

PiXL KnowIT!

GCSE Physics

Edexcel Physics

Magnetism, the motor effect and electromagnetic induction

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Magnetism and the motor effect

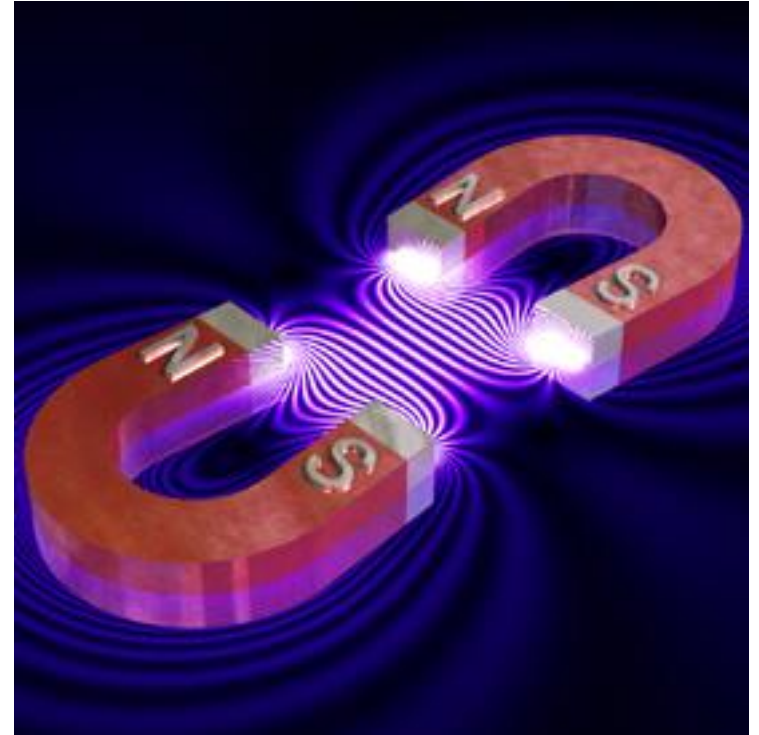
Part 1

- Magnets and magnetic fields
- Electromagnetism
- Magnetic forces (HT)

Electromagnetic induction

Part 2

- Electromagnetic induction (HT)
- The national grid
- Transformers



Part 1

-

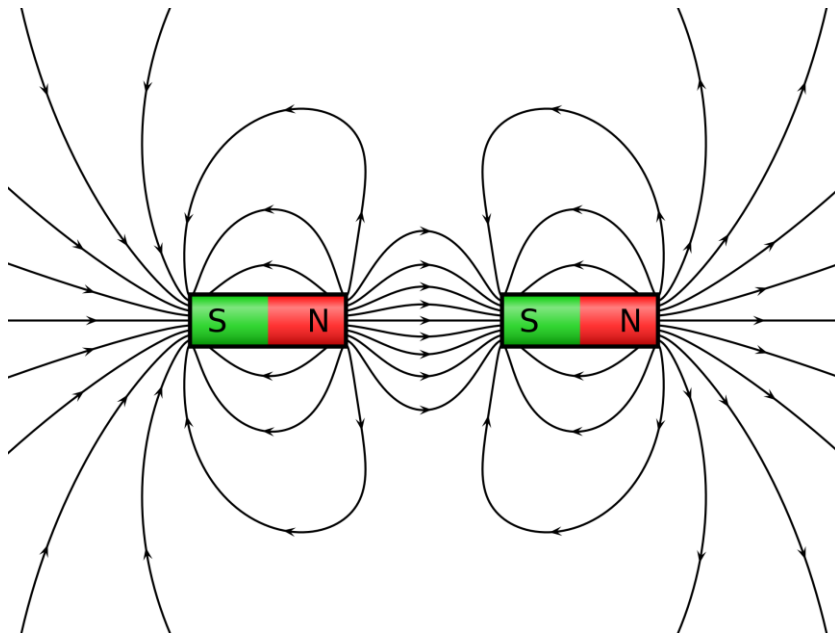
Poles of a Magnet

Object	Definition
Poles	Places where the magnetic forces are strongest.
Permanent Magnets	Produce their own magnetic fields. Permanent magnets can attract and repel.
Induced Magnets	Material that becomes magnetic when placed in a magnetic field. Induced magnets can only attract. When the magnetic field is removed an induced magnet will lose most/all of its magnetism quickly.

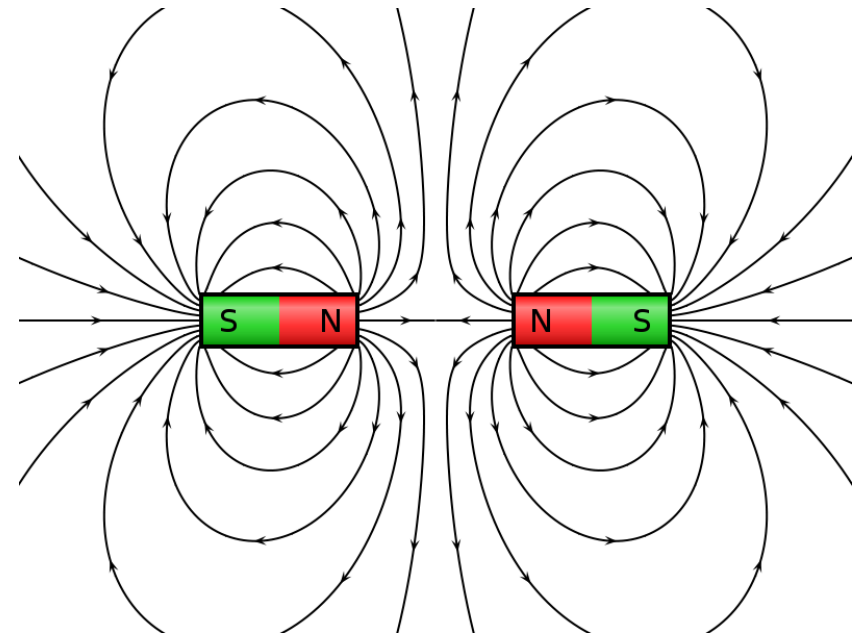
When two magnets are brought together they exert a force on each other. Two like poles **repel** each other, two unlike poles **attract** each other.

Attraction and repulsion are examples of **non-contact force**.

When two poles of two magnets are placed near each other they can either **attract** or **repel** each other. The combination of north and south poles determines whether they attract or repel.



Unlike poles **attract**



Like poles **repel**

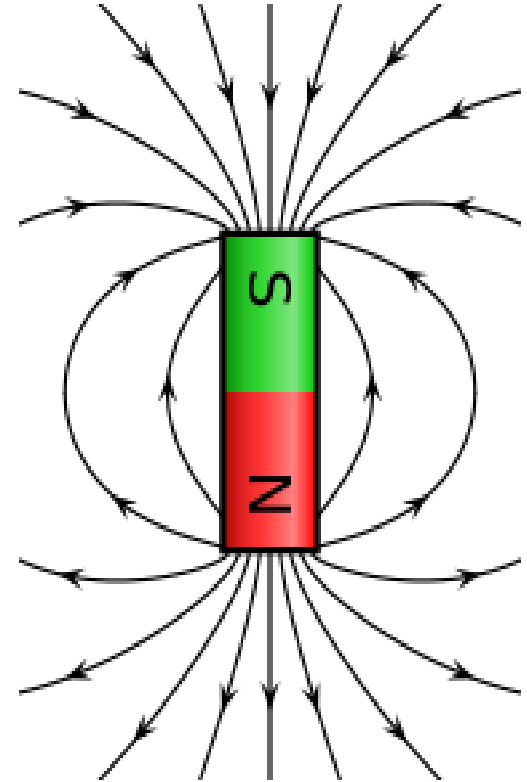
Magnetic Fields

There are four main magnetic materials that you need to know: **iron**, **steel** (because it is made from iron), **nickel** and **cobalt**. There is always a force of **attraction** between magnets and magnetic materials.

Magnetic field = The region around a magnet where a force acts on another magnet (or magnetic material).

The **strength** of a magnetic field depends on the **distance from the magnet**.

The field is **strongest at the poles**.



