MAGNETIC FIELDS

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1777 -1851

Theory

1 Use of field lines to describe magnetic fields.
2 Concept & location of Neutral points
3 Magnetic field patterns around straight wires and short solenoids.
4 Unit of magnetic flux density (Tesla and Webers per square metre)
5 Direction of magnetic field from Right Hand Grip Rule
6 Fleming's Left Hand rule for direction of B.
7 Magnitude of Flux density, B, defined by F=BIl.
8 Vector nature of B and concept of neutral points.
9 Derivation of BQv from BIL
10 Force between parallel conductors.
11 Definition of the Ampere and μ_o

Experiments

1 Investigation of relationship between force and current for a conductor in a magnetic field.
2 Investigation of the path of a charged particle in a magnetic field.
3 Investigations of magnetic flux density around a long straight wire and a long solenoid.
4 Investigations of steady magnetic field with a pre-calibrated Hall probe.

Formulas

1 **Force on a conductor** $F = BIl$

Where B = Flux density (Teslas *or* Wb m^{-2})
I = current through conductor (Amps)
L = length of conductor in magnetic field (metres)

2 **Force on a charged particle** $F = Bqv$

Where B = flux density (T *or* Wb m^{-2})
Q = charge on particle (Coulombs)
v = velocity of charge through magnetic field (ms^{-1})

3 **Magnetic flux around a long, straight conductor** $B = \mu_o \frac{I}{2\pi r}$

Where μ_o = permeability of free space (Hm^{-1})
I = current through conductor (Amps)
r = perpendicular distance from conductor (metres)

4 **Magnetic field inside a long solenoid** $B = \mu_o nI$

Where n = number of turns per unit length (m^{-1})

Magnetic fields

Name & Set

Unless indicated to the contrary you may use the following values where relevant:

Flux density of the Earth's magnetic field, $B_E = 50 \times 10^{-6}$ T

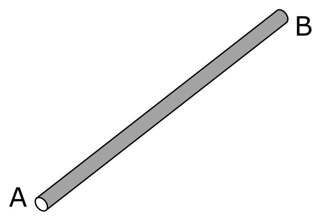
Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}

1 A conductor AB carries a current of 3 Amps from A to B.

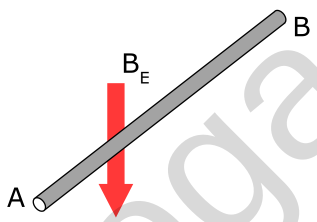
(a) Sketch the magnetic field patterns around the conductor in a plane perpendicular to the conductor seen from the end A in the space to the right for each of the following situations:

(i) Conductor on its own & (ii) conductor within a uniform magnetic field the direction of which is show by the arrow marked B.

(i)



(ii)



(b) Draw an arrow on the conductor in the case of B to show the direction of the force exerted by the uniform field on the conductor.

(c) Calculate the magnitude of this force per metre length of the conductor in case (ii).

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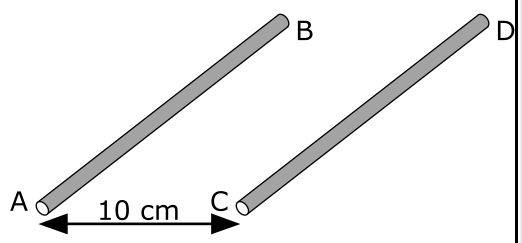
2 In the diagram below a current of 3 amps flows through parallel conductors AB and CD. The current flows through both in the same direction: from B to A and from D to C.

(a) Sketch the field pattern that in this situation in the space on the right. [2]

(iii)



(b) Draw an arrow on the conductors to show the direction of the mutual force exerted by the conductors on each other. [1]

(c) Calculate the magnitude of this force per metre length of the conductor.

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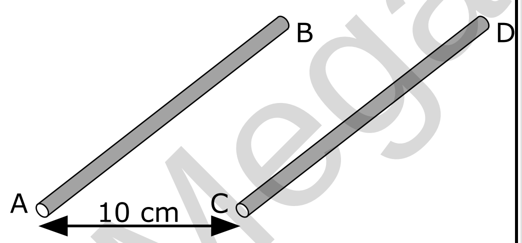
3 In the diagram below a current of 5 amps flows in opposite directions (from B to A and C to D) through parallel conductors AB and CD.

(a) Sketch the field pattern that in this situation [2]

(a)



(b) Draw an arrow on the conductors to show the direction of the mutual force exerted by the conductors on each other. [1]

(c) Calculate the magnitude of this force per metre length of the conductor.

