**R22**

**Code No: 181AB**

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD**
**B. Tech I Year I Semester Examinations, March/April - 2023**
**BASIC ELECTRICAL ENGINEERING**
**(Common to CSE, IT, CSIT, CE(SE), CSE(CS), CSE(DS), CSD)**

**Time: 3 Hours** **Max. Marks: 60**

**Note:** This question paper contains two parts A and B.
i) **Part- A** for 10 marks, ii) **Part - B** for 50 marks.

- Part-A is a compulsory question which consists of ten sub-questions from all units carrying equal marks.
- Part-B consists of **ten questions** (numbered from 2 to 11) **carrying 10 marks each**. From each unit, there are two questions and the student should answer one of them. Hence, the student should answer five questions from Part-B.

**PART- A**

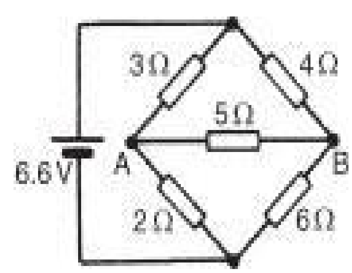
**(10 Marks)**

1.a) What is ideal voltage source? [1]
b) Define KVL. [1]
c) What is active power? [1]
d) Define average value of sinusoidal quantity? [1]
e) What is a step up Transformer? [1]
f) Define regulation of a transformer. [1]
g) What type of material is used for brushes of a d.c machine? [1]
h) How many windings are present at the time of starting a single phase Induction motor? [1]
i) What is the full form of M.C.C.B? [1]
j) What is the energy consumed by 1000 watts heater in 3 hours? [1]

**PART-B**

**(50 Marks)**

2.a) State and explain Thevenin's theorem.
b) For the bridge network shown in figure below, find the current in the 5 resistor, and its direction, by using Thevenin's theorem. [5+5]



3.a) Derive an expression for transient current in R-L series circuit excited by a d.c source.
b) Explain the V-I relation of R, L and C elements. [6+4]

4. The following table gives the corresponding values of current and time for a half cycle of alternating current.

| Time t (msec) | 0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Current i (A) | 0 | 7 | 14 | 23 | 40 | 56 | 68 | 76 | 60 | 5 | 0 |

Assuming the negative half cycle is identical in shape to the positive half cycle, plot the waveform and find (a) the frequency of the supply, (b) the instantaneous values of current after 1.25 ms and 3.8 ms, (c) the peak or maximum value, (d) the mean or average value, and (e) the r.m.s value of the waveform. [10]

**OR**

5.a) Derive an expression for resonance frequency of R-L-C series circuit connected to an alternating supply of variable frequency.
b) A coil has an inductance of 40 mH and negligible resistance. Calculate its inductive reactance and the resulting current if connected to a 240 V, 50 Hz supply. [6+4]

6.a) Derive an e.m.f equation of a single phase transformer.
b) A 4500 V/225 V, 50 Hz single-phase transformer is to have an approximate e.m.f. per turn of 15 V and operate with a maximum flux of 1.4 T. Calculate (i) the number of primary and secondary turns and (ii) the cross-sectional area of the core. [6+4]

**OR**

7.a) What is an Auto transformer? Give its advantages and state its applications.
b) What are the advantages of 3-phase transformers? Draw various schemes of 3-phase transformer connections. [5+5]

8.a) Explain the constructional details of a d.c machine. Explain the working of a d.c generator.
b) Draw the various characteristics of a d.c shunt motor. [6+4]

**OR**

9.a) Explain the working of a 3-phase Induction motor with a neat sketch.
b) The stator of a 3-phase, 4-pole induction motor is connected to a 50 Hz supply. The rotor runs at 1455 rev/min at full load. Determine (i) the synchronous speed and (ii) the slip at full load. [6+4]

10.a) Explain the working of (i) SFU (Switch Fuse Unit) (ii) ELCB.
b) What are the advantages of improving the power factor of a system? [6+4]

**OR**

11.a) What are the differences between primary cells and secondary batteries?
b) Explain different types of wires used in domestic as well as commercial buildings. [4+6]

**--ooOoo–**

# Answer Key

## PART – A

**1.a) What is ideal voltage source?**

An ideal voltage source is a fundamental concept in electrical engineering that helps in the theoretical analysis of circuits by providing a simplified model of a voltage source with a constant voltage, zero internal resistance, and infinite current supply capability.

**1.b) Define KVL.**

Kirchhoff's Voltage Law is a cornerstone in the field of electrical engineering, providing a critical framework for understanding and analyzing the behavior of electrical circuits. It ensures that the conservation of energy principle is maintained within electrical loops, facilitating accurate predictions and designs of electronic and electrical systems.

**1.c) What is active power?**

Active power is the key component of electrical power that is responsible for performing actual work in electrical systems. It is essential for the operation of all electrical devices and is a critical factor in energy efficiency, system design, and electrical billing. Understanding active power and its calculation helps in optimizing the performance and cost-effectiveness of electrical systems.

**1.d) Define average value of sinusoidal quantity?**

The average value of a sinusoidal quantity, such as voltage or current, over one complete cycle is a measure of the arithmetic mean of all instantaneous values of the waveform over that period. For a pure sinusoidal waveform, the average value over a full cycle is zero because the positive half-cycle exactly cancels out the negative half-cycle.

**1.e) What is a step up Transformer?**

A step-up transformer is an electrical device used to increase (step up) the voltage from its primary winding to its secondary winding while decreasing the current. This type of transformer is essential in various applications, particularly in power distribution, where it is necessary to transmit electrical power over long distances efficiently.

**1.f) Define regulation of a transformer.**

Regulation of a transformer refers to the ability of the transformer to maintain a constant secondary voltage as the load varies from no load to full load. It is an important parameter that indicates the performance and efficiency of the transformer under different loading conditions.

