Name: ________________________ ( ) **CT Group: 21S0** ____

RAFFLES INSTITUTION

2021 YEAR 6 JULY COMMON TEST

H2 PHYSICS

Section B

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section B in the spaces provided in this booklet.

For Examiner's Use		
Section A	MCQ	/ 20
Section B	21	/ 9
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Deductions		
Total		/ 95

There are 21 printed pages, inclusive of the cover page, in this booklet.

Section B

21 (a) Hot air balloons used to be a means of transportation through the air. They are now commonly used for altitude sightseeing.

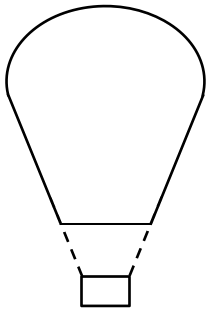

Fig. 21.1

The hot air balloon illustrated in Fig. 21.1 contains 800 m^3 of air at a constant temperature of 400 K. The density of the air at this temperature is 0.905 kg m^{-3}.

The air in the balloon was heated up from its initial temperature of 273 K at constant pressure and the specific heat capacity of the air under the conditions in which it was heated is 1050 J kg^{-1} K^{-1}.

(i) Calculate the mass m of air in the balloon at 400 K.

m = ... kg [1]

(ii) Determine the heat Q required to raise the temperature of the mass m of air from 273 K to 400 K.

Q = ... J [1]

(iii) The density of air is inversely proportional to its thermodynamic temperature at a constant pressure.

Show that the density of air at 273 K is 1.33 kg m^{-3}.

[1]

(iv) Hence, determine the volume which mass *m* of air occupies at 273 K.

volume = ... m^3 [1]

(b) Fig. 21.2 shows that, during the heating process, air which was originally within the balloon spills out from the balloon.

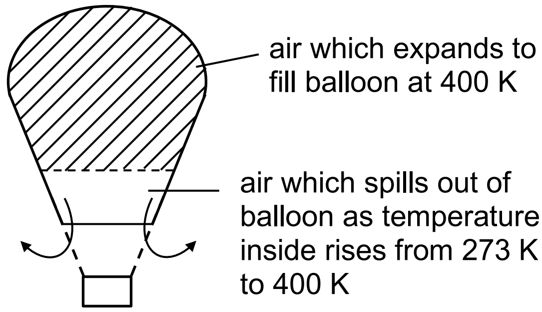

Fig. 21.2

Calculate the work done on the atmosphere during this process. Atmospheric pressure is 1.03×10^5 Pa.

work done = ... J [1]

(c) Calculate the change in the internal energy of the mass *m* of air when heated from its initial temperature of 273 K to its final temperature of 400 K.

change in the internal energy = ... J [2]

(d) State two reasons why in reality, your answer in part **(a)(ii)** is an underestimate of the amount of heat required to raise the temperature of the mass *m* of air from 273 K to 400 K.

1. ....

....

2. ....

.... [2]

22 A piece of bare resistance wire XY of uniform diameter of 0.052 mm is mounted on a metre rule such that X and Y are at the 0 cm and 100 cm markings respectively.

XY is then connected in series to a cell of electromotive force (e.m.f.) 12.0 V with negligible internal resistance and a 2.0 Ω fixed resistor.

(a) A voltmeter is connected across points A and B on the wire as shown in Fig. 22.1 where A and B are at 25 cm and 75 cm markings respectively. The reading on the voltmeter is 3.0 V.

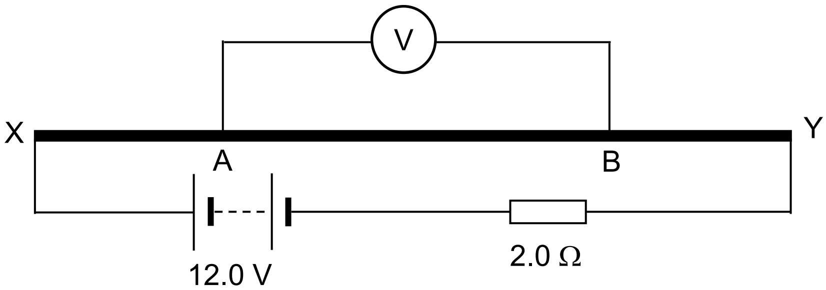

Fig. 22.1

(i) Calculate the resistance of wire XY.

resistance of wire XY = ... Ω [2]

(ii) Determine the resistivity of wire XY.

resistivity = ... Ω m [2]

(b) The voltmeter is replaced by another cell E and a sensitive ammeter as shown in Fig. 22.2. Cell E has negligible internal resistance.

