GOVERNMENT ARTS AND SCIENCE COLLEGE
NAGERCOIL – 629 004

[Affiliated to Manonmaniam Sundaranar University, Tirunelveli – 12]

DEPARTMENT OF PHYSICS

COURSE MATERIAL

NAME OF THE SUBJECT : Skill Based Subject – MAINTENANCE OF ELECTRICAL APPLIANCES

SUBJECT CODE : SSPH3A

YEAR : II B.Sc. PHYSICS

SEMESTER : III

STAFF IN-CHARGE : Dr. JAIN JOHN
ASSISTANT PROFESSOR
DEPARTMENT OF PHYSICS
Government Arts and Science College NAGERCOIL.
Email : stanjain@gmail.com
Mobile No.:8220769969

MAINTANANCE OF ELECTRICAL APPLIANCES

Preamble:This course enable the students to understand the operations and safety handling of certain commonly used domestic appliances. The paper needs a basic knowledge in electricity and magnetism and the learners are expected to gain knowledge to design and trouble shoot electrical circuits

. **UNIT-I**: Resistance - capacitance - inductance and its units - electrical charge - current - potential - units and measuring meters - Ohm's law - Galvanometer, ammeter, voltmeter and multimeter. Electrical energy - power - watt - kWh - consumption of electrical power. (12L)

UNIT-II: Transformer - principle and working - classification of transformers - testing of transformers - Core, Shell and Berry types, auto transformer - construction and uses. Cooling of transformers - Losses in transformer.(10)

Unit-III: Electric bulbs – Fluorescent lamps - Street Lighting - Electric Fans - Wet Grinder – Mixer - Water Heater - Storage and Instant types-electric iron boxmicrowave oven - Washing Machine - Stabilizer, Fridge and Air conditioner. (13L) Page 43 of 54

UNIT-IV: AC and DC- Single phase and three phase connections - RMS and peak values-house wiring - Star and delta connection - overloading - earthing - short circuiting - colour code for insulation wires (13L)

UNIT-V: Electrical protection - Relays - Fuses - Electrical switches - Circuit breakers-ELCB - overload devices - ground fault protection - Inverter - UPS - generator and motor(12L)

Books for study and Reference

1. A text book in Electrical Technology - B L Theraja - S Chand & Co.
2. A text book of Electrical Technology - A K Theraja
3. Performance and design of AC machines - M G Say ELBS Edn.
4. Semi conductor physics and opto electronics by P K Palanichamy
5. Basic Electronics - B L Theraja - S Chand & Co.
6. Principles of Communication Engineering - Arokh Singh and A K Chhabra - S Chand & Co

UNIT-I

Resistance - capacitance - inductance and its units - electrical charge - current - potential - units and measuring meters - Ohm's law - Galvanometer, ammeter, voltmeter and multimeter. Electrical energy - power - watt - kWh - consumption of electrical power

Resistor

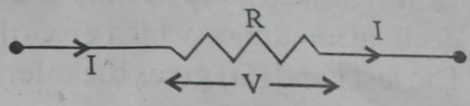


Fig. 3

Resistor is one of the three fundamental passive circuit elements. (The other two are the capacitor and inductor). Resistors are used to control current in a circuit. The resistance of a resistor, by ohm's law is $R = \frac{V}{I}$ where V is the voltage across the resistor and I is the current passing through it. When V is in volt, I is in ampere, R is in ohm. At constant temperature, the ratio $\frac{V}{I}$ is constant. Hence the (I-V) graph for a resistor is a straight line (linear).

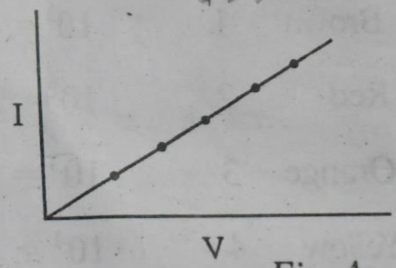
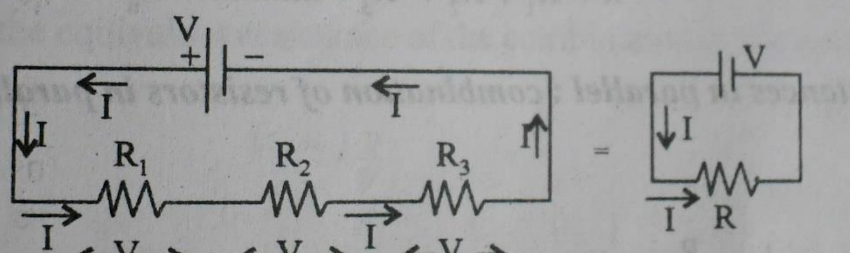


Fig. 4

The resistance R of a resistor depends not only on the specific resistance ρ (resistivity) of the material, but also on the geometry (length l, area of crossection A). The relation between these is given by

$$R = \rho \times \left(\frac{l}{A}\right)$$

Resistances in series : Combination of resistors in series :



$R = R_1 + R_2 + R_3$

Fig. 4 *Resistances in series*

Figure shows three resistors R_1, R_2 and R_3 connected in series with a battery of cells of voltage V. We can apply Ohm's law to find the value of a single resistance R, equivalent to the combination of resistors in series.

The voltage V produces a current I in the circuit. The current in each resistor is the same I. Then,

By Kirchoff's law, $$V = V_1 + V_2 + V_3 \quad .....(1)$$

If R is the single resistance, equivalent to the three resistors in series such that the same current I flows in the circuit then

$$V = IR \quad ... ...(2)$$

By equations (1) and (2),

$$V_1 + V_2 + V_3 = IR$$

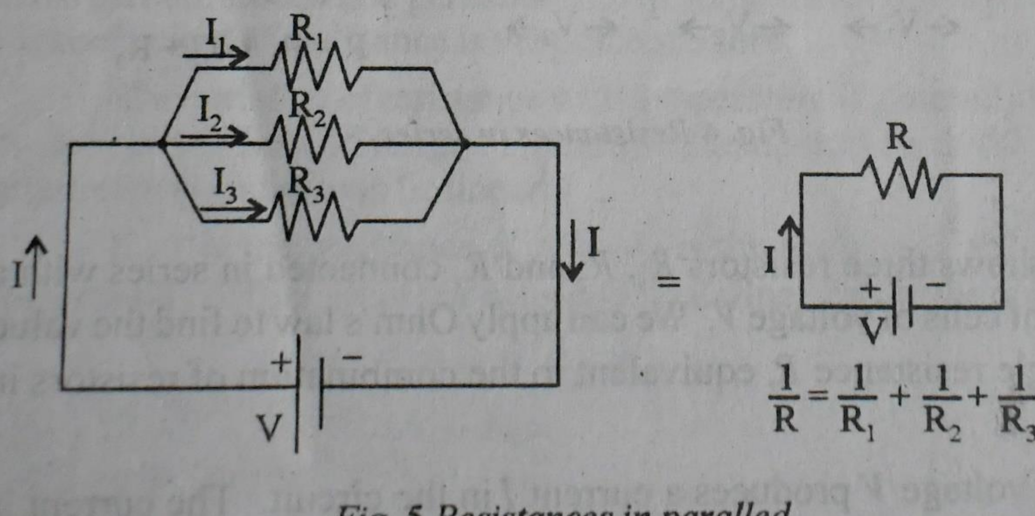
$$IR_1 + IR_2 + IR_3 = IR.$$

$$\therefore R = R_1 + R_2 + R_3$$

This gives the effective resistance of combiration of three resistors in series. If n resistors are in series, then

$$R = R_1 + R_2 + R_3 + ...+ R_n$$

2. *Resistances in parallel* : *combination of resistors in parallel*



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Fig. 5 Resistances in paralled

Figure shows three resistors R_1, R_2 and R_3 connected in parallel. The combination is connected across a battery of cells of voltage V. We can apply Ohm's law to find the value of a single resistance, equivalant to the combination of resistors in parallel.

The voltage V produces a current I in the circuit. The main current (I) divides into branch current I_1 through R_1, I_2 through R_2 and I_3 through R_3. The voltage across each resistor is the same and it is equal to V.

By Ohm's law,

$$V = I_1 R_1 \qquad \therefore I_1 = \frac{V}{R_1}$$

Also, $$V = I_2 R_2 \qquad \therefore I_2 = \frac{V}{R_2}$$

And $$V = I_3 R_3 \qquad \therefore I_3 = \frac{V}{R_3}$$

The total main current $I = I_1 + I_2 + I_3$

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \qquad \text{......(1)}$$

If R is the equivalent resistance of the combination of the resistors in parallel,

$$V = IR$$

$$\therefore I = \frac{V}{R} \qquad \text{......(2)}$$

From equations (1) and (2),

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\therefore \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

TYPES OF RESISTORS

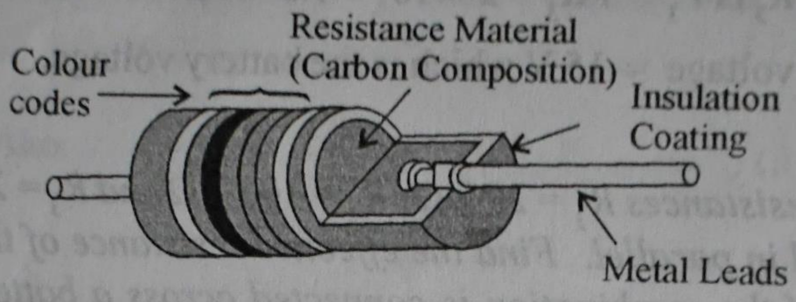


Fig. 6 Carbon composition resistor

1. Carbon - composition resistor : In this type the resistive element consists of a cylinder formed from a mixture of carbon and various impurities. The resistivity of the element is determined by the impurity content and it may be varied for a wide range of resistance. The cylinder is press-formed and it has wire leads, attached to each end. It is encapsulated in a high resistivity epoxy resin or similar material. The manufacture of the resistor is completed by coding with coloured bands (which we shall study later.)

2. *Wire - wound resistor*

The resistive element of wire - wound resistor consists of a length (*L*) of a wire of resistivity (ρ) and crossectional area *A*, wound on a spool. Wire leads of much larger diameter are attached to each end of the resistive element. The assembly is then encapulated. The resistance value is marked on the resistor.

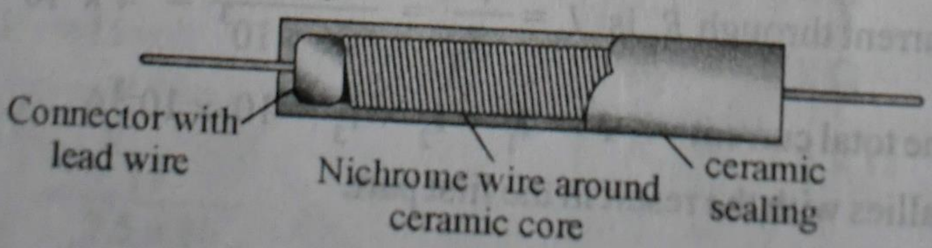


Fig. 7 Wire wound resistor

3. The deposited - film resistor makes use of very thin film of metal as its resistive element. The film is deposited on a glass (or ceramic) cylinder and provided with gold metal caps, with leads attached, are soldered to the film at each end. The unit is then encapsulated in epoxy resin. The reistance values are marked.

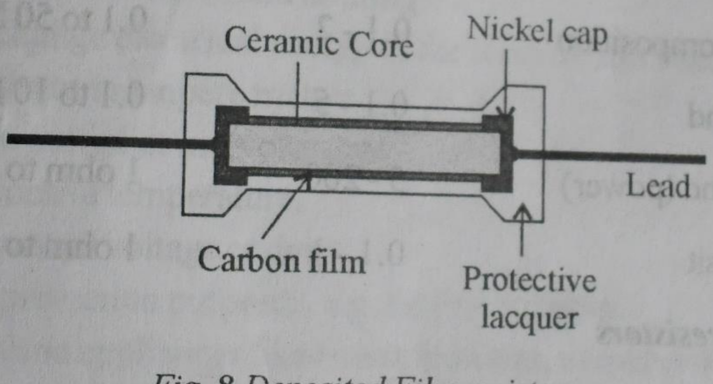


Fig. 8 Deposited Film resistor

4. Fusible Resistors : These kinds of resistors are same like wire wound resistor. When a circuit power rating increased than the specified value, then this resistor is fused, ie. breaks or open the circuit. Thus they limit the current and they can be used as a fuse.

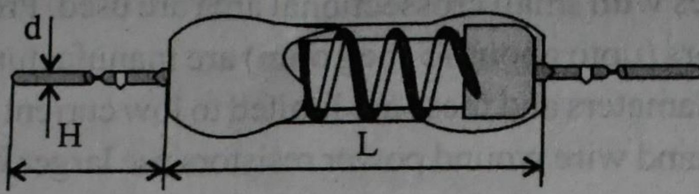


Fig. 9 Fusible resistor

Variable resistors

Resistors with variable resistances are useful in many appliances. There are two types of variable resistors.

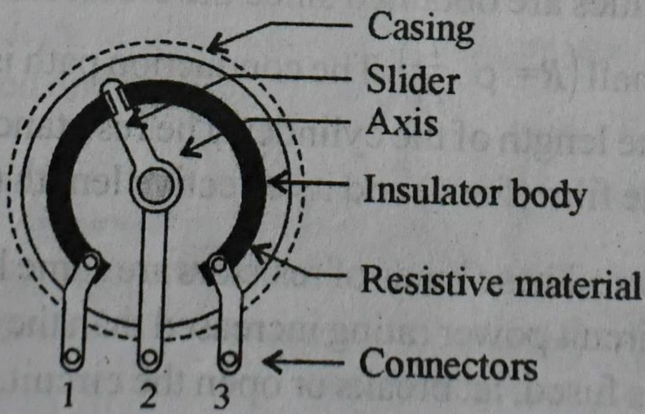


Fig. 10 Variable resistor

The linear variable resistor has a sliding contact, which may be moved along the resistive element maintaining good electrical contact.

The circular variable resistor (Fig) is essentialy the same as the linear type except that the resistive element is circular and the sliding contact is mounted on a shaft (rod) which may be rotated to change the contact position. The resistance between terminals *a* and *c* is constant but the resistance between a and b or b and c depends on the position of the sliding contact and so may be varied. If the terminals a, b and c are connected in a circuit the variable resistor is called potartiometer or simply a pot. If only a and b or b and c are used, then the unit is called a rheostat.

Uses of resistors : Resistors are used

1. for current control and limiting
2. to change electrical energy in the form of heat energy.
3. as shunt in ampere meters.
4. as a multiplier in a voltmeter.
5. to control temperature.
6. to control voltage or drop
7. for protection purposes, e.g. fusible resistors
8. in home appliances like heater, iron box, immersion rod etc.
9. in the electronics industries.

Multiples and submultiples of ohm (resistance)

1ohm	=	1 Ω
1×10^3ohm	=	1 kilo ohm (1kΩ)
1×10^6ohm	=	1 meg ohm (1MΩ)
1×10^9ohm	=	1 giga ohm (GΩ)
1×10^{-3}ohm	=	1 milli ohm (mΩ)
1×10^{-6}ohm	=	1 micro ohm (μΩ)
1×10^{-9}ohm	=	1 nano ohm (nΩ)

Temperature coefficient of resistance

In addition to geometry, the resistance is also a function of temperature (t) of the material of the conductor. For example, the tungsten filament in an electric bulb has a much higher resistance when it is hot than when it is in room temperature.

Some materials show increase of resistance with increasing temperature. A positive coefficient for a material means that its resistance increases with increase of temperature.

Some others show a decreasing resistance with increasing temperature (negative temperature coefficient). Temperature coefficient of resistance is positive for pure metals (Eg : Nickel, iron etc).

Temperature coefficient of resistance is negative for the elements carbon, silicon and germanium. For some metal alloys, temperature coefficient of resistance is very close to zero.

Ohm's Law

At constant temperature, the current in a conductor is directly proportional to the potential difference between the ends of the conductor. This is Ohm's law.

i.e $I \propto V$

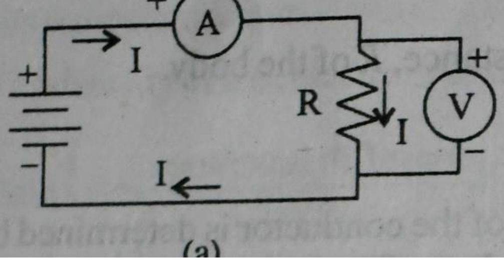
$I = G.V$ where G is the conductance of the material.

$\therefore I = \frac{V}{R}$ But $G = \frac{1}{R}$

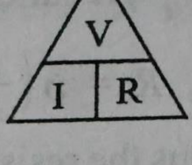
or $V = IR$

When I is in ampere; and V is in volt; R is in ohm.

This relation expresses Ohm's law.



(a)



(b) Ohm's triangle

2. Inductor (inductance coil)

An inductor is just a coil of wire wound around some kind of core. The core could be just air or it could be a magnetic material. It stores electrical energy in a magnetic field when electric current is flowing through it.

Inductor is a passive element used for controlling current in A.C. circuits. Inductance is a basic propecty of the inductor. It is purely a magnetic property in the same way as capacitance is an electrical property and resistance is a property of the material of the resistor and its geometry.

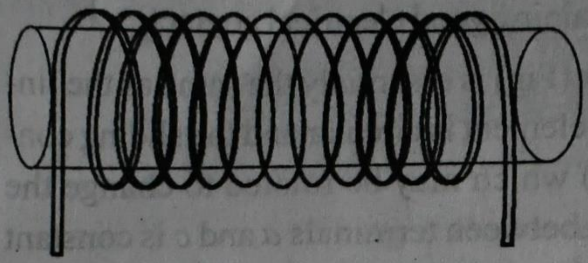


Fig. 11 (a) *Inductance coil (solenoidal type)*

Fig. 11 (b) *Inductance coil (toroidal type)*

The inductance coil may be in different forms : solenoidal or toroidal form. When an inductance coil is connected in an A.C. circuit, the magnetic flux linked with the coil (in each turn) is changed. Whenever there is flux change in the coil, a back e.m.f or induced e.m.f (due to Lenz's law of electro magnetic induction) is produced. The back e.m.f opposes the changing current and A.C. in the circuit is controlled.

The induced e.m.f (e) at any instant is directly proportional to the rate of change of current at that instant.

$$e \propto -\frac{di}{dt} \quad \text{..... (the induced e.m.f opposes the change)}$$

$$e = -L\frac{di}{dt}$$

where L is a constant, which depends on the geometry of the coil and the core of the coil.

$$\therefore L = \frac{e}{-\left(\frac{di}{dt}\right)}$$

The constant L is called self inductance or simply inductance of the coil.

Effective inductance of combination of inductances in series.

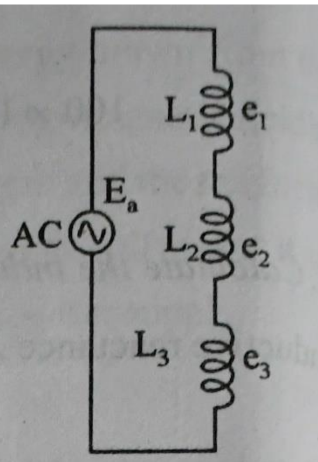


Fig. 15 Combination of inductances in series

Figure shows three inductances L_1, L_2 and L_3 connected in series with a *A.C* source of e.m.f. E_a.

Let us assume that the coils are sufficiently separated from one another so that the magnetic flux of each does not pass through the turns of the other two. i.e., the coils are magnetically independent.

Let the applied A.C voltage be E_a at any instant. It induces e.m.f in the coils. Let the induced e.m.f in L_1, L_2, and L_3 be E_1, E_2, E_3 respectively. At any instant of time, the applied voltage and the sum of induced e.m.fs are equal but opposite in direction.

$$E_a = -(E_1 + E_2 + E_3)$$

$$E_1 = -L_1 \frac{dI}{dt}$$

$$E_2 = -L_2 \frac{dI}{dt}$$

$$E_3 = -L_3 \frac{dI}{dt}$$

Since the current is common in all the elements,

$$E_a = L_1 \frac{dI}{dt} + L_2 \frac{dI}{dt} + L_3 \frac{dI}{dt}$$

Let L_{eq} be the effective inductance of the combination of the inductances. Then

$$E_a = -E_{induced}$$

$$= -\left(-L_{eq} \frac{dI}{dt}\right)$$

$$E_a = L_{eq} \frac{dI}{dt}$$

$$\therefore L_{eq} \frac{dI}{dt} = L_1 \frac{dI}{dt} + L_2 \frac{dI}{dt} + L_3 \frac{dI}{dt}$$

i.e., $$L_{eq} = L_1 + L_2 + L_3$$

…ors in series).

Combination of inductances in parallel

Figure shows a combination of three inductances L_1, L_2 and L_3 connected in parallel. Let us assure that the three inductors are magnetically shielded from one another so that the magnetic flux of each does not pass through the other two.

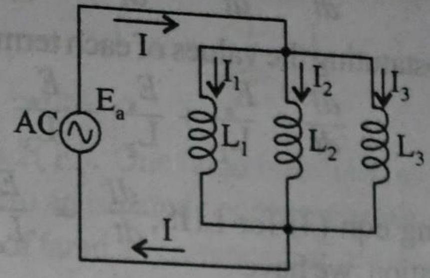


Fig. 16 Combination of inductances in Parallel

Let E_a be the applied voltage across the combination at any instant. Then the main current is

$I = I_1 + I_2 + I_3$ at any instant (The branch currents add to give I)

$$\frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt} + \frac{dI_3}{dt} \quad \text{.... .... (1)}$$

The changing current causes induced e.m.f in each element. If e_{1i}, e_{2i}, and e_{3i} be the induced e.m.fs in these elements,

$$e_{1i} = -L_1 \frac{dI_1}{dt}; \quad e_{2i} = -L_2 \frac{dI_2}{dt}; \quad e_{3i} = -L_3 \frac{dI_3}{dt}$$

$$\therefore \frac{dI_1}{dt} = -\frac{e_{1i}}{L_1}; \quad \frac{dI_2}{dt} = -\frac{e_{2i}}{L_2}; \quad \frac{dI_3}{dt} = -\frac{e_{3i}}{L_3}$$

The applied e.m.f and induced e.m.f are equal in magnitude but opposite indirection

i.e., $E_a = -e_i$

$$\therefore \frac{dI_1}{dt} = -\frac{1.E_a}{L_1}; \quad \frac{dI_2}{dt} = -\frac{1.E_a}{L_2}; \quad \frac{dI_3}{dt} = -\frac{1.E_a}{L_3} \quad \text{.... ... (2)}$$

If L_{eq} be the equivalant inductance of the combination of inductances in parallel, then

$$E_a = -e_i$$

Using eqn (3) for LHS, $\frac{dI}{dt} = \frac{E_a}{L_{eq}}$. Putting this value in the above equation, we have

$$\frac{E_a}{L_{eq}} = \frac{E_a}{L_1} + \frac{E_a}{L_2} + \frac{E_a}{L_3}$$

$$\therefore \frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

From this equation, L_{eq}, the equivalent inductance of the combination is found out.

Uses of inductance coils

1. Air - core types

There have small inductances (like 1mH) and are used at high frequency circuits. For example in radio tuning circuit where fre quency is above 2 mega hertz. They can also be used as of choke to stop radio frequency current along certain paths in the circuit.

Reactancle of the coil $X_L = L\omega = L \times 2\pi f$

Thus, X_L is large for large frequencies (f) and small for small frequencies. So they may be used to separate a desired radio frequency signal (current) from other radio frequency signals.

2. Ferite core inductors

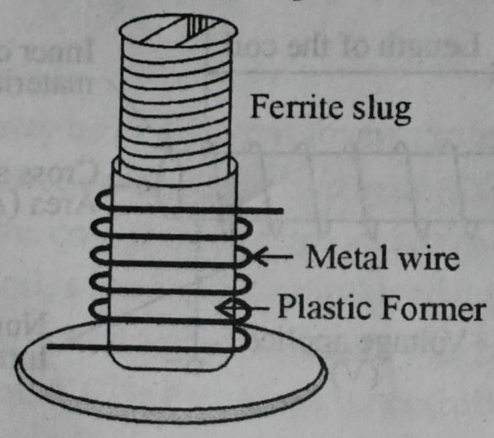


Fig. 13 *Ferrite core inductor*

In a current carrying coil with ferite (magnetic)core, the core becomes magnetized and the strength of the magnetic field is many times greater than that of the coil alone (air core). For a typical iron core inductor, $L = 10$ H. Iron-core inductors are used in relays. Ferrite - core inductances are used in radio tuning circuits. They enable small coils (to occupy less space) to get the required inductance, which may be varried by screwing the core in or out of the coil.

Principle of a Capacitor

Capacitor is a possive two terminal component which stores electric charge. This component consists of two conductors which are separated by a dielectric medium.

A capacitor consists of two conductors. One is charged and the other is earth connected. The idea of forming a capacitor is to increase the capacity of a conductor.

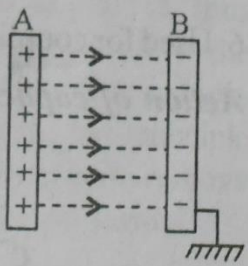


Fig. 17

Let A be the charged conductor and B the earth - connected conductor. In the absence of B, let the charge on A be $+Q$, and the potential be V. The capacity of the conductor is $C = \frac{Q}{V}$.

1 micro farad (1 μ F) = 1×10^{-6} F
1 nano farad (1n F) = 1×10^{-9} F and 1 pico farad (1 p F) = 1×10^{-12} F

WORKING

If B is kept near A, electrostatic induction takes place in the plate B, with the interior surface negatively charged and the other surface positively charged. Since the plate B is earth - connected, the positive charges on the outer surface are neutralised due to the flow of electrons from the ground. As a result of induction from positively charged plate A, the conductor B will be negatively charged. Hence the potential (V) of A

decreases due to the presence of negative charges near it. Hence the capacity $\left(C = \frac{Q}{V}\right)$ of the conductor A gets increased. The capacity can further be increased by keeping dielectric substances like mica, waxed paper etc. in between the conductors. The arrangement of two conductors with dielectric material between them, is known as a condenser or a capacitor. Connecting leads are provided from the conductors.

Combination of capacitors in series

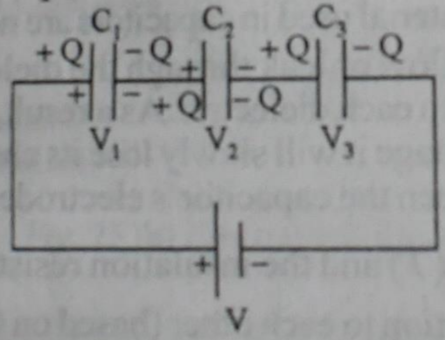


Fig. 26

Figure shows the arrangement of three capacitors C_1, C_2, C_3 connected in series with a battery of voltage V.

The voltage V provides charging potentials to the capacitors. Since the capacitances C_1, C_2, C_3 are different, their charging potentials are different. Let them be V_1, V_2 and V_3. In the process of charging of capacitors, the charges on all the three positive plates are each $+Q$ and the charges on negative plate are each $-Q$, as indicated in the figure.

By Kirchoff's voltage law,

$$V = V_1 + V_2 + V_3 \qquad \text{... ... (1)}$$

By definition of capacitance, $C = \frac{Q}{V}$ $\quad \therefore V = \frac{Q}{C}$.

$$V_1 = \frac{Q}{C_1}; \quad V_2 = \frac{Q}{C_2}; \quad V_3 = \frac{Q}{C_3}.$$

Puting these values in equation (1),

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \qquad \text{... ...(2)}$$

If C be the equivalent single capacitance of the combination of the capacitors,

the charging potential $= V$

charge on each Plate $= Q$.

Then, by definition of capacitance, $C = \frac{Q}{V}$

$$i.e., V = \frac{Q}{C} \qquad \text{... ... (3)}$$

By equations (2) and (3), $\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Combination of capacitors in parallel

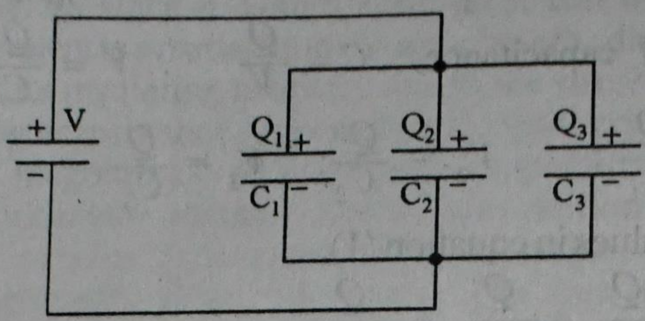


Fig. 27

Consider the parallel combination of capacitors C_1, C_2, C_3 connected in parallel. A battery of voltage V is connected to each of the capacitors as shown in the figure. The charging potential V is the same for all capacitors.

However, since the capacitance values are different, the charges on the capacitors are different. The capacitors are changed to different values. Let the charges be Q_1, Q_2, Q_3 respectively on C_1, C_2, C_3

The total charge (Q) transmitted through the battery in charging the capacitors is the sum of the charges on individual capacitors.

i.e., $Q = Q_1 + Q_2 + Q_3$ ... ...(1)

By definition of capacitance, $C = \frac{Q}{V}$ $\therefore Q = CV$

Now, Charge on capacitor C_1 is $Q_1 = C_1 V$

Charge on capactior C_2 is $Q_2 = C_2 V$

Charge on capactior C_3 is $Q_3 = C_3 V$

Placing these values in equation (1),

$Q = C_1 V + C_2 V + C_3 V$ ... ...(2)

If C be the effective capacitance of the combination and since the charging potential is V, we have

$$Q = CV \quad \text{......(3)}$$

By equations (2) and (3),

$$CV = C_1V + C_2V + C_3V$$

$$C = C_1 + C_2 + C_3.$$

If there are n capacitors in parallel, the effective capacitance of the combination is

$$C = C_1 + C_2 + C_3 + ... + C_n.$$

Types of capacitors

The capacitors in use are of different types such as multiplate capacitor (or fixed capacitor), variable capacitor (air core) and electrolytic capacitors (or polar capacitors).

1. Multiplate (fixed) capacitors

A multiplate capacitor consists of alternate layers of tin foils and mica (or paraffined paper). The odd tin foils are joined together to form one terminal and the even tin foils are joined to form one terminal of the capacitor. If there are n dielectrics within the foils on either side, it is equivalent to having n capacitors in parallel. Thus to form n capacitors one needs $(n+1)$ tin foils.

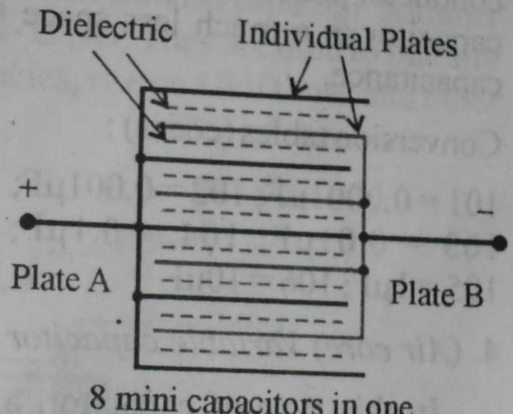
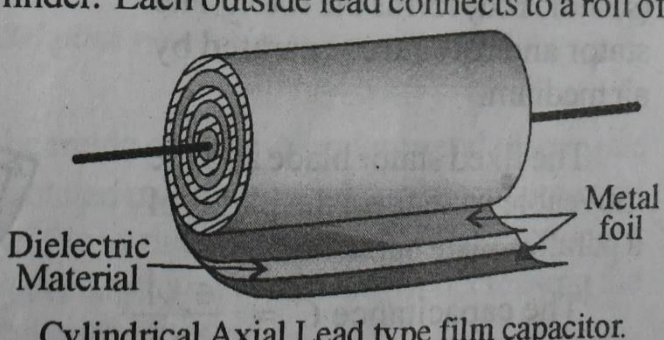


Fig. 21 *Multiplate Capacitor*

2. Paper capacitors

Two rolls of tin foils are separated by tissue paper insulator and they are rolled into a compact cylinder. Each outside lead connects to a roll of tin foil as a plate. Thus, there are two leads for external connection. The entire cylinder is encased in plastic container. The capacitances of this type are in the range 0.001 μF to 1.0 μF.



Cylindrical Axial Lead type film capacitor.

3. *Ceramic capacitor*

The ceramic dielectric materials are made from earth and they are fired under extreme heat. By use of titanium di-oxide or several types of silicates, very high values of dielectric constant (Basium titanate) for the medium can be obtained. In the disc form, silver is fired on to both sides of the ceramic to form the conductor plates. A capacitor of 0.01 F can be obtained with a ceramic capacitor in a much less space than a paper capacitor of the same capacitance.

