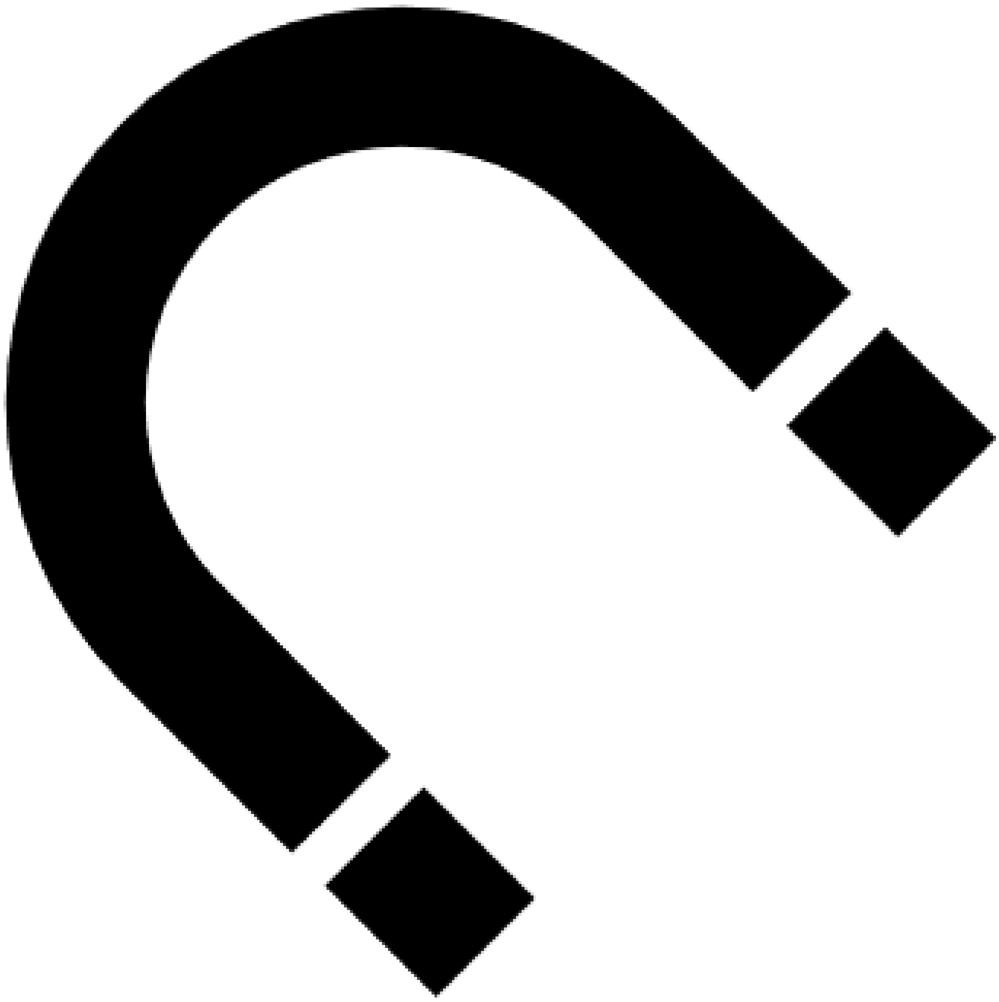
Electromagnetism



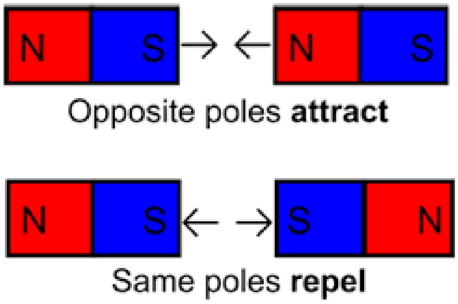
Name ______________________________

Class ______________________________

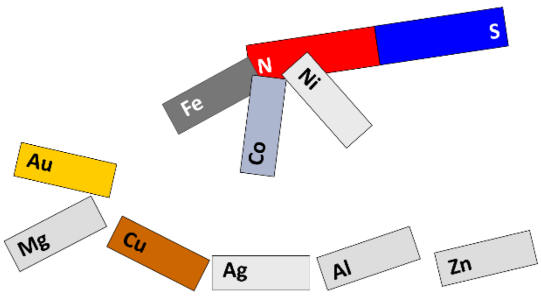
Teacher ______________________________

L1 Magnets and fields

Magnetism produces a **non-contact force**. This means that magnets do not need to touch for their to be a force. The force is carried by a **force field**.



