A Laboratory Manual for

Basics Electrical Engineering (3110005)

B.E. Semester 1st and 2nd (All Branches)

Directorate of Technical Education, Gandhinagar, Gujarat

L. D. College, Ahmedabad

Certificate

This is to certify that Mr./Ms. ___________________________________ ________ Enrollment No. _______________ of B.E. Semester _____ Electrical Engineering of this Institute (GTU Code: 028) has satisfactorily completed the Practical / Tutorial work for the subject **Basics Electrical Engineering (3110005)** for the academic year 2022-23.

Place: __________

Date: __________

Name and Sign of Faculty member

Head of the Department

Preface

Main motto of any laboratory/practical/field work is for enhancing required skills as well as creating ability amongst students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping in view, GTU has designed competency focused outcome-based curriculum for engineering degree programs where sufficient weightage is given to practical work. It shows importance of enhancement of skills amongst the students and it pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates an interest and students can have basic idea prior to performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with competency, industry relevant skills, course outcomes as well as practical outcomes (objectives). The students will also achieve safety and necessary precautions to be taken while performing practical.

This manual also provides guidelines to faculty members to facilitate student centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes. It also gives an idea that how students will be assessed by providing rubrics.

This laboratory manual is designed to supplement the theoretical knowledge gained in the Basics Electrical Engineering course. It provides practical hands-on experience to reinforce concepts such as Ohm's Law, Various laws and theorems, AC/DC circuits, Electrical Machines and safety & protection. The manual includes step-by-step instructions for conducting experiments, as well as detailed explanations of the underlying principles and equations. The experiments in this manual have been carefully selected to cover the key topics in Basics Electrical Engineering and to help students develop critical thinking, problem-solving, and troubleshooting skills. This manual is an essential resource for any student studying electrical engineering, as it provides a practical approach to understanding the theoretical concepts learned in class..

Utmost care has been taken while preparing this lab manual however always there is chances of improvement. Therefore, we welcome constructive suggestions for improvement and removal of errors if any.

Practical – Course Outcome matrix

Course Outcomes (COs):

CO-1 : Apply fundamental electrical laws and circuit theorems to electrical circuits.

CO-2 : Analyze single phase and three phase AC circuits.

CO-3 : Describe operating principle and applications of static and rotating electrical machines.

CO-4 : Comprehend electrical installations, their protection and personnel safety..

Sr. No.	Objective(s) of Experiment	CO1	CO2	CO3	CO4
1.	To verify the Kirchhoff's laws for the given network	√			
2.	To verify the Superposition theorem for the given network	√			
3.	To verify the Thevenin's theorem for the given network	√			
4.	To demonstrate B-H curve			√	
5.	To determine resistance, inductance, power and power factor of series R-L circuit		√		
6.	To verify the current and voltage relationships in three phase star and delta connections		√		
7.	To measure power in three phase circuit using two watt-meter method		√		
8.	To study construction of DC machines			√	
9.	To demonstrate the working of miniature circuit breaker (MCB)				√
10.	To study different types of batteries and its applications.				√

Industry Relevant Skills

The following industry relevant competency are expected to be developed in the student by undertaking the practical work of this laboratory.

1. By performing experiments in Basic Electrical Engineering, students can develop a systematic approach to identify and troubleshoot faults in electrical systems.
2. Students can get aware about elementary electrical safety by following the safety guidelines while performing experiments in the lab.
3. By working in a team and presenting their experimental results, students can develop effective communication skills.
4. Students can develop analytical skills by analyzing the experimental data and drawing meaningful conclusions.
5. By documenting their experimental results, students can develop documentation skills that are essential in the industry.

Guidelines for Faculty members

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain basic concepts/theory related to the experiment to the students before starting of each practical
3. Involve all the students in performance of each experiment.
4. Teacher is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the experimentation.
5. Teachers should give opportunity to students for hands-on experience after the demonstration.
6. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by concerned industry.
7. Give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions or not.
8. Teacher is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the COs, content of the course, teaching and examination scheme, skill set to be developed etc.
2. Students shall organize the work in the group and make record of all observations.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and build confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. apart from those included in scope of manual.
6. Student shall refer technical magazines and data books.
7. Student should develop a habit of submitting the experimentation work as per the schedule and s/he should be well prepared for the same.

Index
(Progressive Assessment Sheet)

Sr. No.	Objective(s) of Experiment	Page No.	Date of performance	Date of submission	Assessment Marks	Sign. of Teacher with date	Remarks
Total							

Experiment No:
To verify the Kirchhoff's law for the given network

Date:

Competency and Practical Skills: Knowledge of Kirchhoff's laws, Familiarity with the network components, Ability to measure voltage and current

Relevant CO: Apply fundamental electrical laws and circuit theorems to electrical circuits.

Objectives: (a) To know the basic principles of Kirchhoff's laws and their significance in circuit analysis.
(b) To measure the currents at different nodes in the circuit and then compare them with the sum of the currents entering and leaving the node.
(c) To measure the voltages across different elements in the circuit and then compare them with the sum of the voltages in the closed loop.
(d) To solve the circuit using KCL and KVL and find the unknown currents and voltages.

Equipment/Instruments: Resistors , Ammeters, Voltmeters, Regulated DC power supply, Connecting probes.

Theory: Kirchhoff's laws Kirchhoff's laws are particularly useful (a) in determining the equivalent resistance of a complicated network and (b) for calculating the currents flowing in the various conductors.

➢ **KIRCHHOFF'S VOLTAGE LAW :**

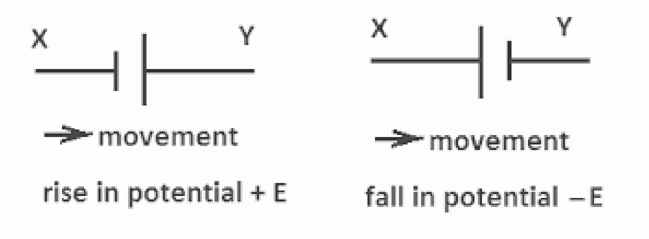
It states that "the algebraic sum of products of currents and resistances in each of the conductors in any closed path in a network plus the algebraic sum of the e.m.fs in that path is zero". In other words,

$$\sum IR + \sum e.m.f. = 0$$

It should be noted that algebraic sum is the sum which takes into account the polarities of the voltage drops. Following sign convention is suggested:

SIGN CONVENTIONS :

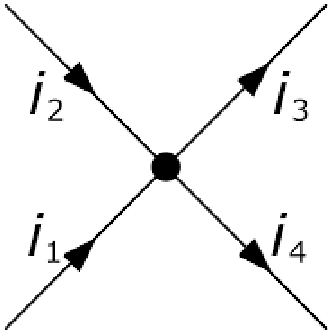
a) battery e.m.f.: A rise in voltage should be given a + ve sign and a fall in voltage a –ve sign. Keeping this in mind, it is clear that as we move from negative terminal of source to positive terminal, there is a rise in potential, hence this voltage should be given a +ve sign. If, on the other hand, we move from +ve terminal to –v terminal of voltage source, then there is a fall in potential, hence it is to be considered as –ve.



b) Sign of IR Drop: Whenever we move in the direction of current there is a drop in voltage, Since the current always flows from point at higher potential to the point at lower potential. Hence Voltage drop in the current direction is taken as –ve. However, if we go in a direction opposite to that of the current, then there is a rise in voltage.

- **KIRCHHOFF'S CURRENT LAW (KCL) :**

It states that "in any electrical network, algebraic sum of the currents meeting a point is zero". In another way, it simply means that the total current leaving a unction is equal to the total current entering that junction. It is obviously true because there is no accumulation or depletion of current at any junction of the network. Consider the case of a few conductors meeting at a node as in fig.

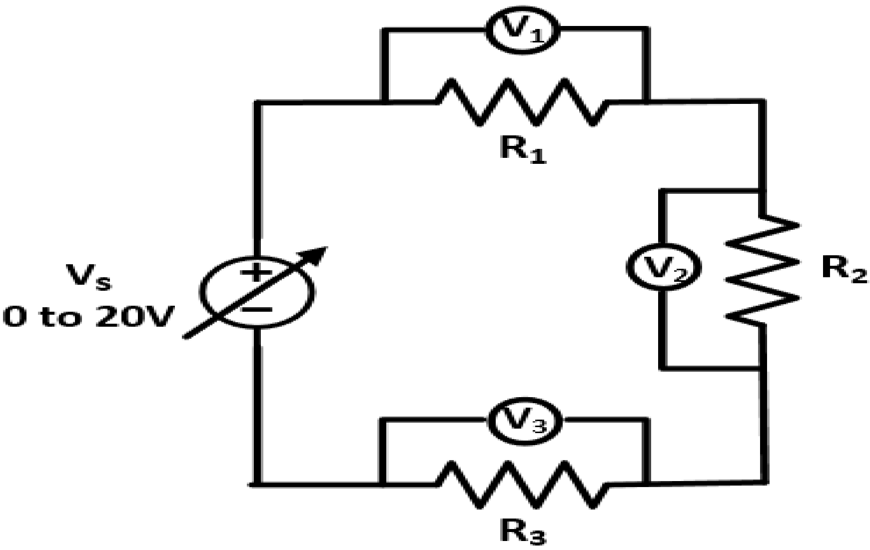


$$i_1 + i_2 = i_3 + i_4$$

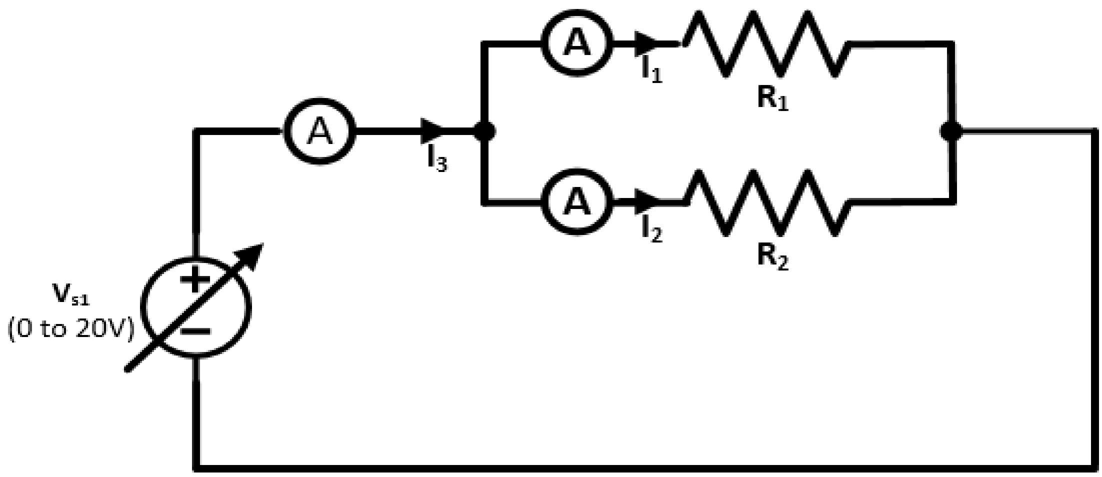
Some conductors have currents leading to node whereas some have currents leading away from node. Assuming the incoming currents to be positive and the outgoing currents negative, applying KCL at node we have,

I1 + I2 -I3 -I4 = 0 OR I1 + I2 = I3 + I4

Set up diagram:



KVL



KCL

Safety and necessary Precautions:
1. Wear protective gear
2. Ensure proper wiring
3. Use appropriate voltage
4. Use appropriate measuring equipment
5. Avoid touching the circuit
6. Handle components with care
7. Follow laboratory guidelines

Procedure:
1. Connect the circuit as per circuit diag.
2. Switch on the DC voltage supply, Adjust the voltage to any suitable value.
3. Take the reading of all the ammeters for KCL experiment and measure the voltages across all the resistors for KVL experiment.
4. Changed the voltage of power supply and repeat step (3) and verify laws.

Observations:

1) KVL:

Measured:

SR No	Voltage V_1 (V)	Voltage V_2 (V)	Voltage V_3 (V)	Total Voltage $V = V_1 + V_2 + V_3$

2) KCL:

Measured:

SR No	Brach Current I_1 (A)	Brach Current I_2 (A)	Source Current I_3 (A)

Calculation:

Results:

KVL:

	Theoretical	Measured
SR No	**Total Voltage $V= V_1+ V_2 + V_3$**	**Total Voltage $V= V_1+ V_2 + V_3$**
1		
2		
3		

KCL:

	Theoretical	Measured
SR No	**Total Current $I3= I_1+ I_2$**	**Total Current $I3= I_1+ I_2$**
1		
2		
3		

Conclusion:

Quiz:

1. State kirchhoff's laws in context of DC circuit.

2. Any closed path formed by the branches in a network is called a______________.
3. In network having N nodes, the number of independent equations required to solve the network, with ground is as the reference node, is__________
4. Differentiate loop and Mesh.

Suggested Reference:

1. "Engineering Circuit Analysis" by William H. Hayt and Jack E. Kemmerly, The McGraw Hill
2. "Basic Electrical Engineering" by T. K. Nagsarkar and M. S. Sukhija, Oxford university press.
3. http://vlabs.iitkgp.ernet.in/be/exp4/index.html, Basic Electronics Virtual Laboratory(IIT KHARAGPUR)

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Writing skills**	**Journal work and submission**	**Total**
Marks					

Experiment No:
To verify the superposition theorem for the given network.

Date:

Competency and Practical Skills: Knowledge of superposition law, Familiarity with the network components, Ability to measure voltage and current

Relevant CO: Apply fundamental electrical laws and circuit theorems to electrical circuits.

