PDG

Candidate Name ______________________ (   ) [   ]

ANDERSON JUNIOR COLLEGE

2015 JC2 Preliminary Examination

PHYSICS **8866/02**
Higher 1
Paper 2 Structured Questions **Thursday 17 September 2015**
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name** and **PDG** in the spaces at the top of this page and all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, 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	
Section B	
6	
7	
8	
Deduction	
Total	

This document consists of **23** 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,	$p = \rho gh$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$

Section A

Answer **all** the questions in this section

1 (a) State two SI base units other than the kilogram, metre and second.

1. ……………………………………………………………………………………………..

2. ……………………………………………………………………………………………..

[1]

(b) The time T for a satellite to orbit the Earth is given by

$$T = \sqrt{\left(\frac{KR^3}{M}\right)}$$

where R is the distance of the satellite from the centre of the Earth,
M is the mass of the Earth,
and K is a constant.

(i) Determine the SI base units of K.

SI base units of K ……………………………. [2]

(ii) Data for a particular satellite are given in Fig. 1.1.

quantity	measurement	uncertainty
T	8.64×10^4 s	± 0.5%
R	4.23×10^7 m	± 1%
M	6.0×10^{24} kg	± 2%

Fig. 1.1

Calculate K and its actual uncertainty in SI units.

K =…………………………… ± ……………………………. [3]

2 A ball B of mass 1.2 kg travelling at constant velocity collides head-on with a stationary ball S of mass 3.6 kg, as shown in Fig. 2.1.

Fig. 2.1

Frictional forces are negligible.

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

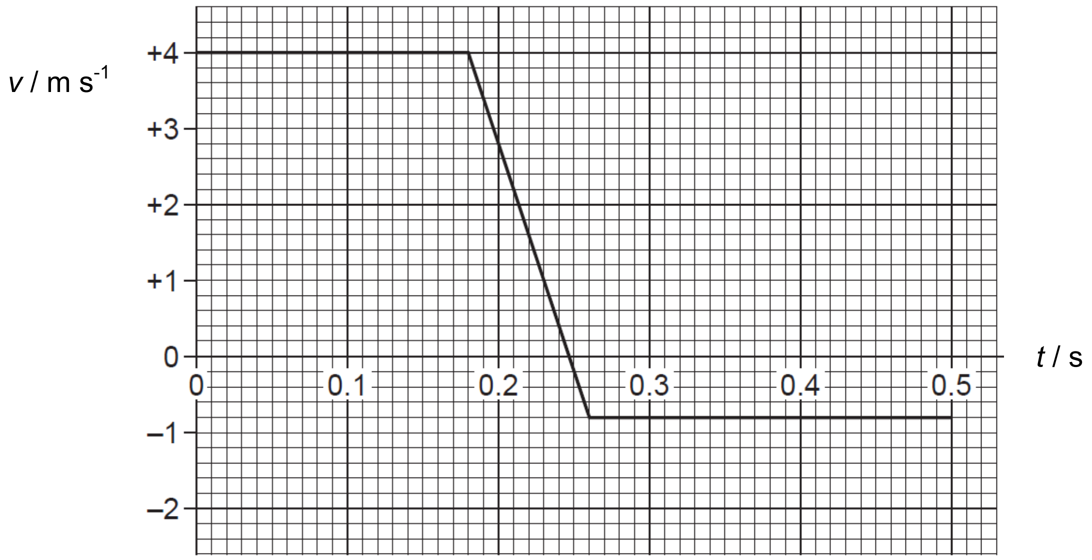

Fig. 2.2

(a) State the significance of positive and negative values for *v* in Fig. 2.2.

………..

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

(b) Use Fig. 2.2 to determine, for ball B during the collision with ball S,

(i) the change in momentum of ball B,

change in momentum = ……………………………N s [2]

(ii) the magnitude of the force acting on ball B.

force = ……………………………N [2]

(c) Calculate the speed of ball S after the collision.

speed = …………………………m s^{-1}[1]

(d) Using your answer in **(c)** and information from Fig. 2.2, deduce quantitatively whether the collision is elastic.

……………………………………………………………………………………………..

