CHAPTER 1

ELECTRIC CURRENT AND OHM'S LAW

LAWS OF RESISTANCE

The resistance R offered by conductor depends on the following factors :

1. It varies directly as its length
2. It varies inversely as the cross-section of the conductor.
3. It depends on the nature of the material.
4. It also depends on the temperature of the conductor.

Neglecting the last factor for the time being, we can sat that R or $R = \rho \frac{l}{A}$

CONDUCTANCE (G) AND CONDUCTIVITY (σ)

Conductance (G) is reciprocal of Resistance. * Whereas resistance of a conductor measures the opposition which is offers to the flow of current. The conductance measures the inducement which its offers to its flow.

From Eq. (i) we have $R = \rho \frac{l}{A}$

$$G = \frac{1}{\rho} \cdot \frac{A}{l} = \frac{\sigma A}{l}$$

Where σ is called the conductivity or specific conductance of a conductor. Its unit is Siemens/metre (S/m). The unit of conductance is Siemens (S) whereas the old unit was mho.

EFFECT OF TEMPERATURE ON RESISTANCE

The effect of rise in temperature is :-

1. To increase the resistance of the pure metals. The increase is large and fairly regular for normal ranges of temperature. The temperature/resistance graph is a straight line (Fig. 1..9). As would be presently clarified, metals have a positive temperature-coefficient of resistance.

2. To increase the resistance of alloys, though, in their case, the increase is relatively small and irregular. For some high resistance alloys like Eureka (60% Cu and 40% Ni) and manganin, the increase in resistance is (or cane be made) negligible over a considerable range of temperature.

3. To decrease the resistance of electrolytes, insulators (such as paper, rubber, glass, mica etc. and partial conductors, such as carbon. Hence, insulators are said to possess a negative temperature-coefficient of resistance.

OHM'S LAW

Whenever electric current flows through a conductor, the following three factors are present:

1. The pressure or potential difference V across the conductor (measured in volts) causing the current to flow.

2. The opposition or resistance R of the conductor (measured in ohms) which must be overcome.

3. The current strength *I* (measured in amperes) which is maintained in the conductor as a result of pressure overcoming the resistance.

There exists a definite relationship between the tree quantities involved and is known as **Ohm's Law**. It may be stated thus :

> The ratio of potential difference (V) between any two points of a conductor to the current (I) flowing between them is constant, provided the temperature of the conductor does not change.

RELATIONS DERIVED FROM OHM'S LAW

Following additional relationships connected directly or indirectly with Ohm's Law are worth nothing.

1. **Power** :- It is given by the product of voltage (V) and current (I)
   $W = VI$

   Its unit is watt.

   Other forms of the above formula are

   $\mathbf{W = V^2/R}$ ---- eliminating I

   $= I^2R$ ---- eliminating V

2. **Resistance**

   $\mathbf{R = V/I = V^2/W = W/I^2}$

3. **Current**

   $\mathbf{I = V/R = W/V = \sqrt{W/R}}$

4. **Voltage**

$$V = IR = W/I = \sqrt{WR}$$

All the above relationship have been summarized in Fig. 1.14.

RESISTANCE IN SERIES

When some conductors having resistance of R_1, R_2 and R_3 etc., are joined end-on-end as Fig. 1.17, they are said to be connected in series.

RESISTANCE IN PARALLEL

Three resistance, as joined in Fig. 1.19, are said to be connected in parallel. In this case (i) p.d. across all resistance is the same (ii) current in each resistor is different and is given by Ohm's Law and (iii) the total current is the sum of the three separate branch currents.

$$\therefore \quad I = I_1 + I_2 + I_3 = V/R_1 + V/R_2 + V/R_3$$

Now, $\quad I = V/R$

CHAPTER 2

DIVISION OF CURRENT

PRIMARY CELL

It essentially consists of two dissimilar conducting electrodes (one anode and the other cathode) immersed in a liquid called electrolyte, which acts chemically on one of the two electrodes more readily than on the other. By using the energy released by chemical action, electrons are shifted from one electrode to another, thereby creating a potential difference between the two electrodes. The value of total potential difference created between the electrodes, when the cell is not connected to an external circuit, is known as its electromotive force (E.M.F.)

CELL AND BATTERY

The word 'cell' means one unit or a combination of materials, for converting chemical energy into electrical energy. A 'battery' means a combination of these units or cells.

E.M.F. AND TERMINAL POTENTIAL DIFFERENCE

The e.m.f. of the cell, as said earlier, is the total potential difference established within the cell between the two electrodes, when the sell is not supplying any current (so that there is no internal voltage drop). The e.m.f. can be measured by connecting a suitable voltmeter across the electrodes. But the terminal potential difference is equal to the e.m.f. minus the internal voltage drop.

Terminal Potential Difference, V = e.m.f. --- ir or V = E -- ir

POLARISATION

If an ammeter is included in the external circuit of the voltaic cell, it indicates a gradual decrease in the current flowing. After some time, the current may cease altogether. The decrease is due to the collection of hydrogen bubbles on the surface of Cu plate. The effect of this layer of hydrogen is two fold :

(i) It acts as an insulator, thus reducing the effective area of the Cu plate and thereby increasing the internal resistance of the cell.

(ii) The sticking layer of positive hydrogen ions on the Cu plate exerts a repulsive force on other hydrogen ions, which are approaching the copper plate. Hence, the current is reduced. This phenomenon is called polarization and the cell which is in this condition is said to be polarized.

LOCAL ACTION

It is found that even when the voltaic cell is not supplying any load current, zinc goes on continuously dissolving in the electrolyte. This is due to the fact that some traces of impurities like iron and lead in the commercial zinc form tiny local cells, which are short-circuited by the main body of zinc. The action of these parasitic cells cannot be controlled, so that there is some wastage of zinc. This phenomenon is known as local action and can be prevented by amalgamating the zinc plate i.e. by rubbing mercury over the zinc plate. Mercury is supposed to cover the impurities and maintain a film of zinc dissolved in mercury.

GROUPING OF CELLS

A given number of cells may be grouped or connected together either for increasing the e.m.f. or the current. Following are the three different ways of grouping the cells.

SERIES GROUPING

In series grouping, the positive electrode i.e. anode of one cell is connected to the cathode of the second sell and the anode of the second cell is connected to the cathode of the third sell and so on, as shown in Fig.2.5.

Let n = number of cells connected in series
r = internal resistance/cell
R = external load resistance
E = the e.m.f./cell

Then, total e.m.f. of the battery of n cells is = nE

Internal resistance of the battery = nr*

Total circuit resistance = R + nr

Circuit current $$\mathbf{I = \frac{nE}{R + nr}}$$

PARALLEL GROPUING

In this method of grouping, anode of all the cells are joined together to give the anode of the combination and all cathodes are joined together to give the cathode of the combination (Fig. 2.6)

Here, battery e.m.f. is the same as the e.m.f. of each cell. Moreover, the equivalent resistance of n resistance each of value r all connected in parallel is r/n. This equivalent resistance is in series with the external resistance R.

Now, e.m.f. of the battery = E

Internal resistance of the battery = r/n

Total circuit resistance $$\mathbf{= R + \frac{r}{n}}$$

∴ **circuit current** $$\mathbf{I = \frac{E}{R + \frac{r}{n}}}$$

MISED GROUPING

In this case, a few cells are connected in series and some such series groups are connected parallel as shown in Fig. 2.7.

Let the number of parallel rows be m and the number of cells, joined in series, in each row be n. The internal resistance of this series parallel group can be found thus (Fig.2.8).

