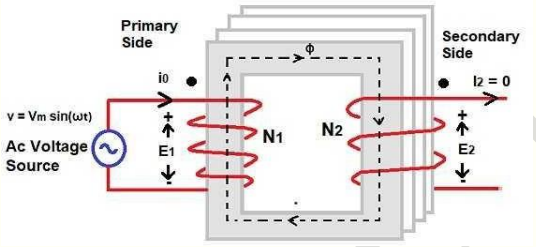
TRANSFORMER

Basic Overview :

A transformer is an electrical device that transfers energy between circuits using electromagnetic induction, primarily for alternating current (AC). It works by changing the voltage and current levels while maintaining power



Transformer Overview

- **Function:**

Transformers transfer electric energy from one AC circuit to another, either increasing (stepping up) or decreasing (stepping down) the voltage.

- **Principle:**

They work based on mutual induction, where a changing magnetic flux in one winding induces a voltage in another.

- **Components:**
  - Core: A magnetic core (usually iron) that provides a path for the magnetic flux.
  - Windings: Two or more coils of wire (primary and secondary) wound around the core.
- **Types:**
  - Step-up: Increases voltage.
  - Step-down: Decreases voltage.
  - Power, Distribution, Instrument, and Current Transformers: Based on their application.
- **Voltage Ratio:**

The ratio of secondary to primary voltage is determined by the turns ratio.

- **Efficiency:**

The ratio of output power to input power.

- **Tests:**

Open-circuit and short-circuit tests are used to determine parameters like impedance.

Let us dive deep into the topic to develop an in-depth understanding:

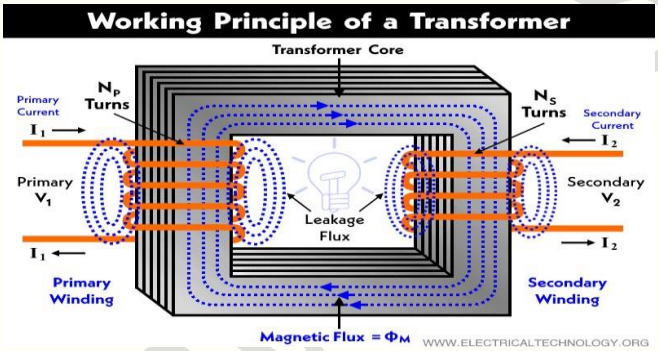
SECTION 1. BASIC CONCEPTS OF TRANSFORMERS

1. What is a transformer?

A transformer is a static electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. It works on the principle of mutual induction and is used to increase (step-up) or decrease (step-down) voltage levels.

2. State the principle of operation of a transformer.

A transformer operates on Faraday's law of electromagnetic induction, where a time-varying current in the primary coil induces a varying magnetic flux that links to the secondary coil, producing an EMF.



3. Why is a transformer called a static device?

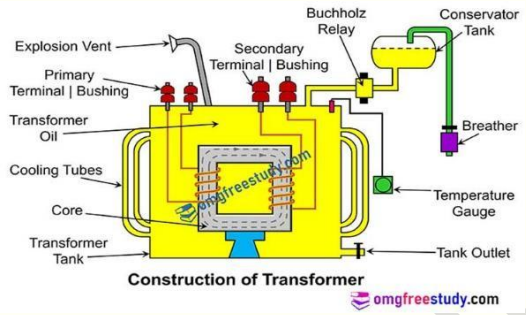
It has no rotating parts; energy conversion occurs via magnetic coupling, making it a static device.

SECTION 2. CONSTRUCTION AND COMPONENTS

4. What are the main parts of a transformer?

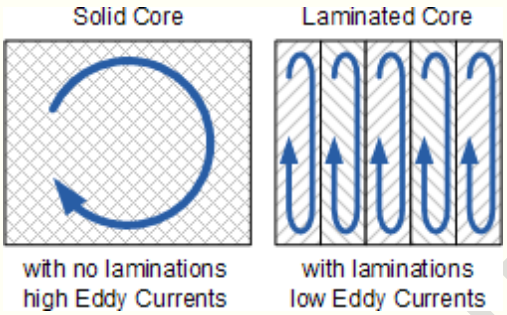
- Core: Provides a path for magnetic flux (usually laminated to reduce eddy current loss).
- Windings: Primary and secondary coils (made of copper or aluminium).
- Insulation: Prevents short-circuiting between turns and windings.
- Tank: Contains the core and windings immersed in oil for insulation and cooling.