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

3 **(a)** Explain what is meant by the following terms when used in the context of forces.

(i) equilibrium ……………………………………………………………………………….

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

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

(ii) centre of gravity ………………………………………………………………………

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

(iii) moment ………………………………………………………………………………..

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

(iv) torque of a couple ………………………………………………………………….....

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

(b) A torque wrench is a type of spanner for tightening a nut and bolt to a particular torque, as illustrated in Fig. 3.1.

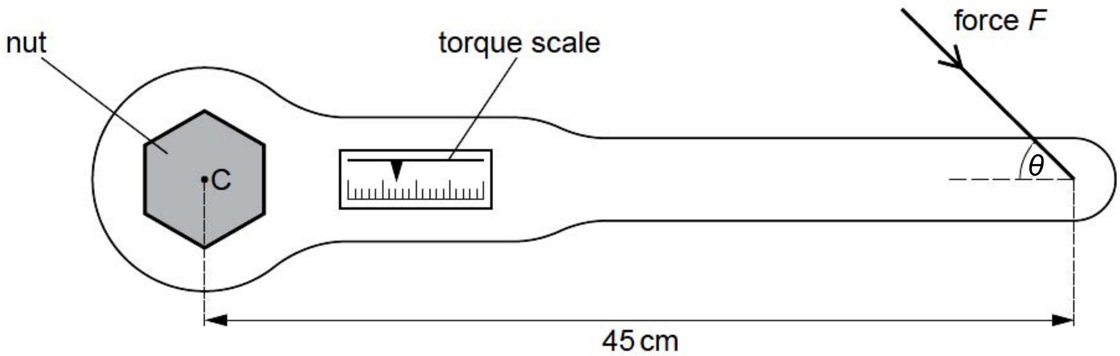

Fig. 3.1

The wrench is put on the nut and a force is applied to the handle. A scale indicates the torque applied.

The wheel nuts on a particular car must be tightened to a torque of 130 N m. This is achieved by applying a force F to the wrench at a distance of 45 cm from its centre of rotation C. This force F may be applied at any angle θ to the axis of the handle, as shown in Fig. 3.1.

For the minimum value of F to achieve this torque,

(i) state the magnitude of the angle θ that should be used,

θ = ……………………………..° [1]

(ii) calculate the magnitude of *F*.

F = ……………………………N [2]

4 **(a)** Define

(i) electric current,

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

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

(ii) resistance.

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

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

(b) When a potential difference of 12.0 V is applied across the uniform filament wire of a headlight, 2.0×10^{20} electrons pass through this filament in 6.0 s. The material of the filament has resistivity 7.9×10^{-7} Ω m and its radius is 9.0×10^{-5} m.

Calculate

(i) the electric current through the filament wire,

current = ……………………………. A [1]

(ii) the resistance of this headlight.

resistance = ………………………… Ω [1]

(c) A battery of e.m.f. 9.0 V and internal resistance *r* is connected to four ideal voltmeters, one ideal ammeter and six resistors, four of which have values as shown in Fig. 4.1. The voltmeter V_2 and V_4 reads 4.0 V and 2.0 V respectively.

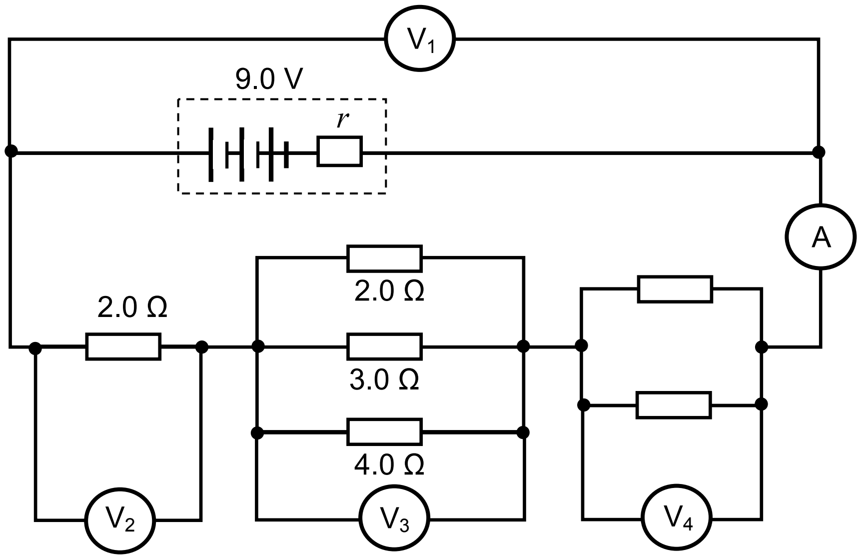

Fig. 4.1

(i) Show that the reading of the ammeter, A, is 2.0 A.

