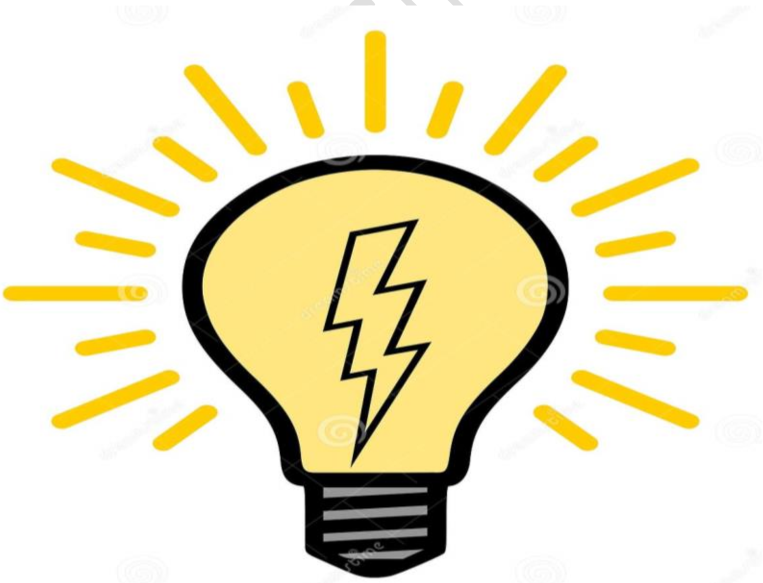
BHADRAK ENGINEERING SCHOOL & TECHNOLOGY (BEST),
ASURALI, BHADRAK

Fundamental of Electrical & Electronics Engg.

[Th- 04(a)]

(As per the 2024-25 syllabus of the SCTE&VT, Bhubaneswar, Odisha)



second Semester

Electrical Engg.

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CHAPTER-WISE DISTRIBUTION OF PERIODS & MARKS

Sl. No.	Chapter No.	Topics	Periods actually needed	Expected marks
1	I	Overview of Electronic Components & Signals	13	22
2	II	Overview of Analog Circuits	07	12
3	III	Overview of Digital Electronics	09	16
4	IV	Electric and Magnetic Circuits	11	16
5	V	A.C. Circuits	13	22
	VI	Transformer and Machines	07	12
Total			**60**	**100**

UNIT -I

Overview of Electronic Components & Signals

LEARNING OBJECTIVES:

Passive Active Components: Resistances, Capacitors, Inductors, Diodes, Transistors, FET, MOS and CMOS and their Applications. (Concept and simple problems of Resistance, Capacitor & Inductor, Definition, classification and Working of diode(PN juction,LED, Zener), transistor, FET, Concept of MOS and CMOS)

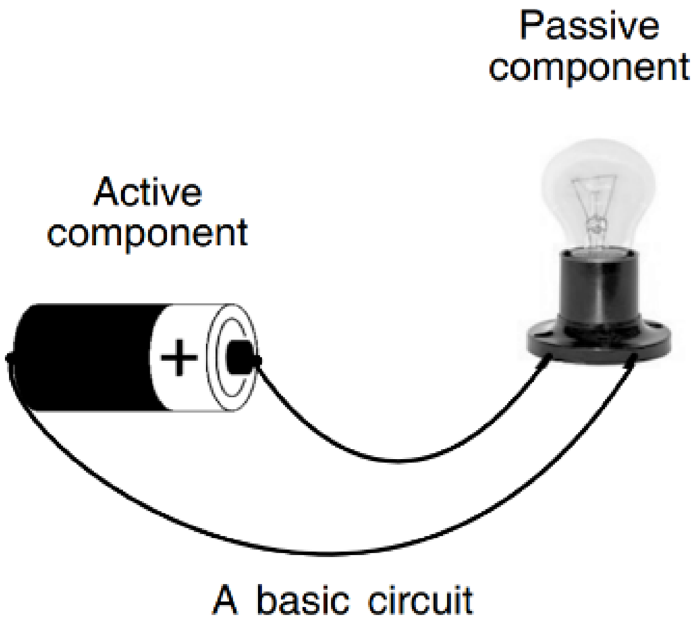
Signals: DC/AC, voltage/current, periodic/non-periodic signals, average, rms, peak values, different types of signal waveforms, Ideal/non-ideal voltage/current sources, independent/dependent voltage current sources. (Definitions).

Introduction:

Circuit Elements:

Electronic elements also known as components that make up a circuit are connected together by conductors to form a complete circuit. They can be classified into two main categories depending on whether they deliver or absorb energy from the circuit:

a. Passive components
b. Active components



a. Passive Elements:

Passive elements are components that do not require an external power source to operate. They do not amplify or generate electrical energy but can store or dissipate it.

These components are typically linear, meaning their response is proportional to the input signal.

Examples: Resistor, Capacitor, Inductor and Diode

b. Active Elements:

elements are components that require an external power source to operate. They can amplify signals, generate power, or control the flow of current. These components are typically nonlinear, meaning their response may not be directly proportional to the input signal.

Examples: Transistor, Integrated Circuit (IC), Zenor diode, LED & Operational amplifier (Op-Amp)

Resistance:

- It is described as the property of a substance due to which it opposes the flow of current through it.
- Resistance is not same for all materials. Conductors like copper, aluminum etc. offer small resistances whereas insulating materials like Bakelite, glass, rubber, mica, dry wood, p.v.c. (polyvinyl chloride), etc. offer high resistance.
- The SI unit for resistance is the ohm, symbolized by the Greek letter Ω (omega) and also represented by letter R.
- **Unit of Measurement:** Resistance is measured in ohms (Ω).
- The relationship between voltage (V), current (I), and resistance (R) is described by Ohm's Law:

  $V=I\times R$

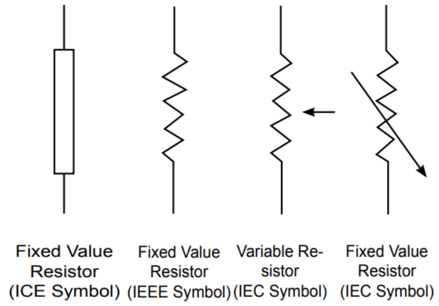
  This means that the voltage across a resistor is equal to the product of the current flowing through it and its resistance.

Factors Affecting Resistance:

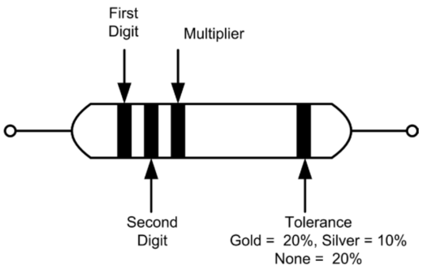
- **Material:** Different materials have different resistivities. Conductors like copper have low resistance, while insulators like rubber have high resistance.
- **Length of the Material:** The longer the material, the higher the resistance.
- **Cross-Sectional Area:** A thicker material (larger cross-sectional area) has lower resistance.
- **Temperature:** For most conductors, resistance increases with temperature, while for some materials, like semiconductors, resistance decreases as temperature increases.

Resistors:

In circuits, resistors are components specifically designed to provide a certain amount of resistance. They are used to control current, divide voltages, and protect other components.



Symbol of Resistors



Colour Coding of Resistors

Conductance:

Conductance is the measure of how easily electricity flows through an object or component. It is the opposite of resistance.

- **Unit of Measurement:** Conductance is measured in **siemens (S)**.
- Conductance (G) is the reciprocal of resistance (R):

Conductivity:

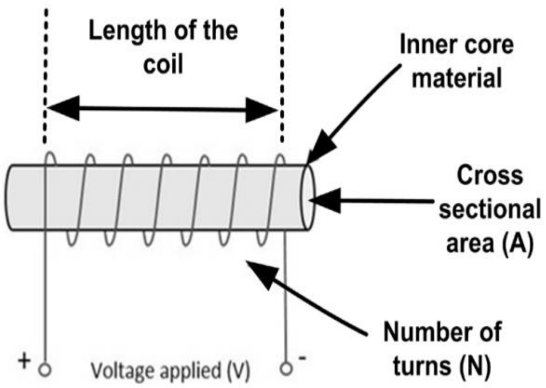
Conductivity is a material property that indicates how well a material can conduct electricity. It reflects the ability of a material itself to allow the flow of electric current.

- **Unit of Measurement:** Conductivity is measured in **siemens per meter (S/m)**.

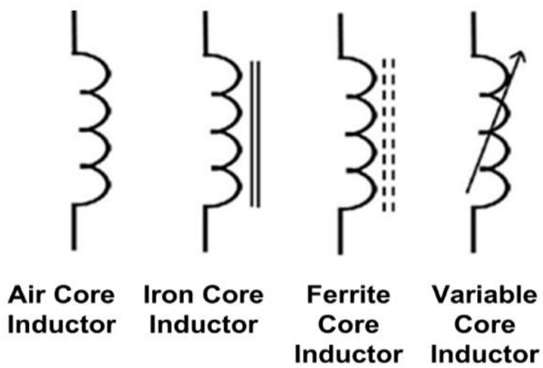
Inductors:

Inductor is a two-terminal component that temporarily stores energy in the form of a magnetic field. It is usually called as a coil. The main property of an inductor is that it opposes any change in current.

- ➢ The unit of inductance is Henry i.e. H. In actual practice, Henry is an extremely large unit. Therefore, much smaller units are used like millihenry (mH) or microhenry (μH). $1\ \text{mH} = 1 \times 10^{-3}$ H and $1\mu\text{H} = 1 \times 10^{-6}$ H.



Parts of an inductor



Symbol of inductors

Factors affecting inductance

The inductance of a coil depends upon the following parameters:

1. Number of turns, N 2. Core material

3.Length of winding 4. Dimension of coil former

Q Factor of an inductor:

• The ability of an inductor to store energy as compared to the dissipation of energy within the inductor is called Quality (or Q) factor.

The Q factor is given by,

$$Q = \frac{Energy\ Stored}{Energy\ Dissipated}$$

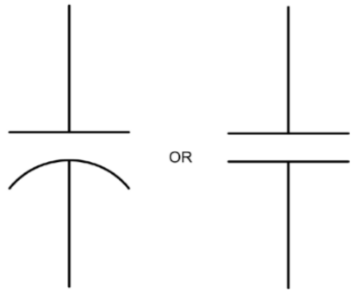
• A high Q factor means little energy dissipation with respect to energy storage, while a low Q factor means energy dissipation as large as energy storage.

• The value of Q factor for coils may range between 5 to 100.

• It may be noted that smaller the value of DC resistance of a coil, higher is the value of Q factor. The high Q coils are preferred in tuning circuits, because it makes the circuit more selective and sensitive

Capacitor:

- A capacitor is a passive component that has the ability to store the energy in the form of Electric Charge or electric field.
- The charge is stored in the form of potential difference between two plates, which form to be positive and negative depending upon the direction of charge storage.
- A non-conducting region is present between these two plates which is called as dielectric. This dielectric can be vacuum, air, mica, paper, ceramic, aluminum etc. The name of the capacitor is given as per the dielectric used.
- Capacitors block direct current (DC) but allow alternating current (AC) to pass. This property makes them useful in filtering applications, where they can separate AC and DC components of a signal.
- Its symbol is C
- Its unit is Farad (F).



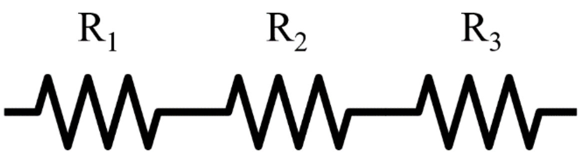
Symbol of a Capacitor

Series and Parallel Circuit:

Resistor in series:

- It is an electrical circuit in which resistors are connected end-to-end in a single path, so the same current flows through each resistor one after another. In a series circuit, there is only one path for the current to follow.
- Since there is only one path, the same amount of current flows through all components
- The voltage across the series circuit is the sum of the voltages across each resistor. Each resistor drops a portion of the total voltage based on its resistance.
- The total resistance in a series connection is the sum of the individual resistances.

  R_{total}= R1+R2+R3+⋯+Rn

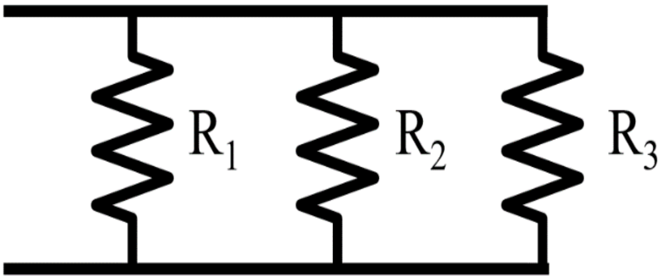


Example: If you have three resistors with values of 2Ω, 4Ω, and 6Ω in series, the total resistance is R_{total}= R1+R2+R3

R_{total}= 2Ω + 4Ω + 6Ω = 12Ω.

Resistor in parallel:

- A **parallel circuit** is an electrical circuit where Resistors are connected across the same two points, creating multiple paths for the current to flow.
- In a parallel circuit, each component is connected directly across the power source, so the voltage across each component is the same.
- The current in a parallel circuit split into different paths, with each component having its own separate path for current flow.
- The voltage across each component in a parallel circuit is the same as the voltage across the power source. This means that each component experiences the same voltage.



- The total resistance of the circuit in a parallel connection is less than the resistance of the smallest individual resistor.

  The formula for total resistance R_{total} is:

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \frac{1}{R_n}$$

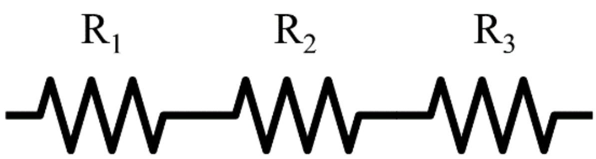
  This means that adding more resistors in parallel decreases the total resistance.

Series Connection:

It is an electrical circuit in which components are connected end-to-end in a single path, so the same current flows through each component one after another. In a series circuit, there is only one path for the current to follow.

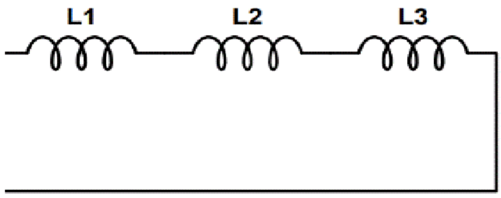
Resistors in Series:

- **Total Resistance (R_{total}):** The total resistance is the sum of the resistances of each resistor.
  $R_{total} = R1 + R2 + R3 + ... + Rn$
- **Current:** The same current flows through each resistor.
- **Voltage:** The voltage drop across each resistor depends on its resistance and is proportional to the total voltage supplied.



Inductors in Series:

- **Total Inductance (L_{total}):** The total inductance is the sum of the inductances of each inductor.
  $L_{total} = L1 + L2 + L3 + ... + Ln$
- **Current:** The same current flows through each inductor.
- **Voltage:** The voltage across each inductor depends on the rate of change of current.

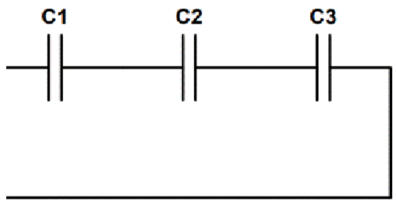


Capacitors in Series:

- **Total Capacitance (C_{total}):** The reciprocal of the total capacitance is the sum of the reciprocals of each capacitor's capacitance.

$$\frac{1}{C_{Total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \frac{1}{C_n}$$

- **Voltage:** The voltage across each capacitor adds up to the total voltage.
- **Charge:** The same charge is stored in each capacitor.



Parallel Connection:

- A **parallel circuit** is an electrical circuit where Resistors are connected across the same two points, creating multiple paths for the current to flow.

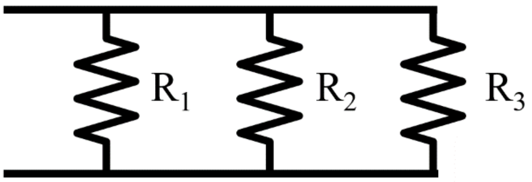
- In a parallel circuit, each component is connected directly across the power source, so the voltage across each component is the same.

Resistors in Parallel:

- **Total Resistance (R_{total}):** The reciprocal of the total resistance is the sum of the reciprocals of each resistor's resistance.

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \frac{1}{R_n}$$

- **Voltage:** The same voltage is applied across each resistor.
- **Current:** The total current is the sum of the currents through each resistor.

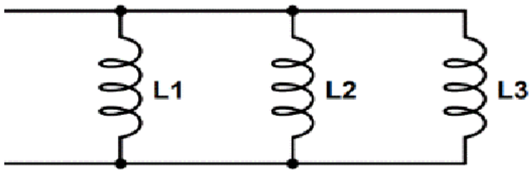


Inductors in Parallel:

- **Total Inductance (L_{Total}):** The reciprocal of the total inductance is the sum of the reciprocals of each inductor's inductance.

$$\frac{1}{L_{Total}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots \frac{1}{L_n}$$

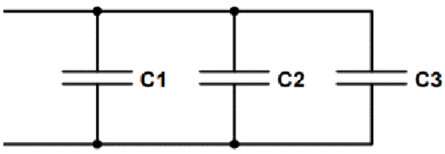
- **Voltage:** The same voltage is applied across each inductor.
- **Current:** The total current is the sum of the currents through each inductor.



Capacitors in Parallel:

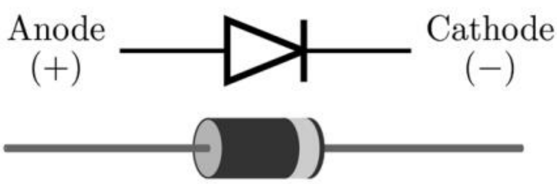
- **Total Capacitance (C_{total}):** The total capacitance is the sum of the capacitances of each capacitor.
  $C_{total} = C1 + C2 + C3 + ... + Cn$

- **Voltage:** The same voltage is applied across each capacitor.
- **Charge:** The total charge stored is the sum of the charges stored on each capacitor.



PN Junction Diode:

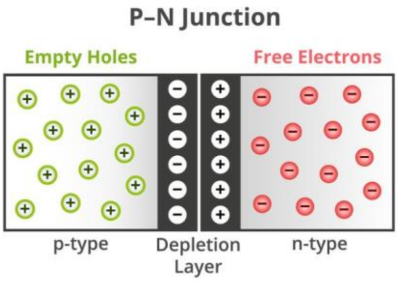
- A **PN junction diode** is a semiconductor device that allows electricity to flow in one direction but not the other. It's like a one-way valve for electric current.
- A PN junction diode is made from two types of semiconductor materials:
  1. **P-type (Positive):** This side has "holes" where electrons are missing.
  2. **N-type (Negative):** This side has extra electrons.



Construction:

When P-type & N-type materials are joined together, they form a **junction**. Right at the junction, some electrons from the N-type side move over to the P-type side and fill the holes.

This movement creates a small area called the **depletion region**, where there are no free charge carriers (no free electrons or holes).



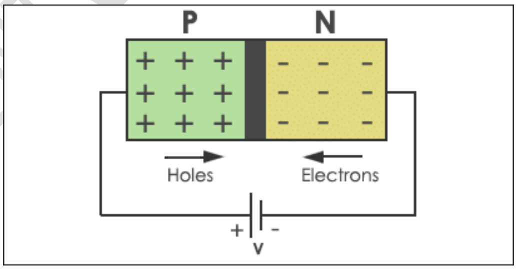
Working of PN junction diode:

The P N junction diode can be operated in two states or conditions namely

1. Forward bias condition.
2. Reverse bias condition.

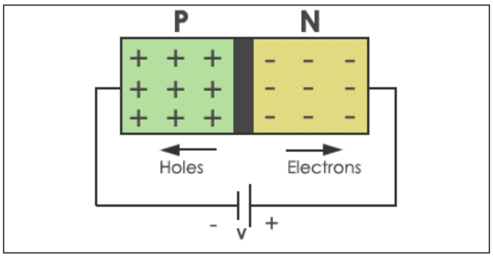
1.Forward bias condition:

- If we connect the positive end of a battery to the P-type side and the negative end to the N-type side, the diode is said to be in forward bias.
- Holes from the P region is repelled by the positive terminal of the battery and move towards the junction. Similarly, electrons from N region move towards the junction. So, the width of depletion region decreases.
- With the depletion region narrowed, current flows through the diode as electrons move from the N-type to the P-type region



2.Reverse Bias:

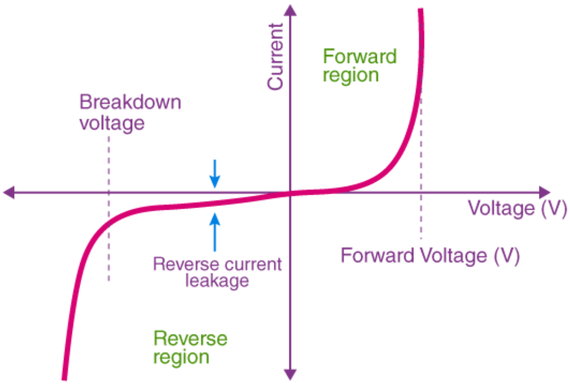
- If we reverse the battery connections (positive to N-type, negative to P-type), the P-N junction is said to be reverse biased
- Holes from P region is attracted towards the negative terminal of the battery and the electrons from N region move towards the positive terminal of the battery. Since the carriers move away from the junction, the width of depletion region increases.
- Thus, there is no current due to majority carriers. But there is very small current from cathode to anode due to minority carriers.



