

Chapter 28

Electrodynamics - Grade 12

28.1 Introduction

In Grade 11 you learnt how a magnetic field is generated around a current carrying conductor. You also learnt how a current is generated in a conductor that moves in a magnetic field. This chapter describes how conductors moved in a magnetic field are applied in the real-world.

28.2 Electrical machines - generators and motors

We have seen that when a conductor is moved in a magnetic field or when a magnet is moved near a conductor, such that the magnetic field is not parallel to the conductor, a current flows in the conductor. The amount of current depends on the speed at which the conductor experiences a changing magnetic field, the number of turns of the conductor and the orientation of the plane of the conductor with respect to the magnetic field. The effect of the orientation of the conductor with respect to the magnetic field is shown in Figure 28.1.

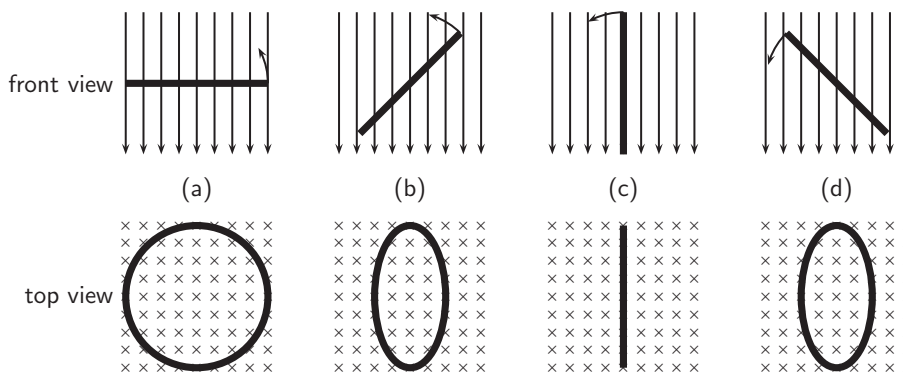


Figure 28.1: Series of figures showing that the magnetic flux through a conductor is dependent on the angle that the plane of the conductor makes with the magnetic field. The greatest flux passes through the conductor when the plane of the conductor is perpendicular to the magnetic field lines as in (a). The number of field lines passing through the conductor decreases, as the conductor rotates until it is parallel to the magnetic field.

If the current flowing in the conductor were plotted as a function of the angle between the plane of the conductor and the magnetic field, then the current would vary as shown in Figure 28.2. The current alternates about the zero value and is also known as an *alternating current* (abbreviated AC).

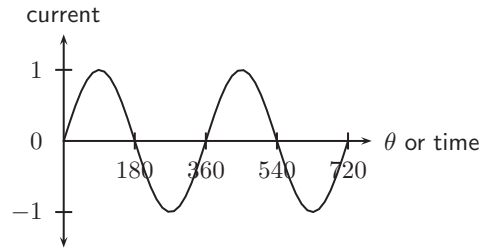


Figure 28.2: Variation of current as angle of plane of conductor with the magnetic field changes.

28.2.1 Electrical generators

AC generator

The principle of rotating a conductor in a magnetic field is used in electricity generators. A generator converts mechanical energy into electrical energy.

Definition: Generator

A generator converts mechanical energy into electrical energy.

The layout of an AC generator is shown in Figure 28.3. The conductor in the shape of a coil is connected to a ring. The conductor is then manually rotated in the magnetic field generating an alternating emf. The slip rings are connected to the load via brushes.

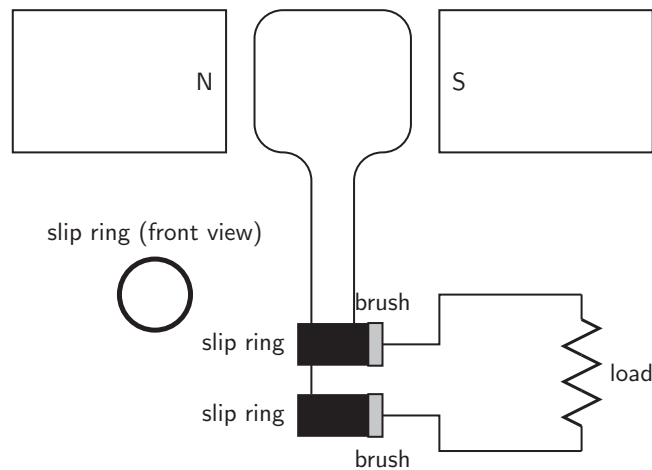


Figure 28.3: Layout of an alternating current generator.

If a machine is constructed to rotate a magnetic field around a set of stationary wire coils with the turning of a shaft, AC voltage will be produced across the wire coils as that shaft is rotated, in accordance with Faraday's Law of electromagnetic induction. This is the basic operating principle of an AC generator.

