ELECTRICAL DEVICES & CIRCUITS

COURSE CODE: NEEE 101
VENUE: NLHC-G3

COURSE INSTRUCTOR: PROF. SOUMYABRATA BARIK

CHAMBER: 131-D; DEPARTMENT OF ELECTRICAL ENGINEERING

EMAIL ID: soumyabrata@iitism.ac.in

TEXTBOOKS & REFERENCES

Textbooks:

William H. Hayt Jr, Jack E. Kemmerly and Steven M. Durbin, “Engineering Circuits Analysis”, McGraw Hill publishers, 2013.

Electric Machines – D. P. Kothari and I. J. Nagrath (Tata McGraw Hill), 5th Edition, 2017.

Reference Books:

M.E. Van Valkenburg, ‘Network Analysis’, Pearson, 2015.

Electrical Machinery – P. S. Bimbhra (Khanna Publ.), 2021.

Electric Machinery – A. E. Fitzgerald, Charles Kingsley Jr., S. D. Umans (McGraw Hill).

SCOPES & OBJECTIVES

ANALYSIS OF ELECTRICAL CIRCUITS

- BASICS
- KCL, KVL
- NODAL & MESH ANALYSIS
- NETWORK THEOREMS
- PROBLEM SOLVING

AC CIRCUITS

- BASICS OF AC CIRCUITS
- PHASOR REPRESENTATION
- 3 PHASE BALANCED & UNBALANCED LOAD
- 3 PHASE POWER MEASUREMENT
- PROBLEM SOLVING

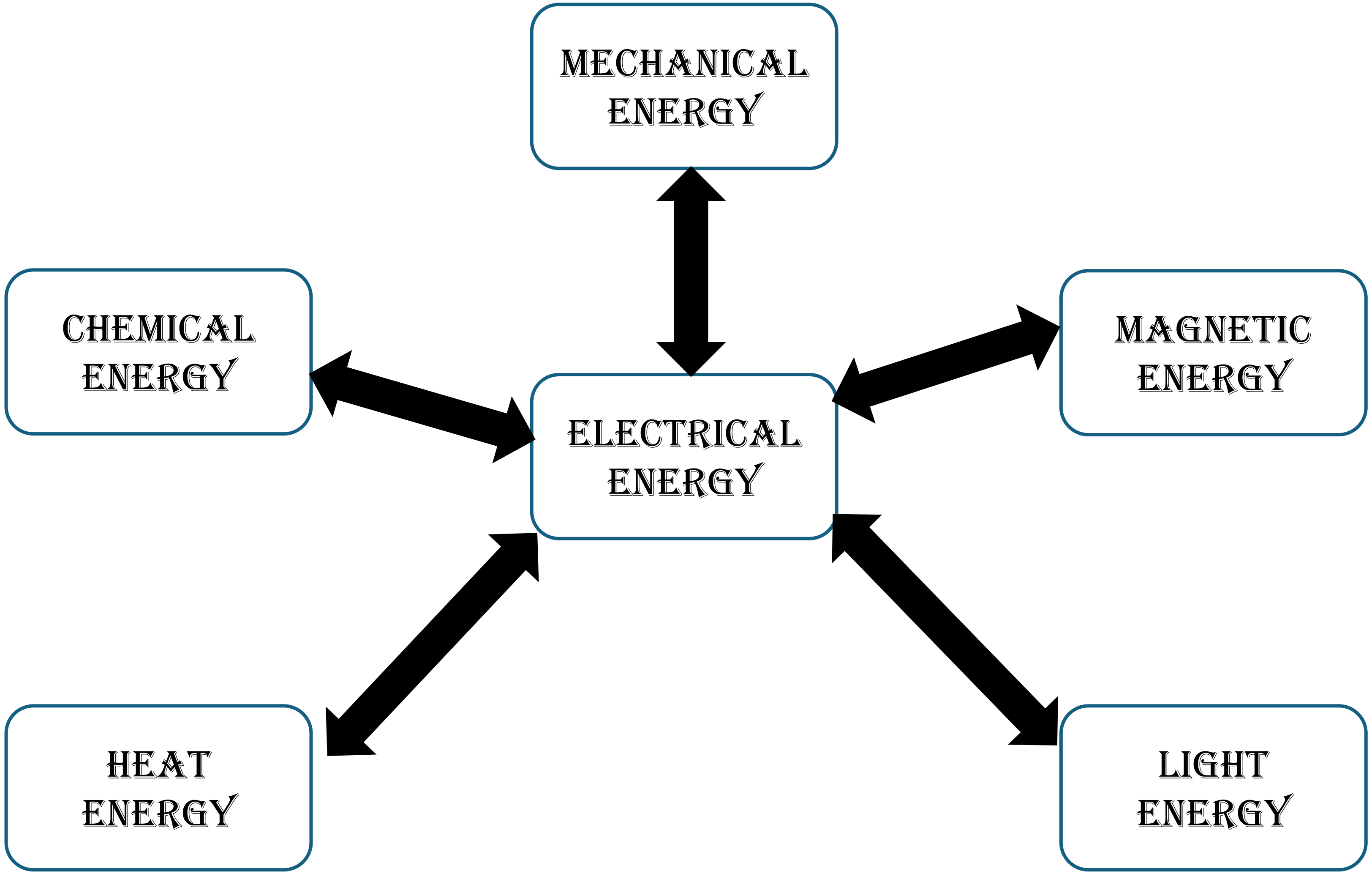
SCOPES & OBJECTIVES

- SINGLE PHASE TRANSFORMER
  - PRINCIPLES & CONSTRUCTIONS
  - EQUIVALENT CIRCUIT
  - PHASOR DIAGRAM
  - REGULATION & EFFICIENCY
  - PROBLEM SOLVING

- DC MACHINES
  - PRINCIPLES & CONSTRUCTIONS
  - EMF EQUATION
  - TYPE OF EXCITATIONS
  - PERFORMANCE CHARACTERISTICS
  - PROBLEM SOLVING

- THREE PHASE INDUCTION MOTOR
  - PRINCIPLES & CONSTRUCTIONS
  - ROTATING MAGNETIC FIELD
  - TORQUE-SLIP CHARACTERISTICS
  - STARTING METHODS
  - PROBLEM SOLVING

ELECTRICAL ENGINEERING



ELECTRICAL ENGINEERING

GENERATION

TRANSMISSION

DISTRIBUTION

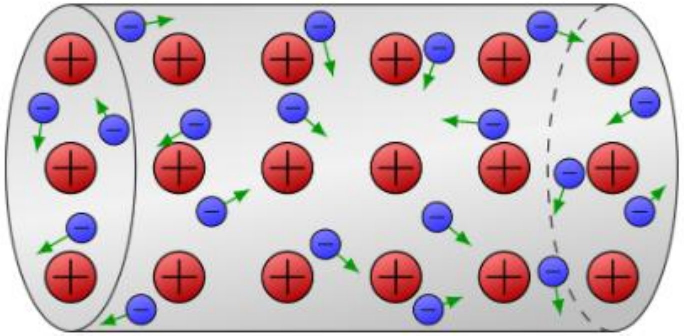
UTILIZATION

** Images are collected from Google Image.

BASICS OF CURRENT FLOW

The drift velocity can be defined as

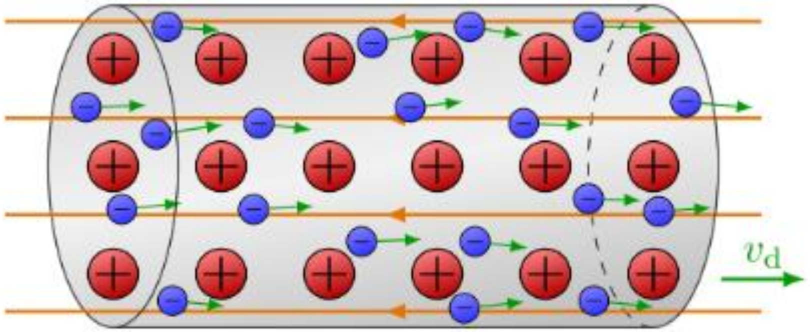
$$v_d = \frac{\sum V_i}{N} = \frac{\sum U^{ini} + \alpha t_i}{N} = \cancelto{\approx 0}{\frac{\sum U^{ini}}{N}} + \alpha \frac{\sum t_i}{N}$$



