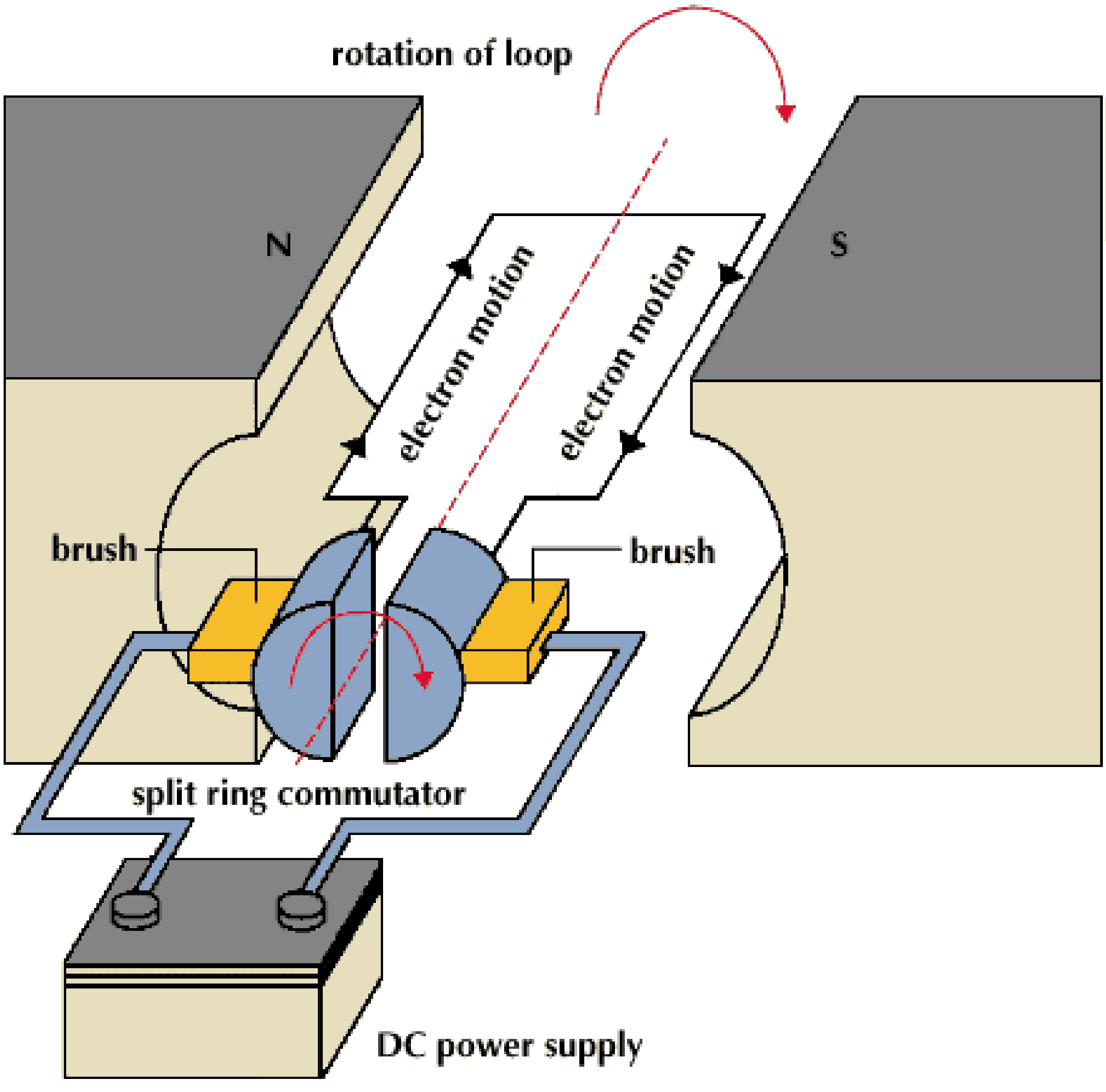
PHYSICS
FORM 5
ELECTOMAGNETIC APPLICATIONS

THE DC MOTOR