Objectives: (a) To construct a circuit containing multiple sources (such as voltage sources or current sources) and resistors.
(b) To measure the response (voltage or current) at a specific point in the circuit using a multimeter.
(c) To verify that the total response of the circuit when all sources are turned on is equal to the algebraic sum of the responses measured when each source is turned on individually
(d) To compare the experimental results with the theoretical predictions based on the superposition theorem

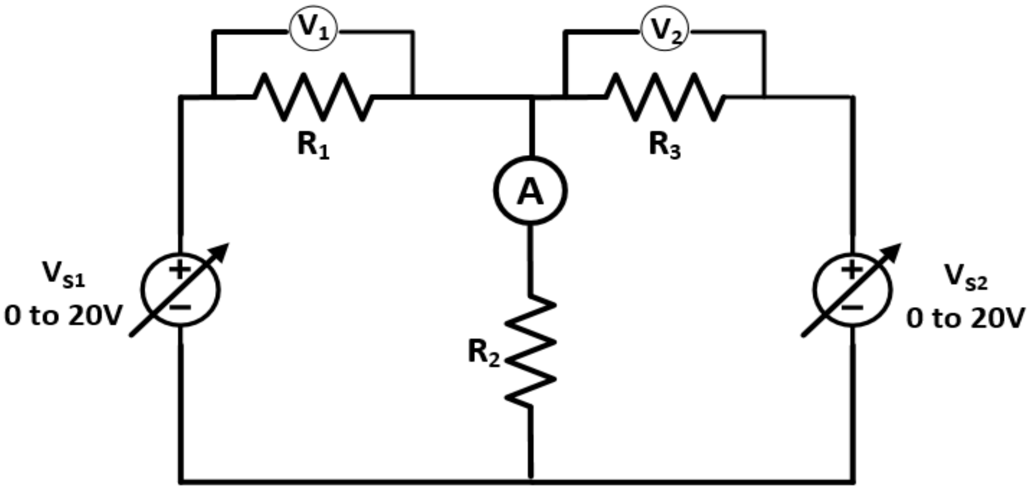
Equipment/Instruments: Resistors , Ammeters, Voltmeters, Regulated DC power supply, Connecting probes.

Theory: The Superposition Theorem is a fundamental principle in electrical engineering that states that the response of a linear circuit to a set of multiple inputs can be calculated by considering the individual responses of the circuit to each input, taken separately.

More specifically, the theorem states that in a linear circuit containing multiple sources (such as voltage or current sources), the total response at any point in the circuit is the sum of the responses due to each individual source acting alone, with all other sources turned off. In other words, the contribution of each source to the final response is calculated independently and then added together to obtain the total response.

The Superposition Theorem is based on the principle of linearity, which states that a linear system's response to a sum of inputs is equal to the sum of the responses to each individual input. The theorem can be applied to any linear circuit, regardless of its complexity, and it is a powerful tool for simplifying circuit analysis and understanding circuit behavior. However, it can only be applied to circuits with linear components, and it assumes that all the sources are independent of each other.

Set up diagram:



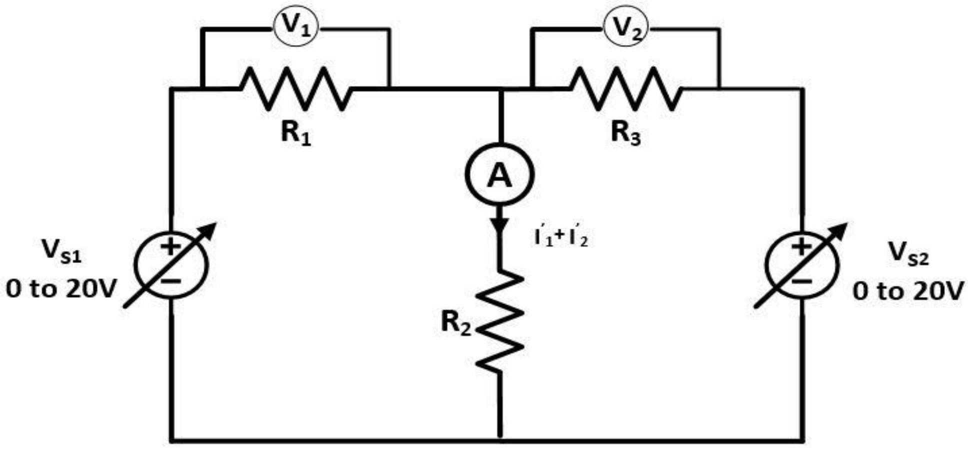
Safety and necessary Precautions:

1. Wear protective gear
2. Ensure proper wiring
3. Use appropriate voltage
4. Use appropriate measuring equipment
5. Avoid touching the circuit
6. Handle components with care
7. Follow laboratory guidelines

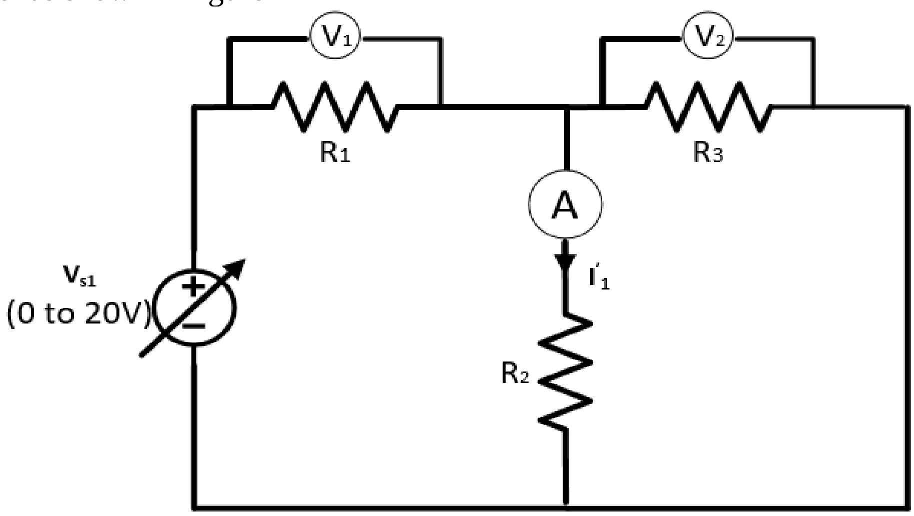
Procedure:

Connection are made as per the circuit diagram shown in figure given above.

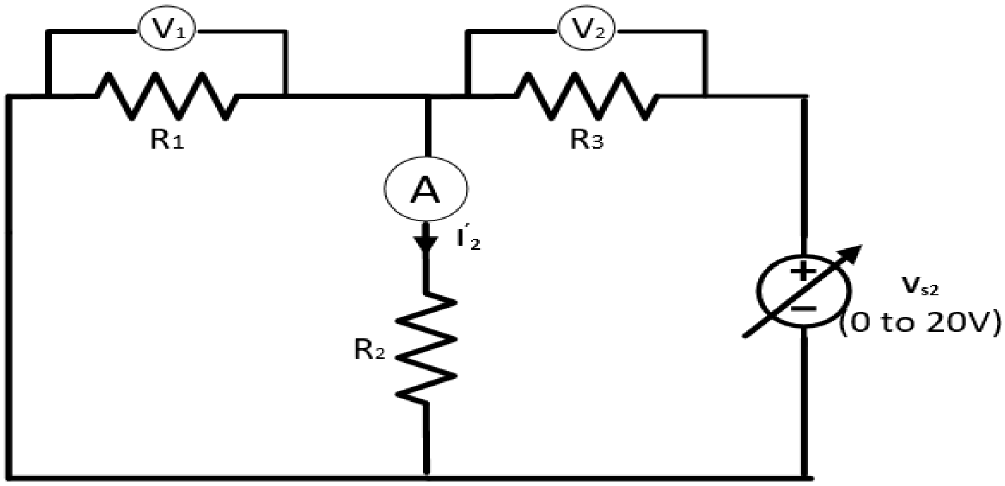
1. Vary the supply voltage V_{S1} & V_{S2} and take the corresponding reading $(I'_1 + I'_2)$from the ammeter.



2. Now VS2 is short circuited. Vary VS1 & take the corresponding reading I'_1 from the ammeter as shown in figure



3. Now VS1 is short circuited. Vary VS2 & take the corresponding reading I'_2 from the ammeter as shown in figure .



4 Finally Verify whether $I = \pm I'_1 \pm I'_2$

Observations:

	Measured Value
When both V_{s1} and V_{s2} are acting ($I'_1+I'_2$)	
When only V_{s1} is acting (I'_1)	
When only V_{s2} is acting (I'_2)	

Calculation:

Result:

	Current Through R_2	
	Theoretical Value	**Measured Value**
When both V_{s1} and V_{s2} are acting ($I'_1+I'_2$)		
When only V_{s1} is acting (I'_1)		
When only V_{s2} is acting (I'_2)		

Conclusion:

Quiz:

1. State superposition theorem.
2. What is Node and super Node?
3. What are limitations of super position theorem?
4. Superposition theorem is applicable for linear network or nonlinear network? Justify your answer.

Suggested Reference:

1. "Engineering Circuit Analysis" by William H. Hayt and Jack E. Kemmerly, The McGraw Hill
2. "Basic Electrical Engineering" by T. K. Nagsarkar and M. S. Sukhija, Oxford university press.
3. **http://vlabs.iitkgp.ernet.in/asnm/exp5/index.html**, Analog Signals, Network and Measurement Laboratory(IIT KHARAGPUR)

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:

To verify Thevenin's Theorem for given network.

Date:

Competency and Practical Skills: Knowledge of Thevenin's law, Familiarity with the network components, Ability to measure voltage and current

Relevant CO: Apply fundamental electrical laws and circuit theorems to electrical circuits.

Objectives: At the end of this experiment, student will be able to

(a) Know about the Thevenin's Law.

(b) Determine voltage across and current through any branch of circuits.

Equipment/Instruments: Resistors , Ammeters, Voltmeters, Regulated DC power supply, Connecting probes.

Theory: Thevenin's theorem states that any linear circuit can be replaced by an equivalent circuit containing a single voltage source and a single series resistor, known as the Thevenin equivalent circuit. This equivalent circuit has the same voltage-current characteristics as the original circuit between two terminals, also known as the load terminals.

To experimentally verify Thevenin's theorem, you can follow these steps:

- Identify the circuit for which you want to find the Thevenin equivalent circuit.
- Disconnect any load or resistor connected to the circuit.
- Measure the open-circuit voltage across the load terminals. This voltage is the Thevenin voltage (Vth).
- Determine the equivalent resistance of the circuit seen from the load terminals. To do this, short-circuit the voltage source and measure the current flowing through the load terminals. This current is the short-circuit current (Isc). The equivalent resistance (Rth) is given by Rth = Vth/Isc.
- Connect the Thevenin voltage source (Vth) in series with the equivalent resistance (Rth) to form the Thevenin equivalent circuit.
- Verify that the Thevenin equivalent circuit provides the same voltage-current characteristics as the original circuit between the load terminals. One can do this by connecting different resistive loads to the load terminals and measuring the resulting currents and voltages. The values should match those obtained from the original circuit.

.

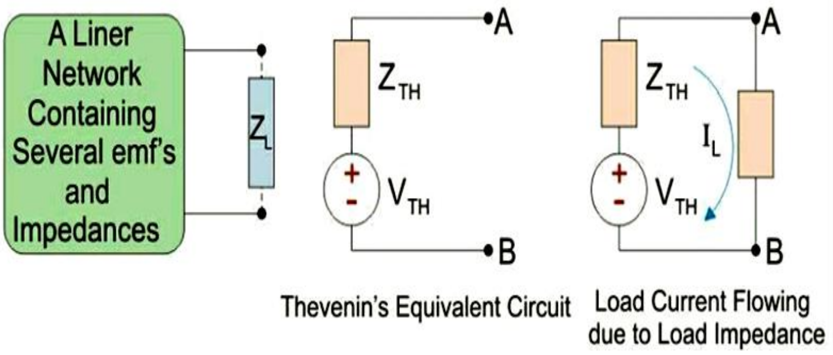


Figure given above illustrates concept of thevenin's theorem. Figure shows that given network is replaced by thevenins equivalent which contains a voltage source Voc or Vth and a thevenins equivalent resistance R_{TH}.

V_{oc} orV_{th}:

This voltage is called open circuit voltage .It is the voltage between open circuited load terminals.

So $V_{oc}=V_{th}=V_{AB}$ with Z_L open circuited.

Set up diagram:

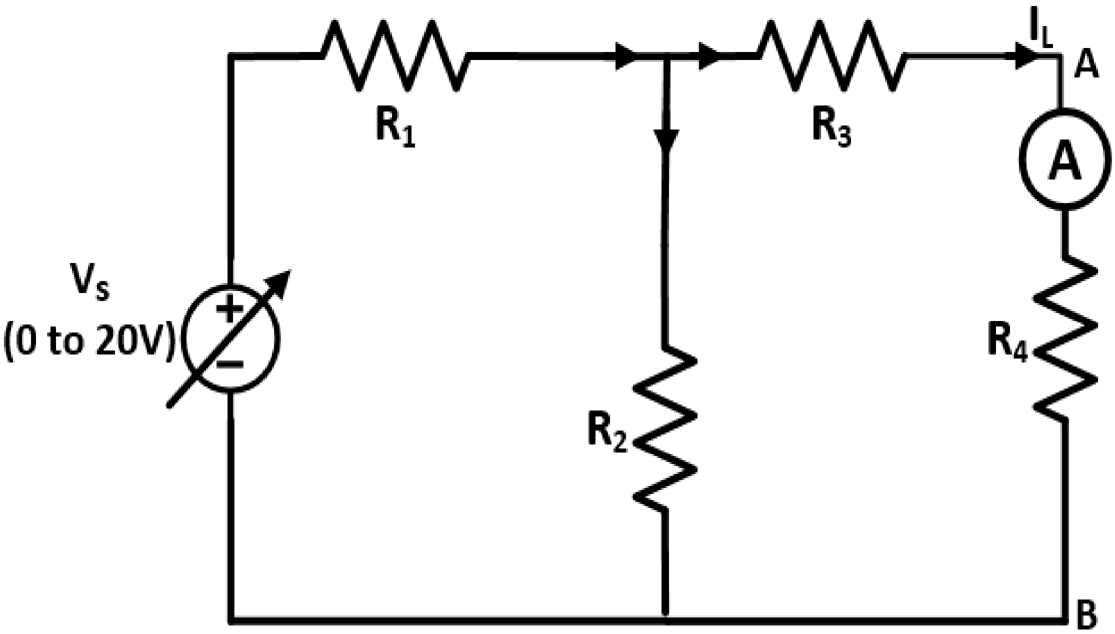


Fig.1

Safety and necessary Precautions:

1. Wear protective gear
2. Ensure proper wiring
3. Use appropriate voltage
4. Use appropriate measuring equipment
5. Avoid touching the circuit
6. Handle components with care
7. Follow laboratory guidelines

Procedure:

1. Connect the circuit as per fig.1.
2. Adjust the output voltage of the regulated power supply(Vs) to an appropriate value.
3. Note down the response (current) through the branch of interest i.e. AB (ammeter reading).
4. Reduce the output voltage of the regulated power supply to 0V and switch-off the supply.
5. Disconnect the circuit and connect circuit as per the fig.2.