Therefore the drift velocity can be written as

$$v_d = \alpha\tau = \frac{eE}{m_e} \times \tau$$

Here $\tau, m_e, e, E, \alpha, N, U^{ini}$ are relaxation time, mass of electron, charge of electron, applied electric field, acceleration, number of collision, and initial velocity just after the collision respectively



- In reality, an electron should have two velocities

  Motion due to drift Velocity+ Random Motion

- Current flows due to the drift motion of the electron.

** Images are collected from Google Image.

BASICS OF CURRENT FLOW

- With the drift velocity of v_d, in one second the distance covered by the electrons is v_d.

- If N is the number of the electrons in per unit volume, then, the total number of charge (due to electron) present in the volume of Av_d in one second is

$$Q = NeAv_d = I$$

- If the current density is $J = I/A$, after replacing the value of the drift velocity

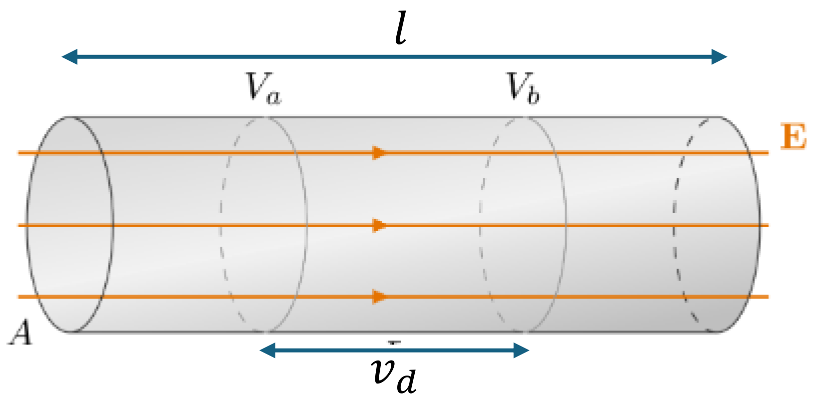
$$J = \sigma E$$

where σ, E are conductivity and the electric field respectively.

$$\sigma = \frac{Ne^2}{m_e}\tau$$

- Applying $E = V/l$, the Ohm's law can be obtained as

$$V = RI$$



** Images are collected from Google Image.

PROBLEMS

Problem-1:

Consider a copper wire having the cross-sectional area of 4 sq mm, and length 4 m. The wire carries a current of 10 A. The volumetric free electron density is $8 \times 10^{23}\ m^{-3}$.

1. Determine the drift velocity of the electron (in m/sec).

2. Determine the time (in sec) taken by the electron to travel the length of the wire with drift velocity.

Answer Keys:

1. $\mathbf{V_{drift} = 1.95 \times 10^{-4}\ ms^{-1}}$

2. $\mathbf{t = 5.7\ Hr}$

PROBLEMS

Problem-2:

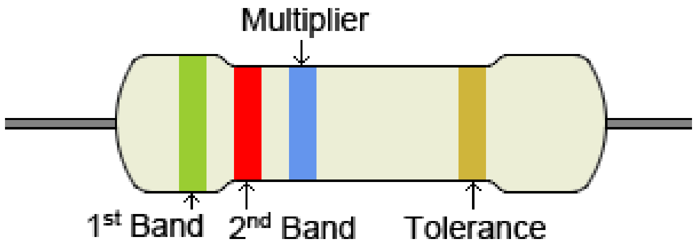
Consider a copper tube with the thickness of 0.5 cm and length 2 m. The external diameter of the copper tube is 10 cm. When measured, the resistance of 1 m length and 1 sqmm of the copper tube gives the resistance of 0.015 Ω.

1. Determine the resistance of the copper tube (in μΩ) considered.

Answer Keys:

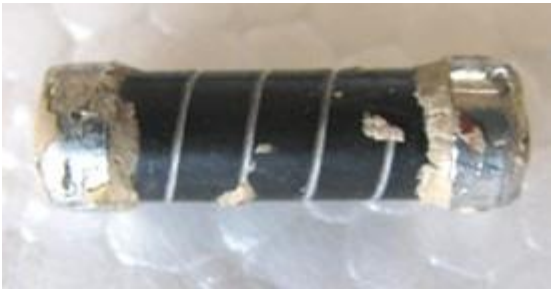
1. $R_{cu} = 20.1038\ \Omega$

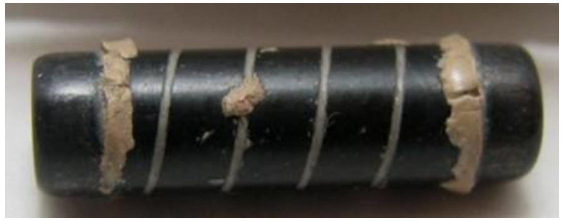
RESISTANCE

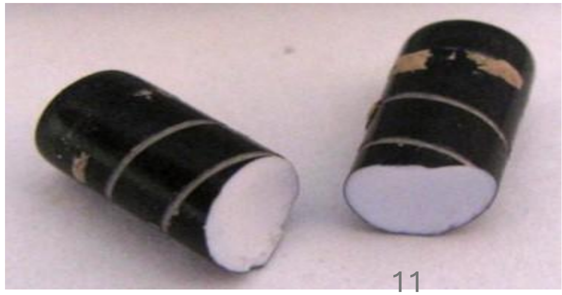


Color	1st, 2nd Band Significant Figures	Multiplier	Tolerance
Black	0	× 1	
Brown	1	× 10	±1% (F)
Red	2	× 100	±2% (G)
Orange	3	× 1K	±0.05% (W)
Yellow	4	× 10K	±0.02% (P)
Green	5	× 100K	±0.5% (D)
Blue	6	× 1M	±0.25% (C)
Violet	7	× 10M	±0.1% (B)
Grey	8	× 100M	±0.01% (L)
White	9	× 1G	
Gold		× 0.1	±5% (J)
Silver		× 0.01	±10% (K)

- When the outer coating is removed, the two metal caps are visible. Metal caps form the connections.
- The solid cylinder has metal alloy wire embedded on it.
- White ceramic is visible when the cylinder is broken.
- The ceramic acts as heat conductor and manage the thermal stress.
- Resistance depends on the length of the metal alloy wire.

