

Gokhale Education Society's
R. H. Sapat College of Engineering, Management Studies and Research
Department of Electrical Engineering

Laboratory Manual

Basic Electrical Engineering

Name of student: _____

Class: _____

Roll No: _____

Academic Year: _____

Exam No: _____

Laboratory Manual

Subject: Basic Electrical Engineering

Course Outcomes:

At the end of course students will be able to

CO1: Differentiate between electrical and magnetic circuits and derive mathematical relation for self and mutual inductance along with coupling effect.

CO2: Calculate series, parallel and composite capacitor as well as characteristics parameters of alternating quantity and phasor arithmetic

CO3: Derive expression for impedance, current, power in series and parallel RLC circuit with AC supply along with phasor diagram.

CO4: Relate phase and line electrical quantities in polyphase networks, demonstrate the operation of single phase transformer and calculate efficiency and regulation at different loading conditions

CO5: Apply and analyze the resistive circuits using star-delta conversion KVL, KCL and different network theorems under DC supply.

CO6: Evaluate work, power, energy relations and suggest various batteries for different applications, concept of charging and discharging and depth of charge.

Sr. No.	Aim of the Experiment	Page No.	Mapped COs/POs
1	To study safety precautions while working on electrical systems, handling of various types of equipment such as multimeter, ammeter, voltmeter, wattmeter, real-life resistor, inductor and capacitor.	01-14	PO6-8
2	To calculate and measure of charging and discharging of the capacitor and observe the response on a storage oscilloscope.	15-27	CO2
3	To measure the steady-state response of series RL and RC circuits on AC supply and observations of voltage and current waveforms on a storage oscilloscope.	28-37	CO3
4	To derive resonance frequency and analyze resonance in series RLC circuit.	38-44	CO3
5	To verify the relation between phase and line quantities in three-phase balanced star-delta connections of the load.	45-56	CO4
6	To determine the efficiency and regulation of the transformer by direct loading test of a single-phase transformer.	57-66	CO4
7	To verify KVL and Superposition theorem.	67-75	CO5
8	To verify Thevenin's theorem in a DC network.	76-81	CO5
9	To measure the insulation resistance of electrical equipment/cable using Megger.	82-89	CO6
10	To study of LT and HT electricity bills.	89-101	PO6-8

Index

Subject: Basic Electrical Engineering

Expt. No.	Title of the Experiment	Date of Performance	Date of Assessment	Grade	Sign of Faculty
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Certificate

This is to certify that Mr./Ms. _____ Roll No: _____
 of Div: _____ has satisfactorily completed the practical of the subject **Basic Electrical Engineering**.

Faculty Incharge

Head of Department

Principal

Experiment No:

Date of Performance: / /	Timely Completion: /10
Date of Assessment: / /	Understanding: /10
Signature of Faculty:	Presentation: /10
	Total: /30

Title: Safety precautions and connection of measuring instruments

Aim: To Study Safety Precautions while Working on Electrical Systems, Handling of Various Equipment's Such As multi meter, Ammeters, Voltmeters, Wattmeter's, Resistors, Inductors and Capacitors

Prerequisite:

- (1) Electrical supply characteristics
 - (2) General safety
-

Learning outcomes: At the end of this experiment students will be able to

- (1) Be familiar with safety precautions, standard practices while working on electrical installations.
 - (2) Select and use of electrical measuring instruments.
 - (3) Specify and select resistance, inductance and capacitance.
-

Theory:
(A) Safety Precautions:

We know electricity is invisible, therefore, while working in electrical installations, everyone should always first take care of personal safety. Casual approach or negligence while working on Electrical installation may lead to fatal accident . Therefore, while working on electrical installation it is necessary to observe and follow safety guidelines and use of appropriate personnel protective equipments (PPE). Following “**safety guidelines**” should always be observed while working on electrical installation.

1. Electrical accidents can be avoided by following safety guidelines while working on Electrical installation.
 2. Do not forget to put off the main switch in the case of a person is Electrocuted.
 3. Do not attempt to disengage a person in contact with live apparatus, which you cannot switch off immediately. Insulate yourself from the earth by standing on a rubber mat or dry board of wood before attempting to get him clear. Evens then do not touch his body, push him clear with a piece of dry wood.
 4. Do not forget to put off main switch and take away the fuse carrier along while working on Electrical installation . Put a caution notice(Tag) on or near the main switch inscribing “danger, men at work”
 5. Do not discontinue artificial respiration until recovery or death is certified by the doctor.
 6. Do not forget to put on your safety belt before starting working on a pole. If used, it must a latter is used, it must be held by another man to avoid slipping.
 7. Do not have any sharp tool protruding from the pocket when working on a high voltage overhead line. Always keep one hand in the pocket.
-

DO's & DON'Ts WHILE WORKING ON ELECTRICAL SYSTEM/INSTALLATIONS

DO's	DON'Ts
Before replacing a lamp or handling a fan, make sure that the supply is switched off	Do not connect single pole switch or fuse in a neutral circuit, but always connect in the live or phase wire.
Use correct size and quality fuse wire when connecting / renewing blown fuse	Do not renew the blown fuse until you are satisfied to the cause and have rectified the irregularity.
When removing the fuse, Pull out the supply first and when replacing the supply, and should be put in last.	Do not use copper wire as substitute for fuse wire.
Place sign " Men Working " or Work in progress board on main switch before commencing work	Do not close any switch unless you are familiar with the circuit which it controls and know the reason for its being opened.
Before working on any circuit or apparatus, make sure that the controlling switches are opened and locked or the fuse removed.	Do not touch or temper with any electrical gear or conductor, unless you have made sure that it is dead and earthed. High voltage apparatus may give leakage shock or flashover without touching.
Always treat electrical circuit as alive until you have proved them to be dead, The insulation of conductor may be defective.	Do not work on live circuits with out the express orders of the person In- charge.
Before working on motor or other rotating machine, make sure that it can not be set in motion without your permission	Make sure that all the safety precautions are taken and you are accompanied by a second person competent to render first aid.
Cultivate the habit of turning your face away whenever an arc or a flashover may occur	Do not disconnect the earthing connections or render in – effectively safety gadgets installed on mains and equipment.
Guard against arcs as well as high voltage, remember that burns from arcs may be very severe.	Do not tamper with meter boards and cutouts, unless you are authorised to do so.
See that all splices and connections are securely made.	Do not expose your eyes to an electric arc. Painful injury may result even with short exposure.
Use extreme care when breaking an inductive circuit as dangerously high voltage is likely to result.	Do not close or open a switch or fuse slowly or hesitatingly, do it quickly and positively.

Thoroughly discharge to earth all cables before working on cores.	Do not place any part of your body in circuit either to ground or across the terminal when making a connection or operating.
Test rubber gloves periodically.	Do not use wires with poor insulation.
Place rubber mats in front of electrical switchboards.	Do not touch an electric circuit when your hands are wet, or bleeding from a cut or an abrasion.
Prevent accumulation of gases in unventilated manholes.	Do not work on energized circuits without taking any extra precautions, such as the use of rubber gloves and wooden handles.
Portable electrical equipment should be inspected, tested and certified for electrical safety every 6 months. After every repairs /alterations it should be rechecked.	Do not use metal case flashlight around apparatus which is energized. Do not provide any joint in flexible wire.

WORKING ON STATIC CAPACITORS:-

- a) Please bear in mind that capacitors store energy and therefore are not necessary dead isolated from the supply. Once charged a capacitor may retain charge for several hours after it is disconnected.
- b) First open the breaker and isolate capacitor. Then wait for 10 minutes for internal resistor / reactor to reduce voltage. Next with the help of hot stick ground and short all terminal of the capacitor. Short should be left on while working.
- c) For taking capacitor bank back into services, jumpers should be removed with hot stick and then close isolators and breaker.
- d) Capacitor body acts as one terminal, hence should not be touched unless properly grounded.

Personnel Protective Equipment Matrix										
Name of the Department: Maintenance										
Year:										
Sr. No.	Work	Name of the PPE given for the protection of								Remark
		Head	Face	Eyes	Ear	Nose	Hand	Feet	Body	
Personnel Protective Equipment Matrix For working in High Voltage Area										
1	Operation Of Isolator	Helmet	-	-	-	-	High Voltage Hand Gloves	Electrical Shoes	-	-
2	Discharge Of Electrical Charge	Helmet	-	-	-	-	High Voltage Hand Gloves	Electrical Shoes	-	Discharge Rod
3	Working On Transformer	Helmet	-	-	-	-	High Voltage Hand Gloves	Electrical Shoes	Safety Belt	Discharge Rod
4	Attending Break down	Helmet	-	-	-	-	High Voltage Hand Gloves	Electrical Shoes	Safety Belt	Discharge Rod
5	Doing PM	Helmet	-	-	-	-	High Voltage Hand Gloves	Electrical Shoes	Safety Belt	Discharge Rod
Personnel Protective Equipment Matrix For Working with Chemicals										
6	Handling of chemical	-	-	Goggle	-	Nose mask	Acid Gloves	Safety shoes	-	-
7	Lab Operati	-	-	Goggle	-	Nose	Acid	Safety	-	-

	on					mask	Gloves	shoes		
Personnel Protective Equipment Matrix For Working in compressor/DG Area										
8	Working in Compressor/DG Area	-	-	-	Ear Muff	-	-	Safety shoes	-	-
Personnel Protective Equipment Matrix For Working in Fuels										
9	Working on Gases	Hand gloves	-	Goggle	-	-	-	-	-	Spark proof tools

(B) Measuring Instruments:**1. Ammeter: -**

Ammeter is used to measure current in electrical circuit and is required to be connected always in series. As ammeter resistance is low hence voltage drop across ammeter is low. The current coil of ammeter has low current carrying capacity using shunt (Constant low resistance connected in parallel with coil of ammeter) in case of DC and current transformer in case of AC ammeter can be used to measure high magnitude currents.

Classification or Types of Ammeter-

Permanent Magnet Moving Coil (PMMC) ammeter.

Moving Iron (MI) Ammeter.

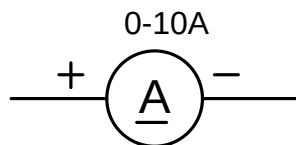
Electrodynamometer type Ammeter.

Induction Type Ammeter.

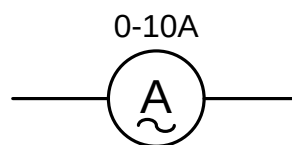
Digital Ammeter (DAM).

Depending on type of supply i.e.AC or DC, ammeter is selected.

DC Ammeter are mainly PMMC instruments, MI can measure both AC and DC currents, also Electrodynamometer type thermal instrument can measure DC and AC, induction meters are not generally used for ammeter construction due to their higher cost, inaccuracy in measurement.

Symbol

A) DC Ammeter



B) AC Ammeter

2. Voltmeter: -

Voltmeter is employed to measure the potential difference (Voltage) across any two points of a circuit. It is connected in the parallel across any element in the circuit. The

resistance of voltmeter is kept very high by connecting a high resistance in series of the voltmeter with the coil of the instrument. The actual voltage drop across the coil of the voltmeter is only a fraction of the total voltage applied across the voltmeter which is to be measured.

Classification or Types of Voltmeter

Permanent Magnet Moving coil (PMMC) Voltmeter.

Moving Iron (MI) Voltmeter.

Electro Dynamometer Type Voltmeter.

Induction Type Voltmeter.

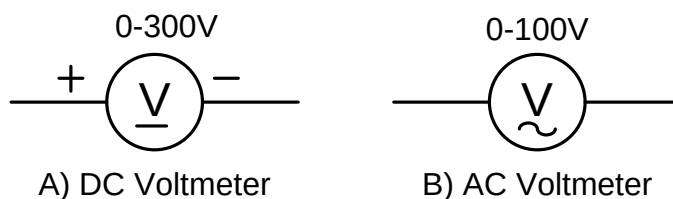
Electrostatic Type Voltmeter.

Digital Voltmeter (DVM).

Depending upon type of electric supply voltmeter is selected for voltage measurements .

For DC voltmeters PMMC instruments are used, MI instrument can measure both AC and DC voltages, electro dynamometer type, thermal instrument can measure DC and AC voltages as well. Induction meters are not used because of their high cost, inaccuracy in measurement. Rectifier type voltmeter, electrostatic type and also digital voltmeter (DVM) can measure both AC and DC voltages.

Symbol



3. Wattmeter: -

The measurement of real power(Active power) in AC circuits is done by using Wattmeter. The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeters are used for measurement of Active power at fundamental frequency .It consists of two coils i.e. pressure coil (parallel) and current coil (series). As the current coil is connected in series with load, it measures the load current and whereas the pressures coil which is connected across the load is used to measure the voltage across the load. Mainly electro-dynamic type of wattmeter is used it's construction is as follows. The real power in AC circuits is given by expression.

$$P = VI \cos \phi. \text{In case of single phase circuit}$$

$$P = 1.732 V_L I_L \cos \phi. \text{In case of three phase AC circuit.}$$

Symbol:

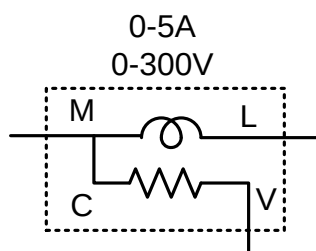


Image of analog meters



4. Digital Multimeters

A digital multimeter is a test tool used to measure two or more electrical values—principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries. Digital multimeters long ago replaced pointer-based analog meters due to their ability to measure with greater accuracy, reliability and increased impedance. Digital multimeters combine the testing capabilities of single-task meters—the voltmeter (for measuring volts), ammeter (amps) and ohmmeter (ohms). Often, they include several additional specialized features or advanced options. Technicians with specific needs, therefore, can seek out a model targeted to meet their needs.



Digital multimeter typically includes four components:

- Display: Where measurement readouts can be viewed.
- Buttons: For selecting various functions; the options vary by model.
- Dial (or rotary switch): For selecting primary measurement values (volts, amps, ohms).
- Input jacks: Where test leads are inserted.

(C) Electrical Parameters

1. Resistance: -

Resistance is the opposition that a substance offers to the flow of electric current. It is represented by the uppercase letter R. The standard unit of resistance is the ohm, sometimes written out as a word, and sometimes symbolized by the uppercase Greek letter omega.

Rheostats are made up of high resistivity material, like, nickel-chromium iron alloy closely wound over a circular tube. These are available both in single tube and double tube. Inter-turn

insulation is provided to avoid short circuiting of turns. The tube of rheostat is made of insulating material, like asbestos. These are employed at places where resistance of a circuit is to be varied without breaking the circuit.

Images of resistances



Symbol:



Fixed Resistance



Variable Resistance

2. Inductance: -

An inductor (also choke, coil or reactor) is a passive two-terminal electrical component that stores energy in its magnetic field. For comparison, capacitor stores energy in an electric field and a resistor does not store energy but rather dissipates energy as heat. An inductor is usually made from a coil of conducting material, like copper wire, that is then wrapped around a core made from either air or a magnetic metal. Capacitor opposes rate of change in voltage while inductor opposes rate of change in current. Inductor is a device which can store energy in the form of magnetic field. The function of an inductor is to provide opposition to a changing or varying current

formula

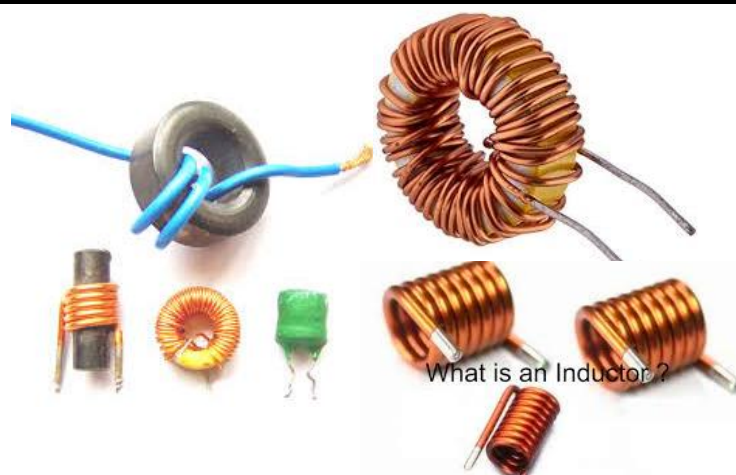
$$E = L \, di / dt$$

E = E.M.F. induced,

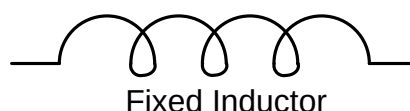
di / dt = rate of change of current through coil,

L = self-inductance

Images of inductor:



Symbol:



3. Capacitance: -

A capacitor is a passive electrical component consisting of a pair of conductors separated by an dielectric . If the dielectric breaks down and becomes a conductor, the capacitor can no longer hold a charge and is useless. The ability of a dielectric to hold a chare without breaking down is known as the dielectric strength. The measure of the ability of the dielectric material to store energy is called dielectric constant. It stores energy in the form of an electrostatic field. The dielectric can be anything from air to paper to plastic materials. In other words, a large value capacitor will have large plates separated by a very thin dielectric layer. Charging and discharging are the two main effects of capacitor.

Capacitance is measure of the ability to store the charge. Capacitance also depends on the dielectric constant of the dielectric material separating the plates. The unit of capacitance is Farad represented as F and named after Michael Faraday. The Farad is actually quite hue unit so it is more common to find capacitors value quoted as micro-farads, nano farads and Pico farads. When two metal conductors are separated by dielectric constitute capacitance. An electric field is formed between two charged plates with in the space between plates. Energy is stored in capacitor in this electric field.

Following are the characteristics of the capacitor:

- Which has the ability to store the charge which is neither a resistor nor an inductor can do.
- Oppose any change in voltage in the circuits in which it is connected.
- Block the passage of direct current through it.
- Capacitors are manufactured in various sizes, shapes types and values.
- Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radio to particular frequencies and for many other purposes.

Formula: $C = q/v$

$$C = \epsilon_0 A / d$$

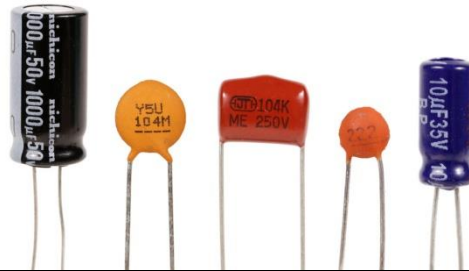
Where

A = area of plate in cm, D = distance between plates, ϵ_0 = permittivity (dielectric constant)

Symbol



Images of Capacitors:



Observations: Enlist at least two meters and parameters with specifications from laboratory.

Sr. No.	Meter/ Parmeter	Specifications with make
1	Ammeter	1. 2
2	Voltmeter	1. 2
3.	Wattmeter	1. 2
4	Multimeters	1. 2
5	Resistor	1. 2
6	Inductor	1. 2
7	Capacitor	1. 2

Conclusion:

=====

LAB ASSIGNMENT

Q1) Match the pairs:

/0.5M

Measuring Instrument	Application
1) Ammeter	i) Measurement of voltage
2) Voltmeter	ii) Measurement of power
3) Wattmeter	iii) Measurement of energy
4) Multimeter	iv) Measurement of all electrical quantities
	v) Measurement of current

Q2) In your laboratory types instruments are generally

/0.5M

- Portable analog
 - Panel mount analog
 - Portable Digital
 - Panel mount digital
-

Q3) Current coil of wattmeter is connected in _____ and pressure coil is connected in _____ with supply.

/0.5M

- series, series
 - parallel, series
 - parallel, parallel
 - series, parallel
-

Q4) In these types of meters, polarity indicated on instrument is very important at the time of connection.

/0.5M

- DC voltmeter
 - AC voltmeter
 - DC Ammeter
 - AC Ammeter
 - Digital multimeter
-

Q5) State true or false and justify reason: A voltmeter is connected in series with supply and an ammeter is connected in parallel with the supply

/1M

Q6) Which are electrical energy storage elements? In which form the energy is stored in it ?

/1M

 =====

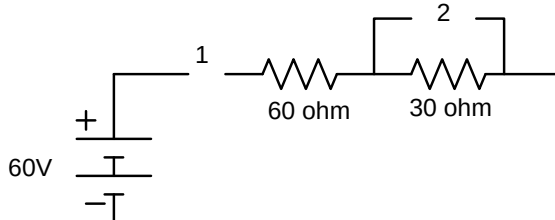
Common data for question 7 and 9

Following different meters are given to you.

AC voltmeter (0-30V), DC voltmeter (0-30V), AC Ammeter (0-1A), DC Ammeter (0-1A), AC voltmeter (0-100V), DC voltmeter (0-100V), AC Ammeter (0-5A), DC Ammeter (0-5A).

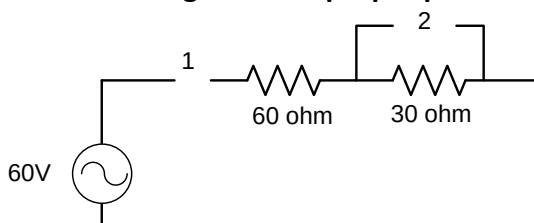
Q7) Suggest the meter for location 1 and 2 in following diagram from above list and redraw the diagram with proper placement of meter.

/2M



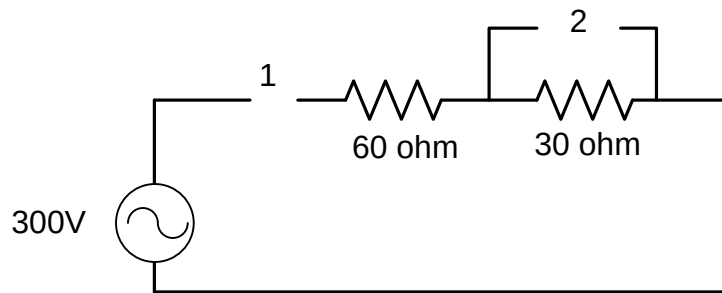
Q8) Suggest the meter for location 1 and 2 in following diagram from above list and redraw the diagram with proper placement of meter.

