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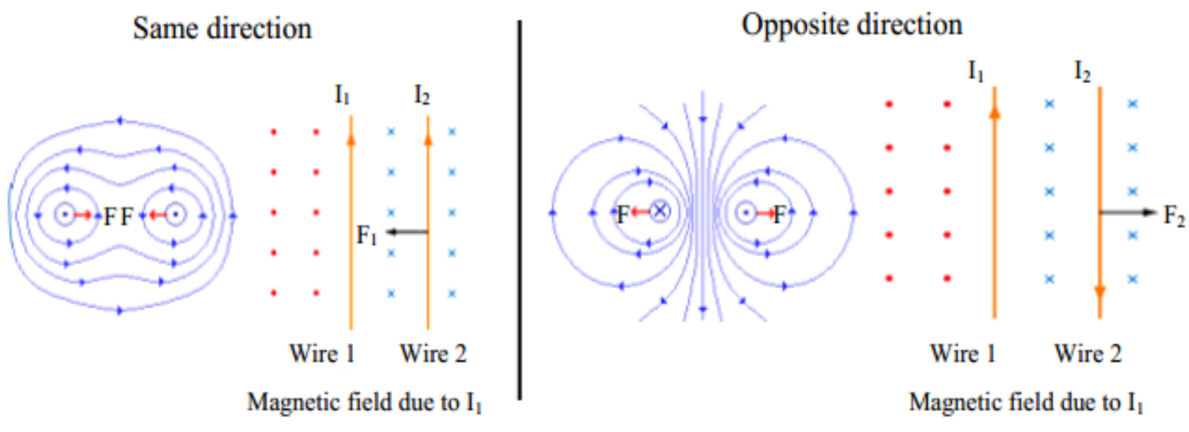
WORKSHEET 21

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**

Forces between Parallel conductors

- When two wires carrying current are placed closed to each other will experience a force of either attraction or repulsion
- When the currents are in the **same direction**, the fields between the wires cancel each other. As a result, the wires are **attract**ed to each other
- When the current is in **opposite direction** then field add up and **force is repulsion**



The magnitude of the magnetic field strength created by conductor I_2 is;

$$\boxed{B_2 = \frac{\mu_o I_2}{2\pi r}}$$

Where: $\frac{\mu_o}{2\pi} = k = 2 \times 10^{-7}\ \text{Tm.A}^{-1}$

And the force per unit length of the conductor is;

$$\boxed{\frac{F}{l} = \frac{k I_1 I_2}{r}}$$

EXAMPLE

1. Two very long straight parallel wires carry currents of 15 A and 5.0 A. The wires are 10 cm apart. Determine the force per unit length.

$$\frac{F}{l} = \frac{k I_1 I_2}{r}$$

$$\frac{F}{l} = \frac{\left(2\times10^{-7}\right)(15)(5)}{0.1}$$

$$\frac{F}{l} = 1.5\times10^{-4}\ \mathrm{N\,m^{-1}}$$

2. Two parallel wires each of length 5m are placed at a distance of 10 cm apart in air. They carry equal currents along the same direction and experience a mutually attractive force of 3.6×10^{-4} N. Find the current through the conductors.

$I_1 = I_2 = I$ $\quad$ $l = 5$ m $\quad$ $r = 10$ cm $= 0.1$ m $\quad$ $F = 3.6\times10^{-4}$ N $\quad$ $I = ?$

$$F = \frac{\mu_o I_1 I_2 l}{2\pi r} = \frac{\mu_o I^2 l}{2\pi r}$$

$$\therefore I^2 = \frac{Fr}{kl} = \frac{3.6\times10^{-4}\times0.1}{2\times10^{-7}\times5} = 36$$

$$I = 6\ \mathrm{A}$$

Hence $I_1 = I_2 = 6$ A

EXERCISE

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

2. Two very long straight parallel wires carry currents of 10 A and 5.2 A as shown in the diagram below. The wires are 10.8 cm apart and point P is a point 5.0 cm from the wire carrying the 5.2 A and in the same plane as the two wires.

