ELECTRODYNAMICS 16 JULY 2013

Lesson Description

In this lesson we:

- Explain how electric motors work
- Explain how generators work
- Compare electric motors and generators

Key Concepts

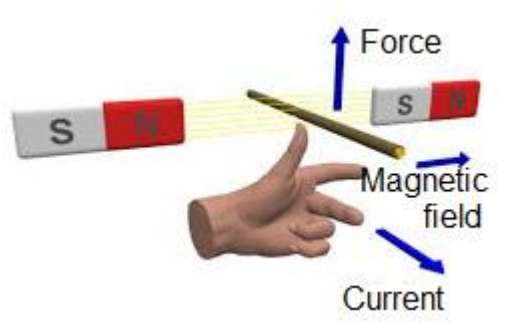
Electric motors

All electric motors use electric energy, supplied by a battery or power source, to turn a coil in a magnetic field. In this way electrical energy is converted into mechanical energy.

The Motor Effect

The principle on which electric motors work is called the motor effect. Remember, there is a magnetic field around any current-carrying conductor. When this current-carrying conductor is placed between the poles of a pair of magnets, the conductor will experience a force. This force is due to the interaction between the magnetic field generated by the current-carrying conductor and the magnetic field formed by the pair of magnets. Fleming's Left Hand Rule or the Right Hand Rule for motors is used to determine the direction of the force that the conductor will experience.

Fleming's Left Hand Rule: When the index finger, the middle finger and the thumb are held perpendicularly to each other, with the index finger pointing in the direction of the magnetic field and the middle finger pointing in the direction of the current, the thumb will give the direction of the force experienced by the current-carrying conductor.

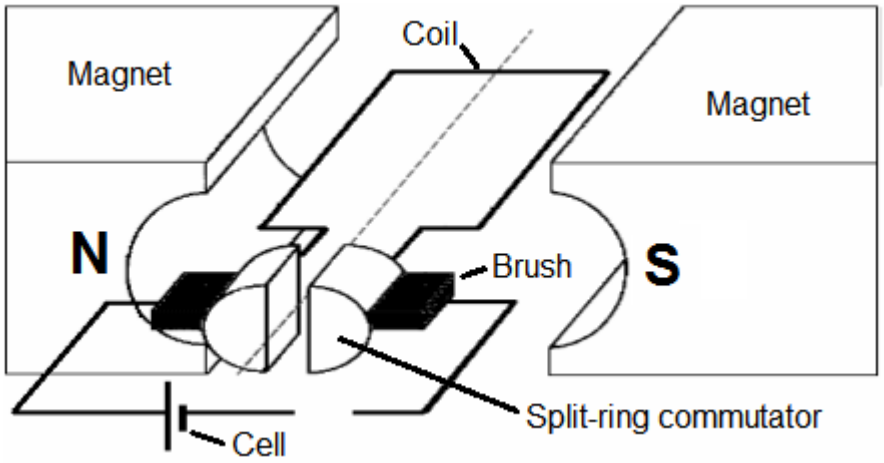


Right Hand Rule: If the right hand is stretched out with the four fingers pointing in the direction of the magnetic field and the thumb pointing in the direction of the conventional current, the perpendicular direction away from the palm of the hand will give the direction of the force experienced by the conductor.

Direct Current (DC) Motors

The simplest electric motor is a direct current motor. DC motors use direct current from electrical energy sources such as batteries and cells. The direction of the current in a DC motor circuit is in one direction only – defined as conventional current, from the positive terminal of the battery to the negative terminal of the battery.

The diagram below shows all the parts of a simple DC motor:



The direction of the current in the left side of the coil and the right side of the coil are opposite to each other. The force on the left side of the coil is down but on the right side it is up. This leads to a turning effect (torque). When the coil is in a vertical position, there is no contact between brushes and the split ring commutator. The coil experiences no force at this point. However, the coil continues to turn due to its momentum. When the contact between the brushes and the split ring commutator is re-established, the force on the left side of the coil is no longer up but down. In this way there is a continuous rotation of the coil in one direction.

Factors affecting the force experienced by the coil

The force experienced by the coil can be increased by:

- Increasing the number of turns on the coil.
- Increasing the current in the coil
- Increasing the strength of the magnets or electromagnets

Electric motors

All electric generators convert mechanical energy into electrical energy. Ina generator a coil and magnetic field move relative to each other and an emf is induced across the ends of the coil.