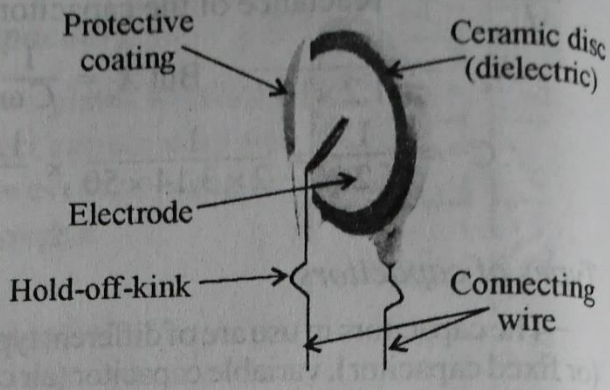


Fig. 23 *Ceramic capacitor*

Conversion tables (codes) :

101 = 0.0001μF; 102 = 0.001μF; 103 = 0.01μF; 104 = 0.1μF; 105 = 1μF; 106 = 10μF

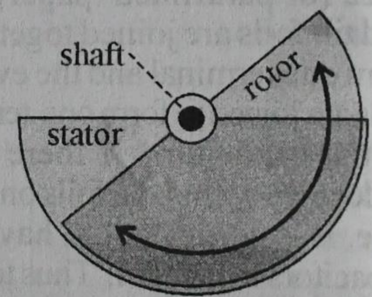


Fig. 24 *Aircore variable capacitor*

4. (*Air core*) *Variable capacitor*

In this type of capacitor, a fixed metal plate forms the stator and a movable plate (a moving vane) connected on the shaft (spindle rod) forms the rotor. The stator and rotor are separated by air medium.

The fixed stator blade and the moveable vane form the plates of a parallel-plate capacitor.

The capacitance $C = \frac{\epsilon_0 A}{d}$,

where ϵ_0 is the permittivity of free

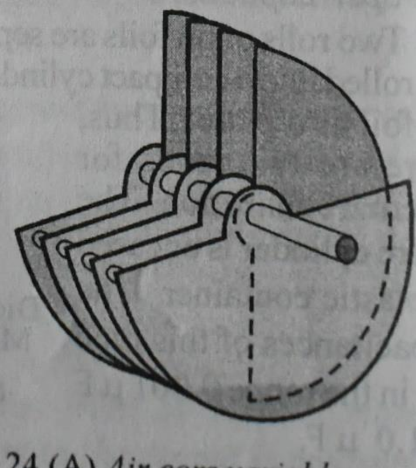


Fig. 24 (A) *Air core variable capacitor multiple plate.*

...in radio receivers.

5. *Trimmer (Padder) Capacitors*

Trimmer capacitors are variable capacitors used for initial calibration and recalibration of equipment during manufacturing and sevicing. It is commonly mounted directly on a PCB. There are two types of trimmer capacitors: air trimmer capacitor and ceramic trimmer capacitor. Trimmer capacitors are set using a small screw- driver. They are used to initially set oscillator frequency values, latencies, rise and fall times and other variables in a circuit.

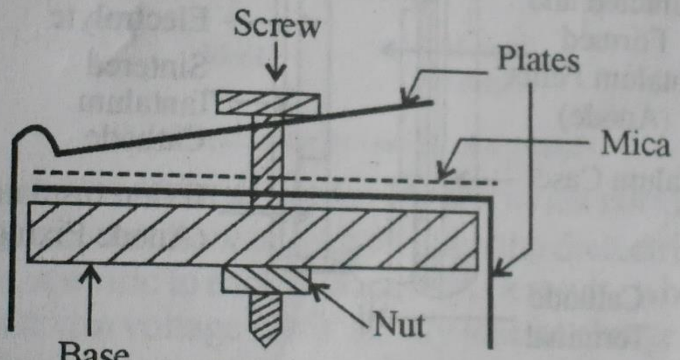


Fig. 25 (a) Parallel plate type trimmer capacitor

Trimmer capacitors can be made of semi-circular metal plates. one is fixed, while the other can be rotated using a screw driver. its construction is similar to the construction of the variable capacitor. The user changes the capacitance by by rotating the shaft and increasing or decreasing the amount of overlap between the two plates.

6. *Electrolytic capacitors*

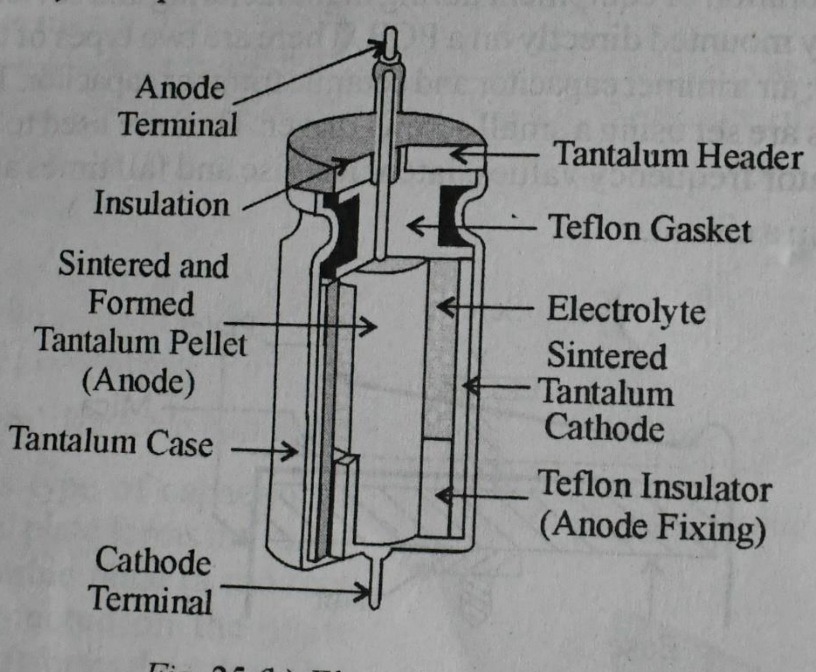


Fig. 25 (b) Electrolytic capacitor

It consists of an aluminium can (container) containing an electrolytic solution of aluminium borate. An aluminium strip is kept dipping into the electrolyte at the middle of the can. The aluminium strip and the electrolyte form the anode and the can is the cathode (negative electrode).

Uses :

1. Capacitors are used in electronic circuits to store electrical energy as in a camera flash light
2. To block direct current in a.c. circuits.
3. The variable capacitor can be used to tune a radio receiver to particular frequency
4. Capacitors are used to improve power factor in A.C. inductive circuits by phase alteration.
5. They can be used parallel to spark gap as in induction coil and ignition coil of a car to minimise the sparking of vibrating contacts.
6. Used for coupling of two stages of Amplifier circuits

Galvanometer

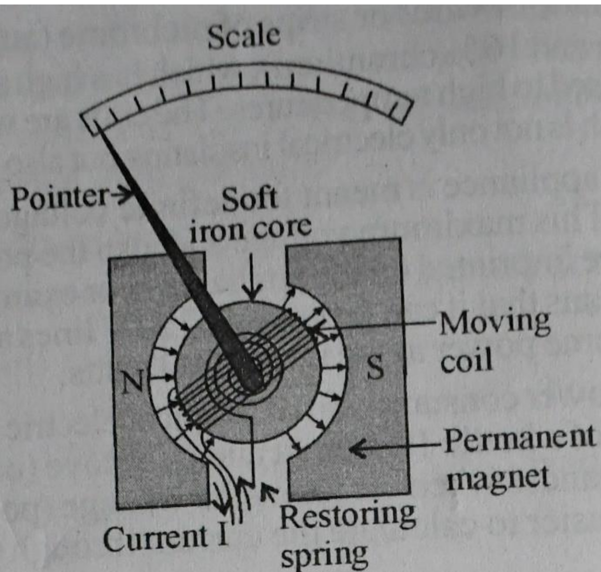


Fig. 28 (a) Moving coil galvanometer

Galvanometer is an instrument that is used to detect whether there is any current in a circuit where the galvanometer is connected. The galvanometer shows deflection. The direction of deflection will indicate the direction of current. The deflection is proportional to the current. Galvanometer does not show how much current is flowing in the circuit.

There are many types of galvanometers such as moving magnet galvanometer (tangent galvanometer) and moving coil galvanometer (mirror galvanometer, pointer type table galvanometer). The moving coil galvanometers are more sensitive than the moving magnet type. A current that can cause unit deflection in the galvanometer is known as current sensitiveness of the galvanometer. It is of the order of micro ampere per division. The minimum voltage that can make unit deflection in the galvanometer is known as voltage sensitiveness of the galvanometer. It is of the order of microvolt per division. So,

Conversion of a galvanometer into an ammeter

An ammeter is an instrument, used to measure electric current in a circuit. For this purpose, it is put in series with the circuit inwhich the current is to be measured. A galvanometer can be converted into an ammeter, by connecting a small (low) resistor, *parallel* to the galvanometer. The resistor is known as *shunt* resistor.

A galvanometer has a particular value of current sensitiveness, k. Depending upon the number of divisions on the galvanometer scale, the galvanometer can read only upto a certain limited value of current. If d be the full scale divisions in the galvanometer,

current per division $= k$

$\therefore$ the full scale current $= k \times d$

This we shall represent as I_g.

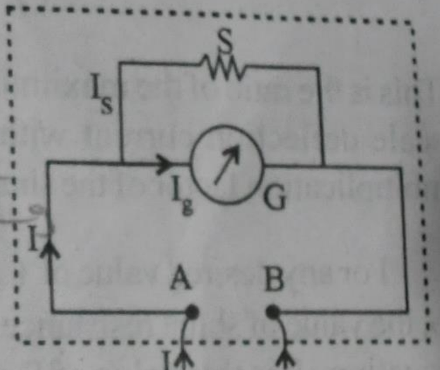


Fig. 29

i.e., Full scale current reading possible in the galvanometer $= I_g$.

We can adopt a galvanometer to measure currents that are larger than I_g (full scale reading), by connecting a resistor S (shunt) parallel to the galvanometer so that some of the main current I by-passes the galvanometer and flows through S. It is the main current I, that we wish to measure with the converted galvanometer (ammeter).

P.D. across AB = $I_g \cdot G$

It is also $= I_s \cdot S$

$$\therefore\ I_s \cdot S = I_g \cdot G \qquad I = I_g + I_s$$

$$(I - I_g) \cdot S = I_g \cdot G \qquad \therefore I_s = (I - I_g)$$

$$\therefore \frac{G}{S} = \frac{I - I_g}{I_g}$$

$$\frac{G}{S} = \frac{I}{I_g} - 1$$

$$\therefore \left(\frac{I}{I_g}\right) = 1 + \frac{G}{S}$$

This is the ratio of the maximum current that can be measured to the full scale deflection current without shunt. This ratio is known as the multiplication factor of the shunt resistor *S*.

For any desired value of (I / I_g), knowing galvanometer resistance *G*, the value of shunt resistance *S* is calculated with the help of the above equation. It is this value of *S*, which is to be connected *parallel* to the galvanometer.

The shunt resistance is a fraction of a ohm. If *R* be the effective resistance offered by the galvanometer and shunt in parallel,

$$\frac{1}{R} = \frac{1}{G} + \frac{1}{S}$$

Since G is much larger than S, $(1/G)$ can be dropped out when compared with $(1/S)$

$$\therefore \frac{1}{R} = \frac{1}{S}$$

i.e., $R = S$, which is a small value.

An ideal ammeter should have zero resistance and it has no p.d. between its terminals (*A* and *B*). This way, a galvanometer can be converted into an ammeter.

Conversion of a galvanometer into a voltmeter

A voltmeter is an instrument, used to measure potential difference (or voltage) between two points in a circuit. The voltmeter is connected to these points.

A galvanometer can be converted into a voltmeter, by connecting a high resistance *in series* with a galvanometer. An ideal voltmeter should have infinite resistance so that it would not draw any current from the circuit, i.e., it does not disturb the circuit. A real voltmeter always has finite resistance and the resistance must be large enough, not to draw any appreciable current from the circuit.

Let k be the current sensitiveness of the galvanometer and d is the full scale divisions in the galvanometer.

Full scale current $= k\,d$. This is represented by I_g.

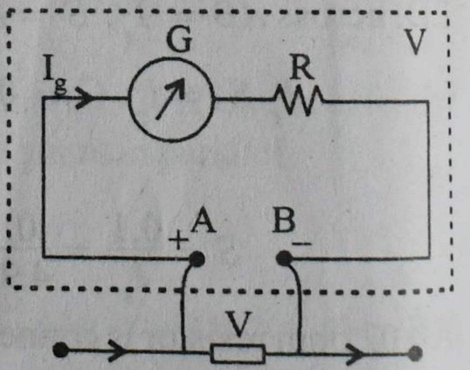


Fig. 31

We can convert a galvanometer to measure voltage V across a circuit element, by connecting a high resistance R in series with the galvanometer as shown in the diagram. A and B are the terminals of the voltmeter connected parallel to a circuit element. V is the full scale voltmeter reading. Let G be the galvanometer resistance.

When the voltmeter is connected parallel to a circuit element (such as resistor), a small part of the main current passes through the galvanometer circuit. This part I_g produces full scale deflection in the galvanometer.

Potential difference between A and B is $= V$

Current through galvanometer circuit $= I_g$

Total resistance in the circuit $= (G + R)$

Applying ohm's law, P.D. = current × reistance

$$V = I_g (G + R) \quad \therefore \frac{V}{I_g} = (G + R)$$

$$\therefore R = \left(\frac{V}{I_s} - G \right)$$

Knowing G and I_g, for any desired range of voltmeter given by V, the corresponding value of the series resistance R can be calculated and used. The voltmenter is thus designed to read full scale voltage of V volt.

Multimeter

Multimeter is a device, used to measure voltage, resistance and current in electronic and electrical equipments. It is used to test continuity between two points i.e., to verify if there is any break in the circuit or in a line.

A multimeter consists of a needle - type galvanometer of resistance of about 500 ohm and of full scale deflection current of about 1 mA. The galvanometer can be used as a voltmeter by providing resistance in series with the galvanometer. There are different resistance for different ranges (2V, 10V, 100V.. ..) the ranges can be selected by turning a range-selector switch. The galvanometer can be used as ammeter by providing shunt resistance in parallel to the galvanometer. There are different resistances for different ranges (10 μA, 1mA, 1A etc). The galvanometer can be used as ohm meter like voltmeter. The meter dial can be used to

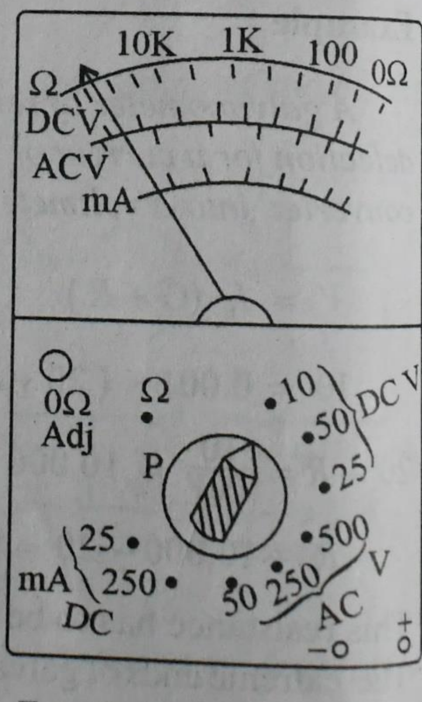


Fig. 32 Analog Multimeter

choose voltage, current or resistance, which is marked on the pannel of the multimeter and also to off position after use. Probes are the handles used to touch the test connection. Red probe is used to connect to the positive point and black probe to the negative point for testing.

Multimeter as voltmeter

Principle

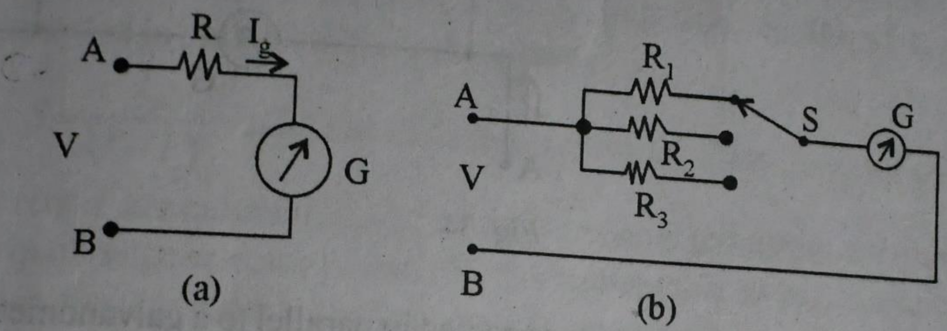


Fig. 33

Let V be the voltage to be measured. Let I_g be the current through the galvanometer and R be the series resistance included in the circuit; G is the galvanometer resistance.

$$V = I_g (R + G)$$

$$\frac{V}{I_g} = R + G$$

$$\therefore R = \frac{V}{I_g} - G$$

I_g is current for full scale deflection in the galvanometer. Knowing G

(b) Multimeter as ammeter

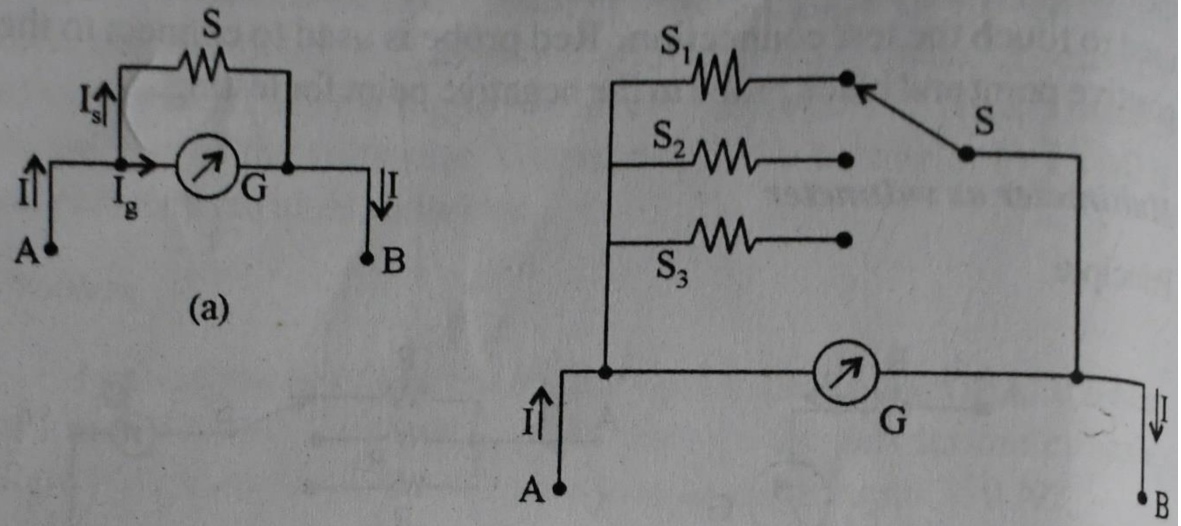


Fig. 34

When a low resistance is cannected in parallel to a galvanometer, the galvanometer becomes an ammeter. Let S be the shunt resistance, I_g be the current for full scale deflection in the galvanometer and I_s be the current through the shunt. Let I be the current to be measured. This is the main current.

p.d. across shunt = p.d. across galvanometer

$$I_S \times S = I_g \times G$$

$$\left(\frac{I_S}{I_g}\right) = \frac{G}{S}$$

$$\frac{I_S}{I_g} + 1 = \frac{G}{S} + 1$$

$$\frac{I_S + I_g}{I_g} = \frac{G + S}{S}$$

$$\frac{I}{I_g} = \frac{G+S}{S} = \frac{G}{S} + 1$$

$$\frac{G}{S} = \frac{I}{I_g} - 1$$

$$\frac{G}{S} = \frac{(I - I_g)}{I_g}$$

$$\therefore S = \frac{I_g}{(I - I_g)} \times G$$

Knowing current for full scale deflection I_g, the resistance G, the value of shunt resistance S for different current can be calculated and this can be connected in parallel to the galvanometer.

Now, $S = \frac{I_g}{(I - I_g)} \times G$. The different values of S for different values of current I are calculated and these are connected in the circuit with the help of range selector switch (S). By turning this switch to a suitable position, the desired d.c. current I can be measured.

Multimeter as ohm meter

The circuit employs a gavanometer of known resistance G and full scale deflection current I_f, connected with a standard battery of e.m.f. V and resistance R. A and B are the terminals of probes, where the resistance to be measured may be connected.

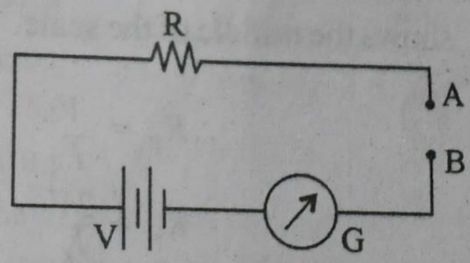


Fig. 35

When there is infinite resistance between the test leads (A and B open), current in the galvanometer is zero. So, the deflection is zero. The meter reading is on the left of the scale, indicating *infinite resistance*.

Now, the leads are touched (A and B shorted). The needle of the galvanometer shows full scale reading on the right extreme of the scale. This happens for a particular value of R.

Total value of resistance in the circuit $R_T = R + G$ Applying ohm's law,

$$R_T = \frac{V}{I_f}$$

But $R_T = R + G$

$\therefore R = R_T - G$

$$R = \left(\frac{V}{I_f}\right) - G$$

where V is the battery voltage and I_f is the full scale current (already known). Knowing V, I_f and G, the value of R can be found out. This value is included in the circuit.

Applications of multimeter

1. Multimeter can be used to test continuity in a circuit. If the circuit is open, multimeter shows infinity reading (on the left of the scale).
2. Multimeter can be used to test diodes and transistors.
3. To measure d.c. voltages across various elements in an electronic circuit.
4. For measuring a.c. voltages across power supply and transformers.

Merits and demerits of multimeter

Merits

1. Multimeter is small in size and easily portable.
2. Multimeter is a single meter that has several measuring function.
3. Multimeter can be employed to make measurements of voltage and current with reasonable accuracy.

Answers

1(c)	2(c)	3(a)	4(b)	5(b)	6(d)	7 (a)
8(d)	9(a)	10(b)	11(a)	12(b)	13(c)	14 (b)
15(d)	16(b)	17(a)	18(c)	19(b)	20(c)	21 (c)
22(b)	23(b)	24(a)	25(a)	26(b)	27(b)	28 (a)
29 (c)	30 (c)	31 (d)	32 (a)	33(d)	34 (c).	

Objective type questions

1. When a thick resistance wire is stretched into a thin wire, its resistivity
   (a) increases (b) decreases (c) remains the same (d) none
2. Electrical resistance of a wire depends on
   (a) resistivity of the material of the wire (b) geometry of the wire
   (c) both (a) and (b) (d) neither (a) nor (b)
3. The resistance of wire R is proportinal to
   (a) $\frac{l}{A}$ (b) $\frac{A}{l}$ (c) Al (d) Al^2
4. mho is the unit of electrical
   (a) resistivity (b) conductance (c) resistance (d) none
5. Temperature coefficient of precision resistors should be
   (a) very high (b) very small (c) moderate (d) none
6. Example of passive circuit element is
   (a) resistor (b) inductor (c) capacitor (d) all the above
7. For ordinary purposes, the resistors used in laboratory have power rating of
   (a) (1/2) W (b) 5W (c) 15W (d) 50W
8. One megohm is
   (a) $1\times10^{-6}\Omega$ (b) $1\times10^{-3}\Omega$ (c) $1\times10^{3}\Omega$ (d) $1\times10^{6}\Omega$
9. The circuit element used for high frequency current control is
   (a) L (b) C (c) R (d) transformer
10. Capacitor is a device that can store energy in
    (a) magnetic field (b) electric field (c) EM field (d) none

11. One farad capacitance is

(a) one colomb / volt (b) one volt/colomb (c) one volt - colomb (d) none

12. A charged capacitor can hold electrical charges on its plates

(a) as long as battery is connected across it

(b) even after the battery is removed

(c) as long as the plates are not heated up

(d) none.

13. One nanofarad is

(a) 1×10^{-12}F (b) 1×10^{-6}F (c) 1×10^{-9}F (d) 1×10^{9}F

14. Many capacitors are connected in parallel to

(a) decrease the effective capacitance

(b) increase the effective capacitance

(c) keep the capacitance steady and constant

(d) none.

15. When a steady current of 0.5A is passed through an inductance coil of resistance 0.5 ohm, the back e.m.f induced in the coil is

(a) 1 volt (b) 0.25 volt (c) 0.5 volt (d) 0 volt

16. One millihenry coil can oppose A.C of frequency of 1000 Hz to the extent of

(a) 1Ω (b) 2π Ω (c) π Ω (d) 0 Ω

17. An inductor carrying A.C stores energy in its

(a) magnetic field (b) electric field (c) gravitational field

(d) none.

18. The unit of electromotive force is

(a) newton (b) joule (c) volt (d) ampere

19. The resistance scale in a multimeter is

(a) linear (b) nonlinear (c) centre - zero (d) none

20. Energy change per second is called

(a) work done (b) joule (c) power (d) weber

21. One kilowatt hour in joule is

(a) one joule (b) 10^6 joule (c) 3.6×10^6 joule

(d) 1 unit of power consumed.

22. One unit of electric power consumption (the number of kilo - w hours) is

(a) $1000 \times$ watt $\times$ hour (b) $\frac{\text{watt} \times \text{hour}}{1000}$ (c) watt $\times$ hour

(d) none

23. A shunt is

(a) a small resistance connected in series with a galvanometer
(b) a small resistance connected parallel to the galvanometer
(c) a high resistance connected parallel to a galvanometer
(d) a high resistance connected in series with a galvanometer

24. The sensitivity of a voltmeter is expressed in

(a) Ω/V (b) V/Ω (c) V / division (d) $\frac{\text{division}}{\text{volt}}$

25. To convert a galvanometer into an ammeter, __________ is connected in parallel to the galvanometer

(a) a small resistance (b) a high resistance

(c) a low frequency choke (c) none

26. To convert a galvanometer into a voltmeter, _______ is connected in series with the galvanometer.

(a) a small resistance (b) a high resistance

(c) a high frequency choke is used (d) none

27. Connecting leads handling high power should be

(a) thin (b) thick (c) long (d) none

28. How many electron's charge will make up one coulomb?

(a) 6.25×10^{18} (b) 1.6×10^{19} (c) 3×10^{8} (d) 6.2×10^{10}

29. The type of resistor used in multimeters is

(a) carbon composition (b) deposited - film

(c) wire - wound (d) all the above.

30. Polarlity is strictly preserved while using

(a) multilayer capacitor (b) Porallel plate capacitor (c) electrolytic capacitor (d) Aircore variable capacitor.

31. A 'wattless' component in A.C circuit is

(a) resistance (b) inductance (c) capacitor

(d) both (b) and (c)

32. A 4 ohm resistance is bent in the form of a circle. The resistance between two diametrically opposite points on the circle is

(a) 1ohm (b) 2 ohm (c) 4ohm (d) 8 ohm

33. Air core trimmers have capacitance of the order of

(a) farad (b) millifarad (c) microfarad (d) picofarad.

34. The current produced by induced voltage in the core of an inductor is known as

(a) induced current (b) wattless current (c) eddy current (d) re-actance current.

Questions

1. Define resistance, capacitance and inductance. State and define the unit for each.
2. Define electric potential at a point. Distinguish between e.m.f and p.d. State Ohm's law and define one ohm.
3. Explain electrical energy. How is it estimated?
4. Define electric power. How is it estimated?
5. Define watt- hour and one kilo-watt-hour (kWh).
6. Write about consumption of power and power rating in electric appliances.
7. Describe, with a neat sketch, the construction of a galvanometer and explain its working.
8. What is the function and requirement of an ammeter? Explain with theory, how a galvanometer may be converted into an ammeter.
9. What is the requirement of a voltmeter? Explain, with theory, how a galvanometer may be converted into a voltmeter. Define sensitivity of the voltmeter.
10. What is a multimeter? Explain how it may be adopted for use as (i) a ohm meter (ii) a voltmeter and (iii) as an ammeter.
11. Describe (i) three forms of resistors and (ii) variable resistors.
12. Describe different types of capacitors. What are trimmers?
13. How are resistors and capacitors rated?
14. Explain how inductors control A.C.
15. Explain the action of capacitors in A.C. circuits.
16. Describe air-core and ferrite-core inductors. Point out their specific uses.

UNIT-II

Transformer - principle and working - classification of transformers - testing of transformers - Core, Shell and Berry types, auto transformer - construction and uses. Cooling of transformers - Losses in transformer

Transformer

A transformer is a static electric machine which transfers electrical power from one A.C. circuit to another circuit without any change in frequency. The transformer can increase or decrease the voltage with corresponding decrease or increase in current at the output. It works on the principle of mutual induction.

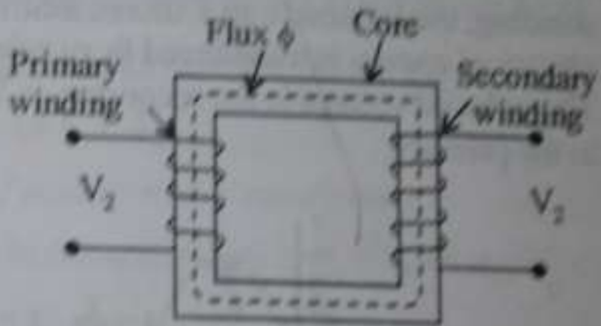


Fig. 42 Transformer principle

Construction

A transformer consists of two coil windings, insulated from each other. The windings are magnetically coupled through the core. The winding, which is connected to the A.C. supply is known as the primary coil. The other winding, connected to the load, is known as the secondary coil. The core of a transformer is made up of laminated sheets or stampings, made of silicon steel. The laminations are insulated from each other and pressed together to reduce eddy current loss of power.The stampings are of different shapes like L, I, E, C etc.

Principle and working

A transformer works on the principle of Lenz's law of electromagnetic induction. When an A.C. supply is given to the primary winding, the magnetic flux linked with each turn goes on changing at the rate of the frequeney of A.C. supply. As the coil is wound over the core, the changing flux is associated with the core also. The closed flux path in the core (shown by dotted line) is known as the magnetic circuit. The secondary coil is tightly wound over the core. So, there is tight coupling of flux lines with the secondary coil. As the flux associated with the coil is rapidly changing, according to Faraday - Lenz's law of electromagnetic induction, an e.m.f. is induced in the secondary coil, which is proportional to the rate of change of flux and the number of turns in the secondary winding.

Induced e. m. f. $e = n_2 \left(\frac{d\phi}{dt}\right)$

where n is the number of turns in the secondary and $\left(\frac{d\phi}{dt}\right)$ is the rate of change of magnetic flux. If now a load is connected to the secondary winding, the induced e.m.f. drives a current through the load. In this way electrical energy is transferred from primary to the secondary windings. The induced voltage in the secondary is 180^0 out of phase with the voltage in the primary.

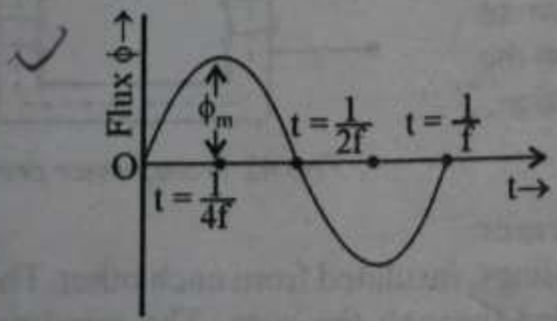


Fig. 43 Rate of change of flux linked with coil

Consider a transformer

having primary turns = n_1

secondary turns = n_2

maximum flux in the core = ϕ_m

(see graph)

frequency of A.C. supply = f

The flux in the core varies sinusoidally, as shown in the figure. The flux increases from zero value to the maximum of ϕ_m in time

$$t = \frac{1}{4f} \text{ second.}$$

Since the flux is changing sinusoidaly the RMS value of induced voltage can be obtained by multiplying the above with the form factor 1.11

$$\left(\text{Form factor} = \frac{\text{RMS value}}{\text{average value}}\right)$$

$\therefore$ RMS value of induced voltage in primary per turn = $1.11 \times 4 f\phi_m = 4.44 f\phi_m$

RMS value of induced voltage in all n_1 turns of the primary is

$$V_1 = 4.44\, n_1 f\, \phi_m$$

This equation is known as *e.m.f equation* of a transformer.

RMS value of induced voltage in the secondary is $V_2 = 4.44\, n_2 f \phi_m$

Voltage transformation ratio is $\dfrac{V_2}{V_1} = \dfrac{n_2}{n_1}$ .... (1)

If $n_2 > n_1$, then $V_2 > V_1$. The transformer works as step - up transformer, stepping up the voltage.

If $n_2 < n_1$, then $V_2 < V_1$. The transformer works as a step down transformer. The frequency is unchanged. Current transformation ratio is $\dfrac{I_2}{I_1}$. In an ideal transformer,

Apparent input power = apparent output power

$$I_1 V_1 = I_2 V_2$$

$$\therefore \left(\frac{I_2}{I_1}\right) = \frac{V_1}{V_2}$$

$$= \frac{n_1}{n_2} \text{ .... (using equation 1)}$$

The ratio $\left(\dfrac{n_1}{n_2}\right)$ is known as the turns ratio of the transformer. Thus, in a transformer,

$$\frac{V_1}{V_2} = \frac{n_1}{n_2} = \frac{I_2}{I_1}$$

Since $I_1 V_1 = I_2 V_2$, the power, it is seen that the turns ratio of the transformer depends on the power handled by the transformer. The transformer output power cannot be greater than the input power.