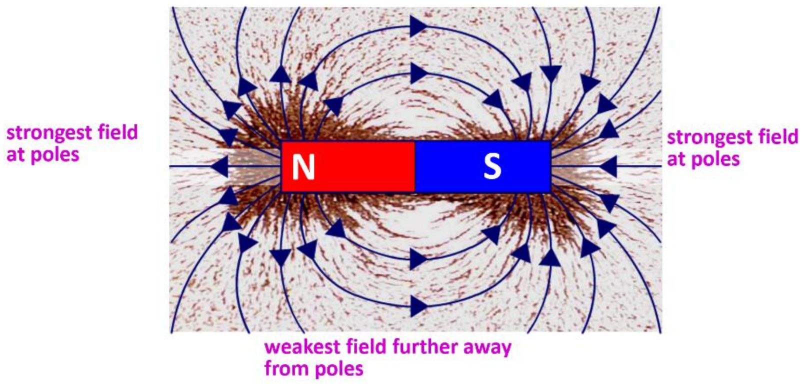
Bar magnets have a north and a south pole. ***Like poles repel, unlike poles attract***.



Magnets can also attract (but not repel) certain metals ***(iron, cobalt, nickel and steel*** but no others).

The region around a magnet where it has a magnetic effect is called its **magnetic field**.

When a magnetic material is placed in a magnetic field it will experience a force. The iron filings feel the effect of the magnetic field and show the direction of the forces in this region. Magnetic field lines flow from **North to South**.



The magnetic field is strongest where the field lines are closest together. The poles of a bar magnet have the strongest field. As you go further from the magnet, the field lines spread out. The magnetic field becomes weaker.

A **permanent magnet** produces its own magnetic field.

An **induced magnet** is a material that becomes a magnet when it is placed in a magnetic field.

Independent Practice

Basic

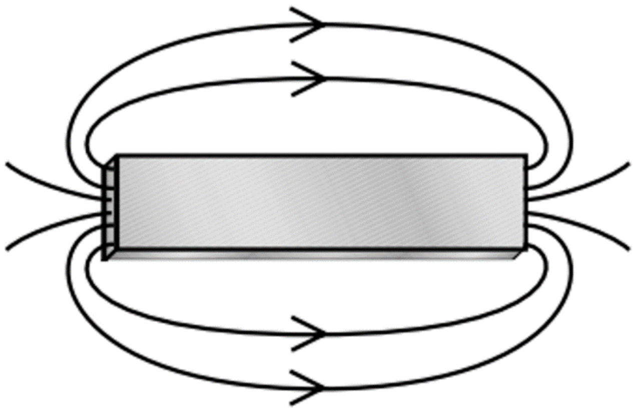
Q1. Magnetism is a contact/non-contact force.

Q2. What is the unit of a force?

Q3. Like poles _________, unlike poles __________.

Q4. What are the three magnetic metals?

Q5. What is the name given to the type of magnet shown in the diagram to the right?



Q6. What are the lines on the diagram called?

Q7. Make the North and South poles on the diagram on the right by writing N and S on the correct ends of the magnet.

Medium

Q8. Answer true/false for the below questions:

a) Magnets need to touch for them to be a force between them.
b) A North pole will repel a South pole.
c) A North pole will attract a South pole.
d) A South pole will attract a South pole.
e) A South pole will attract a North pole.

Q9. Where is the magnetic field strongest by a bar magnet? Explain how we can tell this from the diagram above.

Q10. What is a permanent magnet?

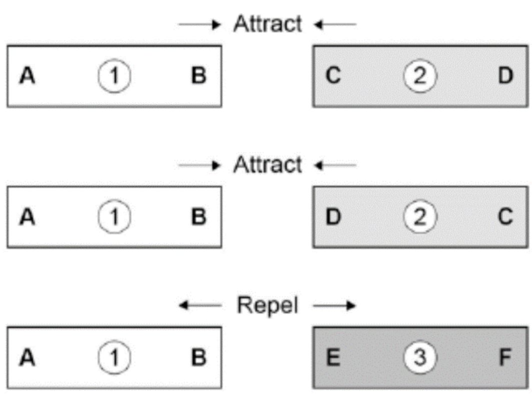
Q11. What is an induced magnet?

Q12. Induced magnetism always causes a force of _______________.

Q13. What do you see when you sprinkle iron filings around a magnet?

Hard

Q14. Which one of the metal bars is a piece of unmagnetized iron? Explain why.



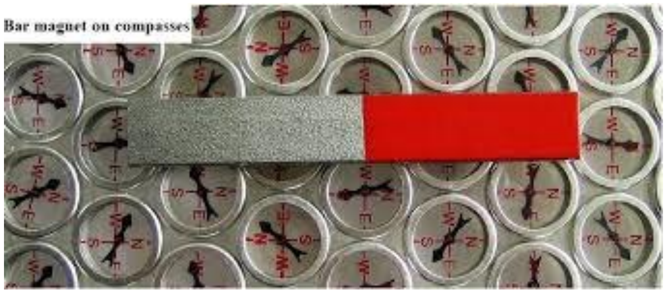
Q15. Sketch magnetic field lines for when:

a) Two North poles of bar magnets are near each other.
b) Two South poles of bar magnets are near each other.
c) A North and a South pole of two bar magnets are near each other.

