LABORATORY MANUAL

FOR

BASIC ELECTRICAL ENGINEERING

2nd Edition

By
Prof. N. K. Jain

DELHI TECHNOLOGICAL UNIVERSITY

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BASICS OF EXPERIMENTATION

PURPOSE

Following are the purposes of performing experiments in laboratories.

1. Getting familiar with basic components, measuring instruments & equipment.
2. Observe & understand basic phenomenon.
3. Verify theorems & laws.
4. Get training in technical report writing.
5. Study important characteristics of various apparatus.
6. Get the knowledge of limitations of accuracies of measuring instruments.

GENERAL INSTRUCTIONS

Following general instructions should be followed while working in a laboratory.

1. Never work **ALONE** in the laboratory.
2. Don't touch any terminal or switch without ensuring that it is dead.
3. Keep away from all moving parts.
4. **Always** wear shoes with rubber sole.
5. **Never** wear loose clothes while working.
6. Use **FUSE WIRE/MCB** of proper rating only.
7. Make sure that electrical connections are **right & tight**.
8. Circuit should be **SWITCHED-OFF** before changing any connection.
9. Use sufficiently long wires, rather joining two or three small ones. In this case you have open joints which are **DANGEROUS**.
10. Familiarize yourself with the **shock chart instructions.**

GENERAL PRECAUTIONS

Following general precautions must be observed while doing any experiment in the laboratory.

1. Note down complete specifications of machines & equipment to be used. Ranges of all instruments to be used in the experiment are to be decided in accordance with the specifications noted.
2. Suitable types of wires should be used for different parts of circuits e.g.: flexible wires for connecting voltmeter & pressure coil (current is negligible) of wattmeter.

3. Never apply full voltage to a motor at the time of starting. Use starter or a variac. Apply a low voltage while by switching-on & increase voltage gradually.
4. Gradually apply & switch-off an Electrical Load.
5. Keep all meters/instruments used for experiment in their proper position.
6. Any live terminal shouldn't be touched while supply is on.
7. Supply should be switched-on only *after* ensuring the correctness of connections.

TREATMENT OF ELECTRIC SHOCK VICTIM

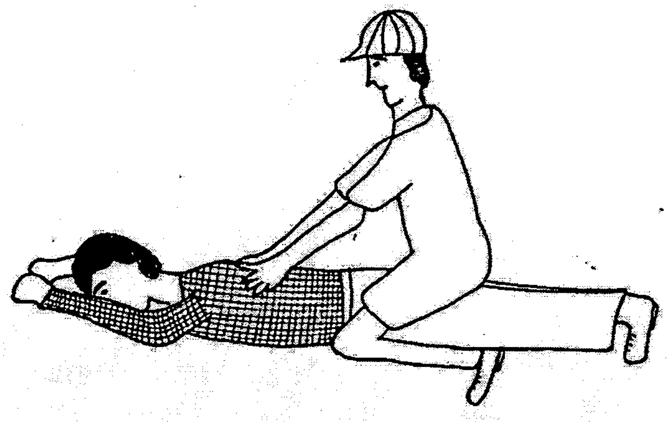
1. Immediately switch-off the power supply.
2. If switch is away or it is difficult to identify switch, pull out the plug top.
3. Pull the victim away using dry wooden stick, dry rope or dry cloth.
4. Make sure that electrical connections are **right & tight**.
5. Circuit should be **SWITCHED-OFF** before changing any connection.
6. Use sufficiently long wires, rather joining two or three small ones. In this case you have open joints which are **DANGEROUS**.
7. Familiarize yourself with the **shock chart instructions.**
8. You can also pull away the victim by hand **provided** you are well insulated from the ground (Standing on insulator or wearing rubber soled shoes)
9. Cut the conductor using some device/tool with insulated handle.
10. Once the Victim is disconnected from supply, he should be treated for recovery as soon as possible. Any one of the Three Methods of **Artificial Respiration** can be used.

Mouth to Mouth Artificial Respiration

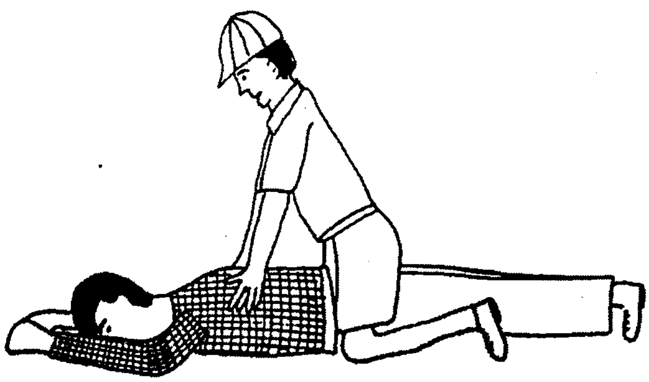
Following steps should be followed for this process

1. Lay the victim on the back with his head slightly down, so that his chin points upwards.
2. To allow proper breathing clear victim's neck from clothing etc.
3. Take a deep breath and blow it into the victim's mouth until his chest rises.
4. Keep victim's noses pinching with your thumb and fore finger. Remove your mouth to allow victim to exhale.
5. Repeat this process as fast as you can.

Schafer's Method for Artificial Respiration



(a)



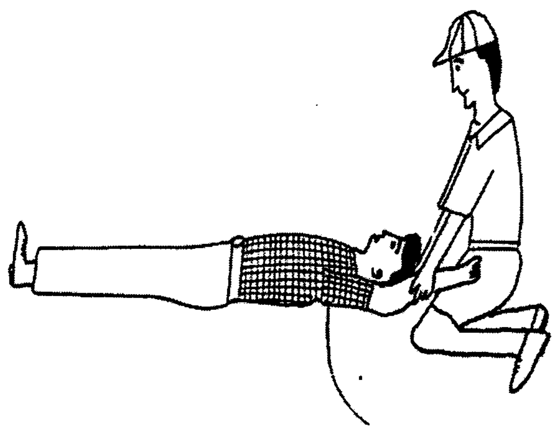
(b)

Steps to be followed for this process are:

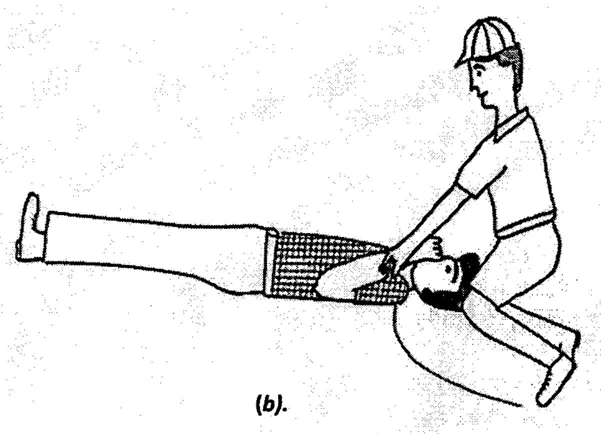
1. Lay the victim on the stomach with his face on one side.
2. To allow proper breathing clear victim's neck from clothing etc.
3. Kneel over the victim (refer fig.a)
4. Place your both hands flat on his back in such a manner that both of your thumbs nearly touch each other and fingers spread.
5. Lean forward over the victim gradually keeping your elbow straight.
6. While doing so put your weight on victim for a moment (refer fig.b)
7. Slowly release the pressure & come to the original position.
8. Repeat process 15 times per minute.
9. Method not to be used if victim has received burns on stomach.

Silvesters's Method for Artificial Respiration

Steps to be followed for this process are:



(a).



(b).

1. Lay victim on his back as shown in figure a.
2. To allow proper breathing clear victim's neck from clothing etc.
3. Place a pillow below his shoulder so that his head falls backwards.
4. Using handkerchief draw out the tongue of victim.
5. Next, take the position as shown in fig. a.
6. Stretch the arms of the victims by holding them below the elbows.
7. Keep arms in position for 2-3 seconds.
8. Then bring the arms on each side of chest, so as to compress the chest (fig. b.)
9. Keep position for 2-3 seconds.
10. Repeat the process until the victim starts breathing normal.
11. Method useful when victim cannot conveniently lie on his stomach.

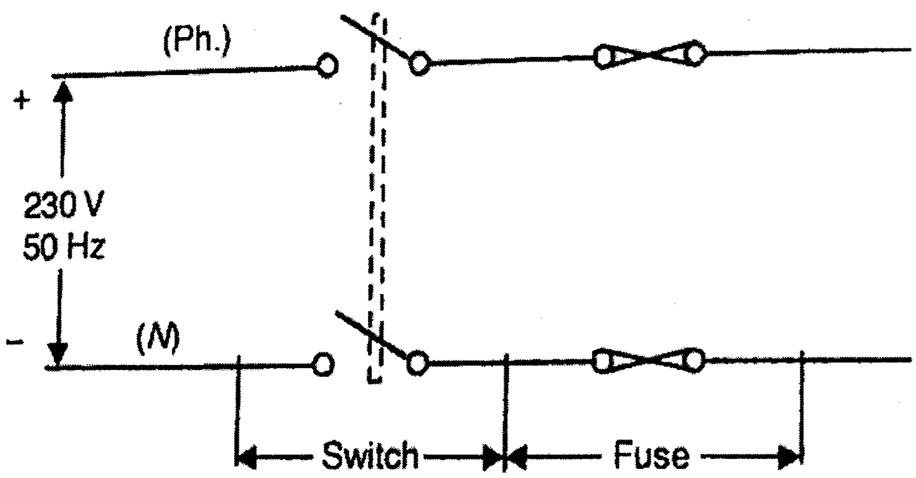
SUPPLY SYSTEMS

Available Supply Systems

(a) A.C. Supply systems.

There are two types mainly:

(i) **<u>Single Phase – 230 volts</u>:** In this system we have two wires, one is known as Phase/line & the other are known as neutral.



(ii) **<u>Three Phase – 430 Volt</u> (line to line)**

1. This system may have three wires, one for each phase/line.
2. This system may also have four wires, three for phase/line & one for neutral.

(b) D.C. Supply Systems

There are of two types namely,

(i) <u>From Battery – 6V or 12V</u> :

1. We may use rectifiers for 6V or 12V D.C. supply for lower current requirements if regular 6V or 12V supply is not available in laboratory.
2. This system has two wires, one being +ve &other -ve.

(ii) **<u>From D.C. Generator (or A.C. & Rectifier)</u>**

1. It is 230 volts d.c.
2. It has two wires one being +ve & other being –ve.

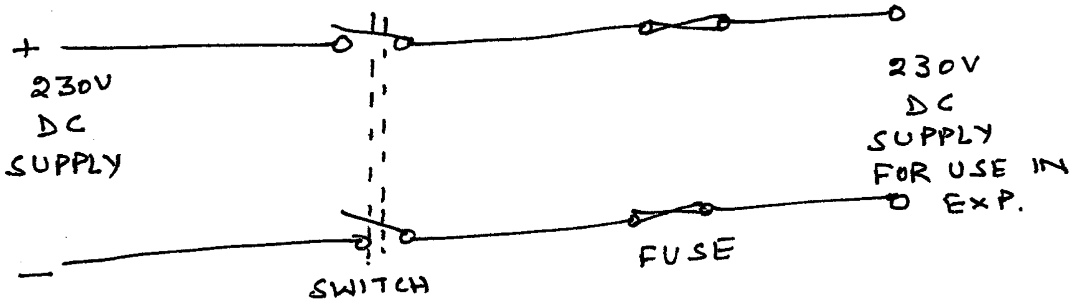


Fig. Supply from a D.C. Generator

Systems to Obtain Variable Voltage Supply from the Available Supply System.

(a) D.C. Circuit: It consists of a tubular resistance having three terminals. The two end terminals A and B are fixed and represent the two ends of a resistance. The third terminal C is a moving contact which slides over AB. The fixed D.C. voltage is applied across AB and a variable D.C. voltage across CB where C is positive and B is negative is obtained. When the sliding contact C is at B and A, the D.C. voltage is zero and equal to supply voltage respectively.