/2M



Q9) Suggest the meter for location 1 and 2 in following diagram from above list and redraw the diagram with proper placement of meter.

/2M



Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:

Presentation: /10

Total: **/30****Title:** Charging and Discharging of Capacitor:

Aim: To calculate and measure of charging and discharging voltage of capacitor and observe the response on storage oscilloscope.

Prerequisite:

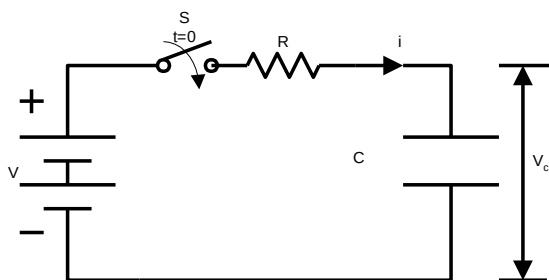
- (1) Fundamental of capacitor
- (2) Concept of charge, current, voltage
- (3) Basic terms in electrostatic.

Learning outcomes: At the end of this experiment students will be able to

- (1) Derive charging and discharging voltage, current in RC circuit connected to DC supply.
- (2) Justify initial and final value of capacitor voltage and current.
- (3) Define time constant and elaborate significance of the same.

Theory:

Consider a capacitor C is in series with the resistance R . The capacitor has initially no charge and no voltage across it. When switch S is closed at $t=0$, the R - C series circuit will get connect to supply voltage V .



At $t=0^-$: when switch 'S' is in OFF condition

Current through capacitor $i=0$

Voltage across capacitor $V_c=0$

At $t=0^+$: when switch 'S' is in ON condition

Current through capacitor $i=i_{\max}=\frac{V}{R}$

Voltage across capacitor $V_c=0$

At $t=\infty$:

Current through capacitor $i=0$

Voltage across capacitor $V_c=V$

Mathematical Analysis:

Let V_c =voltage across capacitor at instant

q =charge on capacitor at any instant

i =current through capacitor at any instant.

By Kirchhoff's law

$$V = iR + V_c \quad (1)$$

But current through capacitor is

$$i = C \frac{dv_c}{dt} \quad (2)$$

From equation (1) and (2)

$$V = CR \frac{dv_c}{dt} + v_c$$

$$V - v_c = CR \frac{dv_c}{dt}$$

$$\frac{V - v_c}{dv_c} = \frac{CR}{dt}$$

$$\frac{dv_c}{V - v_c} = \frac{dt}{CR}$$

Taking integration on both side

$$\int \frac{dt}{CR} = \int \frac{dv_c}{V - v_c}$$

$$\frac{t}{CR} = -\ln(V - v_c) + K \quad 3)$$

Where K is constant of integration

At $t=0$, $v_c=0$ substituting in above equation

$$\frac{0}{CR} = -\ln(V - 0) + K$$

$$0 = -\ln(V) + K$$

$$K = \ln(V)$$

Substituting in equation (3)

$$\frac{t}{CR} = -\ln(V - v_c) + \ln(V)$$

$$\frac{t}{CR} = \ln\left(\frac{V}{V - v_c}\right)$$

Taking antilog of both side

$$e^{\frac{t}{CR}} = \frac{V}{V - v_c}$$

$$V - v_c = \frac{V}{e^{\frac{t}{CR}}}$$

$$v_c = V - \frac{V}{e^{\frac{t}{CR}}}$$

$$\boxed{\begin{aligned} v_c &= V \left(1 - \frac{1}{e^{\frac{t}{CR}}} \right) \\ v_c(t) &= V \left(1 - e^{\frac{-t}{CR}} \right) \end{aligned}} \quad (4)$$

At steady state $V=Q/C$

Similarly at any instant $v_c=q/C$

Substituting in above equations

$$\frac{q}{C} = \frac{Q}{C} \left(1 - e^{\frac{-t}{CR}} \right)$$

$$\boxed{q(t) = Q \left(1 - e^{\frac{-t}{CR}} \right)} \quad (5)$$

From KVL it is known that

$$V - v_c = iR$$

$$i = \frac{V - v_c}{R}$$

From equation (5)

$$i = \frac{V - V \left(1 - e^{\frac{-t}{CR}} \right)}{R}$$

$$i = \frac{V - V + Ve^{\frac{-t}{CR}}}{R}$$

$$\boxed{i(t) = \frac{V}{R} e^{\frac{-t}{CR}}} \quad (6)$$

Substitute above situation

Case1: When Switch S is closed at $t=0$

Substituting in equation (4), (5) and (6)

$$v_c(t) = V \left(1 - e^{\frac{-0}{CR}} \right) = 0 \quad \text{as } e^0 = 1$$

$$q(t) = Q \left(1 - e^{\frac{-0}{CR}} \right) = 0$$

$$i(t) = \frac{V}{R} e^{\frac{-0}{CR}} = \frac{V}{R}$$

Case2: When Switch S is closed at $t=\infty$

Substituting in equation (4), (5) and (6)

$$v_c(t) = V \left(1 - e^{\frac{-\infty}{CR}} \right) = V \quad \text{as } e^{-\infty} = \frac{1}{e^{\infty}} = 0$$

$$q(t) = Q \left(1 - e^{\frac{-\infty}{CR}} \right) = Q$$

$$i(t) = \frac{V}{R} e^{\frac{-\infty}{CR}} = 0$$

Time constant:

The term CR in above in equation is called as time constant of the R-C charging circuit and denoted by τ measured in sec.

When $t=CR=\tau$

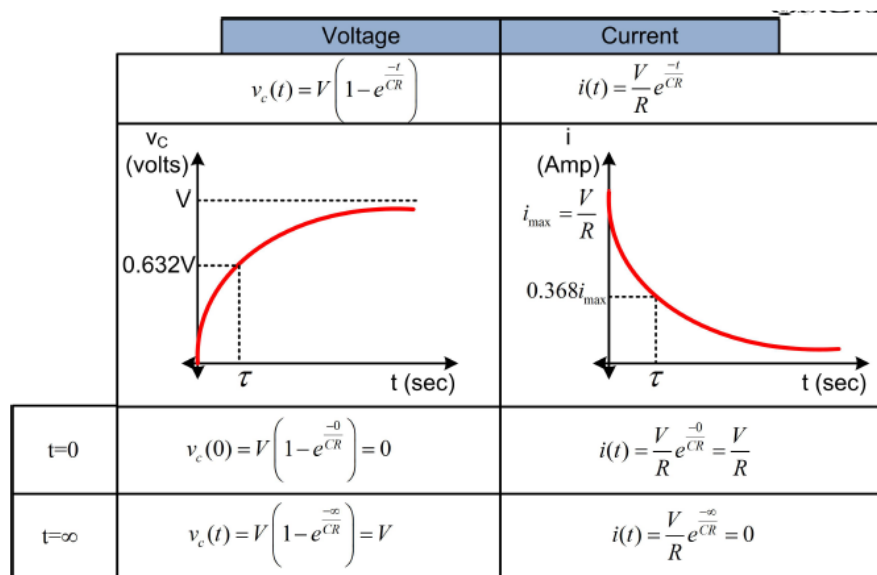
Substituting in equation (76) and (78)

$$v_c(\tau) = V \left(1 - e^{-\frac{\tau}{\tau}} \right) = V(1 - e^{-1}) = 0.632V \quad (7)$$

$$i(t) = \frac{V}{R} e^{-\frac{t}{\tau}} = \frac{V}{R} e^{-1} = 0.368 \frac{V}{R} = 0.368 i_{\max}$$

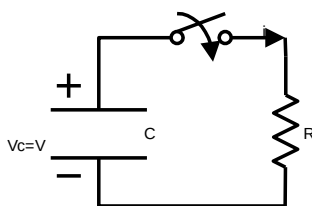
Time constant in R-C circuit can be defined as time required by the capacitor voltage to rise from zero to 0.632 of its final steady state value during charging. OR

Time constant is the time required for the charging current of capacitor to fall to 0.368 of its initial value, starting from its maximum value.



Discharging of Capacitor:

Now consider the capacitor C is being discharged through resistance R by closing switch S at $t=0$. Let capacitor is fully charged with supply voltage V volts.



At $t=0^-$: when switch 'S' is in OFF condition

Current through capacitor $i=0$

Voltage across capacitor $v_c=V$

At $t=0^+$: when switch 'S' is in ON condition

Current through capacitor $i=i_{\max} = -\frac{V}{R}$ as current is opposite to charging current

Voltage across capacitor $v_c = V$

At $t = \infty$:

Current through capacitor $i = 0$

Voltage across capacitor $v_c = 0$

Mathematical Analysis:

Let v_c = voltage across capacitor at instant

q = charge on capacitor at any instant

i = current through capacitor at any instant.

By Kirchhoff's law

$$v_c = iR \quad (8)$$

But current through capacitor is

$$i = C \frac{dv_c}{dt} \quad (9)$$

From equation (8) and (9)

$$v_c = -CR \frac{dv_c}{dt}$$

$$-\frac{v_c}{dv_c} = \frac{CR}{dt}$$

$$-\frac{dv_c}{v_c} = \frac{dt}{CR}$$

Taking integration on both side

$$\int \frac{dt}{CR} = \int -\frac{dv_c}{v_c}$$

$$\frac{t}{CR} = -\ln(v_c) + K \quad (10)$$

Where K is constant of integration

At $t=0$, $v_c = V$ substituting in above equation

$$\frac{0}{CR} = -\ln(V) + K$$

$$K = \ln(V)$$

Substituting in equation (10)

$$\frac{t}{CR} = -\ln(v_c) + \ln(V)$$

$$\frac{t}{CR} = \ln\left(\frac{V}{v_c}\right)$$

Taking antilog of both side

$$e^{\frac{t}{CR}} = \frac{V}{v_c}$$

$$v_c = \frac{V}{e^{\frac{t}{CR}}}$$

$$v_c(t) = Ve^{\frac{-t}{CR}} \quad (11)$$

At steady state $V=Q/C$

Similarly at any instant $v_c=q/C$

Substituting in above equations

$$\frac{q}{C} = \frac{Q}{C} e^{\frac{-t}{CR}}$$

$$q(t) = Qe^{\frac{-t}{CR}} \quad (12)$$

From KVL it is known that

$$v_c = -iR$$

$$i = \frac{-v_c}{R}$$

From equation (12)

$$i = -\frac{Ve^{\frac{-t}{CR}}}{R}$$

$$i(t) = -\frac{V}{R} e^{\frac{-t}{CR}} \quad (13)$$

Substitute above situation

Case1: When Switch S is closed at $t=0$

Substituting in equation (11), (12) and (13)

$$v_c(t) = Ve^{\frac{-0}{CR}} = V \quad \text{as } e^0=1$$

$$q(t) = Qe^{\frac{-0}{CR}} = Q$$

$$i(t) = -\frac{V}{R} e^{\frac{-0}{CR}} = -\frac{V}{R}$$

Case2: When Switch S is closed at $t=\infty$

Substituting in equation (11), (12) and (13)

$$v_c(t) = Ve^{\frac{-\infty}{CR}} = 0 \quad \text{as } e^{-\infty} = \frac{1}{e^{\infty}} = 0$$

$$q(t) = Qe^{\frac{-\infty}{CR}} = 0$$

$$i(t) = -\frac{V}{R} e^{\frac{-\infty}{CR}} = 0$$

Time constant:

The term CR in above in equation is called as time constant of the R-C charging circuit and denoted by τ measured in sec.

When $t=CR=\tau$

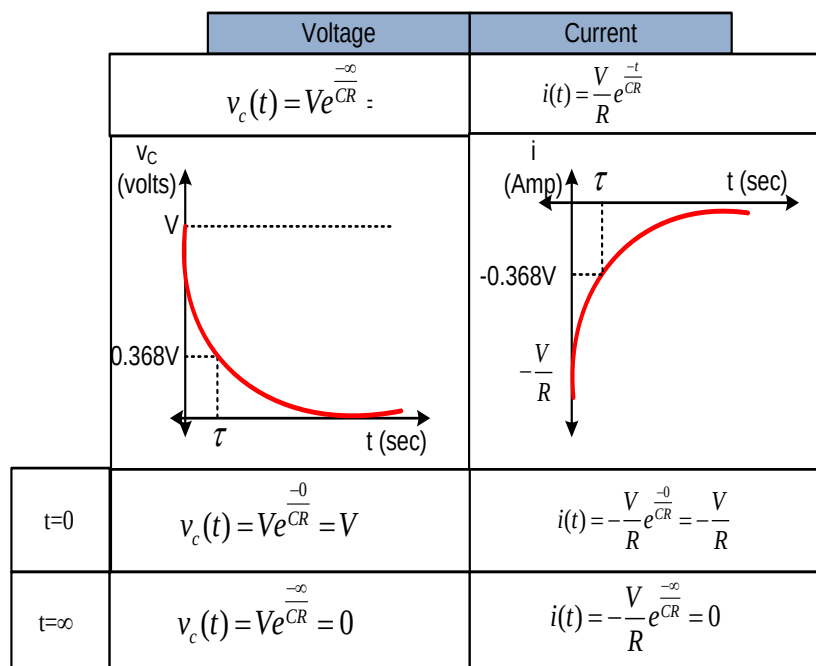
Substituting in equation (12) and (13)

$$v_c(\tau) = V \left(e^{-\frac{\tau}{\tau}} \right) = V(e^{-1}) = 0.368V \quad (14)$$

$$i(t) = -\frac{V}{R} e^{-\frac{t}{\tau}} = -\frac{V}{R} e^{-1} = -0.368 \frac{V}{R} = -0.368 i_{\max}$$

Time constant in R-C circuit can be defined as time required by the capacitor voltage to fall to 0.368 of its initial maximum value during discharging. OR

Time constant is the time required for the charging current of capacitor to fall to 0.368 of its initial value, starting from its initial value.



Apparatus:

Sr. No.	Equipment	Specification
1	Resistor	
2	Capacitor	
3	Function Generator	
4	Digital Voltmeter	
5	Storage Oscilloscope	

Procedure:

A) Charging capacitor:

1. Connect the circuit diagram as shown in Fig.
2. Switch ON the power supply.

3. Set the required input voltage
3. switch on RC series circuit
4. Note down the voltmeter reading which indicate voltage across the capacitance with respect to time.
5. Note down reading till voltage is constant across capacitor.
6. Switch off the supply

A) Charging capacitor:

1. Take the charged capacitor of previous case
2. Switch on capacitor across resistance for discharging.
3. Note down the voltmeter reading which indicate voltage across the capacitance with respect to time.
4. Note down reading till voltage is zero across capacitor.

Observation and Result Table:**(A) Charging of capacitor**Resistance R= _____ Ω ,

Capacitance C= _____ F,

Initial voltage= _____ V

Time constant $\tau = RC =$ _____ sec

Sr. No.	Time (sec)	Voltage across C $V_c (V)$	Calculated $V_c (V) = V(1 - e^{-t/RC})$
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

(B) Discharging of capacitorResistance R= _____ Ω ,

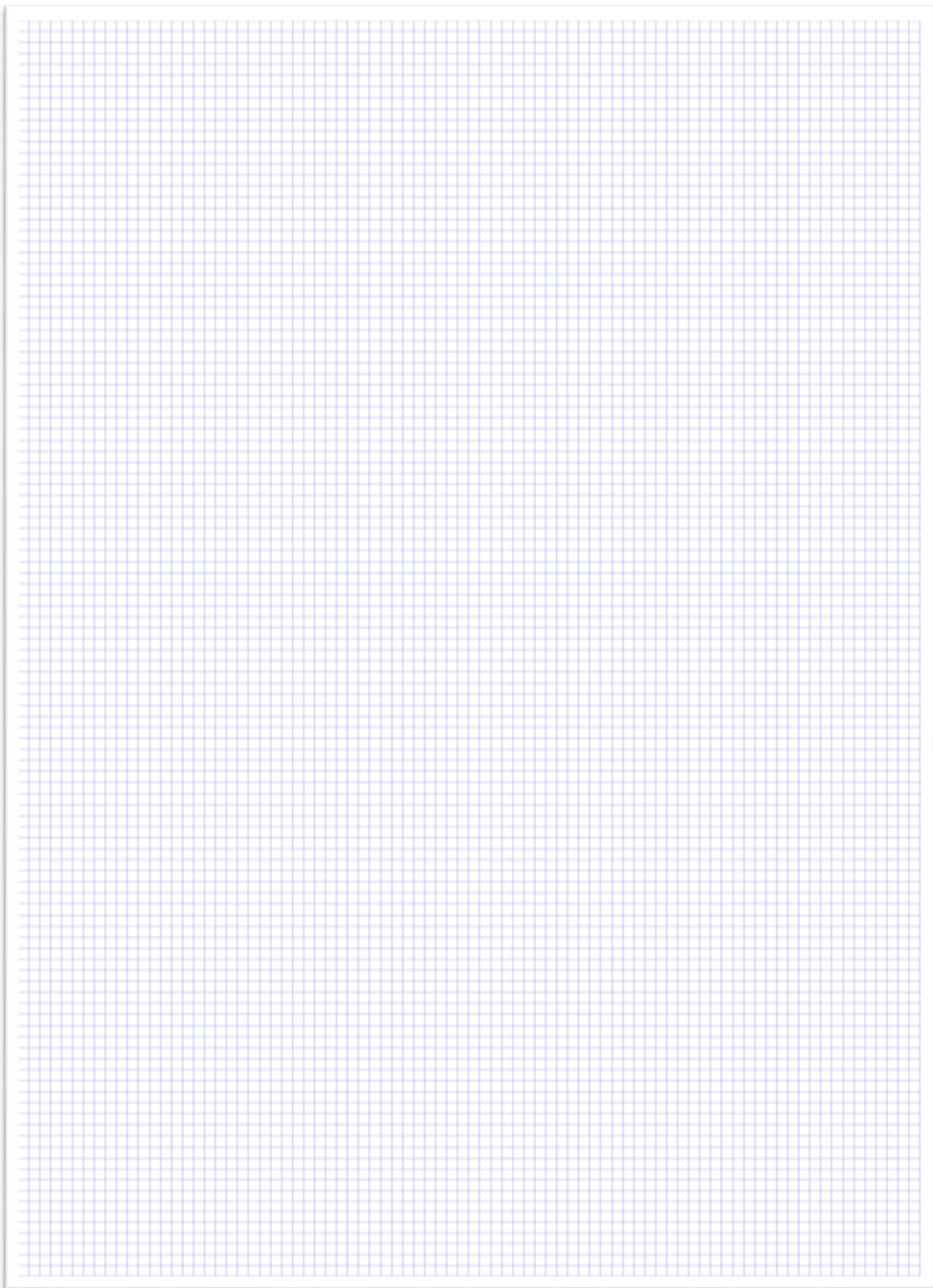
Capacitance C= _____ F,

Initial voltage= _____ V

Time constant $\tau = RC =$ _____ sec

Sr. No.	Time (sec)	Voltage across C $V_c (V)$	Calculated $V_c (V) = V(e^{-t/RC})$
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Connection Diagram:



GRAPH

=====

Conclusion:

LAB ASSIGNMENT

Q1) Fill in the blank: The final value of capacitor voltage in charging of capacitor is equal _____ and final value of capacitor voltage in discharging of capacitor is equal _____ /0.5M

Q2) Fill in the blank: The initial value of capacitor voltage in charging of capacitor is equal _____ and final value of capacitor voltage in discharging of capacitor is equal _____ /0.5M

Q3) The time constant in RC circuit is calculated as? /0.5M

- RC
- R/C
- C/R
- 1/RC

Q4) The final value of current in charging and discharging of capacitor is _____ /0.5M

- RC
- infinity
- 0
- V/R

Q5) What is the significance of time constant in RC circuit? /1M

Q6) What safety precautions have to be taken while performing experiment on capacitor? Why? /1M

=====

Q7) A 100uF capacitor has stored 10C charge. If you touch this capacitor, will you get shock? Give justification with mathematical analysis. (Hint: Body resistance)

/1.5M

Q8) Two capacitors each of 100uF are available with you. If you need to charge this capacitor to 100V through 1000kOhm resistance. Which combination of capacitor bank will charge it fast? Give mathematical justification. (Hint: Try series and parallel combination)

/1.5M

=====

Q9) Download the information about super capacitor and explain it as a new energy storage device.

/1.5M

Q10) List application of AC and DC capacitors

/1.5M

=====

Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:

Presentation: /10

Total: /30

Title: RL and RC Series Circuit

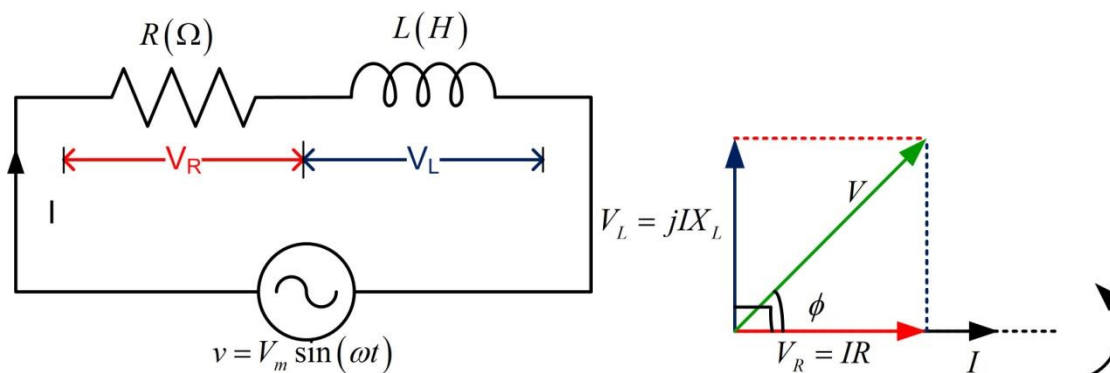
Aim: To measure the steady-state response of series RL and RC circuits on AC supply and observe voltage and current waveforms on a storage oscilloscope.