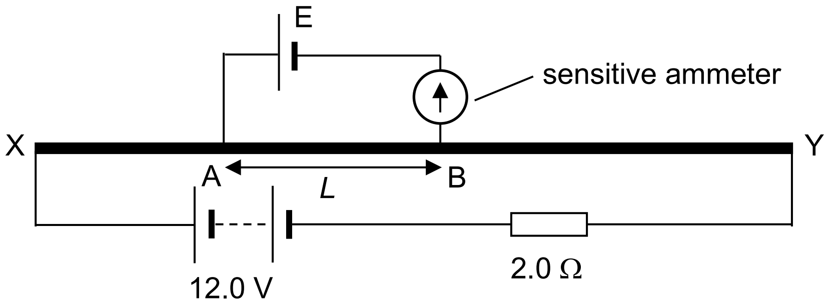

Fig. 22.2

When the contact at B is moved such that length L is 30.0 cm, the ammeter reads zero.

Determine the e.m.f. of cell E.

e.m.f. = ... V [1]

(c) State and explain how the balance length L will change if

(i) a fixed resistor R is placed in series with E as shown in Fig. 22.3.

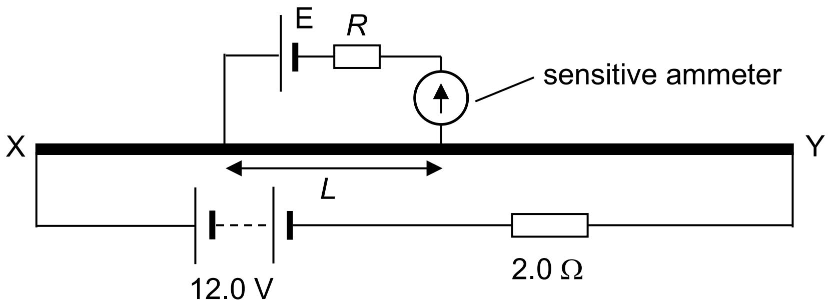

Fig. 22.3

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....

.... [2]

(ii) the 12.0 V battery has internal resistance *r* as shown in Fig. 22.4.

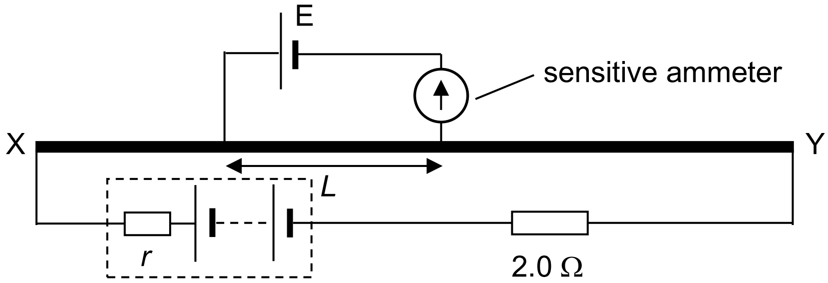

Fig. 22.4

....

....

....

.... [2]

23 **(a)** Define *magnetic flux density*.

....

....

.... [1]

(b) A long wire P is at right angles to the plane of the paper and carries a current out of the plane of the paper as shown in Fig. 23.1.

On Fig. 23.1, sketch the pattern of the magnetic field around wire P in the plane of the paper.

[2]

Fig. 23.1

(c) A long wire Q, at right angles to the plane of the paper is placed at a distance of 0.25 m from wire P as shown in Fig. 23.2. Wire P carries a current of 2.0 A out of the plane of the paper and wire Q carries a current of 3.0 A into the plane of the paper.

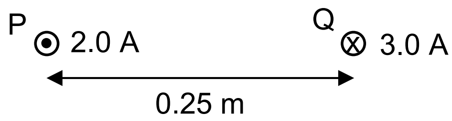

Fig. 23.2

(i) Calculate the magnetic flux density B_P due to the current in wire P at wire Q.

B_P = ... T [2]

(ii) Determine the force per unit length of wire experienced by wire Q.

force per unit length of wire = ... N m^{-1} [2]

(d) A third long wire R is placed along the line joining wire P and wire Q, at a distance of 0.25 m away from wire Q as shown in Fig. 23.3. Wire R carries a current of 4.0 A out of the plane of the paper.

