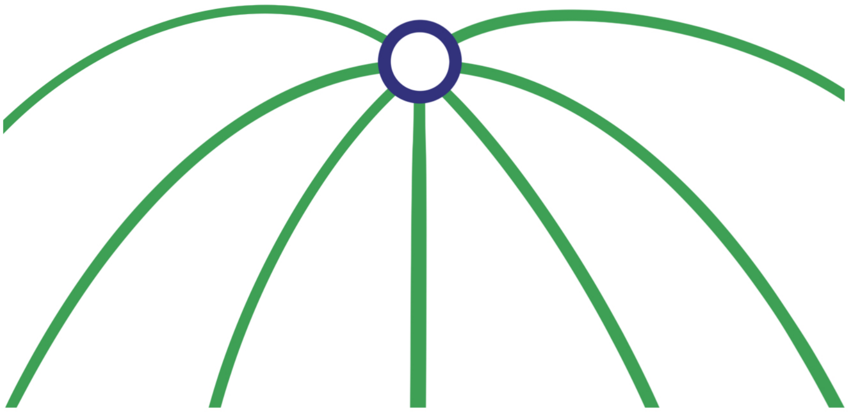
NCEA Level 2 Physics

Electricity

Study Notes



Site

Mr Whibley

YouTube

Electricity Cheatsheet

Voltage (V)

$$E=\frac{V}{d}$$

Electric field (Vm^{-1})
Distance (d)

Electric field (Vm^{-1})

$$F=Eq$$

Force (N)
Charge (C)

Electric potential energy (J)

$$\Delta E_p=Eqd$$

Electric field (Vm^{-1})
Distance (d)
Charge (C)

Velocity (ms^{-1})

$$E_k=\frac{1}{2}mv^2$$

Kinetic energy (J)
Mass (kg)

Charge (C)

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

Current (A)
Time (s)

Electric potential energy (J)
Voltage (V)

$$V=\frac{\Delta E}{q}$$

Charge (C)

Resistance (Ω)

$$V=IR$$

Voltage (V)
Current (A)

Power (W)
Voltage (V)

$$P=IV$$

Current (A)

Electric potential energy (J)
Power (W)

$$P=\frac{\Delta E}{t}$$

Time (s)

$$R_T=R_1+R_2+\ldots$$

Total series resistance (Ω)

$$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

Total parallel resistance (Ω)

Magnetic field (T)
Current (A)

$$F=BIL$$

Force (N)
Wire length (m)

Magnetic field (T)
Charge (C)

$$F=Bqv$$

Force (N)
Velocity (ms^{-1})

Magnetic field (T)
Velocity (ms^{-1})

$$V=BvL$$

Voltage (V)
Wire length (m)

Charge of an electron $=-1.60\times10^{-19}$C

Mass of an electron $=9.11\times10^{-31}$kg

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Charge

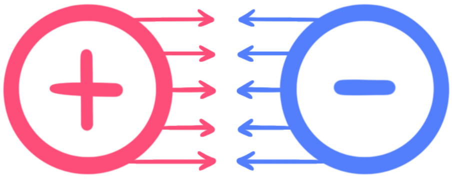
Charge is a physical property of matter, we measure it in coulombs (C).

Charge can be either positive or negative.

We use q as a symbol for a single charge and Q for a group.

✱ Like charges repel

✱ Unlike charges attract



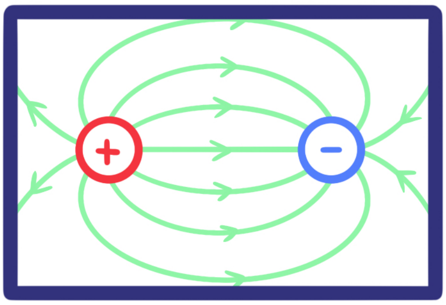
Proton charge = 1.60×10^{-19} C

Electron charge = -1.60×10^{-19} C

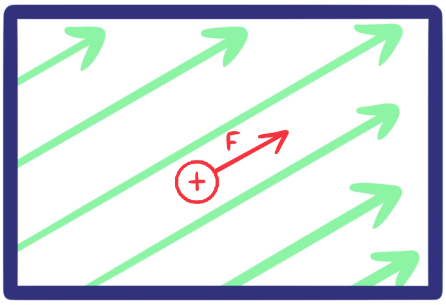
Electric field lines

Electric field lines are imaginary lines used to show the distribution of an electric field.

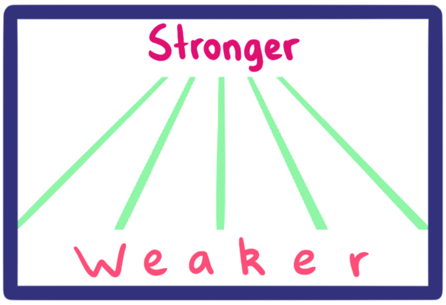
Lines move from positive to negative.



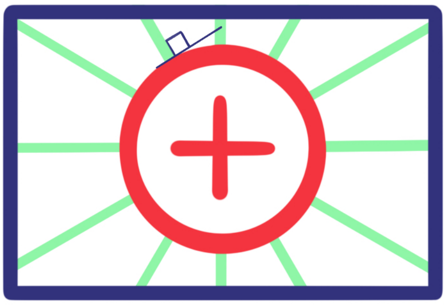
They point in the direction a positive charge would experience a force (opposite for a negative charge).



The closer the lines the stronger the field.



Lines always cross surfaces at right angles.



Electric field strength is defined by the voltage gradient across a particular distance.

Electric field strength (Vm^{-1} or NC^{-1})

$$E = \frac{V}{d}$$

Voltage (V)

Distance (m)

Electrostatic Force

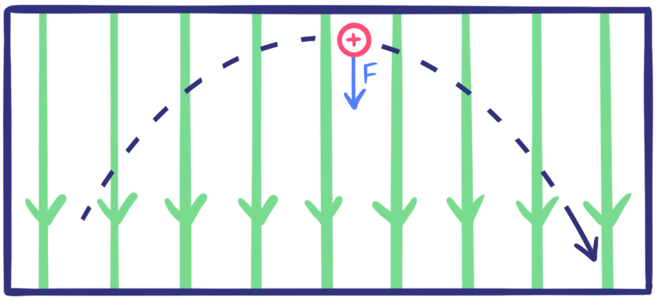
A charge in an electric field will experience an electrostatic force.

Electrostatic force (N)

Charge (C)

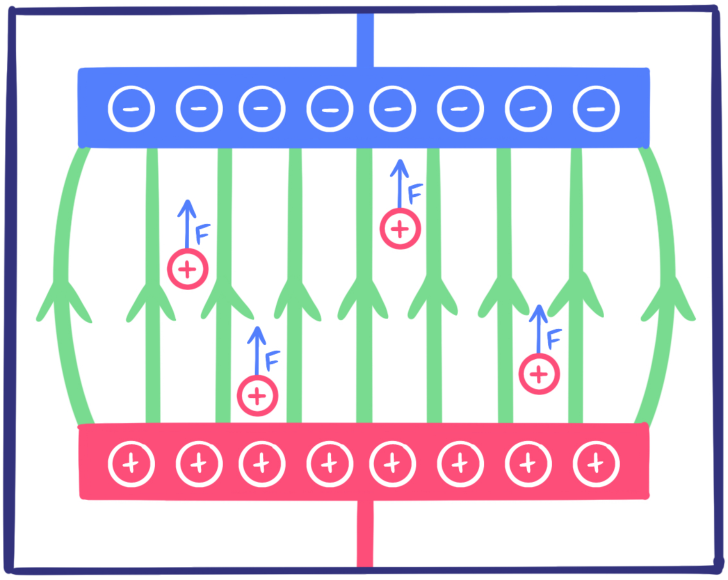
$$F = Eq$$

Electric field strength (NC^{-1} or Vm^{-1})



✱ Charge between parallel plates

Field lines between parallel plates are parallel. This means the electric field strength is constant.