The direction of the magnetic field at any point is given by the direction of the force that would act on another north pole placed at that point.

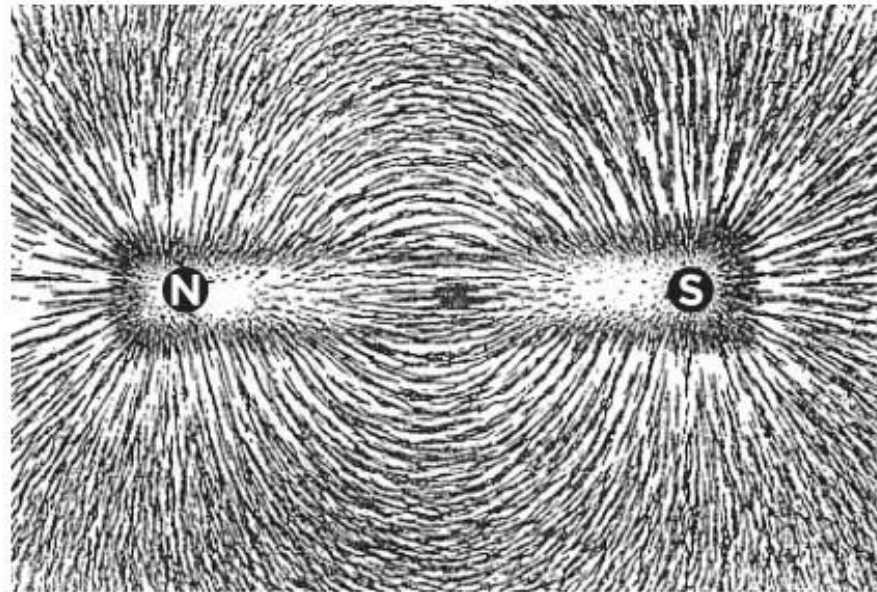
The direction of a magnetic field line is always from north (seeking) pole to south (seeking) pole.



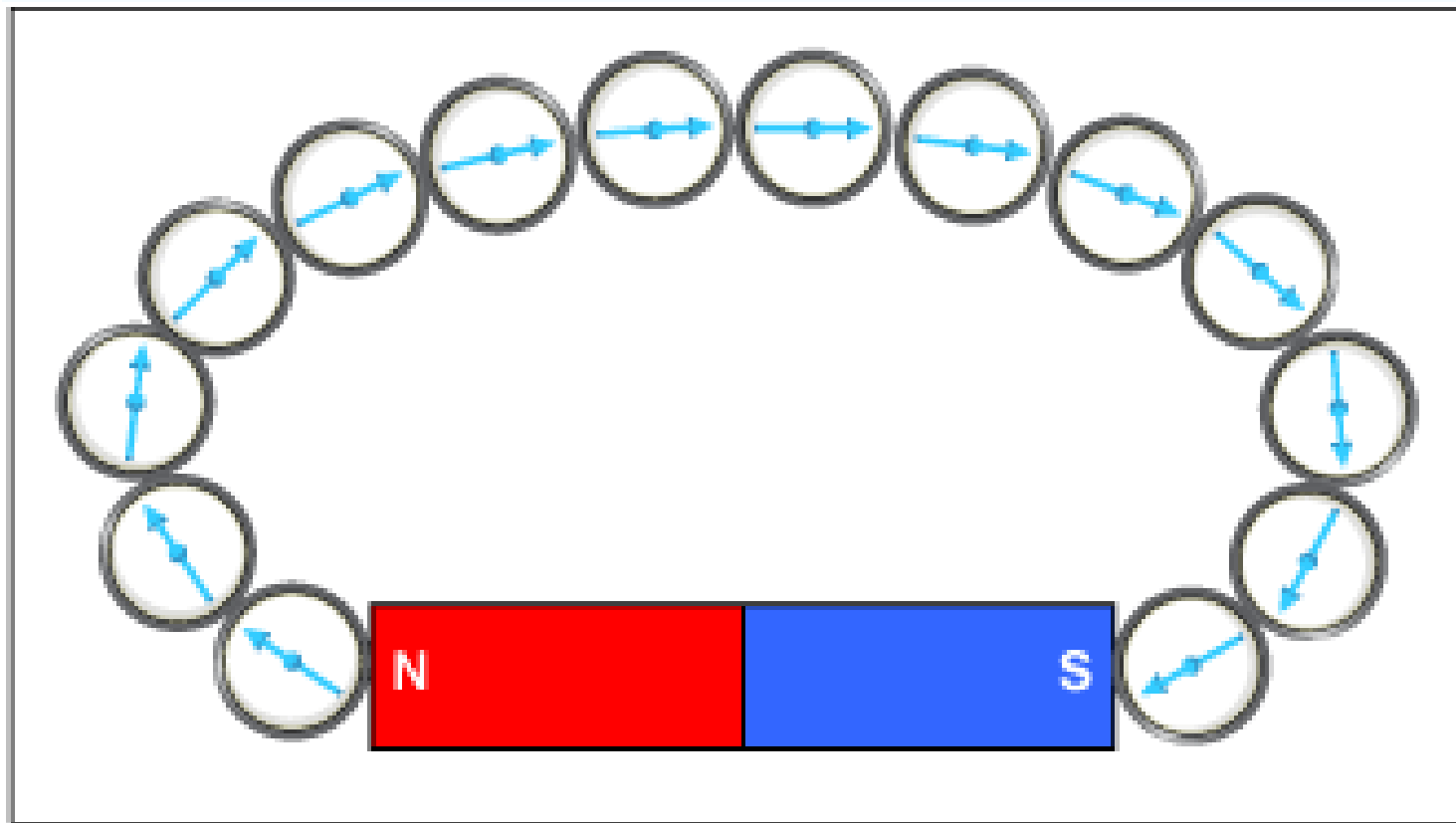
To find the direction of the magnetic field of a bar magnet there are two main techniques.

Place the bar magnet under a piece of paper and sprinkle **iron filings** over the paper.

Tapping the paper will produce the magnetic field pattern of the bar magnet.

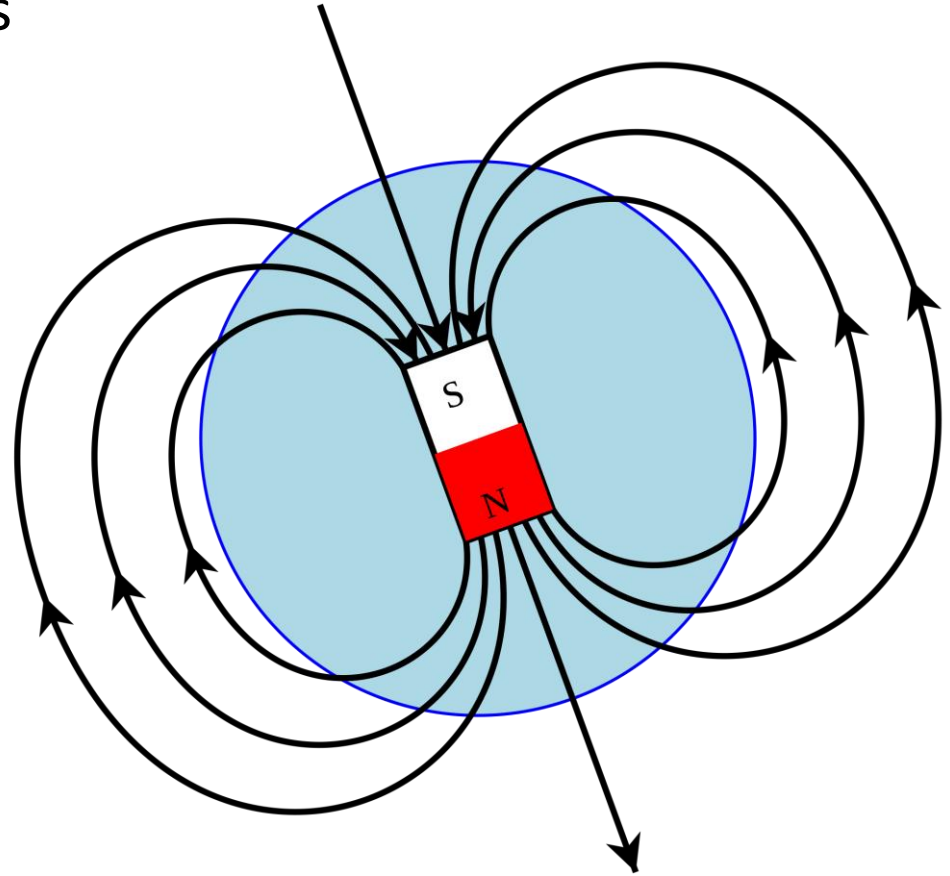


Placing a **magnetic compass** (which contains a small bar magnet) in the magnetic field of a bar magnet causes the compass needle to point in the direction of the magnetic field.