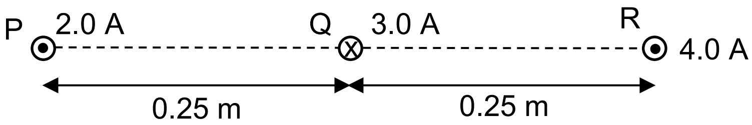

Fig. 23.3

State and explain the direction of the resultant force experienced by wire Q due to the currents in wire P and wire R.

....

....

....

....

.... [2]

24 In an experiment to study the phenomenon of electromagnetic induction, a small coil Q is placed along the axis of a large coil P that carries a steady direct current as shown in Fig. 24.1.

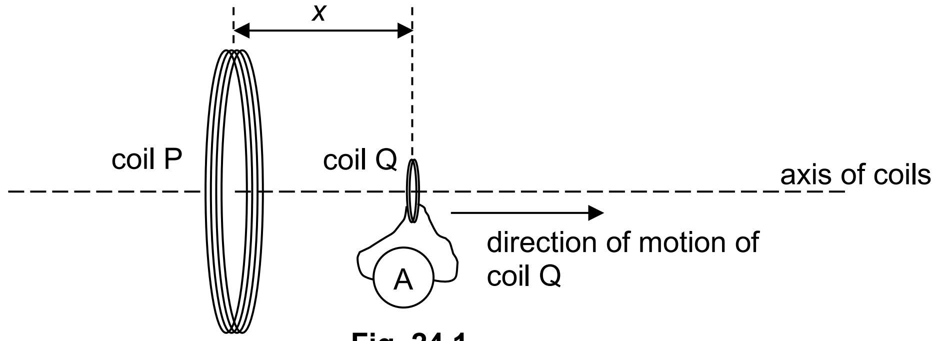

Fig. 24.1

The coil Q is moved along the axis of the coil P at a constant speed such that an e.m.f. is induced in coil Q. The magnetic field is always perpendicular to the plane of coil Q.

Fig. 24.2 shows how the magnitude of the magnetic flux density, B, produced by the coil P varies with the distance x from its centre along the axis.