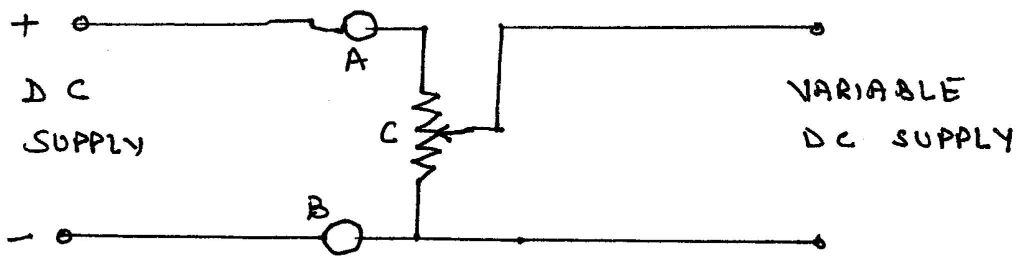


Fig. Obtaining a variable supply from a D. C. source

(b) A.C. Circuit: Here we can get A.C. voltage by replacing a rheostat by auto-transformer, also known as Variac/Dimmerstat. It is a coil wound on a magnetic core with its two ends A and B brought out and sliding contact C. It is capable of providing variable output voltage ranging from 0 to 1.15 of the full input voltage.

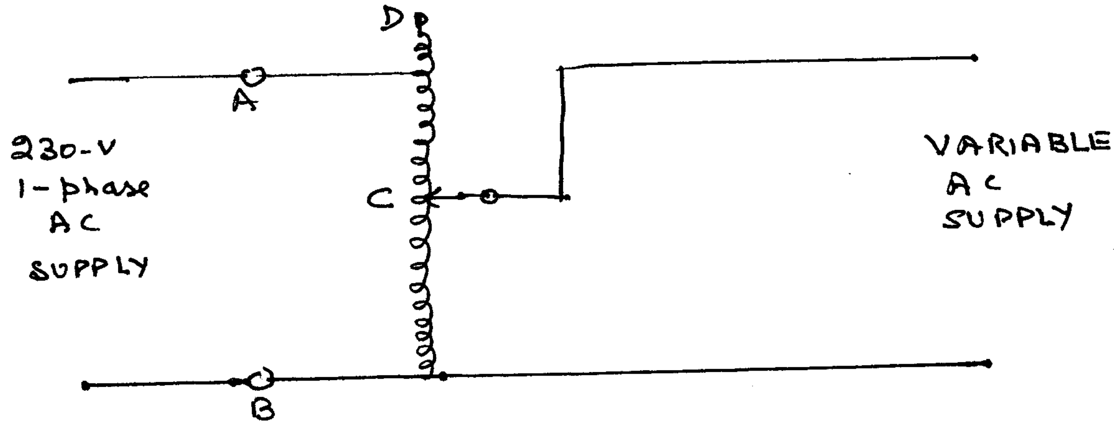


Fig. Obtaining a variable supply from a A. C. source

(c) Three Phase Circuit: If three single phase Variacs are connected in Star-form, it is called as three phase Variac. When the tapping points are all near the neutral the voltage is small whereas if they are near the line terminals the output voltage is large. Any one limb can be used as a single phase Variac as well.

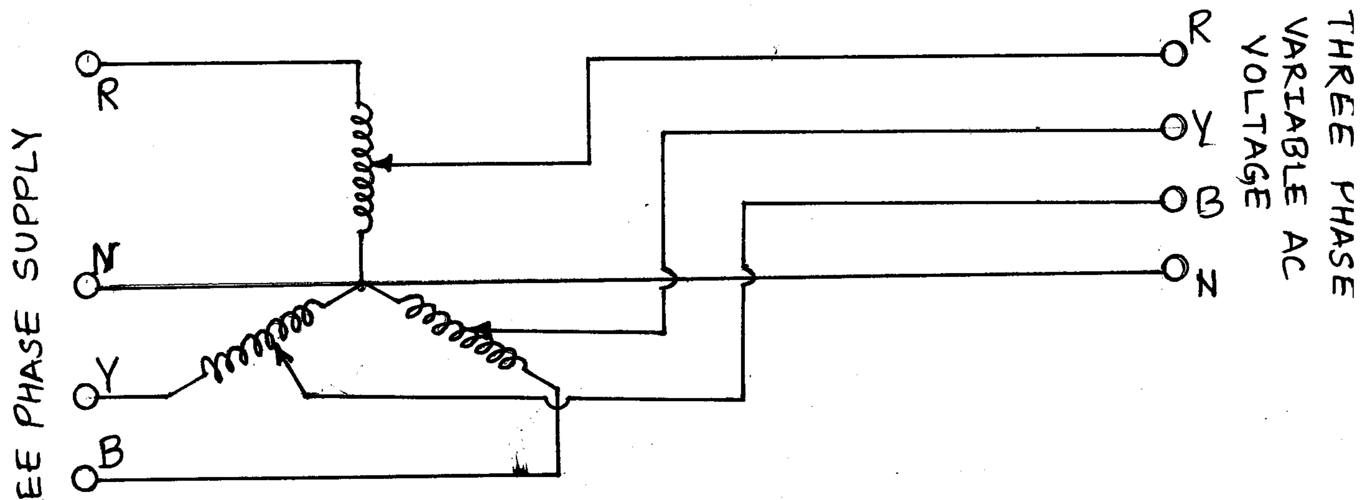


Fig. Obtaining a variable supply from a three phase A. C. source

RHEOSTAT

The salient features of a rheostat are:

(a) Made up of high resistivity materials like nickel-chromium-iron alloy closely wound over a circular tube.
(b) Available in single and double tube.
(c) Inter turn insulation is provided to avoid short circuiting of the turns.
(d) These are employed at places where resistance of a circuit is to be varied without breaking the circuit.
(e) Normally it is 1000 Ω, 1.2 A and 100 Ω, 5 A.

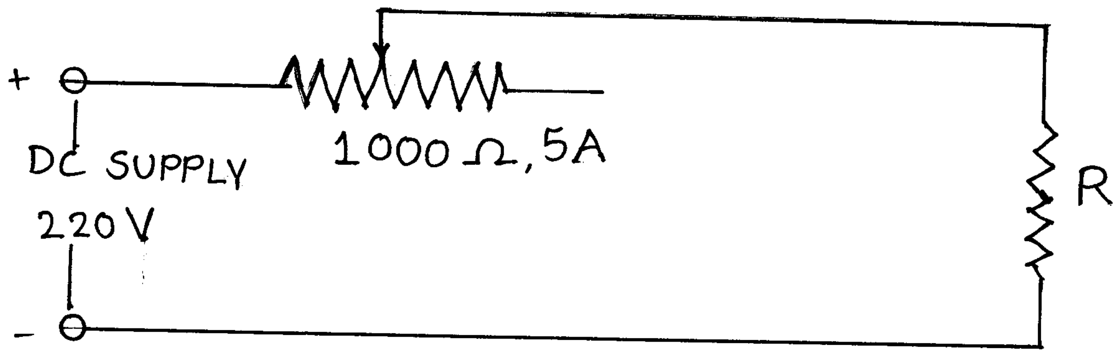


Fig. Using rheostat as a variable resistance

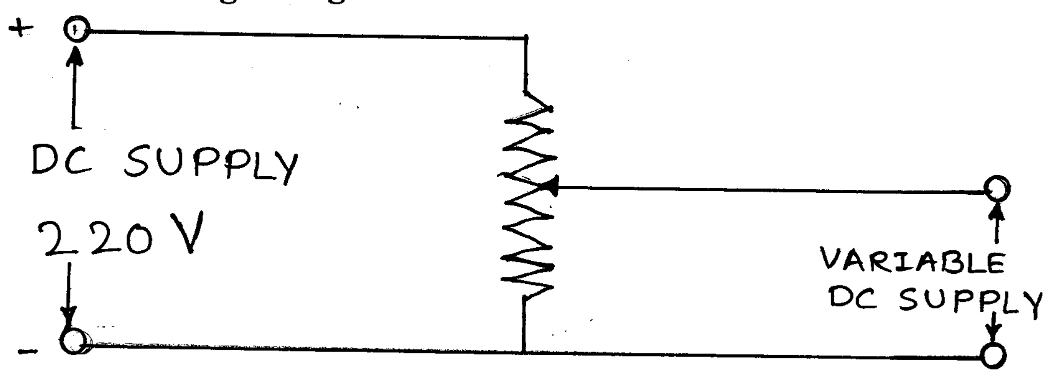


Fig. Using rheostat as a potential divider

PLOTTING A GRAPH

Some important points to be kept in mind while drawing the graphs are:

(a) Graphs are drawn to provide a visual of relationship between two quantities. Some important points to be kept in mind are:
(b) Parameter which is independent is taken on x-axis.
(c) Parameter which is dependent is taken on y-axis.
(d) Scales should be selected in such a way that graph appears to be a square graph.
(e) Curve drawn should be smooth while joining the points.
(f) The points plotted should be marked by small circles, triangles or squares.

REPORT WRITING

1. It is extremely important to write concisely and completely a report on the experiments conducted in the laboratory.
2. These records would prove to be very helpful to students in conceptualizing the knowledge.
3. If the experimental results don't agree with the theoretical results, the student has an opportunity to discuss the reason for this difference.

FORMAT SUGGESTED FOR REPORT WRITING:

1. **OBJECT OF THE EXPERIMENT:** This clearly states the list of test to be performed. Whether the results are desired in graph form or numerical value should also be mentioned.
2. **LIST OF APPARATUS:** This should be complete in all respect. The main apparatus, machine or equipment along with the complete specifications is to be written.
3. **CIRCUIT DIAGRAM:** It forms an essential and integral part of the report. It should include the range and type of instruments used. The type of supply, the voltage and frequency of supply should be marked on it. Use circle master for drawing circles. Choose a proper size of circle and be consistent with it through-out the lab file.

4. **THEORY:** This should include brief theoretical background such as statements of laws, definitions, mathematical expressions and the phasor diagrams regarding the experiment.
5. **PROCEDURE:** It's like an algorithm and should be written step wise put in proper sequence.
6. **OBSERVATIONS:** It should be recorded in tabular form.
7. **CALCULATIONS:** Present the result of the calculations in tabular form and details of one sample calculation can be shown.
8. **GRAPHS:** The graph paper used for making any graph should be cut to the size of the journal page.
9. **PRECAUTIONS:** The steps to be taken to avoid errors in results are actually termed as precautions. Important precautions should be mentioned in the report.
10. **SOURCES OF ERROR:** Here, in this section, the probable sources of error may be environmental, instrumental or personal should be reported.
11. **DISCUSSION:** This section contains, results, conclusions, comparison of the results and anything important about the aim of the experiment and the apparatus used can be mentioned here.

EXPERIMENT No. 1.

OBJECT: To Verify Maximum Power Transfer Theorem

APPARATUS: Variac for a.c. supply, 230/0-270V, 5A; two rheostats 100 Ω, 5A; two voltmeter 0-300 V; M.I. ammeter one 0-10 A.

THEORY:

For D.C. network the **maximum power transfer theorem** is stated as follows.

In a D.C. network the power transferred from the source to resistive load is maximum if the load resistance equals the Thevenin's equivalent resistance of the network as seen from the load terminals.

For a.c. network the **maximum power transfer theorem** is stated as follows.

The power transferred from source to load is the maximum if load impedance is complex conjugate of the Thevenin equivalent impedance of the network as seen from load terminals.

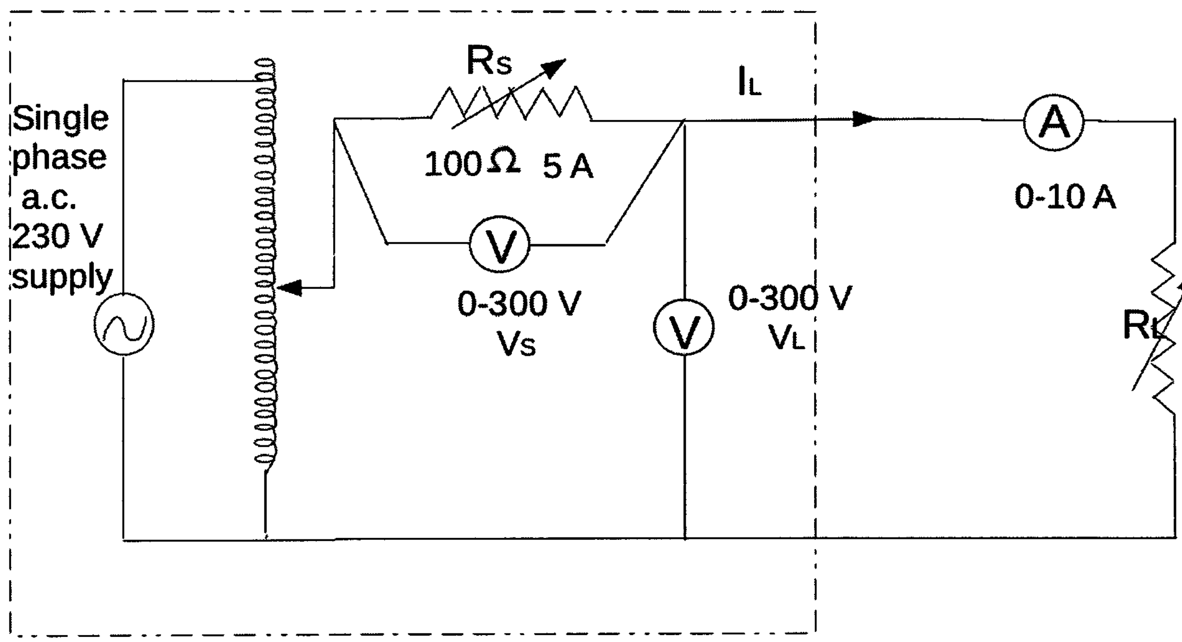


Fig. Circuit for verification of maximum power transfer theorem.