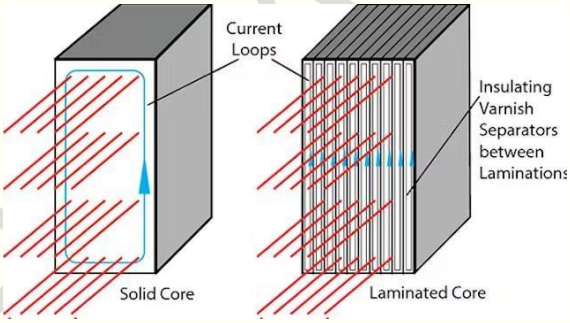
- Cooling system: Air or oil-based systems to dissipate heat.



5. Why are transformer cores laminated?

Laminations reduce eddy current losses by increasing the resistance to circulating currents in the core.





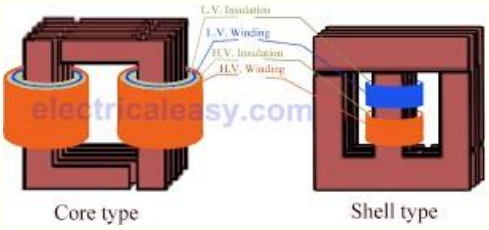
6. Why is silicon steel used in transformer cores?

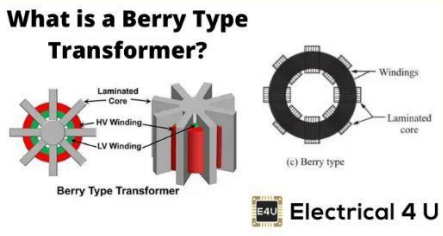
Silicon steel has high magnetic permeability and low hysteresis loss, improving efficiency.

SECTION 3. TYPES AND CLASSIFICATION

7. What are the types of transformers based on construction?

- **Core-type Transformer:** Windings surround the core limbs.
- **Shell-type Transformer:** Core surrounds the windings.
- **Berry-type Transformer:** Cylindrical shape with distributed windings.





8. What are the types based on function?

- **Power Transformers:** Used in transmission networks (high rating).
- **Distribution Transformers:** Used in distribution networks (lower rating).
- **Instrument Transformers:** Include CTs and PTs for metering/protection.
- **Auto Transformers:** Single winding used for both primary and secondary

SECTION 4. WORKING AND OPERATION

9. State the working principle of a transformer.

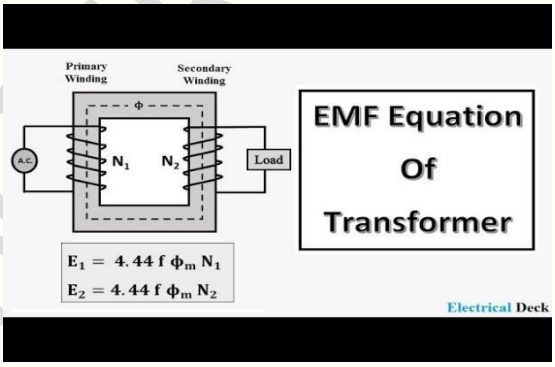
A transformer works on Faraday's Law of Electromagnetic Induction, where a varying current in the primary winding creates a changing magnetic flux, inducing an EMF in the secondary winding.

10. Derive the EMF equation of a transformer.

$$E=4.44fN\phi m$$

Where:

- E = Induced EMF (V)
- f= Frequency (Hz)
- N = Number of turns
- ϕm = Maximum flux in the core (Wb)



11. Why is the frequency of a transformer constant?

Transformers do not alter frequency because they rely on mutual induction, which transfers the same time-varying magnetic field, hence same frequency, to the secondary.