VI Characteristics of a PN Junction Diode:

The VI (Voltage-Current) characteristics of a PN junction diode show how the current through the diode varies with the applied voltage.

- **Forward Bias Characteristics:**
  - When the applied voltage is less than the threshold voltage, the current is very small.
  - Once the applied voltage exceeds the threshold voltage, the current increases rapidly with a small increase in voltage.
- **Reverse Bias Characteristics:**
  - In reverse bias, a small leakage current flows due to minority carriers.
  - At a high reverse voltage, the diode may experience a breakdown, where a large current flows suddenly.



Types of PN-junction diode:

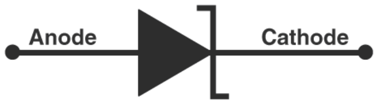
The PN junction diode can be classified into various types based on their construction, application, and specific characteristics. Here's a detailed classification:

1. Standard Diode

- General Purpose Diodes:
  - Used in standard rectification, these diodes convert AC to DC.
  - Typically have higher current and voltage ratings but slower switching speeds.

2. Zener Diode

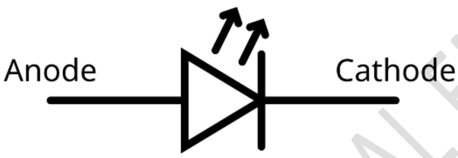
- Voltage Regulation:



  - Operates in reverse bias and is designed to maintain a constant voltage across it when the reverse voltage exceeds a certain value (known as the Zener voltage).
  - Used in voltage regulation and protection circuits.

3. Light Emitting Diode (LED)

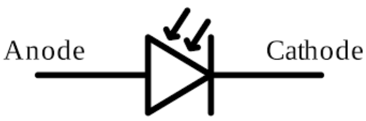
- Light Emission:



  - When this diode is forward biased then it emits light.
  - Special semiconductor materials are used such as GaAs, GaAsP, GaP, SiC.
  - Available in various co
  - lors depending on the semiconductor material used.
  - Commonly used in displays, indicators, and lighting applications.

4. Photodiode

- Light Detection:

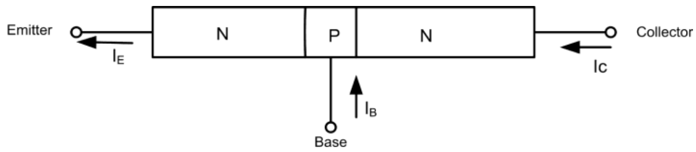


  - Operates in reverse bias, and the current through the diode varies with the intensity of light falling on it.
  - It converts light intensity into current.
  - Used in light detection applications, such as in solar cells, cameras, and light meters.

Transistor:

A **transistor** is a semiconductor device that can both amplify electrical signals and act as a switch to control the flow of electricity in a circuit. It is a fundamental building block of modern electronics, used in everything from amplifiers and radios to microprocessors and digital circuits.

Structure of a Transistor:



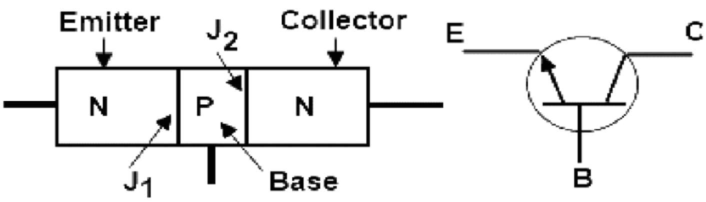
A transistor is composed of three regions:

1. **Emitter (E):**
   - The emitter is heavily doped to increase its conductivity and is responsible for injecting charge carriers (electrons or holes) into the base.
   - In an NPN transistor, the emitter is an N-type material, while in a PNP transistor, it is a P-type material.
2. **Base (B):**
   - The base is thin and lightly doped, allowing it to control the flow of charge carriers from the emitter to the collector.
   - The base plays a crucial role in regulating the transistor's operation. Despite its thinness, it's critical for controlling large amounts of current.
3. **Collector (C):**
   - The collector is moderately doped and larger than the emitter or base.
   - It collects the charge carriers that are injected by the emitter and passed through the base. The collector region is designed to dissipate heat and manage the majority of the transistor's current.

Types of Transistors:

1. NPN Transistor:

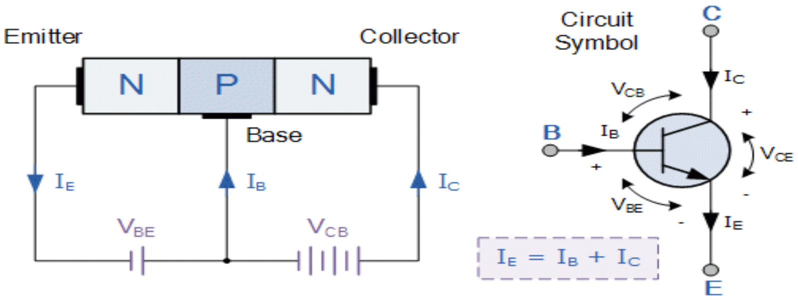
- Made up of two N-type materials separated by a thin layer of P-type material.
- In an NPN transistor, when a small current flows into the base (between the base and emitter), it allows a much larger current to flow from the collector to the emitter.



NPN Transistor

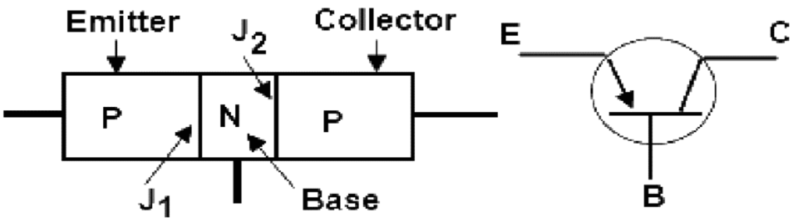
Working of NPN Transistor:

- When a small positive voltage is applied to the base relative to the emitter, the base-emitter junction becomes forward biased, and current begins to flow from the base to the emitter.
- This base current causes a much larger current to flow from the collector to the emitter.
- The ratio of the collector current to the base current is known as the current gain (β), which is a key parameter in designing circuits with BJTs.



2. PNP Transistor:

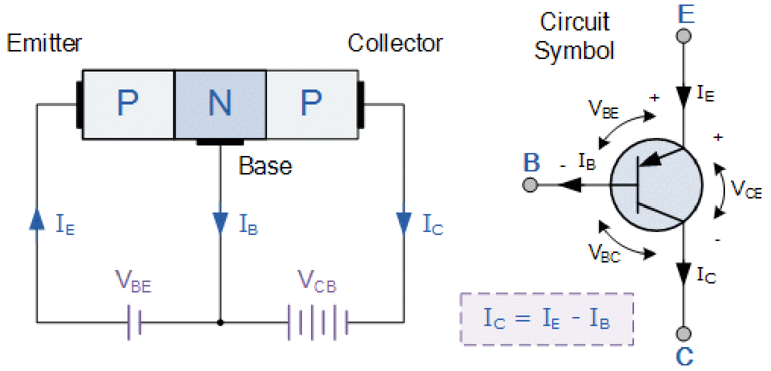
- Made up of two P-type materials separated by a thin layer of N-type material.
- In a PNP transistor, the current flows from the emitter to the collector when a small current flows out of the base.



PNP Transistor

Working of PNP Transistor:

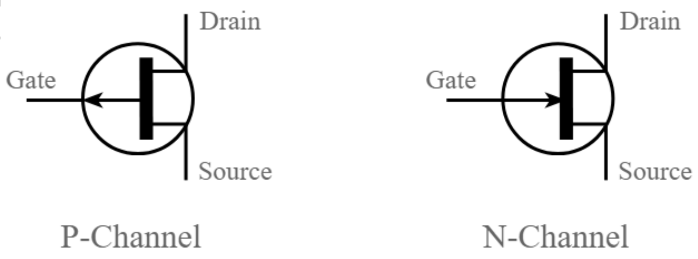
- In a PNP transistor, when a small negative voltage is applied to the base relative to the emitter, the base-emitter junction becomes forward biased, and current begins to flow from the emitter to the base.
- A larger current then flows from the emitter to the collector.



<u>FET:</u>

- A **Field-Effect Transistor (FET)** is a type of transistor that uses an electric field to control the flow of current. Unlike Bipolar Junction Transistors (BJTs), which rely on both electrons and holes for conduction, FETs are unipolar devices, meaning they use only one type of charge carrier (either electrons or holes).
- A typical FET consists of three main terminals:

1. **Source (S):**
    - The terminal through which the charge carriers (electrons or holes) enter the FET.
2. **Drain (D):**
    - The terminal through which the charge carriers leave the FET.
3. **Gate (G):**
    - The terminal that controls the current flow between the source and the drain by applying a voltage. The gate is insulated from the main conducting channel, making FETs very energy-efficient.



Types of FETs

1. **Junction Field-Effect Transistor (JFET):**
    - In a JFET, the gate is formed by a reverse-biased P-N junction, which controls the flow of current through the channel between the source and drain.

➢ **N-Channel JFET:**

- The channel is made of N-type material. Applying a negative voltage to the gate reduces the current flow.

➢ **P-Channel JFET:**

- The channel is made of P-type material. Applying a positive voltage to the gate reduces the current flow.

2. **Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET):**

➢ MOSFETs are the most widely used type of FETs, particularly in digital circuits. The gate is insulated from the channel by a thin layer of oxide, usually silicon dioxide (SiO_2).

MOS (Metal-Oxide-Semiconductor):

MOS technology refers to a type of transistor structure used in semiconductor devices, such as MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors). The "metal" (often now polycrystalline silicon) gate controls the current through a channel formed in the semiconductor material, with an insulating layer of oxide (usually silicon dioxide) separating the gate from the channel.

- **Structure:**

➢ **Gate:** The control terminal where the input signal is applied.

➢ **Oxide Layer:** A thin insulating layer of silicon dioxide.

➢ **Channel:** The pathway through which current flows between the source and drain terminals. The type of channel (N-type or P-type) determines the type of MOSFET (N-channel or P-channel).

Types of MOSFETs:

1. **Enhancement Mode MOSFET:**

➢ Requires a gate-source voltage (V_GS) to induce a channel for current flow.
➢ **N-Channel MOSFET:** Conducts when a positive voltage is applied to the gate.
➢ **P-Channel MOSFET:** Conducts when a negative voltage is applied to the gate.

Enhancement type MOSFETs

2. **Depletion Mode MOSFET:**
   - Already has a conductive channel, and applying a gate-source voltage can either enhance or deplete this channel.
   - **N-Channel MOSFET:** Conducts even without gate voltage, and applying a negative voltage to the gate reduces the current.
   - **P-Channel MOSFET:** Conducts without gate voltage, and applying a positive voltage to the gate reduces the current.

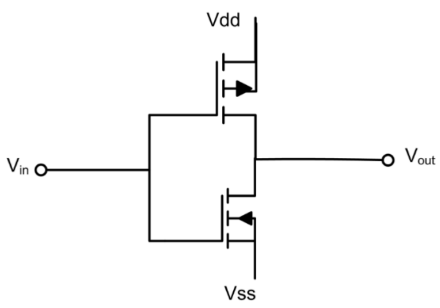
Depletion type MOSFET

Applications:

- MOSFETs are used in a wide range of applications, including amplifiers, digital logic circuits, power management, and switching devices.

CMOS (Complementary Metal-Oxide-Semiconductor) :

CMOS technology uses a combination of N-channel MOSFETs (NMOS) and P-channel MOSFETs (PMOS) in a complementary and symmetrical manner to construct logic gates and other digital circuits. This complementary pairing allows CMOS circuits to have very low power consumption and high noise immunity.



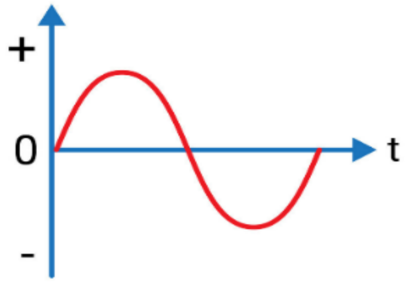
CMOS device

- **Applications:**
  - Microprocessors and Microcontrollers.
  - Digital Logic Circuits.
  - Memory Chips.
  - Analog and Mixed-Signal Circuits.

Signals:

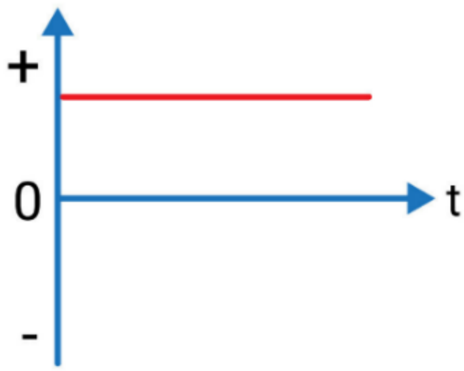
AC. (Alternating Current):

- It is an electrical current whose magnitude and direction change periodically.
- Alternating Current (AC) is the type of electrical current where the flow of electrons periodically reverses direction.



DC. (Direct Current):

- It is an electric current whose magnitude and direction always constant.
- The type of electrical current where the flow of electrons is in a single, constant direction.



Voltage (Or) Potential Difference(V) :

A Charged body has capacity to do work by moving other charges by force of attraction or repulsion.

The capacity of a charged body to do work is called electric potential.

It is also called as voltage.

Electric potential of a charged body is given by :

$$\text{Potential(V)} = \frac{work\ done(W)}{charge(Q)}$$

Unit of electric potential is joule/coulomb or volt

Periodic Signals:

- A **periodic signal** is a signal that repeats itself at regular intervals over time. This means that after a specific duration, known as the **period (T)**, the signal's shape, amplitude, and pattern repeat.

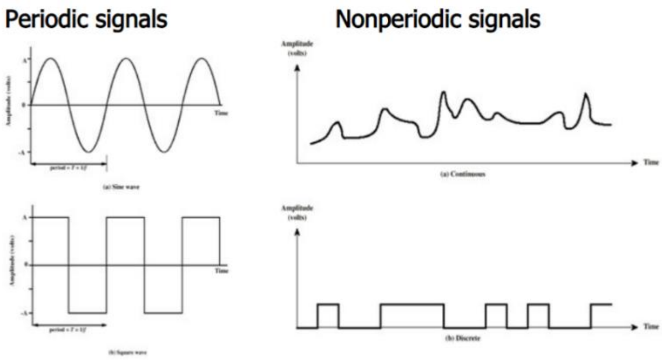
- The signal repeats exactly after each period.

Examples: Sine wave, square wave

Non-periodic Signals:

- A **non-periodic signal** (also known as an aperiodic signal) is a signal that does not repeat itself at regular intervals.
- The signal does not repeat at regular intervals, meaning each portion of the signal can be different from others.

Examples: Speech signal, Music, Random noise.



Average Value:

The **average value** of an AC (alternating current) waveform, often referred to in terms of voltage or current, is the average of all the instantaneous values over a complete cycle.

$$V_{avg} = \frac{2 \times V_{peak}}{\pi}$$

Where:

- V_{avg} is the average value.
- V_{peak} is the peak value of the waveform.
- π is approximately 3.14159.

RMS Value:

The RMS (Root Mean Square) value is the effective value of the AC voltage or current, which would produce the same amount of heat in a resistor as an equivalent DC value.

For a sinusoidal AC waveform:

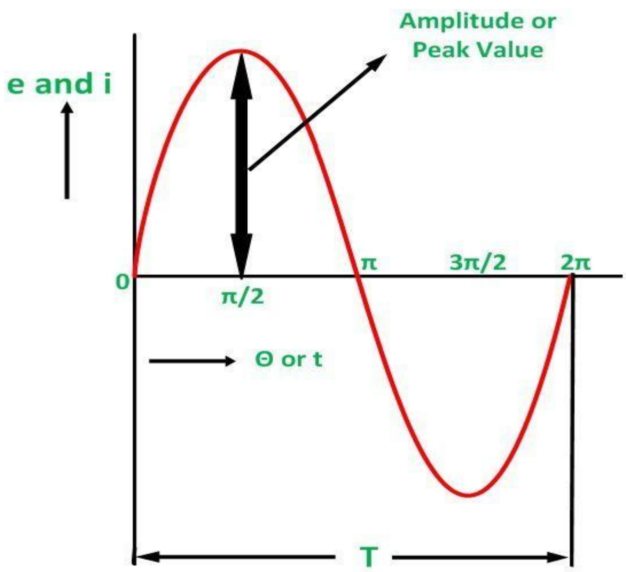
$$V_{RMS} = \frac{V_{peak}}{\sqrt{2}}$$

Where:

- V_{RMS} is the RMS value.
- V_{peak} is the peak value of the waveform.

Peak value:

The peak value of alternating current (AC) is the highest value that the current reaches in a single cycle, whether positive or negative. It's also known as the amplitude value, maximum value, or crest value.



Waveform:

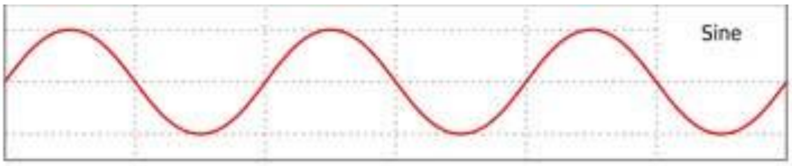
A waveform is a graphical representation of how a signal varies with time. It shows the shape and form of a signal as it moves through a medium. Common types of waveforms include sinusoidal (sine wave), square, and triangular. Each type has unique characteristics and is used in different applications

Different types of Waveform:

There are many different types of waveform that are seen in electronic circuits. Each type of waveform has its own characteristics and is seen in different places.

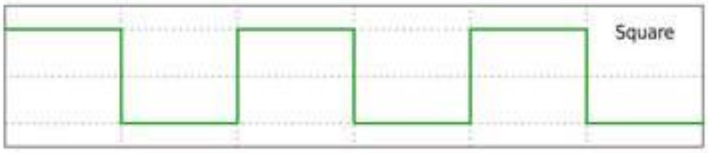
Sine wave:

Sine waves are smooth and continuous, representing a pure frequency with no harmonics. They are fundamental in AC power systems and audio signals due to their clean, periodic nature.



Square wave:

Square waves switch abruptly between high and low states, making them useful in digital electronics and clock signals. The sharp transitions of square waves are ideal for binary data representation, ensuring clear and distinct signal levels in digital circuits. They are also used in pulse-width modulation (PWM) techniques for controlling motors and dimming lights.



Triangle wave:

Triangle waves have a linear rise and fall, characterized by their symmetrical, saw-like shape. These waves are commonly used in audio synthesis and modulation, where their linear properties create unique sound textures and modulation effects. Triangle waves are also used in function generators for testing and calibrating audio equipment.

Ideal voltage Source:

An ideal voltage source is a theoretical component in electrical engineering that generates a fixed voltage output regardless of the current flowing through it or the load connected to it. It is an essential component in many electronic devices and systems, providing a stable and reliable source of electrical power.

Non-Ideal voltage Source:

A non-ideal voltage source is a type of electrical component that provides a varying voltage output, but with some internal resistance or impedance. This means that the voltage output may fluctuate depending on the load connected to the source.

Ideal Current Source:

An ideal current source is a component that provides a constant current output that remains unchanged regardless of the load resistance. In contrast, a real current source has a limited range of output current and may vary with changes in the load or temperature. An ideal current source is an idealized concept that does not exist in reality but serves as a fundamental building block for many electronic circuits.

Non-Ideal Current Source:

A non-ideal current source is a type of electrical component that provides a constant current output, but with some internal resistance or impedance. This means that the current output may change depending on the load connected to the source.

Independent voltage source:

A voltage source whose output voltage does not depend upon the voltage or current of any other part of the circuit is known as an **independent voltage source**. In other words, the independent voltage source is one whose output voltage is not affect by the voltage or current of any other part of the circuit.

Independent current source:

The type of current source whose output current does not depend upon the voltage or current of any other part of the circuit is known as **independent current source**.

Dependent voltage source:

The voltage source whose value is dependent on another voltage or current in a circuit.

Dependent current source:

An independent voltage source is an idealized circuit component that provides a specified voltage across its terminals regardless of the elements connected to it.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q1: What is a resistor?
A: A resistor is a passive component that opposes the flow of electric current, causing a voltage drop according to Ohm's law: V=IRV = IRV=IR.

Q2: What is a capacitor?
A: A capacitor is a passive component that stores energy in the form of an electric field. It opposes changes in voltage by storing and releasing charge.

Q3: What is an inductor?
A: An inductor is a passive component that stores energy in the form of a magnetic field and opposes changes in current.

Q4: What is a PN junction diode?
A: A PN junction diode is a semiconductor device that allows current to flow in one direction (forward bias) and blocks current in the reverse direction (reverse bias).

Q5: What is an LED?
A: An LED (Light Emitting Diode) is a type of diode that emits light when current flows through it in the forward direction.

Q6: What is a Zener diode?
A: A Zener diode is a diode designed to operate in reverse bias, allowing current to flow when a specific reverse voltage (Zener voltage) is reached, often used for voltage regulation.

Q7: What is a transistor?
A: A transistor is a three-terminal active device used for amplification and switching. It comes in two main types: **NPN** and **PNP**.

Q8: What is an FET (Field-Effect Transistor)?
A: An FET is a type of transistor where the current is controlled by an electric field. The most common types are **JFET** and **MOSFET**.

Q9: What is a MOSFET?
A: A MOSFET (Metal Oxide Semiconductor Field-Effect Transistor) is a type of FET that is widely used in digital and analog circuits for switching and amplification.

