Transformer

Objectives

After going through the module the learner will be able to

- Understand the principle of working of a transformer
- Describe the construction of a transformer, know the meaning of 'core', 'primary' , and 'secondary'
- Explain the working of a transformer
- Obtain the relation between the ratio of the voltage across the 'secondary' to that across the 'primary' leading to 'transformer ratio'
- Differentiate between a 'step –up' and a 'step down' transformer
- Appreciate different energy losses in the transformer and list ways to reduce them
- Understand power transfer and appreciate the role of transformers in reducing energy losses associated with large scale transmission and distribution of electrical energy over long distances

Content Outline

- Unit Syllabus
- Module Wise Distribution
- Words You Must Know
- Introduction
- Principle of Working of Transformers
- Design of Transformers
- Working of Transformer
- Transformation Ratio
- Efficiency of a Transformer
- How Transformers are Made
- Transformer Losses
- Summary

Unit Syllabus

Unit IV: Electromagnetic Induction and Alternating Currents

Chapter-6: Electromagnetic Induction

Electromagnetic induction; Faraday’s laws, induced emf and current; Lenz’s Law, Eddy currents; Self and mutual induction.

Chapter-7: Alternating Current

Alternating currents, peak and rms value of alternating current/voltage; reactance and impedance; LC oscillations (qualitative treatment only), LCR series circuit, resonance; power in AC circuits, wattless current; AC generator and transformer

Module Wise Distribution of Unit Syllabus 09 modules

The above unit is divided into 9 modules for better understanding.

Module 1	• Electromagnetic induction • Faraday’s laws, induced emf and current • Change of flux • Rate of change of flux
Module 2	• Lenz’s Law • Conservation of energy • Motional emf
Module 3	• Eddy currents. • Self induction • Mutual induction. • Unit • Numerical
Module 4	• AC generator • Alternating currents • Representing ac • Formula • Graph • Phasor • Frequency of ac and what does it depend upon • peak and rms value of alternating current/voltage;
Module 5	• ac circuits • Components in ac circuits

	• Comparison of circuit component in ac circuit with that if used in dc circuit • Reactance mathematically • Pure R • Pure L • Pure C • Phasor, graphs for each
Module 6	• AC circuits with RL, RC and LC components • Using phasor diagram to understand current and voltage phase differences • Impedance; LC oscillations (qualitative treatment only) • Resonance
Module 7	• Alternating voltage applied to series LCR circuit • Impedance in LCR circuit • Phasor diagram • Resonance • Quality Factor • Power in ac circuit • Power factor • Wattles current
Module 8	• Transformer
Module 9	• Advantages of ac over dc • Distribution of electricity to your home

Module 8

Words You Must Know

Let us remember the words we have been using in our study of this physics course:

- **Electromagnetic Induction:** The phenomenon in which electric current can be generated by varying magnetic fields is called electromagnetic induction (EMI).

- **Magnetic Flux:** Just like electric flux, magnetic flux $Ø_B$ through any surface of area A held perpendicularly in magnetic field B is given by the total number of magnetic lines of force crossing the area. Mathematically, it is equal to the dot product of B and A.

  $\Phi_B = B.A = BA \cos \theta$, where θ is the angle between B and A
- **Induced emf and Induced Current:** The emf developed in a loop when the magnetic flux linked with it changes with time is called induced emf when the conductor is in the form of a closed loop, the current induced in the loop is called an induced current.
- **Weber:** One weber is defined as the amount of magnetic flux, through an area of $1m^2$ held normal to a uniform magnetic field of one tesla. The SI unit of magnetic flux is weber (Wb) or tesla metre squared (Tm^2).
- **Faraday's Laws of Electromagnetic Induction:**
  - **First Law:** It states that whenever the magnetic flux linked with the coil changes with time, an emf is induced in the coil. The induced emf lasts in the coil only as long as the change in the magnetic flux continues.
  - **Second Law:** It states that the magnitude of the emf induced in the coil is directly proportional to the time rate of change of the magnetic flux linked with the coil.
- **Lenz's Law:** The law states that the direction of induced emf is always such that it opposes the change in magnetic flux responsible for its production.
- **Fleming's Right Hand rule:** Fleming's right hand rule gives us the direction of induced emf/current in a conductor moving in a magnetic field.

  If we stretch the fore-finger, central finger and thumb of our right hand mutually perpendicular to each other such that the fore-finger is in the direction of the field, the thumb is in the direction of motion of the conductor, then the central finger would give the direction of the induced current.
- **Induced emf by Changing the Magnetic Field:** The movement of magnet or pressing the key of coil results in changing the magnetic field associated with the coil, this induces the emf.
- **Electric Current:** An electric current equals the rate of flow of electric charge. In electric circuits this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte, or by both ions and electrons such as in plasma.