12. What is meant by mutual induction?

Mutual induction is the phenomenon where a changing current in one coil induces an EMF in another nearby coil through a common magnetic field.

14. Why does a transformer only work on AC?

AC is needed to create a time-varying magnetic field, which is essential for electromagnetic induction. DC would produce a constant flux, hence no induced EMF.

15. What happens if a transformer is connected to a DC supply?

The transformer core saturates, and high current flows through the windings due to the absence of inductive reactance, leading to overheating and potential damage.

16. What happens when a transformer is energized without a load?

It draws a small no-load current (~2–5%) to magnetize the core and supply core losses. This current is highly inductive and lags the voltage by about 80°–85°.

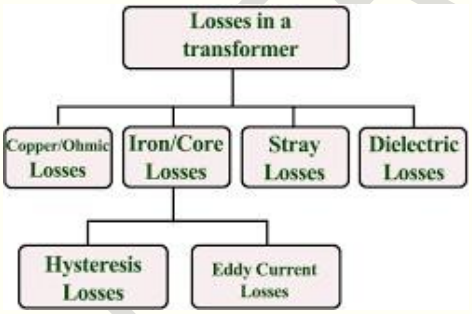
17. Why is the transformer rating in kVA?

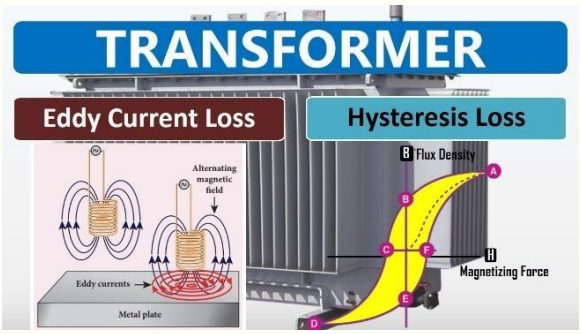
Because losses depend on voltage and current (not power factor), the rating is given in kVA, not kW.

SECTION 5. LOSSES IN TRANSFORMERS

17. What are the losses in a transformer?

- Core (Iron) Loss: Hysteresis and eddy current losses (constant).
- Copper Loss: I^2R losses in windings (variable with load).
- Dielectric Loss: In insulation (usually negligible).
- Stray Losses: Due to leakage flux**.**





18. What is hysteresis loss and how is it reduced?

Hysteresis loss occurs due to repeated magnetization of the core. It is reduced by using high-grade silicon steel.

19. What is eddy current loss and how is it minimized?

It is the loss due to circulating currents in the core. It is minimized by laminating the core to increase resistance.

SECTION 6. EFFICIENCY AND TESTING

20. Define transformer efficiency.

η = [Output Power / Input Power] x100 % = [Output / Output + Losses] x100 %

21. What is the condition for maximum efficiency?

Maximum efficiency occurs when core loss = copper loss.

22. What is all-day efficiency?

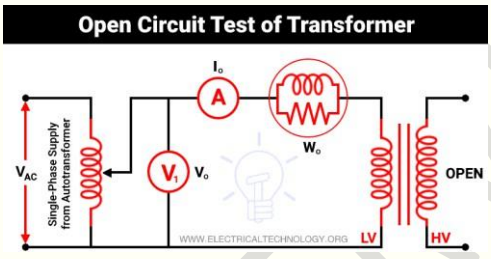
It is the ratio of total energy output to input over 24 hours:

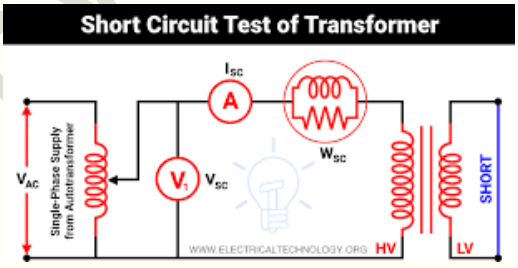
All-day efficiency = [Total kWh Output / Total kWh Input] ×100 %

Important for distribution transformers with varying loads.

23. What tests are done on a transformer?

- **Open Circuit Test (OC):** Measures core loss.
- **Short Circuit Test (SC):** Measures copper loss.
- **Sumpner's Test:** Determines temperature rise and full-load losses.