Resistance of each row = nr

Equivalent resistance of such m rows connected in parallel = nr/m

$$\therefore \textbf{ total circuit resistance} = R + \frac{nr}{m}$$

e.m.f. of the battery = e.m.f. of one row = nE

$$\therefore \quad I = \frac{nE}{R + \frac{nr}{m}} = \frac{mnE}{mR + nr} = \frac{NE}{mR + nr}$$

Where, N = m x n = total number of given cells

EFFICIENCY OF A CELL

In general, the efficiency of any system may be defined by the relation,

$$\textbf{efficiency} = \frac{\textbf{output}}{\textbf{input}} \times 100 \textbf{ percent}$$

Consider a cell having an e.m.f. of e, an internal resistance of r and delivering power to an external load resistance of R. If I is the circuit current, then useful power developed is $I^2 R$ watts and power lost within the cell is $I^2 r$ watts. Total power developed is $I^2 R + I^2 r = EI$ watts.

$$\therefore \quad n = \frac{\text{useful power}}{\text{total power produced}} = \frac{I^2 R}{I^2 R + I^2 r} = \frac{R}{R + r}$$

CHAPTER 4

WORK, POWER AND ENERGY

HEATING EFFECT OF ELECTRIC CURRENT

It is a matter of common experience that a conductor, when carrying current, becomes hot after some time. As explained earlier, an electric current is just a directed flow or drift of electrons through a substance. The moving electrons, as they pass 'through' the molecules or atoms of that substance, collide with other electrons. This electronic collision results in the production of heat. This explains why passage of current is always accompanied by generation of heat. The heat so produced is measured in the following units.

UNIT OF HEAT

The unit generally employed in scientific work is calorie. A calorie is defined as the quantity of heat that will raise the temperature of 1 gram of water through one degree centigrade.

For very accurate work, the particular degree has been specified as from 14.5° C to 15.5° C.

In the SI system, the unit of heat is kilo/calorie (k/cal) which is defined as the amount of heat required to heat one Kg of water through 1° C or 1° K.

JOULE'S LAW OF ELECTRIC HEATING

The amount of work required to maintain a current of I amperes through a resistance of R ohm (Fig. 4.1) for t seconds is

$$
\begin{aligned}
W.D &= l\,Rt \text{ joules} \\
&= VIt \text{ joules} && (\ R = V/I\ ) \\
&= Wt \text{ joules} && (\text{Watt} = V \times I) \\
&= \frac{V_2\,t}{R} \text{ joules} && (\ I = V/R)
\end{aligned}
$$

This work is converted into heat and is dissipated away. Heat produced is

$$\mathbf{H} = \frac{\textbf{work done (W.D)}}{\textbf{mechanical equivalent of heat}} = \frac{\textbf{W.D.}}{\textbf{J}}$$

Where J = 4.186 joules/cal

= 4.2 joules/cal (approx)

= 4,186 joules/kcal

= 4,200 joules/kcal (approx)

$$\therefore \quad \mathbf{H} = \frac{\mathbf{I^2 Rt}}{\mathbf{4.2}}\,\mathbf{cal} = \frac{\mathbf{I^2 Rt}}{\mathbf{4{,}200}}\,\mathbf{kcal}$$

ELECTRIC POWER

Power is the rate of doing work and is independent of the total amount of work to be done. The rate of working (or power) is found by dividing the work done by the time required to do it.

$$\therefore \quad \text{electric power} = \frac{\text{electric work done}}{\text{time taken}}$$

We have seen that work done electrically in time t seconds = VIt joules

$$\therefore \quad \text{power} = \frac{VI\,t}{t} = VI$$

If V is in volts and I in amperes, then product VI is in watts.

∴ power in watts = volt x amperes

One watt may be defined as the rate of doing one joule of work per second.

∴ I watt = 1 joule/second

Bigger units are :

1 kW = 1000W = 10^3 W ; 1 MW = 10^6 W

ELECTRIC ENERGY

The unit of energy is Joule. Other units are:

1 watt-hour (Wh) = 1 watt x 1 hour = (1 J/s) x 3600 s = 3600 J

1 kilowatt-hour (k Wh) = 3600 x 1000 = 36 x 10^5 J

The bill for electric charges is based on the number of k Wh consumed.

CHAPTER 5

ELECTROSTATICS

LAWS OF ELECTROSTATICS

FIRST LAW

Like charges of electricity repel each other, whereas unlike charges attract each other.

SECOND LAW

According to this Law, the force exerted between two point charges (i) is directly proportional to the product of their strength (ii) is inversely proportional to the square of the distance between them and (iii) is inversely proportional to the absolute permittivity (∈) of the surrounding medium.

This law is known as **Coulomb's Law** and can be expressed mathematically as

$$\mathbf{F \propto \frac{Q_1 Q_2}{\in d_2} \quad or \quad F = k \frac{Q_1 Q_2}{\in d^2}}$$

CHAPTER 6

CAPACITANCE

CAPACITOR

A capacitor essentially consists of two conducting surfaces separated by a layer of an insulating medium called dielectric. The conducting surfaces may be in the form of either circular (or rectangular) plates or of spherical or cylindrical shape. The purpose of a capacitor is to store electrical energy by electrostatic stress in the dielectric.

CAPACITANCE

The property of a capacitor is 'store electricity' may be called its capacitance. The capacitance of a capacitor may be defined as the amount of charge required to create a unit potential difference between its plates.

Suppose, we give Q coulombs of charge to one of the two plates of a capacitor and it s p.d. of V volts is established between the two, then its capacitance is

$$C = \frac{Q}{V} \qquad \frac{\text{coulomb}}{\text{volt}}$$

By definition, the unit of capacitance is coulomb/volt which is also called farad (in honour of Michael Faraday).

$\therefore$ 1 farad = 1 coulomb/volt

One farad is defined as the capacitance of a capacitor which requires a charge of one coulomb to establish a p.d. of one volt between its plates.

One farad is actually too large for practical purposes.
Hence, much smaller units like microfarad (μF) and micro-microfarad (μμF) or picofarad (pF) are generally employed.

$1\mu = 10^{-6}$ F

$1\mu\mu F$ or pF $= 10^{-12}$ F

TYPES OF CAPACITORS

A few of the commonly used capacitors are as follows :-

(i) Mica Capacitors
(ii) Ceramic Capacitors
(iii) Paper Capacitors
(iv) Electrolytic Capacitors

CAPACITORS IN SERIES

With reference to Fig. 6.15, let

C_1, C_2, C_3 = capacitance of three capacitors

V_1, V_2, V_3 = p.d. across three capacitors ; V = applied voltage across combination;

C = combined or equivalent capacitance.
In series combination, charge on all capacitors is the same but p.d. across each is different.

$$\therefore \quad \mathbf{V = V_1 + V_2 + V_3}$$

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \quad \text{or} \quad \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

CAPACITORS IN PARALLEL

In this case, p.d. across each is the same but charge on each is different (Fig. 6.16)

$$\therefore \quad Q = Q_1 + Q_2 + Q_3 \quad \text{or} \quad CV = C_1V + C_2V + C_3V$$

$$\text{or} \quad C = C_1 + C_2 + C_3$$

VOLTAGE ACROSS SERIES-CONNESTED CAPACITORS

First consider the case when two capacitors of capacitances C_1 and C_2 are connected in series across a supply voltage of V as shown in Fig. 6.17 (a). If V_1 and V_2 are the voltage developed across them, then

$$V = V_1 + V_2$$

Since charge across each is the same,

$$\therefore \quad Q = C_1 V_1 = C_2 V_2 \quad \text{or} \quad V_2 = V_1 C_1/C_2$$