PROCEDURE

1. Connect the circuit as shown in the figure.
2. Keep the variable point of rheostat R_L at maximum position.
3. Adjust the variable point of rheostat R_S at some suitable position. By suitable position it is meant that the reading in the ammeter should neither be near maximum nor near zero.
4. Vary R_L and note the voltmeter and ammeter readings till R_L reaches a low value.
5. Repeat the steps 2, 3 and 4 with a different position of rheostat R_s.

OBSERVATIONS

Record the observations in the format given below.

S.No.	Observations			Calculations		
	V_L	V_S	I_L	$R_S=V_S/I_L$	$R_L=V_L/I_L$	$P=V_L.I_L$
1.						
2.						
.						
.						
.						
10						

CALCULATIONS

The values of R_S and R_L can be calculated by using the following equations.

$$R_S = V_S / I_L$$

$$R_L = V_L / I_L$$

The power consumed by the load i.e., power delivered by the network shown by dotted lines to the load is given by

$$P= V_L.I_L$$

RESULTS

From the last column of the Table the value of R_L for which power, P is maximum should be chosen and compared to the value of R_S .These should come out to be same. Then the maximum power transfer theorem stands verified.

PRECAUTIONS

Following precautions must be observed while performing this experiment:

1. All connections should be tight.
2. The connections of the rheostat should be made carefully and correctly.
3. The positions of the variable terminals of the rheostats should be selected so that the ammeter reading should not exceed the rheostat current rating.
4. The value of R_S shouldn't change for a fixed position of variable terminal of the rheostat representing R_S.

TUTORIAL QUESTIONS

Pre-experiment Questions:

Q.1. In this experiment if the value of R_S= 5Ω, will the maximum power be transferred exactly at R_L= 5 Ω or some other value?

The maximum power transfer will take place at a value of R_L which is slightly higher than the value of R_S because of the source resistance. This means if the value of source resistance is 1 Ω, then the maximum power transfer will take place at R_L= 6 Ω

Q.2. An a.c. circuit has Thevenin's equivalent impedance of (20+j10) ohm at certain frequency. At what value of load impedance will the power transfer to the load be maximum?

In a.c. circuits the condition of maximum power transfer is that the load impedance should be complex conjugate of the Thevenin's impedance. Therefore, for situation given in this question the load impedance should be (20- j10) ohm for power transfer to the load to be maximum.

Q.3. Is it always possible to operate at maximum power transfer condition?

No, it is not always possible to operate at maximum power transfer conditions. In the circuits where the Thevenin's impedance is very low, the load impedance has also to be very low for achieving the condition of maximum power transfer. If the load impedance is also made low, *the current flow may be undesirably high.* It is because of this reason that it is not always possible to operate under the conditions of maximum power transfer.

Post-experiment Questions:

Q1. Is it always advisable to operate at maximum power transfer conditions?

No, it is not always advisable to operate at maximum power transfer conditions. Particularly in case of power equipment, where efficiency consideration is very important, it is not preferred to operate at maximum power transfer conditions. It is because; the efficiency under maximum power transfer condition is 50%.

Q2. Under what conditions it is advisable to operate at maximum power transfer conditions?

Operation at maximum power transfer conditions is desirable when the *output power requirement is most important e.g.,* public address equipment and communication circuits.

Q3. What characteristics an electric circuit exhibits under maximum power transfer conditions?

The load voltage under the condition of maximum power transfer is one-half of the no load voltage. This means a very poor voltage regulation. The efficiency under maximum power transfer conditions is 50%.

EXPERIMENT No. 2.

OBJECT: To Verify Thevenin's Theorem

APPARATUS: One MI (0-250 V) voltmeter, one MI (0-2.5 A) ammeter, rheostats (100 W, 5 A) 4 nos.

THEORY: Thevenin's Theorem:

Any two terminals XY of a network composed of active, linear and passive elements may be replaced by a simple equivalent circuit consisting of an equivalent voltage source V_{oc} in series with an equivalent resistance R_{th}. The voltage source V_{oc} is equal to the potential difference between the two terminals XY caused by the active network when no external resistance is connected to the terminals. The R_{th} is calculated by looking back into the network at terminals XY with all the sources within the network made inactive. When a load of resistance R_L is connected across XY, the actual current I_L through circuit is given by

$$I_L = V_{oc} / (R_L + R_{th})$$

PROCEDURE

The experiment is performed in the following steps,

1. Connect the circuit as shown in fig. 1below.
2. Switch on the power supply, close the switch S and note down the reading of ammeter and voltmeter. This gives load current I_L.
3. Next open the switch S and note down the reading of the voltmeter. This gives open circuit voltage V_{OC}.
4. Next connect the circuit as shown in fig.2 below and note the readings of voltmeter and ammeter. (*This will help to calculate R_{th}.*).

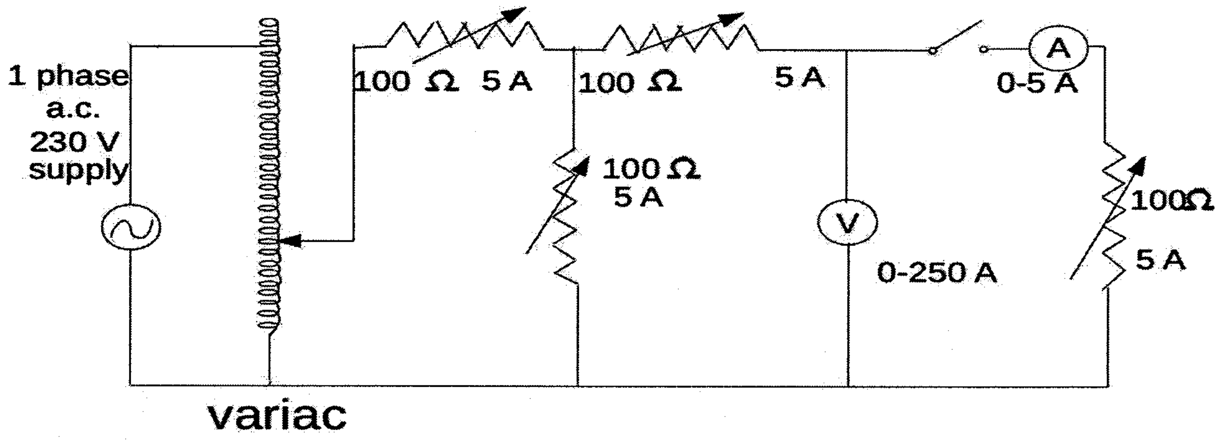


Fig. 1.

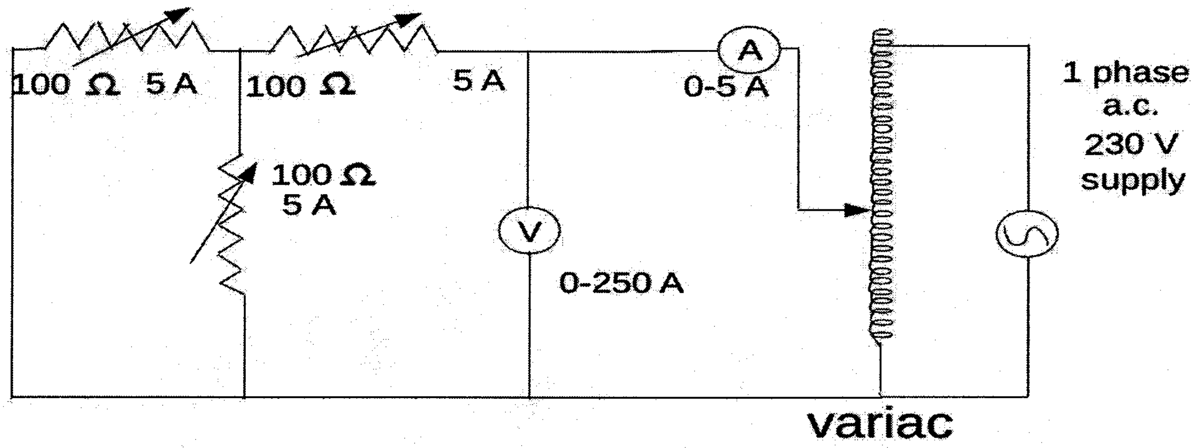


Fig. 2.

OBSERVATIONS

The observations made in the experiment are recorded as under

V_{OC} = ;

I_L = ;

R_{th}=V/I in step 4 of the procedure.

CALCULATIONS

Now, the value of load current can be calculated as:

I_{LC} = calculated value of I_L

$$I_{LC} = V_{OC} / (R_L + R_{th})$$

The value of R_L can be calculated using the voltmeter and ammeter readings taken in step 2 of the procedure.

RESULTS

The actual value of current I_L and the calculated value of load current I_{LC} using Thevenin's theorem should be equal. Then the Thevenin's theorem stands verified.

PRECAUTIONS

1. All connections should be tight.
2. The rheostats should be set at suitable positions so that the current in the ammeter is less than the rheostat current ratings. This value of current should also be readable *i.e.*, it should not be near zero.
3. Before connecting the instruments check their zero settings.
4. The terminals of the rheostats should be connected properly.
5. At no instant of time the current in ammeter should exceed the current rating of rheostat.

TUTORIAL QUESTIONS

Pre-experiment Questions:

Q.1. State Thevenin's theorem.

See theory.

Q.2. What do you mean by open circuit voltage?

Open circuit voltage is the voltage across terminals XY when the terminals XY are open, so that the current into the XY terminals is zero.

Q.3. Why do we use network theorems and techniques to solve electrical circuits?

Network theorems are used to solve electrical circuits because of following advantages:

i. A complicated network can be reduced to its simplest form.

ii. The analytical solution of network is highly simplified.

iii. Many times it is not required to know currents in all the branches of a network. Rather, we are interested only in current through a particular branch or voltage across a particular branch only. In such cases solving the network using Kirchhoff's laws is a time consuming process. For such situations network theorems are used to an advantages.

Post- experiment Questions:

Q.1. What is Norton's theorem?

Norton's theorem states that a two terminal network can be replaced by an equivalent circuit of a constant-current source in parallel with a resistance. The value of the constant-current source is the short circuit current developed when the terminals of the original network are short circuited.

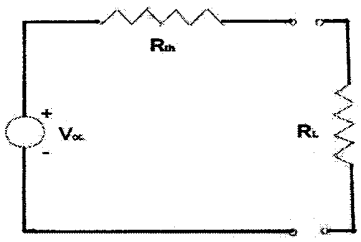
The parallel resistance is the resistance looking back into the original network with all the sources within the network made inactive (*as in Thevenin's theorem*).

Q.2. What is the difference between Thevenin's theorem and Norton's theorem?

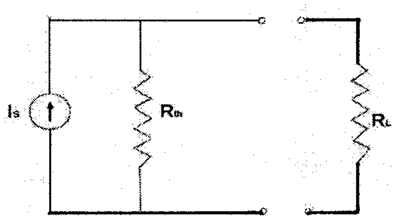
It can be easily realized that Thevenin's theorem and Norton's theorem are one and the same thing. Let us assume that the network under consideration is a "*black box*". The black box contains active sources and a complex network of circuit components. If we measure the terminal voltage, we obtain the *open-circuit voltage* V_{oc}. If we short circuit the terminals and measure the current, we get the short circuit current I_{SC}.

