1. Define *electric field strength* at a point in space.

....

....

[Total 1 marks]

2. Fig. 1 shows a square flat coil of insulated wire placed in a region of a uniform magnetic field of flux density *B*. The direction of the field is vertically out of the paper. The coil of side x has N turns.

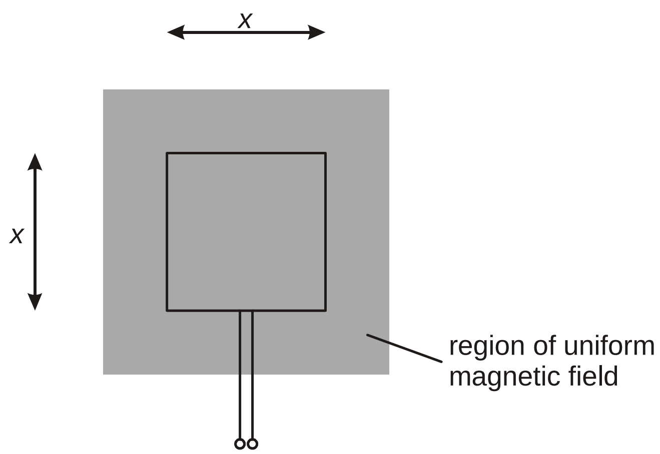

Fig. 1

(a) (i) Define the term *magnetic flux*.

....

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[1]

(ii) Show that the magnetic flux linkage of the coil in Fig. 1 is NBx^2.

[2]

(b) The coil of side x = 0.020 m is placed at position **Y** in Fig. 2 The ends of the 1250 turn coil are connected to a voltmeter. The coil moves sideways steadily through the region of magnetic field of flux density 0.032 T at a speed of 0.10 m s^{-1} until it reaches position **Z**. The motion takes 1.0 s.

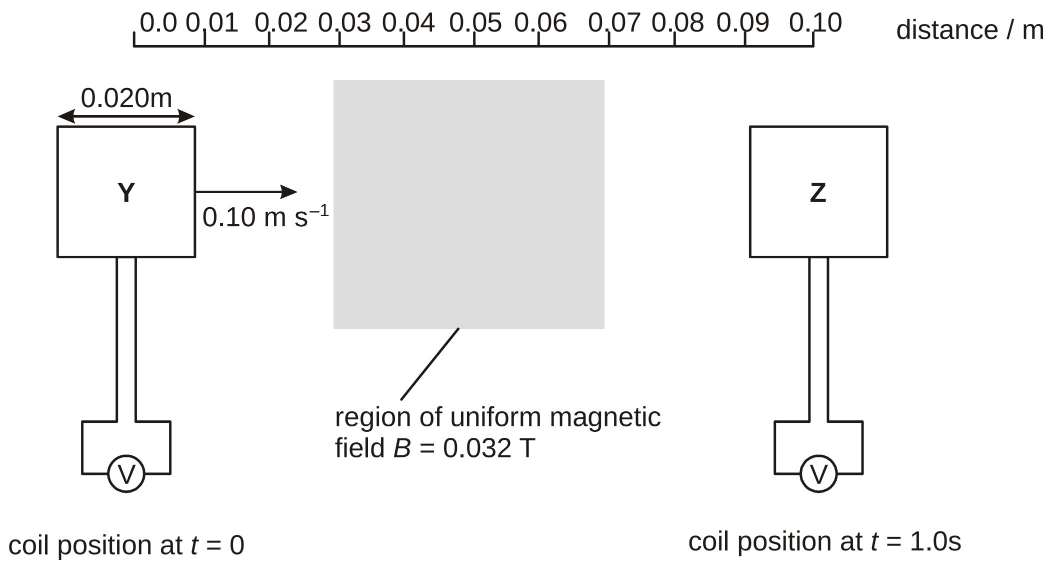

Fig. 2

(i) Show that the voltmeter reading as the coil enters the field region, after t = 0.20s, is 80 mV. Explain your reasoning fully.

[3]

(ii) On Fig. 3, draw a graph of the voltmeter reading against time for the motion of the coil from **Y** to **Z**. Label the y-axis with a suitable scale.