- **Voltage:** Voltage drop, electric potential difference, (electric pressure or electric tension) formally denoted by ΔV or ΔU, but more often simply as V or U, (for instance in the context of Ohm's or Kirchhoff's laws) is the difference in electric potential energy between two points per unit electric charge.
- **Eddy Currents:** Eddy currents are loops of electrical current induced within conductors by a changing magnetic field in the conductor, (as per Faraday's law of induction). Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field. They can be induced within (nearby) stationary conductors by a time-varying magnetic field.
- **Choke Coil:** In electronics, a choke is an inductor used to block higher-frequency alternating current (AC) in an electrical circuit, while passing lower-frequency currents or direct current (DC).
- **Wattless Current:** Wattless current is that AC component of AC current, whereby the power consumed by the circuit is zero.
- **Electrical Conductor:** In physics and electrical engineering, a conductor is an object or type of material that allow the flow of electrical current in one or more directions. A metal wire is a common electrical conductor.
- **Electrical Insulator:** An electrical insulator is a material whose internal electric charges do not flow freely, and therefore make it nearly impossible to conduct an electric current under the influence of an electric field.
- **Electric Generator:** In electricity generation, a generator is a device that converts mechanical energy to electrical energy for use in an external circuit.

Introduction

You are aware that we use alternating voltage to work most of the appliances at home. The electricity companies generate alternating voltage by turning a turbine at high, but regular angular velocities. The turbine has a coil of large number of turns attached to it and the coil is made to rotate in a strong magnetic field. This causes an induced emf in the coil. So the ac generator produces alternating voltage as the conditions for electromagnetic induction are satisfied.

The alternating voltage produced is high, say up to 1000-10,000 volts, but the supply in our homes is only 220V. If you study different devices the operating voltages may be more than or less than the supplied value. This means we need to change the value of alternating voltage according to our need and requirement.

In daily life it is necessary to change an alternating voltage from greater to smaller value or vice- versa. This is done with a device called a transformer**.**

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction.

We have learnt Faraday's **Laws of Electromagnetic Induction**. And we can recall

First law:

It states that whenever the magnetic flux linked with a closed coil or loop changes with time, an emf is induced in the coil.

The induced emf lasts in the coil only as long as the change in the magnetic flux continues.

Second law:

It states that the magnitude of the emf induced in the coil is directly proportional to the time rate of change of the magnetic flux linked with the coil.

So, the first law gives the **conditions for induced emf** which in turn causes a current to flow in the coil.The second law gives us the **magnitude of induced emf**, relating how fast the magnetic flux linked with the coil changes to the induced emf.

You will also recall that the change in flux could be achieved in many ways:

- **By moving a magnet in the vicinity of a coil.**
- **By moving the coil in the vicinity of the magnet.**
- **Changing the area vector associated with a loop with respect to the external magnetic field.**
- **Emf may be induced when a linear conductor moves in a magnetic field (motional emf).**
- **Emf may be induced in the body of a conductor (eddy currents).**

Lenz’s Law

The law states that the **direction of induced emf** is always such that it opposes the change in magnetic flux responsible for its production.

Fleming’s Right Hand rule: Fleming’s right hand rule gives us the direction of induced emf/current in a conductor moving in a magnetic field.

If we stretch the fore-finger, central finger and thumb of our right hand mutually perpendicular to each other such that the fore-finger is in the direction of the field, the thumb is in the direction of motion of the conductor, then the central finger would give the direction of the induced current.

Transformers are used to increase or decrease the alternating voltages in electric power applications.

A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit.

The voltage can be **raised or lowered**, but with a proportional increase or decrease in the current ratings. This gives us two special names for transformers:

A transformer which increases the alternating voltage is called a step up transformer.

A transformer which decreases the alternating voltage is called step down transformer.

You may see some of these images around your homes.

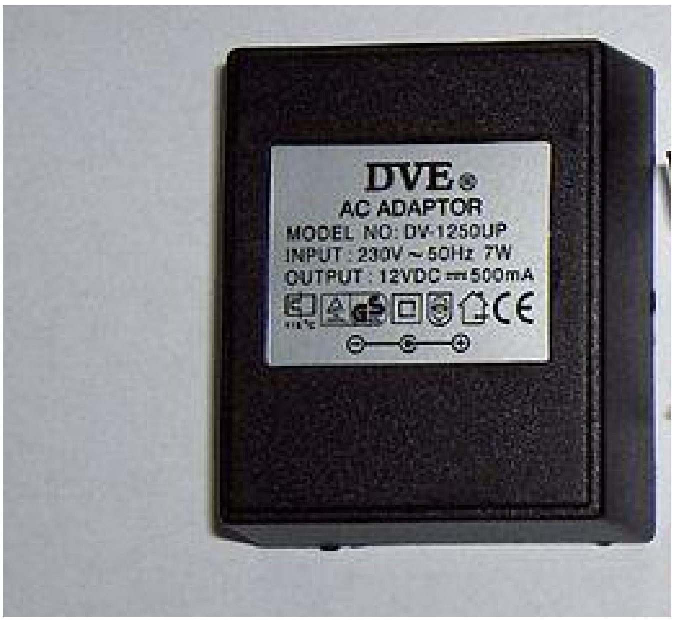
The above image is of a mobile charger. Read the specifications printed on it carefully.

AC Adapter

Model no DV-1250UP

Input 230V~50Hz 7W

Output 12 V DC 500mA



NOTE. **An advantage of DC is that it is easy to store in batteries. That is why portable electronics – flashlights, cell phones, and laptops use DC power.**

AC electricity is a little more complicated because it switches back and forth, but its advantage is that it can be transmitted economically over long distances. That is why AC power comes in through the power lines to our homes. Stationary appliances that use electricity directly from the Mains– lamps, fans, TV, refrigerators, and washing machines use AC power.

Think About This

The charger is plugged into the socket providing 230V AC but the output is 12 V DC!!!