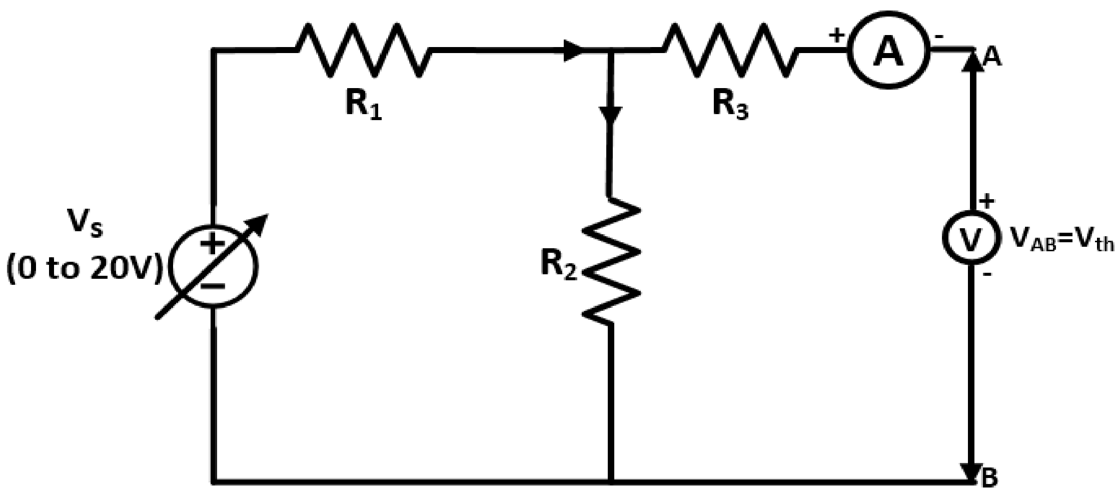


Fig.2

6 Adjust the output voltage of the regulated power supply(V_s) to an appropriate value.
7 Note down the voltage across the load terminals AB (Voltmeter reading) that gives V_{th}.
8 Reduce the output voltage of the regulated power supply to 0V and switch-off the supply.
9 Disconnect the circuit and connect circuit as per the fig.3.

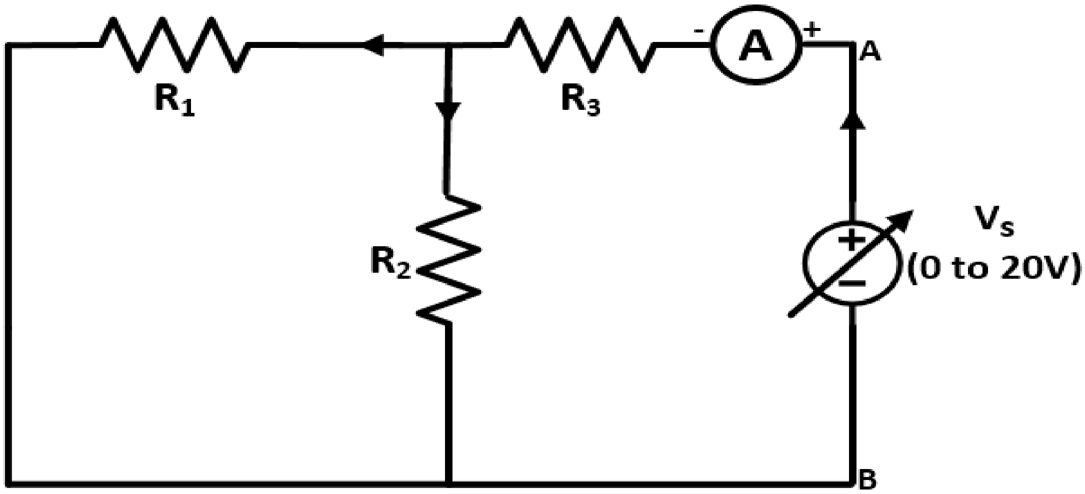


Fig.3

10 Adjust the output voltage of the regulated power supply to an appropriate value.
11 Note down the current (I) supplied by the source (ammeter reading).
12 The ratio of V_s and I gives the R_{th} (Thevenin's Resistance).

Observations:

SR No	Measured Value
1	R_{th}=
2	V_{th} =
3	I_L =

Calculation:

Result:

Theoretical Value	Measured Value
R_{th}=	R_{th}=
V_{th} =	V_{th} =
I_L =	I_L =

Conclusion:

Quiz:

1. State Thevenin’s Theorme.

2. Draw the equivalent circuit for thevenin’s theorem.

3. What is the other name of thevenin’s theorem?

4. Thevenin’s theorem can be applied to networks containing active elements only. True/false?

Suggested Reference:

1. "Engineering Circuit Analysis" by William H. Hayt and Jack E. Kemmerly, The McGraw Hill
2. "Basic Electrical Engineering" by T. K. Nagsarkar and M. S. Sukhija, Oxford university press.
3. **http://vlabs.iitkgp.ernet.in/asnm/exp3/index.html**, Analog Signals, Network and Measurement Laboratory(IIT KHARAGPUR)

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:
To demonstrate B-H curve

Date:

Competency and Practical Skills: Knowledge of Electromagnetism, Familiarity with the Equipment, Basic Knowledge of DSO/CRO Ability to measure voltage and current

Relevant CO: Describe operating principle and applications of static and rotating electrical machines.

Objectives: (a) To determine the magnetic properties of a material.
(b) To study the hysteresis phenomenon.
(c) To analyze the magnetic behavior of a material.
(d) To compare different materials.

Equipment/Instruments: B-H Curve Kit, CRO/DSO, Connecting probes.

Theory: The flux density B is the ratio of the total no of lines of force existing in the magnetic field (in webers) and the area (in m^2) . Thus,
B=Total no. of lines of force (wb)/ Area (m^2)
The permeability (μ) is the ratio of the change in flux density to the change in field intensity.
μ=change in flux density / change in field intensity $= \Delta B / \Delta H$
Materials like cobalt, nickel, iron which posses a value of y much greater than unity are called ferromagnetic materials. Materials with m less than unity are called diamagnetic while materials with μ values slightly greater than unity are termed as paramagnetic. For vacuum, the value of the permeability is unity. When an alternating current is allowed to flow through an air core coil the variation of flux density (B) with magnetising force (H), the flux density increses in phase with the magnetising force.
Similarly the flux density decreases with the magnetising force in phase. However, for an iron cored
Coil or a coil consisting of a core of ordinary steel, the B-H or magnetization curve is exhibit. Due to residual magnetism, the B-H curve or magnetization curve of the Iron core forms a loop called the Hysteresis loop.
Saturable reactors normally use cores of nickel iron or silicon iron alloys. These materials may be of(a) high permeability type (mumetal or permalloy) and (b) grain oriented alloys. Normally saturable reactors employ
a)Thin laminations to reduce eddy current loss
b)Construction without gap to minimise flux leakage.

RETENTIVITY, COERCIVITY AND HYSTERSIS:

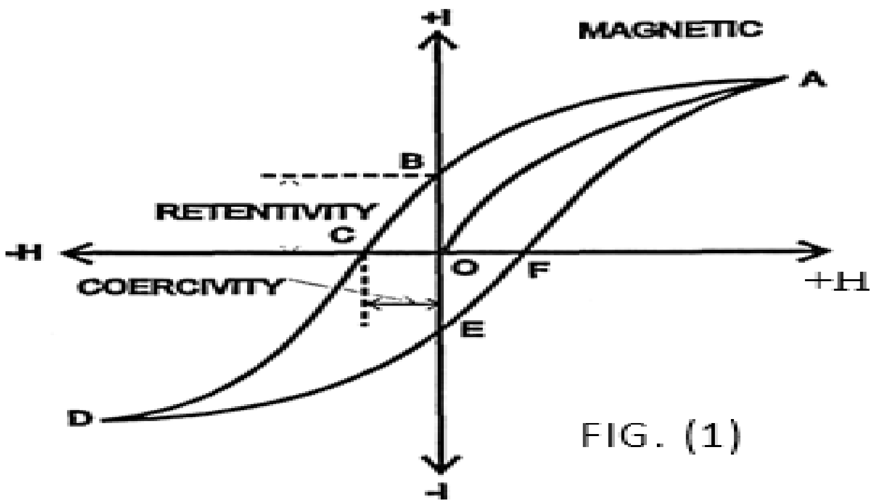


FIG. (1)

Ferromagnetic materials contain large no. of small regions, called domain. In each domain, all the atomic magnets are fixed in rigid parallelism. Thus each domain has a net magnetization in a particular direction distributed randomly. When a specimen of ferromagnetic material is placed in a magnetizing field (H), the specimen is magnetized by induction. As the magnetizing field (H) is varied, the intensity of magnetization of the specimen, ‘I’ changes. The variation in ‘I’ with variation in H is shown in Figure (1). The point O represents an initially unmagnetised specimen and a zero magnetizing field. As H is increased, ‘I’ also increases but not uniformly. When all the domains are aligned in the field direction, the magnetization of specimen gets saturated at A. Any further increase in H result no more increase in ‘I’.

If H is now decreased, ‘I’ also decreases but following a path AB. Thus ‘I’ lags behind H. When H becomes zero, ‘I’ still has a value equal to OB. This amount of magnetization is called the “residual magnetism" or "retentivity” of the specimen. Thus the retentively of a specimen is a measure of the intensity of magnetisation remaining in the specimen when the magnetising field is removed. If the magnetising field H be now increased in the reverse direction, the value of ‘I’ further decreases, still lagging behind H and becomes zero when H has a value equal to OC. This value of the magnetising field is called the “coercive force" or “coercivity” of the specimen. Thus coercivity is a measure of the magnetising field required to destroy the residual magnetism of the specimen.

As H is increased beyond OC, the specimen is increasingly magnetized in the negative direction, until the magnetic saturation is reached at D. By taking H back from its negative saturation value, through zero, to its original positive saturation value, a similar curve DEFA is obtained.

It is thus found that the intensity of magnetization ‘I’ always lags behind the magnetising field H, when H changes. The lagging of I behind H is called “hysteresis”. The closed curve ABCDEFA which represents a cycle of magnetization of the specimen is known as the ’hysteresis ‘curve’ of the specimen. A graph between magnetic induction B and magnetising field H is similar in shape with the only difference that B never becomes constant but always increases with H. Hence in the B-H curve, the corners A and D are not straight but sloping.

Set up diagram:

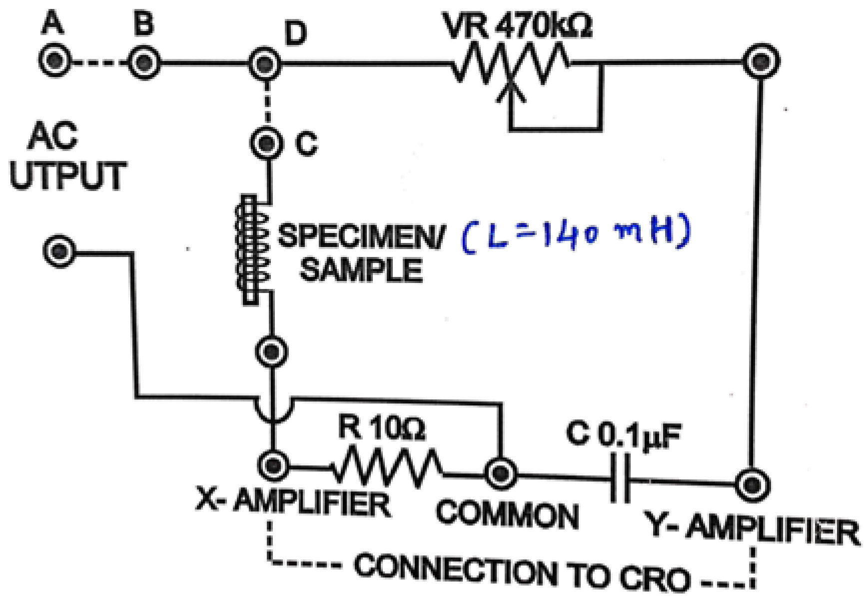


Fig.2

Safety and necessary Precautions:

1. Wear protective gear
2. Ensure proper wiring
3. Use appropriate voltage
4. Use appropriate measuring equipment
5. Avoid touching the circuit
6. Handle components with care
7. Follow laboratory guidelines

Procedure:

1. Arrange the connections as Shown in Fig. (2) i.e. by Connecting the dotted A, B & C, D points through patchcords. Connect X,Y and common points of CRO to points marked On the front panel. Set the AC output between 3V-15V. Throw the sample select switch Towards internal position so that FIG. (2) internal sample connects in the Circuit.
2. Switch ON the instrument using ON/ OFF toggle switch provided on the front panel.
3. To get the proper loop vary the resistance (V_R) & adjust the horizontal and vertical gain controls (G_h and G_v) of the CRO to obtain proper shape and size of the waveform (Hystersis Loop) as shown in Fig. (1).
4. Observe the Coercivity and Retentivity on CRO as shown in Fig. (1).
5. Tracing of B-H Curve: After obtaining a curve of suitable shape on CRO, a tracing paper is put on the screen. Now, set the vertical gain G_v to zero (with maximum horizontal gain) to obtain a straight line on the paper which marks the H-axis and then set the horizontal gain G_h (vertical gain G_v is not zero) to zero to get a straight line which marks B-axis. Now, adjust horizontal and vertical gain controls to their original position to obtain a curve of suitable shape. Trace this curve on the paper.

Observations:

Conclusion:

Quiz:

1. The unit of magnetic field intensity is ________________
2. Magnetic circuit obeys
   a) Kirchoff's Law b) Thevenin's theorem c) Nortorn's theorem d) None of these
3. The word "Hysteresis" means_______________________
4. The unit of H x B is ______________________

Suggested Reference:

1. "Basic Electrical Engineering" by T. K. Nagsarkar and M. S. Sukhija, Oxford university press.

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:
To determine resistance, inductance, power and power factor of series R-L circuit

Date:

Competency and Practical Skills: Knowledge of circuit theory, Familiarity with electrical components, Understanding of measuring instruments, Familiarity with safety measures, Analytical and troubleshooting skills, Ability to construct circuits.

Relevant CO: Analyze single phase and three phase AC circuits.

Objectives: (a) To understand the basic concepts of resistance, inductance, power, and power factor in R-L series circuits and how they are related to each other.
(b) To learn how to measure the resistance and inductance of a circuit using appropriate equipment and techniques, such as mustimeters.
(c) To investigate the relationship between the voltage, current, and phase angle in an R-L series circuit and to determine the power factor of the circuit..
(d) To understand the practical applications of R-L series circuits in electrical engineering, such as in AC power transmission and electric motors.