Prerequisite:

- (1) AC fundamentals
- (2) Properties of resistance, inductance and capacitance
- (3) Response of pure R, pure L and pure C on AC supply
- (4) Concept of inductive and capacitive reactance

Learning outcomes: At the end of this experiment students will be able to

- (1) Derive impedance, power factor, active, reactive and apparent power in RL and RC
- (2) Justify the phase relationship between voltage and current in RL and RC circuits
- (3) Draw waveform and phasor diagram justifying the relation between voltage and current

Theory:**(A) Series RL Circuit:**

Let a single-phase AC supply $v = V_m \sin \omega t$ is applied across a series circuit of resistance $R(\Omega)$, inductance $L(H)$ as shown in the following figure:

If the frequency is $f(Hz)$, then inductive reactance is given by $X_L = 2\pi fL (\Omega)$

If the current flowing through the series circuit is I , the voltage across the resistance is given by $V_R = IR$

The voltage across inductance is given by $V_L = IX_L$

Applying KVL, the total applied voltage is given by $\bar{V} = \bar{V}_R + \bar{V}_L$

From the above equations $\bar{V} = \bar{I}R + j\bar{I}X_L = \bar{I}(R + jX_L) = \bar{I}Z$

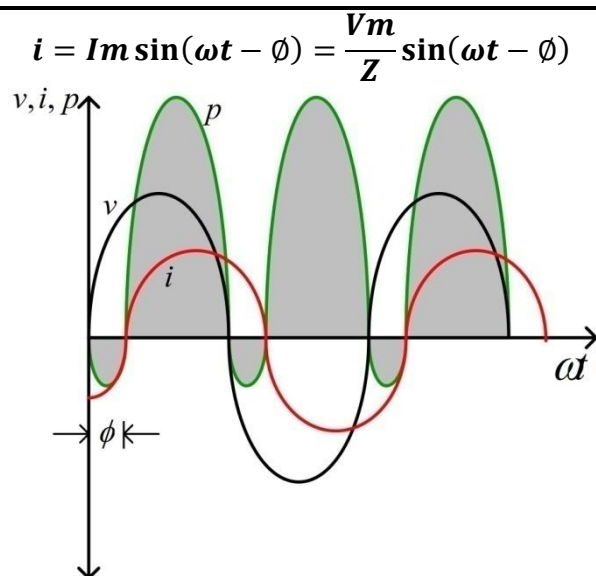
where $Z = R + jX_L$ is known as impedance i.e. opposition offered to ac current.

$$Z = |Z| \angle \phi = \sqrt{R^2 + X_L^2} \angle \tan^{-1} \left(\frac{X_L}{R} \right)$$

It indicates in RL series circuit that current lags behind voltage by ϕ i.e. voltage leads current by ϕ

Instantaneous voltage and current are given by

$$v = V_m \sin \omega t$$



Instantaneous active power is given by

$$\begin{aligned}
 p &= v \times i \\
 p &= (V_m \sin \omega t)(I_m \sin(\omega t - \phi)) \\
 p &= V_m I_m \sin \omega t \sin(\omega t - \phi) \\
 p &= \frac{V_m I_m}{2} [\cos \phi - \cos(2\omega t - \phi)] \\
 p &= \frac{V_m I_m}{2} \cos \phi - \frac{V_m I_m}{2} \cos(2\omega t - \phi)
 \end{aligned}$$

Here $\frac{V_m I_m}{2} \cos(2\omega t - \phi)$ is **fluctuating power** whose average is **zero** over a full cycle.

Similarly $\frac{V_m I_m}{2} \cos \phi$ is **constant power** whose average is **non-zero** over a full cycle.

Hence average active power over a full cycle is given by

$$P = \frac{V_m I_m}{2} \cos \phi = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos \phi = V I \cos \phi \text{ (watt)}$$

Active/real Power (P) [Watt]: It is the power consumed by the circuit. It is the multiplication of RMS values of voltage, current and power factor.

$$P = V I \cos \phi \text{ (watt)}$$

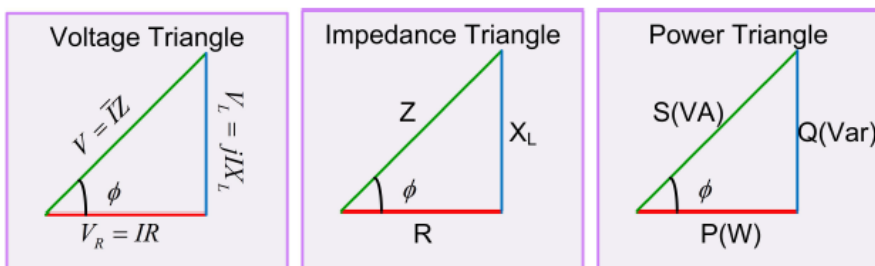
Reactive/imaginary Power (Q) [VAR]: It is the multiplication of RMS values of voltage, current, and sine of the angle of between voltage and current.

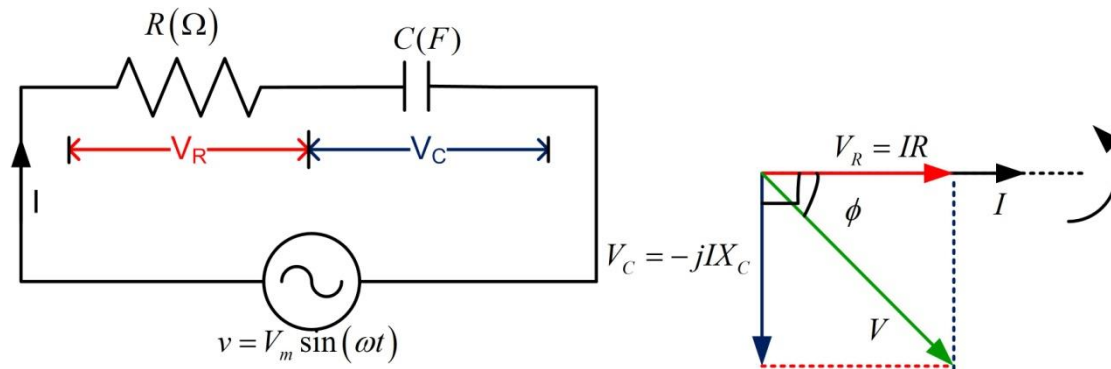
$$Q = V I \sin \phi \text{ (VAr)}$$

Apparent Power (S) [VA]: It is the multiplication of RMS values of voltage, current.

$$S = P + jQ = V I \cos \phi + jV I \sin \phi \text{ (VA)}$$

Useful triangles



(B) Series RC circuits:

Let a single-phase AC supply $v = V_m \sin \omega t$ is applied across a series circuit of resistance $R(\Omega)$, capacitance $C(F)$ as shown in the following figure:

If the frequency is $f(\text{Hz})$, then capacitive reactance is given by $X_C = \frac{1}{2\pi fC} (\Omega)$

If the current flowing through the series circuit is $I(\text{A})$, the voltage across the resistance is given by $V_R = IR$

The voltage across the capacitance is given by $V_C = IX_C$

Applying KVL, the total applied voltage is given by $\bar{V} = \bar{V}_R + \bar{V}_C$

From the above equations $\bar{V} = \bar{I}R - j\bar{I}X_C = \bar{I}(R - jX_C) = \bar{I}Z$

where $Z = R + jX_L$ is known as impedance i.e. opposition offered to ac current.

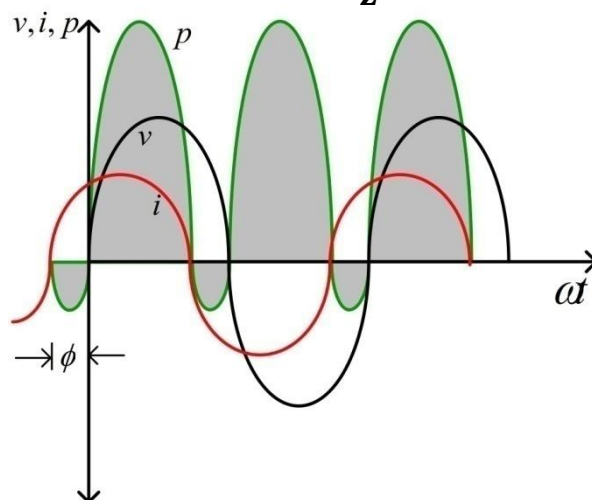
$$Z = |Z| \angle \phi = \sqrt{R^2 + X_C^2} \angle -\tan^{-1}\left(\frac{X_C}{R}\right)$$

It indicates in RC series circuit, current leads voltage by ϕ i.e. voltage lags current by ϕ

Instantaneous voltage and current are given by

$$v = V_m \sin \omega t$$

$$i = I_m \sin(\omega t + \phi) = \frac{V_m}{Z} \sin(\omega t + \phi)$$



Instantaneous active power is given by

$$p = v \times i$$

$$p = (V_m \sin \omega t)(I_m \sin(\omega t + \phi))$$

$$p = VmIm \sin \omega t \sin(\omega t + \phi)$$

$$p = \frac{VmIm}{2} [\cos \phi - \cos(2\omega t + \phi)]$$

$$p = \frac{VmIm}{2} \cos \phi - \frac{VmIm}{2} \cos(2\omega t + \phi)$$

Here $\frac{VmIm}{2} \cos(2\omega t + \phi)$ is **fluctuating power** whose average is **zero** over a full cycle.

Similarly $\frac{VmIm}{2} \cos \phi$ is **constant power** whose average is **non-zero** over a full cycle.

Hence average active power over a full cycle is given by

$$P = \frac{VmIm}{2} \cos \phi = \frac{Vm}{\sqrt{2}} \frac{Im}{\sqrt{2}} \cos \phi = V I \cos \phi \text{ (watt)}$$

Active/real Power (P) [Watt]: It is the power consumed by the circuit. It is the multiplication of RMS values of voltage, current and power factor.

$$P = V I \cos \phi \text{ (watt)}$$

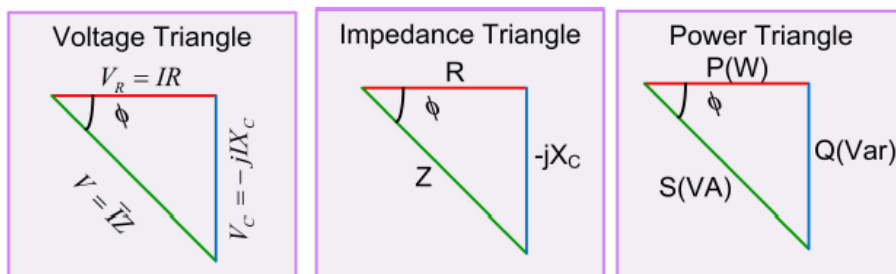
Reactive/imaginary Power (Q) [Var]: It is the multiplication of RMS values of voltage, current, and sine of the angle of between voltage and current.

$$Q = V I \sin \phi \text{ (Var)}$$

Apparent Power (S) [VA]: It is the multiplication of RMS values of voltage, current.

$$S = P + jQ = V I \cos \phi + jV I \sin \phi \text{ (VA)}$$

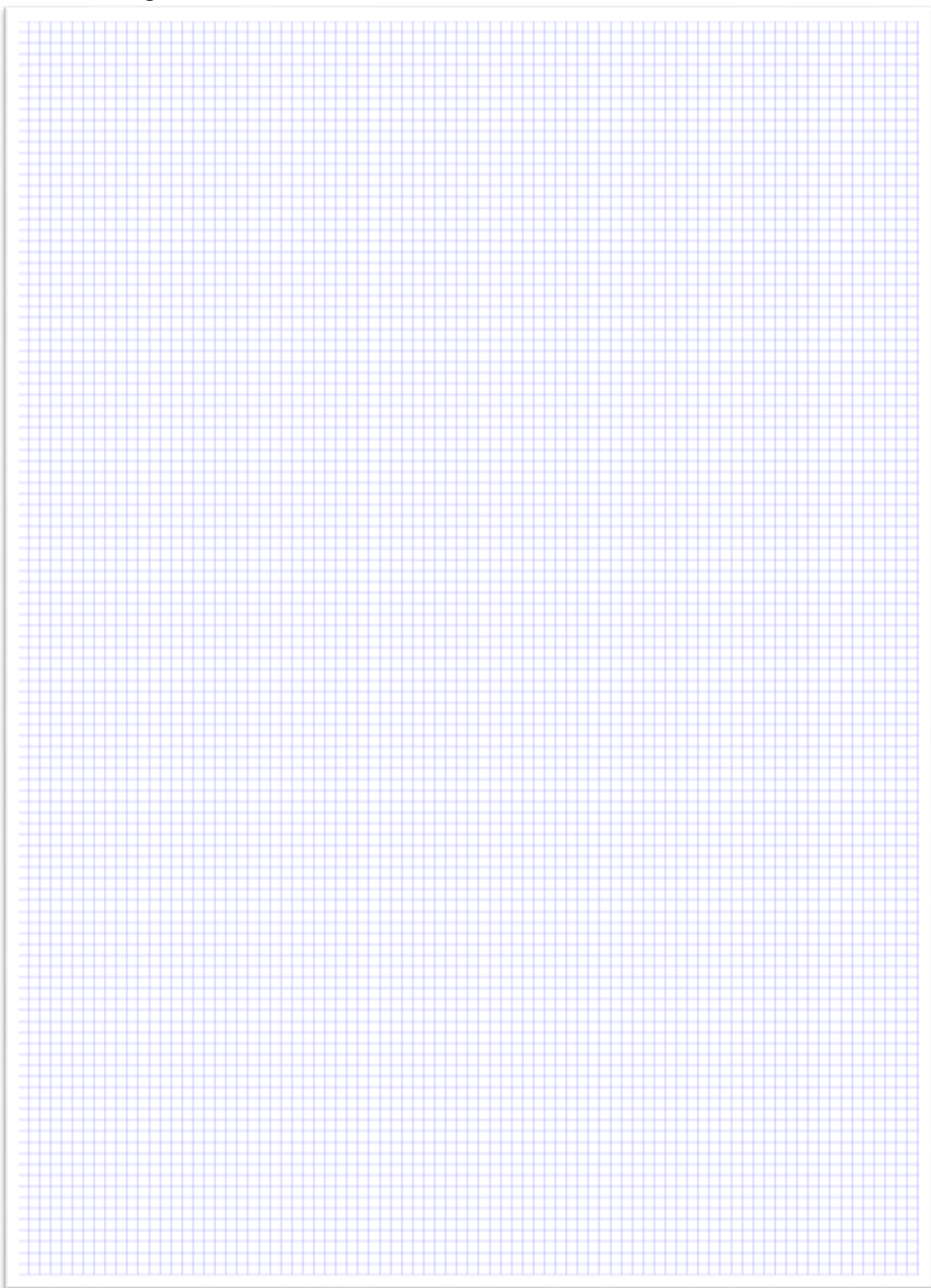
Useful triangles



Apparatus:

Sr. No.	Equipment	Specification
1	Resistor	
2	Inductor	
3	Capacitor	
4	Function Generator	
5	Voltmeter	

Connection Diagram:



Procedure:

1. Connect the circuit diagram as shown in Fig.
2. Switch ON the power supply.
3. Apply required input to the circuit and see the waveform of input and voltage across resistance on a storage oscilloscope.
4. Note down the voltmeter reading which indicates voltage across the resistance and inductive/capacitive reactance
5. Measure the angle between the voltage across resistance and supply voltage. It is the phase angle
5. Switch OFF the power supply and disconnect the circuit.

Observation and Result Table:**(A) For RL series circuit**Resistance R=_____ Ω , Inductance L=_____ H**Observed Values**

Sr.No.	Applied Voltage (V)	Voltage across R V_R (V)	Current $I = \frac{V_R}{R}$ (A)	Phase angle difference t (msec)	Phase angle difference in deg $\phi = \frac{360}{20} t$
1					
2					

Calculated Values

Sr.No.	Applied Voltage (V)	Impedance $Z = R + jX_L$	Current $I = \frac{V}{ Z }$ (A)	Phase angle difference in deg $\phi = \tan^{-1} \frac{X_L}{R}$
1				
2				

Result Table

Sr. No.	From observed values					
	Active Power $P = VI \cos \phi$ (W)	Reactive Power $Q = VI \sin \phi$ (VAr)	Apparent Power $S = VI$ (VA)	Active Power $P = VI \cos \phi$ (W)	Reactive Power $Q = VI \sin \phi$ (VAr)	Apparent Power $S = VI$ (VA)
1						
2						

(B) For RC series circuitResistance R= _____ Ω , Capacitance C= _____ F**Observed Values**

Sr.No.	Applied Voltage (V)	Voltage across R V_R (V)	Current $I = \frac{V_R}{R}$ (A)	Phase angle difference t (msec)	Phase angle difference in deg $\phi = \frac{360}{20} t$
1					
2					

Calculated Values

Sr.No.	Applied Voltage (V)	Impedance $Z = R - jX_C$	Current $I = \frac{V}{ Z }$ (A)	Phase angle difference in deg $\phi = -\tan^{-1} \frac{X_C}{R}$
1				
2				

Result Table

Sr. No.	From observed values					
	Active Power $P = VI \cos \phi$ (W)	Reactive Power $Q = VI \sin \phi$ (VAr)	Apparent Power $S = VI$ (VA)	Active Power $P = VI \cos \phi$ (W)	Reactive Power $Q = VI \sin \phi$ (VAr)	Apparent Power $S = VI$ (VA)
1						
2						

Conclusion:

LAB ASSIGNMENT

Q1) Fill in the blank with phase relationship: In case of RL circuit current is _____ /0.5M
to voltage and in RC circuit current is _____ to applied voltage

Q2) Which is/are the true formula for reactance calculation? /0.5M

- | | |
|------------------------------|-----------------------------|
| • $X_L = 2\pi fL$ | • $X_L = \omega L$ |
| • $X_C = \frac{1}{\omega C}$ | • $X_C = \frac{1}{2\pi fC}$ |
-

Q3) The power factor angle of the RC circuit varies from? /0.5M

- | | |
|-------------|-------------|
| • 30 to 90 | • 0 to 180 |
| • 30 to -90 | • 0 to -180 |
-

Q4) The power factor angle of the RL circuit varies from? /0.5M

- | | |
|-------------|-------------|
| • 30 to 90 | • 0 to 180 |
| • 30 to -90 | • 0 to -180 |
-

Q5) Define active, reactive and apparent power. Also, draw power triangle diagram. /1M

Q6) Draw the phasor diagram of the RLC series circuit. /1M

=====

Q7) A resistor is connected in series with a variable inductor. When the circuit is connected to 200V, 50Hz supply it carries current of 2A with a power factor of 0.707 lagging. If the voltage drop across the resistance is 100V. Find the value of circuit elements. /1.5M

Q8) A series R-L-C circuit has the value: $R = 10\text{-ohm}$, $L = 0.01\text{H}$, $C = 100\text{microfarad}$. If the applied voltage is 200V, 50Hz. Calculate the voltage drop across each and net reactive power in a circuit. /1.5M

=====

Q9) Describe any one application of RL or RC combination used in daily life with advantages and limitations. /3M

=====

Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:

Presentation: /10

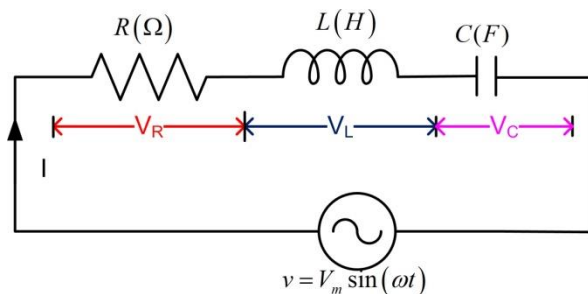
Total: /30

Title: Resonance in Series RLC circuits**Aim:** To derive resonance frequency and analyze resonance in series RLC circuit.**Prerequisite:**

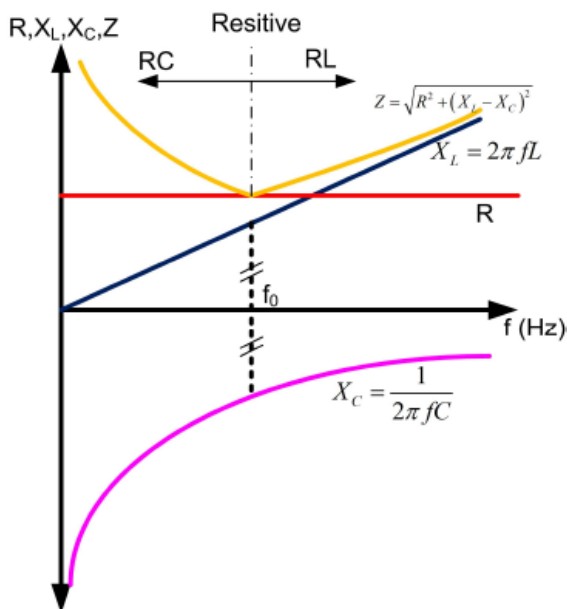
- (1) AC fundamentals
- (2) The response of RL, RC, and RLC to AC supply
- (3) Concept of inductive and capacitive reactance

Learning outcomes: At the end of this experiment students will be able to

- (1) Justify effect of frequency on resistance, inductive and capacitive reactance.
- (2) Calculate impedance of series RLC with variable frequency AC supply.
- (3) Derive the formula for resonance frequency

Theory:**(A) Series RLC circuits:**

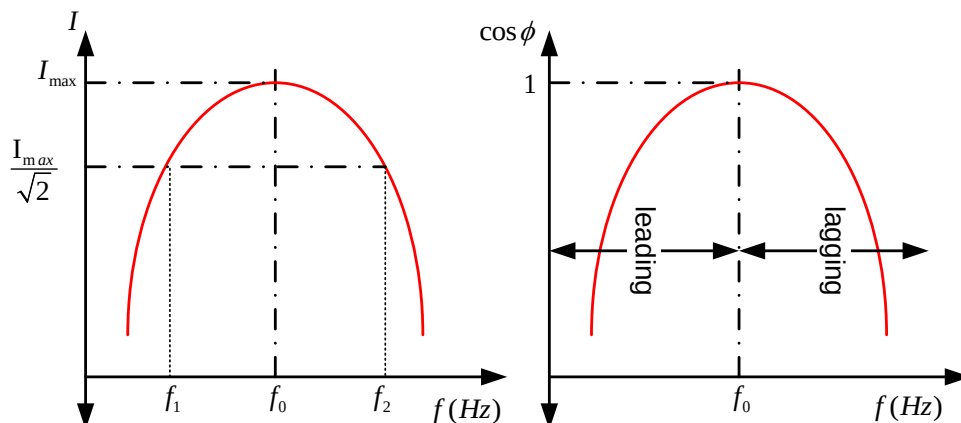
Let a single-phase AC supply $v = V_m \sin \omega t$ with constant V_m and variable frequency $f(\text{Hz})$ is applied across a series circuit of resistance $R(\Omega)$, inductance $L(H)$ and capacitance $C(F)$ as shown in the following figure.