[1]

(ii) Hence, determine *r*, the internal resistance of the battery.

r = ……………………………Ω [3]

5 **(a)** State what is meant by a *magnetic field*.

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

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

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

(b) A uniform magnetic field has constant flux density B. A straight wire of fixed length carries a current I at an angle θ to the magnetic field, as shown in Fig. 5.1.

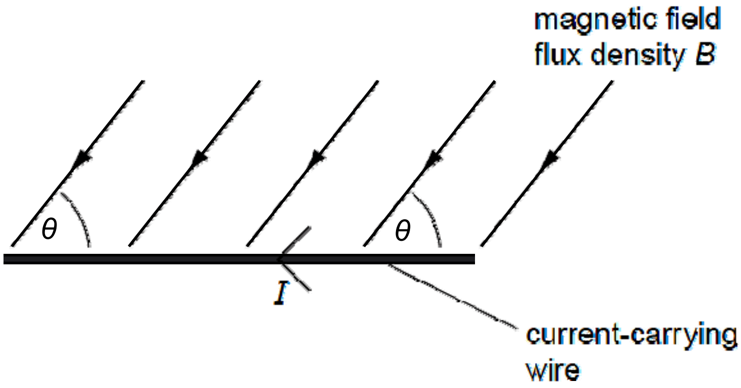

Fig. 5.1

(i) The current I in the wire is changed, keeping the angle θ constant.

On Fig. 5.2, sketch a graph to show the variation with current I of the force F on the wire.

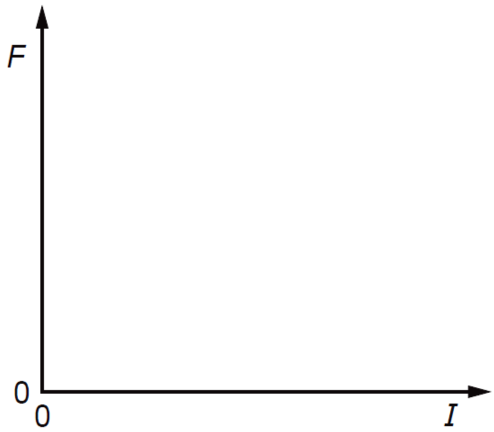

Fig. 5.2

[1]

(ii) The angle θ between the wire and the magnetic field is now varied. The current I is kept constant.

On Fig. 5.3, sketch a graph to show the variation with angle θ of the force F on the wire.

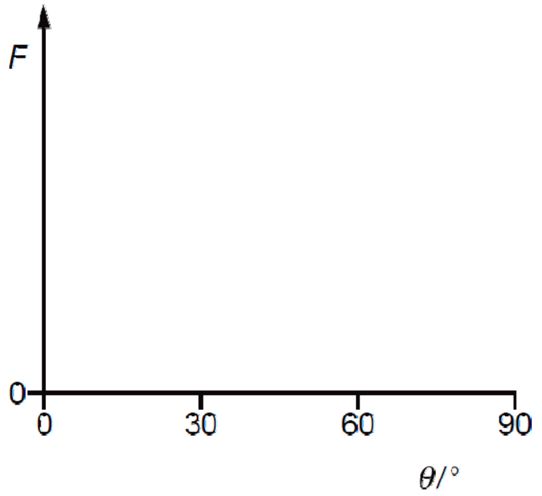

Fig. 5.3

[1]

(c) A uniform magnetic field is directed at right-angles to the rectangular surface PQRS of a slice of a conducting material, as shown in Fig. 5.4.

