PHYSICAL SCIENCE

ELECTRODYNAMICS

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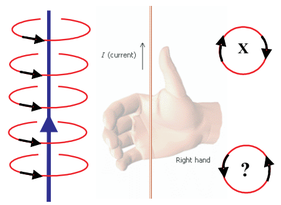
1. **Motors** convert **electrical energy** to **mechanical energy**.
   (motors use electricity to make things move for you)
2. **Generators** convert **mechanical energy** to **electrical energy**.
   (by you making things move, electricity is created)
3. Motors and Generators **both** involve a **coil** that **rotates** in a **magnetic field**.
4. The hand rules described here all use conventional current, i.e. flow of positive charge from positive to negative.
5. All hand rules are swopped if electron flow is used.

Background - Motor Effect
All current carrying conductors are surrounded by a circular magnetic field.
It is amazing to realize that an invisible magnetic field surrounds all the conducting wires around you!
The right-hand wire rule (for conventional currents) is used to determine the direction of this magnetic field.



Current going perpendicularly **INTO PAGE**
Circular clockwise magnetic field visible
Crosswise current = **Clockwise field**

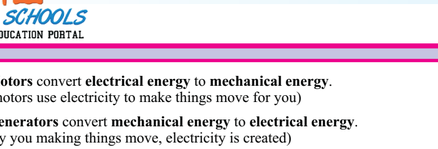
Current coming perpendicularly **OUT OF PAGE**
Circular clockwise magnetic field visible
Dotwise current = **AntiClockwise field**

By coiling the wire to form a solenoid (long, cylindrical coil of wire consisting of a number of turns of insulated wire wound close together) , the magnetic field is increased. Inside the solenoid, the magnetic field is uniform. The strength of the magnetic field is increased hundreds of times if a piece of soft iron is placed inside the solenoid. This is the principle of the electromagnet.

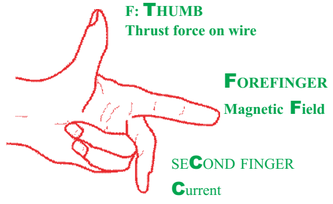
Motors
Two bar magnets can repel each other.

Since a current carrying conductor becomes a bar magnet, when placed next to a real bar magnet, it can also cause repulsion.

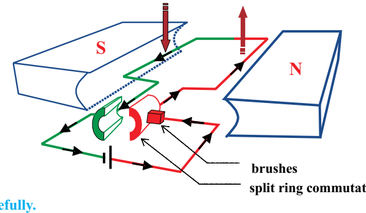
However the direction in which the conductor will feel the repelling force is at right angles to the magnetic field of the bar magnet.



Flemmings Left Hand Motor Rule



The D.C. (Direct Current Motor)
Motors convert **electrical energy** to **mechanical energy**.



Study the diagram carefully.
Two magnets are used for an improved force. The section of wire between the magnets are called LOOPS. The RED LOOP begins with the RED SPLIT RING COMMUTATOR.
So the RED SPLIT RING and the RED LOOP must be regarded as one single unit.

At present the **RED LOOP** is next to the **NORTH** pole. By using the Left Hand Motor Rule, the FORCE is UPWARDS on the RED WIRE.

The section of external **RED WIRE** from the battery ends in **RED BRUSHES**. The external **RED WIRE** and the **BRUSHES** must be regarded as **one single unit.**

The BRUSHES brush against the SPLIT RING COMMUTATOR, and this allows for electrical contact as the ring spins around the brushes.

The RED BRUSH must be seen as a GUN that fires bullets in that direction. As shown, the "bullet" is fired forward into the **RED LOOP.**
When the GREEN LOOP'S SPLIT RING gets in front of the RED BRUSH, "bullets" are fired forward into the GREEN LOOP as well.

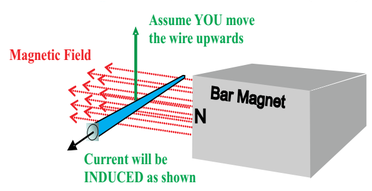
So it DOES NOT MATTER which loop is against the RED BRUSH. The **RED BRUSH** will always fire forward into it. And whichever loop is there, it will move upwards.

So the RED BRUSH "fires into" the RED LOOP, and then into the GREEN LOOP and again into the RED LOOP, and again into the GREEN LOOP as the loops rotate. This goes on and on.

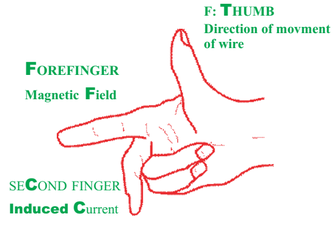
DIRECT CURRENT is used.
Direct Current **is current that flows in one direction only**.