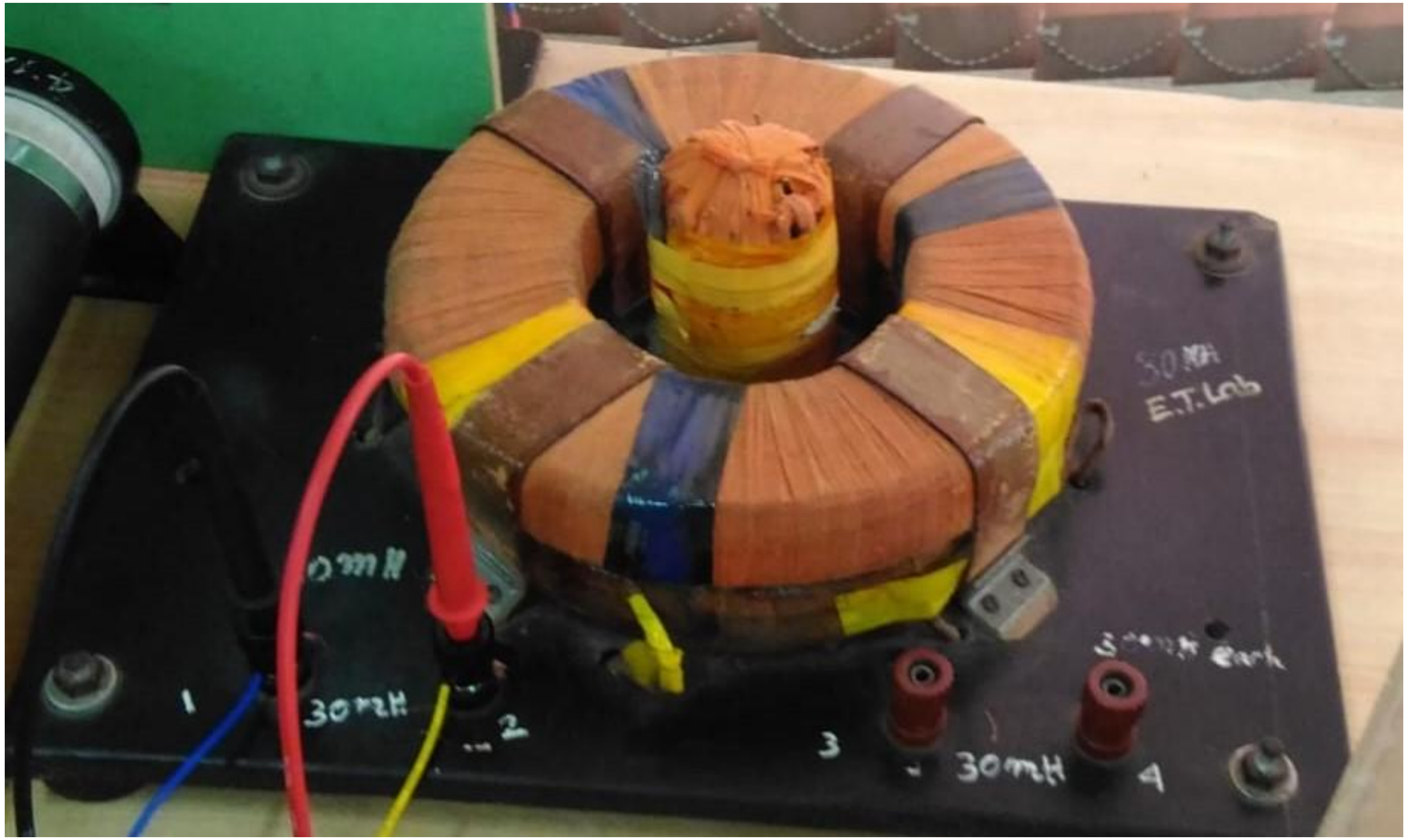






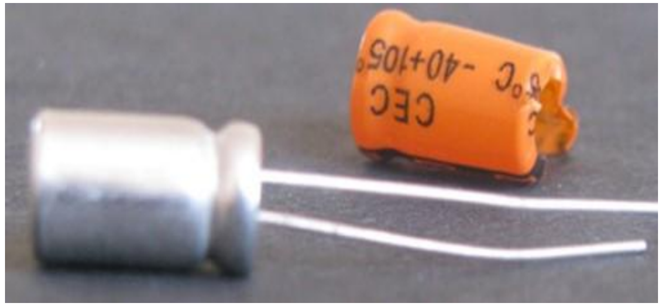
** Images are collected from Google Image

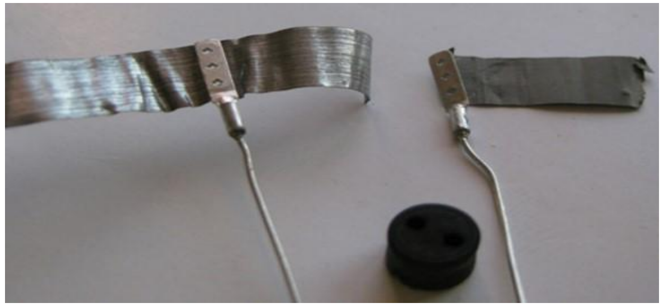
INDUCTANCE



** Images are collected from Google Image

CAPACITANCE



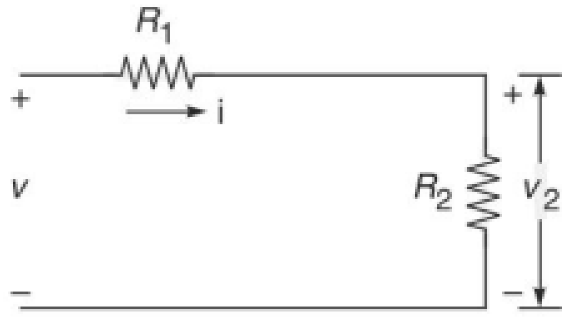


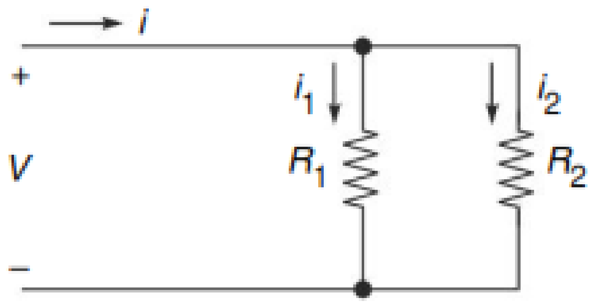
- The main components are contained within a metal container.
- Inside the metal container, there are two metal electrodes and dielectric.
- Metal electrodes are used to store the charges.
- Layers of dielectrics are folded as Swiss roll to minimize the size of the capacitor.
- Usually papers, glass, plastics are used as dielectrics.