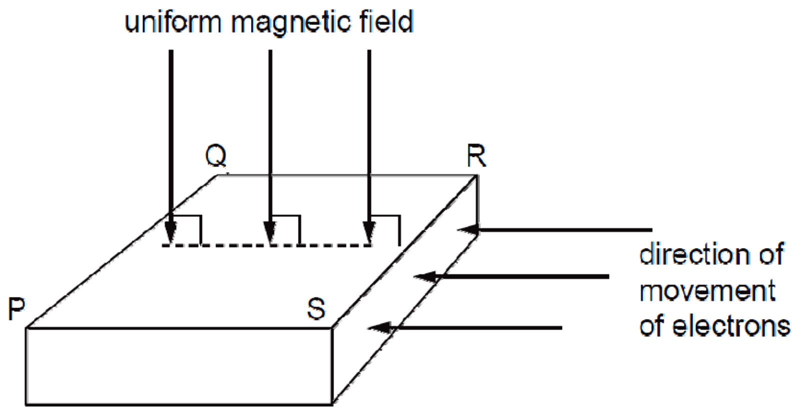

Fig. 5.4

Electrons, moving towards the side SR, enter the slice of conducting material. The electrons enter the slice at right-angles to side SR.

(i) Explain why, initially, the electrons do not travel in straight lines across the slice from side SR to side PQ.

....

....

.... [1]

(ii) Explain to which side, PS or QR, the electrons tend to move.

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

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

(iii) Suggest why after a while, electrons entering side SR will travel in straight lines to side PQ.

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

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

(d) A long, straight vertical wire is placed within Earth's magnetic field.

Fig. 5.5 shows a plan view of the plane ABCD with the current in the wire coming out of the plane.

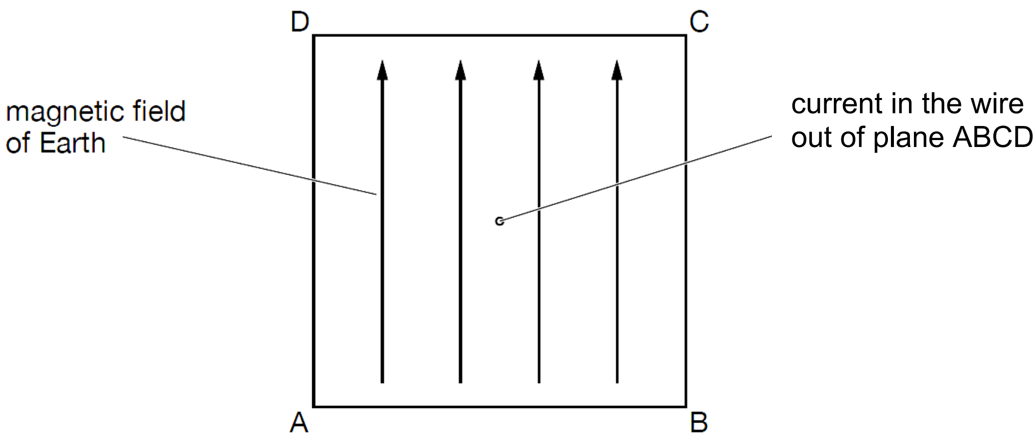

Fig. 5.5

The horizontal component of the Earth's magnetic field is also shown.

(i) On Fig. 5.5, mark with the letter P a point where the magnetic field due to the current-carrying wire could be equal and opposite to that of the Earth.

[1]

(ii) For a long, straight wire carrying current I, the magnetic flux density B at distance r from the centre of the wire is given by the expression

$$B = \mu_0 \frac{I}{2\pi r}$$

where μ_0 is the permeability of free space, given by $\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}.

The point P in **(i)** is found to be 1.9 cm from the centre of the wire for a current of 1.7 A.

Calculate a value for the horizontal component of the Earth's magnetic flux density.

flux density = ……………………………T [1]

(iii) The current in the wire in **(ii)** is increased. The point P is now found to be 2.8 cm from the wire.

Determine the new current in the wire.

current = ……………………………A [2]

Section B
Answer **two** of the questions in this section

6 **(a)** A cyclist is moving up a slope that has a constant gradient. The cyclist takes 8.0 s to climb the slope.
The variation with time t of the speed v of the cyclist is shown in Fig. 6.1.