A **magnetic compass** contains a small **bar magnet**. The Earth has a magnetic field. The compass points in the **direction of the Earth's magnetic field**.

The magnetic field pattern produced by compass needles leads us to conclude that the **Earth's core is magnetic**. The origin of the Earth's magnetic field is thought to be the movement of **molten iron** in the core.

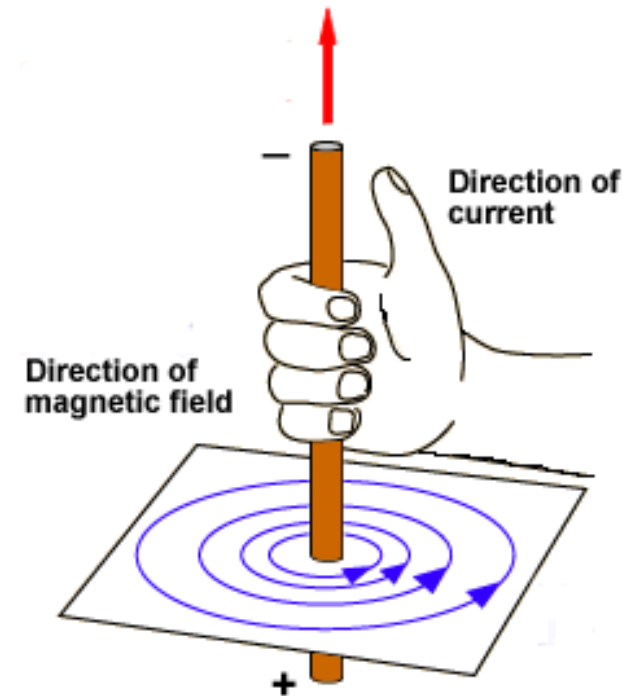


When a current flows through a conducting wire a magnetic field is produced around the wire.

The strength of the magnetic field depends on the current through the wire and the distance from the wire.

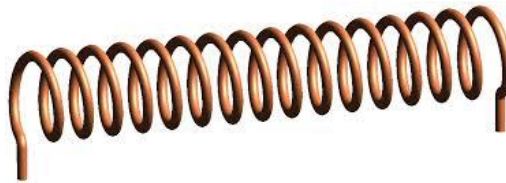
Increasing the current through the wire **increases the strength** of the magnetic field.

Increasing the distance from the wire **decreases the strength** of the magnetic field.

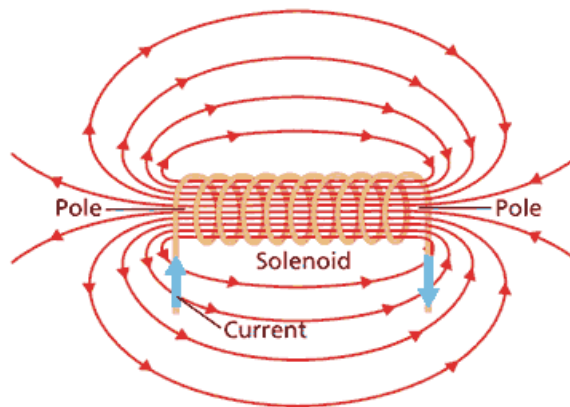


A solenoid is a **coil of wire** used to produce a **magnetic field**.

Shaping a wire to make a solenoid **increases the strength** of the magnetic field created by the current through the wire.



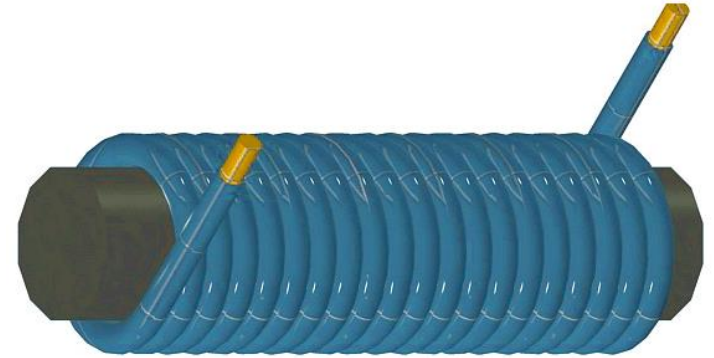
The magnetic field of a solenoid has a **similar shape to that of a bar magnet** – though the magnetic field extends inside the solenoid and is **strong and uniform**.



Making the magnetic field of a solenoid stronger

It is possible to increase the strength of a solenoid's magnetic field by...

1. Adding **an iron core** to a solenoid.
2. **Increasing the current** through the solenoid.
3. **Increasing the number of turns of wire** on the solenoid.



A solenoid with an iron core is an electromagnet.

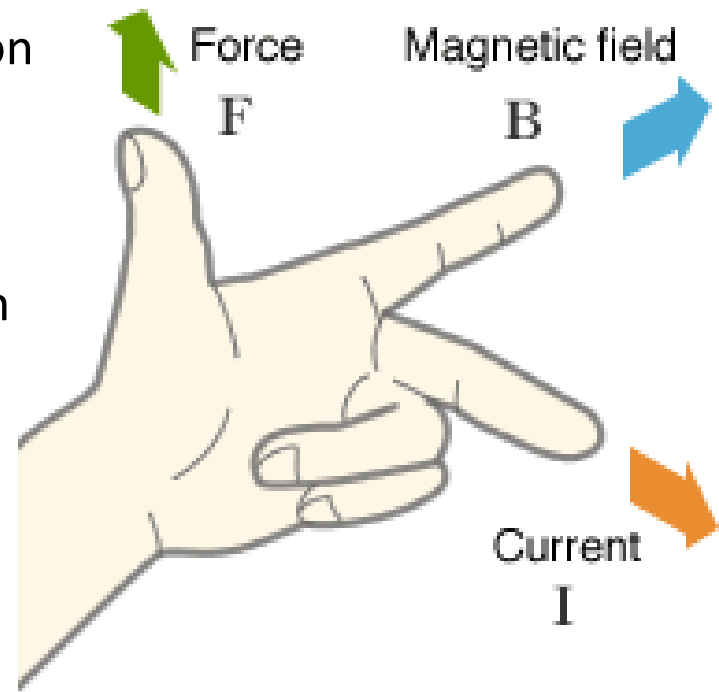
Fleming's Left-Hand Rule

When a **conductor carrying a current** is placed in a **magnetic field** the **magnet** producing the field and the **conductor** exert a **force** on each other. This is called the **motor effect**.

The direction of the force can be found if the direction of the current flow and the direction of the magnetic field are known.

In the diagram the thumb, first finger and second finger are held at right angles to each other.