In an AC generator the two ends of the coil are each attached to a slip ring that makes contact with brushes as the coil turns. The direction of the current changes with every half turn of the coil. As one side of the loop moves to the other pole of the magnetic field, the current in it changes direction. The two slip rings of the AC generator allow the current to change directions and become alternating current.



AC generators are also known as alternators. They are found in motor cars to charge the car battery.

DC generator

A DC generator is constructed the same way as an AC generator except that there is one slip ring which is split into two pieces, called a commutator, so the current in the external circuit does not change direction. The layout of a DC generator is shown in Figure 28.4. The split-ring commutator accommodates for the change in direction of the current in the loop, thus creating DC current going through the brushes and out to the circuit.

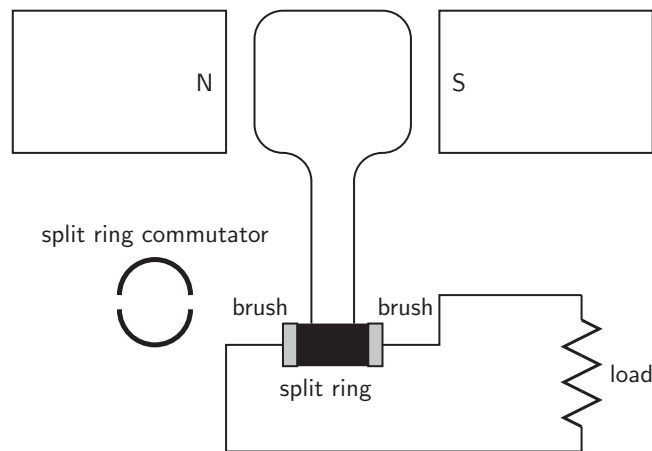


Figure 28.4: Layout of a direct current generator.

The shape of the emf from a DC generator is shown in Figure 28.5. The emf is not steady but is more or less the positive halves of a sine wave.

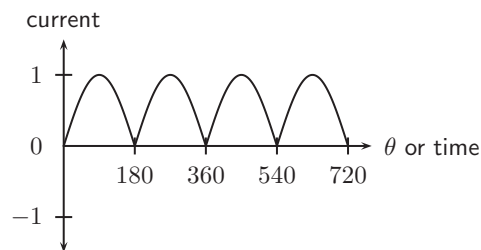


Figure 28.5: Variation of emf in a DC generator.

AC versus DC generators

The problems involved with making and breaking electrical contact with a moving coil should be obvious (sparking and heat), especially if the shaft of the generator is revolving at high speed. If the atmosphere surrounding the machine contains flammable or explosive vapors, the practical problems of spark-producing brush contacts are even greater.

An AC generator (alternator) does not require brushes and commutators to work, and so is immune to these problems experienced by DC generators. The benefits of AC over DC with regard to generator design is also reflected in electric motors. While DC motors require the use

of brushes to make electrical contact with moving coils of wire, AC motors do not. In fact, AC and DC motor designs are very similar to their generator counterparts. The AC motor being dependent upon the reversing magnetic field produced by alternating current through its stationary coils of wire to rotate the rotating magnet around on its shaft, and the DC motor being dependent on the brush contacts making and breaking connections to reverse current through the rotating coil every 1/2 rotation (180 degrees).

28.2.2 Electric motors

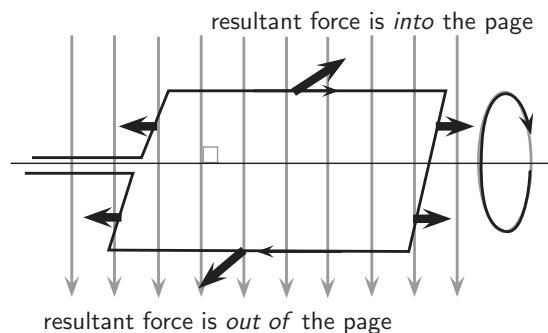
The basic principles of operation for a motor are the same as that of a generator, except that a motor converts electrical energy into mechanical energy.



Definition: Motor

An electric motor converts electrical energy into mechanical energy.

Both motors and generators can be explained in terms of a coil that rotates in a magnetic field. In a generator the coil is attached to an external circuit and it is mechanically turned, resulting in a changing flux that induces an emf. In a motor, a current-carrying coil in a magnetic field experiences a force on both sides of the coil, creating a torque which makes it turn. Any coil carrying current can feel a force in a magnetic field, the force is the Lorentz force on the moving charges in the conductor. We know that if the coil is parallel to the magnetic field then the Lorentz force will be zero. The charge of opposite sides of the coil will be in opposite directions because the charges are moving in opposite directions. This means the coil will rotate.



Instead of rotating the loops through a magnetic field to create electricity, a current is sent through the wires, creating electromagnets. The outer magnets will then repel the electromagnets and rotate the shaft as an electric motor. If the current is AC, the two slip rings are required to create an AC motor. An AC motor is shown in Figure 28.6

If the current is DC, split-ring commutators are required to create a DC motor. This is shown in Figure 28.7.

