SYLLABUS

Course Title:	Elements of Electrical Engineering		
Course Code:	**22EEE13/23**	CIE Marks	50
Course Type (Theory/Practical /Integrated)	Theory	SEE Marks	50
		Total Marks	100
Teaching Hours/Week (L:T:P: S)	2:2:0:0	Exam Hours	03
Total Hours of Pedagogy	40 hours	Credits	03

Course objectives

- To explain the basic laws used in the analysis of DC circuits, electromagnetism.
- To explain the behavior of circuit elements in single-phase circuits.
- To explain three phase circuits, balanced loads and measurement of three phase power.
- To explain the measuring techniques, measuring instruments and domestic wiring.
- To explain electricity billing, equipment and personal safety measures.

Teaching-Learning Process

These are sample Strategies, which teacher can use to accelerate the attainment of the various course outcomes and make Teaching -Learning more effective

1. Chalk and talk 2. Animated/NPTEL videos 3. Cut sections 4. PPTs

Module-1 (08 Hrs)

DC circuits: Ohm's law and Kirchhoff's laws, analysis of series, parallel and series-parallel circuits. Power and energy.
Electromagnetism: Faraday's Laws of Electromagnetic Induction, Lenz's Law, Flemings rules, statically and dynamically induced EMF; concepts of self and mutual inductance. Coefficient of Coupling. Energy stored in magnetic field. Simple Numerical.

Module-2 (08 Hrs)

Single-phase AC circuits: Generation of sinusoidal voltage, frequency of generated voltage, average value, RMS value, form factor and peak factor of sinusoidal voltage and currents.
Phasor representation of alternating quantities. Analysis of R, L, C, R-L, R-C and R-L-C circuits with phasor diagrams, Real power, reactive power, apparent power, and Power factor. Series, Parallel and Series-Parallel circuits. Simple Numerical.

Module-3(08 Hrs)

Three-phase AC circuits: Necessity and advantage of 3-phase system. Generation of 3-phase power. Definition of phase sequence. Balanced supply and balanced load. Relationship between line and phase values of balanced star and delta connections. Power in balanced 3-phase circuits. Measurement of 3-phase power by 2-wattmeter method. Simple Numerical.

Module-4(08 Hrs)

Measuring instruments: construction and working principle of whetstone's bridge, Kelvin's double bridge, Megger, Maxwel's bridge for inductance, Schering's bridge for capacitance, concepts of current transformer and potential transformer.
Domestic Wiring: Requirements, Types of wiring: casing, capping. Two way and three way control of load.

Module-5 (08 Hrs)

Electricity bill: Power rating of household appliances including air conditioners, PCs, laptops, printers, etc. Definition of "unit" used for consumption of electrical energy, two-part electricity tariff, calculation of electricity bill for domestic consumers.
Equipment Safety measures: Working principle of Fuse and Miniature circuit breaker (MCB), merits and demerits.
Personal safety measures: Electric Shock, Earthing and its types, Safety Precautions to avoid shock, and Residual Current Circuit Breaker (RCCB) and Earth Leakage Circuit Breaker (ELCB).

Course outcome (Course Skill Set)

At the end of the course the student will be able to:

CO1	Understand the concepts of DC circuits and Electromagnetism.
CO2	Understand the concepts of single phase and Three phase AC circuits.
CO3	Apply the basic Electrical laws to solve circuits.
CO4	Understand the concepts of measurements and measuring Instruments
CO5	Explain the concepts of domestic wiring, electricity billing, circuit protective devices and personal safety measures.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50). The minimum passing mark for the SEE is 35% of the maximum marks (18 marks out of 50). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50) in the semester-end examination(SEE), and a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation(CIE):

Two Unit Tests each of30 Marks (duration 01 hour)

- First test after the completion of 30-40 % of the syllabus
- Second test after completion of 80-90% of the syllabus

One Improvement test before the closing of the academic term may be conducted if necessary. However best two tests out of three shall be taken into consideration

Two assignments each of 20 Marks

The teacher has to plan the assignments and get them completed by the students well before the closing of the term so that marks entry in the examination portal shall be done in time.Formative (Successive) Assessments include Assignments/Quizzes/Seminars/ Course projects/Field surveys/ Case studies/ Hands-on practice (experiments)/Group Discussions/ others.. The Teachers shall choose the types of assignments depending on the requirement of the course and plan to attain the Cos and POs. (to have a less stressed CIE, the portion of the syllabus should not be common /repeated for any of the methods of the CIE. Each method of CIE should have a different syllabus portion of the course). CIE methods /test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

The sum of two tests, two assignments, will be out of 100 marks and will be scaled down to 50 marks

Semester End Examination(SEE):

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (**duration 03 hours)**

- The question paper shall be set for 100 marks. The medium of the question paper shall be English/Kannada). The duration of SEE is 03 hours.
- The question paper will have 10 questions. Two questions per module. Each question is set for 20 marks.The students have to answer 5 full questions, selecting one full question from each module. The student has to answer for 100 marks and **marks scored out of 100 shall be proportionally reduced to 50 marks**.
- There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.

Suggested Learning Resources:

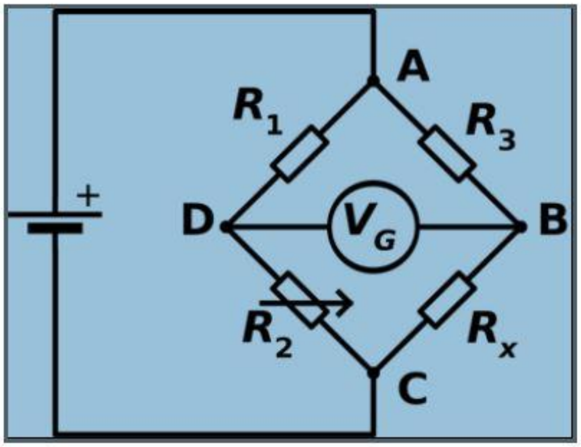
Books (Title of the Book/Name of the author/Name of the publisher/Edition and Year)

Text Books:

1. Basic Electrical Engineering by D C Kulshreshtha, Tata McGraw Hill, First Edition 2019.
2. A text book of Electrical Technology by B.L. Theraja, S Chand and Company, reprint edition 2014.

Module – 4
Measuring Instruments

Wheatstone Bridge



Field strength meter

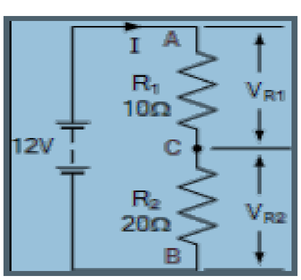
The Wheatstone Bridge was originally developed by Charles Wheatstone to measure unknown resistance values and as a means of calibrating measuring instruments, voltmeters, ammeters, etc, by the use of a long resistive slide wire.

Although today digital multimeters provide the simplest way to measure a resistance. The Wheatstone Bridge can still be used to measure very low values of resistances down in the milli-Ohms range.

The Wheatstone bridge (or resistance bridge) circuit can be used in a number of applications and today, with modern operational amplifiers we can use the Wheatstone Bridge Circuit to interface various transducers and sensors to these amplifier circuits. The Wheatstone Bridge circuit is nothing more than two simple series-parallel arrangements of resistances connected between a voltage supply terminal and ground producing zero voltage difference between the two parallel branches when balanced. A Wheatstone bridge circuit has two input terminals and two output terminals consisting of four resistors configured in a diamond-like arrangement as shown above.

Minimum field strength criteria

When balanced, the Wheatstone bridge can be analysed simply as two series strings in parallel. In our tutorial about Resistors in Series, we saw that each resistor within the series chain produces an IR drop, or voltage drop across itself as a consequence of the current flowing through it as defined by Ohms Law. Consider the series circuit below.



As the two resistors are in series, the same current (i) flows through both of them. Therefore the current flowing through these two resistors in series is given as: V/RT.

