Name : ________________________________ CT group : _________

VICTORIA JUNIOR COLLEGE
2015 JC2 PRELIMINARY EXAMINATIONS

PHYSICS **8866/02**

Higher 1 **14 Sep 2015**

MONDAY

Paper 2 Structured Questions

2 pm – 4 pm

2 Hours

Candidates answer on the Question Paper

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer any **two** 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	
Section A	
1	
2	
3	
4	
5	
6	
Section B	
7	
8	
9	
Total (max. 80):	

This question set consists of a total of **21** printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
acceleration of free fall,	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	$s = ut + (\frac{1}{2})at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = h\rho g$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$

Section A

Answer **all** the questions in this section.

1 A small ball is projected up a smooth incline at an angle θ with an initial speed u as shown in **Fig. 1.1**. It takes a duration of 3.0 s to reach the top of the incline. **Fig. 1.2** shows the vertical velocity of the ball from the point of projection to the point where the ball reaches its maximum height. (Air resistance can be taken as negligible)

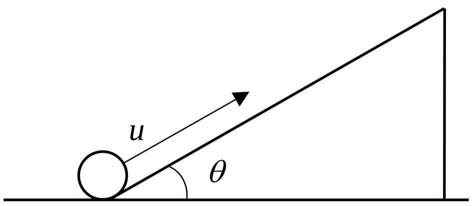

Fig. 1.1

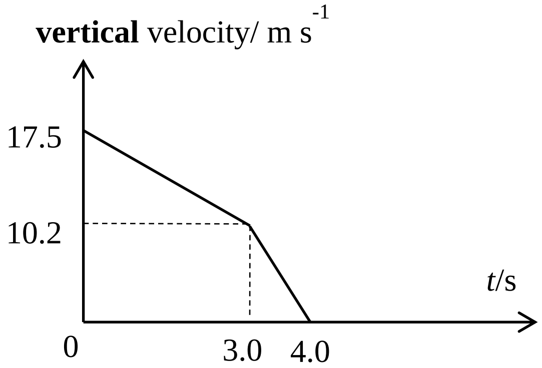

Fig. 1.2

(a) **(i)** Show, by considering the motion of the ball up and along the incline, that the angle θ is 29.9^{o}.

[2]

(ii) Calculate the initial velocity of the ball, u.

u = ……………… m s^{-1} [1]

(b) Sketch a velocity versus time graph, without numerical values, for the **horizontal** component of the ball's velocity up to 4.0 s.

[2]

2 **(a)**

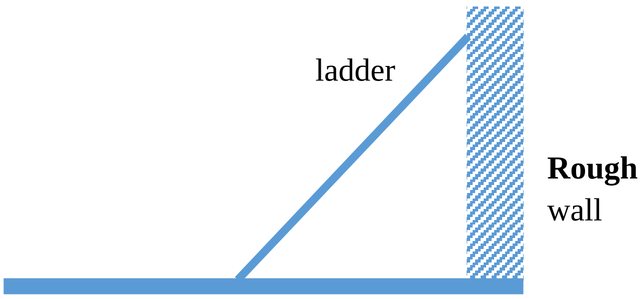

Fig. 2.1

Show, by considering forces, that a uniform ladder cannot be in equilibrium while resting against a rough wall and standing on a **smooth** floor.

[2]

(b)

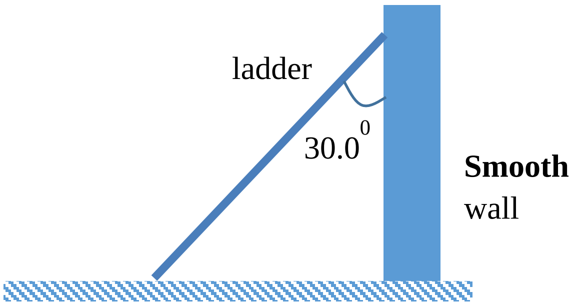

Fig. 2.2

A uniform ladder of weight 200 N rests at an angle of 30.0^o to a smooth vertical wall with the lower end resting on rough horizontal ground, as shown in **Fig. 2.2**. Calculate the magnitude of the total reaction force exerted by the ground on the foot of the ladder.

