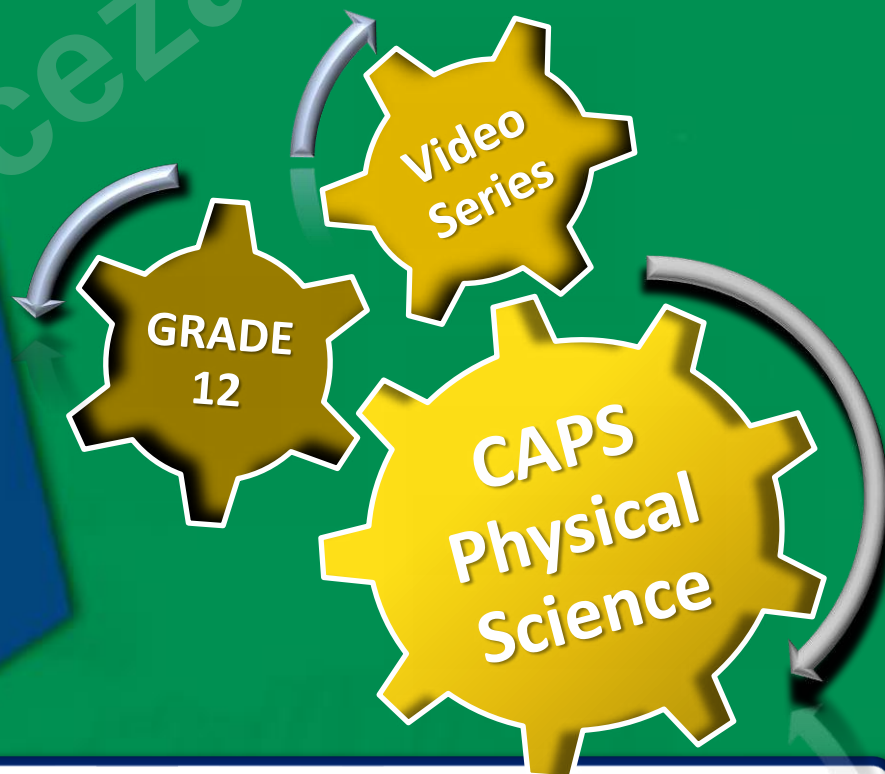
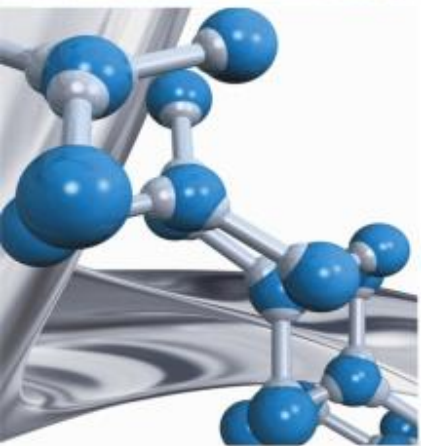




Downloaded from eduresourceza.com

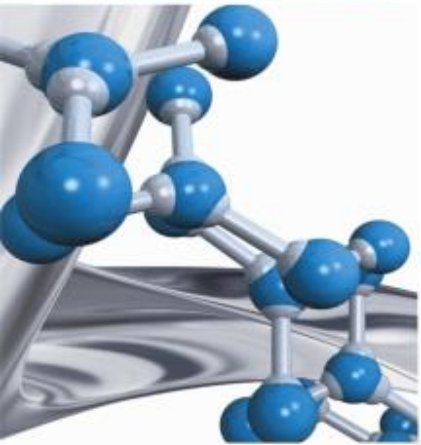


ELECTRICITY AND MAGNETISM

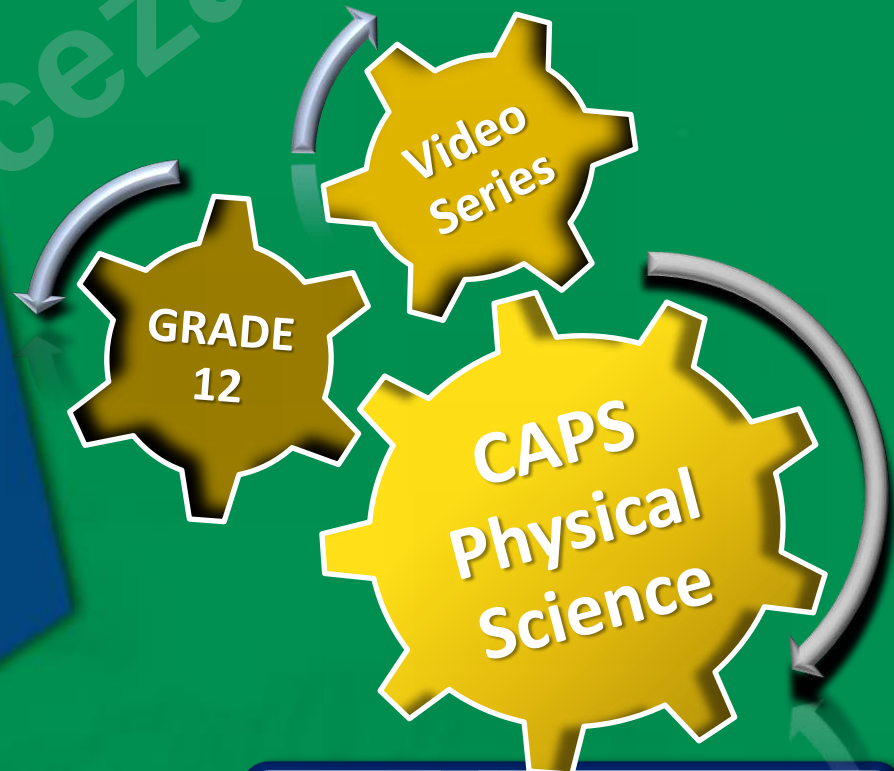
Downloaded from eduresourceza.com

Lesson 4: Electric Motors

Downloaded from eduresourceza.com



Downloaded from eduresourceza.com



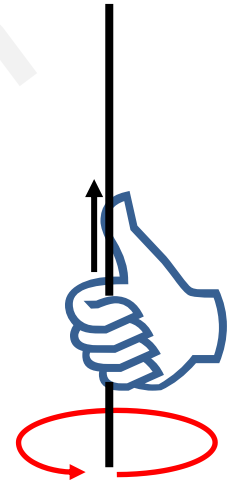
Electrodynamics

To recap

Downloaded from eduresourceza.com

We already know that a current carrying wire is surrounded by a magnetic field.

