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FUNDAMENTALS OF ELELCTRICAL ENGINEERING(FEE) [22212]

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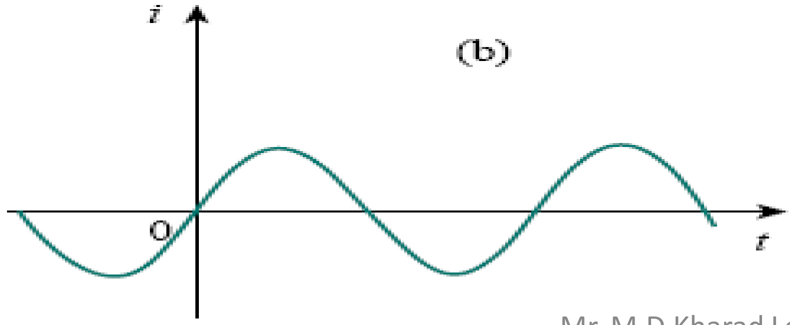
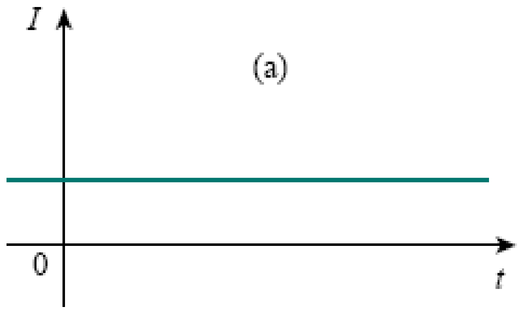
CH.1 BASIC ELECTRICAL PARAMETERS

Contents. (12/70)

- Direct Current (DC),Alternating Current (AC), Voltage Source and Current Source: Ideal and Practical.
- Electric Current, Electric Potential, Potential Difference (P D), Electro- Motive- Force (EMF).
- Electrical Work, Power and Energy.
- Resistance, Resistivity, Conductivity, Effect of Temperature on Resistance.
- Types of Resistor and their Application
- Heating Effect, Magnetic Effect, Chemical Effect of Electric current.

Sr no	**Alternative Current (AC).**	**Direct Current (DC)**
1	signal which changes its magnitude as well as polarity	Signal which does not change its polarity
2	Transformer can used for AC	Transformer cannot use for DC
3	Distribution efficiency is high	Distribution efficiency is low
4	Design of machines is easy	Design of machines is complicated
5	Generation is efficient	Generation is not efficient
6	AC machines, domestic, agricultural and industrial	DC machines, HVDC system, traction system.

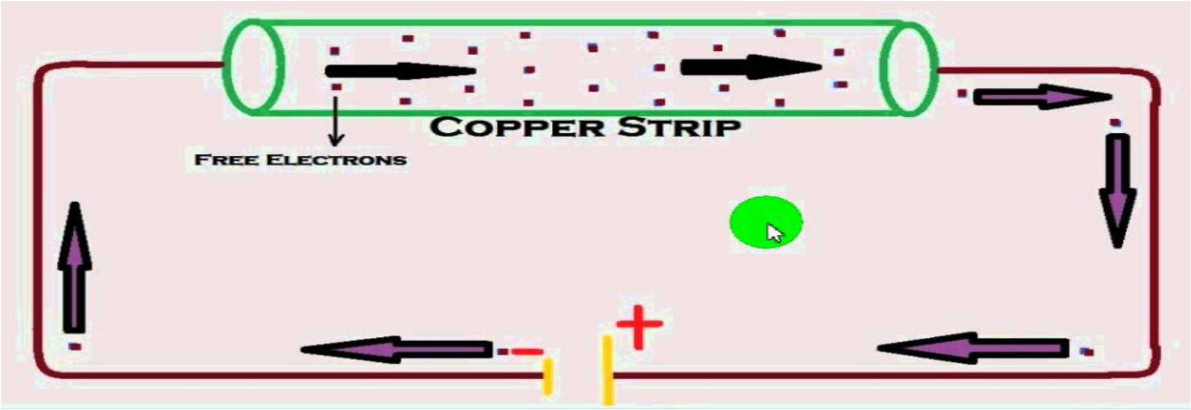




❖ **Electric Current(I)** :*"Current is defined as flow of electrons"*

"It is rate of change of charge with respect to time" $I=Q/t$

Conventional current is the current flowing from a positive potential to a negative potential. Unit: Ampere(A)