Sources of power loss in a transformer

1. *Copper loss*

The primary and the secondary coils may have finite resistances. Hence when current passes through them, the coils may produce heat (I^2Rt) due to Joule's law of electrical heating. The effect of finite resistance of the windings on the loss of energy or power is known as copper loss. This can be minimised by using good quality copper wires. The loss of power in a transformer is mainly due to copper loss.

2. *Leakage of flux*

The flux linked with the primary coil may not be linked fully well with the secondary coil. This would cause some loss in the power transferred from primary windings to the secondary windings.

3. *Loss of power due to eddy currents* (*iron loss*)

The changing magnetic flux induces an emf in the core itself and thereby eddy currents are generated in it. The eddy current is called so because it flows in a circular path through the cross - section of the core. The eddy currents cause wastage of power due to heat produced in the core. The eddy current flux opposes the coil flux, requiring more current drawn from the power supply to maintain its magnetic field.

The eddy current loss will be larger, when the square of maximum flux density of the core (B_m^2) as well as the frequency of a.c. in the coils is large. The power loss due to eddy current can be minimised by using laminated thin sheets of soft iron as core of the transformer. Each thin laminated sheet is insulated by a very thin coating of iron - oxide or varnish. Ferrites have lesser eddy current losses than iron.

4. *Hysteresis loss*

When a.c. flows through the coils, the core of the transformer gets alternately magnetised and demagnetised. ie., the core undergoes hysteresis cycle. During each cycle, there is loss of power in the core. The power loss per cycle is indicated by the area of the hysteresis curve. In order to minimise hysteresis loss, it is desirable to choose the core material that has minimum area of the hysteresis curve. Soft iron and silicon steel are preferred to steel in this respect. The hysteresis loss is of appreciable value for radio frequency transformers. Practically, air core will show no loss of power due to eddy currents and hysteresis. For this reason, R.F. transformers are air-core transformers.

Cooling of transformers

When a transformer is functioning, some heat will always be produced due to the power losses in the transformers. So by some means the windings must be prevented from reaching high temperature. There are different methods of cooling of the transformers. These are :

(1) natural cooling

(2) natural oil cooling

(3) oil blast cooling

(4) forced water cooling

(5) forced air cooling

1. *Natural cooling* : In small transformers of rating 10 to 15 KVA cooling is done through natural circulation of air. The surface area of the core and transformer winding are sufficient to dissipate the heat generated.

2. *Natural oil cooling* : In this system the transformer is placed in a tank, filled with oil known as transformer oil (hydrocarbon mineral oil, Askarels). The oil used in the tank not only helps to cool the transformer but also provides insulation for the windings.

The oil takes heat from the core and windings and gives it to the tank surface. From here the air takes away the heat. To make the system more efficient, the radiating surface area of the tank is increased either by using corrugated sheets or by providing round pipes or elliptical tubes. Due to the heat produced by the transformer, the oil circulates through pipes or the tubes in the tank. The hot oil becomes lighter in weight and goes up. From here it comes down through the pipes to the bottom of the tank after cooling. The oil level in the tank should not fall below the upper end of the pipes.

3. *Oil blast cooling* (OB type cooling)

In this method, the radiator tanks are provided to the side walls of the main tank. The oil circulates through these radiator tanks from the main tank. The radiator tanks are cooled by air blast. This method is used for cooling transformers of ratings above 500 KVA.

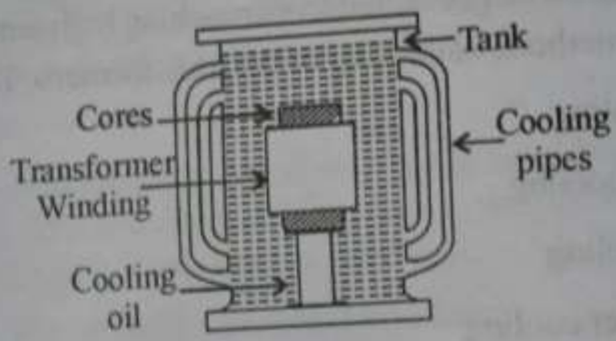


Fig. 44 Oil-cooled transformer

4. *Forced water cooling*

The winding of the transformer is placed inside the tank containing oil. Cold water is passed through the copper pipe spiral, kept in the transformer oil. The cold water absorbs heat and carries away the heat of the oil. Care should be taken to see that there is no leakage of water in the pipe. If water leaks into the oil, it will damage the insulating property of the oil. This may damage the insulation of the winding. This method is used for cooling of transformers of output greater than 500 KVA.

5. *Forced air cooling*

In this method air is first filtered out to eliminate moisture and dust particles and then this filtered air under pressure is forced to pass through the winding, core and the ducts provided in them. The air takes away the heat of these parts of the transformer. This method is used in places where there is scarcity of water.

voltage transformers.

Classification of transformers

Transformers are classified according to the function they perform.

1. *Transmission transformers and distribution transformers*

Power transformers, also known as transmission transformers are used for taking electric power supply from generating station to far off distance by stepping up the voltage to high or extra high values (from 33 KV to 440 KV). The transmission at high voltage reduces the transmission current. Thus it decreases the area of cross section of the conductor required for the lines. This means material saving and cost saving.

Transformers of output upto 500 KVA are called 'Distribution transformers'. They generally step down voltages from 11KV to 440V for domestic and factory usages.

2. *Mains transformer*

In the construction of rectifier circuits, using vacuum diodes or crystal diodes, power transformer is used. Such power transformer works with only 50 Hz frequency. The power transformer is prescribed by the

3. Step-up and Step - down transformer.

In a step-up transformer, the primary winding has lesser number of turns than the secondary. The output voltage is greater than the applied a.c. voltage $n_2 > n_1$.

$$\therefore V_2 > V_1 \quad \text{since} \quad \frac{V_1}{V_2} = -\frac{n_1}{n_2}$$

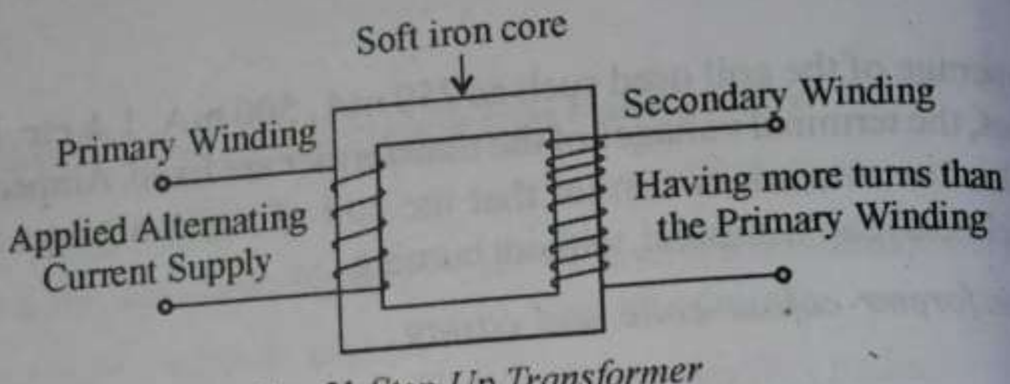


Fig. 51 *Step-Up Transformer*

ep-down transformer

When the secondary winding has lesser number of turns than the rimary, the output voltage V_2 is smaller than the applied voltage, V_1.

$\frac{V_1}{V_2} = -\frac{n_1}{n_2}$. Since $n_2 < n_1$, we have $V_2 < V_1$.

he voltage in the secondary decreases; but the current correpondingly icreases to preserve power value.

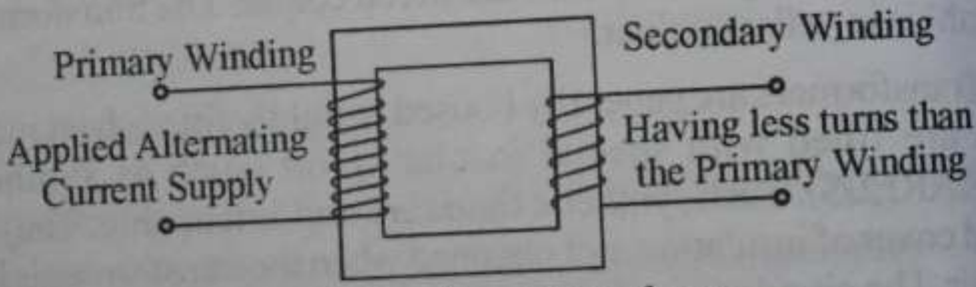


Fig. 52 Step-Down Transformer

4. *Radio frequency (RF) Transformers*

A thin uniform copper wire is wound on a hollow clyndrical paper or plastic framer. This acts as the primary coil. The secondary coil is also wound closely over the same framer. Now, an air core transformer is obtained with four leads.

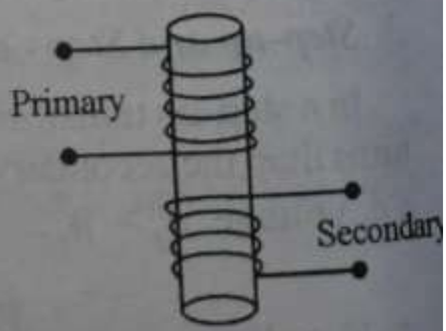


Fig. 53

transformers is of low value such as a micro - henry. Such low inductance transformers are used as R.F. transformers.

5. Audio frequency (A.F.) transformers

A.F. transformers have soft iron core. They function efficiently in telephone sets and radio receiver sets.

In the radio receiver set the primary of the transformer is connected in the collector circuit of the power amplifier. The secondary of the transformer is connected to the loud speaker from which output (audio) is obtained. The transformer in the circuit couples the power amplifier to the loud speaker and it does the function of impedance matching.

6. Instrument transformers

Measuring instruments are not designed to carry large currents or to work at high voltages. To measure large values of current and voltage, current and potential transformers are used.

(i) *Current transformer*

The primary of the transformer has a few turns or a single turn to carry the current to be measured and it is connected in series with the main circuit. The secondary winding with larger number of turns supplies a reduced amount of current to the instrument (say ammeter). The meter scale is calibrated directly in terms of the primary circuit current. The core is worked at low flux density so that the secondary current is constant ratio of main circuit current. When the current is flowing in the

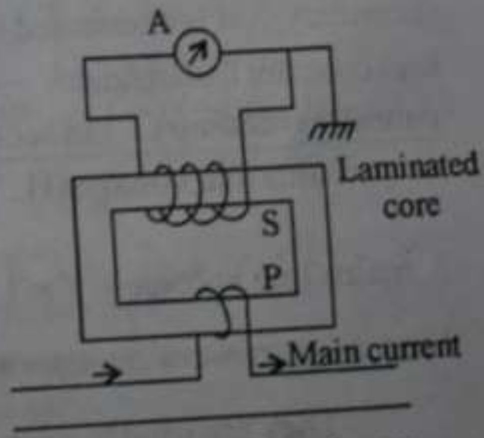


Fig. 54 Current Transformer

primary coil, the secondary circuit should not be opened. In that case the secondary and the core will be heated up and damaged.

(ii) *Potential transformer*

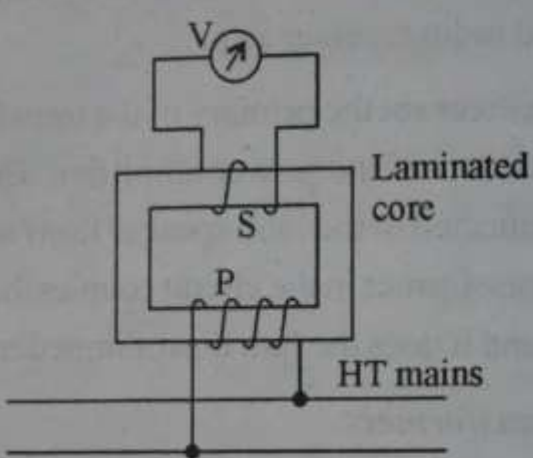


Fig. 55 Potential Transformer

This transformer is used to reduce the primary voltage to a safe value for the operation of voltmeter and other instruments.

The primary is connected to the high tension (H.T) to be measured. The secondary coil is connected to a voltmeter (V). The turns ratio $\left(\frac{n_s}{n_p}\right)$ is kept constant throughout.

7. Impedance matching transformer

In communication circuits power is to be transferred from the source to the load. The elements used in the circuit must be such that there is maximum power transfer.

According to maximum power transfer theorem, the maximum power is absorbed by one net- work from the other net-work connected at the two ends, provided that the impedance of one is the complex conjugate of the other. That is, if the source is inductive, the load should be capacitative. When this condition is satisfied, maximum power is transferred from the source to the load and this process is known as "impedance matching".

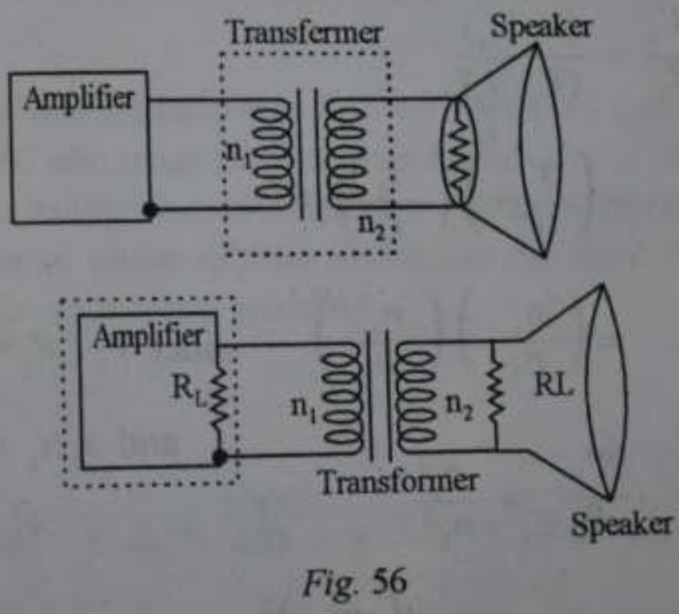


Fig. 56

A transformer can be used as an impedance matching device. If n_1 and n_2 are the number of turns in the primary and secondary windings in the transformer and if R_L is the load resistance (say the resistance of the voice coil of loud speaker), the resistance as seen by the primary coil is given by

$$R'_L = \left(\frac{n_1}{n_2}\right)^2 R_L$$

Core type, Shell type and Berry type transformers

1. *Core type transformer*

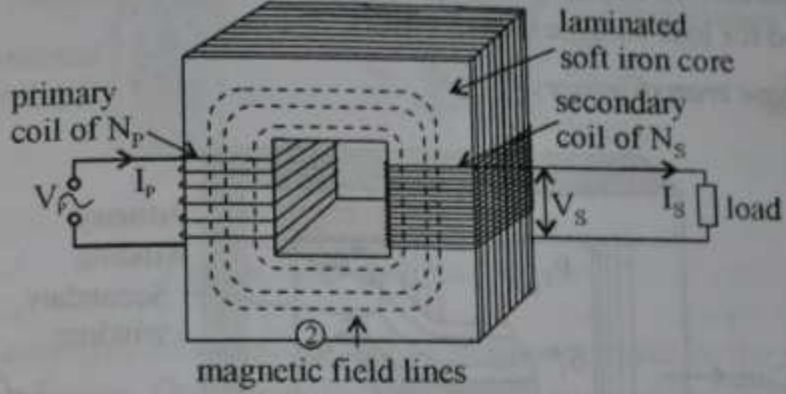


Fig. 45 Core type Transformer

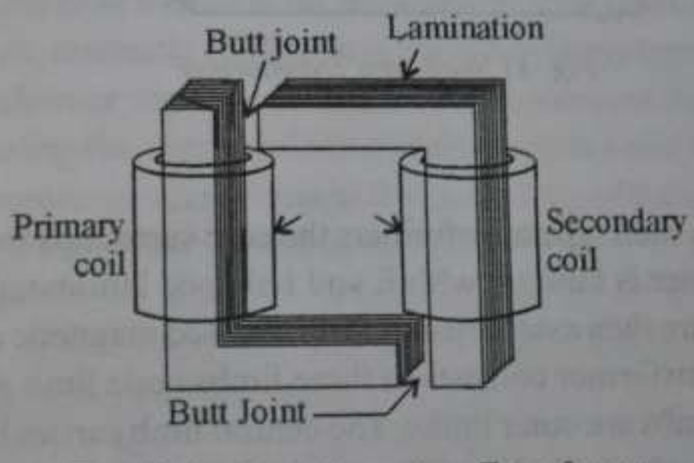


Fig. 46 Laminated core type Transformer

This type of transformer has only *one* closed flux path. The core consists of laminated stampings of silicon iron sheets in the shape of L moved oppositely so that the core is of rectangular shape. Secondary and primary windings are formed and slipped over limbs of the core. A separate yoke is bolted to the top of the coil limbs so that the magnetic flux path is complete (shown by dotted line)

The coils wound are of the cyclindrical type. The coils are wound on helical layers, with different layers insulated from each other by paper or mica. The low voltage coil is placed inside near the core while the high voltage coil surrounds the low voltage coil. Thus in the core type of transformers the windings surround the core. As the windings are uniformly distributed on two limbs, natural cooling will be effective. This type is best suited for low voltage transformers.

2. ***Shell type transformers***

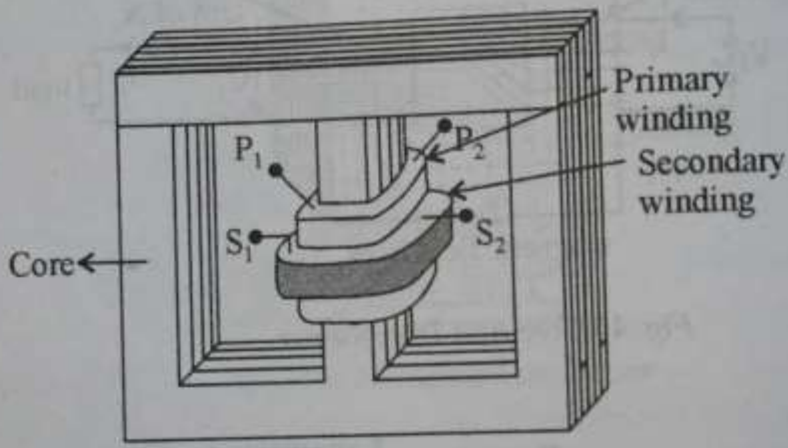


Fig. 47 Shell type Transformer

In the shell type transformers the core surrounds the windings. The transformer is built up with E and I-shaped laminated silica iron cores. These are then assembled to form a closed magnetic circuit (flux path). The transformer consists of three limbs : one limb at the centre and the two limbs are outer limbs. The central limb carries both the primary and secondary windings. During working, the entire flux passes through the central part of the iron core. But outside the central core the flux divides into two parts going in each direction. The low voltage winding is placed next to the core. The high voltage winding is placed around the low voltage winding. As shown in figure, the windings are connected on both sides by cores. As the entire core is in the form of a shell, the transformer is called shell type transformer which is suitable for high voltage transformation.

Berry type transformer

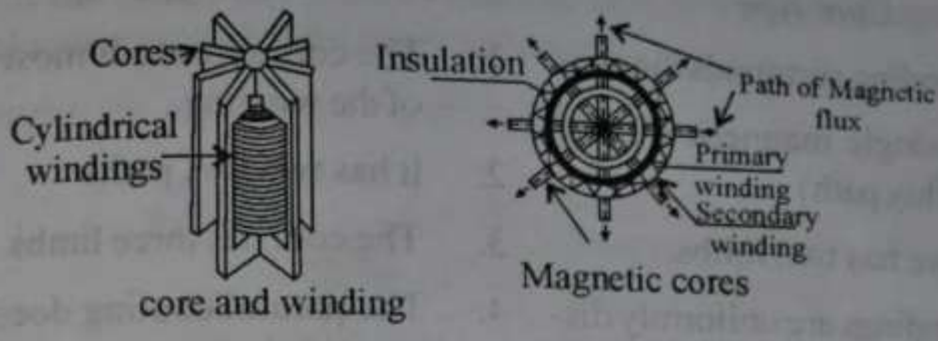


Fig. 48 Berry-type transformer

Berry type of transformer has magnetic cores in the shape of ctangular frames. One limb of all the frames passes through the centre 'the core whereas the other limbs are kept around the coils. (as shown fig). Thus the transformer will have as many parallel paths for flux ıes as the number of frames in the transformer. This type of transform- s having multi magnetic flux paths is known as Berry type transform- s. The transformer can be constructed at a lower cost than the other /o types (having the same operating characteristics and temperature nits) as the cross section of iron in the central leg of the core is made ımewhat less than that external to the coils - in order to save copper. ıe entire transformer assembly is immersed in the oil. The oil serves /o functions : (i) keeps the coils cool by circulation and (ii) provides the ınsformers an additional insulation.

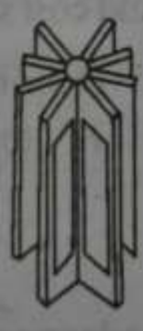


Fig. 49 Core

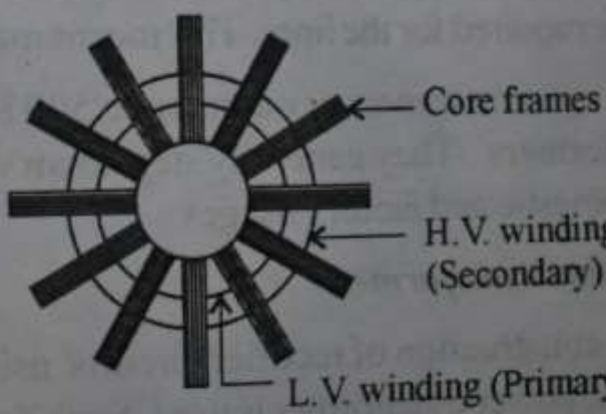
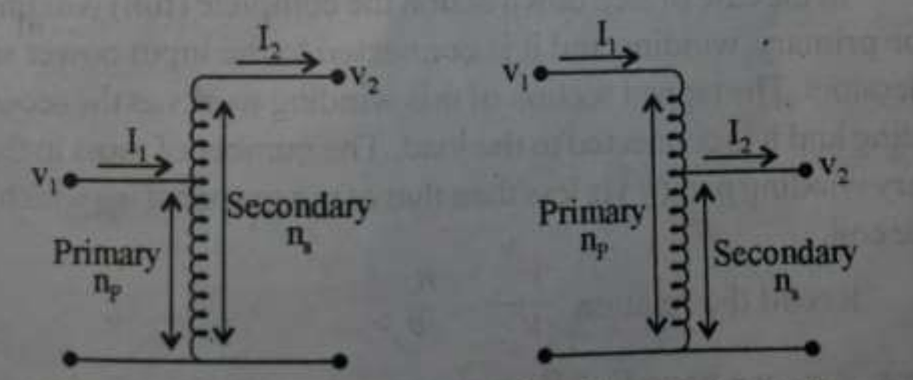


Fig. 49 (a) Berry type Transformer (top view)

Comparison of core type and shell type transformers

Core type	Shell type
1. The winding surrounds the core.	1. The core surrounds most part of the winding.
2. It has single magnetic circuit. (one flux path)	2. It has two flux paths
3. The core has two limbs.	3. The core has three limbs.
4. The windings are uniformly distributed on two limbs. Hence natural cooling is effective.	4. The natural cooling does not exist as the windings are surrounded by the core.
5. The coils can easily be removed for maintenance.	5. The coils cannot be removded easily.
6. Core type is preferable to low voltage transformers.	6. Preferred for high voltage transformers.

Auto transformer



(a) Step up Autotransformer (b) Step down Autotransformer

Fig. 57 Auto Transformer

Principle

An auto transformer works on the principle of self induction. Whenever there is change of current in a coil, the induced e.m.f. in the coil is proportional to the rate of change of current $\left(\frac{di}{dt}\right)$ in the coil.

Induced e.m.f. $e = -L\left(\frac{di}{dt}\right)$

where L is the self inductance of the coil.

$L \propto n$, the number of turns

$\therefore e \propto n$

If V_p is the voltage across the primary and V_s that across the secondary coil and if n_p is the number of turns of the primary and n_s that of the secondary,

$\frac{V_s}{V_p} = \left(\frac{n_s}{n_p}\right)$, the turns ratio of the transformer. This relation is the same as that of the conventional transfomer.

Construction and working

The auto transformer has only one coil, which does the function of both primary and secondary windings. An auto transformer can step up or step down voltage.

In the case of step down action the complete (full) winding acts as the primary. winding and it is connected to the input power supply (generator). The tapped section of this winding works as the secondary winding and it is connected to the load. The number of turns in the secondary winding part (n_s) is less than that of the primary (n_p) which is the whole coil.

Recall the relation $\frac{V_s}{V_p} = \frac{n_s}{n_p}$.

Since $n_s < n_p$, we have $V_s < V_p$ ie, the step down action.

In the step up functioning, the whole winding acts as the secondary coil and it is connected to the loads. The tapped portion of this coil acts as the primary, connected to the input power supply. (V_p). When V_p is applield across the primary, the voltage V_s is induced in *all the turns* of the secondary.

If n_p be the number of turns in the primary and n_s that in the secondary winding, as seen before,

$$\frac{V_s}{V_p} = \frac{n_s}{n_p}$$

Since $n_s > n_p$ we have $V_s > V_p$, which is the step up action.

Uses of autotransformers

Autotransformers are often used because these are compact, efficient and cost less, with only one winding (There is much saving of copper wires).

1. These are used for starting and speed control of induction motors.

2. These can be used for stepping up and stepping down voltages in places, where the transformation ratio is less than unity but close to unity.

3. In places where only small variations of voltage or current are required, autotransformers are used as *regulating* transformers.

4. Autotransformers can be used as *line boosters*. For example, in cable T.V. network the autotransformer is used to give a small boost to correct for the voltage drop in the distribution cable.

Testing of transformers

The primary and secondary coils of a transformer can be separately tested for continuity by using a ohm meter or multimeter set for resistance. A open coil shows infinitely high resistance.

An autotransformer has one coil and three leads. The continuity of the coil from one lead to the other two leads should be tested.

(i) *When primary winding is open,* there is no primary current and so there is no induced voltage in any of the secondary windings.

(ii) *When the secondary winding is open,* it cannot supply power to any load resistance, connected across the secondary. If the transformer has several windings, an open winding in one secondary does not affect the transformer operation for the secondary tappings that are normal.

(iii) *When the secondary winding Is short circuited,* there will be excessive primary current, often burning out the transformer's primary winding.

Apart from these tests on the windings, some other tests for megnetic flux in the core are conducted. We shall see here the open circuit (or no load) test.

QUESTIONS FROM BOOK

Questions

1. What is a transformer? Explain the principle and working of a transformer.

2. Write in detail about classification of transformers.

3. Describe, with neat sketch, core type, shell type and berry type transformers. Give the specific uses of each type.

4. Describe testing of transformers.

5. Describe different methods of cooling of transformers.

6. Explain the sources of power loss in transformers. Describe how these may be minimised.

7. Describe the construction of an auto transformer. Explain its step up and step-down functions. List out the uses of auto transformers.

8. Explain no-load test of transformers.

9. Explain the action of transformer with load.

10. List out the uses of transformers.

11. Write about the maintenance of power transformers.

12. Compare core type and shell type transformers.

Objective type questions

1. Transformers work on the principle of

(a) conservation of momentum (b) Joule's law

(c) Lenz's' law (d) cross B rule

2. In a step up transformer the frequency of AC in the primary winding is __________ at the secondary winding.

(a) decreased (b) increased (c) the same (d) none

3. In a transformer the turns ratio is

(a) $\frac{n_p}{n_s}$ (b) $\frac{n_s}{n_p}$ (c) $\frac{n_s^2}{n_p^2}$ (d) $\frac{n^2}{n_s}$

13. Transformer oil should be

(a) thicker than water (b) moisture - free

(c) with little acidity (d) viscous - free

14. Hysteresis loss of power in a transformer is reduced by

(a) using silicon steel as the core (b) laminating the core

(c) using pure copper as the core (d) none

15. The transformer oil, commonly used is

(a) pure coconut oil (b) petrol (c) Askarels

(d) poly vinyl chloride

16. In power generating stations, step up transformers are used

(a) to increase current in distribution lines

(b) to increase power before distribution

(c) to save material of distribution wires

(d) none

17. The core of a transformer is laminated to minimise

(a) hysteresis loss (b) copper loss (c) eddy currents

(d) none

18. Autotransformer works on the principle of

(a) Joule's heating (b) self induction

(c) mutual induction (d) none

19. Radio frequency (R.F) transformers have

(a) iron core (b)silicon steel core (c) air core (d) none

20. In a transformer immersed in oil tank cooling takes place by

(a) conduction (b) convection (c) radiation (d) both (b) and (c)

21. An open coil has

(a) infinite resistance and zero inductance

(b) zero resistance and high inductance

(c) infinite resistance and normal inductance

(d) zero resistance and inductance

22. Eddy current losses in a transformer ________ with higher fre-quency of alternating current.

(a) increase (b) decrease (c) ramain unchanged (d) none

23. In a transformer copper loss occurs

(a) throughout the day and night

(b) only when the transformer is loaded

(c) when the primary is off and the secondary is loaded

(d) none

24. Iron losses in a transformer are measured by

(a) a multimeter (b) short - circuit test

(c) open - circuit test (d) thermometer

Answers

1. (c)	2. (c)	3. (a)	4. (a)	5. (d)	6. (a)
7. (a)	8. (a)	9. (a)	10. (c)	11. (c)	12. (c)
13. (b)	14. (a)	15. (c)	16. (c)	17. (c)	18. (b)
19. (c)	20. (d)	21. (a)	22. (a)	23. (b)	24. (c)

QUESTIONS FROM PREVIOUS YEAR QUESTION PAPERS

PART A

Which of the following is not a basic elements of a transformer?

(a) core (b) primary winding (c) secondary winding (d) mutual flux

In an ideal transformer,

(a) Windings have no resistance (b) Core has no losses (c) Core has infinite permeability (d) All of the above

The primary and secondary induced emfs E1 and E2 in a two winding transformer are always

(a) equal in magnitude (b) antiphase with each other (c) in phase with each other (d) none of these

A transformer transfer energy by

(a) inductive coupling (b) exchanging (c) conversion (d) none

In relation to a transformer, the ratio 20 : 1 indicates that

(a) there are 20 turns on primary, one turn on secondary

(b) secondary voltage is 1/20th of primary voltage

(c) primary current is 20 times greater than secondary current

(d) for every 20 turns on primary, there is one turn on secondary

In an ideal transformer

(a) windings have no resistance (b) core has no losses (c) core has infinite permeability (d) all of the above

PART B

What is a transformer? Give its working principle.

List the advantages of transformer.

Briefly explain the various uses of transformer.

Compare core, shell and berry type transformers

Obtain an expression for the voltage transfer ratio of a transformer.

Briefly explain the various uses of transformers.

Obtain an expression for the voltage transformation ratio.

List the advantages of transformer.

Describe the working of transformer.

Write the loses in transformer.

PART C

Describe the construction, working and theory of a transformer.

Describe the construction and working of core type transformer.

Describe the construction, working, and uses of an Auto transformer.

Describe the construction and working of core and shell type transformers.

What is a transformer? Explain the principle and working of auto transformer.

Obtain an expression for the voltage transformation ratio and List the advantages of transformer.

Explain the classification of transformers

Describe the construction, working and theory of a transformer

Unit-III

Electric bulbs – Fluorescent lamps - Street Lighting - Electric Fans - Wet Grinder - Mixer - Water Heater - Storage and Instant types-electric iron boxmicrowave oven - Washing Machine - Stabilizer, Fridge and Air conditioner.

Electrical Bulb (incandescent light bulb)

Incandescence is the emission of light (visible electromagnetic radiation) from a hot body as a result of its temperature. Electrical bulb produces light when a tungsten filament wire is heated to a high temperature by an electric current, passing through it.

Principle

When the filament is electrically heated by passing current through it, it acquires thermal energy. ie. the atoms in the filament are excited to higher energy states, where they are not stable. When the atoms de-excite (electronic transition from higher energy level to ground state energy level), energy is emitted as photons. This causes emission of visible light from the filament.

However only less than 10 % of the radiated energy is in the visible region of wavelength (6000 Å). The remaining energy is radiated away as heat (infra-red radiation). The colour of light radiated by the bulb is reddish yellow.

Tungsten is used as the filament material for the following reason: Tungsten has the highest melting temperature and lowest rate of evaporation.