Substituting this value in Eq. (i) above, we have

$$V = V_1 + V_1 \frac{C_1}{C_2} \quad \text{or} \quad V_1 = V \frac{C_2}{C_1 + C_2}$$

$$\text{Similarly,} \quad V_2 = V \frac{C_1}{C_1 + C_2}$$

Now, consider the case shown in Fig.6.17 (b). Here

$$V = V_1 + V_2 + V_3$$

$$\text{Also,} \quad Q = C_1 V_1 = C_2 V_2 = C_3 V_3$$

$$\therefore \quad V_2 = V_1 \frac{C_1}{C_2} \quad \text{and} \quad V_3 = V_1 \frac{C_1}{C_3}$$

Substituting these values in Eq. (i) above, we have

$$\therefore \quad V_1 = V \frac{C_2C_3}{C_1C_2 + C_2C_3 + C_3C_1}$$

Also, $$V_2 = V \frac{C_1C_3}{C_1C_2 + C_2C_3 + C_3C_1}$$ and

$$V_3 = V \frac{C_1C_2}{C_1C_2 + C_2C_3 + C_3C_1}$$

CHAPTER 7

MAGNETISM AND ELECTROMAGNETISM

MAGNETIC FIELD

The space or region around a magnet which is permeated by the lines of force and within which conductors carrying electric current are perceptibly influenced, is conventionally called the magnetic field of force or simply a magnetic field. It is assumed that lines of force emanate from a N-pole, pass through the surrounding medium, re-enter the S-pole and complete their path from S to N pole through the body of the magnet. Since every line of force must have a complete circuit, it is impossible to get a magnet having only one pole. These lines of force complete their paths independently and never cut or cross or merge into each other.

LAWS OF MAGNETIC FORCE

Coulomb was the first to determine experimentally the quantitative expression for the magnetic force between two isolated point poles. It maybe noted here that, in view of the fact that magnetic poles always exist in pairs, it is impossible, in practice, to get an isolated pole. The concept of an isolated pole is purely theoretical. However, poles of a thin but long magnet may be assumed to be isolated point poles for all practical purposes (Fig.7.1) by using a torsion balance, he found that the force between two magnetic poles placed in a medium is

(i) directly proportional to their pole strengths,
(ii) inversely proportional to the square of the distance between them,
(iii) inversely proportional to the absolute permeability of the surrounding medium.

MAGNETIC AND NON-MAGNETIC SUBSTANCES

Different substances can be divided into either (i) magnetic substances or (ii) non-magnetic substances.

Materials that cannot be magnetized are called non-magnetic substances. Examples are : wood, rubber, paper, wax and plastic etc. Those materials that can be magnetized are called magnetic substances. These can be further subdivided as under:

(i) Ferromagnetic Substances:- Which can be strongly magnetized by a magnetic field. Examples are : iron, steel, nickel, cobalt and alloys such as Alnico. Their relative permeability is very high (upto 100,000 or so) but various with the magnetizing force.

(ii) Paramagnetic Substances:- Which are only slightly attracted by a magnetic field. Examples are : aluminium, chromium, sodium and oxygen etc. Their relative permeability is slightly greater than unity. For example, μ, for aluminium is 1.000022.

(iii) Diamagnetic Substances:- Which are slightly repelled by magnetic fields. Examples are: bismuth, zinc, silver, gold, glass, water, hydrogen and nitrogen etc. their relative permeability is only less than unity.

CHAPTER 8

ELECTROMAGNETIC INDUCTION

PRODUCTION OF INDUCED E.M.F. AND CURRENT

In an insulated coil whose terminals are connected to a sensitive galvanometer G. It is placed close to a stationary bar magnet initially at position As it is, some lines of flux from the N-pole of the magnet are linked with or thread through the coil but, as yet, there is not deflection of the galvanometer. Now, suppose that the magnet is suddenly brought closer to the coil in position . Then, it is found that there is a jerk or a sudden but momentary deflection in the galvanometer and that this lasts so long as the magnet is in motion relative to the coil, not otherwise.

The deflection is reduced to zero when the magnet becomes again stationary at its new position . It should be noted that due to the approach of the magnet, flux linked with the coil is increased.

Next, the magnet is suddenly withdrawn away from the coil . It is found that again there is a momentary deflection in the galvanometer and it persists so long as the magnet is in motion, not when it becomes stationary. It is important to note that this deflection is in a direction opposite . Obviously, due to the withdrawal of the magnet, flux linked with the coil is decreased.

The deflection of the galvanometer indicates the production of e.m.f. in the coil. The only cause of the production can be the sudden approach or withdrawal of the magnet from the coil. It is found that the actual cause of this e.m.f. is the change of the flux linking with the coil. This e.m.f. exists so long as the change in flux exists. Stationary flux, however strong, will never induce any e.m.f. in a stationary conductor. In fact, the same results can be obtained by keeping the bar magnet stationary and moving the coil suddenly away or towards the magnet.

The direction of current set up by the induced e.m.f. is as shown in the two figures given below.

The production of this electro magnetically-induced e.m.f. is further illustrated by considering a conductor lying within a magnetic field and connected to a galvanometer . It is found that whenever this conductor is moved up or down, a momentary deflection is produced in the galvanometer. It means that some transient e.m.f. is induced in . The magnitude of this induced e.m.f. (and hence the amount of deflection in the galvanometer) depends on the quickness of the movement of .

From the experiment we conclude that whenever a conductor cuts or shears the magnetic lines of flux, an e.m.f. is always induced in it.

It is also found that if the conductor is moved parallel to the direction of the lines of flux (so that it cuts none of these lines), then no e.m.f. is induced.

FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION

Faraday summed up the above facts into two laws known as Faraday's laws of electromagnetic Induction.

FIRST LAW : It states :-

'When the magnetic flux linked with a circuit changes, an e.m.f. is always induced init.' or 'Whenever a conductor cuts across magnetic lines of flux, an e.m.f. is induced in that conductor.

SECOND LAW: It states :-

'The magnitude of the induced e.m.f. is equal to the rate of change of flux linkages'.

Explanation :- Suppose a coil has N turns and flux through it changes from an initial value of Φ_1Wb to the final value Φ_2Wb in time t seconds. Then, remembering that by flux linkages is meant the product of number of turns by the flux linked with coil, we have

Initial flux linkages = $N\Phi_1$; Final flux linkages = $N\Phi_2$

$$\therefore \quad \text{induced e.m.f. } e = \frac{N\Phi_2 - N\Phi_1}{t}\text{ volt} \qquad \text{or} \quad e = N\frac{\Phi_2 - \Phi_1}{t}\text{volt}$$

putting the above expression in its differential from, we get

$$e = \frac{d}{(N\Phi)} \qquad \text{or} \qquad e = N \frac{d\Phi}{\text{volt}}$$

dt dt

Usually, a minus sign is given to the right-hand side expression to signify the fact that the induced e.m.f. sets up current in such a direction that magnetic effect produced by it oppose the very cause producing .

$$\therefore \quad e = -N \frac{d\Phi}{dt} \text{ volt}$$

CHAPTER 10

D.C. GENERATORS

GENERATOR PRINCIPLE

An electrical generator is a machine which converts mechanical energy (or power) into electrical energy (or power).

This energy conversion is based on the principle of the production of dynamically (or motionally) induced e.m.f. As sen from Fig. 8-3 whenever a conductor cuts magnetic flux, dynamically indued e.m.f. is produced in it according to Faraday's Laws of electromagnetic Induction. This e.m.f. will cause a current to flow if the conductor circuit is closed.