Electromagnetic Induction

All generators use the principle of electromagnetic induction to operate. This principle is describe in Faraday's Law. The emf (electromotive force) induced is directly proportional to the rate of change of magnetic flux. This relationship is described in the equation:

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$$

Where the magnetic flux, $\phi = B.A$

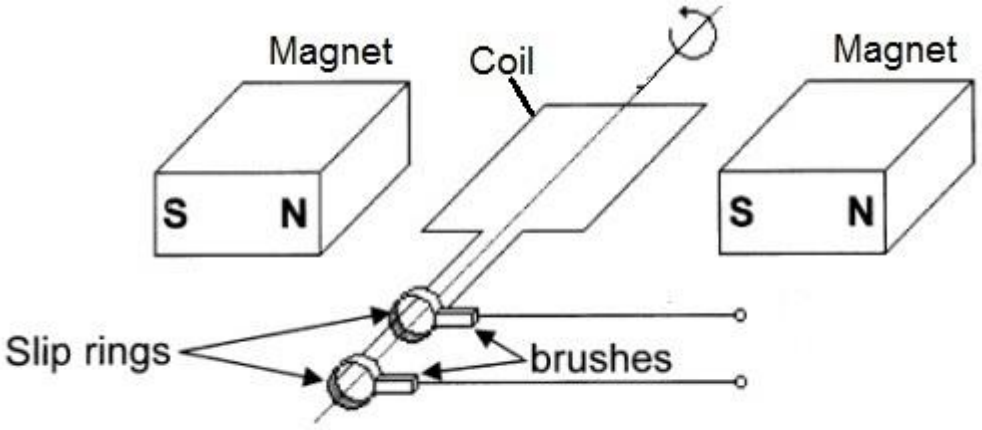
Magnetic flux (ϕ) is the product of the magnetic field (B) and the cross section area (A) through which the magnetic field passes.

When we move a coil or a magnet relative to each other, there is a change in magnetic flux through the coil. As a result an emf is induced across the ends of the coil. The magnitude of the induced emf depends on the following;

- Number of turns on the coil (N)
- The relative speed at which the coil and magnet move
- Strength of the magnetic field (Φ)

Alternating Current (AC) Generator

Most generators (dynamos) produce alternating current. The direction of the current changes during each rotation of the coil in the magnetic field. A simple diagram of an AC generator is shown below.



The direction of the induced current produced when the coil is rotated in the anti-clockwise direction is given by the Right Hand Rule. If the right hand is stretched out with the four fingers pointing in the direction of the magnetic field and the thumb pointing in the direction of the motion of the coil, the perpendicular direction away from the palm of the hand will give the direction of the induced current in the coil.

Questions

Question 1

Tabulate the differences between a DC motor and an AC generator

Question 2

Diesel-electric trains make use of electric motors as well as generators. The table below compares a motor and a generator in terms of the type of energy conversion and the underlying principle on which each operates. Complete the table by writing down the answer next to the question number indicated in the table.

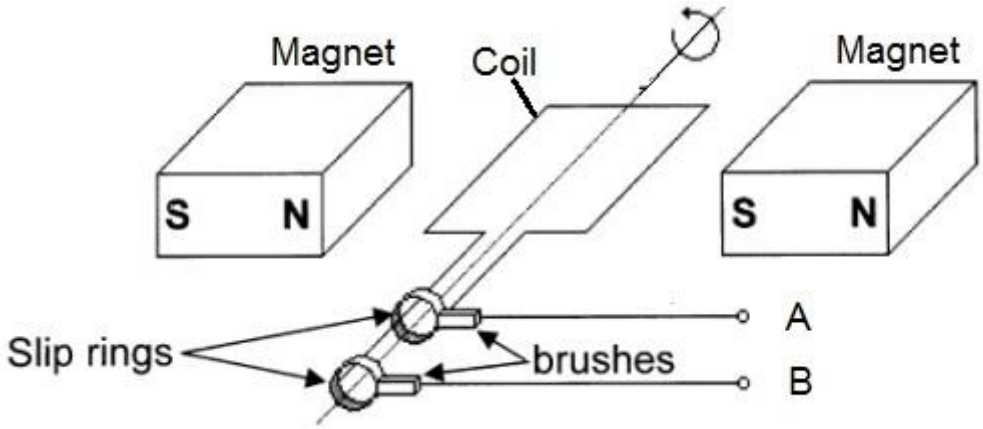
	Type of conversion	**Principle of operation**
Motor	2.1	2.2
Generator	2.3	2.4

Question 3

Write down three changes you can make to a generator to increase the induced emf.

Question 4

A simplified sketch of a generator is shown below.



A learner connects A to the positive terminal of a 12V battery and B to the negative terminal of the battery.

4.1 Describe what would happen.

4.2 How could the learner improve the efficiency of the machine?