**1.g) What type of material is used for brushes of a d.c machine?**

The brushes of DC machines are primarily made from carbon, graphite, metal-graphite, or electrographite. These materials are selected based on their electrical conductivity, wear resistance, lubricating properties, and suitability for the specific operational environment of the DC machine. The choice of brush material ensures efficient and reliable performance of the DC machine while minimizing maintenance and operational issues.

**1.h) How many windings are present at the time of starting a single phase Induction motor?**

At the time of starting a single-phase induction motor, there are two windings involved: the main (run) winding and the starting (auxiliary) winding. The combination of these two windings, along with the starting mechanism (capacitor, high resistance, shaded pole, etc.), creates the necessary phase shift to produce the rotating magnetic field required to start the motor. Once the motor reaches its operating speed, the starting winding is typically disconnected, leaving the main winding to carry the load.

**1.i) What is the full form of M.C.C.B?**

The full form of M.C.C.B. is Moulded Case Circuit Breaker.

An M.C.C.B. is a type of electrical protection device that can automatically switch off electrical circuits during abnormal conditions, such as overloads or short circuits.

M.C.C.B.s play a crucial role in ensuring electrical safety and reliability in both residential and industrial power distribution systems.

**1.j) What is the energy consumed by 1000 watts heater in 3 hours?**

Energy=Power×Time

where:

Power (P) is given in watts (W).

Time (t) is given in hours (h).

Given:

Power (P) = 1000 watts

Time (t) = 3 hours

Energy=1000W×3h

Therefore, the energy consumed by the 1000-watt heater in 3 hours is 3000 watt-hours (Wh) or 3 kilowatt-hours (kWh).

## PART – B

**2.a) State and explain Thevenin's theorem.**

Thevenin's Theorem is a fundamental principle in electrical engineering that simplifies the analysis of linear electrical circuits. It states that any linear electrical network containing several voltage sources and resistances can be replaced by a single voltage source $V_{th}$ in series with a single resistor $R_{th}$ , where $V_{th}$ is the Thevenin voltage and $R_{th}$ is Thevenin resistance. This equivalent circuit can be used to analyze the original circuit's behavior from the perspective of a load connected across its terminals.

Explanation of Thevenin's Theorem:

1.Thevenin Equivalent Circuit:

Thevenin's theorem allows us to replace a complex network of resistors and voltage sources with a simplified equivalent circuit consisting of a voltage source $V_{th}$ and a series resistor $R_{th}$.

$V_{th}$ is the open-circuit voltage at the terminals of the original network when all independent sources are turned off (replaced by their internal resistances).

$R_{th}$ is the equivalent resistance of the network as seen from the terminals after replacing all independent sources with their internal resistances and removing the load.

2. Steps to Determine Thevenin Equivalent:

Step 1: Determining $V_{th}$:

Disconnect the load from the terminals of the network.

Calculate the open-circuit voltage across the terminals where the load was connected.

This voltage is $V_{th}$.

Step 2: Determining $R_{th}$:

Turn off all independent sources (voltage sources replaced by short circuits, current sources replaced by open circuits).

Calculate the equivalent resistance seen from the terminals.

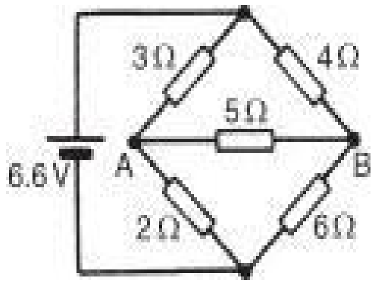
This resistance is $R_{th}$.

3.Application of Thevenin's Theorem:

Once $V_{th}$ and $R_{th}$ are determined, any load connected across the terminals can be analyzed as if it were connected to $V_{th}$ and $R_{th}$.

This simplification is especially useful in circuit analysis, allowing complex networks to be replaced by simpler equivalent circuits without affecting the accuracy of voltage or current calculations at the load.

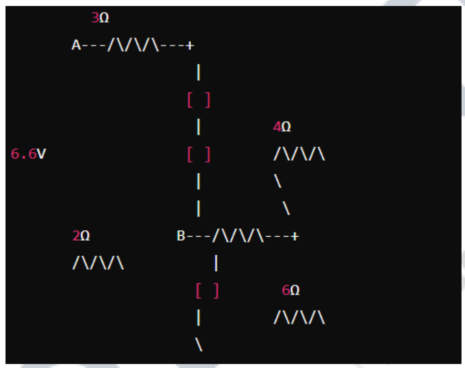
**2.b) For the bridge network shown in figure below, find the current in the 5 resistor, and its direction, by using Thevenin's theorem.**




Following are the steps to solve:

1. Remove the 5Ω Resistor

The modified circuit without the 5Ω resistor is as follows:




2.Find the Thevenin Equivalent Voltage ($V_{th}$)

The 5Ω resistor is open-circuited, and we calculate the voltage across points A and B using voltage division and Kirchhoff's laws.

3.Find the Thevenin Equivalent Resistance ($R_{th}$)

Replace the voltage source with a short circuit.

Calculate the equivalent resistance across A and B.

4.Reattach the 5Ω Resistor

5.Calculate the Current through the 5Ω Resistor

Use the formula:

$$I = \frac{V_{th}}{R_{th} + 5\Omega}$$

Detailed Calculations:

1.Open-Circuit Voltage ($V_{th}$):

Calculate $V_{AB}$: With the 5Ω resistor removed, use voltage division:

First find the voltage across the 3Ω and 4Ω resistors.
Then calculate the equivalent voltage at points A and B.