Hence, the basis essential parts of an electrical generator are (i) a magnetic field and (ii) a conductor or conductors which can move so as to cut the flux.

SIMPLE LOOP GENERATOR

(a) CONSTRUCTION

In Fig. 10.1 is shown a single-turn rectangular copper coil ABCD rotating about its own axis in a magnetic field provided by either permanents or electromagnets. The two ends of the coil are joined to two slip rings or discs 'a' and 'b' which are insulated from each other and from the central shaft. Two collecting brushes (or carbon) press against the slip rings. Their function is to collect the current induced in the coil and to convey it to the external load resistance R.

The rotating coil may be called armature and the magnets as field magnets.

(b) WORKING

Imagine the coil to be rotating in clockwise direction. As the coil assumes successive positions in the field, the flux linked with it changes. Hence, an e.m.f. is induced in it which is proportional to the rate of change of flux linkages ($e = -Nd\Phi/dt$). When the plane of the coil is at right angles to the lines of flux i.e. when it is in position 1, the flux linked with the coil is maximum but rate of change of flux linkages is minimum. This is so because in this position, the coil sides AB and CD do not cut or shear the lines of flux, rather they slide along them i.e. they move parallel to them. Hence, there is no induced e.m.f. in the coil. Let us take this no-e.m.f. or vertical position of the coil as the starting position. The angle of rotation or time will be measured from this position.

As the coil continues rotating further, the rate of change of flux linkages (and hence induced e.m.f. in it) increases, till position 3 is reached where $\theta = 90°$. Here the coil plane is horizontal i.e. parallel to the lines of flux. As seen, the flux lined with the coil is minimum but rate of change of flux linkages or rate of flux cutting is maximum. Hence, maximum e.m.f. is induced in the coil when in this position (Fig. 10.3).

In the next quarter revolution i.e. from 90° to 180°, the flux linked with the coil gradually increases, but rate of change of flux decreases. Hence, the induced e.m.f. decreases gradually till in position 5 of the coil, it is reduced to zero value (Fig.10.3).

So, we find that in the first revolution of the coil, no (or minimum) e.m.f. is induced in it when in position1, maximum e.m.f. is induced when in position 3 and no e.m.f. is induced when in position 5. The direction of this induced e.m.f. can be found by applying Fleming's Right-hand rule which gives its direction from A to B and C to D. Hence, the direction of current flow is ABMLCD. The current through the load resistance R flows from M to L during the first half revolution of the coil.

In the next half revolution i.e. from 180°, the variations in the magnitude of e.m.f. are similar to those in the first half revolution. Its value is maximum when coil is in position 7 and minimum when it is in position 1. But it will be found that the direction of the induced current is from D to C and B to A. Hence, the path of current flow is along DCLMBA which is just the reverse of the previous direction of flow.

Therefore, we find that the current which we obtain from such simple generator reverses its direction after every half revolution. Such a current undergoing periodic reversals is known as alternating current (A.C). It is, obviously, different from a direct current (D.C.) which continuously flows in one and the same direction. It should be noted that A.C. not only reverse its direction, it does not even keep its magnitude constant while flowing in any direction. The two half-cycles may be called positive and negative half cycles respectively

For making the flow of current unidirectional in the external circuit, the slip-rings are replaced by split-rings . the split-rings are made out of a conducting cylinder which is cut into two halves or segments insulated from each other by a thin sheet of mica or some other insulating material.

As before, the coil ends are joined to these segments on which rest the carbons brushes.

It is seen that in the first half revolution, current flows along ABLMCD i.e. brush No.1 which is in contact with segment 'a', acts as the positive end of the supply and brush No.2 and 'b' as the negative end. In the next half revolution , the direction of the induced current in the coil is reversed. But at the same time, the positions of segments ‘a’ and ‘b’ are also reversed with the result that brush No.1 comes in touch with that segment which is positive i.e. segment ‘b’.

Hence, the current in the load resistance again flows from L to M. The wave-form of the current through the external circuit . This current is unidirectional but not continuous like pure direct current.

It should be noted that the position of brushes is so arranged that the changeover of segments ‘a’ and ‘b’ from one brush to the other takes place when the plane of the rotating coils is at right angles to the plane of the lines of flux because in that position, the induced e.m.f. in the coil is zero.

Another important point to remember is that even now the current induced in the coil sides is alternating as before. It is only due to the rectifying action of the split-rings (also called commutator) that it becomes unidirectional in the external circuit. Hence, it should be clearly understood that even in the armature of a d.c. generator, the induced current is alternating.

PRACTICAL GENERATOR

The simple loop generator has been considered in detail merely to bring out the basic principle underlying the construction and working of an actual generator which consists of the following essential parts :

1. Magnetic Frame or Yoke.
2. Pole Cores and Pole Shoes.
3. Pole Coils or Field Coils.
4. Armature Core.
5. Armature Windings or Conductors.
6. Commutator.
7. Brushes and Bearings.

Of these, the yoke, the pole cores, the armature core and air gaps between the poles and the armature core form the magnetic circuit whereas the rest form the electrical circuit.

YOKE

The outer frame or yoke serves double purpose:

(i) It provides mechanical support for the poles and acts as a protecting cover for the whole machine and

(ii) It carries the magnetic flux produced by the poles.

In small generators where cheapness rather than weight is the main consideration, yokes are made of cast iron. But for large machines, usually cast steel or rolled steel is employed.

POLE CORE AND POLE SHOES

The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes. (i) they spread out the flux in the air-gaps and also, being of larger cross-section, reduce the reluctance of the magnetic path and (ii) they support the exciting coils.

POLE COILS

The field coils or pole coils, which consist of copper wire or strip, are former-wound for the correct dimension. Then, the former is removed and the wound coil put into place over the core.

When current is passed through these coils, they electromagnetise the poles which produce the necessary flux that is cut by the revolving armature conductors.

ARMATURE CORE

It houses the armature conductors or coils and causes them to rotate and hence cut the magnetic flux of the field magnets. In addition to this, its most important function is to provide a path of very low reluctance to the flux passing through the armature from a N-pole to a S-pole.

It is cylindrical or drum shaped and is built up of usually circular sheet steel discs or laminations approximately 0.06mm thick

The purpose of using laminations is to reduce the loss due to eddy currents. Thinner the laminations, greater is the resistance offered to the induced e.m.f., smaller the current and hence less the I^2R loss in the core.

ARMATURE WINDINGS

The armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape in a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots which are lined with tough insulating material.

This slot insulation is folded over above the armature conductors placed in the slot and is secured in place by special hard wooden or fiber wedges.

COMMUTATOR

The function of the commutator is to facilitate the collection of current from the armature conductors. It rectifies i.e. converts the alternating current induced in the armature into unidirectional current. It is of cylindrical structure and is built up of wedge-shaped segments of high-conductivity hard-drawn or drop-forged copper. These segments are insulated from each other by thin layer of mica. Each commutator segment is connected to the armature conductors by means of a copper lug or strip (or riser).

BRUSHES AND BEARINGS

The brushes whose function is to collect current from commutators, are usually made of carbons and are in the shape of a rectangular block. These brushes are housed in brush-holders (usually of the box-type variety) which are mounted on brush-holder studs or brackets.

In turn, the brush-holder studs are mounted on a brush yoke or rocker arm. The brush-holder studs are insulated from the brush yoke by means of insulation selves and discs. The brush yoke brush-holder and brushes make up the brush gear .

Because of their reliability, ball bearings are frequently employed: through for heavy duties roller bearing are preferable. The ball and rollers are generally packed in hard oil for quieter operation and for reduced bearing wear, sleeve bearings are used which are lubricated by ring oilers fed from oil reservoir in the bearing bracket.

