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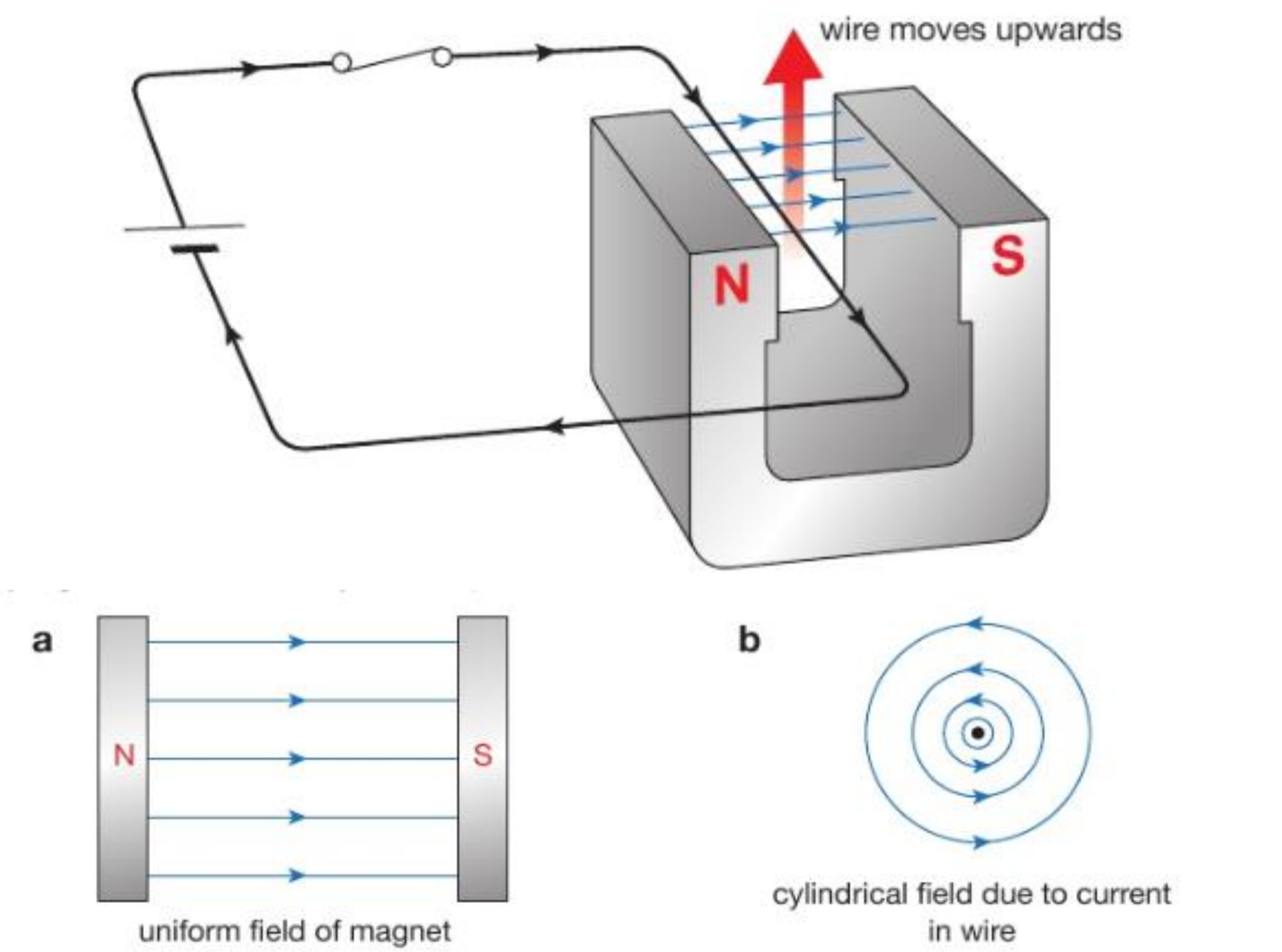
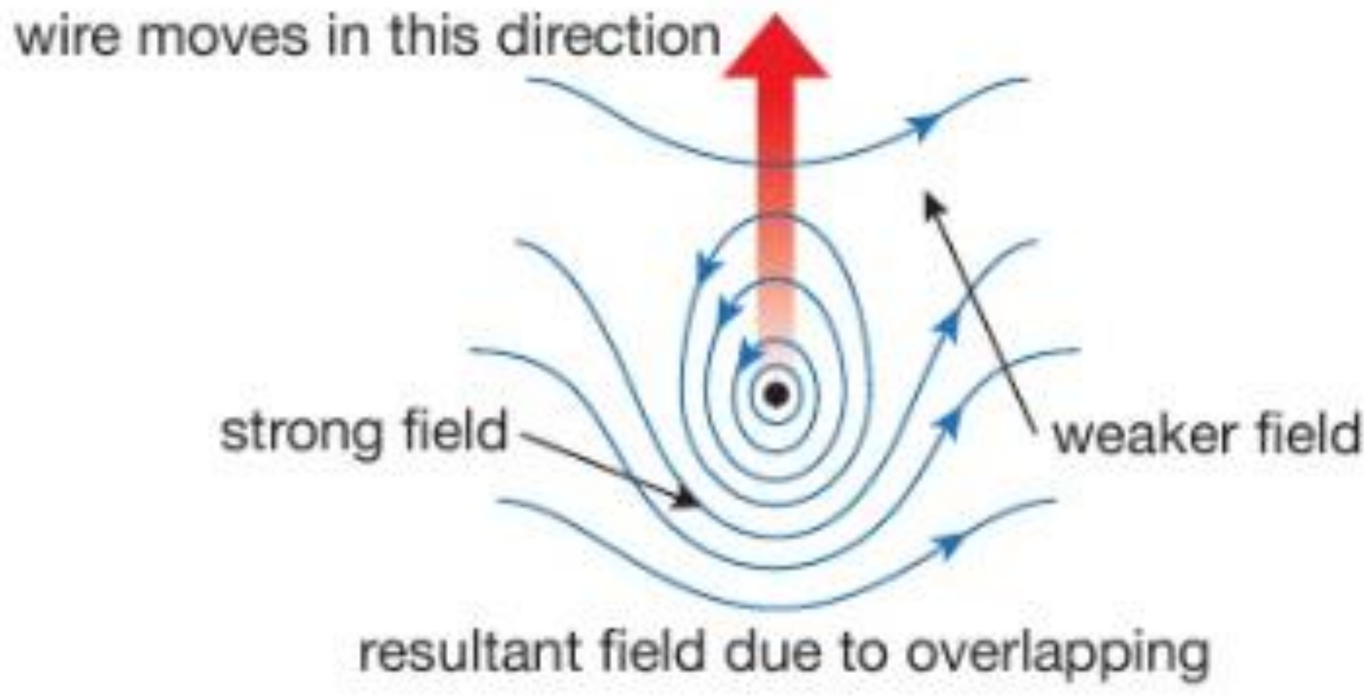
Electric motors & Electromagnetic induction