2.Thevenin Resistance ($R_{th}$)

Calculate $R_{th}$:Combine the parallel and series resistances.

Final Calculation:

After finding $V_{th}$ and $R_{th,}$ the current through the 5Ω resistor is:

$$I = \frac{V_{th}}{R_{th}+5\Omega}$$

This approach provides the current in the 5Ω5 \Omega5Ω resistor and confirms its direction through calculations using Thevenin's theorem.

**3.a) Derive an expression for transient current in R-L series circuit excited by a d.c source.**

To derive the expression for transient current in an R-L series circuit excited by a DC source, we'll consider the circuit elements and analyze how the current changes over time when the circuit conditions are altered, typically by switching or sudden changes in the applied voltage.

Circuit Elements and Initial Conditions:

DC Source: Provides a constant voltage $V_{DC}$.

Resistor (R): Resistance R.

Inductor (L): Inductance L.

Switch: Initially closed (at t=0,it opens).

Steps to Derive Transient Current Expression:

Circuit Description:

Before t=0: The switch is closed, and the DC source maintains a steady current through the series RL circuit.

At t=0: The switch opens, changing the circuit conditions suddenly.

Initial Conditions:

Before opening the switch, assume the circuit has reached a steady state where the current $I_{steady}$ is established due to the DC source.

After Switch Opens (Transient Phase):

When the switch opens at t=0, the circuit transitions into a transient state where the current changes due to the inductive properties of the inductor L.

Transient Current Expression:

The current I(t) in the circuit after the switch opens can be expressed as: $I(t)=I_{steady}e^{-Rt/L}$ where:

$I_{steady}$ is the steady-state current before the switch opened.

R is the resistance of the resistor R.

L is the inductance of the inductor L.

t is the time elapsed after the switch opens.

Derivation Outline:

Step 1: Before the switch opens, the current through the RL circuit is $I_{steady}=V_{DC}$ , where $V_{DC}$ is the DC voltage applied.

Step 2: After the switch opens, the inductor opposes the change in current, leading to a decay of current over time characterized by the time constant τ=L/R.

Step 3: Using Kirchhoff's Voltage Law (KVL) in the transient phase, $V_{DC}-L\,dI(t)/dt-IR=0$, solve for I(t) to obtain the exponential decay form.

**3.b) Explain the V-I relation of R, L and C elements.**

The V-I (Voltage-Current) relationships of R (Resistor), L (Inductor), and C (Capacitor) elements in electrical circuits describe how the voltage across and the current through each element are related. Here's an explanation of each:

1.Resistor (R):

V-I Relationship: For a resistor, the relationship between voltage (V) and current (I) is given by Ohm's Law:

V=IR where:

V is the voltage across the resistor,

I is the current flowing through the resistor,

R is the resistance of the resistor.

Characteristics:

The voltage across a resistor is directly proportional to the current through it.

Resists the flow of current equally at all frequencies (for DC and AC circuits).

2.Inductor (L):

V-I Relationship: For an inductor, the relationship between voltage (V) and current (I) is described by the equation: V=L dI/dt where:

V is the voltage across the inductor,

L is the inductance of the inductor,

dI/dt is the rate of change of current with respect to time.

Characteristics:

Induces a voltage across its terminals that opposes the change in current (inductive reactance $X_L=\omega L$ in AC circuits).

At steady state (DC), inductor behaves as a short circuit (low impedance).

In AC circuits, current lags behind the voltage by 90◦ in phase due to the reactive nature.

3.Capacitor C :

V-I Relationship: For a capacitor, the relationship between voltage (V) and current (I) is given by: I=C dV/dt where:

I is the current flowing into or out of the capacitor,

C is the capacitance of the capacitor,

dV/dt is the rate of change of voltage across the capacitor.

Characteristics:

Stores electrical energy in an electric field between its plates.

Blocks DC current (infinite impedance at DC).

In AC circuits, the current leads the voltage by 90◦in phase due to the capacitive reactance XC=1/ωC .

**4. The following table gives the corresponding values of current and time for a half cycle of alternating current.**

| **Time t (msec)** | **0** | **0.5** | **1.0** | **1.5** | **2.0** | **2.5** | **3.0** | **3.5** | **4.0** | **4.5** | **5.0** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Current i (A)** | **0** | **7** | **14** | **23** | **40** | **56** | **68** | **76** | **60** | **5** | **0** |

**Assuming the negative half cycle is identical in shape to the positive half cycle, plot the waveform and find (a) the frequency of the supply, (b) the instantaneous values of current after 1.25 ms and 3.8 ms, (c) the peak or maximum value, (d) the mean or average value, and (e) the r.m.s value of the waveform.**

Frequency of the Supply:

To find the frequency f of the supply:

The time period T of the waveform is the time between two consecutive zero crossings or peaks.

From the data, we observe the time period T from 0 ms to 3.5 ms (where current goes from 0 A to 76 A and back to 0 A).

Therefore, the time period T is 3.5 ms.

Now, calculate the frequency f:

$F=1/T=1/3.5\times10-3$

$f\approx285.7$ Hz

Instantaneous Values of Current

After 1.25 ms:Estimate the current value by interpolation.

At $t=1.0$ ms,$i=14$ A

At $t=1.5$ ms,$i=23$ A

Interpolating between these points:

$i(1.25\text{ ms})\approx14+(23-14)/0.5\times0.25=14+4.5=18.5$ A

After 3.8 ms: Estimate the current value by interpolation.

At $t=3.5$ ms, $i=76$ A

At $t=4.0$ ms, $i=60$ A

Interpolating between these points:

$i(3.8\text{ ms})\approx76-(76-60)/0.5\times0.2=76-3.2=72.8$ A

Peak or Maximum Value

From the data, the peak current $i_{peak}=76$ A.

