Magnetism & Electromagnets

We can represent a magnetic field by lines of flux. Flux lines are lines to indicate the direction of the magnetic field.

- The density of the flux lines (number of them) shows the strengths of the field.

Direction of flux lines

The direction is defined as leaving a north pole and entering a south pole.

Magnetic Flux

The magnetic flux is represented by the symbol Φ (phi) and is the total flux (all the magnetic flux lines) being considered in a region. Please keep in mind that the magnetic flux unit is Weber (Wb)

Magnetic flux density

This is the number of flux lines per unit area.

Often denoted by the letter B which is measured in T (Tesla)

$$\Phi = B.A$$

Total magnetic flux = flux density x area

$\therefore$ Wb = Tm^2

Electromagnetism

Since any moving charge creates its own magnetic field, then a wire carrying current will have its own magnetic field.

Current and Field Direction

Due to an historical error in Physics, the current direction is always shown as the direction a positive charge would move in the conductor (opposite to that of an electron). This is known as CONVENTIONAL CURRENT.

Right hand grip rule

Imagine gripping the conductor with your right hand, with your thumb pointing in the direction of the conventional current, then the direction your fingers curl around the conductor is the magnetic flux lines direction.

Representing field directions

Across page	Into page	Out of page

Rule: Using your right hand, grasp the wire with the thumb pointing in the direction of the conventional current. The curl of your fingers gives you the direction of the field.

Rule for determining the poles of a current carrying solenoid

Pretend to grasp the solenoid coils with your right hand with your fingers wrapping around it in the direction that conventional current is flowing. Your thumb will point in the direction of the field lines (i.e. north to south)

Magnetic Force

When a wire carrying current is placed in a magnet it experiences a force.

- We know that moving charge creates its own magnetic field.
- A wire carrying current is moving charge; therefore it has a magnetic field around it
- Since magnetic fields attract or repel, the wire will experience a force.

The force experienced is directly proportionate to the length (l) of the conductor in the magnetic field, the strength of the magnetic field (B) and the current (I) carried by the conductor. For a conductor at right angles to the field:

$$\mathbf{F = IlB}$$

For a conductor not at right angles to the field where θ is the angle between the field and the conductor:

$$\mathbf{F = IlB\sin\theta}$$

Example

What would this force be if the conductor was parallel to the field?

$$F = IlB \sin 0$$
$$F = IlB \times 0$$
$$F = 0 \text{ N}$$

Hence no force is experienced.

A 20.0 cm length of wire carrying 0.2A is placed at right angles to a magnetic of flux density 2.6T. What force would it have exerted on it?

$$F = 0.2 \times 0.2 \times 2.6 \sin 90$$
$$F = 0.104 \text{ N}$$

Rule to determine the direction of the force

Use your right hand palm. The thumb represents the direction of the current, the fingers represent the direction of the current, the fingers represent the direction of the field and the direction of the force is out from the palm of the hand as you would push.

FAQ

How would you increase the force exerted on a wire carrying current?

1. Increase length of wire
2. Increase current
3, Increase strength of the magnetic field
4. Increase angle, maximum at right angles.

DC Electric Motors

An electric motor has a stationary permanent magnet called the stator to provide a radial magnet field. The rotating part is called the armature or rotor, and it has a coil through which you can pass a current. This current creates a magnetic field that is repelled by the stationary field, causing the armature to turn. A split ring commutator is required to change the direction of the current every 180° so that the applied force is always turning the rotor in one direction.

Please refer to figure 3.29 on page 112 in your Heineman Physics 3A and 3B text.

Torque

This is the turning effect on the rotor and is equal to the product of the force and perpendicular distance to the line of action of the force.

$$\tau = F \times d$$

where τ = turning effect (torque)
F = force
d = perpendicular distance from the fulcrum to the line of action or force.

FAQ

How do you increase the torque?

- ↑ Current
- ↑ Length of coil
- ↑ Strength of magnets
- Use an iron core
- ↑ Number of turns
- ↑ Number of armature coils
- ↑ Torque radius

Charges in Magnetic Fields

Moving charges have their own magnetic fields. Therefore, when placed in a magnetic field they will experience a force.

$$F = qvB$$

Electromagnetic Induction

Generators convert mechanical energy into DC electrical energy. This process is called electromagnetic induction.

Dynamo Effect

Magnet + Coil + Movement = Electricity

- Flux lines must cut the conductor or the conductor must cut the magnetic flux for a current to flow.
- The moment the conductor stops cutting magnetic flux or vice versa will be when the current stops

EMF Calculations

The total EMF is given by

$$EMF = -\frac{n\Delta\Phi}{t}$$

Where EMF = electromagnetic force (v)
n is number of turns
$\Delta\varphi$ is the change in magnetic flux
t is the time taken for change

or

$$EMF = -\frac{n\Delta BA}{t}$$

where B is the flux density in Tesla
A is the area cut by the loop
t is the time taken for change

Induced EMF in straight lines

Len’s Law – the direction of an induced current is such as to oppose the change causing it.

$$EMF = -lvB$$

where:

l is the length
v is the velocity
B is the density

You may be wondering why there is a negative sign. This is because the current generated is always in such a direction so it opposes the motion that is causing it. Otherwise, you would be creating energy and not converting it to another form.