The direction of the magnetic field can be determined by using the **RIGHT HAND RULE**:



The **RIGHT HAND RULE** states that the magnetic field lines produced by a **straight current-carrying wire** will be oriented in the same direction as the curled fingers of a person's right hand, with the thumb pointing in the direction of the current flow.

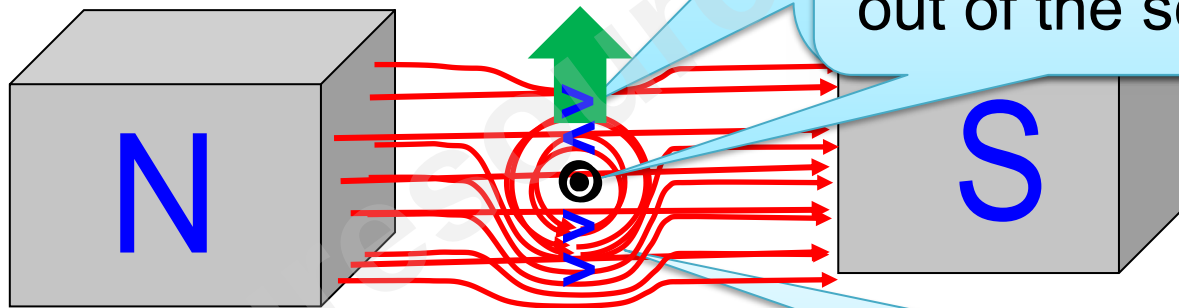
Downloaded from eduresourceza.com

B-fields Interacting

Downloaded from eduresourceza.com

If the current carrying wire is placed in the field of a permanent magnet ...

The magnetic fields will influence one another



The fields here are opposing one another

Current flowing out of the screen

The strengthened field below the wire **exerts a upward force** on the wire, **causing it to move UP**.

The fields are here strengthening one another

Downloaded from eduresourceza.com

The Motor Effect

Downloaded from eduresourceza.com

This phenomenon that a **current-carrying conductor** in a **magnetic field** **will experience a force causing it to move**, is called the

Motor Effect

The strength of the force increases when:

- The current in the conductor increases
- A stronger magnet is used
- The number of turns in the conductor-coil increases.

The force experienced are **strongest** when the conductor lies **perpendicular** to the B-field.

Downloaded from eduresourceza.com

The direction of the force can be determined using

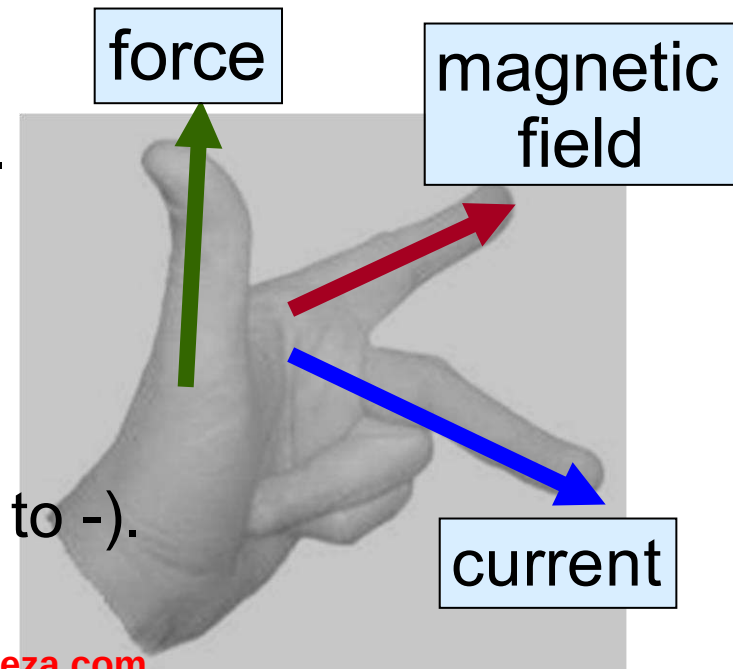
Fleming's Left Hand Motor Rule

The left hand is held with the thumb, first finger and second finger mutually perpendicular to each other (at right angles).

The **F**irst finger represents the direction of the **F**ield. (north to south).

The **S**ec**o**nd finger represents the direction of the **C**urrent (remember that this “current” is conventional current – flowing from + to -).

The **T**humb represents the direction of **F**orce (**T**hrust) on the conductor.

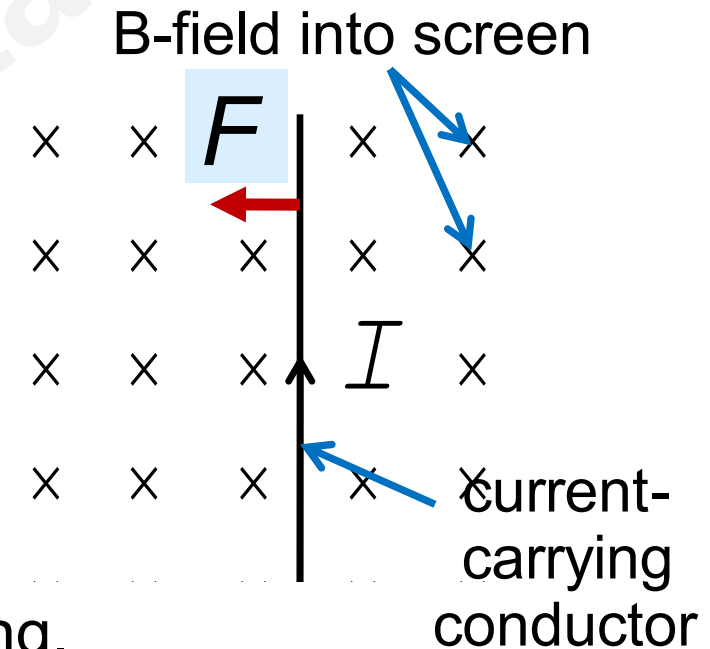
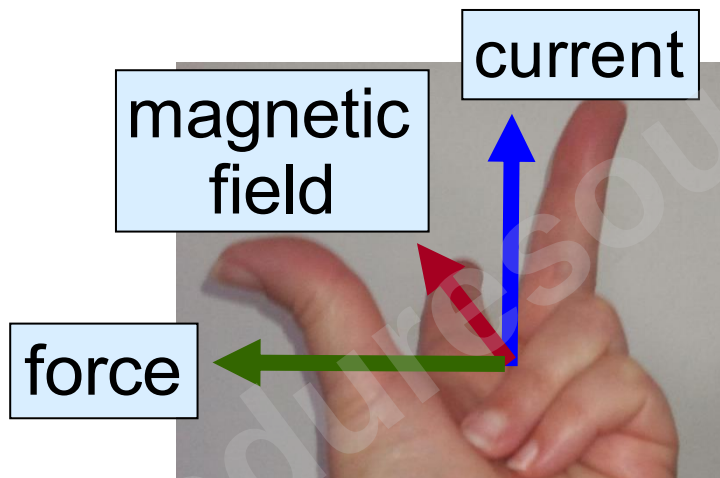