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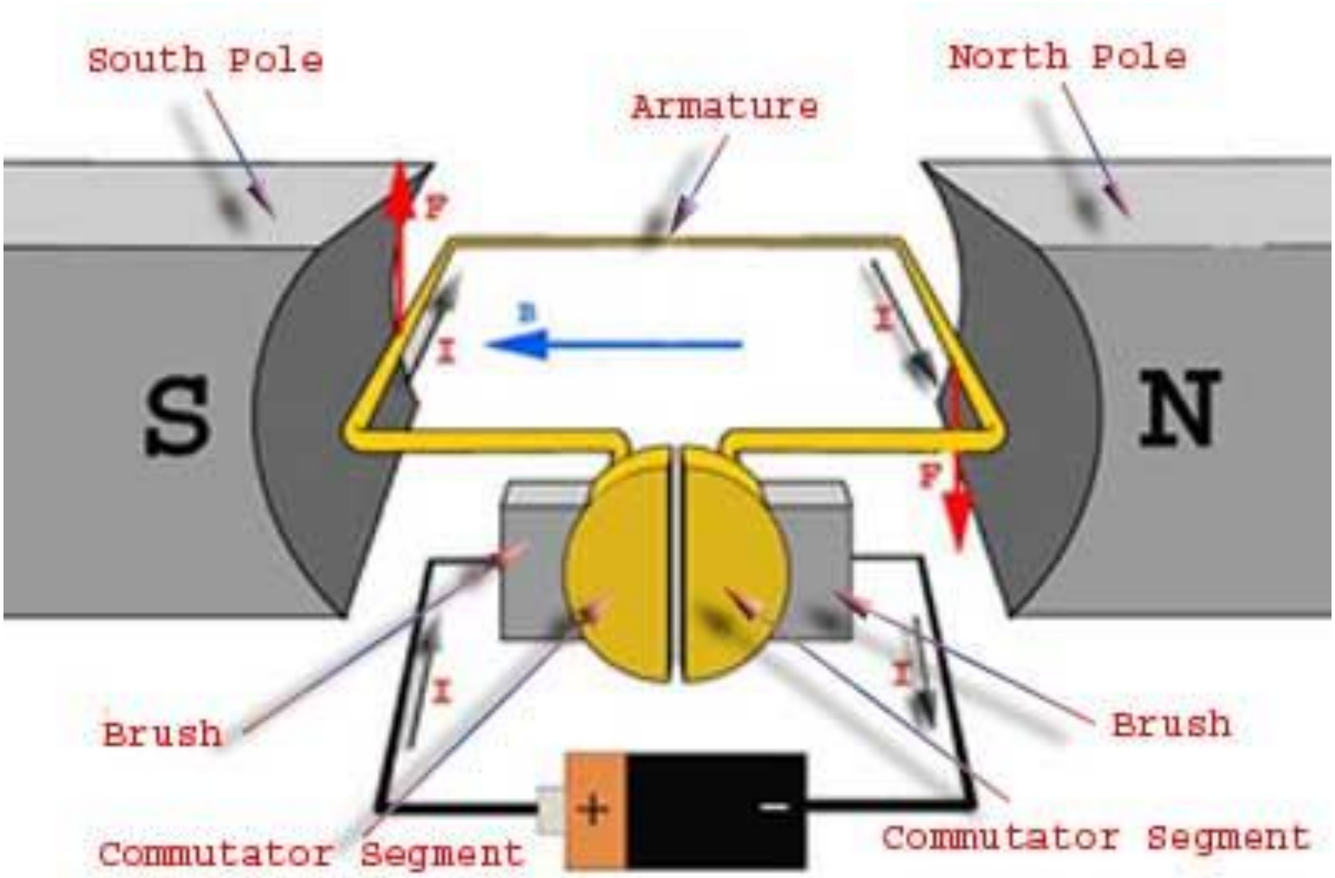
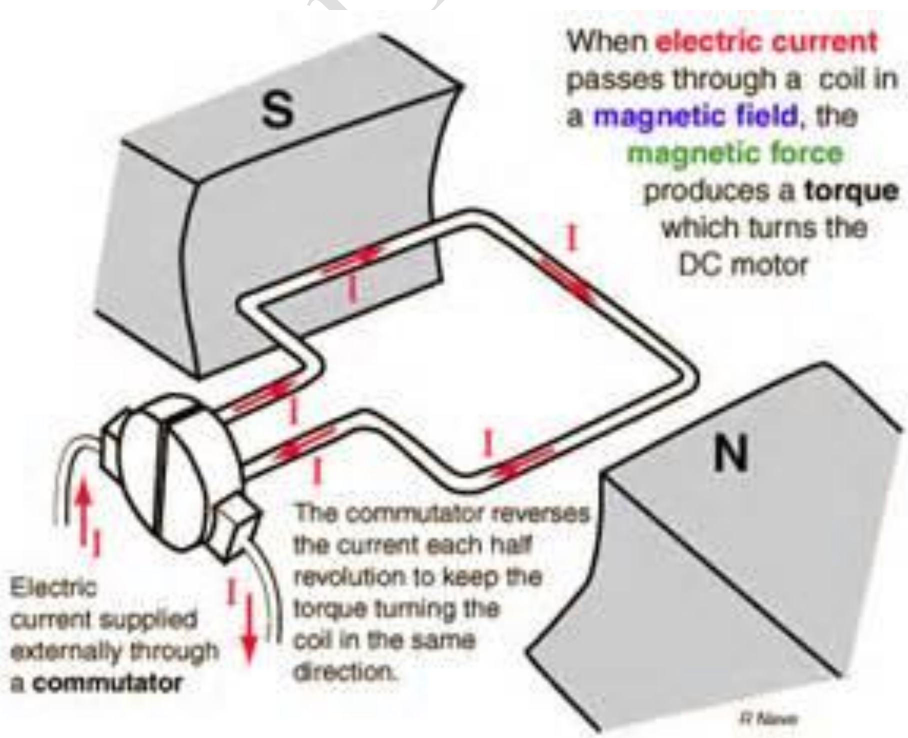