Equipment/Instruments: Rheostat, Ammeters, Voltmeters, Wattmeter, single phase AC Supply, Inductive coil, Connecting probes.

Theory: The series R-L circuit comprises a resistor and an inductor connected in series with a voltage source. When an AC voltage is applied to the circuit, it causes a current to flow through the circuit. Due to the presence of inductance, the current lags behind the voltage by an angle. The phase angle between the voltage and the current is known as the power factor.

The power factor of a circuit is defined as the ratio of the real power (P) to the apparent power (S). The real power is the power consumed by the circuit, while the apparent power is the product of the voltage and current. The power factor ranges from 0 to 1, with a power factor of 1 indicating a purely resistive circuit.

The resistance (R) and inductance (L) of the circuit can be calculated using various electrical measuring instruments, such as a voltmeter, an ammeter, and a wattmeter.

A choke coil can be considered as a series combination of resistance r and self-inductance L. Choke coil is connected in series with a non – inductive resistance R (lamp-bank) across a 230 V, 50 Hz AC supply. As per the fig.1,

$$Z_{ckt} = \frac{V_S}{I} \tag{1}$$

$$Z_{coil} = \frac{V_{coil}}{I} \tag{2}$$

$$R = \frac{V_R}{I} \tag{3}$$

Where Z_{ckt} — Impedance of Total circuit

Z_{coil} — Impedance of choke coil

R — Resistance of Rheostat

V_s – Supply Voltage

V_R – Voltage across Rheostat
r – Resistance of choke coil

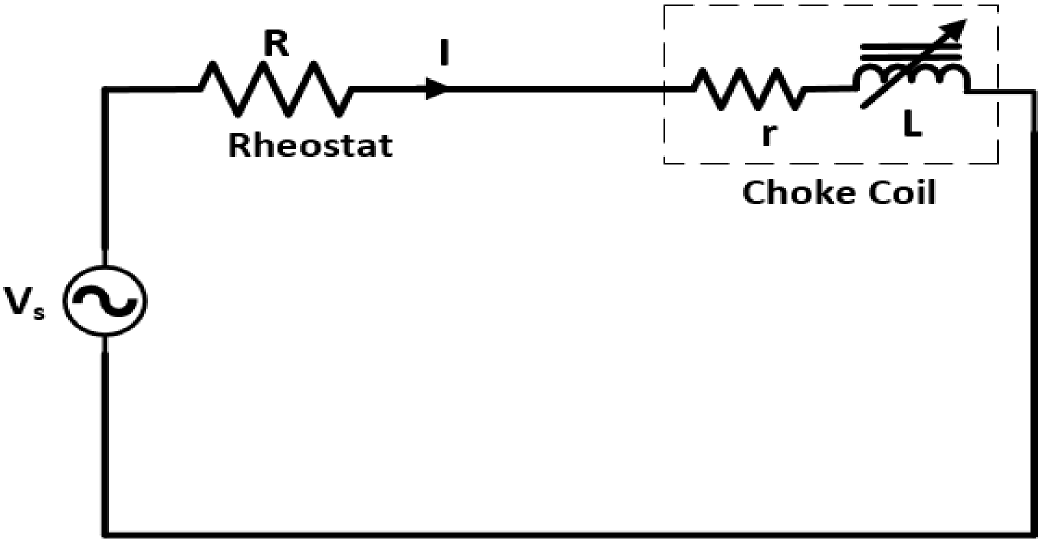


fig.1

It is evident that $(R + r)^2 + X^2 = Z^2_{ckt}$ (4)

$$R^2 + 2Rr + r^2 + X^2 = Z^2_{ckt}$$

But $Z^2_{coil} = r^2 + X^2$

$$\omega L = X$$

$$R^2 + 2Rr + Z^2_{coil} = Z^2_{ckt}$$

$$r = \frac{Z^2_{ckt} - Z^2_{coil} - R^2}{2R} \quad (5)$$

Now, $Z^2_{coil} = r^2 + X^2$

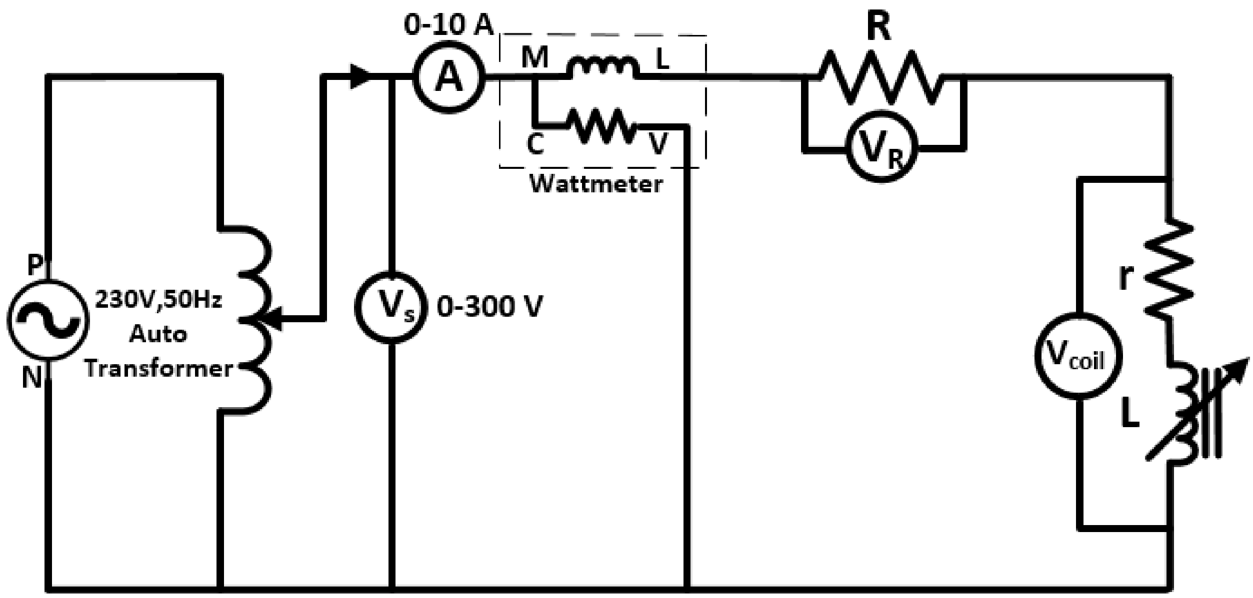
$$X = \sqrt{Z^2_{coil} - r^2} \quad (6)$$

But, $\omega L = X$

$$L = \frac{X}{\omega} = \frac{X}{2\pi f} H$$

Thus, resistance and inductance of choke coil can be calculated.

Set up diagram:



Safety and necessary Precautions:

1 Wear protective gear
2 Ensure proper wiring
3 Use appropriate voltage
4 Use appropriate measuring equipment
5 Avoid touching the circuit
6 Handle components with care
7 Follow laboratory guidelines

Procedure:

1. Set up the series R-L circuit by connecting the rheostat and choke coil in series.
2. Connect the voltmeter across the resistor to measure the voltage (V_R).
3. Connect the ammeter in series with the circuit to measure the current (I).
4. Connect the wattmeter to measure the power consumed by the circuit.
5. Switch on the AC voltage supply, Adjust the voltage to any suitable value
6. Record the readings of voltage, current, and power.
7. Repeat the measurements for different values of voltages.
8. Calculate the resistance (r), inductance (L), power (P), and power factor (PF).

Observations:

Sr. No.	Supply voltage V_s (volts)	Voltage across rheostat V_R (volts)	Voltage across coil V_{coil} (volts)	Current I (amps)	Power P (watts)
1.					
2.					
3.					

Calculation:

(Reading-1)

(1) $Z_{ckt} = \frac{V_s}{I} =$ $Z_{coil} = \frac{V_{coil}}{I} =$ $R = \frac{V_R}{I} =$

(2) $r = \frac{Z_{ckt}^2 - Z_{coil}^2 - R^2}{2R} =$ $X^2 = Z_{coil}^2 - r^2 =$ $L = \frac{X}{2\pi f} H =$

(3) $\cos\phi = \frac{R+r}{Z_{ckt}} =$ Power $P = V_s I \cos\phi =$

(Reading-2)

(1) $Z_{ckt} = \frac{V_s}{I} =$ $Z_{coil} = \frac{V_{coil}}{I} =$ $R = \frac{V_R}{I} =$

(2) $r = \frac{Z_{ckt}^2 - Z_{coil}^2 - R^2}{2R} =$ $X^2 = Z_{coil}^2 - r^2 =$ $L = \frac{X}{2\pi f} H =$

(3) $\cos\phi = \frac{R+r}{Z_{ckt}} =$ Power $P = V_s I \cos\phi =$

(Reading-3)

(1) $Z_{ckt} = \frac{V_s}{I} =$ $Z_{coil} = \frac{V_{coil}}{I} =$ $R = \frac{V_R}{I} =$

(2) $r = \frac{Z_{ckt}^2 - Z_{coil}^2 - R^2}{2R} =$ $X^2 = Z_{coil}^2 - r^2 =$ $L = \frac{X}{2\pi f} H =$

(3) $\cos\phi = \frac{R+r}{Z_{ckt}}$ =   Power $P = V_s I \cos\phi$ =

Result:

Sr. No	**R**	**Z_{ckt}**	**Z_{coil}**	**Resistance of coil *(r)* Ω**	**Inductance of coil (L) H**	**Inductive reactance of coil (X) Ω**	**Power (P) Watt**	**Power factor (cosΦ)**
1.								
2.								
3.								

PHASOR DIAGRAM:

1. Select the scale 1 cm = _______ volts.
2. Draw the current (I) as a reference phasor OE as shown in Fig. 1.
3. Draw the phasor OB (=VR) to the scale in phase with the current phasor OE.
4. From the point B, draw an arc of radius equal to Vcoil (to the scale).
5. From the point O, draw an arc of radius equal to Vs (to the scale) such that it intersects the previous arc at A.
6. Thus, phasor BA represents the voltage across the coil and phasor OA represents the supply voltage.
7. Draw the perpendicular from the point A intersecting the current phasor at D.
8. Phasor BD represents the voltage across the resistance of the coil. Hence BD = Ir.
9. Phasor AD represents the voltage across the inductive reactance of the coil. Hence AD = I_X
10. Determine r and L from the phasor diagram. Compare the results.

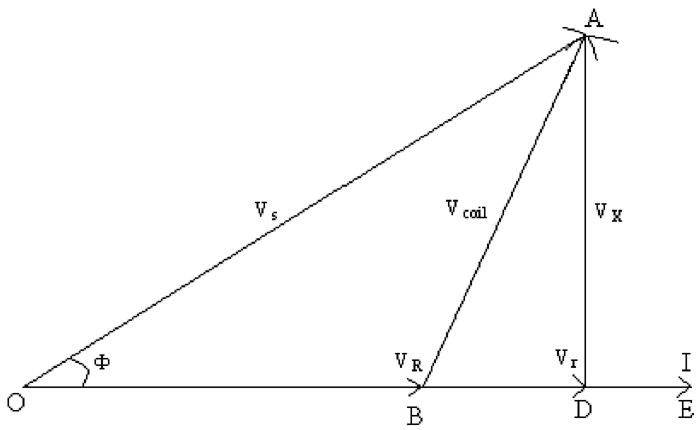


fig.2

Conclusion:

Quiz:

1. Define RMS value.

2. What is phasor?

3. What is impedance triangle?

4. State advantages of sinusoidal alternating quantity.

Suggested Reference:

1. "Basic Electrical Engineering" by T. K. Nagsarkar and M. S. Sukhija, Oxford university press.
2. **https://vlab.amrita.edu/?sub=1&brch=75&sim=332&cnt=1**

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:
To verify the current and voltage relationships in three phase star and delta connections.

Date:

Competency and Practical Skills: Understanding of Three-Phase Systems, Knowledge of Star and Delta Connections, Familiarity with Electrical Instruments, Practical Skills in Wiring, Analytical and Problem-Solving Skills, Safety and Lab Etiquette

Relevant CO: Analyze single phase and three phase AC circuits.

Objectives: (a) To understand the concepts of three-phase power systems, star and delta connections, and their applications in practical scenarios.
(b) To verify the relationship between line and phase voltages and currents in three-phase star and delta connections using various measuring instruments such as voltmeters, ammeters, and wattmeters
(c) To understand the importance of safety measures when working with electrical circuits and equipment.

Equipment/Instruments: 3-phase Auto Transformer, AC voltmeters and Ammeters, lamp load, Connecting wires.

Theory: Three-phase power systems are widely used in electrical power distribution. The three-phase system consists of three conductors carrying alternating currents that are 120 degrees out of phase with each other. The most common configurations for three-phase systems are star and delta connections. In this write-up, we will discuss the current and voltage relationships in both star and delta connections and the methods to verify them.

Star Connection:

In a three-phase star connection, three-phase windings of a transformer or an electrical machine are connected together at a common point called the neutral. The three-phase conductors are connected to the remaining ends of the windings, and the voltage between any two of these conductors is known as the line voltage. The current flowing in each winding is known as the phase current.

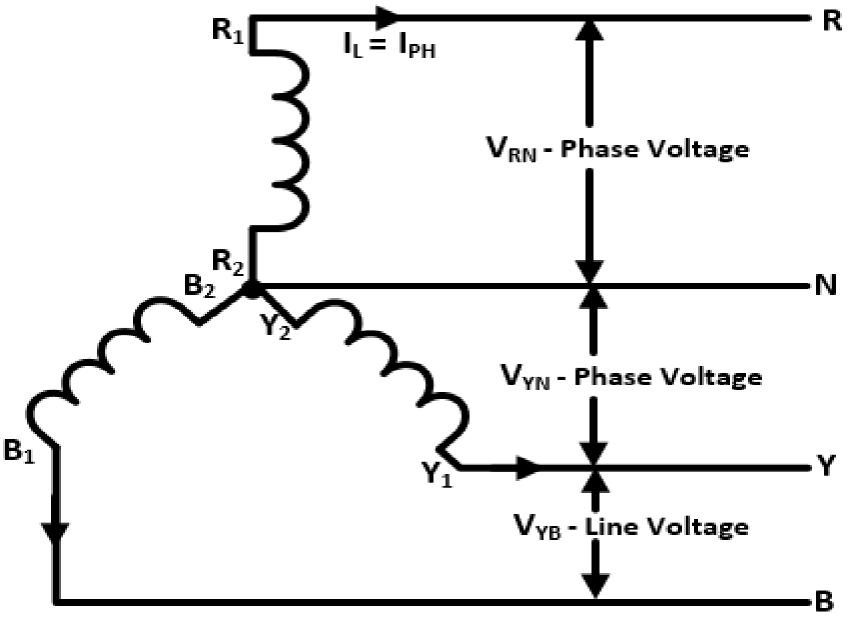


Fig.1

In the three-phase system, where all the three phases wires are connected to a common point. This common point is known as the neutral point. And this type of connection is known as Star Connection. The star connection will be called a three-phase three-wire system when only three live wires are used. And the star connection will be called a three-phase four-wire system when all the three phases and the neutral wire is used. The neutral wire is connected to the neutral point where all three phases are connected. As the star connection looks like the English letter 'Y', it is also known as wye connection.