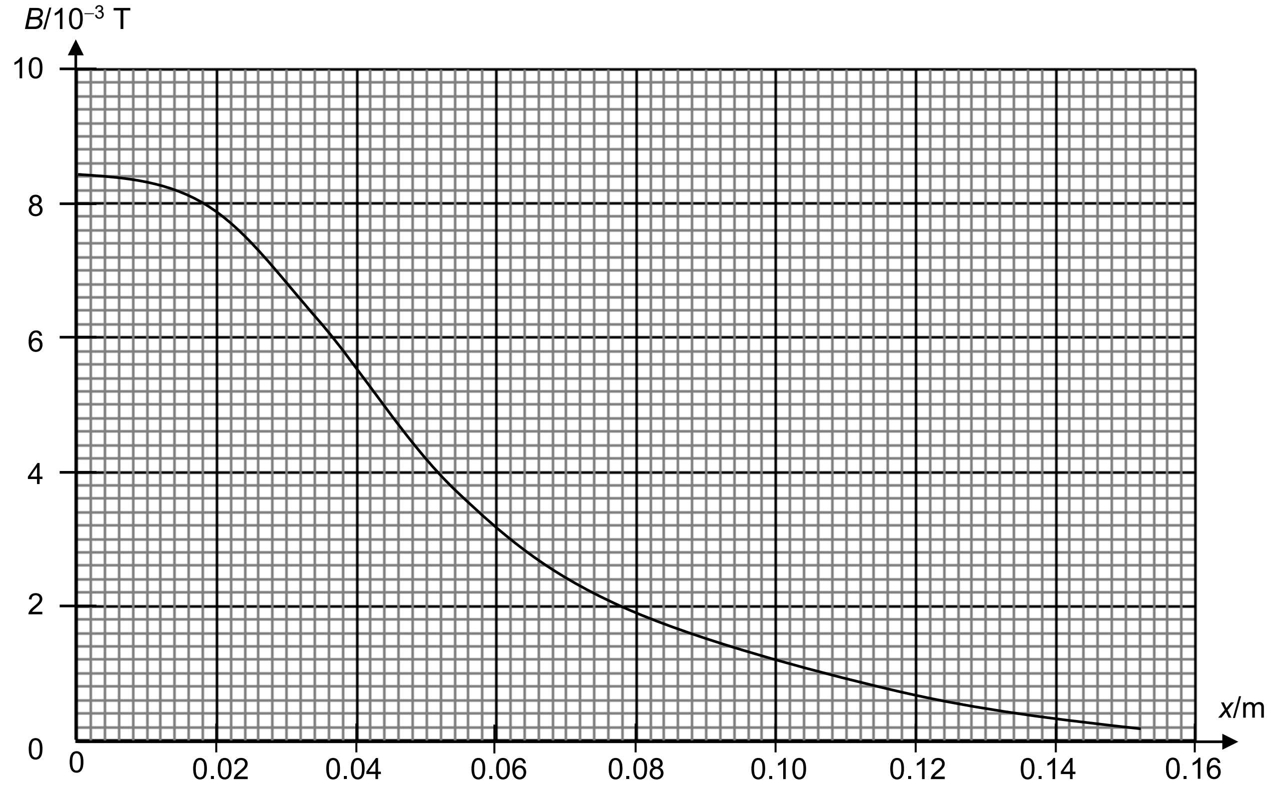

Fig. 24.2

(a) State and explain the direction of the induced current in the coil Q compared with that in the coil P as it is moved along the axis.

....

....

....

....

....

.... [3]

(b) In the experiment, coil Q is moved along the axis from the centre of coil P to a position $x = 0.100\,\text{m}$ in 0.25 s.

(i) Use Fig. 24.2 to determine the change in magnetic flux density which occurs during this time interval.

change in magnetic flux density = ... T [2]

(ii) The coil Q has 5000 turns, each of effective area $1.50 \times 10^{-4}\,\text{m}^2$.

Determine an approximate value for the average e.m.f. induced in the coil Q during the 0.25 s time interval.

induced e.m.f. = ... V [2]

(c) On the axes of Fig. 24.3 below, sketch a graph to show the variation with time of the e.m.f. induced in coil Q as it is moved along the axis from the centre of coil P to x = 0.15 m.

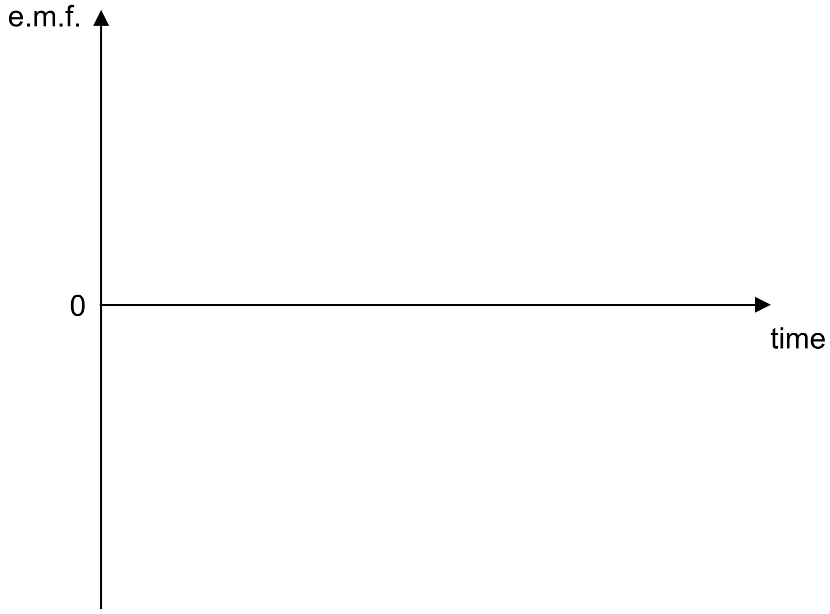

Fig. 24.3

[2]

25 An a.c. power source supplies an e.m.f. that alternates between $+3V_0$ and $-V_0$. It is connected to a 1500 Ω resistor as shown in Fig. 25.1.

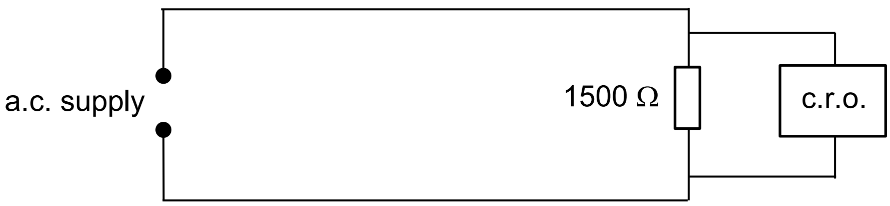

Fig. 25.1

A cathode ray oscilloscope (c.r.o.) is connected across the resistor. The screen of the c.r.o. displays the variation with time of the potential difference (p.d.) across the resistor, as shown in Fig. 25.2.