❖ **Electro-Motive-Force (EMF):** *"the electrical force which causes the flow of electrons to move in particular direction is called as E.M.F."* unit: Volt

❖ **Potential Difference (P D):** *"Potential difference between any two points is defined as the difference between the electric potentials at those points."* unit: Volt

❖ **Electric Potential/ volt:** *"work done against the force of repulsion to bring a charge closer to the other one is called as electric potential"* unit: Volt

V=W/Q (joules/ coulomb), where v=volt, W= work done, Q= charge

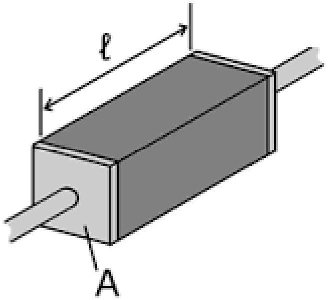
❖ **Resistance(R):** *"Resistance of material is defined as the opposition to flow of current is measured in ohms (Ω)."*

$R = \rho \frac{l}{a}$ Where R= resistance.

ρ=resistivity of material.

l=length of conductor.

a=cross sectional area.



❖ **Resistance depends on the following factors:**

i. Resistance varies directly as length l of material.
ii. Resistance varies inversely as the cross sectional area of conductor.
iii. Resistance depends on resistivity which depends on nature of material.
iv. Resistance also depends on the temperature .

- **Resistivity/ specific resistance($\boldsymbol{\rho}$ rho):** *"The resistivity is defined as the resistance of the piece of that material which is one meter length and unit cross sectional area."*

  $\boldsymbol{\rho = R\frac{a}{l}}$, ρ =R if L=1 m and a= 1 m^2.

  Unit: $\rho = \frac{\Omega m^2}{m}$ = Ω-m(ohm-meter)

- **Conductivity(G):** *"The conductance is defined as the reciprocal of resistance"* Unit: siemens or Ω-1(ohm inverse)

  G=1/R

- **Conductivity:** *" conductivity is defined as the reciprocal of resistivity"* Unit: siemens/ meter or Ω-m -1(ohm-meter inverse)

- **Electrical Work(W):** *"electric work is work done to transfer a charge from one point to other."* Unit: Joules

  W=Q*V where v=volt, W= work done, Q= charge

  (where Q=I*t)

  W=V*I*t Joules

- **Power(P):** *"It is the product of voltage and current"* Unit: Watts

  $P = V*I$ $\quad$ $P=V^2/R$ $\quad$ $P=I^2R$

- **Energy:** *"electrical energy is defined as the product of power and time"* Unit: Joules

- Energy(E)= power(P) * time(t)
- E= V*I*t

  It is ability of work done

A device stores 500J and releases in the form of current of 40A in the duration of 15 msec. Find the terminal voltage.

Ans:

Energy stored $E = VIt$

$$V = \frac{E}{It} = \frac{500}{40 \times 15 \times 10^{-3}} = 833.33V$$

Ex. 1.6.1 : Calculate the resistance of 100 m length of wire having a uniform cross sectional area of 0.01 mm^2 and having resistivity of 50 micro-ohm-cm. **W-08, 4 Marks**

Soln. :

Given : $l = 100$ m, $a = 0.01\ mm^2$, $\rho = 50\ \mu\Omega$-cm.

$$\therefore \quad R = \rho \frac{l}{a}$$

$$= 50 \times 10^{-6} \times 10^{-2} \times \frac{100}{0.01 \times 10^{-6}}$$

$$\therefore \quad R = 5000\ \Omega \quad \text{...Ans.}$$

Ex. 1.6.2 : Find the resistance of the following annealed copper wires :

1. 1 mm^2 cross-section, 100 m long.
2. 25 cm^2 cross-section, 200 m long.