Reaction force = ……………….. N [**3**]

3 **(a)** **(i)** An object of mass *m* is subjected to a driving force *F* and travelling at a constant acceleration *a* after starting from an initial velocity *u*. Show how power *P* is related to time *t* for the motion of the object in terms of *m*, *a*, *u* and *t*.

[2]

(ii) Sketch a labelled graph to show the variation with time *t* of the power *P* of the object.

[1]

(b) Calculate the power exerted by an engine of a train at the instant when its velocity is 10 m s^{-1} and its acceleration is 0.16 m s^{-2} given that the total mass of the train is 3.0×10^5 kg and the resistance to its motion is 3.0×10^4 N.

Power = …………………… W [2]

4 **(a)** The photoelectric experiment provided the first evidence for the particulate nature of light.
Describe one observation from the photoelectric experiment and explain how the wave theory of light fails to account for the observation.

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……………………………………………………………………………… [2]

(b) An experiment where two metal plates X and Y are contained in an evacuated container and are connected in a circuit was conducted as shown in **Fig. 4.1**.
Curve E in **Fig. 4.2** shows the current through the microammeter as a function of the p.d. applied across XY when incident light falls on plate X.

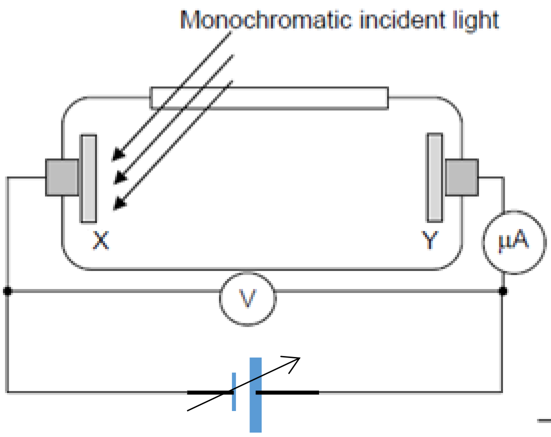

Fig. 4.1

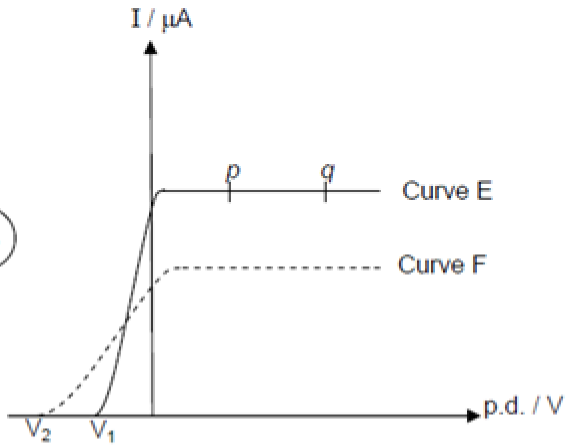

Fig. 4.2

(i) Explain why the current is constant for the section pq shown in curve E in **Fig. 4.2**.

………………………………………………………………………………

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

(ii) The experiment in **Fig. 4.1** was changed to obtain the curve F in **Fig. 4.2** with emitter X unchanged. State and explain the change of p.d. from V_1 to V_2.

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5 The energy levels of electrons in a hydrogen atom are shown in **Fig. 5**.