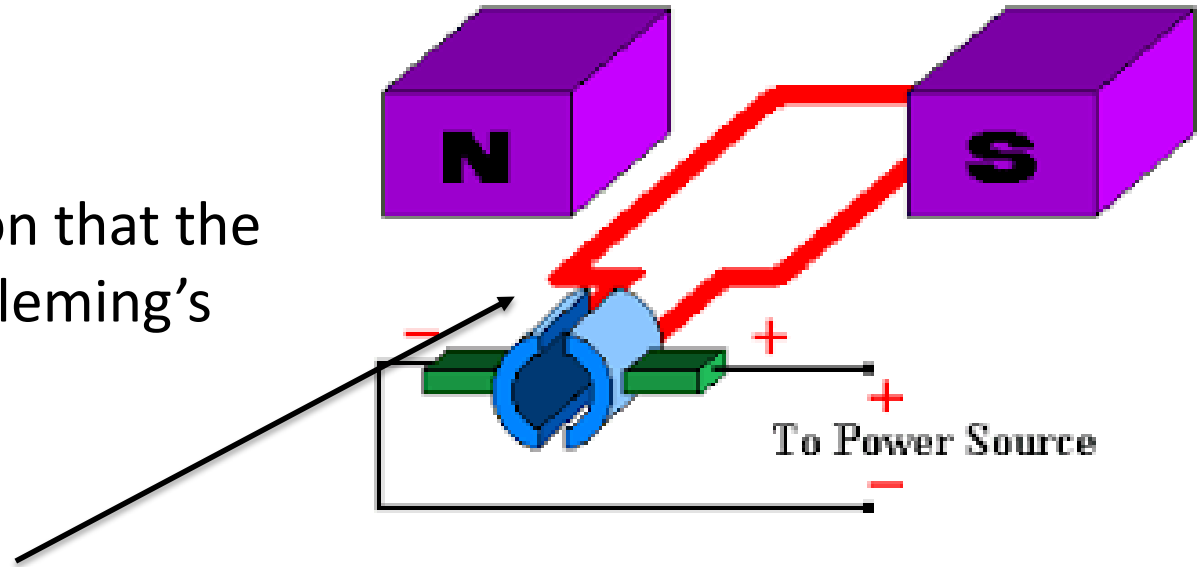
- First Finger** – Field (magnetic N to S)
- Second Finger** – Direction of current flow
- Thumb** – Direction of Force (motion)



Motors

Example:

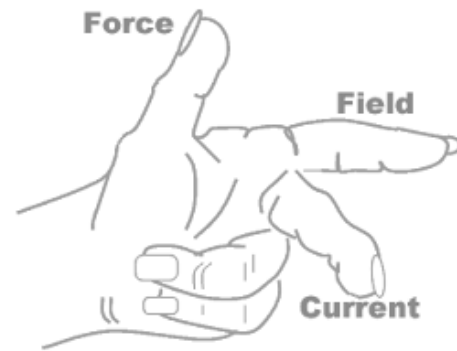
Determine the direction that the motor will spin using Fleming's left-hand rule.



Solution:

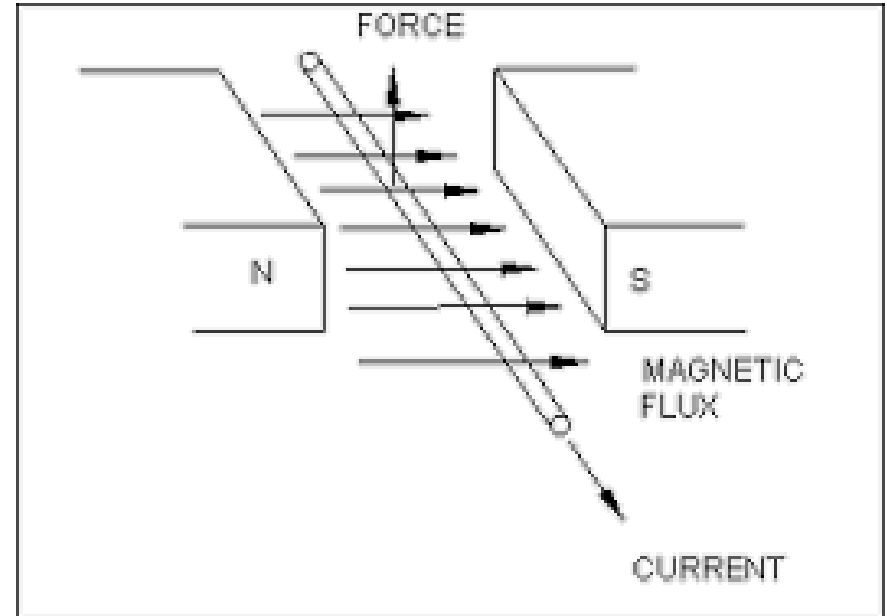
Looking at the wire **next to the North seeking pole** of the magnet...

- **Magnetic field** (first finger) is pointing to the **right** (North to south).
- **Current flow** (second finger) is pointing **towards you**.
- (Remember, conventional flow is + to -)
- **Force/Motion** of the wire will be **upwards** (so the motor will spin clockwise).



The factors that affect the force on a conductor are:

- **Magnetic Flux Density (B) in tesla**
- **Current (I) in amperes**
- **Length of Conductor (l) in metres**



These quantities are linked by the equation:

force on a conductor (N) = magnetic flux density (T) x current (A) x length (m)

$$F = BIl$$

Example:

A 6 cm wire placed in a magnetic field carries a current of 50 mA.

Work out the force on the current carrying wire if the magnetic field strength of the magnetic field is 0.25 T.

Solution:

First step is convert the units: 6 cm = 0.06 m and 50 mA = 0.05 A

Then:

$$F = BIl$$

$$F = 0.25 \times 0.05 \times 0.06$$

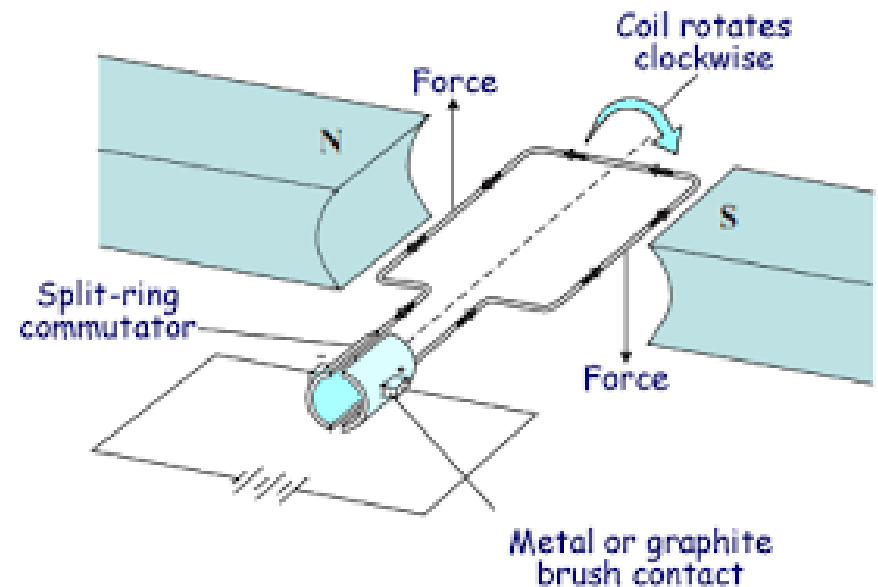
Click to reveal answer

A coil of wire carrying a current in a magnetic field tends to rotate. This is the basis of an electric motor.

As the coil of wire carrying a current is in a magnetic field, the coil will experience a **force** (the direction of which can be found from **Fleming's left-hand rule**).

The coil of wire shown will experience an **upwards force on the left-hand side** of the coil and a **downwards force on the right-hand side of the coil**.

As the coil will be **fixed** to an axle the coil of wire will **rotate in a clockwise direction**.



QuestionIT!

Part 1

- Magnets and magnetic fields
- Electromagnetism
- Magnetic forces



- 1. What are the poles of a magnet?**
- 2. When two magnets are brought together what do they do?**
- 3. When a magnet and a magnetic material are brought together what do they do?**
- 4. What is a permanent magnet?**
- 5. What is an induced magnet?**

- 6. Describe the difference between permanent and induced magnets.**
- 7. Which part of a magnet has the strongest magnetic field?**
- 8. Two magnets are placed close together, north seeking pole to north seeking pole. Describe the forces acting on the two magnets.**
- 9. Name three magnetic elements.**

- 10. Describe two methods for finding the magnetic field pattern of a bar magnet.**
- 11. Draw the magnetic field pattern of a bar magnet.**
- 12. How would you describe the direction of a magnetic field line?**
- 13. What does a magnetic compass contain?**
- 14. Which way does the compass needle point?**
- 15. What do scientists think is the cause of the Earth's magnetic field?**

- 16. What is produced when a current flows through a conducting wire?**
- 17. Name two factors which will impact on your answer to question**
- 18. What is a solenoid?**
- 20. Describe the magnetic field inside a solenoid.**
- 21. State three ways of increasing the strength of the magnetic field produced by a solenoid.**

22. Draw the magnetic field pattern produced by a solenoid.

23. What is an electromagnet?

24. (HT) Describe the motor effect.

