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Electromagnetism

GCSE overview

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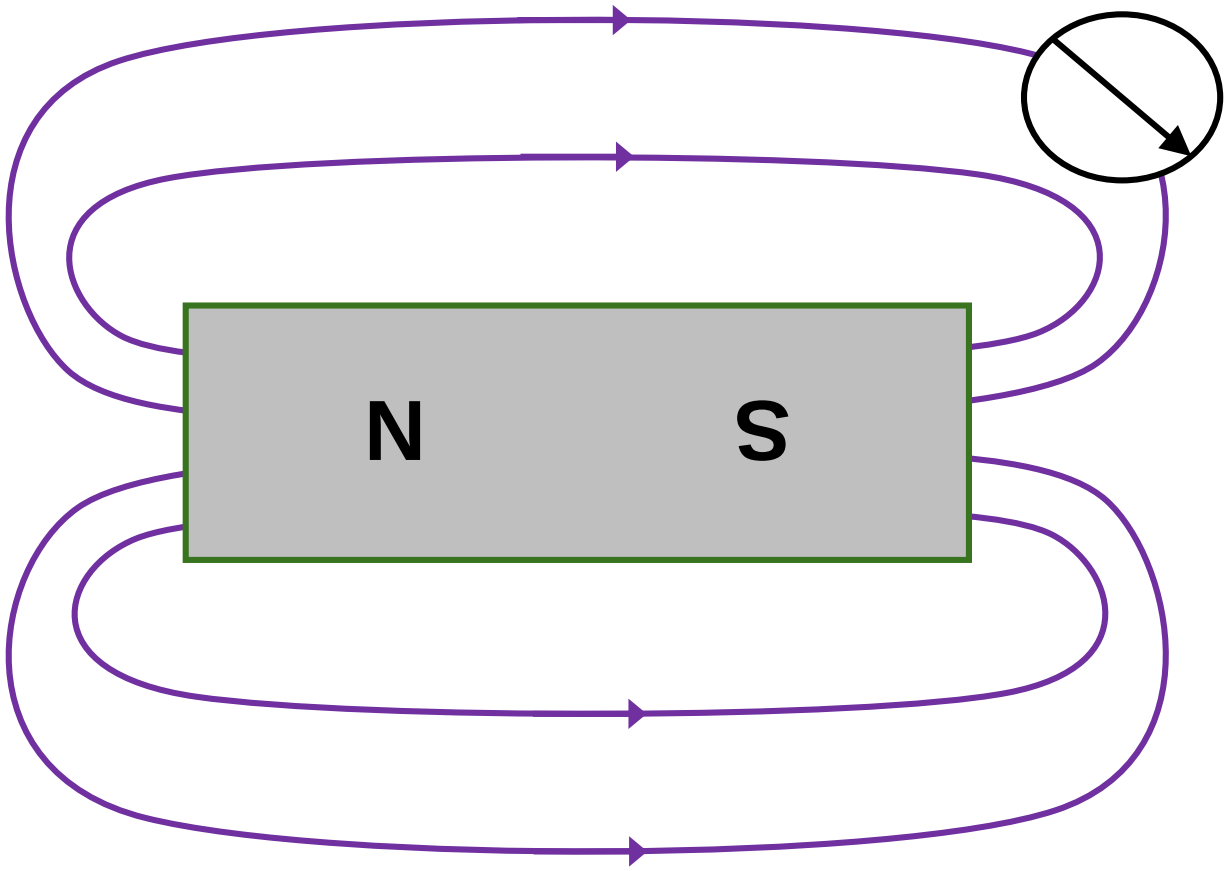
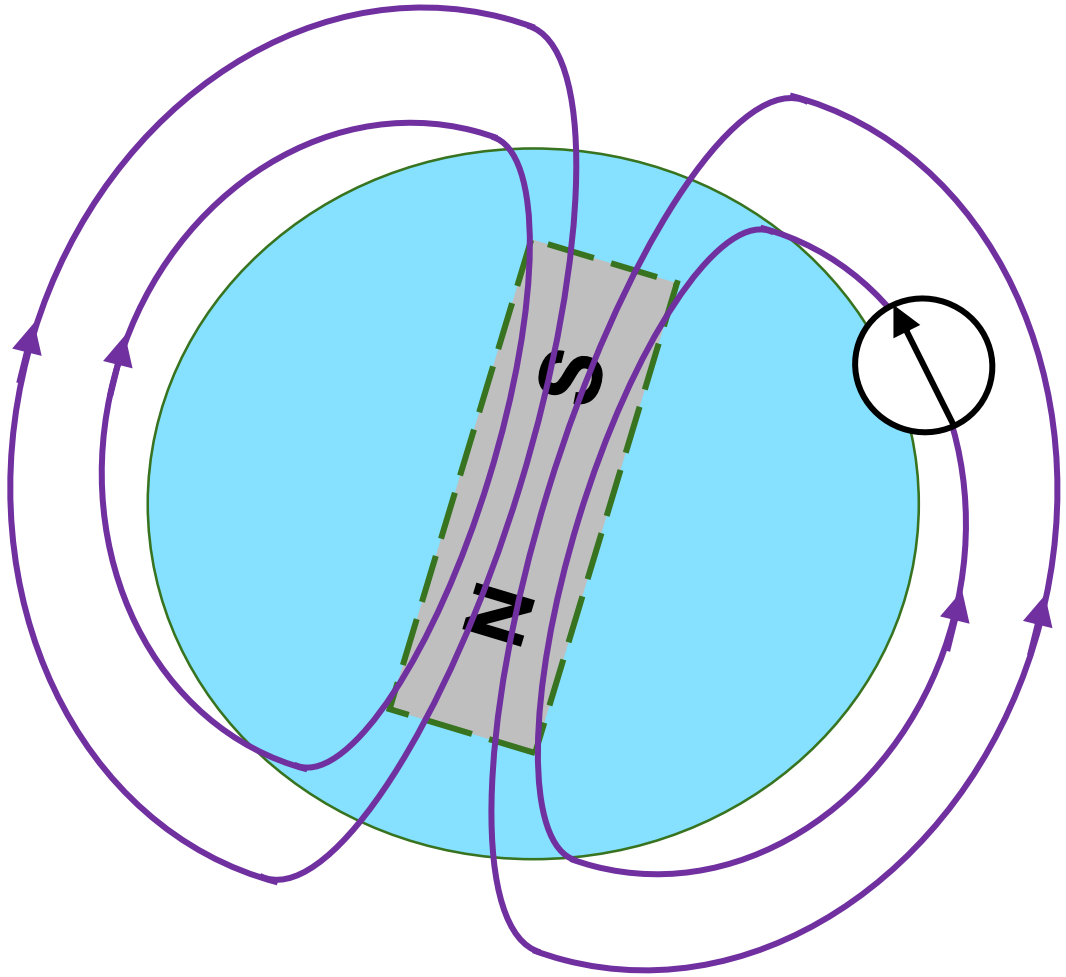
https://isaacphysics.org/pages/remote_learning