Given that ρ is 1.73 micro ohm-cm.

Soln. :

1. $$R = 1.73 \times 10^{-6} \times \frac{100 \times 10^2}{1 \times 10^{-2}} = 1.73\ \Omega$$

2. $$R = 1.73 \times 10^{-6} \times \frac{200 \times 10^2}{25} = 0.001384\ \Omega$$

Ex. 1.6.3 : The length of wire has a resistance of 6Ω. Find the resistance of another wire of same material three times as long and twice the cross sectional area. **W-10, 4 Marks**

Soln. :

Given : Wire has a length l, cross section area a, resistivity ρ and resistance $R_1 = 6\ \Omega$.

Find : Resistance of another wire with same resistivity ρ, Length = $3l$, Area = 2a i.e. find R_2

Step 1 : Find $\rho \frac{l}{a}$:

$$R_1 = \rho \frac{l}{a} = 6\ \Omega \quad \text{...Ans.}$$

Step 2 : Find R_2 :

$$R_2 = \rho \times \frac{3l}{2a} = \frac{3}{2}\left[\rho \frac{l}{a}\right]$$

$$= \frac{3}{2} R_1 = \frac{3}{2} \times 6 = 9\ \Omega \quad \text{...Ans.}$$

Ex. 1.6.4 : Calculate the resistance of a 100m length of wire having a uniform cross sectional area of 0.01 mm^2 and having a resistivity of 50 micro-ohm-cm. If the wire is drawn out to three times its original length, calculate the resistance. **W-11, 4 Marks**

Soln. :

Part I : Find resistance R

Given : $l = 100 \text{ m}, \ a = 0.01 \text{ mm}^2 = 0.01 \times 10^{-6} \text{ m}^2,$

$$\rho = 50 \ \mu\Omega\text{-cm} = 50 \times 10^{-6} \times 10^{-2} = 50 \times 10^{-8} \ \Omega\text{-m}$$

$$\therefore \quad R = \rho \frac{l}{a} = 50 \times 10^{-8} \times \frac{100}{0.01 \times 10^{-6}} = 5000 \ \Omega$$

...Ans.

Part II : Find the new resistance R′

Given : $l' = 3l = 300 \text{ m}$ ρ and a remain same

$$\therefore \quad R' = \rho \times \frac{l'}{a} = \rho \times \frac{3l}{a} = 3R = 3 \times 5000$$

$$\therefore \quad R' = 15 \text{ k}\Omega$$

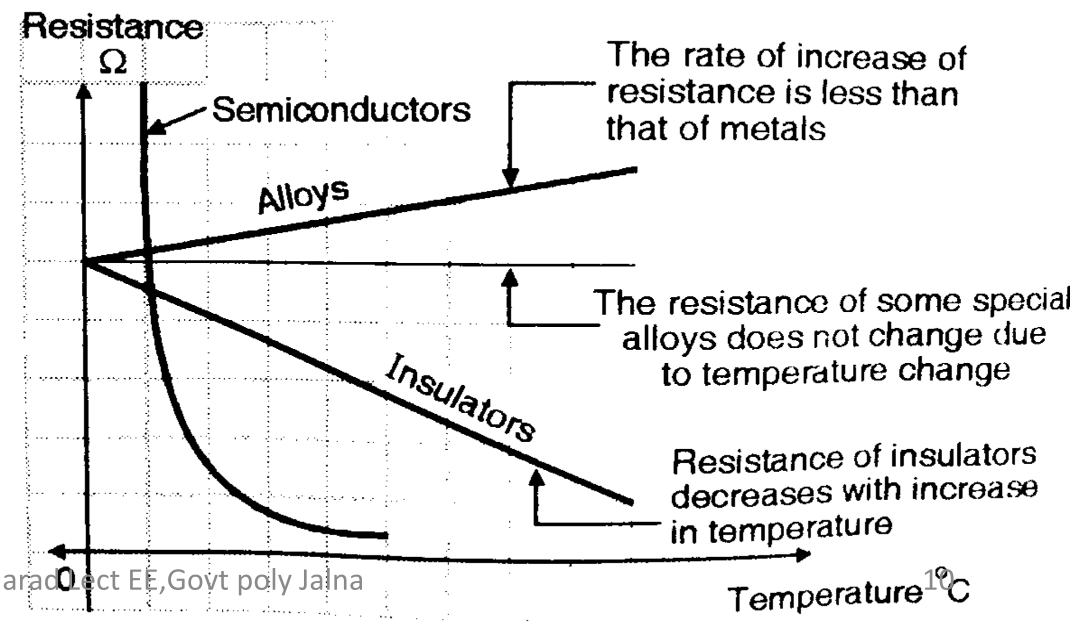
...Ans.