Charges therefore experience the same electrostatic force at all positions.

Field lines curve outwards slightly due to the presense of charge at the plate edges.

Electric potential energy

Objects with mass store energy in gravity fields.

Objects with charge store energy in electric fields.

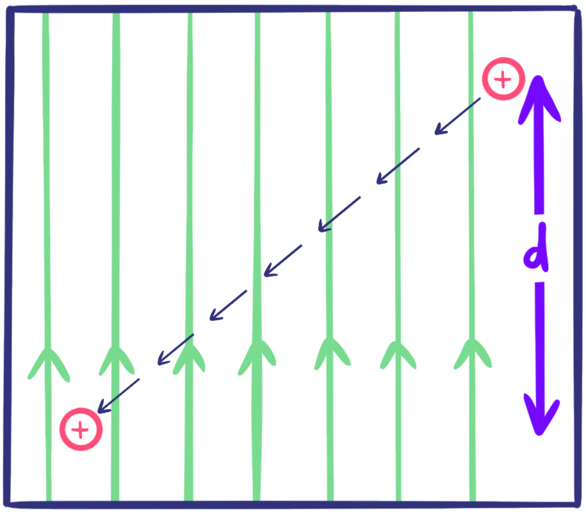
$$E_p = Eqd$$

Electric field strength (Vm^{-1} or NC^{-1})

Distance moved against field (m)

Electric potential energy (J)

Charge (C)



As with gravitational potential energy, the distance is specifically the component in the direction of the field. Not the total distance.

	With field	Against field
Positive charge	Gains energy	Stores energy
Negative charge	Stores energy	Gains energy

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Direct Current

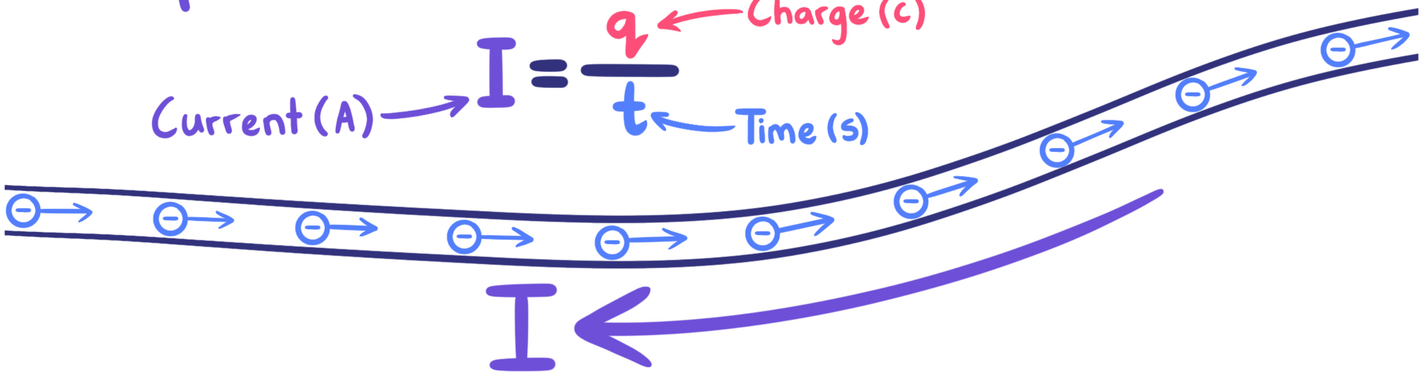
Current is the flow rate of charge, measured in Amperes (A).

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

Charge (c)

Current (A)

Time (s)

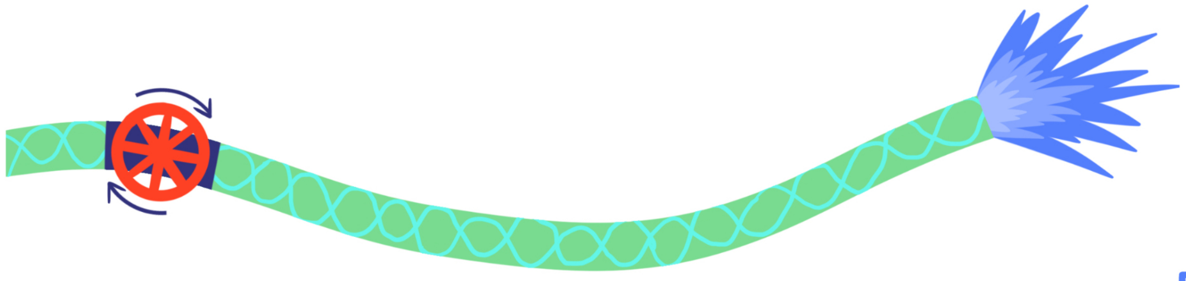


Conventional current direction is defined as the direction of positive charge flow, opposite the direction of negative electron flow.

Changes in current travel at $3 \times 10^{8} ms^{-1}$.

Electrons themselves only travel at millimeters per minute.

Consider opening the tap on a hosepipe. Although it may take several seconds for an individual particle to travel through the hose, if the hose is prefilled water will flow from the end almost immediately.



Voltage

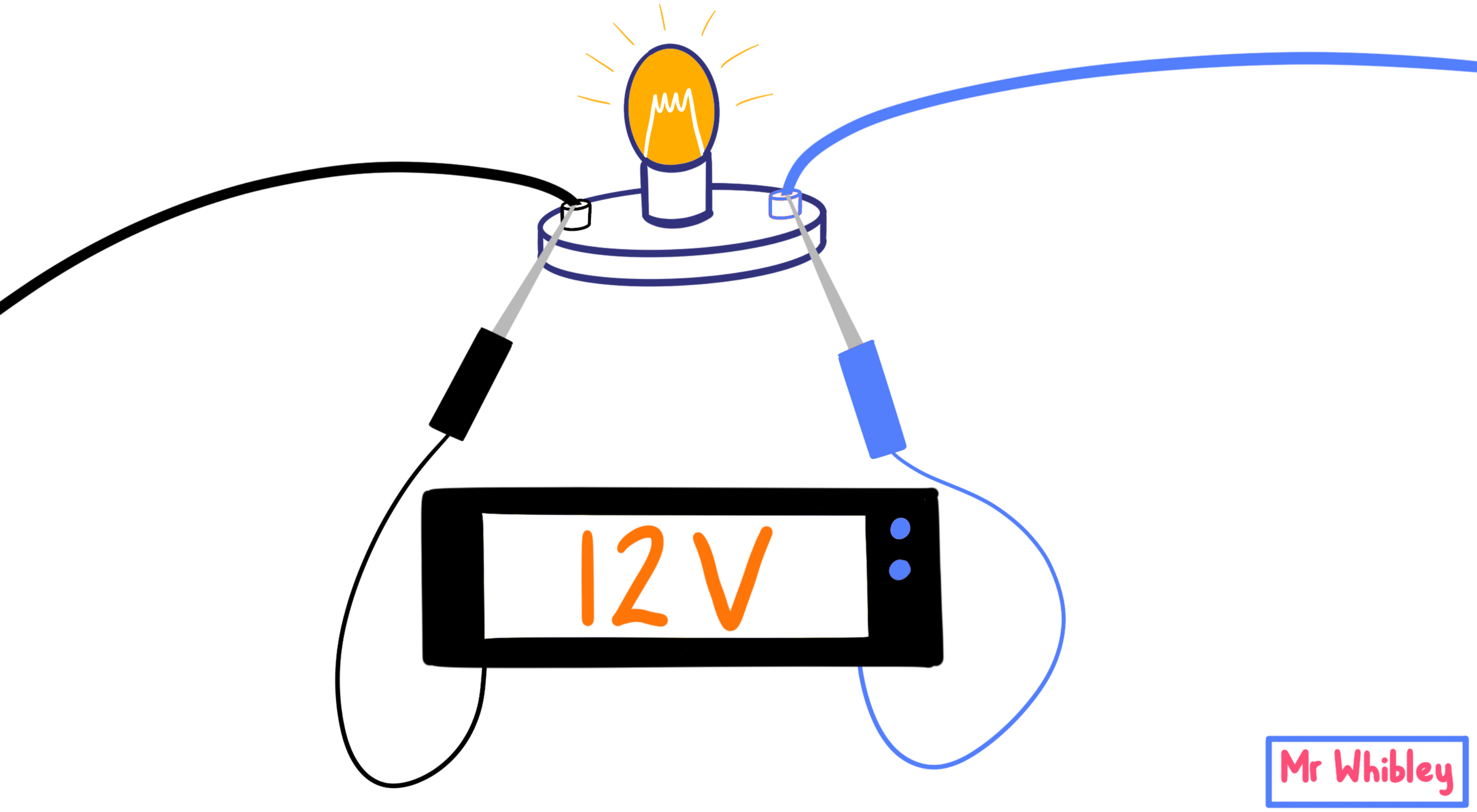
Voltage is the energy lost or gained per charge between points in an electric field.