Field of bar magnet



Field of the Earth

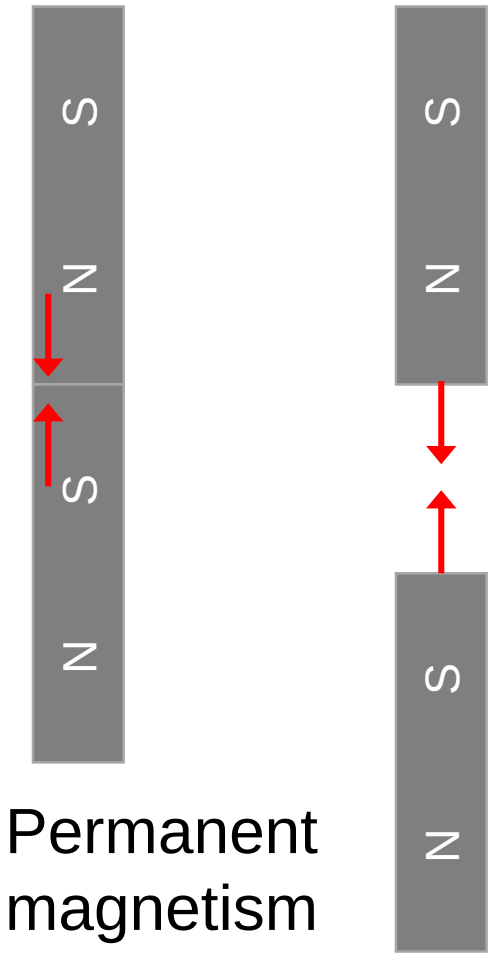


Molten iron moving in the Earth's outer core gives the Earth a magnetic field.

Compasses used in navigation use this field

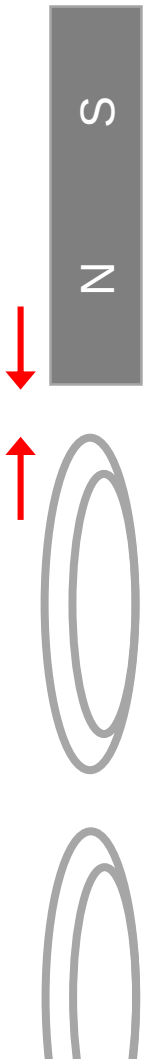
Compasses point North, and therefore, deep under the Arctic, where the polar bears live, there is a magnetic...