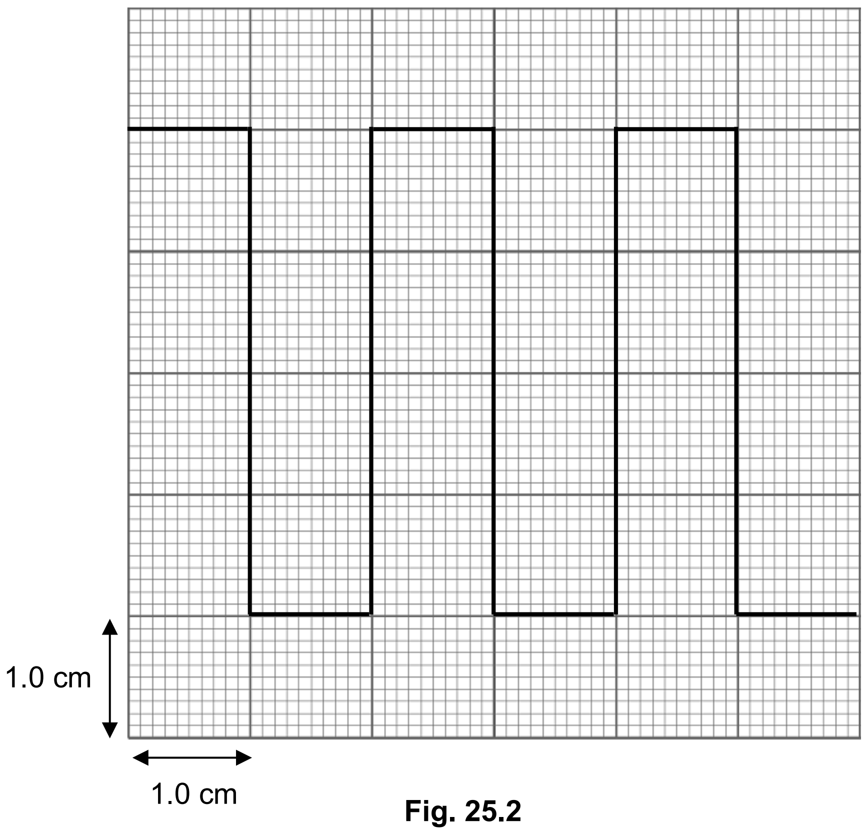

Fig. 25.2

On the vertical scale, 1.0 cm represents 5.0 V. On the horizontal scale, 1.0 cm represents 10 ms.

(a) Use Fig. 25.2 to determine

(i) the frequency of the a.c. supply,

frequency = ... Hz [2]

(ii) the value of V_0,

V_0 = ... V [1]

(iii) the r.m.s. voltage across the resistor,

r.m.s. voltage = ... V [2]

(iv) the mean power dissipated in the resistor.

mean power = ... W [2]

(b) A diode and another 1500 Ω resistor are added to the circuit as shown in Fig. 25.3. At t = 0, the potential difference across the a.c. supply is $+3V_0$ and the diode is forward biased.

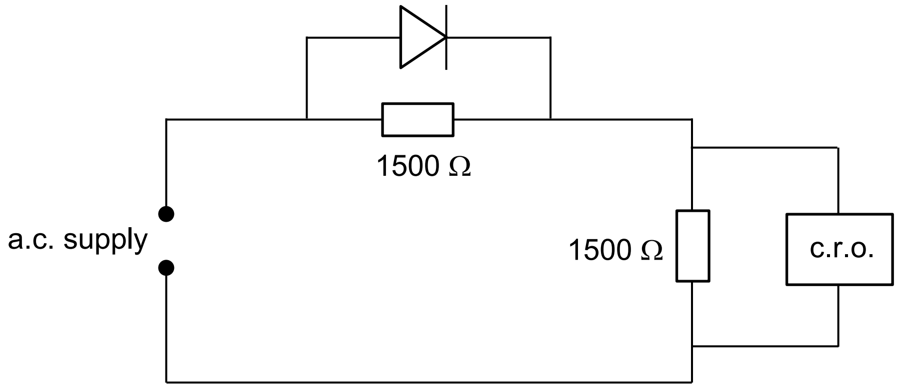

Fig. 25.3

On the axes of Fig. 25.4 below, sketch a graph to show the variation with time of the p.d. across the resistor that is connected in parallel to the c.r.o. for two cycles.

