5.4 Magnetic Effects of Electric Currents

Question Paper

Course	DP IB Physics
Section	5. Electricity & Magnetism
Topic	5.4 Magnetic Effects of Electric Currents
Difficulty	Hard

Time allowed: **50**

Score: **/41**

Percentage: **/100**

Question 1a

Alpha particles travel in a vacuum at speed v and enter an area where there is a uniform magnetic field of flux density B. In this area, it begins to move in a circular trajectory.

(a)
Show that the momentum of a single alpha particle is given by:

$$p = 2eBr$$

where e is the elementary charge and r is the orbital radius.

[3]

[3 marks]

Question 1b

An alpha particle moves across the Earth's equator towards the east. At this point, the Earth's magnetic field has a direction due north and is parallel to the surface.

(b)
Deduce the direction of the force acting on the alpha particle at this instant.

[3]

[3 marks]

Question 1c

Charged particles from the sun, carried by the 'solar wind', may become trapped in the Earth's magnetic field near its poles, causing the sky to glow. Some of these charged particles travel in a circle of radius 45 km in a region where the flux density is 6.0×10^{-5} T.

(c)
Show that these charged particles cannot be electrons.

[3]

[3 marks]

Question 2a

An electron is incident normally into a region of uniform magnetic flux density 0.50 T at a speed of 1.3×10^7 m s^{-1}.

(a)
Show that the percentage reduction in the magnetic force exerted on the electron is 50% when the electron is incident at an angle of 30°.

[3]

[3 marks]

Question 2b

Two electrons, X and Y, travel in a uniform magnetic field. X has kinetic energy E_X and Y has kinetic energy E_Y.
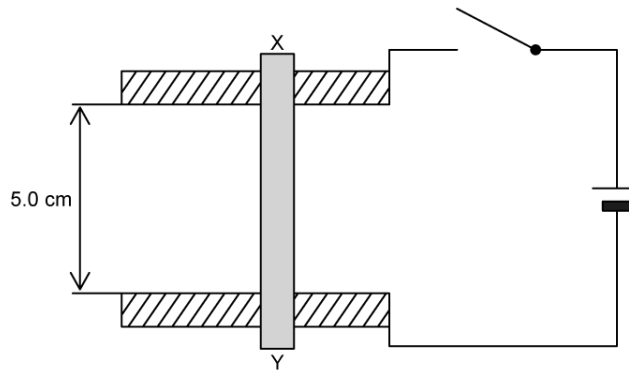
(b)
Calculate the ratio $\dfrac{E_X}{E_Y}$ if X is incident at 30° to the field but Y is incident normally to it.

[2]

[2 marks]

Question 2c

A cylindrical aluminium bar XY of mass 6.0 g rests on two horizontal aluminium rails, separated by 5.0 cm.

The rails are connected via a switch to a cell that can drive a current of 4.5 A through XY. A magnetic field of flux density 0.20 T acts into the screen.
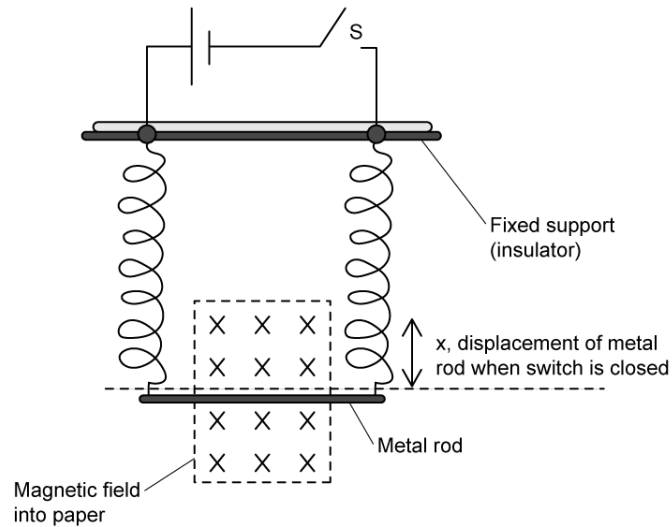
(c)
Calculate the angle to the horizontal to which the rails must be tilted in order to keep XY stationary.

[3]

[3 marks]

Question 2d

A similar metal rod is suspended in a magnetic field by two identical, vertical springs. The cell and the rod have negligible internal resistance.

When the switch S is closed, the metal rod is displaced a distance x from its starting point.

(d)
Show that, when both the spring constant and electrical resistance of each spring is doubled, closing S would cause the rod to be displaced by $\dfrac{x}{4}$.