Q10: What is CMOS?
A: CMOS (Complementary Metal-Oxide-Semiconductor) is a technology used in designing integrated circuits, combining both NMOS and PMOS transistors for low power consumption.

Q14: What is a DC signal?
A: A DC (Direct Current) signal has a constant voltage or current over time.

Q15: What is an AC signal?
A: An AC (Alternating Current) signal has a voltage or current that varies sinusoidally or in another waveform over time.

Q16: Difference between periodic and non-periodic signals? [W-24]
A: A periodic signal repeats itself at regular intervals, while a non-periodic signal does not repeat.

Q17: Define RMS value of alternating current. [W-24]
A: The RMS (Root Mean Square) value is the effective value of an AC signal, representing the equivalent DC value that would deliver the same power.

Q18: What is the peak value of a signal?
A: The peak value is the maximum value (positive or negative) reached by a periodic signal.

Q19: What is an ideal voltage source?
A: An ideal voltage source provides a constant voltage regardless of the current drawn from it.

Q20: What is a non-ideal voltage source?
A: A non-ideal voltage source has internal resistance, causing its voltage to drop as more current is drawn.

Q21. Write down the example of active and passive components. [W-24]

A: passive components: - Resistor, Inductor & Capacitor.

Active Components: - Battery, Diode, Transistor & IC

Q22. Define Periodic and Non-periodic signal. [W-24]

A: Periodic Signal: - The signal repeats its pattern at regular interval is called periodic signal.

Non-Periodic Signal: - The signal doesn't repeats in periodic pattern is called non-periodic signal.

Q23. Write down the advantages of CMOS. [W-24]

A: Simple structure, Low Power consumption, large noise tolerance and strong temp. Stability

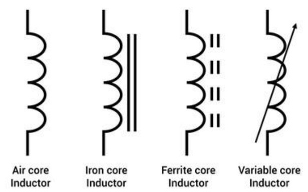
Q24. Define ohms law. [W-24]

A: At constant temperature, current flowing through the conductor is directly proportional to the potential difference of two terminal of the conductor

$$V = I \times R$$

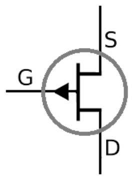
Q25. Draw the symbol of different types of inductor. [W-24]

A:



Q26. Draw the symbol of a P-Channel FET. [W-24]

A:



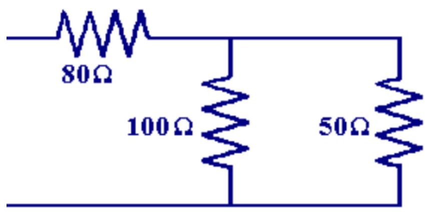
POSSIBLE LONG TYPE QUESTIONS

Q1: Explain the construction and working of a PN junction diode.

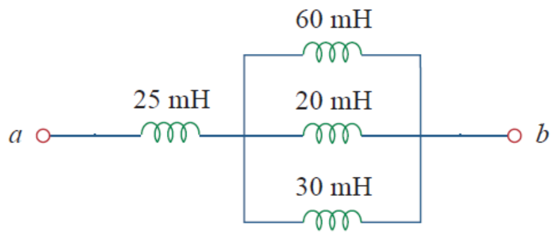
Q2: Explain the working of NPN transistor.

Q3: Explain the working of LED. [W-24]

Q4: find the net resistance between two points.



Q5: find the net resistance between two points.



Q6: Explain the working of N-Channel JFET. [W-24]

Q7. Draw the circuit diagram of both parallel and series connection.

1). Find the total resistance of three resistor connected in parallel having the value of 12, 4 & 6 ohm.

2). Find the total resistance of three resistor connected in series having value of 12, 4 & 6 ohm.

UNIT - II

Overview of Analog Circuits

Learning Objectives:

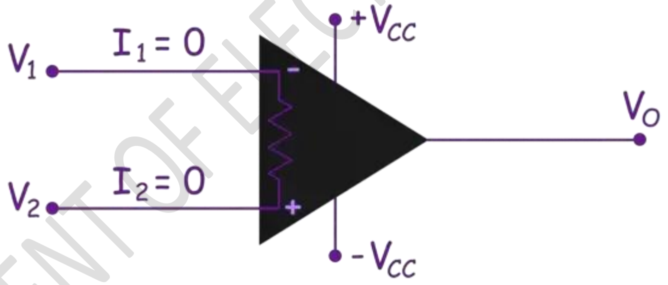
Operational Amplifiers-Ideal Op-Amp, Practical op amp, Open loop and closed loop configurations, Application of Op-Amp as amplifier, adder, differentiator and integrator.

Operational Amplifiers:

- An operational amplifier is an analog circuit block that takes a differential voltage input and produces a single ended voltage output.

Ideal OP Amp:

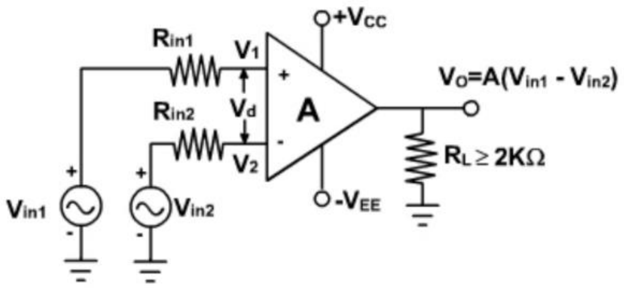
- An operational amplifier (OP Amp) is defined as a direct current coupled voltage amplifier that increases the input voltage passing through it. Ideally, an OP Amp should have high input resistance, low output resistance, and very high open loop gain. In an ideal OP Amp, the input resistance and open loop gain are infinite, while the output resistance is zero.



- The **ideal OP Amp** has zero input current because its infinite input resistance creates an open circuit at the input. This means there is no current at either input terminal.
- With no current through the input resistance, there is no voltage drop between the input terminals. Thus, no offset voltage appears across the inputs of an **ideal operational amplifier**.

Practical op-amp:

A **practical op-amp** refers to a real-world operational amplifier as opposed to the ideal model, which has perfect characteristics. In theory, an ideal op-amp has infinite gain, infinite input impedance, zero output impedance, and infinite bandwidth. However, in real life, practical op-amps come with limitations.



1. Finite Gain

- While ideal op-amps are modeled with infinite gain, practical op-amps have a large but finite open-loop gain, typically ranging from 10^4 to 10^6.

2. Finite Input Impedance

- Practical op-amps have a very high input impedance (often in the range of megaohms to giga ohms), but it's not infinite. This means some current does flow into the input terminals.

3. Non-zero Output Impedance

- While ideal op-amps have zero output impedance, practical op-amps have low but non-zero output impedance, which affects the ability to drive loads.

4. Limited Bandwidth

- Ideal op-amps are assumed to have infinite bandwidth, but practical op-amps have a frequency response that decreases with increasing frequency. This is often characterized by the gain-bandwidth product (GBW), which limits the maximum frequency the op-amp can amplify while maintaining a certain gain.

5. Offset Voltage

- Practical op-amps have a small offset voltage, which means the output might not be exactly zero when the input is zero due to internal imbalances.

6. Input Bias Current

- Practical op-amps require a small bias current (typically in the nanoampere range) to operate, which can affect precision in sensitive circuits.

7. Slew Rate

- This is the maximum rate at which the op-amp's output can change in response to a rapid change in input. Practical op-amps have a finite slew rate, limiting how fast the output can follow a rapidly changing input signal.

8. Noise

- Practical op-amps introduce a small amount of noise, which can affect signal quality, especially in low-signal applications.

9. Power Supply Limitations

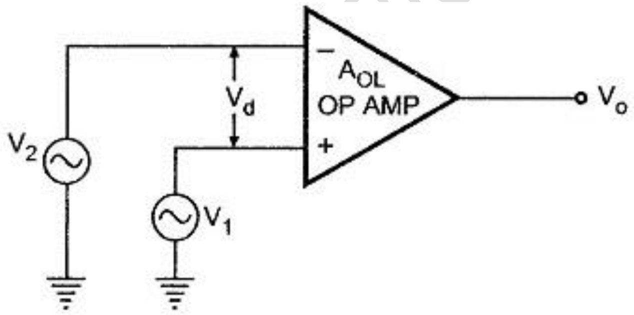
- Practical op-amps need a power supply and have limitations in the output swing, which typically doesn't reach the exact voltage of the supply rails (referred to as "rail-to-rail" limitations).

Common Practical Op-Amps

- Some popular practical op-amps include the **LM741**, **LM358**, and **OP07**, each with different characteristics suited for various applications.

Open-loop Configuration:

In an **open-loop configuration**, there is **no feedback** path between the output and the input of the op-amp. The op-amp operates with maximum gain (open-loop gain), which can be extremely high.

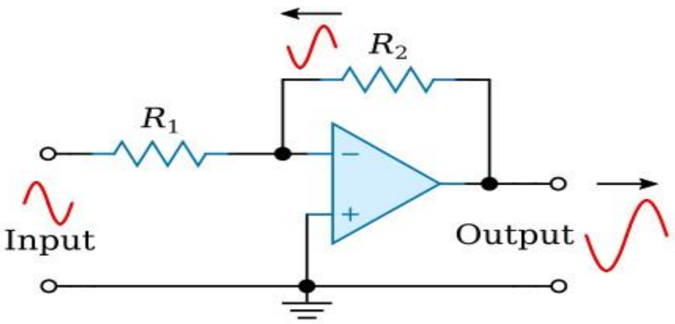


Characteristics of Open-loop Configuration:

- **High Gain**: The gain is extremely large, making it impractical for linear amplification.
- **Non-linear Behavior**: Even a small input voltage difference between the two input terminals drives the output to the extreme (saturation), either near the positive or negative supply voltage.
- **Saturation**: Since the gain is so high, even tiny input differences can saturate the op-amp output, pushing it to the supply voltage limits.
- **No Feedback**: There's no feedback connection from the output to the input, which means the input-output relationship is not controlled.

Closed-loop Configuration:

In a **closed-loop configuration**, feedback is used to control the behavior of the op-amp. The output is fed back to the input (usually the inverting input) through a feedback path (either direct or resistive). This stabilizes the gain of the op-amp and makes it suitable for amplification and other linear applications.



Types of Closed-loop Configurations:

- **Inverting Configuration**
- **Non-inverting Configuration**

Characteristics of Closed-loop Configuration:

- **Controlled Gain**: By using feedback, the gain can be controlled and made predictable based on external resistor values.
- **Linear Operation**: The output is linearly proportional to the input voltage, making the op-amp useful for amplification.
- **Stability**: Negative feedback increases stability and reduces distortion.

<u>Application of Op-Amp as amplifier:</u>

Operational amplifiers (op-amps) are used in many applications as amplifiers, including:

- **Voltage amplifiers:** Op-amps can be used as noninverting or inverting amplifiers. Noninverting amplifiers are also known as voltage followers or buffers.
- **Differential amplifiers:** Op-amps can be used to subtract out noise from input signals.
- **Photocell amplifiers:** Op-amps can be used to amplify photoconductive, photodiode, and photovoltaic cells.
- **Current-to-voltage converters:** Op-amps can be used as current-to-voltage converters, which are often used with transducers.
- **Active rectifiers:** Op-amps can be used as active rectifiers, which have a diode that only conducts on the positive alterations of the signal.
- **Adder or summing amplifiers:** Op-amps can be used as adders or summing amplifiers, which can add AC and DC signals.
- **Threshold detectors:** Op-amps can be used as threshold detectors

1. Op-Amp as an Amplifier:

An op-amp can amplify input signals, with the most common configurations being **inverting** and **non-inverting** amplifiers.

Application: Signal Amplification in Audio Systems

In audio systems, op-amps are used to amplify weak signals from microphones, instruments, or other audio sources to a higher, usable level.

2. Op-Amp as an Adder (Summing Amplifier):

The op-amp can be used to sum multiple input signals together. This is called a **summing amplifier** or **adder**.

Application: Audio Mixer

In an audio mixing console, multiple audio signals from different sources are summed together to form a single output. The op-amp ensures that each input contributes to the output according to its respective weighting (set by resistor values).

3. Op-Amp as a Differentiator:

An op-amp differentiator produces an output that is proportional to the rate of change of the input signal. It is useful in applications where detecting rapid changes in the input is essential.

Application: Edge Detection in Digital Circuits

In digital signal processing, differentiators are used to detect sharp changes (edges) in a signal, such as transitions from low to high voltage in a square wave. Detect rapid changes in voltage (e.g., edges in digital signals).

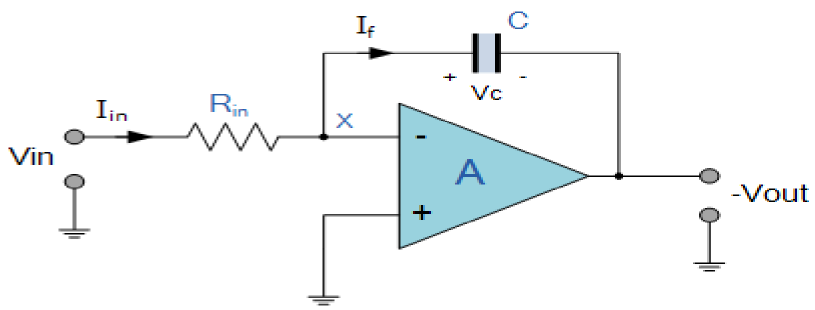
4. Op-Amp as an Integrator:

An op-amp integrator produces an output that is proportional to the time integral of the input signal. It is widely used in applications where accumulating the input over time is essential.

Application: Generating Ramp Signals

Op-amp integrators are used in waveform generators to produce ramp or triangular waveforms by integrating a square wave input.

$$Vout(t)=-1/RC\int Vin(t)dt$$



POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q1: What is an operational amplifier (Op-Amp)?
A: An Op-Amp is a high-gain electronic voltage amplifier with differential inputs and typically a single-ended output. It amplifies the difference between two input voltages.

Q2: What are the characteristics of an ideal Op-Amp?
A:

- Infinite open-loop gain
- Infinite input impedance
- Zero output impedance
- Infinite bandwidth
- Zero offset voltage

Q3: How does a practical Op-Amp differ from an ideal Op-Amp?
A: A practical Op-Amp has limitations such as finite open-loop gain, finite input impedance, non-zero output impedance, and limited bandwidth.

Q4: What is an open-loop configuration of an Op-Amp?
A: In an open-loop configuration, there is no feedback from the output to the input, and the Op-Amp operates with its maximum possible gain.

Q5: What is a closed-loop configuration of an Op-Amp?
A: In a closed-loop configuration, a portion of the output is fed back to the input, typically reducing the overall gain but increasing stability and linearity.

Q6: What is the function of an Op-Amp differentiator?
A: A differentiator outputs a voltage proportional to the rate of change (derivative) of the input signal.

Q7: Write-down two characteristics of an ideal Op-Amp? [W-24]
A:

- Infinite open-loop gain
- Infinite input impedance

POSSIBLE LONG TYPE QUESTIONS

Q1: Describe the open-loop configuration of an Op-Amp.

Q2 Explain the concept of open-loop & closed-loop Op-Amp configurations.

Q3: Discuss the various applications of Op-Amps.

Q4: Different between open loop & closed loop configuration of an op-amp. [W-24]

Q5. Explain the working of Op-Amp as differentiator and integrator. [W-24]

UNIT-III

Overview of Digital Electronics

Learning Objectives:

Introduction to Boolean Algebra, Electronic Implementation of Boolean Operations, Gates-Functional Block Approach (Simple problems of Number system)
Storage elements-Flip Flops-A Functional block approach, Counters: Ripple, Up/down and decade, Introduction to digital IC Gates (of TTL Type).

Introduction to Boolean Algebra:

Electronic circuits and systems are of two types, Analog and Digital. Analog circuits are those in which the voltage and current vary continuously between a maximum and minimum value. Digital circuits are those where the voltage level assume a finite value. In all modern digital systems, there are just two distinct voltage levels. Each voltage level however is a narrow band of finite voltage value. The digital systems use the binary system, where the binary digit 1 used to represent a high voltage level and binary digit 0 is used to represent low voltage level

Number System:

A **number system** is a way to represent numbers using a consistent set of symbols. In **digital electronics** and computing, several number systems are used, each with a different base or radix.

Common Number Systems:

1. **Binary (Base 2)**:
    - Uses only **two digits**: 0 and 1.
    - It is the fundamental number system in digital electronics, as all data in computers is processed as a series of 0s and 1s.
    - Example: 1011_2 (Binary for 11 in decimal).
2. **Decimal (Base 10)**:
    - Uses **ten digits**: 0 to 9.
    - It is the most familiar number system for humans because it's the system we use in everyday life.
    - Example: 123_{10}
3. **Octal (Base 8)**:
    - Uses **eight digits**: 0 to 7.

- It is sometimes used in computing as a shorthand for binary, especially in older systems.
- Example: 57_8(Octal for 47 in decimal).

Number system conversion:

Number system conversion is the process of converting a number from one base (or radix) to another, such as from **binary** to **decimal**, **octal** to **hexadecimal**, and so on. Here's how you can convert between the most common number systems used in digital electronics.

1. Binary to Decimal:

To convert a binary number to decimal, multiply each bit by 2 raised to the power of its position (starting from 0 from the right) and sum the results.

Example:

Convert 1011_2 to decimal:

$10112=(1\times2^3)+(0\times2^2)+(1\times2^1)+(1\times2^0)=8+0+2+1=11_{10}$

2. Decimal to Binary:

To convert a decimal number to binary, divide the decimal number by 2, record the remainder, and repeat until the quotient is 0. The binary number is the sequence of remainders read in reverse order.

Example:

Convert 35_{10} to binary:

2	35	Reminder
2	17	1
	8	1
2	4	0
2	2	0
2	1	0
	0	1 **(MSB)**

So, $35_{10}=100011_2$

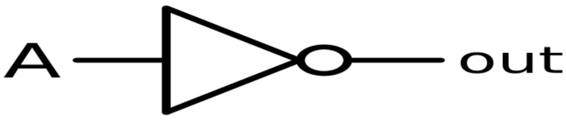
Boolean Algebra:

The Boolean algebra is an algebraic system developed for systematic treatment of logic. It is defined with a set of elements, a set of operators and a number of postulates. Unlike ordinary algebra negative number and fraction do not exist. No subtraction or division operations are there in Boolean Algebra.

Not gate (inverter):-

- A NOT gate, also called and inverter, has only one input and one output.It is a device whose output is always the complement of its input.
- The output of a NOT gate is the logic 1 state when its input is in logic 0 state and the logic 0 state whenits inputs is in logic 1 state.

Logic Symbol



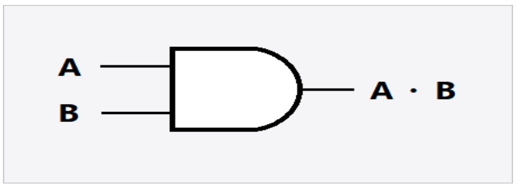
Truth table

INPUT A	OUTPUT A’
0	1
1	0

AND Gate: -

- An AND gate has two or more inputs but only one output.
- The output is logic 1 state only when each one of its inputs is at logic 1 state. The output is logic 0 state even if one of its inputs is at logic 0 state.

Logic Symbol

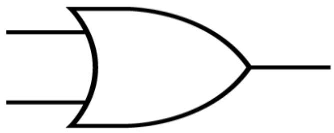


INPUT		OUTPUT
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

OR gate: -

- An OR gate may have two or more inputs but only one output.
- The output is logic 1 state, even if one of its input is in logic 1 state.
- The output is logic 0 state, only when each one of its inputs is in logic state.

Logic Symbol

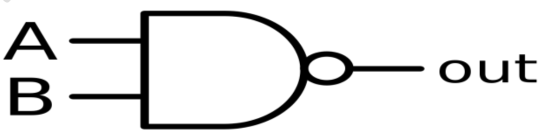


INPUT		OUTPUT
A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

NAND gate: -

- NAND gate is a combination of an AND gate and a NOT gate.
- The output is logic 0 when each of the input is logic 1 and for any other combination of inputs, the output is logic 1.

Logic Symbol-

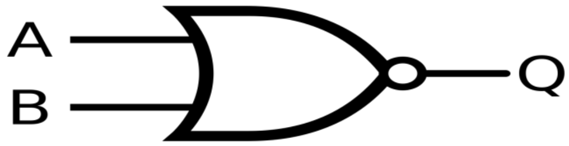


INPUT		OUTPUT
A	B	Y=A.B
0	0	0
0	1	1
1	0	1
1	1	1

NOR GATE: -

- NOR gate is a combination of an OR gate and a NOT gate.
- The output is logic 1, only when each one of its input is logic 0 and for any other combination of inputs, the output is a logic 0 level.

Logic Symbol



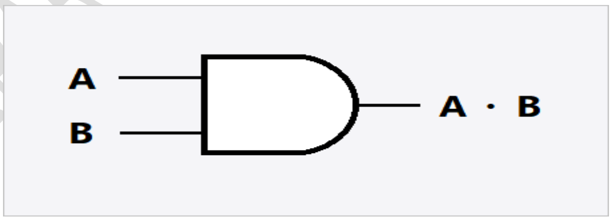
Truth Table

INPUT		OUTPUT
A	B	Q= A + B
0	0	1
0	1	0
1	0	0
1	1	0

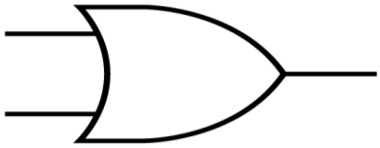
Electronic Implementation of Boolean Operations:

In **digital circuits**, Boolean operations are implemented using **logic gates**, which are basic building blocks for digital systems. These gates perform logical operations like AND, OR, and NOT, corresponding to Boolean algebra.