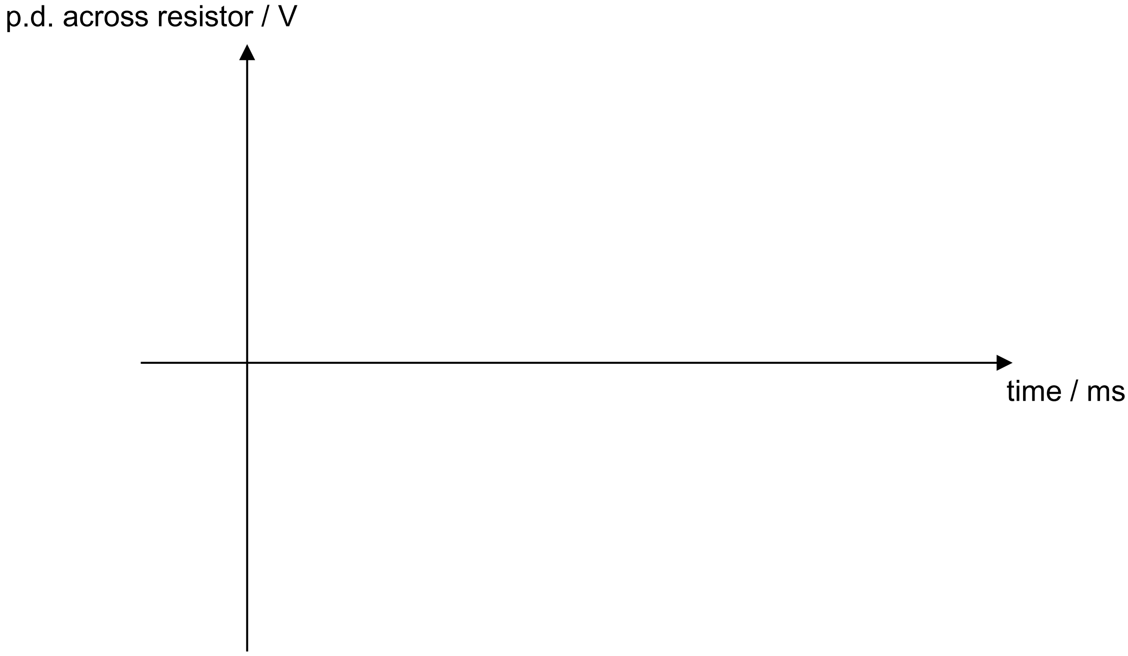

Fig. 25.4

[2]

26 Fig. 26.1 shows an experiment on the photoelectric effect where a clean sheet of platinum with a work function of 6.35 eV was illuminated with light of frequency 1.88×10^{15} Hz.

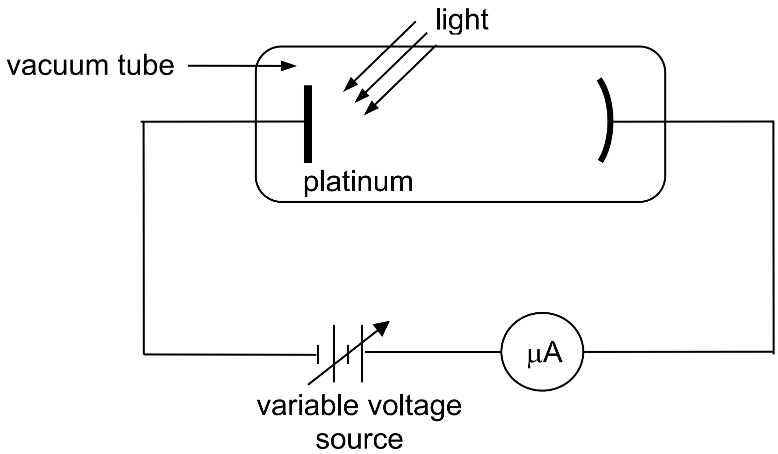

Fig. 26.1

(a) Explain what is meant by the *work function* of a metal.

....

.... [1]

(b) Show that the threshold frequency of platinum is 1.53×10^{15} Hz.

[1]

(c) Calculate the maximum kinetic energy (in eV) of the electrons ejected from the platinum surface.

maximum kinetic energy = ... eV [2]

(d) On the axes in Fig. 26.2 below, sketch the variation with frequency of the maximum kinetic energy E_K of the photoelectrons ejected from the platinum surface.

Indicate the numerical values of both the *x*-intercept and *y*-intercept on the graph.