** Images are collected from Google Image

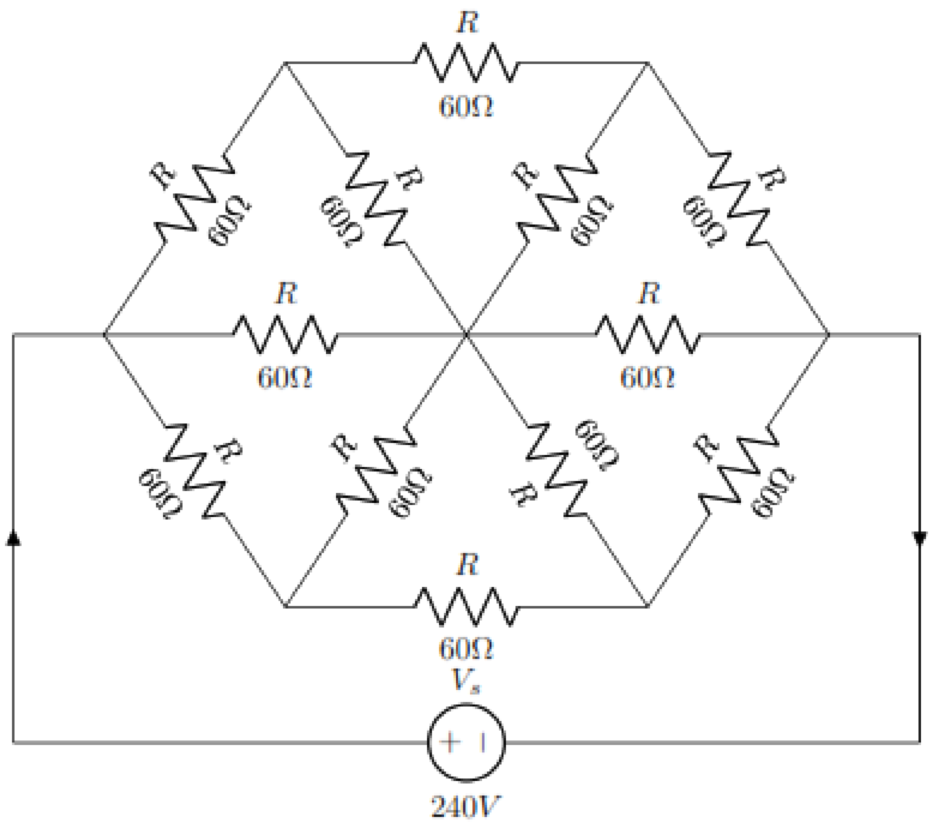
NETWORKS

- Series connection of resistance, inductance & capacitance.
- Parallel connection of resistance, inductance & capacitance.
- Voltage division & current division principles.
- Power absorbed and power produced (sign convention)
- Voltage and current source
- Source transformation





PROBLEMS



<u>Problem-3:</u>

For the given circuit diagram

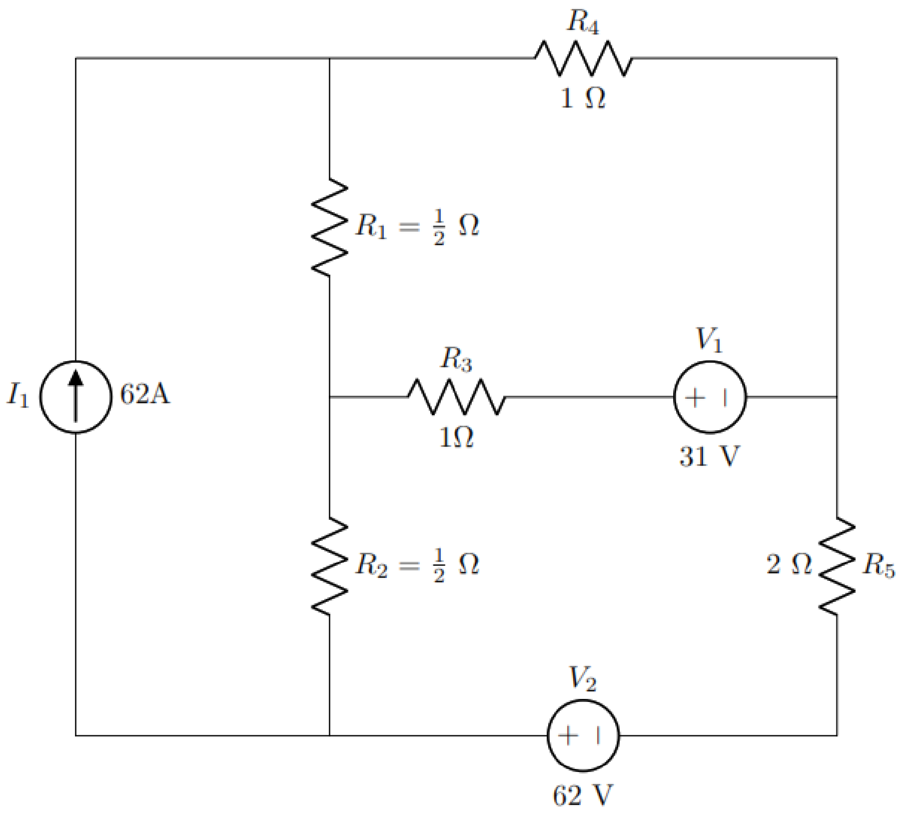
- ❖ Determine the equivalent resistance seen from the voltage source end.

- ❖ Determine the power delivered by the 240 V source to the rest of the circuit.

<u>Answer Keys:</u>

Req=48 Ω; P=1.2 kW

PROBLEMS



Problem-4:

Determine the current flowing through $R_5 = 2\ \Omega$ resistance by using the concept of source transformation.

Answer Keys:

28 A

Types of Circuit Elements

❖ Linear and non-linear elements.

Note: Linear elements satisfy the superposition principle; whereas the non-linear elements does not satisfy that principle.

❖ Active and Passive Elements

Note: Active elements can deliver power for infinite duration of time; whereas passive elements can absorb power and convert into heat or store in electric or magnetic field. Every electronic circuit should contain at least one active element. Active elements can electrically control the electron flow.

❖ Lateral and Bi-lateral elements

Note: Behavior of bi-lateral elements is independent either of the terminal at which current is fed in or of the direction of voltage applied at the terminals. V-I characteristics depends on the direction of the current flow.

❖ Dependent and Independent source

Note: VCVS (Voltage controlled voltage source), CCVS, VCCS, CCCS

NETWORK TERMINOLOGIES

- **Node:** A point in a network where two or more circuit elements are connected.

- **Junction:** A junction is a point in the network where three or more circuit elements are connected.

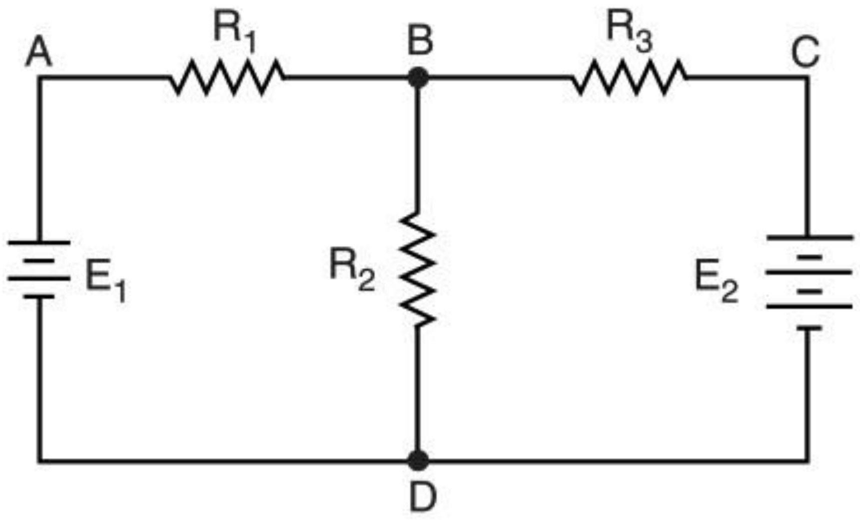
- **Branch:** It is a part of network that lies between two node points.

- **Loop:** It is any closed path in the network.

- **Mesh:** It is a loop that does not contain any other loop within it.