We will now study the principle and working of transformers.

Principle of Working of Transformers

Transformers work on the **principle of mutual inductance**. An emf is induced in a coil due to changing current in a coil in its vicinity,

This is because the condition for electromagnetic induction is satisfied.

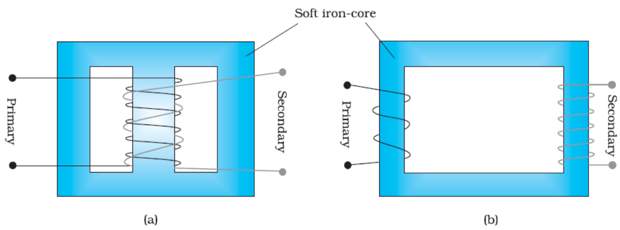
The changing current in one coil causes a changing magnetic flux around it. If the second coil is in the varying magnetic field of the first, an emf is induced in the second coil.
In other words when the magnetic flux linked with a coil changes, an emf is induced in another coil placed near it.

Design of Transformers

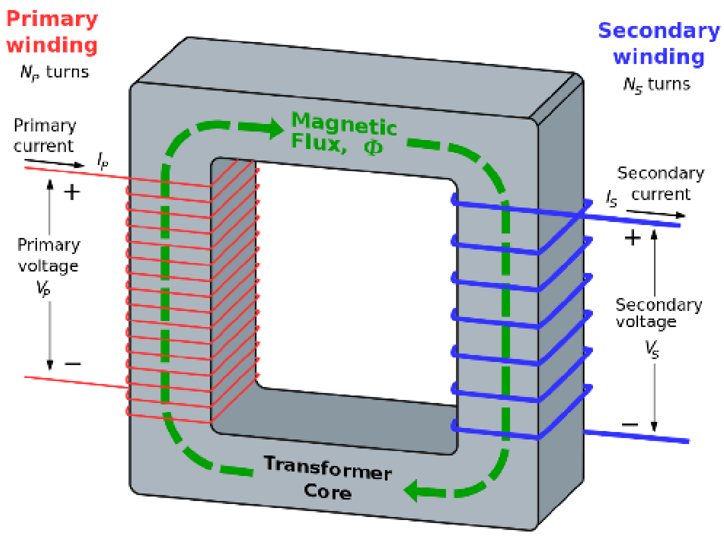
A transformer consists of:

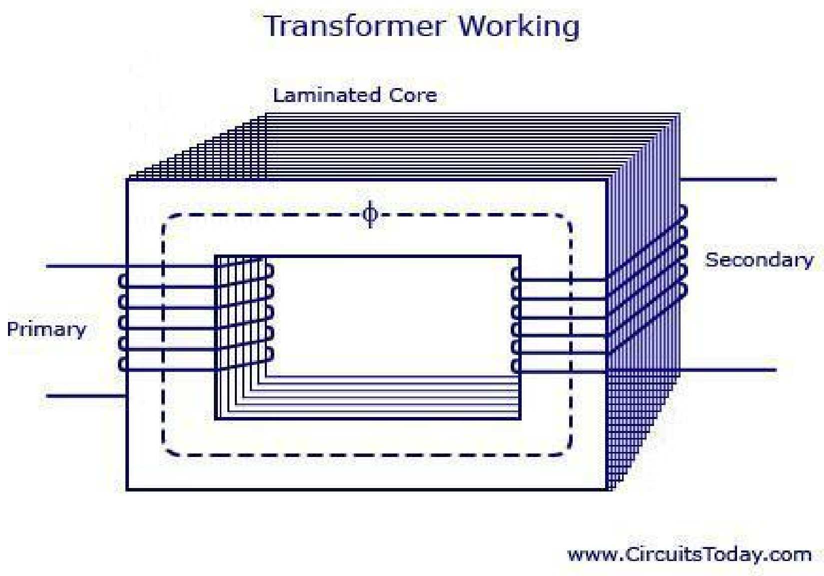
i. a rectangular soft iron laminated core,
ii. primary coil made of insulated copper wire,
iii. secondary coil also made up of insulated copper wire,
iv. both coils are wound on the same core and are well insulated from each other.

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux.
A basic transformer consists of **two coils** that are **electrically separate and inductive**, but are **magnetically linked**. The working principle of the transformer can be understood from the figure below.



The transformer has primary and secondary windings and core laminations are joined in the form of strips. In between the strips you can see that there are some narrow gaps right through the cross-section of the core.
These staggered joints are said to be 'imbricated'.
Both the coils have high mutual inductance. A mutual emf is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction.



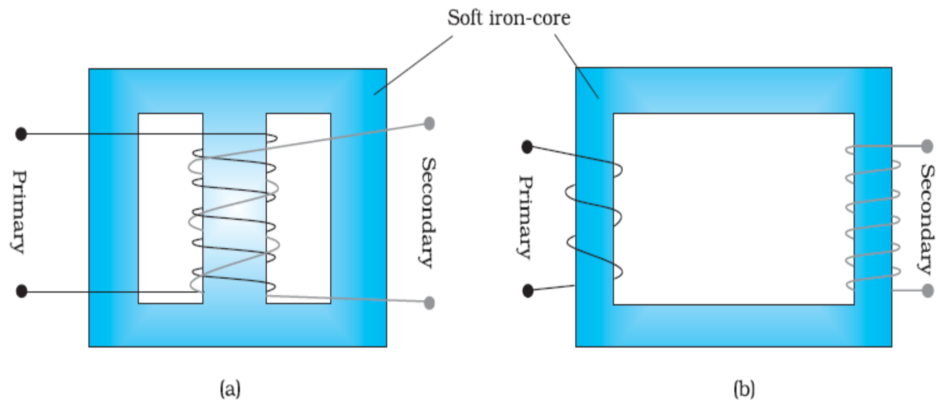


Source:wikipedia

So we can say

- A transformer consists of two sets of coils, insulated from each other.
- They are wound on a soft-iron core, either one on top of the other as in

Fig. (a) .



or on separate limbs of the core as in Fig. (b), this ensures good linkage.