Induced magnetism



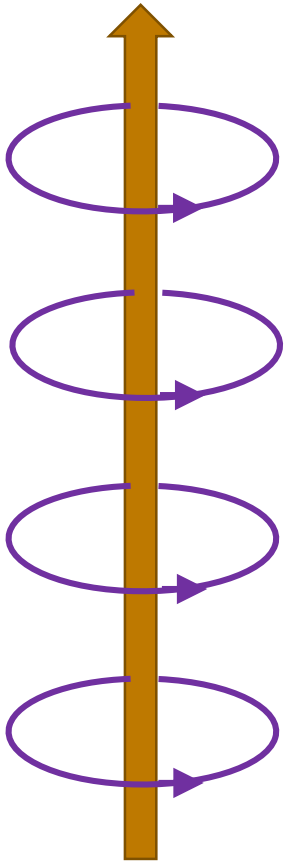
Permanent magnetism

Induced magnetism



magnetically soft paperclip

Field due to an electric current

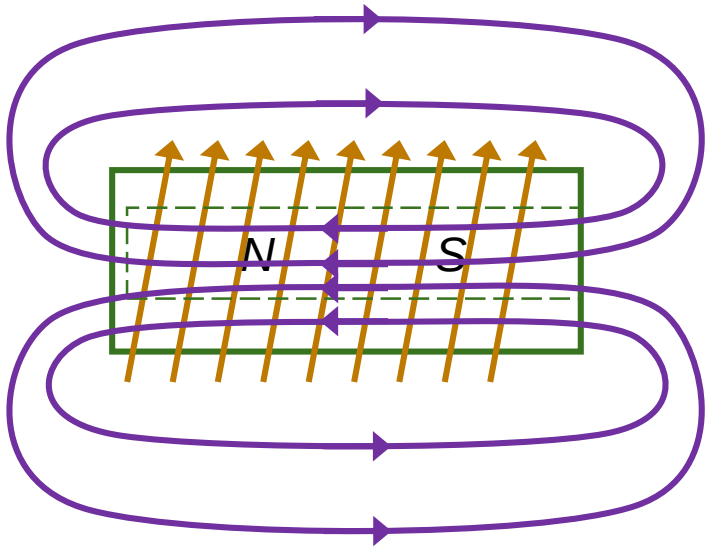


A current flowing in a wire sets up a magnetic field which points around the wire.

The field lines are circles centred on the wire.

The direction of the field can be predicted with the right hand grip rule.

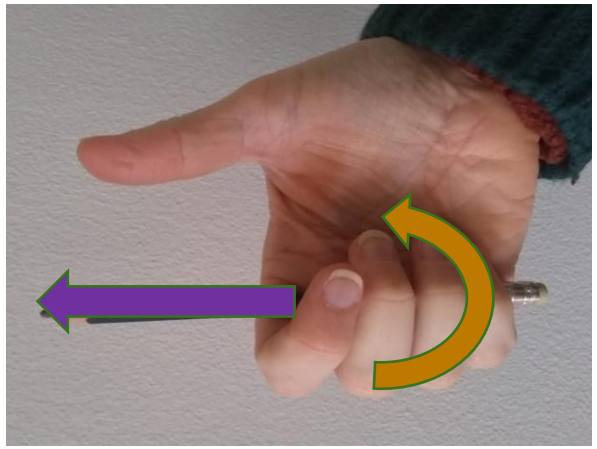
Field from a solenoid



A solenoid is a narrow, tightly wound coil of wire.

When a current flows, it produces a magnetic field similar to a bar magnet.

The direction of the field is predicted using the **right hand grip rule**
Fingers point in direction of current
Thumb points to ‘north pole’, or in direction of field *inside* the coil



Changing the magnetic field

The field from a solenoid can be made stronger by

- using a larger current,
- having more turns of wire on the coil, or
- placing a ‘soft iron’ cylinder (core) inside the coil

