance  $1.0 \Omega$ .

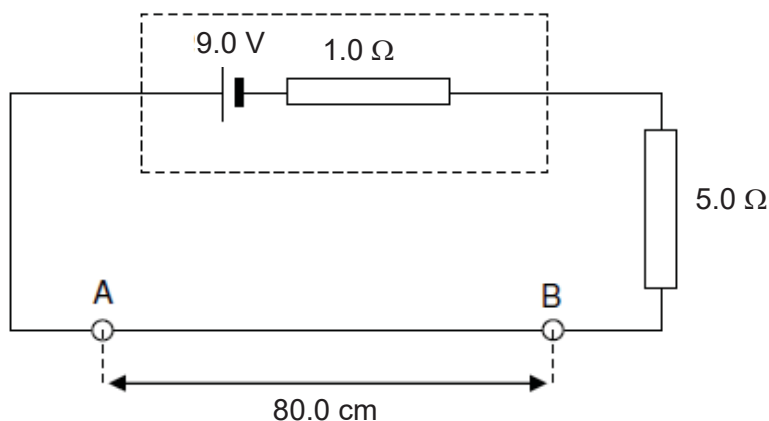


Fig. 5.2

- (i) Calculate the potential difference across wire AB.

potential difference = ..... V [2]

- (ii) A cell C of e.m.f. 1.5 V and internal resistance  $0.80 \Omega$  is connected to the circuit in Fig. 5.2, as shown in Fig. 5.3. The movable contact D can be connected to any point along wire AB.

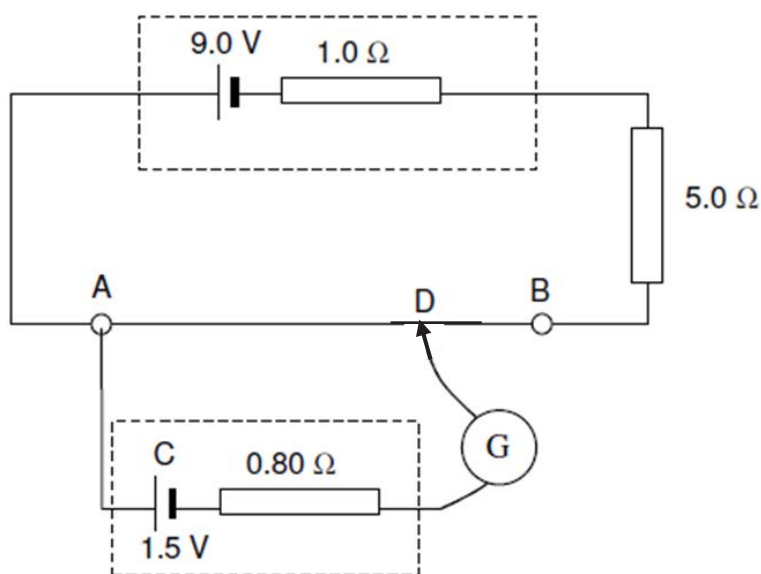


Fig. 5.3

Calculate the length of AD when there is zero current in the galvanometer.

length = ..... m [2]

6 (a) State in words the *first law of thermodynamics*.

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

(b) An adiabatic process is one in which no heat is supplied to or extracted from a system.

(i) Determine the change in the internal energy of an ideal gas when the gas does 600 J of work in an adiabatic process.

change in internal energy = ..... J [1]

(ii) Hence describe how the temperature of the gas in (i) will change at the end of the adiabatic process.

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

- (c) A heat pump is a device which works by changing the state of a gas through a cycle of operations such those shown in Fig. 6.1, changing the state of a sample of gas from A to B, then to C, and then to D, and eventually back to A.

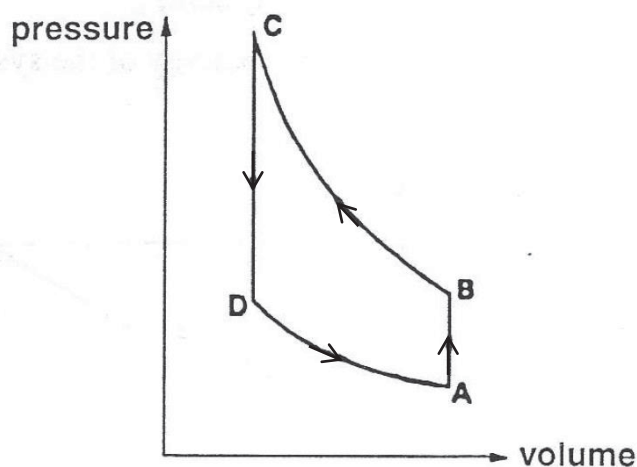


Fig. 6.1

Between A and B the gas absorbs heat from the atmosphere, and between C and D it delivers heat to the inside of a building. Processes BC and DA are adiabatic.

For a certain heat pump, the heat supplied to the gas during each part of the cycle and the corresponding work done on the gas are given in Fig. 6.2. The cycle is completed 20 times per second.

Section of cycle	Heat supplied to gas / J	Work done on gas / J
A → B	280	
B → C		
C → D	-400	
D → A		-70

Fig. 6.2

- (i) Fill in the blank spaces in Fig. 6.2. [2]
- (ii) Explain why the total change in the internal energy of the gas in the pump during a complete cycle must be zero.

.....

..... [1]

- (iii) Calculate the minimum average power of the motor required to run the pump.

minimum average power = ..... W[2]

- (iv) Calculate the average rate of supply of heat by the pump.

average rate of supply of heat = ..... W[2]

- 7 (a) Red and green light, of wavelengths 640 nm and 520 nm respectively, are simultaneously directed through a narrow slit onto a diffraction grating. The grating is at right angles to the light and has a line spacing of  $1.60 \mu\text{m}$ .

- (i) Complete Fig. 7.1 by calculating the values of all the angles of diffraction corresponding to different orders of maxima for both colours. [3]

order $n$	angle for red maximum / °	angle for green maximum / °
0		
1		
2		
3		

Fig. 7.1

- (ii) Sketch on Fig 7.2 the approximate pattern that would be seen on a screen behind the diffraction grating. Label the red and green maxima **R** and **G** respectively. [2]



central maximum

Fig. 7.2

- (iii) Suggest and explain how the spacing of the maxima drawn on Fig. 7.2 can be used to determine whether the light is directed normal to the grating.

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

- (iv) Explain why the same pattern will not be observed on the screen if the diffraction grating has irregularly spaced slits.

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

- (b) (i) The grating in (a) is replaced with a double-slit setup that has the same spacing between slits as the grating in (a). Describe how the new pattern produced will differ from the one drawn in (a)(ii).

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

- (ii) The grating in (a) is replaced with a single slit whose slit width has the same value as the slit spacing of the grating in (a). This produces another pattern. Determine the angle  $\theta$  between two lines, drawn from the centre of the slit to the central maximum and to the first order red minimum in the pattern respectively.

$$\theta = \dots\dots\dots \text{ rad [1]}$$

## Section B

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

- 8 (a) (i) Define *electric field strength*.

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

- (ii) With reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre.

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

- (b) Electrons 'leak' easily from the surface of many stars, so these stars acquire a positive charge. The charging stops when the charge on the star is so large that protons at the surface of the star also begin to be repelled.

This occurs when the sum of the gravitational potential energy and the electric potential energy of a proton at the surface of the star is zero. The star is then considered to be in steady state. It is assumed that each star takes on the shape of a sphere.

- (i) Write down an equation that relates the gravitational potential energy and the electric potential energy of a proton at the surface of a star that has just stopped charging, **defining clearly** all the symbols used in the equation.

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

- (ii) Show that, in the steady state, the maximum charge carried by a star of a given mass is independent of its radius. [1]

(iii) Calculate the maximum charge for Sun, which has a mass of  $2.0 \times 10^{30}$  kg.

maximum charge = ..... C [1]

(c) Two small solid metal spheres A and B have equal radii and are in a vacuum. Their centres are 15 cm apart. Sphere A has charge +3.0 pC and sphere B has charge +12 pC. The arrangement is illustrated in Fig. 8.1.

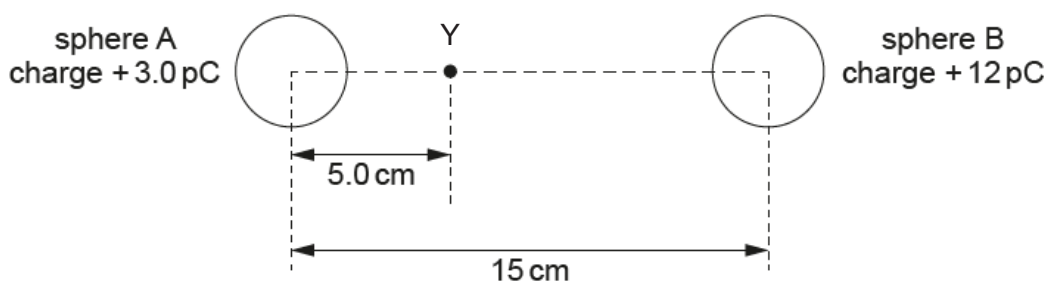


Fig. 8.1

Point Y lies on the line joining the centres of the spheres and is at a distance of 5.0 cm from the centre of sphere A.

(i) Explain why the electric field strength in both spheres is zero.

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

(ii) Show that the electric field strength is zero at point Y. Explain your working. [3]

- (iii) Explain how the electric field strength at point Y is related to the electric potential at that point.

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

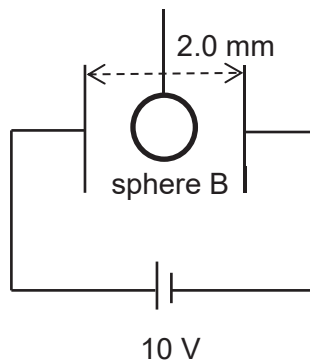
- (iv) Calculate the electric potential at point Y.

electric potential = ..... V [2]

- (v) A silver-107 nucleus ( ${}_{47}^{107}\text{Ag}$ ) has speed  $v$  when it is a long distance from point Y. Use your answer in (iv) to calculate the minimum value of  $v$  such that the nucleus can reach point Y.

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

- (d) Sphere B in Fig. 8.1 is removed and placed at the centre of two parallel, large metal plates which are connected to the terminals of a battery with e.m.f. 10 V, as shown in Fig. 8.2. The distance between the plates is 2.0 mm.



**Fig. 8.2**



- (i) Calculate the electric force  $F_1$  exerted by the plates on sphere B.

$$F_1 = \dots\dots\dots \text{ N [2]}$$

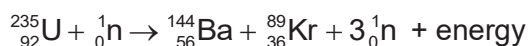
- (ii) Another conducting sphere C, which is initially uncharged and has a radius twice that of sphere B, is placed in contact with sphere B. Determine the new charge on sphere B after sphere C has been removed.

$$\text{new charge} = \dots\dots\dots \text{ C [2]}$$

- 9 In 1954 the world's first nuclear-powered submarine, the USS Nautilus, was launched. Before that, submarines used diesel-electric power. Enriched uranium, which consists of a high percentage of uranium-235 isotope ( ${}^{235}_{92}\text{U}$ ), was used as the source of fuel for USS Nautilus.

Naturally occurring uranium consists mainly of uranium-238 isotope ( ${}^{238}_{92}\text{U}$ ) and only 0.72% of it is made up of  ${}^{235}_{92}\text{U}$ . It can be enriched to increase the percentage of  ${}^{235}_{92}\text{U}$  by up to 90% so as to allow nuclear fission reaction to take place effectively.

- (a) In the nuclear reactor of the submarine, the process of nuclear fission is caused by the bombardment of  ${}^{235}_{92}\text{U}$  with a slow-moving neutron as described by the following equation:



- (i) Explain what is meant by the nuclear binding energy of a uranium-235 nucleus.

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

- (ii) Sketch the variation of average binding energy per nucleon with nucleon number on Fig 9.1. In your sketch, mark the relative positions of  ${}^{235}_{92}\text{U}$ , barium-144 ( ${}^{144}_{56}\text{Ba}$ ) and krypton-89 ( ${}^{89}_{36}\text{Kr}$ ). [2]

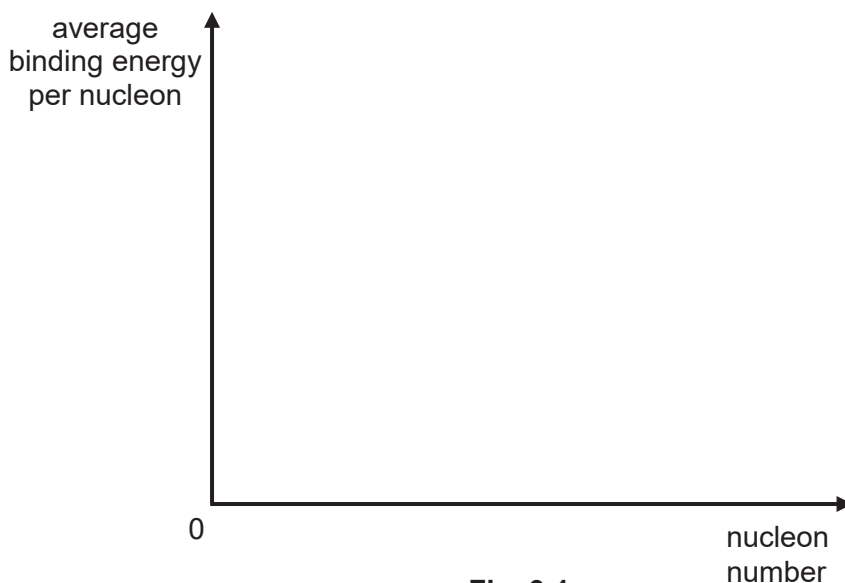


Fig. 9.1

- (iii) Using the concept of binding energy, explain why the fission of  ${}^{235}_{92}\text{U}$  into  ${}^{144}_{56}\text{Ba}$  and  ${}^{89}_{36}\text{Kr}$  results in a release of energy.

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

- (iv) The masses of some of the particles and nuclei involved in the reaction are given in Fig. 9.2.

	mass
${}_{92}^{235}\text{U}$	235.044 <i>u</i>
${}_{56}^{144}\text{Ba}$	143.923 <i>u</i>
${}_{36}^{89}\text{Kr}$	88.917 <i>u</i>
${}_0^1\text{n}$	1.009 <i>u</i>

**Fig. 9.2**

Calculate the energy released for one such fission reaction, to three significant figures.

energy released = ..... MeV [3]

- (v) When tested under laboratory conditions, the total kinetic energy of the products in the fission reaction was found to be 168 MeV. Suggest a reason for the difference (if any) between this value and your answer in (iv).

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

- (vi) The nuclear reactor used to power the USS Nautilus has a power output of 10 MW. The submarine is designed to carry enough nuclear fuel to power the submarine for 25 years.

Assuming the actual energy released per fission reaction is 168 MeV, calculate the mass of  ${}_{92}^{235}\text{U}$  that needs to be carried by USS Nautilus to achieve this.

mass of  ${}_{92}^{235}\text{U}$  = ..... kg [3]

- (vii) The fission reaction involving  ${}^{235}_{92}\text{U}$  is effective as it is a type of nuclear chain reaction. Suggest why the reaction is considered a *chain reaction*.

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

- (viii) State one advantage and one disadvantage in the use of nuclear power instead of diesel-electric power in providing energy for the submarine.

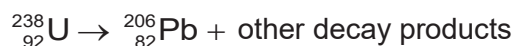
Advantage:

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

Disadvantage:

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

- (b) In a sample of naturally occurring uranium, the isotope  ${}^{238}_{92}\text{U}$ , which has a half-life of  $4.47 \times 10^9$  years, undergoes radioactive decay to form  ${}^{206}_{82}\text{Pb}$ .



- (i) Define *half-life*.

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

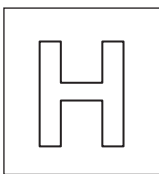
- (ii) Besides  ${}^{206}_{82}\text{Pb}$ , the other decay products formed consist of alpha and beta particles. Determine the number of alpha and beta particles formed when one  ${}^{238}_{92}\text{U}$  isotope decays to form  ${}^{206}_{82}\text{Pb}$ .

number of alpha particles = .....

number of beta particles = ..... [2]

- (iii) A sample of naturally occurring uranium contains 120 kg of  $^{238}_{92}\text{U}$  after some of the isotopes have decayed to  $^{206}_{82}\text{Pb}$ . Given that the original mass of  $^{238}_{92}\text{U}$  in the sample was 200 kg, determine the age of the sample.

age of sample = ..... years [2]



NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

CANDIDATE  
NAME

CLASS

TUTOR'S  
NAME

## PHYSICS

**9749/04**

Paper 4 Practical

**24 August 2017**

**2 hours 30 minutes**

Candidates answer on the Question Paper.

Additional Materials: Will be announced by invigilator

### READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, 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 the laboratory where appropriate in the boxes provided on the right.

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.

<b>Shift</b>
<b>Laboratory</b>

For Examiner's Use	
1	
2	
3	
4	
<b>Total</b>	

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

**[Turn over**

1 This investigation considers the size of the hole needed in a salt shaker for the salt to flow at a suitable rate.

(a) You have been provided with a beaker labelled **P** containing 100 g of salt as shown in Fig. 1.1.

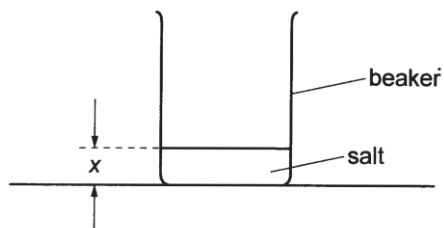


Fig. 1.1

(i) Measure and record the depth  $x$  of salt in beaker **P** using the vernier calipers.

$x = \dots\dots\dots$  [1]

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

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

(b) You have been provided with two cards. Each card has a hole of a different size.

(i) Measure and record the diameter  $d$  of the smaller hole.

$d = \dots\dots\dots$  [1]

(ii) Determine the area  $A$  of the smaller hole.

$A = \dots\dots\dots$  [1]

- (c) (i) Fill the boiling-tube, as shown in Fig. 1.2, with salt from beaker **P**.

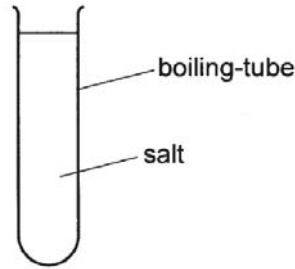


Fig. 1.2

- (ii) Cover the open end of the boiling-tube with the card that has the smaller hole.  
Use tape to attach the card to the boiling-tube.  
The hole should not be covered by tape. When the boiling-tube is inverted, it should not be possible for salt to leave the boiling-tube other than through the hole.
- (iii) Cover the hole with your finger.  
Invert the boiling-tube over the empty beaker **Q**.  
Remove your finger and allow the salt to flow through the hole into beaker **Q** for two minutes.  
It may be necessary to shake the boiling-tube gently to achieve constant flow.
- (iv) Tap beaker **Q** gently on the bench to ensure that the surface of the salt is level.  
Measure and record the depth  $y$  of salt in beaker **Q**.

$y =$  .....

- (v) Estimate the mass  $m$  of salt in beaker **Q**.

$m =$  ..... [1]



4

- (d) The recommended daily intake of salt for an adult is 5 g.

Use your data to calculate the time that a shaker, with a hole the same size as that in (c)(ii), should be inverted to apply 5 g of salt to food.

time = ..... [1]

- (e) It is suggested that the rate of flow  $R$  of salt is proportional to the area  $A$  of the hole.

Use the card with the larger hole to take further measurements to investigate this suggestion. State and explain whether or not you agree with this suggestion. Present your measurements and calculated results clearly.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [6]

(f) A statement found on the internet says that:

*"The salt shaker may be distinguished primarily by the size of the holes, and then by the number of holes. Salt is coarser than pepper, and needs the larger hole. It is also heavier and flows much more freely than pepper, accordingly there are often fewer holes on the salt shaker to help control the flow. However there is no manufacturing standard."*

Suggest changes that could be made to the salt investigation to study the flow of pepper from a shaker.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 15 marks]

You may not need to use all of the materials provided.

2 In this question you will investigate how the light detected by a light-dependent resistor (LDR) depends on the thickness of an absorber.

- (a) (i) Connect the circuit shown in Fig. 2.1. The light-emitting diode (LED) should be connected the right way round so that light is emitted.

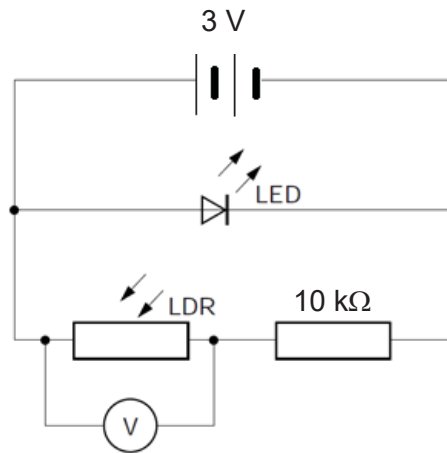


Fig. 2.1

- (ii) Use the black paper and the Sellotape to make a cylinder of length 4 cm. The cylinder should fit neatly over the LDR.
- (iii) Cut the cylinder in half so that you have two cylinders of length 2 cm.
- (iv) Tape one cylinder over the LDR and the other cylinder over the LED as shown in Fig. 2.2.

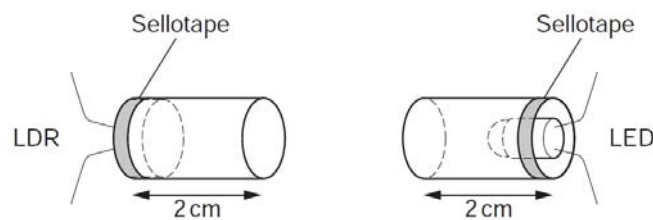


Fig. 2.2

- (b) Place the cylinders together, as shown in Fig. 2.3. Record the voltmeter reading  $V_0$ .

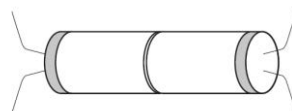


Fig. 2.3

$V_0 = \dots\dots\dots$  [1]

- (c) Fold the sheet of tracing paper in half four times so that you have 16 layers.
  - (i) Measure the thickness of these 16 layers.

thickness of 16 layers = ..... [1]

- (ii) Estimate the percentage uncertainty in this measurement. Show your working.

percentage uncertainty = ..... [1]

- (iii) Determine the thickness  $t$  of one layer of tracing paper.

$t =$  ..... [1]

- (iv) Justify the number of significant figures you have given for  $t$ .

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

- (d) (i) Place four layers of tracing paper between the LED and the LDR as shown in Fig. 2.4. Record the voltmeter reading  $V$ .