Construction

Electrical bulb consists of a tungsten filament wire in an evacuated glass bulb. Two ends of the filament are connected to lead-in wires. The wires are brought out through a sealed cap and then to the electric supply. The glass envelope (bulb) keeps water vapour and oxygen away from the filament which would otherwise oxidise the

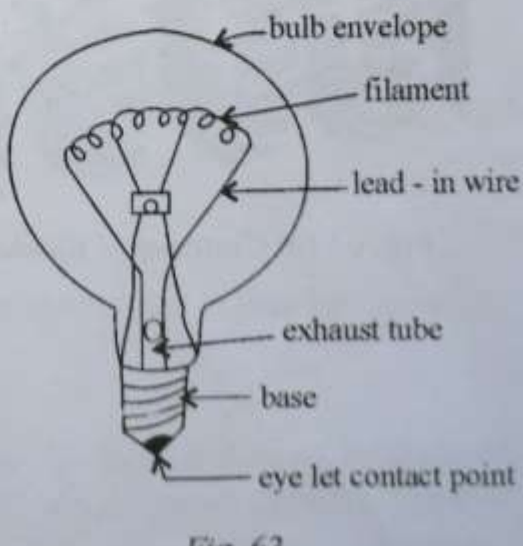


Fig. 63

filament metal. House hold bulbs are made of soda-lime glass. Silica and Pyrex (borosilicate) can be used for higher temperatures, A coiled-coil tungsten wire is used as filament. The molybenum wires support the filament and conduct current to it. The support wires are soldered to the eye let (the bottom brass button). This is connected to the ac mains.

Inside of the bulb is electrostatically coated (process that employs charged particles to paint a workpiece) with fine silica powder, which spreads the brilliant filament light diffusely by Mie scattering.

Most modern bulbs are filled with inert gas such as argon. Argon's high molecular weight and low thermal conductivity retards the tungsten's evaporation and thermally insulates the filament. Thus the high temperature of the filament is maintained. Light bulbs smaller than 25W require no fill gas, just a partial vacuum free of oxygen and water vapour.

Fluorescent Lamp (Tube Light)

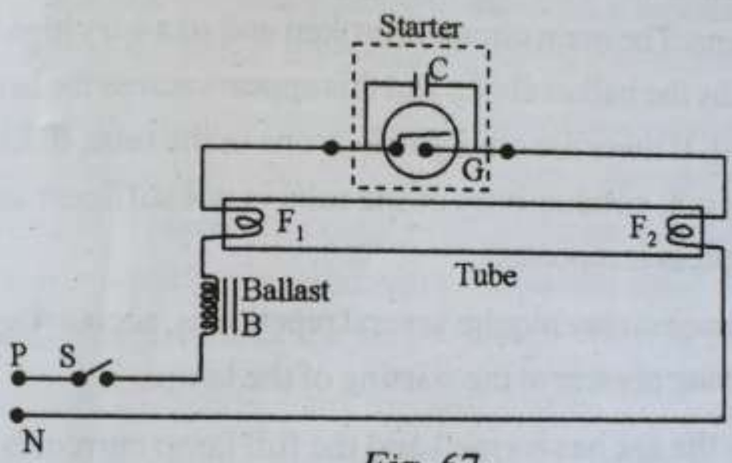


Fig. 67

The fluorescent lamp is a long glass tube, whose inner surface is coated with a fluorescent material (phosphor). It has filaments on either ends and the filament is made of tungsten coated with barium oxide.

Across the tube a glow switch starter having a capacitor C in parallel is connected. In series with the filaments a ballast (choke) coil is connected. It is an iron core coil having high inductance. The tube is energised by a.c. main supply through a switch S.

A small quantity of argon gas and mercury are introduced into the low pressure discharge tube.

Working

When the tube light is switched on, the circuit is closed via the starter which is of glow switch type. A low current glow discharge forms in the starter. The discharge is through neon gas in it. The heat from this glow

is sufficient to expand the bimetallic electrode until it contacts the fixed electrode in it. This makes the starter short-circuited. Due to the flow of current readily through the filaments, electrons (thermions) are emitted from the filaments, one at a time which goes negative during the a.c. cycle. The presence of electrons in the tube increases the conductivity of the tube by ionising the argon gas in it.

The efficiency of a fluorescent lamp is higher than that of an incandescent lamp.

The lamp colour is determind by the selection of chemicals used in the phosphor. Some details are given below:

Calcium tungstate .... blue colour

Calcium borate .... pink

Zinc silicate .... green

Magnesium tungstate .... blue-white

In order to increase the power factor of the lamp, a separate capacitor is connected across the mains supply (3.25 μF for a 40W lamp).

The capacitor (C) of low capacitance is connected across the starter. Electromagnetic wave is produced from the starter during the make and break of the circuit. This may produce noise in the nearby radio receiver set. The capacitor absorbs the radio wave. Hence the radio interference is suppressed due to the use of the small capacitor across the starter.

Fluorescent Light : Trouble shooting and repair

1. Lamp in a fixture (holder) does not light at all : Make sure all power switches are turned on.

2. Ends of a lamp are lit continuously but the rest of the lamp is dark : Starter worn-out. Replace the starter. When the fixture is turned off, if the ends of the lamp appear dark or smoky in colour, the lamp should be replaced.

Correct size starter should be used. FS-2 startes are used with 18" and 24" lamps. FS-4 starters are used with 48" lamps.

3. The lamp is trying to start, but lamp does not light :

- Lamp and starter worn out.
- wrong size starter.
- Choke failing
- Line voltage low.

ter
irst
tors,

- Replace lamp and starter connected to the choke and if the problem persists, replace the choke.

4. It takes a long time for a lamp to initially come an, when switched on:

- slow starter or starter worn-out.
- Replace the starter.

Street Lighting

Street Light is a lamp supported on a lamp-post at the edge of a road for illuminating a street or road way. The street light is illuminated from dusk to dawn. it is energised by electric current. Modern lamps may also have light sensitive photo cells that activate automatically when light is needed or not needed.

The lamp post is a steel tubular pole which is noncorrosive and long lasting. The minimum height for poles that extend over the road is 8 meter. The distance between two poles may be 50 meter. The outreach length of the lamp over the road may be 2m. Many street light systems are being connected underground instead of being connected from one post to another in space by electrical power lines

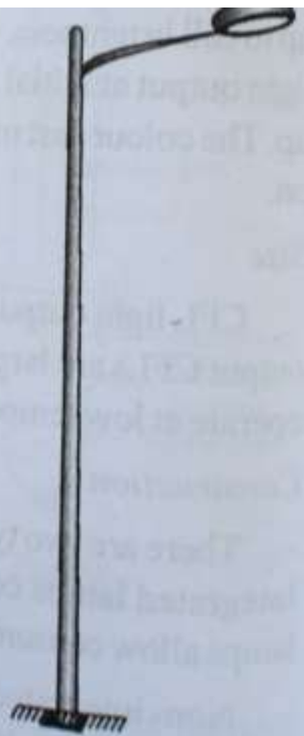


Fig. 69 Street Lighting

Types of street light lamps

Lamps for street lighting can be divided into three main categories: (i) incandescent lamps (ii) luminescent gaseous discharge lamps and (iii) LED

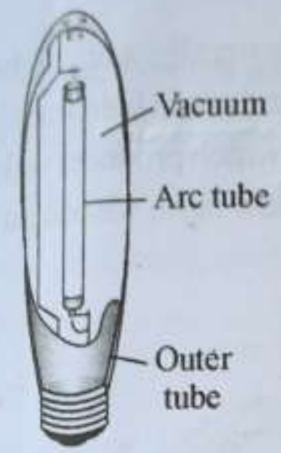


Fig. 70 (a) *High-Intensity Discharge (HID) Lamp*

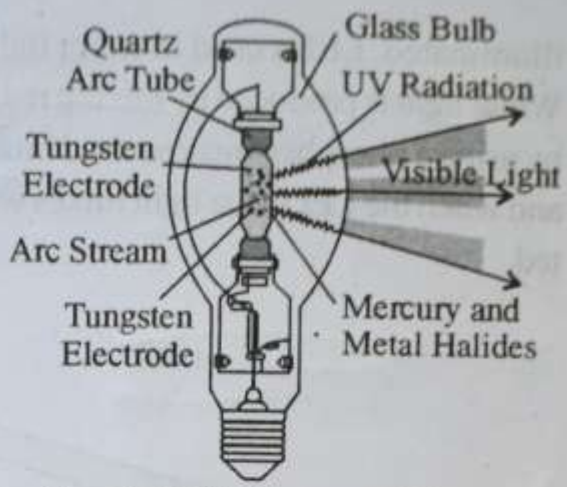


Fig. 70 (b) *High pressure Mercury and Metal Halide lamp.*

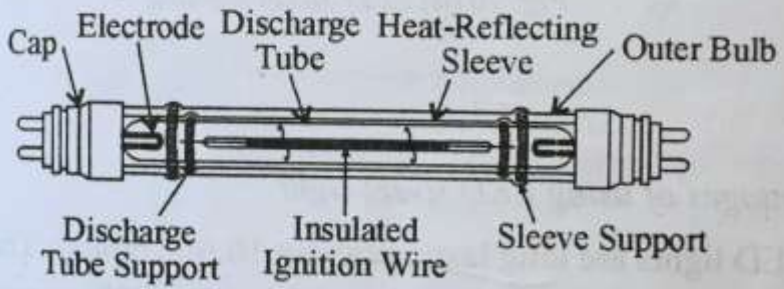


Fig. 70 (c) *Low Pressure Sodium Lamp.*

The lamps used in steet lighting today are mostly high Intensity Discharge (HID) lamps that include high pressure sodium, low pressure sodium (yellow colour), high pressure mercury and metal halide lamps (bluish colour)

In order to reduce the emission of green house gases, energy efficient lamps such as light emitting diodes (LED) for street lighting have been used. Their brightness is much more uniform and can give up to 50% saving over sodium vapour lamps.

LED street lighting

LEDs are light emitting diodes which consist of a semiconductor material which has the property of emitting light as the p-n junction is illuminated. LEDs used in street light are generally white light LEDs. White light is produced by mixing red, blue and green light from LEDs or by using a phospher-incorporated blue LED which produces yellow light and when the LED blue light mixes with yellow light, white light is emitted.

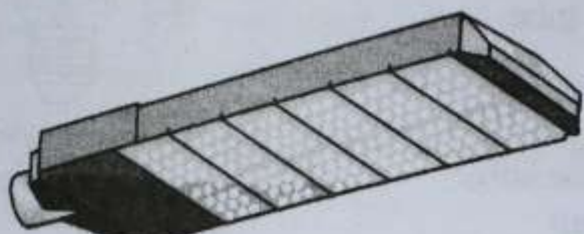


Fig. 70 (d) *LED Street lighting*

Advantages of using LED street light

LED lights are long lasting (about 10,000 hours). They draw less amount of power, only 8W or less. They have 80% energy efficiency. They provide high intensity of light (80 - 200 lumens per watt). LEDs have high colour rendering index (CRI) rating (80-90). They can start up instantly. They are more environment - friendly as they do not use toxic products. They are not affected by voltage fluctuations.

However LEDs produce dir

...d by voltage fluctuations.

However LEDs produce directional light and cannot produce glow in all directions. Their cost of installation is very high.

Maintenance

Most urban street lighting is the responsibility of the local authority (Village council, Municipality or Corporations) to install and keep in working order. Motor way and trunk roads lighting is the responsibility of the high-way agency. Maintenance is carried out by maintenance contractors.

Advantages of effective street lighting

1. Enhanced qulity of life for people.
2. Uniformly lit roads and pathways.
3. Reduced glare and improved visibility.
4. Improved safety and security.
5. Energy savings.
6. Maintenance cost savings.
7. An aesthetically pleasing atmosphere.

Solar Street Lighting System

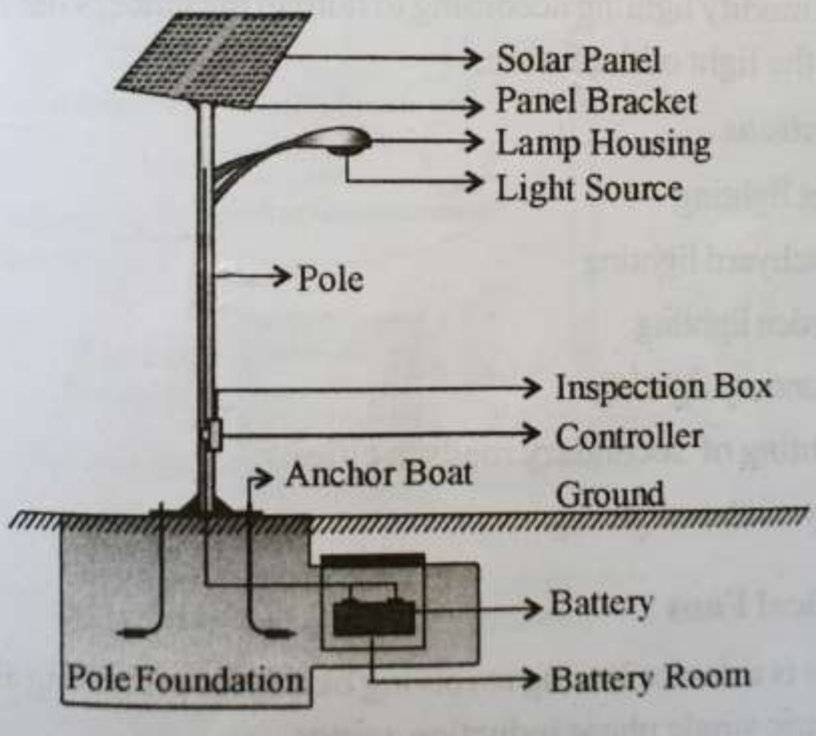


Fig. 71 Solar Street Lighting

Solar street lighting system is also known as stand - alone mast street lighting or all-in-one solar street lighting. Solar street lights use solar energy, which is a form of the renewable energy. The solar street lights comprise of the photo-voltaic cells, which absorb the solar energy during day time. The photo-voltaic cells convert solar energy into electrical energy, which is stored in the storage battery. At the night-time the lamp starts automatically and consumes the electricity already stored in battery. It requires no other wiring. During day time the battery gets recharged and the process keeps on repeating every day.

The LED lights are used in the solar street lighting. The LEDs require very little currents. Hence the solar panels of smaller sizes are required for the solar street lights with LED lamps. With the solar panel, having LED light and battery as one single fixture, this solar steet light is an all encompassing light. Hence it is called All-in-one solar lighting. Passive infrared sensor (PIR sensor) is an electronic sensor that measures infrared light radiating from objects in its field of view. With smart PIR sensors modify lighting according to human presence, solar street lighting is truly the light of the future.

Applications

(i) Street lighting

(ii) Switchyard lighting

(iii) Garden lighting

(iv) Boundary lighting

(v) Lighting of secondary roads in cities

(vi) Any outdoor lighting.

Electrical Fans

Fan is a device having revolving blades for propelling air. It is run by an electric single phase induction motor.

Components of a Fan

1. Electric motor -stator and rotor- capacitor start and run-rated at 230V, 50Hz.
2. Blade-usually made of aluminium sheet, 120 degree and normally 3-4 blades.

3. Blade flanges and body cover.
4. Ball bearings (top and bottam).
5. Regulator.
6. Suspension rod.
7. Terminal box (L,N and E).

Circuit diagram of celing fan and regulator connection.

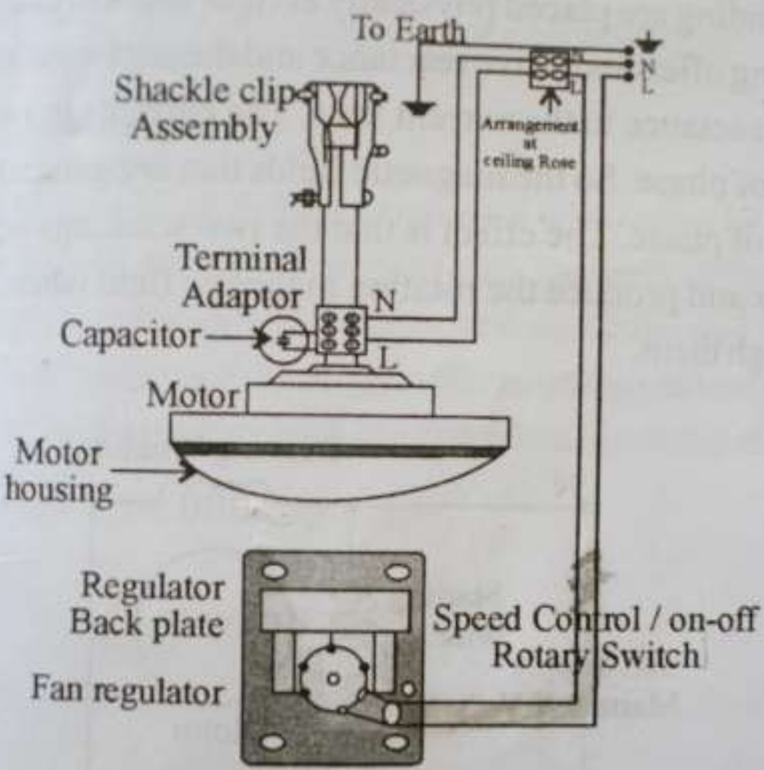


Fig. 72 Electrical fan connection
(Fan blades are not shown)

Principle of working :

Electric fan motor works on the principle of electromagnetic induction and rotating magnetic field. There are two parts in this motor : one is a stator and other is rotor. The stator coil is given single phase A.C voltage which produces sinusoidal flux that links with rotor coil. An emf is induced in the rotor. According to Lenz's law, the rotor coil current opposes the current that has produced it. Due to this the rotor rotates in similar direction as that of the simusoidal field. The blades of the fan attached to the rotar axle also rotates and we get flow of cool air.

Working

The essential part of a fan is a single phase induction motor. Stator is a stationary part of induction motor. Stator consists of the running (main) winding and starting winding. The starting winding along with a capacitor in series in connected parallel to the running winding. The main winding and start winding are placed physically at right angle to each other. The main winding offers inductive reactance and the start winding offers capacitative reactance to the current flow. The currents in each winding are 90° out of phase. So the magnetic fields that are generated by them are 90° out of phase. The effect is that the two windings act like a two phase stator and produce the rotating magnetic field when a.c. current flows through them.

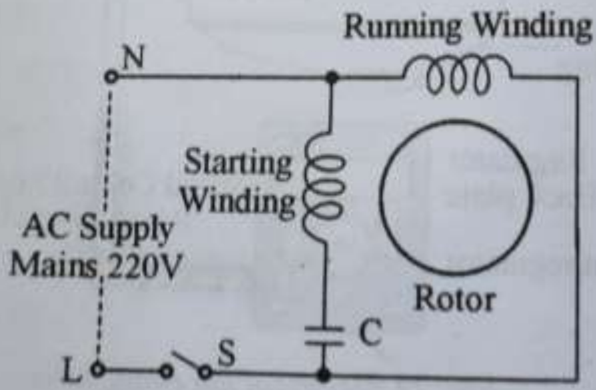


Fig. 73 Electrical Fan motor connection

The rotating flux links with the rotor (rotating part) conductors and an emf is induced in the rotor coil. The rotor current starts flowing in the rotor conductor. This current produces its own flux. Now the main flux and the rotor flux produce the desired torque, which is required by the rotor to rotate. When the full speed in obtained a centrifugal device (switch) opens the start winding. The motor then runs as a single phase induction motor.

Fan Regulators

Fan regulators regulate the speed of rotation (control the speed) of the fan by controlling the supply voltage. Fan regulators provide a convenient environment for the residents. Fan regulators are of four types:

(a) Resistive regulator

(b) Phase angle controlled regulator

(c) Inductive regulator

(d) Capacitive regulator.

(a) *Resistive regulator*

It works by providing different taps on a wire wound resistor, connected in series with the fan. When we rotate the knob, different amount resistance gets inserted in to the circuit. It is cost-effective. But there is considerable power loss as heat, through resistance at low speeds. It is also bulky. It consumes very high energy, when operating at low speed.

(b) *Phase angle controlled regulator*

This type of regulators employ active devices such as DIAC and TRIAC. The basic principle is to change the firing angle of the TRIAC in order to change the voltage across the fan. It is a continuous speed control, low power consumption regulator. But the speed control is not linear and it is expensive. It produces a disturbing humming sound.

(c) *Inductive type fan regulator*

An inductive type fan regulator has a tapping on the winding of the transformer and the inductive reactance is varied to achieve variation in speed. Speed decreases with increase in the number of turns of the inductance coil winding. It is a 2 pole 5 way switch. It has low heat power dissipation. But the power factor is low. It is heavy, bulky and costly.

(d) *Capacitive type fan regulator*

The voltage across the capacitor., $V_c = \frac{Q}{C}$ where Q is the charge on the capacitor and C is the capacitance. Hence $C \propto 1/V_c$. As C increases V_c decreases. Thus, the voltage across the fan increases when connected in series with a capacitor in an a.c. circuit. So the speed of the fan can be increased. Thus by employing suitable combinations of capacitors, the fan speed can be regulated.

The advantages of this type of regulator are: energy efficient, no humming sound during operations, speed linear and high reliability as compared to electronic type regulator.

Types of Fans

1. Celing fans
2. Table Fans - oscillating type
3. Industrial fans - Pedestal fans for halls
4. Air blower fan - hair drier, transformer cooling.
5. Exhaust fans, used in labs and book rooms
6. Duct fains - propeller type, mounted with in a cylindrical duct. Ducted fan propulsion is used in aircraft.

Troubleshooting Fans

The major problems occurring in fans are :

1. fan is not working.
2. fan is wobbling.
3. fan speeds are not working proper.
4. electrical hum (sound)
5. fan running the wrong way.
6. motor over-heating and high current draw.

Recomended action :

1. Check the voltage and adjust if possible.
2. Check the supply points at switch, regulator, ceiling rose and the terminals of the fan.
3. Check the continuity of the starting and main windings.
4. Check the capacitor with a megger or with a multimeter.

Technical data for celing fan

Size of fan (dia) (mm)	speed (rpm)	power consumption (watts)	Air delivery (m^3/hr)	Area cevered (m^2)
900	400	60	145	8.5
1050	380	65	195	10
1200	330	65	220	14
1400	290	70	270	18

Wet Grinder

Grinders are used to make pastes or batter from foodgrains and lentils such as those used in cooking dosas and idlis. These grinders consist of a few stone plates that are rolled again and again against another stone plate with the item to be ground between them. Wet grinder uses water to combine with ground grain to produce batter.

The parts of a grinder are : (i) container, (ii) motor, (iii) stone, (iv) pulley, and (v) frame and stand.

(i) Container : It is made up of stainless steel. All types of grains are stored in container. A hollow stone known as female part is attached to the container. The hollow stone actually keeps the grinding material inside.

(ii) Motor: The motor used in grinder is capacitor - start induction motor. It has two windings ie; starting and running winding. The starting winding has less gauge with more number of turnings. The running winding has more gauge with less number of turnings. The starting winding is connected in series with a capacitor and running winding is connected across the a.c. main supply. After 70 to 80 % of the speed is reached the starting winding is switched off by the centrifugal switching system (governor). The motor then operates only on running winding.

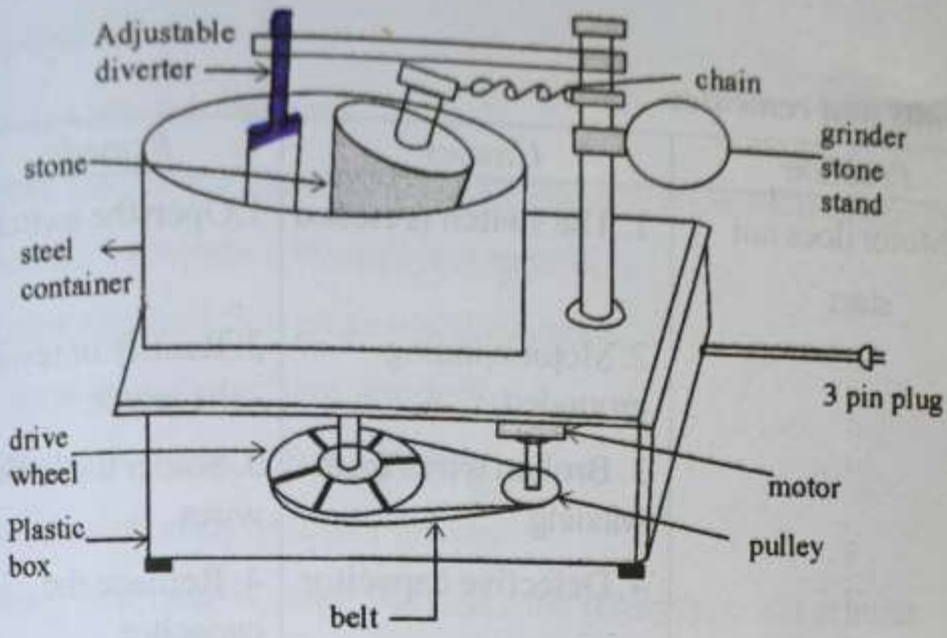


Fig. 75 Wet Grinder

(*iii*) *Stone :* The grinding stone consists of two parts. One male and other is female. The male stone grinds the grinding material during its rotation and the female stone keeps the grinding material inside. The grinding stones are manufactured with hard granite which is whitish black in colour. Wet grinder are largely manufactured in Coimbatore because granite is easily available in this region.

(iv) *Pulley :* The drum speed is lower than the motor speed. The drum speed is 500 to 600 rpm. The motor speed is 1450 rpm. The speed of the drum is reduced by using a larger diameter pulley.

(*v*) *Frame and stand :* All the parts of the grinder are housed in rectangular frame with stainless steel covering or plastic moulding for safety. A separate vertical stand is provided on one side of the grinder for holding the male grinding stone in an idle running condition.

Wet grinders have two advantages over electric mixers or blunders. First, the stone grinder generates less heat than a mixer. The heat affects the flavor of the food. Second, the stones remain sharp for a greater time than with metal blades.

Faults and remedies

Problem	Causes	Remedy
1. Motor does not start	1. The switch is closed	1.Open the switch
	2. Motor winding grounded .	2. Rectify or rewind the motor.
	3. Broken wires from winding.	3. Solder the broken wires
	4. Defective capacitor	4. Replace the capacitor.
	5. Blowing of fuses	5. Check and replace proper fuses.
2. Motor starts but heats up rapidly.	1. Defective centrifugal switch	1. Replace the centrifugal switch.
	2. Short circuited winding	2. Rewind the winding
	3. Grounded winding	3. Rectify or rewind the motor.
3. Motor slows down	1. Short circuited windings	1. Rewind the motor
	2. Shaft bend	2. Replace the shaft
	3. Worn out bushes.	3. Replace the bushes.
4. Motor is noisy.	1. Worn out bearing	1. Replace the bearing
	2. Bend shaft	2. Replace the shaft
	3. Lose parts	3. Tighten the parts

Precautions

1. Do not touch bare wires
2. Make sure, power is turned off before working on electrical equipments.
3. Insulate the winding by applying varnish.
4. Check regularly belt tension and vibration.

There are three types of wet grinders.

(i) Stone rotating type of wet grinder.

(ii) Container rotating type wet grinder

(iii) Tilting type or both stone and container rotary type wet grinder.

Mixer Grinder (mixie)

A mixer grinder is a domestic appliance of kitchen and is used to grind fruits, nuts, vegetables etc and to prepare drinks like milk shakes. Dry grinding of spices, cereals, seeds, dry fruits etc and wet grinding of garlic, onion etc are also done in mixer ginder. There are mixture grinders for mincing meat.

Domestic mixer grinders work on 220 volt AC and commonly have power rating between 500 watt to 1.5 kW. Maximum speed of 18,000 to 20,000 RPM is common.

The main parts of a basic mixer grinder are :

1. Electrical motor
2. Speed control switch
3. Overload protection and reset switch
4. Coupling
5. Jars and blades
6. Body
7. Rubber gasket
8. Accessories

Construction

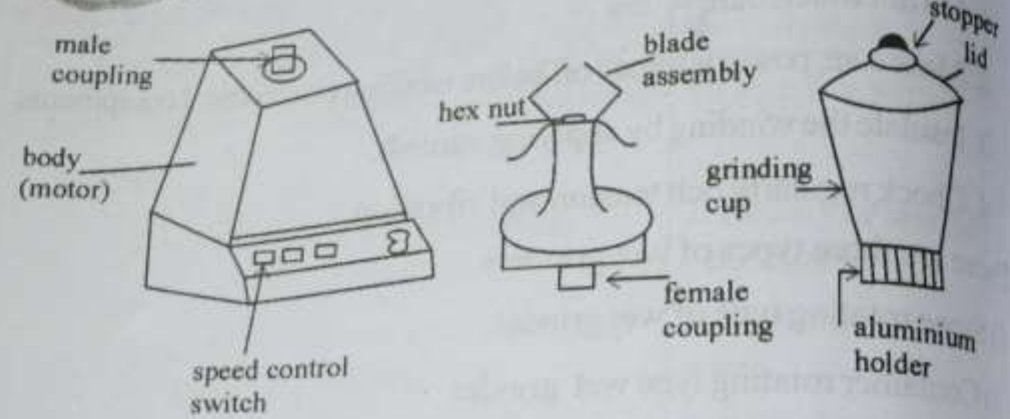


Fig. 75 (a) *Mixie Grinder Parts*

The speed control switch is generally a three speed switch. Low, medium or high speed that can be selected by rotating the knob of the switch. There is overload protection for the motor. If the motor gets overloaded it automatically gets switched off. An overland reset switch is provided at the bottom. Once the motor gets switched off because of overlanding, the motor can again be started after pressing the overload reset switch.

Jars

Jars are made of stainless steel with transparent covers made of polycarbonate material. Coupling is at the bottom and blades are fitted inside. Base is sealed by rubber gaskets in such a way that even a drop of water cannot leak through the base. The body is made of good quality plastic material. It is insulated and shock proof. Accessories include jars of different capacity, blades of different types for dry grinding, wet grinding, vegetable mincing etc; rubber ring, spatula, power cord etc.

The jars are fitted with food material for two thirds of the jar volume and then placed on the top bowl of the mixer grinder. Proper coupling of the jar is ensured and jar cover is put on the jar. During operation jar should be kept securely held by holding the jar cover.

Common problems are defects in the motor or switch, worn out brushes, broken or loose blades, leak in top bowl or jars etc. Mixer grinder should not be continuously run for long periods. There should be a gap of minimum one minute between two successive switching on. The motor must be off and the shaft must be stationary at the instants of placing or removing the grinder or the jar.

Troubleshooting and Repair of mixer grinder

Jammed mixer blade is a common problem. This happens when the seal in the bearing of the mixer blades leaks and salty water from the food seeps into the bearing of the mixie blades causing it to corrode and get jammed. The mixie will stop working under these conditions.

For emergency repairs keep the mixie jar upside down and pour some cooking oil into the space where the motor coupler is. Pour just enough oil to keep the level of the oil to below the rubber or plastic motor coupler. Leave aside for a few minutes and then twist the the plastic motor coupler with the help of a plier. Once it starts turning a few times it will loosen up.

Once the jar blade moves freely, it is put on the motor base, and run it empty for a few seconds at a time, till the mixer jar blads run freely.

To prevent mixer jar blades from getting stuck, it is a good practice to put some fresh water in the jar and run it for a few seconds and throw away this water.

When the grinding jobs are finished, the best way to clean the inside of the mixie jar is to pour about a cup of clean water into the mixer jar and then put it on the mixer motor and run it about 10 seconds. This will make the inside of the jar easier to clean. While cleaning the outside of the mixer jar, make sure that you do not let water come in contact with the mixer jar motor coupling at the base of the mixer jar. Only use damp cloth to wipe the mixe motor base and then again wipe with a dry cloth. It is better not no use detergents like vim liquid or others to clean the body of the mixer motor.

Mixer grinder overload protector

Sometimes the mixer grinder stops when doing tough jobs. This is because the mixer motor gets too hot and mixer grinder safety switch cuts off the power supply to the mixer motor due to overload.

When this happens, pull out the power cord from its plug socket. Turn the mixie motor upside down and press the red overload safety switch under the motor. Wait a few minutes for the motor to cool down before the thermal safety switch will switch on. Once the safety switch engages and you can press it on, it is good to run the mixie without any load for about 30 seconds to further cool the mixer motor.

To avoid overload problem, reduce the amount of material in the jar. If the material is too thick, then add some water.

Water heater: Storage type

We require hot water for domestic purposes like cooking, bathing, etc. Water heating is a thermodynamic process where a source of energy in used to heat water. The energy may be natural gas, liquefied petroleum gas or electricity. Now-a-days solar energy is also used for the water heating.

Principle of electrical water heater

Heating element is used in water heater to convert electrical energy into heat. The working of heating elements is based on the heating effect of electric current. When a current is passed through a resistance, it produces heat. To produce heat, the electrical energy consumed by resistance is given by

$$E = I^2Rt \quad \text{joule.}$$

where, I is current through resistance (in A) R is the resistance of the element (in Ω) and t is the time (in second).

The performance and life of heating element will depend on the material used for heating. The required properties of heating elements are :

1. high melting point
2. free from oxidation in open atmosphere
3. high tensile strength
4. sufficient ductility to draw the material or alloy in the form of wire
5. high resistivity
6. low temperature coefficient of resistance.

The following materials are used for manufacturing the heating element.