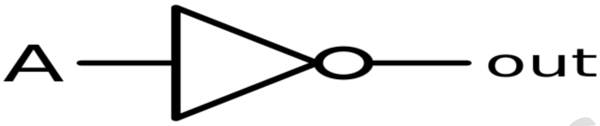
1. **AND Gate**:
   - Implements the Boolean AND operation.
   - Outputs **1** only if **all inputs** are 1.
   - Circuit symbol:



2. **OR Gate**:
   - Implements the Boolean OR operation.
   - Outputs **1** if **any input** is 1.
   - Circuit symbol:



3. **NOT Gate**:
   - Implements the Boolean NOT operation.
   - Outputs the **opposite** of the input (0 becomes 1, 1 becomes 0).
   - Circuit symbol:

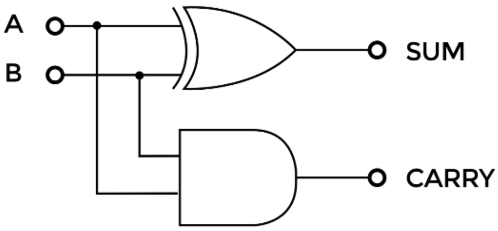


Gates - Functional Block Approach:

In digital circuit design, we often use logic gates as **functional blocks** to perform specific operations. These blocks can be combined to create **larger systems** that perform more complex tasks.

1.Half-Adder:

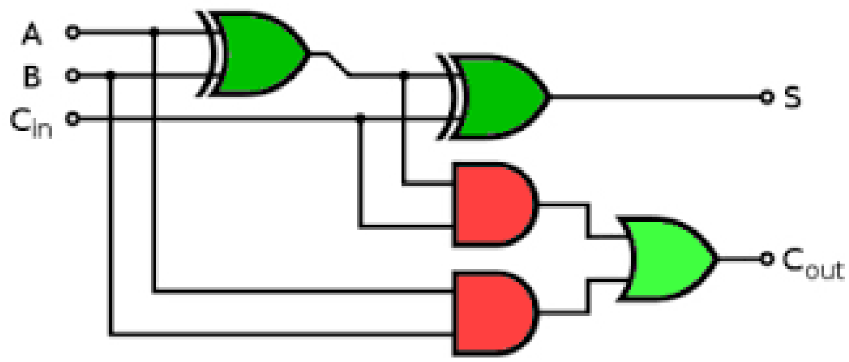
- A half-adder is a basic circuit that can **add two binary digits** (bits). It has two inputs (A, B) and two outputs (Sum, Carry).
- Logic gates used: **XOR** for Sum, **AND** for Carry.



A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

2. **Full-Adder**:

- A full-adder adds **three binary digits** (two inputs and a carry from the previous addition). It has three inputs (A, B, Carry-in) and two outputs (Sum, Carry-out).
- It is built by combining two **half-adders**.



A	B	C_{in}	SUM	C_{out}
0	0	0	0	0
0	1	0	1	0
1	0	0	1	0
1	1	0	0	1
0	0	1	1	0
0	1	1	0	1
1	0	1	0	1
1	1	1	1	1

3.**Multiplexer (MUX)**:

- A multiplexer selects one input from **multiple inputs** based on a select signal and forwards it to the output.
- Can be built using AND, OR, and NOT gates.

4.Demultiplexer (DEMUX):

- A demultiplexer takes a single input and routes it to one of many outputs, based on select signals.
- Also built using basic gates.

5.Encoder:

- Converts **multiple inputs into a smaller number of outputs** (binary representation of the active input).

6.**Decoder**:

- Converts **binary input into a specific output** (activating one output line based on the input combination)

Storage Elements: Flip-Flops (A Functional Block Approach):

Flip-flops are basic storage elements used in digital electronics to store one bit of data (either a 0 or 1). They are sequential circuits that maintain their state until they are triggered by a control signal (like a clock pulse).

Types of Flip-Flops:

1. **SR Flip-Flop (Set-Reset Flip-Flop)**

   - **Inputs**: Set (S), Reset (R).
   - **Outputs**: Q (output), Q' (complement of Q).
   - **Function**:

     - When **S = 1** and **R = 0**, the flip-flop **sets** (Q = 1).
     - When **S = 0** and **R = 1**, the flip-flop **resets** (Q = 0).
     - When **S = R = 0**, the flip-flop holds its previous state.
     - When **S = R = 1**, it results in an undefined state (often avoided in practical designs).
2. **JK Flip-Flop**

   - **Improvement over SR Flip-Flop**: Solves the undefined state of SR by adding toggle behavior.
   - **Inputs**: J (set), K (reset).
   - **Function**:

     - When **J = 1** and **K = 0**, the flip-flop sets (Q = 1).
     - When **J = 0** and **K = 1**, the flip-flop resets (Q = 0).
     - When **J = K = 0**, the flip-flop holds its state.
     - When **J = K = 1**, the flip-flop toggles (Q switches from 0 to 1 or 1 to 0).
3. **D Flip-Flop (Data or Delay Flip-Flop)**

   - **Simplification of JK flip-flop**: Only one input (D) is used.
   - **Input**: D (data).
   - **Function**: On a clock edge, the output Q takes the value of input D.

     - If **D = 1**, the output becomes 1.
     - If **D = 0**, the output becomes 0.

   - **Application**: Commonly used for **data storage** in registers because of its simplicity.

4. **T Flip-Flop (Toggle Flip-Flop)**

   - **Derived from JK flip-flop**: T flip-flop is essentially a JK flip-flop with both inputs tied together.
   - **Input**: T (toggle).
   - **Function**: On every clock pulse, the flip-flop **toggles** its state:

     - If **T = 1**, the output toggles.
     - If **T = 0**, the output remains the same.
   - **Application**: Used in **counters** due to its toggle nature.

Using Flip-Flops as Functional Blocks:

In the functional block approach, flip-flops are combined to build higher-order digital circuits. These circuits can store multiple bits, count pulses, or shift data, depending on how flip-flops are connected.

1. **Registers**

   - **Purpose**: A register is a collection of flip-flops used to store multiple bits of data (e.g., 4-bit, 8-bit registers).
   - **Construction**: Made by grouping several D flip-flops in parallel, each flip-flop storing one bit of data.
   - **Functionality**: Can hold a binary word and can be used for temporary storage of data in microprocessors, buffers, and other memory elements.
   - **Example**: An **8-bit register** is constructed from eight D flip-flops. Each flip-flop stores one bit of the 8-bit data.

2. **Counters**

   - **Purpose**: Counters keep track of the number of pulses or events and output the count in binary form.
   - **Construction**: Made by connecting flip-flops in series. T flip-flops are commonly used in counter circuits due to their toggle functionality.
   - **Types**:

     - **Ripple Counter**: An asynchronous counter where the output of one flip-flop serves as the clock input to the next flip-flop.
     - **Synchronous Counter**: All flip-flops are driven by a common clock signal, and they change states simultaneously.
     - **Up/Down Counter**: Can count both upward and downward based on control signals.
   - **Application**: Used in digital clocks, frequency dividers, and event counters.
3. **Shift Registers**

   - **Purpose**: Shift registers are used to shift data bits either left or right in response to clock pulses.
   - **Construction**: Made by connecting several D flip-flops in series, with each flip-flop passing its data to the next flip-flop on each clock pulse.
   - **Types**:

     - **Serial-In Serial-Out (SISO)**: Data is input serially (bit by bit), and the output is serial as well.
     - **Serial-In Parallel-Out (SIPO)**: Data is input serially, but the output is available in parallel.
     - **Parallel-In Serial-Out (PISO)**: Data is input in parallel, and output is shifted out serially.
     - **Parallel-In Parallel-Out (PIPO)**: Data is input and output in parallel.
   - **Application**: Used in data transfer, data storage, and in various types of communication systems.
4. **State Machines**
   - **Purpose**: State machines control the behavior of sequential circuits, allowing them to move between predefined states based on inputs.

- **Construction**: Built using flip-flops to store the current state, along with combinational logic to determine the next state based on inputs.
- **Application**: Used in control units of microprocessors, communication protocols, and digital systems.

Counters:

Counters are essential sequential circuits in digital electronics that are used to count events, pulses, or clock signals. They consist of a series of flip-flops connected in such a way that they go through a predefined sequence of states in response to input pulses. Counters are widely used in timers, clocks, frequency dividers, and digital systems.

1. Ripple Counter

A **ripple counter**, also called an **asynchronous counter**, is a type of counter where the flip-flops are connected in a chain, and the output of one flip-flop serves as the clock input for the next. In a ripple counter, the flip-flops do not change states simultaneously; instead, they "ripple" from one flip-flop to the next, which causes a delay between state changes.

2. Up/Down Counter

- An **up/down counter** is a counter that can count in both directions: upward and downward, depending on the control signal.
- An **up counter** increments its value (0, 1, 2, 3, etc.) with each clock pulse.
- A **down counter** decrements its value (3, 2, 1, 0, etc.) with each clock pulse.

3. Decade Counter

A **decade counter** is a type of counter that counts from 0 to 9 (a total of 10 states) before resetting back to 0. It is a **mod-10 counter** because it has 10 unique states. After reaching the 9th state (1001 in binary), it resets to 0 (0000).

Introduction to Digital IC Gates (TTL Type):

Digital IC Gates are the fundamental building blocks of digital electronics. These gates perform logical operations (AND, OR, NOT, etc.) on one or more binary inputs to produce a single binary output. **TTL (Transistor-Transistor Logic)** is one of the common families of digital logic circuits built using bipolar junction transistors (BJTs).

TTL:

- **TTL (Transistor-Transistor Logic)** is a type of logic circuit used in the construction of digital systems.
- It uses **bipolar junction transistors (BJTs)** to perform logical functions.
- Introduced in the 1960s, TTL became a widely used technology in integrated circuits due to its speed and reliability.
- **Voltage levels in TTL**:

  - Logic 0 (Low): 0V to 0.8V.

- Logic 1 (High): 2V to 5V.

Basic Types of TTL Logic Gates & ICs:

In TTL logic, there are various types of logic gates that perform different logical operations. Here are the main ones:

1. **AND Gate**:
   - **Operation**: The output is HIGH (1) only if **all inputs** are HIGH (1). Otherwise, the output is LOW (0).
   - **Symbol**: A·B
   - **TTL IC Example**: 7408

2. **OR Gate**:
   - **Operation**: The output is HIGH (1) if **any input** is HIGH (1). Otherwise, the output is LOW (0).
   - **Symbol**: A + B
   - **TTL IC Example**: 7432

3. **NOT Gate (Inverter)**:
   - **Operation**: The output is the opposite of the input. If the input is HIGH (1), the output is LOW (0), and vice versa.
   - **Symbol**: A'
   - **TTL IC Example**: 7404

4. **NAND Gate**:
   - **Operation**: The output is LOW (0) only when **all inputs** are HIGH (1). It is the inverse of the AND gate.
   - **Symbol**: (A·B)'
   - **TTL IC Example**: 7400

5. **NOR Gate**:
   - **Operation**: The output is LOW (0) if **any input** is HIGH (1). It is the inverse of the OR gate.
   - **Symbol**: (A + B)'
   - **TTL IC Example**: 7402

6. **XOR Gate (Exclusive OR)**:
   - **Operation**: The output is HIGH (1) when the number of HIGH inputs is odd (i.e., when inputs are different).
   - **Symbol**: A ⊕ B
   - **TTL IC Example**: 7486

7. **XNOR Gate (Exclusive NOR)**:

- **Operation**: The output is HIGH (1) when the number of HIGH inputs is even (i.e., when inputs are the same).
- **Symbol**: $(A \oplus B)'$
- **TTL IC Example**: 74266

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q1: What is Boolean Algebra?
A: Boolean Algebra is a branch of mathematics that deals with binary variables (0 and 1) and logical operations such as AND, OR, and NOT.

Q2: What are the basic operations in Boolean Algebra?
A: The basic operations are:

- AND (·)
- OR (+)
- NOT (')

Q3: What is the purpose of Boolean Algebra in digital electronics?
A: Boolean Algebra is used to simplify and design logic circuits, enabling efficient implementation of digital systems.

Q4: How are Boolean operations implemented in digital circuits?
A: Boolean operations are implemented using logic gates like AND, OR, and NOT gates, which are the building blocks of digital circuits.

Q5: What is a truth table?
A: A truth table is a table that shows all possible input combinations and their corresponding output for a Boolean expression or logic gate.

Q6: What is a logic gate?
A: A logic gate is a device that performs a logical operation on one or more binary inputs to produce a single binary output.

Q7: What are universal gates, and why are they important?
A: NAND and NOR gates are universal gates because they can be used to create any other logic gate (AND, OR, NOT, etc.).

Q8: What is the role of the XOR gate?
A: The XOR gate outputs HIGH (1) when an odd number of inputs are HIGH (1), and LOW (0) otherwise.

Q9: What are the main types of number systems used in digital electronics?
A: The main types are:

- Binary (base 2)
- Decimal (base 10)
- Octal (base 8)

- Hexadecimal (base 16)

Q10: What is a flip-flop?
A: A flip-flop is a memory element that stores a single bit of data and is capable of switching between two states (0 and 1).

Q11: What is a ripple counter?
A: A ripple counter is a type of asynchronous counter where the flip-flops are triggered one after another, causing a ripple effect in counting.

Q12: What is an up/down counter?
A: An up/down counter can count both upward and downward, depending on the control input.

Q13: What is TTL?
A: TTL stands for **Transistor-Transistor Logic**, a type of digital circuit built using bipolar junction transistors.

Q14: What are the advantages of TTL gates?
A: TTL gates are fast, reliable, and widely used in digital circuits, though they consume more power than modern CMOS gates.

Q15: State De-Morgan's Theorem. [W-24]

A: De Morgan's Theorem states that the complement of a product is equal to the sum of the complements, and the complement of a sum is equal to the product of the complements. In other words, (A ∪ B)' = A' ∩ B' and (A ∩ B)' = A' ∪ B'.

Q16: Write the truth table of D-Flip-Flop. [W-24]

A:

D(Input)	Q(Output)	Q' (Complement)
0	0	1
1	1	0

POSSIBLE LONG TYPE QUESTIONS

Q1: Convert the following decimal numbers to binary, octal, and hexadecimal: (a) 255, (b) 42, (c) 87

Q2: Explain with logic circuit the half & full adder.

Q3: Explain the various types of TTL gates.

Q4: What are flip-flops? Explain the working of different types of flip-flops.

Q5: Describe the working of AND, OR, NOT, NAND, NOR, XOR, and XNOR gates. For each gate, provide the truth table & logic symbol.

Q6: Explain the concept of a functional block approach in digital electronics

Q7: Explain the different number systems used in digital electronics (Binary, Decimal, Octal, and Hexadecimal).

Q8: Convert. **[W-24]**

1. **$(10111001)_2$ to Hexadecimal.**
2. **$(9BA)_{16}$ to decimal.**
3. **$(432)_{10}$ to octal**
4. **$(10111001)_2$ to octal**

Q9: Define counter with neat diagram describer the working of up-down counter **[W-24]**

Unit- IV

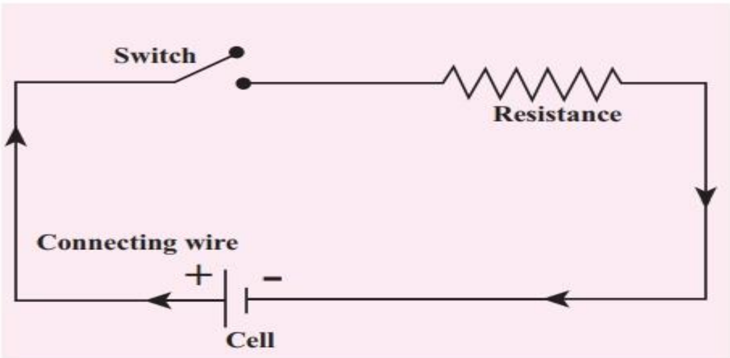
Electric and Magnetic Circuits

Learning Objectives:

EMF, Current, Potential Difference, Power and Energy; M.M.F, magnetic force, permeability, hysteresis loop, reluctance, leakage factor and BH curve; Electromagnetic induction, Faraday's laws of electromagnetic induction, Lenz's law; Dynamically induced emf; Statically induced emf; Equations of self and mutual inductance; Analogy between electric and magnetic circuits.

Electric circuit:

It is an interconnection of electrical elements such as resistors, capacitors, inductors, voltage source etc.



EMF

It is the electromotive force of the cell, also known as the EMF, is the highest potential difference that exists between the two electrodes of a cell.which helps the flow of current.

or

The electromotive force (e) or e.m.f. is the *energy provided by a cell or battery per coulomb of charge passing through it*,

it is measured in volts (V).

CHARGE:-

- The most basic quantity in an electric circuit is the electric charge.
- Electric *charge* is the physical property of matter that causes it to experience a force when placed in an electromagnetic field.
- Charge is an electrical property of the atomic particles of which matter consists,measured in coulombs (C).
- Charge may be positive or negative, is denoted by the letter q or Q.

- electron = -ve charge
- proton = +ve charge
- neutron = having no charge

  $e = -1.6 \times 10^{-19}$ C

CURRENT:-

The rate of flow of charge or electrons in a closed circuit is called as current.
Mathematically : $I = Q / t$.

Where Q is the charge measured in Coulombs (C),

I is the current in amperes (A)

t is the time in second (s).

- Generally currents are of Two types :
  1) A direct current (DC) is a current that remains constant with time.
  2) An alternating current (AC) is a current that varies with time.

Voltage (Or) Potential Difference(V) :-

A Charged body has capacity to do work by moving other charges by force of attraction or repulsion.

The capacity of a charged body to do work is called electric potential.

It is also called as voltage.

Electric potential of a charged body is given by :

$$\text{Potential(V)} = \frac{work\ done(W)}{charge(Q)}$$

Unit of electric potential is joule/coulomb or volt.

Power(P) :

Power is the rate of doing work in an electric circuit.

$$\text{Electric power} = \frac{work\ done}{time}$$

Or

The electric power is the product of voltage and current.

i.e power= voltage × current .($P = V \times I$), watt

watt = volt × ampere.

Unit of power is joule/second or Watt.

- Bigger unit of power are Kilowatt and Megawatt.
- 1KW = 1000W , 1MW= 10^6 W
- 1HP(HORSE POWER) = 746W

Energy(E):

Energy is the capacity to do work.
In electrical circuit the energy is the product of power and time.
Electrical Energy = power * Time

$$= P \times t = V \times I \times t = I^2Rt = \frac{V^2}{R}t$$

It's unit is Watt-hour or KWh.

Magnetic Circuits

A magnetic circuit is defined as a closed path followed by the magnetic flux.

A magnetic circuit consists of a core of materials having high permeability like iron, soft steel etc. It is because these materials offer very small opposition to the flow of magnetic flux.

Magnetic flux(φ):

It is defined as the imaginary lines which are extended from north pole and terminates at south pole.

It is denoted as φ and its unit is weber (Wb)

Magneto motive Force (M.M.F):

- It is defined as the amount of ampere turns it links.
- It is also defined as the product of magnetic flux and reluctance.
- It drives the flux through a magnetic circuit.
- The unit of M.M.F. is ampere–turn (AT)

Magnetic Field Intensity (H) / Magnetizing force:

It is defined as the amount of force experienced by a unit north pole placed in a magnetic field.

$$\text{Magnetic field intensity(H)} = \frac{\text{Magnetomotive force(F)}}{\text{Mean length of the magnetic path(L)}}$$

$$= \frac{\text{N.I}}{\text{Mean length of the magnetic path(L)}}$$

Its unit is N/m. or AT/m

It is also defined as the ratio between flux density and permeability of a medium.

$$\text{i.e Magnetic field intensity(H)} = \frac{\text{B}}{\mu}$$

Flux density(B):

It is the amount of fluxes passing through the unit area.

$$\text{Magnetic flux density} = \frac{\boldsymbol{\varphi}}{A}\ in\ wb/m^2$$

Permeability(μ):

It is the ability of permission to enter magnetic flux to it.

It is defined as the ratio between the magnetic flux density and the magnetic field intensity

$$\text{permeability}(\mu) = \frac{\text{magnetic flux density(B))}}{\text{agnetic field intensity(H)}}$$

Reluctance(S):

It is defined as the property of a material which opposes the magnetic flux.

It is denoted as S and its unit is AT/Wb

$$R\text{eluctance}(S) = \frac{\text{mmf}}{\text{magnetic flux}}$$

Analogy between electric and Magnetic Circuits:

Electric circuit	Magnetic Circuit
EMF drives the electric current	M.M.F drives the magnetic flux
Resistance opposes the flow of current.	Reluctance opposes the flow of magnetic flux
In electric circuit current flows.	In magnetic circuit flux flows.
Conductance is the reciprocal of resistance.	Permeance is the reciprocal of reluctance.