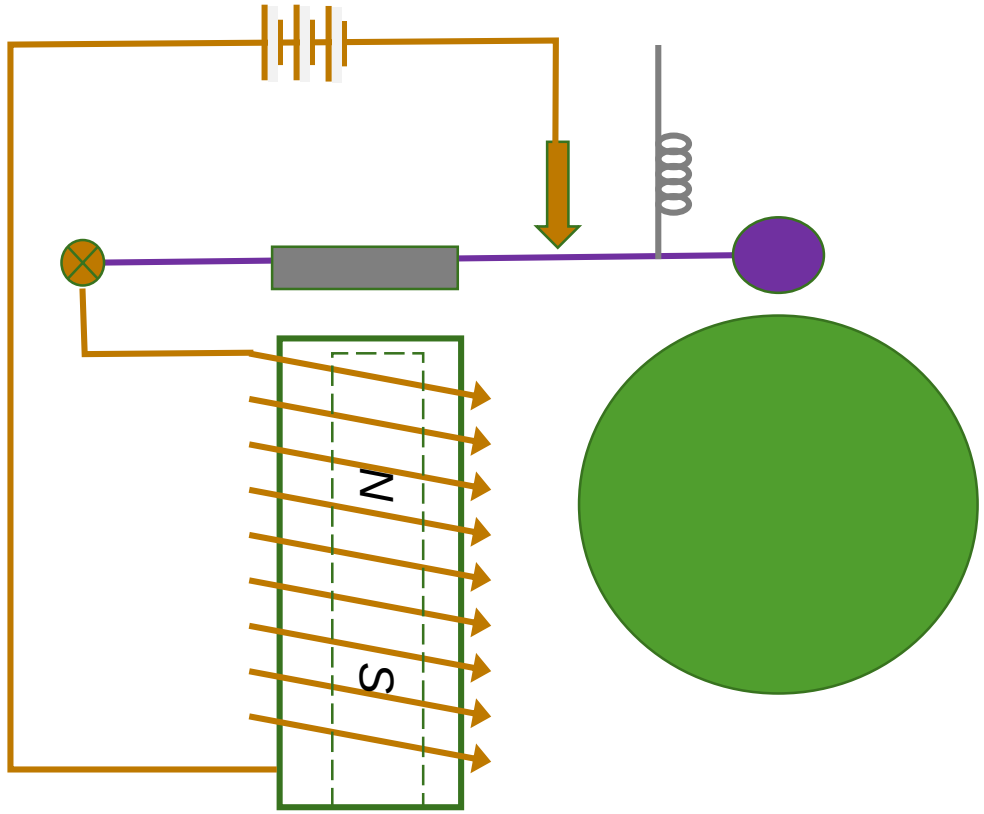
The field can be reversed by

- reversing the current
- winding the coils in the other direction

Iron is magnetically ‘soft’ which means that when the current is turned off, the iron will not be magnetized any more.

Uses of electromagnets

- Electric bells
- Relays – electrically operated switches
- Circuit breakers – electrically operated switch which automatically turns off if the current is too large



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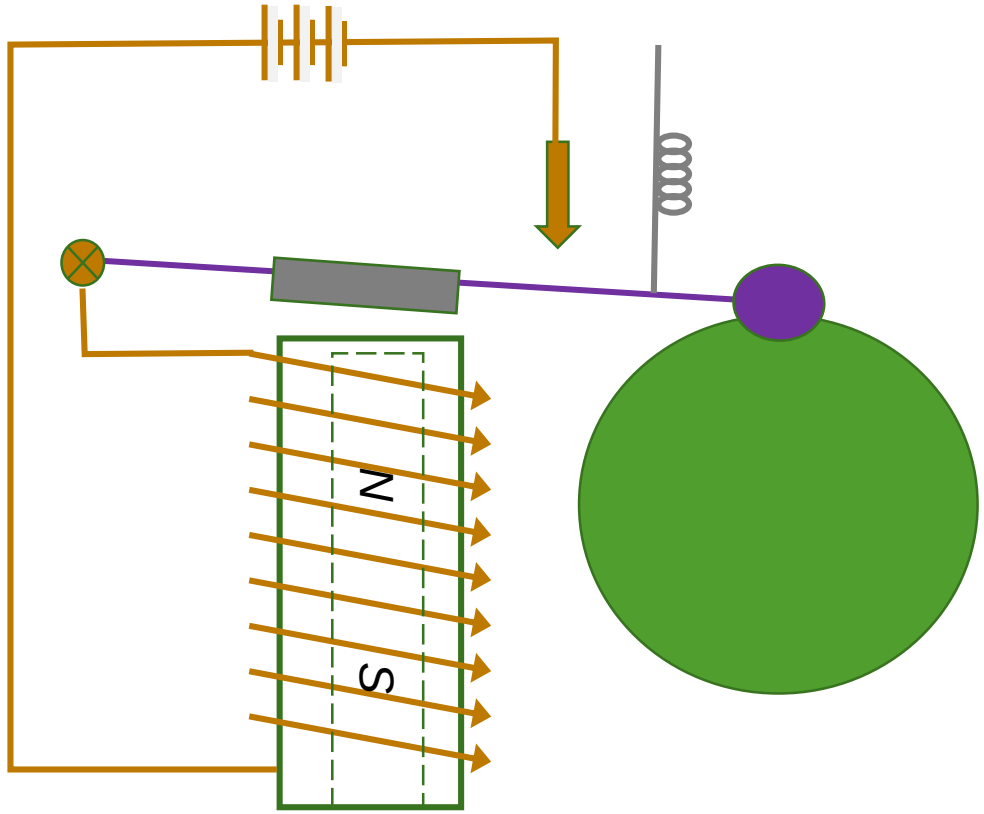
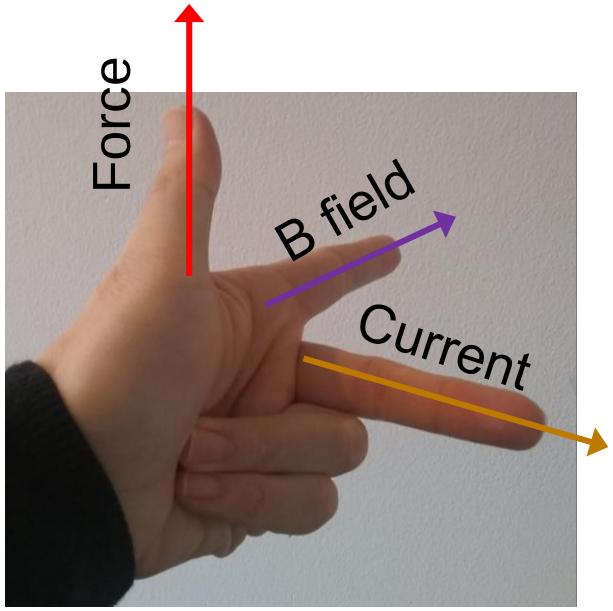