T

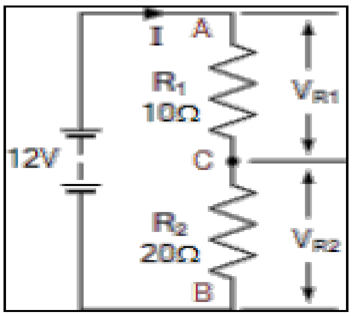
I = V ÷ R = 12V ÷ (10" + 20") = 0.4A

The voltage at point C, which is also the voltage drop across the lower resistor, R2 is calculated as:

VR2 = I × R2 = 0.4A × 20" = 8 volts

Then we can see that the source voltage VS is divided among the two series resistors in direct proportion to their resistances as VR1 = 4V and VR2 = 8V. This is the principle of voltage division, producing what is commonly called a potential divider circuit or voltage divider network.

Now if we add another series resistor circuit using the same resistor values in parallel with the first we would have the following circuit.



As the second series circuit has the same resistive values of the first, the voltage at point D, which is also the voltage drop across resistor, R4 will be the same at 8 volts, with respect to zero (battery negative), as the voltage is common and the two resistive networks are the same. But something else equally as important is that the voltage difference between point C and point D will be zero volts as both points are at the same value of 8 volts as: C = D = 8 volts, then the voltage difference is: 0 volts

When this happens, both sides of the parallel bridge network are said to be balanced because the voltage at point C is the same value as the voltage at point D with their difference being zero.

Now let's consider what would happen if we reversed the position of the two resistors, R3 and R4 in the second parallel branch with respect to R1 and R2. By replacing R4 above with a resistance of known or unknown value in the sensing arm of the Wheatstone bridge corresponding to RX and adjusting the opposing resistor, R3 to "balance" the bridge network, will result in a zero voltage output. Then we can see that balance occurs when:

The Wheatstone Bridge equation required to give the value of the unknown resistance, RX at balance is given as:

$$\frac{R_1}{R_2} = \frac{R_3}{R_X} = 1 \text{ (Balanced)}$$

Where resistors, R1 and R2 are known or pre-set values.

$$V_{OUT} = (V_C - V_D) = (V_{R2} - V_{R4}) = 0$$

$$R_C = \frac{R_2}{R_1 + R_2} \quad \text{and} \quad R_D = \frac{R_4}{R_3 + R_4}$$

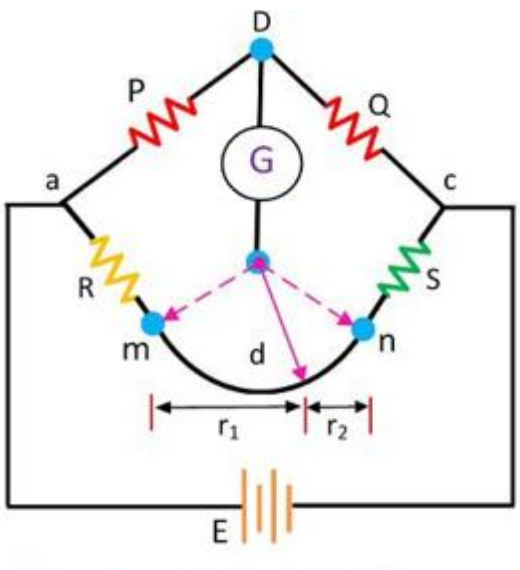
$$\text{At Balance: } R_C = R_D \quad \text{So, } \frac{R_2}{R_1 + R_2} = \frac{R_4}{R_3 + R_4}$$

$$\therefore R_2(R_3 + R_4) = R_4(R_1 + R_2)$$

$$R_2R_3 + \cancel{R_2R_4} = R_1R_4 + \cancel{R_2R_4}$$

$$\therefore R_4 = \frac{R_2R_3}{R_1} = R_X$$

KELVINS BRIDGE:



A Kelvin bridge, also called a Kelvin double bridge and in some countries a Thomson bridge, is a measuring instrument used to measure unknown electrical resistors below 1 ohm. It is specifically designed to measure resistors that are constructed as four terminal resistors. Resistors above about 1 ohm in value can be measured using a variety of techniques, such as an

ohmmeter or by using a Wheatstone bridge. In such resistors, the resistance of the connecting wires or terminals is negligible compared to the resistance value. For resistors of less than an ohm, the resistance of the connecting wires or terminals becomes significant, and conventional measurement techniques will include them in the result. To overcome the problems of these undesirable resistances (known as 'parasitic resistance'), very low value resistors and particularly precision resistors and high current ammeter shunts are constructed as four terminal resistors. These resistances have a pair of current terminals and a pair of potential or voltage terminals. In use, a current is passed between the current terminals, but the volt drop across the resistor is measured at the potential terminals. The volt drop measured will be entirely due to the resistor itself as the parasitic resistance of the leads carrying the current to and from the resistor are not included in the potential circuit. To measure such resistances requires a bridge circuit designed to work with four terminal resistances. That bridge is the Kelvin bridge he operation of the Kelvin bridge is very similar to the Wheatstone bridge, but uses two additional resistors. Resistors R1 and R2 are connected to the outside potential terminals of the four terminal known or standard resistor Rs and the unknown resistor Rx (identified as P1 and P′1 in the diagram). The resistors Rs, Rx, R1 and R2 are essentially a Wheatstone bridge. In this arrangement,

the parasitic resistance of the upper part of Rs and the lower part of Rx is outside of the potential measuring part of the bridge and therefore are not included in the measurement. However, the link between Rs and Rx (Rpar) is included in the potential measurement part of the circuit and therefore can affect the accuracy of the result. To overcome this, a second pair of resistors R′1 and R′2 form a second pair of arms of the bridge (hence 'double bridge') and are connected to the inner potential terminals of Rs and Rx (identified as P2 and P′2 in the diagram). The detector D is connected between the junction of R1 and R2 and the junction of R′1 and R′2.[2]

The balance equation of this bridge is given by the equation Electronic In electronic versions, the perforated disc is replaced by a lamp capable of emitting brief and rapid flashes of light. Typically a gas-discharge or solid-state lamp is used, because they are capable of emitting light nearly instantly when power is applied, and extinguishing just as fast when the power is removed. By comparison, incandescent lamps have a brief warm-up when energised, followed by a cool-down period when power is removed. These delays result in smearing and blurring of detail of objects partially illuminated during the warm-up and cool-down periods. For most applications, incandescent lamps are too slow for clear stroboscopic effects. Yet when operated from an AC source they are mostly fast enough to cause audible hum (at double mains frequency) on optical audio playback such as on film projection.

The frequency of the flash is adjusted so that it is an equal to, or a unit fraction of the object's cyclic speed, at which point the object is seen to be either stationary or moving slowly backward or forward, depending on the flash frequency. Neon lamps or light emitting diodes are commonly used for low-intensity strobe applications, Neon lamps were more common before the development of solid-state electronics, but are being replaced by LEDs in most low-intensity strobe applications Xenon flash lamps are used for medium- and high-intensity strobe applications. Sufficiently rapid or bright flashing may require active cooling such as forced-air or water cooling to prevent the xenon flash lamp from melting.

Applications

Stroboscopes play an important role in the study of stresses on machinery in motion, and in many other forms of research. Bright stroboscopes are able to overpower ambient lighting and make stop-motion effects apparent without the need for dark ambient operating conditions. They are also used as measuring instruments for determining cyclic speed. As a timing light they are used to set the ignition timing of internal combustion engines.

In medicine, stroboscopes are used to view the vocal cords for diagnosis of conditions that have produced dysphonia (hoarseness). The patient hums or speaks into a microphone which in turn activates the stroboscope at either the same or a slightly different frequency. The light source and a camera are positioned by **endoscopy**. Another application of the stroboscope can be seen on many gramophone turntables. The edge of the platter has marks at specific intervals so that when viewed under fluorescent lighting powered at mains frequency, provided the platter is rotating at the correct speed, the marks appear to be stationary. This will not work well under incandescent lighting, as incandescent bulbs don't significantly strobe. For this reason, some turntables have a neon bulb or LED next to the platter. The LED must be driven by a half wave rectifier from the mains transformer, or by an oscillator.

