Magnetic Field Strength

Faraday noticed the force acting on a current passing through a magnetic field.

In order to define "magnetic field strength" we need to define the term "current element".

A "current element" is analogous to a test mass when dealing with gravitational field or a test charge when dealing with electric field.

Current Element

A current element is used to define certain quantities or to derive certain expressions. It is the product of the conventional current I and its length L (i.e. IL) such that the magnitude of the product is small enough not to affect the quantity that is being defined or measured.

Magnitude of force on the current carrying wire:

Empirically it is found that the force on a current carrying wire at right angles to a magnetic field.

$F \propto I$ (the current)

$F \propto B$ (the magnetic field)

$F \propto L$ (the length)

combining: $F \propto BIL$

$F = kBIL$ → Special k! $k = 1$

$F = BIL$ (IL: current element)

$$B = \frac{F}{IL}$$ ← current element

Magnetic field strength is the force per current element

So we have the following expressions for field strength:

Gravitational	Electric	Magnetic
$\vec{g} = \frac{\vec{F}}{m}$	$\vec{E} = \frac{\vec{F}}{q}$	$B = \frac{F}{IL}$

the field is in the direction of the force (can write with vector notation)

the field is perpendicular to F. (DO NOT write with vector notation) → use right hand rule

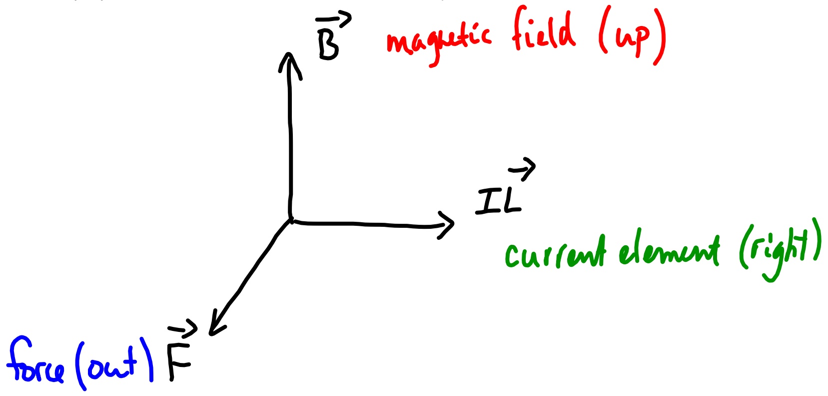
Magnetic Field Strength (Definition)

The magnitude of the magnetic field strength $\vec{B}$ at a point is the magnitude of the Force $\vec{F}$ per unit current element IL acting on a small current element placed at right angles to the field

Direction.

i.e. $B = \frac{F}{IL}$ where I is the conventional current and L is its length in the field.

The direction of the magnetic field is at right angles to both the current and the force.



Unit of Magnetic Field Strength

Since $B = \frac{F}{IL}$ $NA^{-1}m^{-1}$ or T (tesla)

Magnetic Field Strength → vector quant

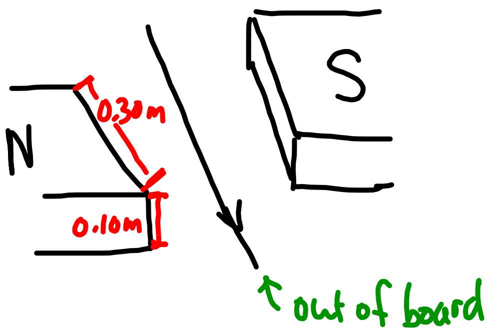
(equation gives use magnitude only

→ use right hand rule to find direction)

Example

A wire carrying a current of 2.0A is placed at right angles to a uniform magnetic field of strength 0.50T as shown. Determin the magnitude and direction of the force acting on the wire:

direction is up



$F = BIL$

$F = (0.50T)(2.0A)(0.30m)$

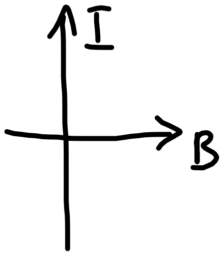
$F = 0.30N$

$\vec{F} = 0.30N$ [up]

General Expression for the force on a current-carrying wire at an angle θ to the magnetic field.

Consider the current at 90° to the field:

$\theta = 90^\circ$



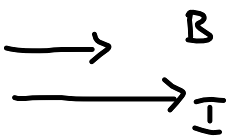
$F = BIL$

(into the page)

(maximum force)

Current and field are parallel:

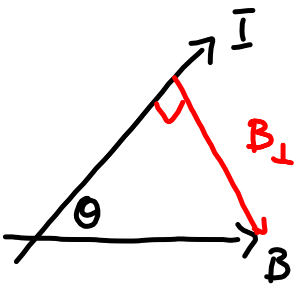
$\theta = 180^\circ$



$F = 0$

(minimum force)

Current and field are at an angle θ to each other.



$B_\perp = B\sin\theta$

We need to find the component of B that is perpendicular to I (i.e. $B_\perp$)

$F = B_\perp I L$

$F = (B\sin\theta) I L$

Data Booklet → $F = BIL\sin\theta$