We measure it in volts (V).

$$\text{Voltage (V)} \longrightarrow V = \frac{E}{q} \quad \begin{matrix} \leftarrow \text{Energy (J)} \\ \leftarrow \text{Charge (C)} \end{matrix}$$

The voltage across the lamp below is 12V.

This means each coulomb of charge delivers 12 joules of energy.



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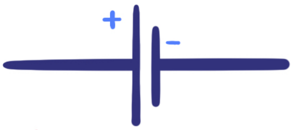
Circuits

A circuit is a closed path for electricity to flow through.

* Circuit components



Voltage source

Lamp

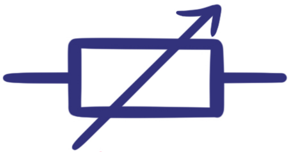
Open switch

Closed switch

Voltmeter

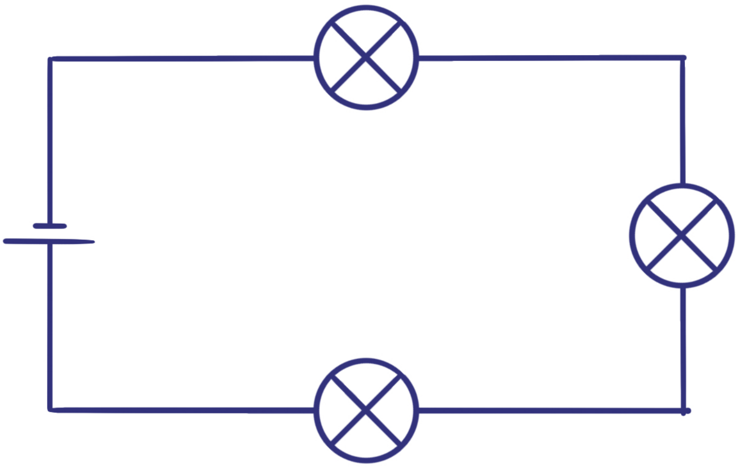
Ammeter

Resistor



Variable resistor

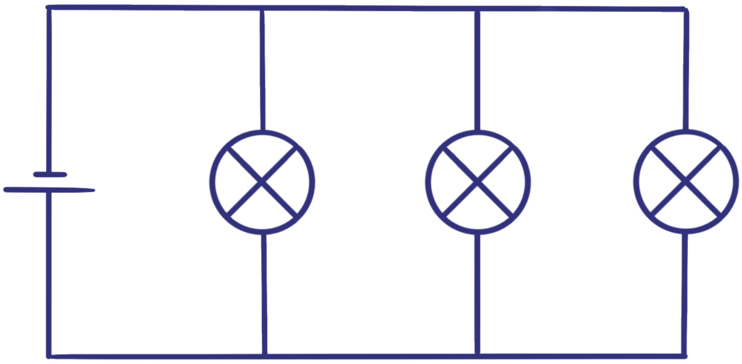
* Configurations



-Series

Current follows a single path.

Voltage is divided between components.



-Parallel

Current is divided at junctions.

Voltage is the same along every path.

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Ohm's law

Charges moving through a conductor encounter resistance. The amount depends on the shape and structure of the material.

We measure it in ohms (Ω).

When a voltage is applied the resulting current is limited by the resistance.

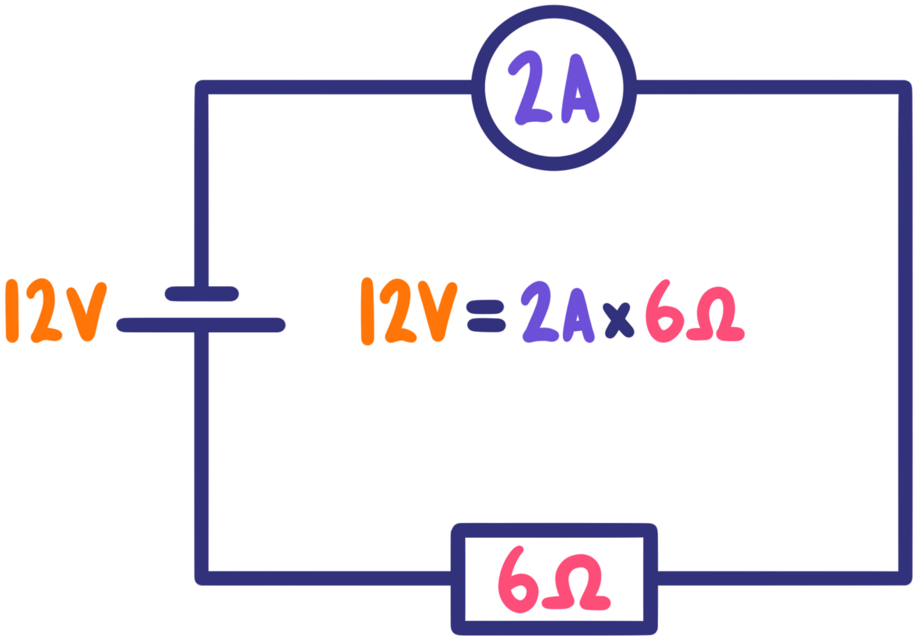
This relationship is called ohm's law.

Current (A)

Voltage (V) $\rightarrow$ $V = IR$

Resistance (Ω)

✱ Example

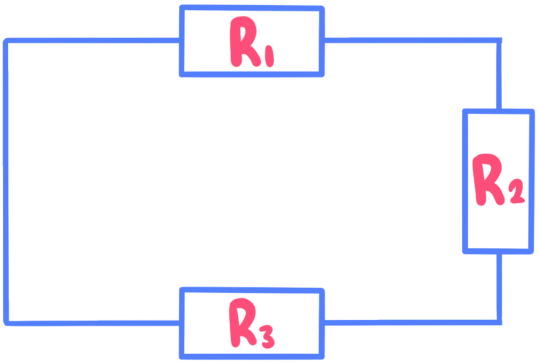


Equivalent resistance

Multiple resistances in a circuit can be combined into a single equivalent resistance.