❖ Effect of Temperature on Resistance:

The effect of temperature on resistance varies according to the type of material as discussed below:

- **Conductors :** Resistance increases linearly with increase in temperature, resistance of metals reduces with reduction in temperature because at low temperature ions inside the conductors are stationery with increasing in temperature ions acquire energy and start oscillating therefore vibrating ions cause opposition to the flow of electrons.
- **Insulators:** Resistance of insulators decreases with increase in temperature. Material act as perfect insulators at low temperature may start conducting at higher temperature.
- **Semiconductors:**

  Resistance decrease with increase in temperature.



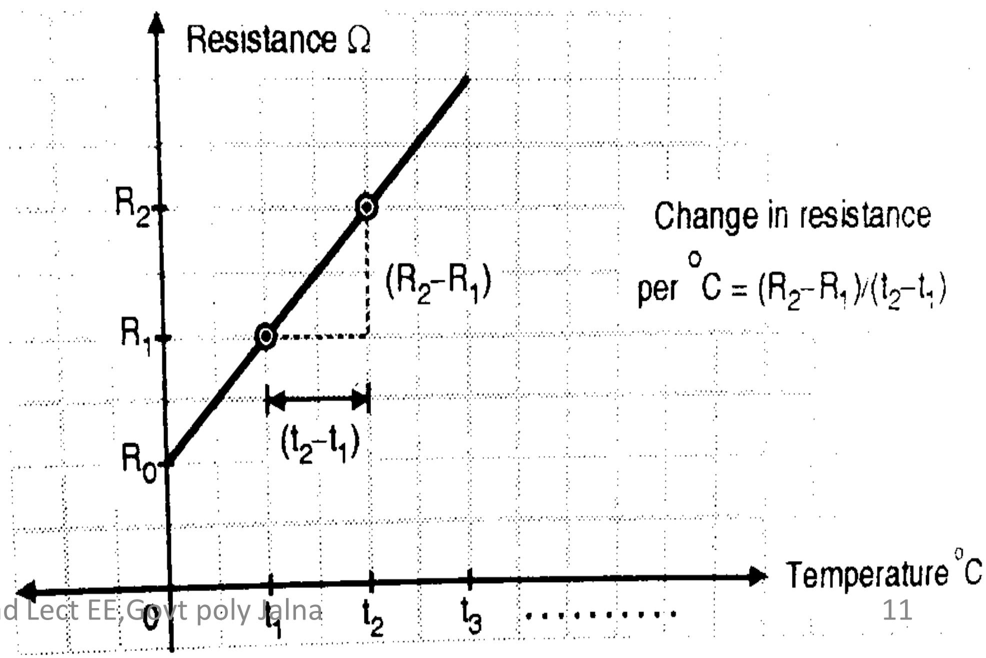
❖ Resistance Temperature Coefficient (RTC):

- *"RTC at t° c is defined as the ratio of change in resistance of the material per degree Celsius to its resistance at t⁰c."*
- RTC at t^0c ($\propto t$)=$\frac{\Delta R/°C}{Rt}$
- $\therefore\ \Delta R\ = change\ in\ resistance, Rt\ = resistance\ at\ t°C.$
- RTC at 0°C.($\alpha 0$)=$\frac{\Delta R/°C}{R0}$