25. (HT) What 3 factors does Fleming's left hand-rule represent?

26. (HT) Give three ways of making the electric motor spin faster.

27. (HT) A 40 cm piece of wire is placed in a magnetic field of strength 0.4 T. The wire carries a current of 60 mA. Work out the force on the wire using the equation: Force = magnetic flux density x current x length.

28. (Physics HT only) Explain how a loudspeaker works.

AnswerIT!

Part 1

- Magnets and magnetic fields
- Electromagnetism
- Magnetic forces



1. What are the poles of a magnet?

- **Places where the magnetic forces are strongest.**

2. When two magnets are brought together what do they do?

- **Exert a force on each other; attraction or repulsion.**

3. When a magnet and a magnetic material are brought together what do they do?

- **Attract.**

4. What is a permanent magnet?

- **Material that produces its own magnetic field.**

5. What is an induced magnet?

- **Material that becomes a magnet when it is placed in a magnetic field.**

6. Describe the difference between permanent and induced magnets.

- Permanent produces its own field/ induced becomes magnetic when placed in a field.
- Permanent can attract or repel/ induced always attracts.
- Induced magnet loses most/all of its magnetism quickly when removed from magnetic field.

7. Which part of a magnet has the strongest magnetic field?

- Poles.

8. Two magnets are placed close together, north seeking pole to north seeking pole. Describe the forces acting on the two magnets.

- Repulsion.

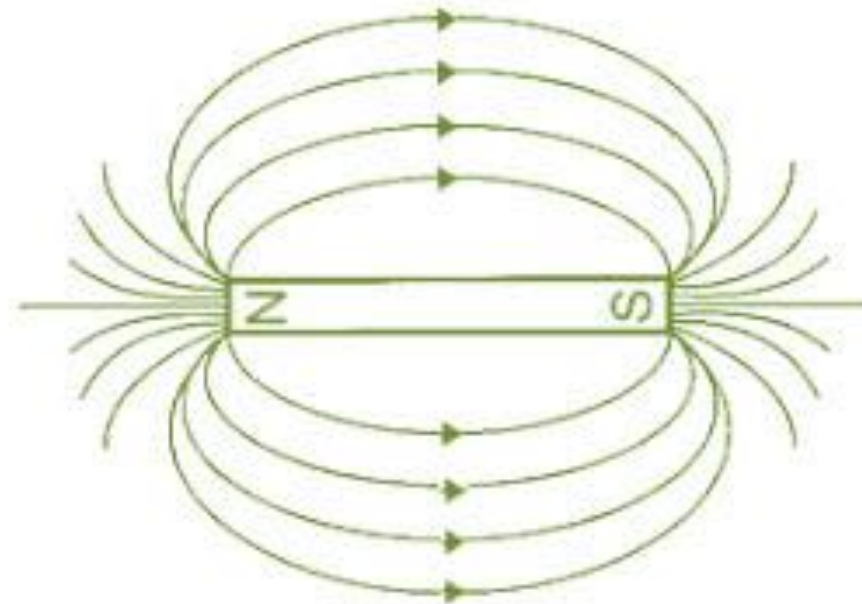
9. Name three magnetic elements.

- Iron, steel, cobalt, nickel.

10. Describe two methods for finding the magnetic field pattern of a bar magnet.

- **Sprinkle iron filings onto paper, tap paper.**
- **Use small compasses to follow field from poles; mark paper at the compass needle end.**

11. Draw the magnetic field pattern of a bar magnet.



12. How would you describe the direction of a magnetic field line?

- **Given by the direction of the force that would act on another north pole placed at that point/ from the north (seeking) pole to the south (seeking) pole.**

13. What does a magnetic compass contain?

- **Small bar magnet.**

14. Which way does the compass needle point?

- **In the direction of the Earth's magnetic field.**

15. What do scientists think is the cause of the Earth's magnetic field?

- **Molten iron core.**

16. What is produced when a current flows through a conducting wire?

- **Magnetic field.**

17. Name two factors which will impact on your answer to question

- **Current flowing through the wire, distance from the wire.**

18. What is a solenoid?

- **Coil of wire in which a magnetic field is created by passing a current through it.**

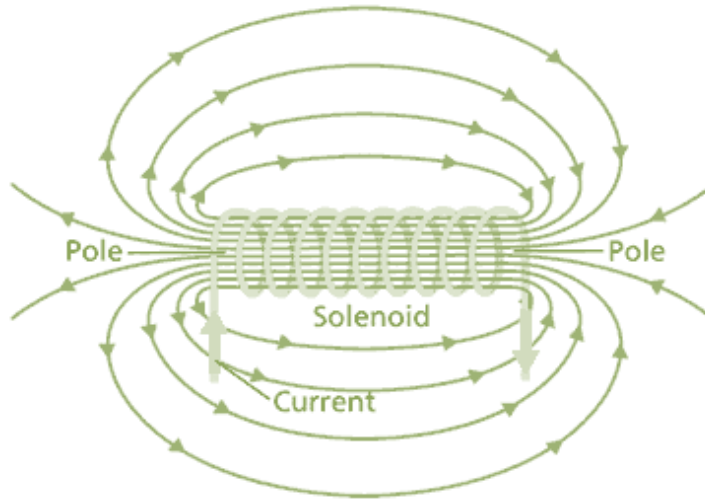
20. Describe the magnetic field inside a solenoid.

- **Strong and uniform.**

21. State three ways of increasing the strength of the magnetic field produced by a solenoid.

- **Increase the current**

22. Draw the magnetic field pattern produced by a solenoid.



23. What is an electromagnet?

- **Solenoid with an iron core.**

24. (HT) Describe the motor effect.

- **Conductor carrying current placed in magnetic field; magnet and conductor exert a force on each other; this force = motor effect.**

25. (HT) What 3 factors does Fleming's left hand-rule represent?

- **The force, the current in the conductor, the magnetic field.**

26. (HT) Give three ways of making the electric motor spin faster.

- **Increase the current; increase the number of turns on the coil; increase the strength of the magnets.**

27. (HT) A 40 cm piece of wire is placed in a magnetic field of strength 0.4 T. The wire carries a current of 60 mA. Work out the force on the wire using the equation: Force = magnetic flux density x current x length.

- 0.0096 N
- 40 cm = 0.4 m
- 60 mA = 0.06 A
- $F = BIl$ $F = 0.4 \times 0.06 \times 0.4 \text{ N}$

28. (Physics HT only) Explain how a loudspeaker works.

- A fluctuating electric current flows through the coil of wire. The coil of wire then becomes an electromagnet.
- The electromagnet is then attracted or repelled away from the magnet.
- This causes the cone to move – producing a sound.

Part 2

-
- A hand holding a sphere covered in educational and professional terms like 'learning', 'knowledge', 'experience', 'education', and 'mathematics'.

If an electrical conductor moves relative to a magnetic field or if there is a change in the magnetic field around a conductor, a **potential difference** is **induced** across the ends of the conductor. If the conductor is part of a complete circuit, a current is **induced** in the conductor. This is called **the generator effect**.

Induced means to bring about, produce or cause. An induced current is one that is produced by moving a conductor relative to a magnetic field.