Magnetic force on a current

When a current flows in a wire at right angles to a magnetic field, it experiences a force

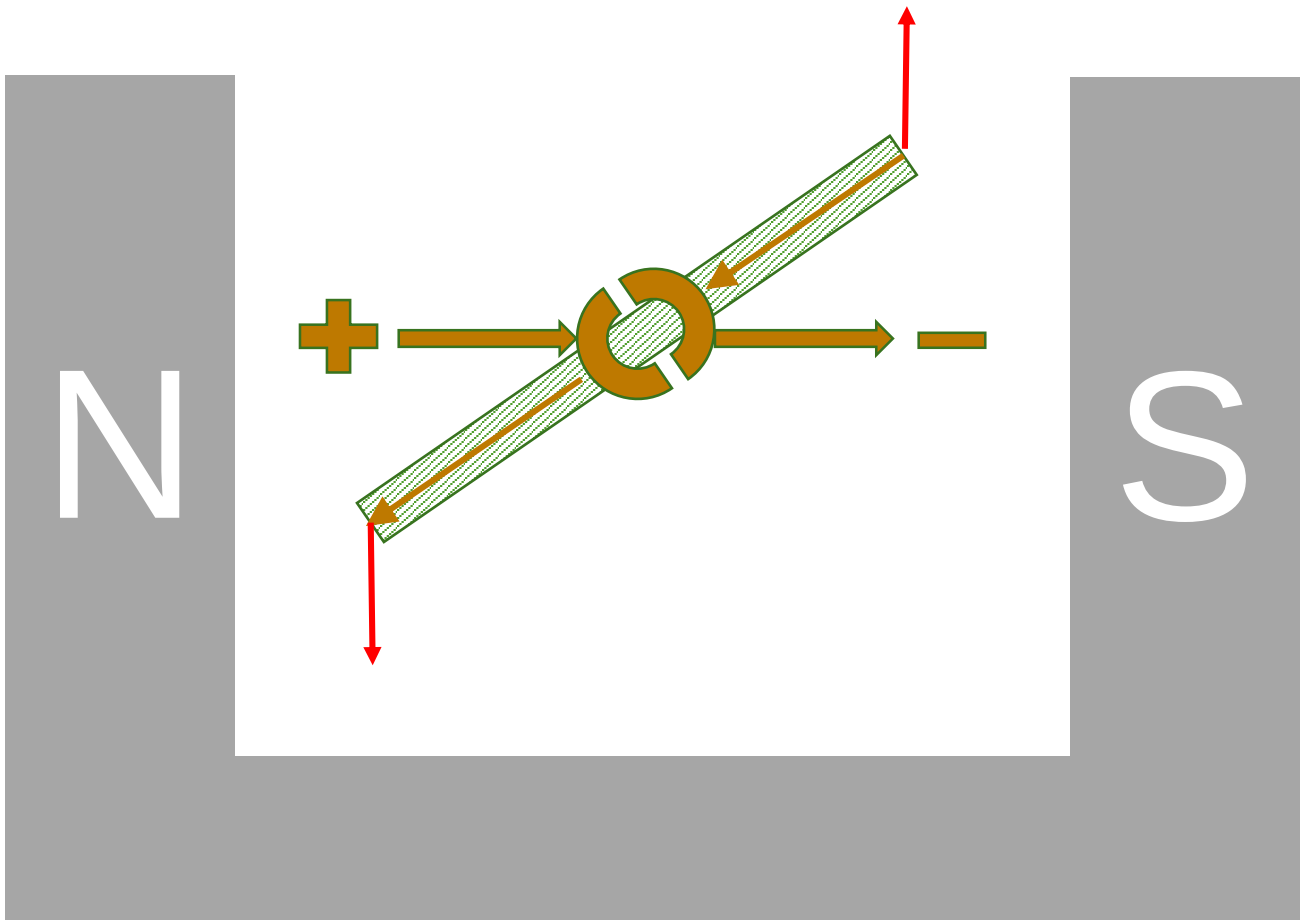
$$F = B\,I\,L$$

where *B* is the magnetic flux density in tesla (T). 1T=1N/(Am)



The direction of the force is given by Fleming's Left Hand Rule.