Example

Downloaded from eduresourceza.com

Consider a conductor placed at right angles to a B-field going into the screen. A current is flowing vertically upward in this conductor.

1. Find the direction of the force experienced by the conductor.



2. Explain why the conductor is moving.

The B-fields of the magnet and current influence one another, causing a thrust on the conductor (the Motor Effect).

Downloaded from eduresourceza.com

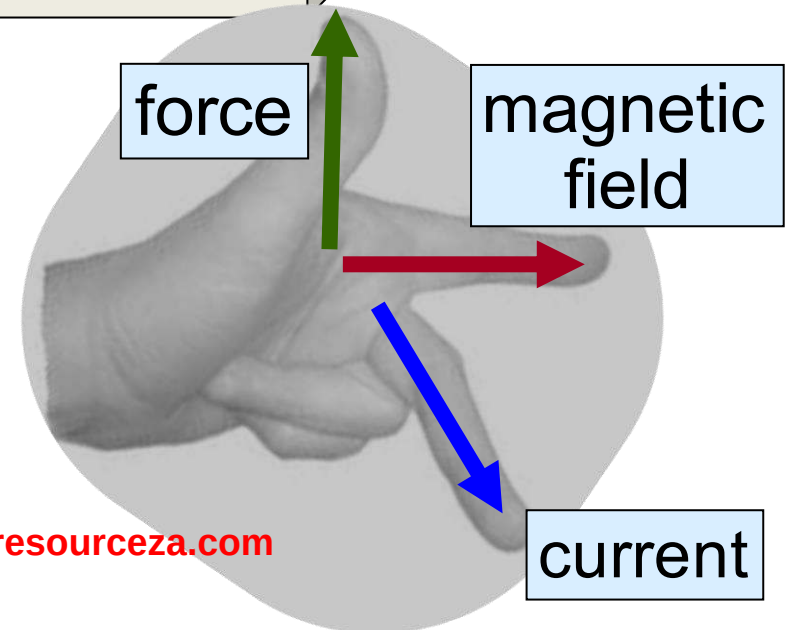
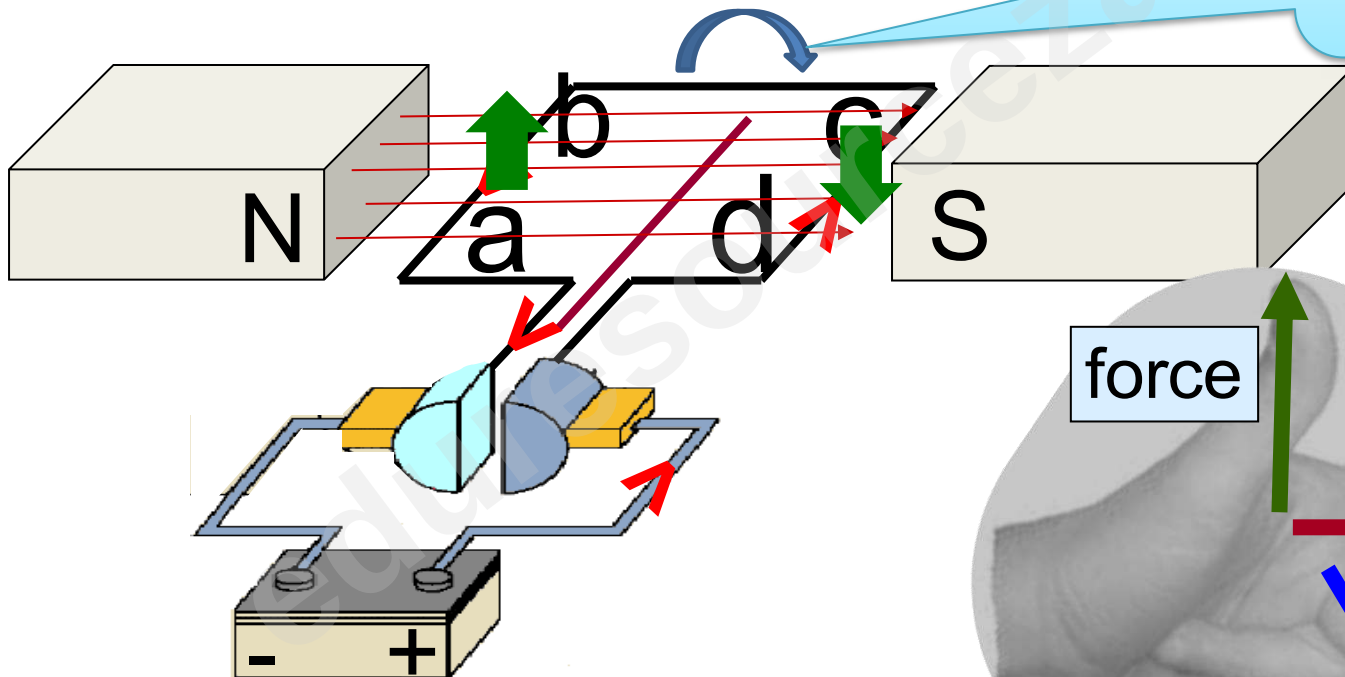
Conducting Coil

Downloaded from eduresourceza.com

When a coil or solenoid is used in stead of a straight conductor,
side ab ...