ARMATURE WINDING

Two basic types of windings mostly employed for drum-type armature are known as (i) Wave winding and (ii) Lap winding.

(a) Wave Winding

The most distinguishing feature of this windings is that electrically it divides the armature conductors into two parallel paths between the positive and negative brushes irrespective of the number of poles of the machine.

As the armature current enters the negative brush, it finds two parallel paths of equal resistance available for going to the positive brush. Hence, it divides equally into two parts. Each path consists of Z/2 conductors connected in series (Z – being the total number of armature conductors) and each carries a current of $I_a/2$ where I_a is the total armature current.

(b) Lap Winding

In this case, the armature conductors are divided into as many parallel paths as the number of poles of the generator. If there are P-poles and Z armature conductors, then there are P parallel paths, each consisting of Z/P conductors connected in series between the positive and negative set of brushes.

The case of a 4-pole machine. As armature current enters the negative brush, it has four parallel paths available for going to the positive brush. Each path has Z/4 conductors and carries a current of $I_a/4$.

TYPES OF GENERATOR

Generators are usually classified according to the way in which their fields are excited. Generators may be divided into (a) separately-excited generators and (b) self-excited generators.

(a) **Separately-excited** generators are those whose field magnets are energized from an independent external source of direct current.

(b) **Self-excited** generators are those whose field magnets are energized by the current produced by the generators themselves. Due to residual magnetism, there is always present some flux in the poles. When the armature is rotated, some e.m.f. and hence some induced current is produced which is partly or fully passed through the field coils thereby strengthening the residual pole flux further.

There are there types of self-excited generators named according to the manner in which their field coils (or windings) are connected to the armature.

(i) Shunt Wound

The field windings are connected across or in parallel with the armature conductors and have the full voltage of the generator applied across them (Fig. 10.14).

The field coil consists of many turns of fine gauge copper wire. Such generators are in much common use.

(ii) Series Wound

In this case, the field windings are joined in series with the armature conductors. As they carry full-load current, they consist of relatively few turns of thick wire or strip. Such generators are rarely used except for special purposes i.e. as boosters etc.

(iii) Compound Wound

It is a combination of a few series and a few shunt windings and can be either short-shunt or long-shunt .

TOTAL LOSS IN A D.C. GENERATOR

The various losses occurring in a generator can be subdivided as follows:

(a) Copper Losses (or I^2R loss)

(i) Armature copper loss $= I_a^2 R_a$ (not $E_g I_a$)

Where R_a = resistance of armature and interpoles and series field winding etc.

This loss is about 30 to 40% of full load losses.

(ii) Field Copper Loss : In the case of shunt generators, it is practically constant and $= I_{sh}^2 R_{sh}$ (or VI_{sh}). In the case of series generators, it is $= I_{sh}^2 R_{sh}$ where R_{sh} is resistance of the series field winding.

This loss is about 20 to 30 % of F.L. losses.

(iii) The loss due to brush contact resistance. It is usually included in the armature copper loss.

(b) Magnetic Losses (also known as iron or core losses)

(i) Hysteresis loss, $W_h \propto B^{1.6}_{max} f$

(ii) Eddy current loss, $W_e \propto B^2_{max} f^2$

These losses are practically constant for shunt and compound-wound generators, because field current, in their case, is approximately constant.

Both these losses total up to about 20 to 30% of F.L. losses.

(c) Mechanical Losses

These consist of :

(i) Friction loss at bearings and commutator.
(ii) Air-friction or windage loss of rotating armature.
These are about 10 to 20% of F.L. losses.

STRAY LOSSES

Usually magnetic and mechanical losses are collectively known as **stray losses.**

CONSTANT AND STANDING LOSSES

As said above, field Cu loss is constant for shunt and compound generators. Hence, stray losses and shunt Cu losses are constant in their case. These losses are known as standing or constant losses W_c.

Hence, for shunt and compound generators,

$$\text{Total losses} = \text{armature copper loss} + W_c$$

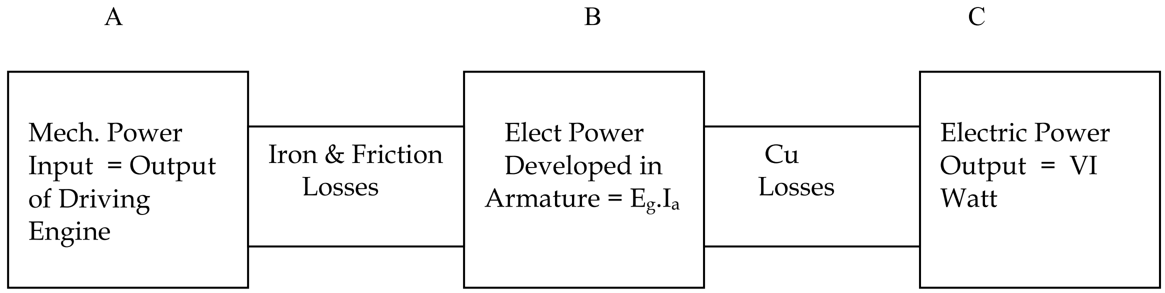
$$= I_a^2 R_a + W_c = (I + I_{sh})^2 R_a + W_c$$

Armature Cu loss, $I_a^2 R_a$ is known as variable loss because it varies with the load current.

$$\therefore \quad \text{total losses} = \text{variable losses} + \text{constant losses } W_c$$

POWER STAGES

Various power stages in the case of a d.c. generator are shown below :



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Following are the three generator efficiencies :

1. **Mechanical Efficiency**

$$\eta_m = \frac{B}{A} = \frac{\text{total watts generated in armature}}{\text{mechanical power supplied}}$$

2. **Electrical Efficiency**

$$\eta_e = \frac{C}{B} = \frac{\text{watts available in load circuit}}{\text{total watts generated}} = \frac{VI}{E_g \; I_a}$$

3. **Overall or Commercial Efficiency**

$$\eta_c = \frac{C}{A} = \frac{\text{watts available in load circuit}}{\text{mechanical power supplied}}$$

It is obvious that overall efficiency $\eta_c = \eta_m \times \eta_e$. For good generators, its value may be as high as 95%.

CONDITION FOR MAXIMUM EFFCIENCY

Generator output = VI watts
Generator Input = output + losses

$$= VI + I_a^2 R_a + W_c$$

$$= VI + (I + I_{sh})^2 R_a + W_c \qquad (I_a = I + I_{sh})$$

However, if I_{sh} is negligible as compared to load current I, then

$$I_a = I \text{ (approx)}$$

$$\eta = \frac{\text{output}}{\text{input}} = \frac{VI}{VI + I_a^2 R_a + W_c}$$

$$= \frac{VI}{\quad} \qquad (I_a = I)$$

$$VI + I^2 R_a + W_c$$

$$= \frac{1}{1 + \left[\frac{IR_a}{V} + \frac{W_c}{VI} \right]}$$

Now, efficiency is maximum when denominator is minimum i.e. when

$$\frac{d}{dI} \left[\frac{IR_a}{V} + \frac{W_c}{VI} \right] = 0$$

Hence, efficiency is maximum when variable loss = constant loss
The load current corresponding to maximum efficiency is given by relation

$$I^2R_a = W_c$$

or $$I = \sqrt{\frac{W_c}{R_a}}$$

ARMATURE REACTION

By armature reaction is meant the effect of magnetic field set up by armature current on the distribution of flux under main poles of a generator (or motor). This armature field has two effects.