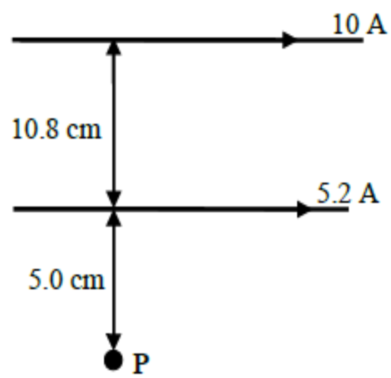


Figure 6.11

a) Determine the magnitude and direction of the magnetic field strength at point **P** due to

   i. the 5.2 A current

   ii. the 10 A current

b) What is the net field strength at **P**?

Now the direction of 10 A current is changed to left while the 5.2 A current remains in the same direction.

c) Determine at **P** the magnitude and direction of the magnetic field strength due to

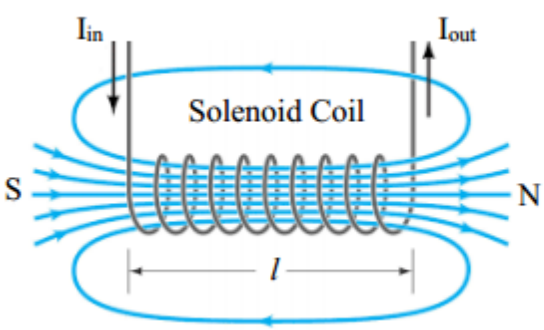
   i. the 5.2 A current.

   ii. the 10 A current.

d) What is the net field strength at **P**?

Ampere's Law

It states that the line integral of the magnetic field around any closed path is the product of and the net current across the area bounded by the path $\int B.dl$ · ie



$$\boxed{\oint B\,dl = \mu_0 I}$$

Magnetic Fields due to Currents

The magnetic fields of solenoid

Using Ampere's Law to find the magnetic field near the centre of a Solenoid;

$$\oint B.dl = Bl$$

$$\boxed{Bl = \mu_o NI}$$

$$\boxed{B = \frac{\mu_o NI}{l} = \mu_o nI}$$

Where: N = number of turns in coil
l = Length of solenoid
$\mu_o = 4\pi \times 10^{-7}\ TmA^{-1}$
n = number of turns per unit length

Note

Magnetic field outside the solenoid is zero and a stronger field is formed inside, centre of the coil.

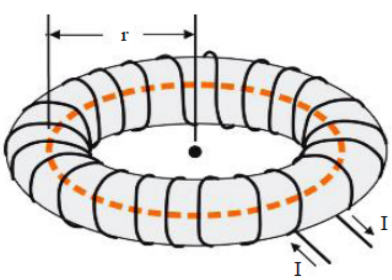
EXAMPLE

Find the magnetic field strength at the centre of a solenoid 15 cm long, which consist of 200 turns of wire carrying a current of 4 A.

$$B = \frac{\mu_o NI}{l} = \frac{(1.26 \times 10^{-6})(200)(4)}{0.15} = 6.72 \times 10^{-3}\ T$$

Magnetic Field of Toroid

- The magnetic field inside is directed tangentially and with the magnitude depending on r, **the field outside is zero. The magnetic field can be found by**



From Ampere's Law

$$\oint B.dl = \mu_o I_c$$

$$B.2\pi r = \mu_o NI$$

$$\boxed{B = \frac{\mu_o NI}{2\pi r}}$$

: r = distance from centre (m)
I = current (A)
B = magnetic field (T)

EXERCISE

1. A wooden ring of mean diameter 0.1 m is wound with a closely spaced **toroidal** winding of 500 turns. Compute the field at a point on the mean circumference of the ring when the current in the windings is 0.3 A.

2. A solenoid is 2m long and 3 cm in diameter. It has 5 layers of windings of 1000 turns each and carries a current of 5A. Find the magnetic induction at its centre along its axis

3. Calculate the magnetic field inside a solenoid 20 cm long, made from 500 turns of wire, carrying current of 5A.

4. A closely wound coil-solenoid has a diameter of 18.0 cm carries a current of 2.50 A. How many turns does it have if the magnetic field at the centre of the coil is 4.19×10^{-4} T?

5. The Figure 6.16 shows a 2.00 m long solenoid that has 2000 loops and carries a 1600 A current.

   a) Determine the number of units per length.

   b) Calculate the magnetic field strength.