# 3055 BA SANGAM COLLEGE

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**WORKSHEET 20**

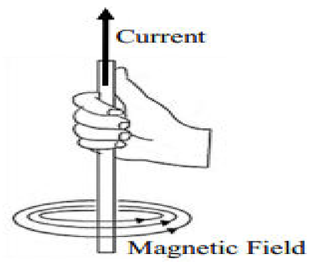
**SCHOOL: BA SANGAM COLLEGE** **YEAR: 13**
**SUBJECT: PHYSICS** **NAME OF STUDENT: ___________________**

| | |
|---|---|
| **STRAND** | **STRAND 6: MAGNETIC FIELD** |
| **SUB-STRAND** | 6.2 Current carrying conductor |
| **LEARNING OUTCOME** | To calculate the force and magnetic field in a current carrying conductor |

## Current carrying conductor

### The magnetic field of a straight conductor

- The magnetic field produced by the current in a wire consists of circular path lines around the wire.
- USE right hand screw rule.




The magnetic field strength at a distance, r, from a wire carrying a current, I, is:

$$B = \frac{\mu_o I}{2\pi r}$$

Where: $\mu_o$ = permeability of free space ($4\pi \times 10^{-7}$ Tm $A^{-1}$)

Substituting $k = \frac{\mu_o}{2\pi}$, Equation 6.5 simplifies to the following equation;

$$B = \frac{kI}{r}$$

Unit = Tesla (T)

NOTE: ***As r increases, B decreases***

**EXAMPLE**

If the current in a conductor is 8.50 A, determine the magnitude of magnetic field at;

a) $r_1 = 10.0$ cm b) $r_2 = 20.0$ cm c) $r_3 = 30.0$ cm

Using Eqn. 6.6; $B = \frac{kI}{r}$

a) $B_1 = \frac{(2\times10^{-7})(8.50)}{0.1}$

$B_1 = 1.7\times10^{-5}$ T

b) $B_2 = \frac{(2\times10^{-7})(8.50)}{0.2}$

$B_2 = 8.5\times10^{-6}$ T

c) $B_3 = \frac{(2\times10^{-7})(8.50)}{0.3}$

$B_3 = 5.7\times10^{-6}$ T

It is clearly evident that magnetic field strength decreases as r increases.

**EXERCISE**

1. A long straight wire carrying current produces a magnetic field of $4 \times 10^{-6}$ T at a point, 15 cm from the wire. Calculate the current through the wire.

**2.** A wire carries a current of 5A, determine the magnetic field at the following distance from the wire

a) 20cm  b) 500mm  c) 0.12m

## Magnetic Flux ($\phi_B$)

The magnetic flux is the amount of magnetic field passing through a given area. In the SI unit system, $\phi_B$ is measured in Weber (Wb). The strength of a magnetic field is also known as magnetic flux density, measured in Tesla (T) or Wb m$^{-2}$.

The magnetic flux through an area, A, is the product of the area and the magnetic field perpendicular to it.

$$\phi_B = BA$$

If the field lines make an angle with the plane, the magnitude of flux tends to decrease and is given as;

$$\phi_B = BA\cos\theta$$

The magnetic flux passing through an area is reduced if the magnetic field is not perpendicular to the area and zero if the magnetic field is parallel to the area.

**EXAMPLE**

A square with sides of length 2 m is perpendicular to a magnetic field of strength 10 T. If the square is rotated by 60º. Calculate the magnetic flux before and after rotation. ( Taking vector A as a reference).

$\phi_B = BA = (10)(2\times2) = 40$ Wb

before rotation

$\phi_B = BA = (10)(2\times2)\cos 60° = 20$ Wb

after rotation

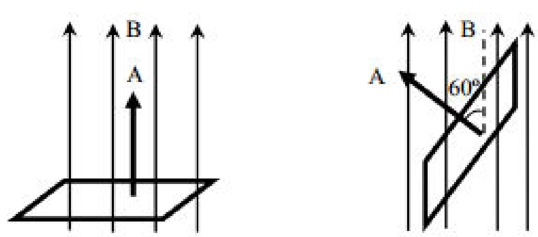



**Figure 6.6**

**Force on a current carrying conductor in a magnetic field (motor effect)**

When a current carrying conductor is placed in a magnetic field, a **FORCE** is produced.