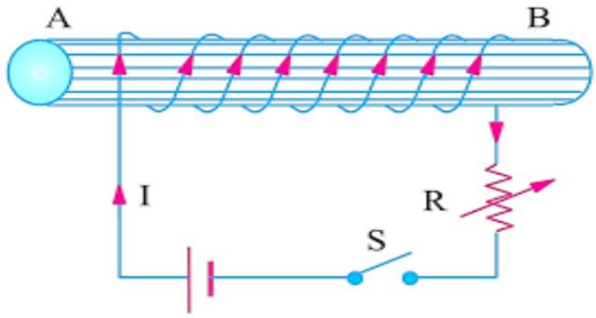
B-H Curve:

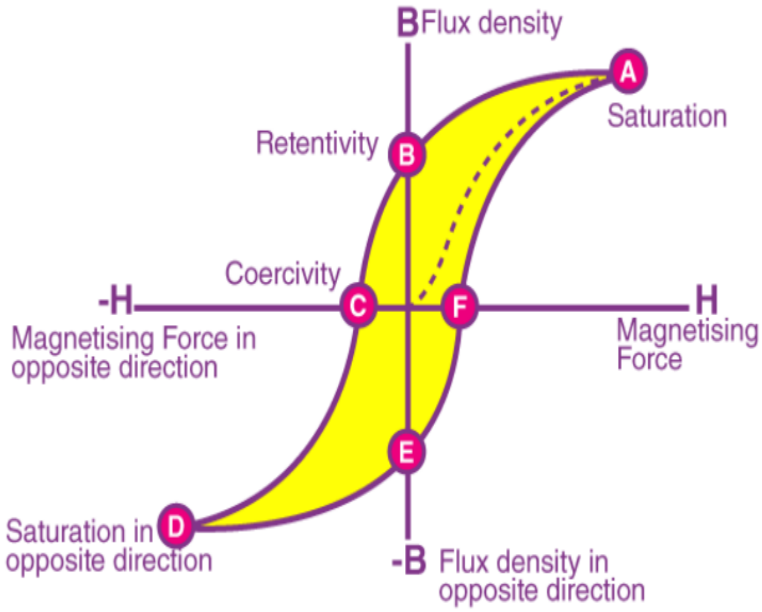
The B-H curve is generally used to describe the nonlinear behaviour of magnetization that a ferromagnetic material obtains in response to an applied magnetic field .

Hysteresis loop:

Magnetic hysteresis is the property of a magnetic material in which flux density(B) lags behind the magnetic field intensity(H).

If flux density is taken along y-axis and field intensity along x-axis with different values a graph such plotted is called as hysteresis loop.





The magnetic flux density (B) is increased when the magnetic field strength(H) is increased from 0 (zero).

With increasing the magnetic field there is an increase in the value of magnetism and finally reaches point A which is called saturation point where B is constant.

With a decrease in the value of the magnetic field, there is a decrease in the value of magnetism. But at B and H are equal to zero, substance or material retains some amount of magnetism is called retentivity or residual magnetism.

When there is a decrease in the magnetic field towards the negative side, magnetism also decreases. At point C the substance is completely demagnetized.

The force required to remove the retentivity of the material is known as Coercive force (C).

In the opposite direction, the cycle is continued where the saturation point is D, retentivity point is E and coercive force is F.

Due to the forward and opposite direction process, the cycle is complete and this cycle is called the hysteresis loop.

Retentivity:

The amount of magnetization present when the external magnetizing field is removed is known as retentivity.

It is a material's ability to retain a certain amount of magnetic property while an external magnetizing field is removed.

The value of B at point b in the hysteresis loop.

Coercivity:

The amount of reverse(-ve H) external magnetizing field required to completely demagnetize the substance is known as coercivity of substance.

The value of H at point c in the hysteresis loop

Electro-Magnetic induction:

The phenomena of production of electricity due to magnetism is called electro magnetic induction.

i.e the induction of electricity because of changing magnetic field.

Faraday's Laws of Electro-Magnetic induction:

First Law:

Faraday's first law of electromagnetic induction states that whenever the flux of magnetic field through the area bounded by a closed loop changes, an emf is produced in the loop.

Second Law:

It states that the magnitude of induced emf is equal to the rate of change of flux linkages.

In other word it states that the emf induced is directly proportional to the rate of change of flux and number of turns.

Mathematically:

$$e = \frac{d\varphi}{dt}$$

$$e \propto N$$

$$e = -N\frac{d\varphi}{dt}$$ ('- ve' sign is due to Lenz's Law)

Where (e = induced emf, N = No. of turns, φ = flux)

Direction of induced e.m.f is given by Fleming's Right Hand Rule:

Fleming's Right Hand Rule:

It states that "hold your right hand with fore-finger, middle finger and thumb at right angles to each other. If the fore-finger represents the direction of field, thumb represents the direction of motion of the conductor, then the middle finger represents the direction of induced emf."

Lenz's Law:

It states that electromagnetically induced current always flows in such a direction that the action of magnetic field set up by it tends to oppose the vary cause which produces it.

OR

It states that the direction of the induced current (emf) is such that it opposes the change of magnetic flux.

Dynamically Induced emf:

In this case the field is stationary and the conductor or coil are rotating in an uniform magnetic field ,the emf induced in conducter or coil is called .Dynamically Induced emf:

Statically Induced emf:

In case of the conductors are remain in stationary and flux linked with it changes by increasing or decreasing.

Self-Inductance:

It is defined as the property of the coil due to which it opposes any change (increase or decrease) of current or flux through it

We know ,

$\varphi \propto I = L \times I$ (for one turn)   (L= Co-efficient of Self-Inductance)

$\Rightarrow N\varphi = L \times I$ (for N turns)

$\Rightarrow \quad L = \frac{N\varphi}{I}$

Where L = Co-efficient of self-induction,

N = Number of turns

φ = flux , I = Current

It is also defined as the ratio of weber turns per ampere of current in the coil.

OR

It is the ratio of flux linked per ampere of current in the coil.

Mutual Inductance:

Mutual inductance is when a changing electric current in one coil (or wire loop) creates a voltage in another nearby coil. This happens because the current in the first coil makes a magnetic field, and when that magnetic field changes, it causes electricity to flow in the second coil.

We know

$\varphi_A \propto I_A$

$\Rightarrow \varphi_A = M I_A$ (for one turn)

$\Rightarrow N_B \varphi_A = M I_A$ (for'N_B' turn in second coil B)

$$M = \frac{NB\varphi A}{IA}$$

Where M = Co-efficient of self-induction,

N_B = Number of turns in second coil B ,

Φ_A = flux due to A coil , I_A = Current in coil A)

Similarly

$$M = \frac{NA\Phi B}{IB}$$

Coefficient of mutual inductance between the two coils is defined as the weber-turns in one coil due to one ampere current in the other.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER:

Q1What is EMF (Electromotive Force)?

A: EMF is the voltage generated by a source, like a battery or a generator, when no current is flowing. It's the force that pushes electric charges around a circuit.

Q2: What is the difference between current and potential difference?

A: Current is the flow of electric charge, while potential difference (voltage) is the force that drives the current between two points.

Q3: How is electrical power calculated?

A: Electrical power (P) is calculated using the formula: P=V×IP = V \times IP=V×I where V is voltage and I is current.

Q4: What is the relationship between energy and power?

A: Energy is the total work done, while power is the rate at which energy is used or transferred. The formula is: Energy=Power×Time\text{Energy} = \text{Power} \times \text{Time}Energy=Power×Time

Q5: What is Magnetomotive Force (M.M.F)?

A: M.M.F is the force that drives magnetic flux through a magnetic circuit, similar to how voltage drives electric current. It is calculated as: M.M.F=N×I\text{M.M.F} = N \times IM.M.F=N×I where NNN is the number of turns and III is the current.

Q6: What is permeability in magnetism?

A: Permeability is a material's ability to allow magnetic flux to pass through it. High permeability means the material is good at conducting magnetic fields.

Q7: What is a hysteresis loop?

A: A hysteresis loop shows how the magnetization of a material responds to a changing magnetic field. It represents the lag between the applied magnetic field and the magnetic flux in the material.

Q8: What is reluctance?

A: Reluctance is the resistance to the flow of magnetic flux in a magnetic circuit, similar to electrical resistance in a circuit.

Q9: What is the B-H curve?

A: The B-H curve shows the relationship between magnetic flux density (BBB) and magnetic field strength (HHH) for a material. It helps in understanding how a material behaves under varying magnetic fields.

Q10: What is dynamically induced EMF?

A: Dynamically induced EMF occurs when a conductor moves through a magnetic field, causing a change in the magnetic flux linked with the conductor (e.g., in generators).

Q: What is statically induced EMF?

A: Statically induced EMF occurs when the magnetic field around a stationary conductor changes over time, inducing a voltage in the conductor (e.g., in transformers).

POSSIBLE LONG TYPE QUESTIOS

Q1 Explain in detail the concepts of electromotive force (EMF), current, potential difference, power, and energy

Q2 Discuss the concept of magneto motive force (M.M.F.) and its role in magnetic circuits

Q3 Difference between electric circuit and Magnetic Circuit. [W-24]

UNIT-V

A.C. Circuits

Learning Objectives:

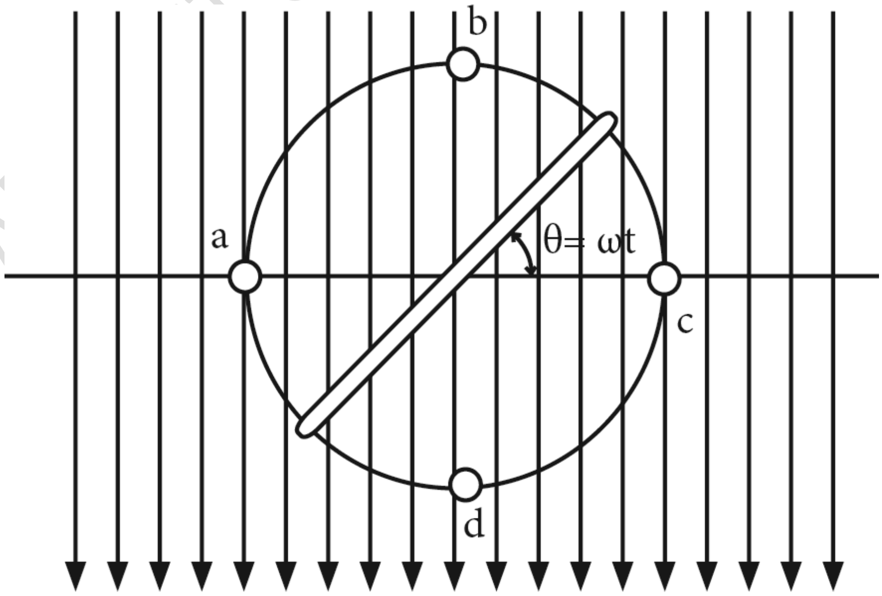
Cycle, Frequency, Periodic time, Amplitude, Angular velocity, RMS value, Average value, Form Factor Peak Factor, impedance, phase angle, and power factor; Mathematical and phasor representation of alternating emf and current; Voltage and Current relationship in Star and Delta connections; A.C in resistors, inductors and capacitors; A.C in R-L series, R-C series, R-L-C series and parallel circuits; Power in A. C. Circuits, power triangle.

Alternating Quantity:

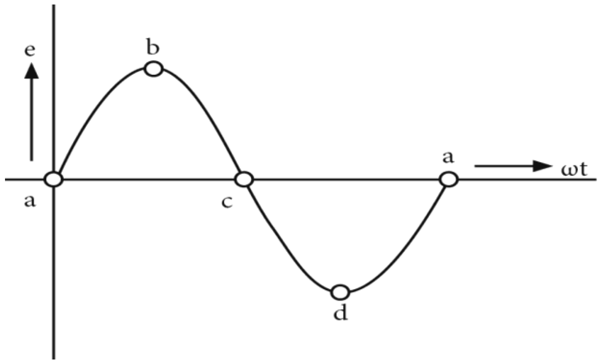
The quantity changes continuously in magnitude and alternates in direction at regular intervals of time is called An alternating quantity.
Alternating quantity is a sinusoidal varying quantity.
It may be alternating current or voltage.

Alternating Voltage and Current:

When a coil is rotated in a magnetic field, an alternating electromotive force (e.m.f.) is induced in that coil. The value of e.m.f. induced depends on number of turns in the coil, strength of the magnetic field and the speed of which the coil is rotated in the magnetic field. Consider a conductor rotating in a uniform magnetic field with constant angular velocity of ‘ω’ radian per second as shown in Fig. 5.2. Its axis of revolution being perpendicular to the magnetic lines of force. As per the different position of conductor such as a, b, c and d, the corresponding value of electromotive force (emf) is shown in Fig. 5.2.



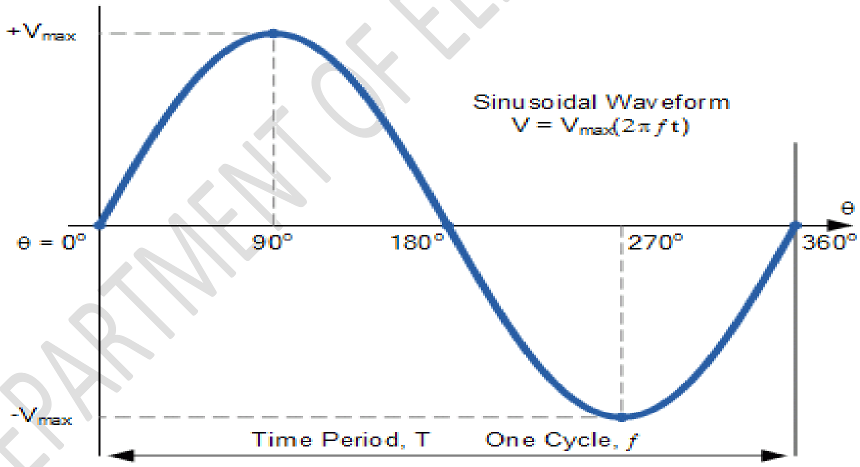
EMF generated in a Coil rotating in a magnetic field



Sinusoidal wave

At point a and point c, the conductor moves parallel to magnetic field. Hence, e.m.f. induced is zero. While at point b and d, the conductor moves in a direction perpendicular to the magnetic field. Hence, e.m.f. induced is maximum. In one complete revolution of a conductor, one complete cycle of e.m.f. is obtained. As the direction of e.m.f. is reversed at points a and c such e.m.f. is known as alternating e.m.f. or alternating voltage. When a coil with induced alternating e.m.f. is connected to external circuit, the alternating current starts flowing. The waveform of this alternating current is similar to waveform of an alternating voltage. Also, e.m.f. varies as sine function. The curve traced is sine curve and, hence, it is known as sinusoidal e.m.f.

Important terms related with an alternating quantity:



Cycle:

One complete set of positive and negative values of an alternating quantity is called as cycle.

1cycle = 1 revolution =2∏ radians= 360^0

Time period (T):

Time taken by an alternating quantity to complete one cycle is called time period.

or

It is the reciprocal of frequency (f)

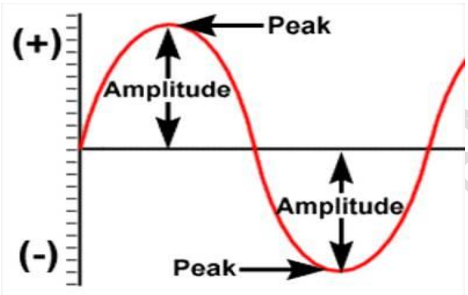
It´s unit is sec.
T = 1/f

Frequency (f):

The number of cycles per second is called the frequency of the alternating quantity.
It´s unit is Hertz (Hz).
f=1/T

Amplitude:

The maximum value ,positive or negative of an alternating quantity is known as its amplitude, or peak value or crest value.



Angular Velocity

Angular frequency is defined as the number of radians covered in one second (i.e. the angle covered by the rotating coil). The unit of angular frequency is rad/sec.

$$\omega = 2\pi / T$$

Instantaneous value:

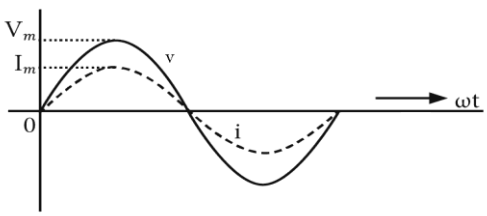
The value of an alternating quantity at any instant of time is called as instantaneous value.

Alternating Voltage and Current

$v = V_m \sin\theta = V_m \sin\omega t = V_m \sin 2\pi f t$

where V_m = Maximum value of voltage,
f = Frequency in Hz, and t = Time in seconds
equation for instantaneous value of alternating current is

$i = I_m \sin 2\pi f t = I_m \sin\omega t$



Average value :

It is that value of AC which produces same charge as that of DC for a given circuit and given time.

I_{AV} = 2Im/∏ for sine wave

RMS value:

It is that value of AC which produces same heat as that of dc for a given circuit and given time.

$I_{RMS} = I_m/\sqrt{2}$

$V_{RMS} = V_m/\sqrt{2}$

Where I_M=Maximum value of current.

Form factor:

It is defined as the ratio of rms value to average value of an alternating quantity .

KF = RMS value/ average value = 0.707 Im/0.637 Im= 1.1

Crest or peak or amplitude factor : (K_a)

It is defined as the ratio of maximum value to rms value of an alternating quantity.

K_a= Maximum value / rms value = Im/(Im/√2)=√2=1.414

Simple problems:

Q-1: An alternating current of frequency 50Hz has a maximum value of 100A .Give its instantaneous expression .

Given data:

f=50 HZ

Im=100A

Required data:

Instataneous current expression ?

Ans:

ω=2¶f=2¶×50=100¶=100×3.142=314.2 rad/sec

We know µ

i=Im sinωt=100 sin314.2t A (Ans)

Q-2: An alternating voltage is expressed as V=300 sin314t.Find(i)Peak voltage(ii) frequency (iii)rms voltage (iv)Find the instantaneous value of 1/600 sec.

Solution:

Given data:

V=300 sin314t

t=1/600 sec

Required data:

(i) Peak voltage (Vm)=?

(ii) Frequency (f)= ?

(iii) rms voltage(VrmS)=?

(iv) V = ?

Solution:

(i) Vm=300 V (Ans)

(ii) f=314/2¶=50 Hz (Ans)

(iii) Vrms= 300/√2 =.707 ×300 = 212.1 V (Ans)

(iv) V =300 sin314 ×(1/600) = 2.74 V (Ans)

Phase :

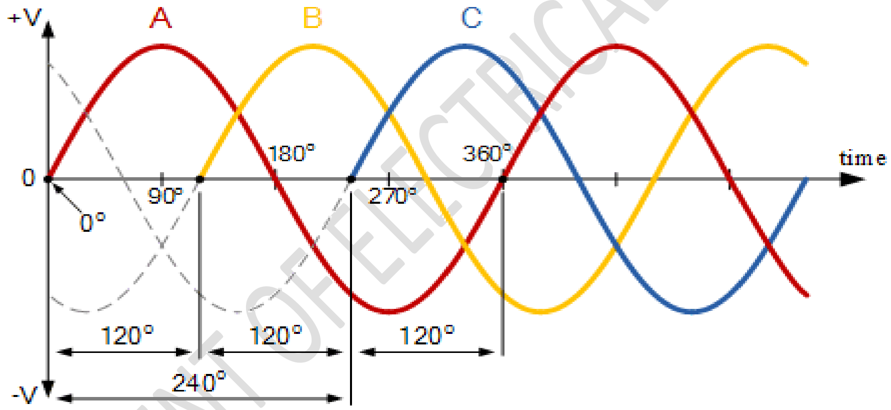
Phase of an alternating quantity is meant the fraction of time period of that alternating quantity.

Phase angle:

Phase angle of an alternating quantity is the fraction of angle in radian.

Phase difference:

The difference between the phases of the two alternating quantities is called as phase difference.



Let, V(t) = Vm sin wt, here the phase is zero as function starts from origin.

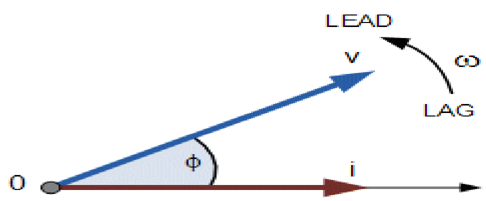
V(t)= Vm sin(wt-θ), here the phase of function is θ degrees to right shift.

V(t)= Vm sin(wt+θ), here the phase of the function is θ degrees to the left shift.

Power factor (p.f):

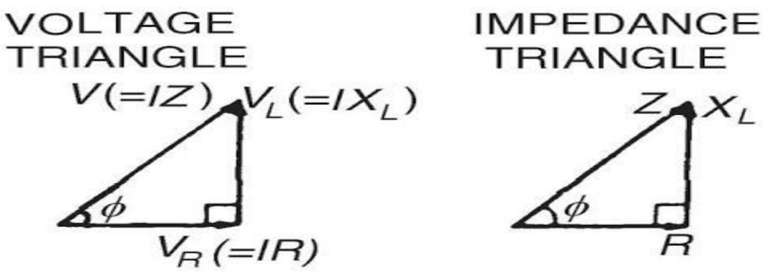
Power factor can be defined as follows :

(1) It is the cosine angle made by phase voltage and phase current.



p.f=cosϕ

(2)p.f: It is the ratio of resistance to impedance.