YOUTUBE- TUTORFOR EXAMPHYSICS

Overlapping magnetic fields




wire moves in this direction
strong field
weaker field
resultant field due to overlapping

Fleming's left-hand rule

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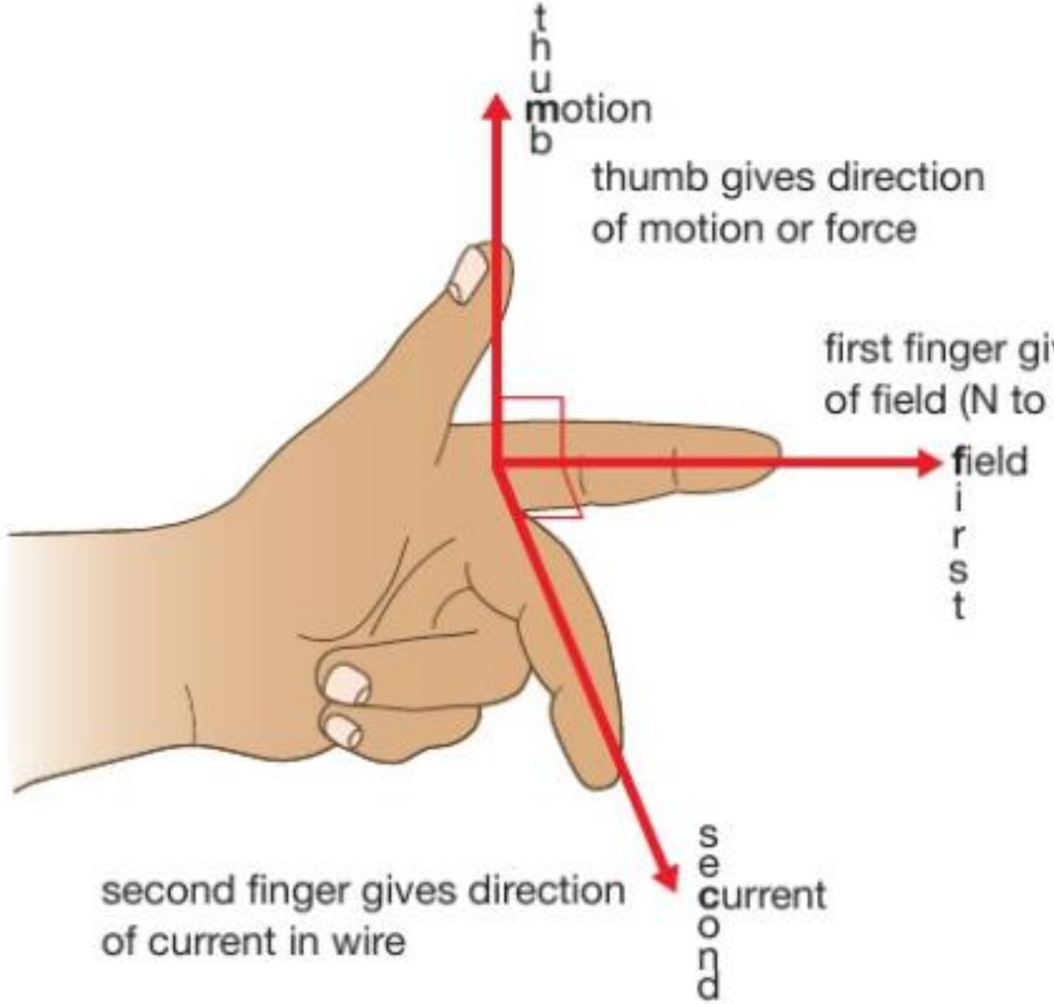