Q3. Given the Thevenin's equivalent of an electrical circuit, how will you determine its Norton's equivalent?

Let the Thevenin's equivalent be given as:



Then the Norton's equivalent would be



In the previous figure (the one showing Norton's equivalent)

We have,

$$I_S = V_{oc}/R_{th}$$

Similarly, if Norton's equivalent is given, Thevenin's equivalent can be found out using the following relation.

$$V_{OC} = I_S.R_{th}$$

Q.4. What are the limitations of Thevenin's theorem?

i. Not applicable to circuits consisting of non-linear elements.

ii. Not applicable to unilateral networks.

iii. There should not be any magnetic coupling between the load and circuit to be replaced by Thevenin's theorem.

iv. In the load side, there should not be controlled sources controlled from some other part of the circuit. If it is so, procedure to be followed is different.

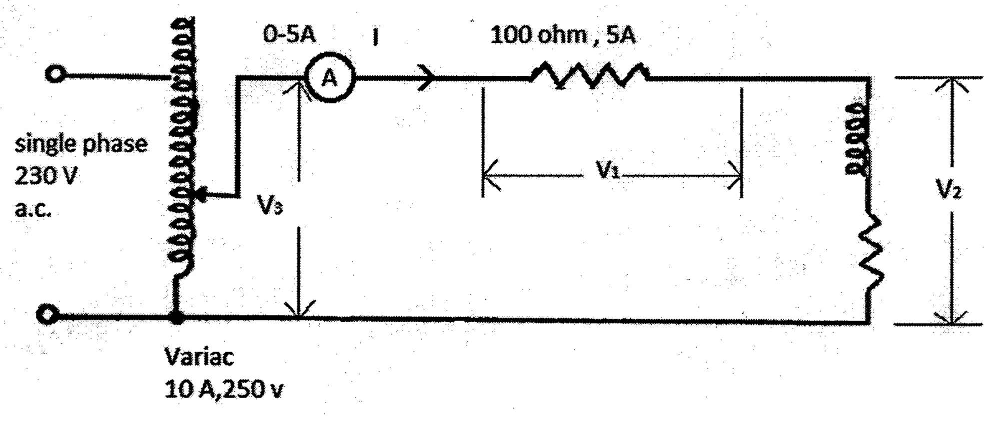
EXPERIMENT No. 3.

OBJECT: To Measure Power And Power Factor in A Single Phase A.C. Circuit Using Three Voltmeters for the following loads:

- i. **Resistor**
- ii. **Inductor**
- iii. **Capacitor**
- iv. **CFL**
- v. **LED lamp**
- vi. **Incandescent lamp**

APPARATUS: Voltmeter 0-300V, MI; 3 no's; Ammeter 0-10A, MI; Single phase load, Rheostat 5A, 100 ohm; Variac 5A, 250V/0-270V, Inductor 0.15 mH, 5A; capacitor 75 μf, 5A; CFL 220V, 50W; LED lamp 220V, 50W; Incandescent lamp 220V, 100W.

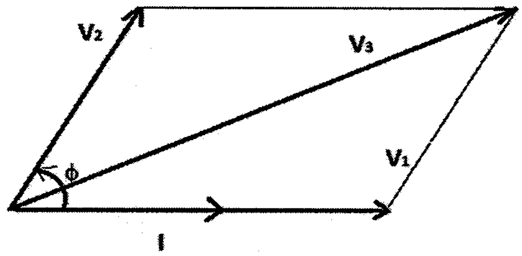
CIRCUIT DIAGRAM:



THEORY

The voltages V_1, V_2 and V_3 are noted with the help of a single voltmeter and a pair of probes. Now, we can draw the phasor diagram for this circuit. Since it is a series circuit, the current I should be taken as reference phasor.

The phasor diagram is given below:



From the phasor diagram we can write

$V_3^2=V_1^2+V_2^2+2V_1V_2\cos\phi$

The power factor of the coil cos ϕ

$\cos\phi= (V_3^2-V_1^2-V_2^2)/(2V_1V_2)$

The power consumed by the coil

$P=V_2I\cos\phi = \{(V_2V_1)/R\} (\cos\phi)$

Resistor

A resistor offers resistance to the flow of current. The resistance is the measure of opposition to the flow of current in a resistor. The unit of resistance is ohm and it is represented as Ω. Resistor is one of the most essential passive elements in electrical and electronics engineering.

It is some time required to introduce electrical resistance in different circuit to limit the current through it. **Resistor** is an element of circuit which does the same. Such as series connected resistor limits the current flowing through the light emitting diode (LED). In addition to that **resistors** serve many other purposes in electrical and electronic applications.

Power Rating of Resistor: When current passes through a resistor there would be I^2R loss and hence as per Joules law of heating there must be temperature rise in the resistor. A resistor must be operated within a temperature limit so that there should not be any permanent damage due high temperature. The power rating of resistor is defined as the maximum power that a resistor can dissipate in form of heat to maintain the temperature within maximum allowable limit. How much power a resistor will dissipate depends upon material, dimensions, voltage rating, maximum temperature limit of the resistor and ambient temperature.

Voltage Rating of Resistor: This rating is defined as the maximum voltage that can be applied across a resistor due to which power dissipation will be within its allowable limit. Actually voltage rating of resistor is related to the power rating. As we know that power rating of resistor is expressed as

$$P = \frac{V^2}{R} \Rightarrow V = \sqrt{PR}$$

Where, V is the applied voltage across the resistor and R is the resistance value of the resistor in ohms. From above equation it is clear that for limiting P, V must be limited for a particular resistor of resistance R. This V is voltage rating of resistor of power rating P watts and resistance R Ω.

INDUCTOR

An **inductor**, also called a **coil, choke** or **reactor,** is a passive two-terminal electrical component that stores electrical energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil around a core.

When the current flowing through an inductor changes, the time-varying magnetic field induces a voltage in the conductor, described by Faraday's law of induction. According to Lenz's law, the direction of induced electromotive force (*e.m.f.*) opposes the change in current that created it. As a result, inductors oppose any changes in current through them.

An inductor is characterized by its inductance, which is the ratio of the voltage to the rate of change of current. In the International System of Units (SI), the unit of inductance is the henry (H) named for 19th century American scientist Joseph Henry. In the measurement of magnetic circuits, it is equivalent to weber/ampere. Inductors have values that typically range from 1 μH (10^{-6} H) to 20 H. Many inductors have a magnetic core made of iron or ferrite inside the coil, which serves to increase the magnetic field and thus the inductance. Along with capacitors and resistors, inductors are one of the three passive linear circuit elements that make up electronic circuits. Inductors are widely used in alternating current (AC) electronic equipment, particularly in radio equipment. They are used to block AC while allowing DC to pass; inductors designed for this purpose are called chokes. They are also used in electronic filters to separate signals of different frequencies, and in combination with capacitors to make tuned circuits, used to tune radio and TV receivers.

CAPACITOR

The capacitor is a component which has the ability or "capacity" to store energy in the form of an electrical charge producing a potential difference (*Static Voltage*) across its plates, much like a small rechargeable battery. There are different kinds of capacitors available from very small capacitor beads used in resonance circuits to large power factor correction capacitors, but they all do the same thing, they store charge.

In its basic form, a capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between a capacitors plates is commonly called the **Dielectric**. Due to this insulating layer, DC current cannot flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge.

Capacitors store the energy in the form of an electrical charge on the plates. Larger the plates and/or smaller their separation the greater will be the charge that the capacitor holds for any given voltage across its plates. In other words, larger plates, smaller distance, more capacitance.

The Capacitance of a Capacitor: Capacitance is the electrical property of a capacitor and is the measure of a capacitors ability to store an electrical charge onto its two plates with the unit of capacitance being the **Farad** (abbreviated to F) named after the British physicist Michael Faraday.

Capacitance is defined as being that a capacitor has the capacitance of **One Farad** when a charge of **One Coulomb** is stored on the plates by a voltage of **One volt**. Note that capacitance, C is always positive in value and has no negative units. However, the Farad is a very large unit of measurement to use on its own so sub-multiples of the Farad are generally used such as micro-farads, Nano-farads and Pico-farads, for example.

Standard Units of Capacitance:

- Microfarad (μF) 1μF = 1/1,000,000 = 0.000001 = 10^{-6} F
- Nanofarad (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10^{-9} F
- Picofarad (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001 = 10^{-12} F

Voltage rating of a Capacitor: All capacitors have a maximum voltage rating and when selecting a capacitor, consideration must be given to the amount of voltage to be applied across the capacitor. The maximum amount of voltage that can be applied to the capacitor without damage to its dielectric material is generally given in the data sheets as: WV, (working voltage) or as WV DC, (DC working voltage).

COMPACT FLUORESCENT LAMP (CFL)

A **compact fluorescent lamp** (CFL), also called **compact fluorescent light**, **energy-saving light**, and **compact fluorescent tube**, is a fluorescent lamp designed to replace an incandescent light bulb, some types fit into light fixtures designed for incandescent bulbs. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and a compact electronic ballast in the base of the lamp.

The principle of operation remains the same as in other fluorescent lighting: electrons that are bound to mercury atoms are excited to states where they will radiate ultraviolet light as they return to a lower energy level; this emitted ultraviolet light is converted into visible light as it strikes the fluorescent coating (as well as into heat when absorbed by other materials such as glass).

There are two types of CFLs: integrated and non-integrated lamps. Integrated lamps combine the tube and ballast in a single unit. These lamps allow consumers to replace incandescent lamps easily with CFLs.

Non-integrated CFLs have the ballast permanently installed in the luminaire, and usually only the fluorescent tube is changed at its end of life. Since the ballasts are placed in the light fixture, they are larger and last longer compared to the integrated ones, and they don't need to be replaced when the tube reaches its end-of-life.

Lifespan: CFLs typically have a rated service life of 6,000–15,000 hours, whereas standard incandescent lamps have a service life of 750 or 1,000 hours. However, the actual lifetime of any lamp depends on many factors, including operating voltage, manufacturing defects, exposure to voltage spikes, mechanical shock, frequency of cycling on and off, lamp orientation, and ambient operating temperature, among other factors.

If a building's indoor incandescent lamps are replaced by CFLs, the heat produced due to lighting is significantly reduced. In warm climates or in office or industrial buildings where air conditioning is often required, CFLs reduce the load on the cooling system when compared to the use of incandescent lamps, resulting in savings in electricity in addition to the energy efficiency savings of the lamps themselves. However, in cooler climates in which buildings require heating, the heating system needs to replace the reduced heat from lighting fixtures. In Winnipeg, Canada, it was estimated that CFLs would only generate 17% savings in energy compared to incandescent bulbs, as opposed to the 75% savings that could have been expected without space heating considerations.

Cost: While the purchase price of a CFL is typically 3–10 times greater than that of an equivalent incandescent lamp, a CFL lasts 8–15 times longer and uses two-thirds to three-quarters less energy.

LED LAMP

White LEDs have advanced to the stage where they are a good substitute for the compact fluorescent lamp. The latest types are exhibiting superior efficacies (mostly because no power is wasted on powering heated cathodes) and a choice of 'colour temperature'. The most common type consists of a blue light emitting diode with a coating of cerium-doped yttrium aluminum garnet which produces yellow light when the blue light from the diode lands on it. The combination of the yellow and blue light produces white light. LED bulbs have a long life of around 25,000 hours. Like CFLs, the light output degrades as the bulb ages though somewhat more slowly.

Dimmable white LED bulbs are available. Some of these offer a warmer dimmed light by including diodes that are of a lower colour temperature than the main diodes.

INCANDESCENT BULB

An **incandescent bulb** is an electric light with a wire filament heated to such a high temperature that it glows with visible light (incandescence). The filament, heated by passing an electric current through it, is protected from oxidation and, to a lesser degree, from evaporation with a glass or fused quartz bulb that is filled with inert gas or more rarely is evacuated of all gases, such as those found in air. The light bulb is supplied with electric current by feed-through terminals or wires embedded in the glass. Most bulbs are used in a socket which provides mechanical support and electrical connections.

Incandescent bulbs are manufactured in a wide range of sizes, light output, and voltage ratings, from 1.5 volts to about 300 volts. Incandescent bulbs are much less efficient than most other types of electric lighting; incandescent bulbs convert less than 5% of the energy they use into visible light, with standard light bulbs averaging about 2.2%. The remaining energy is converted into heat. The luminous efficacy of a typical incandescent bulb is 16 lumens per watt, compared with 60 lm/W for a compact fluorescent bulb or 150 lm/W for some white LED lamps.