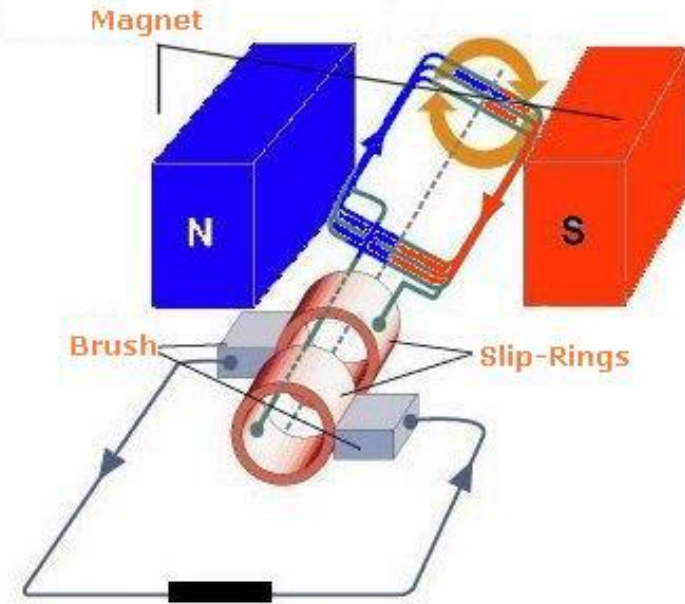
An **induced current generates a magnetic field** that **opposes the original change**, either the movement of the conductor or the change in magnetic field.

A simple generator will have a **coil of wire** that **moves** in a **magnetic field**.

A potential difference is induced across the ends of the conductor – and as there is a complete circuit a current is induced in the coil of wire.

To **increase** the size of the induced potential difference/current...

- The coil of wire should be **rotated faster**;
- The **magnetic field** should be made **stronger**;
- The **number of turns** of wire on the coil should be **increased**.



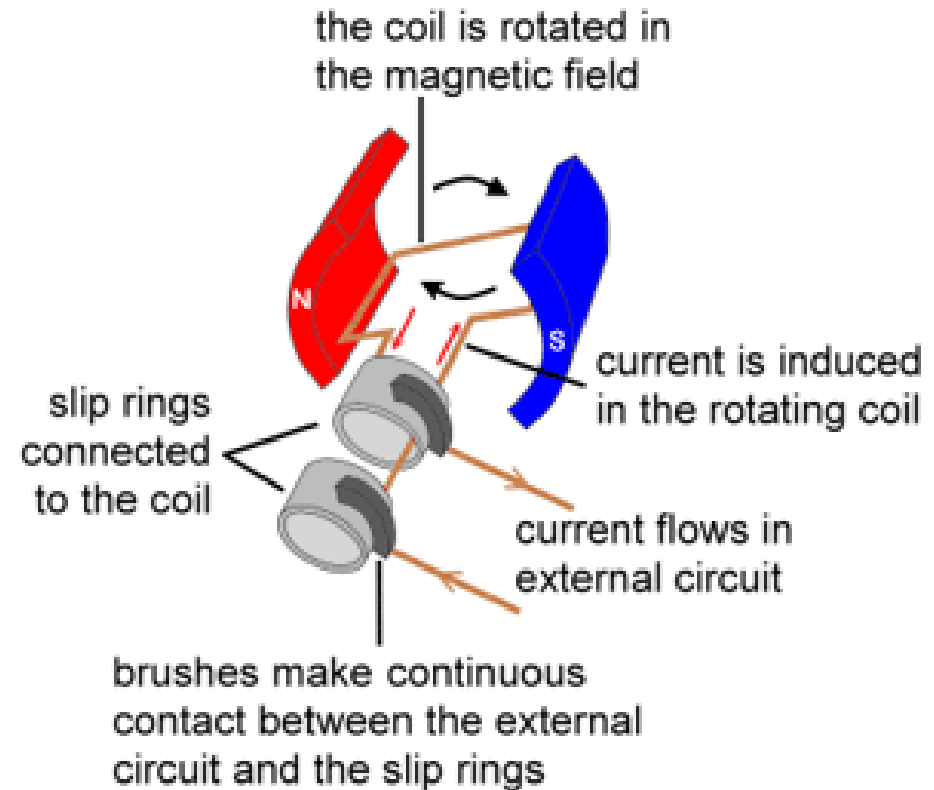
The direction of the induced potential difference/induced current are **dependent on the direction of rotation** of the coil and the orientation of the magnetic field.

- **Reversing the direction** of rotation of the coil will reverse the direction of the induced potential difference/induced current.
- **Swapping the polarity** of both magnets will also reverse the direction of the induced potential difference/induced current.
- **Swapping the direction of rotation** of the coil **AND swapping the polarity** of each magnet will give no change to the direction of the induced potential difference/induced current (as it would have been reversed and reversed again).

Alternators use the **generator effect** to generate an **alternating current** (ac).

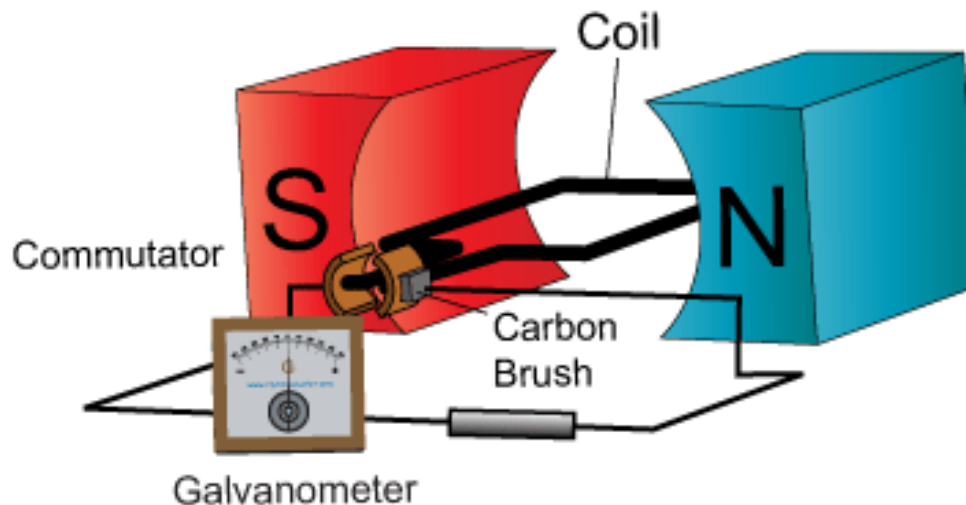
As a coil of wire moves relative to a magnetic field there is an induced potential difference / induced current.

Since the direction of movement of one side of the coil of wire changes, so does the direction of the induced current – so giving ac.



Dynamos use the **generator effect** to generate a **direct current** (dc).

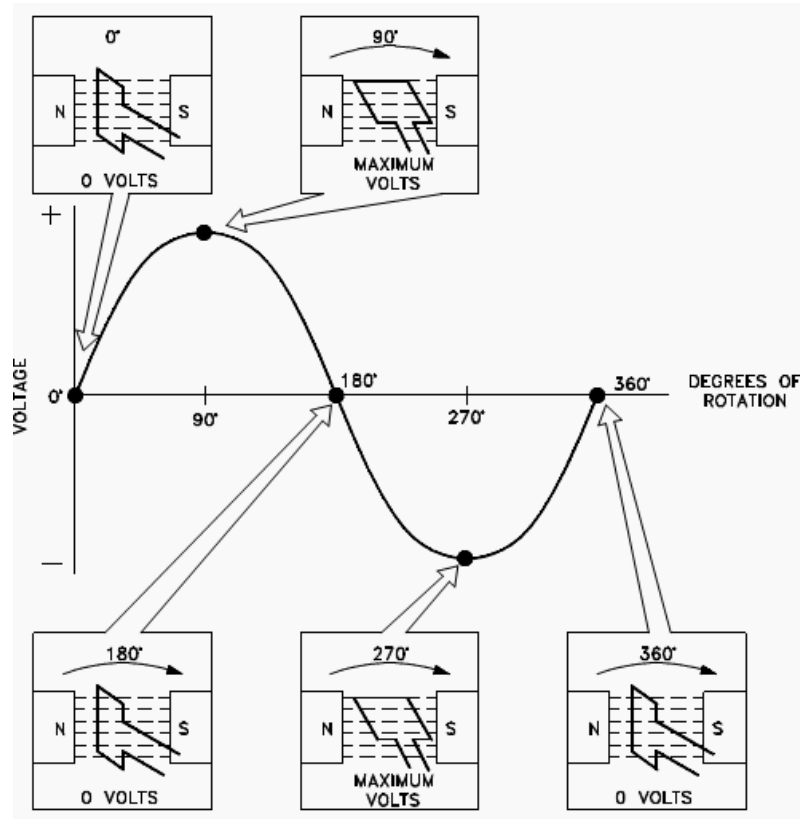
With a dynamo the coil of wire is connected to **split ring commutators** rather than **slip ring commutators**. This means that every half rotation one side of the coil of wire attaches to a different side of the circuit, but as the direction of motion of the coil on the left and right-hand side remain the same the current in the external circuit only moves one way – a dc output.