This equivalent resistance depends on the configuration of the resistors.

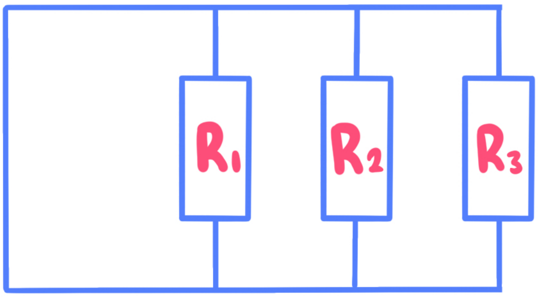
* Series



$$R = R_1 + R_2 + R_3$$

Adding resistors increases resistance

* Parallel



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Adding resistors decreases resistance

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Power

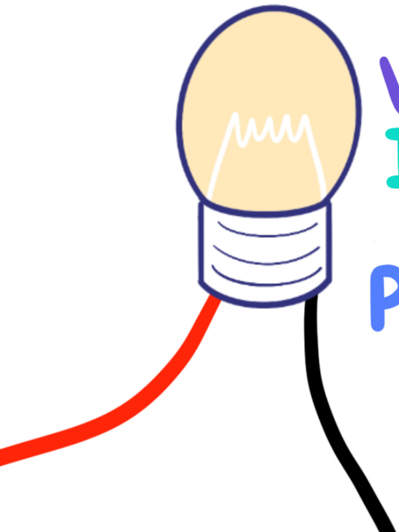
Power describes the rate at which energy is consumed.

It is measured in Joules per second, commonly called Watts (W).

$$\underset{\text{Power (W)}}{P} = \frac{\overset{\text{Energy (J)}}{\Delta E}}{\underset{\text{Duration (s)}}{t}}$$

The power consumed by a component is determined by its Voltage and Current.

$$\underset{\text{Power (W)}}{P} = \overset{\text{Current (A)}}{I}\,\underset{\text{Voltage (V)}}{V}$$



$V = 12V$
$I = 2A$

$P = 2A \times 12V$
$= 24W$

Knowing $V = IR$ we can also write...

$$P = I^2R \quad \& \quad P = \frac{V^2}{R}$$

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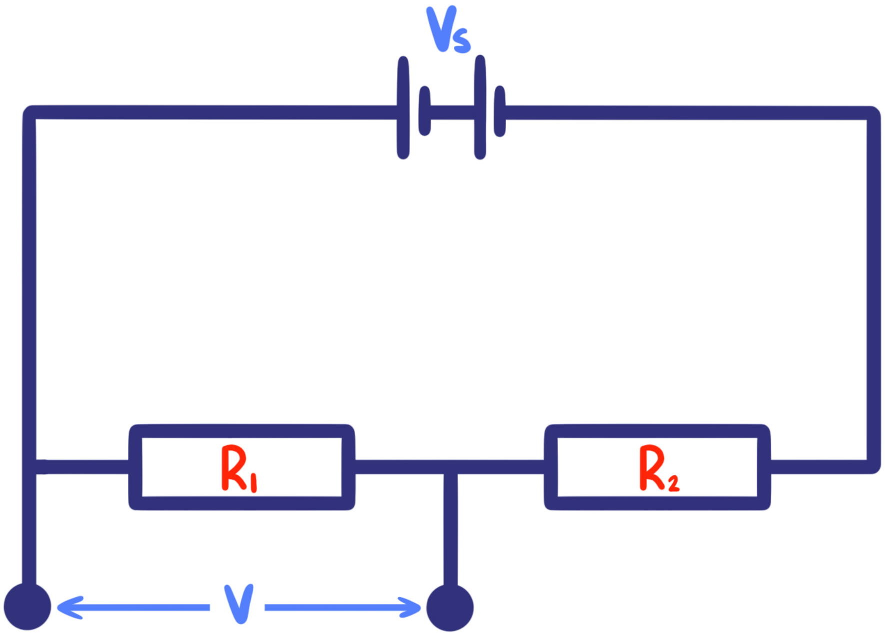
Potential divider

A potential divider uses two resistors to split a voltage drop, creating additional accessible voltages in a circuit.



✱ Whole circuit

$$V_s = I(R_1 + R_2)$$

$$I = \frac{V_s}{(R_1 + R_2)}$$

✱ Resistor R_1

$$V = IR_1$$

$$I = \frac{V}{R_1}$$

$$\frac{V_s}{(R_1 + R_2)} = \frac{V}{R_1}$$

$$\boxed{V = \frac{V_s R_1}{(R_1 + R_2)}}$$

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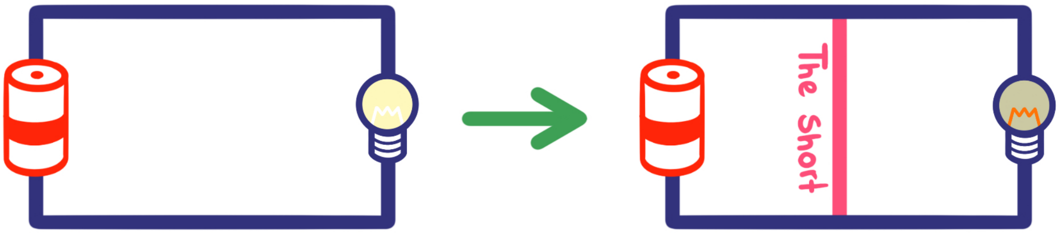
Lamp Circuits

The brighter the lamp, the more energy it uses.

A lamp is shorted when current is given an alternate path with much lower resistance.

As a result, no current flows through the lamp.



✱ Adding lamps in Series...

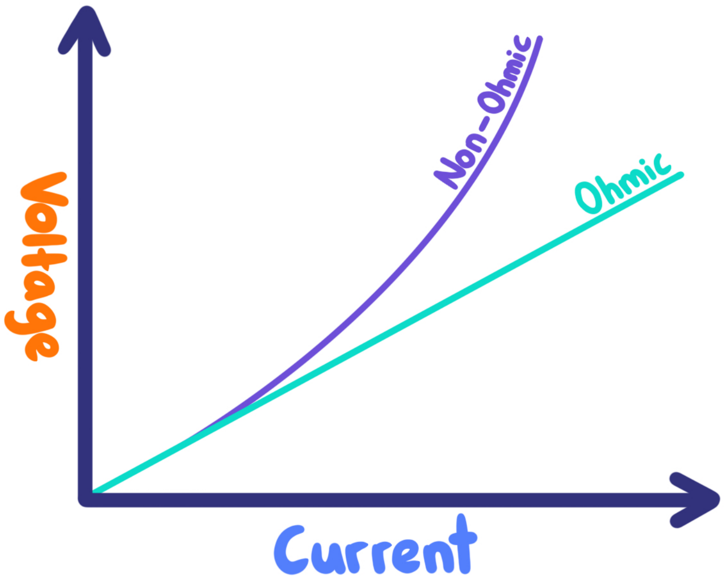
- Increases Resistance
- Decreases Current
- Decreases power
- Decreases brightness

✱ Adding lamps in parallel...