(B) Effect of variable frequency:

- Resistance is independent of frequency
- Inductive reactance is given by $X_L = 2\pi fL$ i.e. $X_L \propto f$. It indicates that as frequency increases inductive reactance increases.
- Capacitive reactance is given by $X_C = \frac{1}{2\pi fC}$ i.e. $X_C \propto \frac{1}{f}$. It indicates that as frequency increases capacitive reactance decreases.
- Impedance $Z = R + jX_L - jX_C$ i.e. $Z = R + j(X_L - X_C)$
- The magnitude of the impedance is $Z = \sqrt{R^2 + (X_L - X_C)^2}$ i.e. Z varies from RC to RL with frequency.
- Power factor or angle $\phi = \tan^{-1} \frac{X_L - X_C}{R}$ it varies -90° to $+90^\circ$ with frequency.
- Hence Power factor $\cos \phi$ varies from

leading to unity to lagging with frequency

- As a result, current also varies from low to maximum and then again to low



(C) Resonance in series RLC:

It is observed that at a certain frequency, inductive reactance becomes equal to capacitive reactance i.e. $X_L = X_C$, this frequency in series RLC is called resonant frequency.

Hence at the resonance frequency,

- Impedance $Z = R + jX_L - jX_C$ will be $Z = R$. The circuit is purely resistive
- The magnitude of the current in the circuit is $I = \frac{V}{Z} = \frac{V}{R}$ hence it is maximum than all other frequencies
- The power factor angle $\phi = \tan^{-1} \frac{X_L - X_C}{R} = \tan^{-1} 0 = 0^\circ$
- Power factor $\cos \phi = 1$ i.e. unity

To derive resonance frequency f_0 we have $X_L = X_C$.

$$\omega_0 L = \frac{1}{\omega_0 C}$$

$$\omega_0^2 = \frac{1}{LC}$$

$$\omega_0 = \sqrt{\frac{1}{LC}} = \frac{1}{\sqrt{LC}} \text{ rad/sec}$$

Resonance frequency is

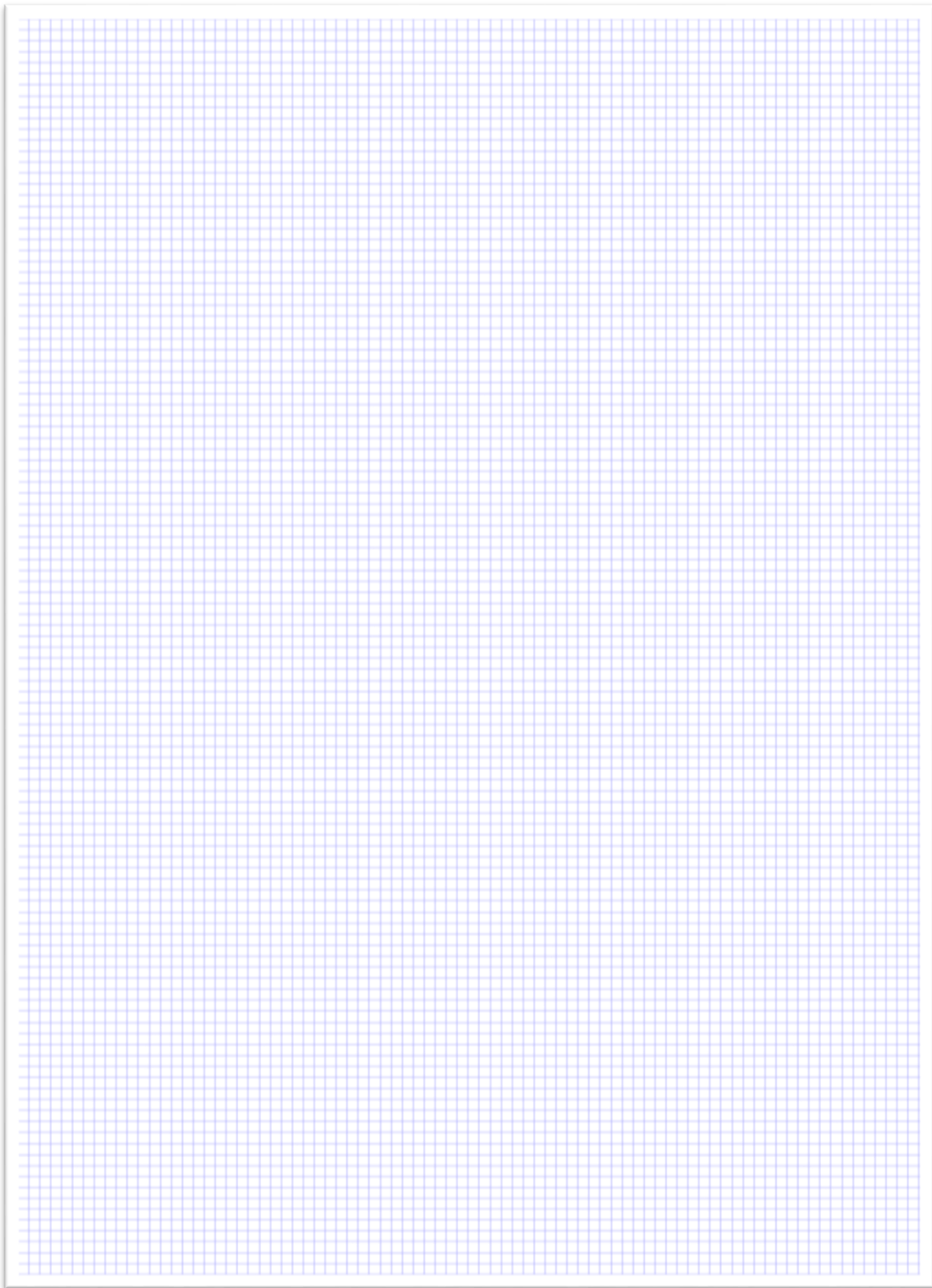
$$2\pi f_0 = \sqrt{\frac{1}{LC}} = \frac{1}{\sqrt{LC}}$$

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

Apparatus:

Sr. No.	Equipment	Specification
1	Resistor	
2	Inductor	
3	Capacitor	
4	Function Generator	
5	Voltmeter	

Connection Diagram:



Procedure:

1. Connect the circuit diagram as shown in Fig.
2. Switch ON the power supply.
3. Vary the frequency step by step in small steps by adjusting frequency variation knob.
4. Note down the voltmeter reading which indicates voltage across the resistance.
5. Switch OFF the power supply and disconnect the circuit.

Observation and Result Table:Resistance R= _____ Ω , Inductance L= _____ H, Capacitance C= _____ F

Sr. No	f (Hz)	$X_L = 2\pi fL$ (Ω)	$X_C = \frac{1}{2\pi fL}$ (Ω)	$Z = R + j(X_L - X_C)$ In polar (Ω)	V_R (volt)	$I = V_R/R$ (amp)
1				$\angle$		
2				$\angle$		
3				$\angle$		
4				$\angle$		
5				$\angle$		
6				$\angle$		
7				$\angle$		
8				$\angle$		
9				$\angle$		
10				$\angle$		
11				$\angle$		
12				$\angle$		
13				$\angle$		
14				$\angle$		
15				$\angle$		

Conclusion:

LAB ASSIGNMENT

Q1) Fill in the blank: As the frequency decreases inductive reactance _____ and capacitive reactance _____. /0.5M

Q2) Which is the true condition for series resonance? /0.5M

- | | |
|-----------------------------------|---------------------|
| • $X_L > X_C$ | • $X_L < X_C$ |
| • $\omega L = \frac{1}{\omega C}$ | • $L = \frac{1}{C}$ |
-

Q3) What will be the power factor at series resonance frequency? /0.5M

- | | |
|-----------|------------|
| • 0.5 lag | • 0.5 lead |
| • 0 lag | • Unity |
-

Q4) How does the series resonant circuit behave under the resonance condition? /0.5M

- | | |
|---------------------|-----------------------|
| • Current Amplifier | • Frequency Amplifier |
| • Voltage Amplifier | • Voltage regulator |
-

Q5) Define bandwidth and Q factor in series resonance. Also, give the relation between them. /1M

Q6) Draw the phasor diagram of series RLC circuit quantities under series resonance condition. /1M

=====

Q7) A resistor and capacitor are in series with a variable inductor. When the circuit is connected to 200V,50Hz supply. The maximum current obtained by varying the inductance is 0.314A. The voltage across the capacitor when the current in the circuit is maximum, is 800V. Find the values of the series circuit elements. /1.5M

Q8) A series R-L-C circuit has the values: $R = 10\text{-ohm}$, $L = 0.01\text{H}$, $C = 100\text{microfarad}$. Calculate resonant frequency, quality factor, and bandwidth. /1.5M

=====

Q9) How the phenomena of resonance are utilized in Electrical Engineering in filter?

/3M

=====

Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:

Presentation: /10

Total: /30**Title:** Star-Delta Connection of Load**Aim:** To Verify the relation between phase and line quantities in three-phase balance star delta connection of load**Prerequisite:**

- (1) Different types of supply systems
- (2) Types of load
- (3) Concept of phasor and phasor arithmetic

Learning outcomes: At the end of this experiment students will be able to

- (1) Derive the relation of phase and line quantities in the three-phase system with star and delta connection of load
- (2) Differentiate between balanced and unbalanced supply and load.
- (3) Calculate power in balanced three-phase star and delta connected load.

Theory:

Three-phase electric power is a common method of alternating current electric power generation, transmission, and distribution. It is a type of poly-phase system and is the most common method used by electrical grids worldwide to transfer power. It is also used to power large motors and other heavy loads.

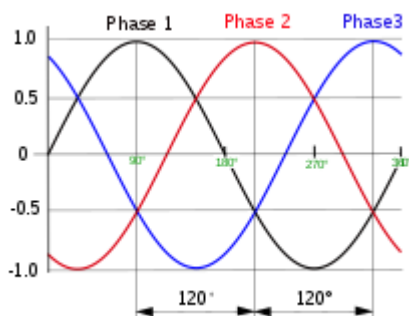
A three-wire three-phase circuit is usually more economical than an equivalent two-wire **phase circuit** at the same line to ground voltage because it uses less conductor material to transmit a given amount of electrical power. Polyphase power systems were independently invented by Galileo Ferraris, Mikhail Dolivo-Dobrovolsky, Jonas Wenström, John Hopkinson and Nikola Tesla in the late 1880s.

(A) Line Voltages and Phase Voltages:

The conductors between a voltage source and a load are called lines, and the voltage between any two lines is called line voltage. The voltage measured between any line and neutral (two-terminal of a load of a single phase) is called phase voltage. For example, for a 440Y/230 volt service, the line voltage is 440 Volts, and the phase voltage is 230 Volts.

(B) Three Phase Supply System:

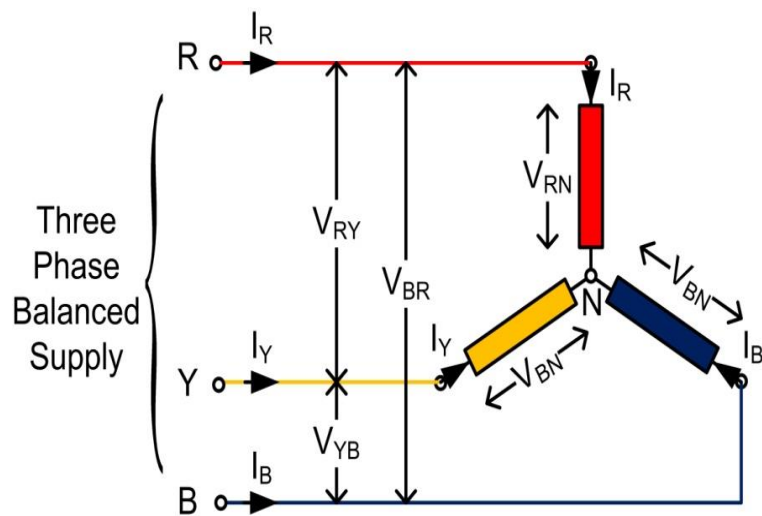
In a symmetric three-phase power supply system, three conductors each carry an alternating current of the same frequency and voltage amplitude relative to a common reference but with a phase difference of one third of a cycle between each. The common reference is usually connected to ground and often to a current-carrying conductor called the neutral. Due to the phase difference, the voltage on any conductor reaches its peak at one third of a cycle after one of the other conductors and one third of a cycle before the remaining conductor. This phase delay gives constant power transfer to a balanced linear load. It also makes it



possible to produce a rotating magnetic field in an electric motor and generate other phase arrangements using transformers. The amplitude of the voltage difference between two phases is $\sqrt{3}(1.732...)$ times the amplitude of the voltage of the individual phases.

(C) In star connected load

If the three start terminals or end points of the three loads are connected together, the result is known as star connection as shown in following figure. The common connecting point N, as



shown in fig is known as star point or neutral point.

$\bar{V}_{RY}, \bar{V}_{YB}, \bar{V}_{BR}$ = Balanced line voltages (equal in magnitude $|V_L|$ and phase difference of 120°).

$\bar{I}_R, \bar{I}_Y, \bar{I}_B$ = Balanced line currents (equal in magnitude $|I_L|$ and phase difference of 120°).

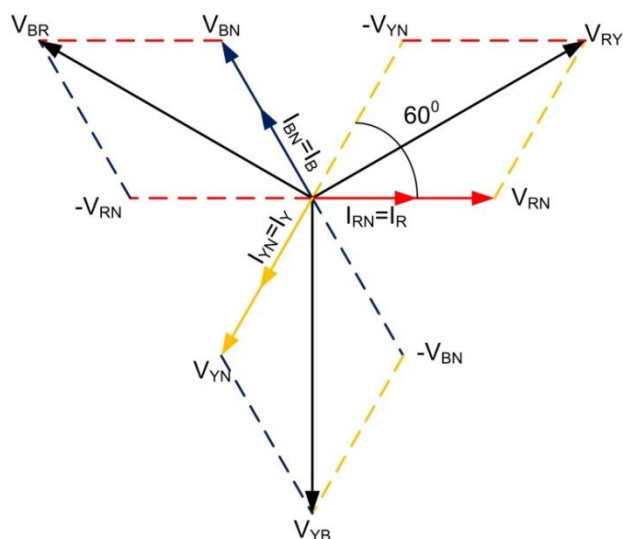
$\bar{V}_{RN}, \bar{V}_{YN}, \bar{V}_{BN}$ = Balanced phase voltages (equal in magnitude $|V_{ph}|$ and phase difference of 120°).

$\bar{I}_{RN}, \bar{I}_{YN}, \bar{I}_{BN}$ = Balanced phase currents (equal in magnitude $|I_{ph}|$ and phase difference of 120°).

From above diagram it is clear that phase values of currents are equal to line values of currents i.e. $|I_R| = |I_Y| = |I_B| = |I_L|$ and $|I_{RN}| = |I_{YN}| = |I_{BN}| = |I_{ph}|$.

$|I_L| = |I_{ph}|$ i.e. **line currents = phase currents**.

From above diagram it is also clear that phase values of voltages are not equal to line values



of voltages i.e. $|V_{RY}| = |V_{YN}| = |V_{BN}| = |V_L|$ and $|V_{RN}| = |V_{YN}| = |V_{BN}| = |V_{ph}|$.

To determine this relation, let balanced supply is applied to three phase balanced star connected resistive load. i.e. phase voltages and respective phase currents are in phase. The same can be represented in phasor diagram as below.

It shows that

$$\bar{V}_{RY} = \bar{V}_{RN} + (-\bar{V}_{YN})$$

The magnitude of $\bar{V}_{RY}$ can be calculated as

$$\begin{aligned} |V_{RY}|^2 &= |V_{RN}|^2 + |V_{YN}|^2 \\ &\quad + 2|V_{RN}||V_{YN}|\cos 60^\circ \\ |V_L|^2 &= |V_{ph}|^2 + |V_{ph}|^2 \\ &\quad + 2|V_{ph}||V_{ph}|\cos 60^\circ \end{aligned}$$

$$|V_L|^2 = |V_{ph}|^2(2 + 2\cos 60^\circ)$$

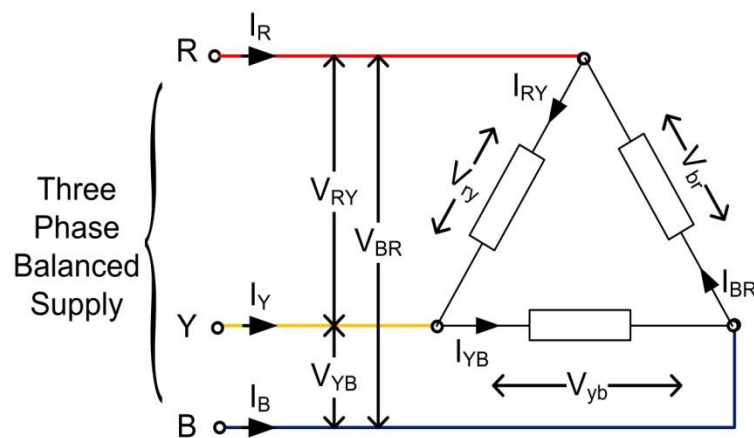
$$|V_L|^2 = |V_{ph}|^2(3)$$

$$|V_L| = \sqrt{3}|V_{ph}|$$

Line voltages = $\sqrt{3}$ phase voltages

(D) In delta connected load

If the start terminals are connected to end terminals of another phase load, the result is known as delta connection as shown in the following the figure.



$\bar{V}_{RY}, \bar{V}_{YB}, \bar{V}_{BR}$ = Balanced line voltages (equal in magnitude $|V_L|$ and phase difference of 120°).

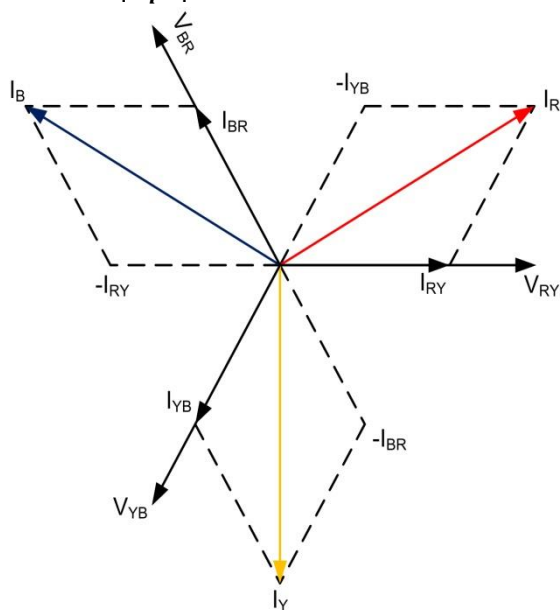
$\bar{I}_R, \bar{I}_Y, \bar{I}_B$ = Balanced line currents (equal in magnitude $|I_L|$ and phase difference of 120°).

$\bar{V}_{ry}, \bar{V}_{yb}, \bar{V}_{br}$ = Balanced phase voltages (equal in magnitude $|V_{ph}|$ and phase difference of 120°).

$\bar{I}_{RY}, \bar{I}_{YB}, \bar{I}_{BR}$ = Balanced phase currents (equal in magnitude $|I_{ph}|$ and phase difference of 120°).

From above diagram it is clear that phase values of voltages are equal to line values of voltages i.e. $|V_{RY}| = |V_{YB}| = |V_{BR}| = |V_L|$ and $|V_{ry}| = |V_{yb}| = |V_{br}| = |V_{ph}|$.

$|V_L| = |V_{ph}|$ i.e. **line voltages = phase voltages**.