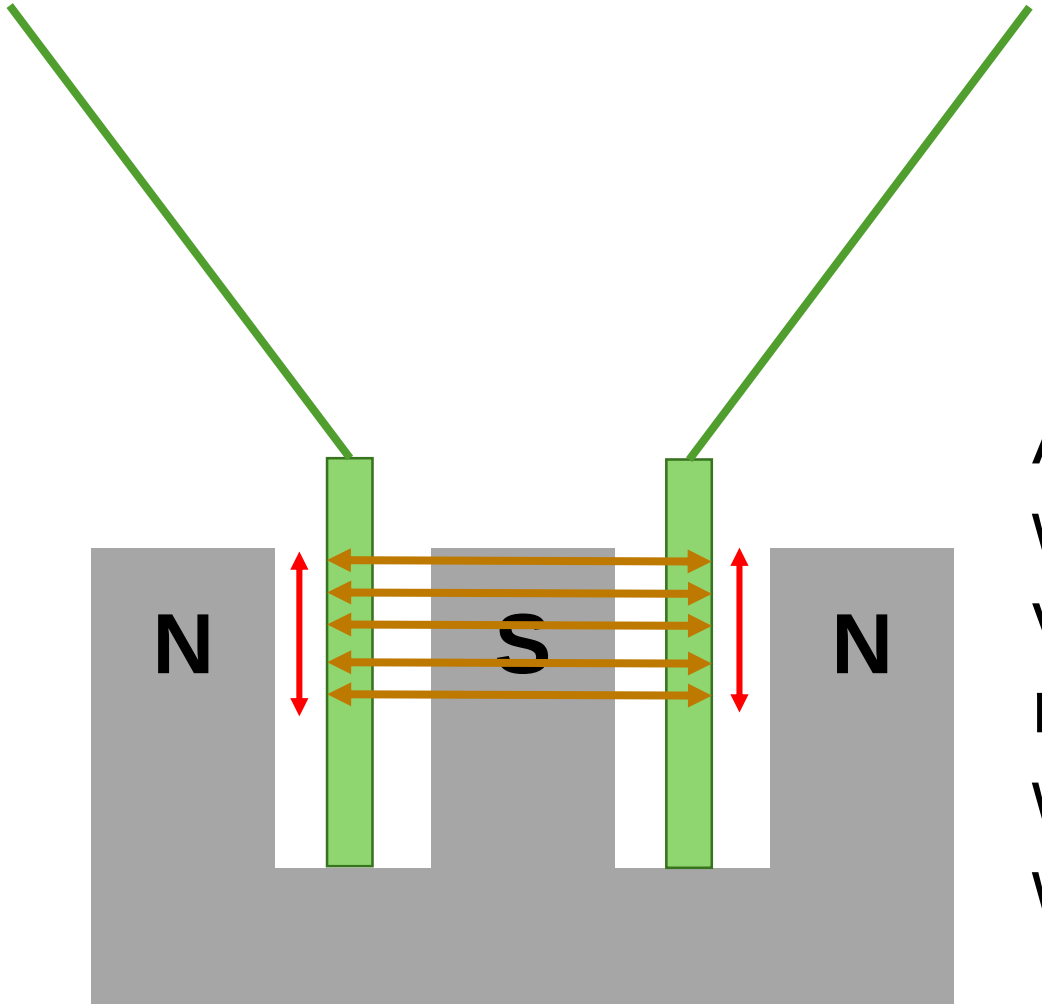
Motors



The wires on the coil furthest from the axis experience forces which cause the coil to rotate.

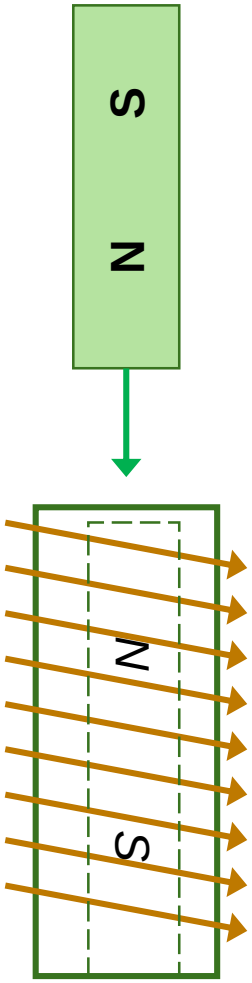
The commutator  rotates with the coil and ensures that the side of the coil on the left always experiences the downward force.