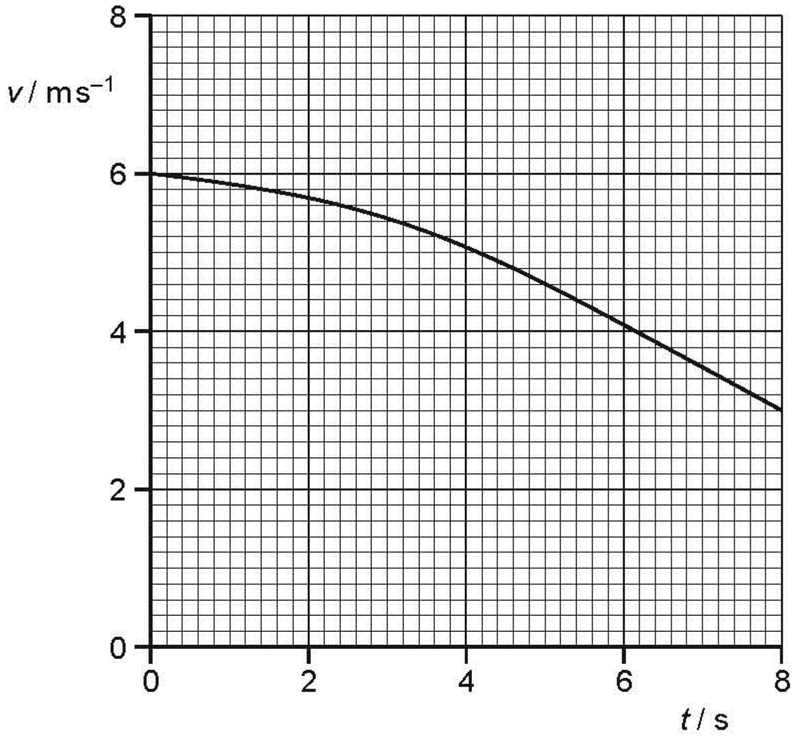

Fig. 6.1

(i) Use Fig. 6.1 to determine the total distance moved up the slope.

distance = ……………………………m [2]

[Turn Over

(ii) The bicycle and cyclist have a combined mass of 92 kg.
The vertical height through which the cyclist moves is 1.3 m.

For the movement of the bicycle and cyclist between t = 0 and t = 8.0 s,

1. use Fig. 6.1 to calculate the change in its kinetic energy,

change in kinetic energy = …………………………….J [2]

2. calculate the change in its gravitational potential energy.

change in gravitational potential energy = ………………….J [1]

(iii) The cyclist pedals continuously so that the useful power delivered to the bicycle is 75 W.
Some energy is used in overcoming frictional forces.

1. Calculate the useful work done by the cyclist climbing up the slope.

work done = …………………………….J [1]

2. Using your answers in **(ii)** and **(iii) part 1**, show that the total energy converted in overcoming frictional forces is approximately 670 J.

[1]

3. Determine the average magnitude of the frictional forces.

average force = …………………………….N [1]

4. Suggest why the magnitude of the total resistive force would not be constant.

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

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

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

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

(b) A ball is thrown from a point P, which is at ground level, as illustrated in Fig. 6.2.

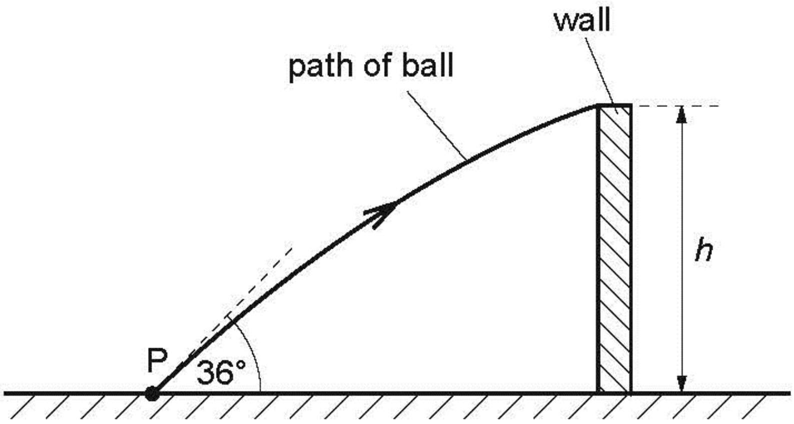

Fig. 6.2

The initial velocity of the ball is 12.4 m s^{-1} at an angle of 36° to the horizontal.
The ball just passes over a wall of height *h*. The ball reaches the wall 0.17 s after it has been thrown.