From above diagram it is also clear that phase values of currents are not equal to line values of currents i.e. $|I_R| = |I_Y| = |I_B| = |I_L|$ and $|I_{RY}| = |I_{YB}| = |I_{BR}| = |I_{ph}|$.

To determine this relation, let balanced supply is applied to three phase balanced star connected resistive load. I.e. phase voltages and respective phase currents are in phase. The same can be represented in phasor diagram as given.

It shows that

$$\bar{I}_R = \bar{I}_{RY} + (-\bar{I}_{YB})$$

The magnitude of $\bar{V}_{RY}$ can be calculated as

$$|I_R|^2 = |I_{RY}|^2 + |I_{YB}|^2 + 2|I_{RY}||I_{YB}|\cos 60$$

$$|I_L|^2 = |I_{ph}|^2 + |I_{ph}|^2 + 2|I_{ph}||I_{ph}|\cos 60$$

$$|I_L|^2 = |I_{ph}|^2(2 + 2\cos 60)$$

$$|I_L|^2 = |I_{ph}|^2(3)$$

$$|I_L| = \sqrt{3}|I_{ph}|$$

Line currents = $\sqrt{3}$ phase currents

(E) Power in star and delta connected load

The active power in single-phase load is given by $P = VI \cos \phi$ watts.

In star network

Active Power in R phase $P_R = V_{RN} I_{RN} \cos \phi_{RN}$

Active Power in the Y phase $P_Y = V_{YN} I_{YN} \cos \phi_{YN}$

Active Power in the B phase $P_B = V_{BN} I_{BN} \cos \phi_{BN}$

Total of three active phase power

$$P = P_R + P_Y + P_B = V_{RN} I_{RN} \cos \phi_{RN} + V_{YN} I_{YN} \cos \phi_{YN} + V_{BN} I_{BN} \cos \phi_{BN}$$

For a balanced three-phase load, total active power is given by

$$P = P_R + P_Y + P_B = V_{ph} I_{ph} \cos \phi + V_{ph} I_{ph} \cos \phi + V_{ph} I_{ph} \cos \phi$$

$$P = P_R + P_Y + P_B = 3V_{ph} I_{ph} \cos \phi$$

In star-connected load, $|I_L| = |I_{ph}|$ and $|V_L| = \sqrt{3}|V_{ph}|$

Hence for a balanced three-phase load, total active power is given by

$$P = 3V_{ph} I_{ph} \cos \phi = 3 \frac{V_L}{\sqrt{3}} I_L \cos \phi$$

$$P = \sqrt{3} V_L I_L \cos \phi$$

In delta network

Active Power in R phase $P_R = V_{RY} I_{ry} \cos \phi_{ry}$

Active Power in the Y phase $P_Y = V_{YB} I_{yb} \cos \phi_{yb}$

Active Power in the B phase $P_B = V_{BR} I_{br} \cos \phi_{br}$

Total of three active phase power

$$P = P_R + P_Y + P_B = V_{RY} I_{ry} \cos \phi_{ry} + V_{YB} I_{yb} \cos \phi_{yb} + V_{BR} I_{br} \cos \phi_{br}$$

For a balanced three-phase load, total active power is given by

$$P = P_R + P_Y + P_B = V_{ph} I_{ph} \cos \phi + V_{ph} I_{ph} \cos \phi + V_{ph} I_{ph} \cos \phi$$

$$P = P_R + P_Y + P_B = 3V_{ph} I_{ph} \cos \phi$$

In star-connected load, $|I_L| = \sqrt{3}|I_{ph}|$ and $|V_L| = |V_{ph}|$

Hence for a balanced three-phase load, total active power is given by

$$P = 3V_{ph} I_{ph} \cos \phi = 3V_L \frac{I_L}{\sqrt{3}} \cos \phi$$

$$P = \sqrt{3} V_L I_L \cos \phi$$

Same can be derived for reactive and apparent power.

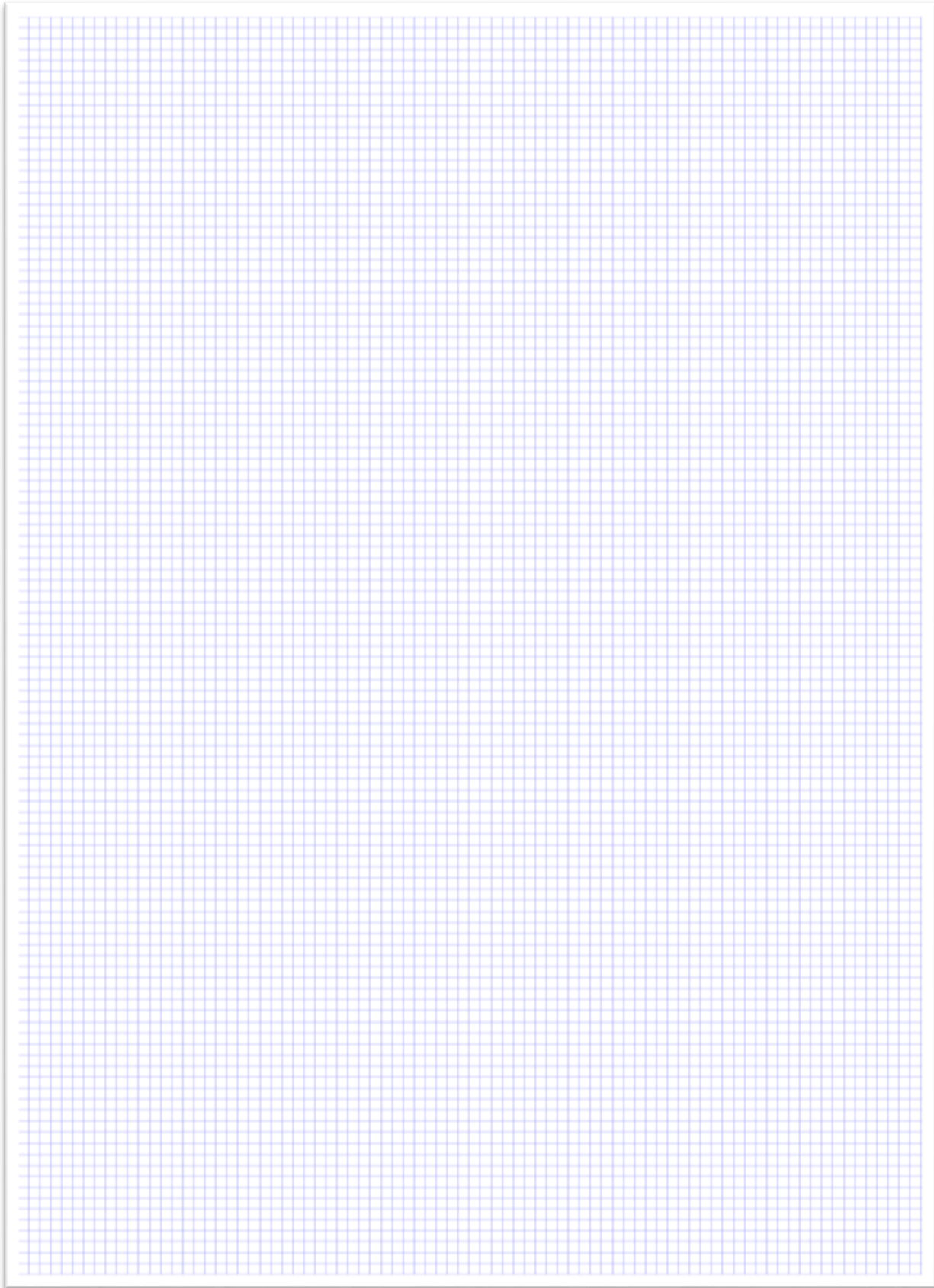
In summary:

Power	Star Connected Load/ Delta Connected Load	
	Line Quantities	Phase Quantities
Active Power	$P = \sqrt{3} V_L I_L \cos \phi$ Watts	$P = 3V_{ph} I_{ph} \cos \phi$ Watts
Reactive Power	$Q = \sqrt{3} V_L I_L \sin \phi$ VAr	$Q = 3V_{ph} I_{ph} \sin \phi$ VAr
Apparent Power	$S = \sqrt{3} V_L I_L$ VA	$S = 3V_{ph} I_{ph}$ VA

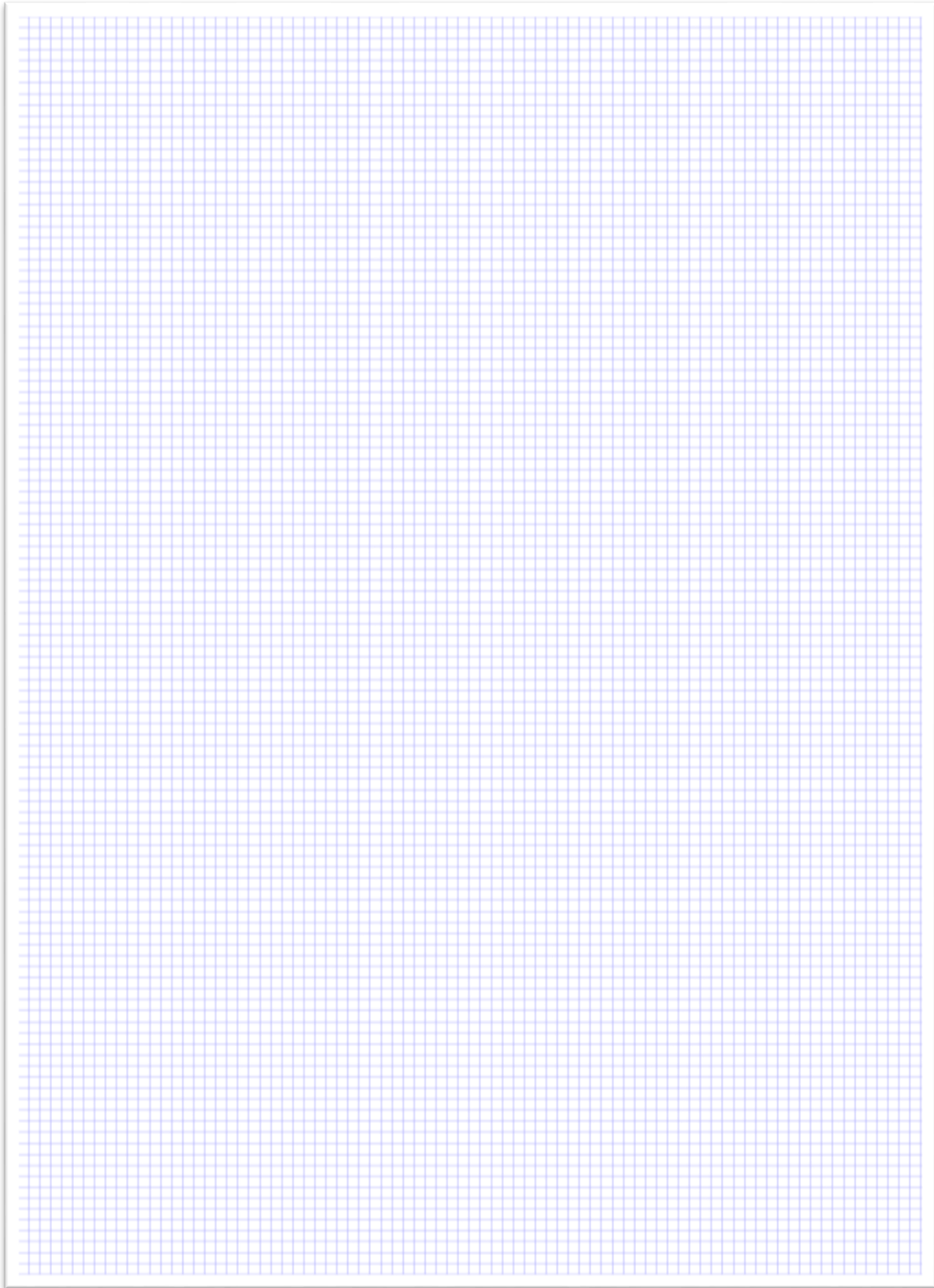
Apparatus:

Sr.No.	Name of equipment/instrument.	Specifications
1	Voltmeter	
2	Ammeter	
3	3-phase resistive load(Lamp bank)	
4	3-phase variac	

Circuit Diagram: For Star Connected Load



Circuit Diagram: For Delta Connected Load



Procedure:**A. Star Connected Three-Phase System:-**

1. Make connections as shown in fig. Connect ammeter and voltmeter of the appropriate range. Observe voltmeter readings and record them in the tabular form.
2. Verify the relation between phase voltages and line voltages.
3. Record ammeter readings.
4. Verify the relation between phase currents and line currents.
5. Take voltmeter and ammeter readings for different loads and verify the relations between them.

B. Delta Connected Three-Phase System:-

1. Make connections as shown in fig. Connect ammeter and voltmeter of the appropriate range. Observe voltmeter readings and record them in the tabular form.
2. Verify the relation between phase voltages and line voltages.
3. Record ammeter readings.
4. Verify the relation between phase currents and line currents.
5. Take voltmeter and ammeter readings for different loads and verify the relations between them

Observation :**A) For Star Connected Balanced Load**

Sr No	Line Voltages			Phase Voltages			Line Currents		
	V_{RY} (V)	V_{YB} (V)	V_{BR} (V)	V_{RN} (V)	V_{YN} (V)	V_{BN} (V)	I_R (A)	I_Y (A)	I_B (A)
1									
2									

Result Table:

Sr. No.	V_L Observed	$V_L = \sqrt{3}V_{ph}$	Remark
1			
2			

B)For Delta Connected Balanced Load

Sr No	Line Current			Phase Current			Line Voltages		
	I_R (V)	I_Y (V)	I_B (V)	I_{RY} (V)	I_{YB} (V)	I_{BR} (V)	V_{RY} (V)	V_{YB} (V)	V_{BR} (V)
1									
2									

Result Table:

Sr. No.	I_L Observed	$I_L = \sqrt{3}I_{ph}$	Remark
1			
2			

e-Resources:

(1) NPTEL Lecture Notes:

[https://nptel.ac.in/courses/108105053/pdf/L-18\(NKD\)\(ET\)%20\(\(EE\)NPTEL\).pdf](https://nptel.ac.in/courses/108105053/pdf/L-18(NKD)(ET)%20((EE)NPTEL).pdf)
Conclusion:

Phasor Diagram (STAR CONNECTION)

Phasor Diagram (DELTA CONNECTION)

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LAB ASSIGNMENT

Q1) For a 3-phase load-balanced condition, each phase has the same value of _____ /0.5M

- Impedance
- Resistance
- Power Factor
- All of the above

Q2) A polyphase system is generated by _____? /0.5M

- Having three generator windings separated by an 120 electrical angle.
- Having three generator windings separated by 90 degree electrical angle
- Having two or more generator windings separated by 0 degree electrical angle
- None of the above

Q3) The sum of balanced load currents of the balanced supply system is /0.5M

- Infinity
- Positive value
- Negative value
- Zero

Q4) A 3 wire, 3 - ϕ supply feeds a load consisting of three equal resistors. By how much is the load reduced if one of the resistors be removed when the load is in star? /0.5M

- 25% of the original load
- 33.33% of the original load
- 50% of the original load
- 66.67% of the original load

Q5) What are the advantage of star and delta connection ?.At low voltage system which connection is preferred ? /1M

Q5) Draw the construction diagram of the three-phase generator with a fixed magnetic field and single rotating conductor /1M

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Q6) If the load connected to three-phase 400V, 50Hz supply system is connected in delta and power consumed by load is 1000W at 0.8 p.f. lagging. Determine the impedance of each phase.

/1.5M

Q8) A system of balanced load connected in star across the three-phase supply of 400V, 50Hz is consuming 1000W power at 0.8 p.f. lagging. Calculate the impedance of each phase. If the same impedance is connected in delta with the same supply, calculate active power consumption and comment on the result obtained.

/1.5M

Q9) Do the load survey in nearby your area where the three-phase load is used. Also, write its connection types and specifications.

/3M

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Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:

Presentation: /10

Total: /30**Title:** Single Phase Transformer.**Aim:** To determine efficiency and regulation of the transformer by direct loading of a single-phase transformer**Prerequisite:**

- (1) Electromagnetic induction
- (2) Construction of single-phase transformer
- (3) Voltage and a current ratio of transformer

Learning outcomes: At the end of this experiment student will be able to

- (1) Find voltage and current ratio.
- (2) Calculate the efficiency of 1 phase transformer at various load condition.
- (3) Determine the maximum efficiency point and the load at which it occurs.
- (4) Calculate the voltage regulation of the 1 phase transformer at different load conditions.

Theory:**(A) Transformer: regulation and efficiency:**

The transformer is a static device which transforms electric power from one ac circuit to another ac circuit individually. It works on Faraday's law of electromagnetic induction. Direct loading method is used for testing a transformer. In this method, the transformer is loaded to its full and the efficiency i.e. output power/input power and the voltage regulation are known.

Voltage Regulation is defined as the change in the voltage across the load from no load to full load condition in terms of Full load voltage. At no-load condition full secondary rated voltage is available across the load but as the load goes on increasing the voltage drop goes on increasing which reduces the voltage across the load.

The graph of regulation Vs load is a straight line.

$$\% \text{ voltage regulation } (\%R) = \frac{\text{No load voltage} - \text{full load voltage}}{\text{Full load voltage}} \times 100$$

Efficiency: The efficiency of the transformer is defined as the ratio output power at secondary to input power at primary terminals

$$\% \text{ efficiency } (\%\eta) = \frac{\text{Output power at secondary}}{\text{Input power at primary}} \times 100$$

(B) Direct loading method:

Now basically we're talking about knowing the performance of the transformer, i.e., we're trying to find its efficiency. Finding efficiency is done by two methods, (i) Direct (ii) Indirect. In direct loading method, the transformer is directly connected to the load to find input and output by metering equipment.

Advantages:

- Simple process,
- no much calculations needed,
- Simple setup

Disadvantages:

- It's not economical to do this test on large rating machines as; just for the sake of the test, you can't waste a large amount of energy.
- You can't get information about the share of different types of losses
- It's a difficult task arrange different kinds for the load (R,L,C) from no load to full load to study performance at different situations.

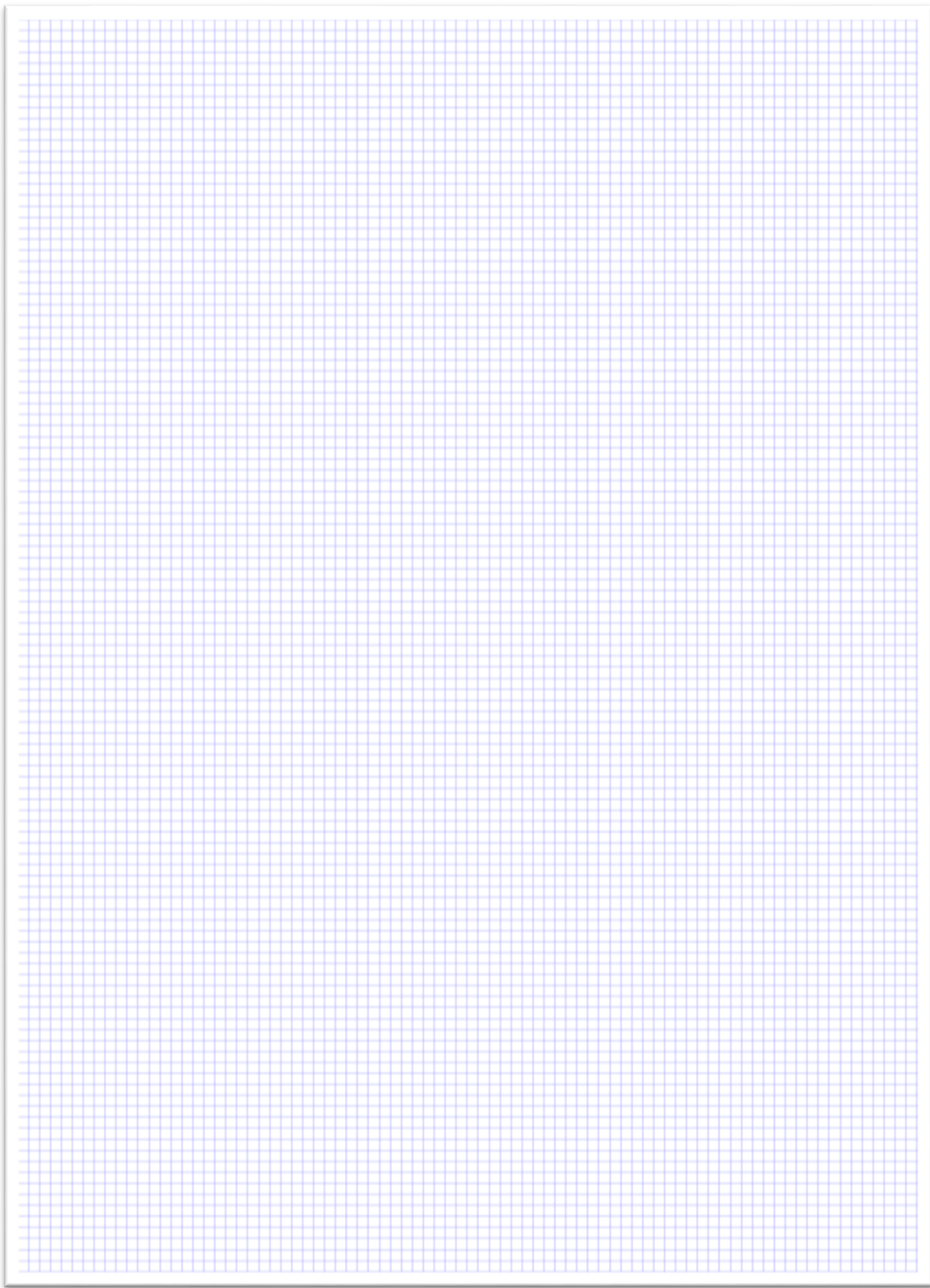
Apparatus:

Sr. No.	Name of equipment/ instrument	Specifications
1.	1 Ph Transformer – 1 No.	
2.	Ammeter – 1 No.	
3.	Ammeter – 1 No.	
4.	Voltmeter – 1 No.	
5.	Voltmeter – 1 No.	
6.	Wattmeter – 2 No.	
7.	1 PhVariac – 1 No.	
8.	Lamp Load	

Procedure:

- 1) Connect the circuit as shown in the circuit diagram.
- 2) Switch ON the supply and apply the rated voltage to the primary side of the transformer and keep this voltage constant throughout the experiment.
- 3) Takedown the readings of ammeter, voltmeter, and wattmeter connected in the primary and secondary circuit at no-load conditions.
- 4) Increase the load gradually and take down the reading of all the meter.
- 5) Take 5 to 6 readings up to full load condition of the transformer.
- 6) Adjust primary voltage to 230V at each reading.