IMPORTANT
1. The **LOOPS** and **RING Rotate.**
2. The **brushes** remain **fixed.** They are **connected** to the **external circuit.**
3. The **current** flows in **one direction** up to the **brushes.**
   The BRUSHES brush against the rings, allowing for electrical contact without being rigidly fixed to the ring.
4. The **SPLIT RING COMMUTATOR** continuously **changes the current direction** in **each half of the loop.**
5. This ensures that whichever loop is next to the north pole, it will always have current in the same direction.
   Charge is "fired into it" by the brush it touches.
6. This allows the loop by the north pole to always have the **force** in the **same direction.**
7. **Continuous rotation is maintained.**
8. Hence the **SPLIT RING COMMUTATOR** is the device that allow for **CONTINUOUS ROTATION** in one direction.
9. The **BRUSHES** ensures **electrical contact** against the **RING.**
10. **Motors** are used in **various** devices. By simply switching on a circuit, **physical movement** is **created**.

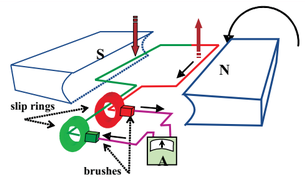
Background - Electromagnetic Induction
1. If a **wire is moved** in a **magnetic field**, a **current** is **induced** (created) in the wire.



2. The current exists in the wire only as long as there is **relative motion between the wire and the magnet.**
3. What happens is that the flux lines linking the conductor with the magnet, changes. This **changing flux** is what **induces** the **current** in the wire.
   3.1. In **open circuit**, only **voltage** is **induced.**
   3.2. In a **closed circuit, both voltage** and **current** is **induced.**
4. The **rate of change of flux linkage** produces an **emf** (electromagnetic force) in the wire.
5. **Faradays Law** states that "the emf produced is directly proportional to the rate of change of flux". In simpler terms, faster movement of the wires creates more current in the wire.
6. **Maximum emf** is induced when the **wire** is at **right angles** to the **magnetic field** of the magnet. **No current** is induced when the **wire** is **parallel** to the **magnetic field**.
7. The direction of the current that is induced can be determined by using **Flemings Right Hand Dynamo Rule.**



The Alternating Current Generator (alternator)
1. Mechanical energy is used to create electrical energy.
2. A coil (loop) is **physically** (**mechanically**) turned in the area of a magnetic field.
3. As a result of Faradays Law, an **electric current** is generated in the **loops**. There is a change In the magnetic flux linkage through the loops



IMPORTANT: The **same** loop is actually **moving up** and **down** in the **same field**, hence **Opposite direction currents** are being **induced**.

DOWN Movement for RED LOOP
Current induced in OTHER DIRECTION

UP Movement for RED LOOP
Current induced in ONE DIRECTION

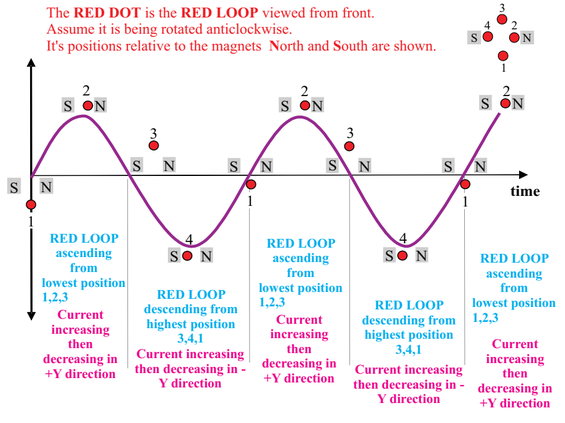
The ammeter would show current that is changing in magnitude and direction.

REMEMBER THAT YOU ARE TURNING THE LOOPS.
SO THE LOOPS ARE ROTATED CONTINUOUSLY IN ONE DIRECTION BY YOU.

4. The **RED LOOP** is **always connected** to the **RED** BRUSH as the loops are rotated round and round. This **GREEN LOOP** is always connected to the **GREEN BRUSH**.
   This is possible due to the **SLIP RINGS**. The **SLIP RINGS** ensure that a particular loop is **ALWAYS** connected to the **same BRUSH**.
5. Consider the **RED LOOP**. According to Flemmings Right Hand Dynamo Rule, as you move the RED LOOP **upwards**, a current is **induced forwards**, which reaches the **RED SLIP RING** and enters the **RED BRUSH**. This current then moves as shown in the external purple wire.
6. But when the **RED LOOP** reaches the **South Magnet Pole**, in would be **moving downwards**. But the **magnetic field** direction is **still** the **same**. So the **RED LOOP** is actually now moving **downwards** in the same magnetic field as before. So current will be induced in the other direction.
7. When the **rotation** takes the RED LOOP back to the **original** position, the **original** current direction will be induced.
8. So, as the **RED LOOP** is rotated in one direction (which **really means UP** and **DOWN** in the **same field**), **CURRENTS** IN **OPPOSITE DIRECTIONS** are induced. This is called **ALTERNATING CURRENT**.