- Network and Circuit these two terms are often used interchangeably.

- Strictly speaking, Network contains all the passive elements; whereas Circuit contains both active and passive elements.



NETWORK ANALYSIS

Network Analysis

Direct Methods

- Nodal Analysis
- Mesh Analysis
- Superposition Theorem

Indirect Methods

- Thevenin's Theorem
- Norton's Theorem
- Star-Delta Transformation

- Analysis of a circuit means to find out all the currents and the voltages in the circuits.
- The above mentioned network analysis methods are only applicable with the networks that contains the linear and the bilateral circuit elements.

KCL & KVL

KCL:

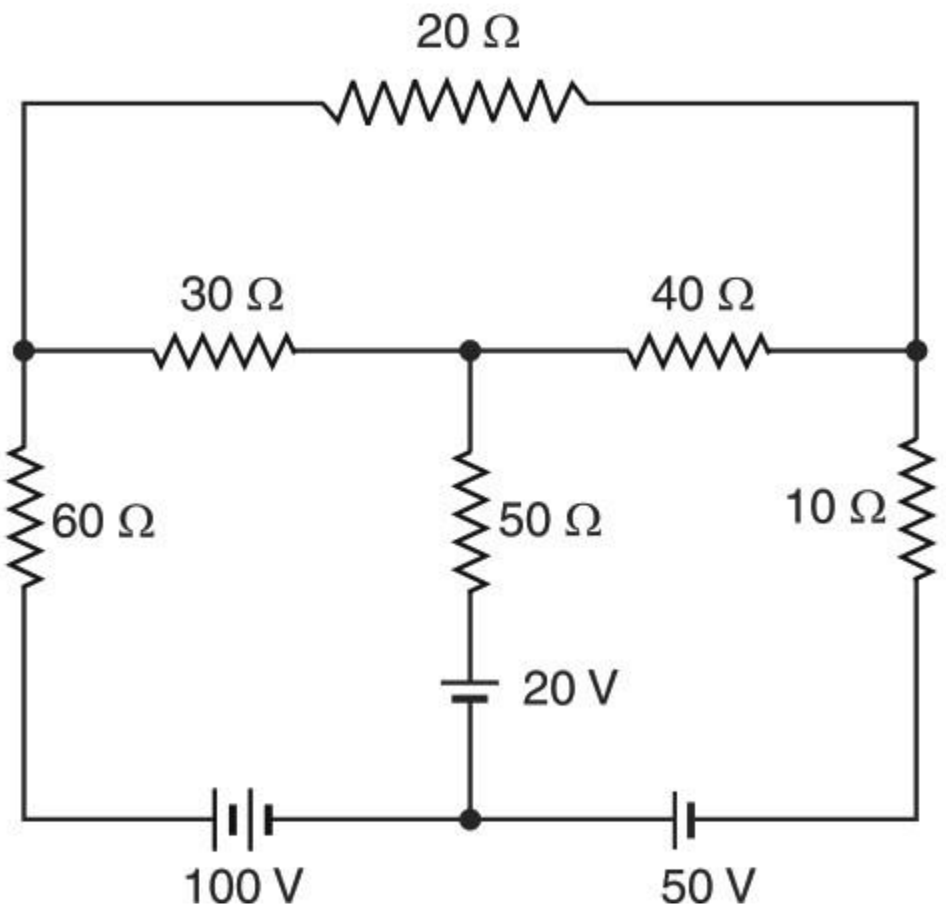
The algebraic sum of currents leaving a node in a circuit is equal to zero on an instant-to-instant basis.

KVL:

The algebraic sum of voltages in any closed path in a circuit is zero on an instant-to-instant basis.

MESH ANALYSIS (INDEPENDENT SOURCE)

- ❑ Use the KCL equations to determine the number of mesh currents.
- ❑ Determine the meshes first.
- ❑ Assign the mesh currents either in clockwise or anti-clockwise direction.
- ❑ Write down the KVL equations for all the meshes using the assigned mesh currents.
- ❑ The branch currents are then found by taking the algebraic sum of the mesh currents which are common to that branch.



Discus the shorter method to form the mesh equations and form the matrix. Solve the matrix using the Cramer’s rule to determine the mesh currents.

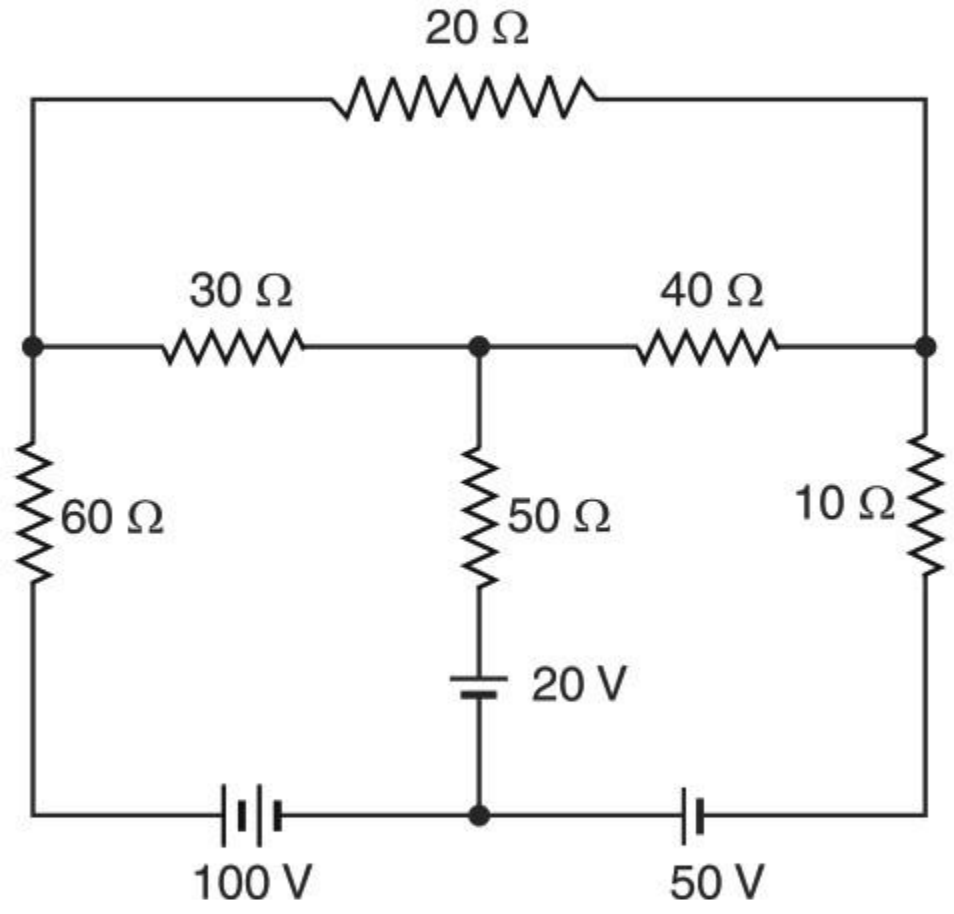
MESH ANALYSIS

- Mesh Current is fictitious current that is not measurable directly.
- Mesh current can be thought of a current that flows through the periphery of the mesh.
- Only the element current is measurable.
- Each element current is a combination of almost two periphery currents.

MESH ANALYSIS (INDEPENDENT SOURCE)

Cond:

Network contains only voltage source and no current source.