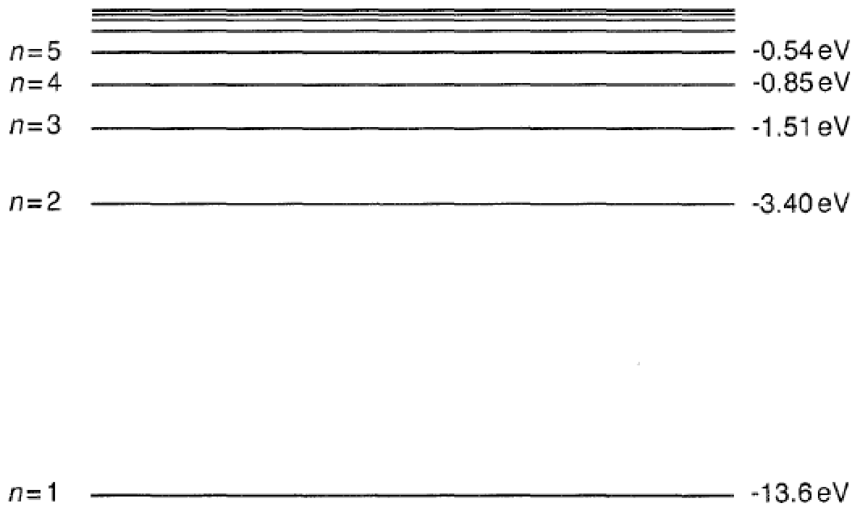

Fig. 5

(a) Deduce the transition that produces ultra-violet radiation of wavelength 103 nm.

Transition: …………………… [3]

(b) Discuss what will happen when light of photon energy 12.5 eV is shone onto the **cool** hydrogen gas.

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…………………………………………………………………………………… [2]

6 When a current is passed through a Direct Current (D.C.) motor, it will exert a torque T on its drive shaft that is proportional to the current I:

$$T = kI \quad -(1)$$

As the coil of current-carrying wire rotates within the magnetic field inside the motor, an e.m.f. will be induced within the coil that opposes the voltage V applied by the battery according to Lenz's Law. This *back e.m.f.* V_e reduces the effective voltage across the motor, and so reduces the current according to:

$$I = \frac{V - V_e}{R} \quad -(2)$$

where R = resistance of the motor between its terminals.

The *back e.m.f.* V_e is proportional to the rotational speed ω of the motor coil:

$$V_e = k\omega \quad -(3)$$

where the constant of proportionality k is the same as that used in equation (1). The rotational speed measures the rate of rotation about an axis and is specified in units of radians per second (rad s^{-1}).

The torque T produced by the motor can be used to turn an external load, such as the wheel of a car. When constant rotational speed has been reached, the torque exerted by the motor is balanced by the sum of the opposing torque due to the external load T_{load} and the frictional torque T_f within the motor itself:

$$T = T_{load} + T_f \quad -(4)$$

Fig. 6.1 lists some of the data for a particular DC motor.

Quantity (symbol)	**Value**
Battery voltage to be used (V)	9.0 V
Terminal resistance (R)	14.5 Ω
No-load rotational speed (ω_o)	1204 rad s^{-1}
no-Load current (I_o)	0.012 A
Stall torque (T_S)	4.46×10^{-3} N m
Friction torque (T_f)	9.0×10^{-5} N m

Fig. 6.1

Fig. 6.2 shows a list of corresponding values of the external load torque T_{load} and rotational speed ω for this motor.

External load torque T_{load} / N m	**Rotational speed ω / rad s^{-1}**
0	1204
1.00×10^{-3}	934
1.50×10^{-3}	799
2.00×10^{-3}	
2.50×10^{-3}	529
3.00×10^{-3}	394
3.50×10^{-3}	259
4.46×10^{-3}	0

Fig. 6.2

Fig. 6.3 shows the graph of rotational speed ω plotted against the external load torque T_{load} .

