Experiment 38

Magnetic field associated with a current-carrying conductor

Purpose of the Investigation

To find how the magnetic field produced by a current in a long straight wire depends on the current in the wire and the distance from the wire.

Background Information

The earth's magnetic field B_e, can be considered uniform and constant at any point on the earth's surface. If the field due to the current through the long straight wire, and the earth's field are perpendicular then they will combine, and a compass will point in the direction of the resultant.

$$\frac{B_I}{B_e} = \tan\theta$$

$$\therefore\ B_I = B_e \tan\theta$$

$$\therefore\ B_I \propto \tan\theta$$

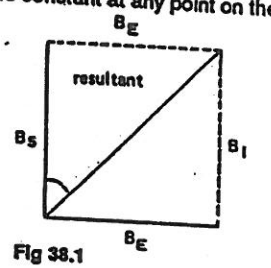


Fig 38.1

The magnetic field due to the current in the long straight wire has a direction perpendicular to the wire and in a horizontal plane directly beneath the wire. Thus, if the wire is aligned along magnetic north-south as shown in Figure 38.2, its field will be perpendicular to the Earth's beneath the wire.

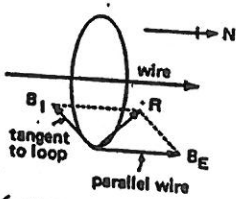


Fig 38.2

Equipment required

A good quality compass such as an orienteering compass
Ammeter - (0-5 A)
Rheostat
Power supply - (0-12 V DC)
Five electrical leads
Metre rule
Two wooden stands and clamps
Long single strand of copper wire - (about a metre)
Blocks of wood which will act as a stand and spacers for the compass
Switch

Part 1: The relationship between magnetic field and current

Procedure

#1 Set up the long straight wire in a north-south direction as far away from any ferro-magnetic material as possible. Figure 38.3 shows the plan viewof the equipment and Figure 38.4 shows the elevation or front view of the equipment.

#2 Connect up the rest of the circuit well clear of the long straight wire.

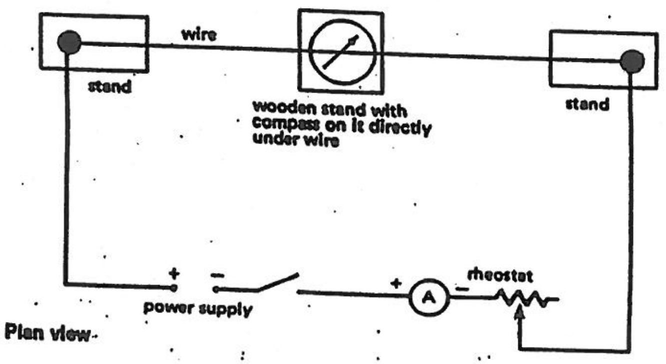


Fig 38.3 Plan view

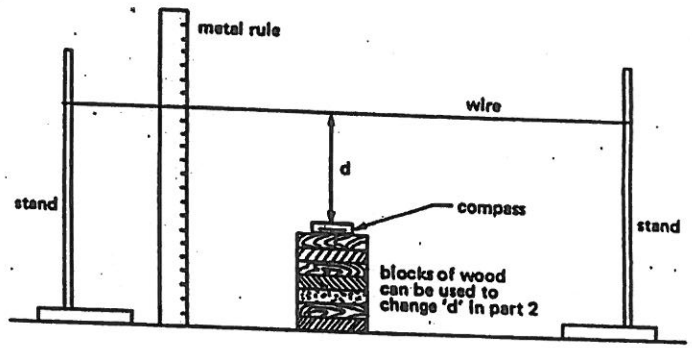


Fig 38.4 Elevation or front view

#3 Place the compass directly beneath the centre of the wire.

#4 Adjust the position of the wire or the compass to a suitable height.

#5 Switch on the current and observe the deflection in the compass.

#6 Draw up a table which has columns to record the current (I), deflection left (θ_1) and right (θ_2), average deflection (θ) and tan θ.

#7 Record current and deflection (θ_1) in the table.

#8 Reverse the direction of the current and record the deflection (θ_2). From this you can determine an average value for the deflection (θ) for a particular current.

#9 Repeat the procedure keeping the distance (d) constant, using a number of different values for I. Make sure that the readings are over as wide a range as possible.

Processing of the results

1 Calculate the average deflection (θ) and tan θ, and record these values on the table.
2 Establish the relationship between tan θ, which is a measure of the magnetic field strength produced by the wire, and I. Plot a graph to show this relationship.

Part 2: The relationship between magnetic field and the distance from the wire

Procedure

#1 Adjust the current to the maximum value and keep it constant.

#2 Vary the separation of the wire and compass (d) and record values of over a large range. This can be done by placing small blocks of wood of known thickness under the compass.

#3 Again reverse the direction of the current for each value to d. This will allow you to calculate the average deflection.

#4 Draw up a table of values for the distance between the wire and the compass, the two deflections, the average deflection, tan θ , the reciprocal of the distance, and the reciprocal of the distance squared.

Processing of the results

1 Plot graphs of:
   a tan θ against d
   b tan θ against 1/d
   c tan θ against $1/d^2$

Conclusion

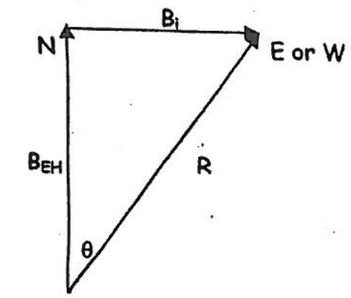
From your results state the relationship that exists between the magnetic field produced and the current in and distance from a long straight wire.

Questions and discussion

1 Why are wooden stands used in this investigation?
2 Why is the rest of the circuit set up well clear of the long straight wire?
3 Give another variable which could influence the magnetic field produced by the wire and which was kept constant in this experiment.

MAGNITUDE OF THE EARTH'S MAGNETIC FIELD

The direction that the compass points in is the resultant of the horizontal component of the earths magnetic field (B_{EH}) and the wires magnetic field (B_I)



θ is the angle of deflection of the compass.

$$\tan\theta = \frac{B_I}{B_{EH}} \qquad \therefore\ B_I = B_{EH}\tan\theta \qquad (1)$$

The magnetic field around a wire can be calculated using the following formula

$$B_I = \frac{\mu_o I}{2\pi d} \qquad (2)$$

Where μ_o = permeability of free space ($4\pi \times 10^{-7}\ NA^{-2}$)

I = current in the wire (A)
d = distance from the wire (m)

Substituting eqn. (1) into eqn. (2)

$$B_{EH}\tan\theta = \frac{\mu_o I}{2\pi d}$$

$$B_{EH} = \frac{\mu_o I}{2\pi d \tan\theta}$$

but $d\tan\theta = \dfrac{\tan\theta}{\frac{1}{d}}$ = gradient of graph

ie $B_{EH} = \dfrac{\mu_o I}{2\pi \frac{\tan\theta}{1/d}}$ Using the gradient of the graph, calculate the value of B_{EH}

In Perth the angle of inclination is 67.1° Calculate the value for B_E