28.2.3 Real-life applications

Cars

A car contains an alternator that charges up its battery power the car's electric system when its engine is running. Alternators have the great advantage over direct-current generators of not using a commutator, which makes them simpler, lighter, less costly, and more rugged than a DC generator.

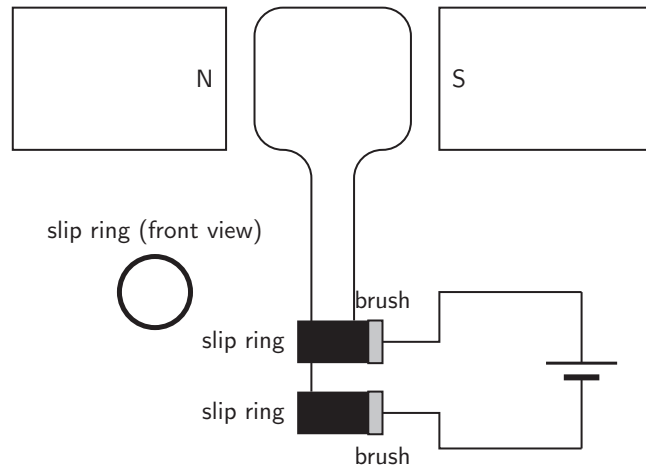


Figure 28.6: Layout of an alternating current motor.

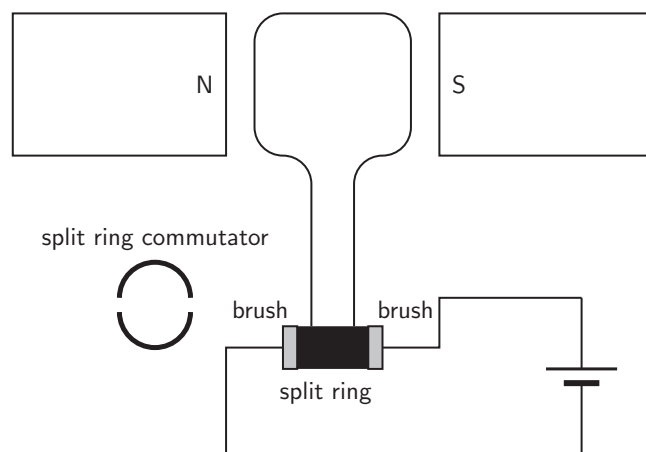


Figure 28.7: Layout of a direct current motor.

Activity :: Research Topic : Alternators

Try to find out the different ampere values produced by alternators for different types of machines. Compare these to understand what numbers make sense in the real world. You will find different numbers for cars, trucks, buses, boats etc. Try to find out what other machines might have alternators.

A car also contains a DC electric motor, the starter motor, to turn over the engine to start it. A starter consists of the very powerful DC electric motor and starter solenoid that is attached to the motor. A starter motor requires very high current to crank the engine, that's why it's connected to the battery with large cables.

Electricity Generation

AC generators are mainly used in the real-world to generate electricity.

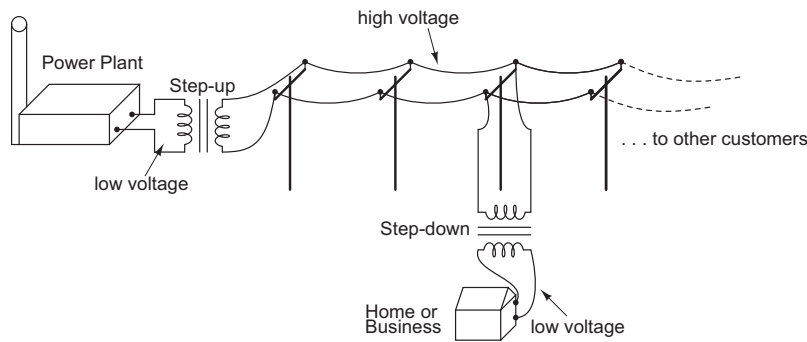


Figure 28.8: AC generators are used at the power plant to generate electricity.

28.2.4 Exercise - generators and motors

1. State the difference between a generator and a motor.
2. Use Faraday's Law to explain why a current is induced in a coil that is rotated in a magnetic field.
3. Explain the basic principle of an AC generator in which a coil is mechanically rotated in a magnetic field. Draw a diagram to support your answer.
4. Explain how a DC generator works. Draw a diagram to support your answer. Also, describe how a DC generator differs from an AC generator.
5. Explain why a current-carrying coil placed in a magnetic field (but not parallel to the field) will turn. Refer to the force exerted on moving charges by a magnetic field and the torque on the coil.
6. Explain the basic principle of an electric motor. Draw a diagram to support your answer.
7. Give examples of the use of AC and DC generators.
8. Give examples of the use of motors