Loudspeakers



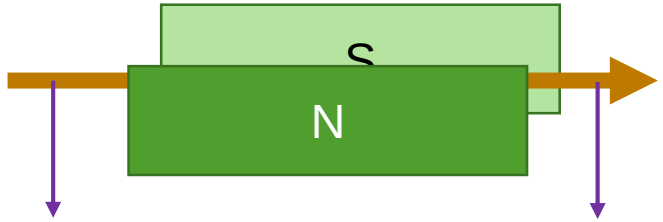
Alternating current flows in coil which experiences alternating vertical force,
moving cone up and down,
which in turn sets up sound wave in air

Electromagnetic induction



A voltage is induced (generated) in the coil when the magnet is moved towards or away from it.

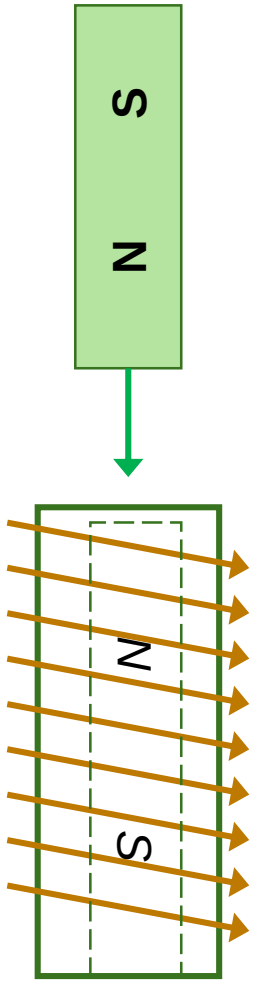
The induction is caused by the changing magnetic field in the coil.



A voltage is induced (generated) in the wire when it is moved between the poles of this magnet.

- A voltage is induced when the wires pass through (or ‘cut’) the magnetic field lines.
- The electrical energy comes from the motion of the magnet or wire.
- Stationary objects = no voltage.

Changing the voltage

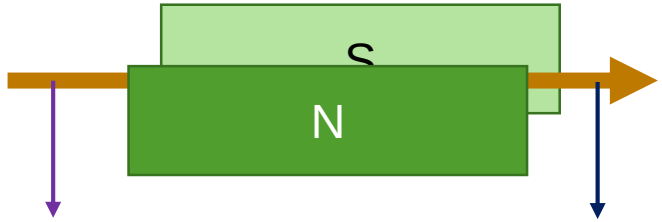


Voltage increased by

- faster motion
- more turns
- stronger magnet

Voltage reversed by

- moving the other way
- reversing the poles
- winding the coil in the other direction



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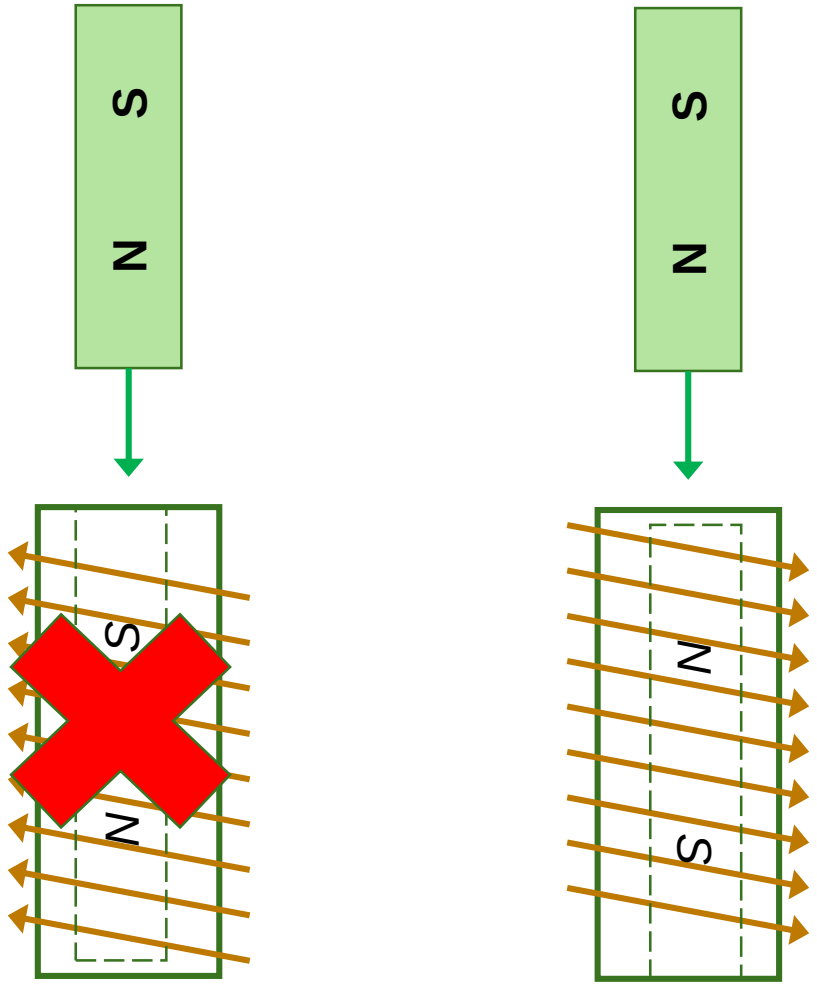
Lenz’s law