1. Nichrome (Ni + Cr) 2. Kanthal (Fe-Cr-Al alloy)

3. Platinum 4. Cupronickel (Cu - Ni - Fe - Mn)

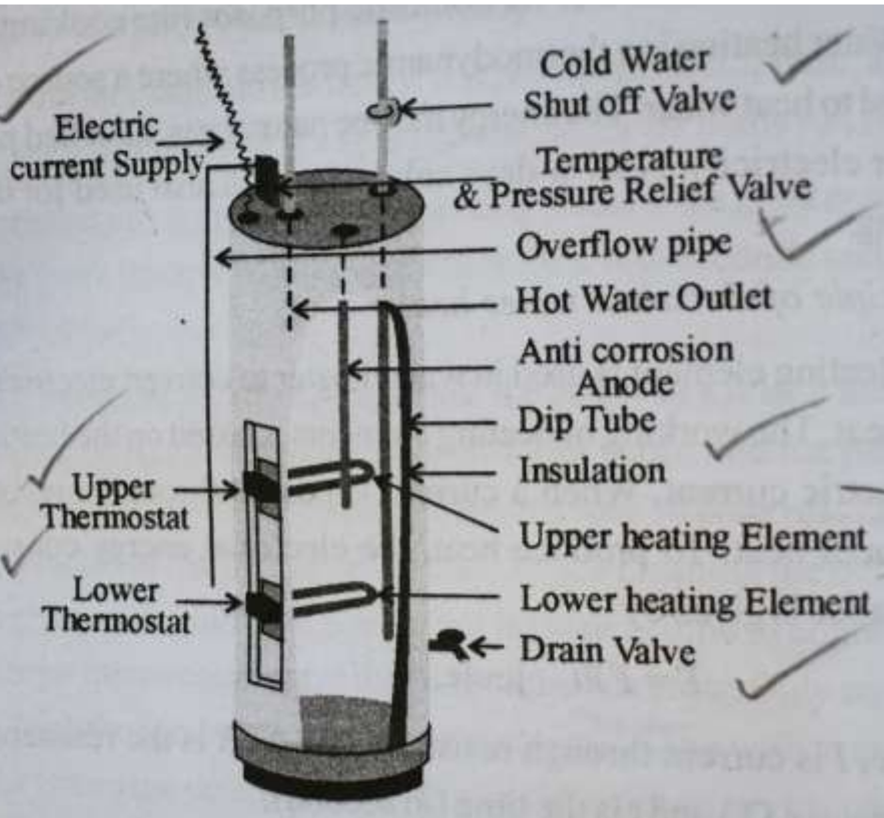


Fig. 76 Water heater: storage type

Parts of an electric water heater

There are three main components : (i) Dip tube (inlet tube) : Cold water enters the tank through this tube.

(ii) Outlet tube : Hot water goes out of tank through the tube.

(iii) Heating element : This element helps in heating the cold water.

There are various other parts used in a water heater.

Steel tank : This unit holds the water. This can withstand the pressure of water inside the tank.

Temperature and pressure relief valve : This valve prevents the heater from explosion during abnormal conditions like high pressure and temperature.

Drain valve : This is used for cleaning and maintenance.

Thermostat : This is used to control or maintain the temperature within the tank.

Anticorrosion anode rod : This rod aids in keeping the steel tank free from corrosion. This rod is made of magnesium, which attracts corrosive elements and thus prevents the tank from corroding. This rod can be replaced when it becames eroded.

Working

Water heaters have two heating elements, each wired with a thermostat. First the top heating element functions until the water in the upper part of the tank is heated to 50 - 60°C. Then the lower heating the element function. This has its own thermostat. When the hot water is consumed, once again cold water enters through the dip tube and the process is repeated.

Advantages of electric heating

1. The temperature can be controlled easily.
2. Electric heating systems are less expensive.
3. Electric heat is quick to respond.
4. Electric heat is clean.

The disadvantage of using - electric heating system is : it is expensive to operate and there is electrical hazard of shock and fire.

Troubleshooting and repair in electric water heater

1. No hot water

Causes : Lack of power to heating element. Faulty electric thermossat or heating element.

Repair : Replace blown fuse. Test upper heating element and thermo stat. Replace the defective part.

2. Water temperature too hot

Causes : Heating unit thermostat setting is too high.

Repair : Check upper and lower heating element thermostat settings and reduce if they are set too high. Normal setting is 43°C to 60°C

3. Water leaks

Causes : Faulty temperature and pressure relief valve (T and P valve) Leak from nearby plumbing connection. Leaking water tank.

Repair : Open and flush the T &P valve; Clear off debris. If leak remains from the valve, replace the T &P valve. If the leak is from the heating element, try to tighten the heating element mounting bolts. If the leak persists, replace heating element gasket.

4. Rust coloured water

Causes : Corrosion occuring inside glass - lined tank. The sacrificial anode rod is failing.

Repair : Replace sacrificial anode rod with magnesium anode rod.

5. Rotten egg odor in hot water

Cause : Bacteria in the tank sediment fed by hydrogen gas created from the decay of sacrificial anode.

Repair : Flush water heater. If the problem persists, replace anode with a zinc - alloy anode.

Electric Iron Box

The iron box is the small appliance used to remove wringles from cloth . Ironing works by loosining the bonds in the dress, between the long-chain polymer molecules in the fibers of the material. While the molecules are hot, the fibers are straightened by the weight of the iron, and they hold their new shape as they cool. Some fabrics, such as cotton, require the addition of water to loosen the intermolecular bonds. Ironing may also be used as a germ / parasite killing hygienic operation.

The basic principle of electric iron is that when a current is passed through a coil of wire, the coil heats up. This heat is distributed to the sole (base) of the electric iron through conduction. When the required temperature is reached the electric iron gets automatically switched off. Heat produced per second is i^2R.

There are basically three types of electric irons : (i) Automatic electric iron (ii) Non-Automatic electric iron and (iii) steam irons.

Automatic iron uses a thermostat to regulate the temperature. Non automatic iron has no provision for controlling or regulating temperature.

Parts of electric iron

1. Sole plate
2. Heating element
3. Pressure plate

4. Cover plate and handle
5. Power cord and plug
6. Thermostat
7. Indicator lamp.

Sole Plate : The sole plate is the tick triangular - shaped slab of iron that forms the base over which the electric iron is built up. The bottom surface and edges are chromium plated, to prevent it from rusting. The base plate should hold the the iron pressure plate and cover plate in position.

Pressure Plate : This plate is called the top plate as it follows the shape of sole plate. The pressure plate is heavy and made of cast iron or a thin sheet of steel. In automatic type of electric iron, the pressure plate has a rectangular hole for heating the thermostat.

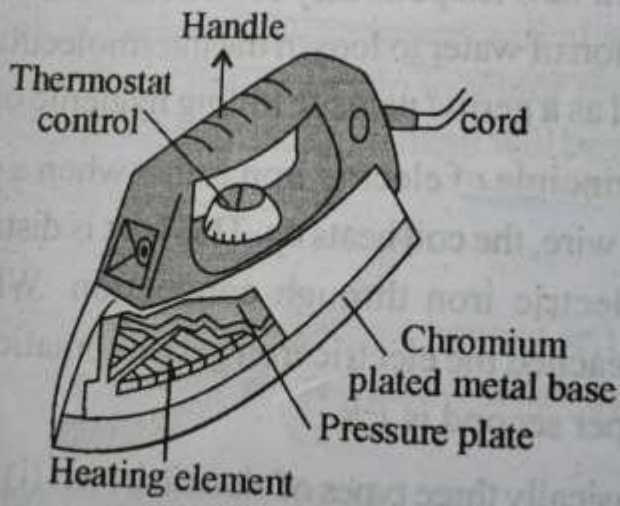


Fig. 78 Electric iron box

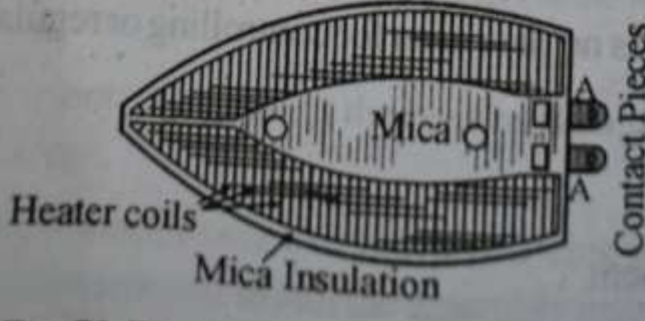


Fig. 79 Electric iron box heating element

Heating element : The heating element is present between the sole plate and pressure plate. It consists of nichrome wire, wound around a sheet of mica. The two ends of the wire are connected to the contact strips. The contact strips are connected to the terminals of the iron. Mica is a very good insulating material. It can also withstand very high temperatures. There is an asbestos sheet, which separates and thermally insulates the top plate from the heating element.

Cover Plate : The cover plate is made of thin sheet of iron. It is placed on top of the base plate and it coves all the internal parts of the iron. The handle and connector are only attached to the cover plate.

Handle : The handle can be made either with wood or with plastic. The handle is attached to the cover plate with the aid of screws.

Thermostat : In non automatic iron there is no provision for controlling or regulating temperature. When the iron is hot it is to be manually switched off and when the temperature is less than that requied, it is to be switched on manually.

In an automatic iron thermostat is used to regulate the temperature and there is a indicator lamp. The indicator lamp is on the top of the cover and glows when the heating is going on. The thernostat is a device which makes and breaks the connection between the two points depending on the temperature. It is like an automatic on-off switch. The transition between on and off depends on temperature which can be chosen or set. There is a dial knob by rotating which temperature can be set as per requirement of the type of fabric. If the set temperature is 150°C, then when the iron is switched on, the thermostat will act as on - switch and will allow current flow through the heating element As current flows through the heating element, temperature rises. Once the temperature rises above 150°C, the thermostat acts as a off-switch and cuts off current flow through the heating element. Then the temperature gradually decreases. Once the temperature is below 150°C, the thermostat acts as on - switch and allows current flow through the heating element. These on and off conditions continue and the tempearture of the iron remains constant approximately at 150°C.

Troubleshooting and Repair

Common problems are break in heating element, defect in power cord or thermostat loose connection and improper earthing. A broken element has to be replaced. Defects in power core and thermostat semetimes can be rectified by adjustment. Loose connection and improper earthing has to be rectified.

Microwave Oven

Principle : Dielectric heating

Each water molecule is made up of one oxygen atom which is slightly negative and two hydrogen atoms which are slightly positive. Thus the

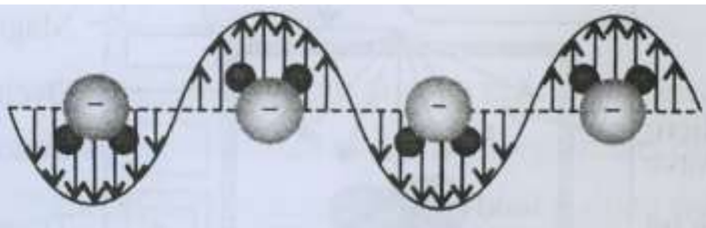


Fig. 81 Dielectric heating principle

If the electric field is oscillating, as in an electromagnetic wave, these molecules turn continously by aligning with it. This is called dipole rotation or dipole polarisation. As the field alternates, the molecules reverse direction.

Rotating molecules push, pull and collide with other molecules (through electric force) distributing energy to adjacent molecules and atoms in the material. Once distributed, this rotational energy appears as heat.

Temperature is related to the average kinetic energy (energy of motion of molecules or atoms in a material). Thus dipole rotation is a mechanism by which energy in the form of micro waves (electromagnetic radiation) can raise the temperature of an object. This principle is used in microwave oven for heating food materials.

Construction and working of microwave oven

A microwave oven is a kitchen appliance used to heat and cook food. Microwaves are centimeter waves. In the case of microwave ovens, the commonly used microwave frequency is 2.5 giga hertz (2.5×10^9 Hz). Electromagnetic waves in this frequency range are absorbed by water, fats and sugars. When they are absorbed, they are converted directly into atomic motion and their motion (kinetic energy) convered into heat. The micro waves are not absorbed by plastics, glass or ceramics. The metal reflects micro waves.

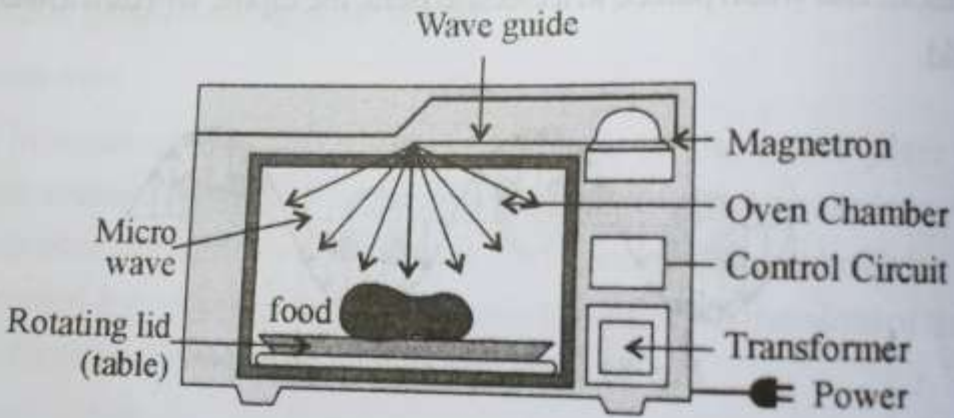


Fig. 82 Microwave oven

Components of microwave oven and their function

1. Inside the strong metal box, there is a microwave generator called magnetron. The magnetron takes electricity from the power outlet and converts into high-powered electromagnetic waves of wave length 12.0 cm.

2. The magnetron blasts these waves into the food compartment through a channel called wave guide.

3. The food is kept on a turntable, spinning slowly round so that the microwaves cook it evenly.

4. The microwaves bounce (reflected) back and forth off the metal walls of the food compartment. When the microwaves reach the food itself. they penetrate inside the food. As they travel through it, they make the molecules inside it vibrate more quickly.

5. The vibrating molecules have heat and the food becomes hot. Thus the microwave pass on their energy to the molecules in the food, rapidly heating it up.

In conventional heating, the object's temperature rises by spreading heat energy from the surface to inside (extenal heating). On the other hand, by microwave heating the object will generate heat on their own by the penetration of the microwave. Hence repid heating is possible by microwave since microwave heats objects internally.(The microwave oven was invented by Percy Spencer in the year 1950).

Advantages

Microwave cooking can be more energy efficient than conventional cooking because foods cook faster and the energy heats only the foods, not the oven compartment. Microwave cooking does not reduce the nutritional value of foods as conventional cooking. Foods cooked in a microwave oven may keep more of its vitamins and minerals, because microwave ovens can cook more quickly and without adding water. Foods high in water content, like vegetables can be cooked more quickly than other foods.

Glass, paper, ceramic or plastic containers are used in microwave cooking because such containers cannot be heated by microwaves.

Additional advantage

(i) Cooking time is short

(ii) No physical change of foods

(iii) Melting process is easy.

(iv) Sterilization effect exists

(v) There is no flame, then treatment is easy.

(vi) The whole heating process is different because we are exciting atom rather than conducting heat.

Disadvantages

(a) Metal container canot be used.

(b) Heat - force control is difficult.

(c) Closed container is dangerous because it could burst.

(d) Surface heating is impossible.

(e) The air in the oven is at room temperature, so there is no way to form a crust (a piece of stale bread)

Precautions on how to use a microwave oven.

1. Use suitable utensils for cooking.
2. Set the correct wattage and time before cooking.
3. Follow the food package heating instructions.
4. Do not leave the food unattended while heating.
5. Do not cook eggs with shell.
6. Do not put sealed cans or bottles in the microwave oven.
7. Do not fry food.
8. Do not use metal utensils.
9. Do not use or operate the microwave oven if there are no food items.

√ **Washing Machine**

Principle

A washing machine is a modern domestic appliance and is used to wash clothes. Washing of clothes involves soaking, application of soap, stirring and rinsing. Dirt gets removed from clothes when soap water is forced through pores in the clothes. Once dirt is removed by soap water, the clothes are to be rinsed with water several times. Rinsing removes soap water. Factors that determine quality of washing are water, detergent, heat, time and physical motion. Application of physical motion like agitation or scrubbing helps dirt remove. In an washing machine washing of clothes is done in two stages : first stage is called the wash - cycle and second stage is called spin - cycle or rinse - cycle. In wash cycle clothes soaked in soap water are agitated or rotated in a tub till dirt gets removed from clothes. Soap water containing dirt is drained out and clothes are rinsed with fresh water by spinning the tub. This is the spin cycle or rinse cycle.

When detergent (soap powder) dissolves in water, its surface tension decreses and the solution is able to penetrate into every fibre of the fabric. Detergent separates the dirt from the fabric with the help of mechanical action. The mechanical action to dislodge dirt from the clothes is provided by washing machine.

Classification

Washing machine are classified as (i) Automatic and (ii) semi automatic. Depending on how clothes are loaded, they are categorised as (i) Front loading and (ii) Top loading.

In automatic washing machine once the dirty clothes, detergent and water are given as input and necessary instructions are given by means of control switches, the machine takes control and completes washing. Dirty clothes are to be loaded and washed clothes are to be unloaded and there is no manual work in between. In case of semi- automatic machines, some manual work is involved inbetween.

In top loading machine the clothes are loaded through a door at the top and the tub is vertical. In front loading machine the clothes are loaded through a door in front of the machine and the tub is horizontal.

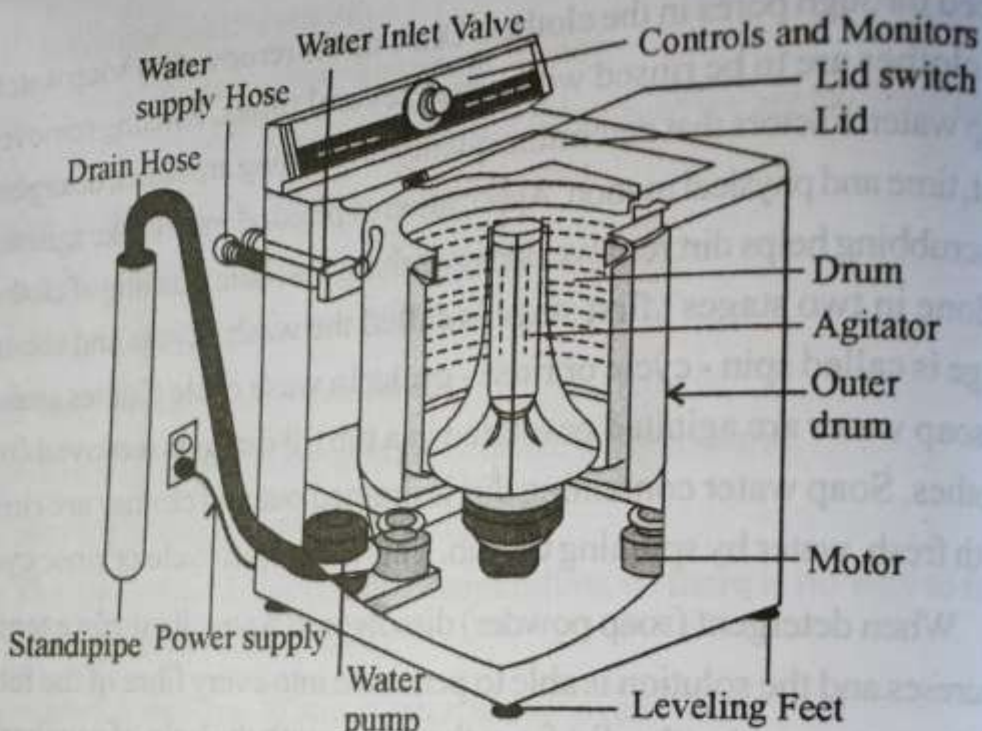


Fig. 83 Washing Machine

Parts of washing machine

Major parts of a basic washing machine are :

1. Washing tub 2. Electric motor 3. Pump 4. Control panel and controlling mechanisms 5. Valves 6. Transmission mechanism 7. Sensors 8. Water lines 9. Agitator 10. Heater 11. Accessories.

Working

Dry clothes are put in a tub. The tub is cylindrical and is made of aluminium or copper or steel or fiber glass. There are small holes on the tub. In top loading machines, the tub is vertical and is fitted inside a solid outer tub. An agitator is there at the centre of the tub. Agitator is driven by a motor and it stirs and agitates soaked clothes. The action of the agitator cleans the clothes by flushing out dirt particles from clothes. Soap water is drained out and the clothes are rinsed with water several times till they become free from soap. Water is extracted from the clothes by spinning the tub. The spinning speed is between 400 to 1000 RPM when the tub is spinned, water from the clothes come out through the holes to the outer tub due to centrifugal force and is drained out. Top loading models without an agitator undergo pulsating oscillation to agitate the soaked clothes.

The washed clean clothes are taken out and are dried outside. The electric motor is a single phase AC motor. It is an universal motor or a capacitor type split phase motor. The same motor is used to drive the agitator during washing and to spin the inner tub during rinsing.

The pump circulates water to fill the tub during washing and drains out water from the tub after spinning. There are valves for hot water, cold water and for mixing.

Voltage Stabilizer

Voltage stabilizer stabilises the astable A.C. main voltage. Mains AC voltage is the input to the voltage stabilizer and constant voltage of 220 volt is the output from the voltage stabilizer. A voltage stabilizer senses the input voltage and compares whether the input is equal to the desired Voltage of 220 volt. If the input is different from 220 volt, some action is initiated to adjust the voltage to 220 volt. Loads (such as fridge, TV, washing machine etc) are connected to the output of the voltage stabilizer. Voltage stabilizer supplies nearly constant voltage even when the input voltage and load varies. The capacity of a voltage stabilizer is expressed in volt ampere (VA). There are stabilizer models with capacity as low as 200 VA and also models with capacity as high as 10KVA. As the mains AC may vary beyond normally tolerable limit, electrically operated equipment are connected through voltage stabilizer for safe and proper operation.

Voltage stabilizers can be classified as

1. Manual voltage stabilizer.
2. Automatic voltage stabilizer
3. Constant voltage Transformer (CVT)
4. Servo voltage stabilizer.

1. Basic principle of operation of voltage stabilizer

The voltage regulation is required for two purposes; over voltage and undervoltage conditions. The process of increasing voltage from undervoltage condition is called *boost* operation. The process of reducing the voltage from over voltage condition is called as buck operations. These two main operations are essential in each and every voltage stabiliser.

The components of voltage stabiliser are a transformer, relays and electronic circuitary. If the stabilizer senses the voltage drop in incoming voltage, it enables the electromagnetic relay so as to add more voltage from transformer so that the loss of voltage will be compensated.

When the incoming voltage is more than normal value, stabiliser activates another electromagnetic relay such that it deducts the voltage to maintain the normal value of voltage.

4. *Working of voltage stabiliser*

Figure shows the working model of a voltage stabiliser that contains a step-down transformer (usually provided with taps on secondary), rectifier, operational amplifier / microcontroller unit and set of relays.

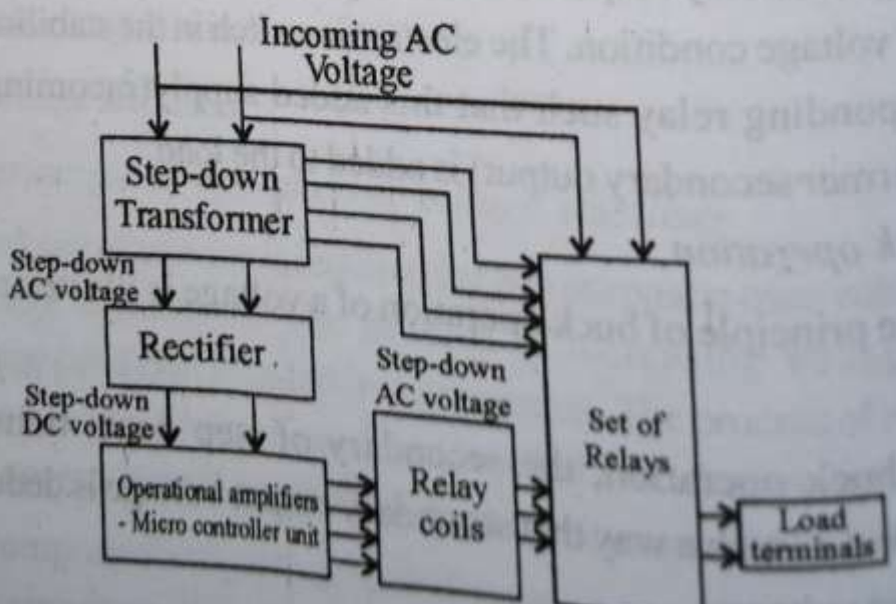


Fig. 86 Voltage stabiliser :Block diagram

In this op-amps are tuned in such way that they could sense varions set voltage such as lower cut off voltage, boost voltage, normal operating voltage, higher cut off voltage and buck operating voltage.

A set of relays are connected in a manner that they trip the load circuit during higher and lower cut off voltages and also they switch buck and boost voltages to the load circuit.

A step-down tap changing transformer has different secondary voltage tapping which are helpful for operating operational amplifier for different voltages and also to add-up and deduct voltages for boost and buck operations respectively.

A rectifier circuit converts AC supply into DC to power-up entire electronic control circuit as well as relay coils.

Refrigerators

A refrigerator is a machine used for producing artificially low temperatures which are much below that of the surrounding atmosphere and maintaining an enclosure at that temperature. The principle used in refrigeration is the production of cooling by making a liquid evaporate rapidly under reduced pressure. The liquid which produces the cooling by evaporation is called the refrigerant. Some of the common refrigerants in use are ammonia, sulphur-dioxide, methyl chloride and freon (CCl_2F_2) In large refrigerating plants ammonia is used, while in small plants used for domestic purposes, sulphur - dioxide and freon are used. The vapour of these gases can be easilyliquefied and a lighter compressor will be sufficient for the compression.

Refrigerations are of two types, depending on the manner in which the low pressure vapour is compressed.

1. Vapour compression type
2. Vapour absorption type

The vapour compression machines are more efficient, particularly for large plants and requires less initial cost. Consequently they are more commonly used than the vapour absorbing machines

Vapour compression machine

In this type of refrigerator, a low pressure vapour like sulphur di-oxide (refrigerant) is compressed by a compressor which is driven by an electric motor. The essential parts of this machine are shown in figure. R is a compression pump which is worked by an electic motor. It is provided with spring - loaded valves V_1 and V_2 at the bottom.

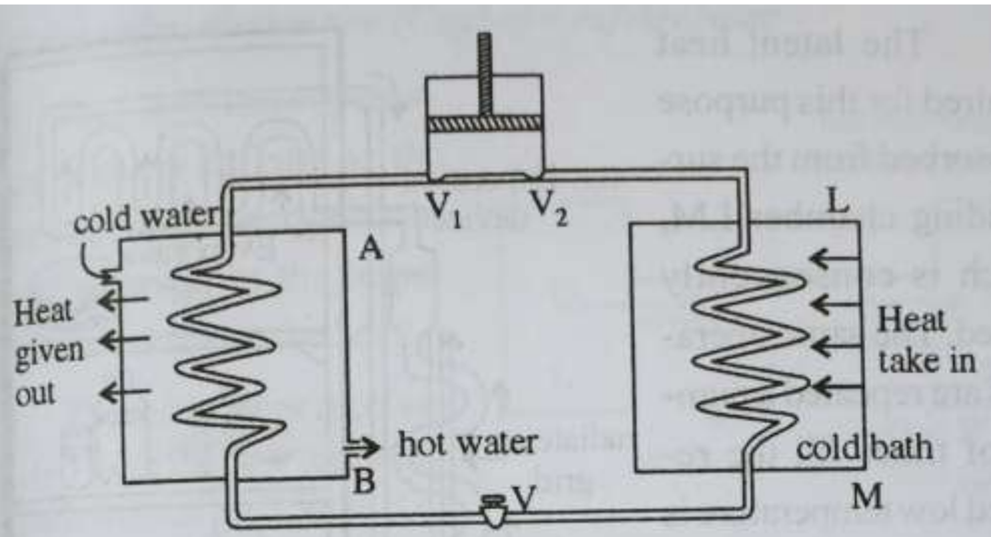


Fig. 87 Refrigerator Working principle

These valves are such that during the downward stroke of the piston, the pressure of the vapour increases and opens V_1 while V_2 remains closed. During the upward stroke of the piston, the pressure of the vapour below it falls resulting in the opening of V_2 and closing of V_1. C is a spiral tube of copper called the condenser coil, which is surrounded by a vessel AB through which a stream of cold water is made to circulate. E is another spiral tube of copper, known as the evaporationg coil which is surrounded by the chamber LM that is to be cooled. V is a throttle valve which is provided with a small hole in it, which allows the refrigerant liquid from the condenser C to pass to the evaporator E, whenever a difference of pressure is set up between the two.

Action: Sulphur dioxide gas is introduced into the barrel of the compression pump. The piston is moved down the barrel by an electic motor. The refrigerant gas is compressed. Value V_1 opens while V_2 is closed. The gas condenses into a liquid. The liquid refrigerant then passes through the throttle valve V into the evaporator E. when the pressure in it is low.

During the upward stroke of the piston, the valve V_1 gets closed and V_2 opens. The liquid in the evaporator E evaporates.

The latent heat required for this purpose is absorbed from the surrounding chamber LM, which is consequently cooled. The same operations are repeated a number of times till the required low temperature is reached by the chamber LM. An automatic device is used for starting or stopping the motor during the compression whenever the temperature rises above or gets lowered below the required temperature.

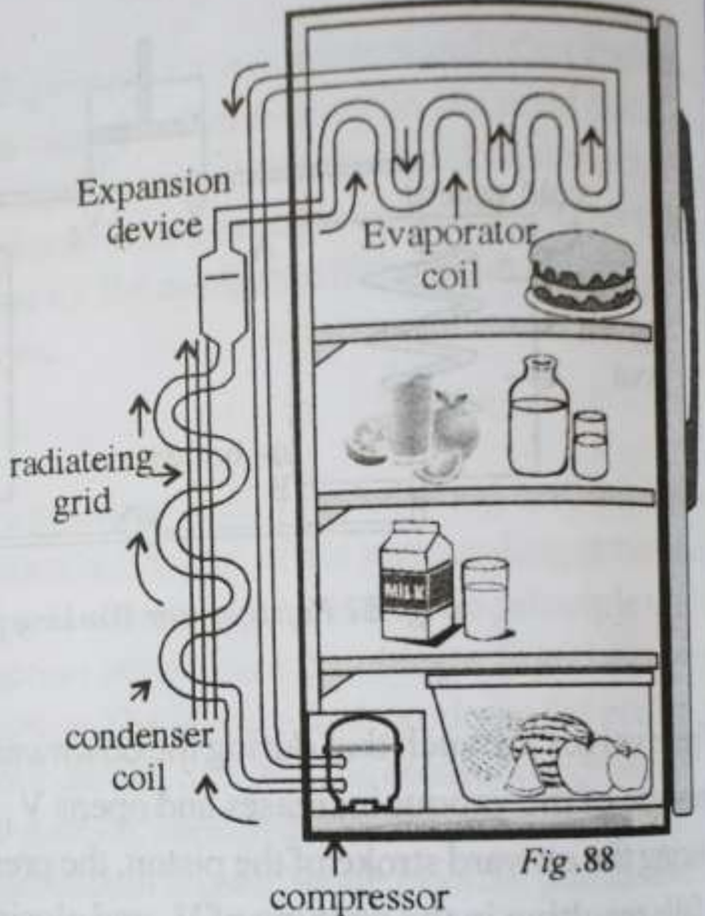


Fig. 88 *Refrigerator*

Freezer section

The freezer section of the refrigerator is a closed chamber. In this the evaporator which is in the form of various coils of copper are kept. Here the foods or the substances which are initially at high temperature are kept for cooling.

When the low temperature and low pressure refrigerant gas passes through the evaporator, it chills the freezer space and food items kept there. It absorbs the heat from the substances to be chilled and so the temperature and pressure of the refrigeant gas rises. It leaves the evaporator or freezer in the vapour state and then enters into the compressor where the cycle is repeated.

The following factors are important while deciding on a suitable refrigerant:

(i) The latent heat of vaporization of the refrigerant liquid should be large so that even a small quantity of it may produce a lage cooling effect.

(ii) The refrigerant must be a vapour at normal temperature and pressure.

(iii) The pressure of the vapour of the refrigerant liquid in the evaporator should be higher than the atmospheric pressure so that impurities in air may not get sucked into the evaporator and block the valves.

(iv) The pressure required to liquefythe vapour in the condenser should not be large as otherwise, the compressor will have to be very strong and heavy in order to prevent any leakage of the vapour into the atmosphere.

(v) The specific volume of the vapour of the refrigerant liquid should not be too large as otherwise, the size of the compressor would become too large and unwieldy.