1. It demagnetizes (or weakens) the main pole flux and
2. It distorts the main flux.

Accordingly, there are two components of armature reaction, one is called the 'demagnetising component' and the other 'distorting components'. Both these components increase with increase in the armature current, that is, with increase in the load on the generator. Under severe overloads or short circuit, the demagnetizing component of armature reaction may become so strong as to reverse the polarity of the main poles. In general, when the main flux Φ is decreased due to armature reaction, the e.m.f. induced in the armature of a d.c. generator is also decreased because $E \propto \Phi$.

The demagnetizing effect of armature reaction is neutralized by adding a few extra ampere-turns to the main filed winding. The distorting effect is neutralized by using 'compensating windings'. These windings are embedded in slots in the pole-shoes and are connected in series with armature in such a way that current in them flows in a direction opposite to that of the armature current flowing in the armature conductors directly below the pole shoes.

COMMUTATION

As briefly explained the induced currents in the armature conductors of a d.c. generator are alternating currents i.e. these currents flow in one direction when conductors are under N-pole and in exactly opposite direction when they are under S-pole. As conductors pass out of the influence of a N-pole and enter that of a S-pole, the current in them is reversed. This reversal of current takes place along magnetic neutral axis (M.N.A.) or brush axis i.e. when the brush-spans and hence short-circuits the particular coil undergoing reversal of current through it.

This process by which current in the short-circuited armature coil is reversed while it crosses the M.N.A. is called 'commutation'.

The brief period during which coil remains short-circuited is known as commutation period T_c.

If current reversal is completed the time T_c, then commutation is ideal. If not, then sparking is produced between the brush and the commutator which damages both.

The main factor which does not allow the armature current to completely reverse its direction within the specified period of T_c is the production of the self-induced e.m.f. called reactance voltage in the conductors through which the current is reversing. If current changes from + I to – I in time T_c, then reactance voltage is $L\ 2I/T_c$ where L is the inductance of the armature conductors. Commutation can be improved i.e. current reversal can be made spark less by using interpoles. These are small poles fixed to the yoke and spaced in between the main poles. They are wound with a few thick copper wire turns and are connected in series with the armature so that they carry full armature current. Their polarity is the same as that of the main pole ahead in the direction of rotation.

CHAPTER 13

SPEED CONTROL OF D.C. MOTORS

FACTORS CONTROLLING THE SPEED

It has been shown earlier that the speed of a motor is given by the relation

$$N = \frac{V - I_a R_a}{\Phi} \times \frac{60\ A}{ZP} = K \frac{V - I_a R_a}{\Phi} \text{ r.p.m.}$$

where R_a = armature circuit resistance.

It is obvious that the speed can be controlled by varying (i) flux per pole, Φ (flux control), (ii) resistance R_a of armature circuit (rheostatic control). These method as applied to shunt and series motors will be discussed below.

SPEED CONTROL OF SHUNT MOTORS

(i) Variation of Flux or Flux Control Method

It is seen from above that $N \propto 1/\Phi$. By decreasing the flux, the speed can be increased and vice versa. Hence, the name flux or field control method. The flux of a d.c. motor can be changed by changing I_{sh} with the help of a shunt field rheostat (Fig. 13.1). Since I_{sh} is relatively small, shunt field rheostat has to carry only small current which means $I^2 R$ loss is small, so that rheostat is small in size. This method is, therefore, very efficient. In non-interpolar machines, the speed can be increased by this method in the ratio 2 : 1. Any further wakening of flux Φ adversely affects the commutation and hence puts a limit to the maximum speed obtainable with this method. In machines fitted with interpoles, ration of maximum to minimum speeds of 6 : 1 is fairly common.

(ii) Armature or Rhestatic Control Method

This method is used when speeds below the no-load speed are required. As the supply normally constant, the voltage across the armature is varied by inserting a variable rhestat or resistance (called controller resistance) in series with the armature circuit . As controller resistance is increased p.d. across the armature is decreased, thereby decreasing the armature speed. For a load of constant torque, speed is approximately proportional to the p.d. across the armature. From the speed Vs armature current characteristic it is seen that greater the resistance in the armature circuit, greater is the fall in speed.

SPEED CONTROL OF SERIES MOTORS

(i) Flux Control Method

Variations in the flux of a series motor can be brought about in any one of the following ways:

(a) Field Divertor

The series windings are shunted by a variable resistance known as field divertor. Any desired amount of current can be passed through the divertor by adjusting its resistance. Hence, the flux can be decreased and consequently, the speed of the motor increased.

(b) Armature Divertor

A divertor across the armature can be used for giving speeds lower than the normal speeds. For a given constant load torque, if I_a is reduced due to armature divertor, then Φ must increase ($T_a \propto \Phi I_a$). This results in an increase in current taken from the supply (which increases the flux) and a fall in speed ($N \propto I/\Phi$). The variations in speed can be controlled by varying the divertor resistance.

(c) Tapped Field Control

This method is often used in electric traction and is shown in Fig. 13.7.
The number of series field turns in the circuit can be changed at will as shown. With full field, the motor runs at its minimum speed which can be raised in steps by cutting out some of the series turns.

(d) Paralleling Field Coils

In this method, used for fan motors, several speeds can be obtained by regrouping the field coils. It is seen that for a 4 – pole motor, three fixed speeds can be obtained easily.

(ii) Variable Resistance in Series with Motor Armature

By increasing the resistance in series with the armature, voltage applied across the armature terminals can be decreased.

With reduced voltage across the armature, the speed is reduced. However, it will be noted that since full motor current passes through this resistance, there is a considerable loss of power in it.

SHUNT MOTOR STARTER WITH PROTECTIVE DEVICES

It consists of an arm or handle A which moves over the studs. When the arm touches the first stud, field circuit is completed through brass are B and full resistance is placed in the armature but is gradually cut out as the handle is moved over. The handle moves against a strong spring as shown. It has a piece of soft iron C attached to it which in the **'FULL-ON'** position is attracted and held by the electromagnet E which is energized by shunt field current. This is known as 'hold-on' coil or 'low-voltage' (formerly No-voltage) release. The action of this protective device is, in case of a failure or disconnection of the supply or a break in the field circuit, to release the arm and allow the spring to bring it back to 'OFF' position. This prevents the fuses from blowing, as they otherwise would if the supply were restored with the handle in the 'FULL-ON' position.

An over-current (or over-load) release is also fitted in the starter. This consists of an electromagnet F which is connected in the supply line. If the machine becomes over-loaded beyond a certain predetermined value, then D is lifted and short-circuits e. Hence, the handle is released and returns to 'OFF' position.

MERITS AND DEMERITS OF RHEOSTATIC SONTROL METHOD

1. Speed changes with every change in load, because speed variation depend not only on controlling resistance but on load current also. This double dependence makes it impossible to keep the speed sensibly constant on rapidly changing loads.

2. A large amount of power is wasted in the controller resistance. Loss of power is directly proportional to the reduction in speed. Hence, efficiency is decreased.

3. Maximum output power developed is diminished in the same ratio as speed.

4. It needs expensive arrangement for dissipation of heat produced in the controller resistance.

5. It gives speeds below the normal speed, not above it because armature voltage can be decreased (not increased) by the controller resistance.

This method is, therefore, employed when low speeds are required for a short period only and that too occasionally as in printing machines and for cranes and hoists where the motor is continually started and stopped.

ADVANTAGES OF FIELD CONTROL METHOD

This method is economical, more efficient and convenient through it can give speeds above (not below) the normal. The only limitation of this method is that commutation becomes unsatisfactory, because the effect of armature reaction is greater or a weaker field.

It should, however, be noted that by combining the two methods, speeds above and below the normal may obtained.