- One of the coils called the **primary coil** has N_p turns.
- The other coil is called the **secondary coil**; it has N_s turns.
- The primary coil is also called the **input coil** and the secondary coil is **the output coil** of the transformer.
- The core is made up of insulated sheets to avoid heating due to eddy currents.

Think About These

- **If the wires were not insulated.**
- **If the primary and secondary coils were not mounted on a soft iron frame.**
- **If the primary and secondary coils were mounted on a wooden frame.**

Working of a Transformer

When **an alternating voltage** is applied to the primary, the resulting current produces an **alternating magnetic flux** which links the secondary and induces an emf in it.

The value of this emf depends on

- **The number of turns in the primary and secondary coils,**
- **Linkage between primary and secondary coils,**
- **The alternating voltage supplied to the primary coil.**

We consider **an ideal transformer** in which the **primary coil** has negligible resistance and all the flux in the core links both primary and secondary windings.

Let ϕ be the flux in each turn in the core at time t due to current in the primary when a voltage $\mathbf{V_P}$ is applied to it.

Then the induced emf or voltage V_S in the secondary with N_S turns is

$\varepsilon_S = -N_S \frac{d\phi}{dt}$

The alternating flux ϕ also induces an emf, called back emf in the primary coil. This can be given by

$\varepsilon_P = -N_P \frac{d\phi}{dt}$

But $\varepsilon_P = V_P$

If this were not so, the primary current would be infinite since the primary has zero resistance (as assumed). If the secondary is an open circuit or has a high resistance or the current taken from it is small, then to a good approximation

$e_S = V_S$

Where V_S is the voltage across the secondary.

So above equation can be written as:

$V_S = -N_S \frac{d\phi}{dt}$ **and** $V_P = -N_P \frac{d\phi}{dt}$

Or we can say

$\frac{V_S}{V_P} = \frac{N_S}{N_P}$

The above relation has been obtained using **three assumptions**:

- The primary resistance and current are small.
- The same flux links both the primary and the secondary as very little flux escapes from the core.
- The secondary current is small.

Transformation Ratio

For a particular transformer with known number of turns in primary and secondary coils

The ratio of number of turns in the secondary to that in the primary is called transformation ratio

Represented by K

$\frac{V_S}{V_P} = \frac{N_S}{N_P} = k$

For step up Transformer

($N_S > N_P$) K is >1

Or

V_S will be greater than V_P

The ratio

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = k > 1$$

For step down Transformer

($N_S < N_P$) K is <1

Or

V_S will be less than V_P

The ratio

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = k < 1$$

Efficiency of a Transformer

If the **transformer is assumed to be 100% efficient (no energy losses), the power input is equal to the power output, and since**

P =VI

$$V_P I_P = V_S I_S$$

Although some energy is always lost, this is a good approximation, since a well-designed transformer may have an efficiency of more than 95%.

So we can write the above relations as

$$\frac{I_P}{I_S} = \frac{V_S}{V_P} = \frac{N_S}{N_P}$$

Since *I* and *V* both oscillate with the same frequency as the ac source,this eqn. also give the ratio of the amplitudes or rms values of corresponding quantities.

Now, we can see how a transformer affects the voltage and current.

$$V_S = \left(\frac{N_S}{N_P}\right)V_P$$

And

$$I_S = \left(\frac{N_P}{N_S}\right)I_P$$

That is, if the secondary coil has a greater number of turns than the primary ($N_S > N_P$), the voltage is stepped up $V_S > V_P$. This type of arrangement is called a step-up transformer: However, in this arrangement, there is less current in the secondary than in the primary $I_S < I_P$.

Think why this is not a violation of Ohm's law that current is directly proportional to the voltage applied to the circuit, for as we have just seen the secondary voltage is higher but the current in it is lesser.

If the secondary coil has less turns than the primary ($N_s < N_p$), we have a *step-down* transformer. In this case, $V_S < V_P$ and $I_S > I_P$. That is, the voltage is stepped down, or reduced, and the current is increased.

https://www.youtube.com/watch?v=w9ugMmrCTg0

watch the video for more clarity

Thus a transformer carries the operations

- Transfer of electric power from one circuit to another.
- Transfer of electric power without any change in frequency.
- Transfer with the principle of electromagnetic induction.
- The two electrical circuits are linked by mutual induction

How are transformers made?

Here are different ways commercial transformers are made.