Flashing lamp strobes are also adapted for pop use, as a lighting effect for discotheques and night clubs where they give the impression of dancing in slow motion. The strobe rate of these devices is typically not very precise or very fast, because the entertainment application does not usually require a high degree of performance.

$$\frac{R_x}{R_s} = \frac{R_2}{R_1} + \frac{R_{\text{par}}}{R_s} \cdot \frac{R_1'}{R_1' + R_2' + R_{\text{par}}} \cdot \left(\frac{R_2}{R_1} - \frac{R_2'}{R_1'}\right)$$

In a practical bridge circuit, the ratio of R′1 to R′2 is arranged to be the same as the ratio of R1 to R2 (and in most designs, R1 = R′1 and R2 = R′2). As a result, the last term of the above equation becomes zero and the balance equation becomes

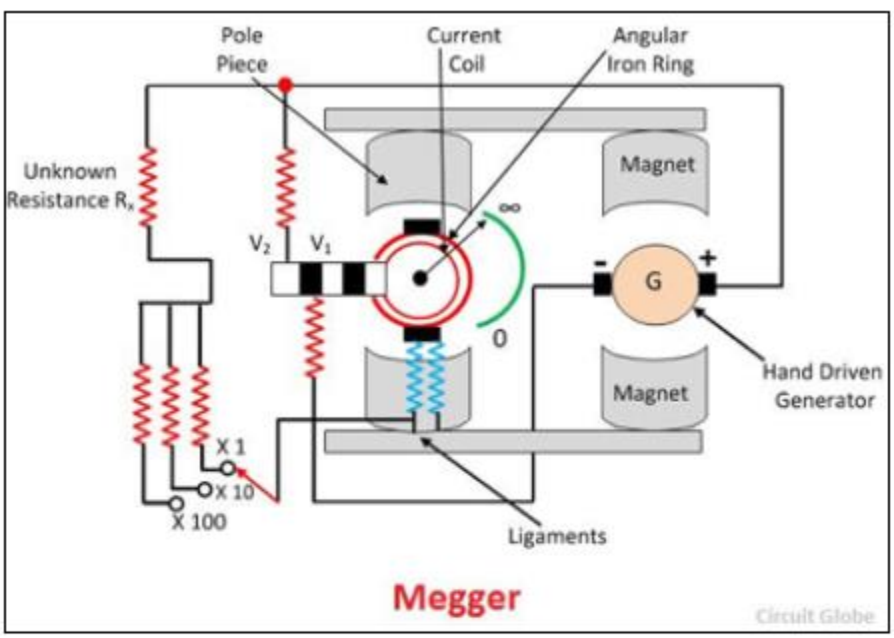
$$\frac{R_x}{R_s} = \frac{R_2}{R_1}$$

Rearranging to make R_x the subject

$$R_x = R_2 \cdot \frac{R_s}{R_1}$$

the parasitic resistance Rpar has been eliminated from the balance equation and its presence does not affect the measurement result. This equation is the same as for the functionally equivalent Wheatstone bridge. In practical use the magnitude of the supply B, can be arranged to provide current through Rs and Rx at or close to the rated operating currents of thesmaller rated resistor. This contributes to smaller errors in measurement. This current does not flow through the measuring bridge itself. This bridge can also be used to measure resistors of the more conventional two terminal design. The bridge potential connections are merely connected as close to the resistor terminals as possible. Any measurement will then exclude all circuit resistance not within the two potential connection

EARTH RESISTANCE



What is a ground?

The US National Electrical Code (NEC) Article 100 defines a ground as: "a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth". Grounding actually encompasses two different subjects: earth grounding and equipment grounding. Earth grounding is an intentional connection from a circuit conductor, usually the neutral, to a ground electrode placed in the earth. Equipment grounding ensures that operating equipment within a structure is grounded properly. These two grounding systems must be kept separate except for connections between the two systems. This prevents differences in voltage potential from a possible flashover from lightning strikes. The purpose of a ground is to provide a safe path for the dissipation of fault currents, lightning strikes, static discharges, EMI and RFI signals and interference.

The US National Fire Protection Agency (NFPA) and Institute of Electrical and Electronics Engineers (IEEE) recommend a ground resistance value of 5 or less. The goal in ground resistance is to achieve the lowest ground resistance value possible that makes sense economically and physically. What affects the grounding resistance? Four variables affect the ground resistance of a ground system: length or depth of the ground electrode; the diameter of the ground electrode; the number of ground electrodes and ground system design. Length/depth of the ground electrode Driving ground electrodes deeper is a very effective way to lower ground resistance. Soil is not consistent in its resistivity and can be unpredictable. The resistance level can generally be reduced by an additional 40% by doubling the length of the ground electrode. It is sometimes impossible to drive ground rods deeper – in areas composed of rock, for instance. In these cases, alternative methods including grounding cement are viable.

Diameter of the ground electrode Increasing the diameter of the ground electrode has very little effect in lowering the resistance. For example, you could double the diameter of a ground electrode and your resistance would only decrease by 10%. Number of ground electrodes Using multiple ground electrodes provides another way to lower ground resistance. More than one electrode is driven into the ground and connected in parallel to lower the resistance. For additional electrodes to be effective, the spacing of additional rods must be at least equal to the depth of the driven rod. The ground electrodes' spheres of influence will intersect and the resistance will not be lowered without proper spacing. Table 1 provides various ground resistances which can be used as a rule of thumb.

Soil resistivity measurement :Soil resistivity is necessary when determining the design of the grounding system for new installations (green field applications) to meet your ground resistance requirements. Ideally, you would find a location with the lowest possible resistance. Poor soil conditions can be overcome with more elaborate grounding systems. The soil composition, moisture content and temperature all impact soil resistivity. Soil is rarely homogenous and its resistivity will vary geographically and at different depths. Moisture content changes seasonally, varies according to the nature of the sublayers of earth and the depth of the permanent water table. It is recommended that the ground rods be placed as deep as possible into the earth as soil and water are generally more stable at deeper strata. Calculating soil resistivity The measuring procedure described here uses the Wenner method and uses the formula:

ρ = 2 & A R

where:

ρ = the average soil resistivity to depth A in: ohm-cm.

& = 3,1416.

A = the distance between the electrodes in cm.

R = the measured resistance value in ohm from the test instrument.

Measuring soil resistance

Definition of **phasemeter.** : a device for measuring the difference in phase of two alternating currents or electromotive forces. **Megger:** an instrument for measuring the resistance of electrical insulation. Phase sequence meter is used for detecting the sequence of the supply in three-phase electric circuits. Since the direction of rotation of three phase electric motors can be changed by changing the phase sequence of supply. And also the correct operation of measuring instruments like 3 phase energy meter and automatic control of devices also depend on the phase sequence. Different types of phase sequence testers are available in today's market like contact or non contact, static or rotating, etc., in a wide range of voltage or power ratings. The sequence in which three phase voltages attain their positive maximum values is defined as the phase sequence. It refers to the relation between the voltages or currents in three phase system. Consider the three phases as red-R, yellow-Y and blue-B phases. The phase sequence can be taken as RYB if R attains its maximum value first with respect to the reference in anti-clockwise direction followed by Y phase 120° later, and B phase 240° later than the R phase.

The phase sequence can be taken as RBY if R followed by B phase is at 120° later and Y phase is at 240° later than the R phase. RYB is considered as a positive sequence, whereas RBY is a negative sequence supply, as shown in the figure.

What is a Phase Sequence Meter or Indicator and Its Working Principle?