PROCEDURE

This experiment can be performed in the following steps

1. The circuit is connected as shown in the circuit diagram.
2. Keep the rheostat at maximum position and variac at its minimum position.
3. Switch on A.C. supply.
4. Increase the variac position gradually, so that some appreciable reading appears in the ammeter.
5. Note down the ammeter reading and the three voltages V_1, V_2 and V_3 using a single voltmeter and a pair of probes.
6. Switch off the AC supply.
7. Change the Load and repeat step 2 to 6..
8. Calculate the value of power consumed P and the value of power factor for each set of observation.

OBSERVATION AND CALCULATIONS:

Record the observation in the format shown below.

S.No.	Type of Load	Observations				Calculations	
		I(A)	V_1(V)	V_2(V)	V_3(V)	Power(W)	cos ϕ
1							
2							
3							
4							
5							

PRECAUTIONS

1. All connections should be tight.
2. The zero settings of all the instruments to be used in the experiment should be checked before connecting them in circuit.

3. The current through ammeter should not be allowed to exceed the current rating of rheostat or load.

TUTORIALQUESTIONS

Pre-experiment Questions

Q.1. What is the principle of operation of CFL?

The principle of operation remains the same as in other fluorescent lighting: electrons that are bound to mercury atoms are excited to states where they will radiate ultraviolet light as they return to a lower energy level; this emitted ultraviolet light is converted into visible light as it strikes the fluorescent coating (as well as into heat when absorbed by other materials such as glass).

Q.2. What is the life span of CFL?

CFLs typically have a rated service life of 6,000–15,000 hours, whereas standard incandescent lamps have a service life of 750 or 1,000 hours. However, the actual lifetime of any lamp depends on many factors, including operating voltage, manufacturing defects, exposure to voltage spikes, mechanical shock, frequency of cycling on and off, lamp orientation, and ambient operating temperature, among other factors.

Q.3. Where are CFL used?

CFLs are produced for both alternating current (AC) and direct current (DC) input. DC CFLs are popular for use in recreational vehicles and off-the-grid housing.

Q.4. What is an inductor?

If a changing flux is linked with a coil of a conductor there would be an emf induced in it. The property of the coil of inducing emf due to the changing flux linked with it is known as inductance of the coil. Due to this property all electrical coil can be referred as inductor. In other way, an inductor can be defined as an energy storage device which stores energy in form of magnetic field.

Q.5. What is self-inductance? On what factors does it depend?

Whenever, current flows through a circuit or coil, flux is produced around it and this flux also links with the coil itself. Self-induced emf in a coil is produced due to its own changing flux and changing flux is caused by changing current in the coil. So, it can be concluded that self-induced emf is ultimately due to changing current in the coil itself. And self-inductance is the property of a coil or solenoid, which causes a self-induced emf to be produced, when the current through it changes.

Q.6. Describe various types of inductors. What are their applications?

Types of Inductor

- Fixed Inductor
- Iron Core Inductor or Iron-core Inductors
- Air Core Inductor
- Toroidal Core Inductor
- Laminated Core Inductor
- Powdered Iron Core

Applications:

1. Energy Storage
2. Sensors
3. Transformers
4. Filters
5. Motors.

Q.7. Why should we use the three voltmeter method when an easier method is available *(using wattmeter)?*

If wattmeter is not available, this method can be used. We need to measure power in single-phase A.C. circuits at places where wattmeter is not available. Wattmeter being a costlier instrument, the three voltmeter method is also cheaper.

Q.8. Under what condition the apparent power and real power are equal?

If an a.c. circuit is purely resistive, the real power equals apparent power.

Post-experiment Questions

Q.1. What is the p.f. of CFL?

The power factor of this lamp is only 0.61.

Q.2. What are the challenges of using CFL?

Recycling:

Health and environmental concerns about mercury have prompted many jurisdictions to require spent lamps to be properly disposed of or recycled, rather than being included in the general waste stream sent to landfills. Safe disposal requires storing the bulbs unbroken until they can be processed.

Q.3. What is charging current?

The flow of electrons onto the plates is known as the capacitors **Charging Current** which continues to flow until the voltage across both plates (and hence the capacitor) is equal to the applied voltage. At this point the capacitor is said to be "fully charged" with electrons.

Q.4. What do you understand by dielectric constant? What are the materials used for dielectric?

The factor by which the dielectric material, or insulator, increases the capacitance of the capacitor compared to air is known as the **Dielectric Constant, k** and a dielectric material with a high dielectric constant is a better insulator than a dielectric material with a lower dielectric constant. Dielectric constant is a dimensionless quantity since it is relative to free space. This dielectric material can be made from a number of insulating materials or combinations of these materials with the most common types used being: air, paper, polyester, polypropylene, Mylar, ceramic, glass, oil, or a variety of other materials.

Q.5. What are the various types of resistors?

The different **types of resistors** are:

1. Carbon Composition Resistor
2. Metal Film Resistor
3. Carbon Film Resistor
4. Non Linear Resistor
5. Varistor
6. Thermistor

Q.6. What are factors that affect the resistance?

1. Temperature
2. Frequency

The effective resistance value of a resistor may be changed when it is subjected to alternating voltage. This change of resistance with frequency is called Boella effect. Actually it is not practically possible to make an ideal resistor. Practically it may have some inductor and capacitance in addition to its resistance. Therefore, the value of impedance of the resistor may vary with frequency. That is why a resistor is referred to be used within its useful frequency range. Useful frequency range is defined as the highest frequency limit beyond which the impedance of the resistor crosses its tolerance value. The impedance of film resistors does not change up to 100 MHz and then it decreases. Film resistors have the most stable high-frequency performance. The high frequency response of a resistor may also depend up to some extent on diameter of the resistor. It is seen that smaller diameter resistor has better frequency response. Because of that the length – diameter ratio of high-frequency resistors is between 4:1 to 10:1.

Q.7. What will happen if voltage greater than the rated voltage is applied to the capacitor?

If the voltage applied across the capacitor becomes too great, the dielectric will break down (known as electrical breakdown) and arcing will occur between the capacitor plates resulting in a short-circuit. The working voltage of the capacitor depends on the type of dielectric material being used and its thickness.The DC working voltage of a capacitor is just that, the maximum DC voltage and NOT the maximum AC voltage as a capacitor with a DC voltage rating of 100 volts DC cannot be safely subjected to an alternating voltage of 100 volts. Since an alternating voltage has an r.m.s. value of 100 volts but a peak value of over 141 volts. Then a capacitor which is required to operate at 100 volts AC should have a working voltage of at least 200 volts. In practice, a capacitor should be selected so that its working voltage either DC or AC should be at least 50 percent greater than the highest effective voltage to be applied to it. At DC a capacitor has infinite impedance (open - circuit), at very high frequencies a capacitor has zero impedance (short-circuit). All capacitors have a maximum working voltage rating, its WV DC so select a capacitor with a rating at least 50% more than the supply voltage.

Q.8. How can you minimize the error in three voltmeter method for measurement of power in a single-phase a.c. circuit?

We can use a single voltmeter and a pair of probes for measuring three voltages instead of three voltmeters in order to reduce the error.

Q.9. Why current is taken as the reference in the phasor diagram with respect to this experiment?

The given circuit being a series circuit, current is common to all the components. Similarly in case of parallel circuits voltage should be taken as the reference phasor.

Q.10. Is there any other method similar to this method for measuring power and power factor in a single phase AC circuit?

Yes, it is known as three ammeter method.

EXPERIMENT No. 4.

OBJECT: To Perform Open Circuit and Short-Circuit Tests On A Single – Phase Transformer and Calculate Its Equivalent Circuit Parameters. Find the Efficiency at Various Loads. Draw Efficiency Vs. Load Curve, Find out the Load at Which the Efficiency is Maximum. Calculate the Voltage Regulation at Full Load at Power Factor

(i) 0.85 Lagging **(ii) 0.85 Leading**

APPARATUS REQUIRED: One variac,230V/0-270V, 20A; One wattmeter 2.5A,250V; One wattmeter 20A,75V; One MI ammeter 2A; One MI ammeter 20A; One MI voltmeter 50V; One voltmeter MI 250V.

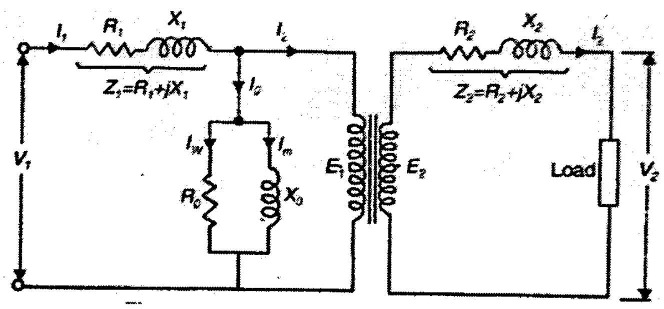
THEORY

We can write Kirchhoff's voltage equation for the primary and secondary side of the transformer as

$V_1 = I_1(R_1+jX_1)-E_1$

$E_2 = I_2(R_2+jX_2)+V_2$

The equivalent circuit gives the interpretation of the above equation



Simplified equivalent circuit:

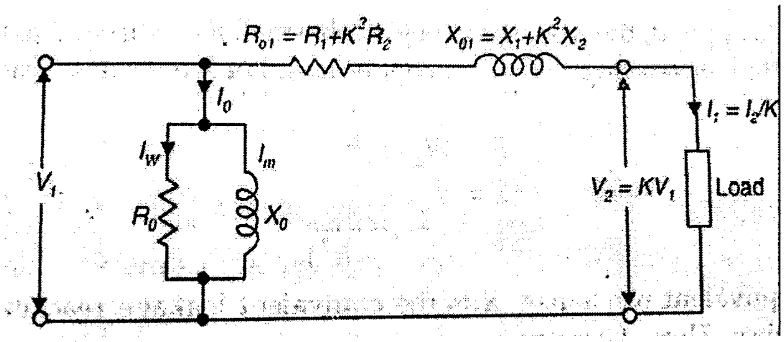
Using the impedance transformation, one can draw the simplified equivalent circuit of a transformer, as referred to the primary or the secondary.

Here $K=N_1/N_2$ is the transformation ratio or turns ratio. Thus, the total resistance and the total reactance as referred to the primary becomes

$$R_{01} = R_1 + K^2R_2$$

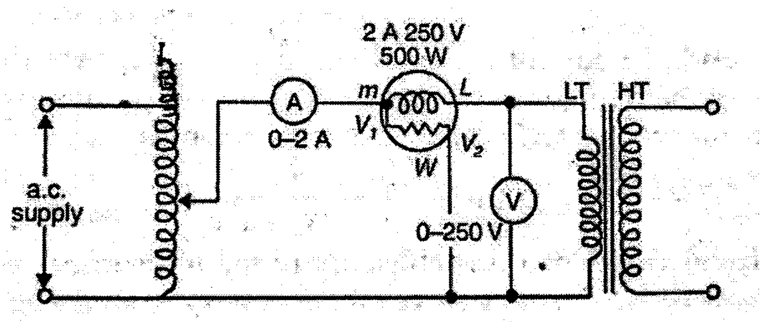
$$X_{01} = X_1 + K^2X_2$$

Simplified equivalent circuit of the transformer as referred to the primary is given below:



OPEN CIRCUIT TEST:

This test is performed to measure iron losses. The no-load current I_0, the iron losses W_0 are measured. From these, R_0 and X_0 parameters of the equivalent circuit can be calculated. Generally HT side is kept open-circuited and the rated voltage is applied to the LT winding.



Circuit for Open Circuit Test

The readings of wattmeter, voltmeter and ammeter are noted.

Let W_0, V_0 and I_0 be their readings.

The iron losses: $P_i = W_0$

The various parameters I_w, I_m, R_0 and X_0 can be calculated as under:

$$I_w = W_0/V_0$$

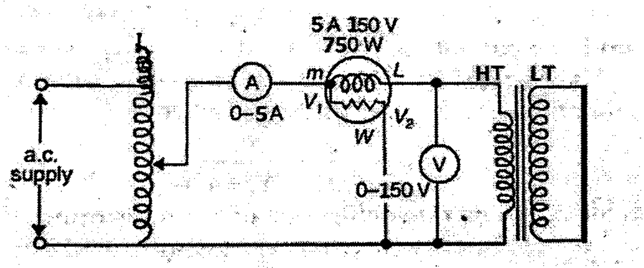
$$I_m^2 = (I_0^2 - I_w^2)$$

$$R_0 = V_0/I_w$$

$$X_0 = V_0/I_m$$

SHORT CIRCUIT TEST:

This test is carried out to determine the equivalent resistance and the leakage reactance of the transformer.