Motor effect

- The **motor effect** occurs:

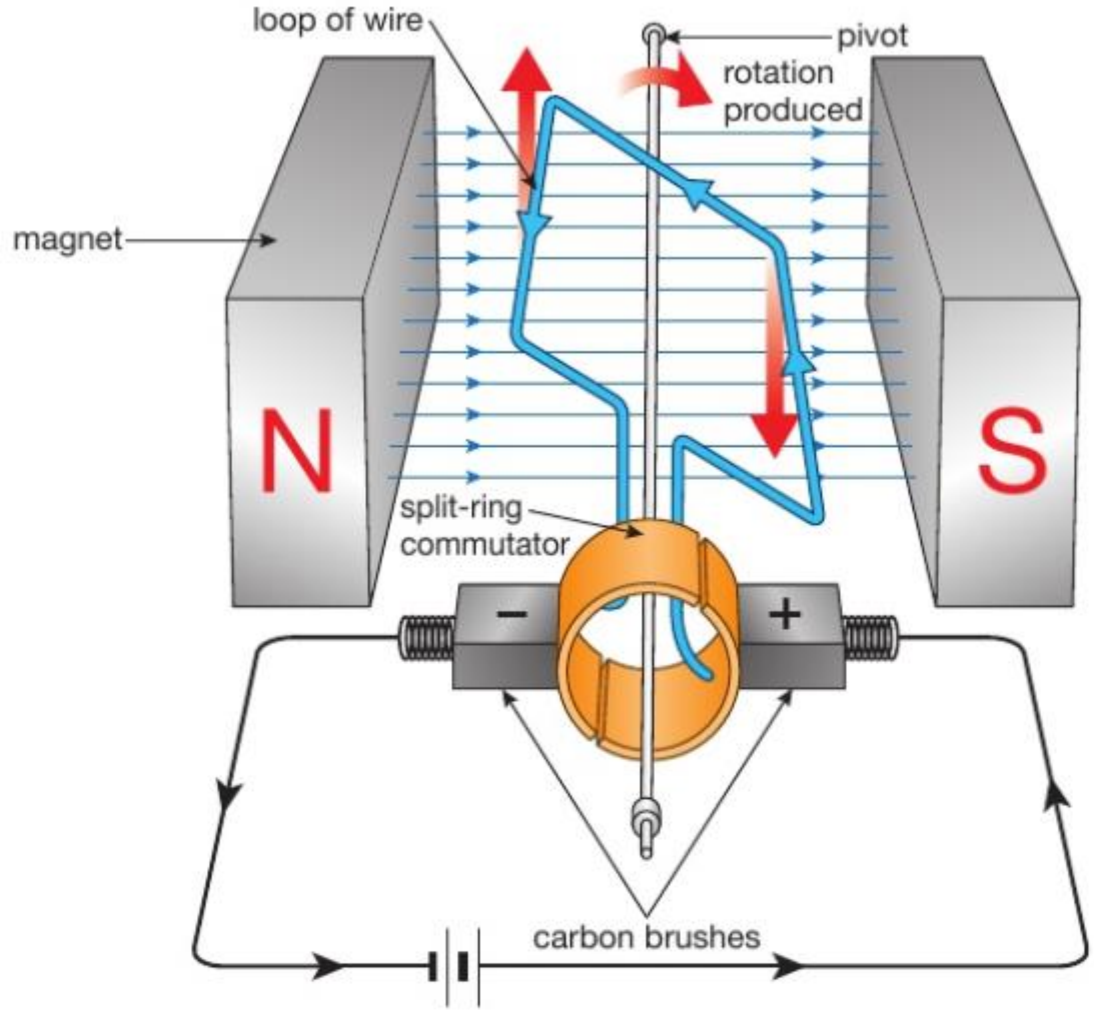
When a wire with current flowing through it is placed in a magnetic field and experiences a force.

- This effect is a result of **two** overlapping **magnetic fields**
  - One is produced around the wire due to the current flowing through it
  - The second is the magnetic field into which the wire is placed, for example, between two magnets
- As a result of the interactions of the two magnetic fields, the wire will experience a **force**

Simple Motors

- The **motor effect** can be used to create a simple **d.c** electric motor.

- The simple d.c. motor consists of a coil of wire (which is free to rotate) positioned in a **uniform magnetic field**:



- When the current is flowing in the coil at 90° to the direction of the magnetic field:

  - The **current** creates a **magnetic field** around the coil
  - The magnetic field produced around the coil interacts with the field produced by the magnets
  - This results in a **force** being exerted on the coil
  - The direction of the force can be determined using **Fleming's left-hand rule**
  - As current will flow in **opposite** directions on each side of the coil, the force produced from the magnetic field will push one side of the coil **up** and the other side of the coil **down**

The split ring commutator

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- The **split ring commutator** swaps the contacts of the coil.This reverses the direction in which the current is flowing
- Reversing the direction of the current will also reverse the direction in which the forces are acting
  - As a result, the coil will continue to **rotate**

Factors Affecting the D.C Motor

- The **speed** at which the coil rotates can be increased by:
  - Increasing the **current**
  - Increasing the strength of the **magnetic field**
- The **direction of rotation** of coil in the d.c motor can be changed by:
  - Reversing the direction of the **current**
  - Reversing the direction of the magnetic field by reversing the **poles** of the magnet
- The **force** supplied by the motor can be increased by:
  - Increasing the **current** in the coil
  - Increasing the strength of the **magnetic field**
  - Adding **more turns** to the coil.