- In the star connection, all three phases are connected to a neutral point. If the voltage across all the phases and the current in each phase are equal, the voltage of the neutral point will be zero.
- In the star connection, the line voltage and phase voltage are different. Line voltage is root 3 times of phase voltage. Line voltage is measured between any two phases whereas phase voltage is measured between any one phase and neutral.
- In a star connection, we can have two different voltages, so we can connect it with two different circuits operated at two different voltages. For example, from a 440V three-phase system, we can get two different voltages such as 440V and 230V.
- In the star connection, the line current is equal to the phase current.
- In the star connection, less insulation is required for each phase as the phase voltage is less than the line voltage.

As the line and phase voltage is different for the star connection,

So relationship of line voltage with phase voltage is,

$$V_L = \sqrt{3} * V_{PH}$$

Line Voltage = $\sqrt{3}$ * Phase Voltage

The relationship of line current in the star connection is

$$I_L = I_{PH}$$

Line Current = Phase Current

Delta Connection:

In a three-phase delta connection, the three-phase windings are connected in a closed loop. Each winding is connected to the next winding in the sequence, and the end of the third winding is connected back to the beginning of the first winding. The voltage between any two of the windings is known as the phase voltage, and the current flowing in each winding is known as the phase current.

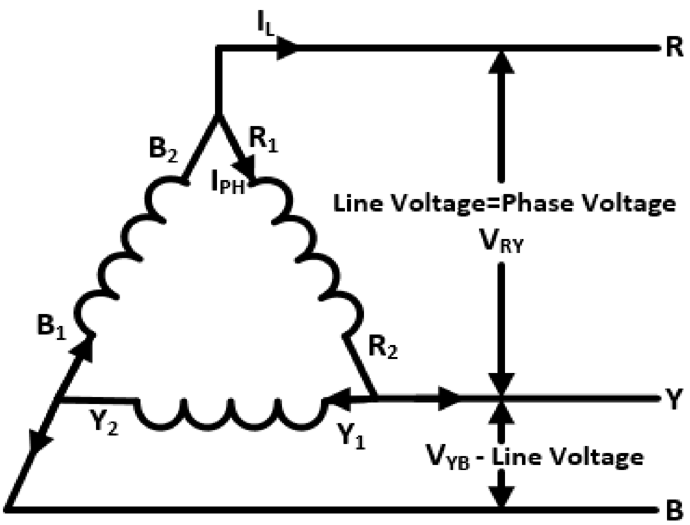


Fig.2

- There is no neutral point in the delta connection.

- In the delta connection, phase voltage is equal to the line voltage.
- In the delta connection, the line current is root three times the phase current.
- Delta connection provides a single voltage. Here, you can not get two different voltages like the star connection.

As the line and phase current is different for the delta connection,
So relationship of line current is,

$$I_L = \sqrt{3} * I_{PH}$$

Line Current = $\sqrt{3}$ * Phase Current

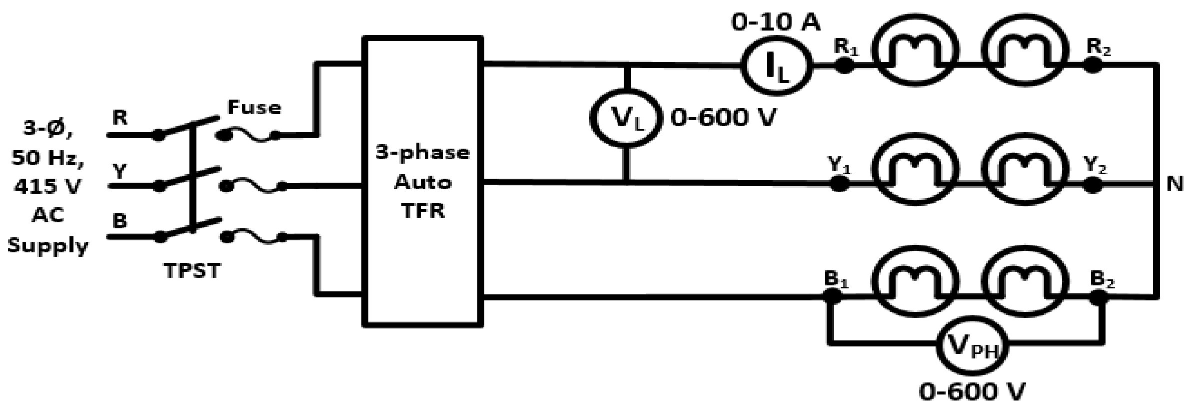
The relationship of line voltage in the delta connection is

$$V_L = V_{PH}$$

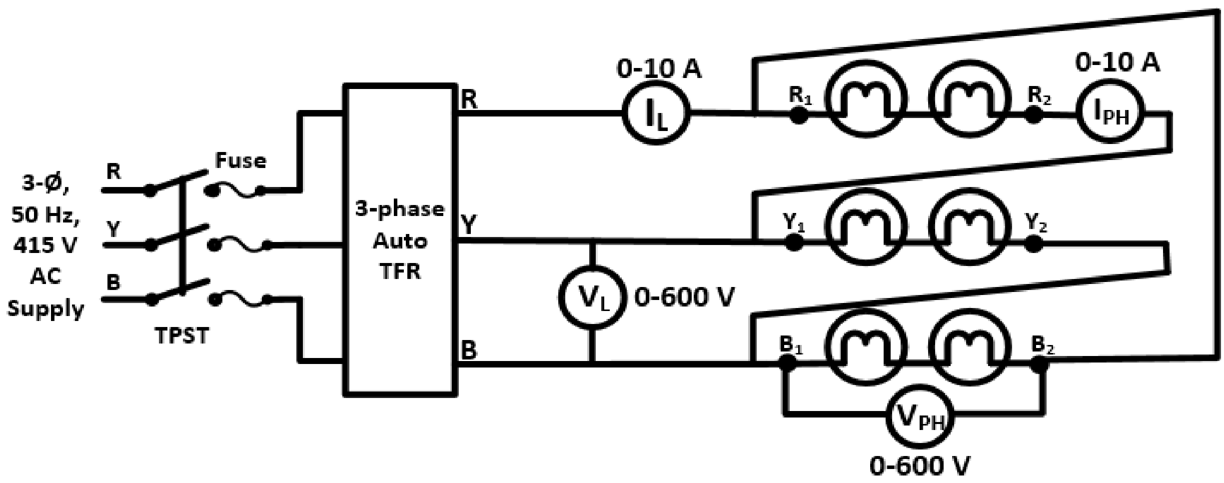
Line Voltage = Phase Voltage

Set up diagram:

Star Connection:



Delta Connection:



Safety and necessary Precautions:

1. Wear protective gear
2. Ensure proper wiring
3. Use appropriate voltage
4. Use appropriate measuring equipment
5. Avoid touching the circuit
6. Handle components with care
7. Follow laboratory guidelines

Procedure:

Star Connected Load

a. Connect the circuit of star connection as per circuit diagram shown above.
b. Switch on the AC voltage supply by keeping the autotransformer in minimum position.
c. Vary the auto transformer voltage and set at appropriate value.
d. Note down corresponding readings of ammeter and voltmeters.
e. Verify $V_{PH} = \frac{V_L}{\sqrt{3}}$ and $I_L = I_{PH}$
f. Repeat the above procedure for different value of voltages.
g. Bring back the auto transformer to minimum position. Switch off the supply and remove all connections.

Delta Connected Load

a. Connect the circuit of delta connection as per circuit diagram shown above.
b. Switch on the AC voltage supply by keeping the autotransformer in minimum position.
c. Vary the auto transformer voltage and set at appropriate value.
d. Note down corresponding readings of ammeter and voltmeters.
e. Verify $V_L = V_{PH}$ and $I_{PH} = \frac{I_L}{\sqrt{3}}$
f. Repeat the above procedure for different value of voltages.
g. Bring back the auto transformer to minimum position. Switch off the supply and remove all connections.

Observations:

Star Connection:

SR No	Line Voltage V_L (V)	Phase Voltage V_{PH} (V)	Line Current I_L (A)	Phase Current I_{PH} (A)	$V_{PH} = V_L/\sqrt{3}$

Delta Connection:

SR No	Line Voltage V_L (V)	Phase Voltage V_{PH} (V)	Line Current I_L (A)	Phase Current I_{PH} (A)	$I_{PH} = I_L/\sqrt{3}$

Calculation:

Conclusion:

Quiz:

1. What are advantages of 3-Ø supply over 1-Ø supply?

2. What do you mean by balanced system?

3. Write the formula of Active power for 3-Ø delta connected load.

4. Phase angle between line voltage and phase voltage in star connected load is__________

Suggested Reference:

1. B. L. Theraja, "Electrical Technology – Part I and II", S. Chand and Co. 2012
2. Basic Electrical Engineering - Nagsarkar and Sukhija, Oxford University Press

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:
To Measure power in three phase circuit by two wattmeter method.

Date:

Competency and Practical Skills: Knowledge of three-phase power systems, Knowledge of Wattmeters, Familiarity with two-wattmeter method, Understanding of safety precautions,

Relevant CO: Analyze single phase and three phase AC circuits.

Objectives: (a) To understand the principle of operation of the two-wattmeter method.
(b) To learn the connection of wattmeters in a three-phase circuit
(c) To verify the theory of two-wattmeter method by calculating power in three-phase circuit.
(d) To observe the phase angle between the voltage and current in a three-phase circuit and to determine the power factor of the circuit.
(e) To compare the power calculated by the two-wattmeter method with the power calculated by the three-wattmeter method and to evaluate the accuracy of the two-wattmeter method

Equipment/Instruments: 3-phase Auto Transformer, AC voltmeters and Ammeters, lamp load, Connecting wires.

Theory: Power in a three phase system with balanced or unbalanced load can be measured by two wattmeter method. The load may be star or delta connected. Here we have considered star connected load as shown in fig, although it can be equally applied to a delta connected load.
Two wattmeter methods is the most common method for the measurement of power in 3- phase system. The current coils are of two wattmeters are connected in series in any two lines and the potential coils are connected between these lines and the third line in which the current coil is not connected. It can be proved that the sum of instantaneous values of power indicated by these wattmeters equal s the total power absorbed by the 3-phase load.
Let us consider two wattmeters connected to measure power in three phase circuit as shown in circuit diagram.

Instantaneous reading of P_1 wattmeter, $P_1 = I_1. (V_1 - V_3)$

Instantaneous reading of P_2 wattmeter, $P_2 = I_2. (V_2 - V_3)$

Sum of instantaneous readings of two wattmeter's, $P = P_1 + P_2$

$$= I_1 (V_1 - V_3) + I_2. (V_2 - V_3)$$
$$= V_1 I_1 + V_2 I_2 - V_3 (I_1 + I_2)$$

From Kirchoff's law, $I_1 + I_2 + I_3 = 0$ OR $I_3 = - (I_1+I_2)$
Therefore, the sum of instantaneous readings of two wattmeters, $V_1I_1 + V_2I_2 + V_3I_3$
Therefore the sum of 2 wattmeter readings is equal to the power consumed by the load. This is irrespective of whether the load is balanced or unbalanced.

<u>For balanced star connected load</u>

ABBREVIATIONS:

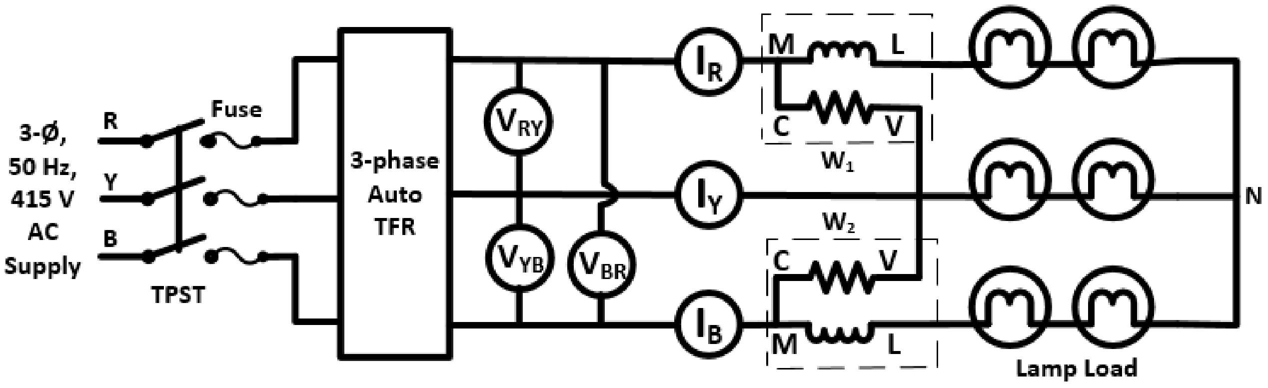
Line Voltage (V_L) = $\sqrt{3}$ Phase Voltage (V_{PH})

Line Voltage (V_L) = $V_{RY} = V_{YB} = V_{BR} = V_L = \sqrt{3}\ V_{PH}$

Phase Voltage (V_{PH}) = $V_R = V_Y = V_B = V_{PH} = V$

Line Current (I_L) = Phase Current (I_{PH}) = I

Set up diagram:



Safety and necessary Precautions:

1. Wear protective gear
2. Ensure proper wiring
3. Use appropriate voltage
4. Use appropriate measuring equipment
5. Avoid touching the circuit
6. Handle components with care
7. Follow laboratory guidelines

Procedure:

1. Make connections as per circuit diagram.
2. Keep operating dial of 3-phase variac at its null ('0') position & then switch ON 3-phase input a.c. supply.
6. By controlling the operating dial of 3-phase variac, set the input phase voltage (V) at appropriate value making sure that the 3-phase supply is balanced.
7. Gradually increase the load equally in all phases and note down various readings
8. Note line voltages and line currents of respective lines.
9. Note readings of wattmeter (W_1) and wattmeter (W_2).
10. Calculate $\emptyset = \tan^{-1}(\sqrt{3}\frac{W1-W2}{W1+W2})$

Observations:

Sr. No.	Observation Table								Calculations	
	Line Voltage			Line Current			Wattmeter Reading		3 ϕ Active Power (= P)	
	V_{RY}	V_{YB}	V_{BR}	I_R	I_Y	I_B	W_1	W_2	$P = W_1 + W_2$	$P = \sqrt{3}\, V_L I_L \cos \phi$
1.										
2.										
3.										