The D.C. Motor consists of a coil of wires found between opposite poles of a permanent magnet. From the coil there are two wires which lead to the split commutator. The commutator is connected to the rest of the circuit via spring contacts. These spring contacts allows the split ring commutator to rotate without the opening the circuit.

Conventional current flows through the coil from A to B then from C to D. From Diagram 1, using Fleming's Left Hand Rule, the coil rotates in an anti-clockwise direction. The electromagnetic force acting on AB is directed downwards.

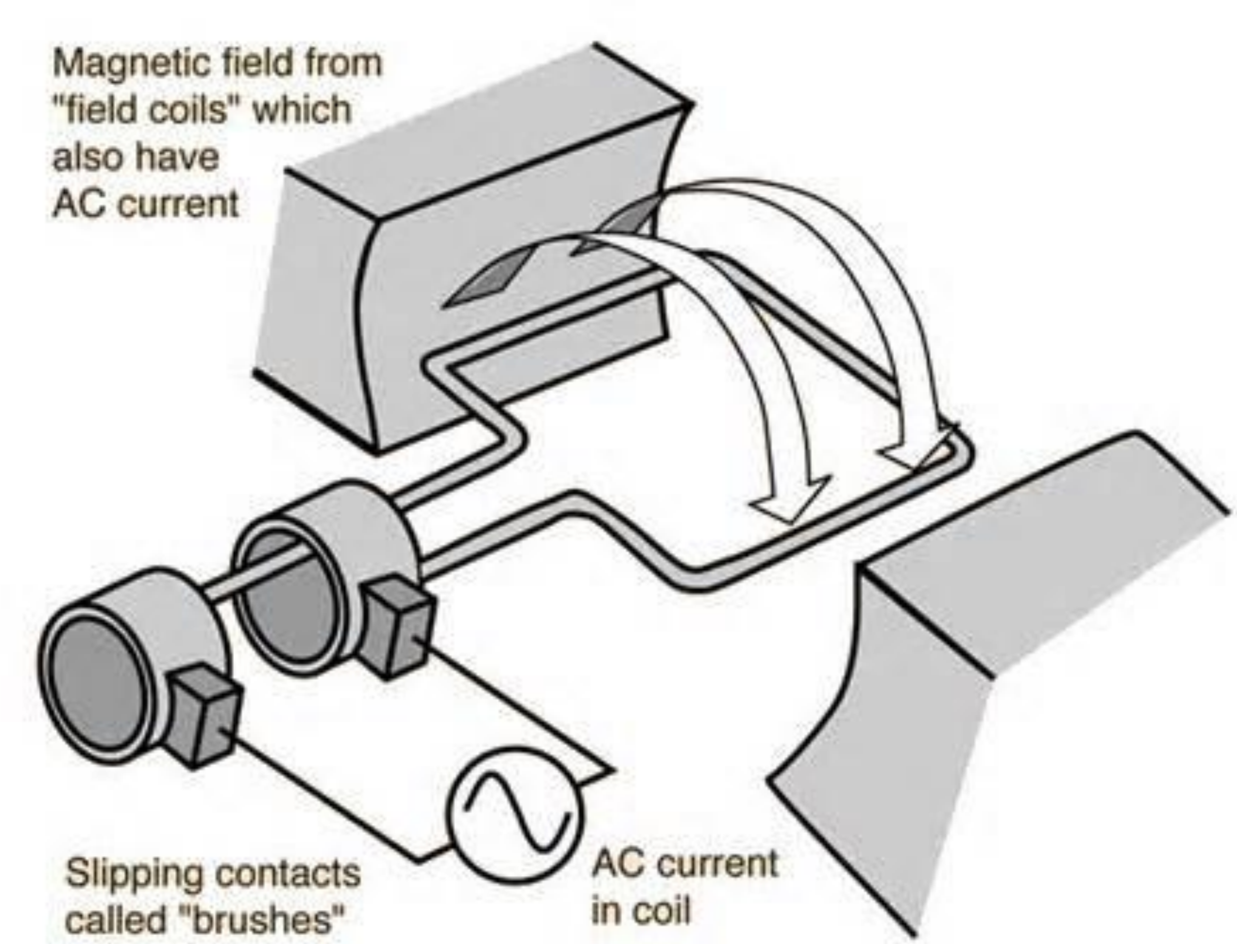
When the coil is perpendicular from its original position (see diagram 2) no current flows. The reason being the metal contacts are not touching the split ring commutator. Instead, they are at the level of the split in the split ring commutator. At this point there is no electromagnetic force being generated. The coil continues to move in an anticlockwise motion due to inertia.