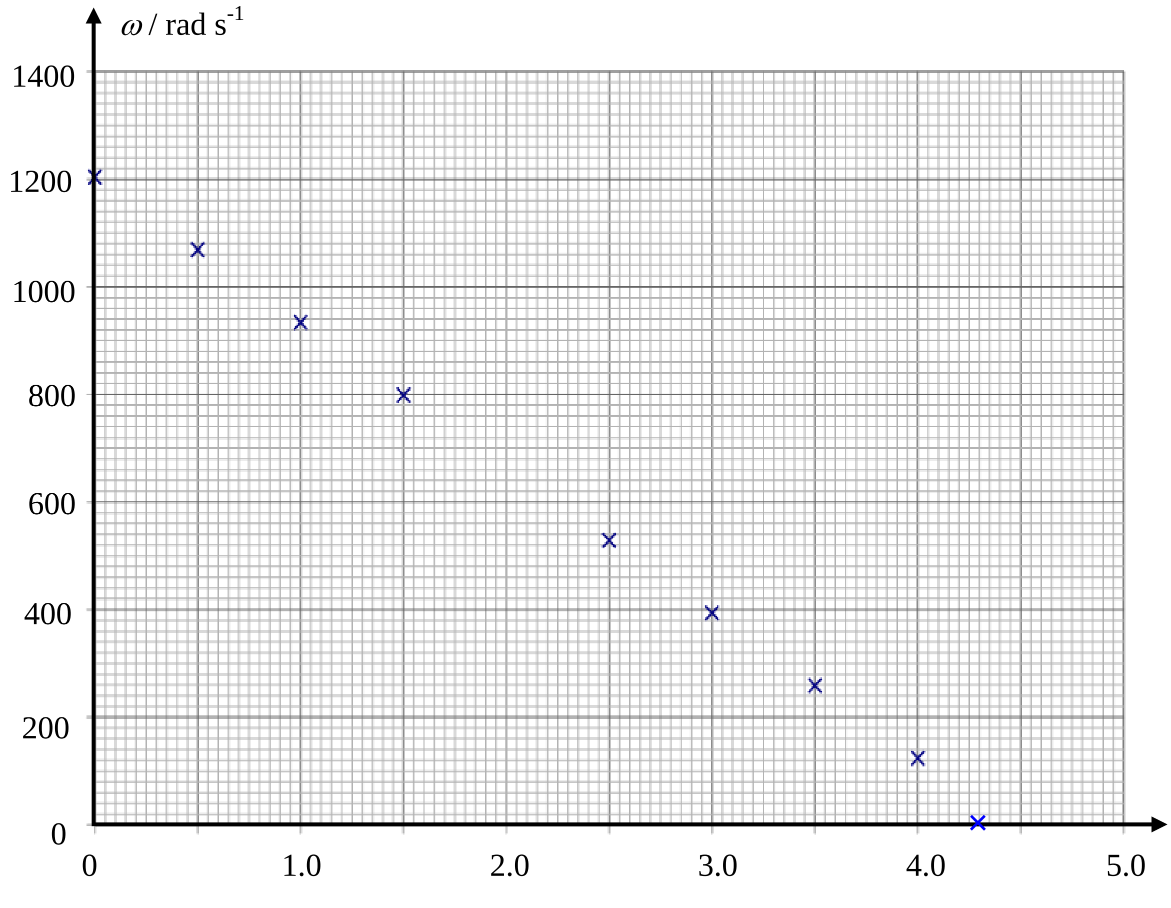

Fig. 6.3

The no-load speed ω_o is the rotational speed of the motor shaft when no external load torque is applied to it.

(a) On **Fig. 6.3**, label the point at which the no-load speed is attained with the numerical value from the table in **Fig. 6.1** and mark it as "ω_o" together with an arrow. [1]

As the torque T_{load} due to the external load increases, the rotational speed ω of the motor shaft will decrease. At a critical value of this external torque, called the stall torque T_S , the motor shaft will just come to rest.

(b) On **Fig. 6.3**, label the point representing the stall torque with the numerical value from the table in **Fig. 6.1** and mark it as "T_S" together with an arrow. [1]

The graph of rotational speed ω against the load torque T_{load} is a straight line.

