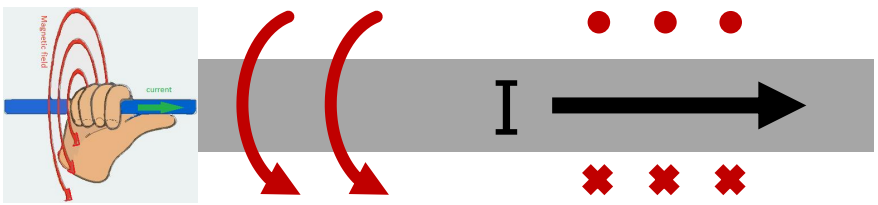
Electromagnetic Force

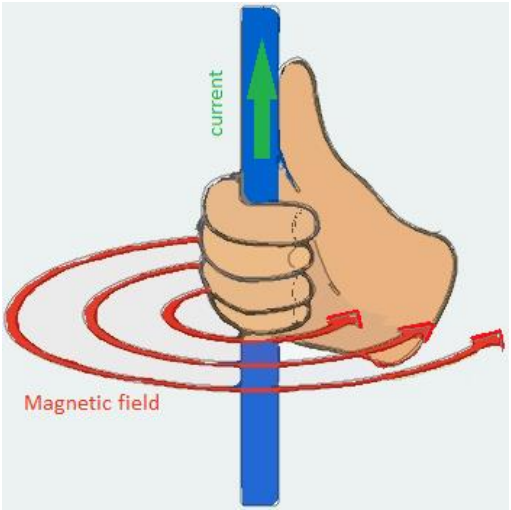
IB PHYSICS | FORCE FIELDS

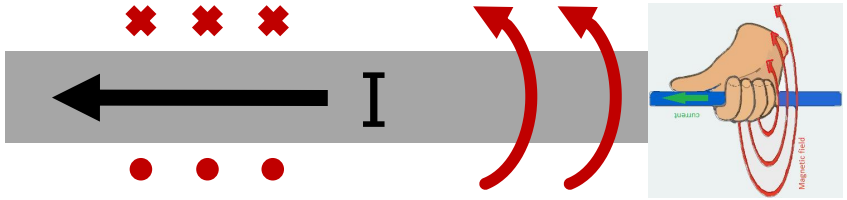
Remember the Right Hand Rule?

Thumb points in direction of the current

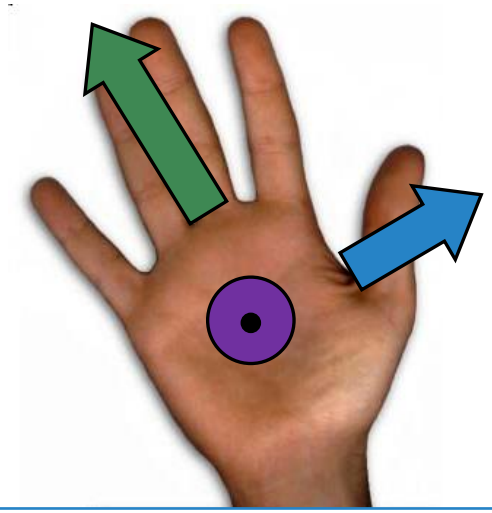
Fingers point in direction of the field lines