Calculation:

3- ϕ Active Power $P = \sqrt{3}\, V_L\, I_L \cos \phi$ = __________

3-ϕ Re active Power $Q = \sqrt{3}\, V_L\, I_L \sin \phi$ = __________

Apparent Power $S = \sqrt{3}\, V_L\, I_L$ = __________

Conclusion:

Quiz:

1. Define power factor.

2. Two wattmeter method is applicable for star connected system or delta connected system or both? Justify your answer.

3. Total number of phase sequence in 3-Ø AC system is___________
4. In the two wattmeter method of measuring power in 3-Ø circuit, the two wattmeter will show equal readings when the power factor angle is equal to______

Suggested Reference:

1. A. Chakrabarti, Circuit Theory (Analysis and Synthesis). Fifth Edition : 2006, Dhanpat Rai and Co.
2. Basic Electrical Engineering - Nagsarkar and Sukhija, Oxford University Press
3. http://vlabs.iitkgp.ernet.in/asnm/exp7/index.html Analog Signals, Network and Measurement Laboratory(IIT KHARAGPUR)

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:
To demonstrate the working of miniature circuit breaker (MCB)

Date:

Competency and Practical Skills: Knowledge of electrical circuits, Familiarity with MCBs, Understanding of measuring instruments, Practical skills in wiring and circuit assembly, Knowledge of safety precautions.

Relevant CO: Comprehend electrical installations, their protection and personnel safety.

Objectives: (a) To understand the operating principles of miniature circuit breakers and their role in electrical circuit protection.
(b) To plot the current vs. time characteristics of the MCB for different levels of overcurrent and to observe the trip time of the MCB.
(c) To identify the limitations and applications of MCBs and to appreciate their importance in electrical safety.

Equipment/Instruments: Ammeter, Voltmeter, Single phase supply, MCB, Connecting Wires.

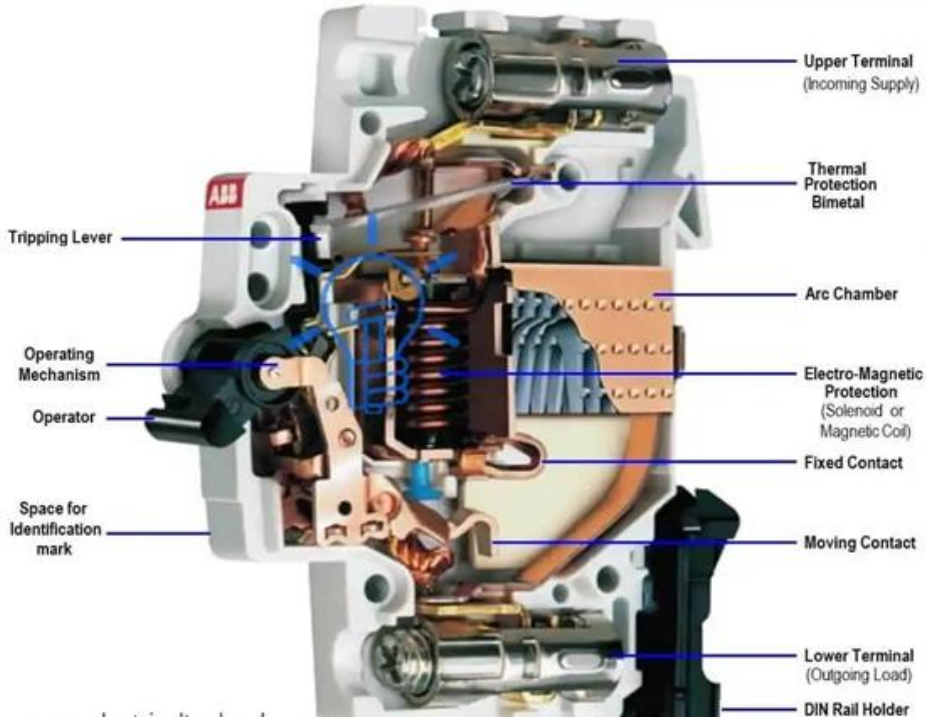
Theory: The theory behind the laboratory experiment to plot the characteristics of miniature circuit breaker (MCB) involves understanding the operation and behavior of the MCB under different abnormal conditions.

An MCB is a type of circuit breaker that is commonly used in low-voltage electrical systems to protect against overcurrents and short circuits. It is designed to trip and open the circuit when the current exceeds a certain value, which is known as the tripping current.

Construction of MCB:

MCB embodies a complete enclosure in a moulded insulating material. This provides mechanically strong and insulated housing.

The switching system consists of a fixed and a moving contact to which incoming and outgoing wires are connected. The metal or current carrying parts are made up of electrolytic copper or silver alloy depending on the rating of the circuit breaker.



As the contacts are separated in the event of an overload or short circuit situation, an electric arc is formed. All modern MCBs are designed to handle arc interruption processes where arc energy extraction and its cooling are provided by metallic arc splitter plates.

These plates are held in a proper position by an insulating material. Also, arc runner is provided to force the arc that is produced between the main contacts.

The operating mechanism consists of both magnetic tripping and thermal tripping arrangements.

The magnetic tripping arrangement essentially consists of a composite magnetic system that has a spring loaded dashpot with a magnetic slug in a silicon fluid, and a normal magnetic trip. A current carrying coil in the trip arrangement moves the slug against spring towards a fixed pole piece. So the magnetic pull is developed on the trip lever when there is a sufficient magnetic field produced by the coil.

In case of short circuits or heavy overloads, strong magnetic field produced by the coils (Solenoid) is sufficient to attract the armature of the trip lever irrespective of the position of the slug in the dashpot.
The thermal tripping arrangement consists of a bimetallic strip around which a heater coil is wound to create heat depending on the flow of current.

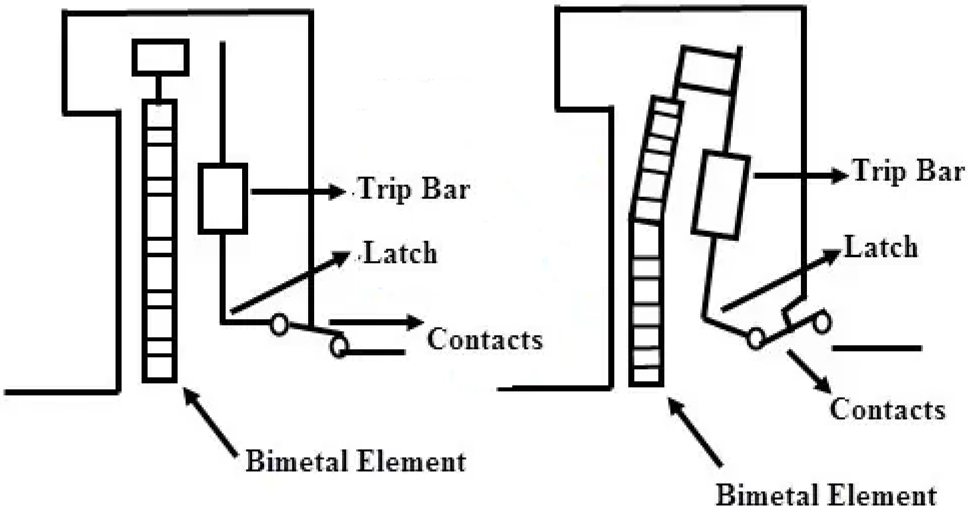
The heater design can be either direct where current is passed through a bimetal strip which affects part of electric circuit or indirect where a coil of current carrying conductor is wound around the bimetallic strip. The deflection of a bimetallic strip activates the tripping mechanism in case of certain overload conditions.

The bimetal strips are made up of two different metals, usually brass and steel. These metals are riveted and welded along their length. These are so designed such that they will not heat the strip to the tripping point for normal currents, but if the current is increased beyond rated value, the strip is warmed, bent and trips the latch. Bimetallic strips are chosen to provide particular time delays under certain overloads.

Working & Operation of MCB

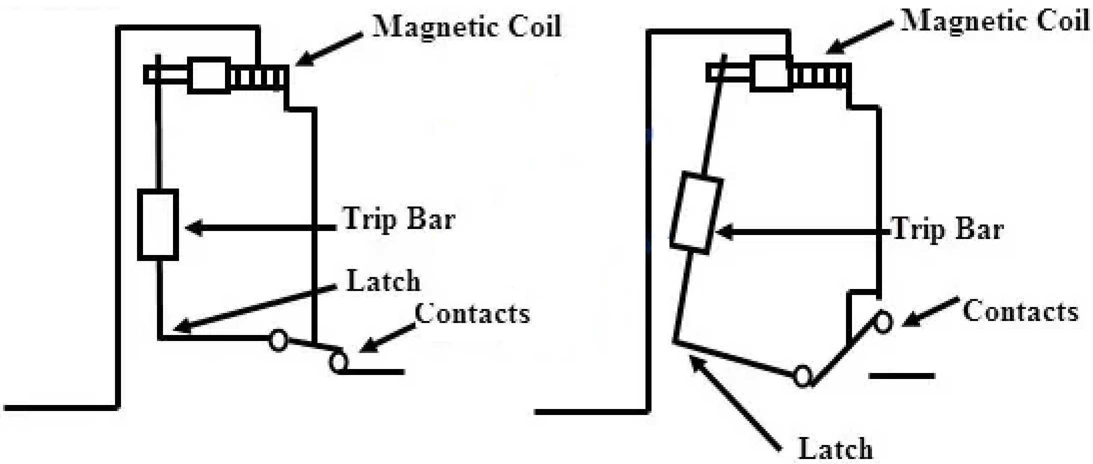
Under normal working conditions, MCB operates as a switch (manual one) to make the circuit ON or OFF. Under overload or short circuit condition, it automatically operates or trips so that current interruption takes place in the load circuit.

The visual indication of this trip can be observed by automatic movement of the operating knob to OFF position. This automatic operation MCB can be obtained in two ways as we have seen in MCB construction; those are magnetic tripping and thermal tripping.



Under overload conditions, the current through the bimetal causes it to raise the temperature of it. The heat generated within the bimetal itself is enough to cause deflection due to thermal expansion of metals. This deflection further releases the trip latch and hence contacts get separated.

In some MCBs, the magnetic field generated by the coil causes it to develop pull on bimetals such that deflection activates the tripping mechanism.



Under short circuit or heavy overload conditions, magnetic tripping arrangement comes into the picture. Under normal working conditions, the slug is held in a position by a light spring because the magnetic field generated by the coil is not sufficient to attract the latch.

When a fault current flows, the magnetic field generated by the coil is sufficient to overcome the spring force holding the slug in position. And hence slug moves and then actuate the tripping mechanism.

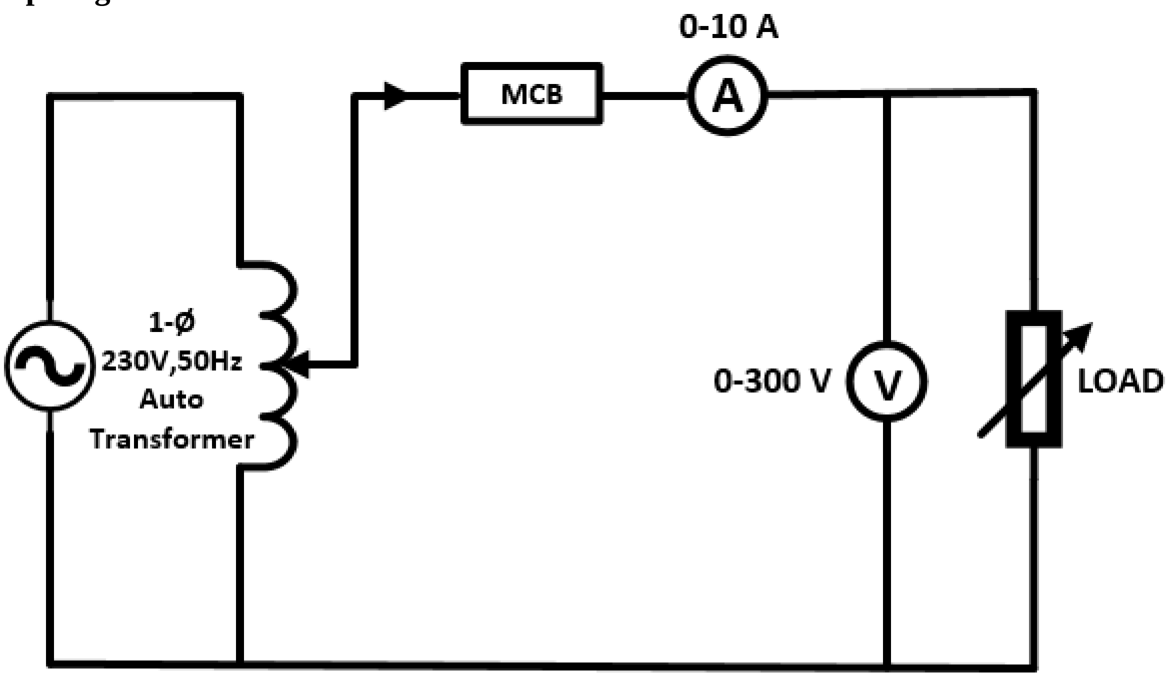
A combination of both magnetic and thermal tripping mechanisms are implemented in most miniature circuit breakers. In both magnetic and thermal tripping operations, an arc is formed when the contacts start separating. This arc is then forced into arc splitter plates via arc runner.

These arc splitter plates are also called arc chutes where arc is formed into a series of arcs and at the same time energy extracted and cools it. Hence this arrangement achieves the arc extinction.

To plot the characteristics of an MCB, the experiment typically involves measuring the tripping current of the MCB under different conditions. This can be done by connecting the MCB in series with a power source and a load, and then introducing different levels of fault current by varying the load or introducing a short circuit.