The phase sequence meter is used for the detection of phase sequence in three phase circuits and there are different types of phase sequence indicators that are as follows:

Types of Phase Sequence Indicators

Phase sequence indicators can be classified into two types:

(a) Rotating Type

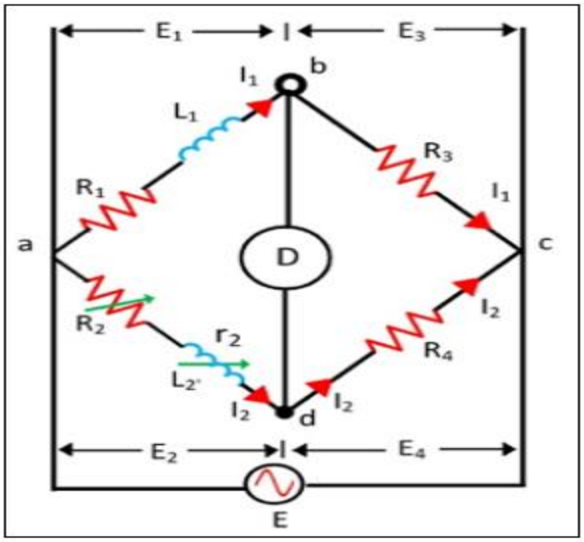
(b) Static Type

Working of Megger

The testing voltage is usually 500, 1000 or 2500 V which is generated by the hand driven generator. The generator has centrifugal clutch due to which the generator supplied the constant for the insulation test. The constant voltage is used for testing the insulation having low resistance. The Megger has three coils two pressure coils and one current coil. The pressure coil rotates the moving coil in the anticlockwise direction, whereas the current coil rotates it in the clockwise direction. When the unknown resistance is connected in the circuit, the pointer of the moving coil becomes stable. The pressure coil and the current coil balance the pointer and set it in the middle of the scale.

The deflection of the pointer is directly proportional to the voltage applied to the external circuit. When the testing circuit is applied across the Megger, and if there is no shorting throughout the insulation then the pointer deflects towards the infinity. Which shows that the resistance has high insulation. For low resistance, the pointer moves towards zero.

MAXWELL’S INDUCTANCE AND CAPACITANCE METER



A Maxwell bridge is a modification to a Wheatstone bridge used to measure an unknown inductance (usually of low Q value) in terms of calibrated resistance and inductance or resistance and capacitance. When the calibrated components are a parallel resistor and capacitor, the bridge is known as a Maxwell-Wien bridge. It is named for James C. Maxwell, who first described it in 1873.

It uses the principle that the positive phase angle of an inductive impedance can be compensated by the negative phase angle of a capacitive impedance when put in the opposite arm and the circuit is at resonance; i.e., no potential difference across the detector (an AC voltmeter or ammeter)) and hence no current flowing through it. The unknown inductance then becomes known in terms of this capacitance.

$$R_3 = \frac{R_1 \cdot R_4}{R_2}$$
$$L_3 = R_1 \cdot R_4 \cdot C_2$$

To avoid the difficulties associated with determining the precise value of a variable capacitance, sometimes a fixed-value capacitor will be installed and more than one resistor will be made variable.

It cannot be used for the measurement of high Q values. It is also unsuited for the coils with low Q values, less than one, because of balance convergence problem. Its use is limited to the measurement of low Q values from 1 to 10.

$$Q = \frac{\omega L}{R}$$

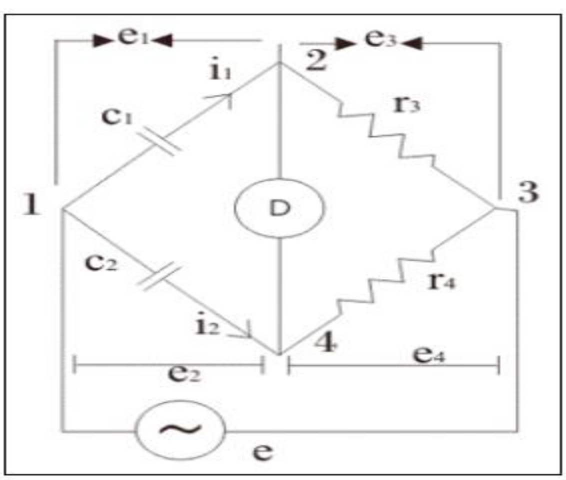
The frequency of the AC current used to assess the unknown inductor should match the frequency of the circuit the inductor will be used in - the impedance and therefore the assigned inductance of the component varies with frequency.

For ideal inductors, this relationship is linear, so that the inductance value at an arbitrary frequency can be calculated from the inductance value measured at some reference frequency. Unfortunately, for real components, this relationship is not linear, and using a derived or
calculated value in place of a measured one can lead to serious inaccuracies.

A practical issue in construction of the bridge is mutual inductance: two inductors in propinquity will give rise to mutual induction: when the magnetic field of one intersects the coil of the other, it will reinforce the magnetic field in that other coil, and vice versa, distorting the inductance of both coils. To minimize mutual inductance, orient the inductors with their axes perpendicular to each other, and separate them as far as is practical. Similarly, the nearby presence of electric motors, chokes and transformers (like that in the power supply for the bridge!) may induce mutual inductance in the circuit components, so locate the circuit remotely from any of these. The frequency dependence of inductance values gives rise to other constraints on this type of bridge: the calibration frequency must be well below the lesser of the self-resonance frequency of the inductor and the self-resonance frequency of the capacitor, Fr < min(Lsrf,Csrf)/10. Before those limits are approached, the ESR of the capacitor will likely have significant effect, and have to be explicitly modeled. For ferromagnetic core inductors, there are additional constraints. There is a minimum magnetization current required to magnetize the core of an inductor, so the current in the inductor branches of the circuit must exceed the minimum, but must not be so great as to saturate the core of either inductor.

The additional complexity of using a Maxwell-Wien bridge over simpler bridge types[ambiguous] is warranted in circumstances where either the mutual inductance between the load and the known bridge entities, or stray electromagnetic interference, distorts the measurement results. The capacitive reactance in the bridge will exactly oppose the inductive reactance of the load when the bridge is balanced, allowing the load's resistance and reactance to be reliably determined.

DESAUTY'S AND SCHERING BRIDGE



De Sauty Bridge

This bridge provide us the most suitable method for comparing the two values of capacitor if we neglect dielectric losses in the bridge circuit. The circuit of De

Sauty’s bridge is shown Battery is applied between terminals marked as 1 and 4. The arm 1-2 consists of capacitor c1 (whose value is unknown) which

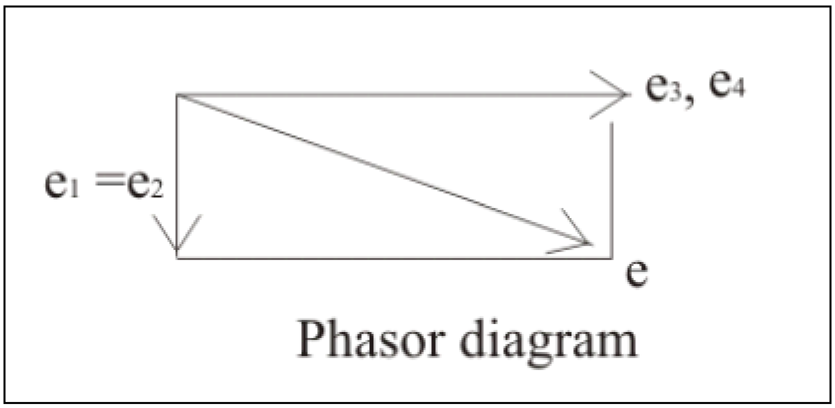
carries current i1 as shown, arm 2-4 consists of pure resistor (here pure resistor means we assuming it non inductive in nature), arm 3-4 also consists of pure resistor and arm 4-1 consists of standard capacitor whose value is already known to us. Let us derive the expression for capacitor c1 in terms of standard

capacitor and resistors. At balance condition we have, In order to obtain the balance point we must adjust the values of either r3 or r4 without disturbing any other element of the bridge.

This is the most efficient method of comparing the two values of capacitor if all the dielectric losses are neglected from the circuit. Now let us draw and study the phasor diagram of this bridge.

