Clarendon
Sixth Form College

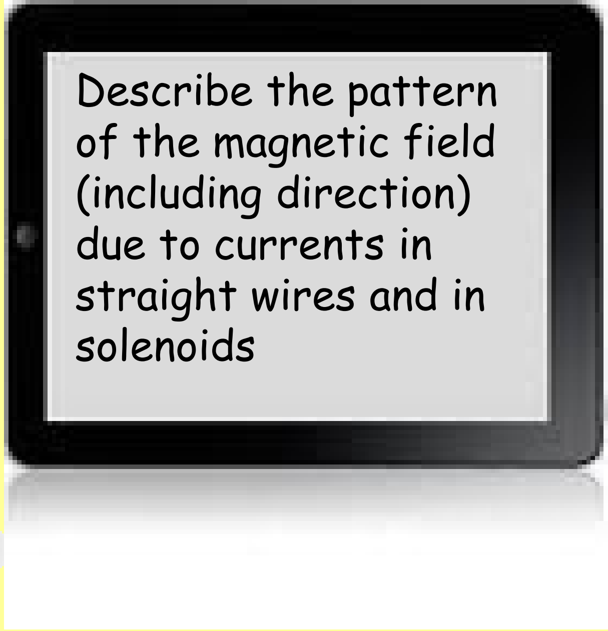
# Electromagnetics

## Electromagnetic Effects (2)

Applicant Study Pack

# LEARNING OBJECTIVES

| Core | Supplement |
| --- | --- |
| • Describe the pattern of the magnetic field (including direction) due to currents in straight wires and in solenoids<br>• Describe applications of the magnetic effect of current, including the action of a relay<br>Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing: – the current – the direction of the field<br>State that a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by: – increasing the number of turns on the coil – increasing the current – increasing the strength of the magnetic field | State the qualitative variation of the strength of the magnetic field over salient parts of the pattern<br>• State that the direction of a magnetic field line at a point is the direction of the force on the N pole of a magnet at that point<br>• Describe the effect on the magnetic field of changing the magnitude and direction of the current<br>State and use the relative directions of force, field and current<br>• Describe an experiment to show the corresponding force on beams of charged particles<br>Relate this turning effect to the action of an electric motor including the action of a split-ring commutator |



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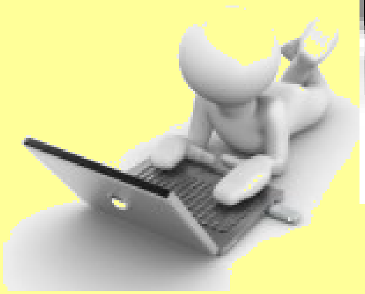
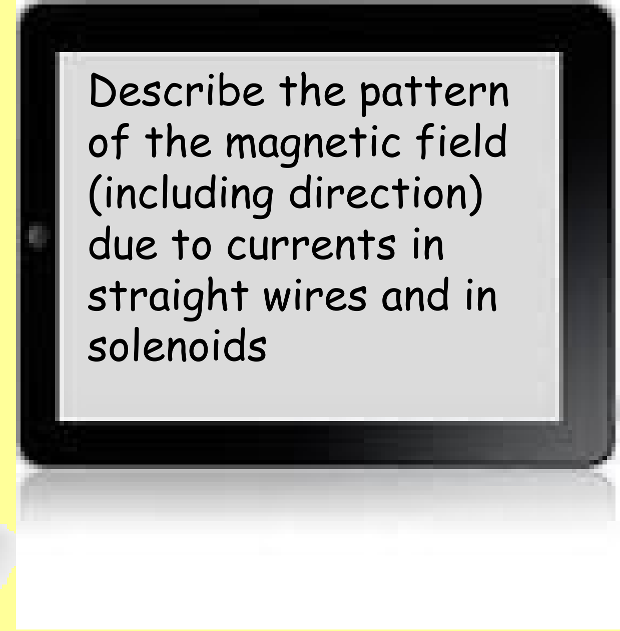
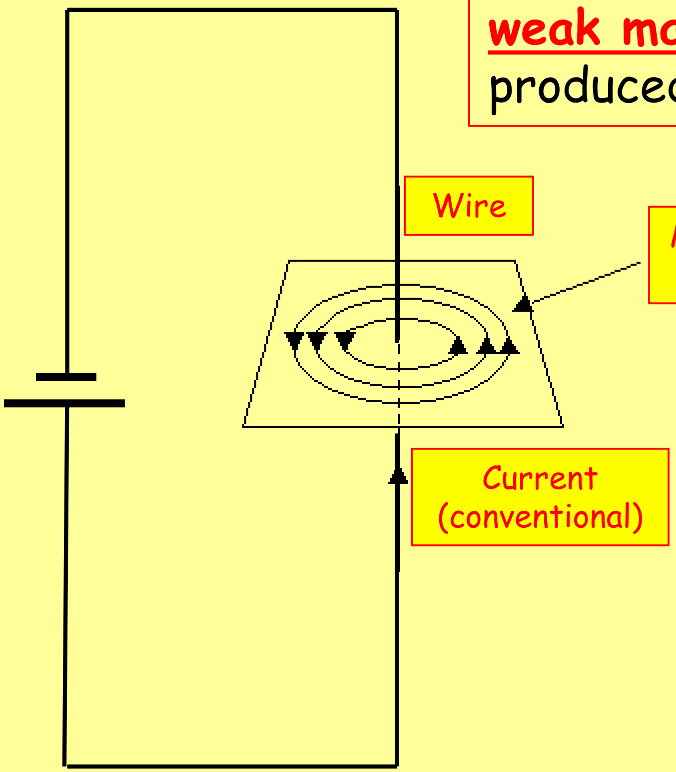
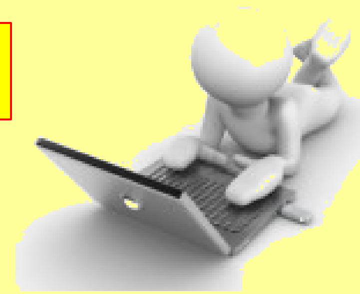
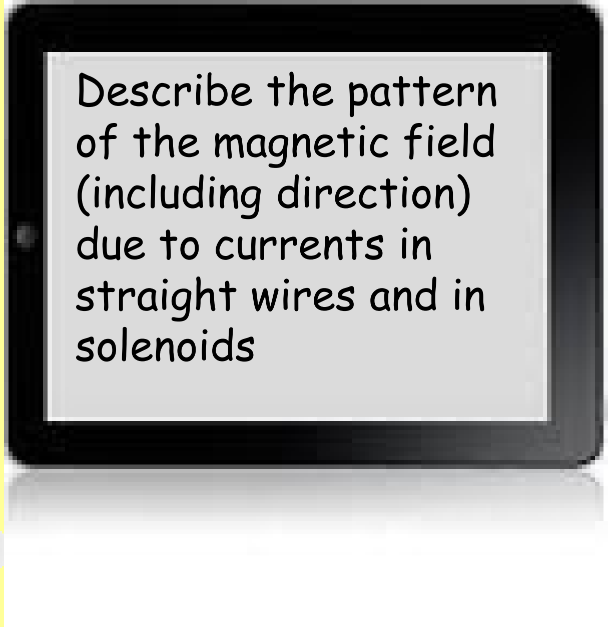





If an **electric current** is passed through a **wire**, a **weak magnetic field** is produced.



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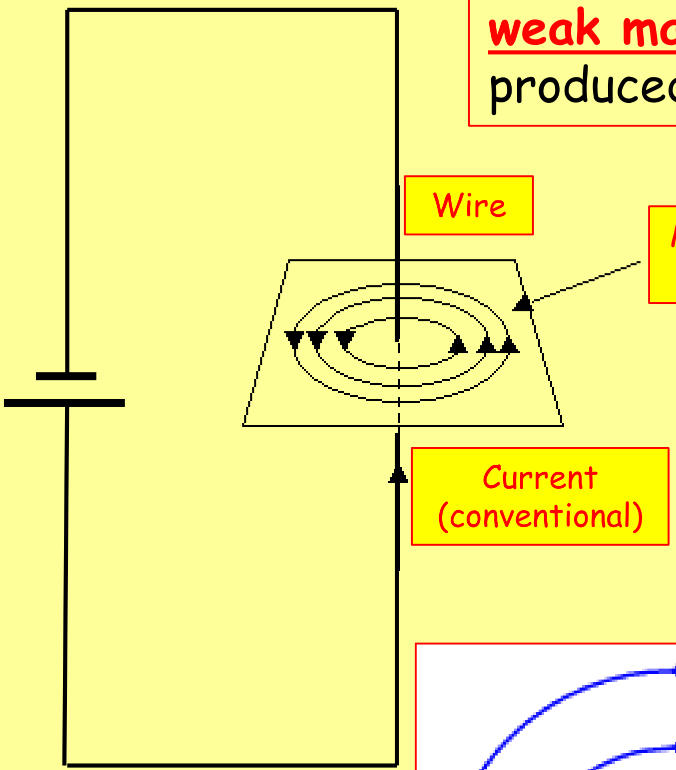
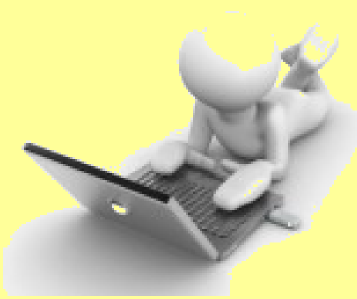
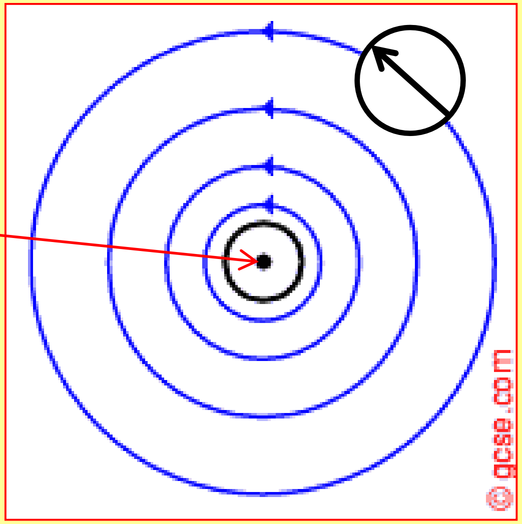
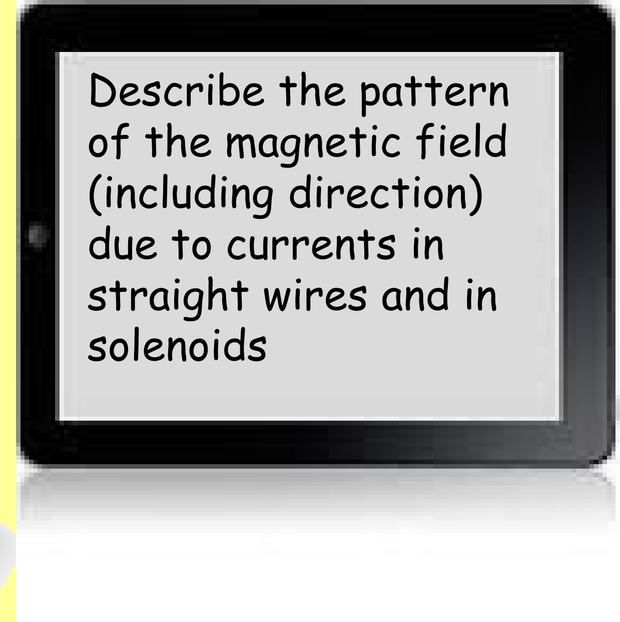


**Field lines** can be followed and plotted using a **plotting compass**.




The 'dot' represents the current flowing upwards (as shown in the diagram above)

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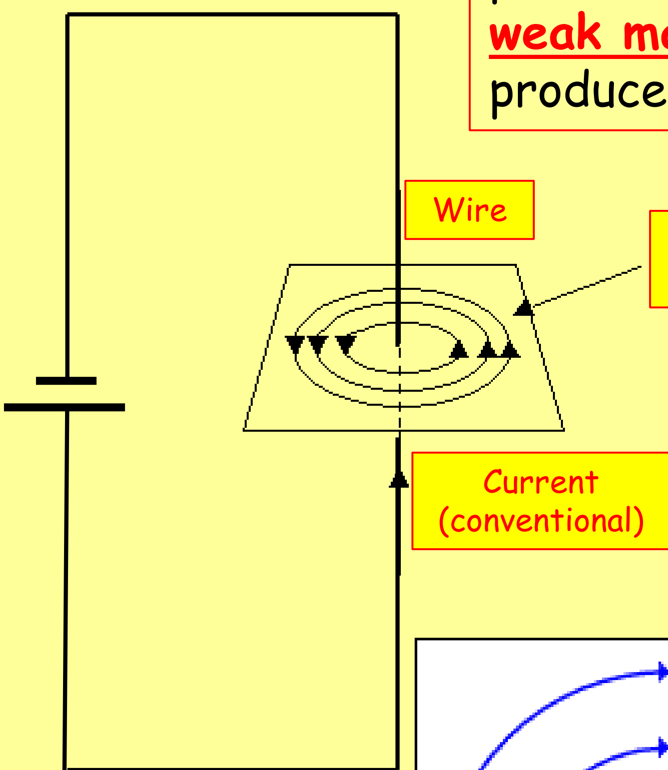


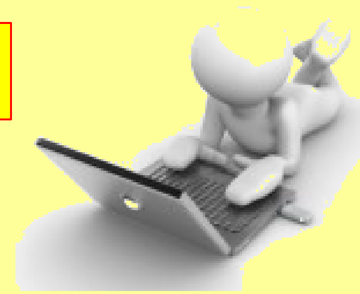

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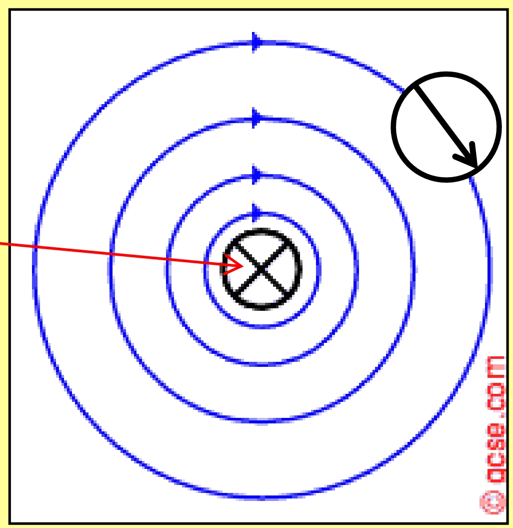

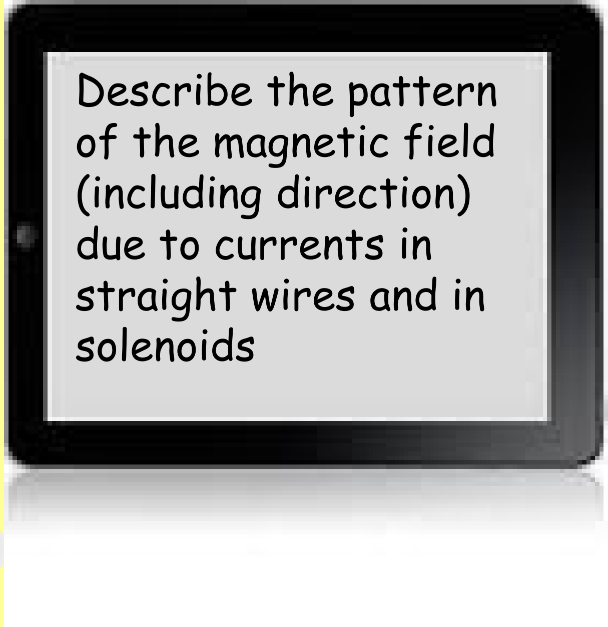


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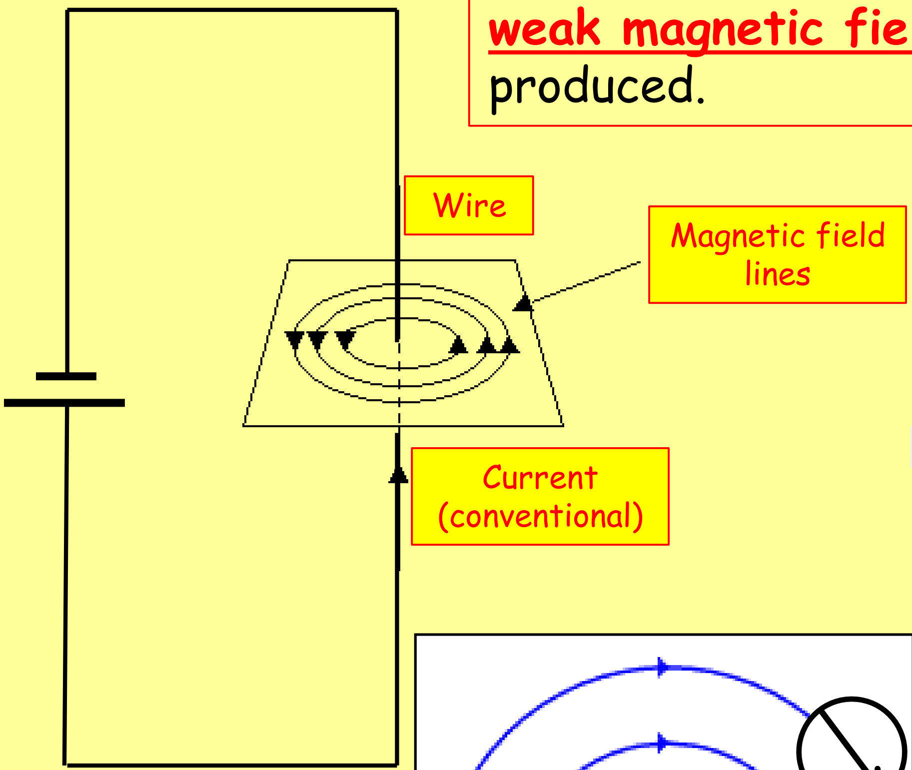


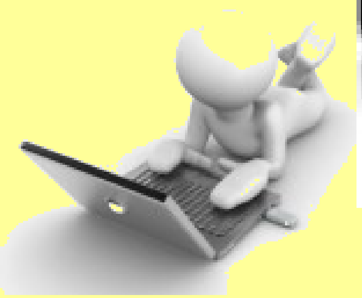

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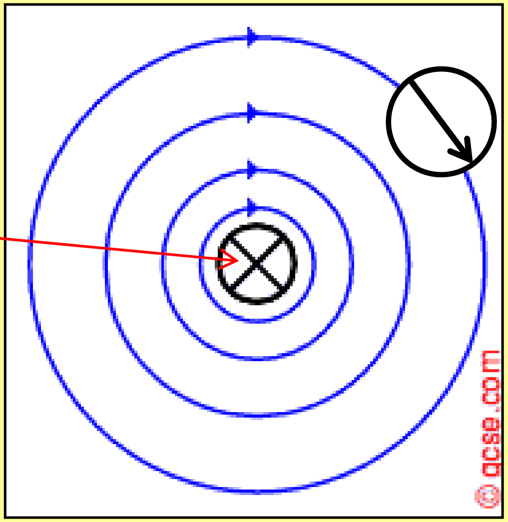


The 'cross' represents the current flowing downwards (the field direction is reversed).

Field features:

1. The **magnetic field lines** are **circles**.
2. The field is **strongest closer** to the wire.
3. Increasing the **current** increases the **field strength**.

How do we know the direction of the magnetic field produced by a current?

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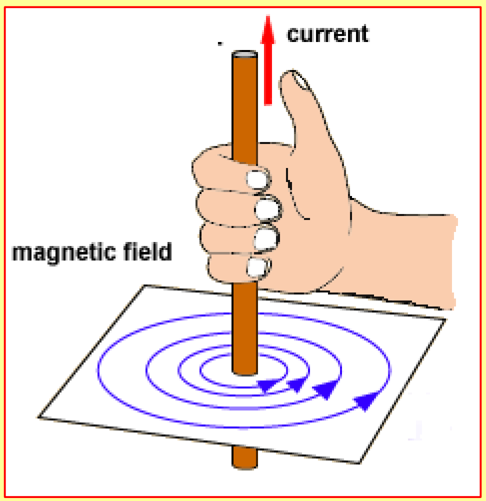
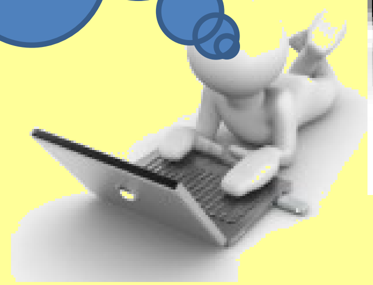



Imagine gripping the wire with your **right hand** so that your **thumb points** in the **current** direction (conventional). Your **fingers** then point in the **same direction** as the **field lines**.

What is a solenoid?