Right Hand Rule #2



Thumb points in direction of the current

Fingers point in direction of the field lines

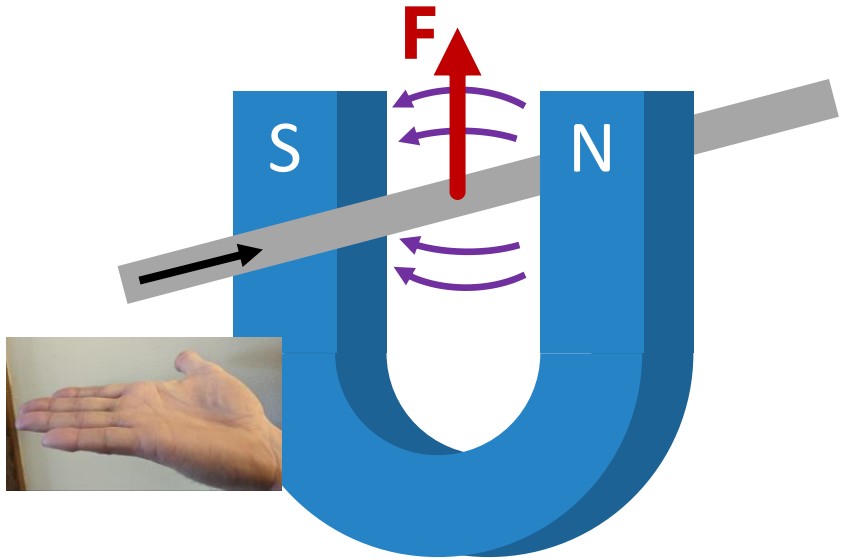
Palm points in direction of the force

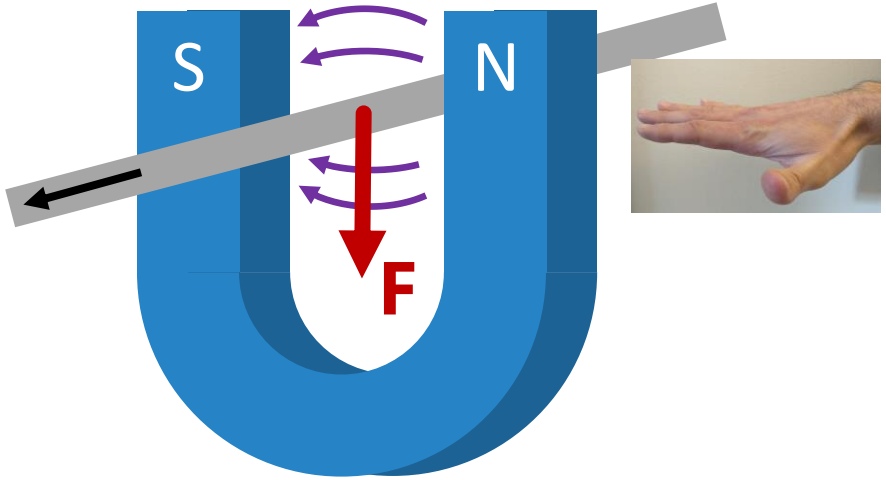
How do you represent a direction that's perpendicular to the paper?

Into the paper	✖
Out of the paper	●

Right Hand Rule #2

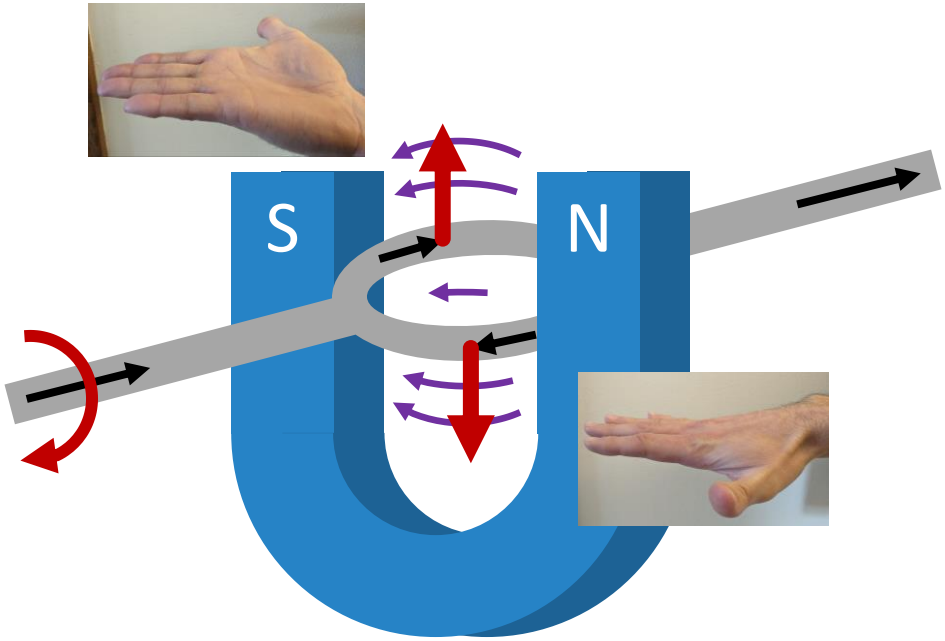
A current-carrying wire is placed in a magnetic field and the magnetic field exerts a force on the wire