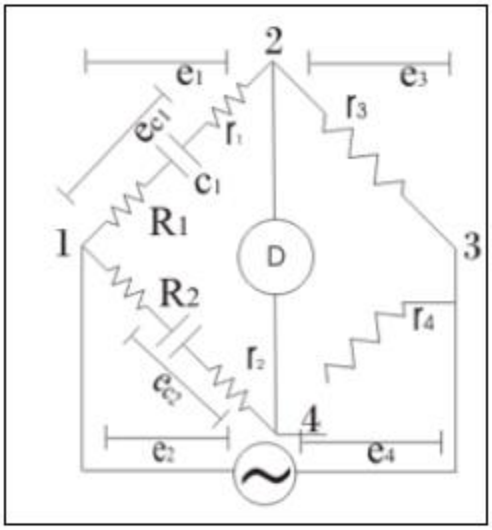
$$\frac{1}{j\omega c_1} \times r_4 = \frac{1}{j\omega c_2} \times r_3$$

Phasor diagram of De Sauty bridge is shown below:



Let us mark the current drop across unknown capacitor as e1, voltage drop across the resistor r3 be e3, voltage drop across arm 3-4 be e4 and voltage drop across arm 4-1 be e2. At balance condition the current flows through 2-4 path will be zero and also voltage drops e1 and e3 be equal to voltage drops

e2 and e4 respectively. In order to draw the phasor diagram we have taken e3 (or e4) reference axis, e1 and e2 are shown at right angle to e1 (or e2). Why they are at right angle to each other? Answer to this question is very simple as capacitor is connected there, therefore phase difference angle obtained is 90o. Now instead of some advantages like bridge is quite simple and provides easy calculations, there are some disadvantages of this bridge because this bridge give inaccurate results for imperfect capacitor (here imperfect means capacitors which not free from dielectric losses). Hence we can use this bridge only for comparing perfect capacitors. Here we interested in modify the De Sauty's bridge, we want to have such a kind of bridge that will gives us accurate results for imperfect capacitors also. This modification is done by Grover. The modified circuit diagram is shown below:



Here Grover has introduced electrical resistances r1 and r2 as

shown in above on arms 1-2 and 4-1 respectively, in order to

include the dielectric losses. Also he has connected resistances R1

and R2 respectively in the arms 1-2 and 4-1. Let us derive the

expression capacitor c1 whose value is unknown to us. Again we

connected standard capacitor on the same arm 1-4 as we have done

in De Sauty's bridge. At balance point on equating the voltage

drops we have:

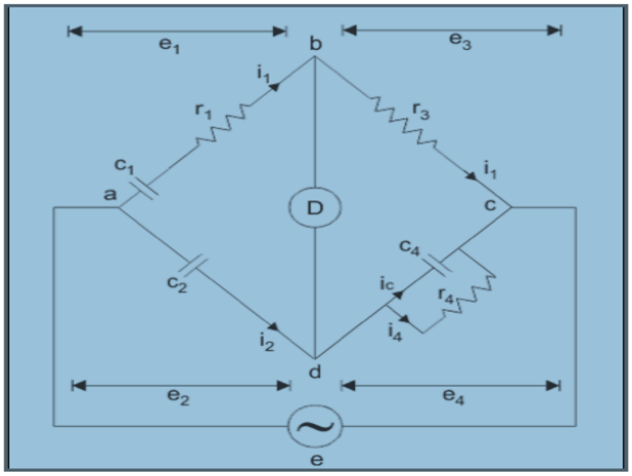
$$\left(R_1 + r_1 + \frac{1}{j\omega c_1}\right) r_4 \;=\; \left(R_2 + r_2 + \frac{1}{j\omega c_2}\right) r_3$$

On solving above equation we get:

$$\frac{c_1}{c_2} \;=\; \frac{R_2 + r_2}{R_1 + r_1} \;=\; r_4 r_3$$

Schering Bridge Theory

This bridge is used to measure to the capacitance of the capacitor, dissipation factor and measurement of relative permittivity. Let us consider the circuit of Schering bridge as shown below:



Here, c1 is the unknown capacitance whose value is to be determined with series electrical resistance r1. c2 is a standard capacitor. c4 is a variable capacitor. r3 is a pure resistor (i.e. non inductive in nature). And r4 is a variable non inductive resistor connected in parallel with variable capacitor c4. Now the supply is given to the bridge between the points a and c. The detector is connected between b and d. From the theory of ac bridges we have at balance condition, Let us consider the phasor diagram of the above Shering bridge circuit and mark the voltage drops across ab,bc,cd and ad as e1, e3,e4 and e2 respectively. From the above Schering bridge phasor diagram, we can calculate the value of tanδ which is also called the dissipation factor.

$$tan\delta = \omega c_1 r_1 = \omega \frac{c_2 r_4}{r3} \times \frac{r_3 c_4}{c_2} = \omega c_4 r_4$$

The bridge arms ab and ad consists of only capacitors as shown the bridge given below and impedances of these two arms are quite large as compared to the impedances of bc and cd. The arms bc and cd contains resistor r3 and parallel combination of capacitor c4 and resistor r4 respectively. As impedances of bc and cd are quite small therefore drop across bc and cd is small. The point c is earthed, so that the voltage across bc and dc are few volts above the point c. The high voltage supply is obtained from a transformer 50 Hz and the detector in this bridge is a vibration galvanometer.

The impedances of arms ab and ad very are large therefore this circuit draws low current hence power loss is low but due to this low current we need a very sensitive detector to detect this low current.

The fixed standard capacitor c2 has compressed gas which works as dielectric therefore dissipation factor can be taken as zero for compressed air. Earthed screens are placed between high and low arms of the bridge to prevent errors caused due to inter capacitance.

Let us study how Schering bridge measures relative permittivity: In order measure the relative permittivity, we need to first measure capacitance of a small capacitor with specimen as dielectric. And from this measured value of capacitance relative permittivity can calculated easily by using the very simple relation:

$$r = \frac{cd}{\epsilon A}$$

Where, r is relative permeability.

c is the capacitance with specimen as dielectric.

d is the spacing between the electrodes.

A is the net area of electrodes.

and ε is permittivity of free space.

INSTRUMENT TRANSFORMER

Instrument transformers are high accuracy class electrical devices used to isolate or transform voltage or current levels. The most common usage of instrument transformers is to operate instruments or metering from high voltage or high current circuits, safely isolating secondary control circuitry from the high voltages or currents. The primary winding of the transformer is connected to the high voltage or high current circuit, and the meter or relay is connected to the secondary circuit.

Instrument transformers may also be used as an isolation transformer so that secondary quantities may be used in phase shifting without affecting other primary connected devices.

Current transformer

Current transformers (CT) are a series connected type of instrument transformer. They are designed to present negligible load to the supply being measured and have an accurate current ratio and phase relationship to enable accurate secondary connected metering. Current transformers are often constructed by passing a single primary turn (either an insulated cable or an uninsulated bus bar) through a well-insulated toroidal core wrapped with many turns of wire. This affords easy

implementation on high voltage bushings of grid transformers and other devices by installing the secondary turn core inside high-voltage bushing insulators and using the pass-through conductor as a single turn primary. A current clamp uses a current transformer with a split core that can be easily wrapped around a conductor in a circuit. This is a common method used in portable current measuring instruments but permanent installations use more economical types of current transformer. Specially constructed wideband CTs are also used, usually with an oscilloscope, to measure high frequency waveforms or pulsed currents within pulsed power systems. One type provides an IR voltage output that is proportional to the measured current; another, called a Rogowski coil, requires an external integrator in order to provide a proportional output.

Ratio

The CT is typically described by its current ratio from primary to secondary. A 1000:5 CT will provide an output current of 5 amperes when 1000 amperes are flowing through its primary winding. Standard secondary current ratings are 5 amperes or 1 ampere, compatible with standard measuring instruments. It is used to step down current for metering purposes for the safety of the equipments as well as operator.

Burden and accuracy

Burden and accuracy are usually stated as a combined parameter due to being dependent on each other.

Metering style CTs are designed with smaller cores and VA capacities. This causes metering CTs to saturate at lower secondary voltages saving sensitive connected metering devices from damaging large fault currents in the event of a primary electrical fault. A CT with a rating of 0.3B0.6 would indicate with up to 0.6 ohms of secondary burden the secondary current will be within a 0.3 percent error parallelogram on an accuracy diagram incorporating both phase angle and ratio errors.