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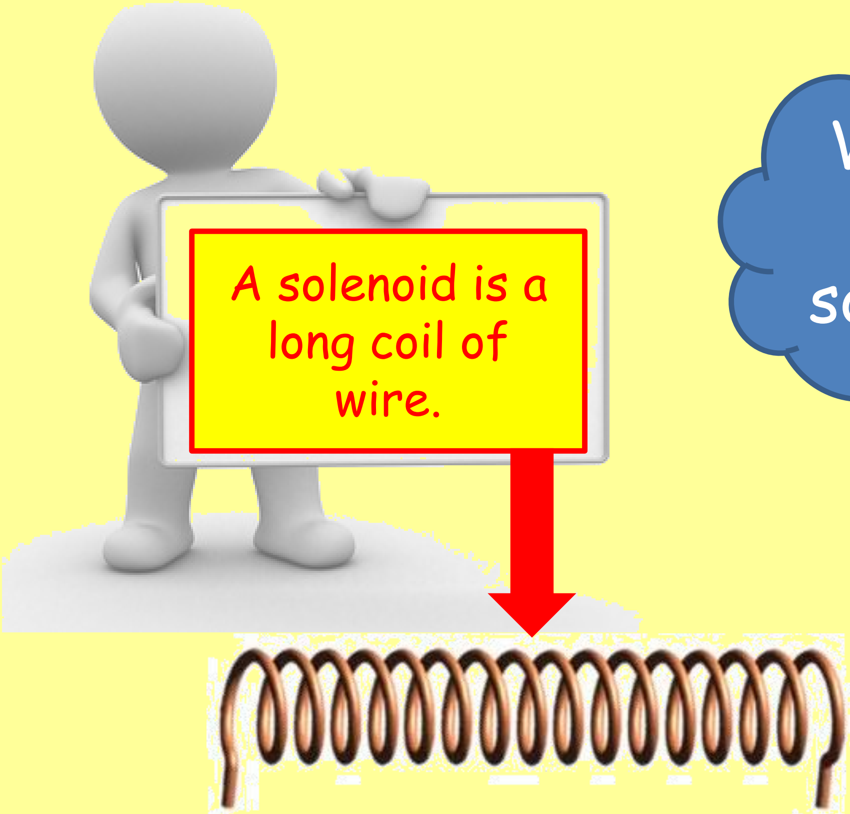
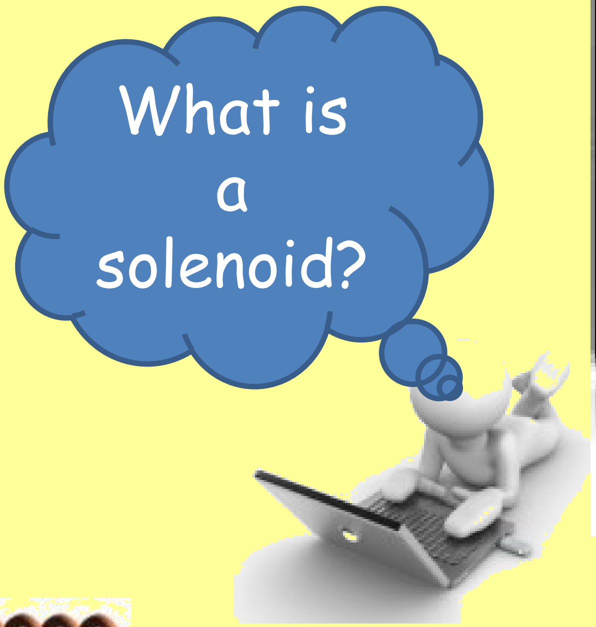

A solenoid is a long coil of wire.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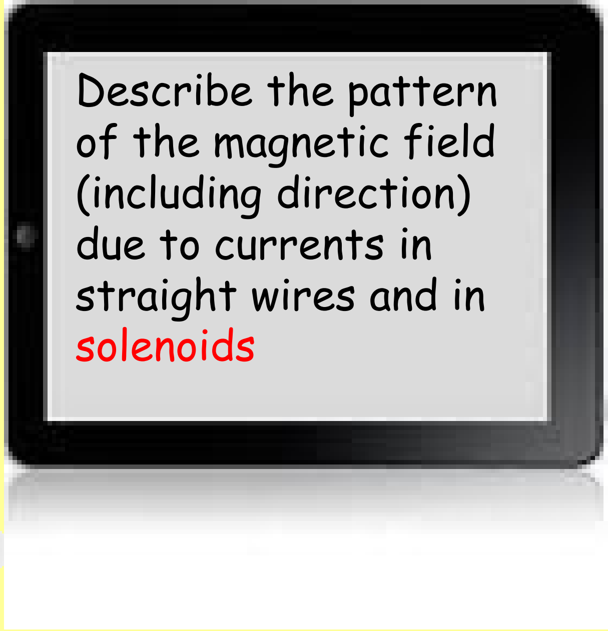
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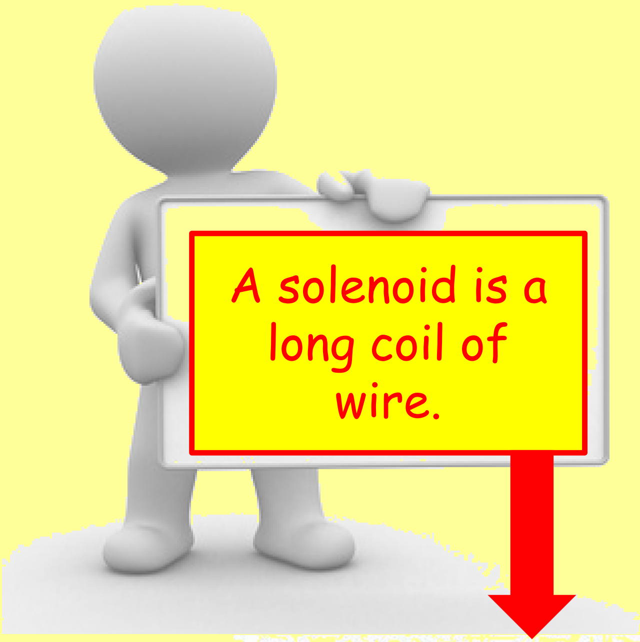


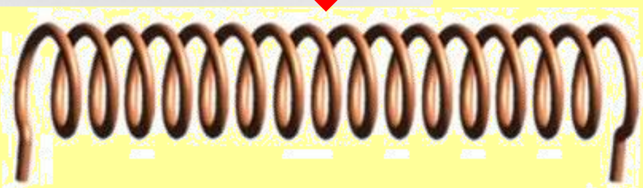

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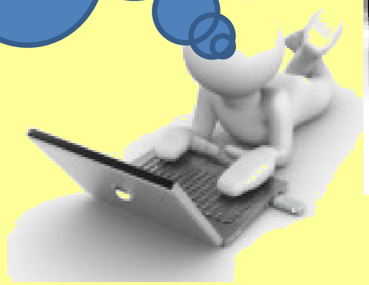
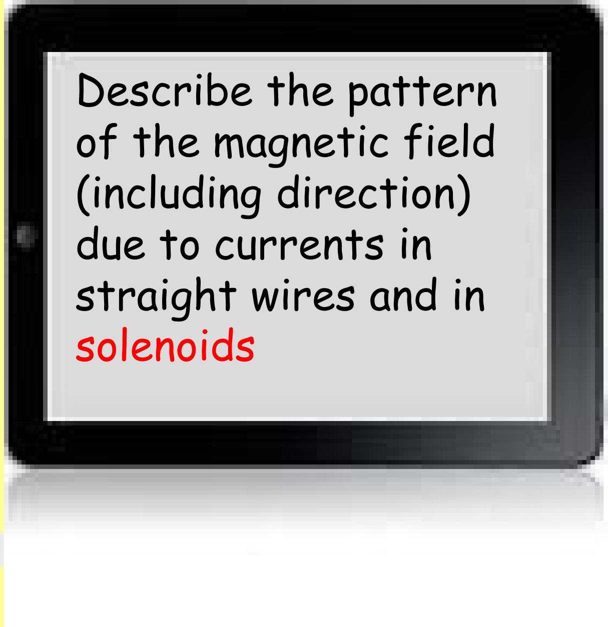
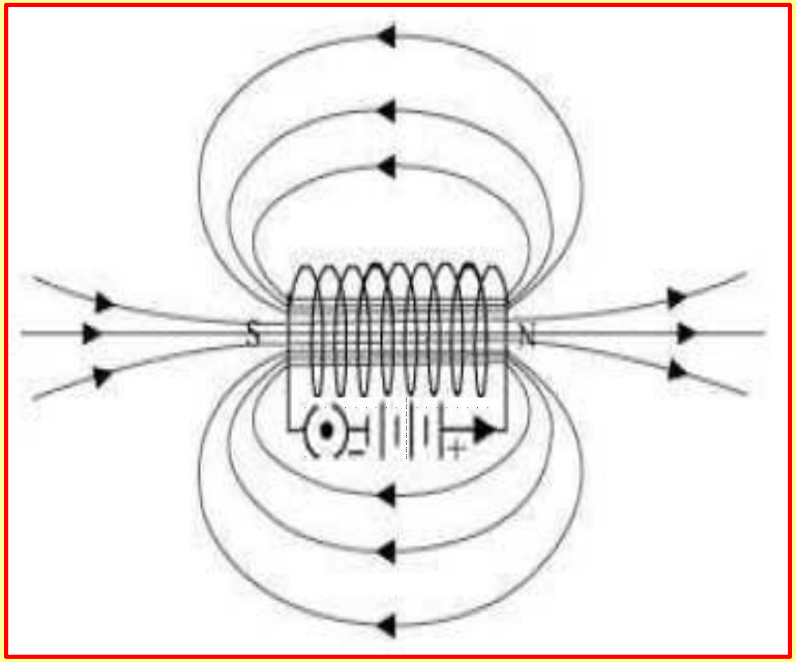


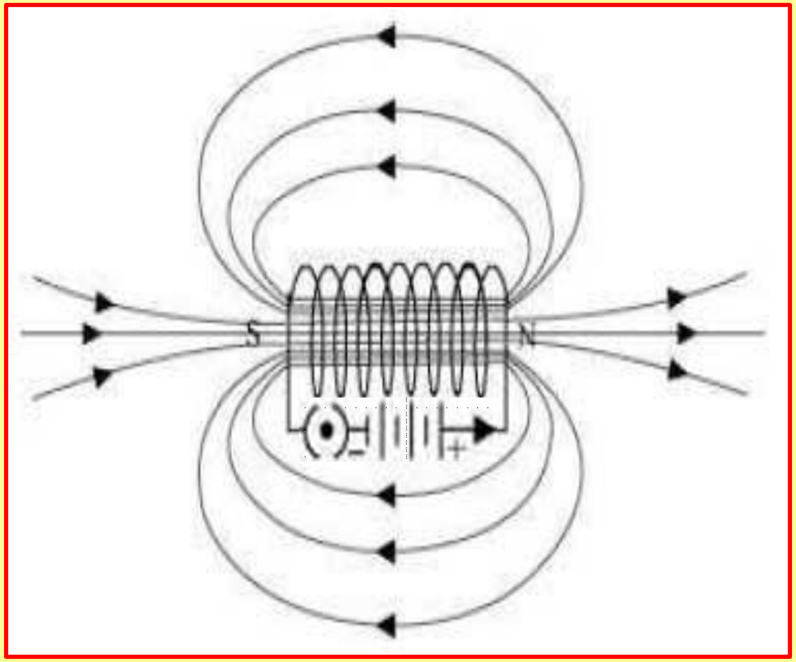



A **current** produces a **much stronger** magnetic field if the **wire** it flows through is **wound** into a **solenoid coil**.




Features of the magnetic field produced:

1. The field is **similar** to that produced by a **bar magnet**, with **North** and **South** poles.
2. The **strength** of the field **increases** as the **current increases**.
3. The **strength** of the field **increases** as the **number of turns** on the coil **increases**.

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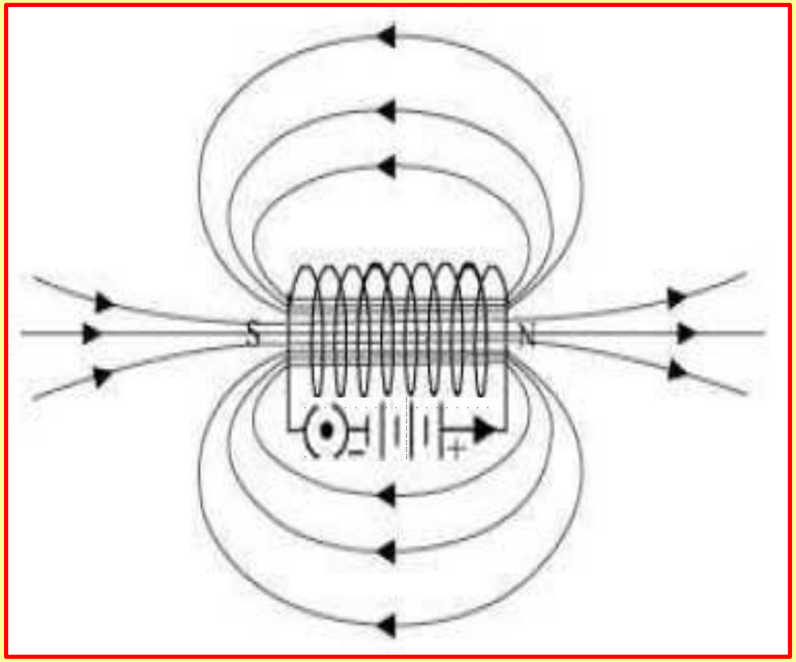


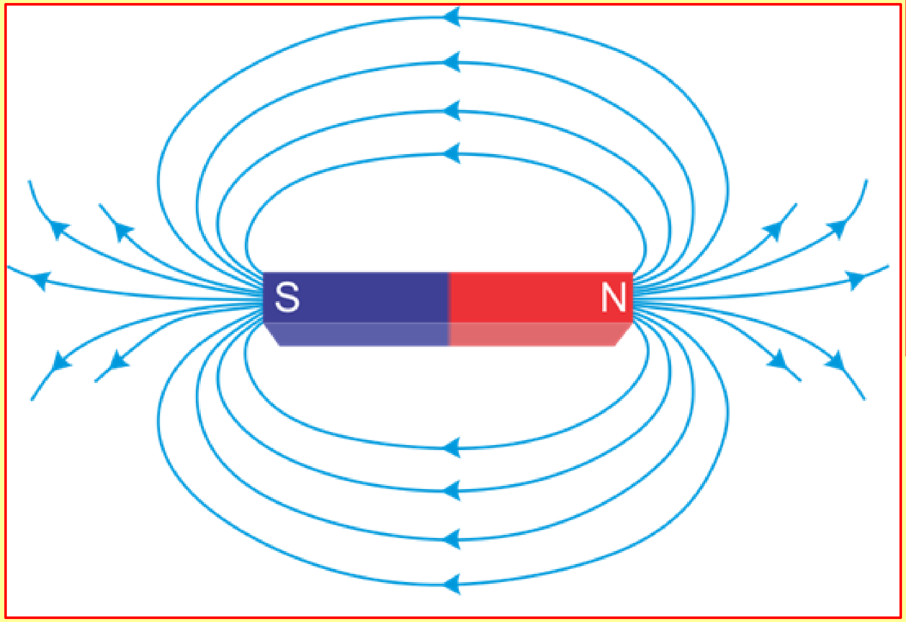


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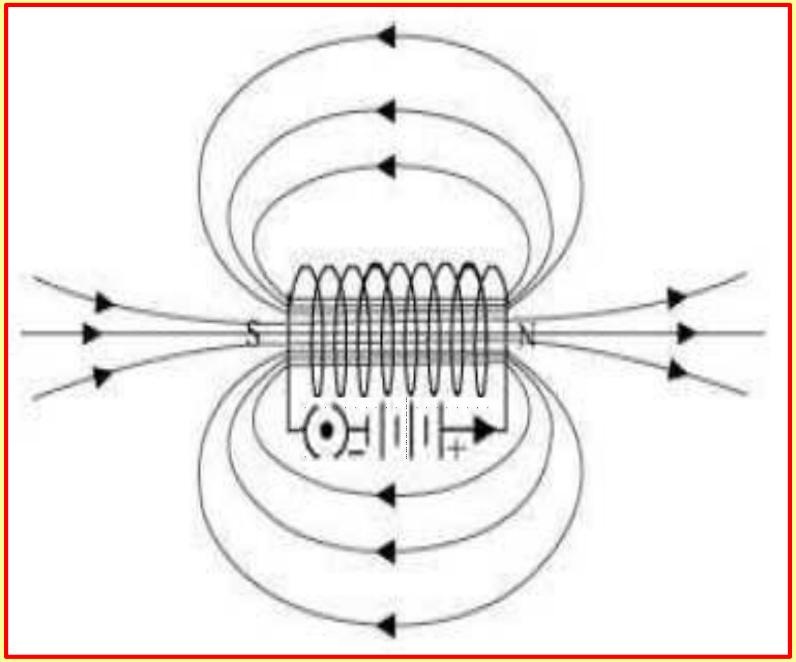


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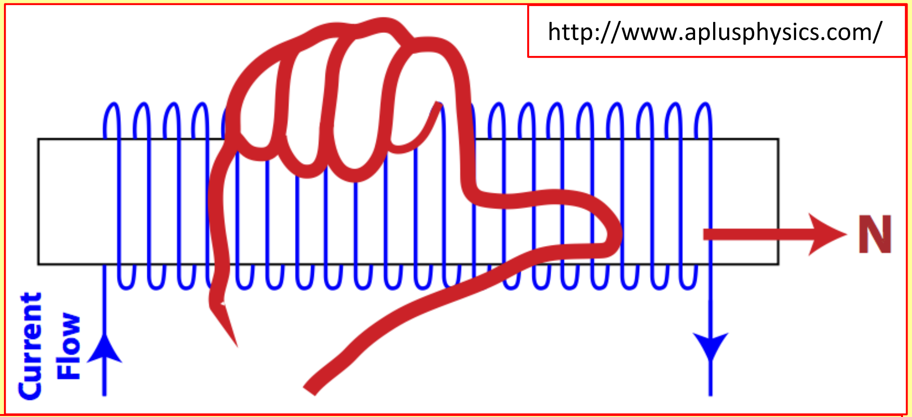
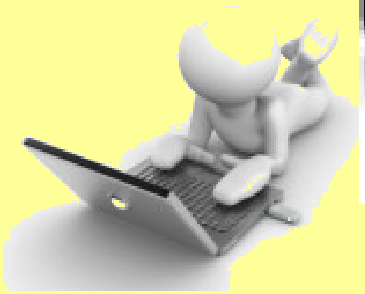
The right-hand grip rule can also be used with the solenoid.




Imagine gripping the coil with your right hand so that your fingers point in the current direction (conventional). Your thumb then points towards the North pole of the coil.



Describe applications of the magnetic effect of current, including the action of a relay

http://science.howstuffworks.com/

Electromagnets!

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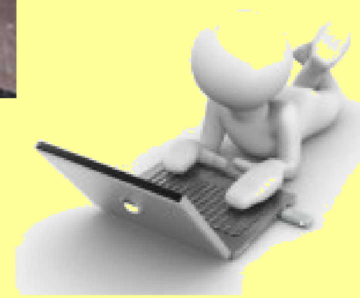

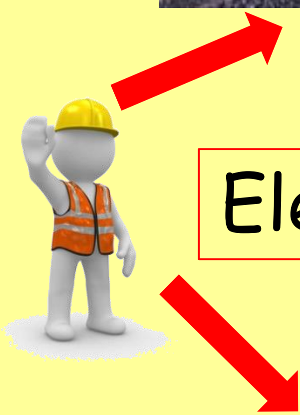

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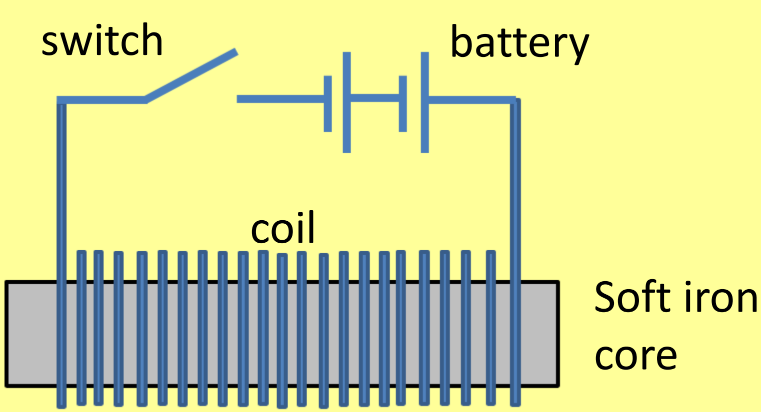

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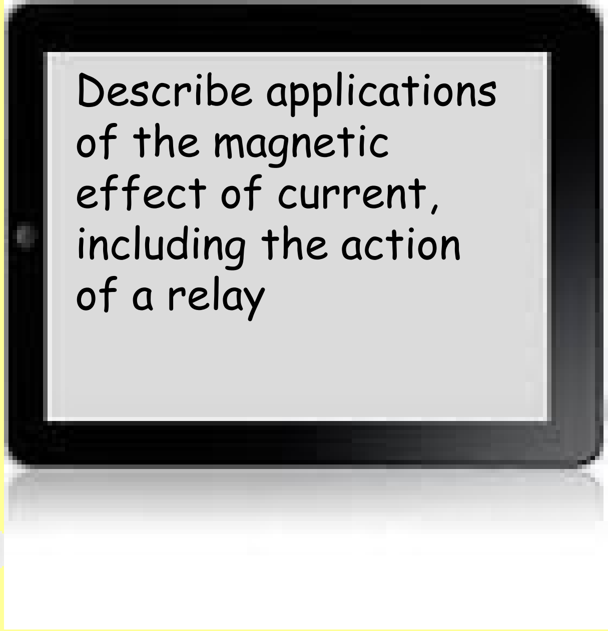
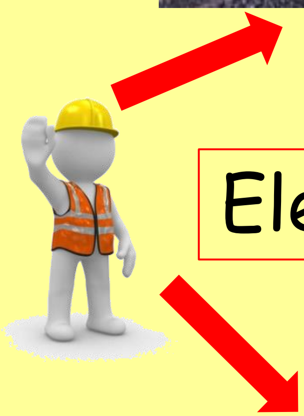
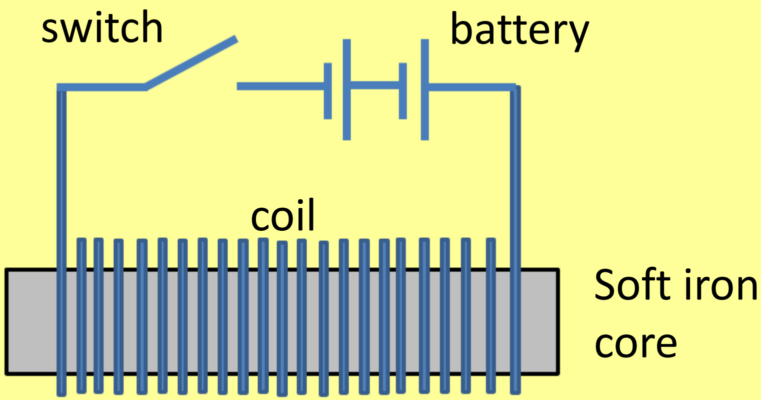


Describe applications of the magnetic effect of current, including the action of a relay



# Electromagnets!

Unlike bar magnets, which are **permanent** magnets, the **magnetism** of **electromagnets** can be turned **on** and **off**.



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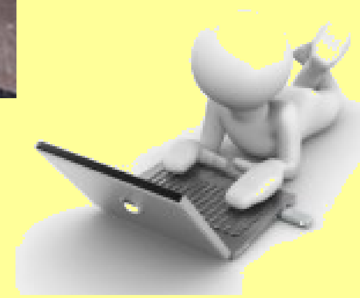

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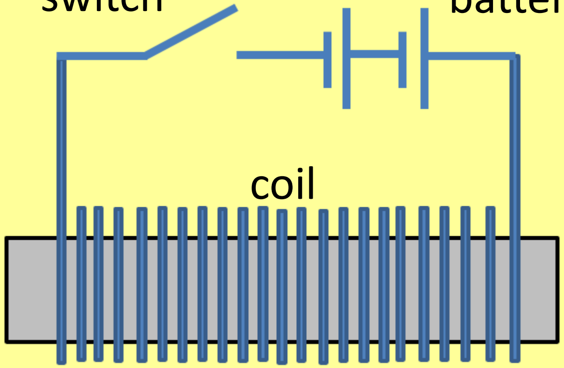


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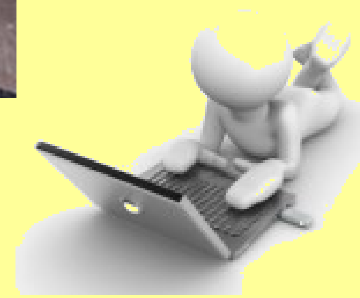

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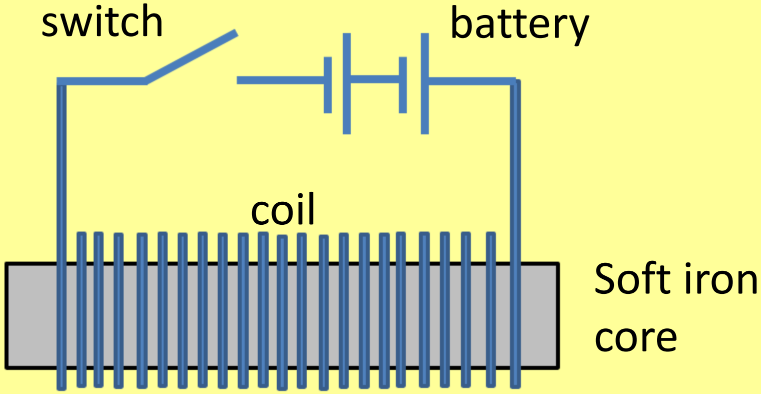


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- **Increasing** number of **turns**

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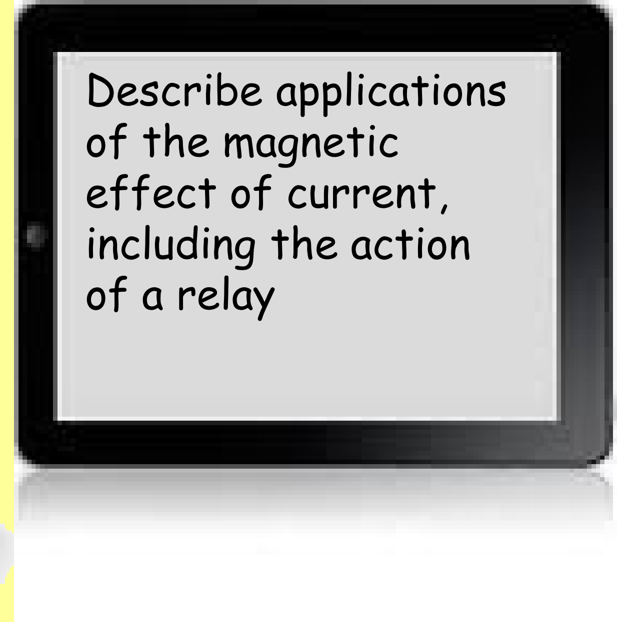


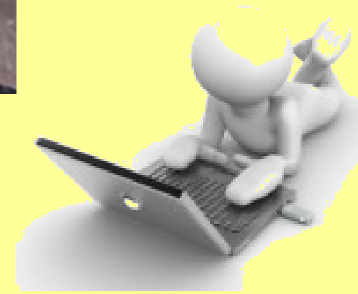

# Electromagnets!

The **core** is usually made of a **soft metal** such as **iron** or **Mumetal.**

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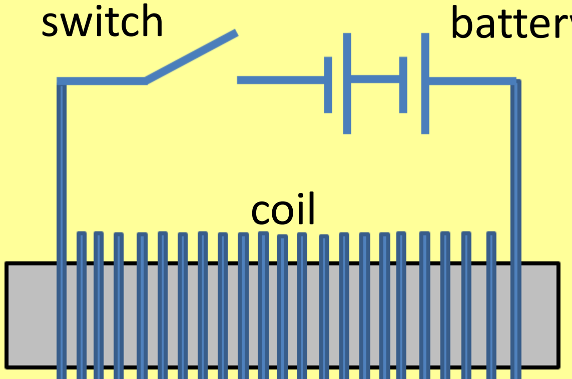


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# Uses of electromagnets

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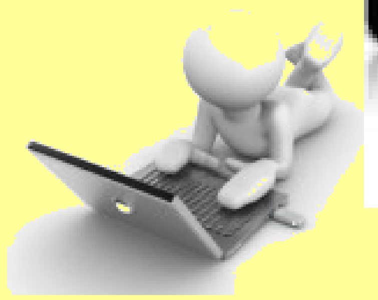
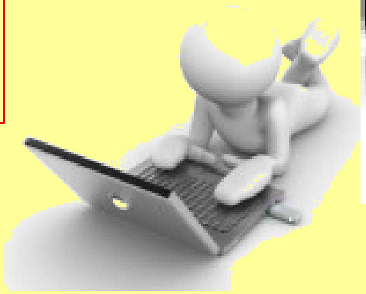


# Uses of electromagnets

Electromagnets are used in **RELAYS**.
A relay is a device which uses a **low current circuit** to switch a **high current circuit** on or off.