Designing a Motor

When electric current is passed through a magnetic field, you get ___motion___



Motors vs Generators

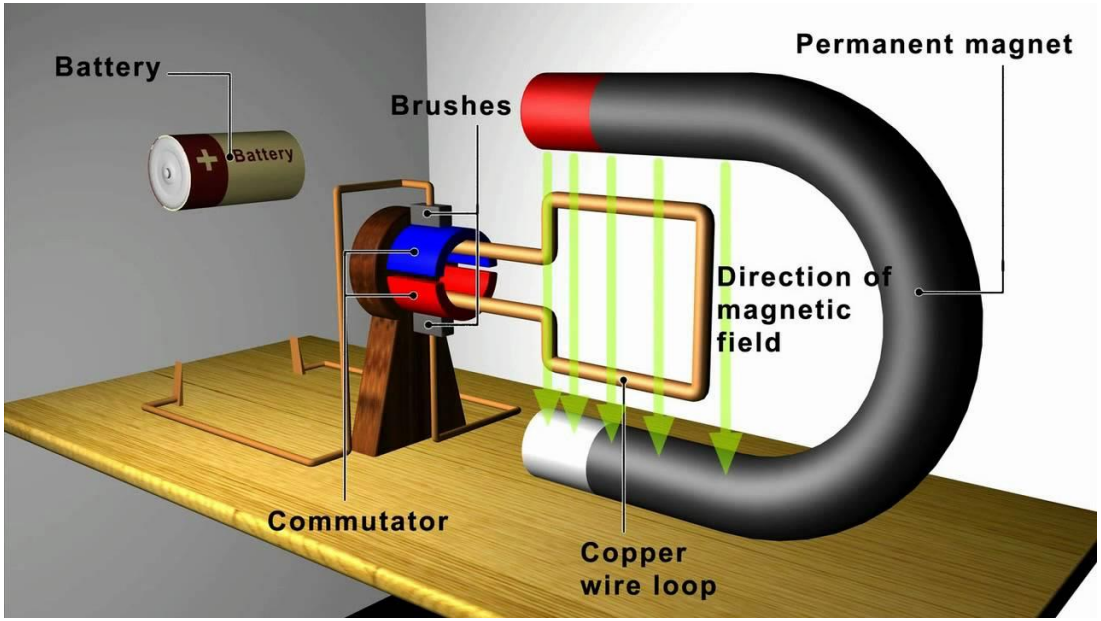
Electric Motors convert

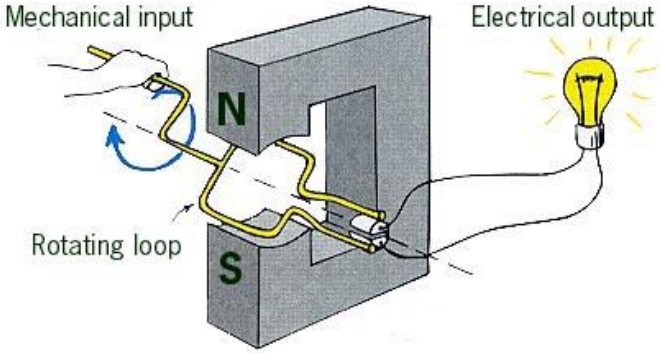
Electricity → Motion

Electric Generators convert