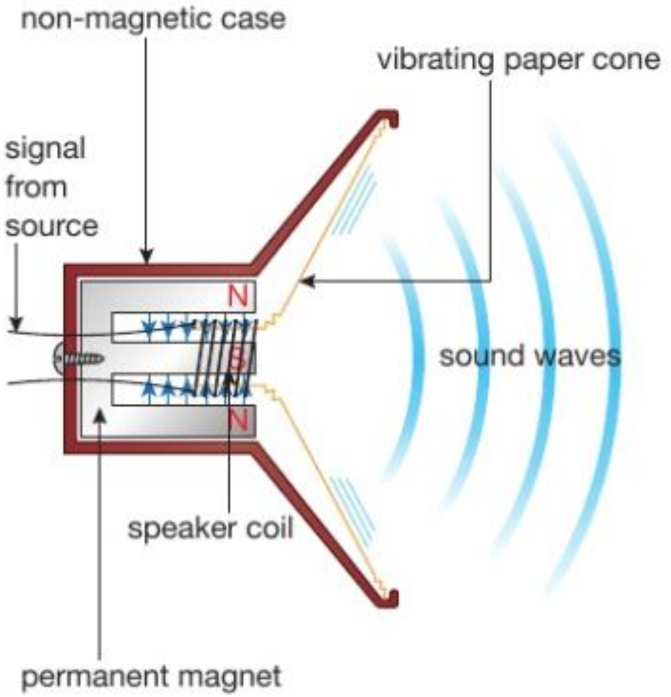
Loudspeaker

•As the current is constantly changing direction, the direction of the magnetic field will be **constantly changing**

•The magnetic field produced around the coil **interacts** with the field from the permanent magnet
•The interacting magnetic fields will exert a **force** on the coil.

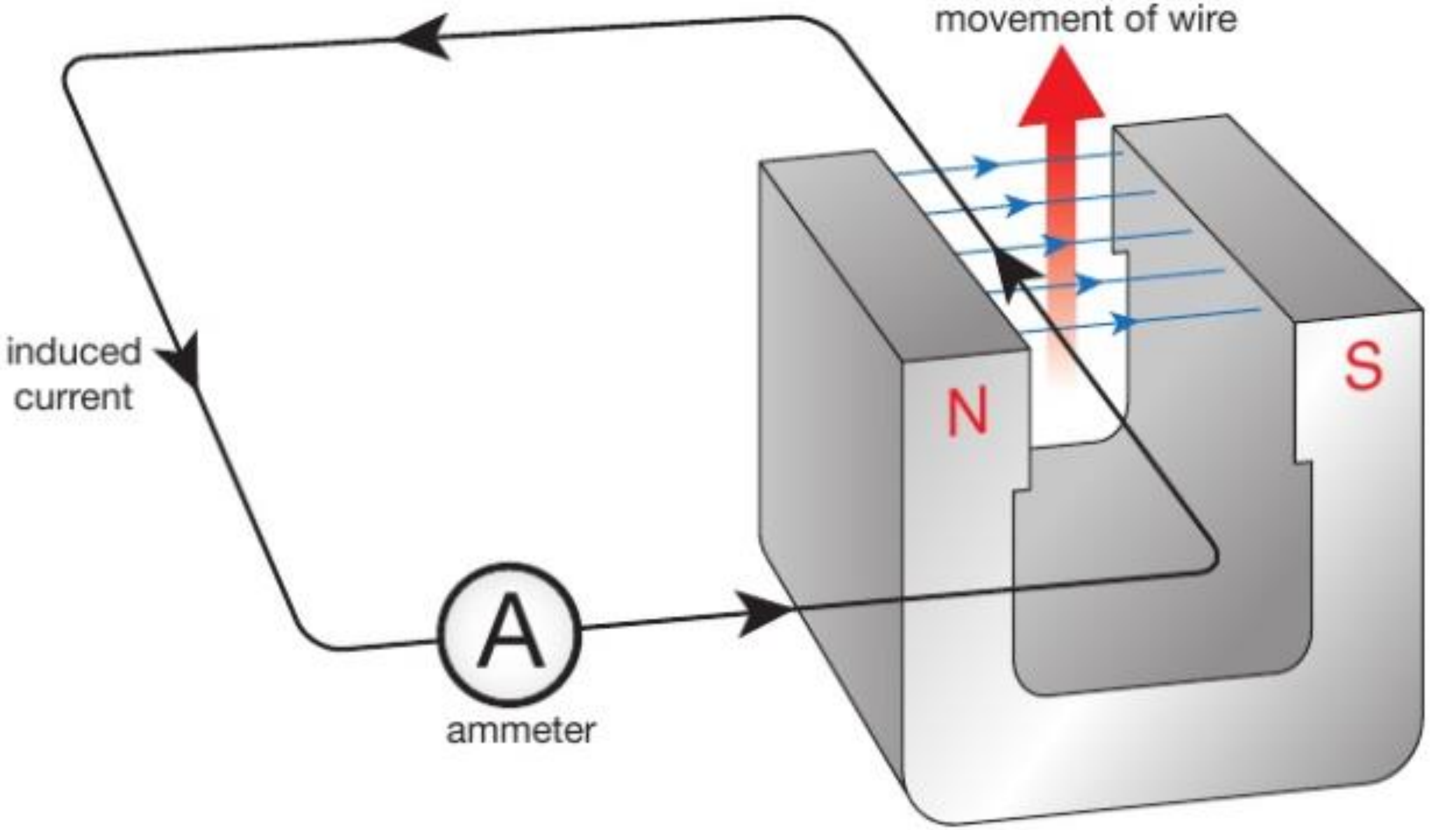
•As the magnetic field is constantly changing direction, the **force** exerted on the coil will **constantly change direction**