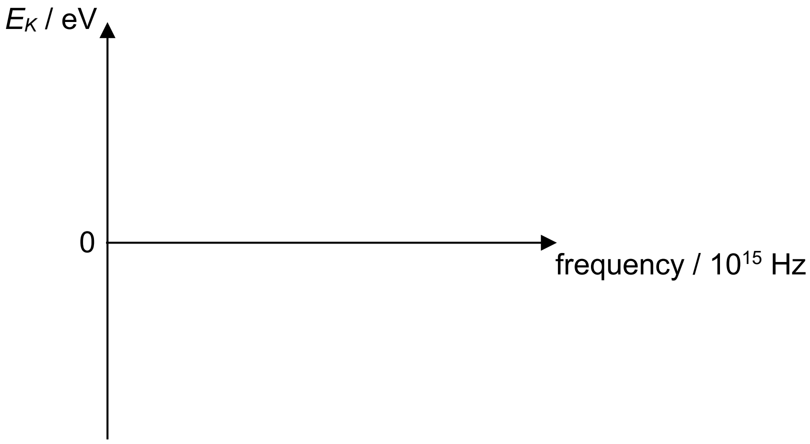

Fig. 26.2

[2]

(e) The power of the light source which was used in the experiment was 0.25 W and the maximum photocurrent obtained was 60.0 μA.

(i) Determine the percentage of the incident photons that produces photoelectrons.

percentage = ... % [3]

(ii) If the platinum sheet is replaced with another metal sheet of a lower work function, state and explain the effect, if any, on the maximum current. The frequency and power of the incident light remain the same.

....

.... [1]

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

We are currently living in a time when Covid-19 has caused over 100 million infections and 2 million deaths worldwide. During this pandemic, the wearing of face masks has helped to reduce the rate of infections. Producing a mask with higher capacity, optimal comfort, and higher efficiency in eliminating bio-aerosols and optimal filtration of airborne particles has been the focus of many scientific studies worldwide.

The single-fibre model, as shown in Fig. 27.1, is the most prevalent model for air filtration. It assumes a 100% adhesion efficiency, meaning that all the particles colliding with a fibre are captured.

Particles can be captured by 3 mechanical methods: inertial impaction, interception and diffusion. Inertial impaction occurs when a particle has a high momentum causing it to deviate from the air streamline and impact a fibre along a straighter path. Interception occurs when the particles do not have sufficient inertia to break away from the air streamline and are captured when the air streamlines that they follow are close enough to a fibre. Diffusion becomes the dominant capture mechanism for very fine particles. These particles move across air streamlines by Brownian motion, which greatly enhances the probability of their collision with fibres.

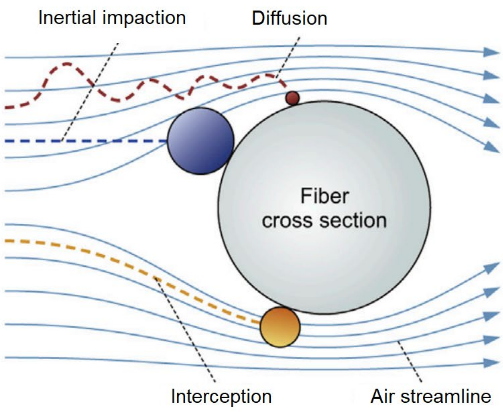

Fig. 27.1

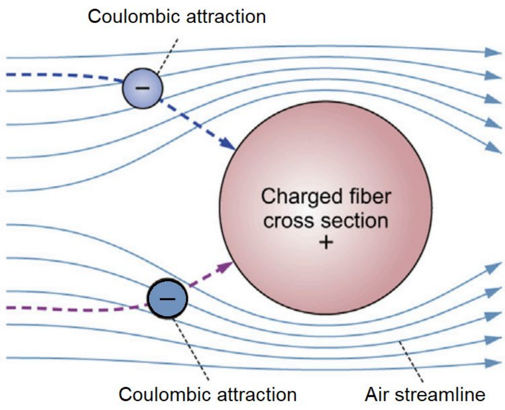

Fig. 27.2

In addition to mechanical capture, some filters employ an electrostatic mechanism (coulombic attraction) to attract and intercept foreign particles as shown in Fig. 27.2. This happens when there are significant electric fields in the mask material, which occur when the fibres are charged. The widely used N95 mask is an example of such a filter and can filter at least 95% of aerosols of diameter 0.3 μm. In typical N95 masks, the electrostatic filtration is performed by a layer of charged polypropylene fibres of diameter 1.0 μm.

However, the charge on the polypropylene fibres undergo significant degradation when open to the surroundings, which is made worse by the warm and humid environment created by respiration during use.

(a) State one characteristic of particles that allows them to be captured by the inertial impaction mechanism.

....

.... [1]

(b) Using the kinetic theory of gases, explain why the diffusion method of capturing particles is more efficient at higher temperatures.

....

....

....

....

....

....

....