Circuit Diagram:



Observation Table:

Sr. No.	Primary voltage V_1 (volt)	Primary current I_1 (amp)	Wattmeter reading W_1 (watt)	Secondary voltage V_2 (volt)	Secondary current I_2 (amp)	Output power $W_2 = V_2 I_2$ (watt)
1.						
2.						
3.						
4.						
5.						
6.						

Sample Calculation:

Sr. No.	Voltage Ratio $\frac{V_2}{V_1}$	Current Ratio $\frac{I_1}{I_2}$	% Regulation $\frac{V'_2 - V_2}{V_2} \times 100$	% Efficiency $\frac{W_2}{W_1} \times 100$
1.				
2.				
3.				
4.				
5.				
6.				

Graph Paper:

Draw Graph Load current I_2 Vs. Regulation and Load current I_2 Vs. efficiency

Conclusion:

GRAPH

GRAPH

LAB ASSIGNMENT	
Q1) Transformation ratio (K) of transformer is _____ <ul style="list-style-type: none"> • N_2/N_1 • E_1/E_2 • V_1/V_2 • I_2/I_1 	/0.5M
Q2) EMF equation for single phase transformer is <ul style="list-style-type: none"> • $E = 1.11 \phi_m f N$ • $E = 1.11 B_m A f N$ • $E = 4.44 B_m A f N$ • $E = 4.44 \phi_m f N$ 	/0.5M
Q3) Efficiency of transformer normally in the range of <ul style="list-style-type: none"> • 50 to 70% • 60 to 75% • 80 to 90% • 90 to 98% 	/0.5M
Q4) The transformer efficiency will be maximum at <ul style="list-style-type: none"> • $P_{cu}=P_i$ • $P_{cu}=0.5P_i$ • $P_{cu}=2P_i$ • $P_{cu}=0.9P_i$ 	/0.5M
Q5) What are the other tests are used to determine the efficiency and regulation of the transformer? Give the advantages of the same.	/1M
Q6) Enlist the different losses taking place in the transformer	/1M

Q7) A 500 KVA transformer has an iron loss of 2 kW & full load copper losses of 5 kW. Calculate the efficiency at 75% of full load and unity power factor. /1M

Q8) A 100 kVA, 50 Hz, 440 V/11,000 V single-phase transformer has an efficiency of 98.5% when supplying full – load current at 0.8 power factor and an efficiency of 99%, when supplying half-full – load current at unity power factor Find the iron losses and the copper losses corresponding to full – load current. /1M

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Q9) Enlist the application of transformer according to its constructions. Collect the product information sheet of a transformer manufacturing company

/1.5M

Q10) As per IS1180 efficiency Level 2 and 3 , list out total losses at 50% and 100% load of 630kVA 11kV/0.433kV Distribution transformer ?

/1.5M

Q11) Explain advantages of dry type transformer over oil cooled transformer ?

/1M

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Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:
Presentation: /10

Total: /30

Title: KVL and Superposition Theorem

Aim: To verify Kirchhoff's current law, Kirchhoff's voltage law and Superposition Theorem for the given circuit

Prerequisite:

- (1) Ohm's law
- (2) Series and parallel combinations of resistances
- (3) Voltage and current source
- (4) Solution of linear simultaneous equations

Learning outcomes: At the end of this experiment student will be able to

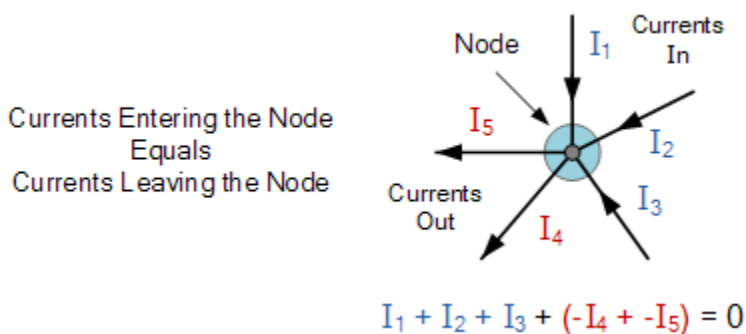
- (1) State KVL, KCL and superposition theorem.
- (2) Apply KVL, KCL and superposition theorem in given circuits.

Theory:

Kirchhoffs Circuit Laws allow us to solve complex circuit problems by defining a set of basic network laws and theorems for the voltages and currents around a circuit. In 1845, a German physicist, Gustav Kirchhoff developed a pair or set of rules or laws which deal with the conservation of current and energy within electrical circuits. These two rules are commonly known as: *Kirchhoffs Circuit Laws* with one of Kirchhoffs laws dealing with the current flowing around a closed circuit, Kirchhoffs Current Law, (KCL) while the other law deals with the voltage sources present in a closed circuit, Kirchhoffs Voltage Law, (KVL).

(A) Kirchhoff's Law:

- (1) **Kirchhoff's current Law (KCL):** The algebraic sum of all the currents at any node in a circuit equals zero, $\sum I = 0$.



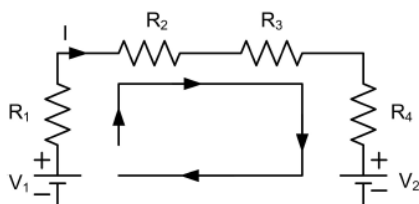
Here, the three currents entering the node, I_1 , I_2 , I_3 are all positive in value and the two currents leaving the node, I_4 and I_5 are negative in value. Then this means we can also rewrite the equation as;

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

The term Node in an electrical circuit generally refers to a connection or junction of two or more current carrying paths or elements such as cables and components. Also for current to flow either in or out of a node a closed circuit path must exist. We can use Kirchhoff's current law when analysing parallel circuits.

- (2) **Kirchhoff's voltage Law (KVL):** The algebraic sum of all the voltages around any closed

path in a circuit equals zero, $\sum U = 0$. That means “in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop” which is also equal to zero. This idea by Kirchhoff is known as the Conservation of Energy.



$$V_1 - IR_1 - IR_2 - IR_3 - IR_4 - V_2 = 0$$

$$V_1 - I(R_1 + R_2 + R_3 + R_4) - V_2 = 0$$

Starting at any point in the loop continue in the same direction noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero. We can use Kirchhoff's voltage law when analysing series circuits.

(B) Superposition Theorem

For every electrical circuit, there are two or additional independent supplies like current, voltage or both the sources. For examining these electrical circuits, **superposition theorem** is widely utilized.

Superposition theorem states that in a linear bilateral network containing more than one source, the current flowing through the branch is the algebraic sum of the current flowing through that branch when sources are considered one at a time and replacing other sources by their respective internal resistances.

To ascertain the contribution of each individual source, all of the other sources first must be "turned off" (set to zero)

- Replacing all other independent voltage sources with a short circuit (thereby eliminating difference of potential. i.e. $V=0$, internal impedance of ideal voltage source is ZERO (short circuit)).
- Replacing all other independent current sources with an open circuit (thereby eliminating current. i.e. $I=0$, internal impedance of ideal current source is infinite (open circuit)).
- This procedure is followed for each source in turn, and then the resultant responses are added to determine the true operation of the circuit. The resultant circuit operation is the superposition of the various voltage and current sources.

Apparatus:

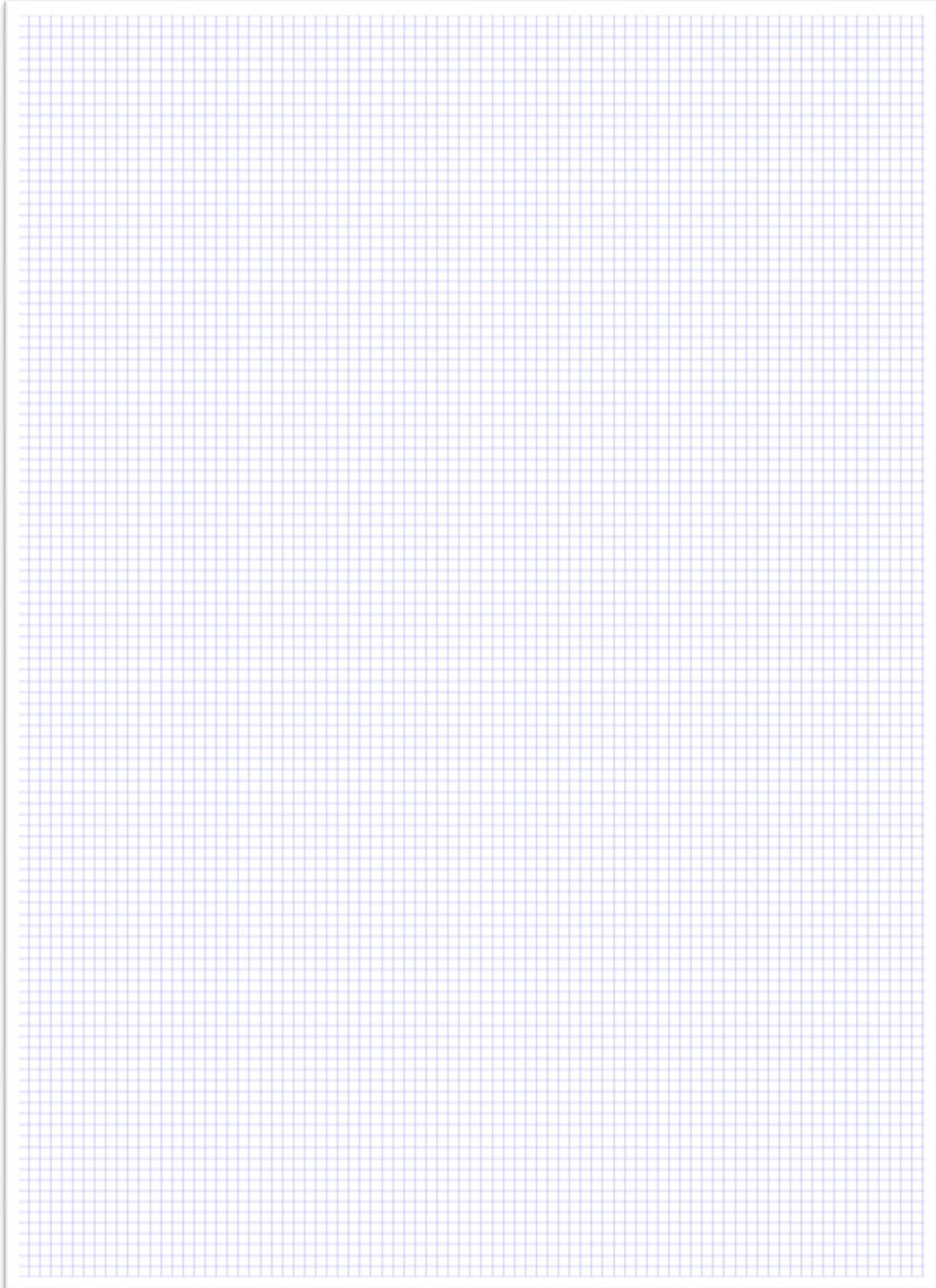
Sr. No.	Apparatus	Specifications
1	Power Supply	
2	Resistors	
3	Multimeters	
4	DC ammeter	

Theoretical Solution: For KCL and KVL

For Superposition theorem:

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Connection Diagram:



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Procedure:**Procedure for KCL:**

1. Give the connections as per the circuit diagram.
2. Set a particular value of voltage sources RPS1 and RPS2
3. Note down the corresponding ammeter reading
4. Repeat the same for different voltages

Procedure for KVL:

1. Give the connections as per the circuit diagram.
2. Set a particular value of voltage sources RPS1 and RPS2.
3. Note all the voltage reading
4. Repeat the same for different voltages

Procedure for Superposition theorem:

1. Give the connections as per the diagram.
2. Set a particular voltage value using RPS1 and RPS2 & note down the ammeter reading
3. Set the same voltage in circuit I using RPS1 alone and short circuit the terminals and note the ammeter reading.
4. Set the same voltage in RPS2 alone as in circuit I and note down the ammeter reading.
5. Verify superposition theorem

Observation and Result Table:**KCL Observation Table****Theoretical values**

Sr.No.	Voltage E1	Voltage E2	I1 in mA	I2 in mA	I3 in mA	I1=I2+I3
1						
2						

Practical values

Sr.No.	Voltage E1	Voltage E2	I1 in mA	I2 in mA	I3 in mA	I1=I2+I3
1						
2						

KVL Observation Table**Theoretical values**

Sr.No.	Voltage E1	Voltage E2	V1	V2	V3	E1=V1+V3	E2=V2+V3
1							
2							

Practical values

Sr.No.	Voltage E1	Voltage E2	V1	V2	V3	E1=V1+V3	E2=V2+V3
1							
2							

Superposition Theorem**Theoretical values**

Sr. No.	Source E1 is acting alone (I')	Source E2 is acting alone (I'')	Source E1 and E2 are acting, (I)
1			
2			

Practical values

Sr. No.	Source E1 is acting alone (I')	Source E2 is acting alone (I'')	Source E1 and E2 are acting, (I)
1			
2			

Conclusion:

LAB ASSIGNMENT

Q1) What is the significance of a negative (-) sign from a calculation when solving circuit problems? /0.5M

- It means you did something wrong on your calculation
- Real resulting current or Voltage is in the opposite direction to one assumed
- You probably used a smaller scaling factor
- None of these

Q2) In Superposition theorem, while considering a source, all other voltage sources are? /0.5M

- Open Circuited
- Short Circuited
- Change its position
- Removed from circuit

Q3) Fill in the blank: The sum of current of all outgoing currents is equal to sum of all _____. /0.5M

Q4) Superposition theorem is only applicable in _____ network /0.5M

- Linear unilateral
- Nonlinear unilateral
- Linear bilateral
- Nonlinear bilateral

=====

Q5) Define linear and nonlinear network with example

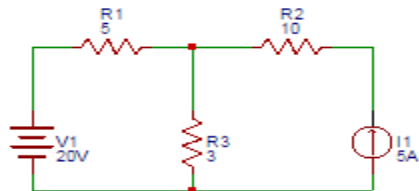
/1M

Q6) Define unilateral and bilateral network with example

/1M

Q7) Find the current through 3 ohm resistance using superposition theorem and same verified using KCL.

/3M



Q8) Down load any open source software for circuit simulation and simulate any one circuit by your own and paste results here.

/3M

Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:

Presentation: /10

Total: /30

Title:Thevenin's Theorem**Aim:**To verify Thevenin's theorem in given circuits**Prerequisite:**

- (1) Ohms law
- (2) Open and short circuit resistance
- (3) KVL, KCL
- (4) Circuit reduction

Learning outcomes: At the end of this experiment student will be able to

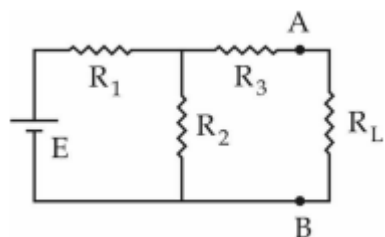
- (1) State Thevenin's theorem.
- (2) Apply and analyze the circuit using Thevenin's theorem.

Theory:**Statement Thevenin's theorem:**

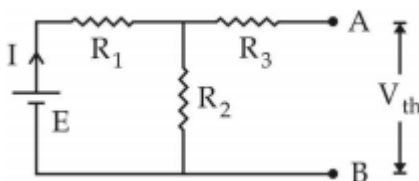
In-circuit theory, Thevenin's theorem for linear electrical networks states that any combination of voltage sources, current sources, and resistors with two terminals is electrically equivalent to a single voltage source E_{th} and a single series resistor R . The Thevenin voltage E_{th} used in Thevenin's theorem is an ideal voltage source equal to the open-circuit voltage at the terminals whereas the Thevenin resistance r used in Thevenin's Theorem is the resistance measured at terminals AB with all voltage sources replaced by short circuits and all current sources replaced by open circuits.

OR

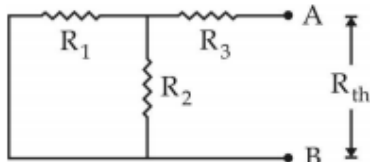
Any linear bilateral, active two-terminal network can be replaced by an equivalent voltage source (V_{TH}). Thevenin's voltage or VOC in series with looking back resistance R_{TH} .

Explanation

Consider a network or a circuit as shown. Let E be the emf of the cell having its internal resistance $r = 0$. $R_L \rightarrow$ load resistance across AB.

To find V_{th} :The load resistance R_L is removed.The current I in the circuit is $= \frac{E}{R_1 + R_2}$ The voltage across AB = Thevenin's voltage V_{th} .

$$V_{th} = I R_2 \Rightarrow \frac{E R_2}{R_1 + R_2}$$

To find Rth :

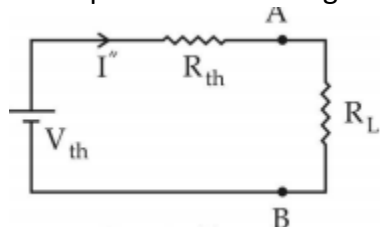
The load resistance R_L is removed. The cell is disconnected and the wires are short as shown.

The effective resistance across AB = Thevenin's resistance R_{th} .

$$R_{th} = R_3 + \frac{R_1 R_2}{R_1 + R_2}$$

[R_1 is parallel to R_2 and this combination in series with R_3]

The equivalent circuit is given by



Current flowing through the load resistance R_L is

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

Apparatus:

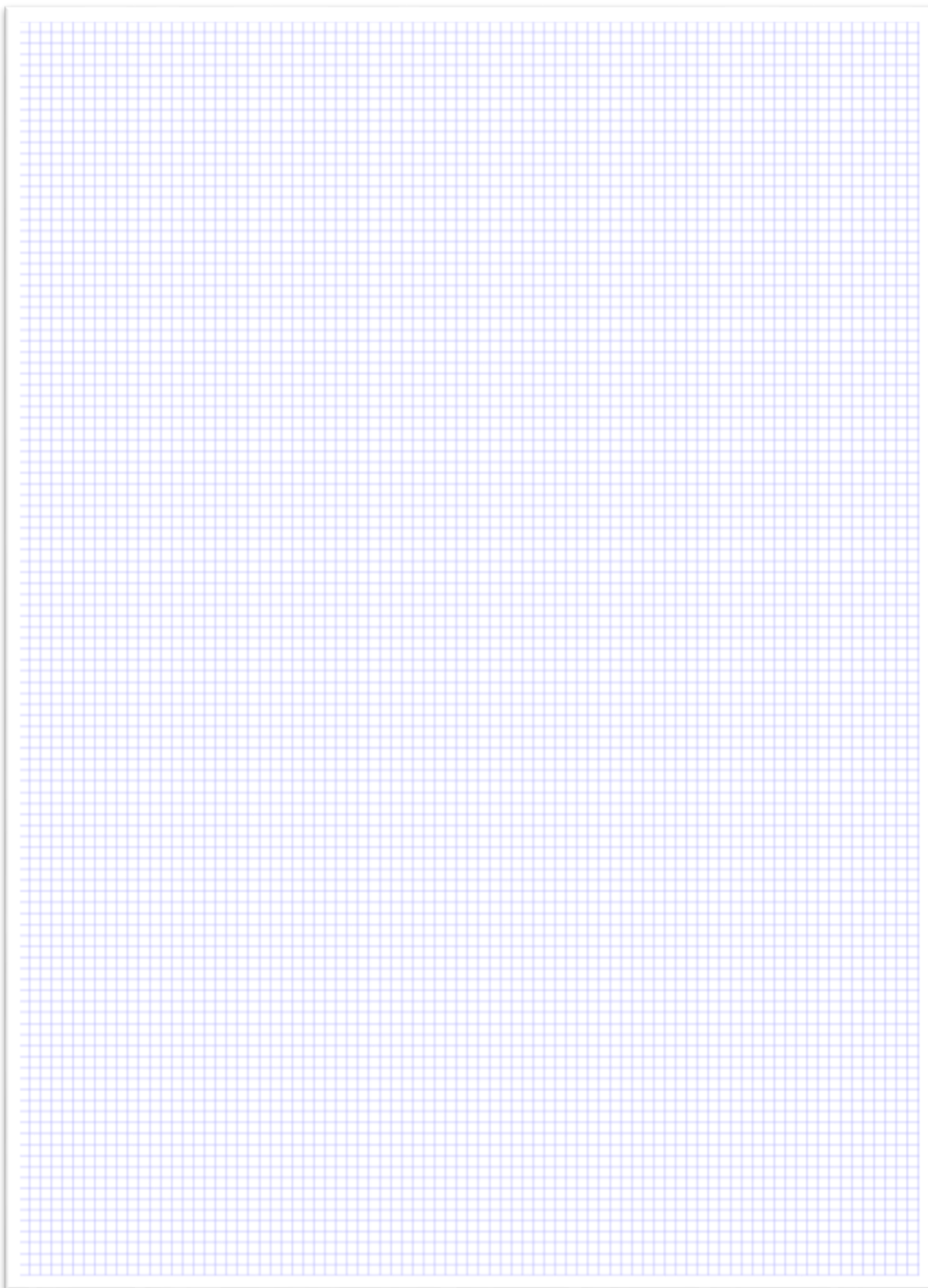
Sr. No.	Equipment	Specifications
1	Power Supply	
2	Resistor	
3	Milliammeter	
4	Multimeter	

Procedure:

Connect the circuit as shown in figure 1 on the breadboard –

1. Measure the voltage across AB (i.e. p.d. across load resistor).
2. Remove load resistor–
3. Measure the open-circuit voltage across AB with the help of multimeter (Placing positive terminal of multimeter at A and negative at B) - Measure the Thevenin's resistance with the help of multimeter (with short-circuiting voltage sources and open circuiting current sources (if any) (Alternatively you can measure the short circuit current through load).
4. Connect the circuit as shown in figure 2; replacing E_{TH} and R_{TH} are open-circuit voltage and Thevenin resistance respectively, as measured in the third step.
5. Connect the load and measure the voltage across the load with the help of a voltmeter.
6. REPEAT above steps for different load resistor.