Ans:

As Discussed in the class

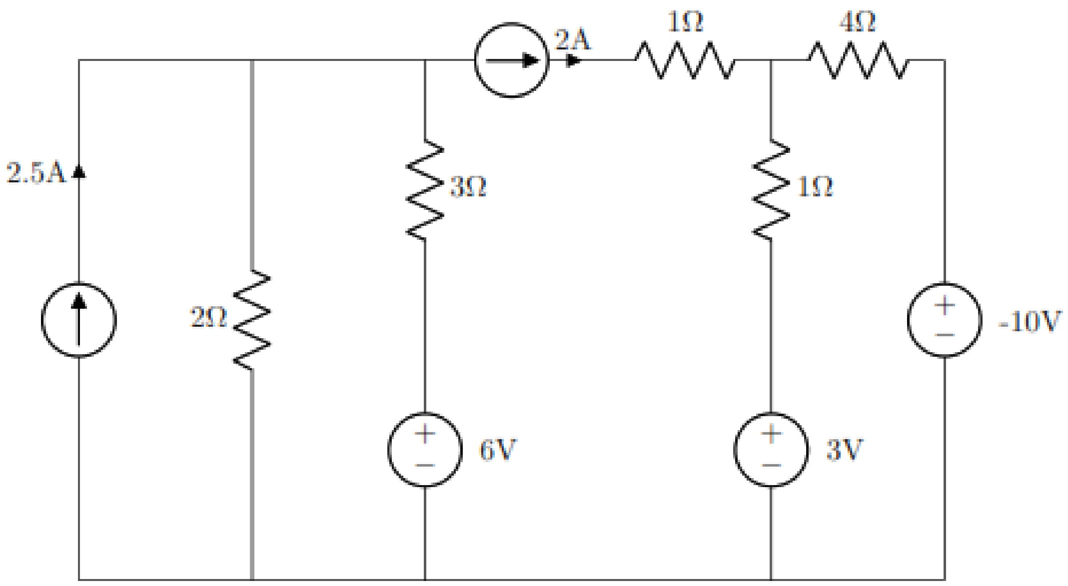
MESH ANALYSIS (INDEPENDENT SOURCE)

Cond:

Current source is in series with resistance and participate only in one mesh.

Ans:

$I_1 = 1\ A;$
$I_2 = 2A;$
$I_3 = 3\ A;$



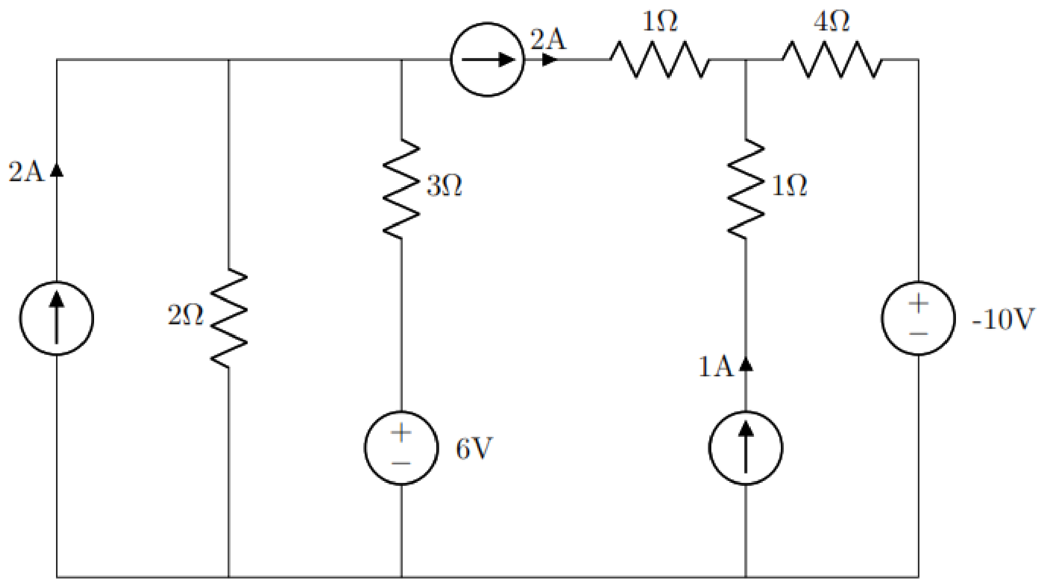
MESH ANALYSIS (INDEPENDENT SOURCE)

Cond:

Current source is in series with resistance and two meshes share that current source.

Ans:

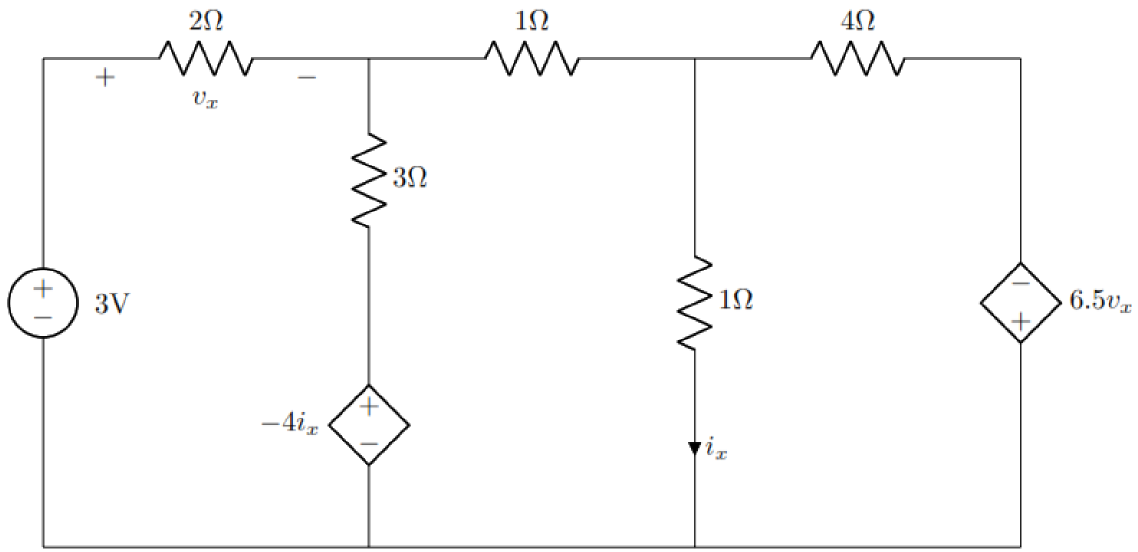
$\boldsymbol{I_1 = 0.8\ A;}$
$\boldsymbol{I_2 = 2.0\ A;}$
$\boldsymbol{I_3 = 3.0\ A;}$



MESH ANALYSIS (DEPENDENT SOURCE)

Cond:

Mesh analysis with dependent sources.