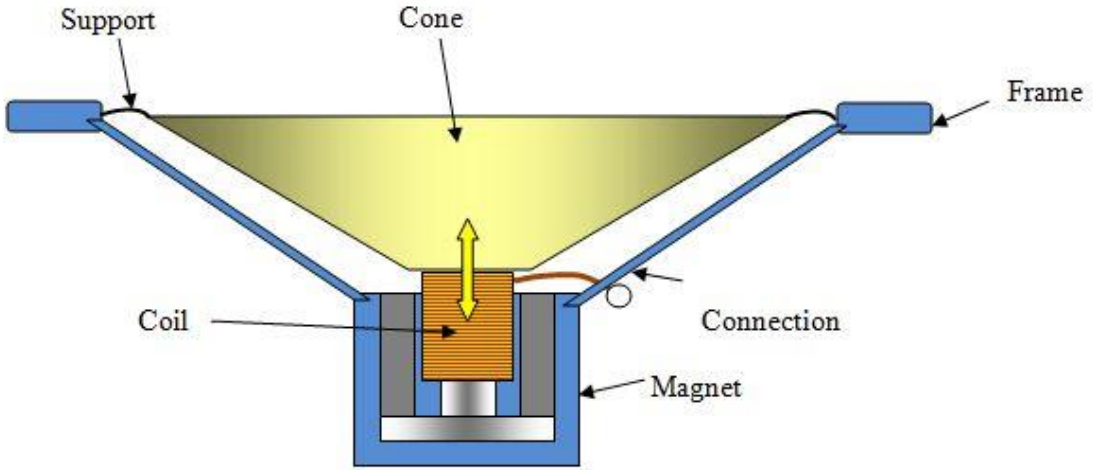
Motion → Electricity

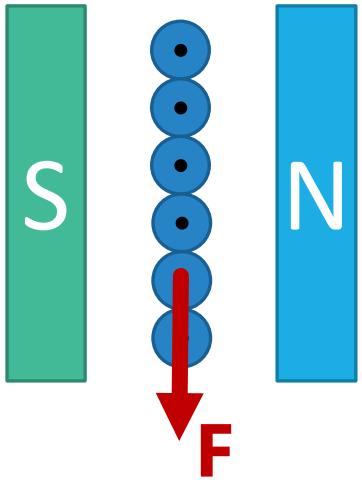
Examples

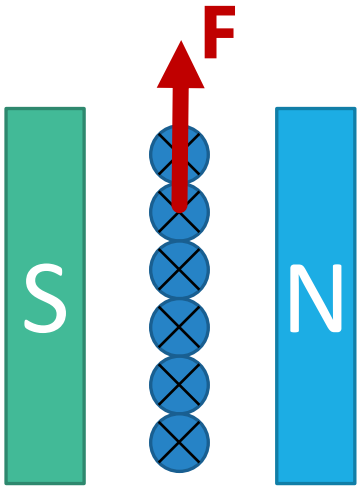

Battery
Battery
Brushes
Permanent magnet
Direction of magnetic field
Commutator
Copper wire loop

