Teacher notes

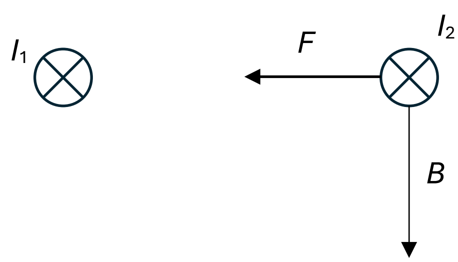
Topic D

The magnetic field of a long current carrying wire

We know that a long current carrying wire produces a magnetic field around the wire. Our syllabus does not give the formula giving the magnetic field strength but this can be derived from what is already on the syllabus.

The guide says that the force per unit length between two parallel current carrying wires a distance r apart is given by $\frac{F}{L}=\frac{\mu_0 I_1 I_2}{2\pi r}$ or $F=\frac{\mu_0 I_1 I_2 L}{2\pi r}$.

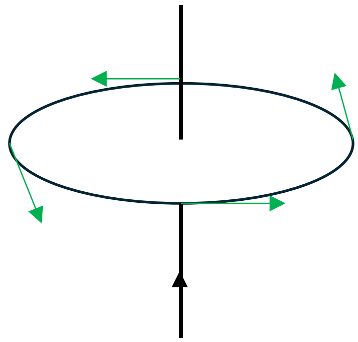
Looking at the figure the force on the wire on the right is also given by $F = BI_2L$



where B is the magnetic field created by the wire on the left at the position of the wire on the right. Comparing $F=\frac{\mu_0 I_1 I_2 L}{2\pi r}$ to $F = BI_2L$ we see that $B=\frac{\mu_0 I_1}{2\pi r}$ i.e. the magnetic field created by a long straight wire carrying current I at a distance r from the wire is

$$B=\mu_0 \frac{I}{2\pi r}$$

We know the direction of the magnetic field is tangent to a circle of radius r around the wire.



The result obtained has the interpretation

$$2\pi r B = \mu_0 I$$

or circumference of circle times magnetic field equals μ_0 times the current piercing the loop.

This is a special case of Ampere's law: $\oint \vec{B} \bullet d\vec{l} = \mu_0 I$. For a long straight wire:

$\vec{B} \bullet d\vec{l} = Bdl\cos 0^\circ = Bdl$ and since the field is constant in magnitude around the circle

$\oint \vec{B} \bullet d\vec{l} = B\int_0^{2\pi r} dl = B2\pi r$ and so $B2\pi r = \mu_0 I$ or $B = \mu_0 \dfrac{I}{2\pi r}$.