(c) Use equations (1) through (4) to show that the equation of this straight line is:

$$\omega = -\frac{R}{k^2} T_{load} + A \quad ,$$

where A is a constant.

$\left(\text{Note:} \quad A = \frac{V}{k} - \frac{R}{k^2} T_f\right)$

[3]

(d) Use the values from **Fig. 6.1** and **Fig. 6.3** to determine the value of the constant k. Express your answer in S.I. units.

k = …………………….. [2]

In **Fig. 6.2**, the data for the rotational speed ω is missing for one value of the load torque, namely, $T_{load} = 2.00 \times 10^{-3}$ N m.

Assume that this external load torque T_{load} of 2.00×10^{-3} N m is applied to the motor shaft.

(e) Determine the torque T that the motor coil must produce internally in order to maintain a constant rotational speed when this external load torque is applied to the motor shaft.

T = …………………… N m [2]

(f) Using **Fig. 6.3**, or otherwise, determine the rotational speed ω of the motor shaft when this external load torque is applied. Write your answer below and in the relevant blank space in **Fig. 6.2**.

ω = ………………. rad s^{-1} [1]

(g) Determine the resulting current I that flows through the motor as it drives this external torque.

I = ………………… A [2]

(h) For this external load torque, calculate the mechanical output power P_{mech} of the motor, given that:

$$P_{mech} = T_{load} \times \omega$$

P_{mech} = …………….. W [1]

(i) On **Fig. 6.3**, shade the *area* to represent the magnitude of the mechanical power output that was calculated in **(h)**. [1]

(j) Calculate the efficiency η of the motor as it drives this external load torque T_{load} of 2.00×10^{-3} N m, given that:

$$\eta = \frac{P_{mech}}{P_{in}} ,$$

where P_{in} = electrical power supplied to the motor.

η = …………………….. [1]

Section B

Answer **two** of the questions in this section.

7

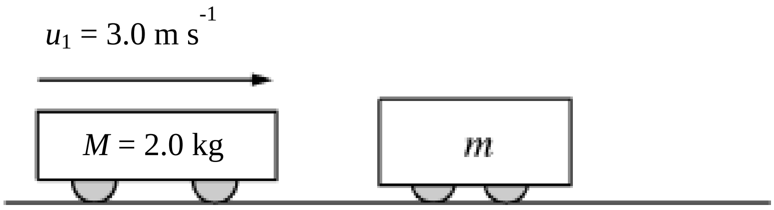

Fig. 7.1

A 2.0 kg frictionless cart is moving at a constant speed of 3.0 m s^{-1} to the right on a horizontal surface as shown in **Fig. 7.1**, when it collides with a second cart of undetermined mass m that is initially at rest. The force F of the collision as a function of time t is shown in **Fig. 7.2** where t = 0 is the instant of initial contact. As a result of the collision, the second cart acquires a speed of $v_2 = 1.6$ m s^{-1} to the right. Assume that friction is negligible before, during, and after the collision.

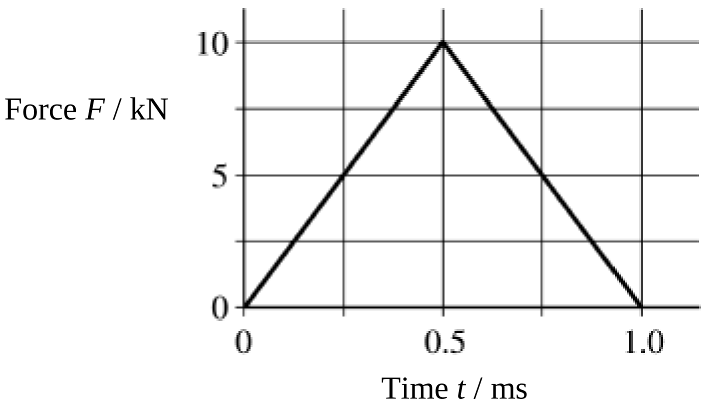

Fig. 7.2

Calculate

(a) the magnitude, and state the direction, of the velocity of the 2.0 kg cart after the collision. Identify the quantity under the force-time graph.