Q16. Explain some similarities and differences between:

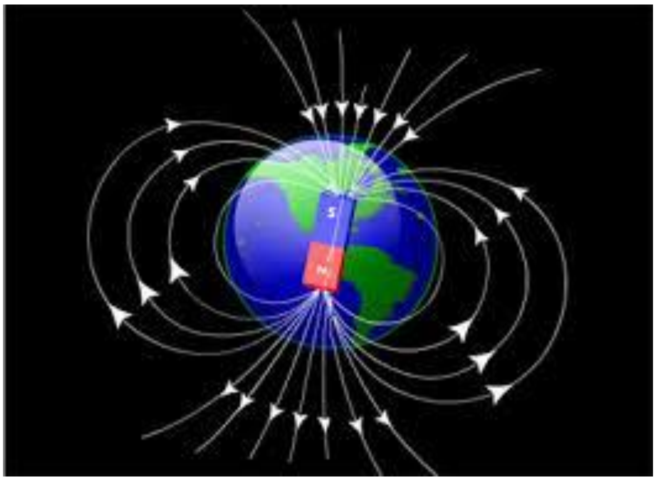
a) Magnetism and gravity.
b) Magnetism and electrostatic forces.

L2 The earths magnetic Field



A **compass** contains a small bar magnet. It always points towards the south pole of a magnet.

The Earth has a **magnetic field** caused by molten (liquid) iron in the Earth's outer core.



The Earth is like a big bar magnet. The north pole of the Earth is actually magnetic south. Compasses point towards geographic north but that is magnetic south.

To plot the magnetic field around a magnet:

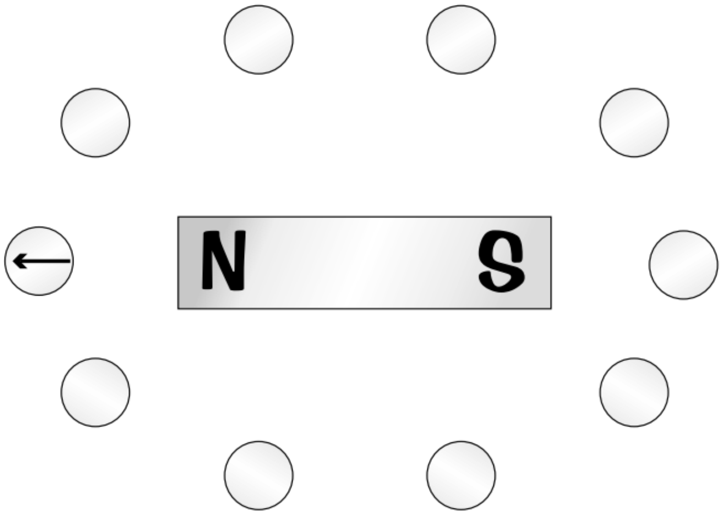
- Place magnet on a sheet of (plain) paper.
- Place the **compass** near the end of the magnet.
- Mark the position that the compass needle points to.
- Move the compass so the opposite end is at this position and mark the new position where the compass tip settles.
- Repeat above and below the magnet and then connect the marks together to construct a field line.

Task: Complete in exercise book.

Basic

Q1. Does a compass point towards the North pole or the South pole of a magnet?

Q2. On the diagram, draw an arrow in each circle to show which way the compass is points.



Medium

Q3.
Earth's North pole is actually magnetic ______________.

Q4. What evidence do we have the Earth's core is magnetic.

Q5. Using the diagram to the left, draw a complete diagram of the Earth's magnetic field.

Q6. What is a compass made of?

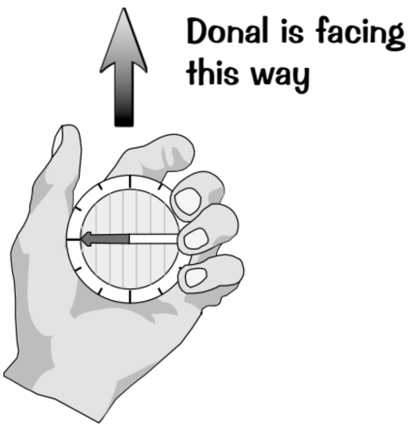
Q7. Describe the process of plotting a magnetic field diagram using a compass.

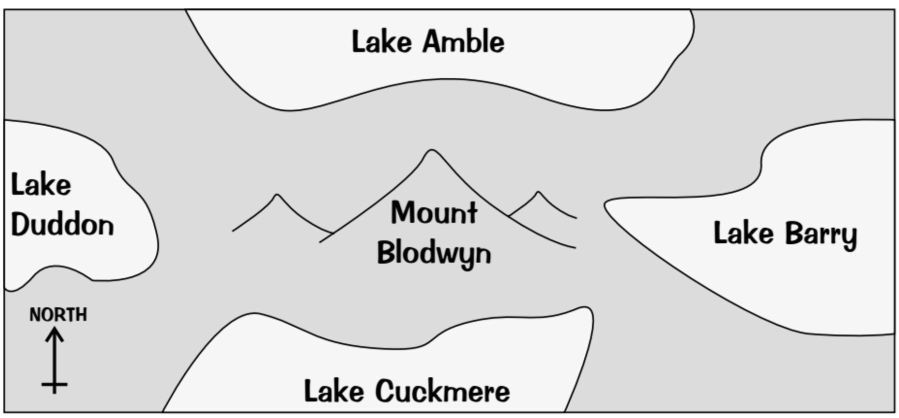
Hard

Q8. Explain why a compass isn't useful if you have something producing a magnetic field nearby (e.g. a credit card or a mobile phone).