Relaying CTs used for protective circuits are designed with larger cores and higher VA capacities to ensure secondary measuring devices have true representations with massive grid fault currents on primary circuits. A CT with a rating of 2.5L400 would indicate it can produce a secondary voltage to 400 volts with a secondary current of 100 amperes (20 times its rated 5 ampere rating) and still be within 2.5 amperes of true accuracy. Care must be taken that the secondary winding of a CT is not disconnected from its low-impedance load while current flows in the primary, as this may produce a dangerously high voltage across the open secondary (especially in a relaying type CT) and could permanently affect the accuracy of the transformer.

Voltage transformer or potential transformer

Voltage transformers (VT), also called potential transformers (PT), are a parallel connected type of instrument transformer. They are designed to present negligible load to the supply being measured and have an accurate voltage ratio and phase relationship to enable accurate secondary connected metering.

Ratio

The PT is typically described by its voltage ratio from primary to secondary. A 600:120 PT will provide an output voltage of 120 volts when 600 volts are impressed across its primary winding. Standard secondary voltage ratings are 120 volts and 70 volts, compatible with standard measuring instruments.

Burden and accuracy

Burden and accuracy are usually stated as a combined parameter due to being dependent on each other. Metering style PTs are designed with smaller cores and VA capacities than power transformers. This causes metering PTs to saturate at lower secondary voltage outputs saving sensitive connected metering devices from damaging large voltage spikes found in grid disturbances. A small PT (see nameplate in photo) with a rating of 0.3W, 0.6X would indicate with up to W load (12.5 watts) of secondary burden the secondary current will be within a 0.3 percent error parallelogram on an accuracy diagram incorporating both phase angle and ratio errors. The same technique applies for the X load (25 watts) rating except inside a 0.6% accuracy parallelogram.

Markings

Some transformer winding primary (usually high-voltage) connecting wires are of many types. may be labeled as H1, H2 (sometimes H0 if it is internally designed to be grounded) and X1, X2 and sometimes an X3 tap may be present. Sometimes a second isolated winding (Y1, Y2, Y3) (and third (Z1, Z2, Z3) may also be available on the same voltage transformer. The primary may be connected phase to ground or phase to phase. The secondary is usually grounded on one terminal to avoid capacitive induction

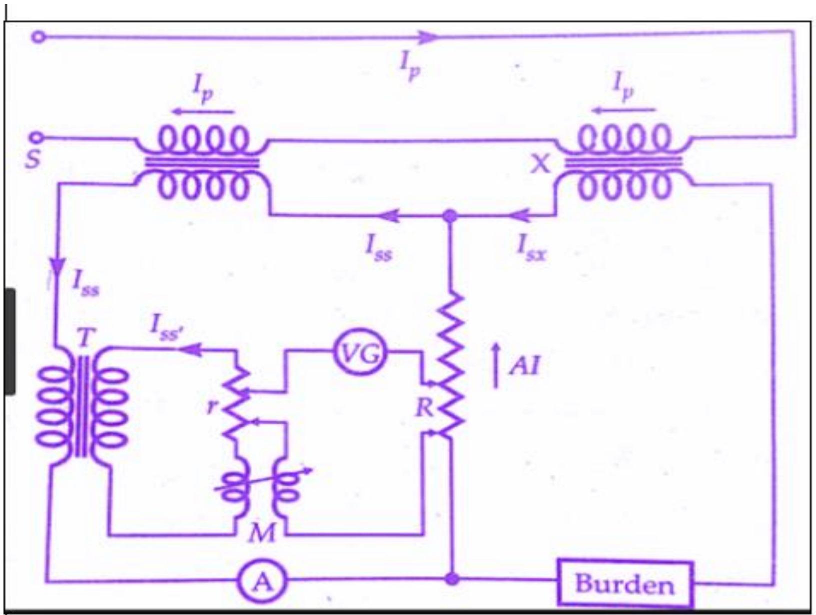
from damaging low-voltage equipment and for human safety.

Types of PTs

There are three primary types of potential transformers (PT):

electromagnetic, capacitor, and optical. The electromagnetic potential transformer is a wire-wound transformer. The capacitor voltage transformer (CVT) uses a capacitance potential divider and is used at higher voltages due to a lower cost than an electromagnetic PT. An optical voltage transformer exploits the Faraday effect, rotating polarized light, in optical materials.

Current Transformer Test Set (Silsbee's Method)



Testing of Current Transformer

There are three methods:

1. Mutual Inductance method: This is an absolute method using null deflection.

2. Silsbee's Method: This is a comparison method. There are two types; deflectional and null.

3. Arnold's Method: This is a comparison method involving null techniques.

Silsbee's Method: The arrangement for Silsbee's deflectional method is shown in Fig.1. Here the ratio and phase angle of the test transformer 'X' are determined in terms of that of a standard transformer 'S' having the same nominal ratio Procedure:

The two transformers are connected with their primaries in series. An adjustable burden is put in the secondary circuit of the transformer under test. An ammeter is included in the secondary circuit of the standard transformer so that the current may be set to desired value. W1 is a wattmeter whose current coil is connected to carry the secondary current of the standard transformer. The current coil of wattmeter W2 carries a current I which is the difference between the secondary currents of the standard and test transformer. The voltage circuits of wattmeters are supplied in parallel from a phase shifting transformer at a constant voltage V.

1. The phase of the voltage is so adjusted that wattmeter W1 reads zero. Under these conditions voltage V is in quadrature with current I_{ss} . The position of voltage phasor for this case is shown as V_q .

Reading of wattmeter, W1 $W_{1q} = V_q I_{ss} \cos 90° = 0$. Reading of wattmeter, W2

$W_{2q} = V_q \times$ component of current I in phase with $V_q = V_q I_q = V_q I_{sx} \sin (\theta_x - \theta_s)$

Where θ_x = phase angle of C.T. under test, θ_s = phase angle of standard C.T.

$= W_{1p} - VI_{sx} \cos (\theta_x - \theta_s) \approx W_{1p} - VI_{sx}$

As $(\theta_x - \theta_s)$ is very small and, therefore, $\cos (\theta_x - \theta_s) = 1$ For above, $VI_{sx} = W_{1p} - W_{2p}$.

Actual ratio of transformer under test $R_x = I_p / I_{sx}$. Actual ratio of standard transformer $R_s = I_p / I_{ss}$.

The phase of voltage V is shifted through 90° so that it occupies a position VP and is in phase with Iss .

Reading of wattmeter W1, W1p = Vp Iss cos θ = Vp Iss.

DOMESTIC WIRING

Introduction

A network of wires drawn connecting the meter board to the various energy consuming loads (lamps, fans, motors etc) through control and protective devices for efficient distribution of power is known as electrical wiring.

Electrical wiring done in residential and commercial buildings to provide power for lights, fans, pumps and other domestic appliances is known as domestic wiring. There are several wiring systems in practice. They can be classified into:

Types of wiring: Depending upon the above factors various types of wiring used in practice are:

1. Cleat wiring
2. Casing wiring
3. Surface wiring
4. Conduit wiring

i) Clear wiring:

In this type V.I.R or P.V.C wires are clamped between porcelain cleats.

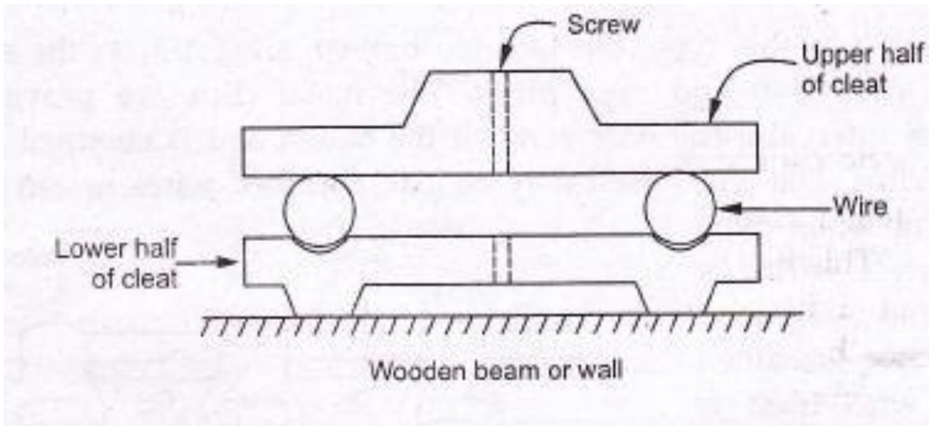


Fig. 16 Cleat wiring

The cleats are made up of two halves. One half is grooved through which wire passes while the other fits over the first. The whole assembly is then mounted on the wall or wooden beam with the help of screws.