24. How is transformer efficiency affected by load?

Efficiency increases with load up to a point (maximum efficiency point) and then decreases due to rising copper losses.

25. What is the purpose of OC and SC tests?

- OC test (on LV side): Determines core loss and no-load current.
- SC test (on HV side): Determines copper loss and equivalent impedance.

SECTION 7. VOLTAGE REGULATION

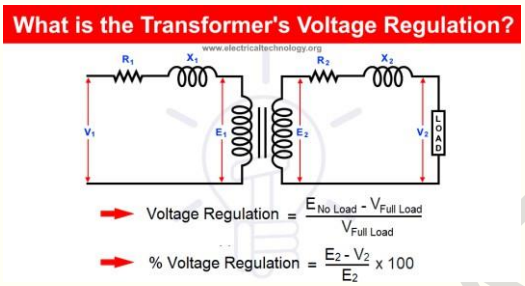
26. What is voltage regulation in transformers?

It is the percentage drop in secondary voltage from no-load to full-load: Regulation (%) = [(VNL−VFL)/VFL] ×100%

Where,

VNL = Voltage at no load

VFL = Voltage at full load



27. What does negative voltage regulation mean?

Occurs when load is capacitive; secondary voltage rises under load due to leading power factor.

SECTION 8. EQUIVALENT CIRCUIT AND PHASOR DIAGRAM

28. What is the purpose of the equivalent circuit?

It models transformer behaviour using resistances and reactances to analyze voltage drops, regulation, and losses.

29. What is the significance of referred parameters?

To simplify analysis, secondary values are referred to the primary (or vice versa) using the turns ratio (K):

K= N2/N1 = V2/V1

SECTION 9: TRANSFORMER RATINGS AND CONNECTIONS

30. Why are transformers rated in kVA, not kW?

Because the losses depend on both voltage and current, not the power factor. Hence, kVA rating includes both real and reactive components.

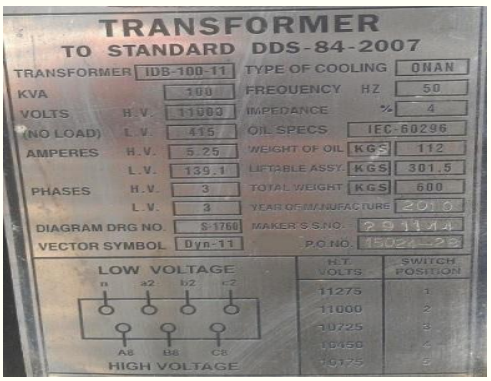
31. What are different transformer connections?

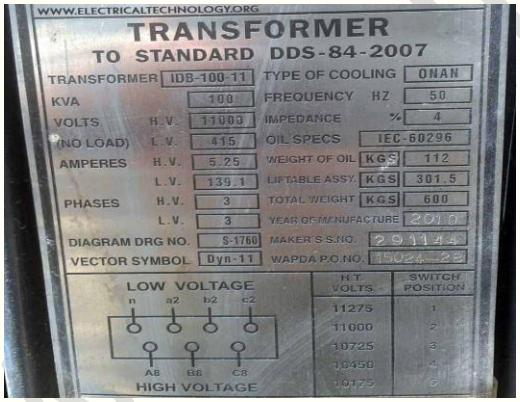
- **Single-phase:**

- Two-winding transformer

- Autotransformer

- **Three-phase:**
  - Star-Star (Y-Y)
  - Delta-Delta (Δ-Δ)
  - Star-Delta (Y-Δ)
  - Delta-Star (Δ-Y)
  - Open-Delta (V-V)





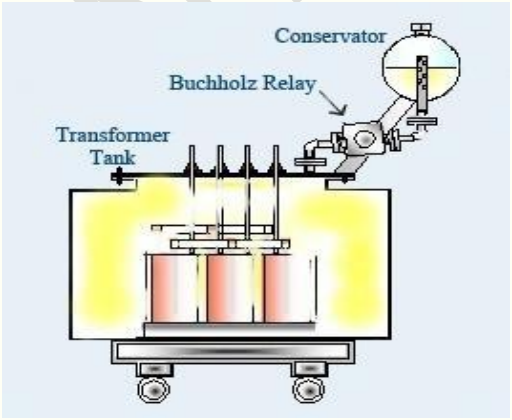
32. What is a vector group?