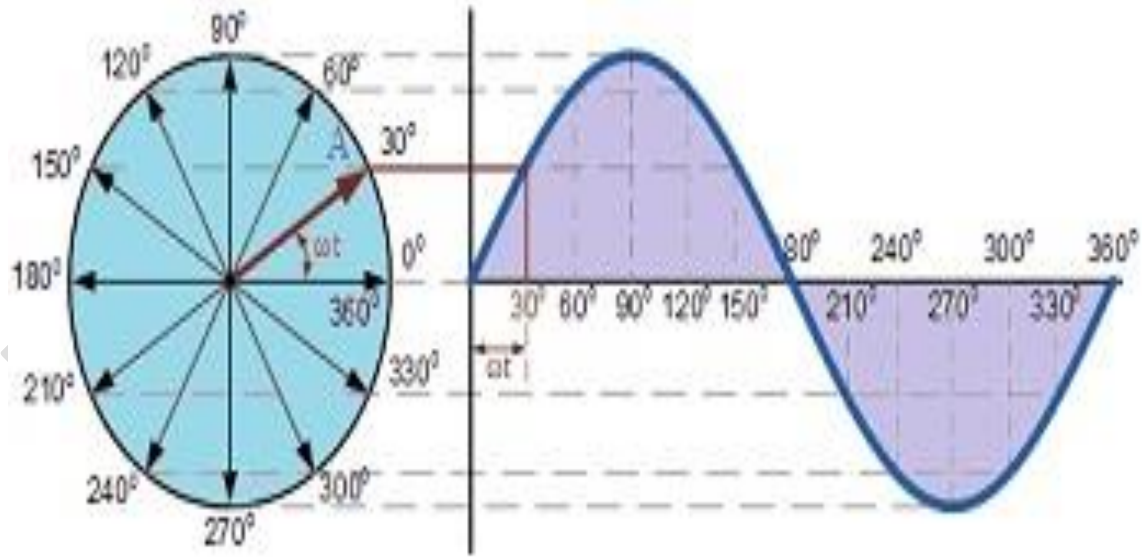


Cosϕ=R/Z

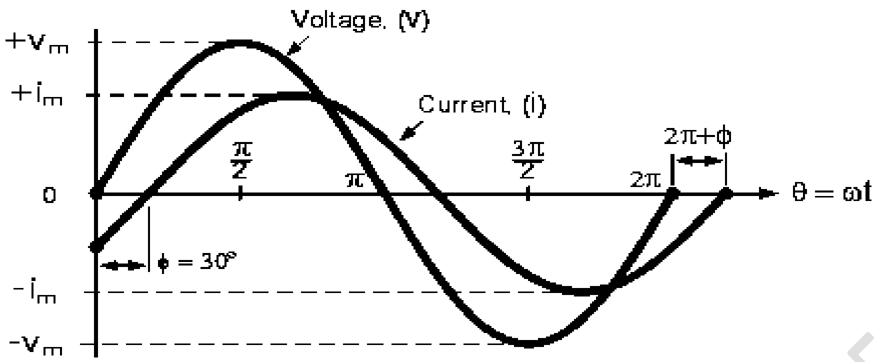
Mathematical and phasor representation of alternating emf and current

Phasor diagrams :

Phasor diagrams are the representations of voltage-current relationship in AC circuits.
A phasor is a vector capable of rotating about the origin with (angular velocity) ‘ω’
The vertical component of phasor will represent the sinusoidally varying quantity.
Considering V = Vm sinωt then the vertical component represents the instantaneous value of voltage.
The magnitude(length of the vector) of the phasor is the peak value at that instant of time.



Phase Difference of a Sinusoidal Waveform

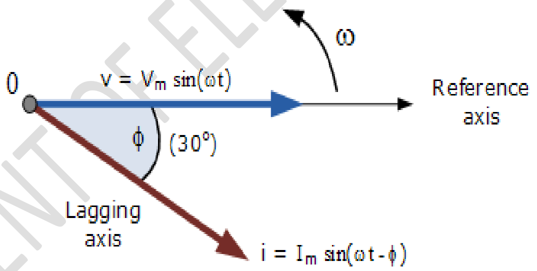


$$v_{(t)} = V_m \sin(\omega t)$$

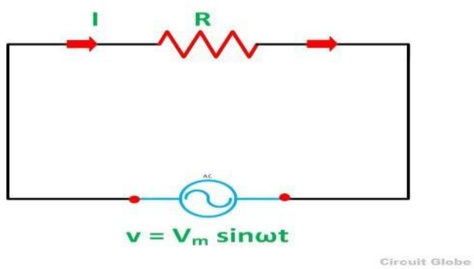
$$i_{(t)} = I_m \sin(\omega t - \phi)$$

The generalized mathematical expression to define these two sinusoidal quantities will be written as

Phasor Diagram of a Sinusoidal Waveform:



AC through pure resistance:



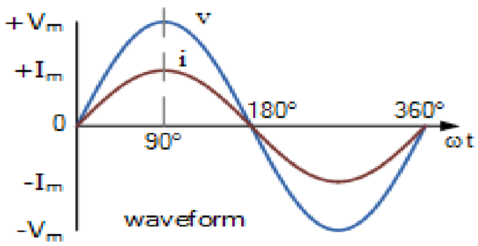
In above figure ,
V= Applied voltage in volt.
I= Current in amp.
R= Resistance in ohm.
V_R=Drop across R in volt.

Here the voltage equation ,

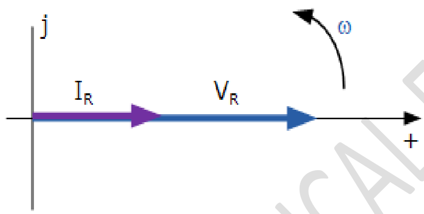
$V= V_m Sin\omega t$ ………………(i)

$I= I_m Sin\omega t$ …………..(ii)

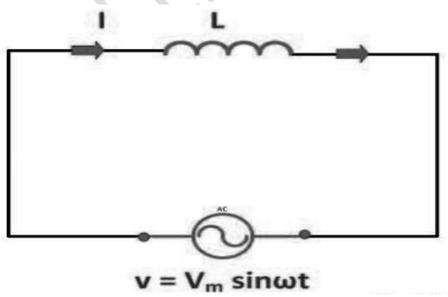
From (i) and (ii) we found that v and I are in the same phase.



(wave diagram)



AC through pure inductance:



Let,

V = applied voltage in volt.

I = circuit current in amp.

L= inductance in Henry.

V_L= voltage across inductor in volt.

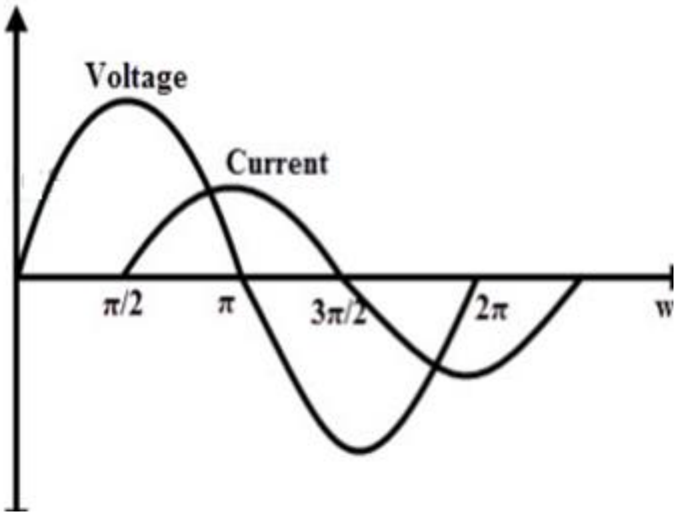
$V = V_m Sin\omega t$ ………… (i)

$I = I_m Sin(\omega t - \prod/2)$ ………(ii)

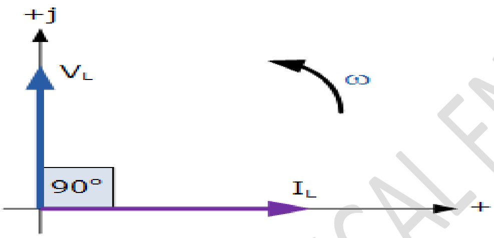
$X_L = \omega L$= inductive reactance in ohm.

$I_m = V_m/\omega L = V_m/X_L$= maximum value of current in amp.

From (i) and (ii) we found that current lags behind voltage by an angle 900 or $\prod/2$.

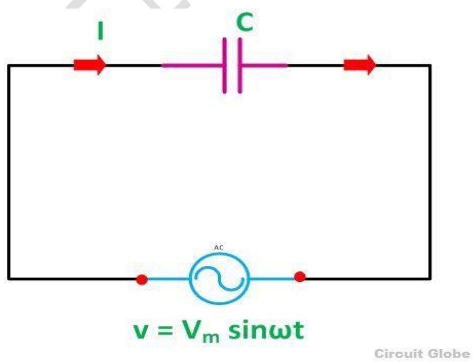


(Wave diagram)



(phasor diagram)

AC through pure capacitance:



Let ,

V= applied voltage in volt.

I = current in amp.

C = capacitance in farad.

V_C =voltage drop in capacitor in volt.

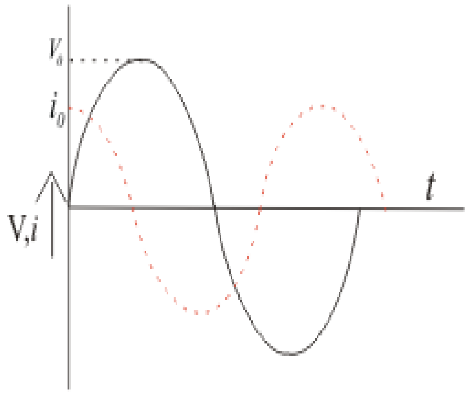
V =VmSinωt ……….(1)

I =Im Sin(ωt+90)………..(2)

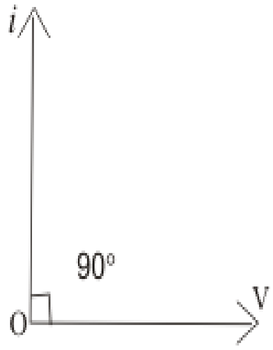
Im =Vm/X_C= maximum current in amp

X_C = 1/ωc=1/2∏fc= capacitive reactance in ohm.

From (1) and (2) we found that current leads voltage by an angle 90or ∏/2.

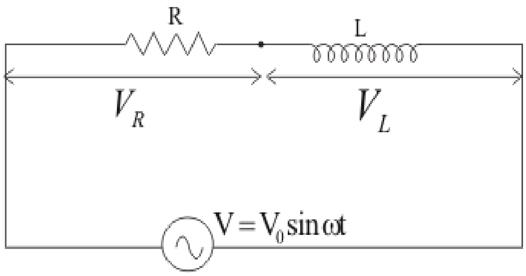


Sinusoidal representation



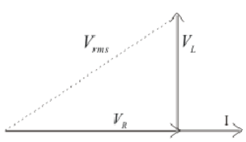
Phaser diagram representation

AC through R-L series circuit:



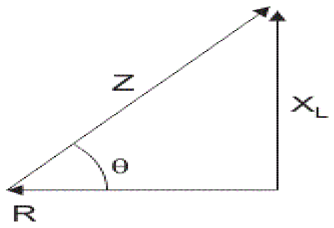
A.C. Circuit containing inductor and an resistor

In above fig,
V = supply voltage in volt.
I = circuit current in amp.
R = Resistance in ohm.
L=Inductance in Henery.
V_R=Voltage drop across R in volt.
V_R = IR
V_L=voltage drop across L in inductor in volt= IX_L
X_L=ωL=2∏f L = inductive reactance in ohm.
For pure resistor I and V_R are in same phase.
For pure inductor I lags behind V_L by 900.



Voltage phasor diagram for LR series circuit

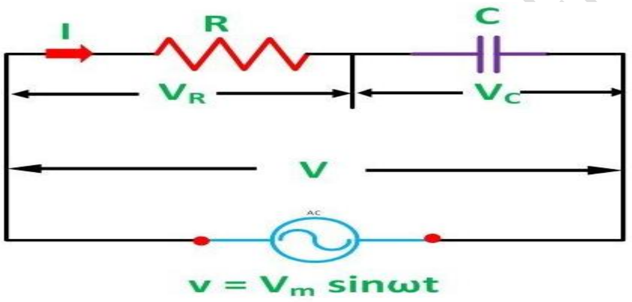
ϕ=phase angle between V and I.
$V=\sqrt{(V_R^2+V_L^2)}$



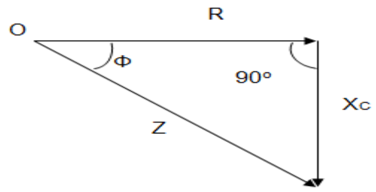
(Impedance triangle)

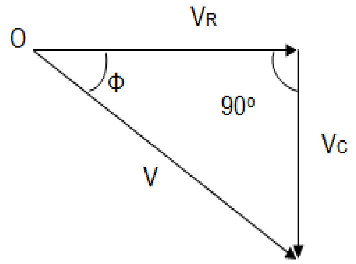
$Z = \sqrt{(R^2+X_L^2)}$
$Z = R + jX_L$
Where Z= impedance in ohm.
Impedance (Z): It is the phasor sum of resistance and inductive reactance.
From voltage triangle we see that I lags behind voltage by an angle ϕ.

AC through R-C series circuit :



In above figure,
V = supply voltage in volt.
I = current in amp.
R = resistance in ohm.
C = capacitance in farad.
V_R = voltage drop across R in volt =IR.
V_C = voltage drop across C in volt = IX_C.
X_C = capacitive reactance in ohm.
$X_C = 1/2\prod fc = 1/\omega c$
V_R and I are in same phase in a pure resistive circuit.
I and V_C by an angle 90 in a pure capacitive circuit.
Taking I as reference vector.





(Voltage triangle) (Impedance triangle)

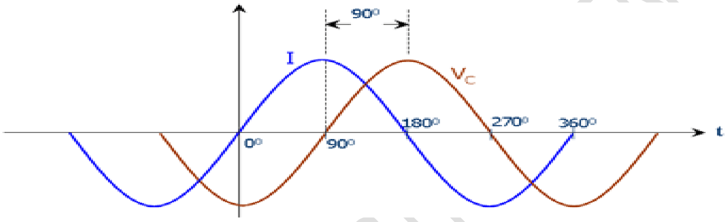
$Z = R - jX_c$

$Z = \sqrt{(R^2 + Xc^2)}$

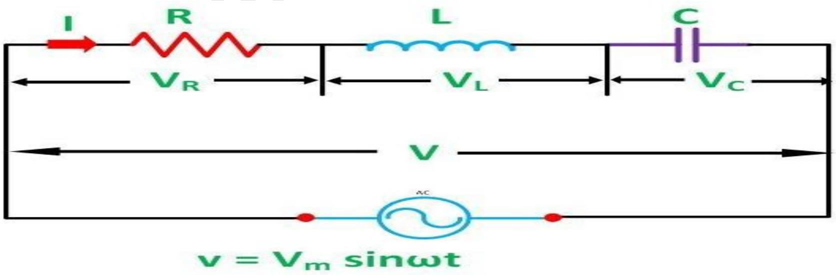
Impedance (Z):Impedance(Z) of an R-C series circuit is the phasor sum of resistance (R) and capacitive reactance(X_c).

From voltage triangle we see that I leads voltage by an angle ϕ.

Hence $i = Im(Sin\omega t + \phi)$



AC through R-L-C series circuit:



Let,

V = supply voltage in volt.

V_R =potential drop in resistor in volt=IR.

V_L =potential drop in inductor in volt=IX_L

V_C = potential drop in capacitor in volt=IX_C

I =current in the circuit in amp.

R = resistance in ohm

L=Inductance in Henery.

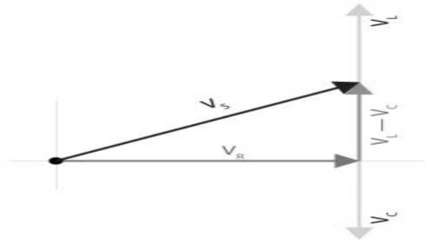
C = Capacitance in Farad.

X_C =Capacitive reactance in ohm=X_C=1/2∏fc=1/ωc

X_L =Inductive reactance in ohm=X_L=ω L=2∏f L

V_R and I in same phase .

I lags VL by 90.
I leads VC by 90.



Voltage triangle for an RLC Series circuit

From above OAB right angle triangle .

$OB^2=OA^2+AB^2$

$=> V^2=(IR)^2+(IX_L-IX_C)^2$

$= I^2R^2+I^2X_L^2+I^2X_C^2-2IX_LIX_C$

$=I^2R^2+I^2X_L^2+I^2X_C^2-2\ I^2X_LX_C$

$= I^2(R^2+X_L^2+X_C^2-2X_LX_C)$

$= I^2[R^2+(X_L-X_C)^2]$

$=> V^2/I^2 =[R^2+(X_L-X_C)^2]$

$=> Z=\sqrt{[R^2+(X_L-X_C)^2]}$

$=> Z= R+ j(X_L-X_C)$

$=>Z= \sqrt{(R^2+X^2)}$

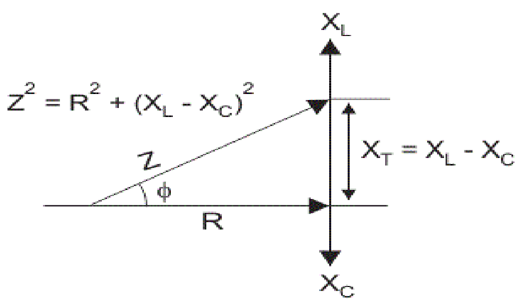
Where ,

Z= Impedance of R-L-C series circuit in ohm.

X= Net reactance of R-L-C series circuit in ohm.

$X= X_L-X_C$

Here impedance is the phasor sum of resistance (R) and net reactance (X) of R-L-C series circuit.



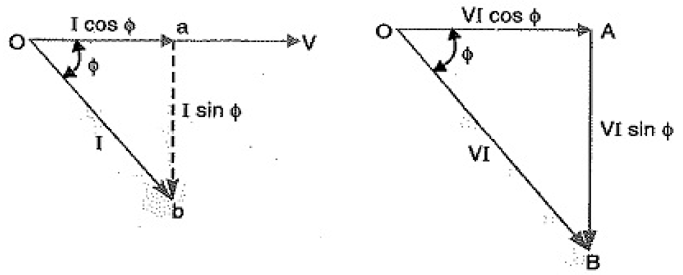
(Impedance triangle)

Circuit behaves

(a) like inductive ,if $X_L > X_C$
(b) like capacitive ,if $X_L < X_C$
So in R-L-C series circuit current lags or leads the supply voltage by angle ϕ.

Power in 1-φ A.C circuit:

Power (p) is known to be three types
(i) Active power or real power or actual power.
(ii) Reactive power or virtual power .
(iii) Total power or apparent power.



Active power(p):

It is the product of voltage and active component of current .
$P=V\,I\,COS\phi$
Its unit is watt, Kilowatt, Megawatt in SI unit.

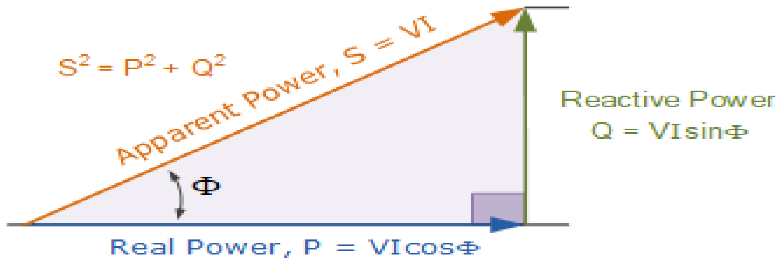
Reactive power (Q):

It is the product of voltage and reactive component of current .
$Q= VI \sin \phi$.
Its unit is VAR, KVAR, MVAR in SI system.

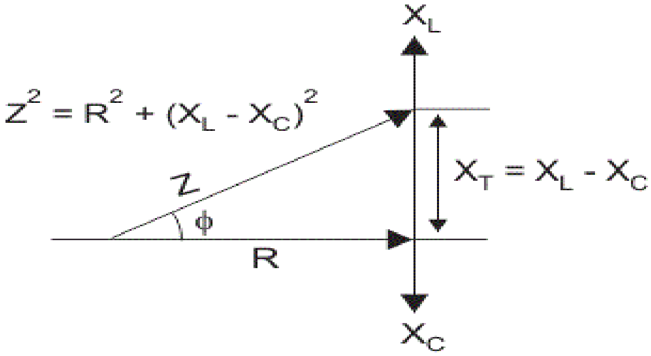
Apparent power (S):

It is the product of voltage and current.
$S= V\,I$.
Its unit is VA,KVA,MVA in SI system.

Impedance triangle and power triangle:



(power triangle)



(Impedance triangle)

SIMPLE PROBLEMS ON RL , RC AND RLC SERIES CIRCUITS:

Q-1 : A 60 Hz voltage of 115 V (RMS) is impressed on a 100 Ω resistance .(i) Write the time equation for the voltage and the resulting current.Let the zero point of voltage wave be at t =0 .(ii) Show the voltage and current on a time diagram (iii) Show the voltage and current on a phasor diagram .