Will experience a thrust UPward

Causing the
coil to
ROTATE!



Symoultaneously cd will
experience a thrust DOWNward.

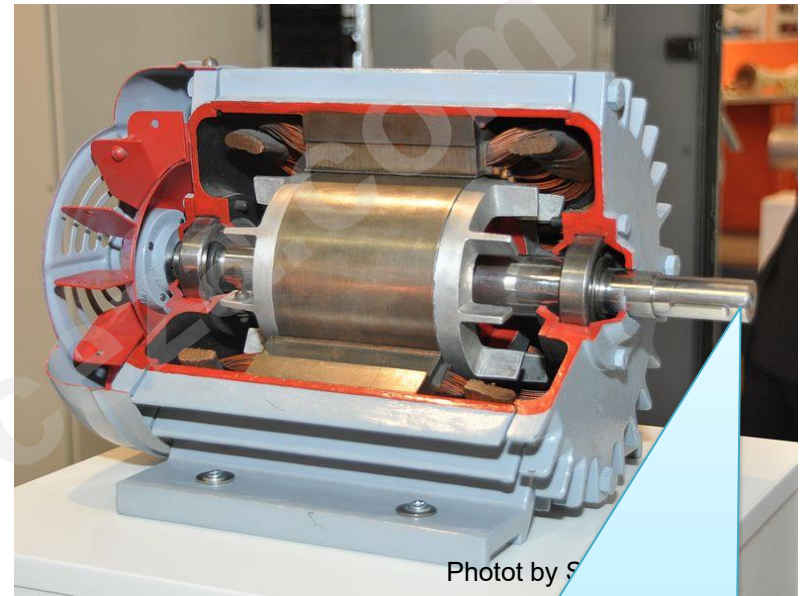
Downloaded from eduresourceza.com

Electric Motors

Downloaded from eduresourceza.com

This turning effect is used in

Electric Motors



Anything that needs to be turned can be attached to the end of this shaft!

Works with electricity!

Downloaded from eduresourceza.com

Split Ring Commutator

Downloaded from eduresourceza.com

What

ab

Be

no

After every half-revolution the current through the coil is reversed and in this way the coil continues turning clockwise.

The change in direction of the current actually takes place when the coil passes the **vertical position**.

Reversing the direction of the magnetic field or of the connections to the battery will cause the illustrated motor to turn anti-clockwise.

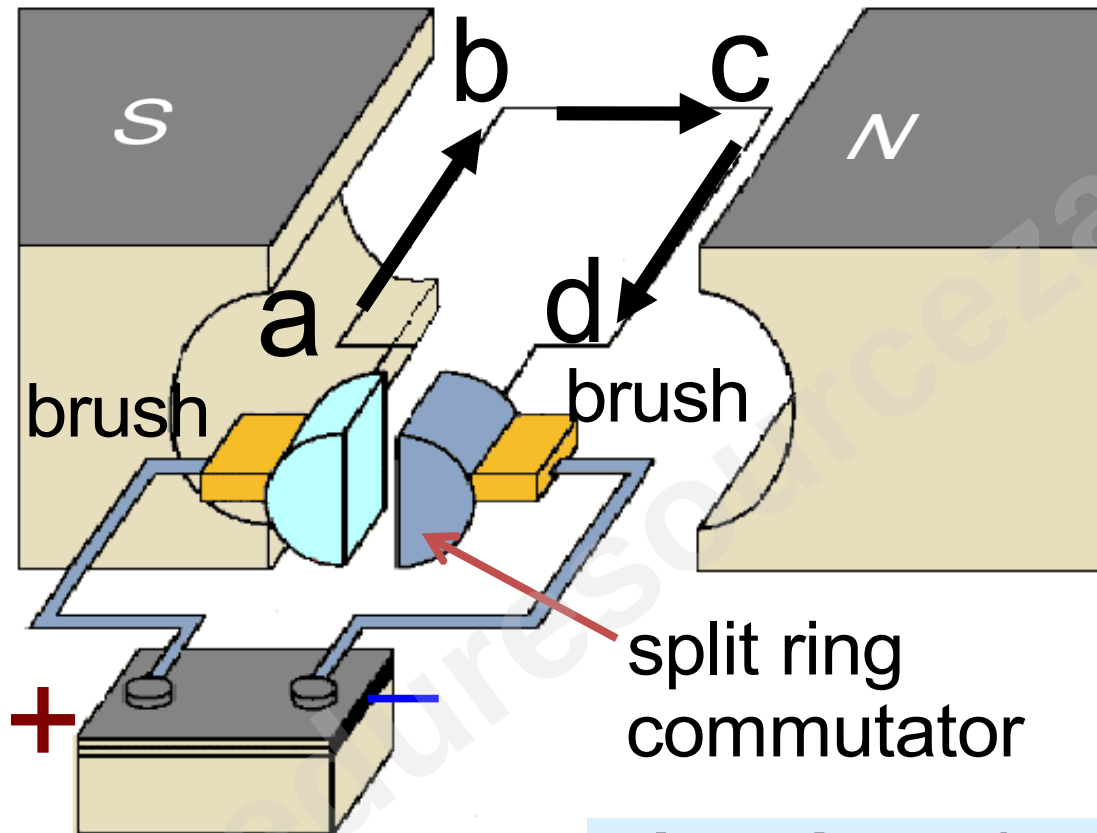
Downloaded from eduresourceza.com



The DC Motor

Downloaded from eduresourceza.com

magnetic field ←



- **abcd**: current carrying loop (armature)

- **split ring commutator**: reverses current after every half-revolution

DC source
e.g. a battery

- **brushes**: do not rotate; make contact between commutator and battery

Downloaded from eduresourceza.com

Torque

Downloaded from eduresourceza.com

TORQUE, also called moment or moment of force, is the tendency of a force to rotate an object about an axis (fulcrum or pivot). Just as a force is a push or a pull, a torque can be thought of as a twist.

Torque = Distance from support (pivot point) x force

The turning moment of the force brought about by the interacting magnetic fields, will ...