Mean or Average Value

Calculate the mean current $i_{mean}$

$i_{mean}=\sum i/N=353/11\approx32.09$ A

RMS Value:

Calculate the RMS (Root Mean Square) value $i_{rms}$ :

$$i_{\mathrm{rms}} = \sqrt{\frac{1}{N}\sum_{k=1}^{N} i_k^2} = \sqrt{\frac{1}{11} \times (0^2 + 7^2 + 14^2 + \ldots + 0^2)}$$
$$i_{\mathrm{rms}} = \sqrt{\frac{1}{11} \times 18110} \approx 37.80 \text{ A}$$

Final output comes are:

Frequency of the supply: f≈285.7 Hz

Instantaneous current after 1.25 ms: ≈18.5 A

Instantaneous current after 3.8 ms: ≈72.8 A

Peak current: 76 A

Mean current: ≈32.09 A

RMS value of the waveform: ≈37.80 A

**5.a) Derive an expression for resonance frequency of R-L-C series circuit connected to an alternating supply of variable frequency.**

To derive the resonance frequency f of an R-L-C series circuit connected to an alternating supply, we need to consider the impedance characteristics of the circuit. Here's the step-by-step derivation:

R-L-C Series Circuit Impedance

The impedance Z of a series R-L-C circuit at a frequency f is given by:

$$Z = R + j(\omega L - \frac{1}{\omega C})$$

where:

R the resistance (in ohms)

L is the inductance (in henries)

C is the capacitance (in farads),

ω=2πf is the angular frequency.

Resonance Condition:

At resonance, the impedance Z is purely resistive, meaning the imaginary part of Z (reactive component) is zero:

$$\omega L - \frac{1}{\omega C} = 0$$

1.Deriving Resonance Frequency $f_0$

Equating Reactance: At resonance,

$$\omega L = \frac{1}{\omega C}.$$

2.Solve for ω:

$$\omega^2 = \frac{1}{LC}$$
$$\omega = \sqrt{\frac{1}{LC}}$$

3.Find $f_0$ : $f_0$ is the frequency corresponding to $\omega_0$.

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

Resonance Frequency $f_0$ Derivation Summary

The resonance frequency $f_0$ of an R-L-C series circuit is:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

This derivation shows how the resonance frequency depends on the inductance L and capacitance C of the circuit, highlighting its importance in electrical engineering for optimizing circuit performance at specific frequencies.

**5.b) A coil has an inductance of 40 mH and negligible resistance. Calculate its inductive reactance and the resulting current if connected to a 240 V, 50 Hz supply.**

To calculate the inductive reactance $X_L$ and the resulting current in the coil connected to a 240 V, 50 Hz supply, follow these steps:

Given:

Inductance (L): 40 mH = 0.04 H

Supply voltage (V): 240 V

Frequency (f): 50 Hz

Calculations:

Calculate Inductive Reactance($X_L$)

Inductive reactance ($X_L$)is given by:

$$X_L = 2\pi f L$$

Substitute the given values:

$$X_L = 2\pi \times 50 \times 0.04$$
$$X_L = 2\pi \times 2$$
$$X_L \approx 6.28 \text{ ohms}$$

Calculate Current(I)

The current I in the circuit can be found using Ohm's law:

$$I = \frac{V}{X_L}$$

Substitute V=240 V and $X_L$=6.28 ohms:

$$I = \frac{240}{6.28}$$
$$I \approx 38.22 \text{ A}$$

Therefore, the inductive reactance of the coil at 50 Hz is 6.28 ohms, and the resulting current when connected to a 240 V supply is approximately 38.22 A. These calculations assume the coil has negligible resistance, so the current is primarily determined by the inductive reactance.

**6.a) Derive an e.m.f equation of a single phase transformer.**

To derive the e.m.f (electromotive force) equation of a single-phase transformer, we'll use the principles of electromagnetic induction as described by Faraday's law. Here's a step-by-step derivation:

Derivation of the e.m.f Equation

1.Magnetic Flux and Voltage Induction

Let:

N1 be the number of turns in the primary winding.

N2 be the number of turns in the secondary winding.

ϕ be the maximum magnetic flux in the core (in webers).

f be the frequency of the AC supply (in hertz).

The magnetic flux ϕ varies sinusoidally with time and can be expressed as:

$$\phi(t) = \phi_{\max} \sin(\omega t)$$

where ϕmax is the peak value of the flux and ω=2πf is the angular frequency.

2. Induced e.m.f in the Primary Winding

According to Faraday's law of electromagnetic induction, the instantaneous e.m.f induced in the primary winding e1(t) is given by:

$$e_1(t) = -N_1 \frac{d\phi(t)}{dt}$$

Substitute the expression for ϕ(t):

$$e_1(t) = -N_1 \frac{d}{dt}[\phi_{\max} \sin(\omega t)]$$
$$e_1(t) = -N_1 \phi_{\max} \omega \cos(\omega t)$$
$$e_1(t) = -N_1 \phi_{\max} \cdot 2\pi f \cdot \cos(\omega t)$$

The RMS value of the induced e.m.f $E_1$ is obtained by dividing the peak value by $\sqrt{2}$:

$$E_1 = \frac{e_{1\max}}{\sqrt{2}} = \frac{N_1 \cdot 2\pi f \cdot \phi_{\max}}{\sqrt{2}}$$
$$E_1 = 4.44 f N_1 \phi_{\max}$$

3.Induced e.m.f in the Secondary Winding

Similarly, the RMS value of the induced e.m.f in the secondary winding $E_2$ is:

$$E_2 = 4.44 f N_2 \phi_{\max}$$

e.m.f Equations for Primary and Secondary Windings

Thus, the e.m.f equations for a single-phase transformer are:

Primary winding e.m.f :

$$E_1 = 4.44 f N_1 \phi_{\max}$$

Secondary winding e.m.f:

$$E_2 = 4.44 f N_2 \phi_{\max}$$

**6.b) A 4500 V/225 V, 50 Hz single-phase transformer is to have an approximate e.m.f. per turn of 15 V and operate with a maximum flux of 1.4 T. Calculate (i) the number of primary and secondary turns and (ii) the cross-sectional area of the core.**

Given :

Primary voltage ($V_{1)}$: 4500 V

Secondary voltage ($V_{2)}$: 225 V

Frequency (f): 50 Hz

Maximum flux density ($B_{max}$): 1.4 T

e.m.f. per turn ($E_{turn}$): 15 V

(i) Calculation of Primary and Secondary Turns

The e.m.f. equation for a transformer is given by:

$$E = 4.44 f N \phi_{\max}$$

We can rearrange this to find the number of turns (N):

$$N = \frac{E}{4.44 f \phi_{\max}}$$

First, we need to calculate the maximum flux ($\phi_{max}$) using the given e.m.f. per turn ($E_{turn}$):

$$E_{\text{turn}} = 4.44 f \phi_{\max}$$

Solving for $\phi_{max}$ :

$$\phi_{\max} = \frac{E_{\text{turn}}}{4.44 f}$$

Substitute the given values ($E_{turn}$=15 V and f=50 Hz):

$$\phi_{\max} = \frac{15}{4.44 \times 50}$$
$$\phi_{\max} = \frac{15}{222}$$
$$\phi_{\max} = 0.06757 \text{ Wb}$$

Next, calculate the number of turns for both the primary and secondary windings.

Primary winding ($N_1$)

$V_1 = 4.44 f N_1 \phi_{max}$

Rearranging to find $N_1$:

$$N_1 = \frac{V_1}{4.44 f \phi_{\max}}$$

Substitute the values:

$$N_1 = \frac{4500}{4.44 \times 50 \times 0.06757}$$
$$N_1 = \frac{4500}{14.9994}$$
$$N_1 \approx 300 \text{ turns}$$

Secondary winding ($N_2$) :

$V_2=4.44f\, N_2\, \phi_{max}$

Rearranging to find $N_2$ :

$$N_2 = \frac{V_2}{4.44 f \phi_{\max}}$$

Substitute the values:

$$N_2 = \frac{225}{4.44 \times 50 \times 0.06757}$$
$$N_2 = \frac{225}{14.9994}$$
$$N_2 \approx 15 \text{ turns}$$

(ii) Calculation of the Cross-Sectional Area of the Core

The maximum flux ($\phi_{max}$) is related to the maximum flux density ($B_{max}$) and the cross-sectional area ($A_c$) of the core by:

$\phi_{max}=B_{max}\times Ac$

Rearranging to find the cross-sectional area $A_c$:

$$A_c = \frac{\phi_{\max}}{B_{\max}}$$

Substitute the values ($\phi_{max}$=0.06757 Wb and $B_{max}$=1.4T) :

$$A_c = \frac{0.06757}{1.4}$$
$$A_c \approx 0.04826 \text{ m}^2$$

**7.a) What is an Auto transformer? Give its advantages and state its applications.**

An autotransformer is a type of electrical transformer with only one winding that acts as both the primary and the secondary winding. Unlike a traditional transformer, which has separate primary and secondary windings, the autotransformer has a single, continuous winding that includes both the primary and secondary sides. It has a tap that can be adjusted to provide different voltage levels.

Advantages of Autotransformers:

1.Efficiency: Autotransformers are more efficient than conventional transformers because they have a single winding, which reduces copper losses.

2.Size and Cost: They are smaller and lighter than conventional transformers for the same capacity, which reduces manufacturing and installation costs.

3.Voltage Regulation: Better voltage regulation is achieved due to the lower impedance of the single winding.

4.Lower Copper Losses: Due to the shared winding, the amount of copper used is less, resulting in lower copper losses.

Applications of Auto Transformer

1.Voltage Regulation:Used in power distribution systems to regulate voltage levels in transmission lines.

2.Motor Starting:Employed to start induction motors, providing a reduced voltage start which helps in limiting the starting current.

3.Interconnection of Power Systems:Used to connect systems with different voltage levels efficiently.

4.Laboratory Equipment:Used in testing and calibration equipment due to its variable voltage supply capability.

5.Railway Traction Systems:Used in railway traction systems for voltage regulation and efficient power distribution.

**7.b) What are the advantages of 3-phase transformers? Draw various schemes of 3-phase transformer connections.**

Advantages of 3-Phase Transformers

1.Efficiency: Three-phase transformers are more efficient than single-phase transformers for the same capacity. They have lower copper and iron losses due to the sharing of components among the phases.

2.Power Capacity: They can handle higher power loads and provide a higher power output than single-phase transformers.

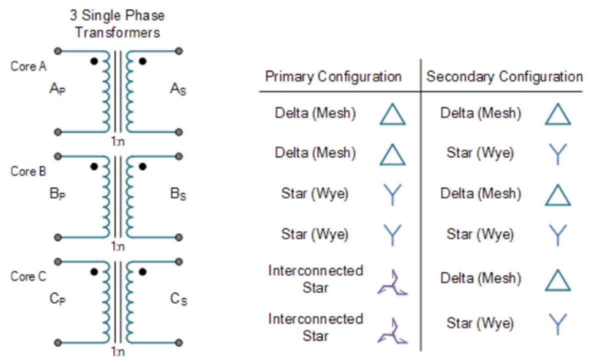
3.Reduced Material Usage: They require less core material and copper winding compared to an equivalent set of three single-phase transformers.