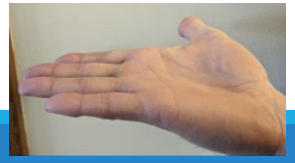

Mechanical input
Electrical output
N
S
Rotating loop

Speakers

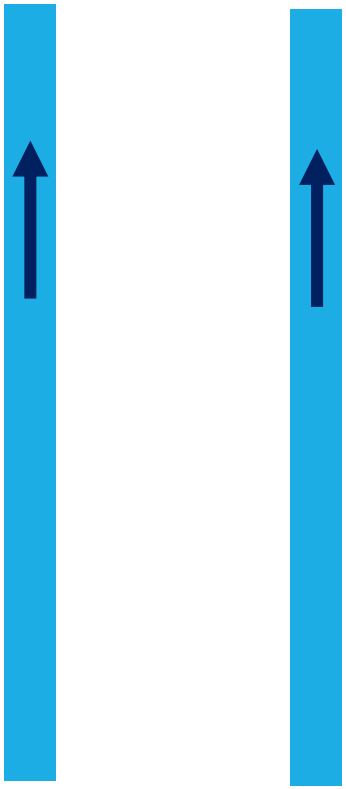




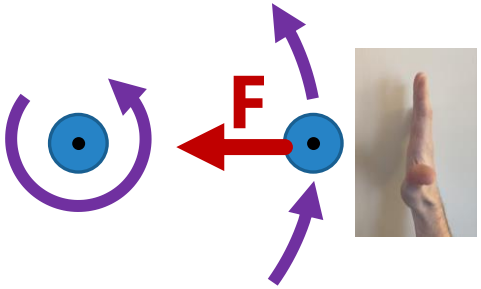


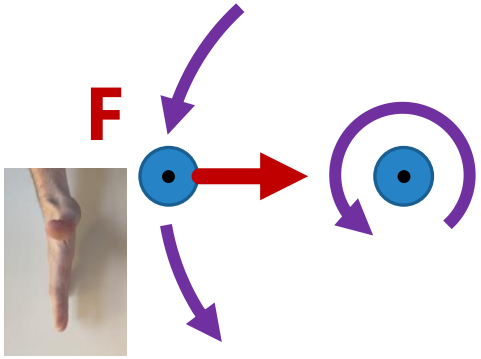


Definition of the Ampere



Consider two parallel wires, with current in the same direction. Do they attract or repel??





***One ampere is defined as the current that would cause a force of 2×10^{-7} N per meter between two long parallel conductors separated by 1 m in a vacuum*

Fields

Gravitational Field

$$g = \frac{F}{m} = \frac{[\mathrm{N}]}{[\mathrm{kg}]}$$

Magnetic Field

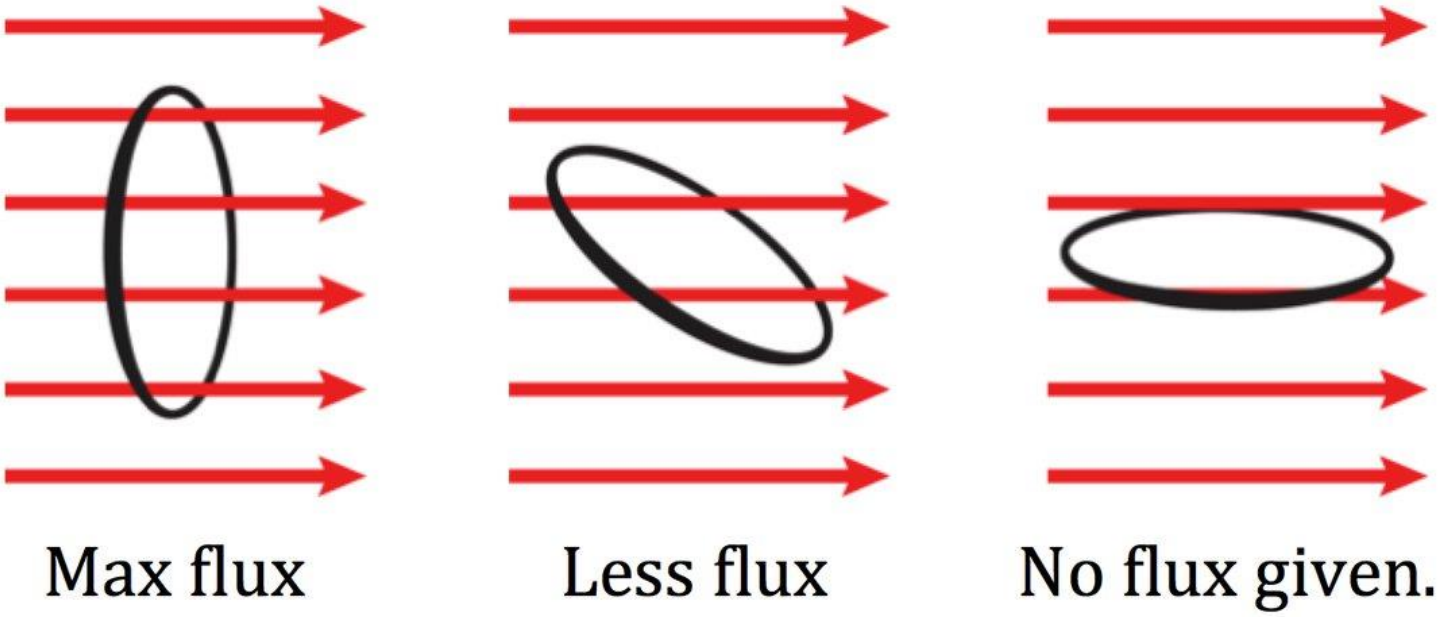
$$B = \frac{F}{I} = \frac{[\mathrm{N}]}{[\mathrm{A}]} = [\mathrm{T}]$$