Air conditioning machine

Air conditioner is a device that removes heat from the air inside a hall or a vehicle and delivers the heat to outside atmosphere, thus lowering the air temperature inside. The condition inside the room must suit to human health and comfort. The comfort chart gives the combination of temperature, relative humidity and air velocity required for maximum comfort satisfactory for an average person. For the average comfort conditions, the requirements are the following :

(i) Temperature : 17° to 22 °C in winter

and 19° to 24 °C in summer

(ii) Relative humidity : 30 to 65 %

(moisture content)

(iii) air movement : 4.5 to 15 metre per minute.

(iv) fresh air to be introduced from outside : 25 % of total air circulation.

Construction

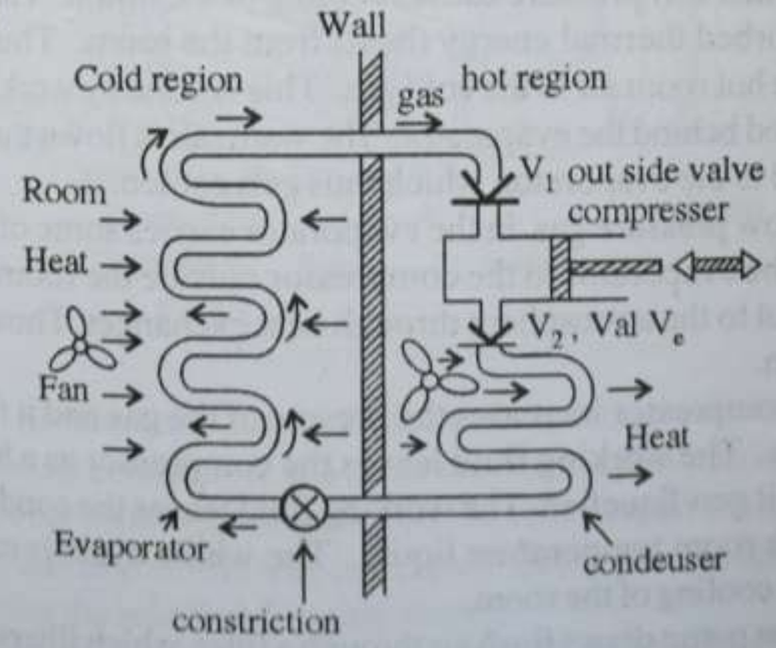


Fig. 90 Air Conditioner working principle

evaporator is a series of zig-zag copper tubing, linned with the copper sheets for increasing the effective area of the cold surface. This serves as the heat exchanger. The constriction unit consists of narrow section of fluid path. It restricts the fluid flow. The compressor works with the help of an electric motor. It produces low pressure to the evaporator section and high pressure to the compressor section with the help of one way valves. The whole unit is filled with the working substance namely the refrigerants like freon, R-12 gas etc.

Working

When the piston of the compressor moves towards the right, the valve V_1 opens and V_2 closes. The low pressure refrigerant gas enters the cylinder. When the piston moves towards the left, the valve V_1 closes and V_2 opens. The gas is compressed and pushed through the heat exchanger pipe. The gas gets cooled due with loss of heat of compression to the atmosphere through the exchanger; the compressed gas gets liquefied. The liquid loses pressure as it passes through the constriction unit and enters the evaporator unit as low pressure liquid. Evaporation of liquid under low pressure causes cooling of the liquid. That is, the fluid has absorbed thermal energy (heat) from the room. Thus, heat flows from the hot room air to the cold gas. This is done by working an electic fan placed behind the evaporator. The warm air is flown through the fins attached to the evaporator, which thus gets cooled.

The low pressure gas in the evaporator carries some of the heat as it leaves the evaporator to the compressor outside the room. The heat is given out to the atmosphere through heat exchanger. Thus heat has left the room.

The compressor increases the presure of the gas and it raises in temperature. The working fluid leaves the compressor as a high pressure gas and it gets liquefied. The working fluid leaves the condenser as high pressure room temperature liquid. The whole cycle is repeated. The result is cooling of the room.

A suction pump draws fresh air through a filter, which filters out particles of dust, smoke etc. This air is passed from one end of the cooling coil to the other through the fins and the air gets cooled. The moisture content exceeding a comfort limit, is precipitated as droplets. on the fins and it is drained out. This is known as dehumidification .

Types of Air Conditioners

There are various types of air conditioners

1. Window air conditioning system
2. Split air conditioning system
3. Central air conditioning system

Questions

1. What are the different kinds of electrical bulbs? Giving neat sketch, explain the functioning of each kind of bulbs.
2. Describe a fluorescent lamp and explain its working. What is the function of choke in fluorescent lamp?

3. What are the characteristics of good street lighting? Describe, giving neat diagrams, the setup and functioning of (i) LED street lighting and (ii) stand - alone mast solar panel - street lighting.

4. Describe, with neat sketch, an electrical fan, with its wiring diagram. How does the fan work? How is the fan speed regulated?

5. Give a lay-out diagram of (i) wet grinder and (ii) mixer. Describe their essential parts and their functions.

6. Explain the principle and working of storage and instant type water heaters.

7. Describe the construction of electric iron box and explain its working. What additional components are used in automatic iron box and how do they work?

8. Describe the essential parts of a microwave oven. Explain the principle and working of microwave oven.

9. Describe the various parts of washing machine. Explain the principle and working of washing machine.

10. What is the need for stabilizers in an electronic appliances? Describe the construction and action of a voltage stabiliser.

11. Describe and explain the working of a fridge. How does the freezer unit work?

12. Describe and explain the working of a domestic air conditioner. What are the different types of air conditioners?

13. Describe the functioning of a central air conditioner.

14. What faults may arise in the working of (i) electric iron box and (ii) electric fan? Describe how these may be troubleshooted.

15. Write about troubleshooting the following devices (i) wet grinder (ii) mixer (iii) microwave oven and (iv) washing machine.

Objective type questions

1. Metal halide lamps emit
   (a) white light (b) red colour light (c) blue colour light
   (d) all the above
2. In which system of street lighting renewable energy is used?
   (a) fluorescent lamp system (b) LED lighting system
   (c) solar lighting system (d) all the abover
3. For line boosting and bucking, voltage stabilisers employ
   (a) Inverter (b) rectifier (c) voltage amplifier
   (d) transformer
4. The capacity of air conditioner is expressed in
   (a) m^2 (b) Ton (c) BTU (d) $^{\circ}C/m^3$
5. A 60 W incandescent bulb light is equivalent to
   (a) 750 lumen (b) 850 lumen (c) 950 lumen
   (d) 1000 lumen
6. Intensitas (I) of light differs with distance (d) from the source as
   (a) $I \propto d^2$ (b) $I \propto d$ (c) $I \propto 1/d$ (d) $I \propto 1/d^2$
7. In an automatic iron box temperature is regulated by
   (a) thermometer (b) thermostat (c) voltage stabiliser
   (d) all the above
8. The heating element in an iron box is made of
   (a) copper (b) zinc (c) iron (d) nichrome
9. An essential part of thermostat is
   (a) bimetallic strip (b) relay (c) time - delay switch
   (d) all the above
10. Power consumption of a ceiling fan is typically
    (a) 40 W (b) 40 - 50 W (c) 60 - 70 W (d) 10 – 120 W

11. PVCs convert

(a) electricity to light (b) solar power to electricity

(c) mechanical power to electricity (d) LED to light

12. Electric fan works onthe principle of

(a) electromagnetic induction (b) rotating magnetic field

(c) both (a) and (b) (d) dynamic stability

13. The heating element in an electric water heater must have

(a) high melting point (b) high resistivity

(c) small temperature coefficient of resistance

(d) all the above

14. The power consumption of a washing machine is of the mange of

(a) 2 - 4 KW (b) 3 - 5 W (c) 30 - 50 W

(d) 50 - 100 W

15. The type of air conditioner suitable for rooms is

(a) central A.C. (b) Split A.C. (c) In door A.C.

(d) none

16. When soap powder dissolves in water in a washing machine, the surface tension of water is

(a) increased (b) decreased (c) unaltered (d) none

17. The capacity of a washing machine is expressed in

(a) litre (b) metre^3 (c) kg (d) farad

18. The capacity of a voltage regulator is expressed in

(a) volt (b) KV (c) VA (d) KVA

Answers

1. (c) 2. (c) 3. (d) 4. (b) 5. (b) 6. (d)
7. (b) 8. (d) 9. (a) 10. (c) 11. (b) 12. (c)
13. (d) 14. (a) 15. (b) 16. (b) 17. (c) 18. (d)

UNIT-IV

AC and DC- Single phase and three phase connections - RMS and peak values- house wiring - Star and delta connection - overloading - earthing - short circuiting - colour code for insulation wires

Direct current (DC) and Alternating current (AC)

Direct current

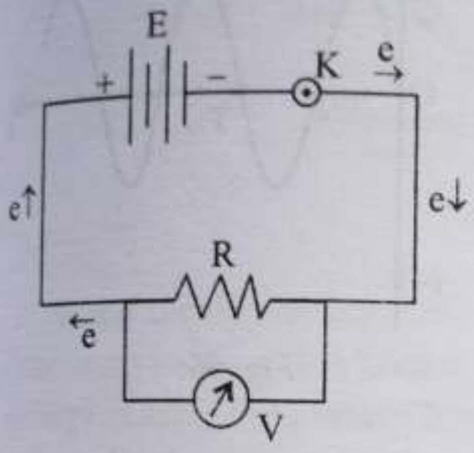


Fig. 94

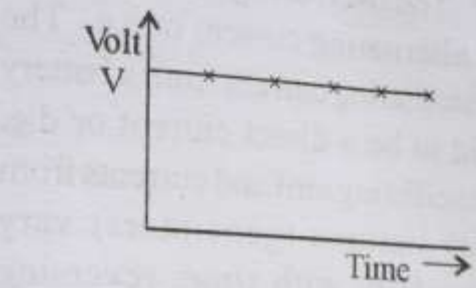


Fig. 95 DC Voltage

Consider and electric circuit inwhich a battery of emf E volt is connected to a resistance R ohm. When the circuit is switched on, electrons (-ve charges) flow in one direction and the current produced is direct current (d.c). The current is unidirectional because the battery due to chemical reaction, maintains the same polarity of output voltage and the voltage is of steady value.

D.C. voltage source produces D.C. current. D.C. voltage is produced by electrochemical cells, photo voltaic cells (PVC) and batteries. All solar panels produce D.C. power. D.C can be obtained from A.C by the use of rectifiers.

D.C. power is used in low voltage applications such as battery charging and cell phone charging and automobile applications and air craft applications. Most electronic systems work on d.c.

An alternating current is one that changes direction of flow periodically. The voltage in AC circuits also periodically reverses because the current changes direction.

Alternating current

The electric power for domestic appliances, office use and for factories is supplied from power generating stations through oscillating currents and e.m.f. The oscillating current is said to be alternating current or a.c. The non-oscillating current from a battery is said to be a direct current or d.c. The oscillating emf and currents from power stations (generators) vary sinusoidally with time, reversing direction 100 times per second or with a frequency of 50 cycles per second or 50 Hz.

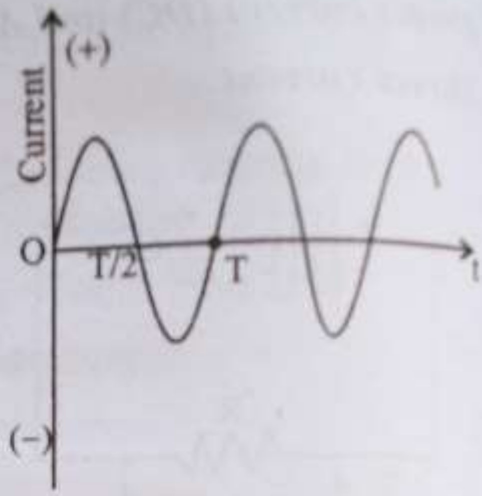


Fig. 96

Advantages of a.c. over d.c.

1. Electric power can be carried from the generating station to distance places in the form of a.c. without much loss of power. The power loss in the transmission line would be larger if d.c. were to be used.
2. The a.c. voltage (or current) can be stepped up or stepped down using transformers. This is not possible with d.c.
3. In a.c. the magnitude of the current can be reduced with the help of a choke coil or a capacitance, without any appreciable loss of energy. In d.c. a resistor alone has to be used to decrease the current, causing loss of energy due to heating (heat loss = $I^2 R t$).
4. Direct current can be obtained from a.c. by using rectifiers

$\omega = 2\pi f$; f is frequency of AC (hertz). $\frac{I_0}{\sqrt{2}}$ or ($0.707 \times I_o$) is the r.m.s current. R is resistance; ($L\omega$) is inductive reactance; $\left(\frac{1}{C\omega}\right)$ is capacitive reactance in ohm. Inductive reactance increases as frequency is increased. Capacitive reactance decreases as frequency is increased. By-pass capacitors have large capacitance. Blocking capacitors have small capacitance.

Y. The star connection

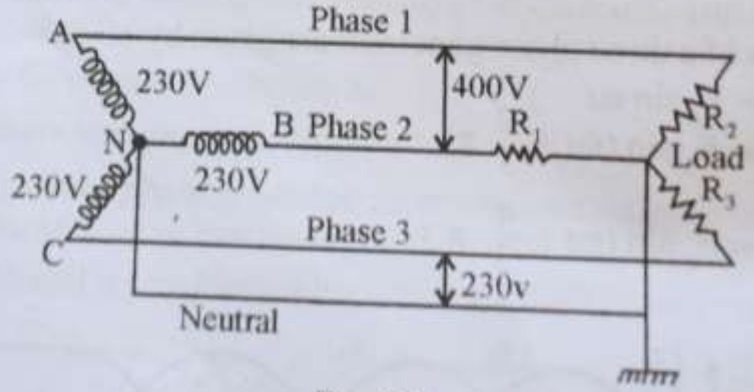


Fig. 108

In the star connection, similar ends of the three coils, carrying currents in 3-phases are joined together so as to form a star point (or neutral point). The three phase lines are drawn from the other ends of the coils.

The star (centre) point is earth-connected.

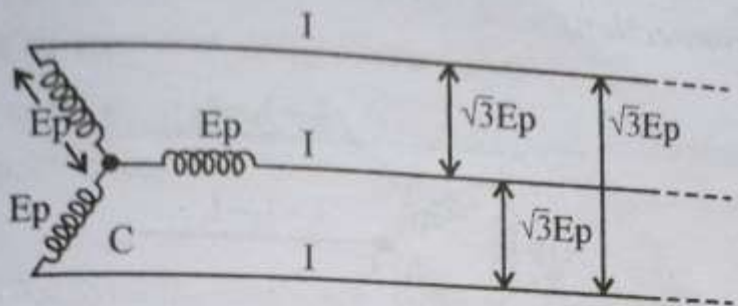


Fig. 109

Phase voltage and line voltage

The potential difference between any line and the neutral gives the phase voltage (E_{ph}). The potential difference between any two lines is the line voltage (E_L).

If E_L is the line voltage and E_{ph} is the phase voltage, then it can be shown that

$$E_L = \sqrt{3} \cdot E_{ph} \text{ for star connection.}$$

If the voltage between the star point and one line is 230 volt then the voltage between any two lines is $230 \times \sqrt{3}$ volt. The line voltages are 120° apart but is 30° ahead of the respective phase voltages.

Phase current and line current

Each line (wire) is in series with its individual phase winding. Hence the line current in each line is same as the current in the phase winding (I_{ph}) to which the line is connected. If the line currents are I_1, I_2 and I_3, then at the balanced load,

$$I_1 = I_2 = I_3 = I_{ph}$$

The neutral wire carries three currents, which are equal in magnitude but 120° out of phase with each other. Hence their vector surn is zero.

i.e. $I_1 + I_2 + I_3 = 0$

2. Delta connection

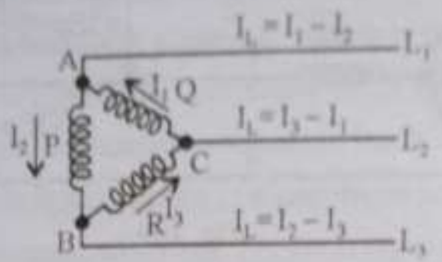


Fig. 110

When the starting end of one coil is connected to the finishing end of the other coil, the delta connection is obtained. The direction of emfs in the coils are taken as positive from the starting end to the finishing end as marked in the figure. This mode of connection is know as 3 phase-3wire delta connected system.

In this system, when the load is balanced, the sum of the three voltages around the closed loop is zero.

Phase voltage and line voltage.

The voltage between any pair of lines of (E_L) is equal to the phase voltage (E_{ph}) of the phase winding, connected between these two lines.

$$E_L = E_{ph}$$

Phase current and line current

Each line drawn out from delta comes from the node where two currents meet. The current towards the node is taken as positive and that leaving that node is taken as negative.

Taking the top most line from node A the line current = I_L

The phase currents are I_1 (positive and I_2 negative)

The line current in line 1 is $I_{L1} = (I_1 - I_2)$

The current in line 2 is $I_{L2} = (I_3 - I_1)$

The current in line 3 is $I_{L3} = (I_2 - I_3)$

I_1, I_2, I_3, are phase currents, as marked in the figure

The difference of phase currents in each bracket have phase difference of 120°. It can be shown that the line current is $\sqrt{3}$ times the phase current.

Salient features of star and delta connections

1. In star connected system similar ends (i.e. starting end to starting end) of coils are connected together. But in delta connection, dissimilar ends are joined.

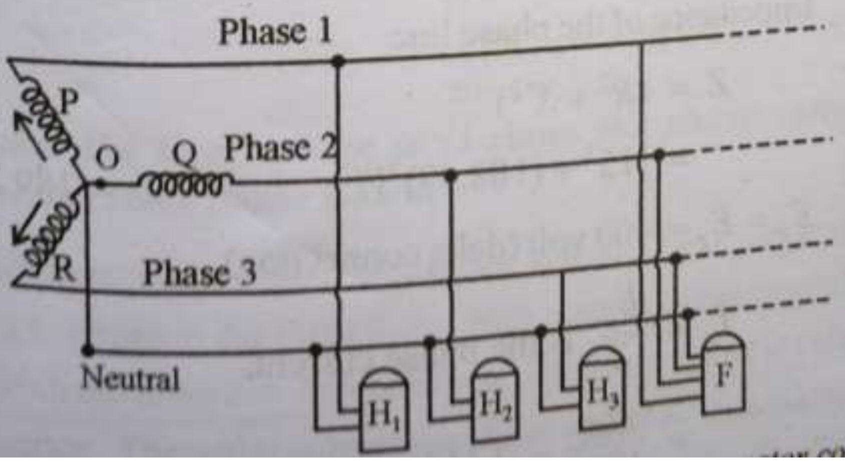
2. In star connected system, the phase. voltage = line voltage.

Hence, the star connected generator requires less number of turns per phase than the delta connected system to give the same line voltage.

3. In a star connected system, the phase current = line current; whereas in delta connected system the phase current = $\frac{1}{\sqrt{3}}$ times the line current.

Three phase - four wire system

This system is used for lighting and for high power loads. This arrangement is possible only with star- connected system. When the star connection is used for power distribution, all electric supplies to houses are given between a phase and the neutral. It actually functions as a single phase supply. But the total load in the house is equally distributed between the three phases, i.e., we have a balanced load. The neutral wire is thin, as the current in it is small (nearly zero), because it is the vector sum of the three single phase currents at any instant. For factories and motors, a higher voltage-say 400V-can be obtained from across any two phases.



RMS and Peak values of A.C.

Root mean square value is the square root of the average of the sum of squares of instantaneous values (of voltage or current) taken for one cycle of A.C.

The instantaneous value of e.m.f in a circuit element is given by

$$E = E_o \sin \omega t. \text{ ..... (sine wave)}$$

where E_o is the peak or maximum value of e.m.f and ω is the angular frequency. The square of the instantaneous value is

$$E^2 = E_o^2 \sin^2 \omega t.$$

Sum of the squares of instantareous values for a period (T) is

$$= \int_0^T E^2 dt$$

$$= \int_0^T E_o^2 \sin^2 \omega t \, dt$$

The mean square value is

$$= \frac{1}{T} \int_0^T E_o^2 \sin^2 \omega t \, dt$$

$$= \frac{E_o^2}{2T} \int (1 - \cos 2\omega t) \, dt$$

$$= \frac{E_o^2}{2T} \left[(t) - \frac{\sin 2\omega t}{2\omega} \right]_0^T$$

$$= \frac{E_o^2}{2T} \left[T - \frac{1}{2\omega} \left(\sin 2 \times \frac{2\pi}{T} \times T - 0 \right) \right]$$

$$= \frac{E_o^2}{2}$$. Taking square root of this, we have

Root mean square value = $\frac{E_o}{\sqrt{2}}$

RMS value of emf = $\frac{\text{peak value of e.m.f}}{\sqrt{2}}$

Similarly, if the maximum value of A.C current is I_o,

RMS value of current = $\frac{I_o}{\sqrt{2}}$

$$I_{rms} = \frac{I_o}{\sqrt{2}} = 0.707 \times I_o$$

Thus, the rms current is 0.707 times the peak current or it is 70.7% of the peak valve. This is true for since waves only. Sine alternating current varies continually with time, its average value over a complete cycle is zero. Hence its effect is measured by RMS value of a.c.

House Wiring

House wiring deals with the distribution of electric power within the domestic premises. In the domestic wiring, arrangements are done for consumption of electric energy at 230V single phase or at 400 V, three phase available at the mains. In three phase connection, the total load in the house has to be divided among the three phases. An earth wire is also run, connecting all the power plugs, from which large quantity of power is drawn for electrical appliances like heater, electric iron, hot plate etc. This section deals with the tools, wires and cables used for domestic wiring and also the function of domestic appliances.

In domestic wiring the mains supply is delivered to houses using a three core wiring called the live, neutral and earth. The live wire is brown in colour and brings in the current, the neutral coloured blue is the return wire. The earth is coloured green or yellow. These wire supply electricity to separate circuits within the house. Two separate circuits are used. One of 15A for appliance with higher power rating and the other of 5A ratings for others. The earth wire is usually connected to a metal plate deep with earth-wear or the house. It is a safety measure and does not in any way affect the supply.

Top electrical tools list :

Pliers, screw drivers and nut drivers, wire strippers utility knife, Fishing tools, measuring devices, labeling machines, power drills and drivers, hammer, power saws and multimeter.

Precautions in handling tools used for wiring

1. The sharp edged tools should never be put in pockets without shield.
2. While cutting with a chisel, always cut away from you rather than towards yourself.
3. Before using a hammer and a screw driver, their handle must be examined.
4. While making a cut with a saw, care must be taken to guide the blade with the thumb of the other hand, as otherwise the blade may break and produce injuries.

Wires and Cables

Copper and aluminum are generally used as conducting wires. The insulators are those substances which offer very high resistance to the flow of electricity through them. Rubber, Polyvinyl chloride (PVC) are used as insulation on wires.

The conducting wires are assigned numbers, depending on their size. British standard wire Gauge is the commonly used gauge. The smallest gauge is number 40, having a diameter of 0.0048 inch. The largest gauge number of wire is 7/0 having a diameter of 0.5 inch. Higher the number of wire gauge, smaller is the diameter.

Gauge number 1 .... 0.3" diameter

" " 2 .... 0.276 "

" " 8 .... 0.16 " and so on

The circular area doubles for every three gauge sizes. For example : number 10 wire has twice the area of number 13 wire. Following are the different types of wires used in electric wiring :

1. Valcanised india Rubber wires (VIR wires)

A VIR wire consists of tinned copper wire, covered with rubber insulation. Tinning prevents the rubber sticking to the conductor. Over the rubber, a cotton tape sheathed cover, mixed with moisture resistant compount is provided. The thickness of rubber insulation depends on the grade of voltage to which the wire is used.

2. Cab Type sheathed wires (CTS wires)

The conductors provided with rubber insulation are not water or heat proof. Over the insulation of conductor, tough rubber sheath is provided for additional insulation and protection against wear and tear. It also protects the wire from moisture. CTS wires are available in single-core, twin-core or three-core.

3. Lead sheathed wires

These are similar in construction to TRS (CTS) wires but they have an outer sheath of lead or lead alloy. The covering is very thin. Such wires are used in snow fall areas.

4. Flexible wires

The flexible cord consists of two separately insulated flexible stranded conductors. They are referred to as 16/0.0076 or 42/0.0076, which means that there are 16 or 42 strands of copper wire, each with a diameter of 0.0076 inch. These wires are usually used for household appliances such as heaters, irons, lamps etc. Flexible wires are convenient to handle along with the equipment and such wires are not broken easily.

Cables :

A current-carrying conductor, provided with insulation layer and then over it with a protective covering against mechanical damage, is known as cable. The conductor may be a solid one or of stranded sections, called cores. Each core is individually insulated, laid up together and then enclosed in one mechanical protective covering or sheath. Cables are classified according to the mode of their laying. There are aerial and underground cables.

The V.I.R. cables, the P.V.C. cables and varnish cambric cables are the types coming under aerial cables. The underground cables consist of cores, insulation over the cores, metallic sheath, bedding (with jute layer for mechanical protection) and armouring (steel tape or wire mesh to protect the cable from mechanical injury).

Two cylindrical conductors in a common covering having common axis, with an insulating material in between them form a coaxial cable. Co-axial cable with an outside diameter of 6.4 mm is used for cable television. Twin lead with a width of 16 mm is used in television for connecting the antenna to the receiver.

Before deciding a particular type of wiring, the following points should be considered:

(i) durability (to withstand for a long period)
(ii) Safety (no danger of leakage or shock)
(iii) mechanical protection (from damage of physical nature)
(iv) appearance (from architectural point of view)
(v) cost (from economic point of view)
(vi) accessibility (facility for extension or renewal)

The following general rules for wiring should be followed in executing the work.

1. The current rating of the conductor should be as per the requirement of the load.
2. Every live (phase or positive) wire should be protected by a fuse of suitable current rating.
3. Every sub-circuit (in various rooms) must be connected with the fuse distribution board.
4. All the metal coverings used for the protecting wires must be connected to the earth so that there may be no danger due to insulation leakage.

5. No fuse or switch is used in earth connection.
6. Every circuit or apparatus should be provided with a separate switch.
7. No additional load should be connected to the existing installation unless it is ensured that the installation can carry safely the additonal load.
8. When the installation is completed, it should be tested for leakage before the mains supply is given.
9. Light wiring and power wiring should be done separately.
10. In three phase, four wire system installation, the load shall be equally divided on all phases.
11. In the case of 3 phase, 4 wire system, indication should be done at the main board in Red, Yellow, Blue. The neutral should be indicated in black.
12. As per I.S.I : 4648 - 5.5, all switches should be installed on the live lines only and never on the neutral.

13. In domestic wiring, 3 pin plug only should be used. (phase, neutral, ground)

Systems of domestic wiring

The various systems of domestic wiring in practice are (i) cleat wiring (ii) casing caping (iii) C.T.S. wiring (iv) metal sheathed wiring and (v) conduit wiring.

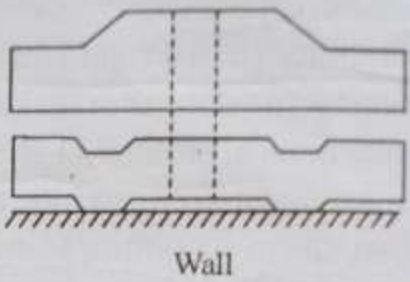


Fig. 117 (a) *Porcelair cleat*

(i) Cleat wiring

In this system, V.I.R conductors are supported in porcelain or wooden cleats. The cleats may have two or three grooves so as to reveive two or three wires.

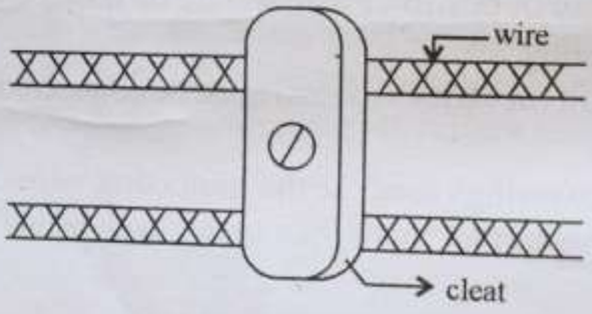


Fig. 117 (b) *Cleat wiring*

Cleat wiring is cheap and most suitable for temporary wiring.

(ii) C.T.S. wiring

The CTS wires used are sheathed with tough rubber. They are carried on wooden batten using joining clips. The wooden battens are fixed on the wall or ceiling.

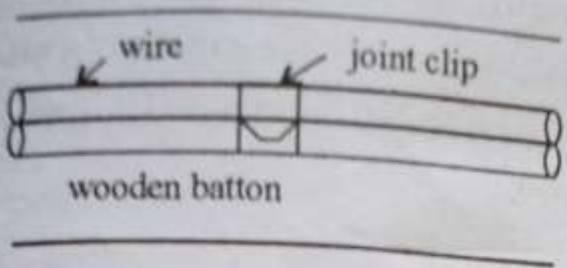


Fig. 118 (a) *C.T.S. wiring*

Fig. 118 (b)

This type of wiring is suitable for damp climate and not suitable for hot weather. But there is also danger of mechanical damage and fire hazard. This type of wiring is not suitable for outdoor use, because of direct sunlight falling over it.

(iii) Wood casing capping wiring

This is the most common type of wiring used for indoor and domestic installations. It consists of rectangular wooden blocks, called casing, made from teak wood. It has usually two grooves into which the wires are laid. The casing at the top is covered by means of capping, which is a rectangular strip of wood of the same width as that of casing and is screwed to it. Two or three wires of the same polarity may be run in one groove. V.I.R. wires are used here.

(iv) Metal sheathed wiring

The wire consists of insulated conductor over which a sheath (covering) of lead-aluminium aloy is provided externally. This covering is meant to protect the cable from mechanical injury. The sheath should be earthed.

Otherwise the covering may deteriorate if there is a leakage of current and consequent electrolytic action. These cables can also be run over wooden beading or batten in residential buildings. The metal sheath cables are costlier than C.T.S. wiring.

(v) Conduit wiring

In this system of wiring the V.I.R. wires are run in fiber steel or iron pipes, called conduits. This is the best system of wiring which provides mechanical protection, safety against fire and shock if bonding and earthing are done well. This is most useful in workshops and public buildings. The pipes are coated with aluminium, to prevent from corrosion.

The conduit is placed in position before drawing of wires. The wires are drawn by means of steel wire from one junction box to the next junction box.

Nowadays the conducting wires are passed through PVC pipes laid inside the walls and concrete blocks. The use of PVC rather than metallic tubes drastically reduces the cost of wiring.

Inspection boxes and bends are provided at frequent intervals to enable drawing of the wire. While drawing, care must be taken that wires are in no case, twisted round one another.

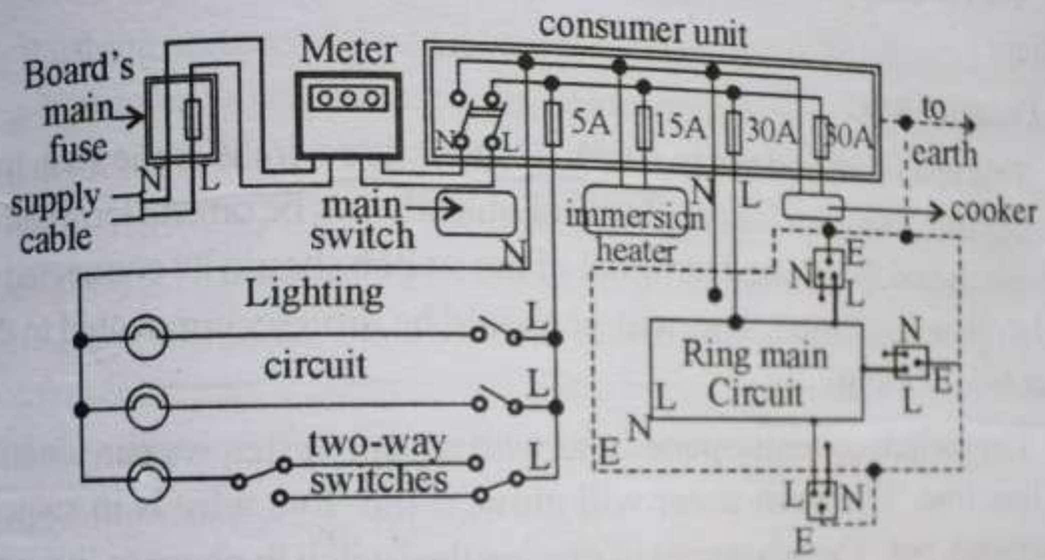


Fig. 119 House wiring

Tests to be carried out on wiring installation before **commissioning**

The following tests should be carried out before commissioning the wiring installation as per Indian Electricity Rule 1956.

(1) Insulation or leakage test using megger

Megger is a portable instrument generally used for testing installation. It is a combined unit of an ohm meter and d.c. hand driven generator.

The resistance shown by meggar connected between ground (E) and the main switch terminal (L) should not be less than one mega ohm for the whole installation. This is done by keeping main switch off.

(2) Continuity or open circuit test

The terminals of the meggar are connected between the phase and neutral of one circuit of the distribution board. The meggar handle is rotated. With switch 'off' position the meggar reading is noted. The meggar reading should be infinity in off position and zero in the ON position. The same test should be carried out with all other circuits in the distribution board separately.