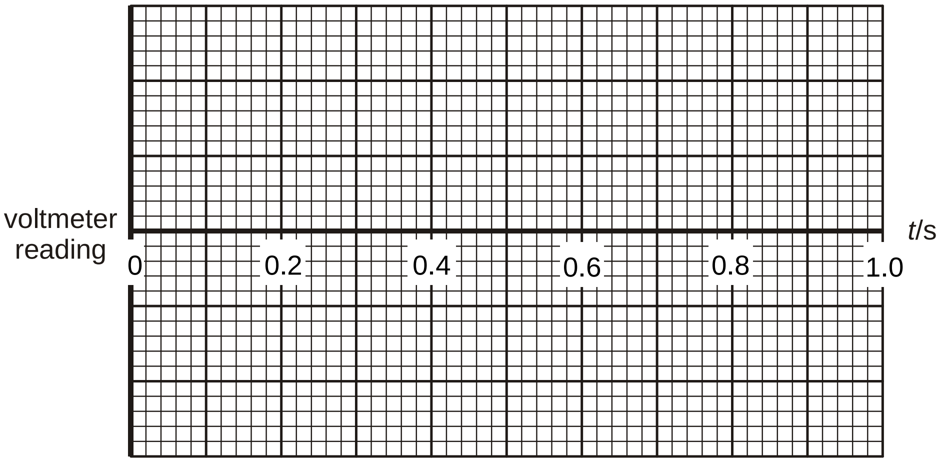

Fig. 3

[4]

[Total 10 marks]

3. In this question, two marks are available for the quality of written communication.

To explain the laws of electromagnetic induction (Faraday's law and Lenz's law) Faraday introduced the concept of magnetic flux. Describe how the flux model is used in these laws.
Start by defining *magnetic flux* and *magnetic flux linkage*.

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[5]

Quality of Written Communication [2]

[Total 7 marks]

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

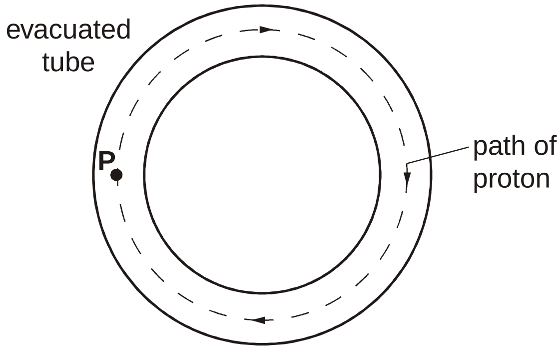
....

....

....

[2]

(b) The figure below shows an evacuated circular tube in which charged particles can be accelerated. A uniform magnetic field of flux density B acts in a direction perpendicular to the plane of the tube.
Protons move with a speed v along a circular path within the tube.



(i) On the figure above draw an arrow at **P** to indicate the direction of the force on the protons for them to move in a circle within the tube.

[1]

(ii) State the direction of the magnetic field. Explain how you arrived at your answer.

....

....

....

[2]

(iii) Write down an algebraic expression for the force F on a proton in terms of the magnetic field at point **P**.

....

[1]

(iv) Calculate the value of the flux density *B* needed to contain protons of speed 1.5×10^7 m s^{-1} within a tube of radius 60 m. Give a suitable unit for your answer.

B = …………………unit………………

[5]

(v) State and explain what action must be taken to contain protons, injected at twice the speed (2*v*), within the tube.

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....

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[2]

[Total 13 marks]

5. This question is about electric forces.

A very small negatively-charged conducting sphere is suspended by an insulating thread from support **S**. It is placed close to a vertical metal plate carrying a positive charge. The sphere is attracted towards the plate and hangs with the thread at an angle of 20° to the vertical as shown in Fig. 1.

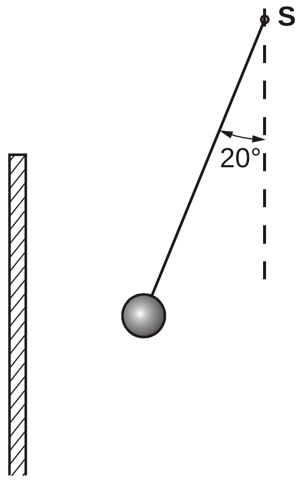

Fig. 1

(a) Draw at least **five** electric field lines on Fig. 1 to show the pattern of the field between the plate and the sphere.

[3]

(b) The sphere of weight 1.0×10^{-5} N carries a charge of -1.2×10^{-9} C.

(i) Show that the magnitude of the attractive force between the sphere and the plate is about 3.6×10^{-6} N.

[3]

(ii) Hence show that the value of the electric field strength at the sphere, treated as a point charge, is 3.0×10^3 in SI units. State the unit.

unit for electric field strength is ....

[3]

(c) The plate is removed. Fig. 2 shows an identical sphere carrying a charge of $+1.2 \times 10^{-9}$ C, mounted on an insulating stand. It is placed so that the hanging sphere remains at 20° to the vertical.