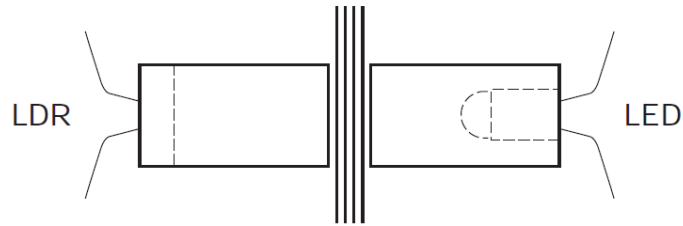


Fig. 2.4

$V =$  .....

- (ii) Repeat (d)(i) using eight layers of tracing paper.

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

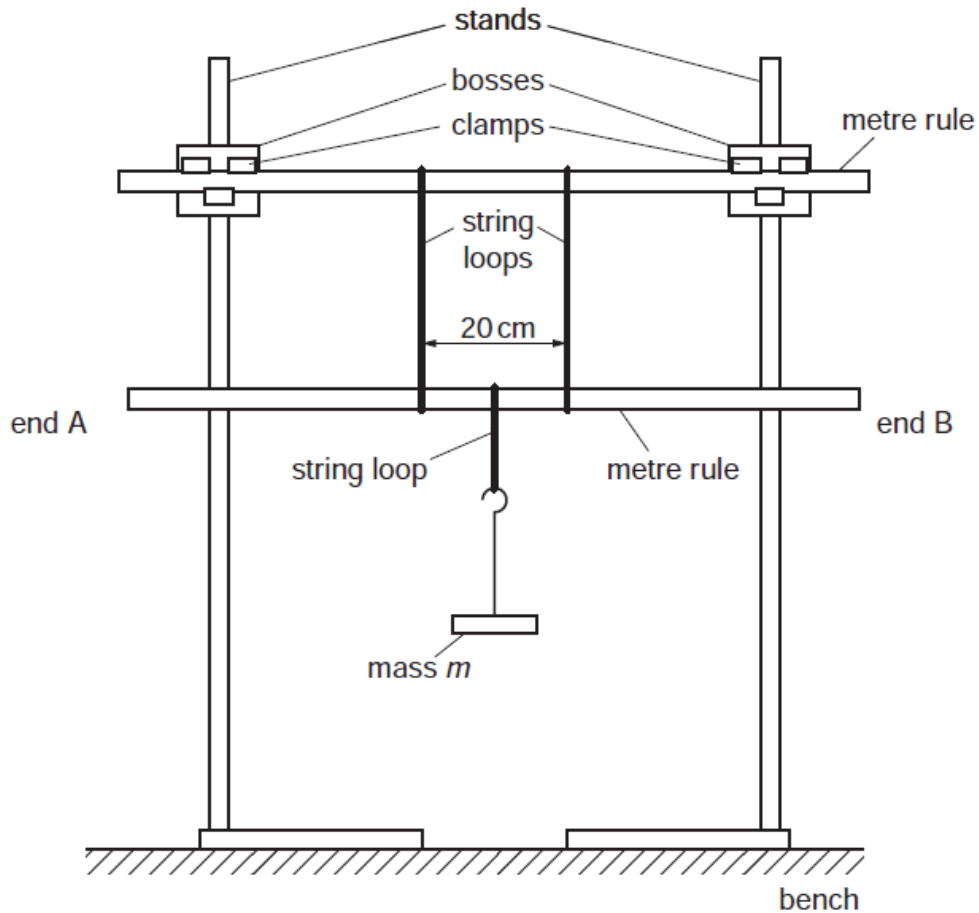
- (e) Explain whether your results support the idea that  $V - V_0$  is proportional to the number of layers  $n$  of tracing paper.

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

[Total: 8 marks]

**You may not need to use all of the materials provided.**

- 3 In this experiment, you will investigate how the motion of an oscillating system depends on the mass attached to the system.
- (a) (i) Set up the apparatus as shown in Fig. 3.1.



**Fig. 3.1**

Slide the two loops of string onto a rule and fix this rule in the clamps.

Adjust the clamps until the rule is parallel to the bench.

Using the string provided, make a loop of circumference 20 cm. Slide this shorter loop onto the second rule and use the longer loops to support this second rule.

Both rules should have their markings facing you. The strings should be vertical, 20 cm apart and at equal distances from the centre of the second rule.

Use the shorter loop of string to suspend a mass  $m$  at the 50 cm mark on the second rule, where  $m = 0.500$  kg.

- (ii)** Move the end A of the lower rule towards you and the end B away from you.  
Release the rule and watch the movement.  
End A will move away from you and back towards you, completing a swing.  
The time taken for one complete swing is  $T$ .  
Determine an accurate value for  $T$ .

$T = \dots\dots\dots$  [1]

- (b)** Change  $m$  and repeat **(a)(ii)** until you have six sets of values of  $m$  and  $T$ .

[7]

- (c) The quantities  $m$  and  $T$  are related by the equation

$$\frac{1}{T^2} = P m + Q$$

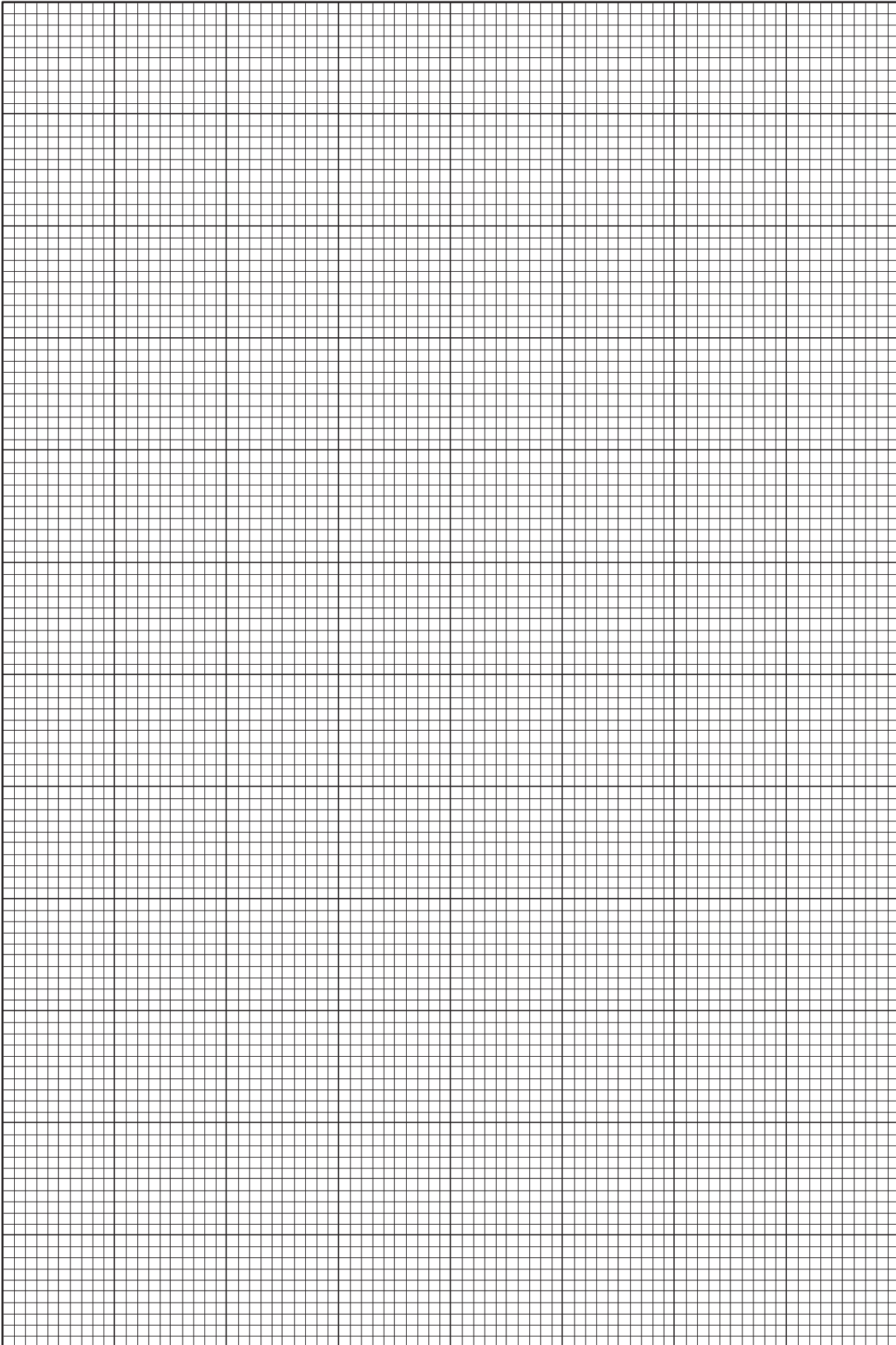
where  $P$  and  $Q$  are constants.

Plot a suitable graph to determine the values of  $P$  and  $Q$ .

$P =$  .....

$Q =$  ..... [4]





[3]

(d) Comment on any anomalous data or results that you may have obtained.

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

(e) State two significant sources of errors in this experiment.

1 .....  
.....  
.....  
2 .....  
.....  
..... [2]

(f) Suggest improvements that could be made to the experiment to address the sources of error identified in (e). You may suggest the use of other apparatus or different procedures.

1 .....  
.....  
.....  
2 .....  
.....  
..... [2]

[Total: 20 marks]

- 4 A student is investigating the motion of magnets falling through a vertical copper pipe as shown in Fig. 4.1.

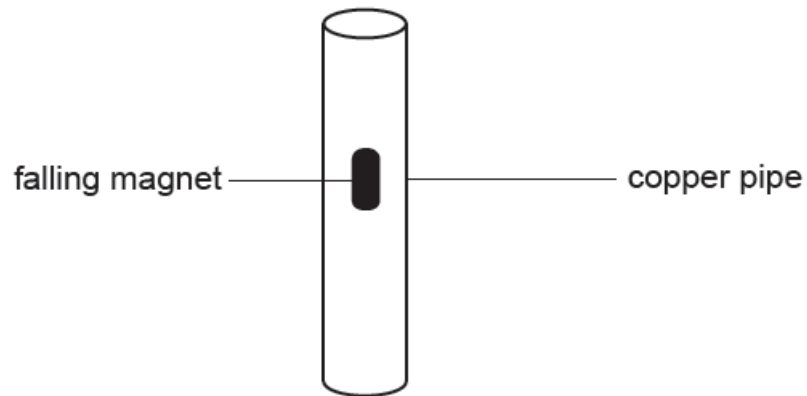


Fig. 4.1

The student releases a magnet above the copper pipe. The magnet has speed  $v$  as it leaves the pipe.

It is suggested that the relationship between  $v$  and  $B$  is

$$v = v_0 e^{-\lambda B}$$

where  $B$  is the magnetic flux density at the poles of the magnet and  $v_0$  and  $\lambda$  are constants.

Design a laboratory experiment to test the relationship between  $v$  and  $B$ . Explain how your results could be used to determine values of  $v_0$  and  $\lambda$ . You should draw a diagram, showing the arrangement of your equipment. In your account you should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any safety precautions to be taken.

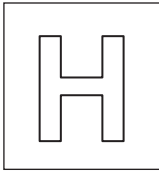
### Diagram











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**PHYSICS**

**9749/01**

Paper 1 Multiple Choice

**26 September 2017**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

---

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

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

Write your name, class and tutor's name 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.



**Data**

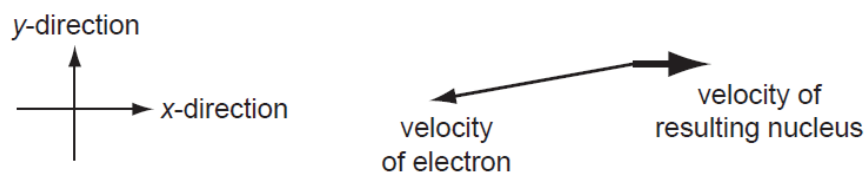
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

**Formulae**

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



- 3 A stationary nucleus undergoes beta-decay. The diagram below shows the velocities of the resulting nucleus and the emitted electron.



How does the diagram support the idea that a unseen third particle is also emitted?

- A If there were only two particles involved, their velocities should be equal and opposite.
- B It is clear that linear momentum is not conserved in the x-direction.
- C Something must carry away the extra energy.
- D The linear momentum of the original nucleus has no y-component.

Ans: **D**

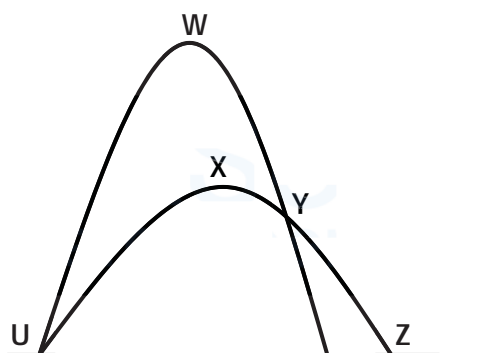
A is incorrect; their MOMENTA would be equal and opposite. The velocity of the electron would be expected to be higher than that of the resulting nucleus, as the mass of an electron is very much smaller than that of a nucleon.

B is incorrect; momentum is the product of mass and velocity. Only velocity is shown in the diagram.

C is incorrect; the concept of energy cannot be shown on a vector diagram.

D is correct; the original nucleus was stationary thus had no y-component of linear momentum. The electron has a y-component for its momentum but the resulting nucleus does not have a y-component for its momentum. The total momentum after the decay must be zero thus there must be a third particle.

- 4 The paths of two identical projectiles, fired with the same initial speed but with different launch angles, are shown below. Which of the following statements is true?



- A** The kinetic energies of both projectiles are the same at Y if there is no air resistance.
- B** The potential energy of the projectile at W is lower than the potential energy of the projectile at X.
- C** The kinetic energy of the projectile at W and the kinetic energy of the projectile at X are both zero.
- D** The kinetic energy of the projectile at W is higher than the kinetic energy of the projectile at X.

Ans: **A**

Using conservation of energy, with same initial KE, at D where the GPE is the same, they must have the same KE.

- 5** A tractor of mass 1000 kg pulls a trailer of mass 1000 kg via a tow-bar. The total resistance to motion has a constant value of 4000 N. One quarter of this resistance acts on the trailer. At first the acceleration of the tractor and trailer is  $2.0 \text{ m s}^{-2}$  but eventually they move at a constant speed of  $6.0 \text{ m s}^{-1}$ .

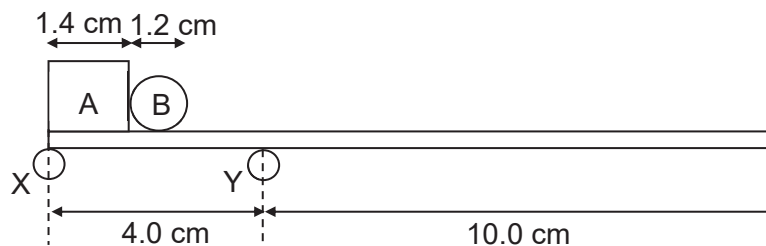
What is the force exerted on the tractor by the tow-bar when the acceleration of the tractor and trailer is  $2.0 \text{ m s}^{-2}$ ?

- A** 1000 N      **B** 3000 N      **C** 5000 N      **D** 8000 N

Ans: **B**

For the trailer,  $\Sigma F = ma$   
 Tensile force  $- 1000 = 1000 (2.0)$   
 Tensile force =  $2000 + 1000 = 3000 \text{ N}$

- 6** A beam of negligible mass is supported by two rods X and Y. Block A of mass 200 g and ball B of mass 100 g rest on the beam as shown. Both A and B have uniform density.



If ball B were to start rolling to the right, what is the distance it would have moved before the beam just loses contact with rod X? Assume that there is negligible friction.

- A** 6.6 cm      **B** 8.0 cm      **C** 8.6 cm      **D** 9.4 cm

Ans: **C**

For losing contact, taking moments about pivot at Y,  
 Clockwise moment = anticlockwise moment  
 $(0.100)(g)x = (0.200)(g)(3.3 \text{ cm})$   
 $x = 6.6 \text{ cm. (from Y)}$   
 distance moved =  $10.6 - 2.0 = 8.6 \text{ cm}$

- 7 A submarine descends vertically at a constant velocity. The three forces acting on the submarine are viscous drag, upthrust and weight. Which of the following relationships between the magnitudes of these three forces is correct?

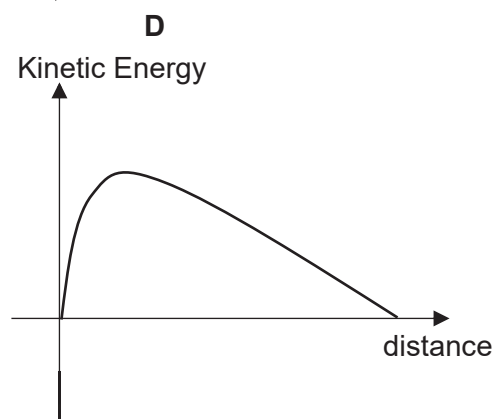
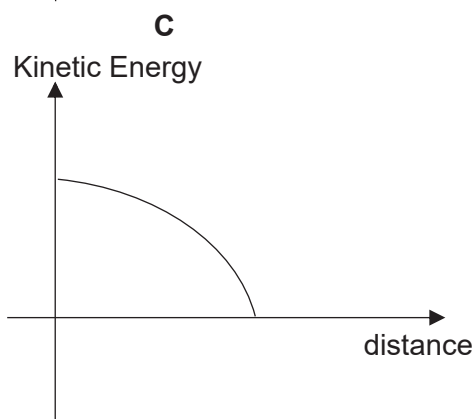
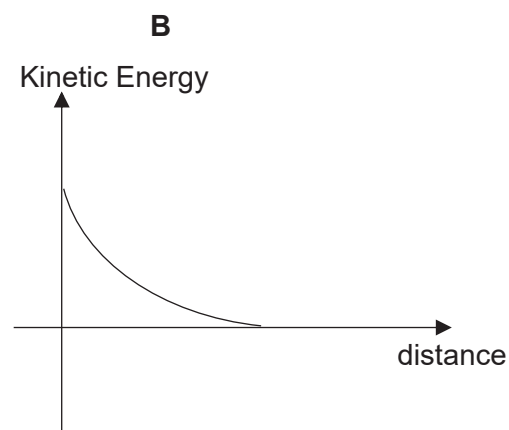
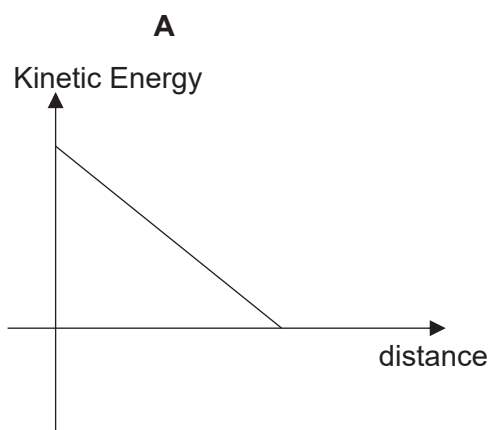
- A weight < drag  
 B weight = drag  
 C weight < upthrust  
 D weight > upthrust

Ans: **D**

Submarine is descending, so  $\Sigma F = W - U - D = 0$  (downwards positive)

A to C options are not possible.

- 8 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 distance travelled by the block after its point of projection?



Ans: **A**

$$\text{Kinetic energy} = \frac{1}{2} mv^2$$

$$\text{Consider } v^2 = u^2 + 2as$$

In this case  $a = g \sin \theta$ , which is a constant, and in opposite direction to initial velocity (up-slope)

$$v^2 = u^2 - 2(g \sin \theta)s$$

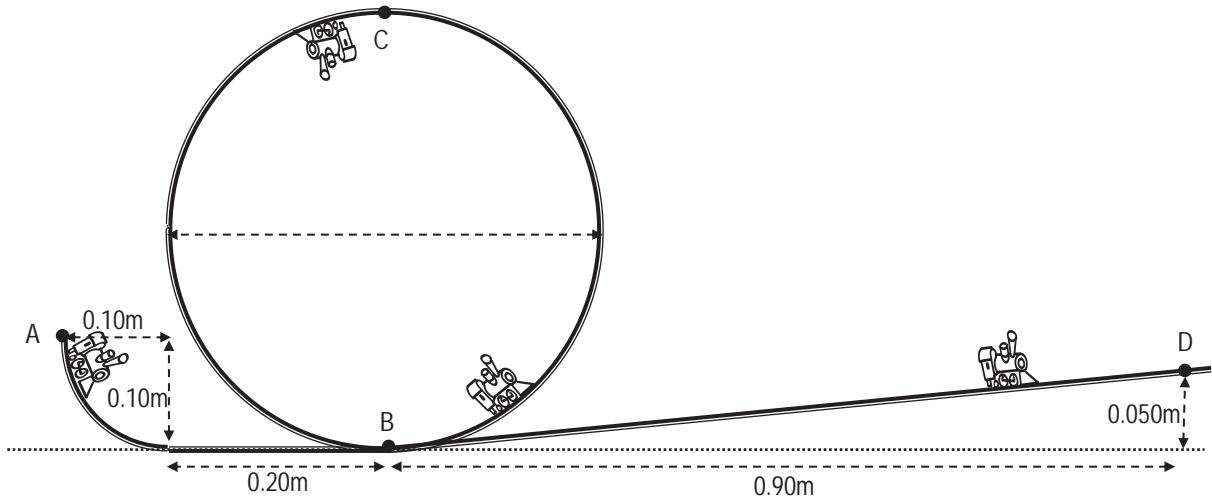
$$\frac{1}{2} m v^2 = -m(g \sin \theta)s + \frac{1}{2} m u^2$$

Hence

$$\text{Kinetic energy} = -m(g \sin \theta)s + \frac{1}{2} m u^2$$

Which is a straight line graph with negative gradient and a positive y-intercept.

- 9 A toy train of mass  $m$  passes point **A** of the track with velocity  $v$ . What is the minimum value of  $v$  such that the train will travel up the loop of radius  $0.20\text{ m}$  via points **B**, then **C** and eventually reach point **D**? You may ignore resistive forces in your calculation.



- A**  $1.0\text{ m s}^{-1}$       **B**  $1.4\text{ m s}^{-1}$       **C**  $2.4\text{ m s}^{-1}$       **D**  $2.8\text{ m s}^{-1}$

Ans: **D**

In order to reach D, train must at least have enough energy to reach the highest point C with min K.E to remain in contact with the loop. Therefore K.E initially required to have at A would be the additional P.E. +  $\frac{1}{2} m v_C^2$  needed.

$$mg(h_C - h_A) + \frac{1}{2} m v_C^2 = \frac{1}{2} m v_A^2$$

$$\frac{mv_C^2}{R} = mg$$

$$v_A = 2.8\text{ ms}^{-1}$$

- 10 What is the speed of a geostationary satellite that is orbiting Earth? The mass of Earth is taken to be  $6.0 \times 10^{24}\text{ kg}$ .