Velocity = ………………… m s^{-1} [2]

Direction = …………………… [1]

Quantity: ……………………. [1]

(b) the mass *m* of the second cart.

m = …………….. kg [2]

(c) the total loss in energy as a result of the collision. Hence state whether the collision is elastic or inelastic, giving a reason.

Loss in energy = ………………. J [2]

The collision is elastic / inelastic because ……………………………………….

……………………………………………………………………………………. [1]

(d) Sketch a labelled graph to show the variation with time of the velocity of the 2.0 kg cart from 0 to 1.0 ms.

[3]

After the collision, the second cart eventually encounters a ramp, which it traverses with no frictional loss. The graph in **Fig. 7.3** shows the speed v of the second cart as a function of time t for the next 5.0 s, where t = 0 is now the instant at which the carts separate.

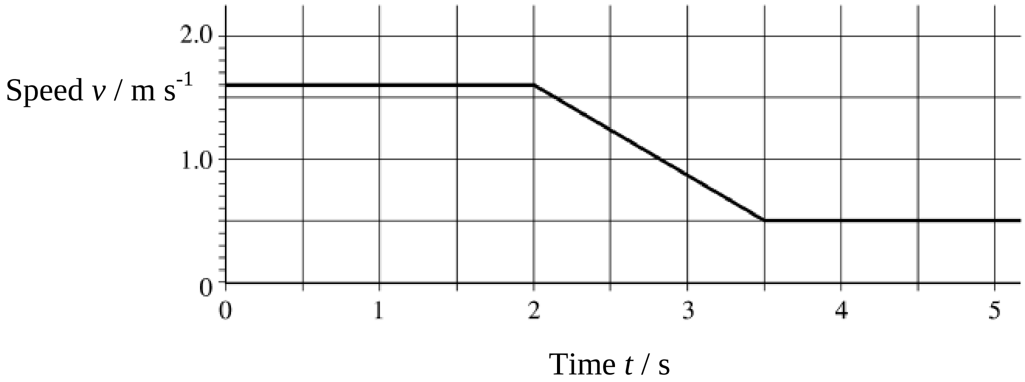

Fig. 7.3

(e) Calculate the acceleration of the cart at t = 3.0 s.

Acceleration = ……………….. m s^{-2} [2]

(f) Calculate the distance travelled by the second cart during the 5.0 s interval after the collision (0 s < t < 5.0 s).

Distance travelled = ………………. m [3]

(g) State whether the second cart goes up or down the slope and calculate the maximum elevation (above or below the initial height) reached by the cart on the ramp during the 5.0 s interval after the collision (0 s < t < 5.0 s).

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…………………………………………………………………………………………

…………………………………………………………………………………… [3]

8 A student conducts four experiments to determine the speed of sound in air as follows:

(Expt 1) Sound from a source reaches a point P via two paths in air which differ in length by 1.20 m. When the frequency of the sound is gradually increased, the resultant intensity at P goes through a series of maxima and minima. A maximum occurs when the frequency is 850 Hz and the next maximum occurs at 1133 Hz.

(Expt 2) Fig. 8.1 shows two similar loudspeakers stationed d = 0.300 m apart and driven in phase from a common audio-frequency source of frequency 15.0 kHz. When the student moves from A to B, the intensity of the sound he hears is alternately loud and soft. The distance between adjacent loud and soft regions is 3.82 m. The experiment is conducted in air.