[3]

[3 marks]

Question 3a

A beam of electrons, each travelling at various speeds, passes through a hole in plate P_1. P_2 is parallel to P_1, also with a hole in it. The region between the plates contains a uniform electric field and a uniform magnetic field. Both the electric field strength E and the magnetic flux density B are adjustable.
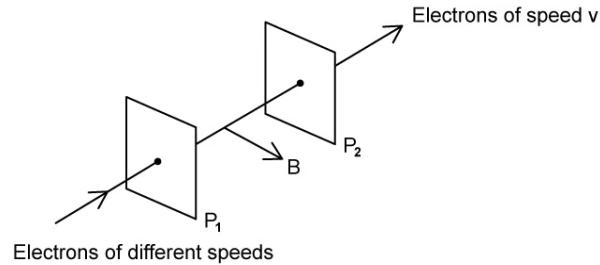
Electrons that are undeviated travel with a particular speed v along the straight line joining the holes in P_1 and P_2.

(a)
Deduce the direction of the electric field between the plates.

[2]

[2 marks]

Question 3b

(b)
Mark with an X a position on P_2 that would indicate where electrons with a speed greater than v may strike P_2.

[2]

[2 marks]

Question 3c

The equipment is adjusted such that a single electron is shot with kinetic energy K through the hole in P_1. The distance between the plates d is fixed, and electric field is switched off, such that the electron is incident in a region of uniform magnetic flux density B only.

(c)
Show that the maximum magnetic flux density B_{max} that ensures the electron reaches P_2 is given by:

$$B_{max} = \frac{\sqrt{2m_e K}}{ed}$$

where m_e is the rest mass of the electron and e is its charge.

[3]

[3 marks]

Question 4a

Very small cracks in some metals can be detected by a method which includes the use of magnetism. In a particular method for steel pipes, a coil of wire is wrapped around it, and a current passed through the coil. This magnetises the pipe and cracks in the direction shown in the image can be found by sprinkling iron filings on the pipe.
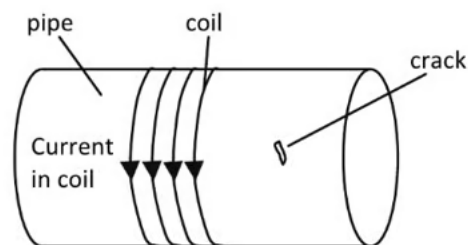
Cracks along or parallel to the length of the pipe do not show up.

(a)
Deduce why this method cannot be used for copper pipes.

[2]

[2 marks]

Question 4b

(b)
Explain why iron filings cluster around the crack shown in the image in part (a).

[2]

[2 marks]

Question 4c

The crack only shows up if it is across the direction of the field.

(c)
Describe and explain how the coil in the image in part (a) should be arranged so that the magnetic field it produces will show cracks cracks that are along the pipe.

[3]

[3 marks]

Question 5a

The image shows the main features of a loudspeaker L. A current-carrying coil is positioned within the magnetic field provided by a permanent magnet, and the current directions in the coil at a particular instant is shown.
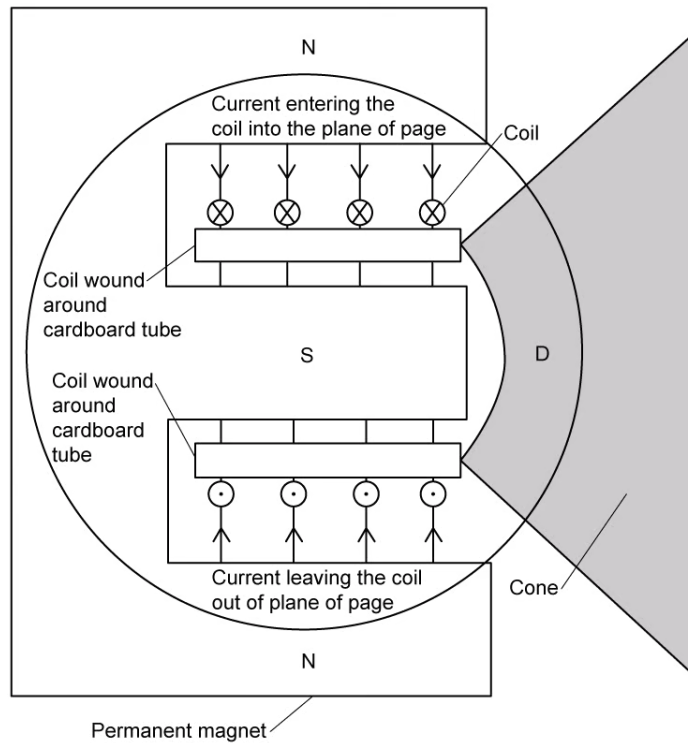
The dust cap D prevents dust from blocking the gap between the cardboard tube and the south pole of the magnet.

(a)
Identify, on the diagram, the direction of the force on the coil at this particular instant with the current directions shown.

[2]

[2 marks]

Question 5b

(b)
Describe how the magnitude and direction of the force on the coil varies over a complete cycle.

[2]

[2 marks]

Question 5c

The coil consists of 200 turns, each of average diameter 2.0 cm. The magnetic flux density created by the permanent magnet is 0.40 mT. The peak current in the coil is 0.48 mA.

(c)
Calculate the maximum magnetic force on the coil.

[3]

[3 marks]