- A**  $3.08 \times 10^3\text{ m s}^{-1}$     **B**  $4.71 \times 10^4\text{ m s}^{-1}$     **C**  $1.80 \times 10^5\text{ m s}^{-1}$     **D**  $4.23 \times 10^7\text{ m s}^{-1}$

Ans: **A**

$$\frac{GM_E m}{r_A^2} = \frac{mv^2}{r_A}$$

$$v^2 = \frac{GM_E}{r_A}$$

And since  $v = r \frac{2\pi}{T}$

$$\frac{1}{r} = \frac{2\pi}{vT}$$

Therefore, 
$$v^3 = \frac{GM_E 2\pi}{T}$$
  

$$v = 3080\text{ m s}^{-1}$$

- 11 A ball which is thrown upward near the surface of Earth with velocity  $v$  will come to rest five seconds later. If the ball were to be thrown upward with the same velocity  $v$  on Planet X, it would still be moving upward at  $31 \text{ m s}^{-1}$  after five seconds.

What is the ratio  $\frac{\text{gravitational field strength near surface of Planet X}}{\text{gravitational field strength near surface of Earth}}$  ?

- A 0.16                      B 0.37                      C 0.53                      D 0.63

Ans: B

On earth,  $v = u + g_e t$

$$u = 49.05 \text{ ms}^{-1}$$

With the same speed,

On planet,  $v = u + g_p t$

$$g_p = 3.61 \text{ ms}^{-2}$$

ratio will be 0.37

- 12 Which of the following statements is *not true* for an oscillating body when light damping is present?
- A The damping force is always in the opposite direction to the velocity of the body.
- B The damping force is always in the opposite direction to the acceleration of the body.
- C The presence of light damping changes the period of oscillation.
- D The presence of light damping changes the maximum potential energy of the body.

Ans: B

A and D is true. C is true only for some cases and hence not true for some cases. As C is not *not true* for all cases it is not the answer. B is always not true because the damping force can be in the same direction as the acceleration of the body.

- 13 A fixed mass of ideal gas in a thermally insulated container is compressed. After compression, the temperature of the gas would have
- A fallen, since more molecules bombard the container so they must be moving slower.
- B fallen, since the molecules collide more frequently with each other so their average speed is slower.
- C remained constant if the compression is very slow.
- D risen, since doing work on the gas increases the kinetic energy of the gas molecules.

Ans: D

- 14 Two vessels X and Y, of volumes  $V_X$  and  $V_Y$  respectively, are kept at temperatures  $T_X$  and  $T_Y$ . They are filled with the same ideal gas and are connected via a narrow tube.

What is the ratio  $\frac{\text{number of molecules in X}}{\text{number of molecules in Y}}$ ?

A  $\frac{T_X V_X}{T_Y V_Y}$

B  $\frac{T_X V_Y}{T_Y V_X}$

C  $\frac{T_Y V_Y}{T_X V_X}$

D  $\frac{T_Y V_X}{T_X V_Y}$

Ans: D

For ideal gas,  $pV = nRT$

$$n = \frac{pV}{RT}$$

since X and Y are filled with the same gas

$$\frac{\text{number of molecules in X}}{\text{number of molecules in Y}} = \frac{\text{number of moles of gas in X}}{\text{number of moles of gas in Y}}$$

$$\begin{aligned} & \frac{p_X V_X}{RT_X} \\ &= \frac{p_Y V_Y}{RT_Y} \end{aligned}$$

$$\begin{aligned} &= \frac{V_X}{V_Y} \frac{T_Y}{T_X} \quad \text{since the pressure of both containers is the same} \end{aligned}$$

$$= \frac{T_Y V_X}{T_X V_Y}$$

- 15 A potential difference is applied between the electrodes of a gas discharge tube of area  $1.3 \times 10^{-3} \text{ m}^2$  so that the gas is ionised into positively charged particles and electrons.

The gas carries a current of 12.2 mA and the number of electrons passing any point in the gas per unit time is  $2.54 \times 10^{16} \text{ s}^{-1}$ . Given that the charge on each positively charged particle is  $3.20 \times 10^{-19} \text{ C}$  and the number of the positively charged particles per unit volume is  $1.0 \times 10^{19} \text{ m}^{-3}$ , what is the drift velocity of these positively charged particles in the gas?

A  $0.98 \text{ m s}^{-1}$

B  $1.96 \text{ m s}^{-1}$

C  $3.91 \text{ m s}^{-1}$

D  $7.82 \text{ m s}^{-1}$

Ans: B

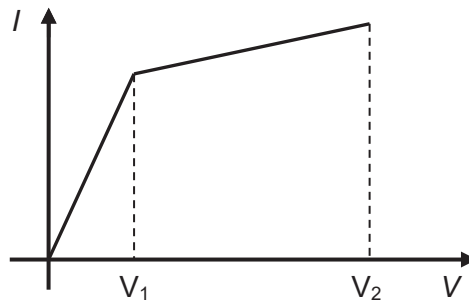
$$I = \frac{Nq_-}{t} + nAq_+v$$

$$12.2 \times 10^{-3} = 2.54 \times 10^{16} \times 1.6 \times 10^{-19} + 10^{19} \times 1.3 \times 10^{-3} \times 3.2 \times 10^{-19}v$$

$$v = 1.96 \text{ m s}^{-1}$$



- 16 The graph below shows the variation of current  $I$  through an electrical component with the potential difference  $V$  across the component.



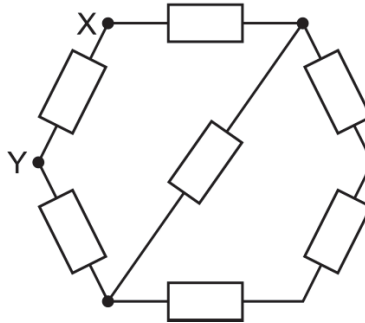
The resistance of the component is

- A** constant from 0 to  $V_1$ , then increases to another constant from  $V_1$  to  $V_2$ .  
**B** constant from 0 to  $V_1$ , then decreases to another constant from  $V_1$  to  $V_2$ .  
**C** constant from 0 to  $V_1$ , then decreases continuously from  $V_1$  to  $V_2$ .  
**D** constant from 0 to  $V_1$ , then increases continuously from  $V_1$  to  $V_2$ .

Ans: **D**

From  $V_1$  to  $V_2$ , the ratio  $I/V$  decreases. Since  $R = V/I$ , the resistance increases.

- 17 The diagram shows a network of 7 resistors, each with resistance  $R$ .



What is the resistance between points X and Y?

- A**  $\frac{2}{3}R$       **B**  $\frac{3}{5}R$       **C**  $\frac{7}{11}R$       **D**  $\frac{11}{15}R$

Ans: **D**

$$(R_{XY})^{-1} = \left( R + \frac{3R \times R}{3R + R} + R \right)^{-1} + R^{-1}$$

$$R_{XY} = \frac{11}{15}R$$

- 18 In a transverse progressive wave with a period of 0.060 s, the least distance between two adjacent points which have a phase difference of  $90^\circ$  is 0.20 m. What is the time taken for the wave to travel a distance of 4.00 m?

A 0.30 s                      B 0.60 s                      C 1.20 s                      D 1.50 s

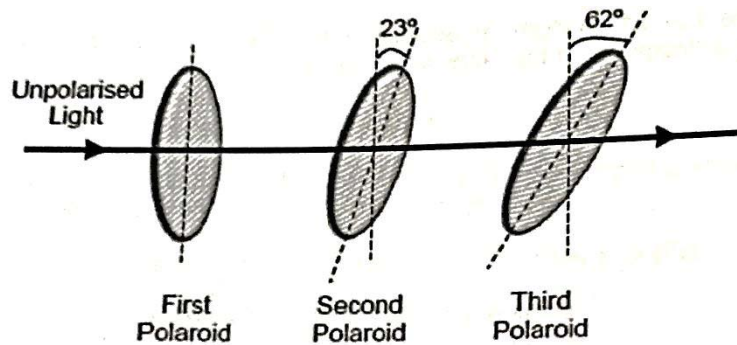
Ans: A

The wavelength of the progressive wave is  $4 \times 0.20 = 0.80$  m

$$\text{Speed of the wave} = \frac{\lambda}{T} = \frac{0.80}{0.060} = 13.3 \text{ m s}^{-1}$$

$$\text{Time taken to travel 4.00m} = \frac{4.00}{13.3} = 0.30 \text{ s}$$

- 19 Light is polarised when it passes through a sheet material known as a polaroid. Three polaroids are stacked, with the polarising axis of the second and third polaroids at  $23^\circ$  and  $62^\circ$  respectively to that of the first polaroid, as shown in the diagram below.



When unpolarised light of amplitude  $A_0$  is incident on the stack of polaroids, its amplitude after passing through the first polaroid is  $A_1$ , and becomes  $A_2$  after it passes through the second polaroid, and subsequently  $A_3$  after it passes through the third polaroid. What is the value of  $\frac{A_3}{A_1}$ ?

A 0.25                      B 0.31                      C 0.43                      D 0.72

Ans: D

By Malus Law,

$$A_3 = [\cos (62^\circ - 23^\circ)] \times \cos 23^\circ \times A_1 = 0.72 A_1$$

- 20 A space shuttle orbits at a height of 330 km above the surface of the Earth. It carries two panels separated by a distance of 24 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.

The observer views the panels with a telescope that has an aperture diameter of 85 mm. Assume that the panels act as point sources of light for the observer. Which of the following is correct?

	Will the two images seen by the observer be resolved?	Angular separation of two sources as measured from aperture / rad
<b>A</b>	Yes	$5.9 \times 10^{-6}$
<b>B</b>	Yes	$7.3 \times 10^{-5}$
<b>C</b>	No	$5.9 \times 10^{-6}$
<b>D</b>	No	$7.3 \times 10^{-5}$

Ans: **B**

$$S=r\theta$$

$$\theta = s/r = 24/330\,000 = 7.3 \times 10^{-5}$$

$$\text{Min resolution} = \lambda/b = 5.9 \times 10^{-6} \text{ rad}$$

- 21 A single slit that is 1.0 mm wide is illuminated by light which has a wavelength of 450 nm. What is the width of the central maximum in the diffraction pattern produced on a screen 5.0 m away?

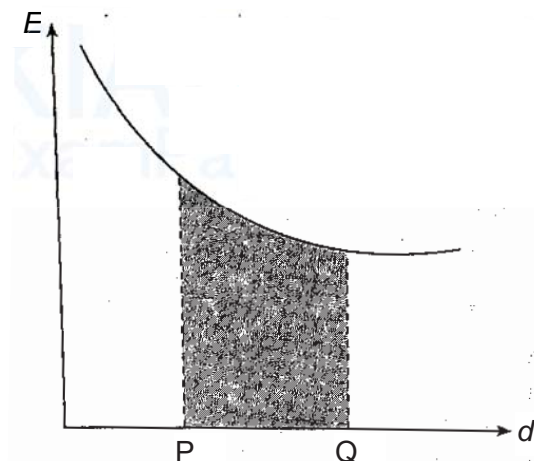
**A** 1.1 mm      **B** 2.2 mm      **C** 4.5 mm      **D** 7.2 mm

Ans: **C**

$$\sin\theta = \lambda/b$$

$$s = 2r\theta = 4.5 \text{ mm}$$

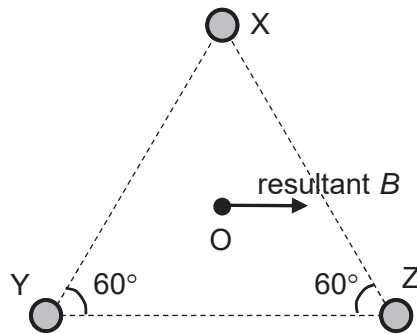
- 22 The graph below shows the variation of the electric field strength  $E$  with distance  $d$  along a straight line in an electric field. What does the shaded area under the curve between P and Q represent?



- A The work done by the electric field to move a charge from P to Q.
- B The total charge that moves between P and Q.
- C The power dissipated when moving a unit charge from P to Q.
- D The potential difference between P and Q.

Ans: D

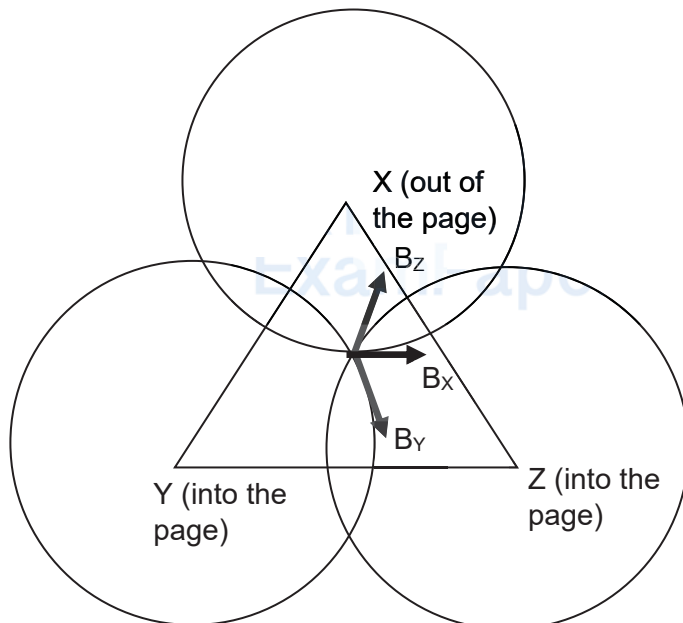
- 23 Three parallel conductors, all carrying currents of the same magnitude, pass vertically through the three corners X, Y and Z of a horizontal equilateral triangle as shown in the diagram below. A resultant magnetic flux density  $B$  acts at the centre O of the triangle, in the direction as shown below. What must be the directions of the currents in X, Y and Z?



	Into the page	Out of the page
A	X	Y and Z
B	Z	X and Y
C	Y and Z	X
D	X, Y and Z	None

Ans: C

For the resultant flux density at O to be as shown, the directions of  $B_x$ ,  $B_y$  and  $B_z$  must be as shown in diagram below. Using the Right Hand Grip Rule, the corresponding direction of current can be found.

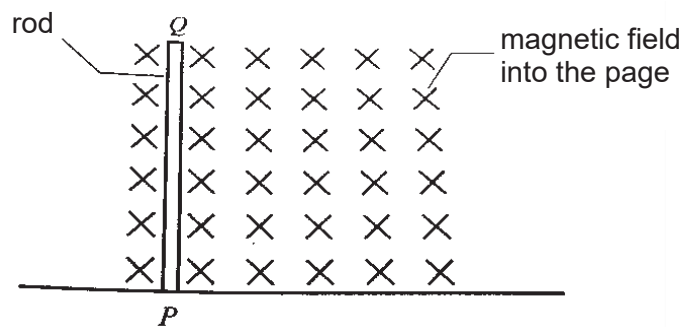


- 24 An electron moves along the axis of a solenoid carrying current. Which of the following is a correct statement about the electromagnetic force acting on the electron?
- A No force acts.
  - B The force acts in the direction of motion.
  - C The force acts against the direction of motion.
  - D The force acts radially outward towards the solenoid.

Ans: A

Since the magnetic flux density acts along the same axis as the current, no electromagnetic force will be experienced by the electron.

- 25 A vertical rod PQ is hinged to a flat surface at the end P and placed in a uniform magnetic field that acts into the page, as shown in the diagram. When the rod is lightly pushed to the right at the end Q, it swings downwards while still hinged at P.



Just before the end Q hits the flat surface, which of the following statements is correct?

- A Q is at a higher electrical potential than P.
- B An upward magnetic force acts on the rod.
- C An induced current flows to Q from P
- D The rod rotates clockwise with a constant angular speed.

Ans: A

By Fleming's left hand rule, the electrons in the rod will accumulate at P, causing Q to be of higher electrical potential.

- 26 A steady current  $I$  dissipates a certain power in a variable resistor, set at  $12\ \Omega$ . To dissipate the same power when a sinusoidal alternating current is used, the resistor has to be set at  $3\ \Omega$ . What is the r.m.s. value of the alternating current?

- A  $\frac{1}{\sqrt{2}} I$
- B  $I$
- C  $\sqrt{2} I$
- D  $2 I$

Ans: D

$$I^2(12) = I_{\text{rms}}^2(3)$$

$$\Rightarrow I_{\text{rms}} = 2I$$

- 27 The four energy levels of the hydrogen atom and their corresponding energy values are

Level	Energy / eV
P	-13.60
Q	-3.40
R	-1.50
S	-0.85

A spectral line of 488 nm could result from an electron transition between levels

- A** Q and P      **B** R and P      **C** R and Q      **D** S and Q

Ans: **D**

Energy released during electron transition

$$= \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^8)}{488 \times 10^{-9}} = 4.08 \times 10^{-19} \text{ J} = 2.55 \text{ eV}$$

- 28 What is the wavelength of a beam of electrons accelerated through a potential difference of 5200 V?

- A**  $1.7 \times 10^{-11} \text{ m}$       **B**  $2.4 \times 10^{-10} \text{ m}$       **C**  $1.4 \times 10^{-7} \text{ m}$       **D**  $2.8 \times 10^{-6} \text{ m}$

Ans: **A**

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

$$v = \sqrt{\frac{2eV}{m}}$$

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

$$= \frac{h}{\sqrt{2emV}} = \frac{6.63 \times 10^{-34}}{\sqrt{2(1.60 \times 10^{-19})(9.11 \times 10^{-31})(5200)}} = 1.7 \times 10^{-11} \text{ m}$$

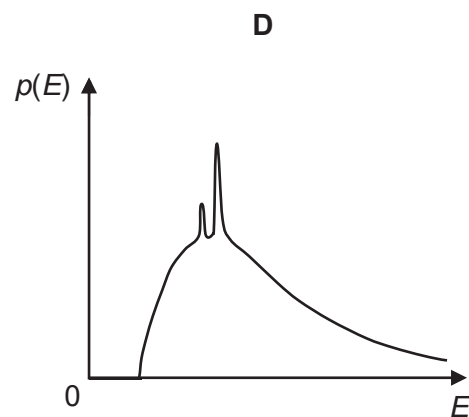
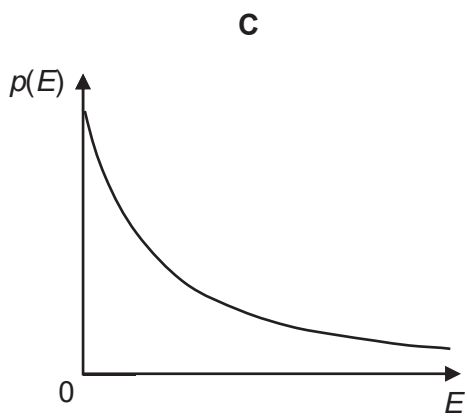
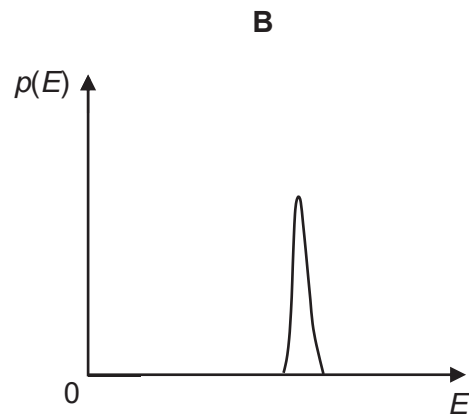
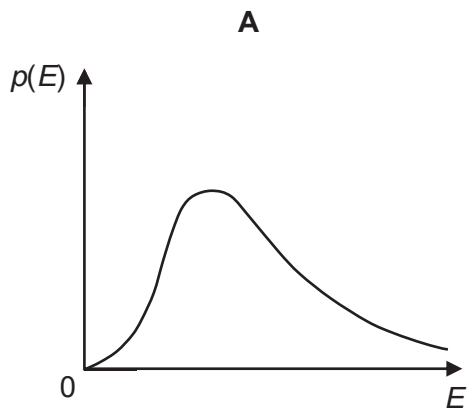
- 29 The deviation of alpha particles by thin metal foils through angles ranging from  $0^\circ$  to  $180^\circ$  can be explained by

- A** random motion of alpha particles.  
**B** diffraction of the alpha particles through the metal due to the wave properties of the alpha particles.  
**C** scattering by small but heavy regions of positive charges.  
**D** scattering by the free electrons in the metal foils.

Ans: **C**

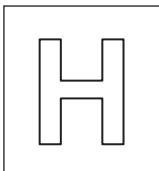
This is the observation from Rutherford's alpha particle scattering experiment.

- 30 Which of the following graphs could represent  $p(E)$ , the distribution of the energies  $E$  of alpha particles that are emitted from a given source?



Ans: **B**

The alpha particles emitted from a given source should have a specific value of energy.



NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

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## PHYSICS

**9749/02**

Paper 2 Structured Questions

**18 September 2017**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required

### READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
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<b>Total</b>	

This document consists of **19** printed pages.

**[Turn over**



**Data**

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

**Formulae**

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

- 1 (a) State how force is related to linear momentum.

**Force** is defined as the rate of change of momentum of the body, and the force acts in the direction of the change in momentum.

[2]

- (b) In a laboratory experiment a small metal cylinder containing liquid carbon dioxide is attached to a trolley as shown in Fig 1.1. The trolley is initially at rest. When the cylinder is punctured, carbon dioxide gas rushes out and the trolley accelerates.

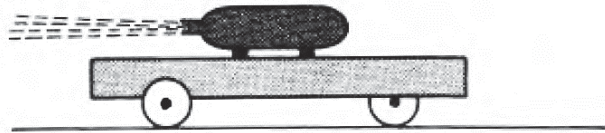


Fig. 1.1

- (i) Using Newton's laws of motion, explain the origin of the force that is accelerating the trolley.

N2L: The cylinder exerts a force on the gas, equal to the rate of change of momentum of the gas (The gas rushes out of the cylinder/the cylinder pushes the gas out)

N3L, the gas exerts an equal force on the gas, in the direction opposite that of the escaping gas, causing a forward force on the cylinder – trolley system

N2L: The forward force on the cylinder – trolley system causes its momentum [3]

to change (it will accelerate) OR any link of this forward force to acceleration

OR mention that no other forces so this causes acceleration

- (ii) The trolley and cylinder have a mass of 0.68 kg and they reach a maximum speed of  $2.7 \text{ m s}^{-1}$ . The total mass of carbon dioxide initially in the cylinder is 12 g.

1. Write an equation relating the initial and final velocities of the trolley-cylinder system in terms of the average acceleration  $a$  of the trolley-cylinder system, and the time  $t$  taken for this system to achieve maximum speed.

$$v = u + a t$$

$$2.7 = 0 + a t$$

$$a = \frac{2.7}{t}$$

[1]

4

2. Write an equation relating the average ejection speed  $v_g$  of the carbon dioxide gas, the average accelerating force  $F$  exerted on the gas and the time  $t$  taken for all the gas to be ejected.

$$F = \frac{m (v_g - u_g)}{t} = \frac{0.012 (v_g - 0)}{t}$$

$$F = \frac{0.012 v_g}{t}$$

[1]

3. Hence calculate the average ejection speed of the carbon dioxide gas.

$$\Sigma F = M a$$

$$\frac{0.012 v_g}{t} = 0.68 \frac{2.7}{t}$$

$$v_g = 150 \text{ m s}^{-1}$$

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

- (iii) The cylinder is then removed from the trolley, and the trolley is given a push so that it collides head-on with a second stationary trolley which is identical to the first one.