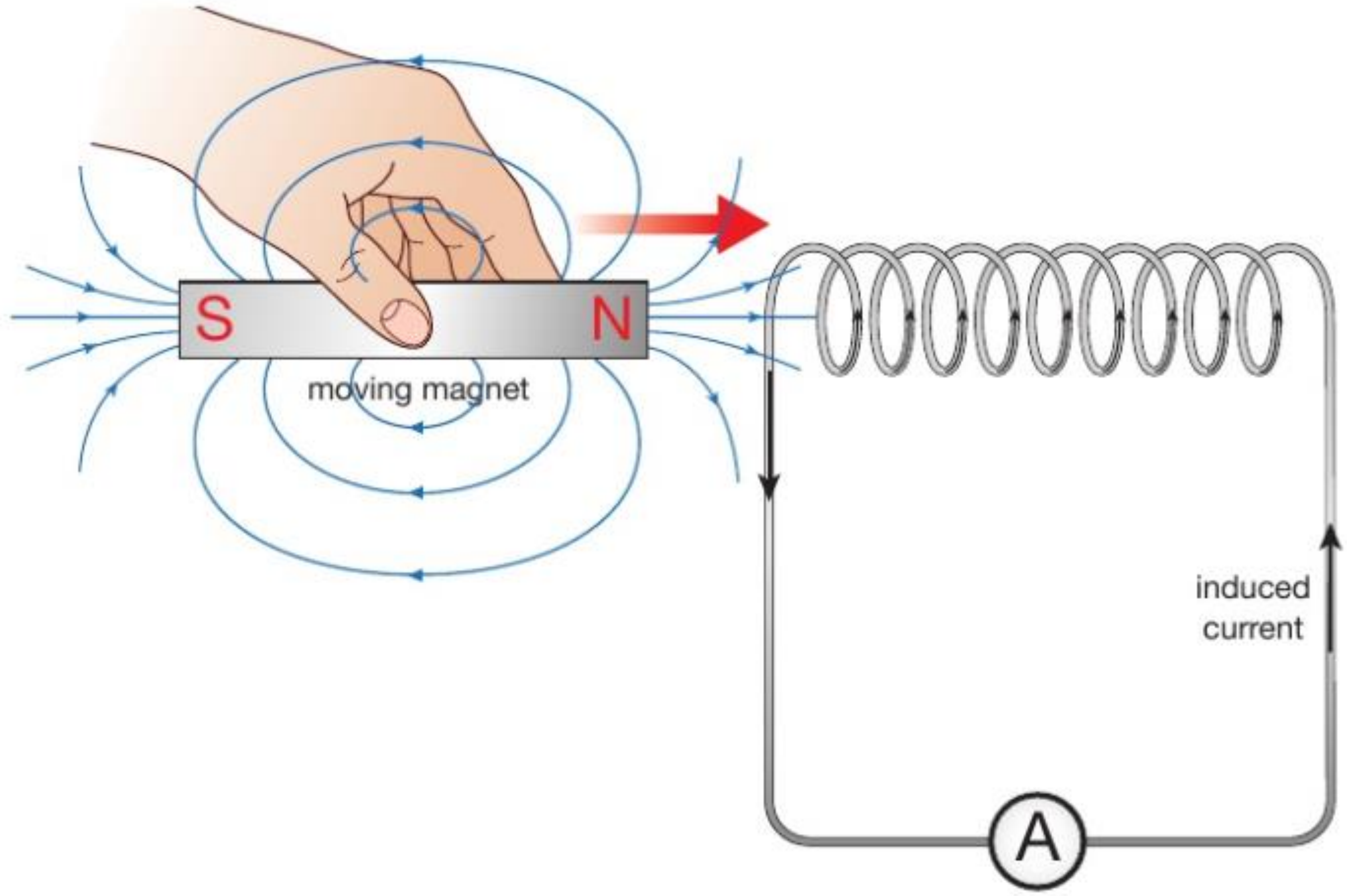
•This makes the coil **oscillate. The** oscillating coil causes the speaker cone to oscillate. This makes the air oscillate, creating **sound waves**



Electromagnetic induction

Electromagnetic induction




S
N
moving magnet
induced
current
A

Potential difference

A **potential difference** or **voltage** is needed to make an electric current flow in a circuit.

Inducing a potential difference

A potential difference can be induced (created) in a **conductor** when there is movement between the conductor and a magnetic field. This can occur in two different ways:

- a coil of wire is moved in a magnetic field
- a magnet is moved into a coil of wire

This is called **electromagnetic induction** and is often referred to as the **generator effect**.