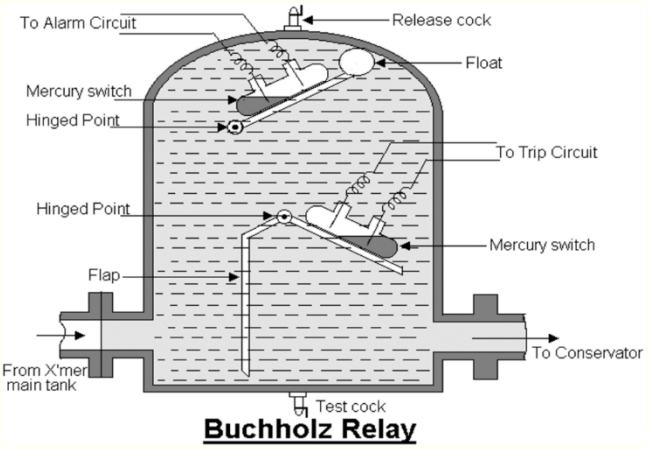
A transformer's vector group indicates its winding configuration and phase displacement. Common examples:

- Dyn11: Delta primary, star secondary, 30° lag
- Yyn0: Star both sides, no phase shift

33. What is a Buchholz relay?

A gas-actuated protection device placed between the main tank and conservator, used to detect internal faults like short circuits or insulation failures.

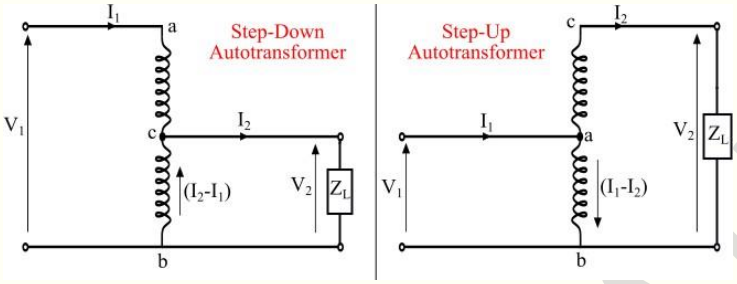




SECTION 10. AUTOTRANSFORMERS

34. What is an autotransformer?

A transformer with a single winding acting as both primary and secondary. Part of the winding is common to both.



35. What are the advantages of an autotransformer?

- Higher efficiency
- Lower copper requirement
- Compact and economical

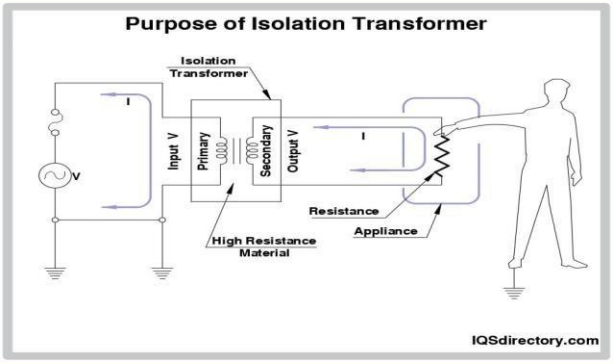
36. What are the disadvantages of autotransformers?

- No electrical isolation
- Not suitable for large voltage differences

SECTION 11. SPECIAL TRANSFORMERS

37. What is an isolation transformer?

It has a 1:1 turns ratio and provides electrical isolation between two circuits for safety.