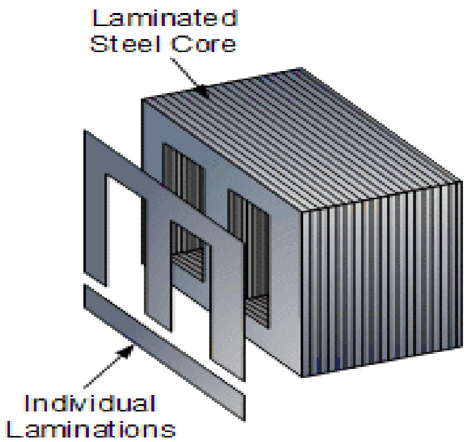
This section has been added to provide some practical insight into this very useful device

Windings

The construction of a simple two-winding transformer consists of each winding being wound on a separate limb or core of the soft iron form which provides the necessary magnetic circuit which is necessary for induction of the voltage between the two windings.

However, this type of transformer construction were the two windings are wound on separate limbs is not very efficient since the primary and secondary windings are well separated from each other. This results in a low magnetic coupling between the two windings as well as large amounts of magnetic flux leakage from the transformer itself.

The efficiency of a simple transformer construction can be improved by bringing the two windings within close contact with each other thereby improving the magnetic coupling. Increasing and concentrating the magnetic circuit around the coils may improve the magnetic coupling between the two windings, but it also has the effect of increasing the magnetic losses of the transformer core.



As well as providing a low reluctance path for the magnetic field, the core is designed to prevent circulating electric currents within the iron core itself. Circulating currents, called “eddy currents”, cause heating and energy losses within the core, decreasing the transformers efficiency.

These losses are due mainly to voltages induced in the iron circuit, which is constantly being subjected to the alternating magnetic fields setup by the external sinusoidal supply voltage. One way to reduce these unwanted power losses is to construct the transformer core from thin steel laminations.

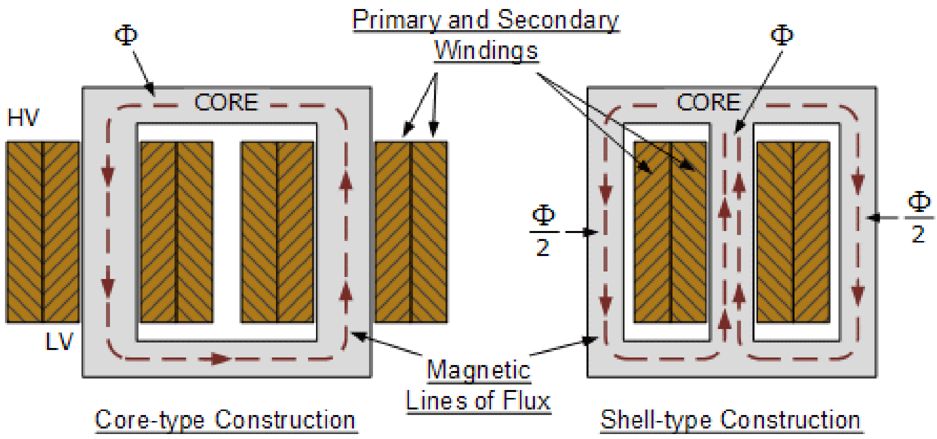
In all types of transformer construction, the central iron core is constructed from a highly permeable material made from thin silicon steel laminations assembled together to provide the required magnetic path with the minimum of losses. The resistivity of the steel sheet itself is high, reducing the eddy current losses by making the laminations very thin.

These steel transformer laminations vary in thickness from between 0.25mm to 0.5mm and as steel is a conductor, the laminations are electrically insulated from each other by a very thin coating of insulating varnish or by the use of an oxide layer on the surface.

The Core

Generally, the name associated with the construction of a transformer is dependent upon how the primary and secondary windings are wound around the central laminated steel core. The two most common and basic designs of transformer construction are the Closed-core Transformer and the Shell-core Transformer.

In the "closed-core" type (core form) transformer, the primary and secondary windings are wound outside and surround the core ring. In the "shell type" (shell form) transformer, the primary and secondary windings pass inside the steel magnetic circuit (core) which forms a shell around the windings as shown below.



In both types of transformer core design, the magnetic flux linking the primary and secondary windings travels entirely within the core with no loss of magnetic flux through air. In the core type transformer construction, one half of each winding is wrapped around each leg (or limb) of the transformers magnetic circuit as shown above.