4.Balanced Load: Three-phase systems provide a balanced load, which results in smoother and more stable power delivery.

5.Cost-Effective: The cost of installing a three-phase transformer is generally lower than installing three single-phase transformers of equivalent capacity.

6.Versatility: Three-phase transformers can be connected in various configurations (Delta, Wye) to match different system requirements.

Various schemes of 3-phase transformer connections.




**8.a) Explain the constructional details of a d.c machine. Explain the working of a d.c generator.**

Constructional Details of a D.C. Machine:

A direct current (DC) machine, which can function as either a generator or a motor, consists of several key components:

1.Yoke:The yoke is the outer frame of the DC machine, usually made of cast iron or steel.It provides mechanical support for the other components and acts as a protective cover.It also serves as the magnetic path for the magnetic flux generated in the machine.

2.Pole Cores and Pole Shoes:These are attached to the yoke.The pole cores, made of laminated steel, carry the field windings which create the magnetic field.Pole shoes, which are wider, spread the magnetic flux over the armature to reduce the reluctance of the magnetic path.

3.Field Windings:These windings are placed on the pole cores.When current flows through these windings, they produce a magnetic field.

4.Armature Core:The armature core is cylindrical and is mounted on the shaft.It is made of aminated steel to minimize eddy current losses.The core has slots on its periphery to hold the armature windings.

5.Armature Windings:These windings are placed in the slots of the armature core.They are made of copper and are where the electromotive force (EMF) is induced.

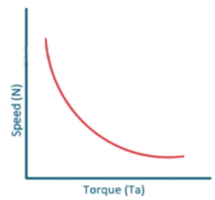
6.Commutator:The commutator is a cylindrical structure made of copper segments insulated from each other.It is mounted on the same shaft as the armature.Its function is to convert the alternating EMF induced in the armature windings into direct current (DC).

7.Brushes:Brushes are made of carbon or graphite and are in contact with the commutator.They conduct current from the commutator to the external circuit (in the

case of a generator) or from the external circuit to the commutator (in the case of a motor).
8.Bearings:Bearings support the rotating shaft and allow smooth rotation with minimal friction.

Working of a D.C. Generator
A DC generator works on the principle of electromagnetic induction, where a conductor moving in a magnetic field induces an electromotive force (EMF) in the conductor. Here’s a detailed explanation of its working:
1.Magnetic Field Creation:When the field windings (excitation windings) on the pole cores are energized by a DC source, a magnetic field is produced around the poles.
2.Armature Rotation:The armature, which is mounted on the shaft, is rotated by an external mechanical force (such as a turbine or an engine).As the armature windings (conductors) rotate within the magnetic field, they cut through the magnetic flux lines.
3.Electromotive Force (EMF) Induction:According to Faraday's Law of Electromagnetic Induction, an EMF is induced in the armature windings due to the relative motion between the conductors and the magnetic field.The direction of the induced EMF is given by Fleming’s Right-Hand Rule.
4.Commutation:The induced EMF in the armature windings is alternating in nature.The commutator, which is segmented and rotates with the armature, reverses the connections of the armature windings at the correct time, thereby converting the alternating EMF into direct current (DC).
5.Current Collection:The brushes, which are in contact with the rotating commutator, collect the direct current from the commutator segments.This direct current is then supplied to the external circuit through the brushes.

**8.b) Draw the various characteristics of a d.c shunt motor.**
Here are the three main characteristics of a D.C. shunt motor:
Torque-Speed Characteristic
Torque-Armature Current Characteristic
Speed-Armature Current Characteristic
1.Torque-Speed Characteristic:
This characteristic shows how the speed of the motor varies with torque. In a D.C. shunt motor, the speed remains almost constant over a wide range of loads, making it ideal for applications requiring constant speed.
Graph:Y-axis: Speed (N),X-axis: Torque (T)
The curve is nearly a horizontal straight line indicating that the speed does not vary much with torque.

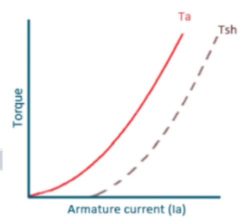



2.Torque-Armature Current Characteristic:

This characteristic shows the relationship between the torque and the armature current. In a D.C. shunt motor, torque is directly proportional to the armature current.

Graph:Y-axis: Torque (T),X-axis: Armature Current ($I_a$)

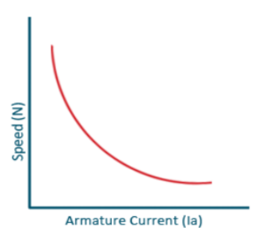
The curve is a straight line passing through the origin, indicating a direct relationship between torque and armature current.




3.Speed-Armature Current Characteristic:

This characteristic shows the relationship between the speed and the armature current. In a D.C. shunt motor, as the load increases, the armature current increases, and the speed slightly decreases.

Graph:Y-axis: Speed (N),X-axis: Armature Current ($I_a$)The curve is slightly downward sloping, indicating that speed decreases slightly as the armature current increases.




**9.a) Explain the working of a 3-phase Induction motor with a neat sketch.**

Working of a 3-Phase Induction Motor

A 3-phase induction motor is an electric motor that operates on 3-phase alternating current (AC) power. It is widely used in industrial and commercial applications due to its robustness, simplicity, and efficiency. The motor consists of two main parts: the stator and the rotor.

Working Principle:

The working of a 3-phase induction motor is based on the principle of electromagnetic induction, discovered by Michael Faraday. When a 3-phase AC supply is given to the stator winding, it produces a rotating magnetic field (RMF) that induces a current in the rotor.