Conservation of energy requires

› magnet’s motion resisted

Current flows in direction

› to make a magnetic field

› which opposes

› the ongoing magnetic change

Flux and induction practice

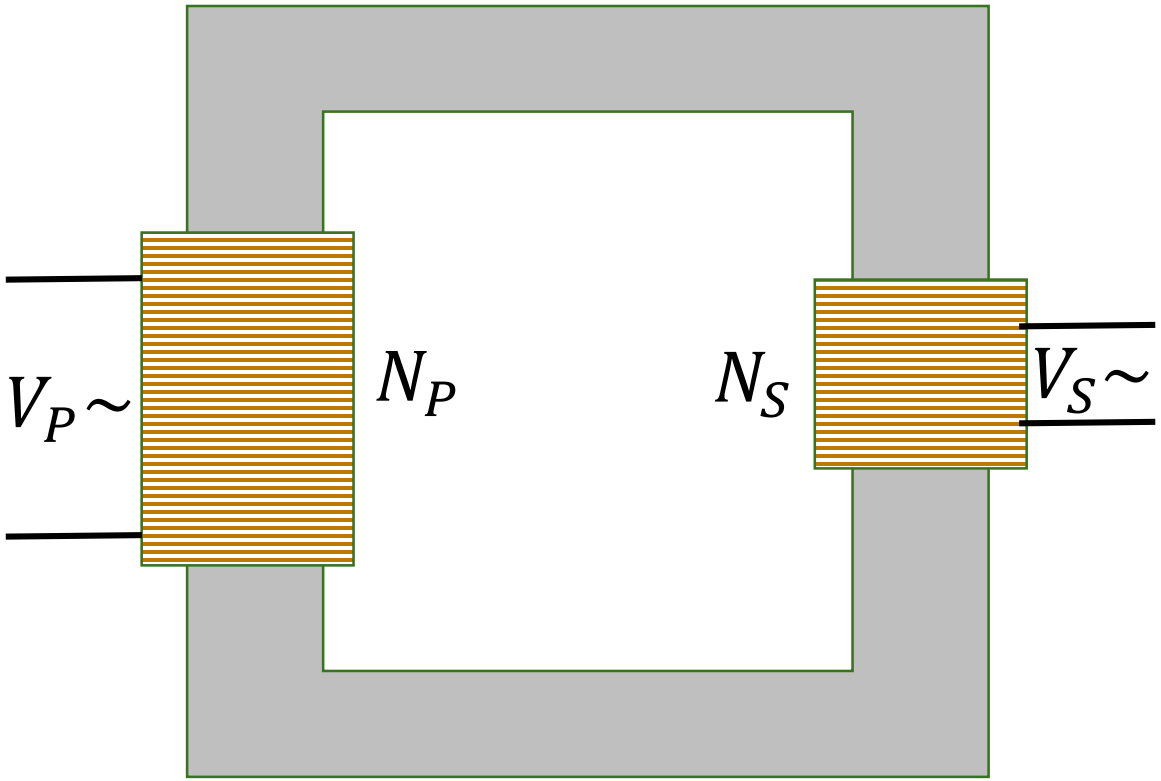
When a magnet is inserted at 0.20m/s into a coil of wire with 600 turns, the voltmeter reads +0.045V. What will the meter read when...

1. **the magnet is removed at a speed of 0.40m/s?**

2. **a magnet of twice the strength (but the same orientation) is inserted at 0.40m/s?**

3. **a magnet of 3000x the strength is held stationary inside the coil?**

Transformer concepts



Alternating current in primary makes alternating field in core, inducing alternating voltage on secondary coil

$\frac{V_P}{N_P} = \frac{V_S}{N_S}$ **and** $\frac{V_S}{V_P} = \frac{N_S}{N_P}$

'turns per volt' same each side

With currents:

$$V_S I_S = \eta\, V_P I_P$$

Transformer use and limitations

Electrical distribution

- Power loss in cables $P = I^2R$
- To save energy, use lower current
- To transmit same power $P = IV$ use higher voltage
- Use transformers to ‘step-down’ the voltage for safe domestic/industrial use.

Transformer practice

1. The 300 turn primary of a transformer is connected to a 12V car battery. What voltage do we expect from the 1200 turn secondary?

2. How many turns are required on the secondary of a 230V – 5V step down transformer if the primary has 9000 turns?

3. What is primary current when a 230V – 12V step down transformer with 84% efficiency is used to power a 48W motor?

Links

GCSE Topic Revision

https://isaacphysics.org/pages/gcse_topic_index#gcse_revision

Consolidation Programme

https://isaacphysics.org/pages/summer_programmes_2021