(i) Assuming air resistance to be negligible,

1. calculate the horizontal distance of point P from the wall,

distance = …………………………….m [2]

2. calculate the height *h* of the wall,

h = ……………………………m [2]

3. describe the difference between the displacement of the ball and the distance that it travels.

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

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

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

(ii) A second ball is thrown from point P with the same velocity as the ball in **(i)**. For this ball, air resistance is not negligible.
This ball hits the wall and rebounds.

On Fig. 6.2, sketch the path of this ball between point P and the point where it first hits the ground.

[2]

(iii) The ball is now thrown vertically upwards from ground level with the speed u. The ball takes time t to reach maximum height. For time $\frac{t}{2}$ after the ball has been thrown, calculate the ratio

$$\frac{\text{potential energy of ball}}{\text{kinetic energy of ball}}.$$

You may assume air resistance to be negligible.

ratio = ……………………………. [3]

7 **(a)** State what is meant by the principle of superposition of waves.

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

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

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

(b) Fig. 7.1 shows an arrangement which can be used to determine the speed of sound in air.

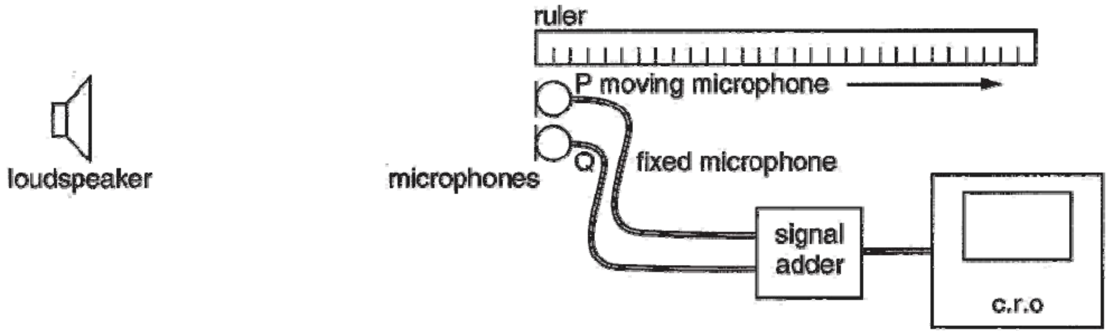

Fig. 7.1

The loudspeaker emits a sinusoidal sound wave. The electrical signals from the two microphones P and Q are added together in the electronic "signal adder" and the resultant signal is displayed on the cathode-ray oscilloscope (c.r.o.) screen. This process may be regarded as equivalent to the superposition of the waves.

Microphone Q is **fixed** and microphone P is **slowly moved** back along the edge of the ruler.

(i) Fig. 7.2 shows the appearance of the trace on the c.r.o. when both microphones are at the left hand end of the ruler i.e. the same distance from the loudspeaker.