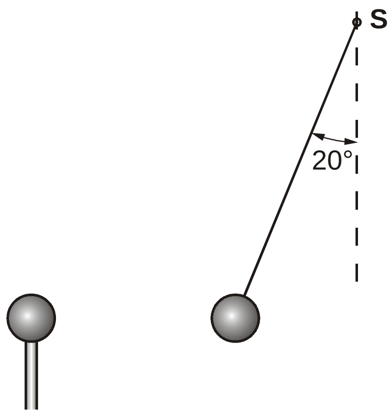

Fig. 2

Treating the spheres as point charges, calculate the distance r between their centres.

r = ... m

[3]

(d) On Fig. 2, sketch the electric field pattern between the two charges. By comparing this sketch with your answer to (a), suggest why the distance between the plate and the sphere in Fig. 1 is half of the distance between the two spheres in Fig. 2.

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[2]

[Total 14 marks]

6. A transformer is assumed to be 100% efficient in its operation. The primary coil is connected to a 230 V a.c. source. The secondary coil is connected to a 50 Ω resistor. The potential difference across the resistor is 12 V a.c.

Calculate

(i) the current through the 50 Ω resistor

current = ... A

[2]

(ii) the current in the primary circuit.

current = ... A

[2]

[Total 4 marks]

7. This question is about forcing a liquid metal, such as molten sodium, through a tube.

(a) The liquid metal is in a tube of square cross-section, side *w*, made of electrically insulating material. See Fig. 1. Two electrodes are mounted on opposite sides of the tube and a magnetic field of flux density *B* fills the region between the electrodes. An electric current I passes across the tube between the electrodes, perpendicular to the magnetic field. The interaction between the current and the field provides the force to move the liquid.

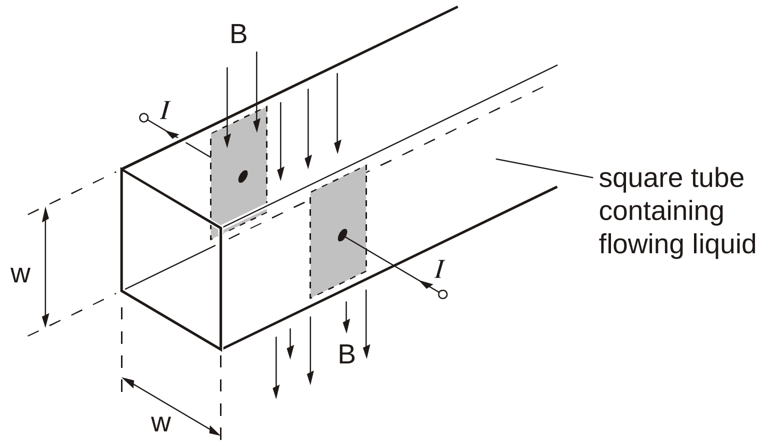

Fig. 1

(i) Draw on Fig. 1 an arrow labelled **F** to indicate the direction of the force on the liquid metal. Explain how you determined the direction.

....

....

[2]

(ii) State a relationship for the force F in terms of the current I, the magnetic field B and the width w of the tube.

....

[1]

(iii) Data for this device are shown below.

B = 0.15 T
I = 800 A
w = 25mm

Calculate the force on the liquid metal in the tube.

force = ... N

[2]

(b) To monitor the speed of flow of the liquid metal, a similar arrangement of electrodes and magnetic field is set up further down the tube. See Fig. 2. A voltmeter is connected across the electrodes instead of a power supply.

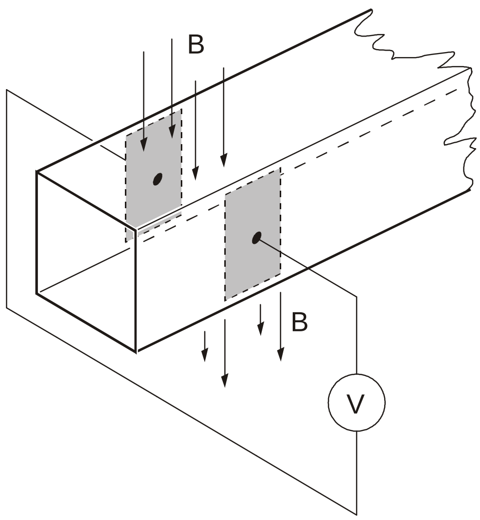

Fig. 2

(i) Explain, using the law of electromagnetic induction, why the voltmeter will register a reading which is proportional to the speed of flow of the metal.

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[3]

(ii) State how and explain why the voltmeter reading changes when the magnetic flux density across the tube is doubled.

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[2]

[Total 10 marks]