Q9. Donal is hiking, but he is a bit lost. He knows that he's standing on top of Mount Blodwyn, but he doesn't know which way he is facing. Looking straight ahead, he can see a lake. The pictures below show Donal's map and compass.

a) What is Donal's compass lined up with?
b) Explain why Donal can use his map and compass to figure out which direction he is looking in.
c) Which lake is Donal looking at?





L3 Electromagnets

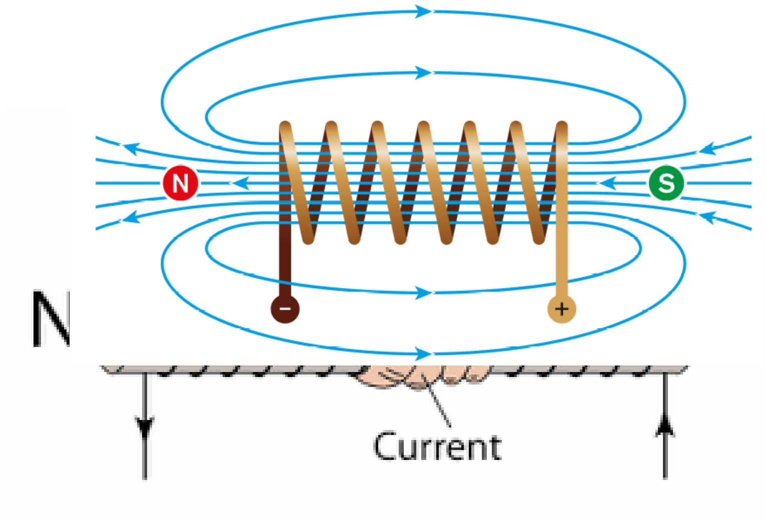
A current flowing through a wire produces a magnetic field.

This effect can be increased by having a coil of wire (called a **solenoid**).

A solenoid creates a field like a **bar magnet**.

The field is strongest inside the solenoid.

You can also use the **right hand grip rule** for a solenoid. This time your thumb gives the direction of the magnetic field lines and your curled fingers give the direction of the current.

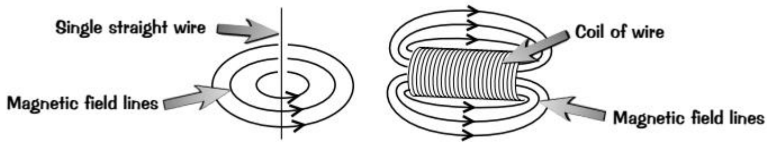


The task on the following page guides you through how electromagnets help some common devices to work. Main points to remember:

1. A **current** flowing causes a **magnetic field**.
2. This magnetic field can then attract an object made **of iron, nickel or cobalt**.
3. Making the object **move**.

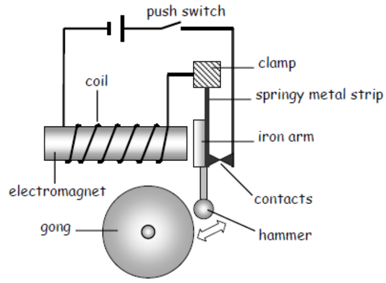
Independent practice

Basic:



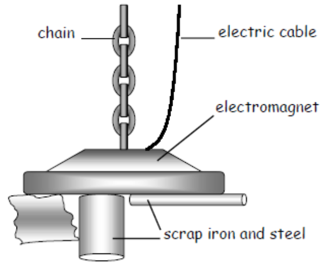
1. What causes a wire to produce a magnetic field?
2. What kind of magnet has the same magnetic field as the long coil of wire?
3. What is the scientific name for a long coil of wire?
4. What is the main advantage of using an electromagnet vs a permanent magnet?
5. Why would steel be bad to use as the core of an electromagnet?
6. Name a metal that would be more suitable to use as the core of an electromagnet.
7. Suggest two other ways of increasing the strength of an electromagnet.

Medium: Describe how some electromagnetic devices work



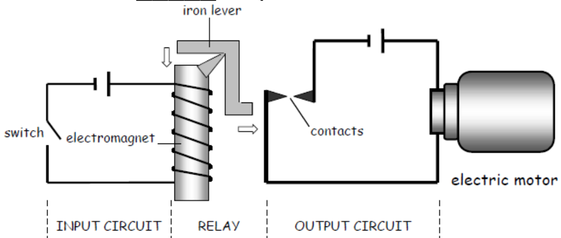
8. **An electric bell:**

When the push switch is closed the current flows through the ___________. The electromagnet then attracts the iron ______. The hammer moves and strikes the _________. As this happens the contacts separate and the circuit is broken. The electromagnet is switched ______ and the hammer springs back.