Electric Field

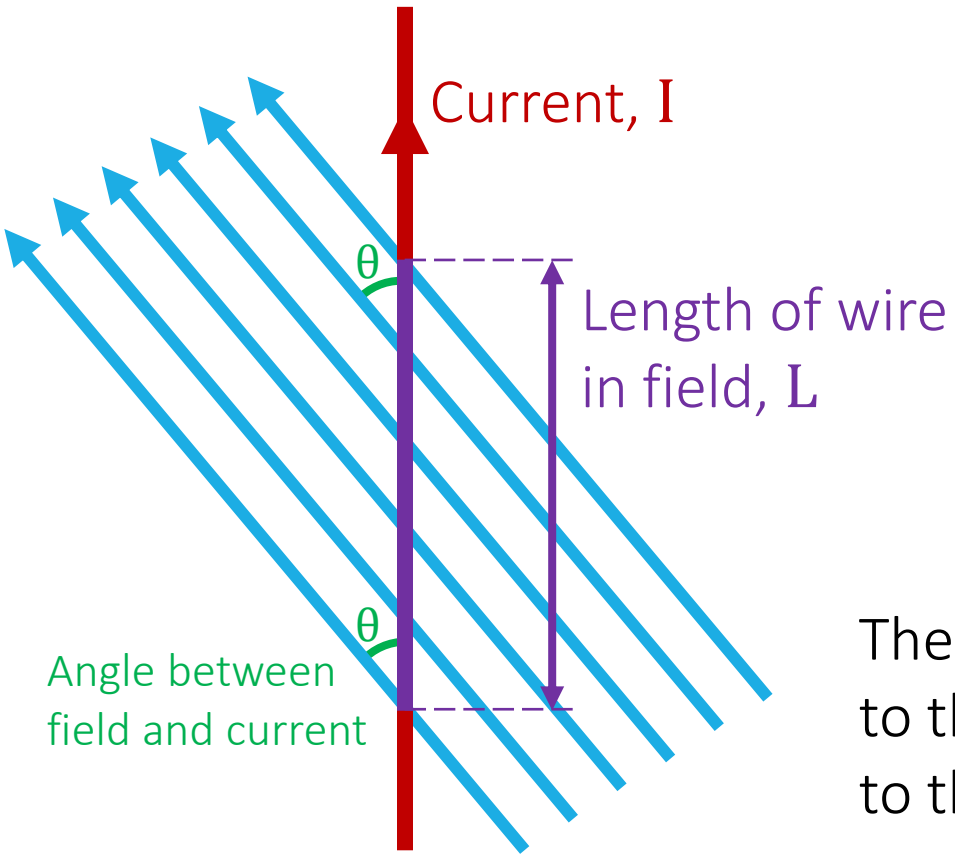
$$E = \frac{F}{q} = \frac{[\mathrm{N}]}{[\mathrm{C}]}$$

Magnetic Flux

The magnetic field strength is sometimes referred to as magnetic flux and depends on how perpendicular the current is in relation to the field direction



Magnetic field Strength



$$B = \frac{F}{ILsin\theta}$$

The force on the wire is proportional to the charge moving perpendicular to the field. Because of these the perpendicular component must be used in the calculation

Fields

$$B = \frac{F}{IL\ sin\theta}$$

$$F = BIL\ sin\theta$$

F	Magnetic force *Newtons [N]*
B	Magnetic field strength *Tesla [T]*
I	Current *Amperes [A]*

L	Length of conductor in uniform magnetic field
θ	Angle between magnetic field and current