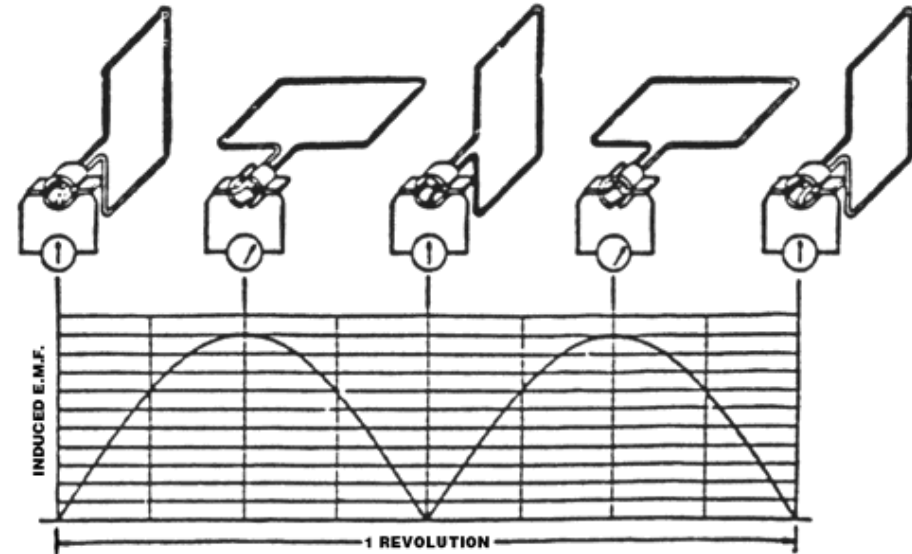
The output of a generator is greatest when the magnetic field lines of the magnets used are being broken at the fastest rate.

For a coil of wire rotating between two magnets the magnetic field lines are being broken fastest when the **coil is moving vertically upwards** – this occurs when the coil of wire and the magnetic field are horizontal.

No current is induced when the coil moves parallel to the magnetic field lines – as no field lines are being broken. The output is zero when the coil of wire is vertical.



Alternator output

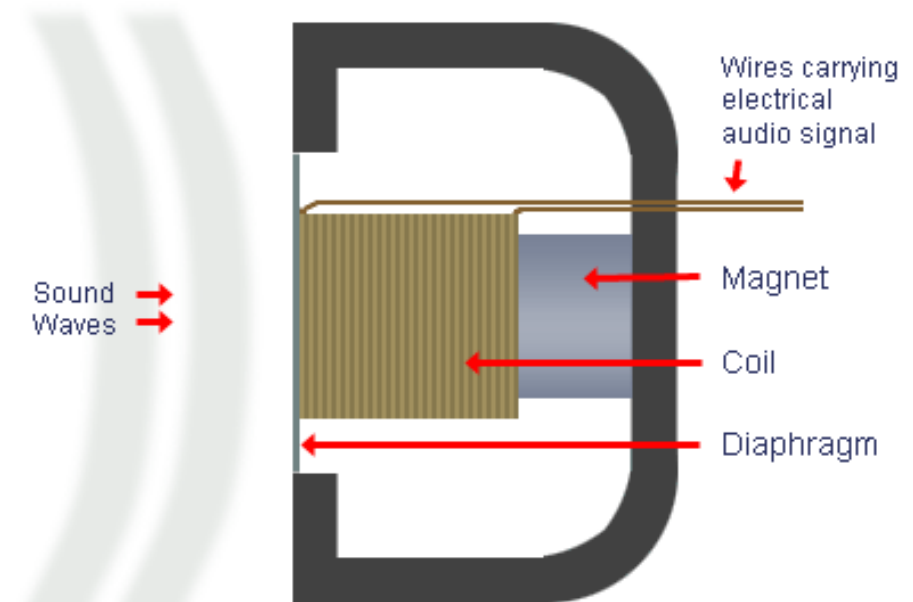


Dynamo output

Microphones use the **generator effect** to convert the **pressure variations** in sound waves into **variations in current** in electrical circuits.

Microphones contain a diaphragm that moves when sound waves hit it. The movement of the **diaphragm** makes the **coil of wire** move relative to the **magnet**, which induces a current in the wires (the generator effect).

Cross-Section of Dynamic Microphone



Loudspeakers and headphones use the **motor effect** to convert **variations in current** in electrical circuits to the **pressure variations in sound waves**.

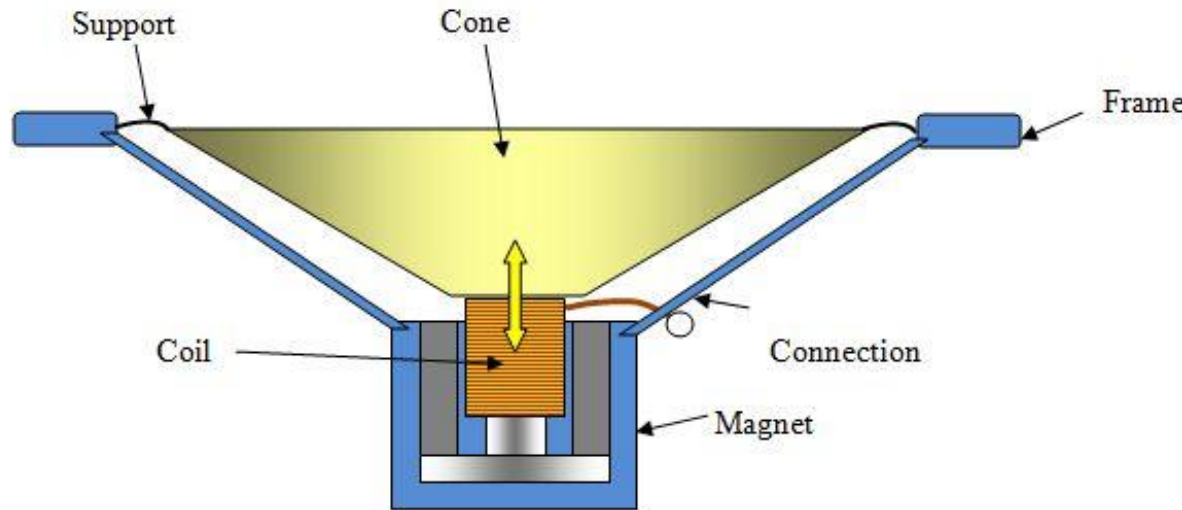


Modern loudspeakers can be wired or wireless.



Headphones are **miniature loudspeakers**. As the headphones only have to move the air inside the ear canal they can be a lot smaller than typical loudspeakers.

Loudspeakers... continued



- A **fluctuating electric current** flows through the **coil of wire**. The coil of wire then becomes an **electromagnet of variable strength**.
- The **electromagnet is then attracted or repelled** away from the **permanent magnet**.
- This **causes the cone to move** – producing a sound.

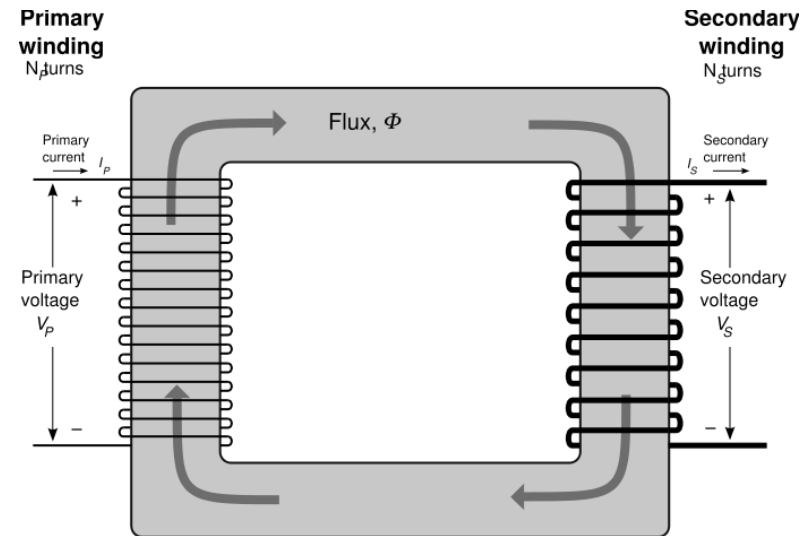
A **basic transformer** consists of a **primary and a secondary coil** wound on an **iron core**.