9. **Sorting scrap metal:**

In a scrap yard electromagnets can be used to separate iron and ________ objects from other materials. A thick __________ supplies current to the electromagnet. The current is switched on to pick the metals up and then switched _____ to put them down.

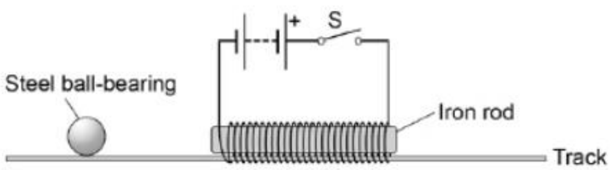


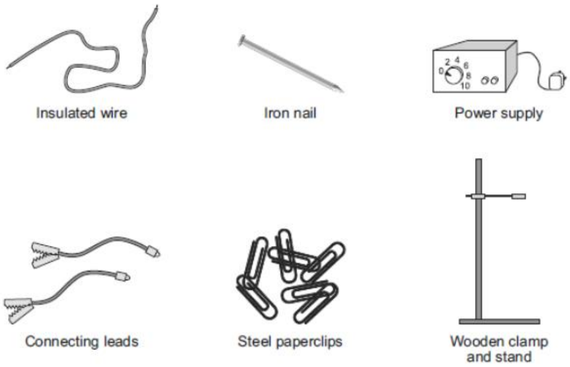
10. **Electromagnetic switches – relays.**

Sometimes it is dangerous to switch on a circuit directly. For example, a car starting motor needs a current of over 100 amps. An electromagnetic switch called a _________ can be used to switch the circuit on safely. When the switch in the _________ circuit is closed the magnet is switched on. This pulls the iron __________ towards it and the ____________ are closed. The motor in the circuit is now switched on.

Hard:

11. Explain how a relay similar to one in the diagram above could be used to turn an electric motor off.
12. Explain how you could use a plotting compass to draw the direction of magnetic field lines around an electromagnet?





13. A student gives a steel ball bearing a gentle push in the direction of the iron rod. At the same time the student closes the switch S. Explain the effect on the motion of the ball bearing when the switch S is closed.

14. Using the equipment shown to the left, describe how students could build an electromagnet. Include in your answer how the students should vary and test the strength of their electromagnet (6).

L4 – The motor effect

The Motor Effect, also known as the Motor Principle, describes the phenomenon of a current-carrying conductor experiencing a force when placed in a magnetic field. This principle is crucial in the functioning of electric motors, where the interaction between a magnetic field and a current-carrying wire results in rotational motion.

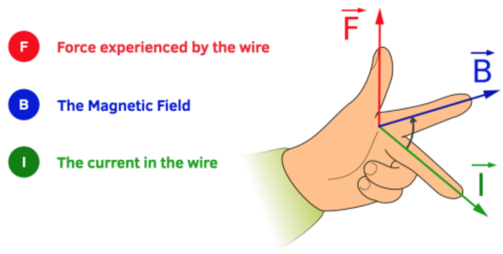


Fig 1. Fleming's Left Hand Rule.

Fleming's Left-Hand Rule:

To predict the direction of this motion, we use Fleming's Left-Hand Rule, which is a mnemonic device to remember the relationship between the three key factors involved: Force (F), Magnetic Field (B), and Current (I). Let's break down how to use this rule:

Thumb (F): Extend your left thumb in the direction of the Force (F). This represents the direction in which the conductor will move.

First Finger (B): Extend your left first finger perpendicular to your thumb. This represents the direction of the Magnetic Field (B).

Second Finger (I): Extend your left second finger perpendicular to both your thumb and first finger. This represents the direction of the Current (I) flowing through the conductor.

The Three Rules:

To sum it up, here are the three rules you need to remember:

Thumb (F) represents the direction of the Force.

First Finger (B) represents the direction of the Magnetic Field.

Second Finger (I) represents the direction of the Current.

Worked Example:

Now, let's apply Fleming's Left-Hand Rule to a practical scenario. Imagine you have a wire carrying a current (I) running from left to right, and it is placed in a magnetic field (B) that points into the page (perpendicular to the paper). Using Fleming's Left-Hand Rule, we can determine the direction of the force (F) acting on the wire.

Thumb (F): Point your left thumb in the direction of the force, which is the upward direction.

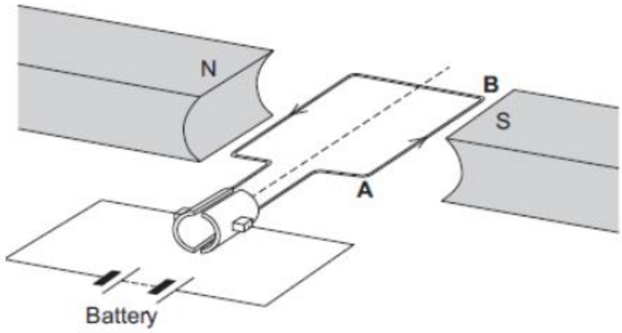
First Finger (B): Point your left first finger into the page, representing the direction of the magnetic field.