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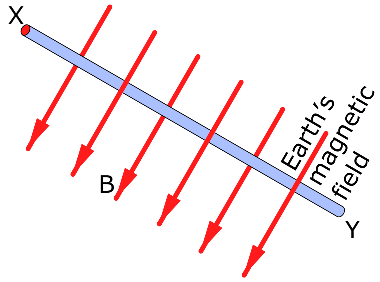
4 A long straight conductor of length 0.75 m is placed so that it lies *perpendicular* to the earth's magnetic field. The strength of this field is 50 μT. A current of 2 amps flows through the conductor in the direction indicated on the diagram. The conductor lies in the plane of the paper.



Find the direction and magnitude of the mutual force between conductor and earth's magnetic field.

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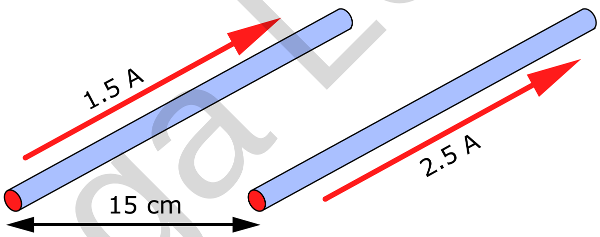
5 What is the magnitude and direction of the mutual magnetic force *per metre length* between the long straight conductors shown in the diagram below?



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(b) Calculate the position of the neutral point given the situation illustrated by the diagram. Ignore the earth's magnetic field.

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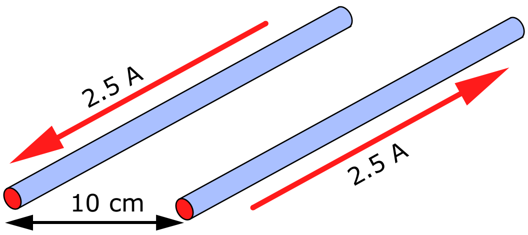
6 What is the magnitude and direction of the mutual magnetic force *per metre length* between the long straight conductors shown in the diagram below?

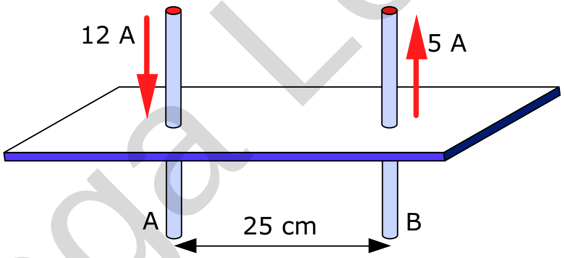


[4]

(b) Calculate the position of the neutral point given the situation illustrated by the diagram. Ignore the earth's magnetic field.

[4]

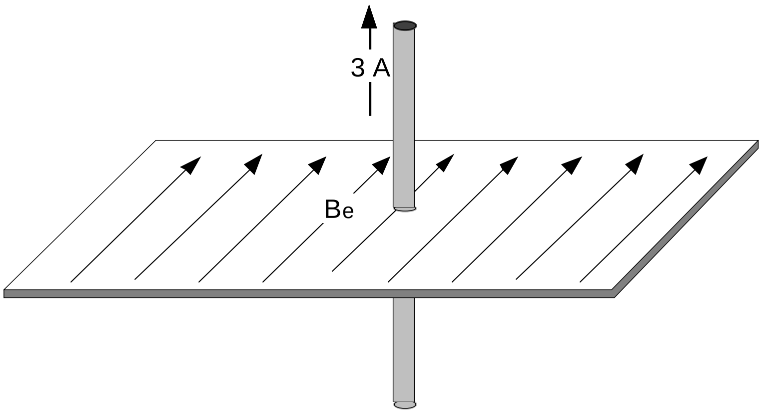
7 (a) Calculate the magnitude of the force between the parallel conductors shown in the figure below.



[4]

(b) Where on the plane is the neutral point? Calculate a value for the position of the neutral point.

8 Calculate the magnitude of the force between the earth's magnetic field and the conductor shown in the diagram below. The earth's magnetic flux density may be taken as 53 μT.



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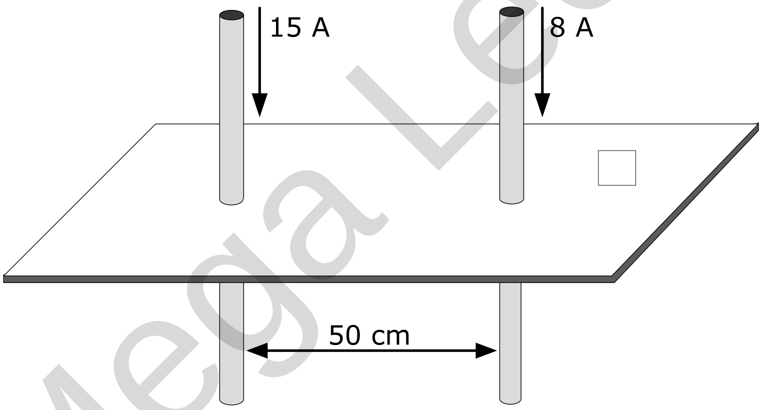
9 (a) Calculate the magnitude and direction of the force between the wires in the figure below.