- Be maximum with $I \perp B$
- Be minimum ($F = 0$) with $I \parallel B$
- Increase if the length of the shaft / axis is increased.

Downloaded from eduresourceza.com

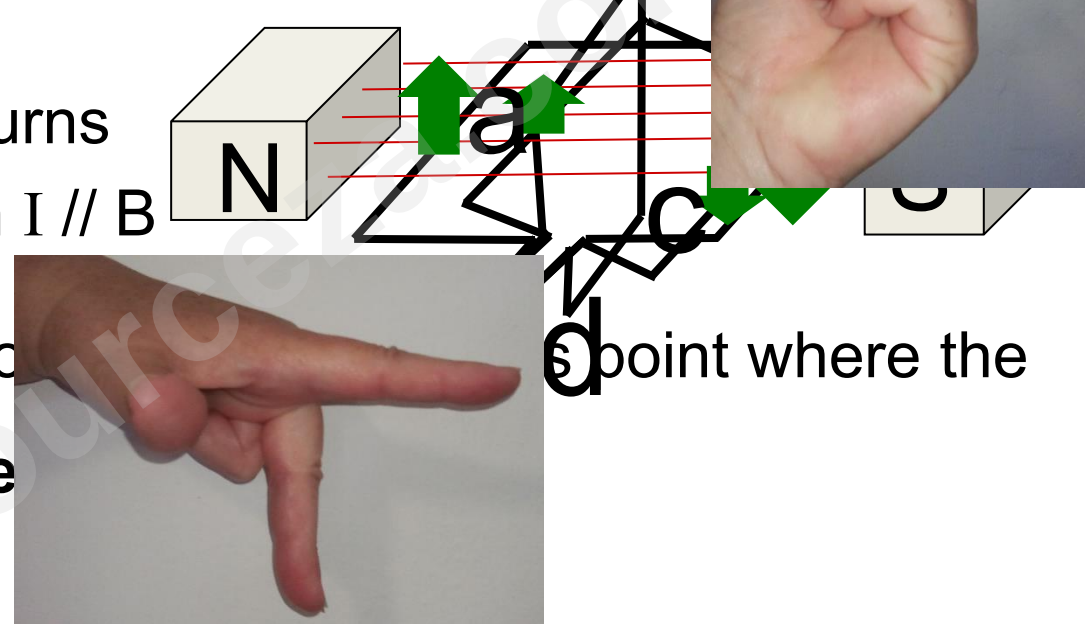
This force is the component of the force **perpendicular** to the object.

Influence of Momentum

Downloaded from eduresourceza.com

The force experienced by the coil:

- Is max with $I \perp B$
- Decreases as the coil turns
- Is minimum ($F = 0$) with $I \parallel B$



The **momentum** of the coil is at a point where the coil experiences **no force**

Continuing the rotation!

When tilted, as well as in the vertical position, sides ad and bc experience a force (ad : to the front, bc : to the back),

but since the coil cannot rotate in that direction, the forces

Downloaded from eduresourceza.com

simply cancel one another $\Rightarrow F_{\text{res}} = 0$.

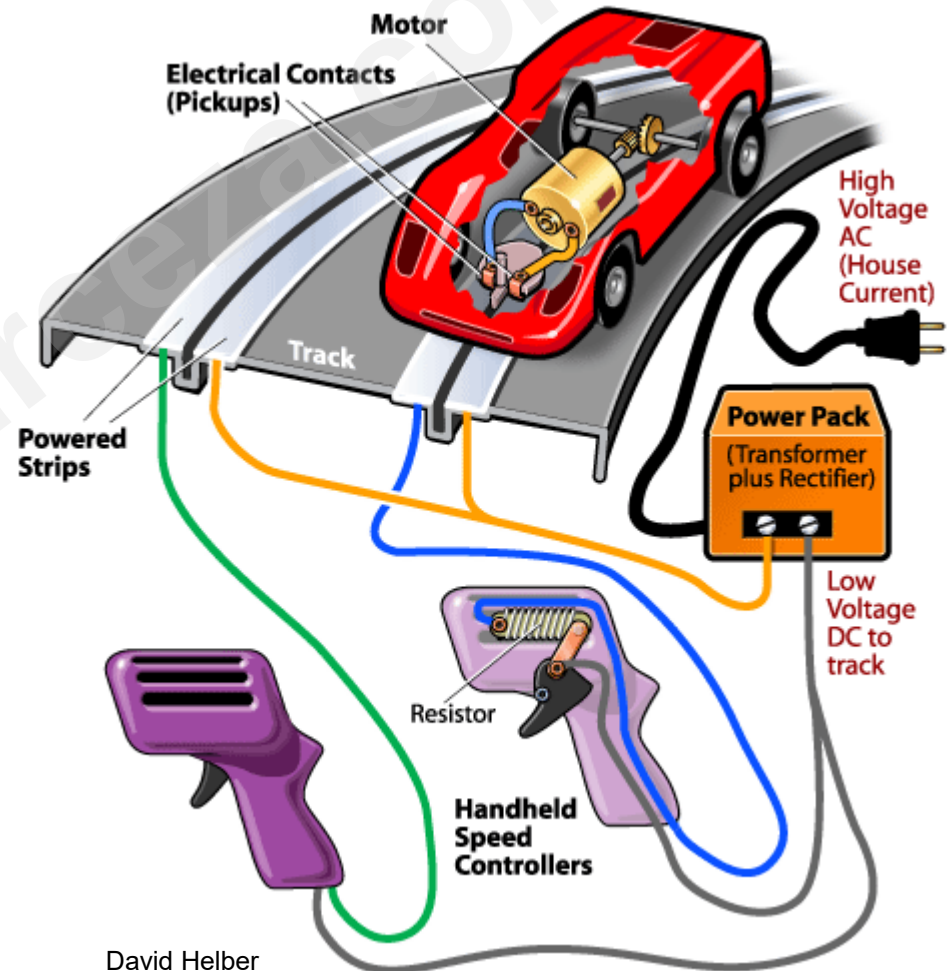
Uses of DC motors

Downloaded from eduresourceza.com

Where ever rotation is brought about with the aid of a battery, a DC motor is most likely involved,

e.g.

- Toy cars
- Small handbag fans
- The starter motor of vehicle engines working from a 12 V or 24 V battery - turning the flywheel.