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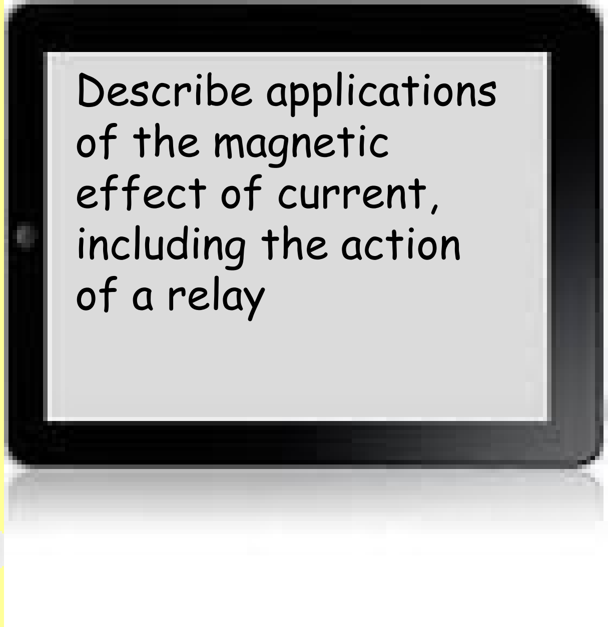


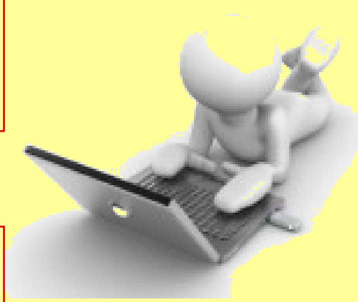

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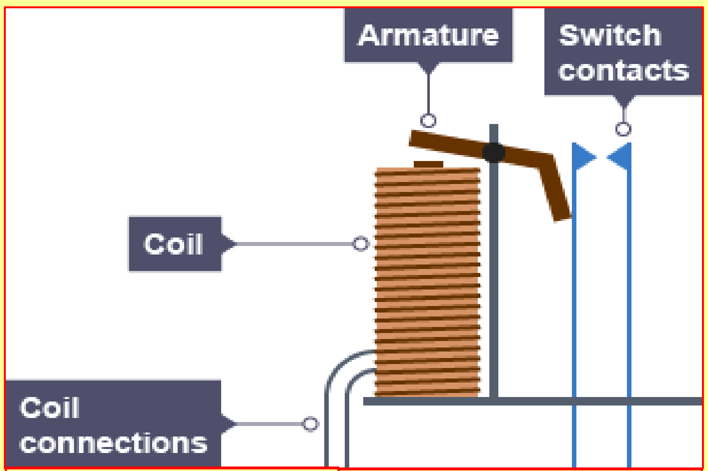
For example, a very big relay is used in **cars** for switching the **starter motor**, because it draws a **very big current**.




Low current circuit | High current circuit

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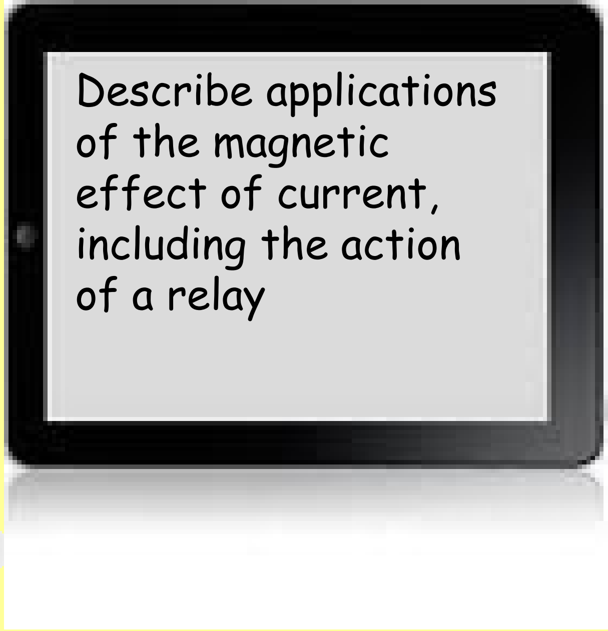


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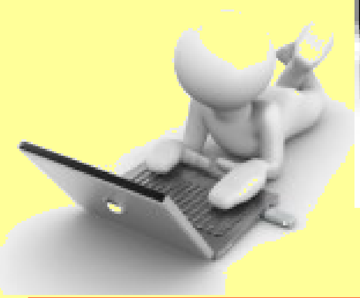

For example, a very big relay is used in **cars** for switching the **starter motor**, because it draws a **very big current**.

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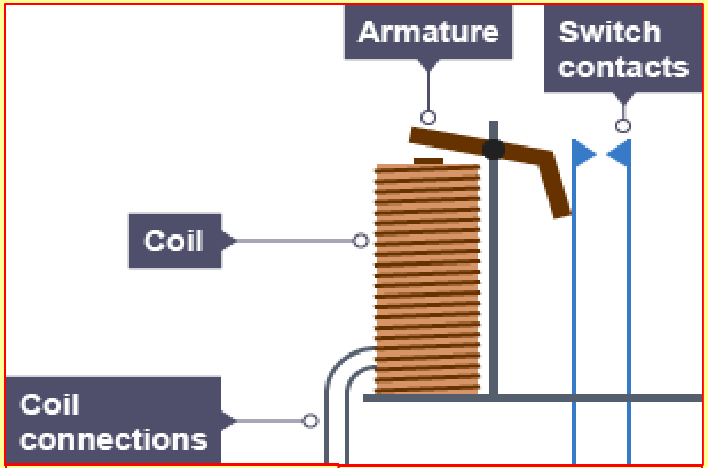


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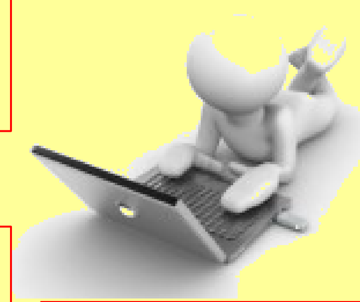

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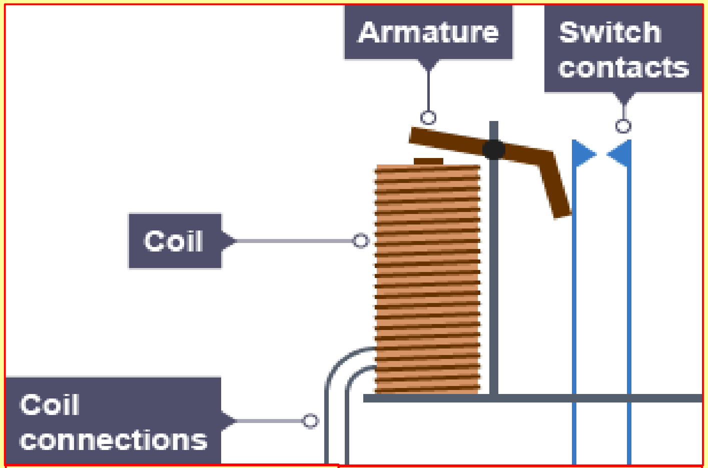
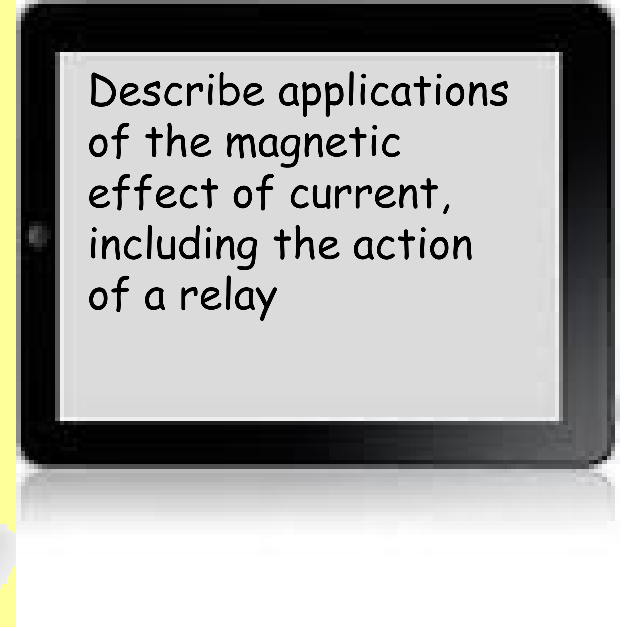


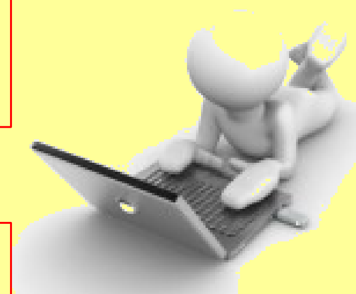

Low current circuit | High current circuit

1. When the switch in the low current circuit is **closed**, it turns the **electromagnet on** which **attracts** the **iron armature**.
2. The armature **pivots** and **closes the switch contacts** in the high current circuit.

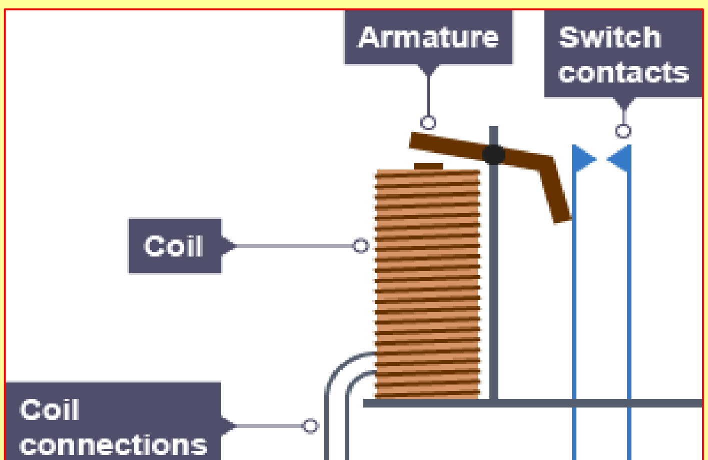
# Uses of electromagnets




Electromagnets are used in RELAYS.
A relay is a device which uses a low current circuit to switch a high current circuit on or off.



For example, a very big relay is used in cars for switching the starter motor, because it draws a very big current.

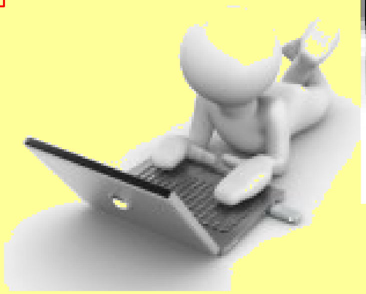



Low current circuit | High current circuit

1. When the switch in the low current circuit is closed, it turns the electromagnet on which attracts the iron armature.
2. The armature pivots and closes the switch contacts in the high current circuit.
3. When the low current switch is opened the electromagnet stops pulling the armature and the high current circuit is broken again.

# Uses of electromagnets

Electromagnets are used in **<u>CIRCUIT BREAKERS.</u>**



Describe applications of the magnetic effect of current, including the action of a relay

# Uses of electromagnets

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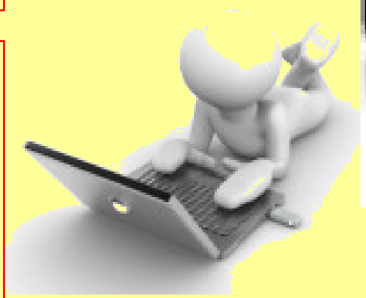

A **circuit breaker** does the same job as a fuse, but it works in a different way. Circuit breakers are **automatic switches** that **'trip'** (turn off) when the current rises above a **specific value**. The circuit breaker can be reset by **pressing a button** (no need to replace).

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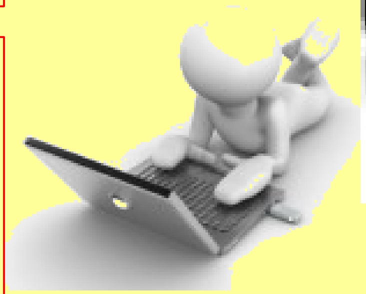

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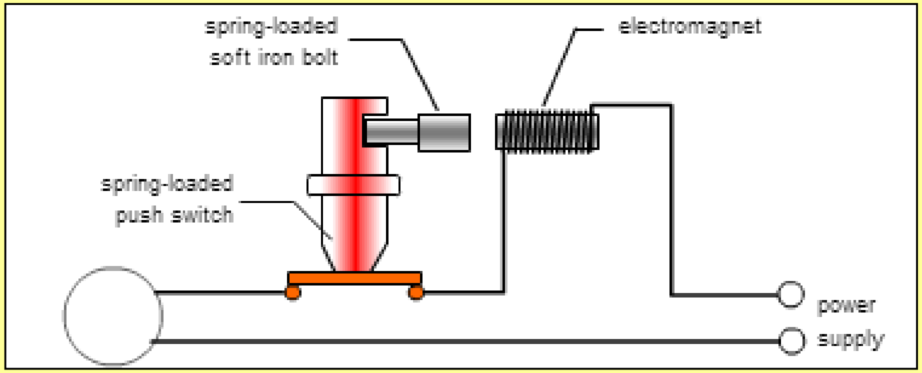


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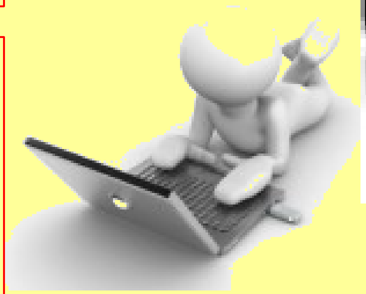

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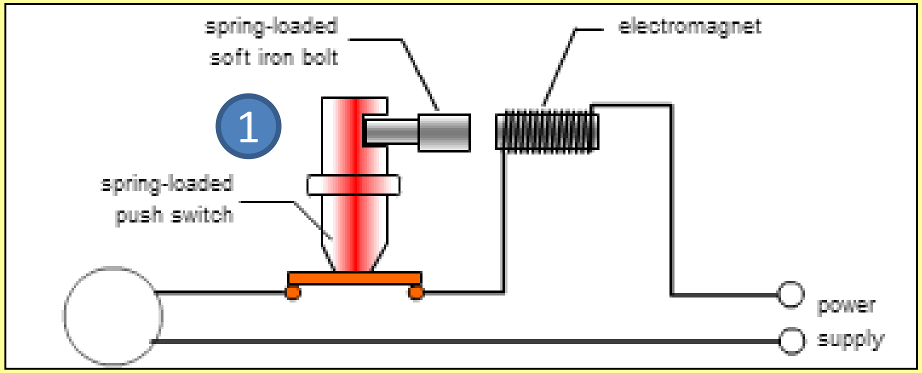


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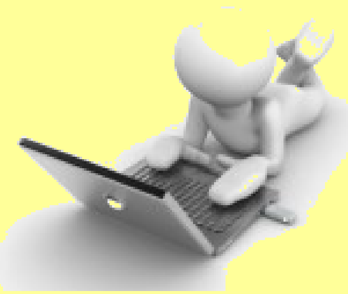

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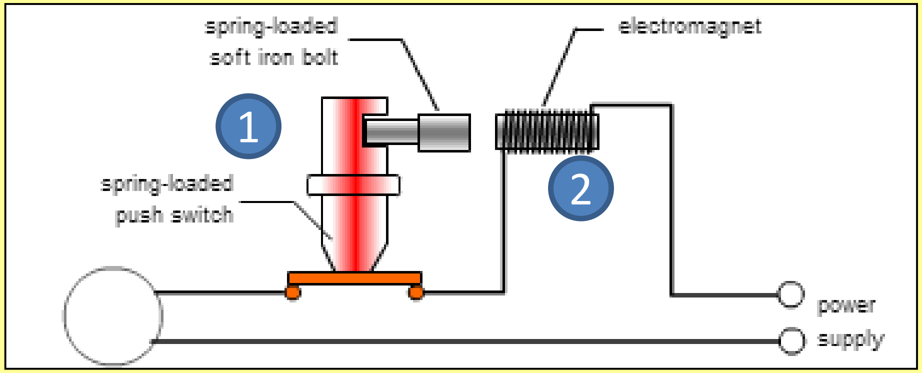


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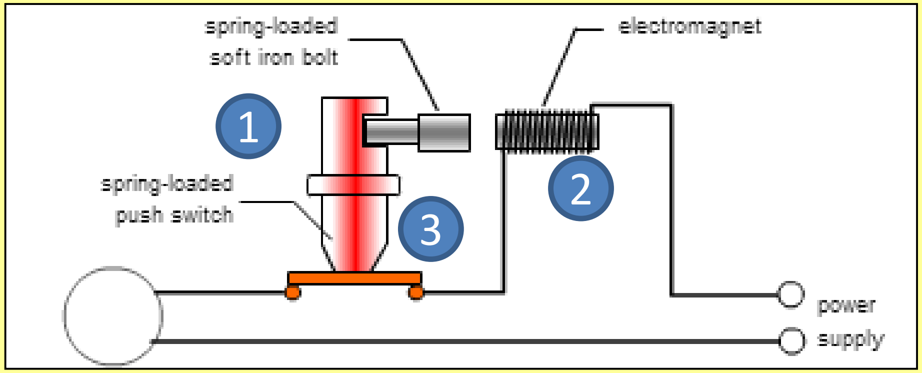


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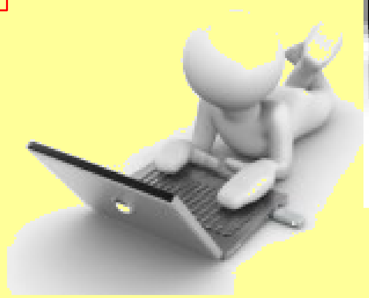
1) A spring-loaded **push switch** is held in the **closed** position by a spring-loaded **soft iron bolt**.
2) **Electromagnet** arranged so it can **pull** the **bolt away from** the switch.
3) If **current** increases beyond set limit then the **electromagnet pulls** bolt towards itself, **releasing** the **push switch** and **breaking** the **circuit**.

# Uses of electromagnets

Electromagnets are used in **MAGNETIC STORAGE.**

Describe applications of the magnetic effect of current, including the action of a relay



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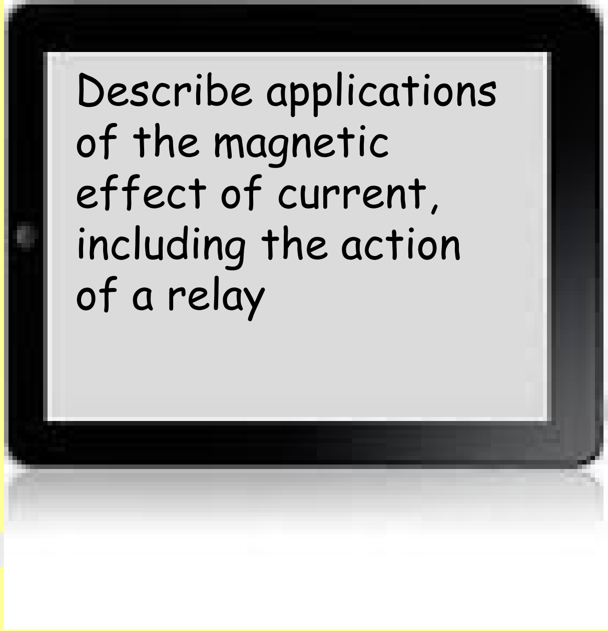

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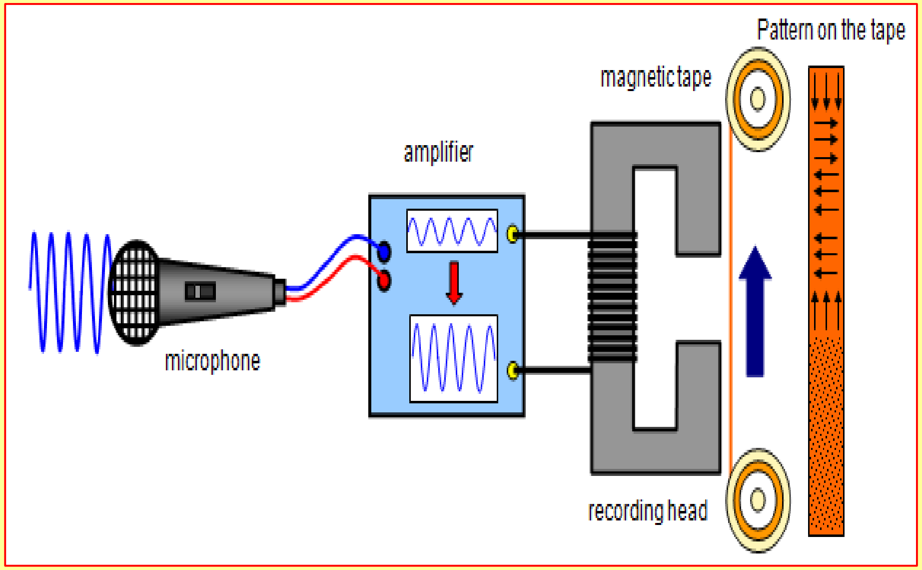


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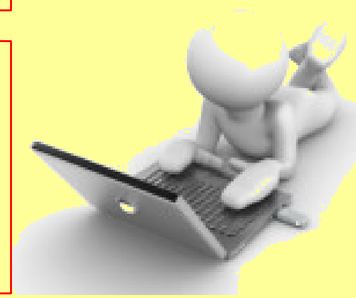

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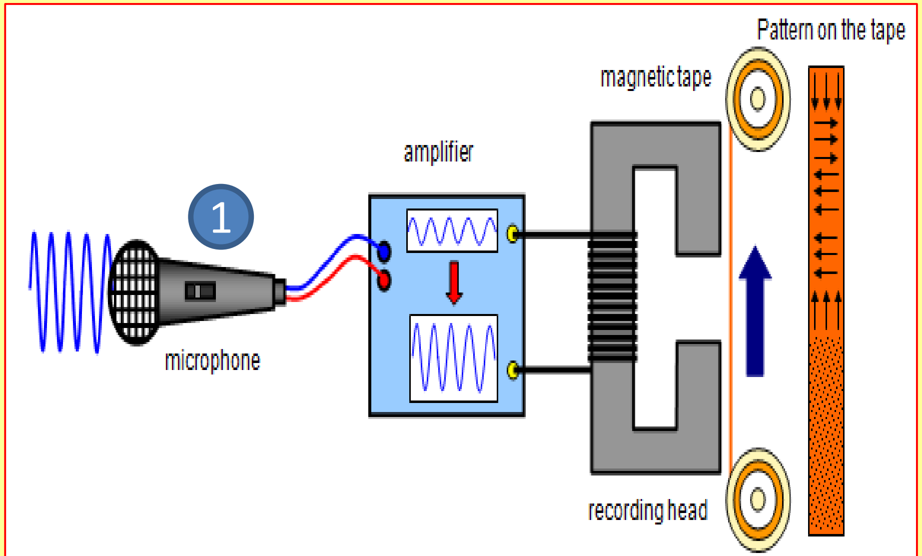


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1) **Microphone** picks up **sound wave** and **converts it** to small changing **voltage**.