Iron is used as it is **easily magnetised**.

You need to know about two types of transformer:

- **Step-up transformer**
- **Step-down transformer.**

Transformers (Physics HT only)



The ratio of the **potential differences (in Volts, V)** across the primary and secondary coils of a transformer V_p and V_s depends on the ratio of the number of **turns on each coil**, N_p and N_s .

$$\frac{\text{potential difference across primary coil}}{\text{potential difference across secondary coil}} = \frac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$$

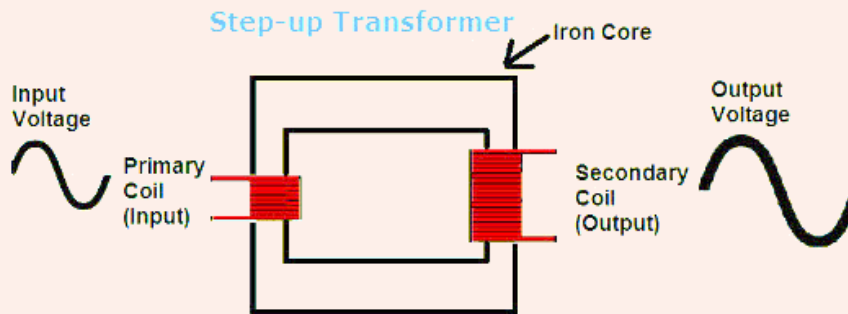
$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

If transformers were **100% efficient**, the **electrical power output** ($V_s \times I_s$) would equal the **electrical power input** ($V_p \times I_p$).

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

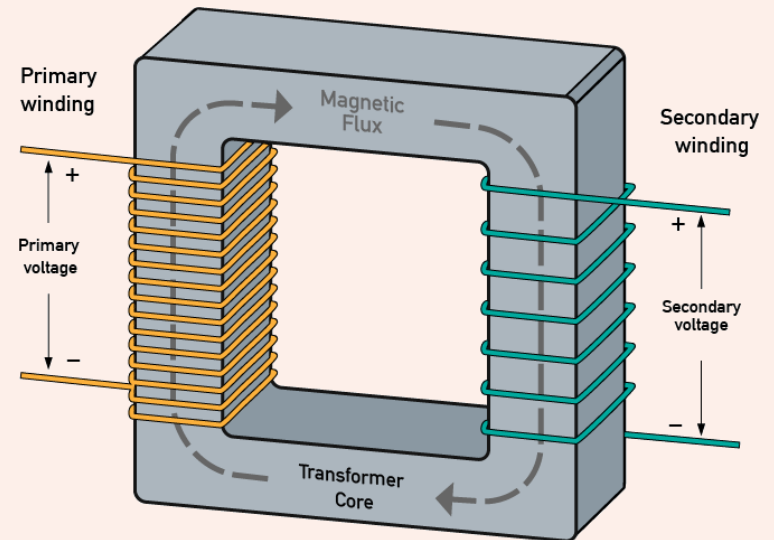
Step-up transformers

- Increase the potential difference so $V_s > V_p$
- More turns on the secondary coil



Step-down transformers

- Decrease the potential difference so $V_s < V_p$
- More turns on the primary coil



- Transformers have a **primary coil of wire** with an **alternating current (ac)** flowing.
- This produces an **alternating magnetic field** in the **iron core**.
- On the **secondary side** of the transformer there is a **coil of wire** and an **alternating magnetic field**.
- So the **magnetic field is moving relative to the coil of wire**.
- This **induces** a potential difference (and **induces** a current if there is a complete circuit). This is the **generator effect**.

Advantages of power transmission at higher voltages

Transformers are used in **the national grid** to make the transmission of electricity more **efficient**.

Increasing the potential difference will **decrease** the current in the overhead powerlines. Assuming that the transformers are 100 % efficient, the power input and power output would be the same, so:

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

Where $V_s \times I_s$ is the power output (secondary coil) and $V_p \times I_p$ is the power input (primary coil).

Potential difference and **current** are **inversely proportional**. A lower current means that the powerlines will heat up less, less energy will be 'lost' as heat.

Example 1

A step-up transformer has 100 turns of wire on the primary coil and 400 turns of wire on the secondary coil.

The input potential difference on the primary coil is 12 V. Work out the output potential difference of the transformer.

Using

$$V_p / V_s = N_p / N_s$$

Substituting gives

$$12 / V_s = 100 / 400$$

Rearranging gives

$$V_s = \frac{12 \times 400}{100}$$

Alternatively, there are four times as many turns of wire on the secondary coil the output potential difference is four times greater.

[Click to reveal answer](#)

Example 2

A step-down transformer has an input potential difference of 230 V. The output potential difference is 12 V and the current in the secondary coil is 30 mA.

Work out the current in the primary coil.

Assuming no power losses in the transformer...

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

Substituting gives

$$12 \times 0.03 = 230 \times I_p$$

Rearranging gives

$$\frac{12 \times 0.03}{230} = I_p$$

[Click to reveal answer](#)

QuestionIT!

Part 2

- Electromagnetic induction
- The national grid
- Transformers



1. What does the term 'induced current' mean?
2. What is a simple generator made of?
3. How can the size of the induced potential difference/ current in a generator be increased?
4. What factors affect the direction of the induced potential difference/ current?
5. What type of current is induced by an alternator?
6. What type of current is produced by a dynamo?

7. Describe two ways of reversing the direction of current flow on a dynamo.
8. At which point of the rotation does a dynamo induce the greatest potential difference?
9. How do microphones use the generator effect?
10. What does a basic transformer contain?
11. Why are cores made of iron?

AnswerIT!

Part 2

- Electromagnetic induction
- The national grid
- Transformers



1. What does the term 'induced current' mean?
Current made by moving a conductor relative to a magnetic field.
2. What is a simple generator made of?
Coil of wire; magnetic field, movement.
3. How can the size of the induced potential difference/ current in a generator be increased?
More turns, stronger magnetic field, increase speed of movement.
4. What factors affect the direction of the induced potential difference/ current?
Direction of movement/ rotation; reversing the polarity.
5. What type of current is induced by an alternator? ac
6. What type of current is produced by a dynamo? dc

7. Describe two ways of reversing the direction of current flow on a dynamo.

Swap the polarity of both magnets.

Spin the coil of wire in the opposite direction.

8. At which point of the rotation does a dynamo induce the greatest potential difference?

When the coil of wire is perpendicular to the magnetic field; it is at this point that the magnetic field lines are being cut at the greatest rate.

9. How do microphones use the generator effect?

Convert the pressure variations in sound waves into variations in current.

10. What does a basic transformer contain?

Primary coil, secondary coil, iron core.

11. Why are cores made of iron? Easily magnetised.

12. What can be said about the potential difference in the primary and secondary coils of a step-down transformer?

$$V_s < V_p$$

13. How do transformers work?

- Transformers have a **primary coil of wire** with an **alternating current (ac)** flowing.
- This produces an **alternating magnetic field** in the **iron core**.
- On the **secondary side** of the transformer there is a **coil of wire** and an **alternating magnetic field**.
- So the **magnetic field is moving relative to the coil of wire**.
- This **induces** a potential difference (and **induces** a current if there is a complete circuit). This is the **generator effect**.

14. A step-up transformer is used in a power station to increase the potential difference output from 25,000 V to 400,000 V. The current through the overhead power lines is 25 A. Work out the current in the primary coil.

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

400 A

16 times more potential difference so 16 times less current.

$V_s \times I_s = V_p \times I_p$ or correct substitution.

15. Why are transformers used when sending electricity through the National Grid?

Increases potential difference; decreases current; decreases loss of energy through heat.