Circuit Diagram:



Theoretical Solution:

Observation Table

	Sr. No.	E1 (V)	E2 (V)	V_{th} (V)	R_{th} (Ohm)	I_L (mA)
Theoretical	1					
	2					
Practical	1					
	2					

Conclusion:

=====

LAB ASSIGNMENT

Q1) The Thevenin voltage is the _____ /0.5M

- Open circuit voltage • Open circuit and short circuit voltage
- Short circuit voltage • Neither open circuit nor short circuit voltage

Q2) Thevenin's theorem is true for _____ /0.5M

- Linear networks • Non-Linear networks
- Both linear networks and nonlinear networks • Neither linear networks nor non-linear networks

Q3) Fill in the blank: In calculation of Thevenin's equivalent resistance all ideal current sources are replaced by _____ circuit /0.5M

Q4) What is the difference between the ideal voltage source and practical voltage source .Give examples of practical voltage sources ? /1M

Q5) What is the difference between the ideal current source and practical current source. Give examples of practical current sources ? /1M

=====

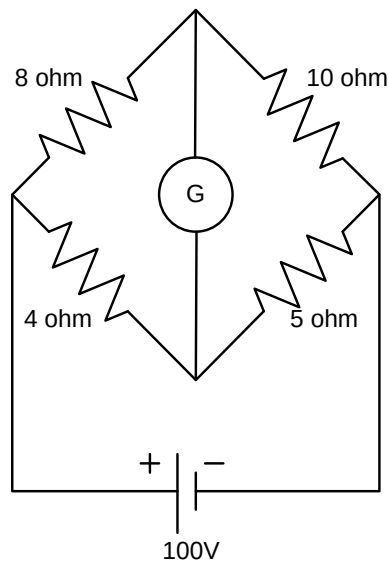
Q6) Give some real-time application of Thevenin's theorem.

/2M

Thevenin's Theorem is especially useful in analyzing power systems and other circuits where one particular resistor in the circuit (called the "load" resistor) is subject to change, and re-calculation of the circuit is necessary with each trial value of load resistance, to determine voltage across it and current through it.

Q7) Calculate the current through galvanometer whose internal resistance is 10ohm

/4M



Experiment No:

Date of Performance: / /

Timely Completion: /10

Date of Assessment: / /

Understanding: /10

Signature of Faculty:

Presentation: /10

Total: /30**Title:** Measurement of Insulation Resistance.**Aim:** To measure the insulation resistance of electrical equipment/cable using Megger**Prerequisite:**

- (1) Nature of conducting, insulating and semiconducting material.
- (2) Concept of resistance
- (3) Different insulating material and dielectric strength.

Learning outcomes: At the end of this experiment students will be able to

- (1) Derive formula of resistance of insulating material.
- (2) Explain the construction of the cable.
- (3) Measure the insulation resistance of a cable with the help of Megger.
- (4) Justify effect of physical parameters on insulation resistance of a cable.

Theory:

Every electric wire in your plant – whether it's in a motor, generator, cable, switch, transformer, etc. – is carefully covered with some form of electrical insulation. The wire itself is usually copper or aluminum, which is known to be a good conductor of the electric current that powers your equipment. The insulation must be just the opposite from a conductor: it should resist current and keep the current in its path along the conductor.

To understand insulation testing you really don't need to go into the mathematics of electricity, but one simple equation – Ohm's law – can be very helpful in appreciating many aspects. Even if you've been exposed to this law before, it may be a good idea to review it in the light of insulation testing. Essentially, "good insulation" means relatively high resistance to current. Used to describe an insulation material, "good" would also mean "the ability to keep a high resistance." So, a suitable way of measuring resistance can tell you how "good" the insulation is. Also, if you take measurements at regular periods, you can check trends toward its deterioration

When your plant electrical system and equipment are new, the electrical insulation should be in top-notch shape. Furthermore, manufacturers of wire, cable, motors, and soon have continually improved their insulations for services in the industry. Nevertheless, even today, insulation is subject to many effects which can cause it to fail – mechanical damage, vibration, excessive heat or cold, dirt, oil, corrosive vapors, moisture from processes, or just the humidity on a muggy day.

(A) Insulation Resistance of a Cable:

Insulation resistance is defined as the resistance offered by an insulating material to the flow of leakage current.

Fig 1 shows the section of a single core cable which is insulated with the help of the layer of insulating material.

In such cables, the leakage current flows radially from the centre towards the surface as shown in the Fig.1(a). Hence the cross-section of the path of such current is not constant but changes with its length. The resistance offered by cable to the path of the leakage current is called an insulation resistance consider an elementary section of the cylindrical cable of radius r

and the thickness dr as shown in the Fig. 1(b). Let us find the resistance of this elementary ring.

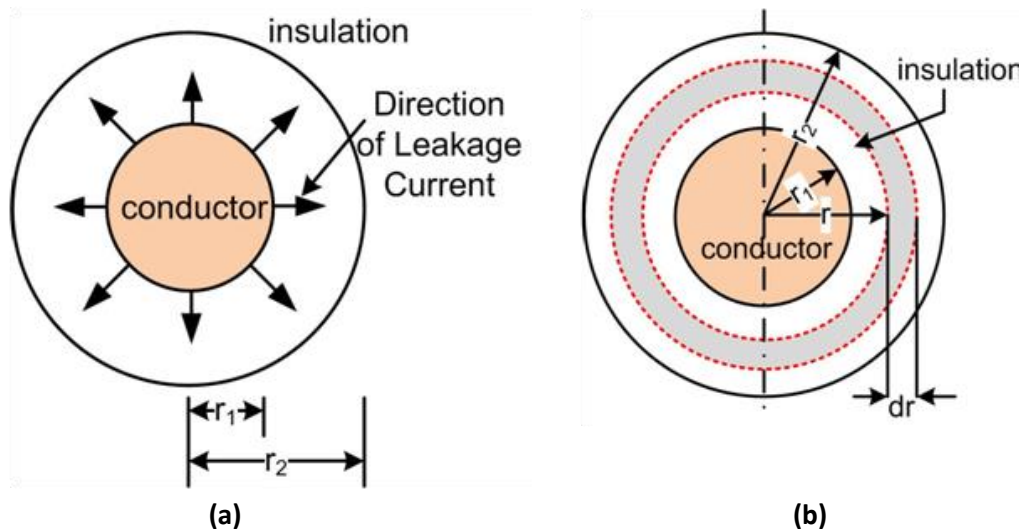


Figure 1: Single Core Cable

Let d = Diameter of core and $r_1 = d/2$ = Radius of core

D = Diameter with sheath and $r_2 = D/2$ = Radius of cable with sheath

ρ_i = Resistivity of insulation material in $\Omega - m$

As the leakage current flows radially outwards, the length along which the current flows in an elementary ring is dr meter. While the cross-sectional area perpendicular to the flow of current depends on the length of l meter of the cable.

Cross-section area = Surface area for length l of cable = $(2\pi r)l \text{ meter}^2$

Length of leakage current path in the cable = $dr \text{ meter}$.

Hence insulation resistance for the elementary ring is dr meter is

$$dR_i = \text{Resistivity} \frac{\text{Length}}{\text{Cross section Area}} = \rho_i \frac{dr}{(2\pi r)l} \Omega$$

The total insulation resistance of the cable can be obtained by integrating the resistance of an elementary ring from inner radius upto the outer radius i.e. r_1 to r_2 meters.

$$R_i = \int_{r_1}^{r_2} dR_i = \int_{r_1}^{r_2} \rho_i \frac{dr}{(2\pi r)l} = \frac{\rho_i}{2\pi l} \int_{r_1}^{r_2} \frac{dr}{r} = \frac{\rho_i}{2\pi l} [\ln r]_{r_1}^{r_2} = \frac{\rho_i}{2\pi l} (\ln r_2 - \ln r_1)$$

Hence insulation resistance is given by

$$R_i = \frac{\rho_i}{2\pi l} \ln \left(\frac{r_2}{r_1} \right) \Omega$$

(B) Factors affecting insulation resistance of a cable:

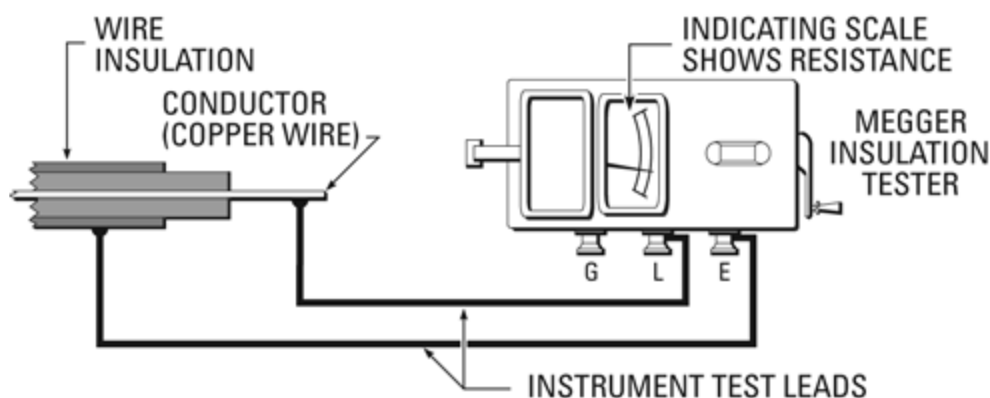
Following factors affect the insulation resistance

- (1) It is inversely proportional to the length of cable
- (2) It is directly proportional to the cross section area that is the thickness of insulating material
- (3) It depends on the type of insulating material
- (4) It decreases with increase in temperature
- (5) It decreases with increase in moisture content.

(C) Measurement of Insulation Resistance:

You have seen that good insulation has high resistance, and poor insulation has relatively low resistance. The actual resistance values can be higher or lower, depending on factors such as temperature or moisture content of the insulation (resistance decreases in temperature or moisture). With a little record-keeping and common sense, however, you can get a good picture of the insulation condition from values that are only relative.

The Megger insulation tester is a small, portable instrument that gives you a direct reading of insulation resistance in ohms or megohms. For good insulation, the resistance usually reads in the megohm range. The Megger insulation tester is essentially a high-range resistance meter (ohmmeter) with a built-in direct-current generator. This meter is of special construction with current and voltage coils, enabling true ohms to be read directly, independent of the actual voltage applied. This method is nondestructive; that is, it does not cause deterioration of the insulation.

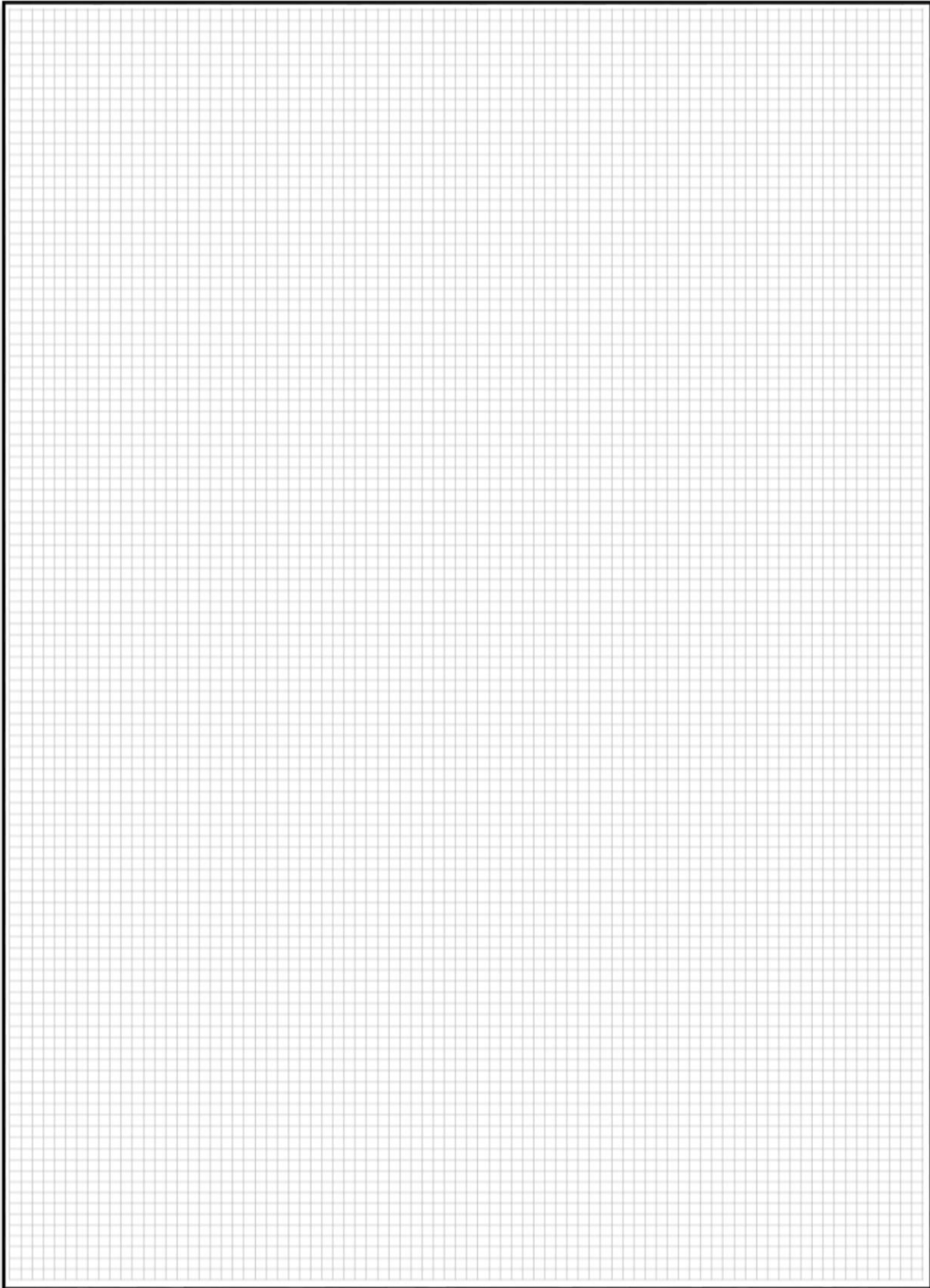
**e-Resources:**

- (1) Youtube Video: <https://youtu.be/eBZdhX9iiSg>
- (2) Youtube Video: <https://youtu.be/v0TsCtGh3nA>
- (3) Youtube Video: <https://youtu.be/MktLS0bmyQ8>

Apparatus:

Apparatus	Specification
Cable	
Megger or Mega-ohm meter	

Connection Diagram:



Procedure:

Safety Precaution: For testing of the insulation, it is necessary to ensure that there is no leakage current through the insulation used i.e. keep the main switch in off state and load in off position where cable under test is connected.

Measurement of Insulation Resistance Between Earth and Conductor:

- 1) Keep all fuse-links, switches, and lamps in position.
- 2) The main supply should be off.
- 3) Connect the one main leads of Megger either to phase or neutral conductor and other to the earth continuity conductor of the system
- 4) Rotate the hand-driven Megger with constant speed to ensure required rated voltage injection and note down the readings of insulation resistance.

Measurement of Insulation Resistance Between Conductors:

- 1) Keep all fuse-links, switches, and lamps in position.
- 2) The main supply should be off.
- 3) Connect the one main leads of Megger either to any conductor of a cable and other to another phase of the cable
- 4) Rotate the hand-driven Megger with constant speed to ensure required rated voltage injection and note down the readings of insulation resistance.

Observation:

Measurement of Insulation Resistance between Earth and Conductor			
Sr. No.	Connection	Value of Insulation Resistance	Remarks
1			
2			
3			
Measurement of Insulation Resistance between Conductors			
Sr. No.	Connection	Value of Insulation Resistance	Remarks
1			
2			
3			

Conclusion:

LAB ASSIGNMENT

Q1) A good insulating material does not have /0.5M

- Low Resistivity • Low conductivity
- High resistivity • Negative temperature coefficient of resistance

Q2) Fill in the blank: Insulation resistance is defined as opposition offered by insulating material to the flow of _____ current. /0.5M

Q3) High resistances are of the order of _____ /0.5M

- 0.1 M Ω • 100 M Ω
- 1 k Ω • 1 G Ω

Q4) Tick mark in the appropriate block /0.5M

Parameter of Cable	The resistance of insulating material of a cable	
	Increase	Decrease
Increase in length		
Increase in thickness of insulation		
Increase in temperature		
Increase in moisture in cable		

Q5) Discuss the effect of temperature on resistance of insulation material with a graph. /1M

Q6) If the insulation resistance of a 100m single core cable with conductor diameter 1cm and thickness of insulation 1cm is 1000M Ω . Calculate the value of insulation resistance if (a) length of cable is doubled and (b) thickness of insulation is halved. /1.5M

Q7) Two cables with 1km of length each is having 10Ω and $100M\Omega$ conductor resistance and insulation resistance respectively. If these two cables are connected in (a) series and (b) parallel, calculate new values of conductor resistance and insulation resistance of the cable. /1.5M

Q8) Enlist the field applications of insulation resistance measurement. Elaborate any advance insulation resistance meter. /1.5M

Q9) What factors contribute to lower insulation resistance /1.5M

Experiment No:			
Date of Performance:	/	/	Timely Completion: /10
Date of Assessment:	/	/	Understanding: /10
Signature of Faculty:			Presentation: /10
			Total: /30

Title: Electricity Bills Reading

Aim: To study of LT and HT electricity bills.

Prerequisite:

- (1) Concept active, reactive and apparent power and energy
- (2) Load calculations
- (3) Power factor
- (4) Types of Tariff

Learning outcomes : Students will be able to

- 1) Evaluate power, energy relations,
- 2) Analyse and calculate energy consumption bill for LT Consumer
- 3) Analyse and Calculate energy consumption bill for HT Consumer

Theory:

LT & HT Electricity Bill Consists of following Charges

(The revised tariffs are to be applied from 1st September 2018 till further Tariff Order.)

1) Wheeling Charges – SOP Standards & Non-Compliance:

The Wheeling Charges shall be levied as per the voltage level on which the consumer is connected irrespective of the Voltage level specified in the SOP(Standard Operating Procedure).

2) Load Factor Incentive:

Load Factor Incentive should not be applicable for the month if the consumer exceeds its Contract Demand in that month. Further, the consumers exceeding contract demand during the off-peak hours (2200 hrs to 0600 hrs) would also not be eligible for load factor Incentive for that month.

3) Power Factor Incentive/Penalty:

Penalty for leading power factor is also introduced. As a first step towards the implementation of kVAh billing system, which is devoid of any separate incentive / penalty for power factor, the Commission has decided to reduce the existing PF Incentive / Penalty by 50%. Accordingly, maximum PF Incentive, which is 7% at Unity power factor, has been reduced to 3.5%. Similarly, Penalty for lower power factor has been rationalized. Whenever the average P.F. is more than 0.95 Lag and upto 1, an incentive shall be given at the rate of percentage in Tariff order at the amount of monthly electricity bill, excluding taxes and duties. And whenever average P.F. is less than 0.9 (Lead or Lag), Penal charges shall be levied at the rate of percentage of amount of monthly electricity bill, excluding taxes and duties.

4) Tariff to Waste Processing / Disposal Facility:

In case of waste processing / disposal facility is present in a premise, exclusively for processing the waste generated within the premise, the tariff applicable to such premise/consumer is applicable to the waste disposal facility as well. However, considering the nature of services provided, as far as the waste disposal facilities operated by local self-government bodies are concerned, they may be categorised under LT III or HT IV (Public Water Works and Sewage Treatment Plants) and the waste disposal facilities operated by private operators is categories under the IT X (8) or HT IX (8) –Public Services Others.

5) Creation of new Tariff Category - Charging Centres/Stations of Electric Vehicle:

In order to promote Electric Vehicles, separate tariff category for Electric Vehicle Charging Stations is created. i.e. LT XI: LT - Electric Vehicle (EV) Charging Stations at LT level and HT X: HT - Electric Vehicle (EV) Charging Stations at HT level. This Tariff category is applicable only for Electric Vehicle Charging Station. It is further clarified that consumers are allowed to charge their own Electric Vehicle at their premises with the Tariff applicable to such premises falling under the respective consumer category. Electricity consumption for other facilities at Charging Station such as restaurant, rest rooms, convenience stores, etc., shall be charged at tariff applicable to Commercial Category.