Let the various readings be W_{SC}, V_{SC}, and I_{SC}

Then

$$R = W_{SC}/I_{SC}^2$$

$$Z = V_{SC}/I_{SC}$$

$$X^2 = Z^2 - R^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Efficiency:

$$P_0 = VI \cos \phi$$

$$\eta = P_0/(P_0 + W_0 + W_{sc})$$

For any other load say, the current changes by a factor of x, then the copper loss will be changed by a factor x^2.

Then,

$$\eta_x = xP_0 / (xP_0 + W_0 + x^2 W_{sc})$$

Condition For Efficiency To Be Maximum:

Iron loss = Copper loss

$$W_0 = X_m^2 W_{sc}$$

Voltage Regulation of a Transformer:

If E is the no-load terminal voltage and V is the full-load terminal voltage, then

$$\% \text{ Regulation} = [(E-V)/(V)] \times 100$$

$$= 100 \times [I_2 R_{02} \cos \Phi + I_2 X_{02} \sin(\Phi)] / V_2$$

PROCEDURE:

The procedures for conducting both the tests mentioned above are given below:

Open Circuit Test:

1. Connect the circuit as shown in figure.
2. Before switching on the supply, ensure that the variac is at a low output voltage. Now, switch on the supply.
3. Adjust the variac output voltage to the rated voltage of the transformer.
4. Record no-load current, voltage applied and no-load power from this set-up and switch off the supply.

Short Circuit Test:

1. Connect the circuit as shown in figure.
2. Before switching on the supply, ensure that the variac is at zero value. Now, switch on the supply.
3. Increase the voltage applied slowly, so that the current flowing in the transformer winding equals the rated value.

PRECAUTIONS

1. All connections should be tight and clean.
2. Special care should be taken while selecting the range of the meters for conducting this experiment.
3. For short circuit test, the voltage applied should be initially set at zero and then increased slowly. If a little higher voltage than the required voltage be applied, there is a danger of transformer being damaged.

TUTORIALQUESTIONS

Pre-experiment Questions

Q1. Explain the working principle of working of a transformer.

Q2. What are different types of losses in a transformer? What tests are performed to determine these losses?

The losses in a transformer are of two Types. First, the iron losses, these occur in the core of the transformer. These are also known as magnetic losses. Second, the copper losses, these occur in the winding of the transformer. The iron losses can be determined by Open circuit test. The copper losses can be determined by short circuit test.

Q3. Why indirect testing is necessary for large size transformers?

Testing for any machine means to find out efficiency at different loading conditions. For a large machine actual loads may not be available at the testing site. So, direct loading may not be possible. For this reason indirect testing is necessary for large machines.

Post-experiment Questions

Q.1. What do you expect to happen, if full rated voltage is applied to a transformer under short circuit test?

A heavy current will flow through the transformer. First of all the fuse of the supply should blow off. If that does not happen, transformer will get overheated, insulation will burn and fumes will come out of the transformer.

Q.2. How do the copper losses vary with load on the transformer?

Copper losses in a transformer depend upon the square of the current flowing in the windings. This means if the current doubles, the copper loss will become four times.

Q.3. Which parameters of the equivalent circuit of a transformer can be found through short-circuit test?

We can calculate the resistance and leakage reactance of both the windings as referred to one of the windings of the transformer.

Q.4. What is the magnitude of no load current as compared to full load current?

The magnitude of no-load current is about 5% of the full load current.

EXPERIMENT No. 5.

OBJECT: To Verify The Relation Between Line Voltage And Phase Voltage, Line Current And Phase Current In Three Phase Load When Connected in (A) Star (B) Delta.

APPARATUS REQUIRED: One three phase auto transformer, 400V, 50Hz; one Voltmeter 0-600V MI type; one Voltmeter 0-300V MI type; two ammeters 0-5A MI type; Three phase load – star and delta connected (a pair of bulbs used in each of three phases i.e. 6 bulbs were used.); Connecting wires.

THEORY

Star Connection:

In a star connection, the potential difference between any line and the neutral gives the phase voltage (V_P) whereas across any two lines gives line voltage (V_L). At no instant the three currents I_R,I_Y and I_B flow in the same direction.

We have,

$$\mathbf{I_R+I_Y+I_B=0}$$

$$\mathbf{I_L}(\text{line current}) = \mathbf{I_P}(\text{phase current})$$

$$V_L=\sqrt{3}\ V_P$$

Delta Connection:

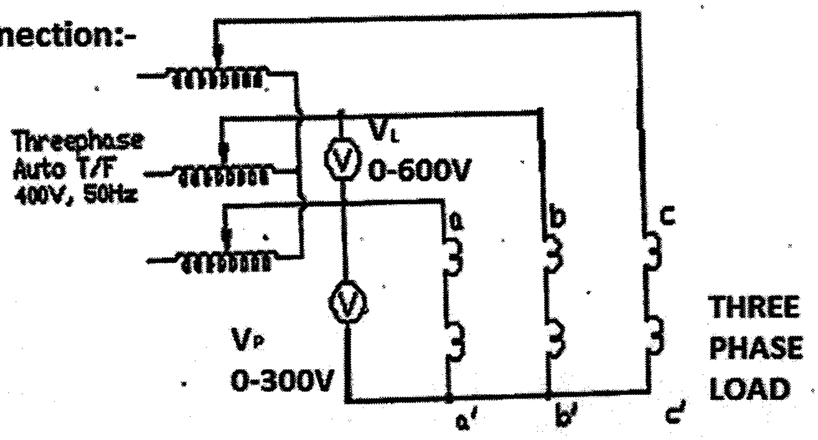
In a delta connection, we have,

$$V_L\ (\text{line voltage}) = V_P(\text{phase voltage})$$

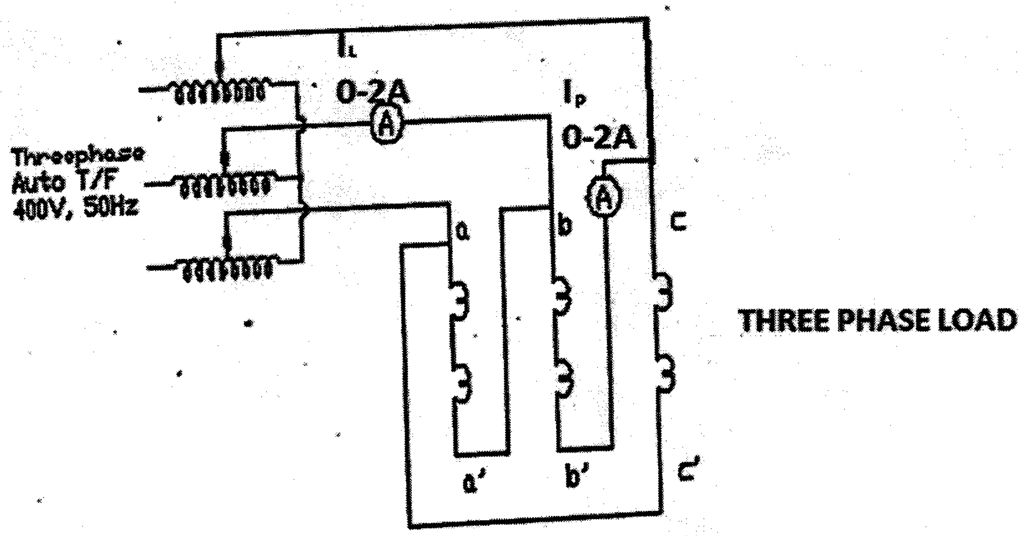
$$I_L=\sqrt{3}\ I_P$$

CIRCUIT DIAGRAM

Star Connection:-



Delta Connection:-



PROCEDURE:

1. The circuit is connected as shown in the diagram (One by one).
2. Vary a.c. supply voltage and note down the reading of voltmeter (star) and reading of ammeter (delta).

OBSERVATIONTABLE

For star connection:

S.No.	Line Voltage V_L(Volts)	Phase Voltage V_P(Volts)	Theoretical Line Voltage $= \sqrt{3}\ V_P$ (Volts)	% Error in V_L
1. 2. . . 10				

For delta connection:

S.No.	Line Current I_L (Amps)	Phase current I_P (Amps)	Theoretical Line current $= \sqrt{3}\ I_P$ (Amps)	% Error in I_L
1. 2. . . 10				

PRECAUTIONS:

1. All connections should be tight.
2. The zero settings of all the instruments to be used in the experiment should be checked before connecting them in circuit.

TUTORIAL QUESTIONS:

Pre-experiment Questions

Q.1. What are the advantages of three phase supply over single phase supply?

The advantages of three phase supply over single phase supply are given below:

1. The conductor material used in a three phase system is much less as compared to that used in a single phase system.
2. There is only one return conductor used and is called neutral. Earth can also be used as return conductor in case of three phase supply. This will further save the conductor material.
3. The return conductor used is of comparatively smaller size, because the phasor sum of current in all phases is zero.
4. For a given frame size, a three phase machine gives higher output than a single phase machine.
5. The power in a single phase circuit is pulsating at twice the supply frequency whereas in three phase system the sum of instantaneous powers is constant. For this reason three phase motors develop a uniform torque whereas a single phase motor develops a pulsating torque.
6. Single phase motors are not self-starting, but a three phase motor is self-starting.
7. Power factor of three motor is higher than that of single phase motor.
8. Efficiency of three motor is higher than that of single phase motor.
9. Three phase system is more reliable.
10. Parallel operation of three phase alternators is simpler as compared to single phase alternators.

Q.2. In case of Delta connections, what is the relation between phase current I_P and the line current I_L?

$$I_L = \sqrt{3} \times I_P$$

Q.3. In case of Delta connections, what is the relation between phase voltage V_P and the line voltage V_L?

$$V_L = V_P$$

Q.4. In case of star connections, what is the relation between phase current I_P and the line current I_L?

$$I_L = I_P$$

Q.5. In case of star connections, what is the relation between phase voltage V_P and the line voltage V_L?

$$V_L = \sqrt{3} \times V_P$$

Post-experiment Questions:

Q.1. Why two bulbs have been used in each branch of the load?

The bulbs used have been rated at 230V, 100W each. The voltage in three phase supply is 440 V. This means, if only one blub is used in each branch, the bulb will blow off. For this reason two bulbs in series have been used.

Q.2. Is the star-delta connections used in this experiment means the same thing as is meant in case of star-delta transformation used in network reduction methods?

No, these are two different concepts.

Q.3. What type of connections should be used on the load side of a distribution transformer? Why?

It should be star connected. The reason being that the supply to be given to various houses and business establishments is normally single-phase. We can do so, by giving connections of one line and neutral. Each phase should also be balanced.

EXPERIMENT No. 6.

OBJECT: To study a series R-L-C circuit and obtain the condition of resonance. Draw the graphs of the following quantities versus voltage across inductance, V_L.

i) Current ii) Power factor iii) Voltage across capacitor V_c

and iv) Voltage across resistance V_R.

APPARATUS: Single phase variac, 15A, 230 /0-270 V – 2nos; Rheostat 100 ohms, 5 A; Capacitor 1 kVA, 230 V, 50 Hz; Ammeter M.I. 0-5 A; Voltmeters M.I. 0-300 V – 4 nos.