- Decreases Resistance
- Increases Current
- Increases power
- Increases brightness

Non-Ohmic Conductors

Non-ohmic conductors have a non-linear relationship between the voltage applied to them and the resulting current.



As the slope on a Voltage-Current graph is resistance, we can also define non-ohmic conductors as having a variable resistance.

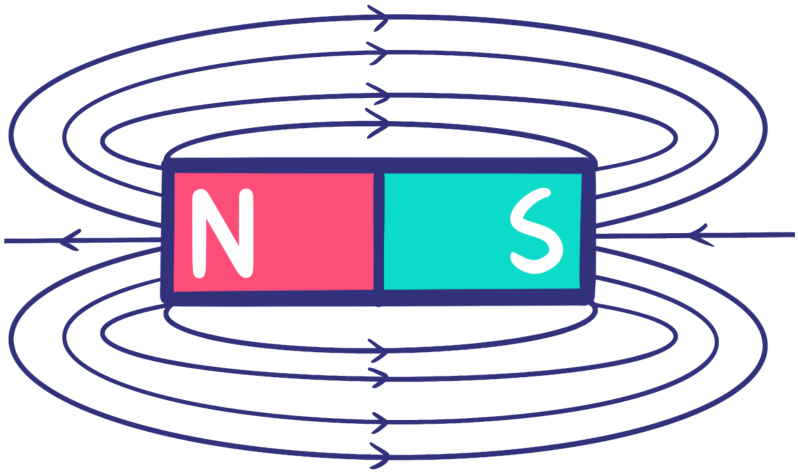
A lamp is a non-ohmic conductor. As the voltage and current through the bulb is increased, the filament temperature increases, resulting in an increased resistance.

This means increasing voltage results in smaller and smaller increases in current.

Magnetism

Some materials exhibit a property called magnetism.

Magnetic objects have two poles (North and South) which act in opposition.

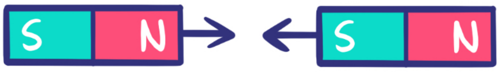


Magnetic field lines are used to visualise magnetic fields. They always point South.

As with electric charges...

Like poles repel

Opposite poles attract



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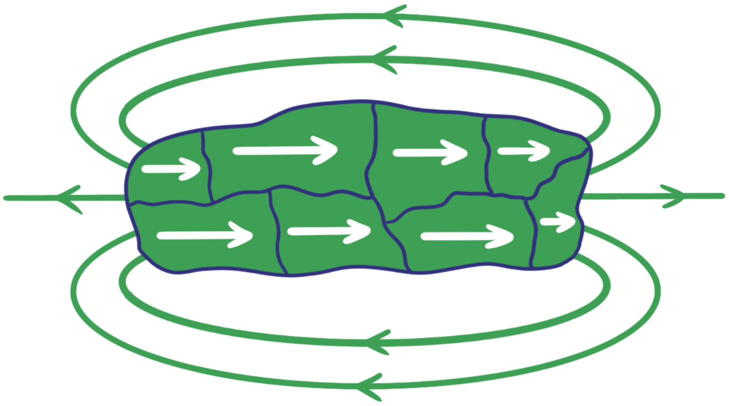
Domain theory

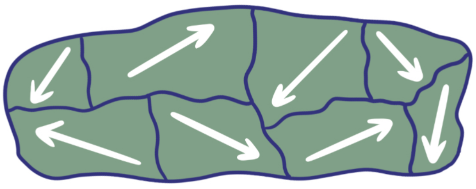
The behaviour of protons and electrons within some atoms causes those atoms to act like small electromagnets.

Due to this, materials made of these atoms contain regions with their own individual magnetic field. We call these magnetic domains.

If these domains align, they combine and the material exhibits a net magnetic field.



If the domains do not align, the fields oppose and cancel.



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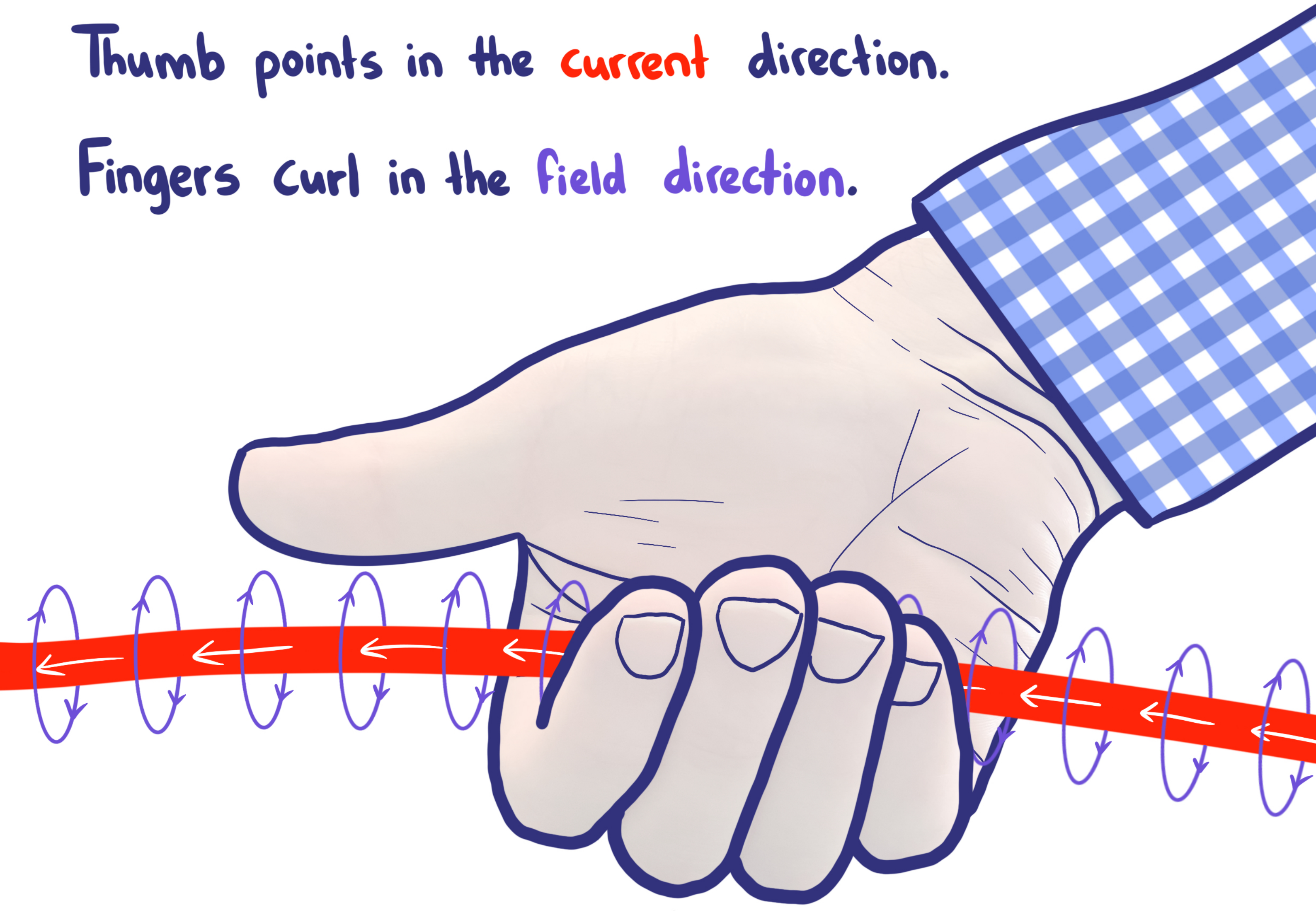
Field around a current

When current flows through a wire, a magnetic field encircles it.