In diagram 3, CD and AB have interchanged positions. The split ring commutator ensures that there is a reversal in the direction of the current within the coil (initially current flowed from A to B however it flows from B to A.) This reversal in the direction of the current within the coil ensures that the direction of the electromagnetic force generated remains the same. The end result is that the coil continues to rotate in an anticlockwise direction.

Factors Affecting The DC Motor

1. The number of turns in the coil – the greater the number of turns, the greater the magnetic force is generated.
2. Magnitude of Current – Larger current produces a larger electromagnetic force.
3. Strength of Magnet - The stronger the magnet, the greater the electromagnetic force. (stronger magnets are created by using electromagnets.)

THE AC GENERATOR



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The a.c. generator produces alternating current when supplied with motion. It consists of a wire coil placed between the end of a magnet. When the coil rotates an electric current is generated. The wires of the coil cuts the magnetic field lines and this results in the formation of an induced current.

In diagram 1 the coil cuts the magnetic field lines maximally. This produces a maximum current. If the coil is rotating clockwise then the current in arm AB moves into the paper (using the right hand rule). The current in arm CD moves out of the paper.

When the coil is vertically positioned, diagram 2, no magnetic field are cut, therefore no current flows.

When the coil rotates from diagram 1 to diagram 2, less field lines are being cut at right angles. The magnitude of the current decreases until no current flows.

In diagram 3, the coil has made a 180 degree turn when compared to diagram 1. Using the right hand rule it can be seen that the direction of current within the arm of the coil are reversed.

The reversal of the current is maintained by the slip ring commutator. The result is the current output shown in diagram 4.

Factors Affecting The Current Produced

1. Strength of the magnet – An increase in strength of the magnet increase the magnitude of the current.
2. Number of turns – Increase in turns in the coil result in an increase of the magnitude of the current (Faraday's Law).
3. The rate at which the coil turns – The faster the rate of coil rotation the greater the magnitude of current (Faraday's Law).

Usually for mains supply, rotation occurs at a rate to produce a frequency of 50-60Hz (50-60 rotations in a second).