Step-by-Step Working:

1.Production of Rotating Magnetic Field (RMF):

When the 3-phase AC supply is given to the stator winding, it produces a magnetic field that rotates in space.The speed of this rotating magnetic field is known as the synchronous speed ($N_s$) and is given by:

$$N_s = \frac{120f}{P}$$

where f is the supply frequency and P is the number of poles of the motor.

2.Induction of EMF in the Rotor:

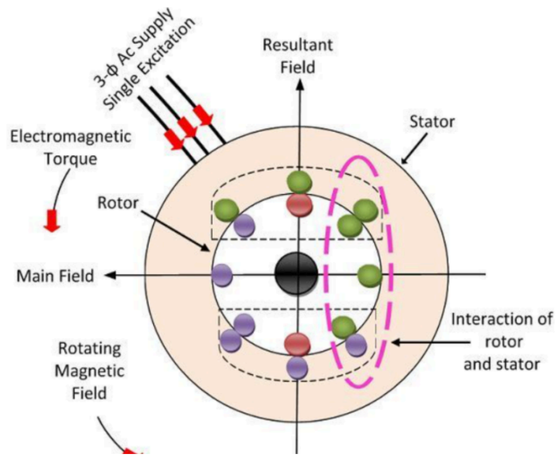
As the RMF rotates, it cuts the rotor conductors.According to Faraday's Law of Electromagnetic Induction, an electromotive force (EMF) is induced in the rotor conductors.Because the rotor circuit is closed, the induced EMF causes a current to flow in the rotor.

3.Production of Torque:

The current-carrying rotor conductors placed in the magnetic field experience a force due to the Lorentz force law.This force produces a torque on the rotor, causing it to rotate in the direction of the RMF.The rotor speed ($N_r$) is slightly less than the synchronous speed, and the difference in speed is known as slip (s):

$$s = \frac{N_s - N_r}{N_s}$$

Continuous Operation:The rotor continues to rotate, trying to catch up with the RMF but never reaching the synchronous speed.The relative motion between the RMF and the rotor induces continuous EMF in the rotor, sustaining the torque and rotation.
Sketch of Three Phase Induction Motor:




**9.b) The stator of a 3-phase, 4-pole induction motor is connected to a 50 Hz supply. The rotor runs at 1455 rev/min at full load. Determine (i) the synchronous speed and (ii) the slip at full load.**

To determine the synchronous speed and slip of a 3-phase, 4-pole induction motor connected to a 50 Hz supply, we can use the following formulas:

1. Synchronous Speed

The synchronous speed ($N_s$) of an induction motor is given by the formula:

$$N_s = \frac{120\times f}{P}$$

where:

f is the supply frequency in Hz

P is the number of poles

Given:

f=50 Hz

P=4

Substituting the values:

$$N_s = \frac{120\times 50}{4}$$
$$N_s = \frac{6000}{4}$$
$$N_s = 1500\,\text{rev/min}$$

So, the synchronous speed is 1500 revolutions per minute (rev/min).

2.Slip at Full Load

Slip (s) is the difference between the synchronous speed and the rotor speed, expressed as a percentage of the synchronous speed. The slip can be calculated using the formula:

$$s = \frac{N_s - N_r}{N_s} \times 100\%$$

where:

$N_s$ is the synchronous speed

$N_r$ is the rotor speed at full load

Given:

$N_r$=1455 rev/min

Substituting the values:

$$s = \frac{1500-1455}{1500} \times 100\%$$
$$s = \frac{45}{1500} \times 100\%$$
$$s = 0.03 \times 100\%$$
$$s = 3\%$$

So, the slip at full load is 3%.

**10.a) Explain the working of (i) SFU (Switch Fuse Unit) (ii) ELCB.**

(i) SFU (Switch Fuse Unit):

A Switch Fuse Unit (SFU) is a device used in electrical circuits to provide both switching and overcurrent protection. It combines a switch and a fuse in a single unit.

Working Principle:

1.Normal Operation:

When the switch of the SFU is in the ON position, it allows the current to flow through the circuit.The fuse remains intact under normal operating conditions, allowing the current to pass through without interruption.

2.Overcurrent or Short Circuit:

If an overcurrent condition occurs due to a short circuit or overload, the current through the circuit increases beyond the rated capacity.This excess current heats up the fuse element.When the current exceeds the rated value of the fuse, the fuse element melts or blows, breaking the circuit.By breaking the circuit, the SFU disconnects the power supply, thereby protecting the circuit and devices connected to it.

(ii) ELCB (Earth Leakage Circuit Breaker)

An Earth Leakage Circuit Breaker (ELCB) is a safety device designed to detect and disconnect electrical circuits in the event of earth faults or leakage currents to prevent electric shock and fire hazards.

Working Principle:

1.Current Imbalance Detection:

The ELCB continuously monitors the current flowing through the live (hot) and neutral wires of the circuit.Under normal conditions, the currents in the live and neutral wires are equal and opposite, resulting in zero net current.

2.Earth Fault Detection:

When an earth fault occurs (e.g., due to insulation failure or human contact with live parts), some current flows to the earth ground.This creates an imbalance in the currents flowing through the live and neutral wires.

3.Operation:

When the imbalance exceeds the sensitivity threshold of the ELCB (typically 30 mA for human protection), the device trips and disconnects the circuit.Rapid disconnection helps prevent electric shock by cutting off the power supply to the faulty circuit.

**10.b) What are the advantages of improving the power factor of a system?**

Advantages of improving the power factor of a system are:

1.Reduced Energy Costs:

Lower Demand Charges: Many utility companies charge for the maximum power demand (kVA) a customer uses. By improving the power factor, the real power (kW) usage becomes more efficient, reducing the apparent power (kVA) and consequently lowering demand charges.

Reduced Energy Losses: A higher power factor means less current is needed to deliver the same amount of real power, resulting in lower losses in the electrical distribution system.