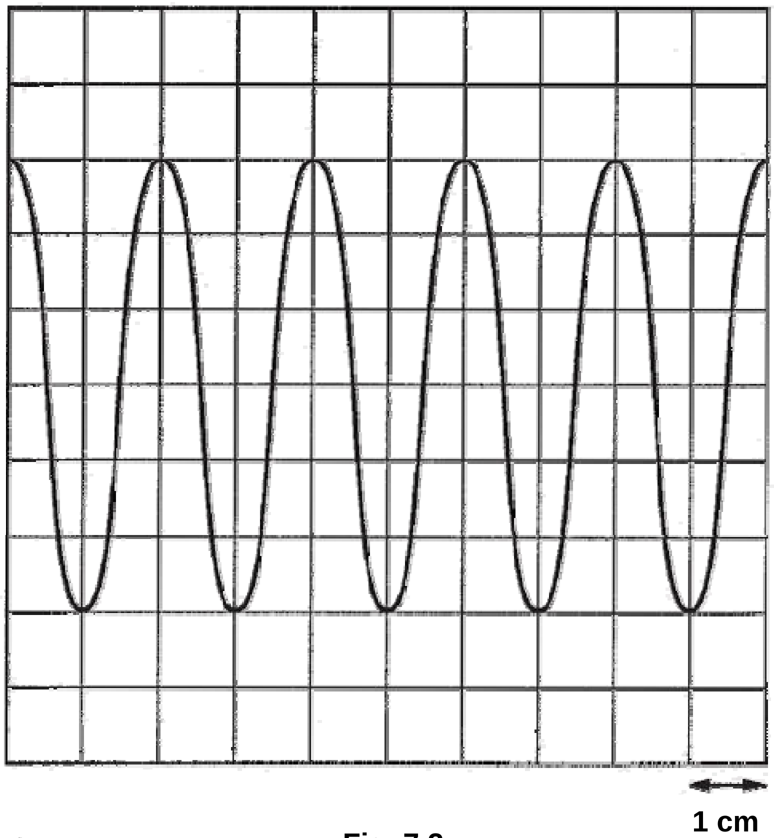

Fig. 7.2

The time-base setting of the c.r.o. is 0.2 ms / cm.
Determine the frequency of the sound wave.

frequency = ……………………………. Hz [1]

(ii) As P is moved slowly along the edge of the ruler, the amplitude of the trace is seen to decrease, then increase, then decrease and so on. Explain

1. why the amplitude is a maximum when P and Q are at the left end of the ruler,

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

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

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

2. why the amplitude of the trace varies.

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

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

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

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

(iii) The first minimum of the amplitude occurs when P is at a distance of 6.8 cm from the left hand end of the ruler. Determine the speed of the sound in air.

speed = ……………………………. m s^{-1} [2]

(c) Fig. 7.3 shows an arrangement for producing stationary waves in a tube that is closed at one end.

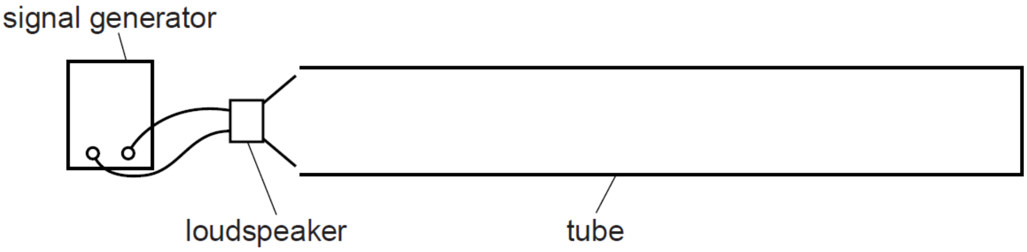

Fig. 7.3

(i) Explain how waves from the loudspeaker produce stationary waves in the tube.

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

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

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

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

(ii) One of the stationary waves that may be formed in the tube is represented in Fig. 7.4.

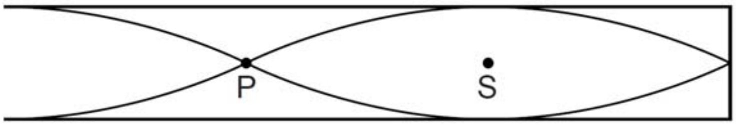

Fig. 7.4

1. Describe the motion of the air particles in the tube at

A. point P,

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

B. point S.

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

2. The wavelength of the sound is 0.375 m. Calculate the length of the tube.

length = …………………. m [1]

(d) Fig. 7.5 represents light of wavelength 589 nm emitted from two sources. The time axes have the same scales.