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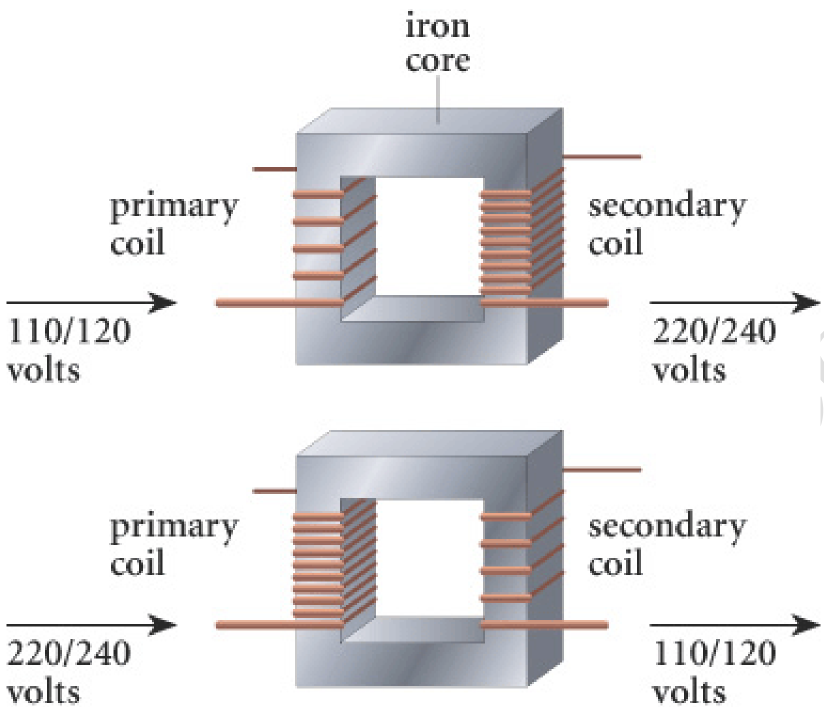
Transformers



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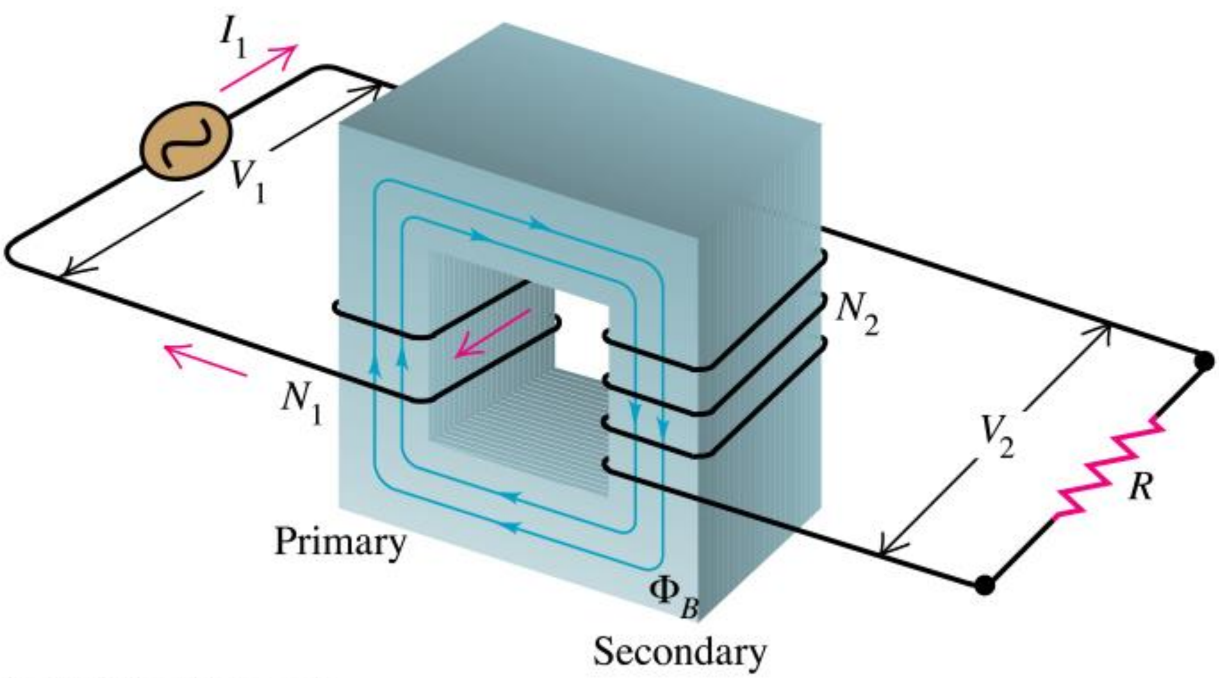

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These are electrical devices that are used to change the magnitude of the voltage and hence current. There are two types of transformers:

1. Step-up transformer which increases the voltage
2. Step-down transformer which decreases the voltage

Principle Operation of A Transformer

Transformers consist of two circuits, a primary circuit (input) and a secondary circuit (output). There is a soft iron core with two arms. One arm the primary circuit is connected to a coil of wires, when current flows into this coil a solenoid is produced.