CHAPTER 21

TRANSFORMER

WORKING PRINCIPLE OF A TRANSFORMER

A transformer is a static (or stationary) piece of apparatus

by means of which electric power in one circuit is transformed to electric power of the same frequency in another circuit. It can raise or lower the voltage in a circuit but with a corresponding decrease or increase in current. The physical basis of a transformer is mutual induction between two circuits linked by a common magnetic flux. In its simplest form, it consists of two inductive coils which are electrically separate but magnetically linked through a path of low reluctance . The two coils possess high mutual inductance. If one coil is connected to a source of alternating voltage, an alternating flux is set up in the laminated core, most of which is linked with the other coil in which it produces mutually-induced e.m.f. If the second coil circuit is closed, a current flows in it and so electric energy is transferred from the first coil to the second coil. The first coil, in which electric energy is fed from the a.c. supply mains, is called primary winding and the other, from which energy is drawn out, is called secondary winding. In brief, a transformer is a device that :

1. transfers electric power from one circuit to another;
2. does so without change of frequency;
3. accomplishes this by electromagnetic induction; and
4. where the two electric circuits are linked by mutual induction.

TRANSFORMER CONSTRUCTION

The simple elements of a transformer consist of two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and from the steel core. Other necessary parts are : some suitable container for the assembled core and windings; a suitable medium for insulating the core and its windings from its container; suitable bushings (either of porcelain, oil-filled or capacitor-type) for insulating and bringing out the terminals of the winding from the tank.

In all types of transformers, the core is constructed of transformer sheet steel laminations assembled to provide a continuous magnetic path with minimum of air-gap included. The steel used is of high silicon content sometimes heat treated to produce a high permeability and a low hysteresis loss at the usual operating flux densities. The eddy current loss is minimized by laminating the core, the laminations being insulated from each other by a light coat of coreplate varnish or by oxide layer on the surface. The thickness of laminations varies from 0.35mm for a frequency of 50Hz to 0.5 mm for a frequency of 25Hz. The core laminations (in the form of strips) are joined as shown in Fig. 21.2. It is seen that the joints in the alternate layers are staggered in order to avoid the presence of narrow gaps right through the cross-section of the core. Such staggered joints are said to be ‘imbricated’.

Constructionally, the transformers are of two general types, distinguished from each other merely by the manner in which the primary and secondary coils are placed around the laminated steel core. The two types are known as (i) core-type and (ii) shell-type. Another recent development is spiral core or wound-core type, the trade name being spirakore transformer.

In the so-called core-type transformers, the windings surround a considerable part of the core whereas in shell-type transformers, the core surrounds a considerable portion of the windings as shown schematically in Fig. 21.3 (a) and (b) respectively.

In the simplified diagram for the core-type transformers [Fig. 21.3 (a)] the primary and secondary windings are shown located on the opposite legs (or limbs) of the core, but in actual construction, these are always inter-leaved in order to reduce the leakage flux. As shown in Fig. 21.4, half the primary and half the secondary winding have been placed side by side or concentrically on each limb, not primary on one limb (or 'leg') and the secondary on the other.

CONDITION FOR MAXIMUM EFFICIENCY

Cu loss $= I_1^2 R_{01}$ or $I_2^2 R_{02} = W_{cu}$

Iron Loss = hysteresis loss + eddy current loss $= W_h + W_e = W_i$

Considering primary side,

Primary input $= V_1 I_1 \cos\phi_1$

$$\therefore \quad \eta = \frac{V_1 I_1 \cos\phi_1 - \text{ losses}}{V_1 I_1 \cos\phi_1} = \frac{V_1 I_1 \cos\phi_1 - V^2_1 R_{01} - W_i}{V_1 I_1 \cos\phi_1}$$

$$= 1 - \frac{V_1 R_{01}}{V_1 \cos\phi_1} - \frac{W_i}{V_1 I_1 \cos\phi_1}$$

Differentiating both sides with respect to I_1, we get

$$\frac{d\eta}{d I_1} = 0 - \frac{R_{01}}{V_1 \cos\phi_1} + \frac{W_i}{V_1 I^2_1 \cos\phi_1}$$

For η to be maximum,

$\frac{d\eta}{d I_1} = 0$. Hence, the above equation becomes

R_{01} W_i

$$\frac{}{V_1 \cos\phi_1} = \frac{}{V_1 I^2_1 \cos\phi_1} \quad \text{or} \quad W_i = I_1^2 R_{01} \quad \text{or} \quad = I_2^2 R_{02}$$

or Cu Loss = Iron Loss

The output current corresponding to maximum efficiency is

$$I_2 = \sqrt{\frac{W_i}{R_{02}}}$$

It is this value of the output current which will make the Cu loss equal to the iron loss. By proper design. It is possible to make the maximum efficiency occur at any desired load.

In fig. 21.32, Cu and iron losses are plotted as a percentage of power input and the efficiency curve as deduced from these is also shown. It is obvious that the point of inter-section of the Cu and iron loss curves gives the point of maximum efficiency. It would be seen that the efficiency is high and is practically constant from 25% load to 25% overload.

FITTING SHOP

MICROMETER

A micrometer is an instrument for making more precise measurements than can be got with rules and calipers. The most commonly used type of a micrometer is SHOWN IN FIG. 1.22. It consists of a stiff flat, bow shaped circular frame. A hardened gauging face is provided at one end of this bow. Exactly opposite to this face, there is a machined tube or hub with an inside thread.

FORGING SHOP

HAMMERS

These are the principal striking tools made of forged steel, used by a black smith. Hammers may be broadly classified as :-

1. Hand Hammers
2. Sledge Hammers
3. Power Hammers

1. HAND HAMMERS :-

As the name indicates, this hammer is used by the black-smith himself. It is comparatively having less weight and small size. They are graded on the basis of their weight or size.

2. SLEDGE HAMMERS :-

Sledge hammers are heavier than hand hammers and are used by blacksmith's helper named hammer-man used sledge hammers are 4 lbs to 20 lbs.

3. POWER HAMMERS:-

Hand hammers and sledge hammers find their application as far as hand forging is concerned. Their use for satisfactory job production is limited to small forging operations only. For heavy smithy works power hammers are used. Commonly used Power hammers are :

1. Spring Power Hammers
2. Pneumatic Power Hammers
3. Steam Hammers
4. Drop Hammers

SPRING POWER HAMMERS:-

A spring power hammers is used for small forging works as it is a light hammer.

PNEUMATIC POWER HAMMERS:-

A Pneumatic Power Hammer consists of two cylinders. One carries a piston to work inside it. It is connected to the motor shaft. Between the two cylinders, there is an air passage having a valve operated by a hand lever. The second cylinder also carries a piston having a tup at its bottom.

STEAM HAMMERS:-

These are similar to Pneumatic Power Hammers with the basis difference that the compression of steam or air takes place separately i.e. the steam or air is supplied to the hammer under some pressure. The air valve in the pneumatic hammers is replaced by a steam exhaust valve at the top of the hammer. The steam or air is supplied from both sides of the piston to get both the strokes performed by the pushing action of the compressed steam.

DROP HAMMERS:-

Drop hammers consist of two dies or simply speaking one die made in two halves. The upper half is attached to the tup and the lower half is fastened to the anvil block. The tup carrying upper die is raised to the desired height to get desired height of fall. The metal to be hammered is placed on the lower half of the die. The tup is then allowed to fall freely under gravitation.

ELECTRIC SHOP

TOOLS USED IN ELECTRIC SHOP

Following are the tools which are commonly used in electric workshop :-

1. Knife :- Knife is used for cutting insulation from a wire. The correct method to remove insulation from a wire is to use the knife as in the process of sharpening a pencil.