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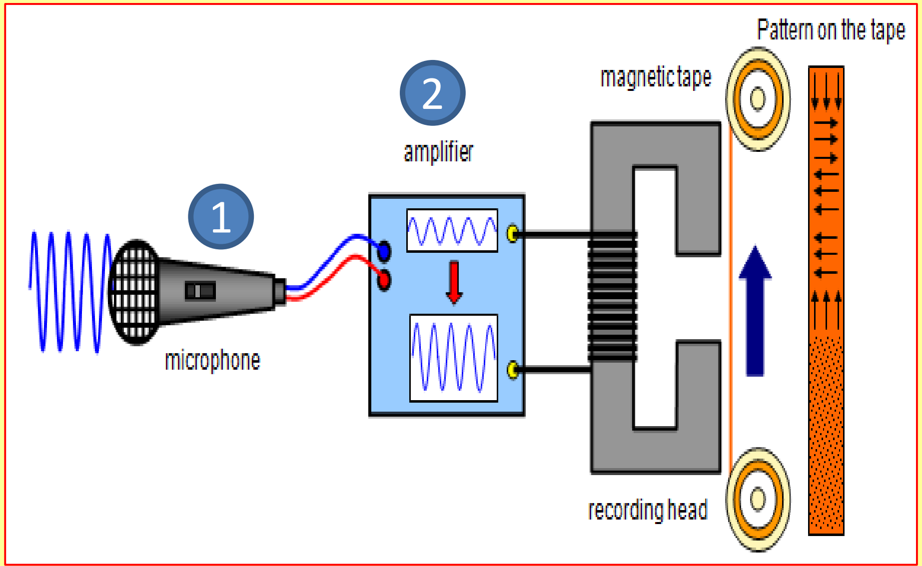


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1) **Microphone** picks up **sound wave** and **converts it** to small changing **voltage**.
2) The amplifier **amplifies** this voltage.

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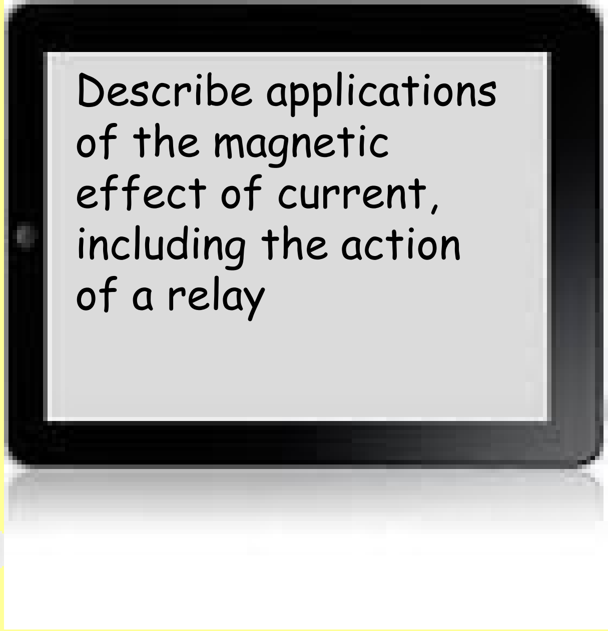


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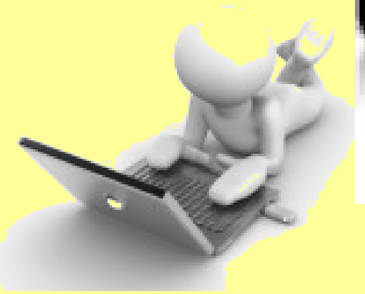

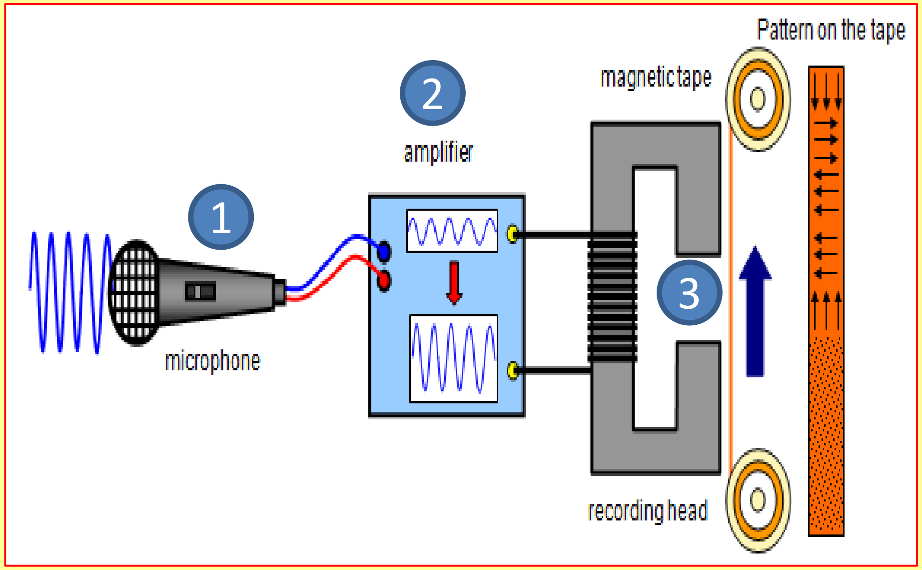


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1) **Microphone** picks up **sound wave** and **converts it** to small changing **voltage**.
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3) Output from amplifier fed to **recording head** where **changing magnetic field** is produced.

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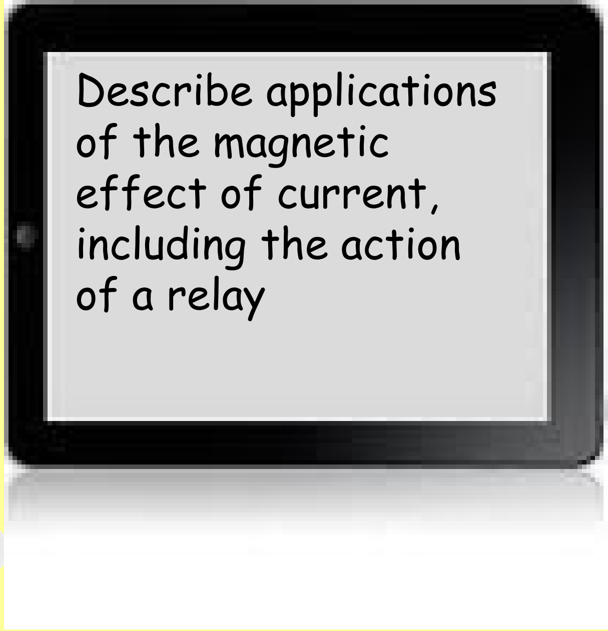


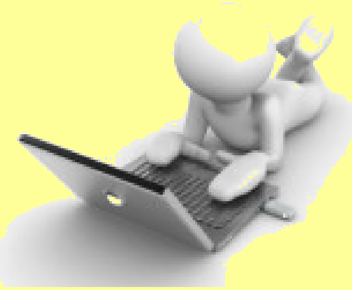

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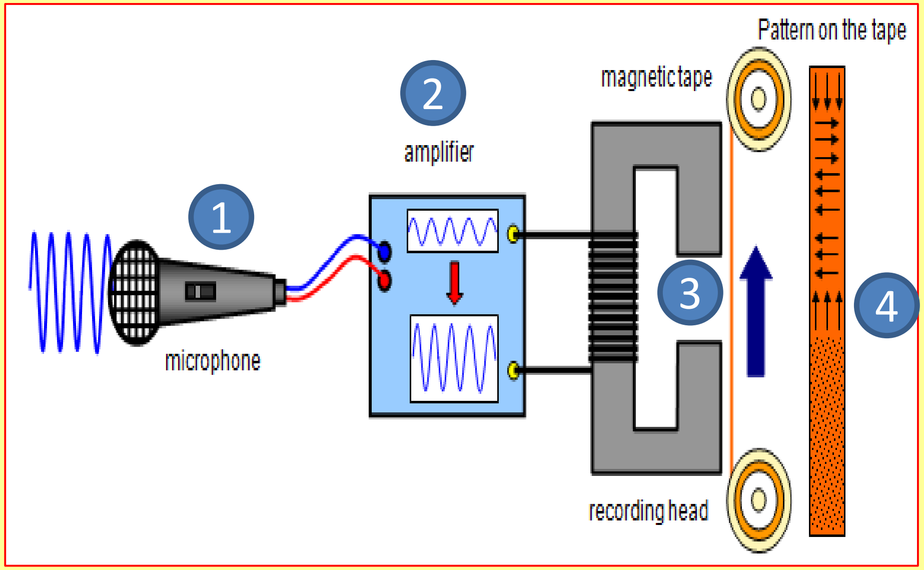


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1) **Microphone** picks up **sound wave** and **converts it** to small changing **voltage**.
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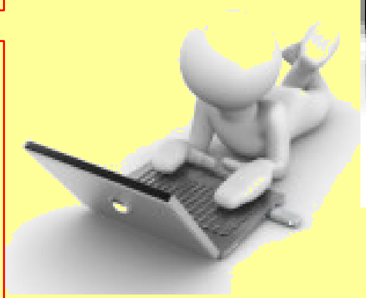
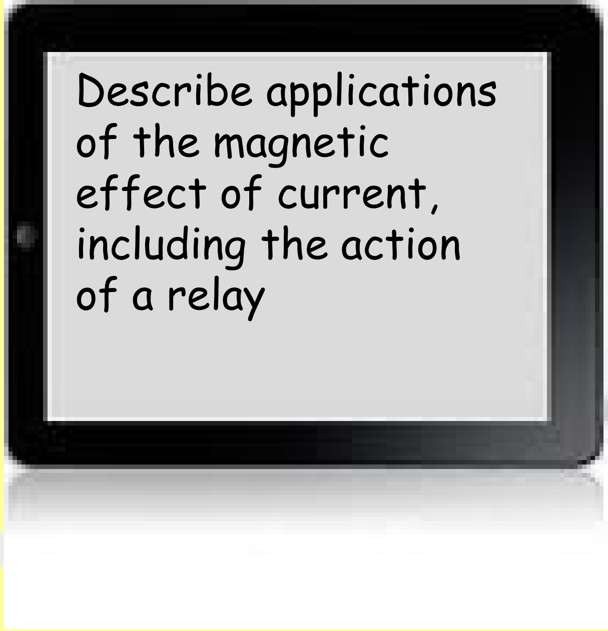
3) Output from amplifier fed to **recording head** where **changing magnetic field** is produced.
4) Changing magnetic field arranges **iron oxide grains** onto pattern that **mirrors** changing **sound input**.

# Uses of electromagnets

Electromagnets are used in **MAGNETIC STORAGE.**

At the simplest level, a **computer hard disk drive** is not that different from a **magnetic cassette tape**. Both hard disks and cassette tapes use the same **magnetic recording techniques** previously described.





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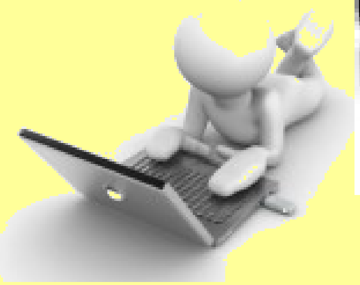

The **recording head** contains a tiny **electromagnet** which is used to create **tracks of varying magnetism** on a **spinning disc**.

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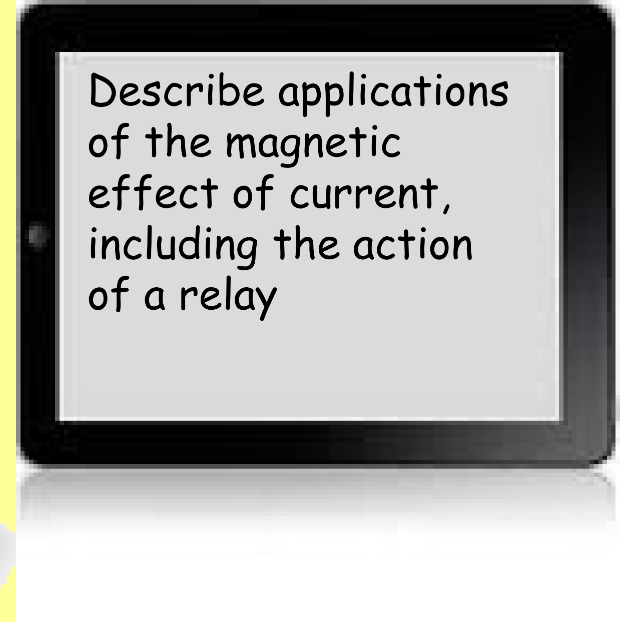


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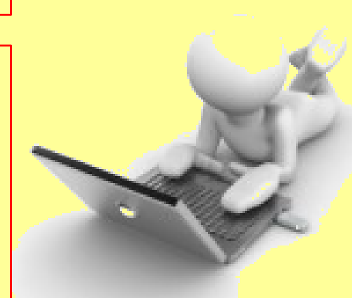
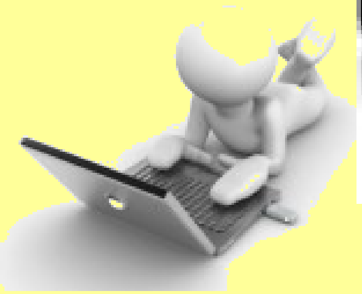


The **recording head** contains a tiny **electromagnet** which is used to create **tracks of varying magnetism** on a **spinning disc**.

Hard disks and cassette tapes also share the major **benefits** that the **magnetic medium** can be easily **erased** and **rewritten**, and 'remembered' for **many years**.

Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing:
– the current – the direction of the field



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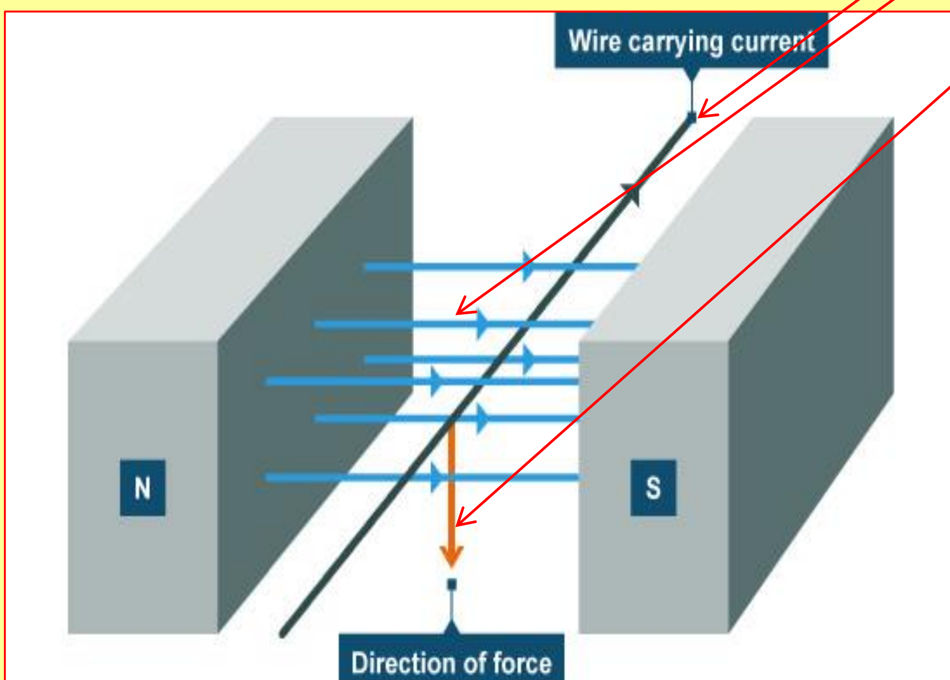


http://www.bbc.co.uk/schools/gcsebitesize

If a wire **carrying a current** is placed in a **magnetic field** (with lines of force at **right angles** to the wire) then it will **experience a force**:

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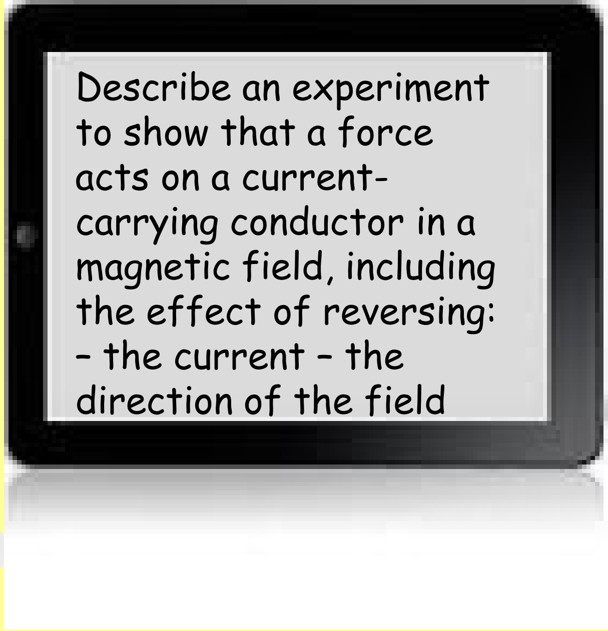


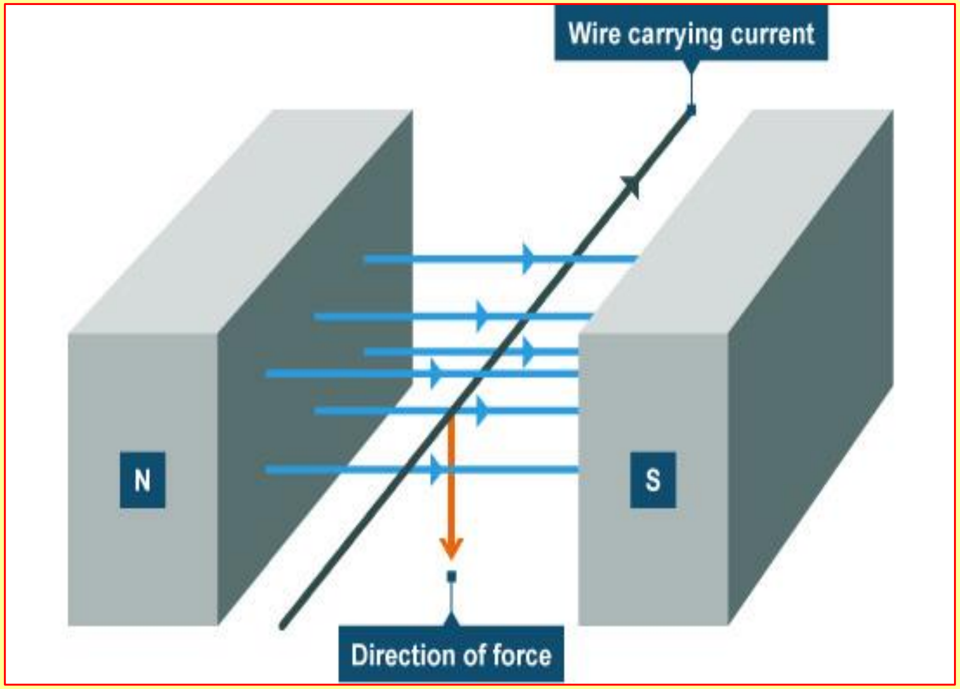


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If a wire carrying a current is placed in a magnetic field (with lines of force at right angles to the wire) then it will experience a force:

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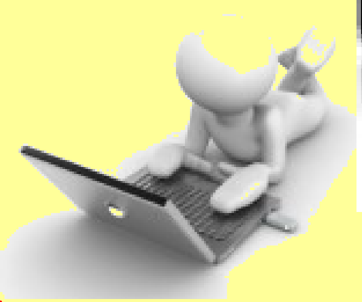

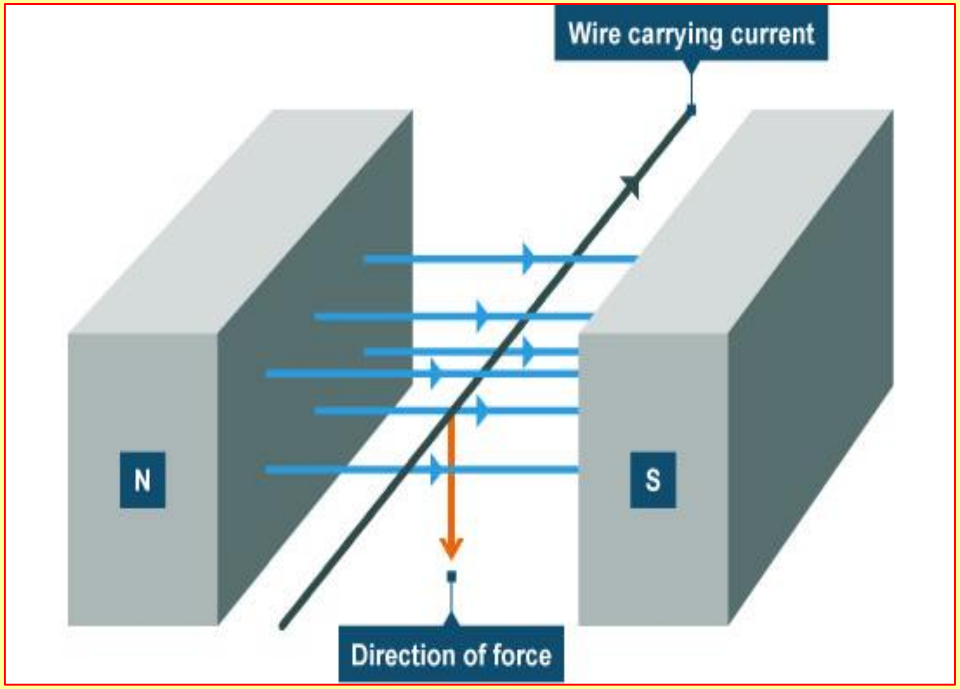


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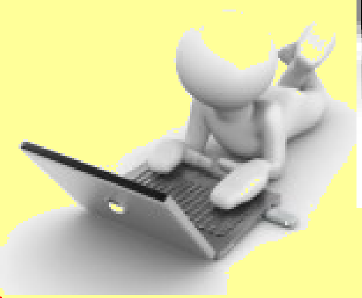