Factors affecting the induced potential

The direction of the induced potential difference or induced current depends on the direction of movement. The current is reversed when:

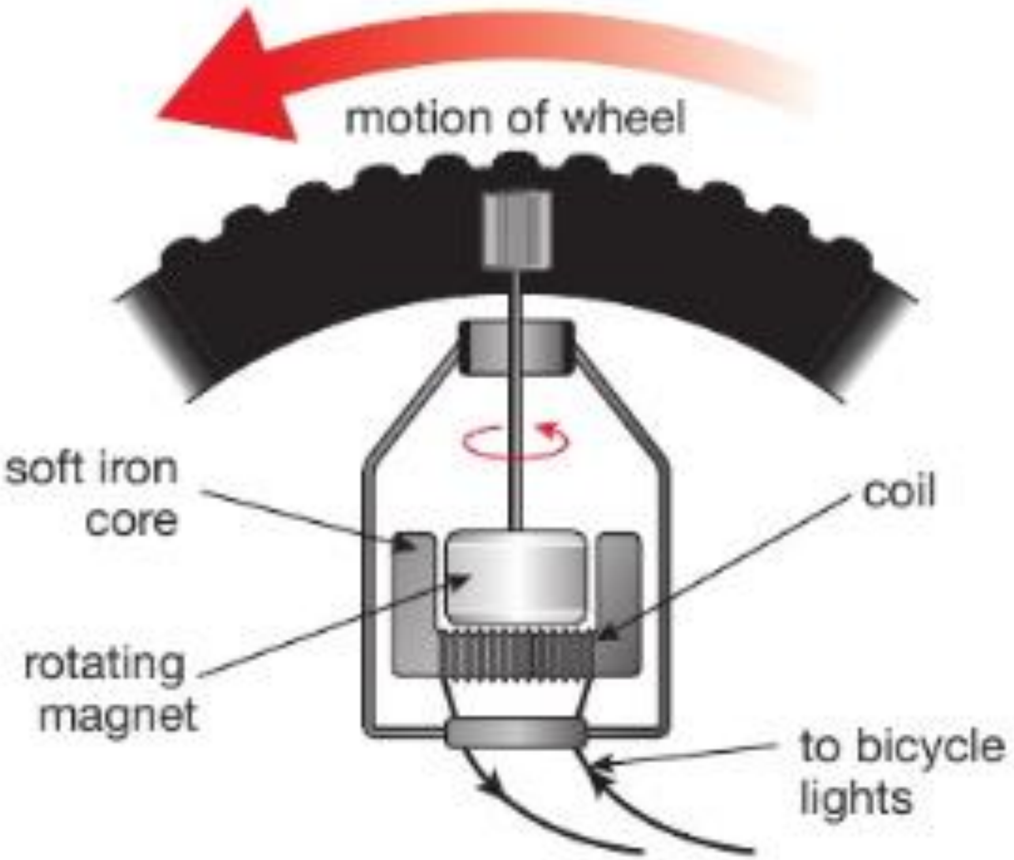
•the magnet is moved out of the coil
•the other pole of the magnet is moved into the coil

An induced potential difference or induced current will increase if:

- the speed of movement is increased
- the magnetic field strength is increased
- the number of turns on the coil is increased

We can summarise all the discoveries from these experiments by saying:

- a voltage is induced when a conductor cuts through magnetic field lines
- a voltage is induced when magnetic field lines cut through a conductor
- the faster the lines are cut the larger the induced voltage.