*Current* + *Field* ⟶ *Force* (motion)

The magnitude of the force is given by:

$$F = BIL$$

*where:* $B$ = magnetic field strength (T)

$I$ = current flowing (A)

$L$ = Length of conductor(wire) in the field (m).

The magnetic force experienced on a conductor carrying a current, I at angle, θ is given by:

$$F_B = BIL\sin\theta$$

*The above formula shows that the size of the force depends on:*

(i) ***the strength of the magnetic field.*** (ii) ***the size of the current***. (iii) ***the length of the conductor.***

The direction of the force is given by the right-hand slap rule. Thumb – force 1st finger – magnetic field 3rd finger – current (**FBI or FMC**)

*Points to note:*

1. When the wire is **perpendicular** to the field, force is **maximum**.
2. If the wire is **parallel** to the field, then force is 0 ie. **F = 0.**

Example 1

A wire 2m carries a current of 5A and is at right angles to a magnetic field of strength 6T. What force is exerted on the wire?

L = 2m
I = 5A
B = 6T
F = ?

$$F = BIL = (6)(5)(2) = \underline{60N}$$

2. The force on a wire 20cm long carrying a current of 100A at right angles to a magnetic field is 0.6N. What is the magnetic field strength?

L = 20cm = 0.2m
I = 100A
F = 0.6N
B = ?

$$F = BIL$$

$$B = \frac{F}{IL} = \frac{0.6}{(100)(0.2)} = 0.03\ T$$

The torque on a current loop is given by;

$$\tau = BANI\cos\theta$$

Where: N = number of turns of wire in the coil
B = magnetic field strength of the magnetic field
I = current in the coil
A = cross sectional area of the coil
θ = angle between the coil and field

The product IA is called the magnetic moment or the magnetic dipole moment μ of the single loop.

**EXAMPLE**

A rectangular horizontal coil ABCD of 100 turns has length AB = 6.0 cm and breath BC = 3.0 cm. The current, I, flowing through the loop is 10 A and the uniform horizontal magnetic field B is 0.50 T.

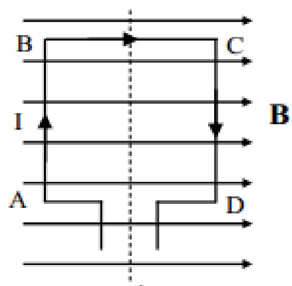


**Figure 6.9**

a) Calculate the force on side AB.

$$F = BIL\sin\theta$$
$$F = (0.5)(10)\left(\frac{6}{100}\right)\sin 90^\circ$$
$$F = 0.3\,N$$

For this coil using Fleming's Left Hand Rule;

The direction of force on AB is into the page.
The direction of force on CD is out of the page.
Hence, the coil rotates in clockwise direction

b) Determine the force on side BC.

There is no force experienced by side BC. Since magnetic field and current are parallel to each other.

c) Calculate the torque on the coil when the plane of the coil is parallel to the field.

$$\tau = BANI\cos\theta$$
$$\tau = (0.5)(1.8\times10^{-3})(100)(10)\cos 0^\circ$$
$$\tau = 0.9\,Nm$$

d) What is the torque on the coil when the plane of the coil makes an angle of 30º to the field?

$$\tau = BANI\,Cos\,\theta$$
$$\tau = (0.5)(1.8\times10^{-3})(100)(10)\cos 30^\circ$$
$$\tau = 0.78\,Nm$$

**EXERCISE 2** **(2Marks each)**

1. The force on a wire 0.50m long carrying a current of 15A at right angles to a magnetic field is 6N. What is

the magnetic field strength?

2. A wire 150cm carries a current of 4A and is at 30° horizontal to a magnetic field of strength 3T. What force is exerted on the wire?

3. A rectangular loop of dimensions 7 cm and 14 cm is oriented in a magnetic field of strength 0.50 T at an angle
of 35º. The current in the loop is 2.5 A. Find the magnitude of the torque at that instant.

4. A circular loop of radius 10cm is oriented in a magnetic field of strength 2 T at an angle of 60º. The current in the loop is 3 A. Find the magnitude of the torque at that instant.