CIRCUIT DIAGRAM:

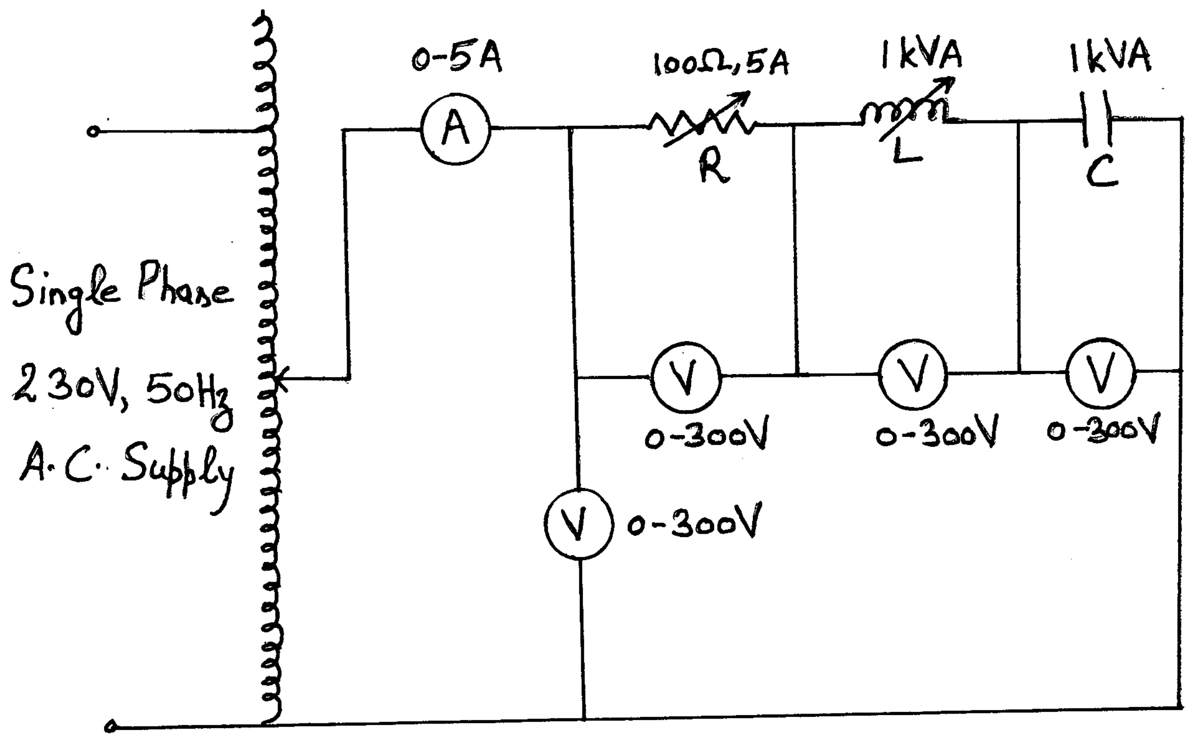


Fig. 1 Circuit Diagram

THEORY:

A series R-L-C circuit is shown in Fig.2. Writing Kirchhoff's voltage law equations we get

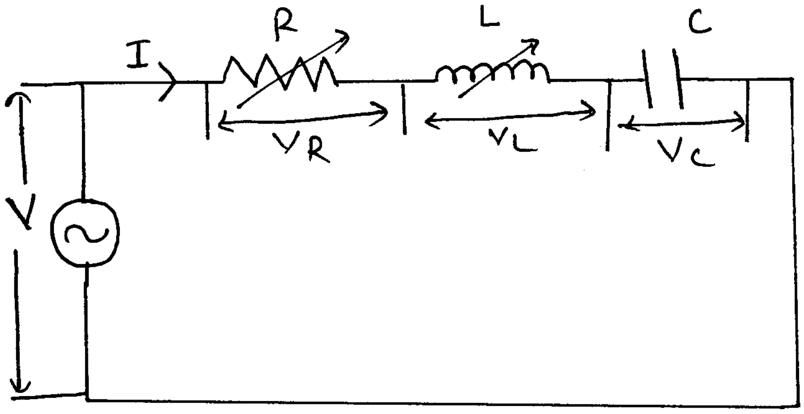


Fig. 2 Series R-L-C circuit.

$$\mathbf{V = V_R + V_L + V_C \;\; = IR + I\,(j\omega L) + I\,(1/j\omega C)}$$

$$= \mathbf{I[R + j\,\omega L +} \frac{1}{j\omega C}] \qquad = \mathbf{I}\,[R + j\,\{\omega L - \frac{1}{\omega C}\}] \;=\; \mathbf{IZ}$$

Here Z is the complex impedance which can be written as

$$Z = R + j\,\{\omega L - \frac{1}{\omega C}\} = \sqrt{R^2 + \{\,\omega L \;-\; \frac{1}{\omega C}\}^2} \angle \tan^{-1}\frac{\{\,\omega L - \frac{1}{\omega C}\}}{R}$$

The current **I** through the circuit can be written as

$$\mathbf{I} = \mathrm{I} \angle \theta = \frac{V\angle 0^{\circ}}{\sqrt{R^2 + \{\,\omega L \;-\; \frac{1}{\omega C}\}^2}} \angle - \tan^{-1}\frac{\{\,\omega L \;-\; \frac{1}{\omega C}\}}{R}$$

Where,

$$\mathrm{I} = \frac{V}{\sqrt{R^2 + \{\,\omega L - \frac{1}{\omega C}\}^2}} \qquad \text{and} \qquad \theta = -\tan^{-1}\frac{\{\,\omega L - \frac{1}{\omega C}\}}{R}$$

In a series R-L-C circuit, one cannot definitely say whether the current leads or lags the voltage. It depends upon the relative values of terms ωL and $1/_{\omega C}$. There can be three possibilities:

(a) $\omega L > 1/_{\omega C}$, (b) $\omega L < 1/_{\omega C}$ and (c) $\omega L = 1/_{\omega C}$.

In case (a), when $\omega L > 1/_{\omega C}$, the angle θ is negative. It means that the current lags the voltage. So, the circuit behaves as an inductive circuit. This condition can be achieved by increasing L, ω or C.

In case (b), when $\omega L < 1/_{\omega C}$, the angle θ is positive. It means that the current leads the voltage. So, the circuit behaves as a capacitive circuit. This condition can be achieved by decreasing L, ω or C.

Case (c) is a special case, when $\omega L = 1/_{\omega C}$, the angle θ becomes zero. The circuit then behaves as a purely resistive circuit. The current through the circuit becomes in phase with the source voltage. This condition is known as the resonance.

PHASOR DIAGRAM

Fig. 3 shows the phasor diagrams for the series R-L-C circuit for three different cases. Since it is a series circuit, current should be taken as reference phasor. In this figure, ab represents the current phasor **I**. We know that the voltage across the resistor is in phase with the current through it. Let ac along ab represents the voltage across the resistor R. Starting from the point c, a phasor cd is drawn to represent the voltage across inductor ($I.X_L$). Obviously cd leads ab by 90°. Phasor ce is drawn at 90° lagging ab. It represents the voltage drop across the capacitor ($I.X_C$). The directions of cd and ce happen to be opposite. The resultant of cd and ce is represented by cf. This phasor cf is positive in case (a), negative in case (b) and zero in case (c). Lastly, phasor af represents the resultant voltage across the source voltage.

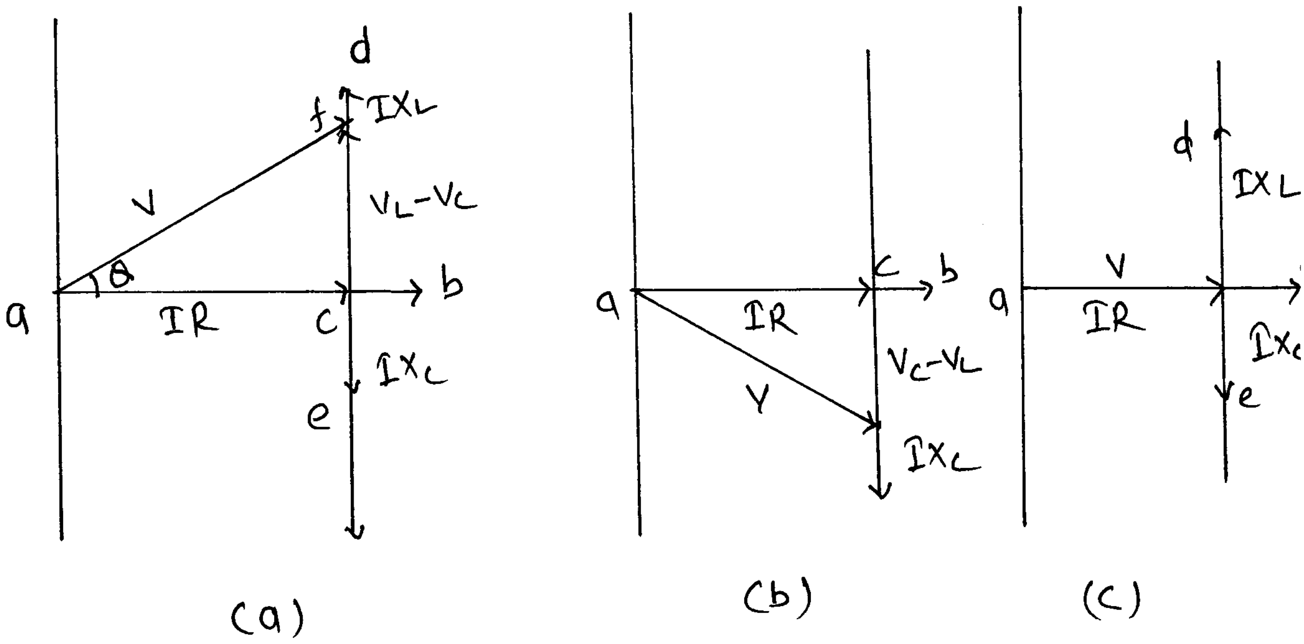


Fig. 3 Phasor Diagrams

PROCEDURE

1. Connect the circuit as shown in figure 1. A variac is used as variable inductance.
2. Set the variable point of the rheostat to a value of about 20 Ω.
3. Set the variable inductance to its minimum value.
4. Set the variac to zero value.
5. Switch on the AC supply
6. Set the variac to a suitable value so that readings in all the meters are readable (say about 100 V).
7. Note down the readings of all the meters.
8. Keep the position of rheostat and variac fixed. Change the value of inductance in steps and note down the readings of all the meters.
9. Take about 12 readings.
10. One reading for the condition that voltages across inductance and capacitance are exactly equal. This signifies the condition of resonance.
11. Record the observations as shown in the following table.
12. Make the calculations for various quantities as shown in the table 2.
13. Draw the various graphs on the same axis.

Table 1: Observations for series R-L-C circuit.

S.No.	V	I	V_R	V_L	V_C
1.					
2.					
.					
.					
12					

Table 2: Calculations for series R-L-C circuit.

S.No.	$R = \frac{V_R}{I}$	$X_L = \frac{V_L}{I}$	$X_C = \frac{V_C}{I}$	$Z = \frac{V}{I}$	$\tan\theta = \frac{V_L - V_C}{V_R}$	θ	$\cos\theta$
1.							
2.							
.							
.							
12							

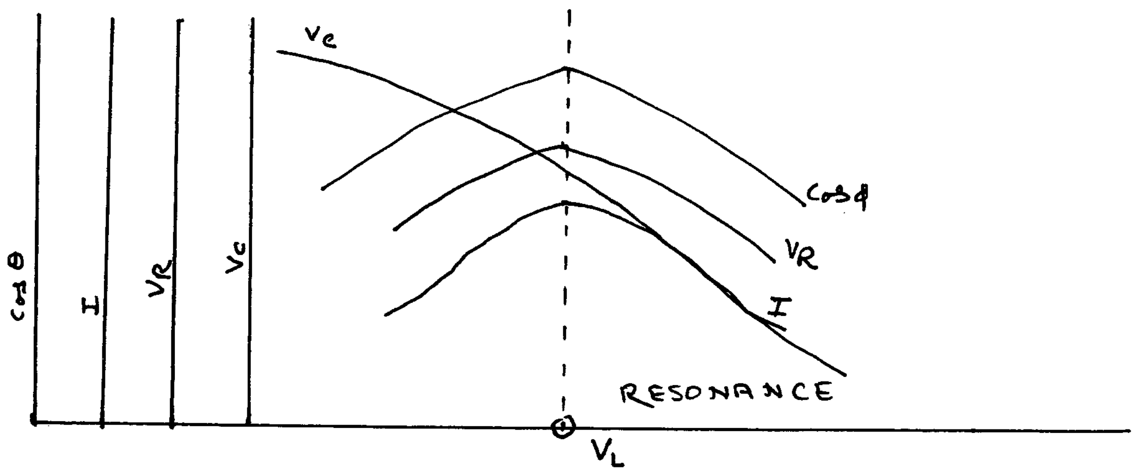


Fig. 4. Graphs

PRECAUTIONS

Following precautions should be taken care of while performing this experiment.