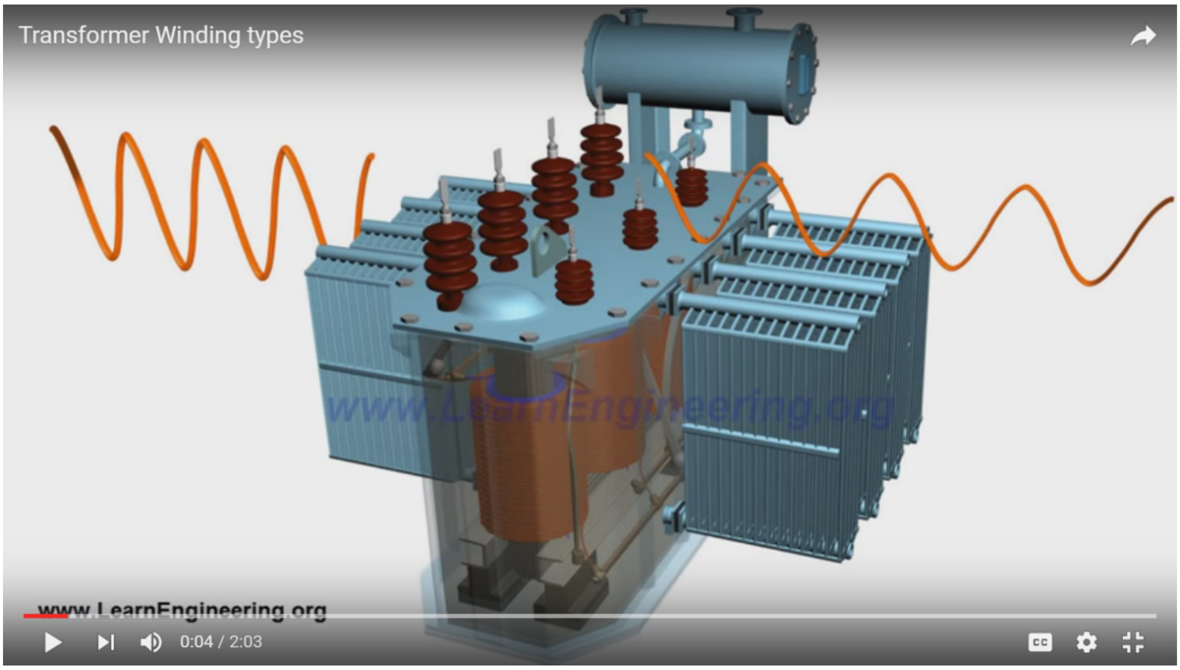
The coils are not arranged with the primary winding on one leg and the secondary on the other but instead half of the primary winding and half of the secondary winding are placed one over the other concentrically on each leg in order to increase magnetic coupling allowing practically all of the magnetic lines of force go through both the primary and secondary windings at the same time. However, with this type of transformer construction, a small percentage of the magnetic lines of force flow outside of the core, and this is called "leakage flux".

Shell type transformer cores overcome this leakage flux as both the primary and secondary windings are wound on the same center leg or limb which has twice the cross-sectional area of the two outer limbs. The advantage here is that the magnetic flux has two closed magnetic paths to flow around external to the coils on both left and right hand sides before returning back to the central coils.

This means that the magnetic flux circulating around the outer limbs of this type of transformer construction is equal to Φ/2. As the magnetic flux has a closed path around the coils, this has the advantage of decreasing core losses and increasing overall efficiency.

Transformer Winding Arrangements

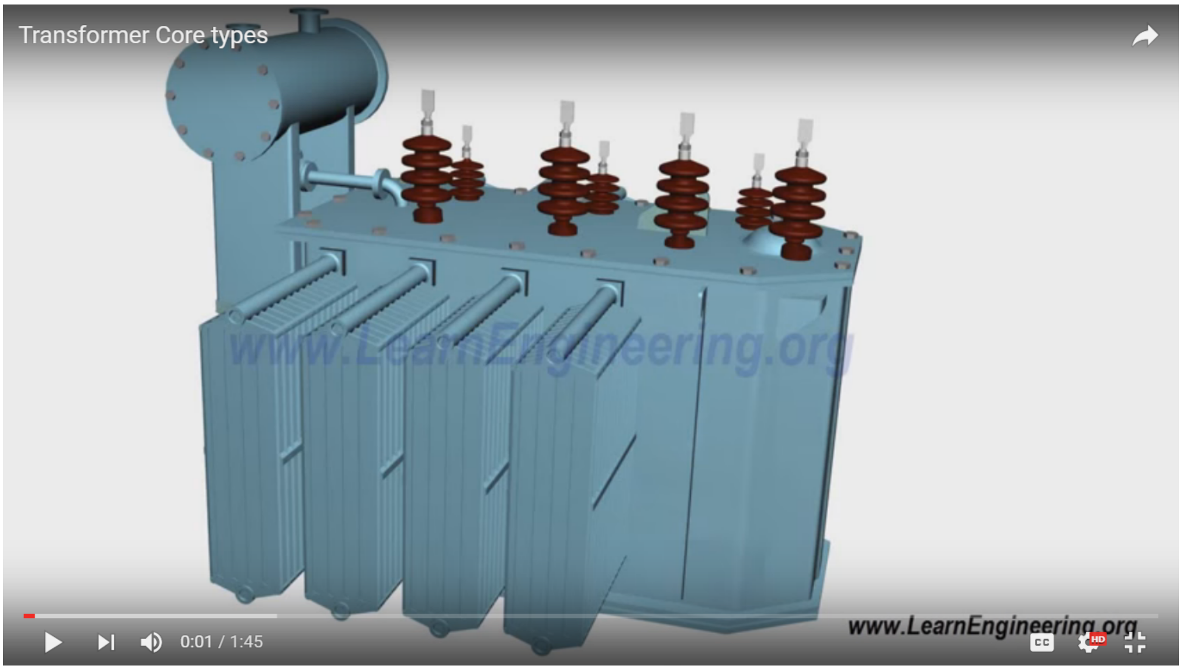
Transformer windings form another important part of a transformer construction, because they are the main current-carrying conductors wound around the laminated sections of the core. In a single-phase two winding transformer, two windings would be present as shown. The one which is connected to the voltage source and creates the magnetic flux called the **primary winding**, and the second winding called the secondary in which a voltage is induced as a result of mutual induction.