.... [4]

(c) In one scenario where interception is the mechanism for particle capture, a particle of mass 2.0×10^{-15} kg travelling at $1.2\ \text{m s}^{-1}$ intercepts with a fibre strand. The particle travels a distance of 8.8×10^{-8} m along the surface of the fibre strand before it comes to rest.

Calculate the magnitude of the average force acting on the particle during the interception.

average force = ... N [2]

(d) Fig. 27.3 shows the cross-section of a polypropylene fibre A of diameter 1.0 μm that contains a point charge of +0.050 nC at its centre. A particle P, of diameter 0.30 μm and charge −0.030 nC, approaches A from a distance of 1.5 μm. The kinetic energy of P is 4.0×10^{-6} J at this instant.

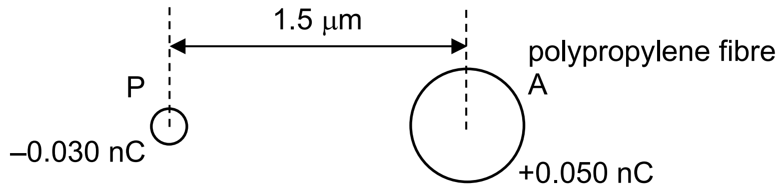

Fig. 27.3

(i) Determine the electric force acting on P due to A at this instant.

electric force = ... N [2]

(ii) Calculate the electric potential energy of P at this instant.

electric potential energy = ... J [2]

(iii) Due to coulombic attraction, particle P travels in the curved path shown in Fig. 27.4 and eventually collides with A.

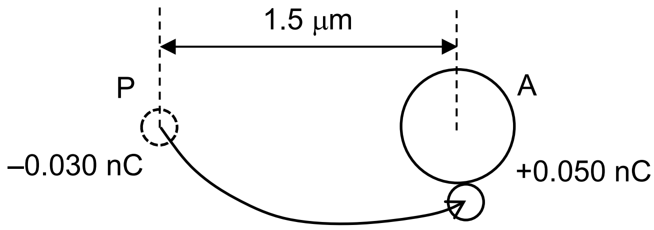

Fig. 27.4

Calculate the final kinetic energy of P just before collision.

kinetic energy = ... J [3]

(e) In one scientific study, a modified N95 mask is fitted with a filter cartridge to increase its filtration efficiency and lifespan. The filter cartridge comprises two rubber frames placed on both sides of the polypropylene fibre and then sandwiched by two metallic screens as seen in Fig. 27.5.

The metallic screens are placed 0.50 cm apart and connected to a 2000 V source. The source has an energy capacity of 15 kJ. A strong electric field is set up in a current limited condition of 20 μA so that there is no risk of discharge or shocking.

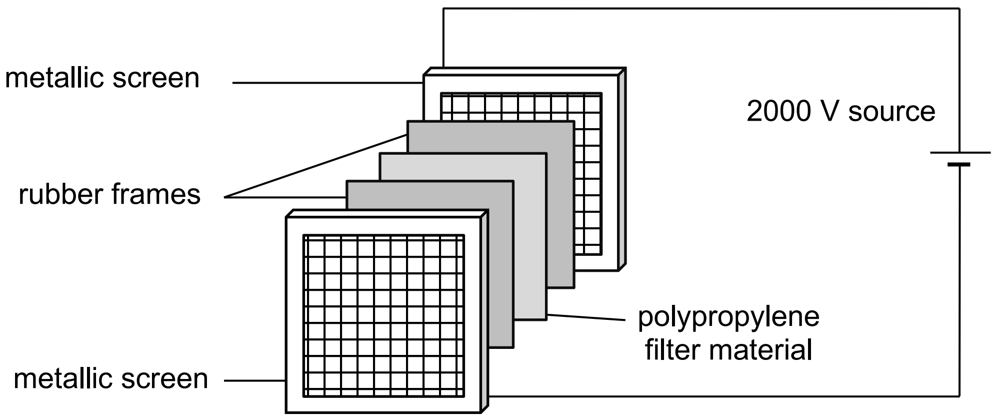

Fig. 27.5 (not to scale)

(i) Suggest the function of the rubber frames in Fig. 27.5.

....

.... [1]

(ii) Calculate the electric field strength between the metallic screens as seen in Fig. 27.5.

electric field strength = ... V m^{-1} [2]

(iii) Determine the maximum power delivered by the source.

maximum power = ... W [1]

(iv) Using your answer in **(e)(iii),** calculate the time taken in hours, for the source to be depleted.

time taken = ... h [1]

(v) State why a modified N95 mask fitted with the filter cartridge has a longer lifespan.

....

.... [1]