6) Open Access Charges:

Billing commission has approved Wheeling charge, Cross subsidy surcharge, additional surcharge for the open access consumers. In case of an Open Access consumer procuring power from RE source, the full Cross Subsidy Surcharge (CSS) as determined shall be applicable.

7) Wheeling Charges / losses: The charges for FY2018-19 and FY2019-20 are as follows:

Particulars	Wheeling Loss %	Wheeling Charges (Rs./ KWh)
Financial Year 2018-2019		
33 Kv	6.00 %	0.15
22 Kv	7.50 %	0.38
11 Kv	9.00 %	0.78
LT Level	12.00 %	1.30
Financial Year 2019-2020		
33 Kv	6.00 %	0.15
22 Kv	7.50 %	0.37
11 Kv	9.00 %	0.76
LT Level	12.00 %	1.28

7) Additional Surcharge on wheeling:

The Commission has approved the Additional Surcharge of RS.1.25 per unit to be applicable with effect from 1st September 2018. The Additional Surcharge shall be applicable to third party open access consumer and Captive users of Group captive power plant in addition to open access consumer with prospective effect.

8) Operating Charges:

For Open Access Capacity $\leq$ 5 MW Rs. 14,500/ Month.

For Open Access Capacity $>$ 5 MW Rs. 28,000/ Month.

9) Energy Banking Charges:

Banking Charges shall be in kind @ 2% of the energy banked.

10) Application Processing Fee:

Open Access Capacity	Processing Fee per Application	G.S.T. (18%)	Total
For Load upto 1 MW	Rs. 14,500 /-	Rs. 2,610 /-	Rs. 17,110 /-
For Load more than 1 MW and upto 5 MW	Rs. 22,000 /-	Rs. 3,960 /-	Rs. 25,960 /-
For Load more than 5 MW and upto 20 MW	Rs. 44,000 /-	Rs. 7,920 /-	Rs. 51,920 /-
For Load more than 20 MW	Rs. 75,000 /-	Rs. 13,500 /-	Rs. 88,500 /-

11) Delayed Payment Charges:

In case the electricity bill is not paid within the due date mentioned on the bill, delayed payment charges of 1.25 percent shall be levied on the total amount of the electricity bill (including Taxes and Duties).

12) Rate of Interest on Arrears:

The rate of interest chargeable on the arrears of payment of billed dues shall be as given below:

Sr. No.	Delay in Payment (months)	Interest rate per annum %
1	Payment made after 60 days and before 90 days from the date of billing	12 %
2	Payment made. after 90 days and up to 180 days from the date of billing	15 %
3	Payment made after 180 days from the date of billing	18 %

13) Discount / Incentive for Digital/ Online Payment for LT Category Consumers:

A discount of 0.25% of the monthly bill (excluding taxes and duties), subject to a cap of Rs. 500/- per month per bill, shall be provided to LT category consumers for payment of current electricity bills through various modes of digital payment such as credit cards, debit cards, UPI, BHIM; internet banking, mobile banking, mobile wallets, etc.

LT Electricity Bill

Low Tension (LT) Consumers are having voltage less than 1.1 Kv supply i.e. 230 volts Single Phase or 440 Volts Three Phase supply. Electricity usage charges are applied on KWh. A trade unit means number of units. 01 KWh = 01 Unit. All the charges are applied on number of units.

Following are the various types of LT Consumers

LT I (A): LT – Residential (BPL)

This Below Poverty Line (BPL) tariff category is applicable to Residential consumers who have a Sanctioned Load upto 0.25 kW and who have consumed upto 360 units per annum in the previous financial year.

Consumption Slab (kWh)	Fixed /Demand Charge (Rs per month)	Wheeling Charge(Rs/kWh)	EnergyCharge (Rs/kWh)
BPL Category	20.00	-	1.06

LT I (B): LT – Residential

Applicability:

This tariff category is applicable for electricity used at Low/Medium Voltage for operating various appliances used for purposes such as lighting, heating, cooling, cooking, washing/cleaning, entertainment/leisure, water pumping in the following premises:

- Private residential premises, Government/semi-Government residential quarters;
- Premises used exclusively for worship, such as temples, gurudwaras, churches, mosques, etc.; provided that halls, gardens or any other part of such premises that may be let out for a consideration or used for commercial activities would be charged at the applicable LT-II tariff;
- All Students Hostels affiliated to Educational Institutions;
- All other Students' or Working Men/Women's Hostels;

Consumption Slab	Fixed / Demand Charges	Wheeling Charge	Energy Charges
------------------	------------------------	-----------------	----------------

(kWh)	(Rs. Per month)	(Rs./kWh)	(Rs./kWh)
0-100 units	Single Phase: Rs. 80 per month	1.30	3.00
101-300 units		1.30	6.73
301-500 units	Three Phase : Rs. 300 per month	1.30	9.75
501-1000 units		1.30	10.50
Above 1000 units		1.30	11.50

LT II: LT – Non-Residential or Commercial**LT II (A): 0 - 20 kW**

Applicability:

This tariff category is applicable for electricity used at Low/Medium voltage in non-residential, non-industrial and/or commercial premises for commercial consumption meant for operating various appliances used for purposes such as lighting, heating, cooling, cooking, washing/cleaning, entertainment/ leisure and water pumping in, but not limited to, the following premises:

- Non-Residential, Commercial and Business premises, including Shopping Malls and Showrooms;
- Combined lighting and power supply for facilities relating to Entertainment, including film studios, cinemas and theatres (including multiplexes), Hospitality, Leisure, Meeting/Town Halls, and places of Recreation and Public Entertainment;
- Offices, including Commercial Establishments;
- Marriage Halls, Hotels / Restaurants, Ice-cream parlours, Coffee Shops, Guest Houses, Internet / Cyber Cafes, Telephone Booths not covered under the LT I category, and Fax / Photocopy shops;
- Automobile and all other types of repairs, servicing and maintenance centres (unless specifically covered under another tariff category); Retail Gas Filling Stations, Petrol Pumps and Service Stations, including Garages;
- Tailoring Shops, Computer Training Institutes, Typing Institutes, Photo Laboratories, Beauty Parlours and Saloons;
- Banks and ATM centres, Telephone Exchanges, TV Stations, Microwave Stations, Radio

Consumption Slab (kWh)	Fixed /Demand Charge (Rs per month)	Wheeling Charge (Rs/kWh)	Energy Charge (Rs/kWh)
(i) 0 to 200 Units per month	350.00	1.30	6.00
(ii) Above 200 Units per month (Only Balance consumption)	350.00	1.30	9.20

LT II (B): > 20 kW and ≤ 50 kW and (C) > 50 kW

Applicability:

As per the applicability described in LT II (A) and for the Sanctioned Load in the range applicable in this sub-category, i.e. LT II (B) and LT II (C). Stations, Telecommunications Towers;

Consumption Slab (kWh)	Fixed /Demand Charge (Rs per month)	Wheeling Charge (Rs/kWh)	Energy Charge (Rs/kWh)
-------------------------	-------------------------------------	--------------------------	------------------------

LT II (B): > 20 kW and ≤ 50 kW	350.00	1.30	9.30
LT II (C): > 50 kW		1.30	11.60
ToD Tariffs (in addition to above base Tariffs)			
2200 Hrs – 0600 Hrs			- 1.50
0600 Hrs – 0900 Hrs & 1200 Hrs – 1800 Hrs			0.00
0900 Hrs – 1200 Hrs			0.80
1800 Hrs – 2200 Hrs			1.10

LT XI: LT – Electric Vehicle (EV) Charging Stations

Applicability:

This Tariff category is applicable for Electric Vehicle Charging Station In case the consumer uses the electricity supply for charging his own electric vehicle at his premises, the tariff applicable shall be as per the category of such premises. Electricity consumption for other facilities at Charging Station such as restaurant, rest rooms, convenience stores, etc., shall be charged at tariff applicable to Commercial Category.

Consumption Slab (kWh)	Fixed /Demand Charge (Rs per month)	Wheeling Charge (Rs/kWh)	Energy Charge (Rs/kWh)
All Units	70	1.30	4.70
ToD Tariffs (in addition to above base Tariffs)			
2200 Hrs – 0600 Hrs			- 1.50
0600 Hrs – 0900 Hrs & 1200 Hrs – 1800 Hrs			0.00
0900 Hrs – 1200 Hrs			0.80
1800 Hrs – 2200 Hrs			1.10

HT Electricity Bill

High Tension (HT) Consumers are having voltage more than 1.1 Kv supply. Electricity usage charges are applied on KWH, KVARH & KVAH. A trade unit means number of units of each. 01 KWH = 01 Unit. All the charges are applied on number of units

HIGH TENSION (HT) TARIFF**HT I: HT – Industry****HT I (A): Industry – General**

Applicability:

This tariff category is applicable for electricity for Industrial use at High Voltage for purposes of manufacturing and processing, including electricity used within such premises for general lighting, heating/cooling, etc.

It is also applicable for use of electricity / power supply for Administrative Offices / Canteen, Recreation Hall / Sports Club or facilities / Health Club or facilities/ Gymnasium / Swimming Pool exclusively meant for employees of the industry; lifts, water pumps, fire-fighting pumps and equipment, street and common area lighting; Research and Development units, etc. -

Provided that all such facilities are situated within the same industrial premises and supplied power from the same point of supply.

This tariff category shall be applicable for use of electricity / power supply by an Information Technology (IT) or IT-enabled Services (ITeS) Unit as defined in the applicable IT/ITes Policy of Government of Maharashtra. Where such Unit does not hold the relevant

permanent registration Certificate, the tariff shall be as per the HT II category, and the HT I tariff shall apply to it after receipt of such permanent registration Certificate and till it is valid.

It shall also be applicable for use of electricity / power supply for (but not limited to) the following purposes:

- a. Flour Mills, Dal Mills, Rice Mills, Poha Mills, Masala Mills, Saw Mills;
- b. Ice Factories, Ice-cream manufacturing units, Milk Processing / Chilling Plants (Dairy);
- c. Engineering Workshops, Engineering Goods manufacturing units; Printing Presses; Transformer Repair Workshops; Tyre Remoulding/Rethreading units, and Vulcanizing units;
- d. Mining, Quarrying and Stone Crushing units;
- e. Garment Manufacturing units
- f. LPG/CNG bottling plants, etc.;
- g. Sewage Treatment Plant/ Common Effluent Treatment Plant for industries, and not covered under the HT – PWW category
- h. Start-up power for Generating Plants, i.e., the power required for trial run of a Power Plant during commissioning of the Unit and its Auxiliaries, and for its start-up after planned or forced outage (but not for construction);
- i. Brick Kiln (Bhatti);
- j. Biotechnology Industries covered under the Biotechnology Policy of Government of Maharashtra;
- k. Cold Storages not covered under HT V (B)– Agriculture (Others);
- l. Food (including Seafood) Processing units.
- m. Seed manufacturing.
- n. Dedicated Water Supply Schemes to Power Plants
- o. Auxiliary Power Supply to EHV/Distribution Substations(but not for construction)

1) Wheeling Charge

Supply voltage level	(Rs./kWh)
66 kV and above	-
33 kV	0.15
22 kV	0.38
11 kV	0.78

Plus

2) Demand/Fixed Charge and Energy Charge (for all Supply Voltage Levels)

Consumer Category	Demand Charge (Rs/ kVA/ month)	Energy Charge (Rs/kWh)
HT I: HT – Industry		
HT I (A): Industry - General	350.00	7.10
HT I (B): Industry - Seasonal	350.00	7.40
ToD Tariffs (in addition to above base Tariffs)		
2200 Hrs-0600 Hrs		-1.50
0600 Hrs-0900 Hrs & 1200 Hrs-1800 Hrs		0.00
0900 Hrs-1200 Hrs		0.80
1800 Hrs-2200 Hrs		1.10

HT X: HT – Electric Vehicle (EV) Charging Stations

Applicability:

This Tariff category is applicable for Electric Vehicle Charging Station

In case the consumer uses the electricity supply for charging his own electric vehicle at his premises, the tariff applicable shall be as per the category of such premises.

Electricity consumption for other facilities at Charging Station such as restaurant, rest rooms, convenience stores, etc., shall be charged at tariff applicable to Commercial Category.

1) Wheeling Charges and Energy Charges

Supply voltage level	Wheeling Charge (Rs./kWh)	(Rs./kWh)
66 kV and above	-	-
33 kV	0.15	5.85
22 kV	0.38	5.62
11 kV	0.78	5.22

Plus

2) Demand/Fixed Charge and Energy Charge (for all Supply Voltage Levels)

Consumption slab (kWh)	Demand Charge (Rs/ kVA/ month)	Energy Charge (Rs/kWh)
All units	70	
ToD Tariffs (in addition to above base Tariffs)		
2200 Hrs-0600 Hrs		-1.50
0600 Hrs-0900 Hrs & 1200 Hrs-1800 Hrs		0.00
0900 Hrs-1200 Hrs		0.80
1800 Hrs-2200 Hrs		1.10

3) MISCELLANEOUS AND GENERAL CHARGES**1) Fuel Adjustment Charge (FAC) Component of Z-factor Charge****2) Electricity Duty and Tax on Sale of Electricity****3) Power Factor Incentive**

- Applicable for HT-I :Industry, HT II - Commercial, HT-III: Railways, Metro & Monorail, HT-IV : PWW, HT-V: Agriculture, HT-VI: Group Housing Society, HT VIII -Temporary Supply, HT IX: Public Service, HT X: Electric Vehicle Charging Station, LTII: Non-Residential/Commercial [LT II(B), LT II (C)], LT III: Public Water Works , LTV (A) (ii): Industry – Power looms (above 20 kW) , LT V (B) (ii): Industry – General(above 20 kW), LT X : Public Services [LT X (A) (ii) , LT X (A) (iii) , LT X (B) (ii) andLT X (B) (iii) categories], LT XI: Electric Vehicle Charging Station.
- Whenever the average Power Factor is more than 0.95 lag and upto 1, an incentive shall be given at the rate of the following percentages of the amount of the monthly electricity bill, excluding Taxes and Duties:

Sr. No	Range of Power Factor	Power Factor Level	Incentive
1	0.951 to 0.954	0.95	0 %
2	0.955 to 0.964	0.96	0.5 %
3	0.965 to 0.974	0.97	1.0 %
4	0.975 to 0.984	0.98	1.5 %

5	0.985 to 0.994	0.99	2.5 %
6	0.995 to 1.000	1.00	3.5 %

4) Power Factor Penalty

1. Applicable for HT-I :Industry, HT II - Commercial, HT-III: Railways, Metro & Monorail, HT-IV : PWW, HT-V: Agriculture, HT-VI: Group Housing Society, HT VIII -Temporary Supply, HT IX: Public Service, HT X : Electric Vehicle Charging Station ,LT II: Non-Residential/Commercial [LT II (B), LT II (C)], LT III: Public Water Works, LT V (A) (ii): Industry – Power looms (above 20 kW), LT V (B) (ii): Industry – General(above 20 kW), LT X : Public Services [LT X (A) (ii) , LT X (A) (iii), LT X (B) (ii) and LT X (B) (iii) categories], LT XI: Electric Vehicle Charging Station.
2. Whenever the average PF is less than 0.9 (lag or lead), penal charges shall be levied at the rate of the following percentages of the amount of the monthly electricity bill, excluding Taxes and Duties:

Sr. No	Range of Power Factor	Power Factor Level	Penalty
1	0.895 to 0.900	0.90	0 %
2	0.885 to 0.894	0.89	1.0 %
3	0.875 to 0.884	0.88	1.5 %
4	0.865 to 0.874	0.87	2.0 %
5	0.855 to 0.864	0.86	2.5 %
6	0.845 to 0.854	0.85	3.0 %
7	0.835 to 0.844	0.84	3.5 %
8	0.825 to 0.834	0.83	4.0 %
9	0.815 to 0.824	0.82	4.5 %
10	0.805 to 0.814	0.81	5.0 %

5) Prompt Payment Discount

A prompt payment discount of one percent of the monthly bill (excluding Taxes and Duties) shall be provided to consumers for payment of electricity bills within 7 days from the date of their issue.

6) Discount for digital payment

A discount of 0.25% of the monthly bill (excluding taxes and duties), subject to a cap of Rs. 500/-, shall be provided to LT category consumers for payment of electricity bills through various modes of digital payment such as credit cards, debit cards, UPI, BHIM, internet banking, mobile banking, mobile wallets etc.

7) Delayed Payment Charges

In case the electricity bill is not paid within the due date mentioned on the bill, delayed payment charges of 1.25 percent shall be levied on the total amount of the electricity bill (including Taxes and Duties).

8) Rate of Interest on Arrears

The rate of interest chargeable on the arrears of payment of billed dues shall be as given below:

Sr. No.	Delay in Payment (months)	Interest Rate per annum (%)
1	Payment made after 60 days and before 90 days from the date of billing	12 %
2	Payment made after 90 days and up to 180 days from the date of billing	15 %
3	Payment made after 180 days from the date	18 %

	of billing	
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9) Load Factor Incentive

Consumers having Load Factor above 75% and upto 85% will be entitled to an incentive in the form of a rebate of 0.75% on the Energy Charges for every percentage point increase in Load Factor from 75% to 85%. Consumers having a Load Factor above 85 % will be entitled to a rebate of 1% on the Energy Charges for every percentage point increase in Load Factor from 85%. The total rebate will be subject to a ceiling of 15% of the Energy Charges applicable to the consumer.

10) Penalty for exceeding Contract Demand

In case a consumer (availing Demand-based Tariff) exceeds his Contract Demand, he will be billed at the applicable Demand Charge rate for the Demand actually recorded, and also be charged an additional amount at the rate of 150% of the applicable Demand Charge (only for the Demand in excess of the Contract Demand).

11) Additional Demand Charges for Consumers having Captive Power Plant

For consumers having a Captive Power Plant, additional Demand Charges at the rate of Rs. 20/kVA/month shall be payable only on the extent of the Stand-by demand component and not on the entire Contract Demand. The additional Demand Charges will be levied on the Standby component only if the consumer's demand exceeds his Contract Demand.

12) Consumers' Security Deposit

Subject to the provisions of Section 47(5) of the Electricity Act, 2003, the Distribution Licensee shall require any person to whom supply of electricity has been sanctioned to deposit an amount as security in accordance with the provisions of Section 47(1) (a).

The amount of the Security Deposit shall be equal to the average of three months' of billing or the billing cycle period, whichever is lesser. For determining the average billing, the average of the billing to the consumer for the last twelve months or, where supply has been provided for a shorter period, the average of the billing of such shorter period, shall be considered

Definitions**Maximum Demand**

Maximum Demand in kilo-Watts or kilo-Volt Amperes, in relation to any period shall, unless otherwise provided in any general or specific Order of the Commission, mean twice the highest number of kilo-watt-hours or kilo-Volt Ampere hours supplied and taken during any consecutive thirty minute blocks in that period.

Contract Demand

Contract Demand means the demand in kilo-Watt (kW) or kilo-Volt Amperes (kVA), mutually agreed between the Distribution Licensee and the consumer as entered into in the agreement or agreed through other written communication. (For conversion of kW into kVA, the Power Factor of 0.80 shall be applied.)

Sanctioned Load

Sanctioned Load means the load in kW mutually agreed between the Distribution Licensee and the consumer.

In case the meter is installed on the LV/MV side, the methodology to be followed for billing purpose is as follows

- 2% to be added to MV demand reading, to determine the kW or kVA billing demand,
- 'X' units to the MVA reading to determine the total energy compensation to compensate the transformation losses, where is calculated as follows
- $'X' = (730 * \text{kVA rating of transformer}) / 500 \text{ Units/month}$, to compensate for the iron losses, plus one percent of units registered on the LT side for copper losses.

Conclusion:

LAB ASSIGNMENT

Q1) The highest power factor is _____. Keeping this factor you will get _____. /0.5M

- 1, penalty
- 0, penalty
- 1, incentive
- 0, incentive

Q2) One unit of energy consumption= /0.5M

- 1kW
- 1kWh
- 1Wh
- 1W

Q3) In residential building, fixed charges are _____. /0.5M

- Based on kVA
- Constant value
- Based on kWh
- Based on kW

Q3) ToD tariff is _____. /0.5M

- Time of Day
- Taste of Day
- Time of Dollar
- Taste of Dollar

Q5) Enlist different types of tariff. /1M

Q6) Why low power factor of any industry causes penalty? /1M

Q7)

/1M

In a house, total load consists of 5 lamps of 40 W each, 2 fans of 75 W each, 1 refrigerator of 800 W, 1 washing machine of 950 W and 1 air conditioner of 1500 W. If the supply is 230 V, then for an average loading of 50% throughout the day, energy consumed in 24 hours (in kWhr)-

Q8)

/1M

In a cyber cafe, total load consists of 6 lamps of 20 W, 4 fans of 75 W, 10 computers of 200 W, 2 air conditioner of 1500 W and 2 printers of 50 W. If the supply is 230 V and basic monthly meter charge is 100/- then for an average loading of 50% throughout a day, what will be the electric bill for 1 month? Assume cost per unit for 1st 500 units be 2/- and after that 4/-.

Q9) Calculate your monthly bill for current month and compare with actual bill. /2M

Q10) Who frames Electricity tariff in state of Maharashtra /1M

Q11) What are benefits of TOD tariff to Customer and Electricity supply company /1M