This solenoid has a magnetic field similar to that of a bar magnet. The size of the magnetic field of the solenoid depends on the magnitude of the current in the input circuit. Since the input circuit uses alternating current the size of the magnetic field will therefore change.

The input circuit uses alternating current. Alternating current changes magnitude and direction continuously. When current flows through the primary coil a solenoid is produced which has a magnetic field pattern similar to that of a bar magnet. The size of a magnetic field changes as the size of current changes.

When the voltage is at A, that it there is no current, then there is no magnetic field, as the current increases from A to B, the size of the magnetic field increases. At point B the magnetic field would be at its maximum size and intensity. From B to C, the size of the field decreases until there is no field at C. From C to D, the magnetic field size increases to reach a maximum size at D, however the direction of the magnetic field line is reversed.

When the field lines move they are cut by the turns of the secondary coil. This produces an induced current. The induced current is also a.c. due to the changes in the magnetic field of the primary coil.

The size of the induced current is dependent upon the rate at which the field lines are cut. (Faraday's Law).

The rate at which the field lines are cut is dependent upon the number of turns in the secondary coil.

If the number of turns in the secondary coil is more than that of the primary then a step-up transformer is produced.

If the number of turns in the secondary coil is less than that of the primary, then a step-down transformer is produced.

The input circuit uses alternating current ONLY. If direct current was used then the magnetic field produced in the primary circuit would be a constant. The rate at which the field lines are cut would be zero, therefore no current would be produced.

Efficiency of A Transformer

This is calculated by using the formula:

$$\frac{Power\ (output\ circuit)}{Power\ (input\ circuit)} \times 100$$

Efficiency is expressed as a percentage. If the efficiency is 100%, it means that the power input is equal to the power output.

Factors Affecting the Efficiency of A Transformer

1. Energy is lost if some of the primary magnetic field does not pass through the secondary.
2. Eddy currents are induced into the soft iron core as well as the coil.

Efficiency is defined as a ratio of the power output to the power input expressed as a percentage.

Transformers are designed to have an efficiency as close as possible to 100%. The design helps to reduce power loss.

1. Transformers are generally 99% efficient.
2. Since transformers are used in the transmission of electricity over large distances and even if 1% of energy is lost, this represents a large quantity of energy. (Thousands of kilowatts of energy is transmitted along the electrical lines).
3. Many transformers may have more than one secondary coil so that different secondary circuits is produced with different output voltages.

Cause of power loss in a transformer	Design to reduce the power loss
The heating effect of the current in the copper wires increases the power loss. The reason being the resistance increases. Power loss $=I^2R$	The copper wires are relatively thick; to decrease the resistance. Transformers are immersed in oil which absorbs the heat being generated thereby helping to cool the transformer.
The soft iron core will also cut the magnetic field lines resulting in the production of unwanted currents called eddy currents. The eddy currents heat up the soft iron core which would result in an increase in the resistance of the copper wires.	The soft iron core is made of sheets of a non-conductor (lamination). The eddy currents are not able to flow long distances due to the presence of the non-conductor. Eddy current formation is therefore reduced.
When current flows through the primary coil, the soft iron core becomes magnetised, as the direction of the current is reversed, the soft iron core becomes demagnetised and then magnetised in the opposite direction. This causes the soft iron core to heat up.	Soft iron is used since it is easily magnetised and readily loses its magnetic properties.
Some of the magnetic field lines of the primary coil do not cut the secondary coil thus results in energy lost.	The primary coil and the secondary coil are arranged so that all the magnetic field lines of the primary coil are cut by the secondary coil.

$$Power\ Output = Power\ Input$$

$$I_S V_S = I_P V_P$$

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Electrical transmission is done using alternating current for several reasons:

1. Alternating current can be stepped up to very high voltages so that the current can be very small and the power loss therefore is reduced.
2. The voltages cab be stepped down to a safer level prior to reaching the point of use (home).
3. Transmission over very long distances can result in significant power loss and hence a reduced voltage. Alternating current can be stepped up so that the transmission can continue over long distances.

Kilowatt-Hour (kWh)

This is used as a measure of energy used industrially and for domestic purposes. Since the kilowatt hour is a measure of energy its unit is Joules (J).

The kilowatt-hour unit is used for the purpose of calculating cost of electricity. Using Kilowatt-hour to make calculations is much more convenient since it removes large numbers.