IB Physics Data Booklet

Sub-topic 5.1 – Electric fields	Sub-topic 5.2 – Heating effect of electric currents
$I = \frac{\Delta q}{\Delta t}$ $F = k\frac{q_1 q_2}{r^2}$ $k = \frac{1}{4\pi\varepsilon_0}$ $V = \frac{W}{q}$ $E = \frac{F}{q}$ $I = nAvq$	Kirchhoff's circuit laws: $\Sigma V = 0$ (loop) $\Sigma I = 0$ (junction) $R = \frac{V}{I}$ $P = VI = I^2R = \frac{V^2}{R}$ $R_{\text{total}} = R_1 + R_2 + \cdots$ $\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$ $\rho = \frac{RA}{L}$
Sub-topic 5.3 – Electric cells	**Sub-topic 5.4 – Magnetic effects of electric currents**
$\varepsilon = I(R + r)$	$F = qvB\sin\theta$ $\boxed{F = BIL\sin\theta}$

Try This…

A current of 3.8 A in a long wire experiences a force of 5.7×10^{-3} N when it flows through a magnetic field of strength 25 mT. If the length of wire in the field is 10 cm, what is the angle between the field and current?

$$F = BIL\,sin\theta$$

$$\theta = sin^{-1}\left(\frac{F}{BIL}\right) = sin^{-1}\left(\frac{(5.7 \times 10^{-3})}{(25 \times 10^{-3})(3.8)(0.1)}\right)$$

$F = 5.7 \times 10^{-3}$ N

$B = 25$ mT $= 25 \times 10^{-3}$ T

$I = 3.8$ A

$L = 10$ cm $= 0.1$ m

$$\boxed{\theta = 36.87°}$$

Force on a Charged Particle

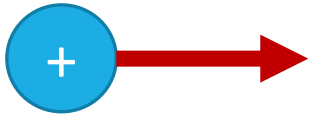
When there is a magnetic force on a current carrying wire, the force is really on the moving charges inside of the conductor.

Single charged particles can also experience a magnetic force when moving through a magnetic field…

$$F = BIL\,sin\theta$$

$$F = B\left(\frac{q}{\cancel{t}}\right)(v\cancel{t})\,sin\theta$$

$$F = Bqv\,sin\theta$$



$$v = \frac{L}{t}$$

$$L = vt$$

$$I = \frac{q}{t}$$

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Sub-topic 5.3 – Electric cells	**Sub-topic 5.4 – Magnetic effects of electric currents**
$\varepsilon = I(R + r)$	$F = qvB\sin\theta$ $F = BIL\sin\theta$

Try This…

What is the magnetic force acting on a proton ($+1.6 \times 10^{-19}$ C) moving at an angle of 32° across a magnetic field of 5.3×10^{-3} T at a speed of 3.4×10^{5} m s^{-1}?