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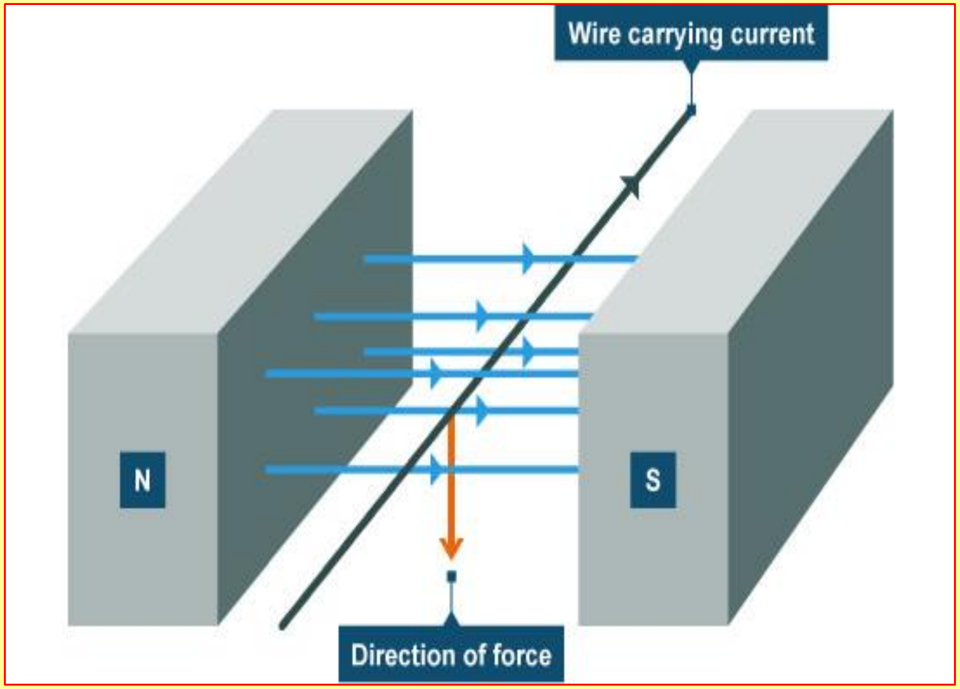


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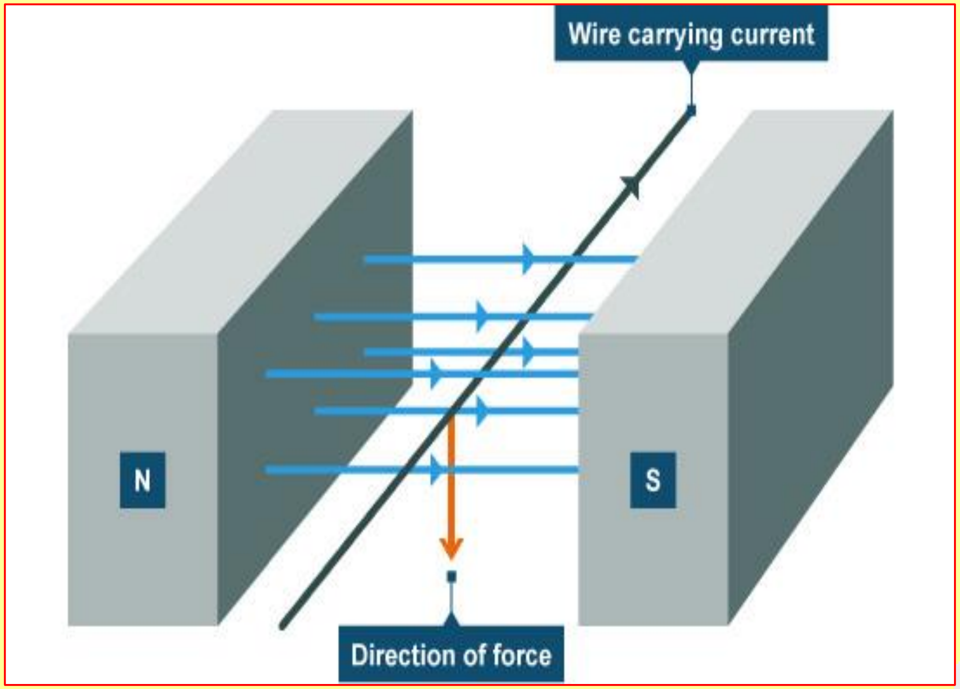
The force on the wire is increased if:

- The current is increased
- A stronger magnet is used
- The length of the wire in the field is increased

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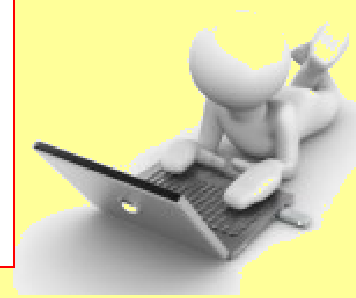
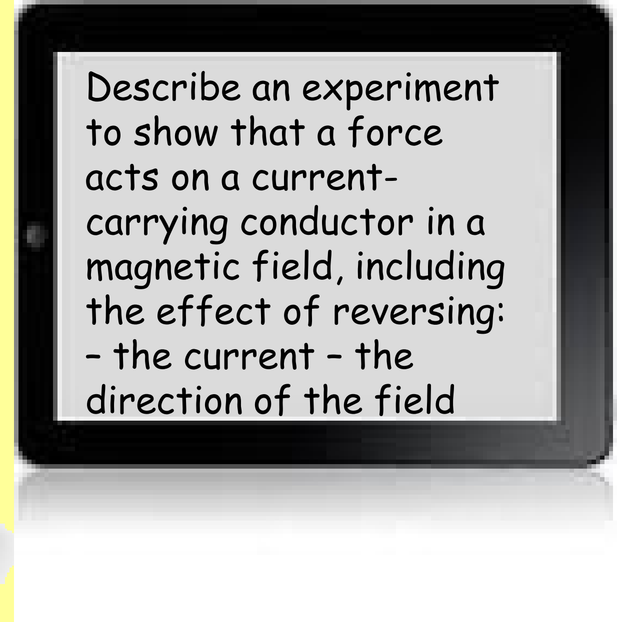
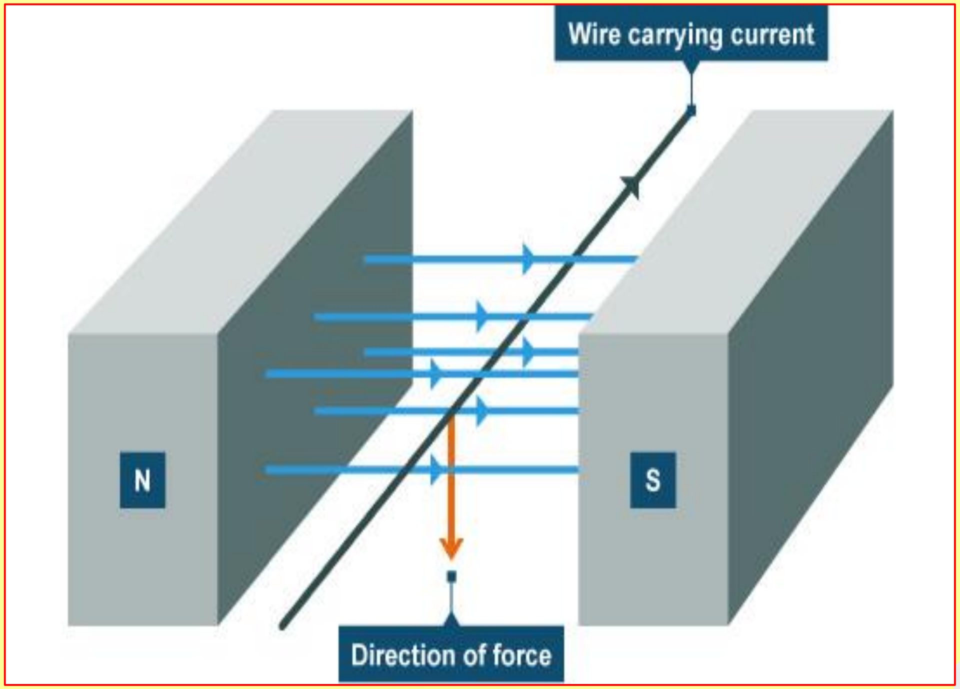





How can we predict the direction of the force on the wire?

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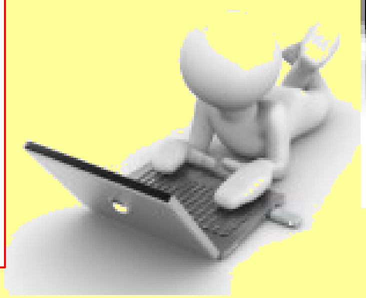

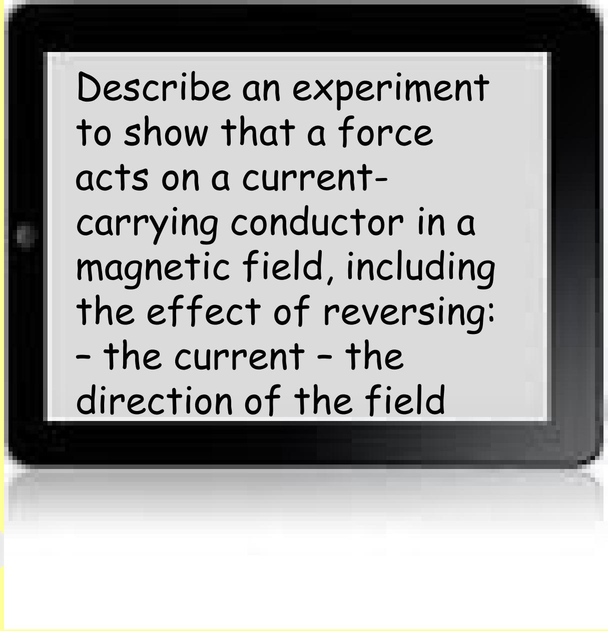


How can we predict the direction of the force on the wire?

To predict the direction we can use **Fleming's left-hand rule**

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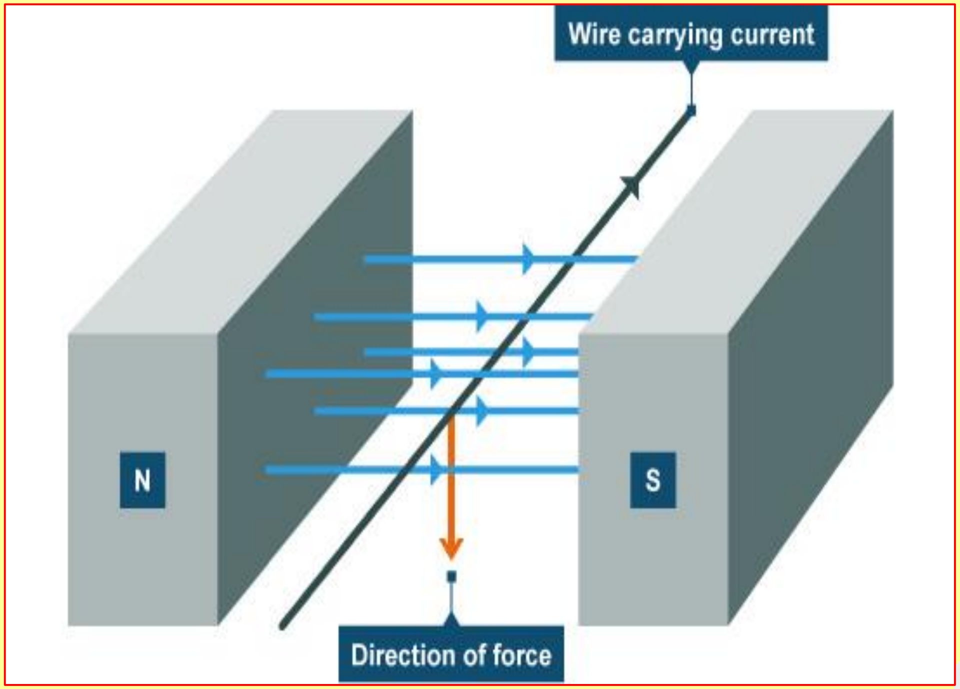


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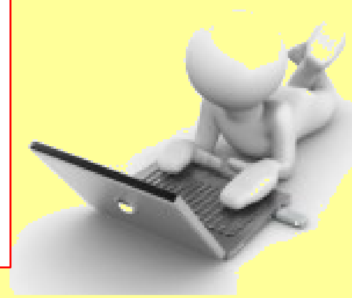

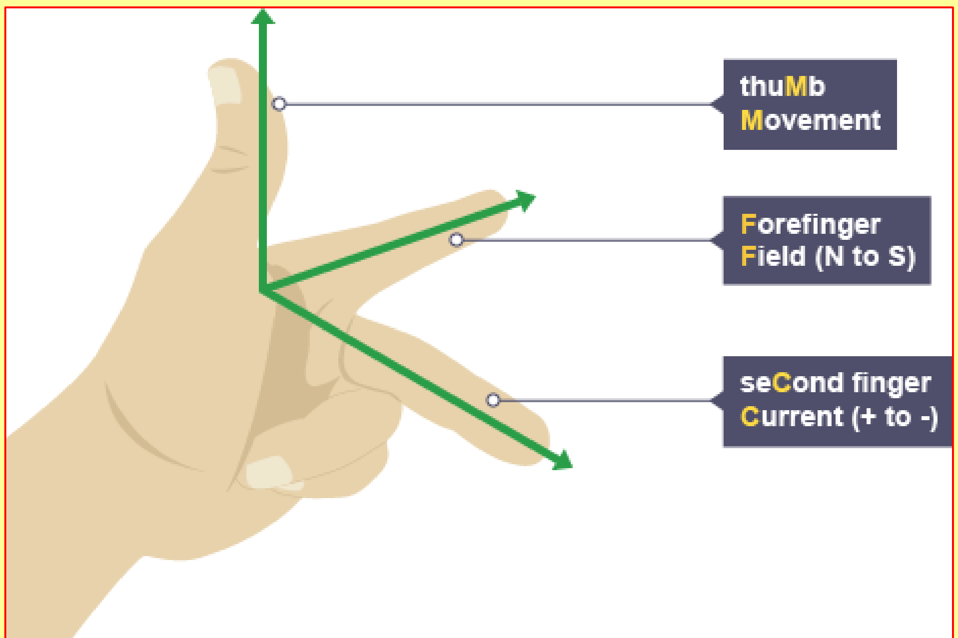


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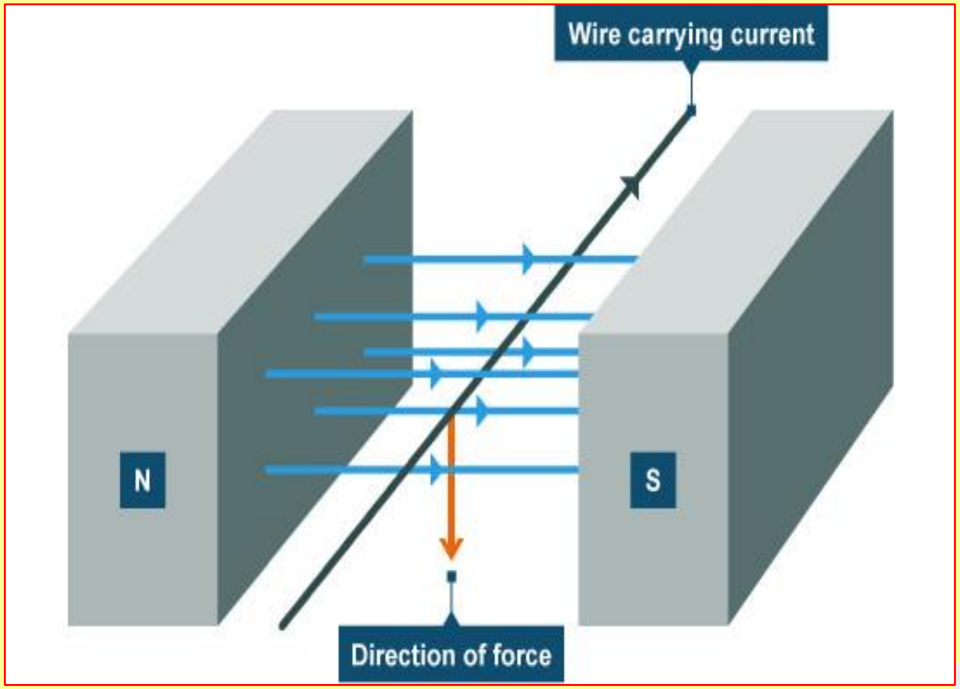


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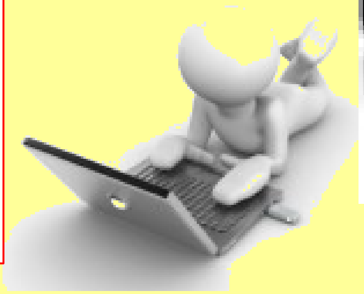

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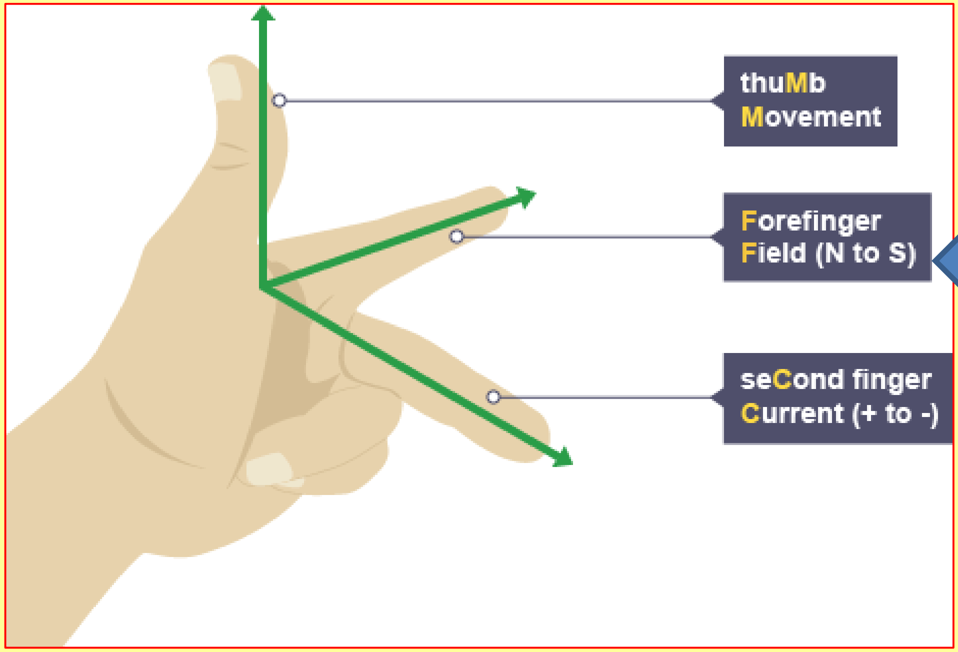


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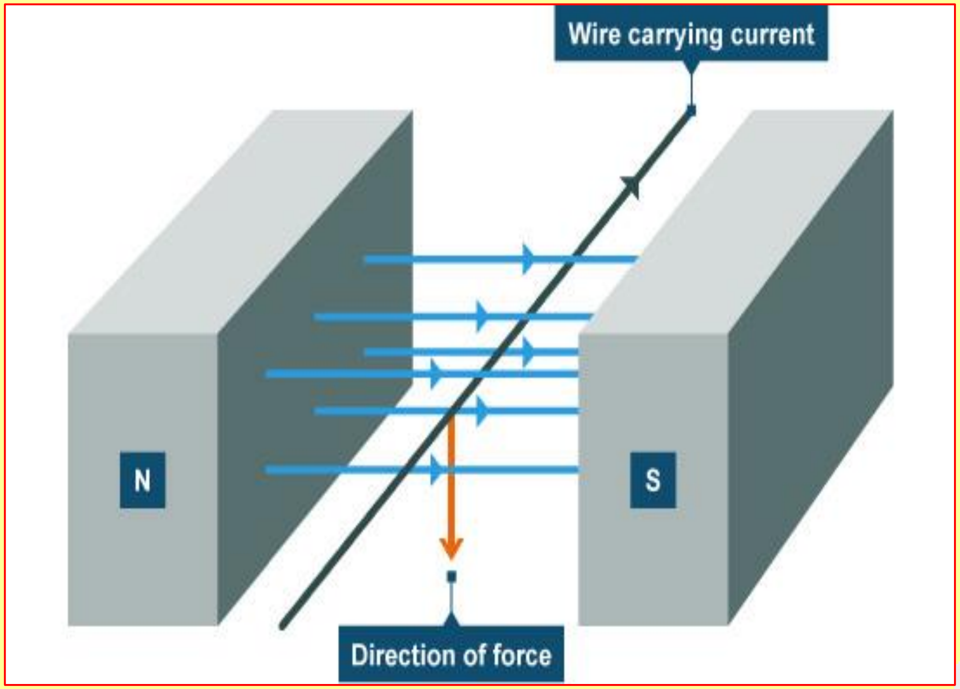
The forefinger represents the direction of the field between the N and S poles of the magnet.