Solution:

Given data:

f = 60 Hz

Vrms = 115 V

R = 100 Ω

ϕ = 0

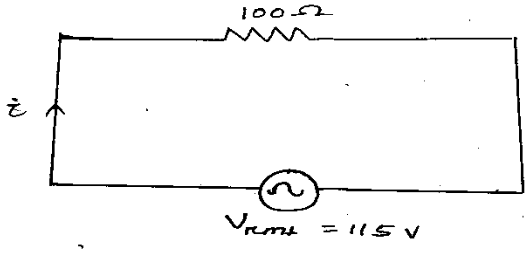
Required data:

(i) Write V and I time equation

(ii) Show V and I time diagram

(iii) Show V and I Phasor diagram

Ans:



(i) We know

Vm= Vrms× √2 =115 × √2 = 162.63 V

ω = 2¶ × f = 2¶ × 60 = 376.99 = 377 rad/s

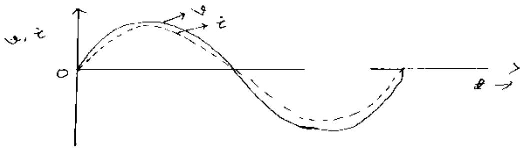
So the time equation for the voltage ,

V(t) = 163 sin377t (Ans)

Then we know i(t) = Im sinωt

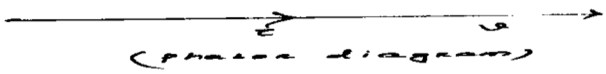
Im = Vm/R = 163 /100 = 1.63 A

So the time equation for the current ,
i(t) = 1.63 sin377t (Ans)
(ii)



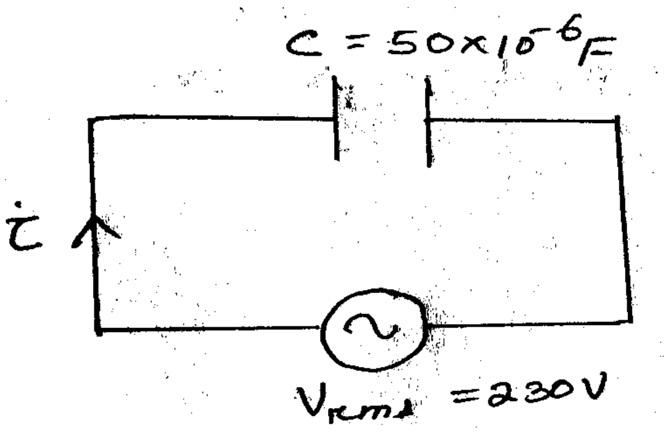
wave diagram or time diagram

(iii)



Q -2 : The reactance of a capacitor at 50 Hz is 5 Ω.If the frequency is increased to 100 Hz .Calculate the new capacitive reactance .
Solution :
Given data:
X_C = 5 Ω
f = 50 Hz
R = 5 Ω
Required data:
X_C1= ?
Ans:
X_C = 1/2¶fc
=> C = 1/(2¶×f× XC)
=> C = 1/(2¶×50×5) =0.00063 F
X_C1 = 1/(2¶×100×0.00063) = 0.25 Ω (Ans)

Q-3 : A 50 μF capacitor is connected across a 230 V, 50 Hz supply .Calculate (a) the reactance offered by the capacitor (b) the maximum current and (c) the rms value of the current drawn by the capacitor .
Solution:
Given data:
C=50μF=50×10-6F
Vrms=230V
f=50Hz
Required data:
(a) X_C=? (b) Im=? (c) Irms=?



Ans:

We know,

(a) X_C=1/2¶fc=1/(2¶×50×50×10-6)=63.66 Ω (Ans)

(b) Vm=Vrms×√2=325.26 V

Im=Vm/X_C=325.26/63.66=5.10Ω (Ans)

(c) Irms= Im/√2=5.10/√2=3.61 A (Ans)

Q-4 A choke coil takes 4A from AC source of 20V and 50Hz .The power factor of the coil is 0.8 lagging .Find the resistance and inductance of the circuit .

Solution:

Given data:

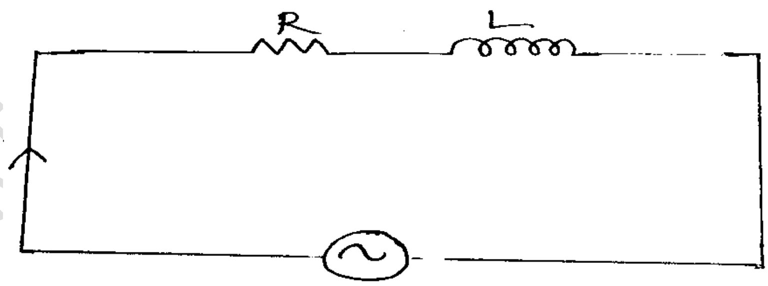
R-L series circuit

I=4A ,V=20V ,f=50Hz ,pf=0.8(lagging)

Required data:

(a) R=? (b) L=?

Ans:



(a) we know ,Z=V/I=20/4=5 Ω,

cosØ= R/Z =>R=ZcosØ=5×0.8=4Ω (Ans)

$Z^2=R^2+X_L^2$

$=>5^2=4^2+X_L^2$

$=>X_L^2=25-16$

$=>X_L=\sqrt{9}=3Ω$ (Ans)

$X_L = \omega L = 2¶fL$

$=> L = X_L/2¶f = 3/(2¶\times50) = 0.0095$ H (Ans)

Q-5 A pure resistance of 50Ω is in series with a pure capacitance of 100µF.The series combination is connected across 100V,50Hz supply.Find (a) the impedance (b) current (c) power factor (d) phase angle (e) voltage across resistor (f) voltage across capacitor.

Solution:

Given data:

V=100V

f=50Hz

$C=100\mu F=100\times10^{-6}F$

R=50Ω

$C=100\mu F=100\times10^{-6}F$

Required data:

(a) Z=?

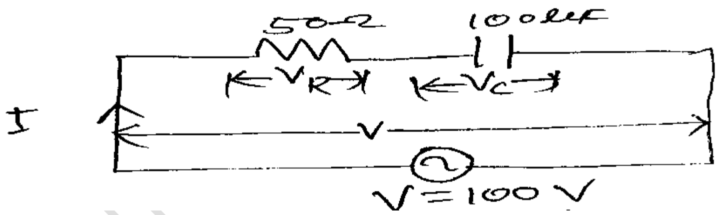
(b) I=?

(c) pf=?

(d) ϕ=?

(e) VR=?

Ans:



We know,

$X_C = \frac{1}{2\pi fc} = \frac{1}{2\pi\times50\times100^{-6}}$ =31.83 Ω

(a) Z= $\sqrt{R^2 + {X_c}^2} = \sqrt{50^2 + 31.38^2}$ = 59.27Ω (Ans)

(b) I=V/Z=100/59.27=1.687 A (Ans)

(c) p.f= R/Z=50/59.27=0.843 (Lead) (Ans)

(d) $\phi=\cos^{-1}(0.843)=32.54^o$ (Ans)

(e) $V_R=IR=1.687\times50=84.35$ V (Ans)

(f) $V_C=IX_C=1.687\times31.83=53.69$ V (Ans)

Q-6 A series circuit consists of resistance of 10Ω and inductive reactance of 50Ω and capacitive reactance of 30Ω.It is connected to a 230V,50Hz ac supply.calculate (i) the

current(ii) active and reactive power consumed (iii) power factor(iv)apparent power of the circuit .

Solution:

Given data: **Required data:**

R-L-C series circuit (i) I=?

$R=10\Omega$ (ii) $\cos\phi$=?

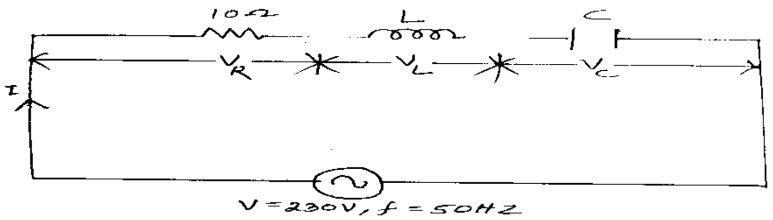
$X_L=50\Omega$ (iii) P=? and Q=?

$X_C=30\Omega$ (iv) S=?

V=230V

f=50Hz

Ans:



We know,

$Z=\sqrt{[R^2+(X_L-X_C)^2]}=\sqrt{[10^2+(50-30)^2]}=\sqrt{(100+400)}=\sqrt{500}=22.36$, Ω

(i) I=V/Z=230/22.36=10.28A (Ans)

(ii) $\cos\phi$=R/Z=10/22.36=0.44(lagging) (Ans)

$\phi=\cos^{-1}(0.44)=63.89^0$

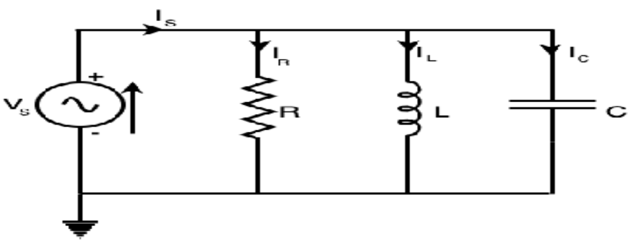
(iii)Active power, P=VI $\cos\phi$=230×10.28×0.44=1040.33=1.043 KW (Ans)

Reactive power ,Q=VI $\sin\phi$=230×10.28×sin 63.89=2123.11 VAR=2.123 KVAR (Ans)

(iv) Apparent power ,S = $\sqrt{(P^2+Q^2)}=\sqrt{(1.043^2+2.123^2)}$=2.36 KVAR(Ans)

<u>AC through R-L-C parallel circuit:</u>

Consider a RLC circuit in which resistor, inductor and capacitor are connected in parallel to each other. This parallel combination is supplied by voltage supply, V as shown in Fig. In series RLC circuit, the current flowing through all the three components i.e the resistor, inductor and capacitor remains the same, but in parallel circuit, the voltage across each element remains the same and the current gets divided in each component depending upon the impedance of each component. That is why parallel RLC circuit is said to have dual relationship with series RLC circuit. The total current is drawn from the supply is equal to the vector sum of the resistive, inductive and capacitive current, not the mathematical sum of the three individual branch currents, as the current flowing in resistor, inductor and capacitor are not in same phase with each other; so they cannot be added arithmetically



Let V be the supply voltage;

I_S =total source current;

I_R, =current flowing through the resistor;

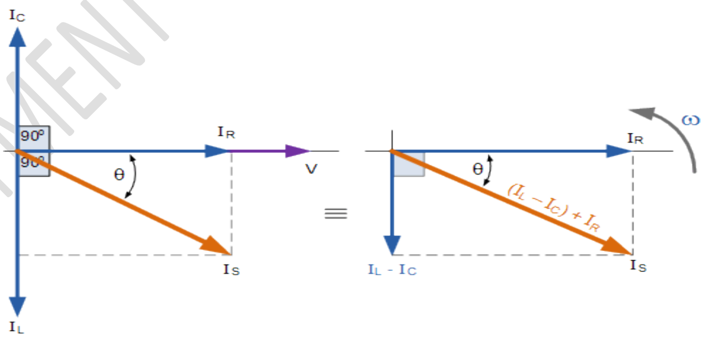
I_C, =current flowing through the capacitor;

I_L, =current flowing through the inductor; and

θ =phase angle difference between supply voltage and current

Phasor Diagram of Parallel RLC Circuit

For drawing the phasor diagram of parallel RLC circuit, voltage is taken as reference since voltage across each element remains the same and all the other currents i.e. IR, IC, IL are drawn relative to the voltage vector. In case of resistor, voltage and current are in same phase; current vector IR is drawn in same phase and direction to voltage. In case of capacitor, current leads the voltage by 90^0, so drawing IC vector leading voltage vector, V by 90^0. For inductor, current vector IL lags voltage by 90^0 so drawing IL lagging voltage vector, V by 90^0. The resultant of IR, IC and IL i.e. current IS at a phase angle difference of θ with respect to voltage vector, V as shown in below Fig.



We can see from the phasor diagram above that the current vectors produce a rectangular triangle, comprising of hypotenuse I_S, horizontal axis I_R and vertical axis $I_L – I_C$ Hopefully you will notice then, that this forms a Current Triangle. We can therefore use Pythagoras's theorem on this current triangle to mathematically obtain the individual magnitudes of the branch currents along the x-axis and y-axis which will determine the total supply current I_S of these components as shown.

Current Triangle for a Parallel RLC Circuit

$$I_S^2 = I_R^2 + (I_L - I_C)^2$$

$$I_S = \sqrt{I_R^2 + (I_L - I_C)^2}$$

$$I_S = \sqrt{(\frac{V}{R})^2 + (\frac{V}{X_C} - \frac{V}{X_C})^2}$$

Three phase circuit:

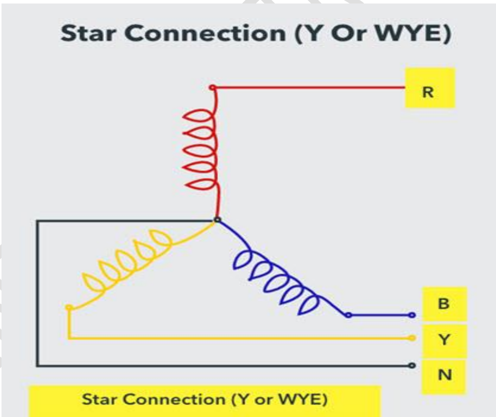
The three-phase system consists of a three-phase voltage source connected to a three-phase load by means of transformers and transmission lines

Star and Delta Connection:

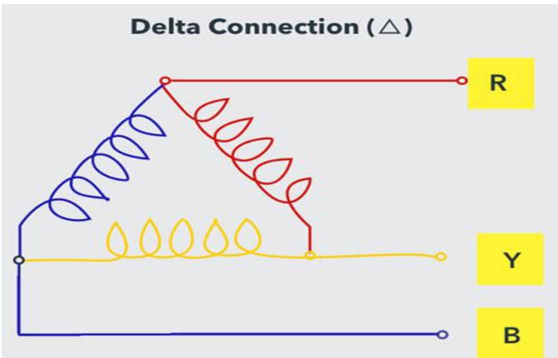
The three phase circuits can be connected in two ways.

Star connection:

In star connection as shown in above Fig. three ends of a coil or resistance are shorted together to make point N. This junction acts as a neutral point. Remaining three ends named as R, Y and B are the supply terminals.



Delta connection In delta connection two ends, one from one coil or resistance and, other from other coil or resistance are joined together. Thus, it forms three junctions as shown in Fig.. Three junctions named as R, Y and B are the supply terminals



Relationship between Line and Phase Values of Voltages and Currents

In case of three phase connection, the voltage between two outer conductors or lines is called 'Line voltage'. It is denoted by V_L. The voltage across each coil or phase is called 'phase voltage'. It is denoted by V_p. Similarly, the current flowing in outer conductor or line is called 'Line current'. It is denoted by IL. The current flowing in a coil or phase is called 'phase current'. It is denoted by I_p. All these are shown in Fig. and it will help in finding the relation between V_L and V_p, I_L and I_p in case of star and delta connections.

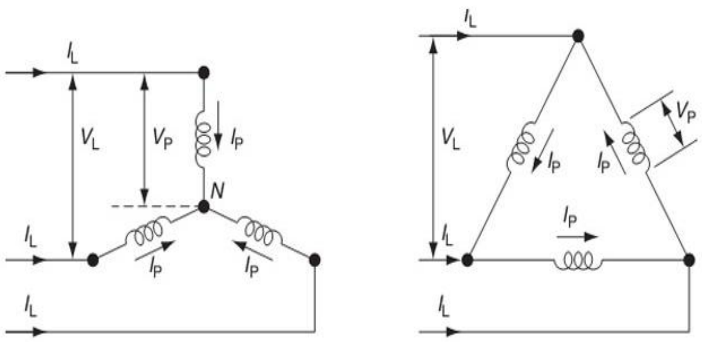
Star connection

In star connection as shown in Fig, it is seen that line current is equal to phase current . $I_L = I_p$.

Regarding voltage, Line voltage is equal to √3 times the phase voltage

i.e. $V_L = \sqrt{3}\, V_p$ or $V_p = V_L / \sqrt{3}$

Also, phase current current $I_p = \dfrac{\text{Phase voltage } (V_p)}{\text{Impedance per phase } (Z)}$



Delta connection

For delta connection as shown in above Fig, it is seen that line voltage equal to phase voltag

. $V_L = V_p$

Regarding voltage, Line current is equal to √3 times the phase current
i.e. $I_L = \sqrt{3}\, I_p$ or $I_p = I_L / \sqrt{3}$

Also, phase current current $I = \dfrac{\text{Phase voltage } (V_p)}{\text{Impedance per phase } (Z)}$

Power in Three Phase Connection

The power consumed in each phase for star and delta connections is $V_p\, I_p \cos\varphi$.

The total power in the circuit is the sum of the three phase powers.

∴ Total power consumed is given by $W = 3\ V_p\ I_p\ cos\varphi$.

Now $I_p = I_L$; $V_p = V_L /\sqrt{3}$ for star connection and $V_p = V_L$;

$I_p = I_L/\sqrt{3}$ for delta connection

Converting these phase values of V_p and I_p into line values i.e. V_L and I_L, the above expression for total power in both star as well as delta connection become $W = \sqrt{3}\ V_L I_L\ cos\ \phi$.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER:

Q-1 Define AC current.
Ans: The type of current in which magnitude and direction changes with time periodically is called as AC.

Q-2 Define frequency. [S-18]
Ans: The number of cycles per second is called the frequency of the alternating current.

Q-3 Define amplitude. [W-17]
Ans: The maximum value of positive or negative o an alternating quantity is known as its amplitude or peak value or crest value.

Q-4 Define time period.
Ans: Time taken by an alternating quantity to complete one cycle is called time period.

Q-5 Define form factor . [S-18,19]
Ans: It is defined as the ratio of rms value to average value of an alternating quantity.

Q-6 Define Amplitude factor or crest factor . [S-18,19]
Ans: It is defined as the ratio of maximum value to rms value of an alternating quantity.

Q-7 Define impedance.
Ans: It is the phasor sum of resistance and net reactance of the R-L-C series circuit.

Q-8 Define power factor. [S-19, W-19]
Ans: It is the cosine of angle made by phase voltage and phase current.
$\cos\phi = \frac{R}{Z}$

Q-9 Define active power.
Ans: It is the product of voltage and active component of current.
$P=VI\cos\phi$, W

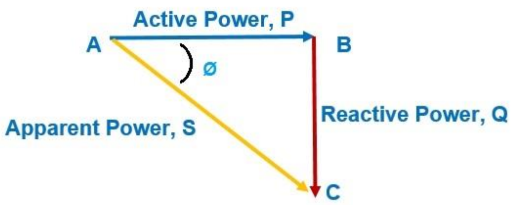
Q-10 Define reactive power.
Ans: It is the product of voltage and reactive component of current.
$Q = VI\sin\phi$, VAR

Q-11 Define apparent power .
Ans: It is the product of voltage and current .
S=VI ,VA

Q12: Name the different types of power in AC circuit and draw the power triangle.

A:

1. Active power
2. Reactive power.
3. Apparent Power.



POSSIBLE LONG TYPE QUESTIOS

Q-1 Write the difference between AC and DC. [W-19]

Q-2 : A 60 Hz voltage of 115 V (RMS) is impressed on a 100 Ω resistance .(i) Write the time equation for the voltage and the resulting current. Let the zero point of voltage wave be at t =0 .(ii) Show the voltage and current on a time diagram (iii) Show the voltage and current on a phasor diagram .

Q-3 The reactance of a capacitor at 50 Hz is 5 Ω. If the frequency is increased to 100 Hz .Calculate the new capacitive reactance.

Q-4 A 50 µF capacitor is connected across a 230 V, 50 Hz supply .Calculate (a) the reactance offered by the capacitor (b) the maximum current and (c) the rms value of the current drawn by the capacitor.

Q-5 A series circuit consists of resistance of 10Ω and inductive reactance of 50Ω and capacitive reactance of 30Ω.It is connected to a 230V, 50Hz ac supply. Calculate (i) the current (ii) active and reactive power consumed (iii) power factor (iv) apparent power of the circuit.

Q.6 Explain a.c through R-C series circuit. [S-18,19]

Q.7 Explain a.c through R-C series circuit. [S-18]

Q.8: A pure resistance of 50 ohm is in series with a pure capacitance of 100 uf. The series combination is connected across 100V, 50Hz Supply. Find

a) Impedance, b) Current, c) Power factor, d) Phase angle, e) Voltage across resistor, capacitor and draw the phasor diagram. [W-24]

Q9: Describe the voltage & Current relationship in star delta connection. [W-24]

Unit- VI

Transformer and Machines

Learning Objectives:

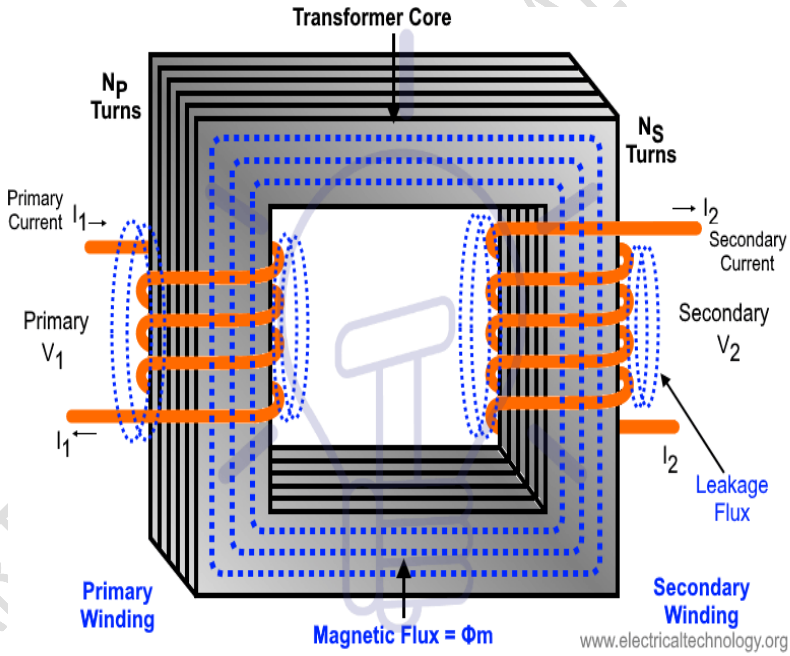
General construction and principle of different type of transformers; Emf equation and transformation ratio of transformers; Auto transformers; Construction and Working principle of motors; Basic equations and characteristic of motors.