David Helber

Downloaded from eduresourceza.com

Electric Aircraft

Downloaded from eduresourceza.com

An **electric aircraft** runs on an electric motors rather than an internal combustion engine.

The electricity is supplied by batteries, solar cells and other sources of electrical power.



Photo by Anibus2202



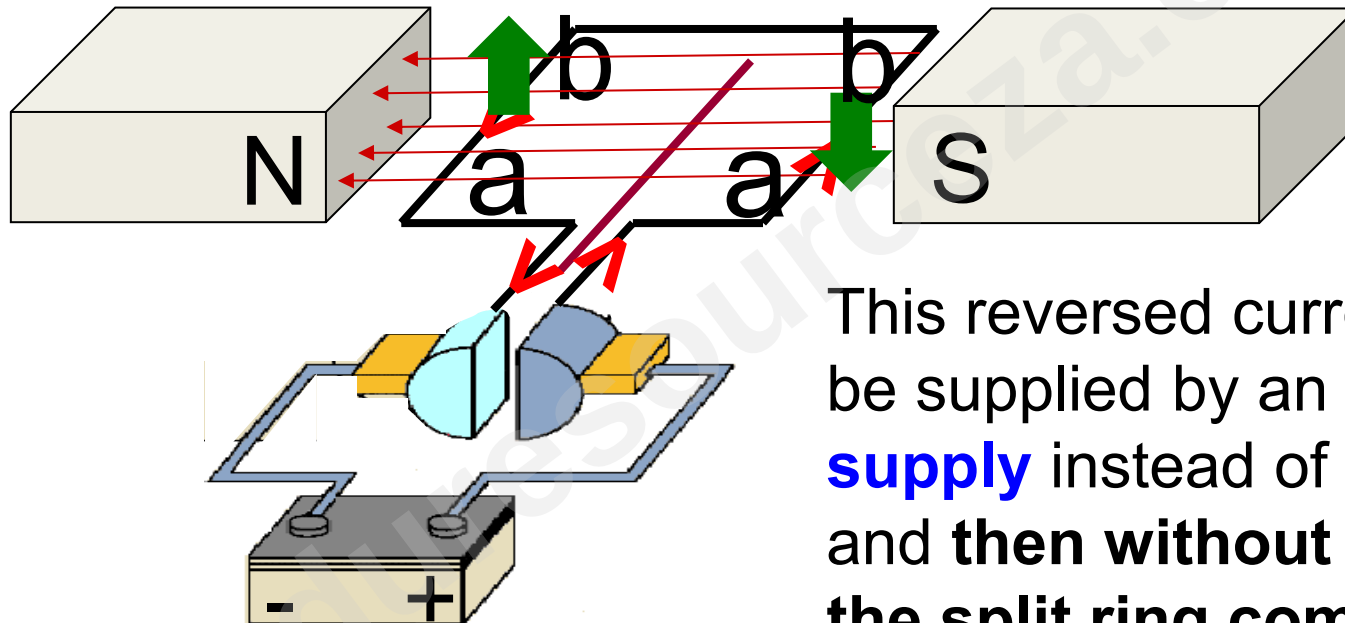
Photo by NASA

Downloaded from eduresourceza.com

The AC Motor

Downloaded from eduresourceza.com

We have seen that the current in the electric motor needs to be reversed at each half cycle in order for the coil to continue turning in the same direction.



This reversed current can also be supplied by an **AC power supply** instead of a DC battery and **then without the need of the split ring commutator.**

These AC motors are most commonly used in industry and households (e.g. washing machines, vacuum cleaners, fans, sliding gates, etc.)

Downloaded from eduresourceza.com

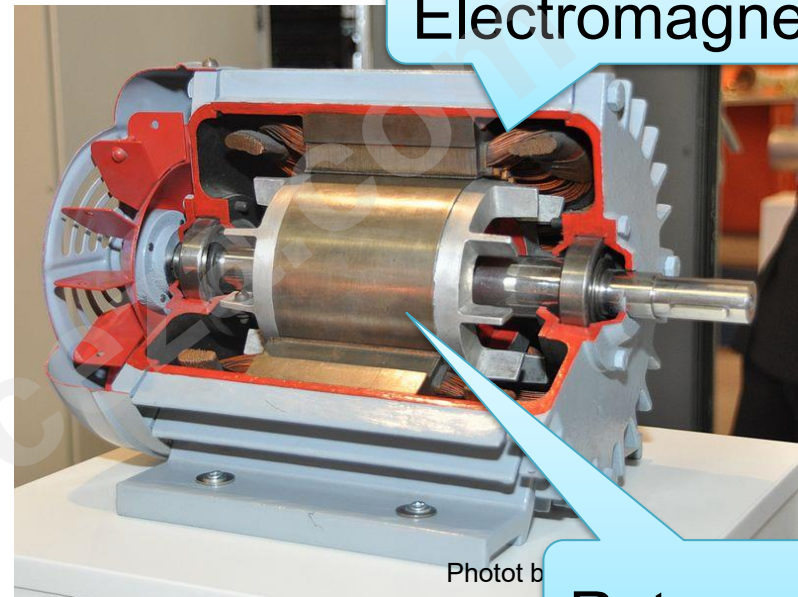
Induction Motor

Downloaded from eduresourceza.com

In an induction motor, the magnetic field is not supplied by permanent magnets, but by **electromagnets**.

If connected to an **AC source**, the polarity of the electromagnets are reversed all the time, inducing an **alternating current in a secondary coil** built into the rotor, producing a **changing magnetic field in the rotor**.

The interacting **B-fields** supply the force needed to turn the rotor.



Downloaded from eduresourceza.com

Class Exercise 1/1

Downloaded from eduresourceza.com

1. Modern motors are altered to increase efficiency.
 - 1.1. Mention ways in which the turning moment of a single motor can be increased.

Increase the number of coils around armature

Increase the current in the coil.

Use stronger magnets.

- 1.2. What is the function of the split-ring commutator in the DC motor?

The commutator reverses the current in the coil every half-cycle so that the armature continues to move in the same direction.

- 1.3. What is the function of the brushes?

Ensures electrical contact between circuit and coil.