(3) Short circuit test

This is similar to the continuity and open circuit test as described earlier.

(4) Polarity test

This test is carried out to check whether live wire is in the switch or not. By rule, live wire (or the phase) should always be on one terminal of the switch and the second terminal of the switch should be connected to the lamp or appliance. The neutral should be directly connected to the other side of lamp.

The switch cover is opened and with a Neon tester, we can identify the live line. The neon tester will glow, if the live wire is in switch. Otherwise, not. The advantage of placing the switch in phase or live wire is that the work man can safely rectify the defects by switching off the supply.

(5) Earthing system test

Earth continuity test is carried out with test lamp. One end of the test lamp is connected to the phase and other on the earth terminal. Now the lamp should glow, if the earth is satisfactory.

Good grounding (earthing) and its need

The purpose of doing good grounding is to obtain zero electric potential point in the body of electrical appliances so as to save human life from danger shock or death in case it comes in contact with charged frame, due to any fault and leakage current.

In a.c. supply system the neutral wire is always earthed to maintain line voltage constant.

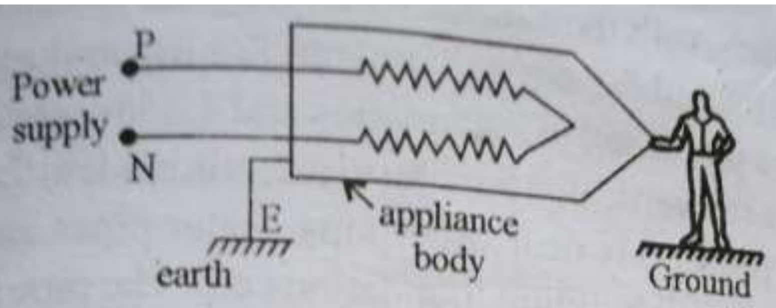
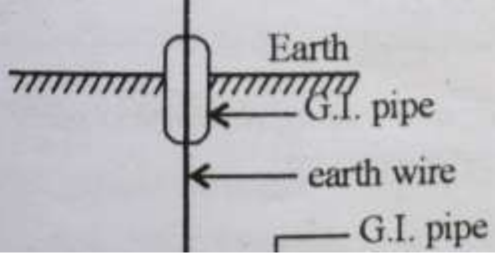


Fig. 120 Earthed body of appliances

Earthing is done to protect large buildings from atmospheric lightning. It is done by connectiong the lightning arresters (metal spikes) to earth, by employing good conductor, know as Earthwire.

When earthing is done, the earthing conductors shall be encased in pipe which is firmly supported and continued down to 0.3m depth. No joints are permitted in the earth bus (earth wire). Whenever, there is a lightning conductor system installed in a building, its earthing shall not be bonded to the earthing of the electrical installations.

1. Earthing through a G.I.Pipe



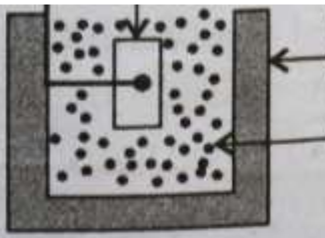


Fig. 121 *Earthing through G.I. pipe*

In this method, a G.I.pipe is used as an earth electrode. The size of the pipe will depend on the current to be carried and type of soil in which the earth electrode is burried. (Any plate or pipe embeded in the earth to obtain effective electrical connection with the general mass of earth is known as earth electrode.)

2. Earthing through a plate

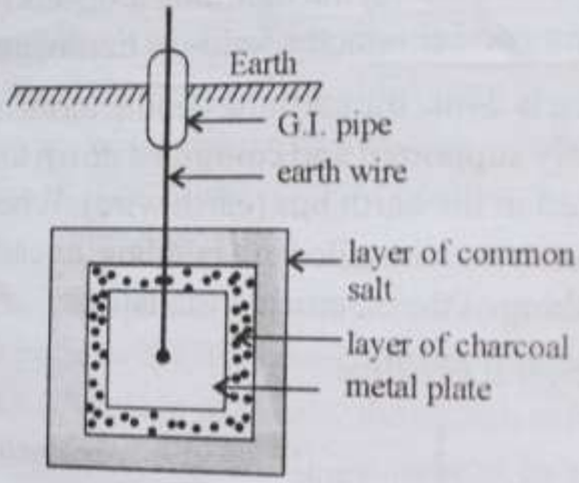


Fig. 122 *Electrical earthing through a plate (Grounding)*

Here, a copper plate is used as an earth electrode. The copper plate shall be of dimensions 0.3 m × 0.3m × o.32 mm thick. The plate is buried to a depth of not less than 2 m in moist places (close to water tap, water drain etc) and at least 0.6 m away from building foundations. The plate shall be completely covered by 8 cm of charcoal with a layer of common salt of 3 cm all around it, keeping the faces of the plate vertical.

The copper electrodes are used to avoid corrosion due to electrolytic action.

Electrical Wiring Colour Codes

In order to use electricity in our house, a proper wiring is required. The collection of electrical wiring and electrical devices like swiches, sockets, meters and fittings is called electrical installation or building wiring. An electrical wire is a single solid or twisted copper or aluminium conductor with or without any insulation.

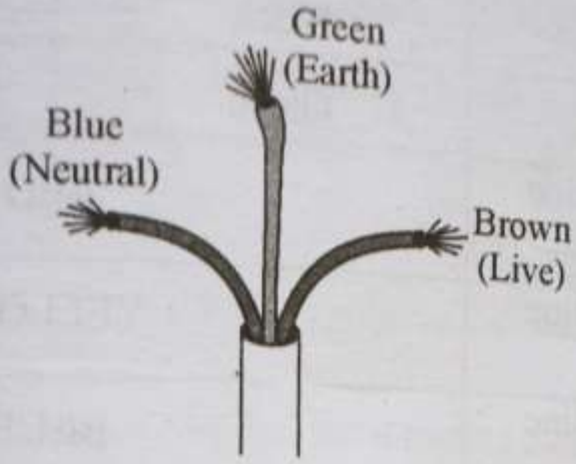


Fig. 123 Colour code for insulation wire

Each wire used for electrical wiring is marked with information like wire gauge, ampacity, maximum voltage, and maximum temperature. But a general colour code in used to identify different types of conductors which are used in electrical wiring. We know that the power can be in either sigle-phase or three - phase.

The standard for electrical wiring colour code in india is as follows. According to old standard, Red is used for live (or line) power conductor, black for neutral and green for protective earth or ground.

The new colour code is introduced recentrly (although the old convention is pretty much still widely used). In the new colour code for electrical wires, Brown is used for live (or line), Blue is used for neutral conductor and green for earths.

...f Red Yel-

... and green for earths.

In case of a three phase power supply, the combination of Red, Yellow and Blue are used for the active line power conductors, black colour for neutral conductor and Green or Green- Yellow for protective ground.

Function	India colour code (old)	India colour code (New)
Single phase line line or (live)	Red	Brown
Neutral	Black	Blue
earth or ground	Green	Green
Three phase line (L1)	RED	
Three phase line (L2)	YELLOW	
Three phase line (L3)	BLUE	
Three phase Neutral	BLACK	
Three phase earth ground	green	green - Yellow

Electrical Circuit overloading

The current in a circuit depends on the power rating of the appliances connected to it. The choice of wire depends upon the maximum current estimated to pass through them. If the power rating of the appliances exceeds this permitted limit, they tend to draw a large current. This is known as over loading. Over loading happens when an excessive amount of electric current passes through the wire and excessive heating takes place in it.

In domestic electrical wiring the appliances are connected in parallel to one another with the main circuit. When large number of appliances are connected, the total load resistance becomes very low and large current is consumed. Thus connecting too many appliances to a single socket (plug) consumes excessive current more than the capacity of supply wire and excessive heating takes place in the wiring cable. This causes overloading of the circuit.

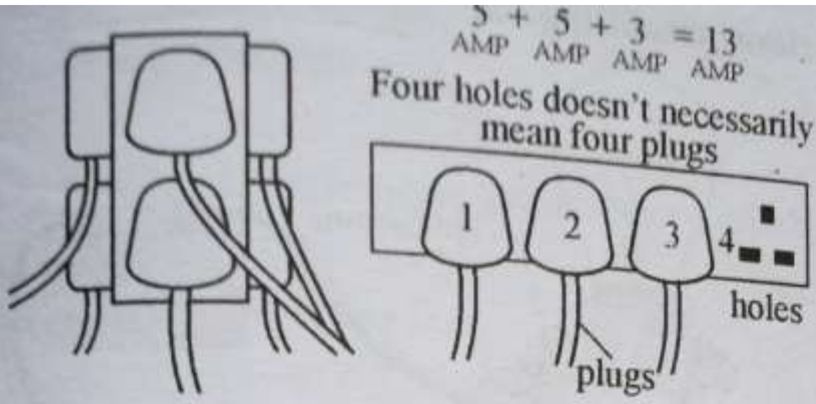


Fig. 124 (a) *Overloading (six plugs at a terminal point)*

When a circuit becomes overloaded it breaks the circuit breaker if there is any (also known as blowing a fuse). Without a circuit breaker the insulation on the wire could heat up, melt and short the conductors, which could possibly creates a fire.

Most branch circuits in the domestic wiring are designed to carry 10 amps for lighting. They can carry 2200 watts. The general purpose circuits are designed for 15 amps. They can carry 3500 watts of power. Amperage is a measure of electrical current through a circuit. It can be calculated by dividing the amount of wattage of appliance by the voltage.

An electrical circuit with too many electrical devices turned on can exceed the circuit limit. Preventive measures to avoid overloading :

1. Never use extension cords or multi - outlet converters.
2. All major appliances should be plugged directly into a wall receptacle outlet.
3. Only use appropriate watt bulb for any lighting fixture.
4. Use power strips (extension block) to add additional outlets.
5. Only use one adaptor per socket.
6. Do not plug adaptors into adaptors.

Electrical Short circuiting

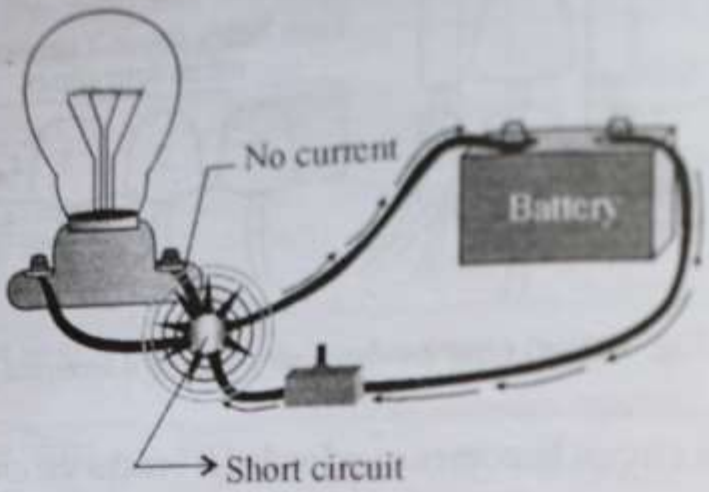


Fig. 124 (b) *Electrical short circuiting*

An electrical short circuit is simply a low resistance (or nil resistance) connection between the two conductors supplying electrical power to any circuit. This will result in excessive current flow in the power source through the 'short' and may even cause the power source to be destroyed. If a fuse is in the supply circuit, it will do its job and blow out, opening the circuit and stopping the current flow. A short circuit may be in a D.C. or A.C circuit. If it is a battery that is shorted, the battery will be discharged very quickly and will heat up due to the high currents flow.

Short circuits can produce very high temperature due to high power dissipation in the circuit. Arc welding is a common example of the practical application of the heating due to a short circuit. The points of contact between the welding rod and the both metal surfaces get heated to the melting point, fusing a part of the welding rod and both metal surfaces into a single piece.

Reasons for short circuit

1. Wires may loose their insulation and touch each other in the circuit.
2. There could be a fault (improper wiring) in a device.
3. Intensionally connecting both ends of a cell

A short circuit can cause heating, melting of wires, harmful smoke and blinding light (e.g. welding)

Questions

1. List out the effects of AC and DC on (i) resistance (ii) inductance and (iii) capacitor
2. Describe production of A.C and D.C
3. What are the advantages of A.C over D.C?
4. Define R.M.S and peak values of A.C. Derive expression for RMS value of sine wave current.
5. Describe with a neat sketch three phase power generator and explain its working. Sketch the waveform of output voltage.
6. Giving neat wiring diagram, describe star connection and (ii) delta connection. Define (i) Star line current and phase current and (i) phase voltage and line voltage in each connection.
7. What is house wiring? What are the various systems of house wiring? Describe the main features of each system giving their advantages and disadvantages.
8. Describe in detail, conduit wiring system. What are its advantages?
9. What is the need for earthing? Describe any one method of good earthing. How is good earthing tested?
10. What is meant by (i) short circuit and (ii) overload? Explain how the adverse effects of these may be overcome.
11. Give the colour code for insulating wires.
12. Derive the relation connecting phase voltage and line voltage in star connection.
13. Desive the relation connecting phase current and line current in star connection.
14. Derive the relation connecting phase voltage and line voltage in delta connection.

Objective type questions

1. In an A.C generator maximum e.m.f is induced when the plane of the coil is
   (a) parallel to the magnetic field
   (b) perpendicular to the magnetic field
   (c) inclined at 45° to the magnetic field
   (d) none.
2. RMS value of sinusoidal A.C is
   (a) peak current (b) $\sqrt{2}$ × peak current (c) $\frac{\text{peak current}}{\sqrt{2}}$
   d) equal to mean current in one cycle.
3. For A.C. voltage varying as a sine wave, the peak to peak voltage is
   (a) $\sqrt{2}\,V_{rms}$ (b) $2V_{rms}$ (c) $\frac{V_{rms}}{\sqrt{2}}$ (d) $2.828\,V_{rms}$
4. In a 3-phase power generator, voltage in each phase is out of phase by
   (a) 45° (b) 90° (c) 120° (d) 180°
5. D.C can be converted to A.C. by
   (a) rectifier (b) filter (c) transformer (d) inverter
6. Overloading is a result of
   (a) gravity (b) high voltage generator (c) short circuit
   (d) none.
7. In three phase A.C. distribution the neutral wire is ________ in colour
   (a) white (b) brown (c) black (d) red
8. A light switch in series with a lamp should be
   (a) on the live side of the A.C line
   (b) on the earth side of the A.C line
   (c) any where on the A.C. line
   (d) none.
9. A good earthing path has
   (a) Very low resistance (b) very high resistance
   (c) zine rod (d) none
10. An insulator has
    (a) very low resistance (b) very high resistance
    (c) good electrical conductivity (d) none

11. In star connection of 3- phase power distribution the line voltage is
(a) $\sqrt{3}\,E_{ph}$ (b) $\frac{E_{ph}}{\sqrt{3}}$ (c) $\sqrt{2}\,E_{ph}$ (d) $\frac{E_{ph}}{\sqrt{2}}$

12. In delta connection
(a) $E_L = \sqrt{3}\,E_{ph}$ (b) $E_L = \sqrt{2}\,E_{ph}$ (c) $E_L = E_{Ph}$ (d) none

13. In delta connection, the phasor sum of the line currents is
(a) $3\,I_L$ (b) $\sqrt{2}\,I_L$ (c) $\sqrt{3}\,I_L$ (d) zero

14. 3-phase - four wire distribution of power is possible with
(a) star connection (b) delta connection (c) step up transformer
(d) none

15. Phase current means
(a) current in a single phase generator
(b) current through an armature coil in 3 phase generator
(c) current leading voltage by a phase factor
(d) none.

16. Apparent power of an A.C. circuit is
(a) $V_{Peak} \times I_{Peak}$ (b) $V_{max} \times I^2_{max}$ (c) $V_{rms} \times I_{rms}$
(d) $V_{rms} \times I_{rms} \times \cos\theta$

17. 400V.50Hz marking on apower supply board means
(a) peak voltage is 400V (b) RMS voltage is 400V
(c) virutal power is 50W (d) Real power is 20 kW.

18. When A.C voltage is applied across a resistor only, the current in the circuit
(a) leads e.m.f by $\pi/2$ (b) lags behind emf by $\pi/2$
(c) is in phase with the voltage (d) none

19. In an A.C circuit containing inductance only, the current
(a) leads emf by 90° (b) lags behind emf by 90°
(c) is in phase with e.m.f (d) none

20. In an A.C circuit with capacitor only, the current

(a) leads e.m.f by 90° (b) lags behind emf by 90°

(c) is in phase with emf (d) none

21. Inductive reactance is

(a) L (b) Lω (c) $\frac{1}{L\omega}$ (d) zero always

22. Capacitative reactance in

(a) Cω (b) $\frac{1}{C\omega}$ (c) $\frac{1}{LC}$ (d) $\frac{1}{\sqrt{LC}}$

23. In star connection of 3 phase power distribution the common point where the similar ends of armature coils meet is

(a) the neutral and earth connected.

(b) the high tension point, connected to the three lines

(c) the low tension point

(d) none

24. Reactance is measured in

(a) ohm (b) joule (c) watt (d) kelvin

25. A leaky capacitor in an A.C circuit is equivated to

(a) high reactance (b) high resistance

(c) short circuit (d) no harm.

26. 70.7% of peak A.C is called

(a) average of A.C (b) RMS valve of A.C (c) full power of A.C

(d) none

27. In d.c. distribution the colour of insulation wire for negative line is

(a) Blue (b) Green (c) Black (d) Yellow

28. In earthing fish wire is

(a) a wire with which cable is wound round.

(b) a wire tied to the cable with which it is drawn through a pipe

(c) a wire that is grounded

(d) all the above.

29. A.C can be converted into D.C with

(a) filter (b) inverter (c) rectifier (d) all the above

30. House wiring instalation is tested with the help of the instrument

(a) ammeter (b) voltmeter (c) megger (d) wattmeter

31. By-pass capacitors have

(a) large capacitance (b) small capacitance

(c) air core (d) none

32. Blocking capacitors have

(a) large capacitance (b) small capacitance (c) air core

33. Trimmer has

(a) Adjustable very large capacitance

(b) Adjustable very small capacitance

(c) fixed capacitance

(d) none.

34. Solar pannels produce

(a) A.C. power (b) D.C. power

(c) both D.C and A.C power (d) none

35. A short circuited capacitor has

(a) zero resistance (b) full capacitance

(c) infinite resistance (d) none

Answers

1 (c)	2 (c)	3 (d)	4 (c)	5(d)
6 (c)	7 (c)	8 (a)	9 (a)	10 (b)
11 (a)	12 (c)	13 (d)	14 (b)	15(b)
16 (c)	17 (b)	18 (c)	19 (b)	20(a)
21 (b)	22 (a)	23 (a)	24 (a)	25(c)
26 (b)	27 (c)	28 (b)	29 (c)	30 (c)
31 (a)	32 (b)	33 (b)	34 (b)	35(a)

UNIT-V

Electrical protection devices and motor

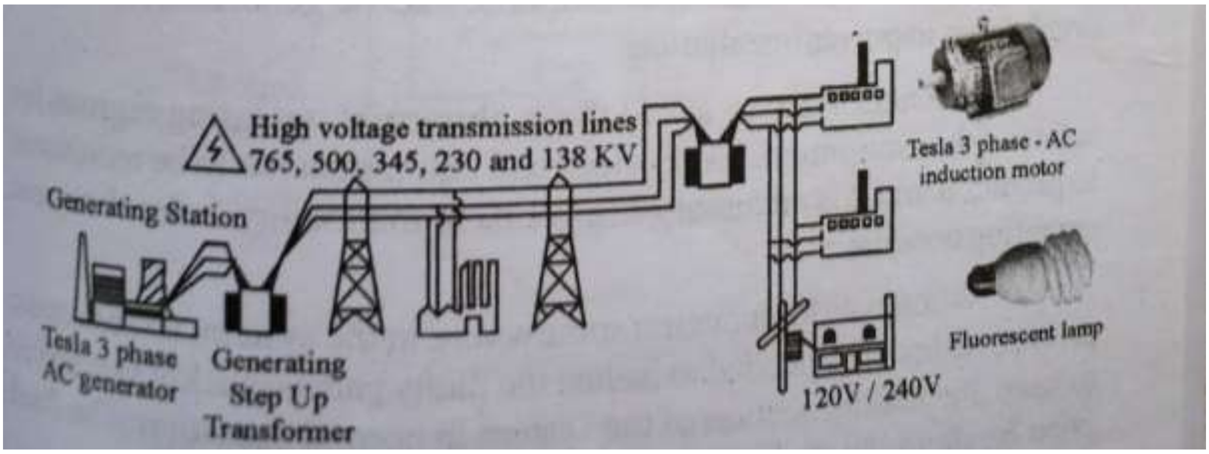
Electrical protection - Relays - Fuses - Electrical switches - Circuit breakersELCB - overload devices - ground fault protection - Inverter - UPS - generator and motor.

Electrical Power system

Electric power system consists of components that produce electrical energy and transmit this energy to consumers. There are six main components in an electrical power system.

1. Power plants which generate electric power
2. Transformers which raise or lower the voltage as needed
3. Transmission lines to carry power
4. Substations at which the voltage is stepped down for carrying power over the distribution lines
5. Distribution lines
6. Distribution transformers which lower the voltage to the level needed for consumer equipment.

The basic structure of a power system is shower in the figure.



Electrical power system Protection

Electrical power system protection is the science of detecting problems with power system components and isolating these components.

The problems on the power system are :

(1) Short circuits

(2) Abnormal conditions

and (3) Equipment failures

Purpose of Power system Protection

(i) Protect the public

(ii) Improve system stability

(iii) Minimise damage to equipments

and (iv) Protect against overloads.

Need for electrical protection

Electrical power system operates at various voltage levels from 415V to 400 KV or even more. Electrical apparatus used may be enclosed (e.g. motor) or placed in open (e.g) transmission lines. A tree falling on an overhead line, lightning strike, degradation of insulation, a worn - out bearing in a motor, variation of frequency at AC generator etc. lead to breakdown in power installation.

It is necessary to avoid these abnormal operating regions for safety of the equipment. Every electrical equipment has to be monitored to protect it and it is necessary to provide human safety under abnormal operating conditions.

Whenever fault occurs somewhere in the system, an automatic protective device is needed to isolate the faulty part as quickly as possible to keep the healthy section of the system in normal operation. The fault must be cleared within a fraction of a second.

Hence it is necessary to have the arrangements with which all these equipments can be switched on or off under no load or load conditions or even fault conditions. The collection of various equipments used for the switching and protecting purpose in a power system is called switchgear. The various components of switchgear are switches, fuses, relays, circuit breakers at. The switchgear protects the system from fault and abnormal conditions and it assures continuity of an electric supply.

The requirements of a protection system are speed, reliability, security and sensitivity.

All the circuit breakers of electrical power system are DC operated. When total failure of incoming power occurs, still the circuit breakers can be operated for restoring the situation by using the power of storage station battery.

Relay

Relays are simple switches which are operated both electrically and mechanically. Relays consist of an electromagnet and also a set of contacts. Switching is carried on by electromagnets. A relay consists of electromagnets, movable armature, switch point contacts and springs.

Working of a relay:

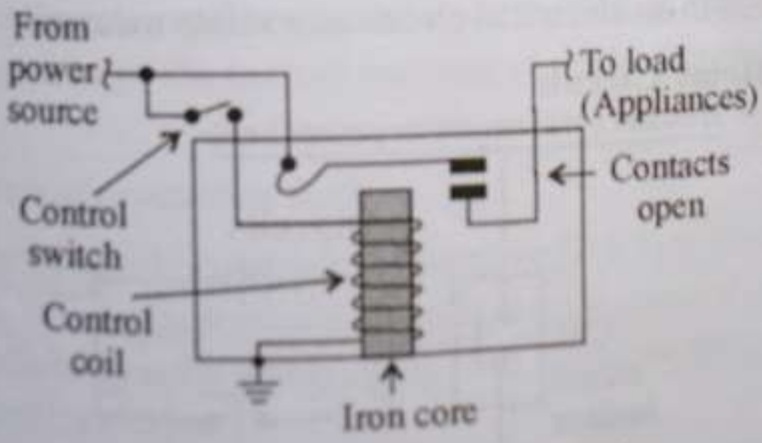


Fig. 126 Principle of electrical relay

Figure shows an inner section of a relay. An iron core is surrounded by a control coil. The power source is connected to the electromagnet through a control switch. The power is also connected to the load through a contact point. When current flows through the control coil, the electromagnet is energised. The upper contact arm with armature is attracted towards the lower fixed arm. This causes a short circuit for the power to the load.

(On the other hand, if the relay was already de - energised when the contacts were closed, then the contact move oppositely and make an open circuit.)

As soon as the coil current is off, the movable armature will be returned by a force back to its initial position due to spring action.

Protective Relay

Whenever there is a fault in an electrical system, the protective relay device detects the fault. Then it sends signal to circuit breaker to isolate the faulty part from rest of the power system.

The relays detect the abnormal conditions in the electrical system by measuring electrical quantities such as voltage, current, frequency and phase angle. After detecting the fault, the relay operates to close the trip circuit of the circuit breaker. The circuit breaker disconnects the faulty circuit.

A circuit breaker (CB) is an automatic device for stopping the flow of current in an electrical circuit as a safety measure.

Protective Relay Circuit

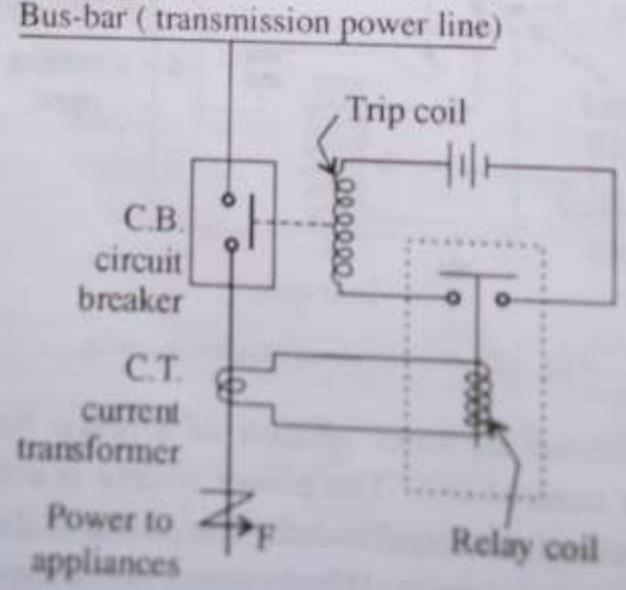


Fig. 127 Protective relay

There are three parts in a relay circuit connection :

1. Primary winding of a current transformer (CT), which is connected in series with the line to be protected.
2. Secondary winding of C.T. and CB (circuit breaker) and the relay operating coil.
3. The tripping circuit which may ac or dc. It consist of a source of supply, the trip coil of the circuit breaker and the relay stationary contacts.

Working:

When a short circuit occurs at point F (in an appliance) on the transmission line the current flowing in the line increases to an abnormal value. This results in a heavy current flow through the relay coil. This causes the relay to operate by closing its contacts.

This in turn closes the trip circuit of the breaker, making the circuit breaker open. Thus the faulty section is isolated from the rest of the system.

Thus the relay ensures the safety of the circuit equipments from damage. Also it helps the normal working of the healthy portion of the system.

Requirements of protection Relay

1. *Reliability* : The relays remain inoperative for a long time before the fault occurs. When a fault occurs, the relays must respond instantly and correctly. Reliability is the ability of the relay system to operate under the predetermined conditions.

2. *Selectivity* : It is the ability of the protective system to select correctly that part of the system in trouble and disconnect the faulty part without disturbing the rest of the system. Thus, if a fault occurs at bus - bars on the last zone, then only breakers nearest to the fault should open.

3. *Speed* : The relay system should disconnect the faulty section as fast as possible for the following reasens:

(a) Electrical apparatus may be damaged if they are made to carry the fault currents for a long time

(b) A failure on the system leads to a greater reduction in the system voltage. The low voltage may shut down consumer's motor.

(c) The high speed relay system decreases the possilility of development of one type of fault into other more severe type.

(d) *Sensitivity* : It is the ability of the relay system to operate with low value of actuating quantity. It is a function of the volt - ampere input to the coil of the relay neecssary to cause its operation. The smaller the volt-ampere input required to cause relay operation, the more sensitivity the relay has.

Different type of relays : Depending on the operating principle and structural features, relays are of different types such as electromagnetic relays, thermal relays, solid state relays, Hybrid relays, and Reed Relays.

Electrical Fuse

What is a Fuse : When there happens a fault in an electric circuit, a large amount of electric current passes through the appliance. It causes the wires to get overheated and the appliance gets damaged. This situatian is extremely dangerous as it can lead to a fire.

A safety device called fuse is used to prevent the damage of electric appliance from an excessive flow of current.

The basic components of most fuses are metal alloys. They are designed to easily melt when an excessive amount of electric current flows through it. Thus the circuit is opened and the electrical equipments are protected.

Principle of an electric fuse

The electric fuse works on the principle of heating effect of current. The greater the current in a wire, the more is the heating caused in it. An electric fuse consists of a thin wire usually placed inside a glass or ceramic cartridge. The wire is made of a material that melts easily when heated (i.e., it has low melting point). It is designed such that only a certain amount of current can flow through it. If the current exceeds this amount, the heating in the wire causes it to melt. We say that the fuse 'blows'. This breaks the circuit and stops the flow of current in the circuit.

Fuse symbol

The common symbol used for an electric fuse is shown below.

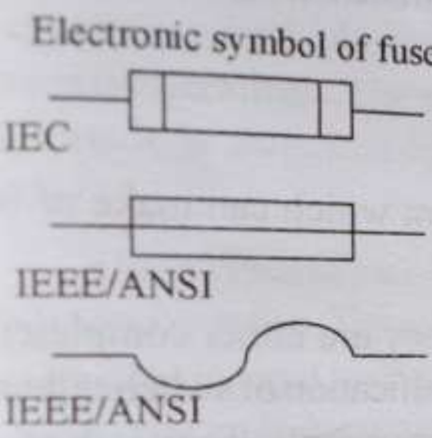
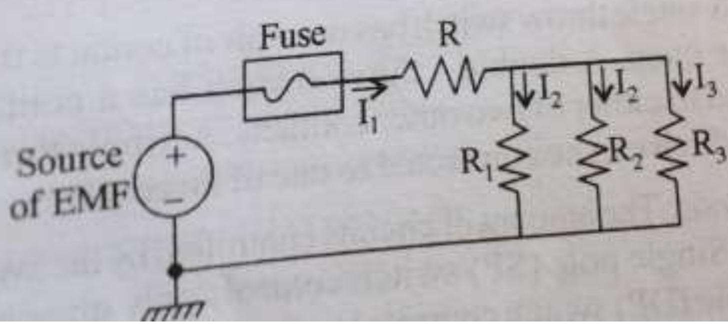


Fig. 128 (a) *Electronic symbol of fuse*

Fig. 128 (b) *Cartridge type fuse*

Connection of fuse in electrical circuit



Fuse is connected in sesies with the circuit we want to protect as in figure. Sum of all currents flows through fuse. In the event of short circuit or abnormal increase in circuit current, the fuse will quickly oper and the large current cannot flow anymore to the circuit.

When the fuse blows, do not replace it with a fuse of another rating. Instead, maintain the same rating as it is practically designed for the circuit. Replacing the fuse rating to a higher one will put the cricuit in danger since it will not blow on a specified current and time. On the other hand, if a fuse rating has been replaced by a smaller one, the circuit will keep on opening even though the current is not yet reaching the specified trip level. One can also install fuse to any branch in figure as needed. Be sure to realise the purpose of the fuse.

Electrical Switches

Switch is an electrical component which can make or break electrical circuit automatically or manually.

Switches are binary devices : They are either completely on (closed) or computely off (open). The classification of switches depends on the connection they make. Two vital components of a switch are *pole* and *throw*.

The terms pole and throw are also used to describe switch contact variations. The number of 'poles' is the number of separate circuits which are controlled by a switch. The number of 'throws' is the number of separate positions that the switch can adapt.

A single throw switch has one pair of contacts that can either be closed or open. A double - throw switch has a contact that can be connected to either of two other contacts. A tripple throw switch has a contact which can be connected to one of three other contacts, etc.

Pole : The amount of circuits controlled by the switch is indicated by poles. Single pole (SP) switch controls only one electrical circuit. Double pole (DP) switch controls two independent circuits.

Throw : The number of throws indicates how many different output connections every switch pole can connect its output. A single throw (ST) switch is a simple on / off switch. When the switch is *ON*, the two terminals of switch are connected and current flows between them. When the switch is *OFF* the terminals are not connected, so current does not flow.

Four Types of switches

Basic types of switches are *SPST*, *SPDT*, *DPST* and *DPDT*.

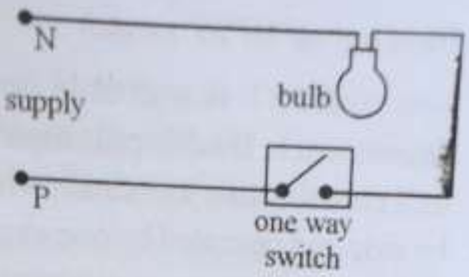


Fig. 130

Working of SPST switch

The Single Pole Single Throw *(SPST)* is a basic on / off switch that just connects or breaks the connection between two terminals. The power supply to a circuit is switched by the *SPST* switch.