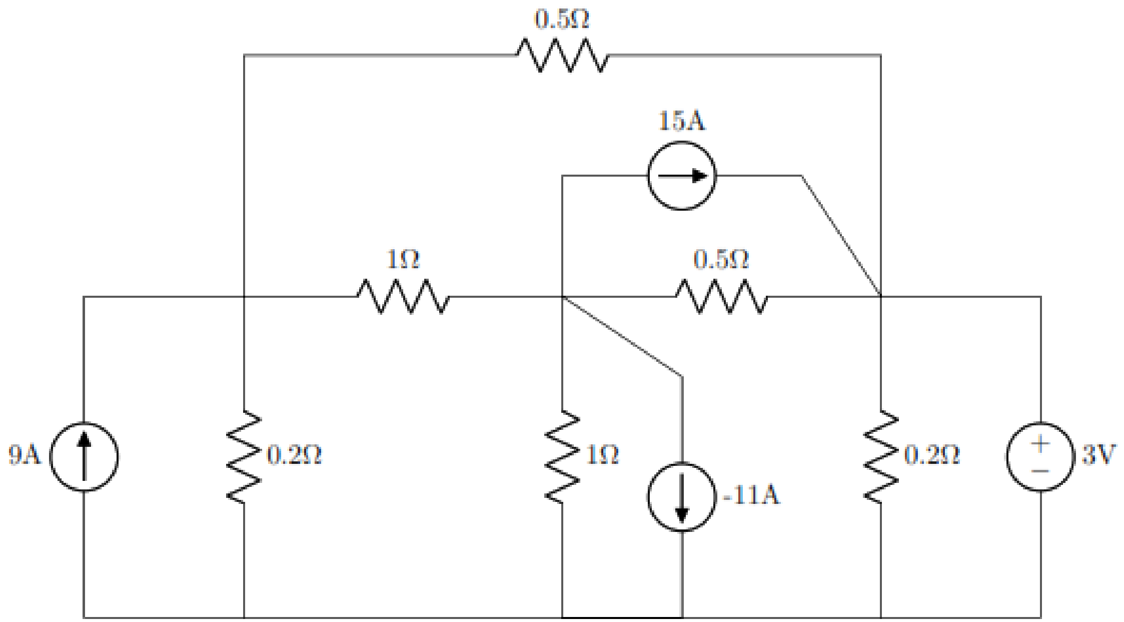


Ans:

$I_1 = 1.0\ A$;
$I_2 = 2.0\ A$;
$I_3 = 3.0\ A$;
$i_x = -1.0\ A$;
$v_x = 2\ V$

NODAL ANALYSIS (INDEPENDENT SOURCE)

- ❑ Use the KCL equations.
- ❑ Determine the nodes first.
- ❑ Assign the node voltages.
- ❑ Write down the KCL equations for all the nodes using the assigned node voltages.
- ❑ The branch currents are then found after solving the KCL equations.
- ❑ One node should have to be considered as the reference/datum node.

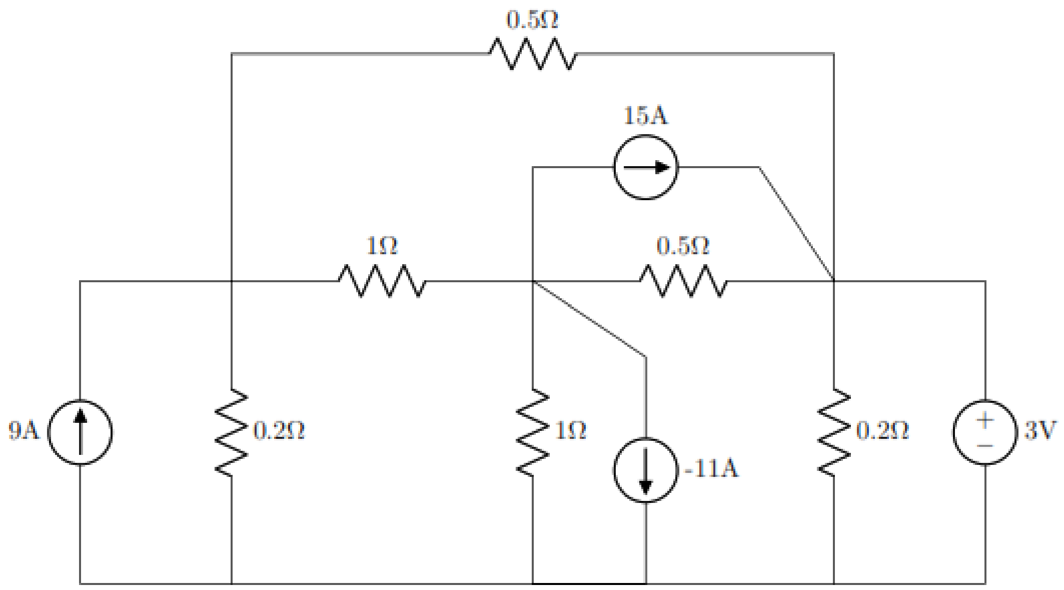


Discus the shorter method to form the mesh equations and form the matrix. Solve the matrix using the Cramer’s rule to determine the node voltages.

NODAL ANALYSIS (INDEPENDENT SOURCE)

Cond:

Voltage source appears between a node and the reference node.



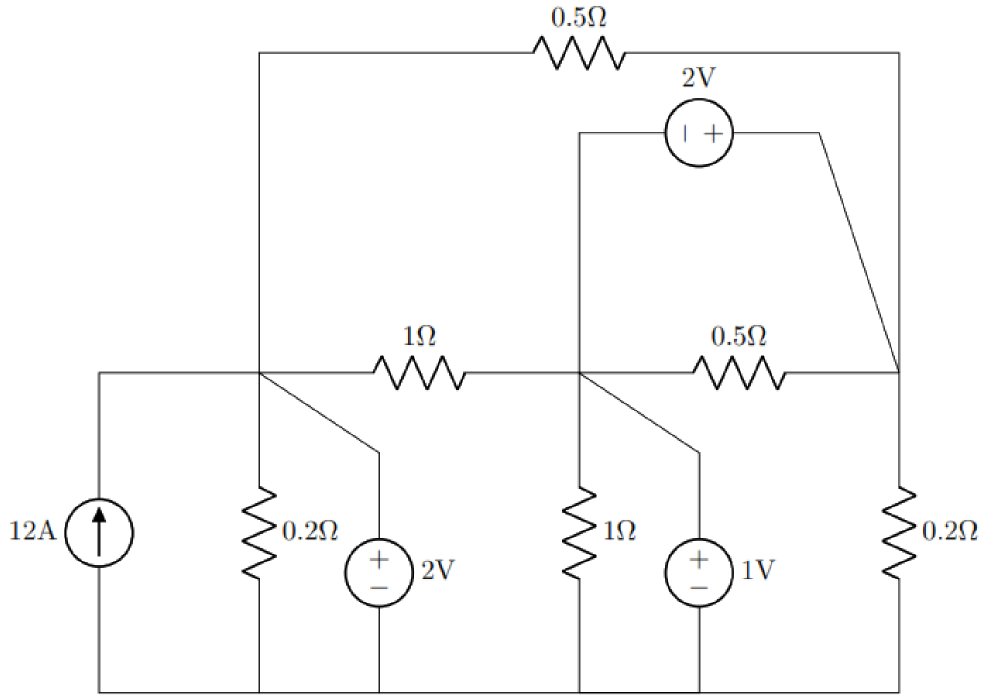
Ans:

$$V_1 = 2\ V; V_2 = 1\ V, V_3 = 3\ V$$

NODAL ANALYSIS (INDEPENDENT SOURCE)

Cond:

Fully constrained circuit for nodal analysis.