Downloaded from eduresourceza.com

Class Exercise 1/2

Downloaded from eduresourceza.com

2. Electric motors are important components of many electrical appliances. AC motors are used in washing machines, vacuum cleaners; DC motors in toys and tools.

2.1. What energy conversion takes place in electric motors?

Electric energy into rotational mechanical energy.

2.2. What is the essential difference in the design between DC and AC motors?

A DC motor reverses current direction with the aid of the commutator whenever the coil is in the vertical position to ensure continuous rotation.

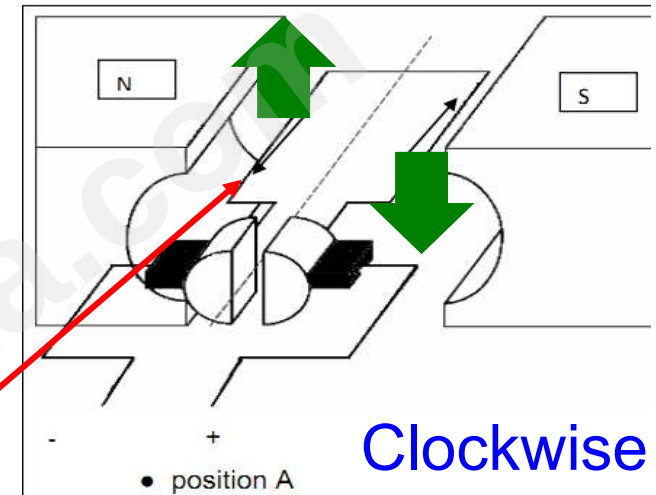
An AC motor, with alternating current as input, works without commutators since the current of the power supply alternates.

Downloaded from eduresourceza.com

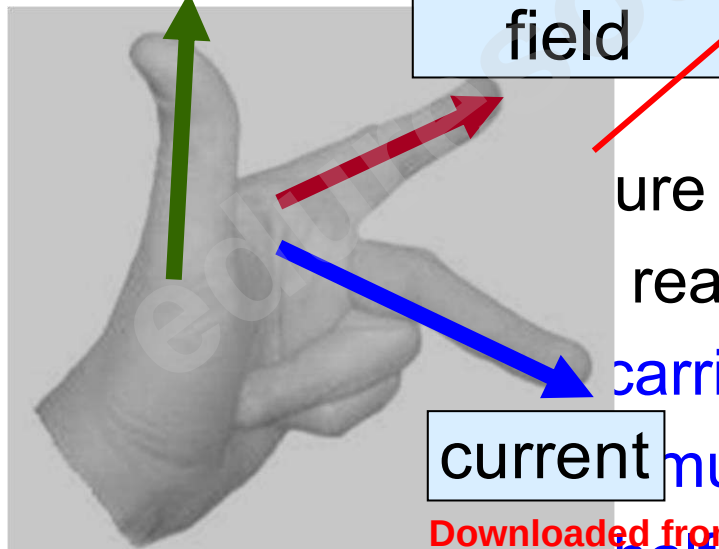
Class Exercise 1/3

Downloaded from eduresourceza.com

3.1. Consider the diagram. The current flows in the direction indicated by the arrows. In which direction (clockwise or anti-clockwise), as seen from position A, will the coiled armature rotate if force



3.2.



ure continue moving in the same reached the vertical position?

carries it over the vertical position

mutator changes the direction of

Downloaded from eduresourceza.com

the current at every half turn.

Class Exercise 1/4

Downloaded from eduresourceza.com

4. Which of the following can change the direction of rotation of a DC motor?

(1) Increase the current in the coils.

Would only increase the rotation speed

(2) Exchange the poles of the magnet.

This would change the direction of rotation

(3) Reverse the direction of the current and exchange the poles of the magnet at the same time.

This would change the direction of rotation twice, leading to no change at all.

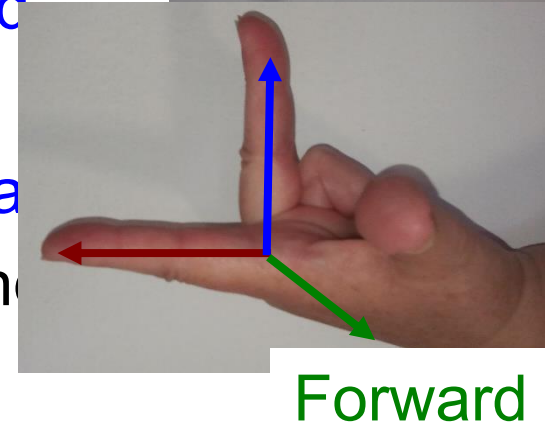
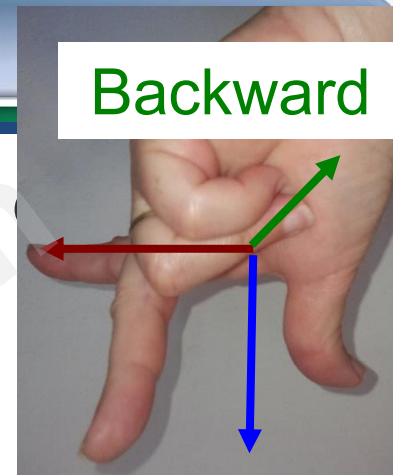
A only

B (2) only

C (1) and (2) only

D (2) and (3) only

Downloaded from eduresourceza.com



Class Exercise 1/5

Downloaded from eduresourceza.com

5. Which of the following concerning a DC motor is correct?

(1) It converts electrical energy to mechanical energy. ✓

(2) The commutator rotates together with the coil in the magnetic field. ✓

(3) The rotating speed of the coil is the greatest when the plane of the coil is perpendicular to the direction of magnetic field of the magnets.

A (1) only

B (2) only

☒ C (1) and (2) only

D (2) and (3) only

Downloaded from eduresourceza.com

Key Concepts 1

Downloaded from eduresourceza.com

A **DC motor** consists of a current carrying loop which is connected to a **DC power supply** (e.g. a battery).

- The loop is situated in a magnetic field.
- Current direction is changed by brushes and a split ring commutator at every half turn.

The reversing current can also be supplied by an **AC power supply**, without need of a commutator.

The current carrying conductor **experiences a force** due to the **interaction between the B-fields**, causing it to move.