1. All connections should be tight.
2. Meters used should of proper range.
3. Before connecting the meters in the circuit, check their zero settings.
4. The current should not increase the safe limit at any time during the experiment.
5. A variac is being used as inductance in this experiment. The output terminals are used for this purpose. The input terminals remain open during experiment. A sufficient voltage may appear across the input terminals. While doing the experiments, if you happen to touch these terminals you may get a shock. Therefore, it is advisable to put insulating tape on the input terminals of the variac.

DISCUSSIONS

The shapes of the various graphs are given in the following figure. The important points in the condition of resonance are mentioned below.

1. V_L should be equal to V_C.
2. The current should be the maximum.
3. Power factor should be the maximum and unity.
4. V_R should be maximum and equal to supply voltage.

If there is/are any deviation(s) from the above facts, the reason should be explained.

TUTORIAL QUESTIONS

Pre-experiment Questions

Q.1. What do you understand by the term power factor in reference to a.c. circuits?

Power factor of an a.c. circuit can be defined as cosine of the phase angle between voltage applied and current flowing. Alternatively, it is also defined as the ratio between real power and apparent power, in an a.c. circuit.

Apparent power = VI

Real power = VI cos ϕ

Power factor = cos ϕ = (Real power)/(Apparent power)

Also, another definition,

Power factor=R/Z

Q.2. What do you mean by a lagging power factor?

When the current flowing in a.c. circuit lags behind the applied voltage, the current is said to have a lagging power factor. This happens when the inductive reactance of the circuit is more than capacitive reactance. It is associated with a positive sign.

Q.3. What do you mean by a leading power factor?

When the current flowing in a.c. circuit leads the applied voltage, the current is said to have a leading power factor. This happens when the inductive reactance of the circuit is less than capacitive reactance. It is associated with a negative sign.

Q.4. Define the term resonance in reference to a.c. circuits.

Resonance fundamentally means a condition under which the applied voltage and the current through the circuit are in phase. For a.c. circuit containing R, L and C, when the effect of inductance counter balances the effect of capacitance, the circuit is said to be in resonance. Under the condition of resonance following facts can be stated:

1. Current has maximum value.
2. Impedance of the circuit is minimum.
3. Inductive reactance equals capacitive reactance.

Post-experiment Questions

Q.1. What is the phase difference between the current and the applied voltage in an a.c. circuit containing a pure inductance only?

In a purely inductive circuit the current lags the applied voltage by an angle of 90 degrees.

Q.2. How can you find the value of frequency at which an R-L-C circuit will have resonance?

The frequency of resonance can be found using the following relation:

$$f = \frac{1}{2\Pi\sqrt{LC}}$$

Q.3. Suppose an inductor is connected in series with a lamp. What would be its effect?

The lamp will be dim. The current in the circuit will reduce due to inductance. However, the life of the lamp will increase.

Q.4. What is quality factor of a coil?

The term quality factor (Q) is used to describe the effectiveness of a coil. It is defined as the ratio of the energy stored to the energy dissipated per cycle. Thus for a coil

$$Q = \frac{\text{Stored power}}{\text{Dissipated power}} = \frac{I^2 X_L}{I^2 R} = \frac{X_L}{R} = \tan\Phi$$

EXPERIMENT No. 7.

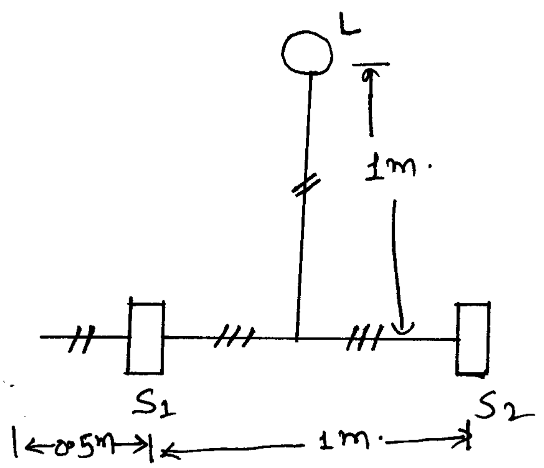
OBJECT: To control one lamp from two different places using 2-way switches as in stair-case wiring.

TOOLS REQUIRED: Screw driver (12"), plier (8"), Wire cutter & stripper, electrician knife (6"), hand saw (12") and line tester.

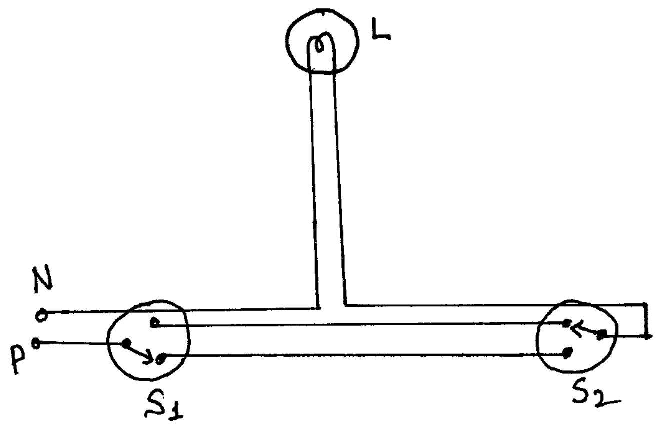
MATERIAL REQUIRED:

S.No.	Material	Specification
1	PVC insulated copper wire	3/20 SWG
2	2-way switch	240V, 6A
3	Bulb holder	Batten type
4	Round block	PVC
5	Casing-capping	PVC 0.75"
6	Wooden screw	2"
7	Wooden screw	½"
8	Gang box	1-way PVC
9	Bulb	100W, 240V
10	Insulation tape	PVC

Route Diagram



Wiring Diagram



PROCEDURE: Following are the steps to carry out this experiment.

1. Make the route diagram on the wooden board by deciding proper placement of bulb and switches.
2. Cut the casing-capping of required length.
3. Fix the casing on the route defined with the help of wooden screws.
4. Lay the wires of proper length in the casing.
5. Fix the switches on the gang boxes and bulb holder on the round block.
6. Make connections of the bulb and the switches. Fix the switches and bulb holder on their place with the help of wooden screws.
7. Get your connections checked by the teacher and then switch ON the supply and test the wiring.
8. Make the truth table according the relationship of input and output.

ESTIMATING AND COSTING:

S.No.	Material	Specification and type	Qty	Rate	Cost
1	PVC insulated copper wire	3/20 SWG			
2	2-way switch	240V, 6A			
3	Bulb holder	Batten type			
4	Round block	PVC			
5	Casing-capping	PVC 0.75”			
6	Wooden screw	2”			
7	Wooden screw	½”			
8	Gang box	1-way PVC			
9	Bulb	100W, 240V			
10	Insulation tape	PVC			
	Labour cost				
	Total				

PRECAUTIONS:

1. Joints must not be there in the wires, if there's any it must be covered properly with the insulation tape.
2. All connections must be tight and intact.
3. All accessories must be fixed properly.
4. Get the connections checked by the Instructor / Faculty before switching 'ON' the supply.
5. Tools should be used with proper care and deposited back with the lab staff after use.
6. Switch must be connected in the phase (live) wire and not in the neutral.

TUTORIAL QUESTIONS:

Pre-experiment Questions

Q.1. What types of switches are used for staircase wiring?

Two way switches are used in staircase wiring.

Q.2. Explain the function of staircase wiring with the help of a truth table.

Post-experiment Questions

Q.1. What are the precautions to be observed to prevent electrical accidents?

Electrical accidents can be prevented by using good quality rubber sole shoes and by ensuring that the clothes and hands are not wet.

Q.2. Under what conditions are electric shocks fatal? What are the basic treatments for victim of electric shock?

Q.3. Why is it necessary to use switch in the Live wire and not in the Neutral wire?

If we connect the switch in Neutral wire then the terminals of the equipment are always live and possess a shock hazard.

EXPERIMENT No. 8.

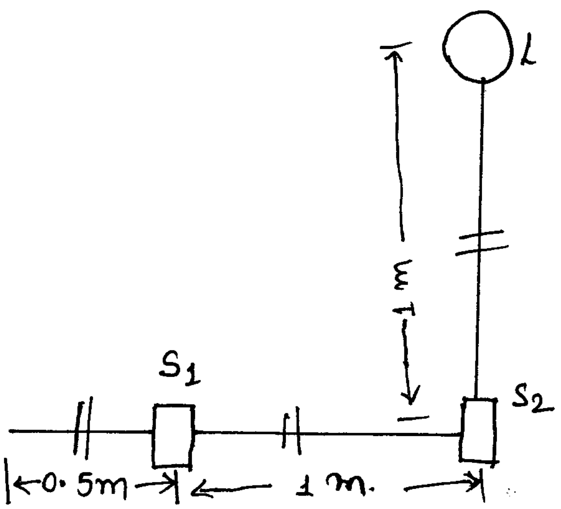
OBJECT: To control one lamp from two different places using 1- way switches as in bed switch wiring.

TOOLS REQUIRED: Screw driver (12"), plier (8"), Wire cutter & stripper, electrician's knife (6"), hand saw (12") and line tester.

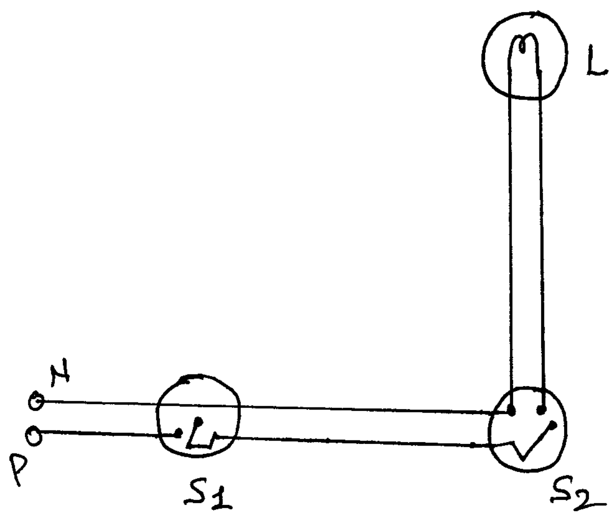
MATERIAL REQUIRED:

S.No.	Material	Specification
1	PVC insulated copper wire	3/20 SWG
2	1-way switch	240V, 6A
3	Bulb holder	Batten type
4	Round block	PVC
5	Casing-capping	PVC 0.75"
6	Wooden screw	2"
7	Wooden screw	½"
8	Gang box	1-way PVC
9	Bulb	100W, 240V
10	Insulation tape	PVC

Route Diagram



Wiring Diagram



PROCEDURE: Following are the steps to carry out this experiment.

1. Make the route diagram on the wooden board by deciding proper placement of bulb and switches.
2. Cut the casing-capping of required length.
3. Fix the casing on the route defined with the help of wooden screws.
4. Lay the wires of proper length in the casing.
5. Fix the switches on the gang boxes and bulb holder on the round block.
6. Make connections of the bulb and the switches. Fix the switches and bulb holder on their place with the help of wooden screws.
7. Get your connections checked by the teacher and then switch ON the supply and test the wiring.
8. Make the truth table according the relationship of input and output.

ESTIMATING AND COSTING:

S.No	Material	Specification and type	Qty	Rate	Cost
1	PVC insulated copper wire	3/20 SWG			
2	1-way switch	240V, 6A			
3	Bulb holder	Batten type			
4	Round block	PVC			
5	Casing-capping	PVC 0.75"			
6	Wooden screw	2"			
7	Wooden screw	½"			
8	Gang box	1-way PVC			
9	Bulb	100W, 240V			
10	Insulation tape	PVC			
	Labour cost				
	Total				

PRECAUTIONS:

1. Joints must not be there in the wires, if there's any it must be covered properly with the insulation tape.
2. All connections must be tight and intact.
3. All accessories must be fixed properly.
4. Get the connections checked by the Instructor / Faculty before switching 'ON' the supply.
5. Tools should be used with proper care and deposited back with the lab staff after use.
6. Switch must be connected in the phase (live) wire and not in the neutral.

TUTORIAL QUESTIONS:

Pre-experiment Questions

Q.1. What do three holes in a socket represent?

One hole is for line wire, another is for neutral wire and the third is for earth wire.

Q.2. What is the main motivation of using this type of wiring?

Convenience and safety during night is the main motive for this type of wiring. Energy is also saved.

Post-experiment Questions

Q.1. What are the different types of wires and switches available in electrical wiring? What do you understand by "SWG"?