Describe the subsequent motion of the trolleys if they make

1. an elastic collision,

The first trolley will stop, the second trolley will move with a velocity of

.....  
same magnitude and direction as that of the first trolley before collision. [2]

2. a completely inelastic collision.

They will stick together and move in the same direction as before, with a

.....  
smaller speed than that of the first trolley before collision. [1]

[1]

- 2 (a) (i) Define *gravitational potential* at a point in a gravitational field.

Gravitational potential is defined as work done per unit mass by an external agent on the test mass to move from infinity to a point in the gravitational field without a change in kinetic energy.

[1]

- (ii) Explain why gravitational potential is always negative.

Gravitational potential at infinity defined as zero and since gravitational force is attractive, work done by external agent as object moves from infinity to a point in the gravitational field so potential is negative.

[1]

- (b) Fig. 2.1 shows the variation of gravitational potential between the surface of Moon and the surface of Earth along the line joining their centres.

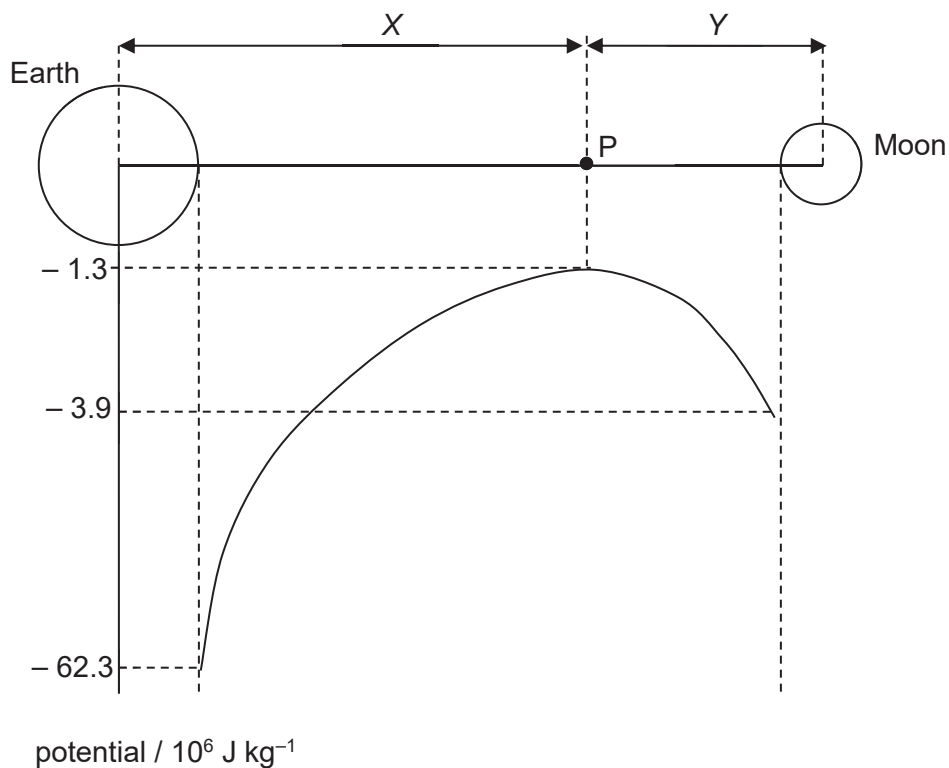


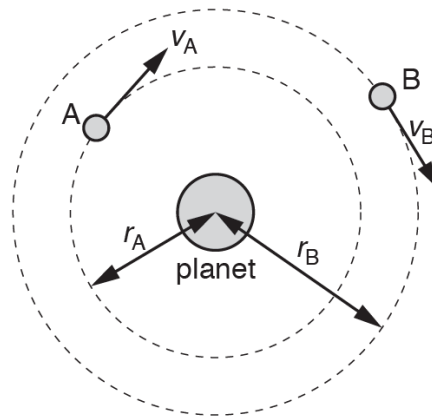
Fig. 2.1

Explain why the gradient of the graph near the surface of Earth and that near the surface of Moon have opposite signs.

The gradient of the potential –displacement graph gives the gravitational field strength, which is a vector, thus, the sign indicates the direction of the gravitational field strength. Near the earth, the net gravitational force is directed towards the earth due to larger influence of earth (larger mass and smaller distance) than moon while near the moon, the net gravitational force is directed towards the moon due to larger influence of moon ( smaller distance), their sign are opposite.

[2]

- (c) Two moons A and B move in circular orbits about a planet, as illustrated in Fig. 2.2.



**Fig. 2.2**

Moon A has an orbital radius  $r_A$  of  $1.3 \times 10^8$  m, linear speed  $v_A$  and orbital period  $T_A$ . Moon B has an orbital radius  $r_B$  of  $2.2 \times 10^{10}$  m, linear speed  $v_B$  and orbital period  $T_B$ .

- (i) Determine the ratio

1.  $\frac{v_A}{v_B}$ , and

Since the gravitational force the planet exerts on moon A and B provides the centripetal force for them to rotate about the planet,

$$\frac{GM_p M_A}{r_A^2} = \frac{M_A v_A^2}{r_A}$$

$$\frac{GM_p}{r_A} = \frac{v_A^2}{1}$$

Since  $GM_p$  are constant,  $v_A^2 \propto 1/r$

$$\begin{aligned} v_A / v_B &= (r_B / r_A)^{1/2} \\ &= (2.2 \times 10^{10} / 1.3 \times 10^8)^{1/2} \\ &= 13 \text{ (13.0)} \end{aligned}$$

ratio = ..... [3]

2.  $\frac{T_A}{T_B}$ .

$$v = 2\pi r / T$$

$$v \propto r / T$$

$$\begin{aligned} T_A / T_B &= (r_A / r_B) \times (v_B / v_A) \\ &= (1.3 \times 10^8 / 2.2 \times 10^{10}) \times (1 / 13) \\ &= 4.5 \text{ (4.54)} \times 10^{-4} \end{aligned}$$

ratio = ..... [1]

- (ii) The planet spins about its own axis with angular speed  $1.7 \times 10^{-4}$  rad s<sup>-1</sup>. Moon A is always above the same point on the planet's surface. Determine the orbital period  $T_B$  of moon B.

$$T = 2\pi / 1.7 \times 10^{-4} = 3.70 \times 10^4 \text{ s}$$

$$\begin{aligned} T_B &= 3.70 \times 10^4 / 4.54 \times 10^{-4} \\ &= 8.1 \times 10^7 \text{ s} \end{aligned}$$

$T_B = \dots\dots\dots$  s [2]

- 3 At a shooting gallery in a fun fair, a mobile target lion sways horizontally with simple harmonic motion as shown in Fig. 3.1. Hidden in a metal container below the lion target is a motor-driven circular rotating disc with a knob that slides along a frictionless groove attached to the lion. As the disc rotates with constant angular frequency, it pushes the lion target horizontally left and right.

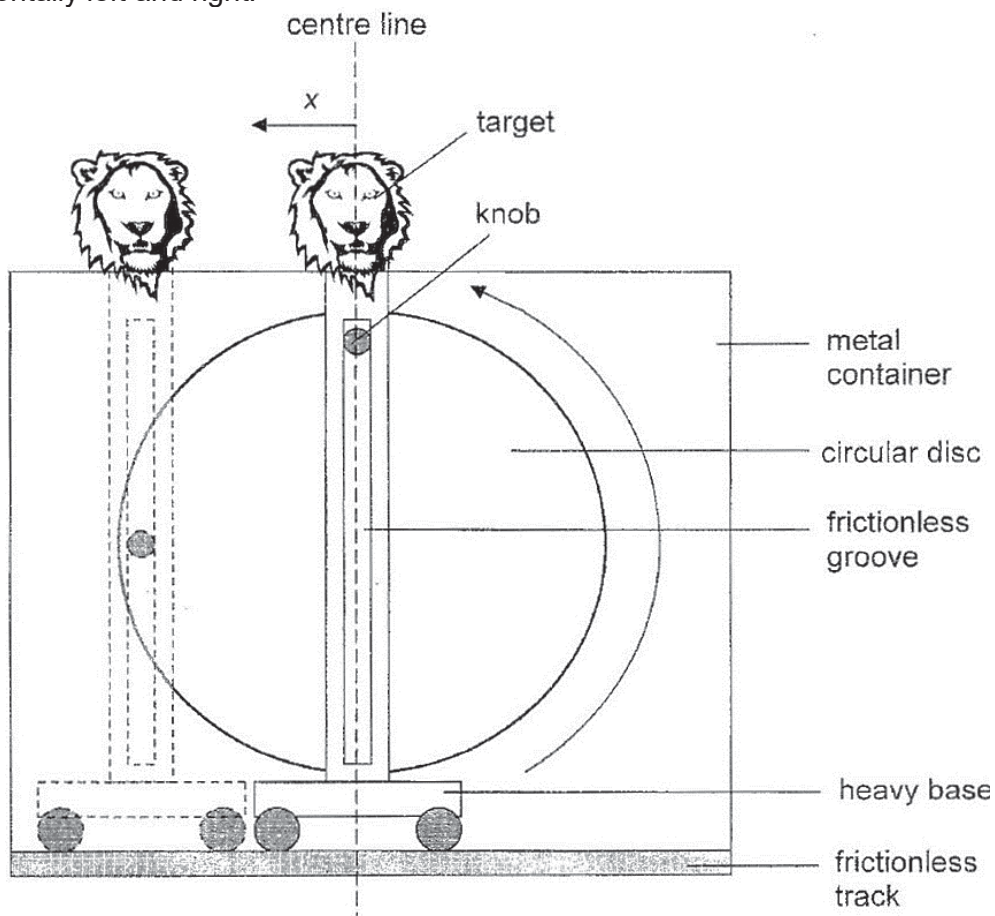


Fig. 3.1

Fig. 3.2 shows how the kinetic energy  $KE$  of the lion target varies with its displacement  $x$  from the centre line and Fig. 3.3 shows how its velocity  $v$  varies with its displacement  $x$ .

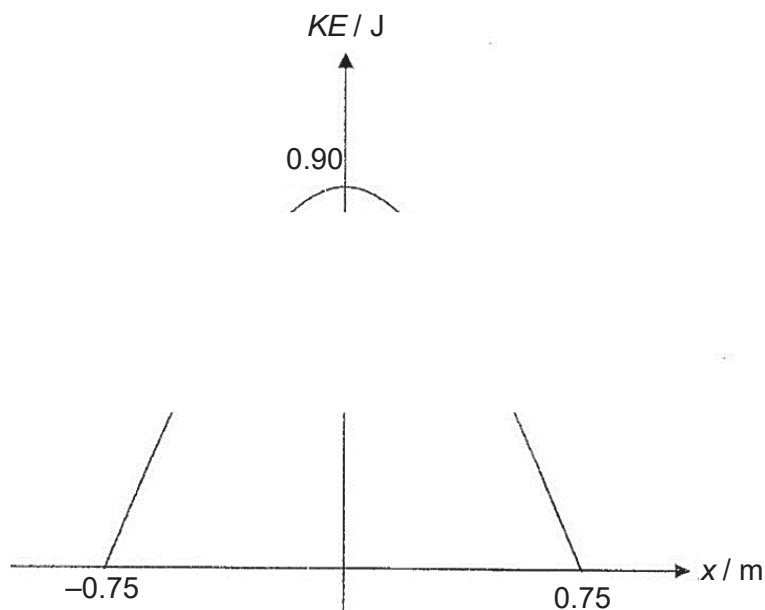


Fig. 3.2

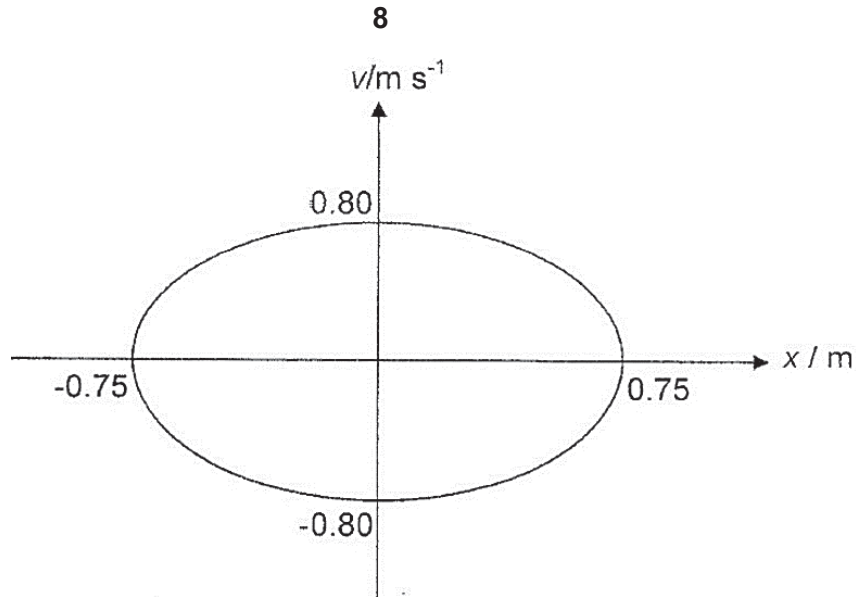


Fig. 3.3

(a) Deduce, from Fig. 3.2 and Fig. 3.3,

(i) the mass of the lion target,

$$KE_{lion, max} = \frac{1}{2} m_{lion} v_{lion, max}^2$$

$$0.90 = \frac{1}{2} (m_{lion}) (0.80)^2$$

$$m_{lion} = 2.81 \text{ kg}$$

mass = ..... kg [2]

(ii) the number of revolutions per second of the circular disc,

consider lion,

$$v_0 = \omega_{lion} x_0$$

$$0.80 = 2\pi f (0.75)$$

$$f_{lion} = 0.17 \text{ Hz}$$

Since the disc completes 1 round in the same time as the lion complete 1 oscillation,

$$f_{disc} = f_{lion} = 0.17 \text{ Hz}$$

number of revolutions per second = ..... s<sup>-1</sup> [2]

(iii) the speed of the knob when the displacement of the lion is maximum.

speed of knob is constant regardless of displacement of lion: 0.80 m s<sup>-1</sup>

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

- (b) When the lion target is at its leftmost position, a ball was tossed towards the middle position between the leftmost position and the centre line, with the aim of hitting the lion target. The ball takes 0.74 s to reach that middle position. Determine and explain whether the ball will hit the lion target right at its nose.

$$x = x_0 \cos(\omega t)$$

$$\frac{0.75}{2} = 0.75 \cos[2\pi(0.17)(t)]$$

$$t = 0.98 \text{ s}$$

Since the target takes 0.98 s to reach the position where the ball is tossed at, the ball does not hit the lion target right at the nose.

Alternatively,

0.74 s is 1/8 of the lion's period. Given that time, the knob moves 45 degrees. However, in order for ball to hit the lion right in the nose, the knob has to move 60 degrees in 0.74 s. Hence the ball does not hit the lion.

- 4 A positively charged particle passes through a region of uniform magnetic field of flux density 0.75 T, as shown in Fig. 4.1.

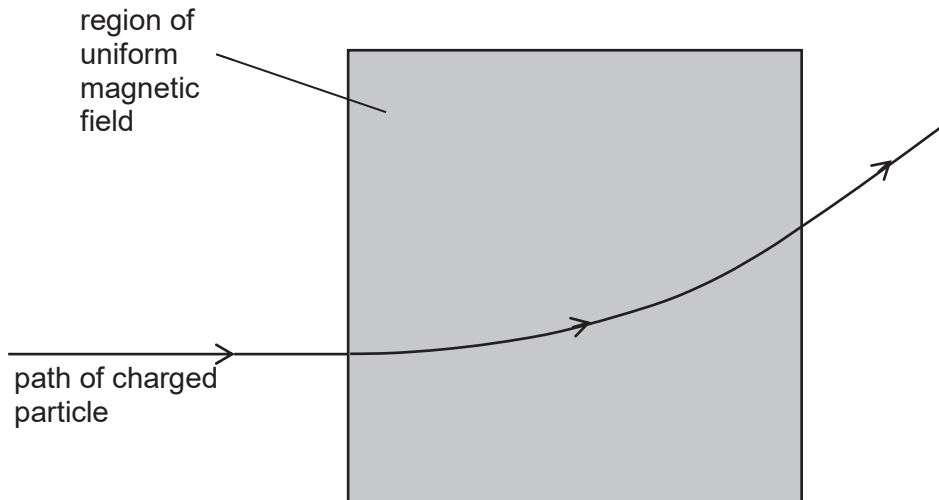


Fig. 4.1

The radius  $r$  of the path of the particle in the magnetic field is 25 cm.

- (a) Define the *tesla*.

.. One tesla is defined as the magnetic flux density of a magnetic field in which a .....  
 force per unit length of one newton per metre acts on a conductor which is .....  
 .. carrying a current of one ampere in a direction perpendicular to the field. ....  
 ..... [2]

- (b) State the direction of the magnetic field.

Into the plane of the paper. .... [1]



- (c) (i) The specific charge of a particle is the ratio of its charge to its mass,  $\frac{q}{m}$ . Given that the speed of the particle is  $9.0 \times 10^6 \text{ m s}^{-1}$ , calculate the specific charge of the particle.

When the charged particle enters the magnetic field, the magnetic force acting on it provides the centripetal force for it to undergo circular motion,

$$\Sigma F = ma$$

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

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

$$\frac{q}{m} = \frac{v}{Br}$$

$$= \frac{9.0 \times 10^6}{0.75(25 \times 10^{-2})}$$

$$= 4.8 \times 10^7 \text{ C kg}^{-1}$$

specific charge = ..... C kg<sup>-1</sup> [3]

- (ii) Using your answer in (i), suggest the name of a possible charged particle which has entered the uniform magnetic field. Show your working.

Since the elementary charge is  $1.60 \times 10^{-19} \text{ C}$  and the unified atomic mass unit is  $1.66 \times 10^{-27} \text{ kg}$ , a ratio of 1 e to 1 u will be

$$\frac{e}{u} = \frac{1.60 \times 10^{-19}}{1.66 \times 10^{-27}} = 9.64 \times 10^7 \text{ C kg}^{-1}$$

Therefore, it can be observed that

$$\frac{q}{m} = 4.8 \times 10^7 = \frac{1}{2} \left( \frac{e}{u} \right)$$

Since the specific charge is 0.5, the charged particle could be an alpha particle (helium-4 nucleus) or hydrogen-2 nucleus (or any other nuclides with a proton-to-neutron ratio of 0.5).

.....  
... [2]

- (iii) Explain how the path of the charged particle in the uniform magnetic field will be different if it were an electron projected into the field with the same speed as the positively charged particle in (i).

Upon entering the field, the charged particle will bend downwards instead of upwards. This is so as electron is negatively charged and by Fleming's Left Hand Rule, it can be seen that the magnetic force acting on the electron will be opposite to a positively charged particle. Also, since the specific charge is higher for the electron due to its relatively small mass, the radius of the circular path will be smaller than that of the positively charged particle.

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

- 5 (a) State Faraday's law of electromagnetic induction.

The induced e.m.f. is proportional to the rate of change of magnetic flux linkage.

.....

.....

..... [1]

- (b) Induction heating is commonly used for heating up electrically conductive materials in a clean, efficient and controlled manner. In industry, induction heating is a simple and reliable method for bottle sealing. It welds a circular piece of aluminium foil across the necks of medicine and drink bottles.

As shown in Fig. 5.1, a bottle is first filled at position 1. A plastic cap, complete with a piece of aluminium foil, is applied to the bottle neck at position 2. The foil is also coated with 'hot-melt glue' before being screwed onto the top of the bottle during manufacture. As the bottle passes under the induction heater (positions 3, 4, 5) on the production line, the foil is rapidly heated. The heat generated melts the glue and seals the foil onto the top of the bottle by position 5. When the cap is removed, the foil remains attached, providing an airtight seal and preventing any tampering or contamination of the bottle contents until the customer pierces the foil.

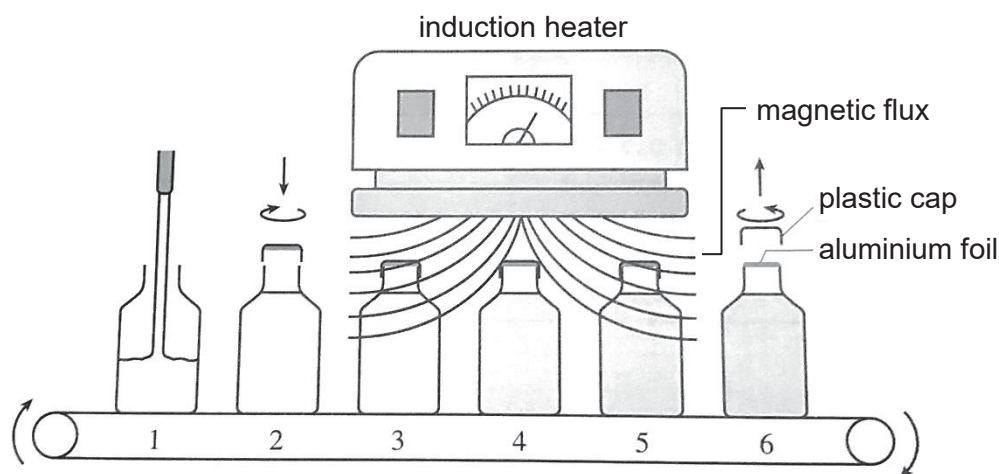


Fig. 5.1

- (i) State one advantage of using induction heating.
- Any of the following:

The heating process is contact-free, avoiding contamination.

More efficient compared to conduction heating or manually attaching the seals

Minimise contact with hot surfaces: reduces chance of injury

..... [1]

- (ii) Using laws of electromagnetic induction where appropriate, explain how the glue is melted.

**Source of B field:** There is an **alternating current in the** induction heater, which  
.....  
produces the magnetic field.

**How emf is generated:** By Faraday's law, the change in flux linkage **caused by the**  
.....  
**oscillating magnetic field** over time when the foil is under the induction heater (or  
.....  
positions 3-5), generates an induced emf.

**Why are there eddy currents:** Since the foil is **an extended piece of electrically**  
.....  
**conducting material**, the induced emf produces an eddy current that flows in the foil.  
..... [3]

The resistance of the foil and the eddy current cause the foil to heat up and melts the glue.