The **direction of the force** can be determined using **Fleming's Left Hand Motor Rule**.

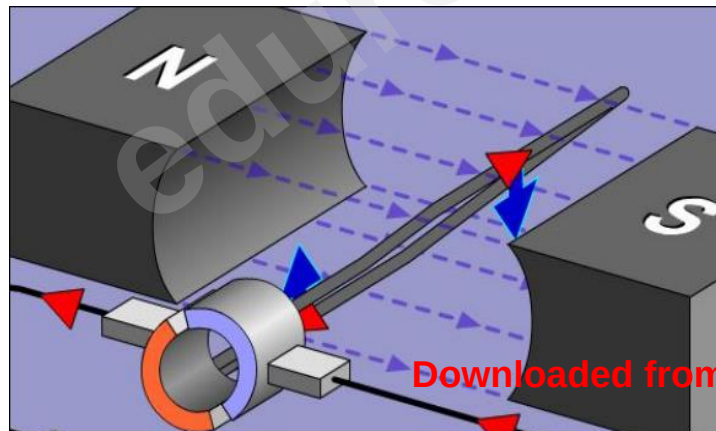
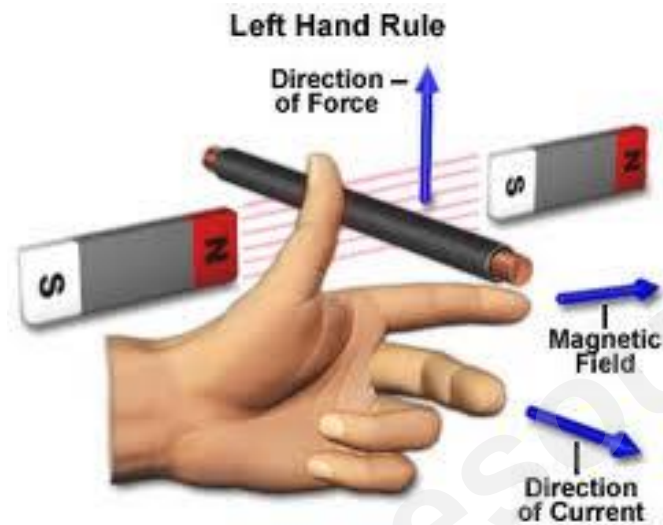
Electric Motors **convert electrical energy into mechanical energy**.

Downloaded from eduresourceza.com

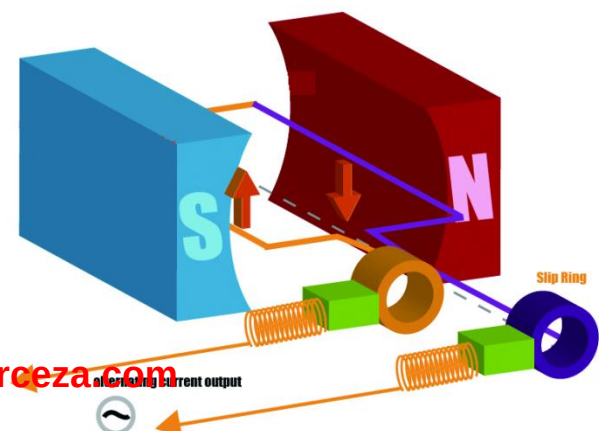
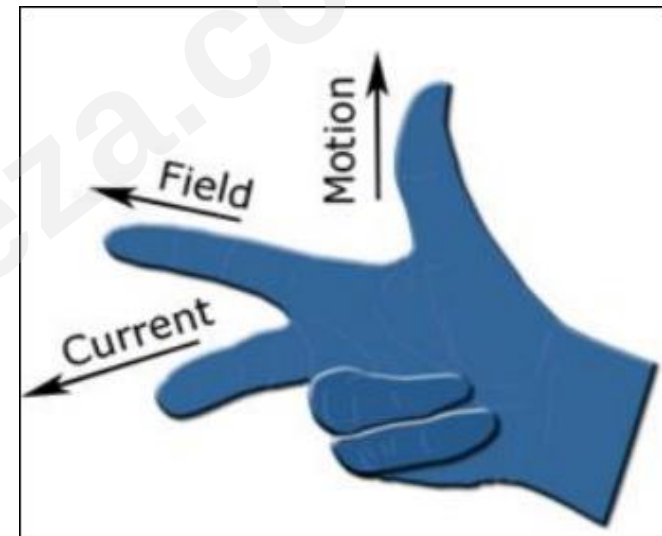
Key Concepts 2

Downloaded from eduresourceza.com

Electric Motor



Electric Generator



Downloaded from eduresourceza.com

Key Concepts 3

Downloaded from eduresourceza.com

Electric Motor	Electric Generator
Electric $E \rightarrow$ mechanical E	Mechanical $E \rightarrow$ electric E
Split rings $\Rightarrow$ reversed current	Split rings $\Rightarrow$ DC output
AC supply replaces commutator	Slip rings $\Rightarrow$ AC output
Current in B-field $\Rightarrow$ Force	Motion in B-field $\Rightarrow$ Current
Force strengthened by:	Current strengthened by:
• Stronger magnets • More turns in rotor coil • Stronger current through coil	• Stronger magnets • More turns in armature coil • Faster rotation of armature

Downloaded from eduresourceza.com

Commutator: an attachment connected with the armature of a dynamo which directs and makes continuous the current produced.

Rotor: A rotary part of a machine.

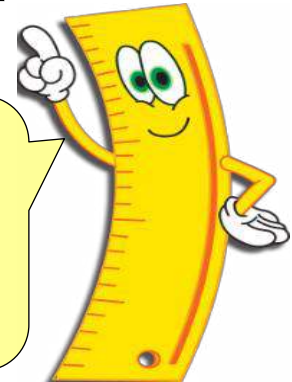
Electromagnet: A soft metal core made into a magnet by the passage of electric current through a coil surrounding it.

Thrust: The propulsive force developed by an electric motor.

Torque: The moment of a system of forces tending to cause rotation.

- **Memorise** the various definitions
- **Review** the exercises you had difficulty with ...
- and do some **additional exercise** ...
 - as given in your **workbooks** that accompany this video series or from your school textbook

Continue your learning by watching the
next video lesson in this series:
Lesson 5: Alternating Current



PhiniseD