We can visualise this using the right hand grip rule.

Thumb points in the current direction.

Fingers curl in the field direction.



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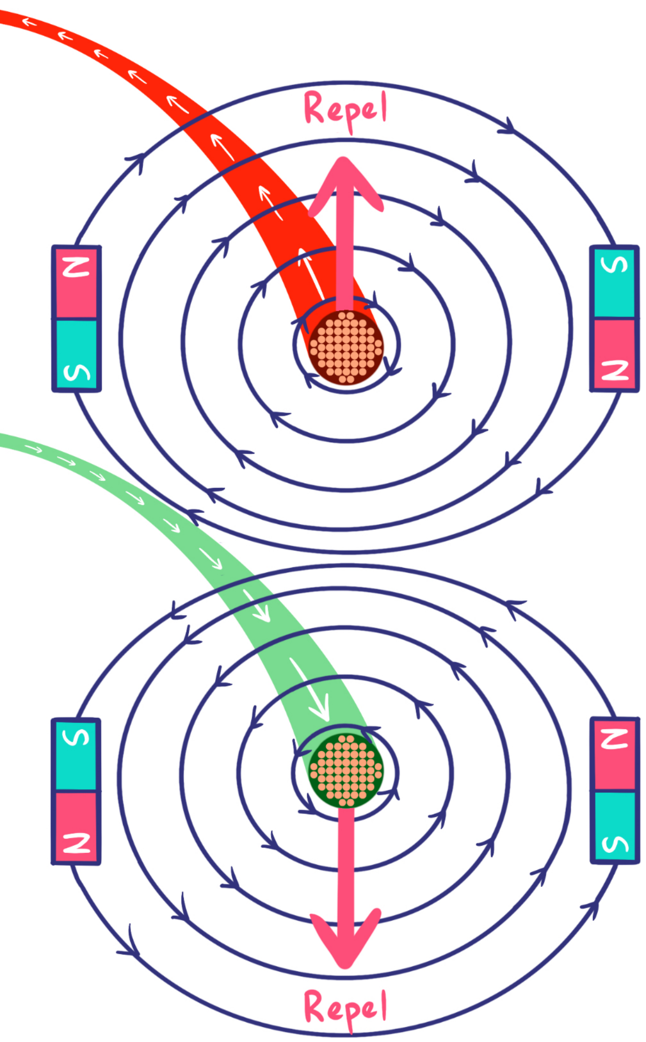
Parallel Wires

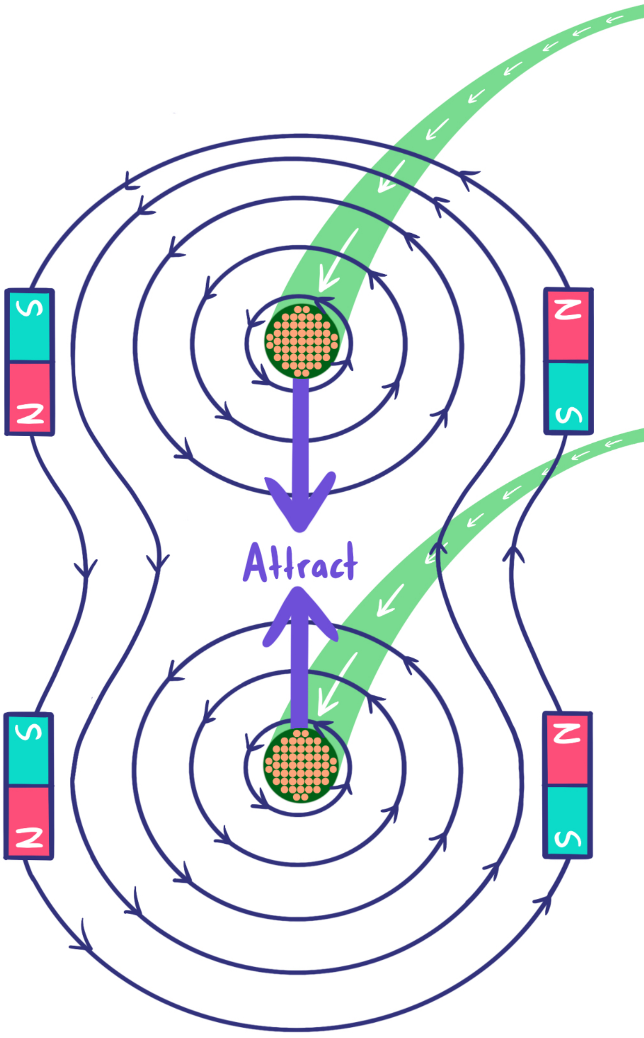
✱ Opposite direction

Adjacent wires carrying current in opposite directions establish magnetic fields that repel each other.

✱ Same direction

Adjacent wires carrying current in the same direction establish magnetic fields that attract each other.





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Magnetic force on a Current

As a current carrying wire generates a magnetic field, when placed in another magnetic field it will experience a force...

$$F = BIL$$

Magnetic field (T)

Length of wire in field (m)

Force (N)

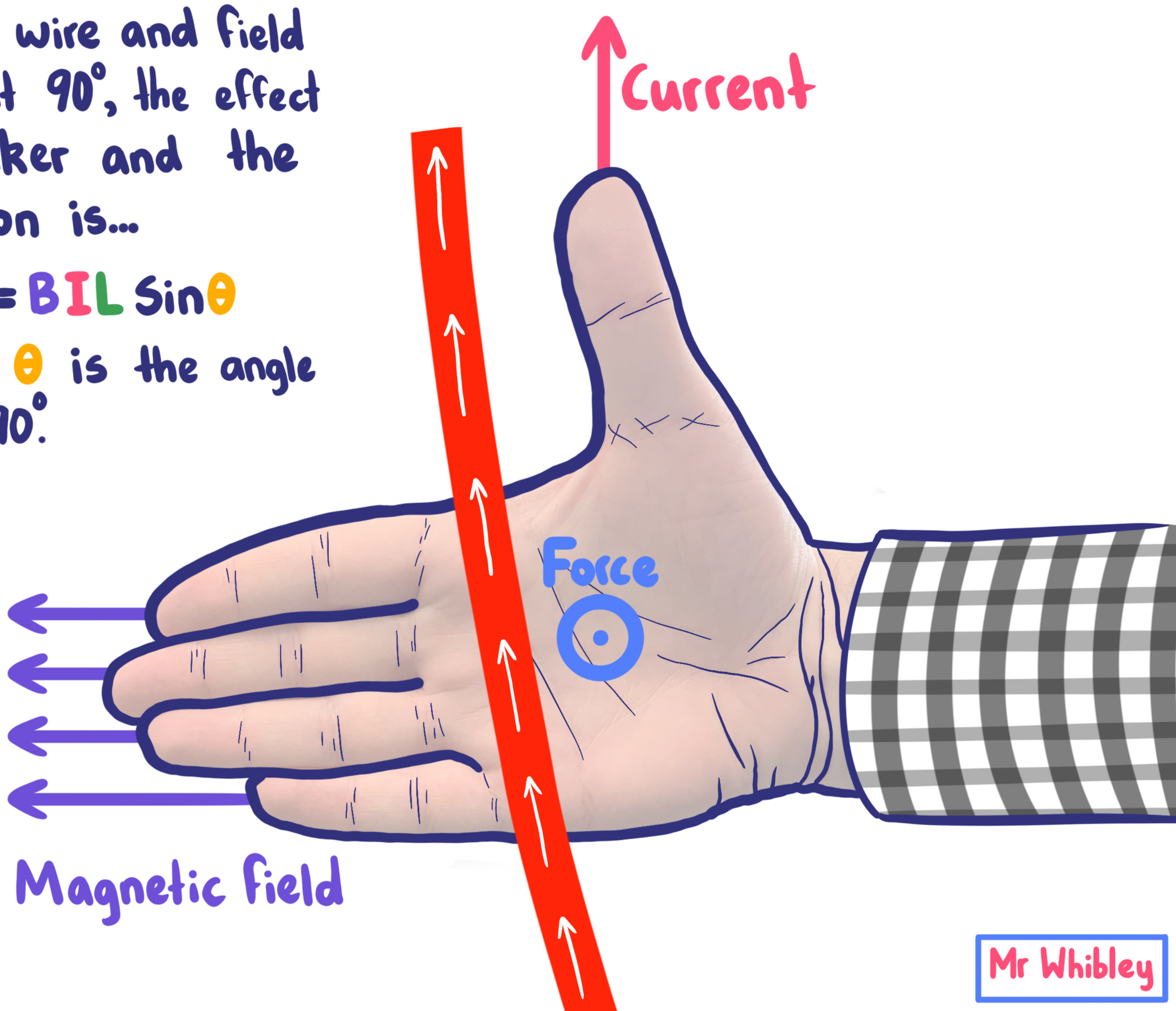
Current (A)