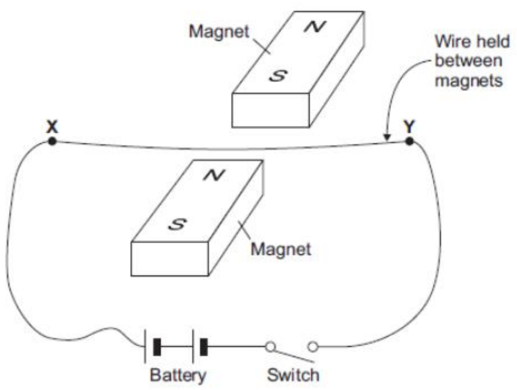
Second Finger (I): Now, extend your left second finger from left to right, representing the direction of the current.

With your thumb pointing up (F), your first finger pointing into the page (B), and your second finger pointing from left to right (I), you will find that your palm is facing you. This indicates that the force on the wire is directed toward you, perpendicular to the paper. Therefore, the wire will experience an upward force.

Independent Practice:

1. Now, let's test your understanding of the Motor Effect and Fleming's Left-Hand Rule with some questions:
2. What is the Motor Effect, and why is it important in the study of electromagnetism?
3. Explain Fleming's Left-Hand Rule and its three key components.
4. If a wire carrying current (I) points from top to bottom, and the magnetic field (B) points from left to right, use Fleming's Left-Hand Rule to determine the direction of the force (F) on the wire.
5. How can the Motor Effect be applied in real-life devices or applications?
6. What would happen if the current in a wire is increased while it is in a magnetic field according to the Motor Effect?
7. Describe the role of Fleming's Left-Hand Rule in understanding the operation of an electric motor.
8. How does the direction of the current affect the direction of the force experienced by a wire in a magnetic field?
9. What would happen if you reversed the direction of the magnetic field while keeping the current the same in the Motor Effect experiment?
10. Explain how the Motor Effect differs from the Magnetic Effect.
11. How does the strength of the magnetic field influence the force experienced by a current-carrying wire in the Motor Effect? In which direction does the force on the wire act?
12. Suggest three changes that would decrease the force acting on the wire.
13. In which direction does the force on the wire **AB** act?
14. Suggest two changes that would reverse the direction of the force acting on the wire **AB**.





15. Closing the switch creates a force that acts on the wire XY. Explain why a force acts on the wire XY when the switch is closed.
16. The force causes the wire **XY** to move. In what direction does the wire **XY** move?
17. The student replaced the battery with a low frequency alternating current (AC) power supply. The student closed the switch. Describe the movement of the wire & explain why the wire moves this way.

L4 – Magnetic field and force calculations

A **current carrying wire at right angles** to a magnetic field experience the following force:

Force = magnetic flux density × current × length of wire in field

F = B × I × L

Where:

The force, F, in measured in **Newtons** (N)

The magnetic flux density, B, is measured in **Tesla** (T)

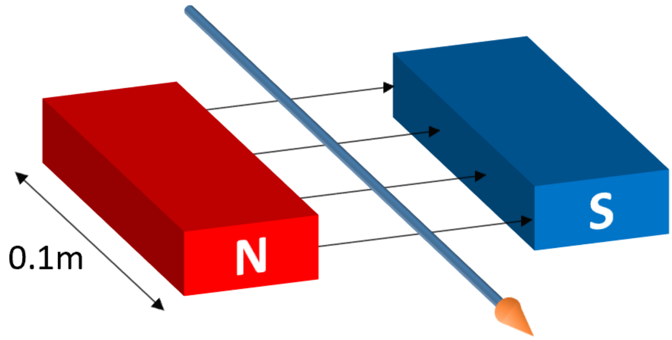
Current, I, is measured in **Amps** (A)

Length, L, is measured in **metres** (m).

This is known as the **motor effect**.

Three ways that the force can be increased:

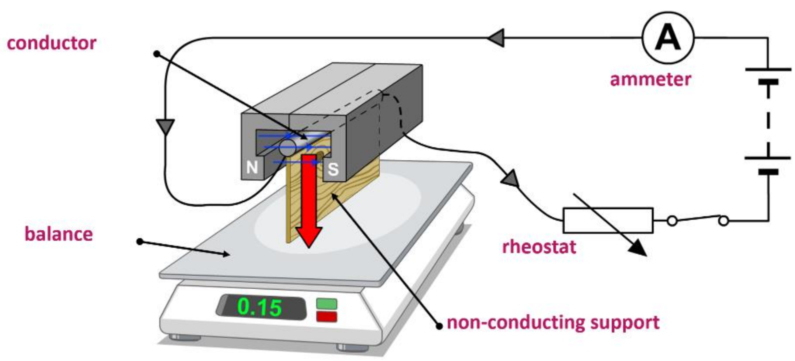
1) Increase **current**.
2) Increase **magnetic flux density**.
3) Increase **length of wire** in magnetic field.