- (iii) The amount of heat produced in the aluminium foil can be estimated using a small coil placed underneath the induction heater. The coil has a cross-sectional area of  $2.40 \text{ cm}^2$  and contains 150 turns of wire. The resistance of the coil is  $6.8 \times 10^{-3} \Omega$ . Given that the magnetic flux density increased from zero to 500 mT in 0.30 s,

1. calculate the maximum magnetic flux linkage through the coil, and

$$\Phi = NBA = 150 \times 0.500 \times \frac{2.4}{100 \times 100}$$

$$\Phi = 1.8 \times 10^{-2} \text{ Wb}$$

maximum magnetic flux linkage = ..... Wb [2]

2. determine the power dissipated by the coil.

$$\varepsilon = \frac{1.8 \times 10^{-2}}{0.30} = 6.0 \times 10^{-2} \text{ V}$$

$$P = \frac{\varepsilon^2}{R} = 0.529 \text{ W}$$

power dissipated = ..... W [2]

- (iv) Explain if this method can be used to fix a plastic seal around the bottle instead.

No. Plastic is an electrical insulator in which eddy current cannot flow.  
.....

Allow: non electrical conductor.  
.....

..... [1]

- 6 (a) Describe three observations of the photoelectric effect that provide evidence for the particulate nature of electromagnetic radiation.

Any three of the below:

- 1) There is a minimum frequency of radiation required, below which photoelectric emission does not occur. ....
- 2) There is no time lag between the illumination of the metal surface and the emission of photoelectrons, if the frequency of radiation is higher than the threshold frequency. ....
- 3) The maximum kinetic energy of the photoelectron is dependent on the frequency of light but independent of the intensity of radiation. ....
- 4) The rate of emission of photoelectrons is proportional to the intensity of radiation. ....

..... [3]

- (b) Light of wavelength  $\lambda$  is incident on a metal surface having a work function energy  $\Phi$ . Photoelectrons of maximum kinetic energy  $E_{MAX}$  are emitted from the surface.

The variation with  $1/\lambda$  of  $E_{MAX}$  is shown in Fig. 6.1.

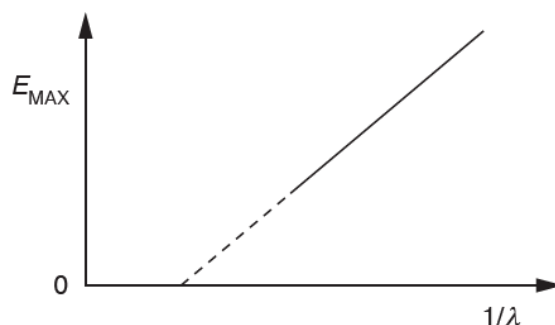


Fig. 6.1

- (i) Explain why the gradient of the line in Fig. 6.1 does not depend on the type of the metal surface.

$$\frac{hc}{\lambda} = \Phi + E_{MAX}$$

$$E_{MAX} = hc \left( \frac{1}{\lambda} \right) - \Phi$$

The gradient of the graph is given by  $hc$ , where  $h$  is the Planck constant and  $c$  is the speed of light in free space. Since both  $h$  and  $c$  are constants, the gradient does not depend on the type of the metal surface.

..... [2]

- (ii) The work function energy of sodium is 2.28 eV. Determine the minimum wavelength  $\lambda_0$  at which  $E_{MAX}$  is zero.

$$\frac{hc}{\lambda_0} = \Phi + 0$$

$$\frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{\lambda_0} = 2.28(1.60 \times 10^{-19})$$

$$\lambda_0 = 5.45 \times 10^{-7} \text{ m}$$

minimum wavelength = ..... m [2]

- (c) An electron gun is used to shoot a beam of electrons towards a screen, at a speed of  $6.00 \times 10^6 \text{ m s}^{-1}$ , through a slit of width 2.00 mm. Determine the distance between the slit of the gun and the screen, in order to see the beam of electrons spread by 1.00 cm on the screen because of the uncertainty principle.

$$\Delta x \Delta p \geq h$$

$$\Delta x = 0.00200 \text{ m}$$

(i.e. uncertainty in position is due to slit width of gun from where electrons are ejected)

$$\Rightarrow \Delta p \geq \frac{6.63 \times 10^{-34}}{0.00200} = 3.32 \times 10^{-31} \text{ kg m s}^{-1}$$

Hence the minimum uncertainty in momentum of the particle is

$$\Delta p = 3.32 \times 10^{-31} \text{ kg m s}^{-1}.$$

$$p = mv = (9.11 \times 10^{-31})(6.0 \times 10^6) = 5.47 \times 10^{-24} \text{ kg m s}^{-1}$$

$$\tan \theta = \frac{\Delta p}{p} = \frac{3.32 \times 10^{-31}}{5.47 \times 10^{-24}} = 6.06 \times 10^{-8}$$

$$\therefore \frac{\Delta d}{d} = 6.06 \times 10^{-8} \text{ (where } \Delta d \text{ is the spreading of the electrons)}$$

$$d = \frac{0.0100}{6.06 \times 10^{-8}} = 1.65 \times 10^5 \text{ m}$$

distance = ..... m [3]

- 7 The walls of music halls are acoustically covered with a sound-absorbing panel that is able to absorb certain sound frequencies more than others.

One particular design is to use the resonance of a perforated panel as shown in Fig. 7.1.

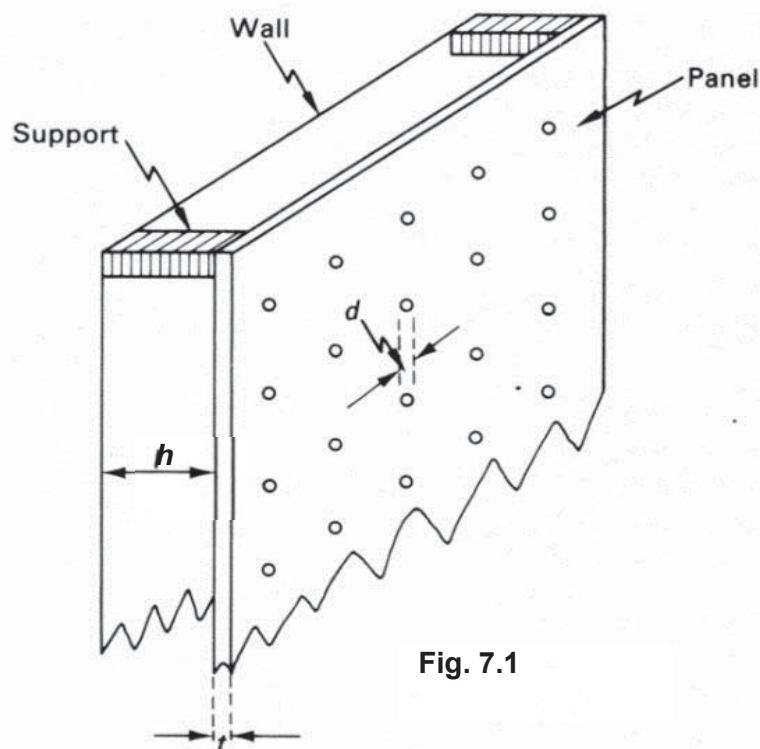


Fig. 7.1

It is found  
resonates

frequency and hence can absorb sounds of that frequency more than others. A suggested formula for this resonant frequency  $f$  is given as:

$$f = k \sqrt{\frac{x}{h(t + 0.8d)}} \quad \text{--- Equation 7.1}$$

where  $k = 5000 \text{ mm s}^{-1}$ ,  
 $h$  = depth of airspace with unit mm,  
 $t$  = thickness of panel with unit mm,  
 $d$  = hole diameter with unit mm, and  
 $x$  = percentage of panel surface area occupied by holes (e.g.  $x = 10 \%$ )

Using identical hardboard panels having holes of the same diameter of 10 mm, the resonant frequencies  $f$  for different  $x$  values are measured, keeping  $h$  and  $t$  constant. The results are shown in Fig. 7.2:

$x / \%$	2	4	6	8	10	12
$f / \text{Hz}$	530	750	920	1070	1190	1300

Fig. 7.2

- (a) Using the results from Fig. 7.2, state and explain whether the formula for  $f$  given in Equation 7.1 is correct.

$$f = k \sqrt{\frac{x}{h(t + 0.8d)}}$$

Assume  $f = A\sqrt{x}$  where  $A$  is constant

When $f = 530$ , $x = 2\%$ $A = 375$	When $f = 750$ , $x = 4\%$ $A = 375$	When $f = 920$ , $x = 6\%$ $A = 376$
---	---	---

Since  $A$  is almost constant, the formula of  $f$  is correct.

..... [3]

- (b) Determine suitable values for  $h$  and  $t$  when  $x = 10\%$ , such that the results from Fig. 7.2 satisfy the given formula for  $f$  in Equation 7.1.

$$A = 375, \Rightarrow \frac{k}{\sqrt{h(t + 0.8d)}} = 375$$

Assume  $t = 2\text{mm}$ ,  $h = 18\text{mm}$

Acceptable range for  $t$ : 1 – 6 mm

Acceptable range for  $h$ : 18 – 12 mm

$h = \dots\dots\dots$  mm

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

- (c) Using a panel with  $x$  fixed at 10% and  $d$  fixed at 5 mm, the engineer decides to investigate the effect of filling the air space with 2 different absorbers. He obtains the absorption characteristics shown in Fig. 7.3.

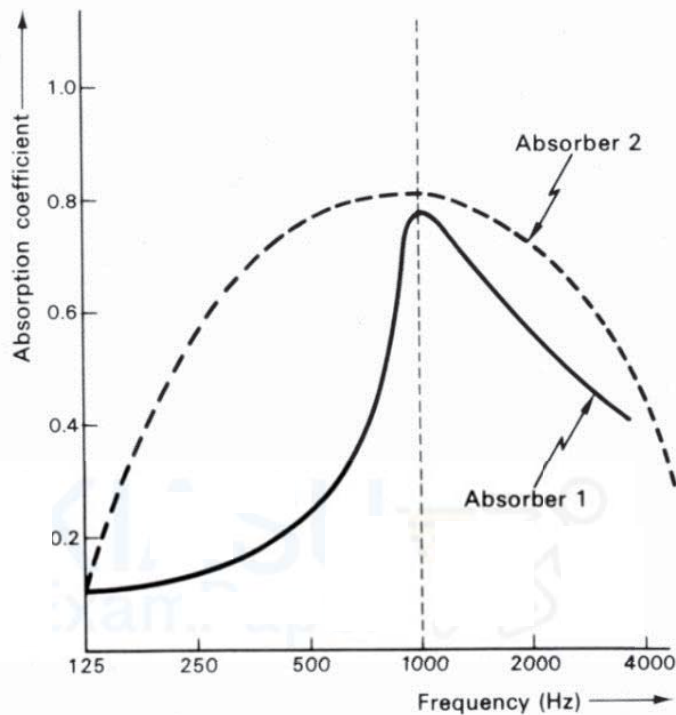


Fig. 7.3

Absorption coefficient is an indication of how much sound waves can be absorbed i.e. the higher the absorption coefficient, the stronger the absorption.

- (i) Using your knowledge on resonance, state one effect that absorbers have on the resonant frequency when they are inserted into the air space.

The resonant frequency will decrease .....

..... [1]

- (ii) State and explain which of the two absorbers would be preferred in a room in which

1. absorption over a wide frequency range is required,

From the graph, the absorption coefficient for absorber 2 is higher than absorber 1 for all frequencies. Hence absorber 2 is preferred. ....

..... [1]

2. sounds below 500 Hz need amplification.

From the graph, the absorption coefficient for absorber 1 for frequency < 500 Hz is significantly lower than those values above 500 Hz. Hence absorber 1 is preferred. ....

..... [1]

- 8 In 2012 skydiver Felix Baumgartner jumped out of a helium-filled balloon from a height of 39 km above sea level. His free fall of over 36 km lasted 4 minutes and 20 seconds. In this free fall, he became the first person whose speed exceeded the speed of sound  $330 \text{ m s}^{-1}$ , without the use of an aeroplane or rocket.

During the fall, Felix Baumgartner opened his parachute at about 1500 m above sea level, when his speed is  $192 \text{ km hr}^{-1}$ , and he landed safely 15 minutes later. All height and speeds were recorded by GPS.

Some data on the air atmosphere and helium is collected and given in Fig. 8.1.

	sea level	39 km above sea level
Temperature of atmosphere / °C	15	-25
Atmospheric pressure / Pa	101 000	318
Air density	-	0.00447
Helium density / $\text{kg m}^{-3}$	-	0.00065

Fig. 8.1



- (a) Using data given in Fig. 8.1, determine the minimum volume of helium required in the balloon at sea level, for a skydiver in the helium-filled balloon to reach a height of 39 km above sea level at constant speed. Assume that the total mass of the skydiver and the helium-filled balloon is 3140 kg, and that helium behaves as an ideal gas.

$$\begin{aligned}\Sigma F &= 0 \text{ (since speed is constant)} \\ \text{Upthrust} - \text{weight of skydiver} &= 0 \\ V(0.00447)g - 3140g &= 0 \\ V &= 7.02 \times 10^5 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\frac{P_1 V_1}{T_1} &= \frac{P_2 V_2}{T_2} \Rightarrow \frac{(101000)V_1}{15 + 273} = \frac{318(7.02 \times 10^5)}{-25 + 273} \\ V_1 &= 2600 \text{ m}^3\end{aligned}$$

(Solution if assume weight of helium unknown)

$$\begin{aligned}\Sigma F &= 0 \\ U - 3140g - \text{weight of helium air in balloon} &= 0 \\ V(0.00447)g - 3140g - V(0.00065)g &= 0 \\ V &= 8.2 \times 10^5 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\frac{P_1 V_1}{T_1} &= \frac{P_2 V_2}{T_2} \Rightarrow \frac{(101000)V_1}{15 + 273} = \frac{318(8.2 \times 10^5)}{-25 + 273} \quad \dots\dots\dots \text{m}^3 \text{ [3]} \\ V_1 &= 3000 \text{ m}^3\end{aligned}$$

Two main forces acting on the skydiver of mass  $m$  are his weight and air resistance. The air resistance  $F$  can be written as follows

$$F = \frac{1}{2} C_D A \rho v^2$$

where  $\rho$  is the density of air,  $A$  is effective cross-sectional area and  $C_D$  is the drag coefficient.

- (b) (i) Show that the terminal speed  $v_T$  that can be achieved by the skydiver as he falls is given by

$$v_T = \sqrt{\frac{2mg}{C_D A \rho}}$$

At terminal speed, net force = 0

$$\begin{aligned}F - mg &= 0 \\ mg &= \frac{1}{2} C_D A \rho v_T^2\end{aligned}$$

[1]

- (ii) Explain why the skydiver's terminal speed will not be constant as he falls.

The air density will increase as he falls. ....

..... [1]

(c) The acceleration  $a$  of the sky diver when he is falling at a speed  $v$  is given by

$$a = g \left( \frac{v^2}{v_T^2} - 1 \right) \quad \text{--- Equation 8.1}$$

The variation of the skydiver's speed with time as he falls is shown in Fig 8.2. The terminal speed  $v_T$  based on the expression given in (b)(i) is also plotted in Fig. 8.2 (denoted by the dashed line).

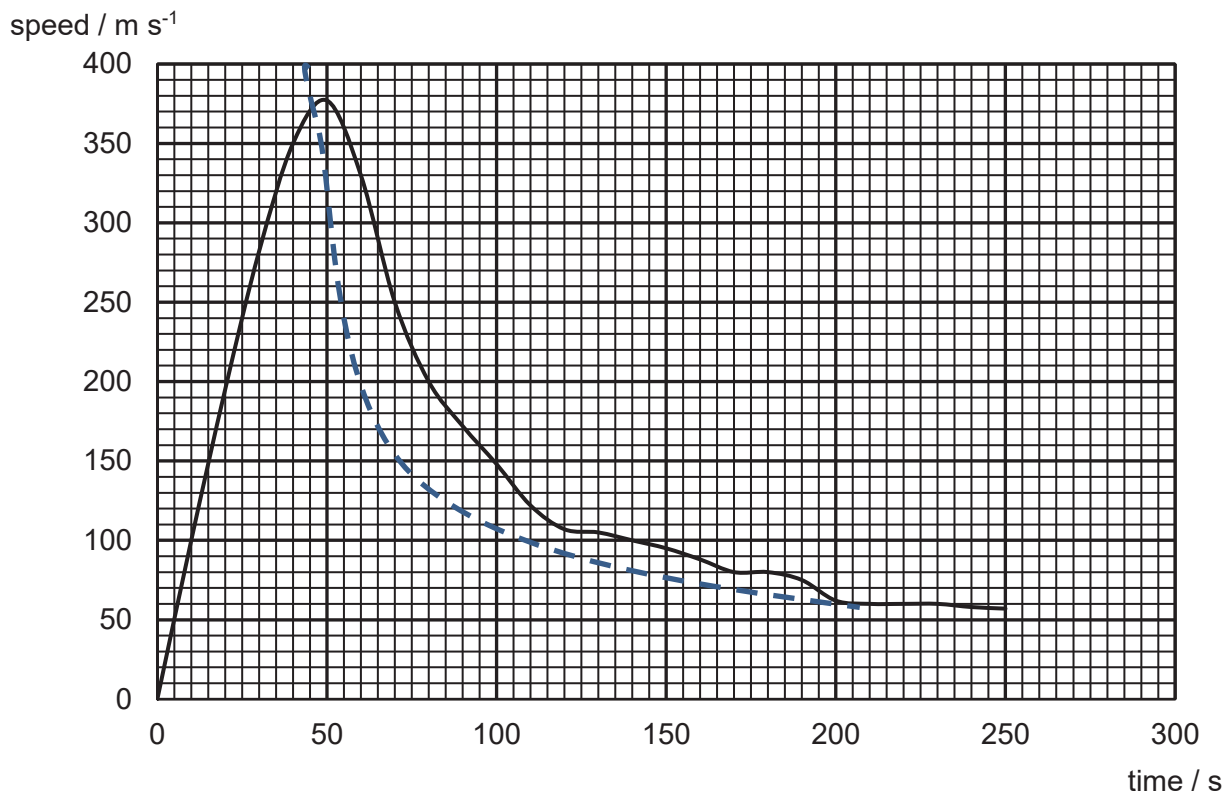


Fig. 8.2

(i) Deduce from Fig 8.2 the duration of time when the skydiver exceeds the speed of sound during his fall.

Duration is about 22 – 24 s.

duration = ..... s [1]

(ii) Use Fig 8.2 to determine the total distance fallen when the sky diver reaches his maximum speed.

Total distance = area under the graph

Acceptable range = 10500 – 12500 m

total distance fallen = ..... m [2]

- (iii) Using Fig. 8.2 and Equation 8.1, describe and explain the variation in the speed of the skydiver from time = 50 s to 250 s.

The speed of the skydiver is decreasing from 50 s – 200 s. Since his speed is greater than terminal speed, based on Equation 8.1, the acceleration is negative causing his speed to decrease until  $V = V_T$ . He reached an almost constant speed from 200 – 250 s.

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

- (d) (i) Suggest why a helium-filled balloon is used to bring the skydiver to a height of 39 km above sea level, instead of using an aircraft.

The density of the air is too small to generate enough lift force at this height.

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

- (ii) Suggest a major health hazard to the skydiver at such a high altitude, even with the use of oxygen supply.

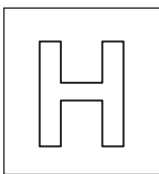
1) Due to the extreme low pressure, his blood will boil.

OR

2) Exposure to cosmic rays/dangerous radiation causing cancers.

3) Unknown virus from space.

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



NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

CANDIDATE  
NAME

**SOLUTION**

CLASS

TUTOR'S  
NAME

## PHYSICS

**9749/03**

Paper 3 Longer Structured Questions

**21 September 2017**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required

### READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.

#### Section A

Answer **all** questions.

#### Section B

Answer any **one** question.

You are advised to spend about one and a half hours on Section A, and about thirty minutes on Section B.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8	
9	
Total	

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

[Turn over

**Data**

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

**Formulae**

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

## Section A

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

- 1 A hot air balloon P is moving vertically upward at a uniform speed when weather condition turns windy. A constant breeze blows horizontally across the sky at a speed  $4.0 \text{ m s}^{-1}$ , which causes the hot air balloon to travel with a resultant velocity  $11 \text{ m s}^{-1}$  at an angle  $\theta$  to the horizontal, as shown in Fig. 1.1 below.

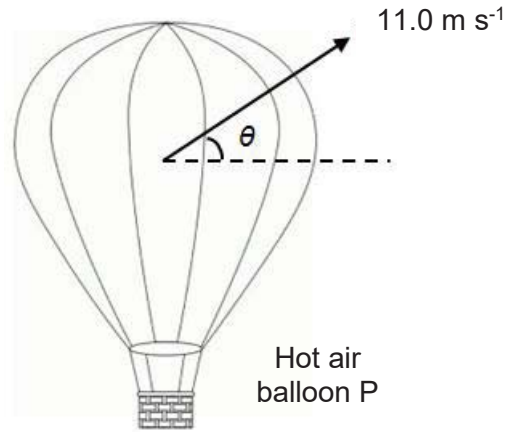


Fig. 1.1

A sandbag is released from the balloon P. Ignore the effects of air resistance. Assuming that the sandbag has yet to land on the ground after 2.3 s, and that the velocity of balloon P is not affected by the release of the sandbag,

- (a) determine the horizontal distance of the sandbag from balloon P after 2.3 s, and

Since the sandbag and hot air balloon have the same horizontal speed, the horizontal distance between them will be 0 m at all time before the landing of the sandbag.

horizontal distance = ..... m [1]

- (b) show that the vertical distance of the sandbag from balloon P after 2.3 s is 26 m. [2]

The vertical speed of the balloon is  $\sqrt{11.0^2 - 4.0^2} = 10 \text{ m s}^{-1}$

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

For the sandbag,

$$\begin{aligned} S_y &= u_y t + \frac{1}{2} a_y t^2 \\ &= (+10)(2.3) + \frac{1}{2} (-9.81)(2.3)^2 \\ &= -2.9 \text{ m} \end{aligned}$$

( 2.9 m below the initial point of release )

For the hot air balloon,  $s = (10)(2.3) = 23 \text{ m}$

( 23 m above the initial point of release )

The distance between them is  $23 + 2.9 \approx 26 \text{ m}$

- (c) There is a second hot air balloon Q which is at a stationary position below the first hot air balloon P. At the instant when the released sandbag passes in front of this second air hot balloon Q at 2.3 s, the person inside balloon Q throws another sandbag at this first sandbag that was released from P. The second sandbag is thrown from Q at an angle of  $45^\circ$  below the horizontal.

- (i) Determine the speed at which the second sandbag is thrown from Q if both sandbags reach the ground at the same time.