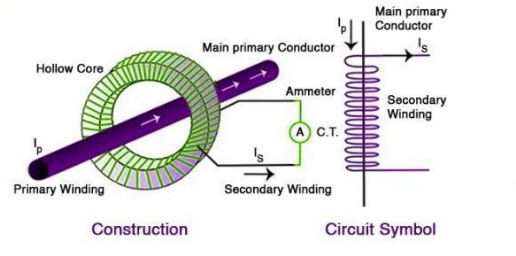


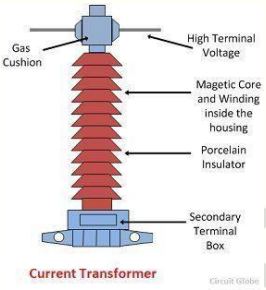
38. What is a distribution transformer?

Used to step down voltage at the final stage of power distribution. It operates with high efficiency and low regulation and is typically oil-cooled.

39. What is a current transformer (CT)?

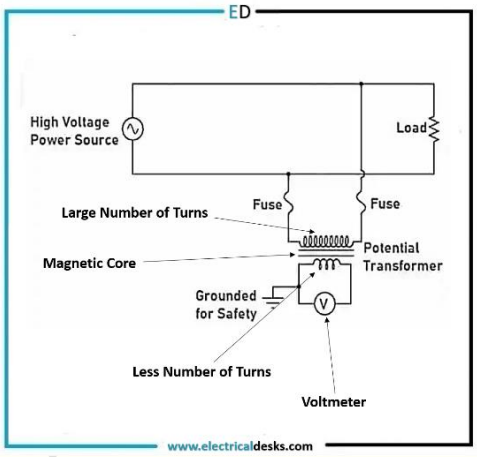
Used to step down high currents to measurable levels. Its secondary is always connected to a burden/load to avoid dangerously high voltages.





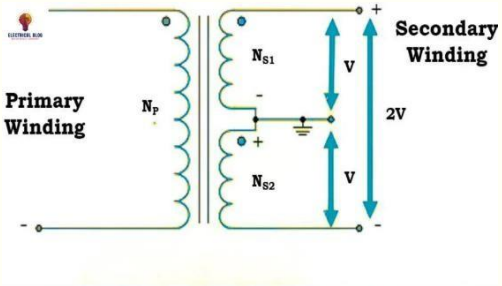
40. What is a potential transformer (PT)?

Used to step down high voltage to a safe level for metering. Designed to maintain voltage accuracy under light load.



41. What is a center-tap transformer?

A transformer with a secondary winding tapped at the center, providing two equal voltages (e.g.,
±12V), commonly used in full-wave rectifiers.



SECTION 12. COOLING AND PROTECTION

42. What are different cooling methods in transformers?

- ONAN: Oil Natural Air Natural
- ONAF: Oil Natural Air Forced
- OFAF: Oil Forced Air Forced
- OFWF: Oil Forced Water Forced

43. What is the role of Buchholz relay?

It is a gas-actuated protection device that detects internal faults in oil-immersed transformers.

SECTION 13. PRACTICAL ASPECTS AND MAINTENANCE

44. Why is the primary winding of a step-up transformer on the low-voltage side?

To reduce insulation cost and withstand lower voltage stress.

45. Why are transformers rated in kVA and not in kW?

Because the losses (and hence heating) depend on voltage and current, independent of power factor.

46. What happens if a transformer is overloaded?

It leads to excessive heating, insulation failure, and may cause fire or breakdown.

SECTION 14. ADVANCED AND APPLICATION-BASED QUESTIONS

47. How does load affect transformer power factor?

Transformer does not alter power factor but delivers power at the same PF as the load.

48. What is the purpose of tap changers?

To regulate output voltage under varying load conditions:

- Off-load tap changers: Operate when transformer is de-energized.
- On-load tap changers: Operate during operation without interrupting supply.

49. What is inrush current in transformers?

A transient current drawn when the transformer is switched on due to core magnetization. It can be 6–10 times the rated current.

50. How are transformers protected?

- **Differential protection** (internal faults)
- **Buchholz relay** (gas detection)
- **Overcurrent relay**
- **Temperature sensors**
- **Lightning arrestors**

51. What is oil used for in transformers?

Used for:

- Insulation
- Cooling
- Arc suppression (in tap changers)
  Must be regularly tested for dielectric strength.

53. What causes humming in transformers?

Due to magnetostriction (core vibration) and mechanical vibrations of windings.