The force is zero if the current goes in **same direction** as magnetic field.

This effect can be investigated by:

1. Having a permanent magnet on a balance.
2. Changing the current in the circuit by changing resistance of rheostat.
3. Measuring the change in mass recorded on the balance.

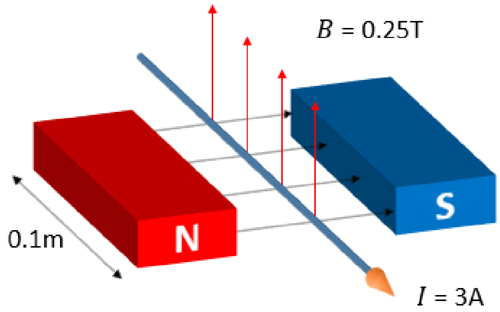


Independent Practice

F = B × I × l

Basic

1. Give the symbol and unit for:
   a) Magnetic flux density
   b) Current
   c) Length
2. Calculate the force on the following current carrying wires:
   a) B = 0.2 T, I = 5 A, l = 2 m
   b) B = 0.01 T, I = 0.02 A, l = 0.5 m
   c) B = 0.3 T, I = 2 A, l = 1.2 m
   d) B = 0.005 T, I = 0.2 A, l = 0.015 m
   e) B = 4 T, I = 13 A, l = 0.8 m
3. Using the numbers in the diagram opposite, calculate the **force** exerted on the wire.



Medium: Wordy questions that you need to rearrange the formula for.

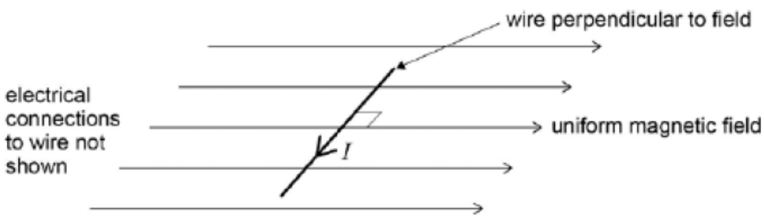
4. Rearrange the equation to give equations for the magnetic flux density, current and length of wire.
5. Calculate the **current** on a wire that has length 0.2m, a force on it of 1.2 N and is in a magnetic field of flux density 0.12T.
6. Calculate the **length** of a wire that has a current of 0.5A flowing through it, has a force of 14 N on it and is in a magnetic field of flux density 0.04T.
7. Calculate the **magnetic flux density** that a wire of length 1.6m, that has a current of 13A flowing through it and has a force of 0.8N exerted on it.
8. Calculate the **current** on a wire that has length 0.25m, a force on it of 0.2 N and is in a magnetic field of flux density 0.03T.

Hard: Unit conversions and a tricky multi-step calculation to finish.

cm → m ÷ 100

mT → T ÷ 1,000

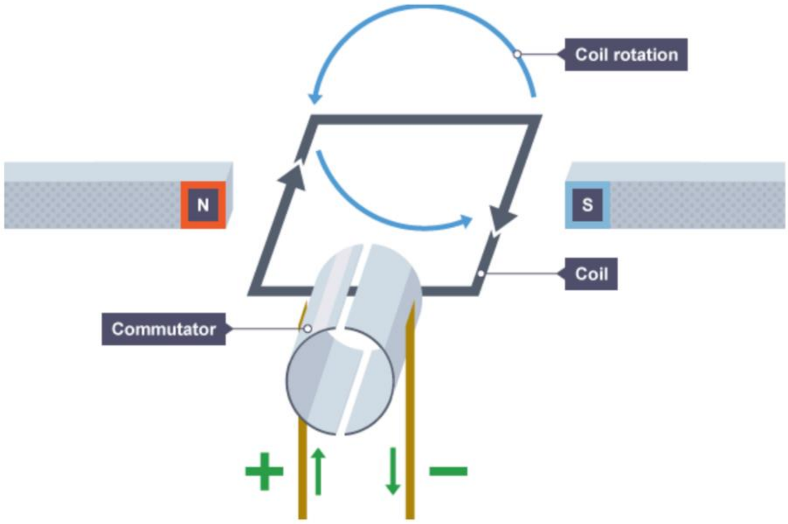
9. Calculate the **magnetic flux density** that a wire of length 12 cm, that has a current of 13A flowing through it and has a force of 0.8N exerted on it.
10. What is the **current** in a 4.00m wire at right angles to the field lines of a magnetic flux of magnetic flux density 300 mT, which experiences a force of 15.3 N.
11. How **long** is a conductor that carries a current of 0.200A at right angles to a magnetic field with a magnetic flux density of 120mT, and which experiences a force of 1.20N?
12. A horizontal straight wire of length 0.30m carries a current of 1.5A perpendicular to a horizontal uniform magnetic field of flux density 5.0×10^{-2} T. The wire "floats" in equilibrium in the field. What is the **mass** of the wire?