For them to reach the ground at the same time, they have to have the same vertical speed at the same displacement,

$$\begin{aligned} \text{For the first sandbag, the vertical speed at that time is } v_y &= u_y + at \\ &= (10) + (-9.81)(2.3) \\ &= -12.6 \end{aligned}$$

$$\begin{aligned} \text{For the second sandbag, the speed, } v \sin 45 &= 12.6 \\ v &= 18 \text{ ms}^{-1} \text{ (17.8)} \end{aligned}$$

$$\text{speed} = \dots\dots\dots \text{ m s}^{-1} [2]$$

- (ii) The person inside Q wants the sandbag that was thrown out from Q in (i) to reach the ground within a shorter time. Therefore he throws out another sandbag from Q with the same speed and angle of projection as the sandbag which he threw out in (i) but this time, he uses a heavier sandbag. Comment on whether he will succeed.

He will not succeed as acceleration due to gravity is independent of mass.

..... [1]

- 2 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 2.1.

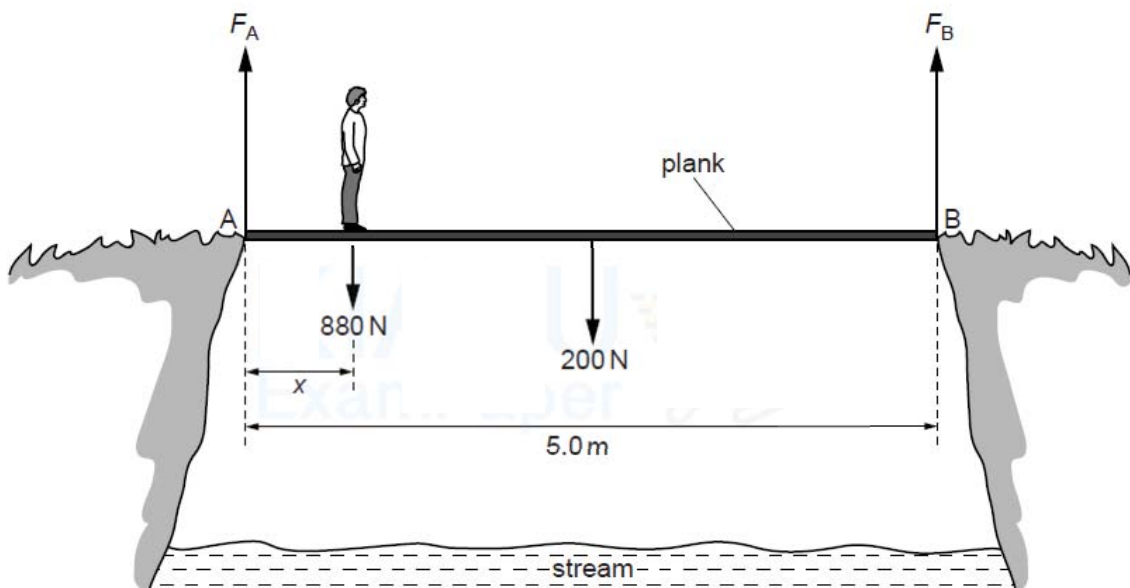


Fig. 2.1

A man of weight 880 N stands at a distance  $x$  from end A. The ground exerts a vertical force  $F_A$  on the plank at end A and a vertical force  $F_B$  on the plank at end B. As the man moves along the plank, the plank is always in equilibrium.

- (a) (i) Define *moment of a force*.

The moment of a force about a point is defined as the product of the force and the perpendicular distance from the line of action of the force to that point.

..... [1]

- (ii) Explain why the sum of the forces  $F_A$  and  $F_B$  is constant no matter where the man stands on the plank.

Since the plank is in equilibrium, the resultant force is zero. As there are no horizontal forces, the vertical forces must balance. The sum of force exerted by man on plank (equal to weight of man) and weight of plank must be equal to sum of  $F_A$  and  $F_B$ , and as the mass of man and plank do not change, the sum of  $F_A$  and  $F_B$  are constant.

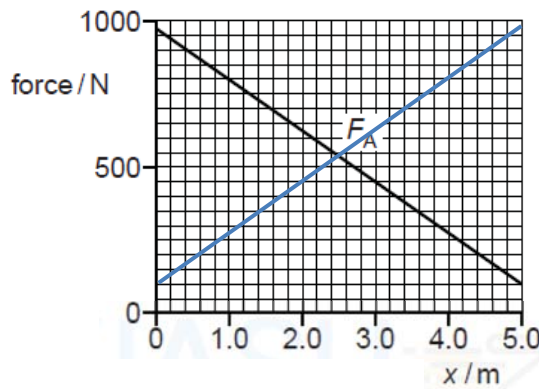
..... [2]

- (iii) The man stands at a distance  $x = 0.50$  m from end A. Determine the magnitude of  $F_B$ .

(anticlockwise moments) = (clockwise moments)  
 $F_B \times 5.0 = 880 \times 0.5 + 200 \times 2.5$   
 $F_B = (440 + 500) / 5.0 = 188$  N

$F_B =$  ..... N [2]

- (b) The variation with distance  $x$  of the magnitude of force  $F_A$  is shown in Fig. 2.2.



On Fig. 2.2, sketch the variation with  $x$  of the magnitude of force  $F_B$ . [2]

A straight line with positive gradient with start point (0.0, 100) and finish point (5.0, 980)



- 3 A student attempts to set up a “Rube Goldberg Machine”, which is a contraption consisting of a series of devices that perform simple tasks which are linked together to produce a domino effect, where the activation of one device triggers the next device in the sequence.

A part of the contraption is shown in Fig 3.1. It consists of a small block of mass 40 g, initially at rest, which slides down a rough slope from X to P. When the block reaches point P, it attains a speed of  $0.35 \text{ m s}^{-1}$ .

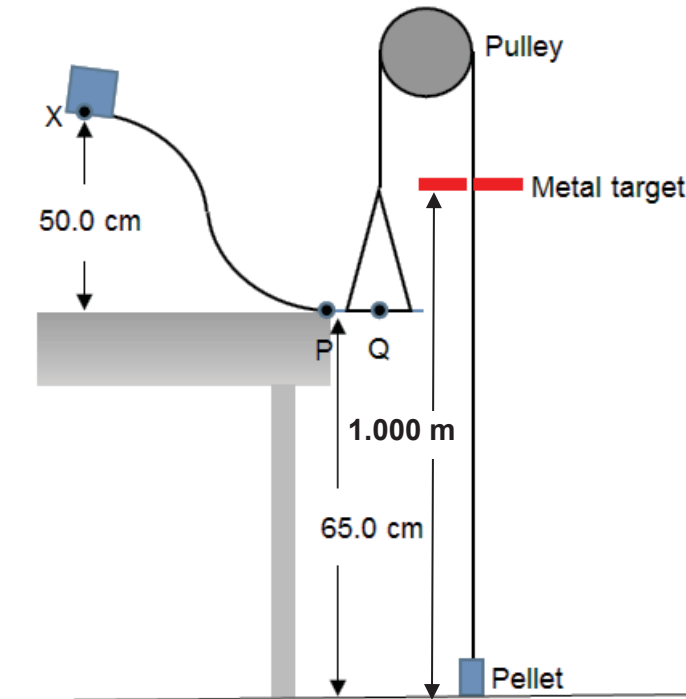


Fig. 3.1

- (a) Determine the work done against friction when the block slides from X to P.

$$\begin{aligned} \text{Loss in GPE} &= \text{Gain in KE} + \text{Work done against friction} \\ (0.040 \times 9.81 \times 0.500) &= (0.5 \times 0.040 \times 0.35^2) + \text{Work done against friction} \\ \text{Work done against friction} &= 0.194 \text{ J (2 s.f. or 3 s.f. allowed)} \end{aligned}$$

work done = ..... J [2]

- (b) At P, the block continues to slide forward a little and comes to a complete stop at point Q on a movable platform connected to a pulley. Its weight causes the pulley to turn and the block eventually hits the ground 65.0 cm below, lifting a small 15 g rectangular pellet from the ground in the process.

- (i) Determine the speed of the pellet just as the 40 g block hits the ground.

$$\begin{aligned} \text{Loss in GPE} &= \text{Gain in KE} \\ [(0.040 - 0.015) \times 9.81 \times 0.650] &= [0.5 \times (0.040 + 0.015) \times v^2] \\ v &= 2.41 \text{ m s}^{-1} \end{aligned}$$

speed = .....  $\text{m s}^{-1}$  [2]

- (ii) The contraption is designed such that when the pellet hits a metal target during its upward motion, it will make a loud sound. The target is placed 1.000 m above the ground. State and explain whether the pellet will hit the target, showing your working clearly.

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

$$0^2 = 2.41^2 + 2(-9.81) s$$

$$s = 0.296 \text{ m}$$

$$\text{Maximum height reached by pellet} = 0.296 + 0.650 = 0.946 \text{ m}$$

Hence the pellet will not hit the target.

OR

Gain in GPE = Loss in KE

$$0.015 \times 9.81 \times h = (0.5 \times 0.015 \times 2.41^2)$$

$$h = 0.296 \text{ m}$$

$$\text{Maximum height reached by pellet} = 0.296 + 0.650 = 0.946 \text{ m}$$

Hence the pellet will not hit the target.

..... [3]

- (iii) State an assumption you have made in your calculation in (ii).

Any of the following:

.....  
Air resistance is negligible.

..... [1]  
The string has negligible mass.

- 4 A turntable is rotating at a constant speed of 15 revolutions per minute. A small five-cent coin of mass 1.56 g is placed at the rim of the turntable and it moves with the turntable without slipping.

- (a) Show the angular velocity of the rotating coin is  $1.57 \text{ rad s}^{-1}$ . [1]

$$\omega = 2\pi f$$

$$= 2 \times \pi \times \frac{15}{60}$$

$$= 1.57 \text{ rad s}^{-1}$$

- (b) Given that the kinetic energy of the coin is  $2.5 \times 10^{-5} \text{ J}$ , determine the radius of the turntable.

$$\frac{1}{2}mv^2 = 0.000025$$

$$\frac{1}{2}(0.00156)v^2 = 0.000025$$

$$v = 0.179 \text{ m s}^{-1}$$

$$v = r\omega$$

$$r = \frac{v}{\omega} = \frac{0.179}{1.57}$$

$$r = 0.114 \text{ m}$$

radius = ..... m [2]

- (c) If the maximum friction between the coin and the turntable is 0.012 N, calculate the maximum number of complete revolutions that the turntable can make per minute, such that the coin can still remain on the turntable.

Friction provides the centripetal force for the coin to remain in circular motion:

$$f = mr\omega^2$$

$$0.012 = 0.00156 \times 0.114 \times \omega^2$$

$$\omega_{max} = 8.21 \text{ rad s}^{-1}$$

$$\omega = 2\pi f$$

$$f_{max} = \frac{\omega}{2\pi} = 1.31 \text{ Hz}$$

max. number of revolutions per minute =  $1.31 \times 60 = 78$  (round down)

maximum number of revolutions per minute = ..... min<sup>-1</sup> [3]

- (d) If the rotational speed of the turntable continues to increase, the coin is observed to slip off the turntable and fall to the ground. Describe the path of the coin after it leaves the turntable until it reaches the ground.

Coin initially moves off at a tangent to the circular path at the point of departure. It then

falls to the ground in a parabolic path like a typical projectile motion. [2]

- 5 (a) In order to determine the internal resistance of a 12.00 V battery, a student sets up the circuit shown in Fig. 5.1. The rheostat CD has a maximum resistance of 1000  $\Omega$ .

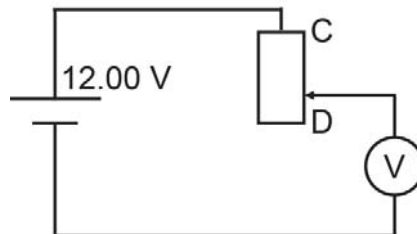


Fig. 5.1

When the sliding contact of the rheostat is placed at C, the voltmeter reading is 11.99 V. When the sliding contact moves from C to D, the voltmeter reading drops from 11.99 V to 11.00 V.

- (i) State the potential difference across the internal resistance of the battery when the sliding contact of the rheostat is placed at C.

potential difference = ..... 0.01 ..... V [1]

- (ii) Explain why the presence of internal resistance in the battery reduces its output power.

Internal resistance reduces the terminal potential difference of the battery.  
 .....  
 Since the output power is proportional to its terminal p.d., the presence of  
 ..... [1]  
 internal resistance reduces the output power of the battery.

- (iii) Determine the internal resistance  $r$  of the battery and internal resistance  $R$  of the voltmeter.

Using potential divider concept,

$$\left(\frac{r}{r+R}\right)\varepsilon = V_r$$

$$r\varepsilon = rV_r + RV_r$$

$$r(\varepsilon - V_r) = RV_r$$

$$r = \frac{V_r}{\varepsilon - V_r}R \quad - (1)$$

$$\left(\frac{R}{r+1000+R}\right)\varepsilon = V_R$$

$$R\varepsilon = rV_R + RV_R + 1000V_R$$

$$rV_R = R(\varepsilon - V_R) - 1000V_R$$

$$r = \frac{\varepsilon - V_R}{V_R}R - 1000 \quad - (2)$$

Substitute (1) into (2),

$$\frac{V_r}{\varepsilon - V_r}R = \frac{\varepsilon - V_R}{V_R}R - 1000$$

$$\frac{0.01}{12.00 - 0.01}R = \frac{12.00 - 11.00}{11.00}R - 1000$$

$$R = 11100 \Omega$$

Substitute  $R = 11100 \Omega$  into (1),

$$r = \frac{V_r}{\varepsilon - V_r}11100$$

$$r = 9.26 \Omega$$

$r = \dots\dots\dots 9.26 \dots\dots\dots \Omega$

$R = \dots\dots\dots 11\ 100 \dots\dots\dots \Omega$  [4]

- (b) In another circuit shown in Fig. 5.2, a uniform wire AB of length 80.0 cm and resistance  $1.5 \Omega$  is connected in series with a resistor of  $5.0 \Omega$  and a cell of e.m.f.  $9.0 \text{ V}$  with internal resistance  $1.0 \Omega$ .

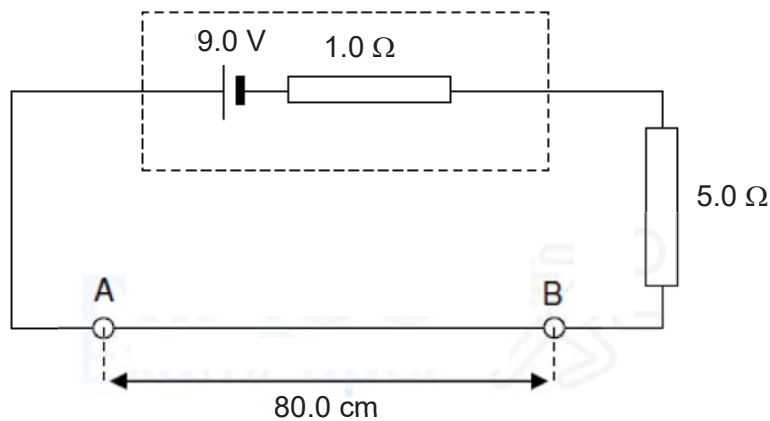


Fig. 5.2

- (i) Calculate the potential difference across wire AB.

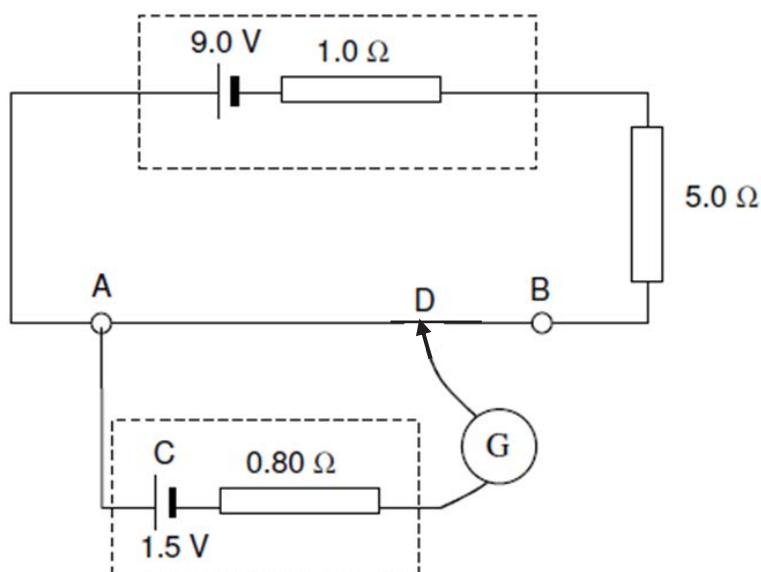
Using potential divider rule,

$$\left(\frac{1.5}{1.0 + 5.0 + 1.5}\right) 9.0 = V_{AB}$$

$$V_{AB} = 1.8 \text{ V}$$

potential difference = ..... 1.8 ..... V [2]

- (ii) A cell C of e.m.f. 1.5 V and internal resistance 0.80  $\Omega$  is connected to the circuit in Fig. 5.2, as shown in Fig. 5.3. The movable contact D can be connected to any point along wire AB.



**Fig. 5.3**

Calculate the length of AD when there is zero current in the galvanometer.

0 A in galvanometer:  $V_{AD} = 1.5 \text{ V}$

Using potential divider rule,

$$\frac{1.5}{1.8} = \frac{L_{AD}}{0.800}$$

$$L_{AD} = 0.67 \text{ m}$$

length = ..... 0.67 ..... m [2]

- 6 (a) State in words the *first law of thermodynamics*.

In a closed system, the increase in internal energy is equal to the sum of

.....  
the heat supplied to the system and the work done on the system.  
.....

[1]

- (b) An adiabatic process is one in which no heat is supplied to or extracted from a system.
- (i) Determine the change in the internal energy of an ideal gas when the gas does 600 J of work in an adiabatic process.

$$\begin{aligned}\Delta U &= Q_{\text{in}} + W_{\text{on}} \\ &= 0 - 600 \\ &= -600 \text{ J}\end{aligned}$$

change in internal energy = ..... J [1]

- (ii) Hence describe how the temperature of the gas in (i) will change at the end of the adiabatic process.

The temperature of the gas will decrease because the internal energy of

.....  
an ideal gas is proportional to the temperature of the gas.

..... [1]

- (c) A heat pump is a device which works by changing the state of a gas through a cycle of operations such those shown in Fig. 6.1, changing the state of a sample of gas from A to B, then to C, and then to D, and eventually back to A.

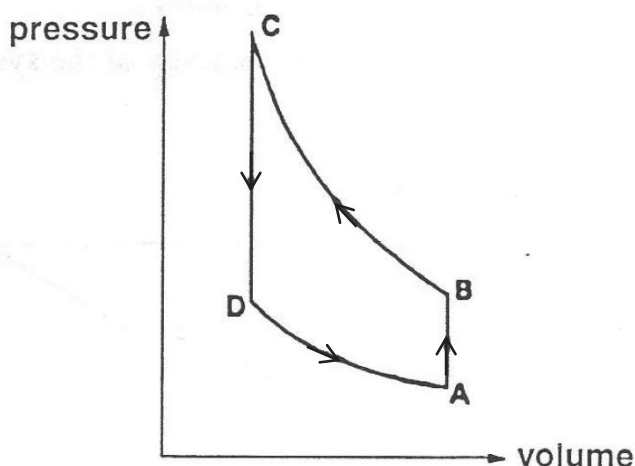


Fig. 6.1

Between A and B the gas absorbs heat from the atmosphere, and between C and D it delivers heat to the inside of a building. Processes BC and DA are adiabatic.

For a certain heat pump, the heat supplied to the gas during each part of the cycle and the corresponding work done on the gas are given in Fig. 6.2. The cycle is completed 20 times per second.

Section of cycle	Heat supplied to gas / J	Work done on gas / J
A → B	280	0
B → C	0	190
C → D	-400	0
D → A	0	-70

Fig. 6.2

(i) Fill in the blank spaces in Fig. 6.2. [2]

(ii) Explain why the total change in the internal energy of the gas in the pump during a complete cycle must be zero.

A cyclic process brings the state of a system through a sequence of changes and finally returns back to its original state, that is, to its original internal energy. Thus the change in internal energy at the end of a complete cycle is zero. [1] OR

A cyclic process brings the state of a system through a sequence of changes and finally returns back to its original state, i.e. the original temperature. As internal energy is proportional to temperature, the internal energy at the end of the cycle is the same as all that at the beginning of the cycle

(iii) Calculate the minimum average power of the motor required to run the pump.

The motor of a heat pump does work on the gas.

Net work done per cycle =  $190 - 70 = 120 \text{ J}$

Minimum average power =  $\frac{120}{\frac{1}{20}} = 2400 \text{ W}$

minimum average power = ..... W[2]

(iv) Calculate the average rate of supply of heat by the pump.

The heat supplied by the pump in one cycle =  $400 \text{ J}$

Rate of heat supply =  $\frac{400}{\frac{1}{20}} = 8000 \text{ W}$

average rate of supply of heat = ..... W[2]

- 7 (a) Red and green light, of wavelengths 640 nm and 520 nm respectively, are simultaneously directed through a narrow slit onto a diffraction grating. The grating is at right angles to the light and has a line spacing of 1.60  $\mu\text{m}$ .

- (i) Complete Fig. 7.1 by calculating the values of all the angles of diffraction corresponding to different orders of maxima for both colours. [3]

order $n$	angle for red maximum / $^\circ$	angle for green maximum / $^\circ$
0	0	0
1	23.6	19.0
2	53.1	40.5
3		77.2

Fig. 7.1

- (ii) Sketch on Fig 7.2 the approximate pattern that would be seen on a screen behind the diffraction grating. Label the red and green maxima **R** and **G** respectively. [2]

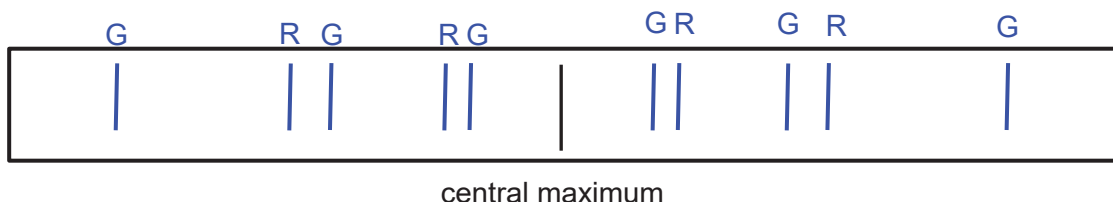


Fig. 7.2

- (iii) Suggest and explain how the spacing of the maxima drawn on Fig. 7.2 can be used to determine whether the light is directed normal to the grating.

.. The spacing of the bright lines for each order and colour from the central maximum should be symmetrical if the light is directed normal to the grating. The path difference between each wavetrain entering the slits will be zero if the light is directed normal to grating. [2]

- (iv) Explain why the same pattern will not be observed on the screen if the diffraction grating has irregularly spaced slits.

If the slits are irregularly spaced, then the path difference between each wave exiting each slit will be different. Hence it is very difficult to have constructive interference taking place at most positions. [1]



- (b) (i) The grating in (a) is replaced with a double-slit setup that has the same spacing between slits as the grating in (a). Describe how the new pattern produced will differ from the one drawn in (a)(ii).