$$F = qvB\ sin\theta$$

$$F = (1.6 \times 10^{-19})(3.4 \times 10^{5})(5.3 \times 10^{-3})sin32°$$

$q = 1.6 \times 10^{-19}$ C

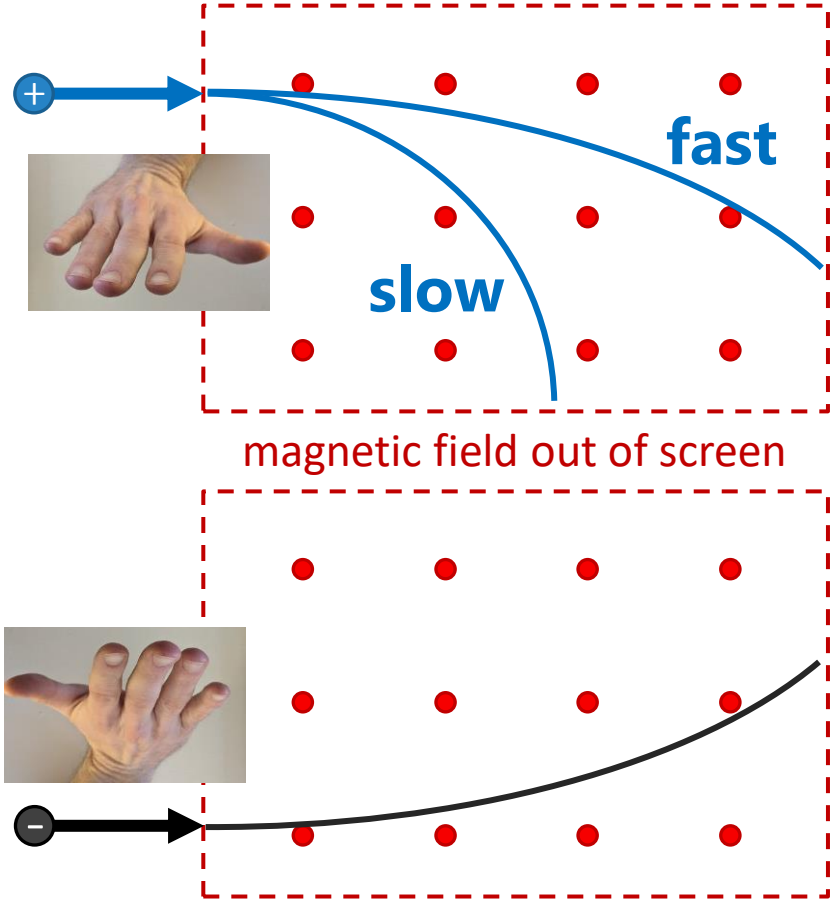
$v = 3.4 \times 10^{5}$ m s^{-1}

$B = 5.3 \times 10^{-3}$ T

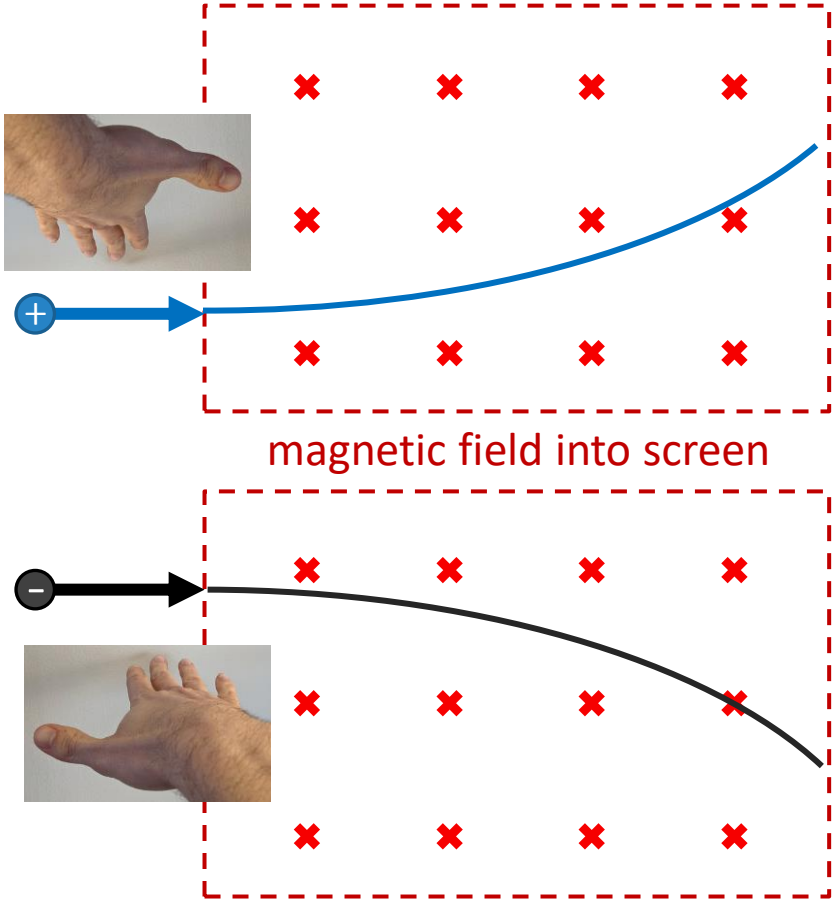
$\theta = 32°$

$$\boxed{F = 1.5 \times 10^{-16}\ \mathrm{N}}$$

Particles Moving Across Fields



magnetic field out of screen



magnetic field into screen