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(b) Calculate a value for the position of the neutral point between the wires.

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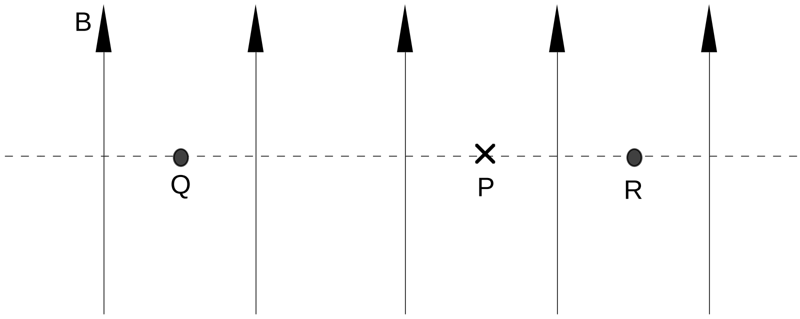
10 The diagram shows a uniform magnetic flux density B in the plane of the paper. Q and R mark the points where two long, straight parallel wires carry the same current, ***I***, in the same direction and perpendicular to the paper. The line through QR is at right angles to the direction of ***B***.

P is a point where the resultant magnetic flux density is zero, i.e. it is a neutral point.

P is closer to R than to Q



(a) Explain whether the direction of the current I is into or out of the paper and sketch a diagram that shows the directions of the different magnetic flux densities present at P.

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(b) If I is increased slightly, will the neutral point at P move towards Q or towards R? Explain.

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(c) There is a second neutral point on the line through QR. State, giving reasons, whether it is to the left of Q, between Q and R or to the right of R.

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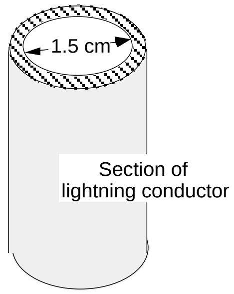
11 Hollow lightning conductors are often crushed by the passage of the current from a stroke of lightning. In other words, the conductor collapses in on itself. Explain why this is not totally unexpected.

To help you answer this question you will need to know that peak lightning currents may reach 20,000 amps for 1/20 millisecond and that the average current over the duration of the typical stroke (which may last up to 1 millisecond) is 8000 amps. Take the internal diameter of the conductor to be 1.5 cm



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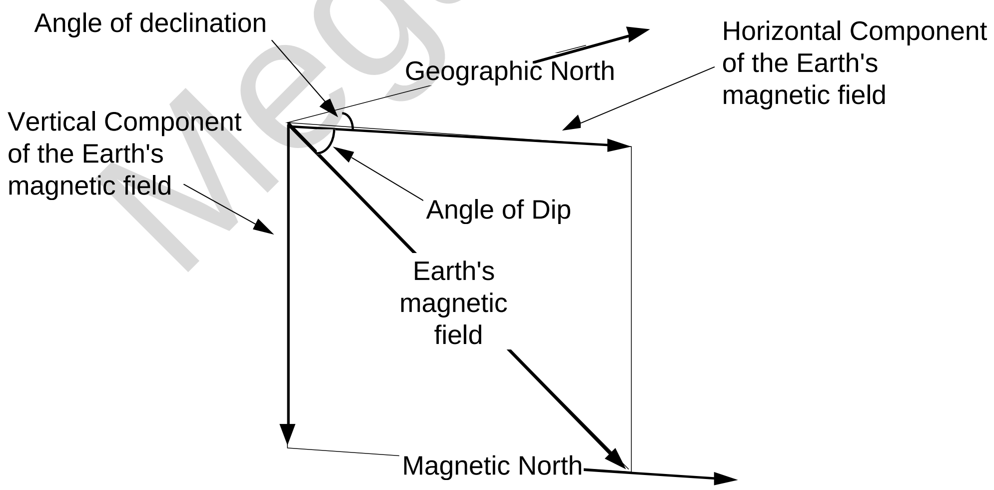
12 A long straight conductor is placed so that it axis is exactly perpendicular to earth's magnetic field. At our latitude this enters the earth's surface at an angle of 70 degrees to the horizontal. This angle is known as the angle of dip. When a current passes through the conductor the neutral point due to the interaction between them lies 7.5 cm to the left of the wire. Draw a diagram to show the shape of the resultant magnetic field and calculate a value for the current through the wire. Indicate on your diagram whether the current flows into or out of the plane of the paper.