13. A conductor has a resistance of 200 Ω, and there is a potential difference of 12V across the conductor. There is a force of 5 N on the conductor, and it is of length 5cm. What is the **magnetic flux density** that the conductor is in?

L5 – Electric motors

A **DC motor** is made out of a coil of wire within a magnetic field.



When a current flows through the coil this creates a **magnetic field**.

This magnetic field interacts with the permanent magnetic field in the motor, causing a **force**.

There is an **equal and opposite** force on each side of the coil. This is because the current on each side of the coil is flowing in **opposite directions**.

This force causes the motor to **rotate**. However, when the coil has rotated 180 degrees, the current are now flowing in opposite directions to before.

This means that the coil would experience a force in the opposite direction.

To prevent this, a **split ring commutator** changes the direction of every half turn. This is due to two halves of the coil swapping from one **carbon brush** to another.

This allows for the motor to experience a force in the same direction. The commutator disconnects the current every half turn, but momentum keeps the motor rotating.

To make the motor spin in the opposite direction, we can:

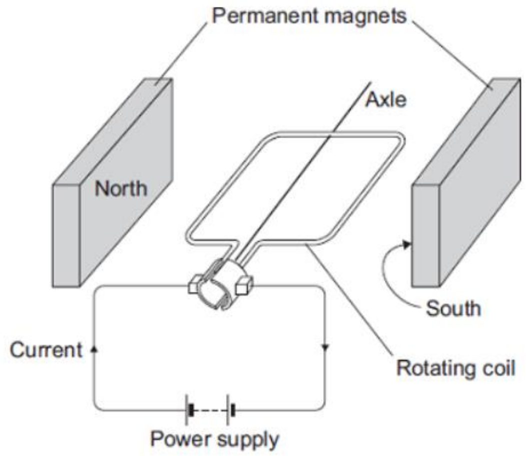
1. Reverse the **direction of current**.
2. Reverse the **direction of the magnetic field lines**

To make the motor spin faster, we can:

1. Increase the **current**.
2. Increase the **magnetic flux density**.
3. Increase the **number of turns** in the coil.

Independent Practice

Basic



The diagram shows a simple electric motor. The following statements explain how the motor creates a turning force. The statements are in the wrong order.

M – The magnetic field interacts with the magnetic field of the permanent magnets.

N – A magnetic field is created around the coil.

O – The power supply applies a potential difference across the coil.

P – This creates a force that makes the coil spin.

Q – A current flows through the coil.

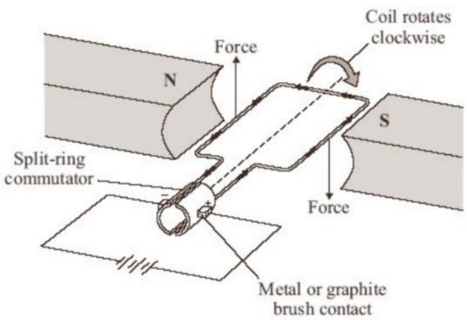
Q1. Arrange the statements in the correct order. Two of them have been done for you.

O → ☐ → ☐ → ☐ → P

Q2. Why do the opposite sides of the coil in a dc motor feel forces in opposite directions?

Q3. In what direction will the motor spin?

Medium



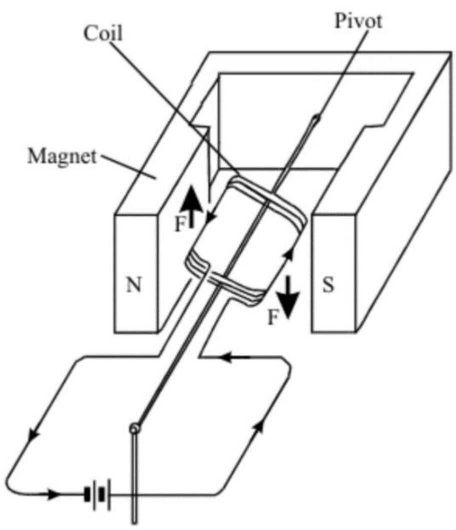
Q4. What does a split ring commutator do?

Q5. In a dc motor, the commutator disconnects the current every half turn. Why doesn't the motor stop?

Q6. The electric motor produces a turning force. Give two ways of increasing the turning force.

Q7. Suggest two changes to the electric motor, each one of which would make the coil spin in the opposite direction.

Q8. When there is a current in the coil, the coil rotates continuously. Explain why.



Q9. The battery has been used for a long time and the potential difference across it has decreased from 3V to 2V. What effect does this have on the turning force of the electric motor? Explain your answer. **Hard**

Q10. The diagram to the left shows an electric motor, without a split ring commutator. What is the purpose of a split ring commutator?

Q11. The arrows labelled F show the direction of the forces acting on the sides of the coil. Describe the motion of the coil until it comes to rest.

Q12. A resistor is placed in series with the battery and coil. What effect, if any, does this have on the force F? Explain why.