Definition:-

It is defined as a static electrical device which transfer electrical energy or power from one circuit to another circuit through a magnetic medium with same frequency.

Working principle

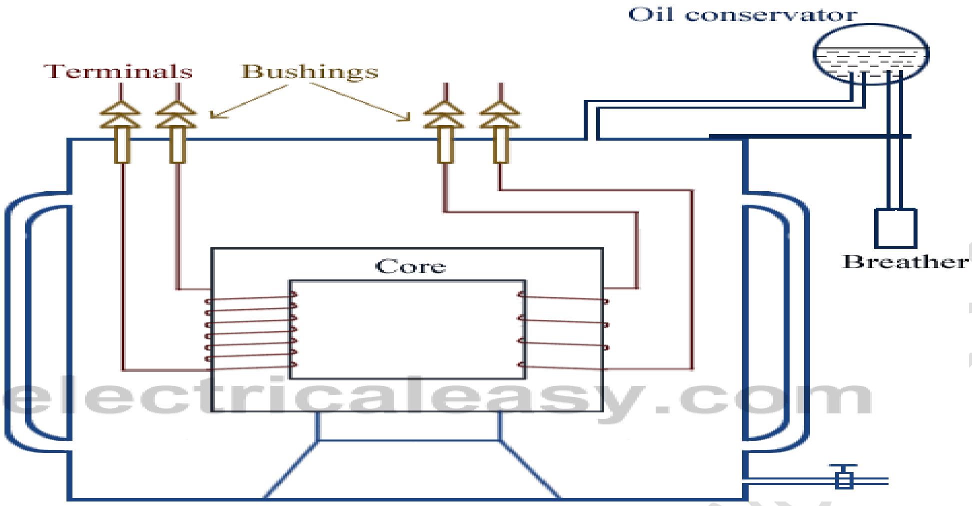
It works under the principle of mutual induction.



In a transformer basically their are two windings which are wound in a common magnetic core. The winding which is connected to the supply is known as primary winding from which the power is taken is known as secondary winding i.e load is connected in this secondary winding.

When single phase AC supply is given to the primary winding a current is flowing through the winding which produces an alternating flux which link with the primary coil it self and produces an induce e.m.f (E_1) or back e.m.f Then the flux passes through the core and link with the secondary winding and induced voltage (E_2).This voltage $E_2$is known as mutual induced e.m.f.

Constructional feature of Transformer.



Following are the important parts of a transformer-

- Windings
- Core
- Tank
- Conservator
- Breather
- Bushings

Winding:-

The winding are made up of copper wire in the form of rectangular or circular shape.

Core:-

The core is constructed from sheet steel laminations in the form of rectangular shape. The steel is of high silicon contain to reduce the hysteresis loss. It is laminated to reduce the eddy currentloss.

Tank:-

After winding the transformer is kept inside a tank which is made of sheet steel and is air tight inside the tank some insulating oil is kept so that the core of the transformer is not electrically contact with the tank. The additional function of the oil is to cool the winding.

Conservator:-

In the top of the tank there is a small cylindrical tank known as conservator. When the transformer oil heat it expand so for expansion of the oil the conservator is required.

Breather:-

For expansion and contraction or compression of oil in the conservator a breather is kept on the top of the conservator. In the breather some silica gel are kept to observe moisture and dust from the atmosphere and allow pure air into the tank.

Bushings:-

The transformer winding which are kept inside the tank are brought out of the tank through the bushings. These bushings are either porcelain or oil field or capacitor type.

Arrangement of core & winding in different types of transformer:

Types of transformers:-

The transformer can be divided into various types various types in various ways

According to construction – It is divided in two types

1. Core type transformer.
2. Shell type transformer.

Core type transformer:-

If in a transformer cores are surrounded by the winding then it is called as core type transformer.

Example- In generating stations, grids and distribution purposes

Shell type transformer:-

If in a transformer windings are surrounded by the cores then it called as shell type transformer.

Example- Stabilizers and application in all electronic circuits.

According to voltage – The transformer is divided into two types

1. Step up transformer
2. Step down transformer.

Step up transformer:

- It is defined as a transformer which makes low voltage into high voltage.

Condition-

$E2>E1$ & $N2>N1$

Application:-

It is used in generating stations and transmission lines.

Step down transformer:-

It is defined as a transformer which makes high voltage into low voltage.

Condition-

$E1>E2$ & $N1>N2$

Application:-

It is used in secondary transmission and distribution purposes.

Derivation of EMF equation:

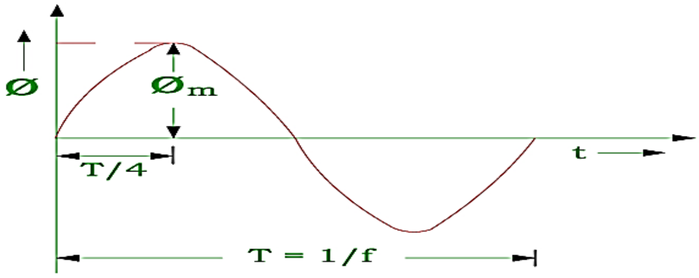


FIG A : AN ALTERNATING FLUX WAVEFORM

Let,

V_1=supply voltage to the primary, V

V_2=secondary terminal voltage, V

N=No. of turns in the winding.

N_1=No. of turns in the primary windings.

N_2= No. of turns in the secondary windings.

E_1=Primary induced e.m.f V

E_1=secondary induced e.m.f, V

f= frequency of the supply voltage, Hz

$(\varphi)_m$=Maximum flux in the core, Watt

When a voltage V1 is applied to the primary a flux $(\varphi)_m$ is produce. Whose nature is alternating (sinusoidal) as in figure?

The flux will be maximum after T/4 sec i.e 1/(4f) sec.

The change in flux to achieve maximum flux i.e $d\varphi=\varphi_m$

The change in time dt=1/4f

According Faraday's laws of electromagnetic induction, the average induced e.m.f for N no. of turns is given by.

$$e = N (d\varphi/dt)$$
$$=N\times\varphi_m/(1/4f)$$

$$e = 4f\varphi_m N$$

R.M.S value of e.m.f,

$$E_{rms}=\text{Form factor} \times \text{Avg e.m.f}$$

$$=F.\ f \times e$$

$$E=1.11\times 4f\,\varphi_m N$$

$$\Rightarrow E=4.44f\,\varphi_m N,\ V$$
Now $E_1=4.44f\,\varphi_m N_1$,V (for primary)
& $E_2=4.44f\,\varphi_m N_2$,V (for secondary)

Transformation ratio of transformer:

Let,

E_1=primary induced e.m.f , V

E_2=secondary induced e.m.f ,V

V_1=primary supplied voltage, V

V_2=secondary load voltage, V

I_1= primary current, A

I_2=Secondary current,A

N_1=primary no. of turns.

N_2=Secondary no. of turns.

K= Transformation Ratio.

From e.m.f equation we know that

$E_1 \alpha N_1$

$E_2 \alpha N_2$

=> $E_2/ E_1 = N_2/N_1$--------- (1)

In an Idea transformer,

$E_1 = V_2$& $E_2 = V_2$

=> $E_2/E_1 = V_2/V_1$ -------------- (2)

Again in an ideal transformer losses are neglected.

Hence input power=Output power

$V_1 I_1 = V_2 I_2$

=>$V_2/V_1 = I_1/I_2$ ------------- (3)

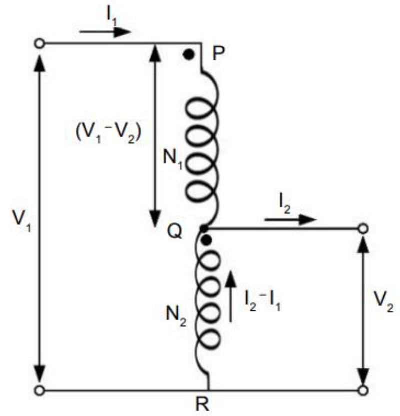
Comparing equation (1),(2)&(3)

we get,

$E_2 /E_1 = V_2/V_1 = N_2/N_1 = I1/I_2 = K$

Autotransformer

A transformer in which a part of the winding is common to both the primary and secondary circuit is known as an auto transformer. The primary is electrically connected to the secondary as well as magnetically coupled to it as shown in below Fig. Unlike a two winding transformer, an autotransformer is not electrically isolated.



PR is the primary winding having N_1 turns and QR is the secondary winding having N_2 number of turns. The input voltage and current are V_1 and I_1 and the output voltage are V_2 and I_2

respectively. If the internal impedance drop &losses are neglected, then V1 $I_1 = V_2 I_2$ or

$$V_2/V_1 = N_2/N_1 = I_1/I_2 = K$$

Power Transfer Formula:

1. Power transferred Inductively $= V_2(I_2 - I_1)$
   $= V_2(I_2 - I_2 K)$
   $= V_2 I_2 (1-K)$
   $= V_1 I_1 (1-K)$ (where in ideal case $V_2 I_2 = V_1 I_1$)
   $= P_1 (1-K)$
2. Power Transferred Conductively =input - Power transferred Inductively
   $= P_1 - P_1 (1-K) = P_1 K$

Uses of Auto transformer:

An auto transformer is used

i) In Electric locomotives to control equipment's

ii) In Transmission lines as 1:1 transformer

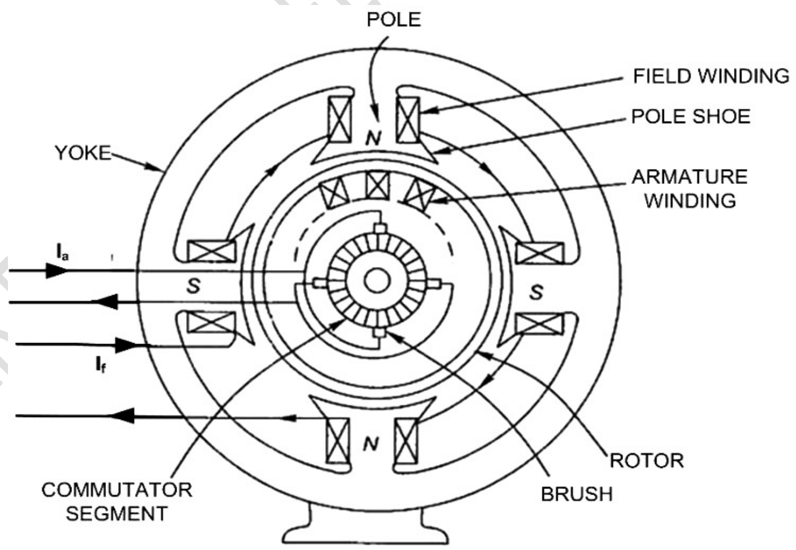
iii) As starter in 3-phase induction motor

iv) As furnace transformer

DC Motor:

An electric motor is a machine which coverts electrical energy into mechanical energy. If the electric energy is supplied in form of DC supply, the motor is called DC motor.

Construction of DC Motor:



The field poles of a DC machine are located on the stator. The iron poles are projected inwards from the inside surface of the cylindrical shaped magnetic core called the stator yoke. The yoke serves as a return path for the magnetic flux. The iron pole consists of a narrow portion on which the field winding coils are placed. A pole shoe usually laminated distribute the pole flux over the rotor surface. The rotor or armature made of cylindrical silicon steel core consists of a stack of slotted laminations. The slots are cut on the surface of the laminated core along the axial length of the core, in which the coil sides of the armature winding are placed. The coils in the form of conductor wire or bars are made of copper or aluminum and the conductor size depends on the current and voltage requirement of the machine. The armature coils are held in place by wood wedges driven into the slot along the slot length. The coil terminal ends are connected to the Commutator. The Commutator consists of segments made of copper, the segments separated from each other by insulating material usually mica. The current is conducted to the armature coils by carbon brushes. The brushes are held in brush holder and is fitted in such a way that they should slide freely over the Commutator surface. To maintain proper contact between the brush contact and Commutator, adjustable springs are placed in the brush holder assembly to ensure the contact force.

Principle of DC Motor

The principle on which the DC motors work is based on Fleming's left hand rule. When a current carrying conductor is placed in a steady magnetic field, such that the conductor makes right angle with the field, it experiences a mechanical force, whose direction is given by the Flemings left hand rule. The movement of the conductor is in the direction of force. In short, when electric fields and magnetic fields interact, a mechanical force arises. The magnitude of the mechanical force in Newton experienced by the conductor is given by eq.

$$F = BIL$$

where, B is the field strength in Wb/m2 , I is the current flowing through the conductor in amperes and L is the length of conductor in metres.

Working of a DC Motor

When direct current is passed through armature and field-winding of a DC motor, magnetic flux is established by the field current (Ampere turns). Since the armature conductors are perpendicular to the magnetic field and they are carrying current, they experience mechanical force. The resultant of these forces is a torque. Under the influence of this torque rotor starts rotating. Any mechanical device(load) coupled to it does useful work. If the mechanical load is increased more torque will be produced by drawing more current from DC supply. Thus motor converts electrical energy into mechanical energy.

Back EMF:

When armature of a motor rotates, an emf is induced in the conductors as they cut the lines of magnetic force. The induced emf is in opposition to the applied voltage (V) and is called back or counter emf (E_b).

Its magnitude is given by $E_b \propto Ø N$

where Ø is the field flux and N the armature speed

Types of DC Motors

Depending on the nature of connection of armature winding and field windings,

DC motors can be classified into two types:

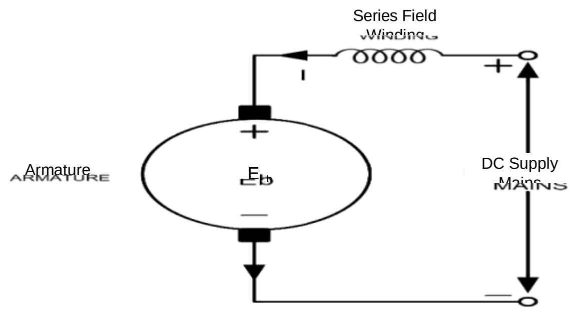
I DC series motor

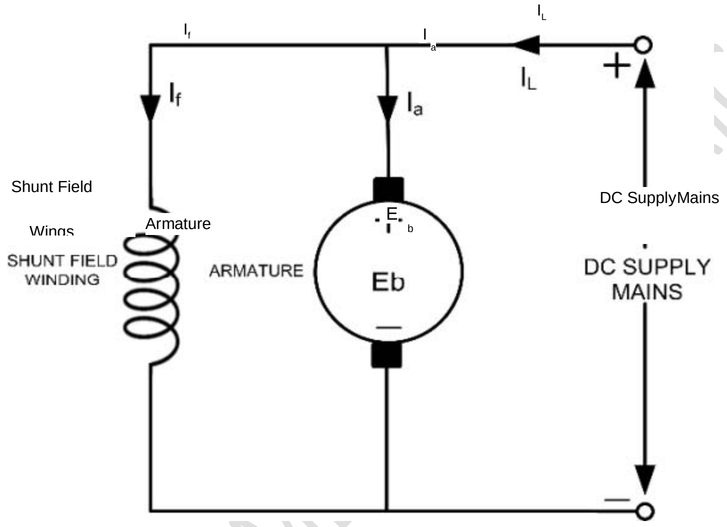
ii. DC shunt motor

Another type of DC motor is the DC Compound motor, in which field winding is connected in series as well as in parallel

. i. DC series motor: A series motor is one in which field winding is connected in series with the armature in that the current drawn by the motor passes through the field winding as well as armature Field winding has a few turns of thick conductors. Magnetic flux varies with current till saturation.

i. DC shunt motor: A shunt motor is one in which the field winding consisting of large number of turns of comparatively thin wire is connected in parallel with armature . In the case of shunt motor, the field current is costant because of the DC supply is constant. Therefore, flux remains practically constant.





Characteristics of DC Motors

The two most important characteristic of a DC motor are the torque characteristics

. Torque Characteristic (T vs. I_a):

The torque characteristic represents the variation of torque with armature current. The torque developed in a motor is the result of the interaction between the magnetic flux produced by field current and the current flowing through armature conductor. If the magnetic flux increases due to increase in field current, torque produced for the same armature current will increase

i.e. T α Ø for I_a constant. Similarly, if the armature current increases because of increase in shaft load, then also torque will increase for the same value of magnetic flux

i.e. T α I_a for Ø constant. Now if both Ø and Ia are changing then in general, it can be written as $T \alpha ØI_a$

DC series motor:

The torque equation is given as $T \alpha ØI_a$. For a series motor the same current flows in the field winding as well as in the armature winding. So, up to magnetic saturation, the field flux $Ø \alpha Ia$ and therefore the torque developed is $T \alpha (Ia)^2$ This means that the torque is proportional to square of the current up to magnetic situation.

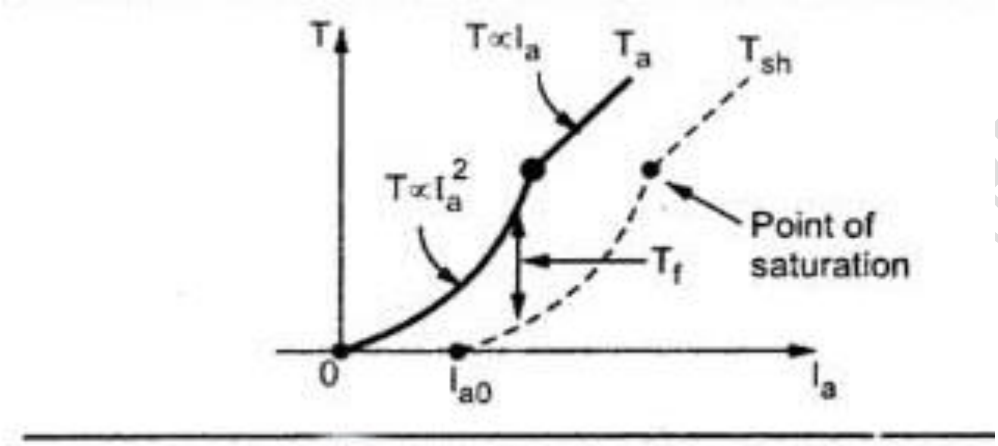
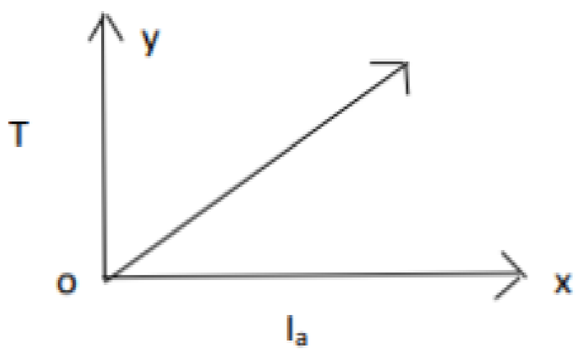


Fig. (a) T Vs I_a for series motor

This part of the characteristic is a parabola. However, after magnetic saturation, T / Ia curve becomes straight line because flux Ø becomes independent of armature current and hence torque increases with armature current only. The characteristic curve is shown above Fig. Since the torque is proportional to the square of current, the starting torque is extremely high. The high starting torque is advantageous for certain applications. Hence DC series motors are used where large starting torque is required.

DC Shunt motor:

In case of a DC shunt motor, the flux Ø is constant Hence the torque $T \alpha ØI_a$ is directly proportional to the armature current, whatever the speed may be. As armature current (Ia) increases, torque (T) increases and vice-versa. Below Fig. shows the torque characteristic of a DC shunt motor.



Uses of different types DC motors:

Name of DC motor	Applications
Shunt motor	➢ Centrifugal pumps. ➢ Machine tools. ➢ Blowers and fans. ➢ Reciprocating pumps.
Series motor	➢ Electric locomotives. ➢ Rapid transit system. ➢ Cranes and hoists. ➢ Trolley cars. ➢ Conveyors
Compound motor	➢ Shears and punches. ➢ Elevators. ➢ Rolling mills. ➢ Ice machines. ➢ Air compressors. ➢ Printing press.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

Q-1 Write down the various parts of dc motor. [W-16, 17, 18]

Ans: The various parts of dc machines are:

- Eye bolt
- Yoke
- Field winding
- Pole shoes
- Field pole
- Armature conductors and windings
- Armature
- Commutator
- Carbon brush

Q2. What is use of an auto transformer?

Ans: An auto transformer is used

i) In Electric locomotives to control equipment's

ii) In Transmission lines as 1:1 transformer

iii) As starter in 3-phase induction motor
As furnace transformer

Q-4 Write down the DC motor which is used as a reciprocating pumps.
Ans: DC shunt motor.

Q.7 Why Commutator is used in D.C motor? [S-18]
Ans: Commutator is used in D.C machines because it converts a.c to d.c in d.c generator and d.c to a.c in d.c motor.

Q8. Write down the EMF equation of transformer. [W-24]
A: $E=4.44f\phi mN$
Where, f = Frequency.
Φ = Maximum magnetic flux.
N = Number of turns.

POSSIBLE LONG TYPE QUESTIOS

Q-1 Write the classification of DC motor with circuit diagram. [W-17]

Q-2 Explain various parts and working of single -phase Transformer

Q 3.What is an auto transformer, explain with a neat diagram?

Q.4 a single phase transformer has 400 primary and 1000 secondary winding turns. The cross sectional area of the core is 60 cm2. Determine the peak value of the flux density in the core if the primary supply voltage is 500V, with frequency = 50 Hz.

Q5. With neat diagram explain the working principle of DC motor. [W-24]

Q6. Derive the basic equation of different types of DC motor. [W-24]