motion of wheel
soft iron core
coil
rotating magnet
to bicycle lights

Alternators

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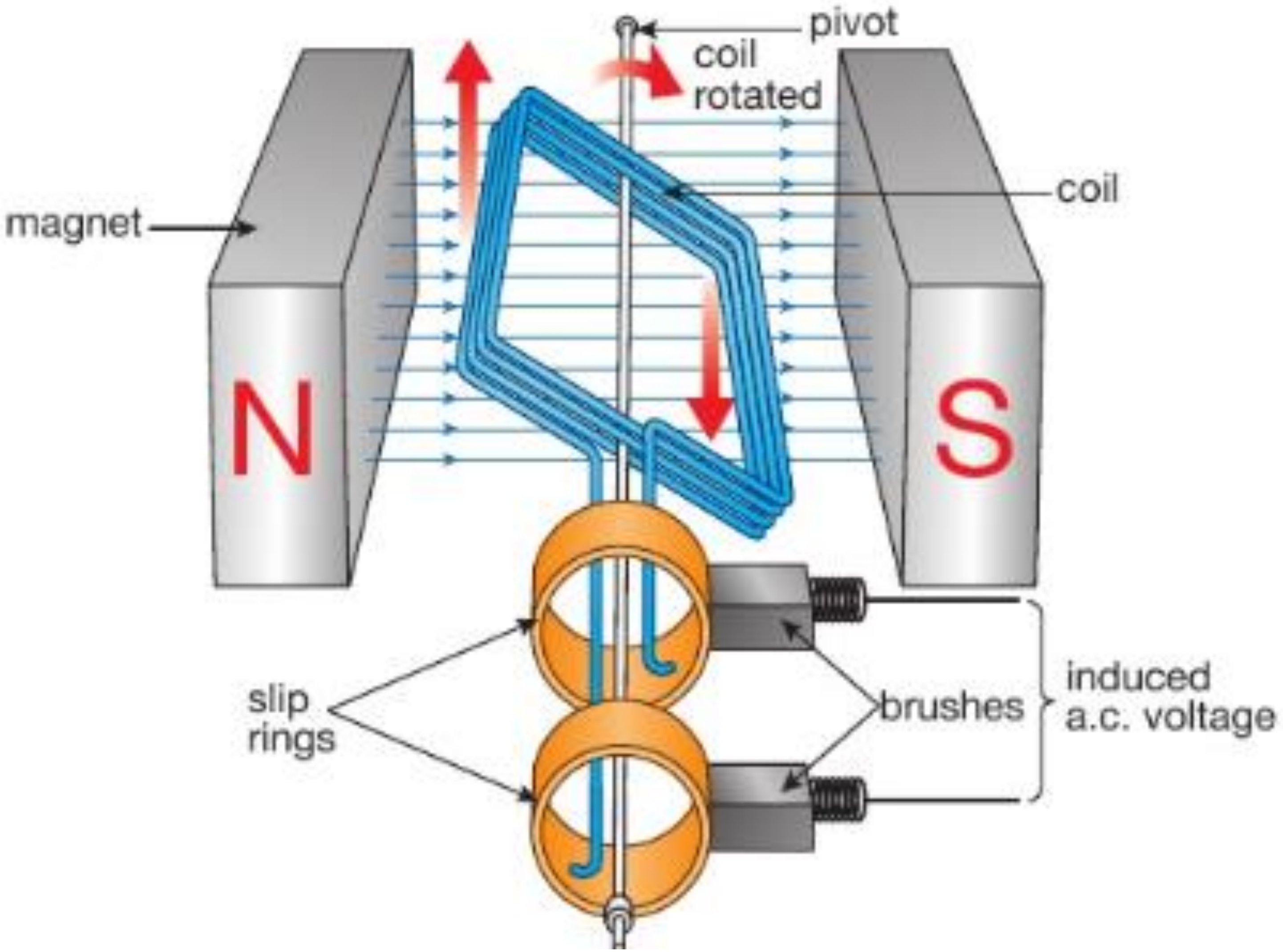
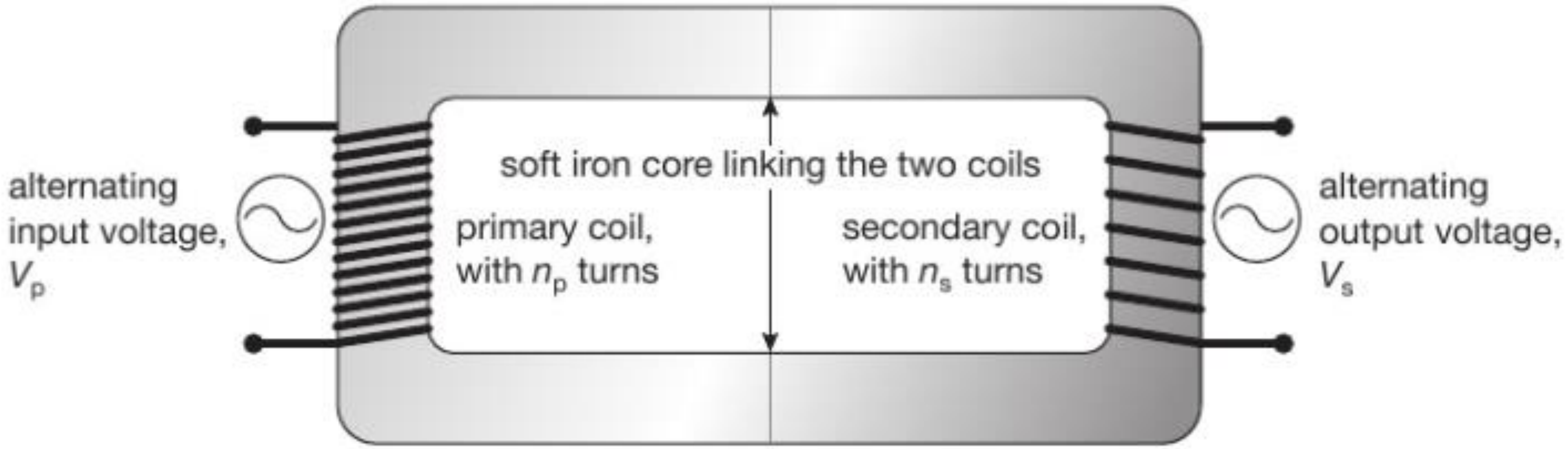
An alternating current (ac) **generator** is a device that produces a **potential difference.**

A simple **ac** generator consists of a coil of wire rotating in a magnetic field. This is used in power stations in the large-scale generation of electricity to supply homes and factories.

Cars use a type of ac generator, called an **alternator** to keep the battery charged and to run the electrical system while the engine is working.


pivot
coil rotated
coil
magnet
N
S
slip rings
brushes
induced a.c. voltage

Transformers



Transformers can only work with alternating current.