1<sup>st</sup> Difference : Instead of discrete colour lines with different spacing, a  
 .. dark and bright fringe pattern of equal spacing will be observed . .....

.. 2<sup>nd</sup> Difference: Instead of distinct red and green colours lines, the bright  
 red fringes will be slightly longer than green fringes and mostly .....

.. overlapped . . [2]

- (ii) The grating in (a) is replaced with a single slit whose slit width has the same value as the slit spacing of the grating in (a). This produces another pattern. Determine the angle  $\theta$  between two lines, drawn from the centre of the slit to the central maximum and to the first order red minimum in the pattern respectively.

$$\sin \theta = \frac{\lambda}{b} = \frac{6.4 \times 10^{-7}}{1.6 \times 10^{-6}}$$

$$\theta = 0.41 \text{ rad}$$

$$\theta = \dots\dots\dots \text{ rad [1]}$$

## Section B

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

- 8 (a) (i) Define *electric field strength*.

The electric field strength at a point in an electric field is defined as the force per unit positive charge acting on a test charge placed at that point. ..... [1]

- (ii) With reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre.

The electric field lines, along which the electric forces exerted by the charged sphere on other charges act, are always perpendicular to the surface of the sphere (i.e. the electric field lines are radial). ..... [2]

Hence the field lines appear to originate from the centre of the sphere, so the charge on the sphere may be considered to act as a point charge at its centre.

- (b) Electrons 'leak' easily from the surface of many stars, so these stars acquire a positive charge. The charging stops when the charge on the star is so large that protons at the surface of the star also begin to be repelled.

This occurs when the sum of the gravitational potential energy and the electric potential energy of a proton at the surface of the star is zero. The star is then considered to be in steady state. It is assumed that each star takes on the shape of a sphere.

- (i) Write down an equation that relates the gravitational potential energy and the electric potential energy of a proton at the surface of a star that has just stopped charging, **defining clearly** all the symbols used in the equation.

$$-\frac{GMm}{r} + \frac{Qq}{4\pi\epsilon_0 r} = 0, \text{ where}$$

G = gravitational constant,

M = mass of star,

m = mass of proton,

r = radius of star,

Q = maximum charge of star,

q = charge of proton,

$\epsilon_0$  = permittivity of free space.

..... [2]

- (ii) Show that, in the steady state, the maximum charge carried by a star of a given mass is independent of its radius. [1]

$$-\frac{GMm}{r} + \frac{Qq}{4\pi\epsilon_0 r} = 0$$

$$\Rightarrow Q = \frac{4\pi\epsilon_0 GMm}{q}$$

Hence the maximum charge Q of the star is independent of its radius r.

- (iii) Calculate the maximum charge for Sun, which has a mass of  $2.0 \times 10^{30}$  kg.

$$Q = \frac{4\pi\epsilon_0 GMm}{q}$$

$$= \frac{4\pi(8.85 \times 10^{-12})(6.67 \times 10^{-11})(2.0 \times 10^{30})(1.67 \times 10^{-27})}{1.60 \times 10^{-19}} = 155 \text{ C}$$

maximum charge = ..... C [1]

- (c) Two small solid metal spheres A and B have equal radii and are in a vacuum. Their centres are 15 cm apart. Sphere A has charge +3.0 pC and sphere B has charge +12 pC. The arrangement is illustrated in Fig. 8.1.

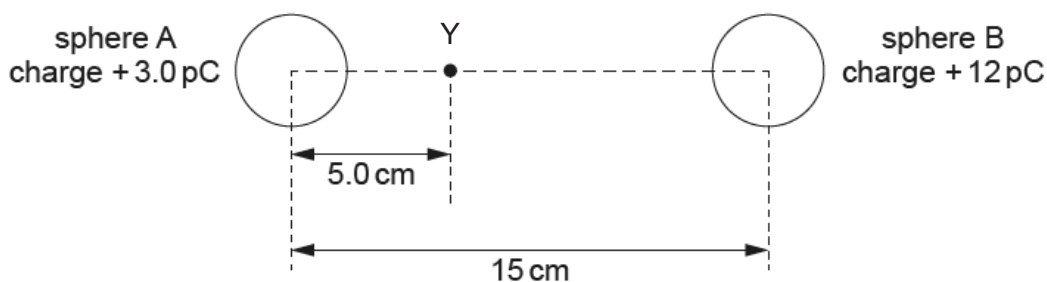


Fig. 8.1

Point Y lies on the line joining the centres of the spheres and is at a distance of 5.0 cm from the centre of sphere A.

- (i) Explain why the electric field strength in both spheres is zero.

.. In the presence of an electric field, the charges in a conductor would .....  
 .. move. Since the charges in spheres A and B do not move, this means that .....  
 .. there is no resultant force exerted on these charges. Hence there is no .....  
 .. electric field, so the electric field strength in both spheres is zero. ....  
 ..... [1]

- (ii) Show that the electric field strength is zero at point Y. Explain your working. [3]

At point Y, the electric field strength due to sphere A is directed towards the right, while that due to sphere B is directed towards the left.

Hence resultant electric field strength at Y

$$= E_A - E_B$$

$$= \frac{Q_A}{4\pi\epsilon_0 r^2} - \frac{Q_B}{4\pi\epsilon_0 (0.15 - r)^2}$$

$$= \frac{3.0 \times 10^{-12}}{4\pi(8.85 \times 10^{-12})(0.050)^2} - \frac{12 \times 10^{-12}}{4\pi(8.85 \times 10^{-12})(0.15 - 0.050)^2}$$

$$= 0$$

- (iii) Explain how the electric field strength at point Y is related to the electric potential at that point.

The electric field strength at point Y is equal to the negative of the electric potential gradient at that point. ....

OR

The magnitude of the electric field strength at point Y is equal to the value of the electric potential gradient at that point, and the direction of the electric strength is in the direction of decreasing electric potential.

[1]

- (iv) Calculate the electric potential at point Y.

$$\begin{aligned} V &= V_A + V_B \\ &= \frac{3.0 \times 10^{-12}}{4\pi\epsilon_0(0.050)} + \frac{12 \times 10^{-12}}{4\pi\epsilon_0(0.10)} \\ &= 1.62 \text{ V} \end{aligned}$$

electric potential = ..... V [2]

- (v) A silver-107 nucleus ( ${}^{107}_{47}\text{Ag}$ ) has speed  $v$  when it is a long distance from point Y. Use your answer in (iv) to calculate the minimum value of  $v$  such that the nucleus can reach point Y.

Loss in KE = Gain in EPE

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

$$\frac{1}{2}(107u)v^2 = 47eV$$

$$\frac{1}{2}(107)(1.66 \times 10^{-27})v^2 = 47(1.60 \times 10^{-19})(1.62)$$

$$v = 1.17 \times 10^4 \text{ m s}^{-1}$$

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

- (d) Sphere B in Fig. 8.1 is removed and placed at the centre of two parallel, large metal plates which are connected to the terminals of a battery with e.m.f. 10 V, as shown in Fig. 8.2. The distance between the plates is 2.0 mm.

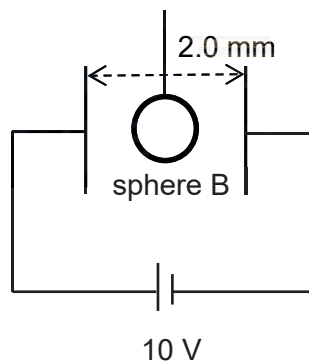


Fig. 8.2

- (i) Calculate the electric force  $F_1$  exerted by the plates on sphere B.

$$F_1 = Q_B \left( \frac{\Delta V}{d} \right)$$

$$= (12 \times 10^{-12}) \left( \frac{10}{0.0020} \right) = 6.0 \times 10^{-8} \text{ N}$$

$F_1 = \dots\dots\dots$  N [2]

- (ii) Another conducting sphere C, which is initially uncharged and has a radius twice that of sphere B, is placed in contact with sphere B. Determine the new charge on sphere B after sphere C has been removed.

$$V_B = V_C$$

$$\frac{Q_B}{4\pi\epsilon_0 r} = \frac{Q_C}{4\pi\epsilon_0 (2r)}$$

$$Q_C = 2Q_B$$

$$\text{Since } Q_B + Q_C = 12 \times 10^{-12},$$

$$\Rightarrow 3Q_B = 12 \times 10^{-12}$$

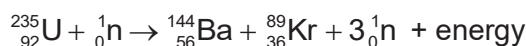
$$Q_B = 4.0 \times 10^{-12} \text{ C}$$

new charge =  $\dots\dots\dots$  C [2]

- 9 In 1954 the world's first nuclear-powered submarine, the USS Nautilus, was launched. Before that, submarines used diesel-electric power. Enriched uranium, which consists of a high percentage of uranium-235 isotope ( ${}^{235}_{92}\text{U}$ ), was used as the source of fuel for USS Nautilus.

Naturally occurring uranium consists mainly of uranium-238 isotope ( ${}^{238}_{92}\text{U}$ ) and only 0.72% of it is made up of  ${}^{235}_{92}\text{U}$ . It can be enriched to increase the percentage of  ${}^{235}_{92}\text{U}$  by up to 90% so as to allow nuclear fission reaction to take place effectively.

- (a) In the nuclear reactor of the submarine, the process of nuclear fission is caused by the bombardment of  ${}^{235}_{92}\text{U}$  with a slow-moving neutron as described by the following equation:



- (i) Explain what is meant by the nuclear binding energy of a uranium-235 nucleus.

The binding energy of a uranium-235 nucleus is defined as the energy needed to separate completely the nucleus into its individual nucleons. ....

[1]

- (ii) Sketch the variation of average binding energy per nucleon with nucleon number on Fig 9.1. In your sketch, mark the relative positions of  ${}^{235}_{92}\text{U}$ , barium-144 ( ${}^{144}_{56}\text{Ba}$ ) and krypton-89 ( ${}^{89}_{36}\text{Kr}$ ). [2]

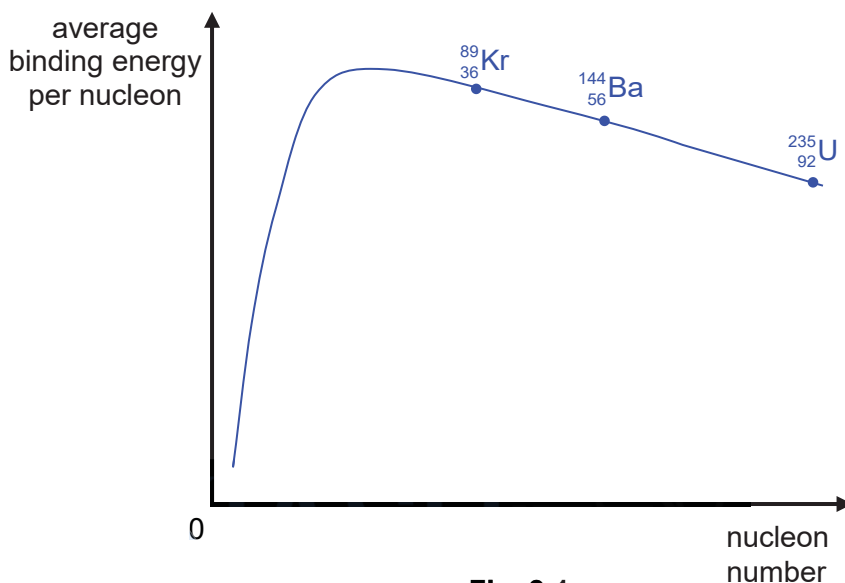


Fig. 9.1

- (iii) Using the concept of binding energy, explain why the fission of  ${}^{235}_{92}\text{U}$  into  ${}^{144}_{56}\text{Ba}$  and  ${}^{89}_{36}\text{Kr}$  results in a release of energy.

The sum of the binding energies of the products of the fission reaction,  ${}^{144}_{56}\text{Ba}$  and  ${}^{89}_{36}\text{Kr}$  is higher as compared to the binding energy of the reactant,  ${}^{235}_{92}\text{U}$ . As such, less energy is needed to separate  ${}^{235}_{92}\text{U}$  and more energy is consequently released when the products  ${}^{144}_{56}\text{Ba}$  and  ${}^{89}_{36}\text{Kr}$  are formed, resulting in a net release of energy. ....

[2]

- (iv) The masses of some of the particles and nuclei involved in the reaction are given in Fig. 9.2.

	mass
${}_{92}^{235}\text{U}$	235.044 u
${}_{56}^{144}\text{Ba}$	143.923 u
${}_{36}^{89}\text{Kr}$	88.917 u
${}_0^1\text{n}$	1.009 u

Fig. 9.2

Calculate the energy released for one such fission reaction, to three significant figures.

$$\begin{aligned}
 &\text{Energy released in a single fission} \\
 &= \Delta mc^2 \\
 &= [235.044 + 1.009 - (143.923 + 88.917 + 3 \times 1.009)] \times 1.66 \times 10^{-27} \times \\
 &\quad (3.00 \times 10^8)^2 \\
 &= 2.779 \times 10^{-11} \text{ J} \\
 &= 2.779 \times 10^{-11} / 1.60 \times 10^{-19} \times 10^6 \\
 &= 174 \text{ MeV}
 \end{aligned}$$

energy released = ..... MeV [3]

- (v) When tested under laboratory conditions, the total kinetic energy of the products in the fission reaction was found to be 168 MeV. Suggest a reason for the difference (if any) between this value and your answer in (iv).

.. Other sources of energy such as gamma radiation may also be released .....  
in the fission reaction. [1]

- (vi) The nuclear reactor used to power the USS Nautilus has a power output of 10 MW. The submarine is designed to carry enough nuclear fuel to power the submarine for 25 years.

Assuming the actual energy released per fission reaction is 168 MeV, calculate the mass of  ${}_{92}^{235}\text{U}$  that needs to be carried by USS Nautilus to achieve this.

$$\begin{aligned}
 &\text{Amount of energy needed} \\
 &= P t \\
 &= 10 \times 10^6 \times 25(365)(24)(3600) \\
 &= 7.884 \times 10^{15} \text{ J} \\
 &\text{Since one fission reaction can release 168 MeV of energy.} \\
 &\text{Therefore, number of } {}_{92}^{235}\text{U required} \\
 &= 7.884 \times 10^{15} / (168 \times 10^6 / 1.60 \times 10^{-19}) = 2.933 \times 10^{26} \\
 &\text{Mass of required} \\
 &= 2.933 \times 10^{26} \times 235.044 \times 1.66 \times 10^{-27} = 114 \text{ kg}
 \end{aligned}$$

mass of  ${}_{92}^{235}\text{U}$  = ..... kg [3]

- (vii) The fission reaction involving  $^{235}_{92}\text{U}$  is effective as it is a type of nuclear chain reaction. Suggest why the reaction is considered a *chain reaction*.

The fission reaction produced three neutrons which have high energy. This will in turn react with more uranium-235 nucleus to trigger more fission reactions. .... [1]

- (viii) State one advantage and one disadvantage in the use of nuclear power instead of diesel-electric power in providing energy for the submarine.

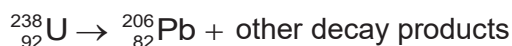
Advantage:

.. Any positive reasons relating to the small amount of fuel needed or to the sustainability of the fuel (less need of refuelling) will be accepted. .... [1]

Disadvantage:

.. Any reasons relating to the hazardous nature of the fission reactants and products (such as their radioactive nature, need of shielding or danger of meltdown) will be accepted. .... [1]

- (b) In a sample of naturally occurring uranium, the isotope  $^{238}_{92}\text{U}$ , which has a half-life of  $4.47 \times 10^9$  years, undergoes radioactive decay to form  $^{206}_{82}\text{Pb}$ .



- (i) Define *half-life*.

.... Half-life refers to the time needed for half the radioactive nuclei to decay. .... [1]

- (ii) Besides  $^{206}_{82}\text{Pb}$ , the other decay products formed consist of alpha and beta particles. Determine the number of alpha and beta particles formed when one  $^{238}_{92}\text{U}$  isotope decays to form  $^{206}_{82}\text{Pb}$ .



number of alpha particles = .....

number of beta particles = ..... [2]

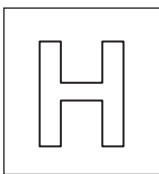


- (iii) A sample of naturally occurring uranium contains 120 kg of  ${}_{92}^{238}\text{U}$  after some of the isotopes have decayed to  ${}_{82}^{206}\text{Pb}$ . Given that the original mass of  ${}_{92}^{238}\text{U}$  in the sample was 200 kg, determine the age of the sample.

$$m = m_0 e^{-\lambda t} \Rightarrow \lambda t = -\ln\left(\frac{m}{m_0}\right)$$

$$t = -\ln\left(\frac{m}{m_0}\right) \div \lambda = -\ln\left(\frac{m}{m_0}\right) \div \left(\frac{\ln 2}{t_{1/2}}\right) = -\ln\left(\frac{120}{200}\right) \div \left(\frac{\ln 2}{4.47 \times 10^9}\right) = 3.29 \times 10^9 \text{ years}$$

age of sample = ..... years [2]



NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 2

CANDIDATE  
NAME

**SOLUTION**

CLASS

TUTOR'S  
NAME

**PHYSICS**

**9749/04**

Paper 4 Practical

**24 August 2017**

**2 hours 30 minutes**

Candidates answer on the Question Paper.

Additional Materials: Will be announced by invigilator

**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, 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 the laboratory where appropriate in the boxes provided on the right.

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.

<b>Shift</b>
<b>Laboratory</b>

For Examiner's Use	
1	
2	
3	
4	
<b>Total</b>	

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

**[Turn over**

- 1 This investigation considers the size of the hole needed in a salt shaker for the salt to flow at a suitable rate.
- (a) You have been provided with a beaker labelled **P** containing 100 g of salt as shown in Fig. 1.1.

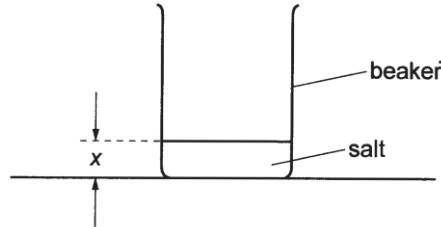


Fig. 1.1

- (i) Measure and record the depth  $x$  of salt in beaker **P** using the vernier calipers.

$$x = \frac{1.95 + 1.91}{2}$$

$$x = 1.93 \text{ cm}$$

$$x = \underline{\hspace{2cm} 1.93 \text{ cm (2 d.p.)} \hspace{2cm}} \quad [1]$$

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

$$\Delta x = 0.05 \text{ cm}$$

$$\frac{\Delta x}{x} \times 100\% = \frac{0.05}{1.93} \times 100\%$$

$$\text{percentage uncertainty} = 3\%$$

$$\text{percentage uncertainty} = \underline{\hspace{2cm} 3\% (1 \text{ s.f.}) \hspace{2cm}} \quad [1]$$

- (b) You have been provided with two cards. Each card has a hole of a different size.

- (i) Measure and record the diameter  $d$  of the smaller hole.

$$d = \frac{0.33 + 0.33}{2}$$

$$d = 0.33 \text{ cm}$$

$$d = \underline{\hspace{2cm} 0.33 \text{ cm (2 d.p.)} \hspace{2cm}} \quad [1]$$

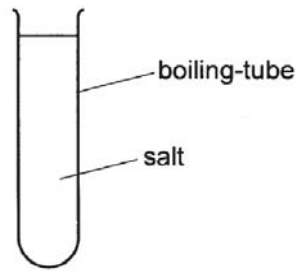
- (ii) Determine the area  $A$  of the smaller hole.

$$A = \pi \left( \frac{0.33}{2} \right)^2$$

$$A = 0.086 \text{ cm}^2$$

$$A = \underline{\hspace{2cm} 0.086 \text{ cm}^2 (2 \text{ s.f.}) \hspace{2cm}} \quad [1]$$

- (c) (i) Fill the boiling-tube, as shown in Fig. 1.2, with salt from beaker **P**.



**Fig. 1.2**

- (ii) Cover the open end of the boiling-tube with the card that has the smaller hole. Use tape to attach the card to the boiling-tube. The hole should not be covered by tape. When the boiling-tube is inverted, it should not be possible for salt to leave the boiling-tube other than through the hole.
- (iii) Cover the hole with your finger. Invert the boiling-tube over the empty beaker **Q**. Remove your finger and allow the salt to flow through the hole into beaker **Q** for two minutes. It may be necessary to shake the boiling-tube gently to achieve constant flow.
- (iv) Tap beaker **Q** gently on the bench to ensure that the surface of the salt is level. Measure and record the depth  $y$  of salt in beaker **Q**.

$$y = \frac{0.81+0.85}{2}$$

$$y = 0.83 \text{ cm}$$

$$y = \dots\dots\dots 0.83 \text{ cm (2 d.p.)} \dots\dots\dots$$

- (v) Estimate the mass  $m$  of salt in beaker **Q**.

Assuming that the cross-sectional area of both beakers are the same,

$$\frac{\text{mass in Q}}{\text{mass in P}} = \frac{y}{x}$$

$$m = \frac{0.83}{1.93} \times 100$$

$$m = 43 \text{ g}$$

$$m = \dots\dots\dots 43 \text{ g (2 s.f.)} \dots\dots\dots [1]$$

- (d) The recommended daily intake of salt for an adult is 5 g.

Use your data to calculate the time that a shaker, with a hole the same size as that in (c)(ii), should be inverted to apply 5 g of salt to food.

Assuming constant flow rate,

$$\frac{43 \text{ g}}{\text{time needed for 43 g to flow}} = \frac{5 \text{ g}}{\text{time needed for 5 g to flow}}$$

$$\text{time needed for 5 g to flow} = 5 \times \frac{120}{43}$$

$$\text{time needed for 5 g to flow} = 14 \text{ s}$$

time = ..... [1]

- (e) It is suggested that the rate of flow  $R$  of salt is proportional to the area  $A$  of the hole.

Use the card with the larger hole to take further measurements to investigate this suggestion. State and explain whether or not you agree with this suggestion. Present your measurements and calculated results clearly.

For the smaller hole

$$R_1 = \frac{43}{120} = 0.36 \text{ g s}^{-1}$$

For the bigger hole,  $d = 0.60 \text{ cm}$

$$A = \pi \left( \frac{d^2}{4} \right) = \pi \left( \frac{0.60^2}{4} \right) = 0.28 \text{ cm}^2$$

When  $t = 15 \text{ s}$ , depth = 1.07 cm

$$\frac{m_Q}{100} = \frac{1.07}{1.93}$$

$$m_Q = 55 \text{ g}$$

$$R_2 = \frac{55}{15} = 3.78 \text{ g s}^{-1}$$

If  $R = k A$ , then the two experiment must yield the same  $k$

$$k_1 = \frac{R_1}{A_1} = \frac{0.36}{0.086} = 4.2$$

$$k_2 = \frac{R_2}{A_2} = \frac{3.7}{0.28} = 13.2$$

$$\frac{k_2}{k_1} = \frac{13.2}{4.2} = 3$$

Since  $k_2$  is three times  $k_1$ , the rate of flow of salt is NOT proportional to the area of the hole.