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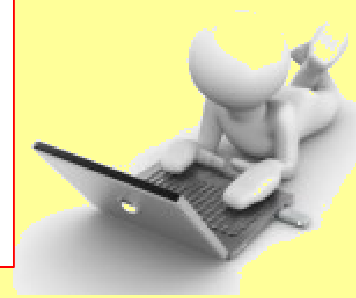
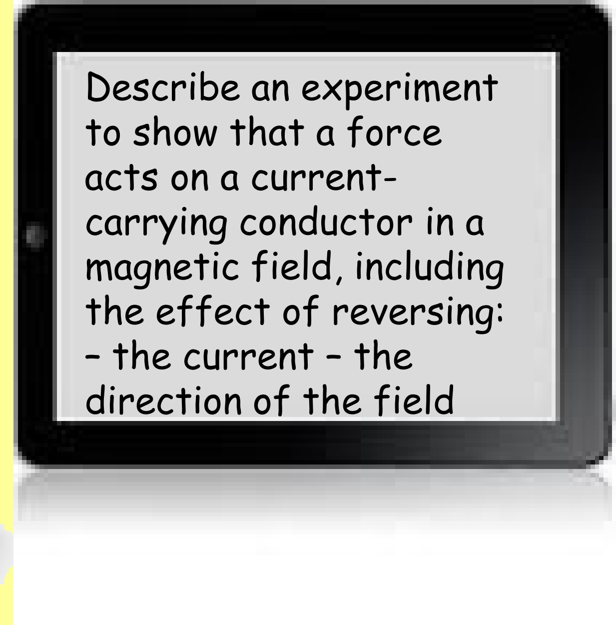
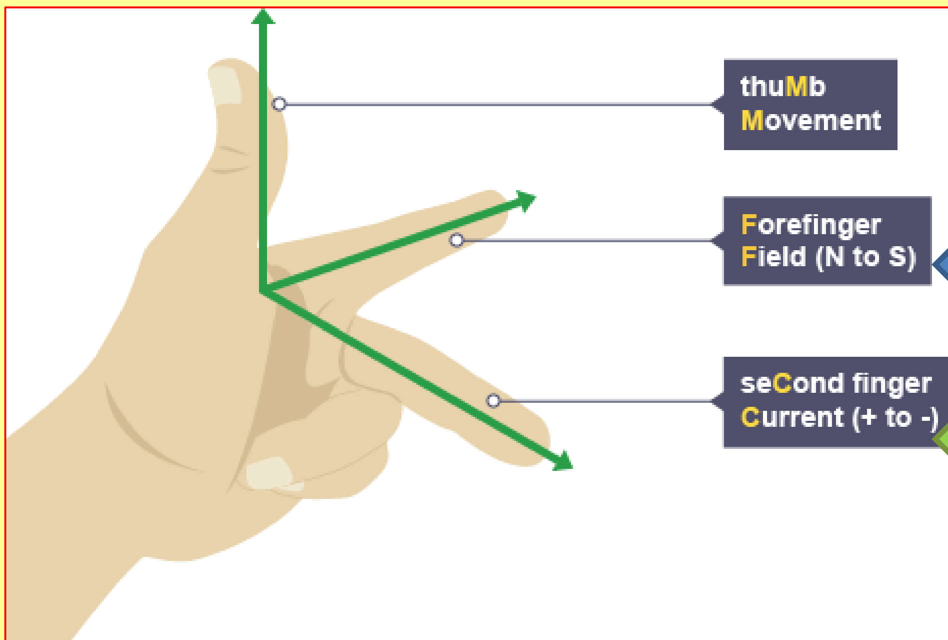




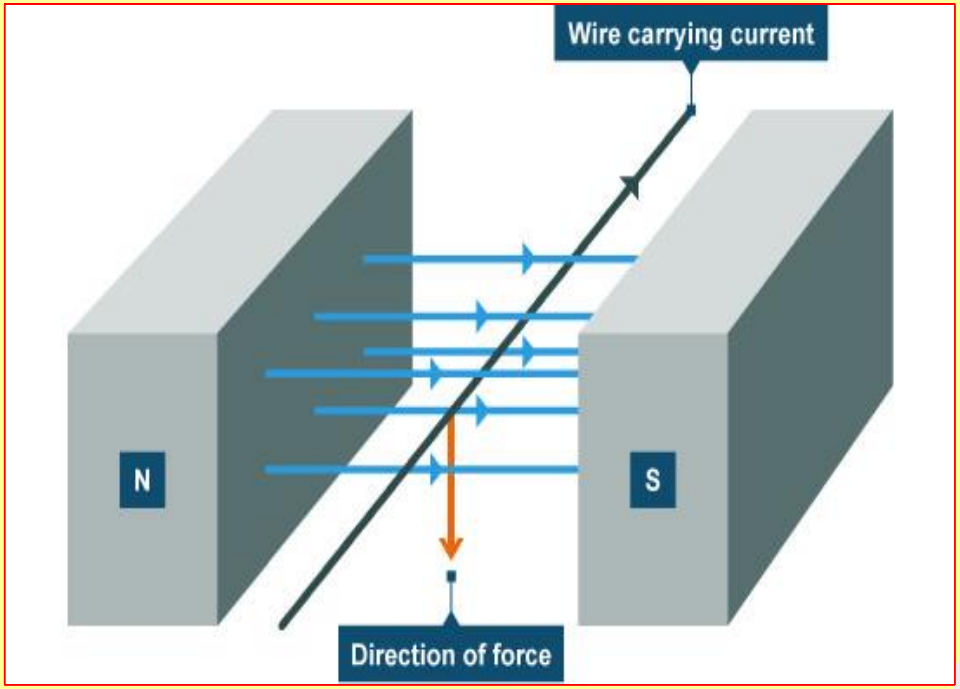




http://www.bbc.co.uk/schools/gcsebitesize

The forefinger represents the direction of the field between the N and S poles of the magnet.

The second finger represents the direction of the current in the conducting wire

Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing: – the current – the direction of the field

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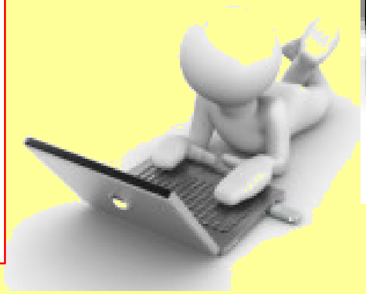
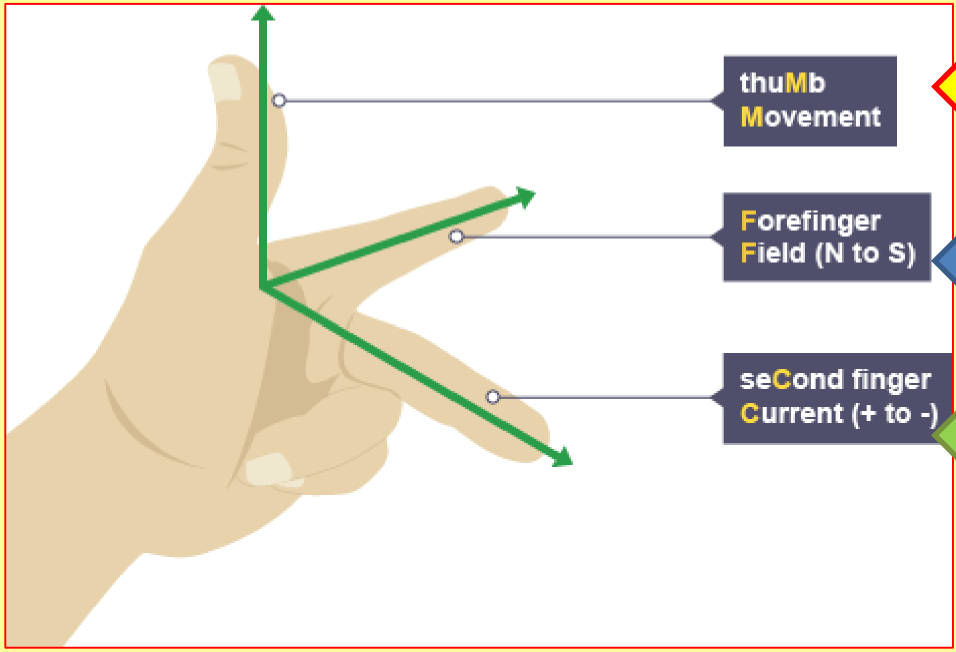


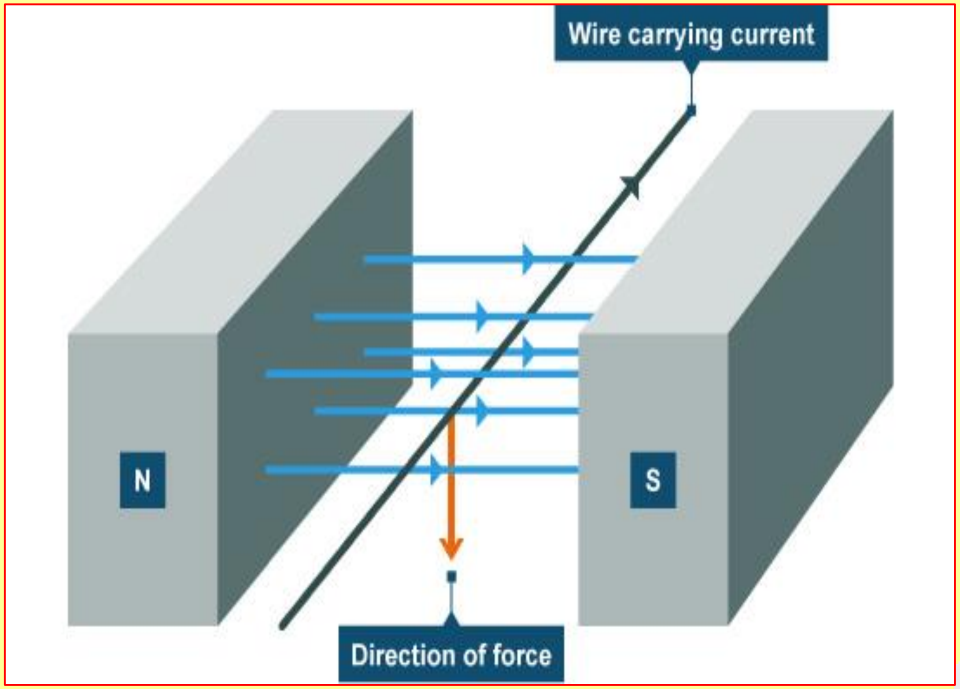



http://www.bbc.co.uk/schools/gcsebitesize

The thumb shows the resultant force acting on the wire.

The forefinger represents the direction of the field between the N and S poles of the magnet.

The second finger represents the direction of the current in the conducting wire

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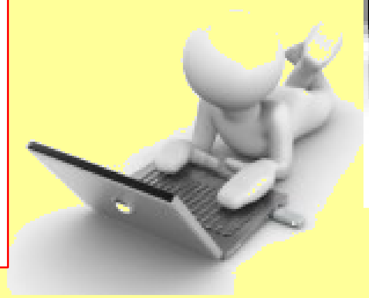
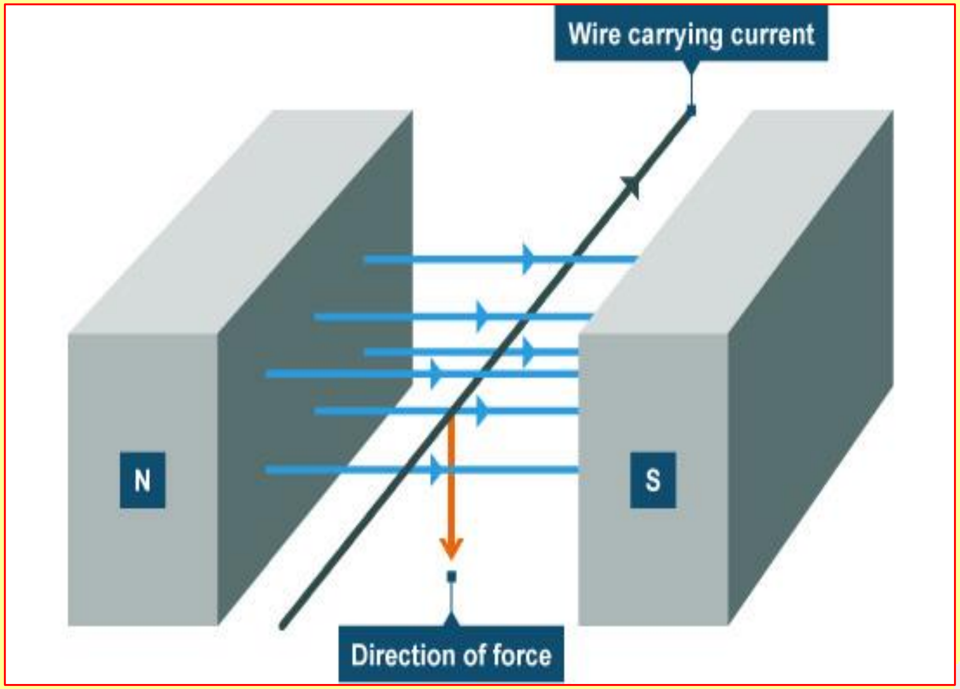


Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing:
– the current – the direction of the field

So, applying Fleming's left-hand rule to the example given ....

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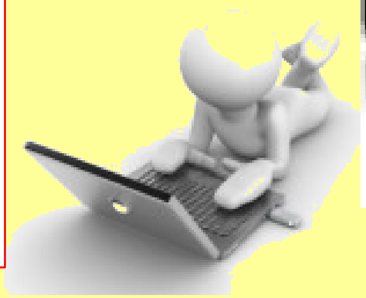
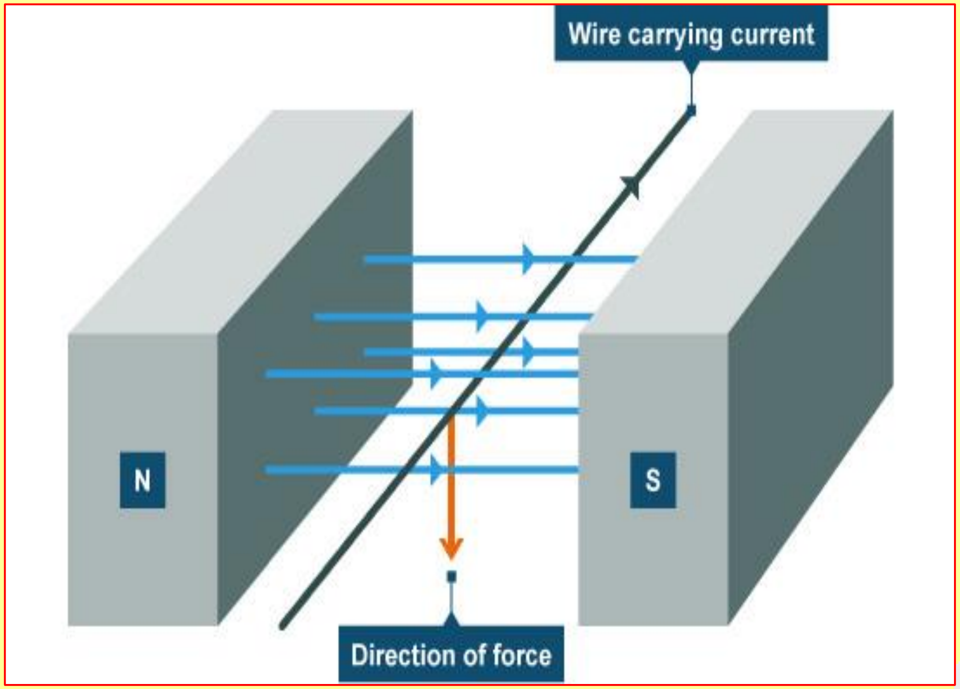


Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing: – the current – the direction of the field

So, applying Fleming's left-hand rule to the example given ….

Forefinger (magnetic field)

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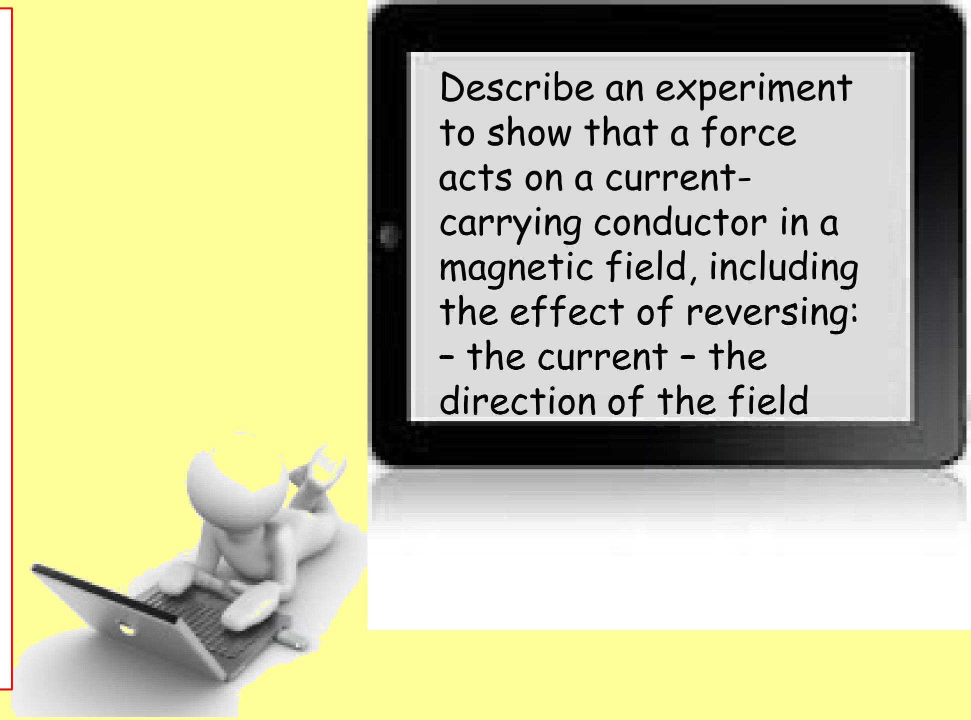


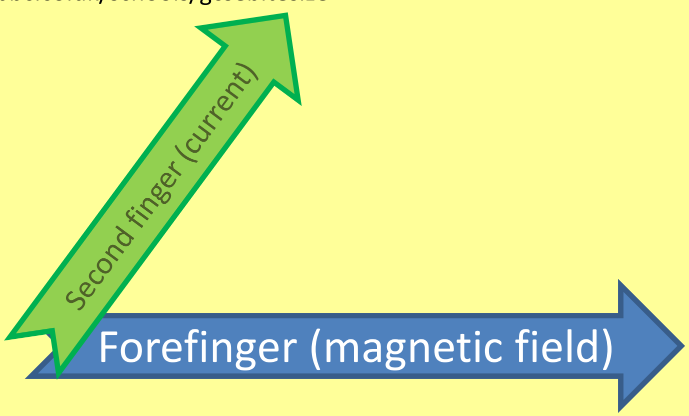


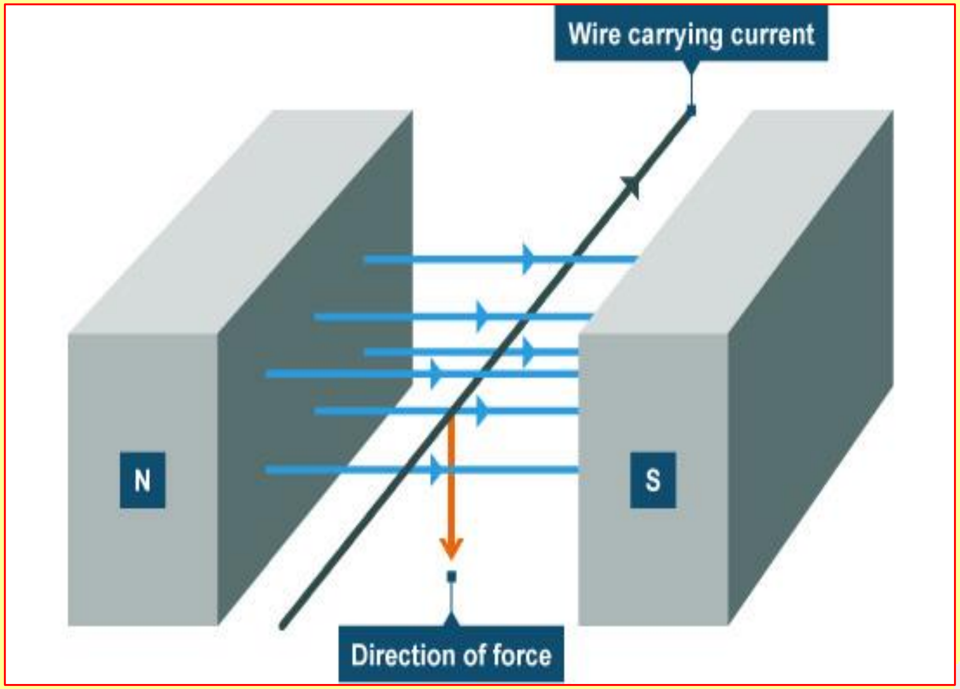


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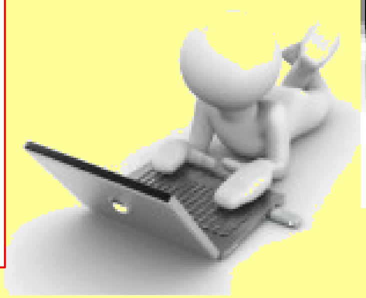
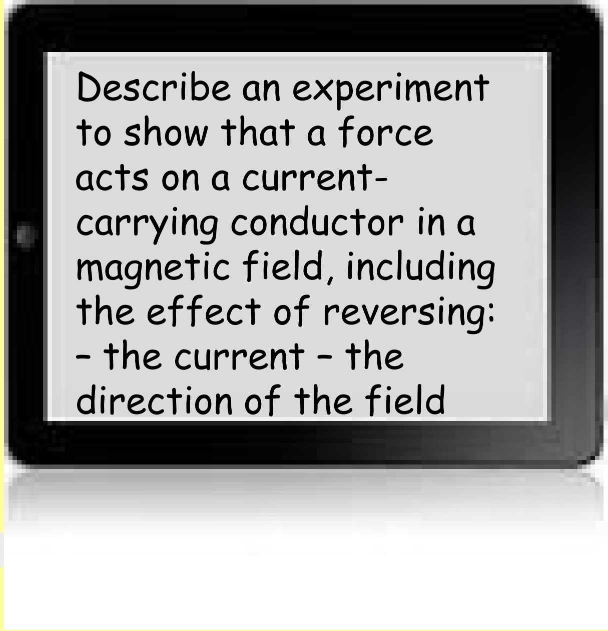
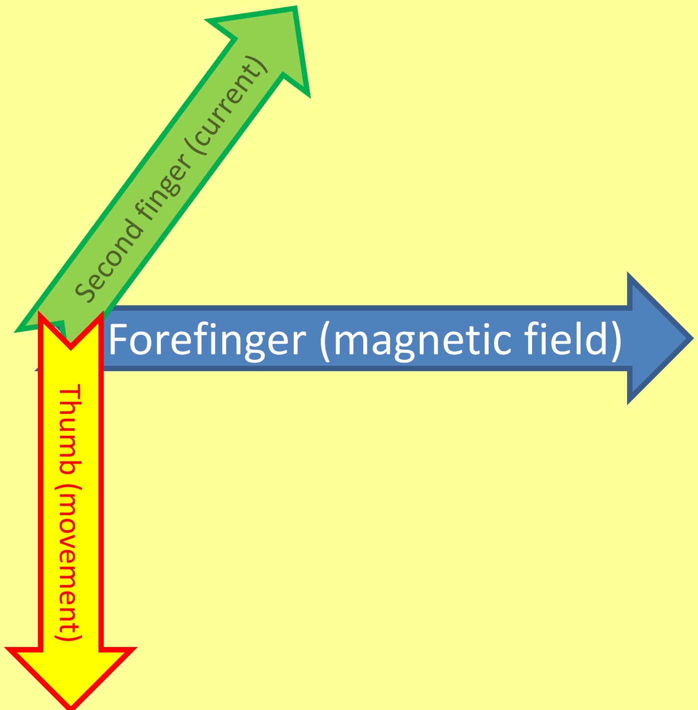
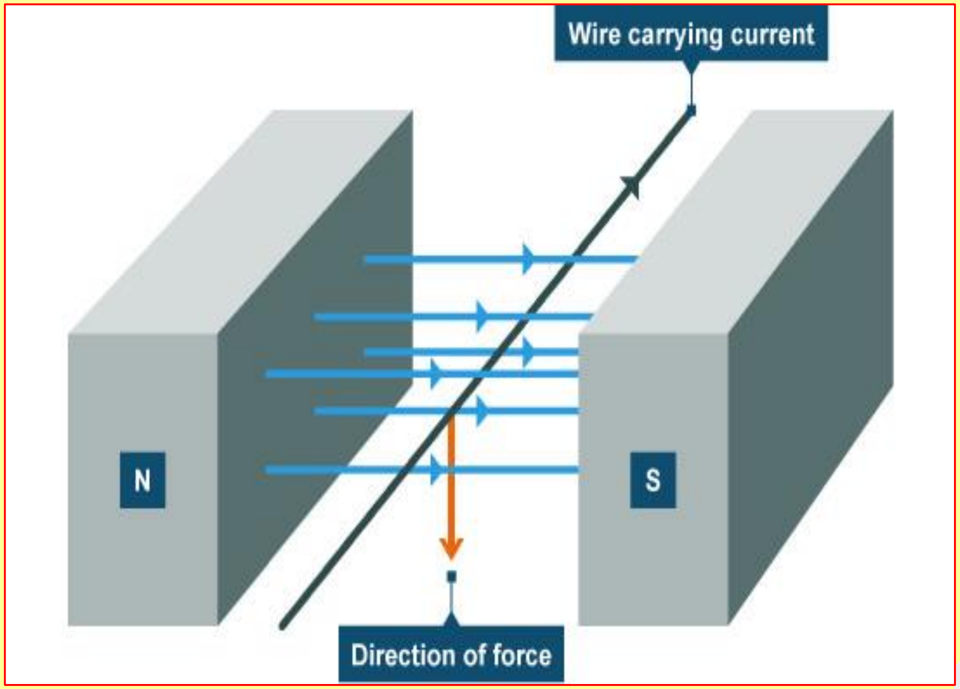