Transformers

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A **transformer** is a device that can change the **potential difference** or **voltage** of an alternating current:

- a step-up transformer increases the voltage
- a step-down transformer reduces the voltage

When a transformer is working:

1.a primary voltage drives an **alternating current** through the primary coil

2.the primary coil current produces a magnetic field, which changes as the current changes

3.the iron core increases the strength of the magnetic field

4.the changing magnetic field induces a changing potential difference in the secondary coil

5.the induced potential difference produces an alternating current in the external circuit

Potential difference

The ratio of potential differences on the **transformer** coils matches the ratio of the numbers of turns on the coils.

$$\frac{primary\ voltage}{secondary\ voltage} = \frac{number\ of\ turns\ on\ primary\ coil}{number\ of\ turns\ on\ secondary\ coil}$$

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

Concept Learning Questions.

A mains (230 volt) transformer has 11,500 turns on its primary coil and 600 turns on its secondary coil. Calculate the voltage obtained from the secondary coil.

Transformer power transfer

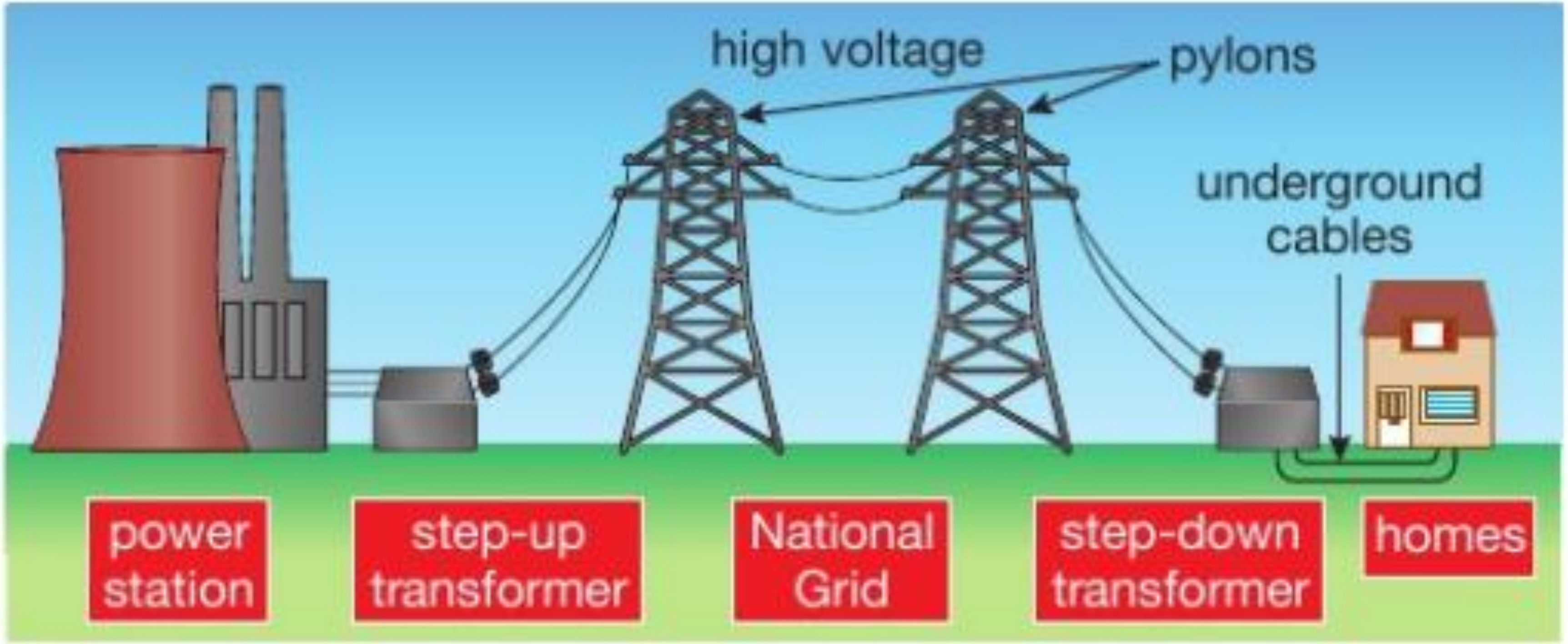
- Assuming that a **transformer** is 100% efficient, the following equation can be used to calculate the power output from the transformer:

- potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil

$$V_s \times I_s = V_p \times I_p$$

Concept Learning Questions.

A step-down transformer converts 11 500 V into 230 V. The power output is used to run a 2,000 W kettle.
Calculate the current flowing in the primary coil.


high voltage
pylons
underground cables
power station
step-up transformer
National Grid
step-down transformer
homes

High voltage power transmission

- The **National Grid** carries electricity around Britain. The higher the current in a cable, the greater the energy transferred to the surroundings by heating. This means that high currents waste more energy than low currents.
- To reduce energy transfers to the environment, the National Grid uses step-up transformers to increase the voltage from power stations to thousands of volts, which lowers the current in the transmission cables. Step-down transformers are then used to decrease the voltage from the transmission cables, so it is safer to distribute to homes and factories.

In the National Grid, long distance transmission cables use very high voltages, up to 400,000 V. As shown in the kettle example above, the equation $P = VI$ means that for a given power transfer, the higher the voltage used, the lower the current needed.

Heat energy wastage through electrical resistance is proportional to the square of the current, as given by the equation $P = I^2R$. Reducing the current can create huge reductions in energy lost to the surroundings through resistance.

To maximise these energy savings, cross-country transmission lines use the highest possible voltage, limited by the limit of the electrical insulating properties of air.