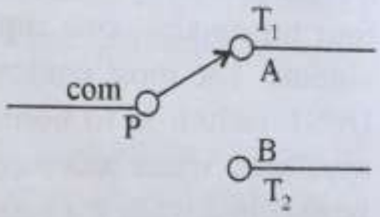


Fig. 131 (a) *SPDT Switch*

These types of switches are also called toggle switches. This switch has two contacts. One is input and other ouput. In the figure the switch controls one wire (pole) and it makes one connectian (throw). This is an on / off switch. When the switch is closed, current flows and bulb glows. When the switch is open, there is no current flow in the circuit.

Working of SPDT switch

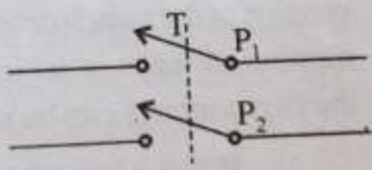


Fig. 132 (a) *DPST Switch*

The single pole double throw (SPDT) switch is a three terminal switch, one for input and other two for the outputs. It connects a common terminal to one or the other two terminals. We can use COM and A or COM and B.

In the figure the SPDT switch is used in a three way circuit to turn a light ON/OFF from two locatians, such as from the top and bottom of a stairway. When switch A is closed, light A is ON and light B is off. When switch B is closed, light B is ON and light A is off. Here we are controlling the two circuits via one way or source.

Working of DPST switch

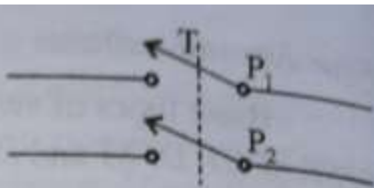


Fig. 132 (a) *DPST Switch*

DPST is a double pole single throw switch. Double pole means that the unit contains two identical switches side by side and operated by one single toggle or lever. ie, two separate circuits are at a time controlled through one push. A DPST switch turns two circuits on or off. It has four terminals : two inputs and two outputs. The most common use for a DPST switch is to control a 240 V appaliance, where both supply lines must be switched, while the neutral wire may be permanently connected. Here when this switch is toggled, current starts flowing through two circuits and interrupted when it is turned off.

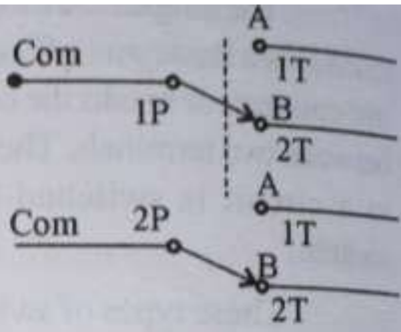


Fig. 132 (b) *DPDT Switch*

Working of DPDT switch

DPDT is a double pole double throw switch; this is equivalent to two SPDT switches. It routes two separate circuits, connecting each of two inputs to one of two outputs. The position of the switch determines the number of ways in which each of the two contacts can be routed.

When it is in ON-ON mode or ON-OFF-ON mode they work like two discrete SPDT switches, worked by similar actuator. At a time only two loads can be ON. *A* DPDT switch can be used in any application that needs an open and closed wiring system.

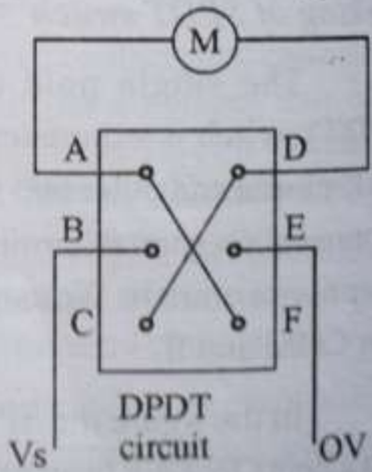


Fig. 132 (c) *Reversing Motor switch*

Maintenance and Replacement of switches

Switches are a very reliable electrical component. This means, they don't fail very often. Most switches are designed to operate 1,00,000 times or more without failure if the voltage and current ratings are not exceeded.

Checking switches :

There are two basic methods to check a switch. One can use an ohm meter or a voltmeter.

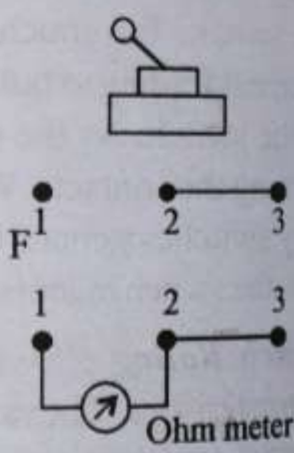


Fig. 133

The position of the switch is shown in figure.

The ohmmeter is connected between terminal 1 and 2 of the switch. The ohmmeter reads infinite resistance. When the ohmmeter is connected between terminals 2 and 3, it reads zero ohms. With the ohmmeter, connected to terminals 1 and 3, it indicates infinite resistance.

Replacement of switches :

When a switch is faulty, it must be replaced. The substitute switch must have the same characteristics as the original. In addition, the type of actuator (toggle, push button, rocker, etc) should be the same as the original switch.

Circuit Breaker

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its base function is to detect a fault condition and interrupt current flow.

In domestic electrical equipment such as wet grinder, water heater, TV, fridge, etc, the outer metallic body of the equipment is connected to the earth. In certain times, there may be failure of insulation of equipment which causes the metallic body of the equipment to touch the phase of electrical mains. The voltage of the equipment body rises, which could cause the difference between earth and load (equipment) body voltage. Then there is danger of electirc shock due to high (risistance) earth connection.

Earth Leakage Circuit Breaker (ELCB)

An earth leakage circuit breaker (ELCB) in a device used to directly detect currents, leaking to earth from an installation and cut the power. It is mainly used in TT earthing system. In TT earthing system, the protective earth connection of the load equipments is provided by a local connection to earth, independent of any earth connection at the generator. TT earthing does not have the risk of broken neutral.

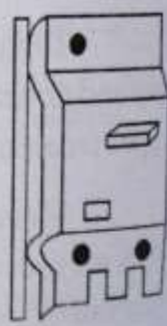


Fig. 135

There are two types of ELCBs:

1. Voltage Earth Leakage Circuit Breaker (voltage-ELCB)

2. Current Earth Leakage Circuit Breaker (current-ELCB). The current ELCB is also called as residual current device (RCD). Residual current refers to any current over and above the load current.

(I) Voltage - ELCB

Voltage - ELCB is a voltage operated circuit breaker. The device will function when the current passes through the ELCB. Voltage -

ELCB contains ralay coil which is being connected to the metallic load body at one end and it is connected to ground wire at the other end.

The voltage of the equipment body may rise due to the contact of phase to metal part or failure of insulation of equipment. This could cause a difference between earth and the equipment body voltage, and there is danger of electric shock.

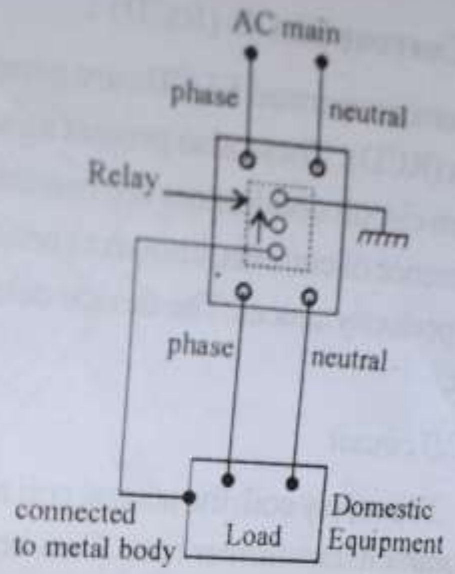


Fig. 136 Earth leak circuit Braker (ELCB)

This voltage difference will produce an electric current from the load metallic body. This current passes through relay loop to earth. Then voltage on the equipment body happens to rise to the danger level, (which exceeded to 50 volt) the flowing current through the relay loop could move the relay contact by disconnecting the supply current. This will avoid any danger of electric shock. The relay remains off until manually reset. A voltage - sensing ELCB does not sense fault currents from live to any other earthed body.

Advantages : When properly installed, the ELCB provides

(i) Overload and short-circuit protection.

(ii) Earth-leakage protection when leakage exceeds circuit breaker rating of 15 to 30 mA.

Disadvantages

(i) It does not protect people who are in contact with both power wires or either power wire and the neutral.

(ii) Electrically leaky appliances such as some water heaters, washing machines and cookers may cause the ELCB to trip.

(2.) Current ELCB (RCD) :

Current operated ELCBs are generally known as residual current devices (RCD). These also protect against earth leakage. Both supply and return circuit conductors are run through a sensing coil. If there is any difference of currents, known as residual, current the magnetic field does not perfectly cancel. The device detects the difference and trips the contact.

RCD circuit

The supply coil, the neutral coil and the search coil, all are wound on a common transformer core. On a healthy circuit the same current passes through the phase coil (i_1), the load and return back through the neutral coil, (i_2).Both the phase and the neutral coils are wound in such a way that they will produce an opposing magnetic flux. With the same current ($i_1 = i_2$) passing through both coils, magnetic effect will cancel out under a healthy circuit condition.

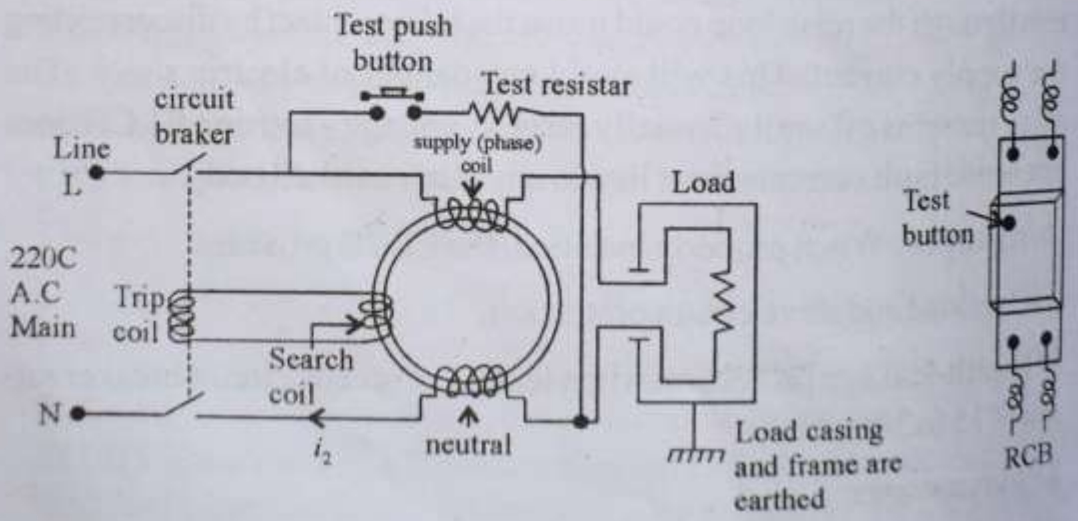
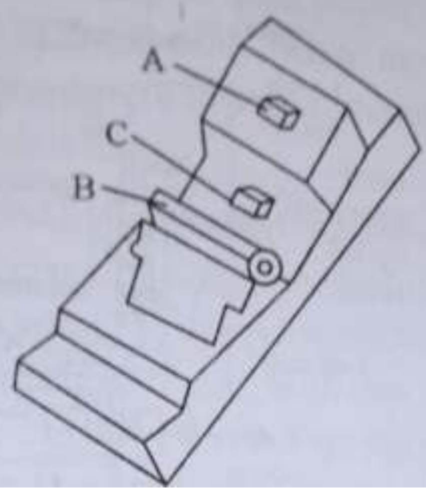


Fig. 137 Earth Leak circuit braker

Circuit breaker testing



Turn off all loads that come under the breaker. Turn on power to panel board. Turn on circuit breaker.

Press Test button (A). If circuit breaker is operating correctly, power will be disconnected, handle (B) will move to the center (tripped) position and red trip indicator (C) will appear. If circuit breaker is not operating correctly, re check wiring and installation.

To reset circuit breaker, push handle (B) to the off (O) position and then to the (I) position. Test the circuit breaker each month.

Uses :

When properly installed, the circuit breaker provides:

(i) overload and short-circuit protection.

(ii) Earth- leakage protection when leakage exceeds circuit breaker rating of 15 to 30 mA. However, it does not protect people who are in contact with both power wires or either power wire and the neutral. It works on heavy lightning impulse and the load circuit is broken each time.

Overload Protection Devices

A circuit overload occurs when the amount of current flowing through the circuit exceeds the rating of the protective devices. Every electrical circuit in a wiring system must be protected against overloads.

The amount of current flowing in a circuit is determined by the load. For example, if a circuit is rated for 15 amps maximum, then a fuse or circuit breaker of that rating will be put in that circuit. It the current flow exceeds this rated amperage in this circuit, the circuit breaker will open up, cutting off any more current flow. Without overload protection wires can get hot, or even melt the insulation and start a fire.

Signs of overloaded circuits are:

(i) Flickering of light

(ii) Spark from appliances or wall outlets

(iii) Worn - out switch plates

(iv) Dimming lights or television sets.

(v) A worn - out extension cord or plug.

There are two kinds of protection for electrical units that need to be considered.

1. Protection of the electrical wires supplying the circuits against an overload.

2. Protection of individual appliances and electrical equipment connected to a supply circuit from an overload. Both types of protection involve either fuses or breakers, but are based on different ideas.

Ground Fault Protection

What is a ground fault?

A ground fault is an inadvertent (unexpected) contact between an energised conductor and ground or equipment frame. The return path of the fault current is through the grounding system and any personnel or equipment that becomes part of the system. Ground faults are frequently the result of insulation breakdown. It is important to note that damp, wet and dusty environments require extra care in design and maintenance. Since water is conductive, it exposes degradation of insulation and increases the chance for hazard to develop.

What is the purpose of grounding?

The primary purpose of grounding electrical systems is to give protection against electrical faults. However, this was not realised until 1970's. Until then, most commercial and industrial systems were ungrounded. Although ungrounded systems do not cause significant damage during the first ground fault, the numerous disadvantages associated with ground faults resulted in a change to grounding philosophy. There are other advantages for a grounded system, such as reduction of shock hazards and protection against lightning.

Electrical faults can be broken down into two categories : phase - to - phase faults and ground faults. Studies have shown that 98% of all electrical faults are ground faults. Fuses can protect against phase - to - phase faults. Additional protection, such as protection relays, are typically required to protect against ground faults.

Earth fault current

Earth fault current is the current that flows directly from phas conductors to earth. It may also refer to a current that flows from protective conductors from the point of an insulation breakdown.

To avoid earth fault current, a protection is implemented to the supply of a current to a circuit or system. Interruption is only set to occur when current leakage to the earth is detected. The current leakage must be higher than the predetermined threshold value, if it exceeds it, then interruption will occur.

Power inverter or Inverter

An inverter is an electronic device that changes direct current (DC) to alternating current (A.C) of a given voltage and frequency.

Working principle of the inverters

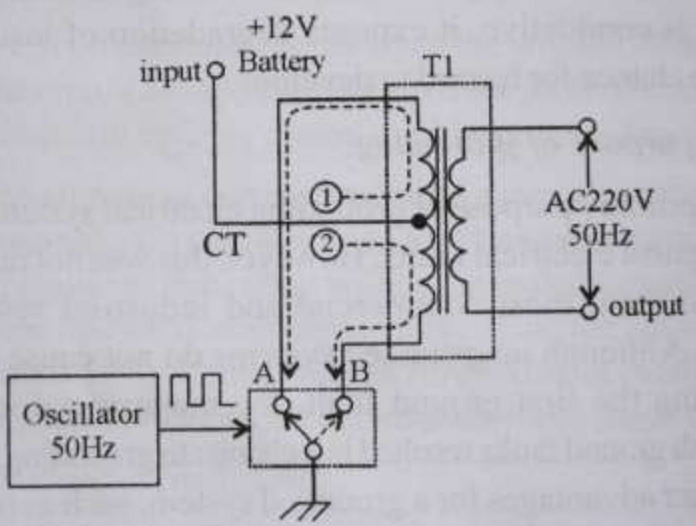


Fig. 140 Electrical inverter

The inverter circuit is shown in the figure. The main device is a transformer, which has a primary 12V-0-12V, iron core, and 220 V secondary output turns. $V_2/V_1 = n_2/n_1$. ie., $n_2 = n_1 \times V_2/V_1$.

The 12 volt input power source is a battery supply into the center tap of the primary coil. The ends of the primary coils A and B are connected to ground through a 2 - way switch.

First let us consider that the ground is connected to the terminal point A by the 2 way switch. This will cause an electric current (number one 1), flows from the positive terminal of the battery into the center tab point of primary of the transformer. Then the current flows up to top of the primary coil to contact point A of the switch to ground.

During this growth time a voltage of 220V is induced across the secondary of the transformer CD with terminal C having positive potential with respect to D terminal.

When the 2-way switch is moved to the points of B, the electric cenrent is stopped in path 1. Now the current from the battery is redirected along the path 2 through center tap down below and contact B of the switch to ground. Now the point D of the secondary terminal of the trans former is of a positive voltage of $220V$ with respect to terminal C. Thus an alternating potential is generated at the output of the transformer as the two way switch connects the battery to ground alternately.

A FET oscillator of frequency 50Hz controls the two way on - off switch. The switching speed is 50 times per second. This makes an electric current *No* 1 and *No* 2 alternating flow rate of 50 times per second. The current flows through the switch to ground all the time.

The charging magnetic field induces a 220V AC 50Hz frequency current at the output (CD) of the transformer. The voltage available at the output of the transformer can be used for various types of electrical devices of 220V 50 *Hz* rating.

Uninterrupted power supply (UPS)

An uninterrupted power supply (UPS) is an electrical device that provides emergency power to a load, when the input power source or mains power fails. A UPS differs from emergency power system or standby generator. UPS provides instantaneous protection from input power interruptions, by supplying energy stored in battery. A UPS is used to protect hardware such as computers, data centers or telecommunication equipment where an unexpected power failure could cause data loss.

Basic principle of UPS

UPS converts incoming AC to DC through a rectifier, and converts it back with an inverter. Batteries store energy to use in a utility failure. A bypass circuit routes power around the rectifier and inverter, running the load on incoming utility power.

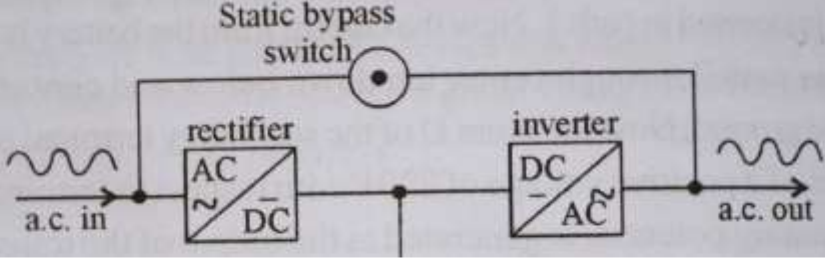


Fig. 141 Uninterrupted power supply (UPS)

The Working of UPS

The main components of an UPS are rectifier, batteries, power inverter and static bypass.

1. *Rectifier :* Rectifier converts AC into direct current. It has two main functions. First, the alternating current (AC) into direct current (DC), through the supply of filtered load; second, to provide battery charging voltage.

2. *Battery :* UPS battery is used as a storage energy device, which consists of several cells in series. When the electricity is normal, the electrical energy is converted into chemical energy and stored in the battery internal. When the electricity fails, the battery provides electrical energy to the inverter or the load.

3. *Inverter :* It is a device that converts a DC into alternating current (AC). It consists of transformer or inverter bridge control logic and filter circuit.

4. *The static bypass:* The online UPS has an internal static bypass circuit. In the event of a system (rectifier, battery and inverter) failure, the static bypass automatically closes (switches on) the circuit and allows the incoming power to divert around the rectifier, batteries and the inverter to supply current directly to the load. It allows your systems to continue functioning even if the UPS's internal components fail.

Uses of UPS

1. Electricity has become a life line of the home and the corporate world. Without electricity our computers would cease to work. An UPS can be a life savior when the power goes out.It allows one to properly shutdown the computer without loss of documents.

2. Whenever there is irregular power supply and spikes and surges in voltage, the basic stand by UPS can sense the voltage and will automatically go to battery power until normal power returns.

3. The common power problem can be surges and spikes. i.e., the incoming voltage jumps rapidly. A UPS can help to arrest most problems.

4. A UPS supplies regulating power to the electronic items connected to it in the event of power surges or jumps.

Maintenance of UPS

The important component which needs maintenance in UPS is the battery. The common causes for the failure of battery are

1. High or uneven temperatures
2. Inaccurate float charge voltage
3. Loose inter-cell connectors
4. Loss of electrolyte due to drying out or a damaged case
5. Lack of maintenance and aging.

D.C. Generator

Working principle

Generator is a machine which produces emf dynamically from a mechanical input. ie., It is a machine which converts mechanical energy to electrical energy. DC generator gives dc output voltage.

DC generator works on the principle of Faraday's laws. It states that, whenever a conductor moves in a magnetic field it cuts the magnetic flux (ϕ), due to which emf is induced. The amount of emf is directly proportional to rate of change of flux linkages.

$$E = -\, d\phi/dt.$$

This emf will cause a current to flow, if the conductor circuit is closed.

DC generator produces director power. AC generator produces alternating power.

Hence the most basic two essential parts of a generator are

1. A magnetic field
2. Conductors which move inside that magnetic field.

Basic construction of d.c. generator

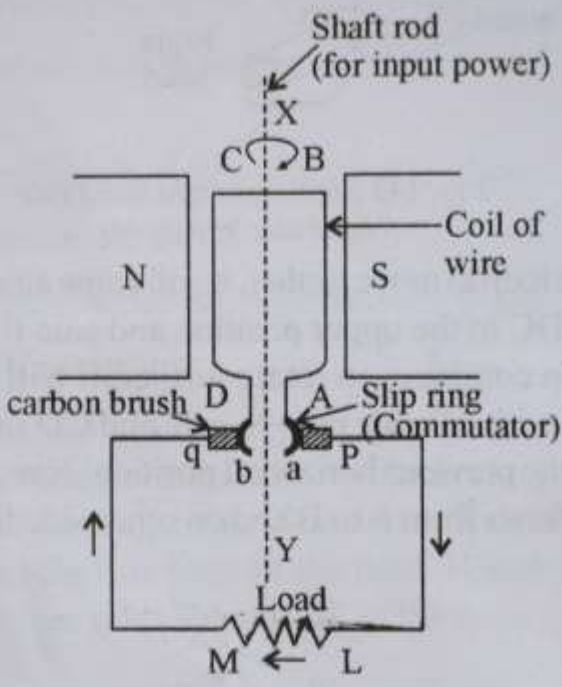


Fig. 145 *D.C. Generator*

ABC D is a coil of wire which can be rotated about the XY axis by an external force. The ends of the coil ane joined to two split rings *a* and *b*. The split rings are made out of a conducting cylinder which is cut into two segments insulated from each other by thin sheet of mica. Two carbon brushes *p* and *q* press against the slip rings *a* and *b*. The brushes collect the current induced in the coil.

In the first half rotation current flows along *BAaPLMqbDC*. In the second half rotation, direction of current in the coil is reversed. The position of segment *a* and *b* are also reversed. So in the second half rotation split ring *b* comes in contact with brush *p* and *a* with brush *q*.

Hence the current flows in the same direction. *L* to *M* in the load. Hence the current is unidirectional current in the external load as shown in the graph. (To minimise the ripple, the number of coils in the armature should be increased.)

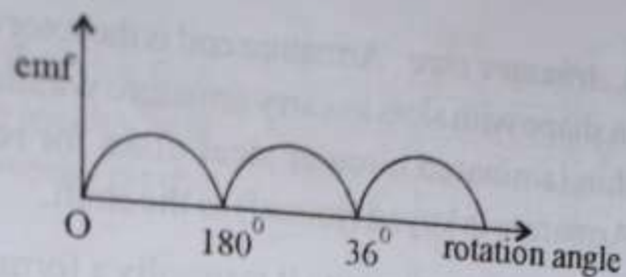


Fig. 146 *Single phase generator emf wave form*

Types of a DC generator :

DC generators can be classified in two main categories viz: (i) separately excited and (ii) self excited.

(i) seperately excited : In this type, field coils are energised from an independent external DC sources.

(ii) self excited : In this type, field coils are energised from the current produced by the generator itself. Initial emf generation is due to residual magnetism in field poles. The generated emf causes a part of current to flow in the field coils, thus strengthening the field flux and thereby increasing emf generation.

Electric Motor

An electric motor is a device that converts electric energy into mechanical energy. The electric motor works on the following principle:

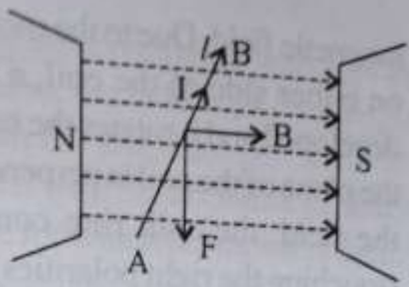


Fig. 147 (a)

If a wire is placed in a uniform magnetic field, there will be a force on the wire as soon as current flows in the wire. This force is called the motor force.

D.C. Motor

A simple form of *D.C.* motor is shown in the figure. It consists of a split-ring of copper whose two halves are insulated from each other and joined to the ends of the coil. The coil carrying current is in a uniform magnetic field. Due to the motor forces on either side of the coil, a torque is developed and it rotates the coil. When the plane of the coil is perpendicular to the field, the split ring commutator (touching the right polarities) reverses the direction of current in the coil. So, the torque continues to act in the same direction, thereby maintaining the rotation.

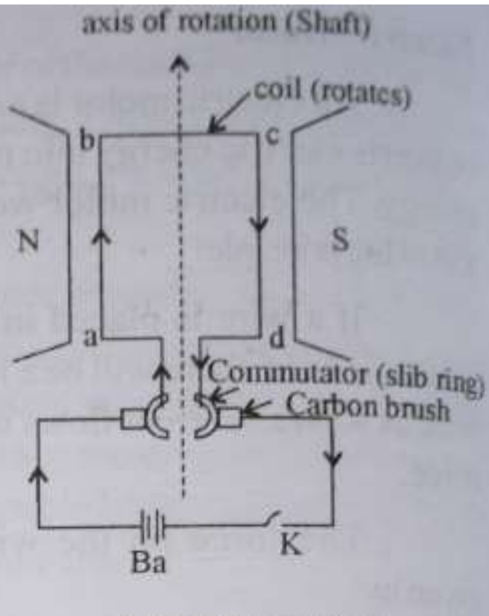


Fig. 149 *D.C. Motor*

In actual practice, several coils are wound in equally spaced slots in a (laminated) soft iron cylinder. This is called the armature or rotor.

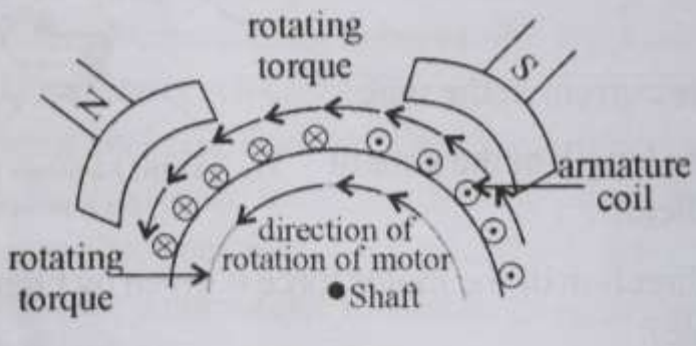


Fig. 150

The coils are connected to a special type of commutator with many segments. By the arrangement of several coils in the armature, greater and steadier rotating torque can be obtained.

The magnetic field is provided by electromagnets with concave pole-pieces. When electromagnets are used, the field coils (to energise the electromagnet) may be in series with the armature coil (then it is called series - wound moter) or in parallel with the armature (a shunt - wound motor), depending on the purpose for which the motor is used.

Electric motors are important components in various devices such as domestic appliances (mixie, grinder, vacuum cleaners, fan etc) and electric locomotives, lifts and windscreen wipers in cars, computers, printers and automatic cameras.

Questions

1. What are relays? Describe, with a neat sketch, a relay and its functioning. Give two applications of relays.
2. What are fuses? How do they function ? Write about different types of fuses, their rating and specific uses.

3. Describe, giving relevant diagrams, the different ways of arranging 'poles' and 'throws' to work as switches.

4. Describe the different types of switches and their specific uses.

5. What is the need of circuit breakers? How do they function?

6. Describe, with neat diagram, the earth leak circuit breaker (ELCB). Explain its woring.

7. Write about overload devices.

8. Describe a ground fault protection method.

9. What is an inverter? Draw the circuit diagram of an inverter and explain its working.

10. Explain the functioning of U.P.S.

11. Describe the construction and working of (i) A.C. generator (ii) D.C. generator (iii) D.C. motor and any one type of A.C motor. Where are these commonly used?

Objective type questions

1. An electrically operated switch is
   (a) fuse (b) relay (c) thermostat (d) none
2. A fuse wire should have
   (a) low melting point (b) high melting point
   (c) low thermal conductivity (d) very small thickness.
3. A good fuse has
   (a) very low resistance and zero p.d. across it
   (b) high resistance and zero p.d. across it
   (c) very low resistance and maximum p.d across it
   (d) none
4. Thinner the fuse wire, _________ is the current rating
   (a) smaller (b) larger (c) complex (d) nothing
5. When a fuse is blown off, p.d between its terminals is
   (a) equal to zero (b) is equal to supply voltage
   (c) equal to the p.d across the nearby capacitor (d) none
6. Glass catridge type of fuse, used in power line of T.V. receiver has current rating of the order
   (a) $\frac{1}{4}$ A (b) 5A (c) 10A (d) 50A.

7. Plug fuses in house wiring have current rating of the order

(a) $\frac{1}{4}$ A (b) 5A (c) 15A (d) 100A.

8. The type of switch used in high power on-off switching is

(a) push button (b) toggle (c) rotary wafer (d) key board

9. A.C falls to zero __________ in a cycle.

(a) Once (b) twice (c) thrice (d) never

10. Sparking across the air gap, when a switch is switched off lasts longer with

(a) a.c (b) d.c (c) both ac and d.c (d) none

11. A relay changes

(a) mechanical energy to electrical energy

(b) electrical energy to mechanical energy

(c) electrostatic energy to electromagnetic energy

(d) none

12. Motors are used in

(a) washing machines (b) vacaum cleaners

(c) refrigerators (d) all the above

14. Stepper motors used to turn robot's arm are driven by

(a) a.c (b) d.c (c) pulses of current (d) all the above

15. A device that gives no power gain

(a) amplifier (b) oscillator (c) loud speaker (d) transformer

16. The number of separate circuits which the switch makes or breaks at the same time is known as

(a) boosters (b) poles (c) throws (d) frequency

17. The number of positions to which each pole can be switched is known as

(a) poles (b) throws (c) frequency (d) boosters

18. The speed of the motor varies with load in

(a) series wound motor (b) shunt wound motor

(c) compound - wound motor (d) none

19. The motor that runs at steady speed, even if the load varies, is

(a) series wound motor (b) shunt wound motor

(c) compound wound motor (d) none

20. The induction motor (A.C) works on principle of

(a) production of eddy currents due to moving magnetic fields.

(b) rotational inertia

(c) law of electromagnetic induction

(d) Newtonr's law

21. MCD is

(a) a fuse to cut current in a circuit (b) an electromagnetic device

(c) an electromechanical device (d) all the above.

22. Resetting MCD is

(a) automatic (b) done by relay (c) hand- opearted (d) none

23. ELCB is meant for

(a) over current and earth leak protection (b) control of motor speed

(c) testing power line (d) testing earth connection.

24. Switches should always be

(a) in the live wire (b) in the neutral wire

(c) in the earth wire (d) any where.

25. Electrical shock begins to be felt by most people due to passage of ________ current through the body.

(a) 2-5 mA (b) 20 mA c) 100 mA (d) 1A

26. RCD is

(a) Resistance - capacitance Devices (b) Reverse - Charge Devices

(c) Residual Current Devices (d) none

27. Normally in power supply to an appliance, the current in the live wire

(a) is greater than that in the neutral wire.

(b) is less than that in the neutral wire

(c) equals that in the neutral wire (d) all the above

28. No starting resistance is needed for

(a) induction motors (b) series wound motors

(c) shunt wound motors (d) all the above.

Answers

1 (b)	2 (a)	3 (a)	4 (a)	5 (b)	6 (b)	7 (c)
8 (b)	9 (b)	10 (b)	11 (b)	12 (d)	13 (c)	14 (c)
15 (b)	16 (b)	17 (b)	18 (a)	19 (b)	20 (a)	21 (c)
22 (c)	23 (a)	24 (a)	25 (a)	26 (c)	27 (c)	28 (a)