This method is one of the cheapest method and most suitable for temporary work. It can be very quickly installed and can be recovered without any damage of material. Inspection and changes can be made very easily.

This method does not give attractive appearance. After some time due to sagging at some places, it looks shabby. Dust and dirt collects on the cleats. The wires are directly exposed to atmospheric conditions like moisture, chemical fumes etc. maintenance cost is very high.

Due to these disadvantages this type is not suitable for permanent jobs.

ii) Casing capping: This is very popularly used for residential buildings. In this method, casing is a rectangular strip made from teak wood or new a day‟s made up of P.V.C. It has two grooves into which the wires are laid. Then casing is covered with a rectangular strip of wood or P.V.C. of the same width, called capping. The capping is screwed into casing is fixed to the walls the help or porcelain discs or cleats.

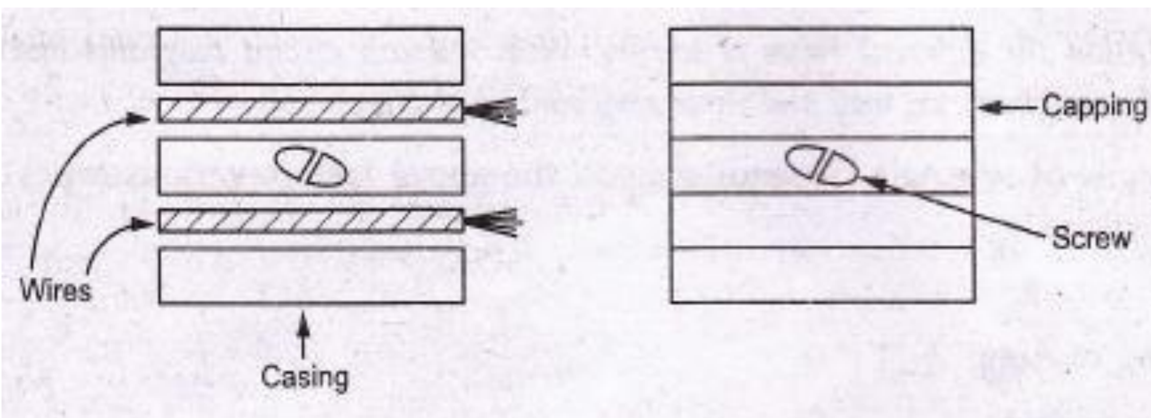


Fig. 17 Casing capping

Good protection to the conductors from dangerous atmospheric conditions, neat and clean appearance are the advantages of this type.

In case of wooden casing capping, there is high risk of fire along with the requirement of skilled labour. The method is costly.

Surface wiring: in this type, the wooden battens are fixed on the surface of the wall, by means of screws and rawl plugs. The metal clips are provided with the battens at regular intervals. The wire runs on the batten and is clamped on the batten using the metal clips. The wires used may lead sheathed wires or can tyre sheathed wires. Depending upon type of wire used surface wiring is also called lead sheathed wiring or cab tyre sheathed wiring. If the wire used is though rubber Sheathed then it is called T.R.S. wiring while if the wire used is cab tyre Sheathed Then it is called C.T.S wiring.

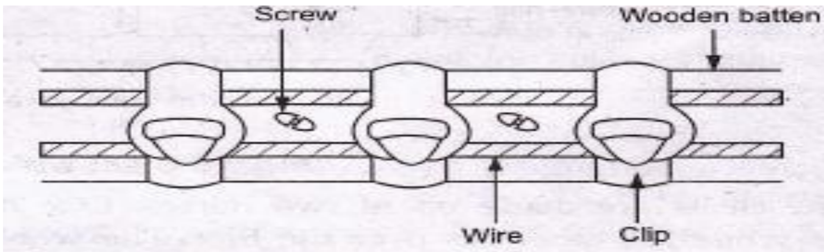


Fig. 18 Wooden batten wiring

Conduit wiring: In this method, metallic tubes called as conduits are used to run the wires. This is the best system of wiring as it gives full mechanical protection to the wires. This is most desirable for workshops and public Buildings. Depending on whether the conduits are laid inside the walls or supported on the walls, there are two types of conduit wiring which are :

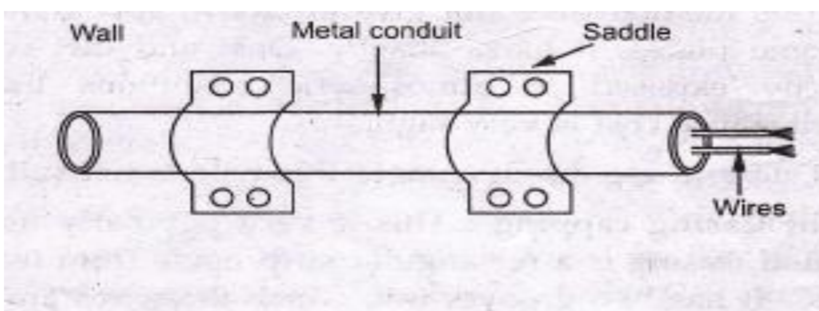


Fig. 19 Surface conduit wiring

i) Surface conduit wiring: in this method conduits are mounted or supported on the walls with the help of pipe books or saddles. In damp situations, the conduits are spaced apart from the wall by means of wooden blocks.

ii) Concealed conduit wiring: In this method, the conduit are buried under the wall at the some of plastering. This is also called recessed conduit wiring.

The beauty of the premises is maintained due to conduit wiring. It is durable and has long life. It protects the wires from mechanical shocks and fire hazards. Proper earthing of conduits makes the method electrical shock proof. It requires very less maintenance.

The repairs are very difficult in case of concealed conduit wiring. This method is most costly and erection requires highly skilled labour. These are few disadvantages of the conduit type of wiring. In concealed conduit wiring, keeping conduit at earth potential is must.

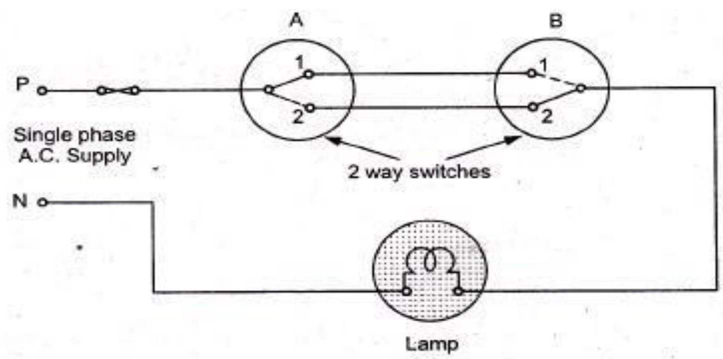


Fig. 20 Control of one from two points

FACTORS AFFECTING THE CHOICE OF WIRING SYSTEM:

The choice of wiring system for a particular installation depends on technical factors and economic viability.

1. Durability: Type of wiring selected should conform to standard specifications, so that it is durable i.e. without being affected by the weather conditions, fumes etc.

2. Safety: The wiring must provide safety against leakage, shock and fire hazards for the operating personnel.

3. Appearance: Electrical wiring should give an aesthetic appeal to the interiors.

<u>4.</u> <u>Cost</u>: It should not be prohibitively expensive.

<u>5.</u> <u>Accessibility</u>: The switches and plug points provided should be easily accessible. There must be provision for further extension of the wiring system, if necessary.