The experiment involve measuring the tripping current at different time intervals to observe the behavior of the MCB over time. This can help to determine the tripping characteristics of the MCB, such as the time-delay characteristics and the instantaneous trip characteristics.

Set up diagram:



Safety and necessary Precautions:
1. Wear protective gear
2. Ensure proper wiring
3. Use appropriate voltage
4. Use appropriate measuring equipment
5. Avoid touching the circuit
6. Handle components with care
7. Follow laboratory guidelines

Procedure:
1. Connect the circuit as per circuit setup diag.
2. Switch on 1-Ø AC supply and set appropriate voltage.
3. Gradually vary the load until MCB gets tripped.
4. Note down the tripping current.

.

Observations:
Tripping Current=

Conclusion:

Quiz:

1. What is the function of MCB?

2. State difference between MCB and MCCB.

3. What is the difference between fuse and MCB?

Suggested Reference:

1. "Switchgear and protection" by Sunil S Rao, Dhanpat rai.
2. **MCB (Miniature Circuit Breaker) - Construction, Types & Working (electricaltechnology.org)**

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:
To Study Construction of DC Machine (Generator & Motor)

Date:

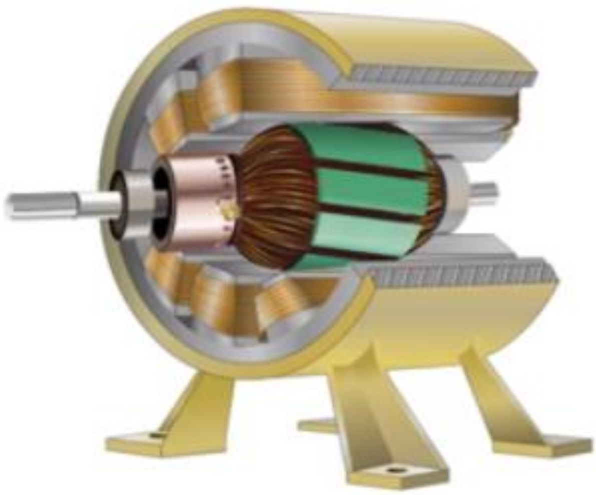
Competency and Practical Skills: Basic Electrical Knowledge, Reading and Understanding Electrical Diagrams, Knowledge of safety precautions.

Relevant CO: Describe operating principle and applications of static and rotating electrical machines

Objectives: (a) To understand the constriction of DC machines.
(b) To familiarize with DC machine terminologies.
(c) To study working principle of DC machines.

Equipment/Instruments: Cut section of DC Machine.

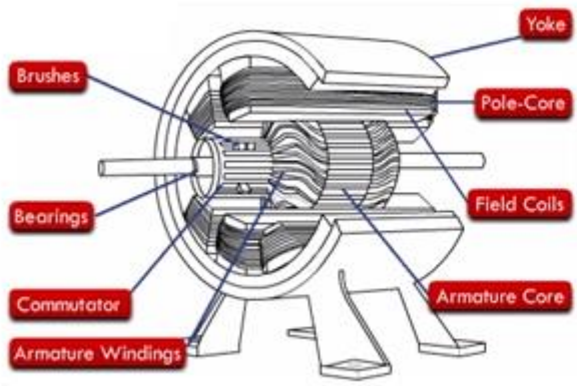
Theory: The dc generators and dc motors have the same general construction. In fact, when the machine is being assembled, the workmen usually do not know whether it is a dc generator or motor. Any dc generator can be run as a dc motor and vice-versa.

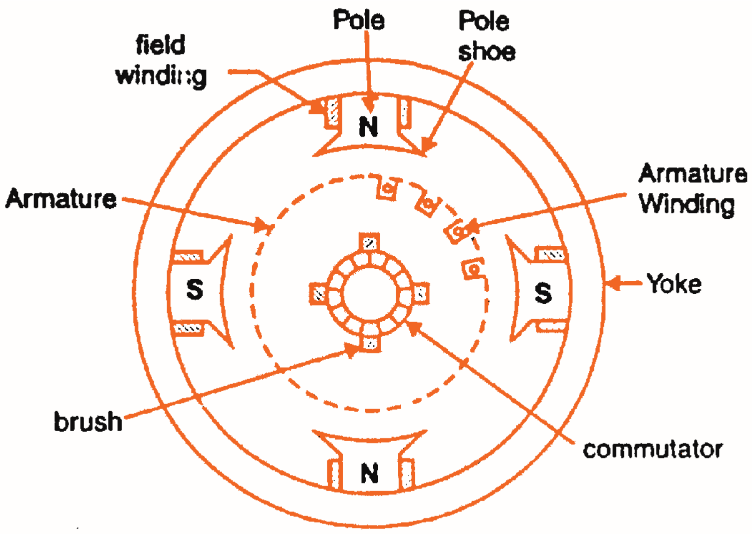


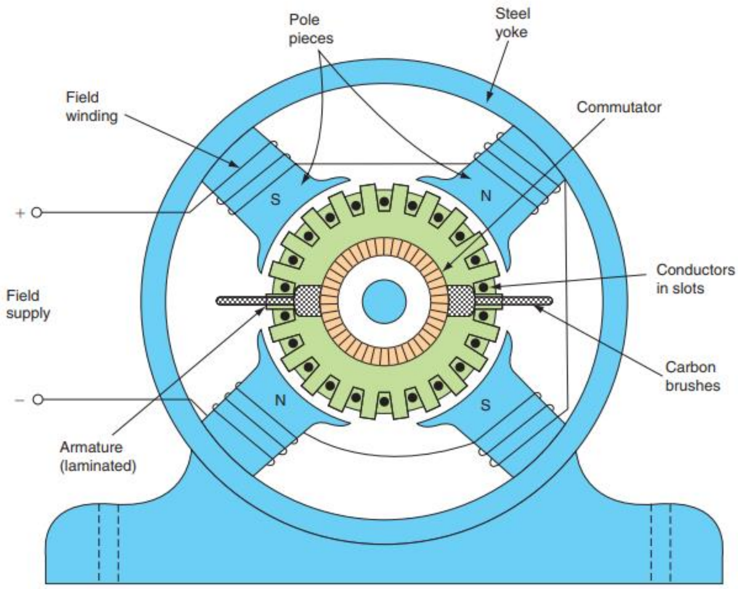
All dc machines have five principal components

1. Magnetic frame or Yoke
2. Pole Cores and Pole Shoes
3. Pole Coils or Field Coils
4. Armature core
5. Armature winding
6. Commutator
7. Brushes and Bearings

The diagram given below represents the various parts of a DC machine.



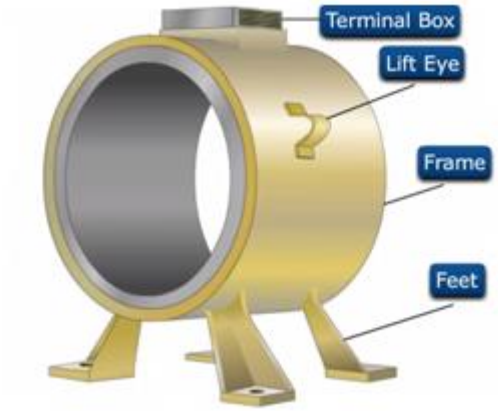




Yoke

The outer frame or yoke serves double purpose :

1. It provides mechanical support for the poles and acts as a protecting cover for the whole machine
2. It carries the magnetic flux produced by the poles.

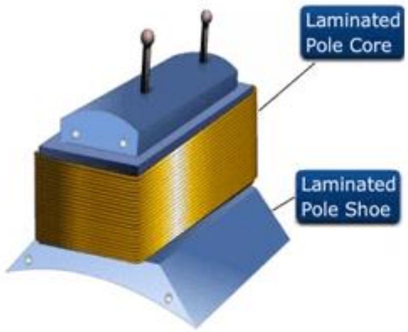


In small generators where cheapness rather than weight is the main consideration, yokes are made of cast iron.
But for large machines usually cast steel or rolled steel is employed.
The modern process of forming the yoke consists of rolling a steel slab round a cylindrical mandrel and then welding it at the bottom. The feet and the terminal box etc. are welded to the frame afterwards. Such yokes possess sufficient mechanical strength and have high permeability.

Pole Cores and Pole Shoes

The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes: they spread out the flux in the air gap and also, being of larger cross-section, reduce the reluctance of the magnetic path

1. they support the exciting coils (or field coils) There are two main types of pole construction.



- The pole core itself may be a solid piece made out of either cast iron or cast steel but the pole shoe is laminated and is fastened to the pole face by means of counter sunk screws
- In modern design, the complete pole cores and pole shoes are built of thin laminations of annealed steel which are rivetted together under hydraulic pressure. The thickness of laminations varies from 1 mm to 0.25 mm.

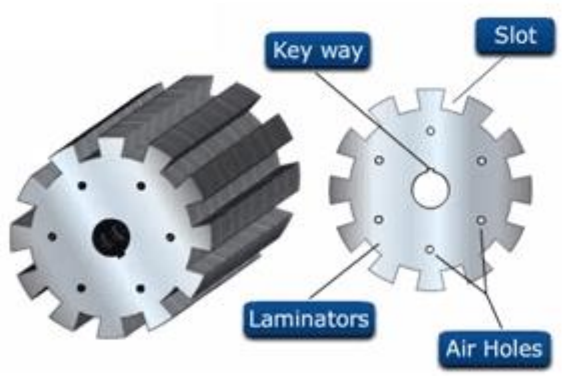
Field system

The function of the field system is to produce uniform magnetic field within which the armature rotates. Field coils are mounted on the poles and carry the dc exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity. The m.m.f. developed by the field coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature and the frame. Practical d.c. machines have air gaps ranging from 0.5 mm to 1.5 mm.

Since armature and field systems are composed of materials that have high permeability, most of the m.m.f. of field coils is required to set up flux in the air gap. By reducing the length of air gap, we can reduce the size of field coils (i.e. number of turns).

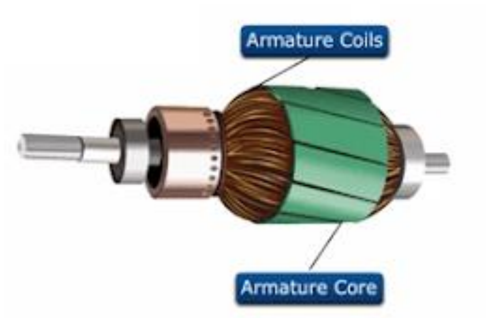
Armature core and Laminations

The armature core is keyed to the machine shaft and rotates between the field poles. It consists of slotted soft-iron laminations (about 0.4 to 0.6 mm thick) that are stacked to form a cylindrical core as shown in figure.
The laminations are individually coated with a thin insulating film so that they do not come in electrical contact with each other. The purpose of laminating the core is to reduce the eddy current loss. Thinner the lamination, greater is the resistance offered to the induced e.m.f., smaller the current and hence lesser the I^2R loss in the core.The laminations are slotted to accommodate and provide mechanical security to the armature winding and to give shorter air gap for the flux to cross between the pole face and the armature "teeth".



Armature winding

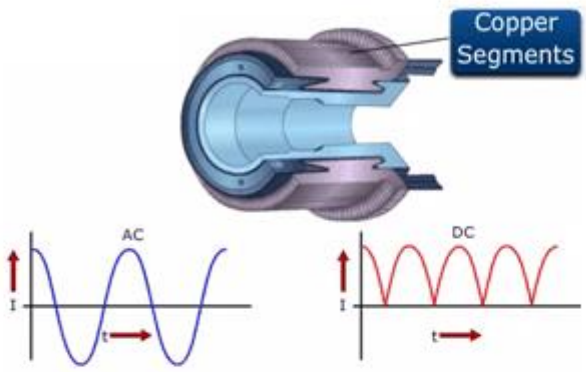
The slots of the armature core hold insulated conductors that are connected in a suitable manner. This is known as armature winding.This is the winding in which "working" e.m.f. is induced. The armature conductors are connected in series-parallel; the conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current.



The armature winding of a d.c. machine is a closed-circuit winding; the conductors being connected in a symmetrical manner forming a closed loop or series of closed loops. Depending upon the manner in which the armature conductors are connected to the commutator segments, there are two types of armature winding in a.c.machine viz.,
(a) lap winding
(b) wave winding.

Commutator
A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes.
The commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine . The armature conductors are soldered to the commutator segments in a suitable manner to give rise to the armature winding.

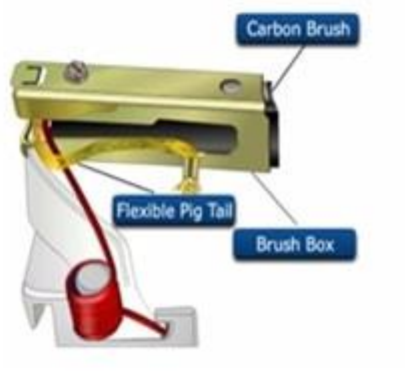
Depending upon the manner in which the armature conductors are connected to the commutator segments, there are two types of armature winding in a d.c. machine viz.,
(a) lap winding
(b) wave winding.



Great care is taken in building the commutator because any eccentricity will cause the brushes to bounce, producing unacceptable sparking. The sparks may bum the brushes and overheat and carbonize the commutator.

Brushes

DC motors are of two types : one is brushed dc motor and the other one is brushless dc motor. Brushless dc motors are mainly used in high speed applications such as multicopters (eg:-quadcopters). The purpose of brushes in a dc generator is to ensure electrical connections between the rotating commutator and stationary external load circuit. The brushes are made of carbon and rest on the commutator. The brush pressure is adjusted by means of adjustable springs.



If the brush pressure is very large, the friction produces heating of the commutator and the brushes. On the other hand, if it is too weak, the imperfect contact with the commutator may produce sparking.

Multipole machines have as many brushes as they have poles. For example, a 4-pole machine has 4 brushes. As we go round the commutator, the successive brushes have positive and negative polarities. Brushes having the same polarity are connected together so that we have two terminals viz., the +ve terminal and the -ve terminal

Conclusion:

Quiz:

1. What is the function of Commutator?

2. What is the function of brush and what material is it made of?

3. Why armature core is laminated?

Suggested Reference:

1. "Basic Electrical Engineering" by T. K. Nagsarkar and M. S. Sukhija, Oxford university press.
2. https://nptel.ac.in/courses/108105017

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Experiment No:

To study different types of batteries and its applications.