..... [6]

- (f) A statement found on the internet says that:

*"The salt shaker may be distinguished primarily by the size of the holes, and then by the number of holes. Salt is coarser than pepper, and needs the larger hole. It is also heavier and flows much more freely than pepper, accordingly there are often fewer holes on the salt shaker to help control the flow. However there is no manufacturing standard."*

Suggest changes that could be made to the salt investigation to study the flow of pepper from a shaker.

Use smaller holes, pepper is finer

.....  
Use more holes, does not flow as freely as salt

.....  
Use a mass balance to weigh the exact mass of pepper that flows out as pepper can stick to the side of beaker and height of pepper will be inaccurate.

.....  
Pour the pepper carefully with the boiling tube lowered into the beaker/ Use a taller beaker /Use a cover to prevent pepper that fly out of beaker and height of pepper will be inaccurate.

..... [3]

[Total: 15 marks]

You may not need to use all of the materials provided.

2 In this question you will investigate how the light detected by a light-dependent resistor (LDR) depends on the thickness of an absorber.

(a) (i) Connect the circuit shown in Fig. 2.1. The light-emitting diode (LED) should be connected the right way round so that light is emitted.

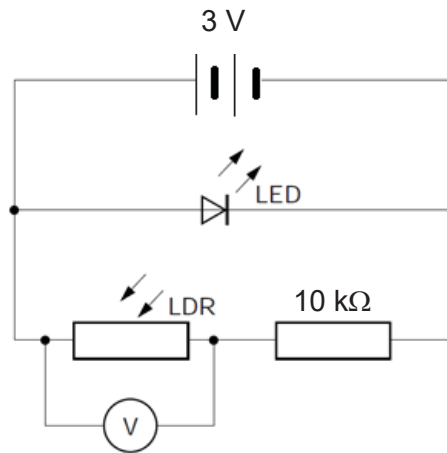


Fig. 2.1

- (ii) Use the black paper and the Sellotape to make a cylinder of length 4 cm. The cylinder should fit neatly over the LDR.
- (iii) Cut the cylinder in half so that you have two cylinders of length 2 cm.
- (iv) Tape one cylinder over the LDR and the other cylinder over the LED as shown in Fig. 2.2.

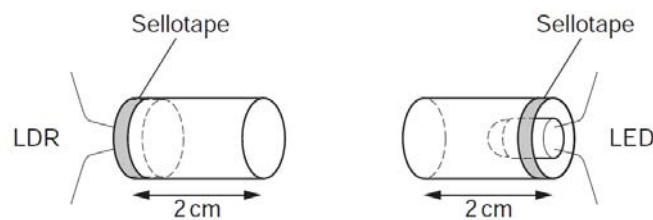


Fig. 2.2

(b) Place the cylinders together, as shown in Fig. 2.3. Record the voltmeter reading  $V_0$ .

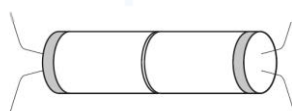


Fig. 2.3

$$V_0 = \dots\dots\dots 1.87 \text{ V (2 d.p.)} \dots\dots\dots [1]$$

(c) Fold the sheet of tracing paper in half four times so that you have 16 layers.

(i) Measure the thickness of these 16 layers.

$x_1 / \text{mm}$	$x_2 / \text{mm}$	$\langle x \rangle / \text{mm}$
1.35	1.37	1.36

thickness of 16 layers = ..... **1.36 mm (2 d.p.)** ..... [1]

(ii) Estimate the percentage uncertainty in this measurement. Show your working.

$$\Delta x = 0.01 \text{ cm (1 s.f.)}$$

$$\begin{aligned} \text{Percentage uncertainty} &= \frac{\Delta x}{x} \times 100\% \\ &= \frac{0.01}{1.36} \times 100\% \\ &= 0.74 \% \text{ (2 s.f.)} \end{aligned}$$

percentage uncertainty = ..... **0.74 % (2 s.f.)** ..... [1]

(iii) Determine the thickness  $t$  of one layer of tracing paper.

$$\begin{aligned} t &= \frac{x}{16} \\ &= \frac{1.36}{16} \\ &= 0.0850 \text{ mm} \end{aligned}$$

$t =$  ..... **0.0850 mm** ..... [1]

(iv) Justify the number of significant figures you have given for  $t$ .

.. - Since the uncertainty of the measured value of thickness of 16 layers,  $x$ , .....  
.. is 0.01 mm (from Part (ii)), hence  $x$  is measured to 2 decimal places (i.e. ....  
.. where the significant figure in  $\Delta x$  occurs). ..

.. - Therefore the measured value of  $x$  has 3 significant figures. ....

.. - The value of the calculated thickness of one layer,  $t$ , follows the same ..... [1]  
.. number of significant values as that of  $x$  (because there is no uncertainty  
.. associated with the number 16). Hence  $t$  is recorded to 3 significant  
.. figures as well.



- (d) (i) Place four layers of tracing paper between the LED and the LDR as shown in Fig. 2.4. Record the voltmeter reading  $V$ .

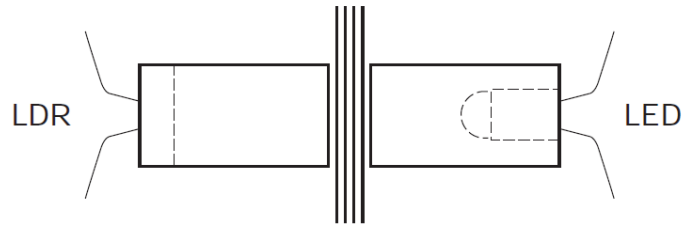


Fig. 2.4

$$V = \underline{\hspace{10em} 2.83 \text{ V (2 d.p.)} \hspace{10em}}$$

- (ii) Repeat (d)(i) using eight layers of tracing paper.

$$V = \underline{\hspace{10em} 2.89 \text{ V (2 d.p.)} \hspace{10em}} \quad [1]$$

- (e) Explain whether your results support the idea that  $V - V_0$  is proportional to the number of layers  $n$  of tracing paper.

If  $V - V_0$  is proportional to  $n$ , then  $V - V_0 = kn$ , where  $k$  is a constant.

$n$	$(V - V_0) / V$	$k = \left( \frac{V - V_0}{n} \right) / V$
4	0.96	0.24
8	1.02	0.128

Percentage difference in the two values of  $k$  obtained

$$= \frac{|0.24 - 0.128|}{0.24} \times 100 \% \\ = 47 \%$$

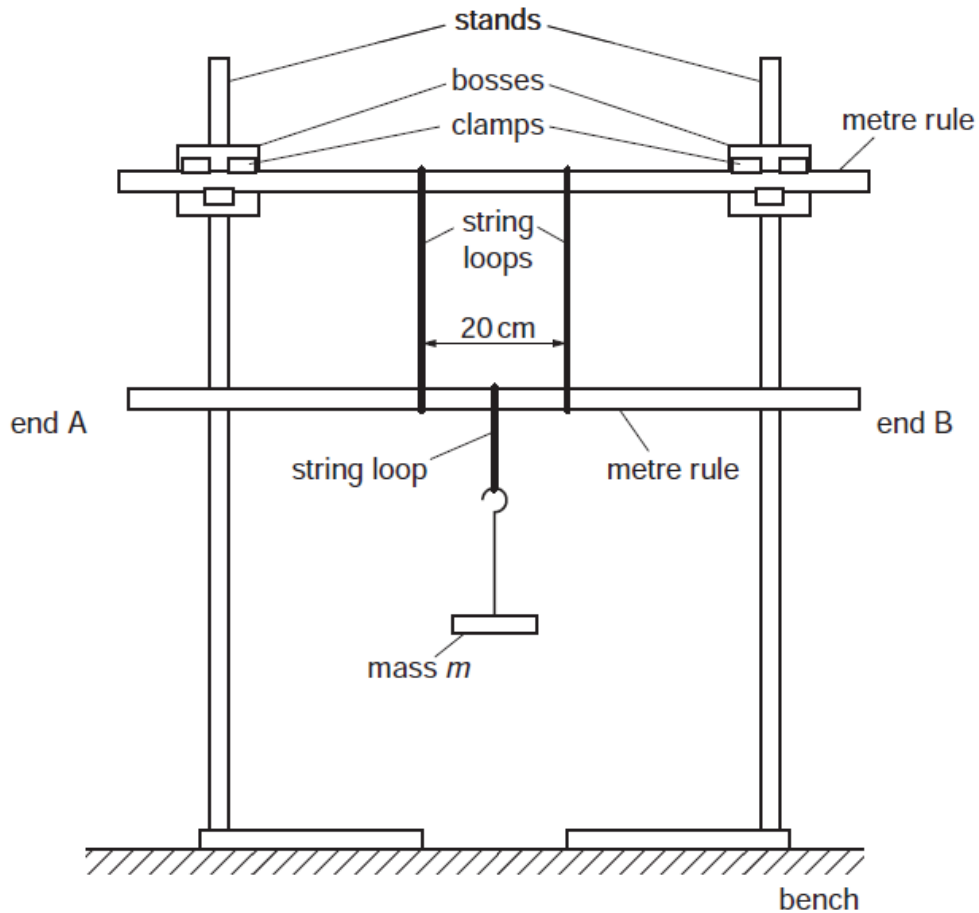
Since the percentage difference in the two values of  $k$  is **more than 10 %**,  $k$  cannot be considered to be a constant, and hence the results **do not** support the idea that  $V - V_0$  is proportional to  $n$ .

..... [2]

[Total: 8 marks]

**You may not need to use all of the materials provided.**

- 3 In this experiment, you will investigate how the motion of an oscillating system depends on the mass attached to the system.
- (a) (i) Set up the apparatus as shown in Fig. 3.1.



**Fig. 3.1**

Slide the two loops of string onto a rule and fix this rule in the clamps.

Adjust the clamps until the rule is parallel to the bench.

Using the string provided, make a loop of circumference 20 cm. Slide this shorter loop onto the second rule and use the longer loops to support this second rule.

Both rules should have their markings facing you. The strings should be vertical, 20 cm apart and at equal distances from the centre of the second rule.

Use the shorter loop of string to suspend a mass  $m$  at the 50 cm mark on the second rule, where  $m = 0.500$  kg.

- (ii) Move the end A of the lower rule towards you and the end B away from you. Release the rule and watch the movement. End A will move away from you and back towards you, completing a swing. The time taken for one complete swing is  $T$ . Determine an accurate value for  $T$ .

m/g	m/kg	N	$t_1/s$	$t_2/s$	$\langle t \rangle/s$	$T/s$
500	0.500	25	20.4	20.3	20.4	0.814

$$T = \dots\dots\dots 0.814 \text{ s} \dots\dots\dots [1]$$

- (b) Change  $m$  and repeat (a)(ii) until you have six sets of values of  $m$  and  $T$ .

m/g	m/kg	N	$t_1/s$	$t_2/s$	$\langle t \rangle/s$	$T/s$	$T^2/s^2$
100	0.100	16	22.2	22.2	22.2	1.39	0.519
150	0.150	18	20.7	20.8	20.8	1.15	0.753
200	0.200	18	22.6	22.7	22.7	1.26	0.632
300	0.300	22	21.9	22.0	22.0	1.00	1.00
500	0.500	25	20.4	20.3	20.4	0.814	1.51
600	0.600	30	22.5	23.4	23.0	0.765	1.71
800	0.800	35	22.9	22.9	22.9	0.654	2.34

[7]

- (c) The quantities  $m$  and  $T$  are related by the equation

$$\frac{1}{T^2} = P m + Q$$

where  $P$  and  $Q$  are constants.

Plot a suitable graph to determine the values of  $P$  and  $Q$ .

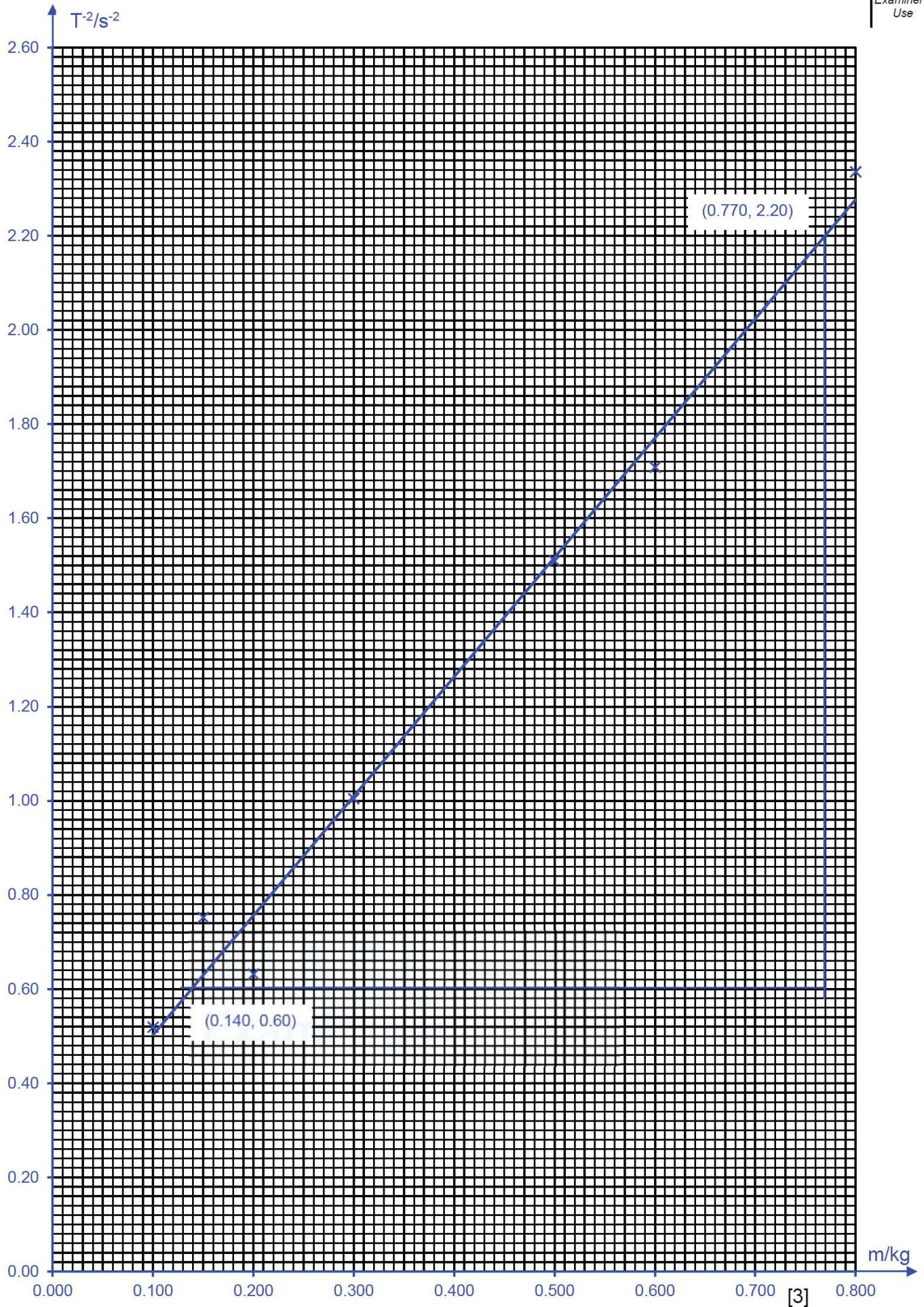
Plot a graph of  $\frac{1}{T^2}$  against  $m$ , where  $P$  is the gradient and  $q$  is the y-intercept

$$\begin{aligned} \text{gradient} &= \frac{2.20 - 0.60}{0.770 - 0.140} \\ &= \frac{1.60}{0.630} \\ &= 2.54 \\ P &= 2.54 \end{aligned}$$

$$\begin{aligned} \text{y-intercept} &= Y - (\text{gradient}) X \\ &= 2.20 - 2.54 ( 0.770 ) \\ &= 2.20 - 1.96 \\ &= 0.24 \\ Q &= 0.24 \end{aligned}$$

$$P = \text{.....} 2.54 \text{ kg}^{-1} \text{ s}^{-2} \text{.....}$$

$$Q = \text{.....} 0.24 \text{ s}^{-2} \text{.....} [4]$$



- (d) Comment on any anomalous data or results that you may have obtained.

There are no anomalous points. All data points are scattered evenly about the best fit line. Overall, the results obtained have a consistent trend.

OR

There is one anomalous point (----,-----). This point is further from the best-fit line compared to the other points.

[3]

[1]

- (e) State two significant sources of errors in this experiment.

- 1 It is difficult to judge visually the position of the start and stop of a complete oscillation, thus affecting the accuracy of the values of  $t$  and  $T$  obtained.
- 2 The loops of string of 30 cm circumference are not exactly the same size, affecting the accuracy of the values of  $t$  and  $T$  obtained.
- 3 The rulers are not exactly horizontal, affecting the accuracy of the values of  $t$  and  $T$  obtained.
- 4 The loops slide on the rules during oscillations, affecting the accuracy of the values of  $t$  and  $T$  obtained.
- 5 The mass of the slotted masses may not be exactly what is labelled, affecting the accuracy of the  $m$  values. (In this experiment, this particular source of error is much more insignificant than the others, and may not be awarded marks in the A levels)

[2]

- (f) Suggest improvements that could be made to the experiment to address the sources of error identified in (e). You may suggest the use of other apparatus or different procedures.

- 1 Using a third retort stand, clamp a 30 cm ruler so that it points horizontally at the equilibrium position of end A of the lower ruler, to act fiducial marker for the oscillation.
- 2 Instead of tying a knot with the string itself, tie the knot at the correct length with a thin thread or tape at the correct length.
- 3 Use a spirit level to check that both rulers are horizontal, by placing the level on top of each ruler, before commencing each set of readings.
- 4 Tape or glue the strings to the lower rule so that they remain in the same position on the rule.
- 5 Use an electronic balance to measure the total mass of the mass holder and the masses before hanging each configuration of masses on the lower loop. (In this experiment, this particular source of error is much more insignificant than the others, and may not be awarded marks in the A levels)

[2]

[Total: 20 marks]

- 4 A student is investigating the motion of magnets falling through a vertical copper pipe as shown in Fig. 4.1.

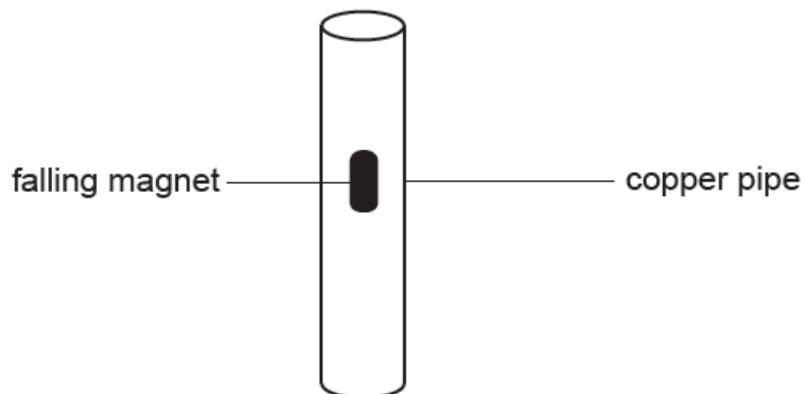


Fig. 4.1

The student releases a magnet above the copper pipe. The magnet has speed  $v$  as it leaves the pipe.

It is suggested that the relationship between  $v$  and  $B$  is

$$v = v_0 e^{-\lambda B}$$

where  $B$  is the magnetic flux density at the poles of the magnet and  $v_0$  and  $\lambda$  are constants.

Design a laboratory experiment to test the relationship between  $v$  and  $B$ . Explain how your results could be used to determine values of  $v_0$  and  $\lambda$ . You should draw a diagram, showing the arrangement of your equipment. In your account you should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any safety precautions to be taken.

### Diagram

[Total: 12 marks]

**Suggested marking scheme**

<b>Method of data collection [4](M)</b>
<p><b>Methods/instruments to measure I.V.</b></p> <ul style="list-style-type: none"> <li>Method to measure <math>B</math>, e.g. Hall probe placed near pole of magnet. <math>B</math> is calculated using <math>B=kV</math>. (Vis the voltmeter reading as voltmeter is connected to Hall Probe)</li> </ul> <p><b>Methods/instruments to measure D.V.</b></p> <ul style="list-style-type: none"> <li>Method to determine time at bottom of tube e.g. use of light gate(s) attached to timer</li> </ul> <p><b>Method to vary the I.V</b></p> <p><b>Method to create the condition in order to measure the I.V. / D.V. may be required.</b></p> <ul style="list-style-type: none"> <li>Labelled diagram showing a magnet and the vertical copper tube supported.</li> </ul> <p><b>Correct positioning or connection of apparatus</b></p> <ul style="list-style-type: none"> <li>Method to ensure that copper tube is vertical, e.g. set square, spirit level, plumb line.</li> </ul>
<b>Method of analysis [2](A1, A2)</b>
<ul style="list-style-type: none"> <li>Plot a graph of <math>\ln v</math> against <math>B</math> and relationship is valid if the graph is a <u>straight line</u>.</li> <li><math>\lambda = -\text{gradient}</math> and <math>v = e^{\text{y-intercept}}</math></li> </ul>
<b>Additional detail (max 4)(D) and 1 mark for control variable(C)</b>
<p><b>Correct method to ensure C.V. constant/monitor C.V.</b></p> <ul style="list-style-type: none"> <li>Keep the mass of magnet constant and check it with an electronic balance.</li> </ul> <p><b>A list of specific steps taken to taken to further improve accuracy of results or good experimental practice.</b></p> <ol style="list-style-type: none"> <li>Adjust Hall probe until maximum reading obtained/perpendicular to field.</li> <li>Use Hall probe to take readings for both poles and average.</li> <li>Method to calibrate Hall probe using a known field.</li> <li>Repeat experiment with magnets reversed and average or Repeat <math>v</math> (or <math>t</math>) for same <math>B</math> and average.</li> <li>Mechanism to release magnet eg stop gate/string method/electromagnetic switch.</li> <li>Distance between light gates is kept small for more accurate measurement of <math>v</math>.</li> <li>The expt should not be done with external magnetic field.</li> </ol>
<b>Safety precautions [1](S)</b>
<ul style="list-style-type: none"> <li>use sand tray/cushion to soften fall of falling magnet.</li> </ul>

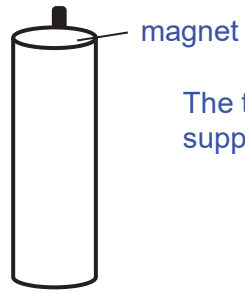
## Marking code

M: method of data collection, A: method of analysis, C:control variable,

D: additional details, S: Safety consideration



Suggested diagram



The tube and the light gates are supported by retort stands.