6 <u>Maintenance Cost</u>: The maintenance cost should be a minimum

7. <u>Mechanical safety</u>: The wiring must be protected against any mechanical damage

Specification of Wires:

The conductor material, insulation, size and the number of cores, specifies the electrical wires. These are important parameters as they determine the current and voltage handling capability of the wires. The conductors are usually of either copper or aluminum. Various insulating materials like PVC, TRS, and VIR are used. The wires may be of single strand or multi strand. Wires with combination of different diameters and the number of cores or strands are available.

For example: The VIR conductors are specified as 1/20, 3/22,….7/20 ………

The numerator indicates the number of strands while the denominator corresponds to the diameter of the wire in SWG (Standard Wire Gauge). SWG 20 corresponds to a wire of diameter 0.914mm, while SWG 22 corresponds to a wire of diameter 0.737 mm.

A 7/0 wire means, it is a 7-cored wire of diameter 12.7mm (0.5 inch). The selection of the wire is made depending on the requirement considering factors like current and voltage ratings, cost and application.

Example: Application: domestic wiring

1. Lighting - 3/20 copper wire
2. Heating - 7/20 copper wire

The enamel coating (on the individual strands) mutually insulates the strands and the wire on the whole is provided with PVC insulation. The current carrying capacity depends on the total area of the wire. If cost is the criteria then aluminum conductors are preferred. In that case, for the same current rating much larger diameter of wire is to be used.

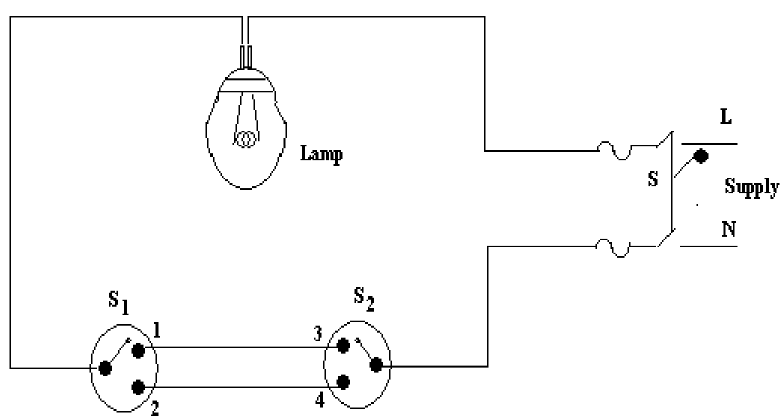
Two- way and Three- way Control of Lamps:

The domestic lighting circuits are quite simple and they are usually controlled from one point. But in certain cases it might be necessary to control a single lamp from more than one point (Two or Three different points).

For example: staircases, long corridors, large halls etc.

Two-way Control of lamp:

Two-way control is usually used for staircase lighting. The lamp can be controlled from two different points: one at the top and the other at the bottom - using two- way switches which strap wires interconnect. They are also used in bedrooms, big halls and large corridors. The circuit is shown in the following figure.



Two -way control of lamp

Switches S_1 and S_2 are two-way switches with a pair of terminals 1&2, and 3&4 respectively. When the switch S_1 is in position**1** and switch S_2 is in position **4**, the circuit does not form a closed loop and there is no path for the current to flow and hence the lamp will be **OFF.** When S_1 is changed to position **2** the circuit gets completed and hence the lamp glows or is **ON**. Now if S_2 is changed to position **3** with S_1 at position **2** the circuit continuity is broken and the lamp is off. Thus the lamp can be controlled from two different points.

Position of S1	Position of S2	Condition of lamp
1	3	ON
1	4	OFF
2	3	OFF
2	4	ON

Three- way Control of lamp:

In case of very long corridors it may be necessary to control the lamp from 3 different points. In such cases, the circuit connection requires two; two-way switches $\mathbf{S_1}$and $\mathbf{S_2}$ and an intermediate switch $\mathbf{S_3}$. An intermediate switch is a combination of two, two way switches coupled together. It has 4 terminals ABCD. It can be connected in two ways

a) Straight connection

b) Cross connection

In case of straight connection, the terminals or points AB and CD are connected as shown in figure 1(a) while in case of cross connection, the terminals AB and

C D is connected as shown in figure 1(b). As explained in two –way control the lamp is ON if the circuit is complete and is OFF if the circuit does not form a closed loop.

Three -way control of lamp

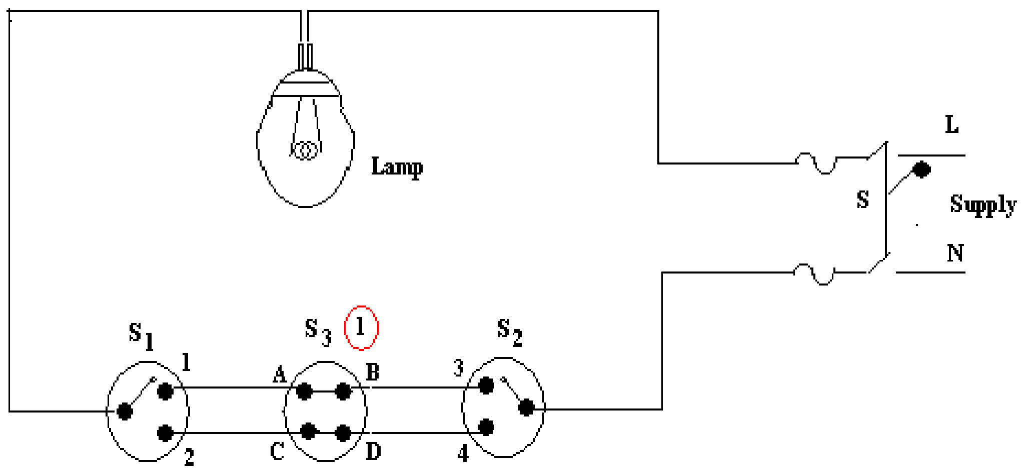


Figure 1 (a) Straight connection

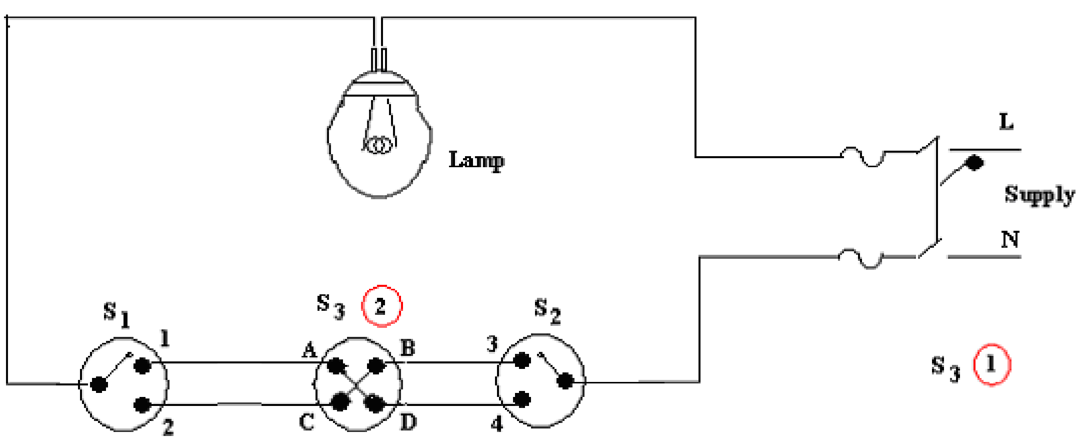


Figure 1 (b) Cross connection

The condition of the lamp is given in the table depending on the positions of the switches $\mathbf{S_1}$, $\mathbf{S_2}$ and $\mathbf{S_3}$.

POSITION OF SWITCH-1	POSITION OF INTERMEDIATE SWITCH	POSITION OF SWITCH-2	CONDITION OF LAMP
A	EF,GH	C	ON
A	EF,GH	D	OFF
B	EF,GH	C	OFF
B	EF,GH	D	ON
A	EH,GF	C	OFF
A	EH,GF	D	ON
B	EH,GF	C	ON
B	EH,GF	D	OFF