Date:

Competency and Practical Skills: Knowledge of basic chemistry, Familiarity with electrical circuits, Understanding of battery technology.
Relevant CO: Comprehend electrical installations, their protection and personnel safety.

Objectives: (a) To understand the basic principles of battery operation.
(b) To identify the differences between primary and secondary batteries, and their respective advantages and disadvantages.
(c) To explore the various types of primary batteries, such as alkaline, lithium, and zinc-carbon batteries, and their unique properties and applications.
(d) To investigate the different types of secondary batteries, such as lead-acid, nickel-cadmium, and lithium-ion batteries, and their specific characteristics and uses.

Equipment/Instruments: Batteries.

Theory: A battery is a collection of one or more cells that go under chemical reactions to create the flow of electrons within a circuit. There is lot of research and advancement going on in battery technology, and as a result, breakthrough technologies are being experienced and used around the world currently. Batteries came into play due to the need to store generated electrical energy. As much as a good amount of energy was being generated, it was important to store the energy so it can be used when generation is down or when there is a need to power standalone devices which cannot be kept tethered to the supply from the mains. Here it should be noted that only DC can be stored in the batteries, AC current can’t be stored.

Battery cells are usually made up of three main components;

1. The Anode (Negative Electrode)
2. The Cathode (Positive Electrode)
3. The electrolytes

The anode is a negative electrode that produces electrons to the external circuit to which the battery is connected. When batteries are connected, an electron build-up is initiated at the anode which causes a potential difference between the two electrodes. The electrons naturally then try to redistribute themselves, this is prevented by the electrolyte, so when an electrical circuit is connected, it provides a clear path for the electrons to move from the anode to the cathode thereby powering the circuit to which it is connected. By changing the arrangement and material used to build the Anode, Cathode and Electrolyte we can achieve many different types of battery chemistries enabling us to design different types of battery cells.

Types of Batteries

Batteries generally can be classified into different categories and types, ranging from chemical composition, size, form factor and use cases, but under all of these are two major battery types;

1. Primary Batteries
2. Secondary Batteries

1. Primary Batteries

Primary batteries are batteries that **cannot be recharged** once depleted. Primary batteries are made of electrochemical cells whose electrochemical reaction cannot be reversed.

Primary batteries exist in different forms **ranging from coin cells to AA batteries**. They are commonly used in standalone applications where charging is impractical or impossible. A good example of which is in military grade devices and battery powered equipment. It will be impractical to use rechargeable batteries as recharging a battery will be the last thing in the mind of the soldiers. Primary batteries always have high specific energy and the systems in which they are used are always designed to consume low amount of power to enable the battery last as long as possible.

Some other **examples of devices using primary batteries include**; Pace makers, Animal trackers, Wrist watches, remote controls and children toys to mention a few.

The most popular type of primary batteries are **alkaline batteries**. They have a high specific energy and are environmentally friendly, cost-effective and do not leak even when fully discharged. They can be stored for several years, have a good safety record and can be carried on an aircraft without being subject to UN Transport and other regulations. The only downside to alkaline batteries is the low load current, which limits its use to devices with low current requirements like remote controls, flashlights and portable entertainment devices.

2. Secondary Batteries

Secondary batteries are batteries with electrochemical cells whose chemical reactions can be reversed by applying a certain voltage to the battery in the reversed direction. Also referred to as **rechargeable batteries**, secondary cells unlike primary cells can be recharged after the energy on the battery has been used up.

They are typically used in high drain applications and other scenarios where it will be either too expensive or impracticable to use single charge batteries. Small capacity secondary batteries are used to power portable electronic devices like **mobile phones**, and other gadgets and appliances while heavy-duty batteries are used in powering diverse **electric vehicles** and other high drain applications like load levelling in electricity generation. They are also used as standalone power sources alongside **Inverters to supply electricity**. Although the initial cost of acquiring rechargeable batteries is always a whole lot higher than that of primary batteries but they are the most cost-effective over the long-term. Secondary batteries can be further classified into several other types based on their chemistry**.** This is very important because the chemistry determines some of the attributes of the battery including its specific energy, cycle life, shelf life, and price to mention a few.

The following are the **different types of rechargeable batteries** that are commonly used.

1. Lithium-ion(Li-ion)
2. Nickel Cadmium(Ni-Cd)
3. Nickel-Metal Hydride(Ni-MH)
4. Lead-Acid

1. Nickel-Cadmium Batteries

The nickel–cadmium battery (NiCd battery or NiCad battery) is a type of rechargeable battery which is developed using nickel oxide hydroxide and metallic cadmium as electrodes. Ni-Cd batteries excel at maintaining voltage and holding charge when not in use. However, NI-Cd batteries easily fall a victim of the dreaded "memory" effect when a partially charged battery is recharged, lowering the future capacity of the battery.

In comparison with other types of rechargeable cells, Ni-Cd batteries offer good life cycle and performance at low temperatures with a fair capacity but their most significant advantage will be their ability to deliver their full rated capacity at high discharge rates. They are available in different sizes including the sizes used for alkaline batteries, AAA to D. Ni-Cd cells are used individual or assembled in packs of two or more cells. The small packs are used in portable devices, electronics and toys while the bigger ones find application in aircraft starting batteries, Electric vehicles and standby power supply.

Some of the properties of Nickel-Cadmium batteries are listed below.

- Specific Energy: 40-60W-h/kg
- Energy Density: 50-150 W-h/L
- Specific Power: 150W/kg
- Charge/discharge efficiency: 70-90%
- Self-discharge rate: 10%/month
- Cycle durability/life: 2000cycles

2. Nickel-Metal Hydride Batteries

Nickel metal hydride (Ni-MH) is another type of chemical configuration used for rechargeable batteries. The chemical reaction at the positive electrode of batteries is similar to that of the nickel–cadmium cell (NiCd), with both battery type using the same nickel oxide hydroxide (NiOOH). However, the negative electrodes in Nickel-Metal Hydride use a hydrogen-absorbing alloy instead of cadmium which is used in NiCd batteries

NiMH batteries find application in high drain devices because of their high capacity and energy density. A NiMH battery can possess two to three times the capacity of a NiCd battery of the same size, and its energy density can approach that of a lithium-ion battery. Unlike the NiCd chemistry, batteries based on the **NiMH chemistry are not susceptible to the “memory”** effect that NiCads experience.

Below are some of the properties of batteries based on the Nickel-metal hydride chemistry;

- Specific Energy: 60-120h/kg
- Energy Density: 140-300 Wh/L
- Specific Power: 250-1000 W/kg
- Charge/discharge efficiency: 66% - 92%
- Self-discharge rate: 1.3-2.9%/month at 20^{o}C
- Cycle Durability/life: 180 -2000

3. Lithium-ion Batteries

Lithium-ion batteries are one of the most popular types of rechargeable batteries. There are many **different types of Lithium batteries**, but among all the lithium-ion batteries are the most commonly used. You can find these lithium batteries being used in different forms popularly among electric vehicles and other portable gadgets. If you are curious to know more about batteries used in Electric vehicles, you can check out this article on Electric Vehicle Batteries. They are found in different portable appliances including mobile phones, smart devices and several other battery appliances used at home. They also find applications in aerospace and military applications due to their lightweight nature.

Lithium-ion batteries are a type of rechargeable battery in which lithium ions from the negative electrode migrate to the positive electrode during discharge and migrate back to the negative electrode when the battery is being charged. Li-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in non-rechargeable lithium batteries.

Lithium-ion batteries generally possess high energy density, little or no memory effect and low self-discharge compared to other battery types. Their chemistry alongside performance and cost vary across different use cases, for example, Li-ion batteries used in handheld electronic devices are usually based on lithium cobalt oxide ($LiCoO_2$) which provides high energy density and low safety risks when damaged while Li-ion batteries based on Lithium iron phosphate which offer a lower energy density are safer due to a reduced likelihood of unfortunate events happening are widely used in powering electric tools and medical equipment. Lithium-ion batteries offer the best performance to weight ratio with the lithium sulphur battery offering the highest ratio.

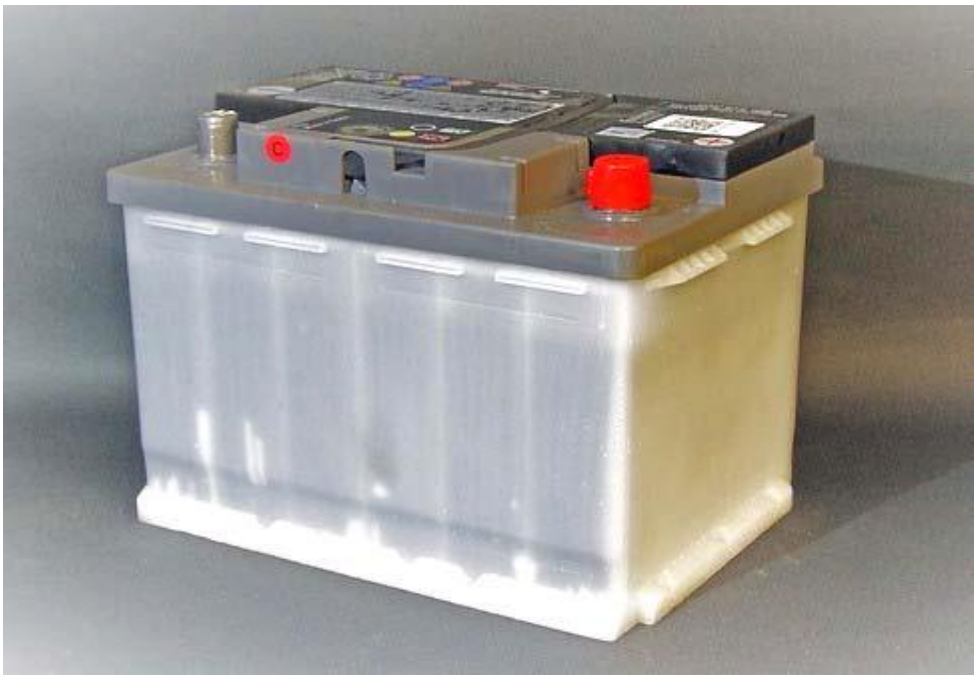
Some of the attributes of lithium-ion batteries are listed below;

- Specific Energy: 100: 265W-h/kg
- Energy Density: 250: 693 W-h/L
- Specific Power: 250: 340 W/kg
- Charge/discharge percentage: 80-90%
- Cycle Durability: 400: 1200 cycles
- Nominal cell voltage: NMC 3.6/3.85V

4. Lead-Acid Batteries

Lead-acid batteries are a low-cost reliable power workhorse used in heavy-duty applications.

They are usually very large and because of their weight, they're always used in non-portable applications such as solar-panel energy storage, vehicle ignition and lights, backup power and load levelling in power generation/distribution. The lead-acid is the oldest type of rechargeable battery and still very relevant and important into today's world. Lead-acid batteries have very low energy to volume and energy to weight ratios but it has a relatively large power to weight ratio and as a result, can supply huge surge currents when needed. These attributes alongside its low cost make these batteries attractive for use in several high current applications like powering automobile starter motors and for storage in backup power supplies.



Selecting the right battery for your application

One of the main problems hindering technology revolutions like IoT is power, battery life affects the successful deployment of devices that require long battery life and even though several power management techniques are being adopted to make the battery last longer, a compatible battery must still be selected to achieve the desired outcome.

Below are some factors to consider when selecting the right type of battery for your project.

1. **Energy Density:** The energy density is the total amount of energy that can be stored per unit mass or volume. This determines how long your device stays on before it needs a recharge.

2. Power Density: Maximum rate of energy discharge per unit mass or volume. Low power: laptop, i-pod. High power: power tools.

3. Safety: It is important to consider the temperature at which the device you are building will work. At high temperatures, certain battery components will breakdown and can undergo exothermic reactions. High temperatures generally reduces the performance of most batteries.

4. Life cycle durability: The stability of energy density and power density of a battery with repeated cycling (charging and discharging) is needed for the long battery life required by most applications.

5. Cost: Cost is an important part of any engineering decisions you will be making. It is important that the cost of your battery choice is commensurate with its performance and will not increase the overall cost of the project abnormally.

Some important characteristics of batteries include:

Capacity: This refers to the amount of energy that a battery can store and deliver. The unit of measurement for capacity is ampere-hours (Ah) or milliampere-hours (mAh), and it determines how long a battery can power a device before it needs to be recharged.

Voltage: This is the electrical potential difference between the positive and negative terminals of a battery. It determines the amount of electrical energy that can be delivered by the battery and is typically measured in volts (V).

Chemistry: The chemical composition of a battery determines its performance characteristics, such as its capacity, voltage, and discharge rate. Different types of batteries use different chemical compositions, including alkaline, lithium-ion, lead-acid, and nickel-cadmium.

Discharge rate: This refers to how quickly a battery can deliver its energy. It is usually measured in amperes (A) or milliamperes (mA) and can be affected by factors such as the temperature, load, and age of the battery.

Cycle life: This is the number of charge and discharge cycles that a battery can go through before its performance starts to degrade. It is influenced by factors such as the chemistry of the battery, its usage patterns, and the quality of its construction.

Self-discharge rate: This refers to the rate at which a battery loses its charge when it is not in use. It can vary depending on the chemistry of the battery and its storage conditions.

Temperature range: The performance of a battery can be affected by the temperature at which it is used and stored. Different types of batteries have different temperature ranges for optimal performance.

Overall, these characteristics are important to consider when selecting a battery for a particular application, as they can impact the battery's performance, lifespan, and overall cost-effectiveness.

Conclusion:

Quiz:

1. What is primary cell and secondary cell?

2. Do temperature have effect on battery?

3. Mercury cell is primary cell. True/False? Justify your answer.

Suggested Reference:

1. https://nptel.ac.in/courses/113105102
3. **Different Types of Batteries and their Applications (circuitdigest.com)**

References used by the students:

Rubric wise marks obtained:

5=Excellent 4=Very Good 3=Good 2=Fair 1=Needs more work					
Rubrics	**Knowledge**	**Calculations**	**Participation**	**Journal work and submission**	**Total**
Marks					

Basics Electrical Engineering
3110005

Lab manual prepared by
Prof.M.I.Siddiqui
Assistant Professor, Electrical Engineering,
L.D. College of Engineering
Ahmedabad

Branch Coordinator
Dr. J.R.Iyer
Professor, Electrical Engineering
L.D. College of Engineering
Ahmedabad

Committee Chairman
Dr N M Bhatt
Professor of Mechanical Engineering
L. E. College, Morbi