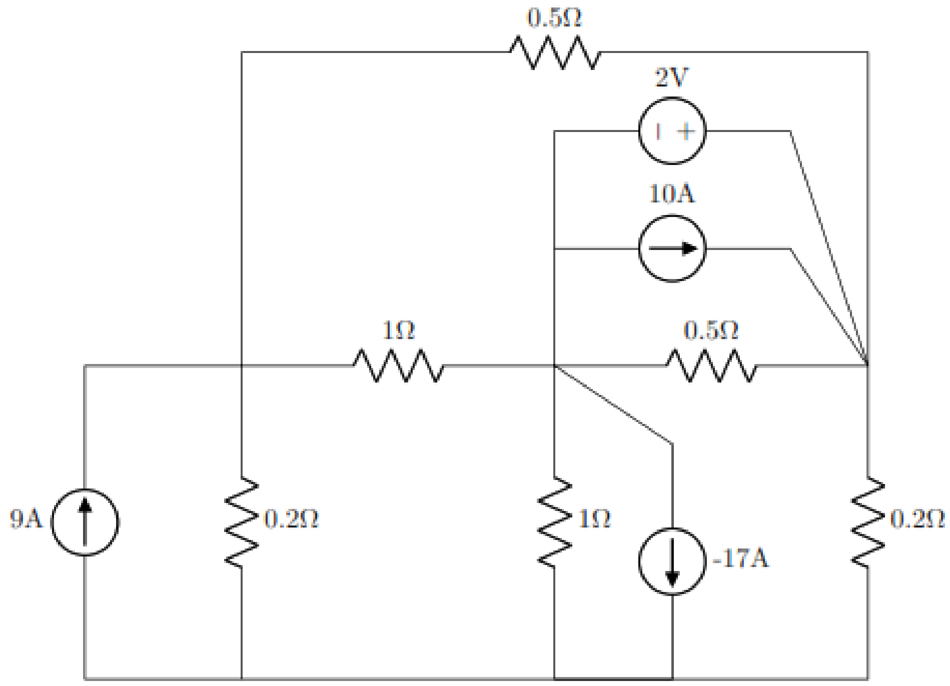
Ans:

$$V_1 = 2\ V; V_2 = 1\ V, V_3 = 3\ V$$

NODAL ANALYSIS (INDEPENDENT SOURCE)

Cond:

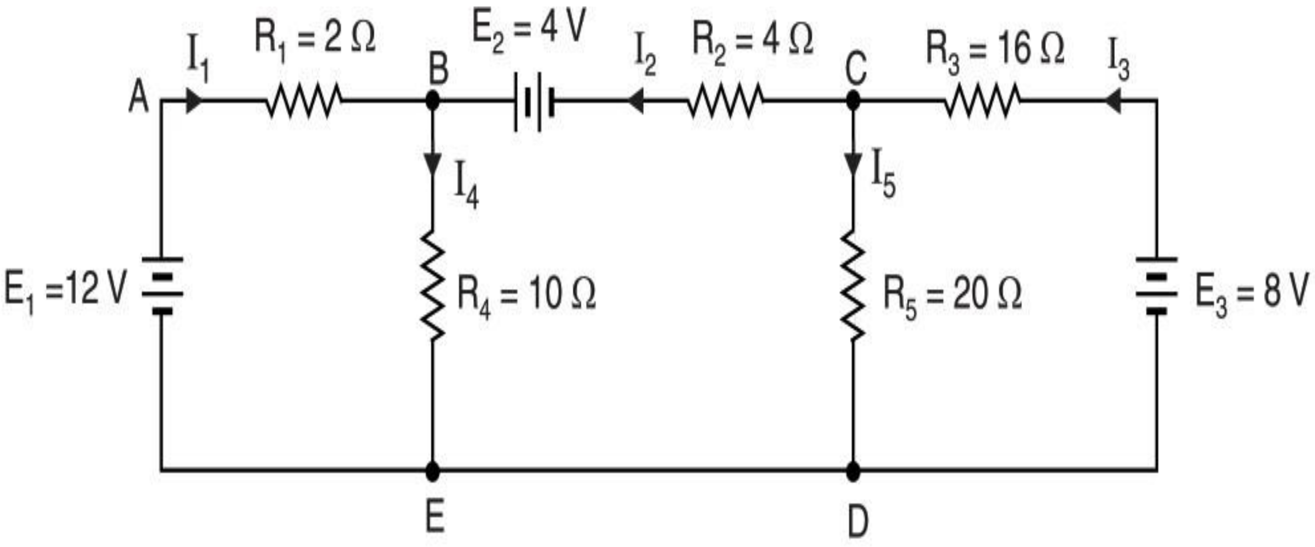
Voltage source appears between two nodes.



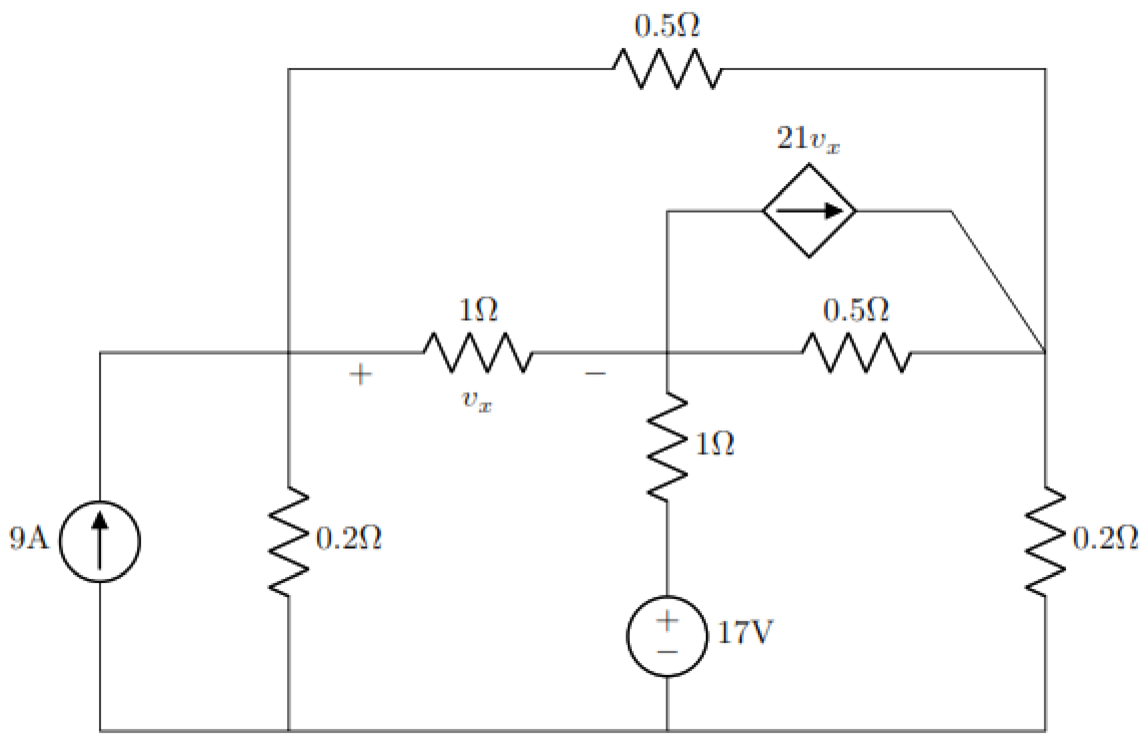
Ans:

$$V_1 = 2\ V; V_2 = 1\ V, V_3 = 3\ V$$

NODAL ANALYSIS (INDEPENDENT SOURCE)



NODAL ANALYSIS (DEPENDENT SOURCE)



Answer Keys:

Discussed in the class