Use the diagram below to help you answer this question.



12 Calculate the minimum current that would be needed to make a copper wire of length 10 cm and diameter 1.0 mm resting on a horizontal surface just levitate (i.e. the mutual magnetic force is equal to the weight of the wire.)

Take the horizontal component of the earth's magnetic field as 1.8×10^{-5} T and the density of copper as 8000 kg m^{-3}.

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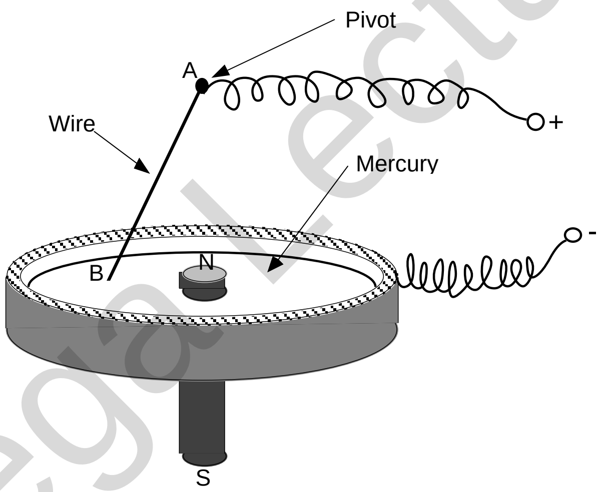
13 Faraday was responsible for constructing the world's first electric motor. The diagram shows its essential features. A long bar magnet is placed with its north pole at the centre of a metallic dish containing mercury. A freely pivoted wire just touches the surface of this mercury. Explain what you would expect to happen when a current passes through from A to B as indicated on the diagram. You may assume that the wire is free to move about the pivot in any direction. Ignore the almost negligible effect of the earth's magnetic field.



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14 A solenoid is constructed by winding 120 turns of insulated copper wire on a cylinder 10 cm long.

(i) How many turns per unit length is this?

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(ii) What will the flux density be at the centre of this coil if a current of 4.0 amps is passed through the solenoid?

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15 A power line that lies at right angles to the horizontal component of the earth's magnetic field carries a current of 50 A. that flows from E to W. What is the magnitude and direction of the force acting on the wire per metre length.

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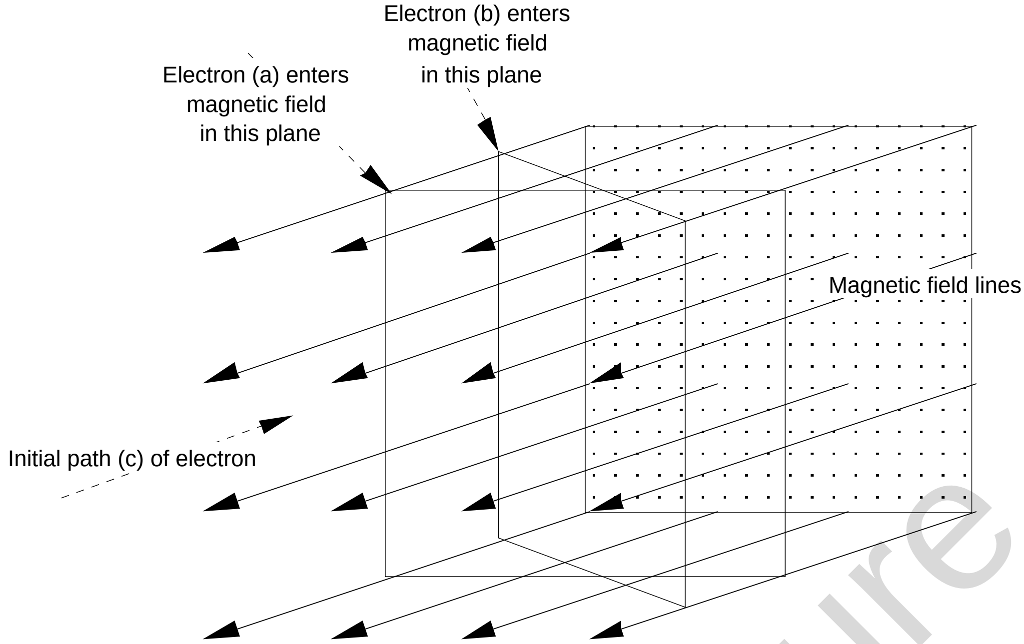
16 An electron enters a uniform magnetic field.



Describe its subsequent path if it enters the field

(a) perpendicular to the field

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(b) at a slight angle to the field

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(c) parallel to the field

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What happens in each of these cases if the electron is released within the magnetic field?

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