2. Piler :- Generally three types of pilers are used in the electric workshop, as explained below :-

(i) Flat Nose Piler :- This piler is used for holding a job or cutting wires. It has long slotted jaws are tapered. As its jaw are tapered so it is also used to tighten or loosen small nuts or screws.

(ii) Side cutting Piler :- This type of piler is used for cutting thin wires or strips and removing the insulation from the insulated wires.

(iii) Round Nose Piler or Long Nose Piler :- This type of piler is used to hold or cut wires and strips. Its cutting edge is long and round at the top.

3. Screw Driver :- Screw driver is used to loosen or tighten the screws. It is available in various size generally 40mm to 600mm. It has two parts viz. wooden or plastic handle and the blade. Sometimes voltage garde is also mentioned on some screw drivers.

4. Poker :- It is a pointed tool. It is used for making holes in wood.

5. Tenon Saw :- This tool is the same one as used in the carpentry shop which has been described in the chapter on carpentry shop.

6. Hack Saw :- This is used to cut the metals.

7. Hammer-cum-nail puller :- This type of hammer is also known as a claw hammer. Its one side has hammer head and the other side has a nail pulling arrangement or claw.

8. Mallet :- It is a wooden hammer, either rectangular or circular in shape. It is made of hard wood and is used to give light blows.

9. Hand Drill Machine :- It is used for drilling holes in the wooden boards. It is driven by hand. Pressure is applied with the help of the handle at the end and the bit is rotated by rotating wheel.

10. Machine Drill or Electric Drill Machine :- When the thickness of the board is more and the holes are required in lesser time, electric drill machine are used.

11. Standard Wire Gauge :- This is used for finding the size of wire. This is made of an iron disc with slots in its circumferences.

12. Test Pen :- Test pen is the most common and widely used tool in the electric-workshop. This is used for finding the phase terminal of the supply. It can also be used as a screw drive

SAFETY PRECAUTIONS

Safety Practice

Cause for accident:

Unawareness of danger
Disregard for safety
Negligence
Lack of understanding of proper safety procedures
Untidy condition of workplace
Inadequate light and ventilation
Improper use of tools
Unsafe condition

Safe Attitudes :

Peoples's attitudes govern what they do or fail to do so. In most case where some one has working with unsafe equipment or in an unsafe situtation, somebody has allowed that state of affairs to come about by some thing they have done or failed to do so. Most accident don’t’s just happen, they are caused by people who damage equipment or see it is faulty but don’t’s report it, or leave tools and equipment lying about for other people to trip over.

Lifting and handling Loads:

Types of injury and how to prevent them:

Cuts And abrasions:

- By rough surfaces and jagged edges
- By splinters and sharp or projections.

Crushing of feets or hands: Feet or hands should be positioned so that they cannot be trapped by the load. Timber wedges can be used when raising and lowering heavy loads to ensure that the fingers and hands are not caught and crushed.Safety shoes with steel toe caps will protect the feet.

Strains to muscles and joints:

- Lifting aload which is to heavy.
- Lifting incorrectly.

Preparing to lift:

Beforelifting or handling any load ask yuorself the following questions.

What has to moved ?

where from and where to ?

Will assistance be required ?

The weight, a person can lift will vary according to:

- Age
- physique and
- condition such as health factors.
- kinetic methode of liftng.

Moving heavy equipment:

- Cranes and slings
- Winches
- Machine moving platforms
- Layers and rollers

Electrical safety:

The severity of an electric shock will depend on the level of current which passes through the body and the length of time of contact. Do not delay, act at once. Make sure that electric current has been disconnected.

If the casulty is still in contact with the supply – break the contact either by switching off the power, removing the plug or wrenching the cable free.

Others factors that contribute to the severity of shock are;

- age of persons
- not wearing insulating footwear or wearing wet footwear
- weather condition
- floor is wet or dry
- mains voltage etc.

Effects of electric shock:

The effect of current at very low levels may only be an unpleaent tingling sensation, but this in itself may be sufficient to cause one to lose balance and fall.

At higher levels of current, the person receiving the shock may be thrown off his feet and will experience severe pain, and possibly minors burns at the point of contact.

Electric shock can also cause burning of the skin at the point of contact.

Treatment of electric shock:

Electric burns: A person receiving an electric shock may also sustain burns when the current passes through his body. Do not waste time by applying first aid to the burns until breathing has been restored and the patient can breathe normally

Burns and scalds: burns are very painfull. If a large area of the body is burnt, give no treatment, except to exclude the air.

Severe bleeding: Any wound which is bleeding profusely, especially in the wrist, hand or fingers must be considered serious and must receive professional attention. As immediate first aid measure, presure on the wound itself s the best means of stoping the bleeding and aoiding infection.

- Make the patient lie down and rest

- if possible, raise the injured part above the level of the body
- apply pressure to the wound
- summon assistance.

To control severe bleeding: Squeeze together the sides of the wound. Apply pressure as long as it is necessary to stop the bleeding. When the bleeding has stopped, put a dressing over the wound, and cover it with a pad of soft material.

Large Wound: For abdominal stab wound, such as may be caused by falling on a sharp tool, keep the patient bending over the wound to stop internal bleeding. Apply a cleen pad and bandages firmly in place. If bleeding is very sever apply more than one dressing.

EXPINDITURE DETAILS FOR THE BATCH OF 20 TRAINEES

1 Faculty Charges

Total allocation =7800/- batch

Internal Faculty @Rs 100/hr, for 34 hours =3400/-

Guest faculty @ Rs 250/hr for 18 hrs=4500/-

Honorarium to Institute staff

1	Principal	150/- batch
2	Group Inst	120/- batch
3	Co-oordinator	120/- batch
4	Office Sudpt	80/- batch
5	Clerk	75/- batch
6	Caisher	75/- batch
7	Store Keeper	75/- batch
8	Workshop Attendant	100/- batch
9	sweeper	100/- batch
10	Head office	25/- batch
	Total	900=/-batch

Total Rs 3400+4500+900=Rs 7800/-

2 Charge for use of hardware, tool & equipment

Total Allocation= Rs.6600/- batch

(a) Rs 100/- per traomee will be charged for Non- Reciromg Chargers(For meeting the deficiencies fo tool & equipments)

(b) (b) Rs.150/- per trainee per batch will be charged ro recurining expenditure.(Wear & Tear of tools & equipments or depreciation charges)

(c) c) Rs. 80/- per trainee AV aids charges for using LCD . Projector , OHP computer sound system etc.

3 Course Material

Total allocation = Rs,4500/- batch

i) Rs 150/- trainee will be charged for providing notes prepared by Instructor in the from of booklet.

ii) Rs. 25/- trainee for the statinery provided

iii) Rs. 10/- trainee for the electrical charges.

iv) Rs. 5/- trainee for the Water charges.

v) Rs. 10/- Telephone charges.

Total Rs. 200/- trainee

4 Infrastructure Charges:-

Total allocation =1400/- natch

1 This includes the charges for building furniture & other accessories required for classroom

Rs 70/- per trainee

5 Miscellaneous Charges:-

Total allocation =3200/- natch

Rs 160/- trainee per batch.

This including expenditure incurred of refreshment charges to fuest faculty or any other Visitor, Photo copycharges, Dispensary Charges, Lobrary Charges or any unforeseen charges.

6 Consumable charges

Total allocation =4000 /- batch

Rs. 200 per trainee per batch. These charges are for the material to be provided for training (Theroetical and/or Practical)