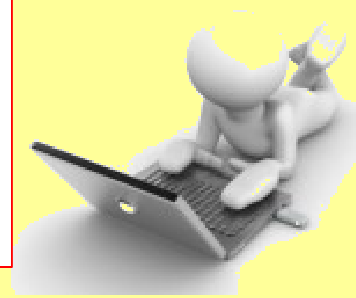



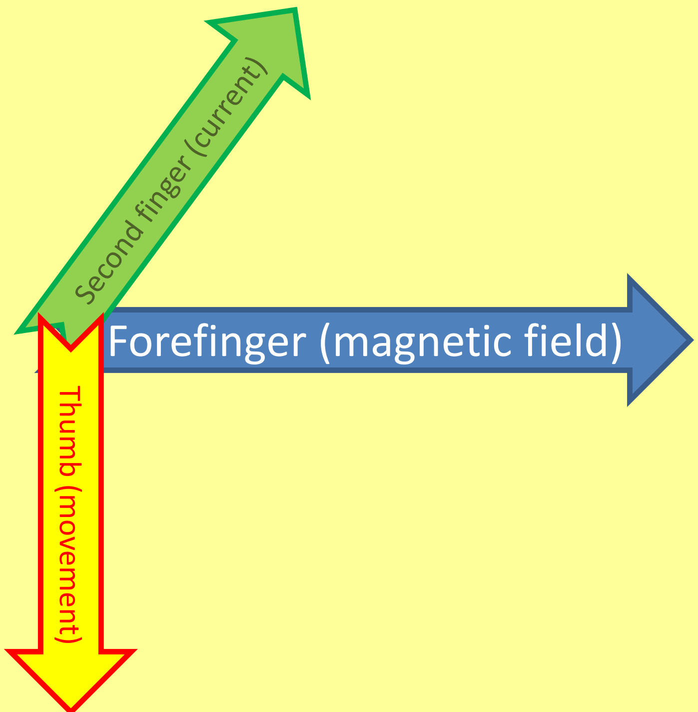

So, applying Fleming's left-hand rule to the example given ….




http://www.bbc.co.uk/schools/gcsebitesize

Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing:
- the current
- the direction of the field

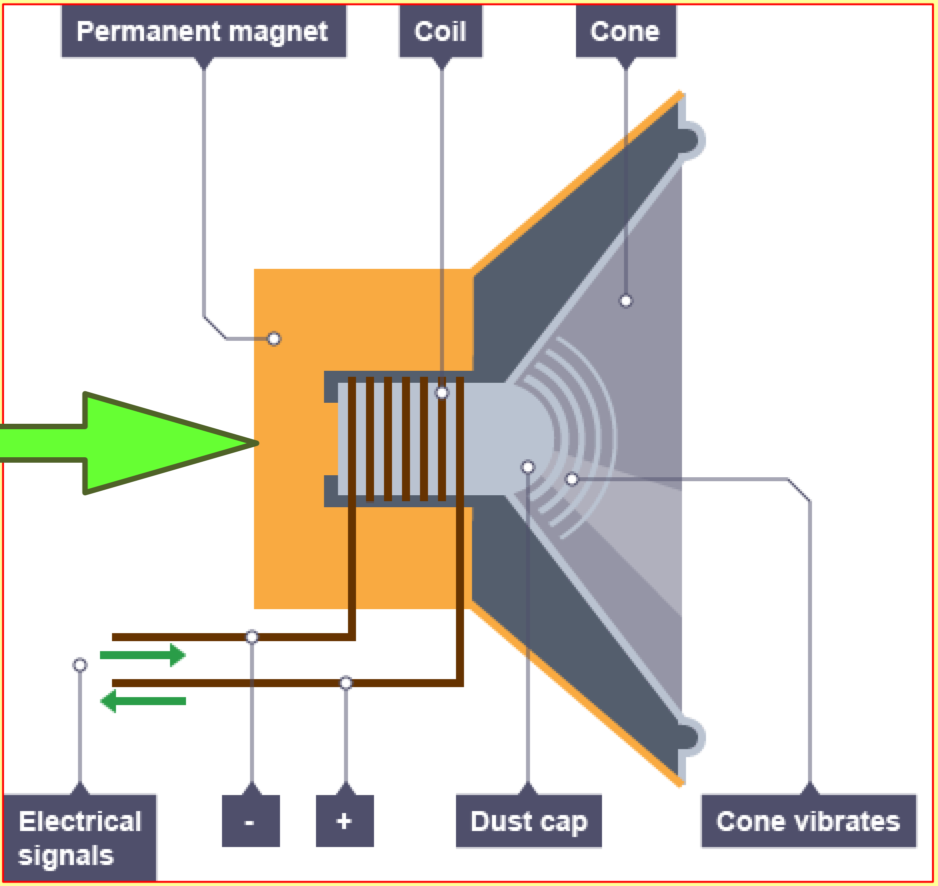




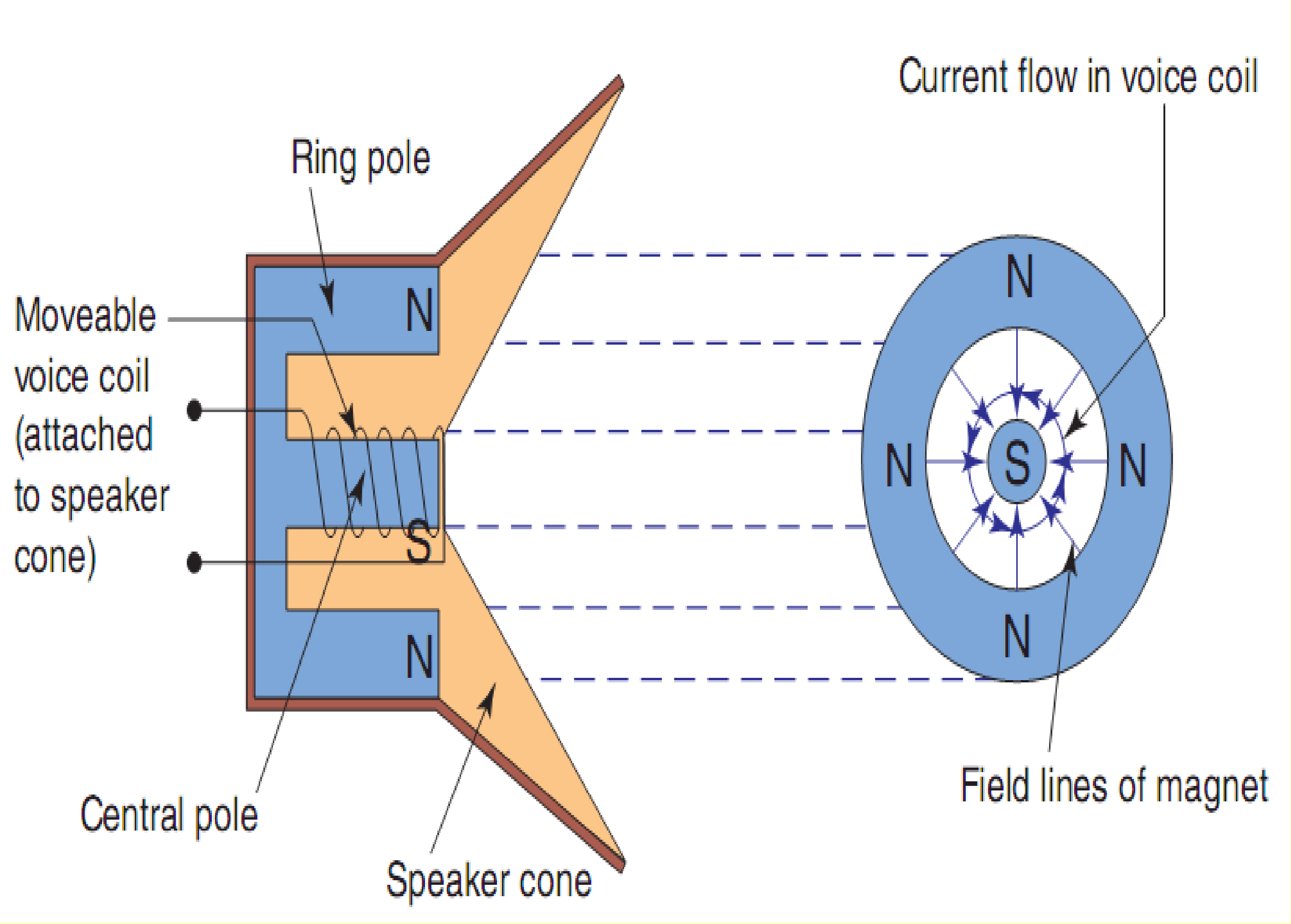

Some devices use the fact that there is a force on a current-carrying conductor in a magnetic field – for example, a loudspeaker.

http://www.bbc.co.uk/schools/gcsebitesize

1. The **cylindrical magnet** produces a strong **radial** ('spoke-like') magnetic field at **right angles** to the wire in the coil, which is **attached** to a stiff paper or plastic cone.



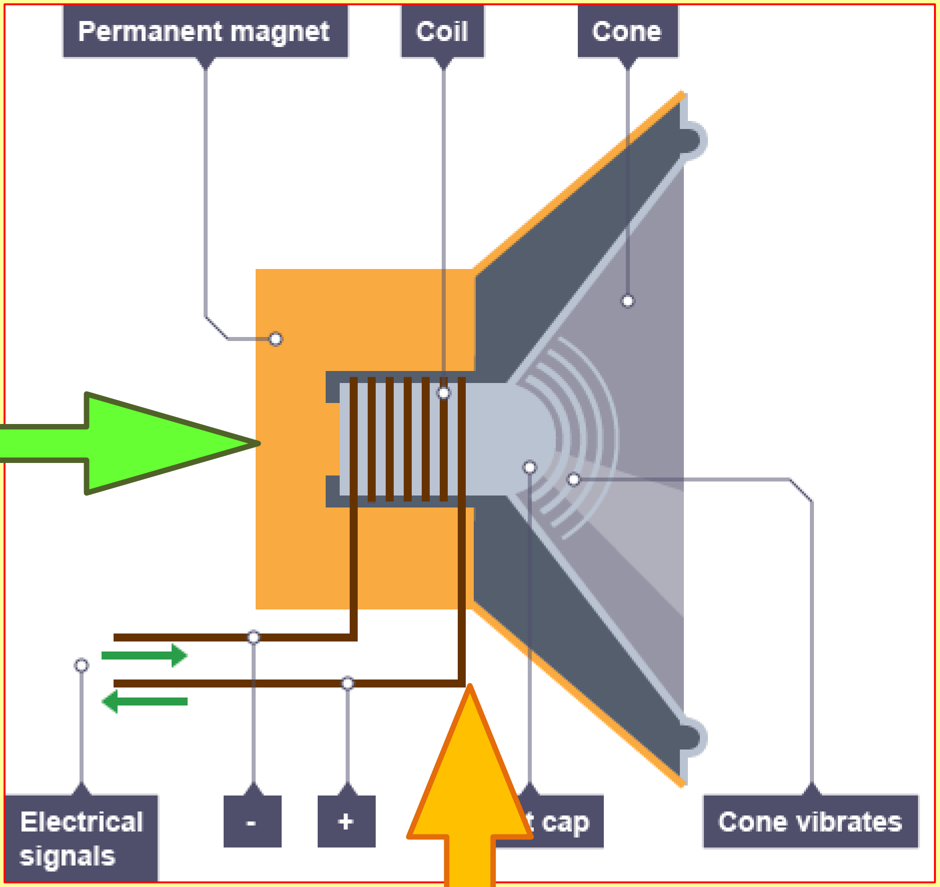
1. The **cylindrical magnet** produces a strong **radial** ('spoke-like') magnetic field at **right angles** to the wire in the coil, which is **attached** to a stiff paper or plastic cone.




Notice the shape of the **Magnetic Field**, all of the field lines point From the **Outer North poles** **towards** the **central South Pole.**

http://www.bbc.co.uk/schools/gcsebitesize

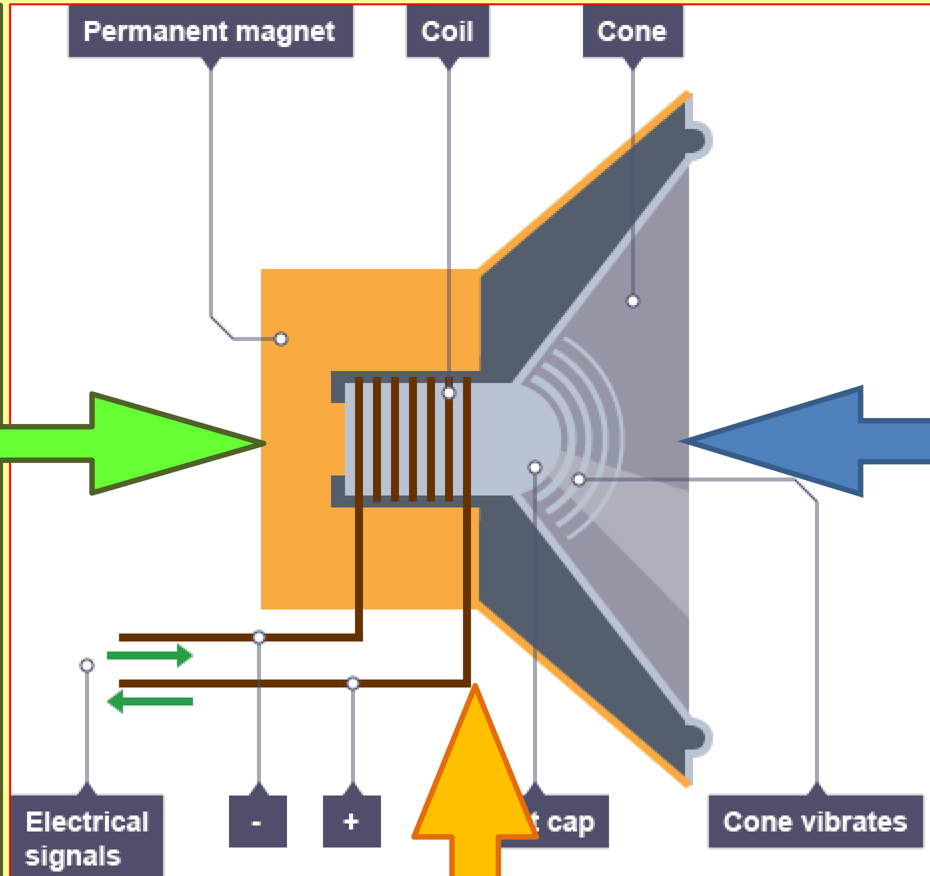
1. The **cylindrical magnet** produces a strong **radial** ('spoke-like') magnetic field at **right angles** to the wire in the coil, which is **attached** to a stiff paper or plastic cone.




2. The loudspeaker is connected to an **amplifier**. The current is AC and so continually **changes direction**. This causes the **magnetic field** around the **electromagnet** to **continually change**.

http://www.bbc.co.uk/schools/gcsebitesize

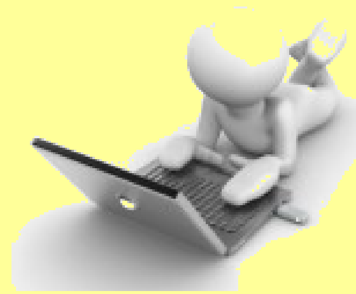
1. The **cylindrical magnet** produces a strong **radial** ('spoke-like') magnetic field at **right angles** to the wire in the coil, which is **attached** to a stiff paper or plastic cone.



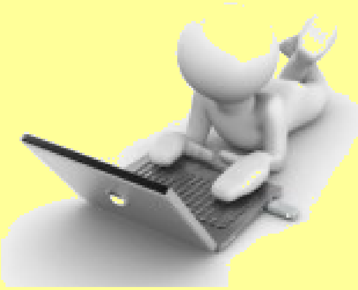

3. The **electromagnet** moves back and forth, and as a result the **speaker cone** also moves back and forth, generating **sound waves**.

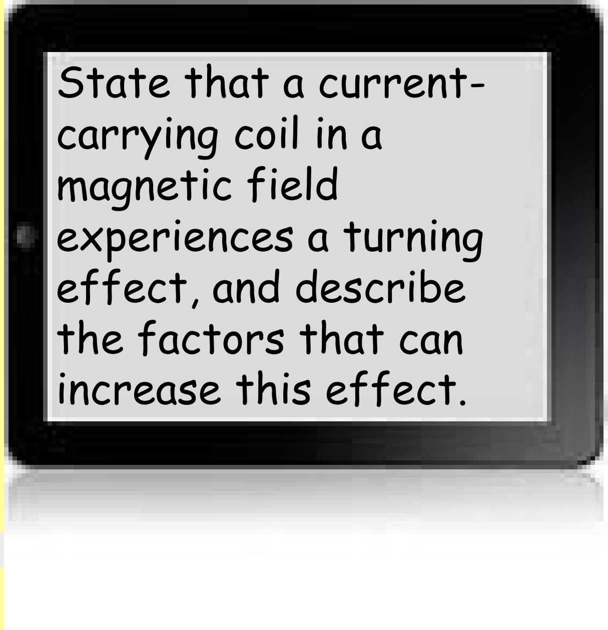
2. The loudspeaker is connected to an **amplifier**. The current is AC and so continually **changes direction**. This causes the **magnetic field** around the electromagnet to **continually change**.

State that a current-carrying coil in a magnetic field experiences a turning effect, and describe the factors that can increase this effect.



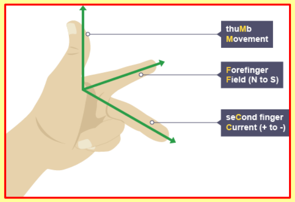
Turning effect → Simple motor





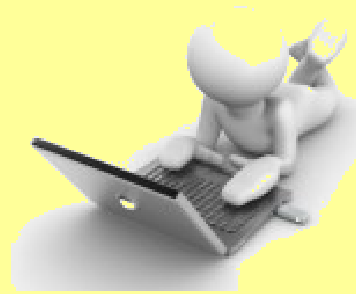

# Turning effect

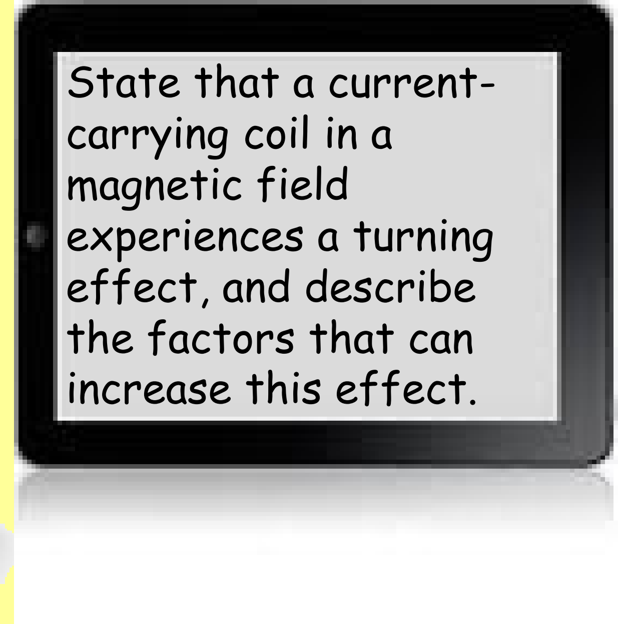
Current-carrying wire



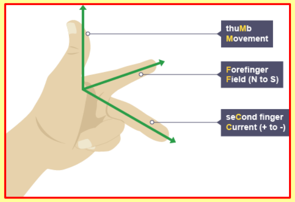

Magnetic field

Force on the wire





# Turning effect

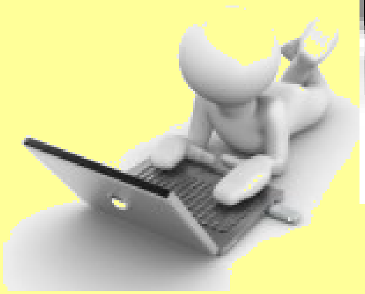


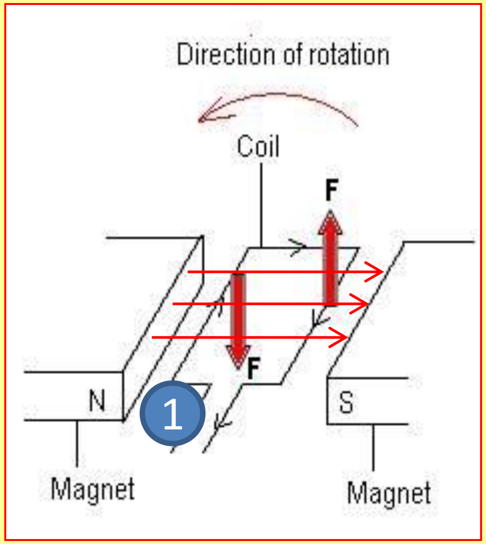

Current-carrying wire

Magnetic field

Force on the wire

State that a current-carrying coil in a magnetic field experiences a turning effect, and describe the factors that can increase this effect.

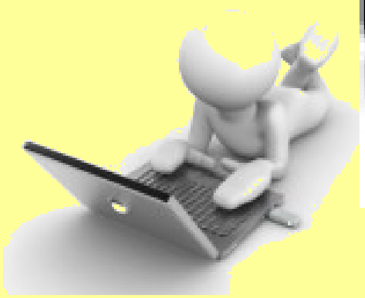


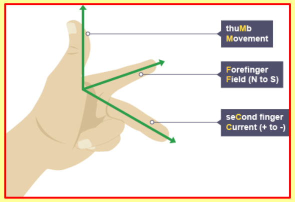



1) In the coil of wire the **current flows** along one side in **one direction**, and in the **opposite direction** on the other.

# Turning effect

State that a current-carrying coil in a magnetic field experiences a turning effect, and describe the factors that can increase this effect.