The Alternating Current Generator (alternator)
9. As the **loops rotate** through the magnetic field, they make **different angles with** the **field**. This **results** in **different magnitudes** of **current** being **induced**.
10. **As shown**, the **current** would be **maximum**. As the **loops ascend** to reach the **top**, the **current** would decrease to **zero**. Then as the loops continue to rotate (descend), current would be induced in the opposite direction, increasing to a maximum as the loop reaches the South magnet. As it passes the South magnet, the current would then decrease in magnitude.
11. Then the loops starts to ascend from below the magnets. Current is now induced in the original direction, reaching maximum when the loop reaches the North magnet again.
12. This goes on and on! Round (Up) and round (Down).
13. Although the speed of rotation is constant, the magnitude of induced current is not constant. The current increases and decreases as the angle the conductor makes with the magnetic field changes.
14. The two aspects of the induced current, **change in direction** and **change in magnitude** can be represented in a graph (sine graph).

The **RED DOT** is the **RED LOOP** viewed from front.
Assume it is being rotated anticlockwise.
It's positions relative to the magnets North and South are shown.



TIP

Upward Movement 1 to 2 to 3 ⇨ Current in one direction	Downward Movement 3 to 4 to 1 is ⇨ Current in other direction	**Position 2 and 4** Whenever the loop is next to a magnet, the induced current is greatest.	**Position 1 and 3** When it is "out" of the magnets, the induced current is zero.

IMPORTANT POINTS

1. **A Split Ring Commutator (a ring that is split) is found in a DC motor. It changes the direction of current in the loops, ensuring that the electricity from a battery is able to produce continuous rotation of the loops.**
2. **A Slip Ring (has no splits in it) is found in a Alternating Current Generator. Its purpose is to allow for electrical contact with the brushes. It does not change current direction. Current direction in the circuit is being changed by the up and down movement of the loops. Each loop is always connected to the same brush.**
3. **What would happen if the Slip Ring in an A.C. Generator is replaced with a Split Ring?**
   With Slip Rings:
   - when the RED LOOP ascends past the North Magnet,
   - it induces a current "out of the page",
   - and sends it to the RED BRUSH.

   - when the RED LOOP descends past the South Magnet,
   - it induces a current into the page,
   - and still sends it through the RED BRUSH.

   Hence the opposite directions of current throughout the circuit.

   The **Split Ring** would make the RED LOOP connect to the RED BRUSH and then to the GREEN BRUSH, and back to the RED BRUSH etc. This means that:
   - the RED LOOP when ascending past the North Magnet,
   - would produce a current out of the page,
   - into the RED BRUSH.

   - But now when it descends past the South Magnet,
   - it still induces a current "into the page",
   - but it would be connected to the GREEN BRUSH.

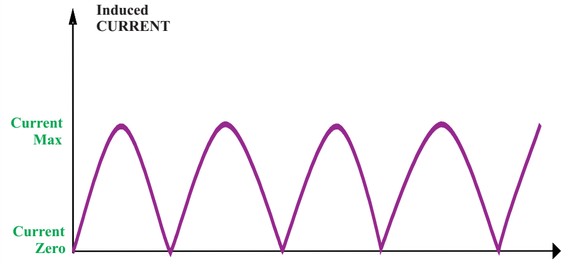
   The **current** in the **loops** would **still** be **alternating**, but the **Split Rings** would be **alternately connecting** each **loop** to the **other brush**.

   Hence the **CURRENT** in the **EXTERNAL CIRCUIT** would be in **ONE DIRECTION**. This means that **Direct Current** would be **induced**.

   Replacing the Slip Rings of an a.c. generator with a Split Ring Commutator would mean:
   - **that the current in the external circuit would now flow in one direction**
   - **that the A.C. Generator would now function as a D.C. Generator.**

   However, since the loops are still passing through various angles with the magnetic field, the magnitude of the induced current would still be constantly changing from minimum to maximum to minimum.

   The Induced Current Graph would now look like this.



4. **If you are going to use alternating current to power a d.c. motor, what change should you make in the motor?**
   Remove the Split Ring and replace with two Slip Rings, one for each loop.
   There would be no need for split rings to change the current direction since the current would already be changing its direction since it is alternating current.
   The slip rings would be needed to ensure that the wires do not get tangled after one rotation.
5. **Remember that each device needs either ONE Split Ring Or TWO Slip Rings.**
   Each half of a Split Ring is connected to one loop.
   Each entire Slip Ring is connected to each loop.

BEST OF LUCK FOR THE EXAMS!