If the secondary output voltage is less than that of the primary input voltage the transformer is known as a “Step-down Transformer”. If the secondary output voltage is greater than the primary input voltage it is called a “Step-up Transformer”.

Core-type Construction

The type of wire used as the main current carrying conductor in a transformer winding is either copper or aluminum. While aluminum wire is lighter and generally less expensive than copper wire, a larger cross sectional area of conductor must be used to carry the same amount of current as with copper so it is used mainly in larger power transformer applications.



Small kVA power and voltage transformers used in low voltage electrical and electronic circuits tend to use copper conductors as these have a higher mechanical strength and smaller conductor size than equivalent aluminum types. The downside is that when complete with their core, these transformers are much heavier.

Transformer windings and coils can be broadly classified in to concentric coils and sandwiched coils. In core-type transformer construction, the windings are usually arranged concentrically around the core limb as shown above with the higher voltage primary winding being wound over the lower voltage secondary winding.

Sandwiched or “pancake” coils consist of flat conductors wound in a spiral form and are so named due to the arrangement of conductors into discs. Alternate discs are made to spiral from outside towards the center in an interleaved arrangement with individual coils being stacked together and separated by insulating materials such as paper or plastic sheet. Sandwich coils and windings are more common with shell type core construction.

Helical Windings also known as screw windings are another very common cylindrical coil arrangement used in low voltage high current transformer applications. The windings are made up of large cross sectional rectangular conductors wound on its side with the insulated strands wound in parallel continuously along the length of the cylinder, with suitable spacers inserted between adjacent turns or discs to minimize circulating currents between the parallel strands. The coil progresses outwards as a helix resembling that of a corkscrew.

Source: helx.htm

Transformer Losses

The insulation used to prevent the conductors shorting together in a transformer is usually a thin layer of varnish or enamel in air cooled transformers. This thin varnish or enamel paint is painted onto the wire before it is wound around the core.

In larger power and distribution transformers the conductors are insulated from each other using oil impregnated paper or cloth. The whole core and windings are immersed and sealed in a protective tank containing transformer oil. The transformer oil acts as an insulator and also as a coolant.

Thus in brief actual transformers have small energy losses occur due to the following reasons:

- **Flux Leakage:**

There is always some flux leakage; that is, not all of the flux due to primary passes through the secondary due to poor design of the core or the air gaps in the core. It can be reduced by winding the primary and secondary coils one over the other.

- **Resistance of the windings:**

  The wire used for the windings has some resistance and so, energy is lost due to heat produced in the wire ($I^2 R$). In high current, low voltage windings, these are minimized by using thick wire.

- **Eddy currents:**

  The alternating magnetic flux induces eddy currents in the iron core and causes heating. The effect is reduced by having a laminated core.

- **Hysteresis:**

  The magnetization of the core is repeatedly reversed by the alternating magnetic field. The resulting expenditure of energy in the core appears as heat and is kept to a minimum by using a magnetic material which has a low hysteresis loss.

Example:

Give reasons why?

a. A transformer cannot be used with DC.
b. A transformer only changes the amplitude of the alternating voltage , it does not change the frequency of the alternating voltage.
c. An ideal transformer is not possible.
d. A step down transformer cannot be used as step up transformer merely by interchanging the primary and secondary coils.
e. When current flows in the transformer coils the core becomes hot.
f. Primary and secondary coils do not have any electrical contact but current flows in the secondary coil whenever alternating current is supplied to the primary coil.
g. The primary and secondary coils are mounted on a fixed frame core .

Solution:

a. As there will be no mutual inductance as the steady current will produce steady magnetic flux around the secondary.
b. The rate of change of flux is the primary is the same for the secondary coil.
c. An ideal transformer should have no power loss

$V_P I_P = V_S I_S$

But the wire making up the coil will have some resistance and heat would be produced.

d. In order to keep the power losses to a minimum, the two coils have different resistances .In a step down transformer primary current is lower than the secondary coil current, the primary coil is made of thinner wire (higher resistance) than the secondary. The wires may burn out if the primary coil is made the secondary coil.

e. Eddy currents are produced in the core. A laminated core made up of plates instead of bulk reduces the heat produced in the core.

f. mutual inductance

g. for better coupling between the primary and secondary coils

Example:

A transformer steps down 220 V AC to 2.2 V AC.

a. Determine the transformation ratio.

b. What will be the output voltage if 110 volt AC is applied to the same transformer?

Solution:

a. $\frac{V_S}{V_P} = \frac{N_S}{N_P} = k$

$K = \frac{2.2}{220} = \frac{1}{100}$

b. 1.1 V AC

Example:

A power transmission line feeds input power at 2300V to a step down transformer with its primary windings having 4000 turns.What should be the number of turns in the secondary in order to get output power at 230V?

Solution:

$V_1 = 2300\ volt \quad n_1 = 4000$

$V_2 = 230$ volt

$\frac{V_2}{V_1} = \frac{n_2}{n_1}$

$n_2 = n_1 \frac{V_2}{V_1} = 400 \times \frac{230}{2300} = 400\ turns$

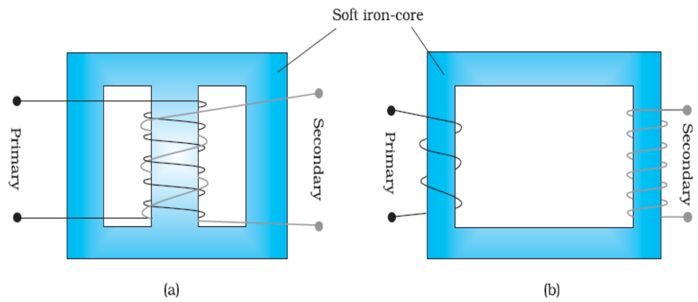
Example:

Out of the two arrangements given below for windings of primary and secondary coils in a transformer.

a. Which arrangement do you think will have higher efficiency and why?

b. Show in an ideal transformer when a voltage is stepped up by a certain factor the current in the secondary is stepped down by the same factor.

c. Give reasons why it is not possible to make an ideal transformer.