The direction of the force can be determined using the right hand slap rule...

If the wire and field aren't at 90°, the effect is weaker and the equation is...

$$F = BIL \sin\theta$$

...where θ is the angle from 90°.



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Magnetic force on a charge

Similar to a current carrying wire, we can write the force experienced by an individual charge in a magnetic field as...

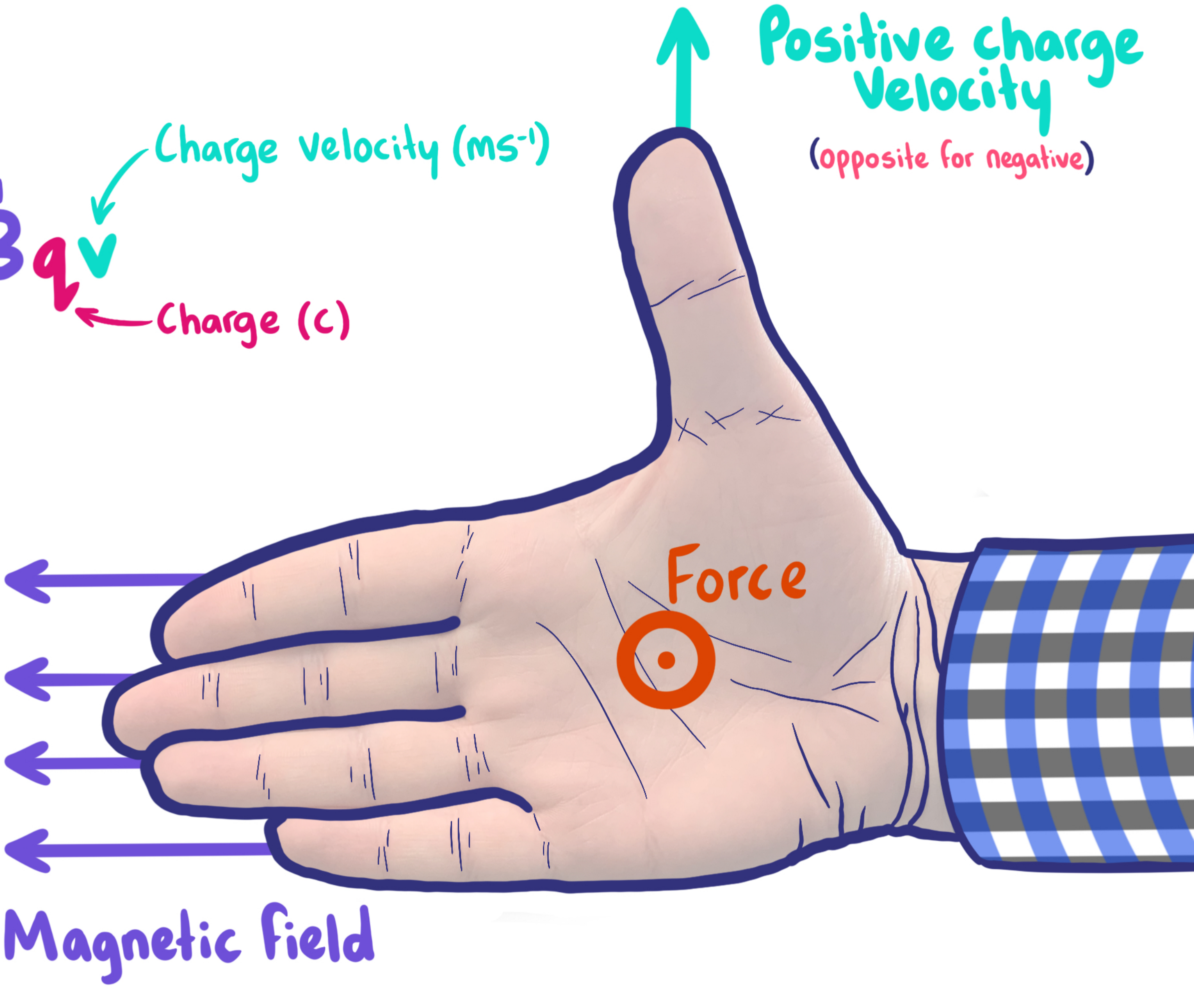
Magnetic field strength (T)

Charge velocity (ms^{-1})