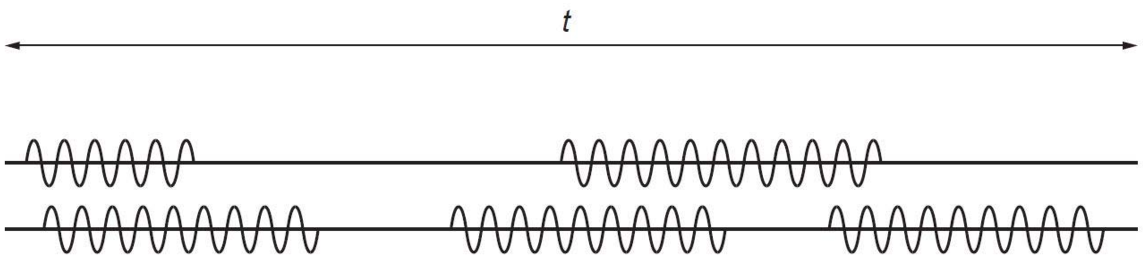

Fig. 7.5

(i) Calculate the frequency of the light waves of wavelength 589 nm.

frequency = ……………………………. Hz [1]

(ii) Find the approximate value of time *t* shown in Fig. 7.5.

t = ……………………………. s [2]

(iii) Explain why the light from these two sources is not coherent.

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

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

(iv) Explain why sources that are not coherent do not produce a visible interference pattern.

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

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

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

8 **(a)** Explain what is meant by a *photon*.

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

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

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

(b) An X-ray photon of wavelength 6.50×10^{-12} m is incident on an isolated stationary electron, as illustrated in Fig. 8.1.

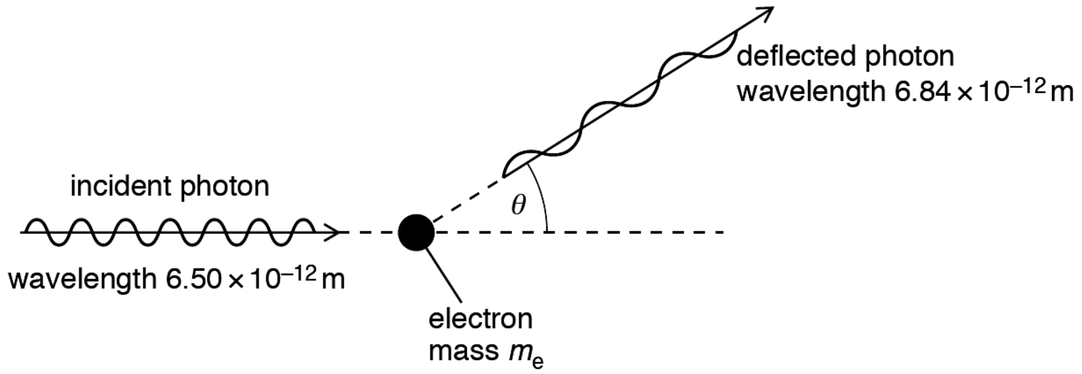

Fig. 8.1

The photon is deflected elastically by the electron of mass m_e. The wavelength of the deflected photon is 6.84×10^{-12} m.

(i) On Fig. 8.1, draw an arrow to indicate a possible initial direction of motion of the electron after the photon has been deflected. [1]

(ii) Calculate

1. the change in energy of the deflected photon.

change in photon energy = …………………………… J [2]

2. the speed of the electron after the photon has been deflected.

speed = ………………………..… m s^{-1} [2]

(c) Explain why the magnitude of the final momentum of the electron is not equal to the change in magnitude of the momentum of the photon.

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

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

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

(d) The angle θ through which the photon is deflected is given by the expression

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

where $\Delta\lambda$ is the change in wavelength of the photon, h is the Planck constant and c is the speed of light in free space.

(i) Calculate the angle θ.

θ = ……………………………… ° [2]

(ii) Use energy considerations to suggest why $\Delta\lambda$ must always be positive.

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

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

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

(e) **(i)** State what is meant by the *de Broglie wavelength* of the electron.

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

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

(ii) An electron is accelerated from rest in a vacuum through a potential difference of 4.7 kV.

Calculate the de Broglie wavelength of the accelerated electron.

wavelength = …………………………….m [4]

(iii) By reference to your answer in **(ii)**, suggest why such electrons may assist with an understanding of crystal structure.

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

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

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

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