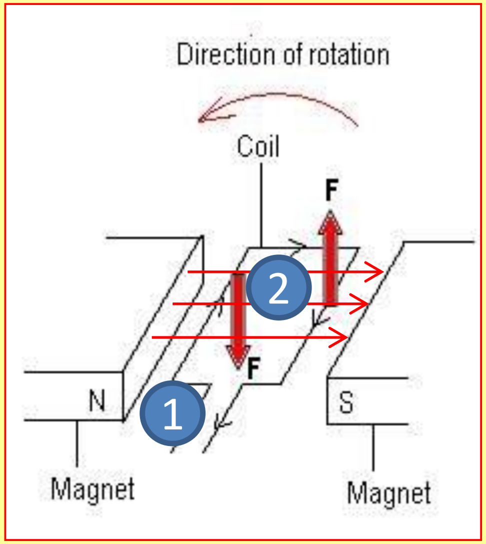





Current-carrying wire

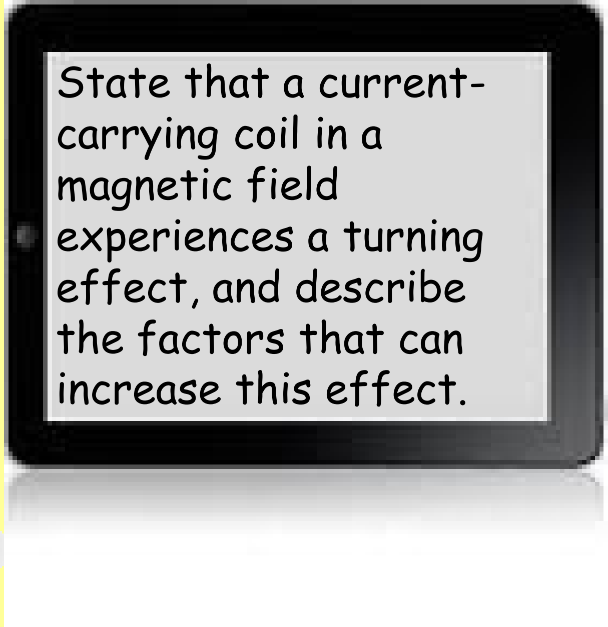
Magnetic field

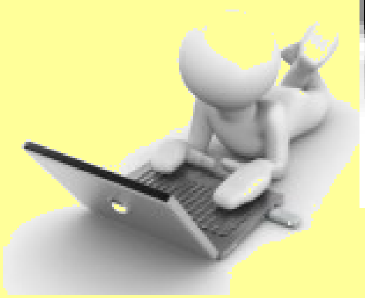
Force on the wire



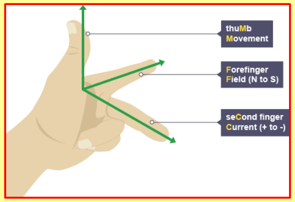

1) In the coil of wire the <u>current flows</u> along one side in <u>one direction</u>, and in the <u>opposite direction</u> on the other.
2) According to <u>Fleming's left hand rule</u> one side is <u>pushed up</u> by the magnetic field, and one is <u>pushed down</u>.

# Turning effect



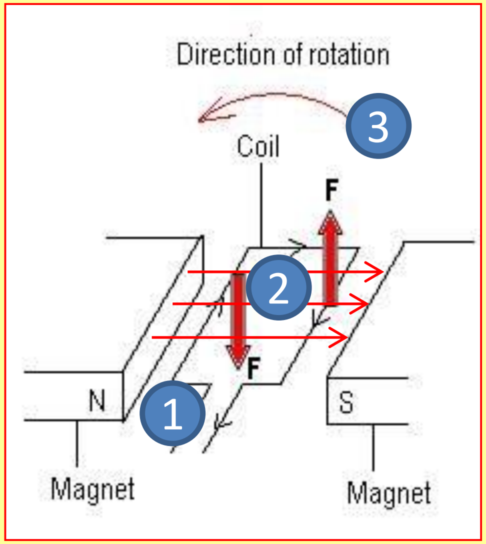



Current-carrying wire




Magnetic field

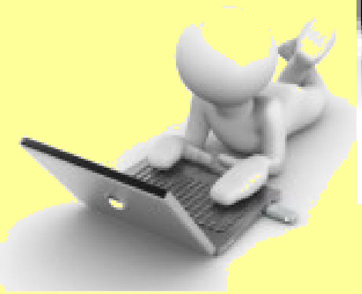
Force on the wire



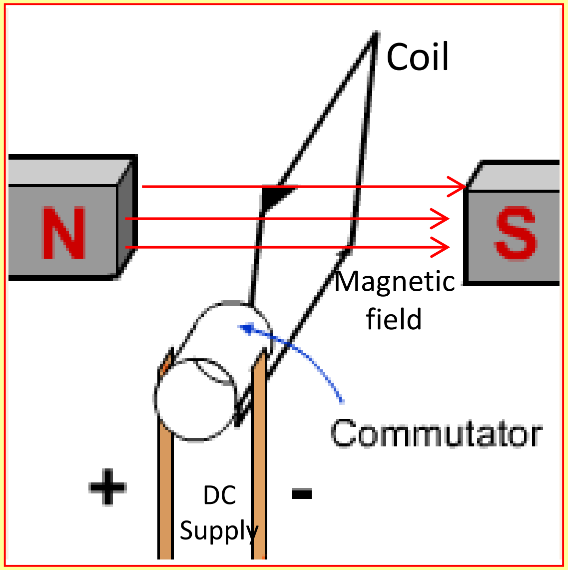

1) In the coil of wire the current flows along one side in one direction, and in the opposite direction on the other.
2) According to Fleming's left hand rule one side is pushed up by the magnetic field, and one is pushed down.
3) These opposing forces on the coil of wire will result in a turning effect.

# Turning effect

State that a current-carrying coil in a magnetic field experiences a turning effect, and describe the factors that can increase this effect.



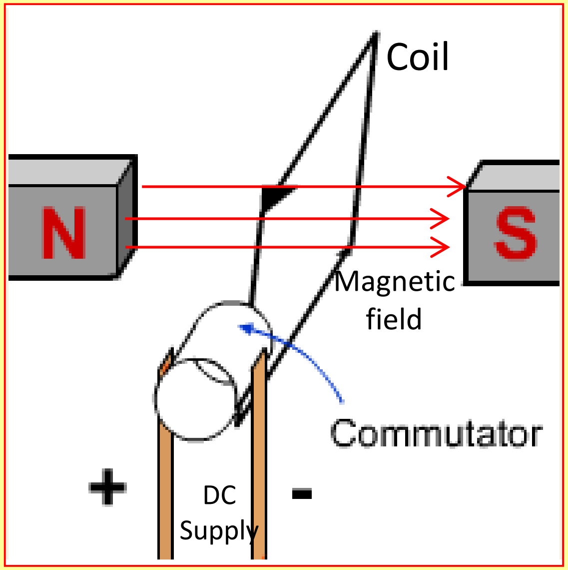
## Simple DC motor




Coil is made from **insulated copper** wire, and is **free** to **rotate** between the poles of the magnet. The **commutator** (or **split ring**) is fixed to the coil, and is in contact with the **brushes** from the DC supply.

# Turning effect

## Simple DC motor

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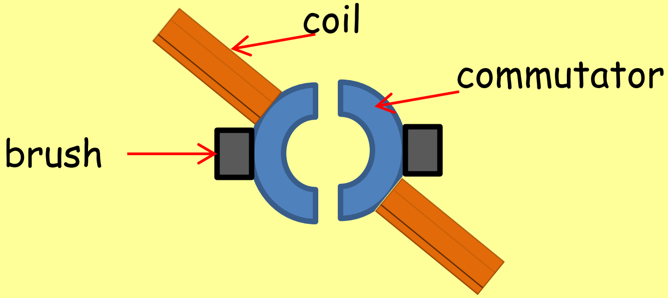
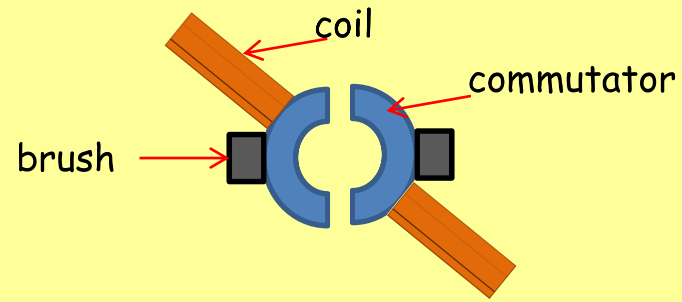
## Commutator detail

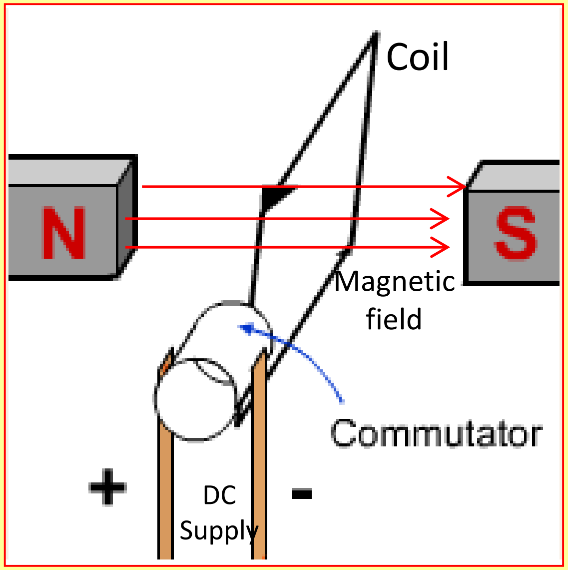


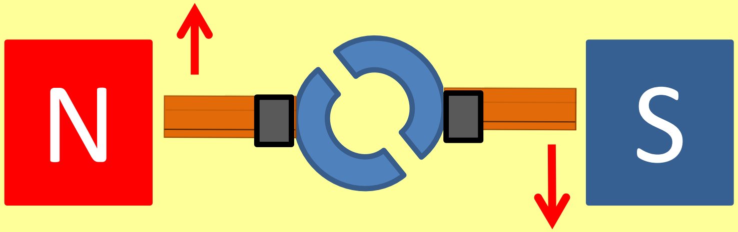
# Turning effect

Commutator detail




Simple DC motor



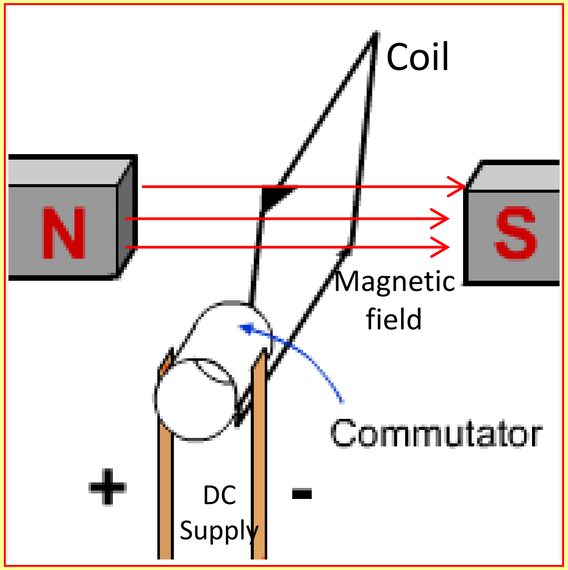




Coil is made from <u>**insulated copper**</u> wire, and is <u>**free**</u> to <u>**rotate**</u> between the poles of the magnet. The <u>**commutator**</u> (or <u>**split ring**</u>) is fixed to the coil, and is in contact with the <u>**brushes**</u> from the DC supply.

When the coil is <u>**horizontal**</u> between the <u>**poles**</u> of the <u>**magnet**</u> the forces have their <u>**maximum turning effect**</u> (leverage) on the coil.

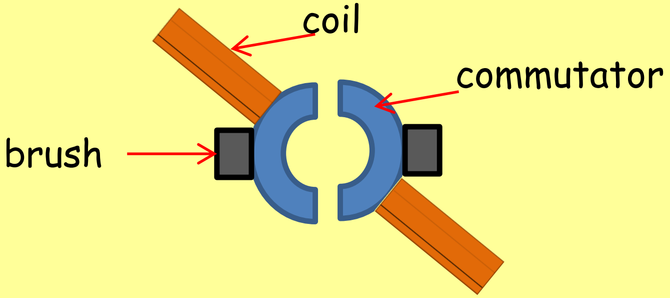
# Turning effect

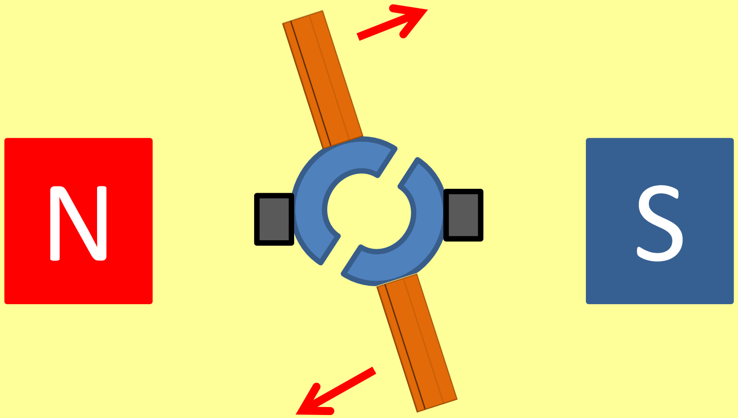
## Simple DC motor




Coil is made from **insulated copper** wire, and is **free** to **rotate** between the poles of the magnet. The **commutator** (or **split ring**) is fixed to the coil, and is in contact with the **brushes** from the DC supply.

## Commutator detail

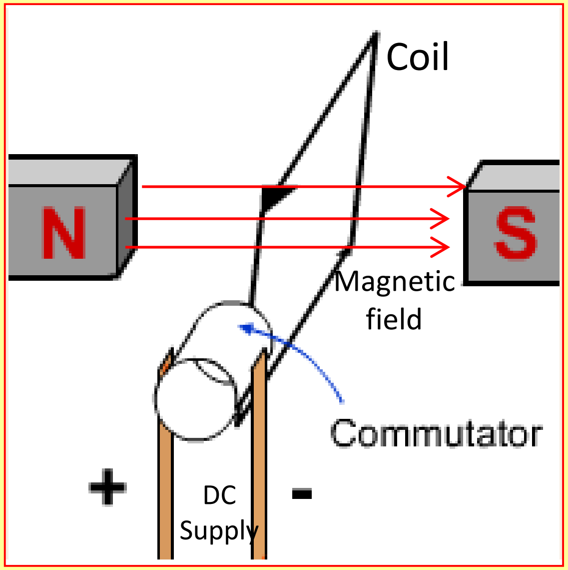



If there was **no change** to the forces then the coil would **come to rest** in the **vertical position**

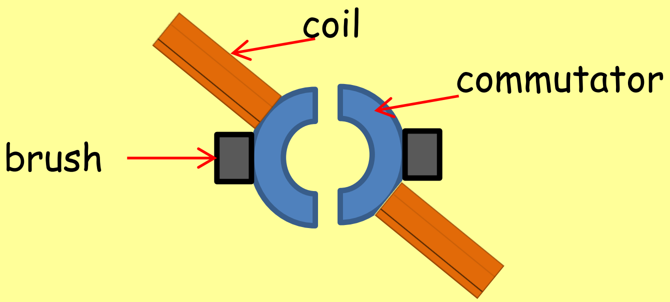
# Turning effect

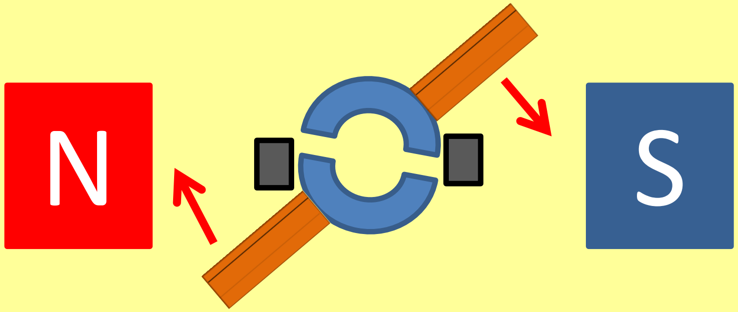
## Simple DC motor




Coil is made from **insulated copper** wire, and is **free** to **rotate** between the poles of the magnet. The **commutator** (or **split ring**) is fixed to the coil, and is in contact with the **brushes** from the DC supply.

## Commutator detail

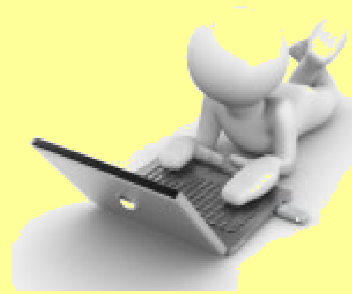


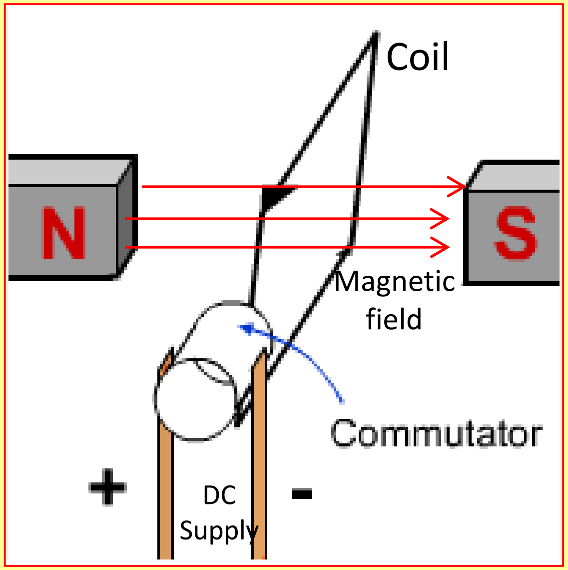

But the coil has **momentum**, so it **overshoots** the **vertical** position, the **commutator changes the direction** of the current through it, so the **forces change direction** and keep the coil **turning**.

# Turning effect

State that a current-carrying coil in a magnetic field experiences a turning effect, and describe the factors that can increase this effect.



## Simple DC motor

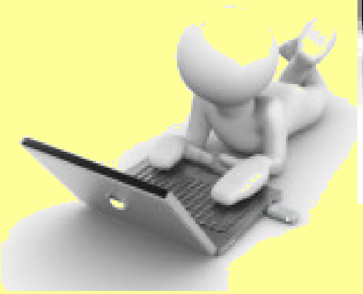



Coil is made from **insulated copper** wire, and is **free** to **rotate** between the poles of the magnet. The **commutator** (or **split ring**) is fixed to the coil, and is in contact with the **brushes** from the DC supply.

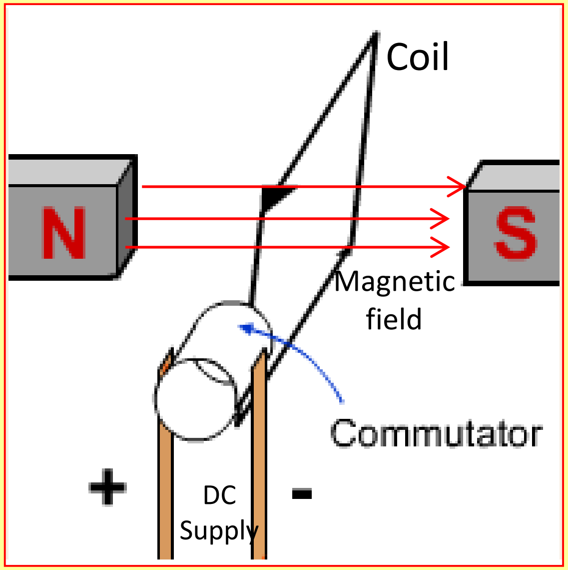
The coil would rotate **anticlockwise** if either the **battery** or the **poles of the magnet** were the **other way round.**

# Turning effect

State that a current-carrying coil in a magnetic field experiences a turning effect, and describe the factors that can increase this effect.



## Simple DC motor



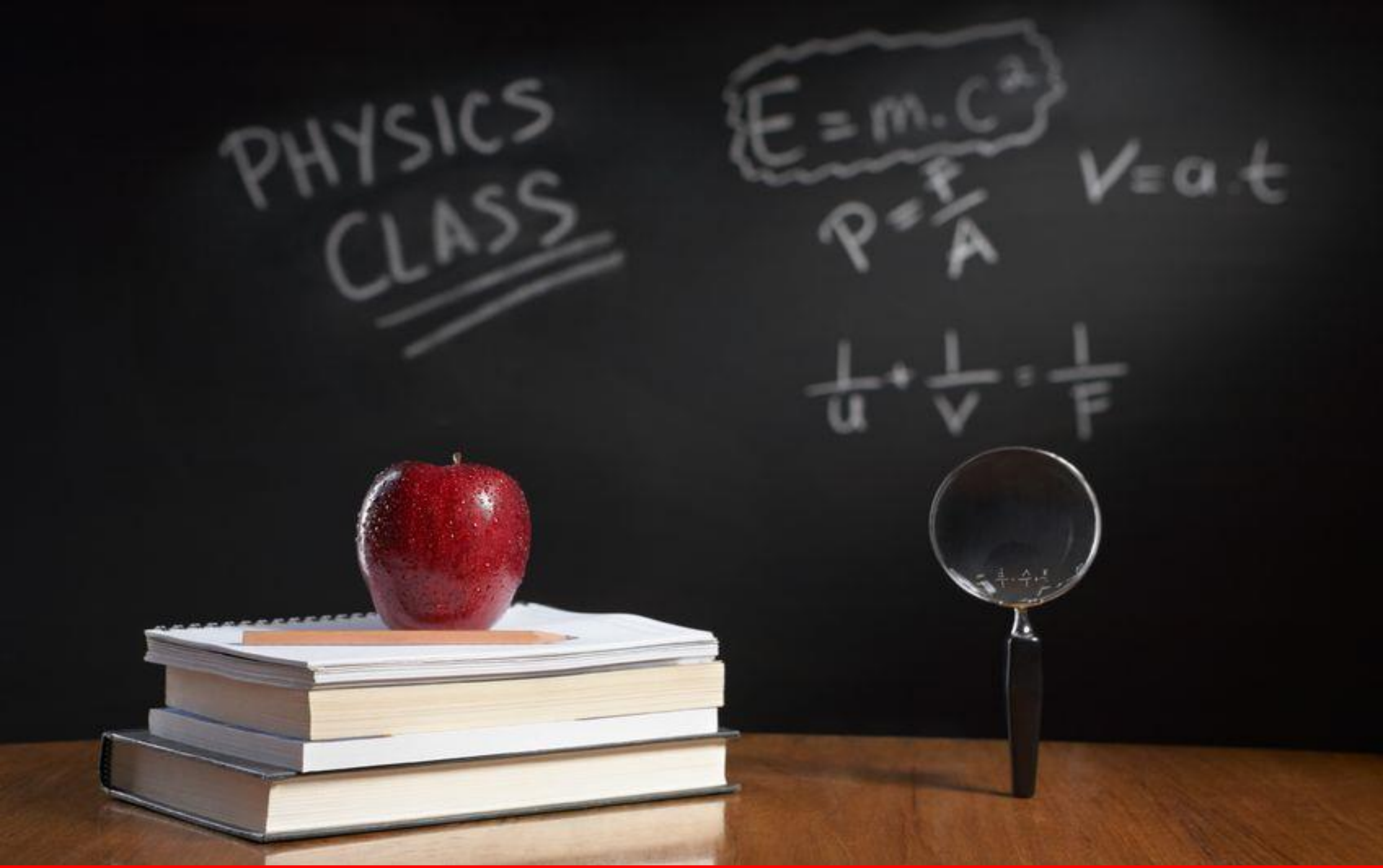

Coil is made from **insulated copper** wire, and is **free** to **rotate** between the poles of the magnet. The **commutator** (or **split ring**) is fixed to the coil, and is in contact with the **brushes** from the DC supply.

The **turning effect** on the coil can be **increased** by:

- Increasing the **current;**
- Using a **stronger** magnet;
- Increasing the **number of turns** on the coil;
- Increasing the **area of the coil**.

# LEARNING OBJECTIVES

| Core | Supplement |
|---|---|
| • Describe the pattern of the magnetic field (including direction) due to currents in straight wires and in solenoids<br>• Describe applications of the magnetic effect of current, including the action of a relay<br>Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing: – the current – the direction of the field<br>State that a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by: – increasing the number of turns on the coil – increasing the current – increasing the strength of the magnetic field | State the qualitative variation of the strength of the magnetic field over salient parts of the pattern<br>• State that the direction of a magnetic field line at a point is the direction of the force on the N pole of a magnet at that point<br>• Describe the effect on the magnetic field of changing the magnitude and direction of the current<br>State and use the relative directions of force, field and current<br>• Describe an experiment to show the corresponding force on beams of charged particles<br>Relate this turning effect to the action of an electric motor including the action of a split-ring commutator |




PHYSICS – Electromagnetic effects (2)