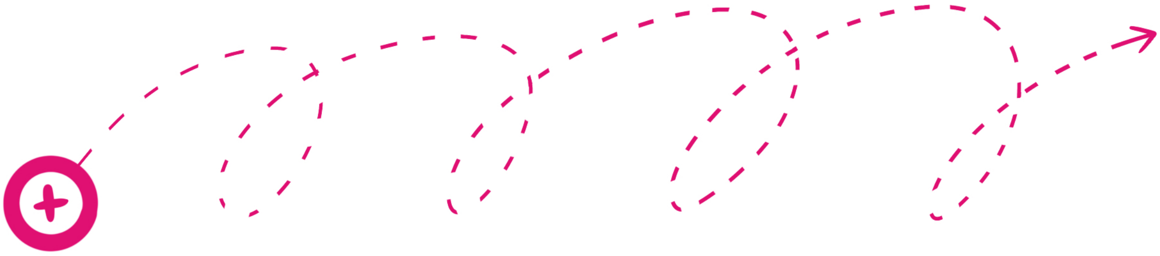
$$F = Bqv$$

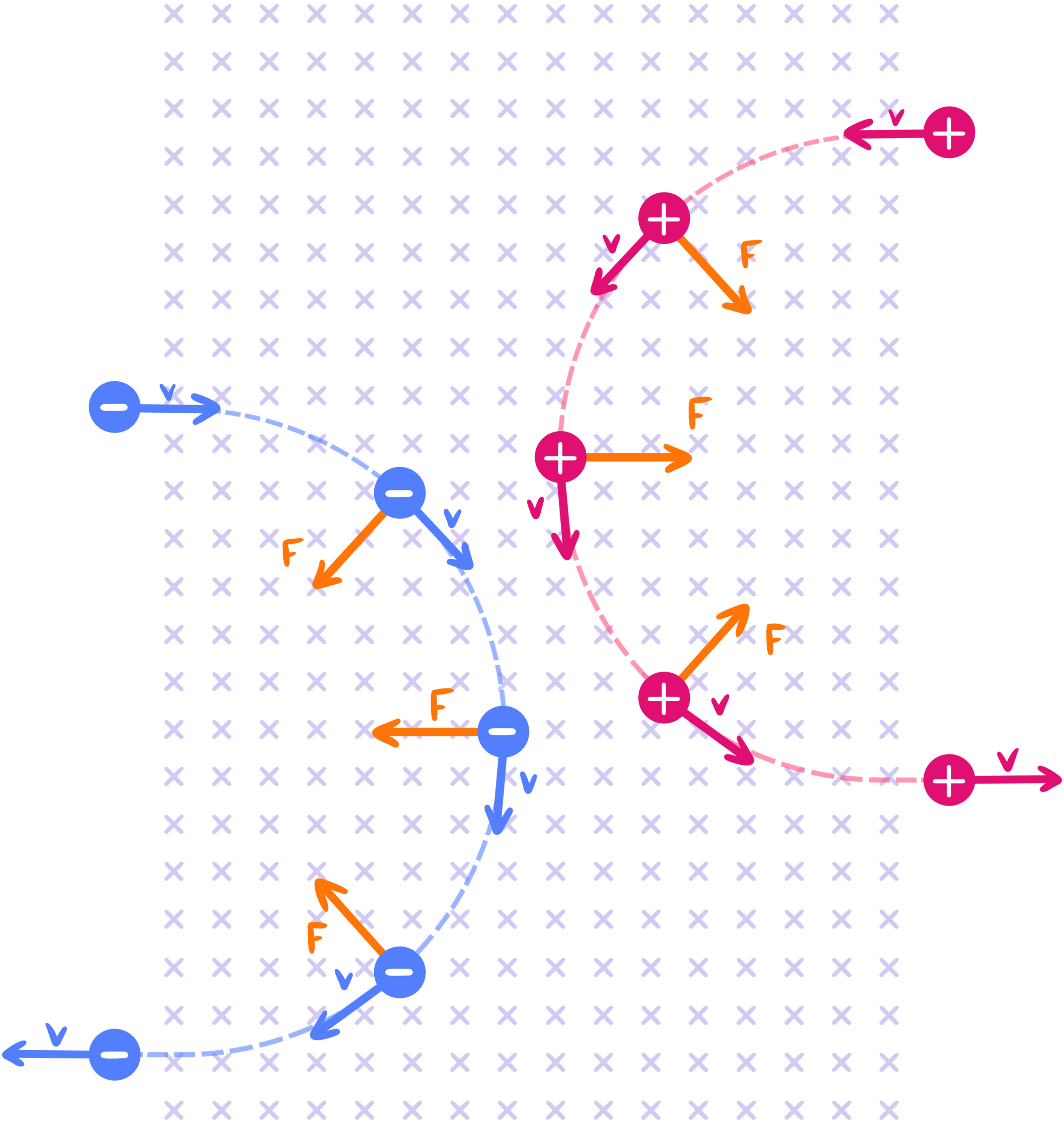
Charge (C)

Force (N)



Since the force is perpendicular to the charge velocity, it exhibits centripetal motion.





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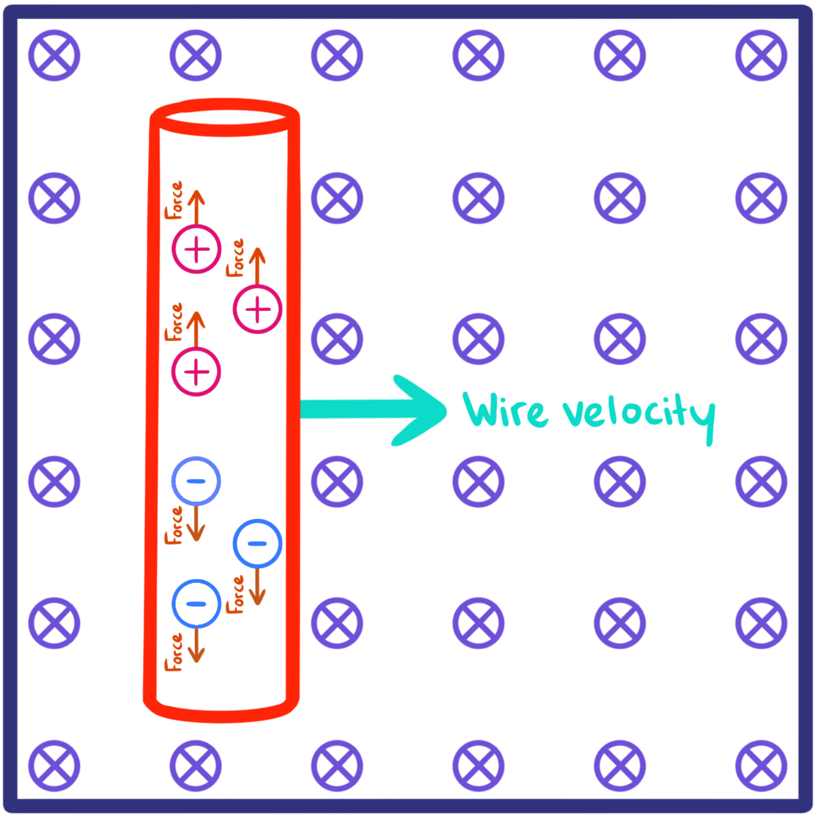
Voltage induced in a wire

Consider a wire moving through a magnetic field.

The positive and negative charges within experience equal and opposite forces, creating a separation of charge and therefore a voltage.



Magnetic field strength (T)

Length of wire in field (m)

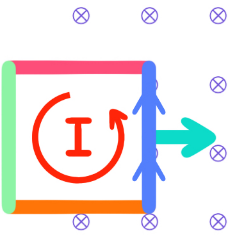
$$V = BvL$$

Voltage (v)

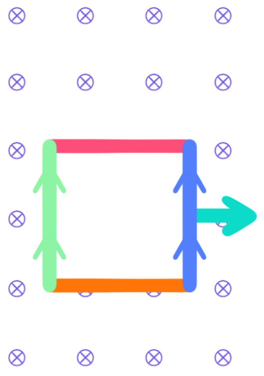
Velocity (ms⁻¹)

Loops moving through magnetic fields

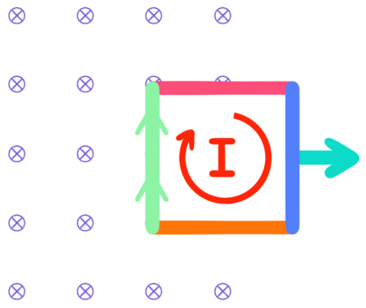
In the field below positive charges are forced upward.



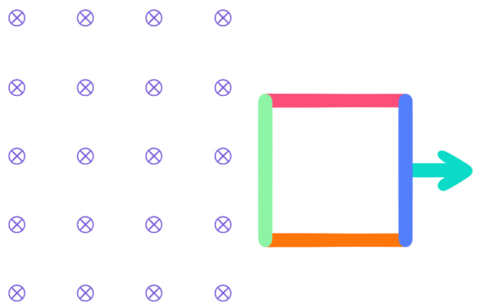
Charges flow in right section.
Counterclockwise current



Charges flow in right section.
Charges flow in left section.
No current



Charges flow in left section.
Clockwise current



No sections in field.
No current

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