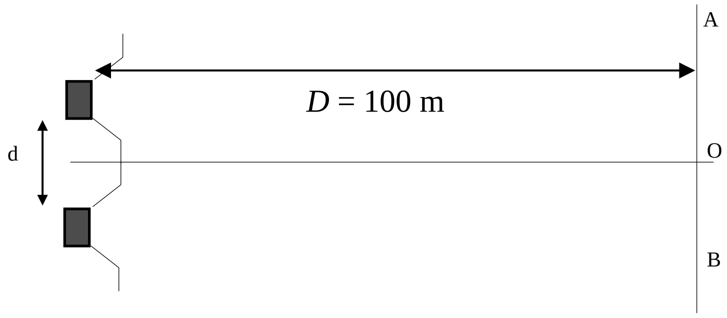

Fig. 8.1

(Expt 3) Fig. 8.2 shows a long horizontal plastic tube containing some fine powder. One end of the tube is closed and a loudspeaker is connected to a signal generator positioned at the other end.

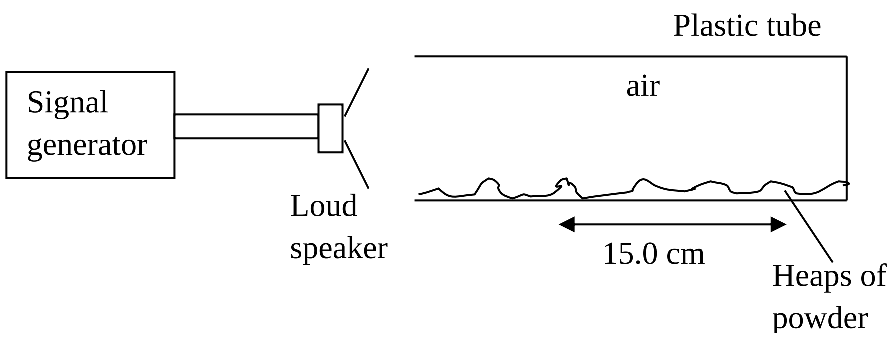

Fig. 8.2

At a frequency of 3400 Hz, the powder within the tube forms heaps.

(Expt 4) Two coherent identical sound sources connected by a common signal generator are set 3.00 m apart in a room. A microphone connected to a CRO is placed at the apex X (centred between the two loudspeakers) of an isosceles triangle 4.00 m from the horizontal dotted line separating the two loudspeakers as shown in **Fig. 8.3**.

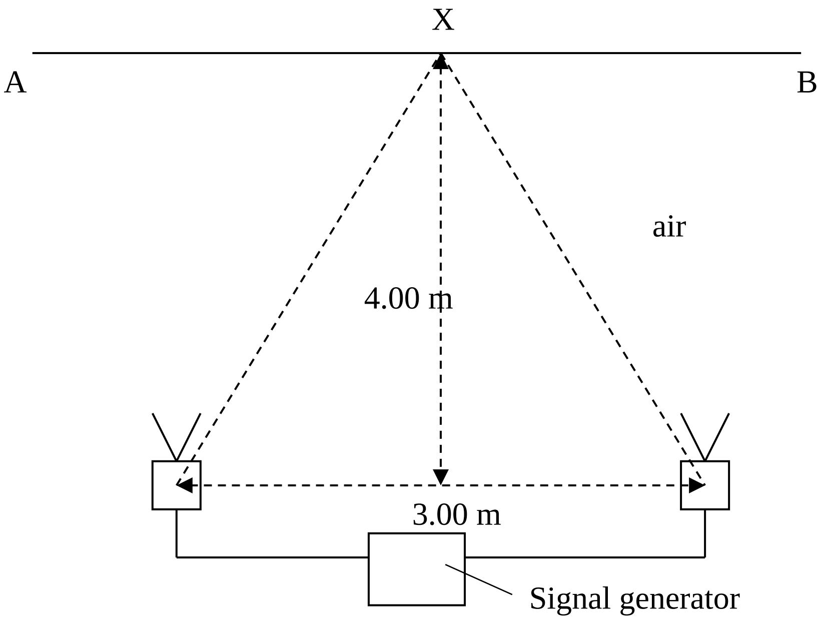

Fig. 8.3

The microphone is moved along AB to a point to the right of X by 10.0 cm where a first sound minimum is detected. The frequency of the sound is 2400 Hz.