Solution:

a. Arrangement (a) will have higher efficiency because leakage of flux will be the least

b. Hint for an ideal transformer

$$V_P I_P = V_S I_S$$

so if the voltage is stepped up by a factor

$$\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} \quad or \quad V_S = \left(\frac{N_S}{N_P}\right)V_P \quad or \quad I_S = \left(\frac{N_P}{N_S}\right)I_P$$

c. It is difficult to have perfect coupling between primary and secondary coils, the coil wire will have some résistance, hysteresis will occur ,some loss will take place as the laminated core will heat up.

Try these

1. **What is meant by an ideal transformer?**

   A power transmission line feeds input power at 2100 V to a step-down transformer with its primary windings having 1000 turns. What should be the number of turns in the secondary in order to get output

   power of 210 V?

2. A small town with a demand of 1000 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire lines carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.
   a. Estimate the line power loss in the form of heat.
   b. How much power must the plant supply, assuming there is negligible power loss due to leakage?
   c. Characterize the step up transformer at the plant.

3. If the frequency of ac in the primary coil is 50 Hz in a step up transformer . What will be the frequency of ac in the secondary coil ?

4. Why is it not possible to step up or step down DC voltages using a transformer?

Additional information - Types of Transformer

Electrical application designs require a variety of transformer. Although they all share the basic characteristic transformer principles, they are customized in construction or electrical properties for certain installation requirements or circuit conditions. This information is given as we have learnt only about step up and step down transformers, but since they are commonly used one may come across specific names.

Autotransformer: Transformer in which part of the winding is common to both primary and secondary circuits.

Capacitor voltage transformer: Transformer in which capacitor divider is used to reduce high voltage before application to the primary winding.

Distribution transformer-power transformer: International standards make a distinction in terms of distribution transformers being used to distribute energy from transmission lines and networks for local consumption and power transformers being used to transfer electric energy between the generator and distribution primary circuits.
Phase angle regulating transformer: A specialized transformer used to control the flow of real power on three-phase electricity transmission networks.

Grounding transformer: Transformer used for grounding three-phase circuits to create a neutral in a three wire system, using a wye-delta transformer, or more commonly, a zigzag grounding winding.

Leakage transformer: Transformer that has loosely coupled windings.
Resonant transformer: Transformer that uses resonance to generate a high secondary voltage.

Audio transformer: Transformer used in audio equipment.

Output transformer: Transformer used to match the output of a valve amplifier to its load.
Instrument transformer: Potential or current transformer used to accurately and safely represent voltage, current or phase position of high voltage or high power circuits.

Pulse transformer: Specialized small-signal transformer used to transmit digital signaling while providing electrical isolation, commonly used in Ethernet computer networks as 10BASE-T, 100BASE-T and 1000BASE-T
wikipedia

Summary

In this module you have learnt

- **Transformer:** A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Or **a device which can change alternating voltage values is called a transformer.**
- The principle of the transformer is mutual induction.
- Transformer consists of a set of 2 coils made of insulated wires, of small resistance make up primary and secondary coils.
- The coils are wound on a soft iron laminated frame which ncreases flux value between primary and secondary coils
- Increases flux linkage between primary and secondary coils
- Reduces energy loss in the form of heat as smaller eddy currents are produced.

- Alternating voltage to be increased or decreased is placed in the primary coil of known turns. the output is obtained across the load resistance placed in the secondary coil.
- **Step-Up Transformer:** A transformer that increases voltage from primary to secondary (more secondary winding turns than primary winding turns) is called a step-up transformer.
- **Step-Down Transformer:** A step down transformer has less turns on the secondary coil that of the primary coil.
- **Transformation Ratio K** it is the ratio of number of turns in the secondary to the number of turns in the primary.
- In an ideal transformer power in primary is the same as power in the secondary.
- This means in a step up transformer voltage increases and the current decreases, or in a step down transformer voltage decreases and the current increases.
- A transformer suffers voltage losses due to the following:
- **Flux Leakage:** There is always some flux leakage; that is, not all of the flux due to primary; passes through the secondary due to poor design of the core or the air gaps in the core. It can be reduced by winding the primary and secondary coils one over the other.
- **Resistance of the windings:** The wire used for the windings has some resistance and so, energy is lost due to heat produced in the wire ($I^2 R$). In high current, low voltage windings, these are minimized by using thick wire.
- **Eddy currents:** The alternating magnetic flux induces eddy currents in the iron core and causes heating. The effect is reduced by having a laminated core.
- **Hysteresis:** The magnetization of the core is repeatedly reversed by the alternating magnetic field. The resulting expenditure of energy in the core appears as heat and is kept to a minimum by using a magnetic material which has a low hysteresis loss.