2.Increased System Capacity:

Enhanced Utilization of Equipment: Improving the power factor allows the existing electrical infrastructure (transformers, cables, and switchgear) to handle more load without overheating or exceeding their capacity.

Deferment of Upgrades: With a higher power factor, the system can carry additional loads without needing immediate upgrades, deferring capital expenditures on infrastructure improvements.

3.Improved Voltage Regulation:

Stabilized Voltage Levels: A higher power factor reduces the voltage drop in the system, resulting in better voltage regulation and more stable voltage levels at the load terminals.

Enhanced Performance: Improved voltage regulation ensures that electrical equipment operates within their optimal voltage range, enhancing performance and lifespan.

4.Environmental Benefits :

Energy Efficiency: Improved power factor leads to reduced energy losses, contributing to overall energy efficiency and a lower carbon footprint.

Sustainable Operations: By reducing unnecessary energy consumption, organizations can contribute to more sustainable and environmentally friendly operations.

5.Enhanced Load Handling Capability:

Optimized System Design: Systems with improved power factor are designed to handle additional loads more efficiently, optimizing the overall system design and performance.

Reduced Strain on Infrastructure: Higher power factor reduces the electrical strain on the infrastructure, minimizing the risk of overloading and potential faults.

6.Improved Power Quality:

Minimized Harmonics: Improving power factor can help in minimizing harmonics in the system, which can cause interference and damage to sensitive electronic equipment.

Enhanced Reliability: With better power quality and fewer disturbances, the reliability of the entire electrical system is improved, reducing downtime and operational disruptions.

**11.a) What are the differences between primary cells and secondary batteries?**

Primary cells and secondary batteries are two main categories of batteries, each with distinct characteristics, advantages, and limitations. Here are the key differences between them:

1.Reusability:

Primary Cells: Designed for single-use. Once discharged, they cannot be recharged

and must be disposed of.
Secondary Batteries: Rechargeable and can be used multiple times. They can be discharged and then recharged by applying an external electrical current.

2.Chemical Reaction:

Primary Cells: Chemical reactions are irreversible. Once the active materials are used up, the cell stops producing electricity permanently.

Secondary Batteries: Chemical reactions are reversible. The active materials can be restored to their original state by recharging the battery.

3. Applications:

Primary Cells: Suitable for low-drain and infrequently used devices, such as remote controls, clocks, and smoke detectors.

Secondary Batteries: Ideal for high-drain and frequently used devices, such as smartphones, laptops, power tools, and electric vehicles.

4.Cost and Environmental Impact:

Primary Cells: Generally less expensive initially, but the cost can add up with frequent replacements. Disposal can be environmentally harmful if not done properly.

Secondary Batteries: Higher initial cost but more cost-effective over time due to reusability. Although they still need proper disposal, many have recycling programs to mitigate environmental impact.

**11.b) Explain different types of wires used in domestic as well as commercial buildings.**

Types of Wires Used in Domestic and Commercial Buildings
1. Non-Metallic Sheathed Cable (NM Cable):
Description: Commonly known as Romex (a brand name), NM cable consists of two or more insulated conductors and a bare ground wire, all encased in a flexible plastic sheath.
Usage: Widely used in residential wiring for lighting, outlets, and appliances.
Advantages: Easy to install, cost-effective, and suitable for dry, protected areas inside walls, ceilings, and floors.
Limitations: Not suitable for outdoor use or in moist environments.
2.Armored Cable (AC) and Metal-Clad Cable (MC):
Description: Consists of insulated conductors encased in a flexible metal sheath made of aluminum or steel. MC cables include an additional bonding strip or wire.
Usage: Used in both residential and commercial applications, particularly where added protection is needed, such as in walls, floors, and exposed areas.

Advantages: Provides excellent protection against physical damage and electromagnetic interference. Suitable for both dry and damp locations.
Limitations: More expensive and harder to install than NM cable.
3.Thermoplastic High Heat-resistant Nylon-coated (THHN) Wire:
Description: Single conductor wire with insulation made of thermoplastic and a nylon coating for additional protection.
Usage: Used in both residential and commercial buildings for a variety of applications, including wiring in conduit, machine tools, and control circuits.
Advantages: Heat-resistant, moisture-resistant, and has good abrasion resistance. Suitable for both dry and damp locations.
Limitations: Must be installed in conduit for protection, adding to the installation complexity and cost.
4.Underground Feeder (UF) Cable:
Description: Similar to NM cable but with thicker insulation and a durable sheathing for direct burial underground.
Usage: Used for outdoor lighting, pumps, and other outdoor applications where wiring needs to be buried directly in the ground.
Advantages: Designed for direct burial without additional conduit. Resistant to moisture, sunlight, and physical damage.
Limitations: More expensive than NM cable and harder to work with due to its thickness and stiffness.

5.Service Entrance (SE) Cable:

Description: Used to bring power from the utility service point to the building's main distribution panel. Comes in two types: SER (Service Entrance Cable, Reinforced) for above-ground use and USE (Underground Service Entrance) for direct burial.
Usage: Used for overhead or underground service drops from the utility pole to the house.
Advantages: Durable and able to withstand environmental factors like UV radiation and moisture.
Limitations: Requires careful installation to ensure safety and compliance with local codes.

6.Low Voltage Cables:

Description: Includes various types of cables designed for low-voltage applications (typically under 50 volts), such as speaker wires, doorbell wires, and thermostat wires.
Usage: Used for home automation systems, audio-visual equipment, alarm systems, and intercoms.
Advantages: Generally inexpensive and easy to install. Suitable for specific low-voltage applications.

Limitations: Not suitable for standard electrical wiring due to their low voltage rating.