(a) Calculate the velocity of sound obtained in Experiment **1**. Express your answer to 3 significant figures.

Velocity = ……………… m s^{-1} [3]

(b) Calculate the velocity of sound obtained in Experiment **2**. Express your answer to 3 significant figures.

Velocity = ……………… m s^{-1} [3]

(c) **(i)** In Experiment **3**, suggest why the powder forms heaps in the tube.

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

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

(ii) Calculate the velocity of sound obtained in Experiment **3**. Express your answer to 3 significant figures.

Velocity = ……………… m s^{-1} [3]

(iii) Suggest why the powder disperses when the frequency of sound is altered slightly.

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

(d) **(i)** In Experiment **4**, state and explain whether the signal picked up at X is a maximum or a minimum.

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

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

(ii) Calculate the velocity of sound obtained in Experiment **4**. Express your answer to 3 significant figures.

Value of quantity = ………………… [3]

(e) Calculate the average value of the velocity of sound obtained from all four experiments and express it together with its uncertainty. Explain your calculation of the uncertainty.

Average value of velocity = ………………………………… m s^{-1} [3]

9 **(a)** A source of e.m.f. E has an inherent internal resistance r.

(i) Define the e.m.f. (electromotive force) of a source.

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

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

(ii) The source described in **(a)** is connected to an external circuit with resistance R.

1 Explain how the efficiency of power delivery by the source is affected by the presence of internal resistance r.

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2 With the aid of a circuit diagram, derive an expression in terms of R and r for the efficiency η of the power output of the source to the external load.

[2]

(b)

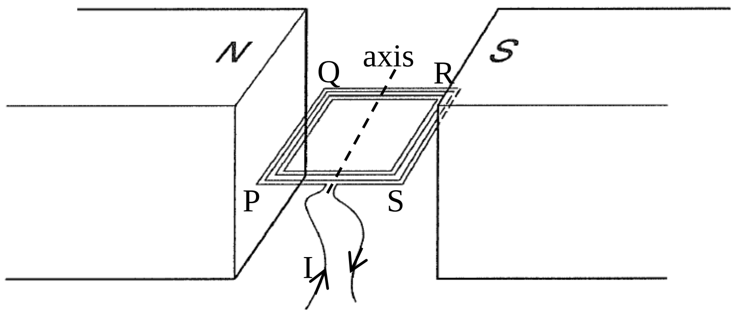

Fig. 9

The setup shown in **Fig. 9** consists of a square coil PQRS pivoted about a horizontal axis. The plane of the coil is initially horizontal and placed between the poles of a magnet producing a uniform horizontal magnetic field of flux density 4.5×10^{-2} T.

PQRS has 40 turns of coil with sides each of length 6.0 cm. The resistivity of the coil wire is 9.0×10^{-8} **Ω** m and its diameter is 0.50 mm. A potential difference of 2.0 V is applied between the two ends of coil to cause a current *I* as shown in **Fig. 9**.

(i) Calculate the current *I*.

I = ………………. A [3]

(ii) In **Fig. 9**, draw in the forces that will act on the coil PQRS due to the current *I*. Ignore the effect of the Earth's magnetic field. [2]

(iii) Calculate the magnitude of your labelled forces acting on the coil.

Force = ……………...... N [2]

(iv) State and explain the effect of the forces on the coil.

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

(v) **1** Describe and explain the motion of the coil from the instant the current starts flowing in it until the instant when it comes to rest.

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2 State what happens to the coil's rotational energy when it has come to rest.

……………..……………..……………..……………..…………. [1]

3 State the final orientation of the coil when it has come to rest.

……………..……………..……………..……………..…………. [1]

End of paper