Change in resistance Per ^{0}c (slope) = $\frac{(R2-R1)}{(t2-t1)}$

$\therefore \propto t\ = \frac{((R2-R1)/(t2-t1))}{Rt}$ $\quad \therefore \therefore \propto 0\ = \frac{((Rt-R0)/(t))}{R0}$

- $Rt\ =R_0(1+\propto 0t)$



- Unit of RTC=/°C
 (per degree Celsius)

Effect of RTC:

- RTC is positive→ $conductor$
- RTC is negative→insulator.

Ex. 1.8.2 : A coil has a resistance of 200 Ω at 20°C. Find its resistance at 0°C. Take $\alpha_0 = 0.004/°C$. Find its resistance at 50°C. **W-07, 4 Marks**

Soln. :

Given : $R_{20} = 200\ \Omega$, $T_1 = 20°C$, $\alpha_0 = 0.004/°C$

To find : R_0 and R_{50}.

Step 1 : Find R_0 :

$$R_{20} = R_0 [1 + \alpha_0 \Delta T)]$$

$$R_{20} = R_0 [1 + \alpha_0 (T_1 - 0)]$$

$$\therefore\ 200 = R_0 [1 + (0.004 \times 20)]$$

$$\therefore\ R_0 = 185.19\ \Omega$$ ...Ans.

Step 2 : Find R_{50} :

$$R_{50} = R_0 [1 + (\alpha_0 \times 50)]$$

$$= 185.19 [1 + 0.004 \times 50]$$

$$R_{50} = 222.22\ \Omega$$ ...Ans.

Ex. 1.8.3 : The resistance of copper coil increases from 80 Ω at 10°C to 98.8 Ω at 62°C. Find the temperature coefficient of material at 0°C. **S-08, S-14, 4 Marks**

Soln. :

Given : $R_1 = 80\ \Omega$, $T_1 = 10°C$, $R_2 = 98.8\ \Omega$, $T_2 = 62°C$.

To find : α_0.

The R.T.C. at zero degree Celsius is defined as

$$\alpha_0 = \frac{\text{Slope of the characteristics}}{\text{Resistance at } 0°C}$$

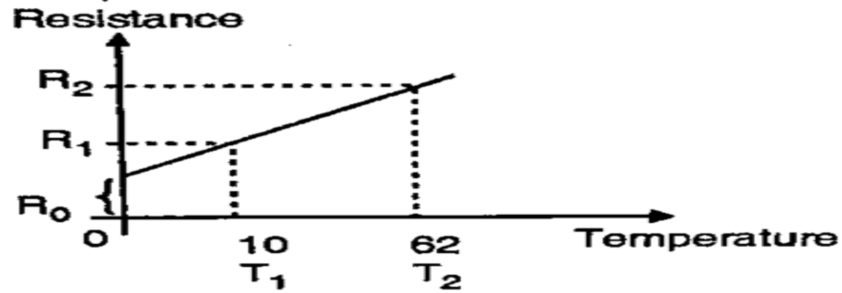
$$\therefore\ \alpha_0 = \frac{\text{Slope}}{R_0}$$

$$\text{Slope} = \frac{R_2 - R_1}{T_2 - T_1} = \frac{98.8 - 80}{62 - 10} = 0.3615\ \Omega/°C$$

$$\text{Also slope} = \frac{R_1 - R_0}{T_1 - 0}$$

$$\therefore\ 0.3615 = \frac{80 - R_0}{10}$$

$$\therefore\ R_0 = 76.38\ \Omega$$



(A-2714) **Fig. P. 1.8.3**

$$\therefore \alpha_0 = \frac{0.3615\ \Omega/°C}{76.38\ \Omega}$$

$$= 4.7326 \times 10^{-3} / °C \quad \text{...Ans.}$$

Ex. 1.8.4 : A certain winding has resistance of 16.5 Ω at 20°C and 18 Ω at 55°C calculate :

1. Temperature co-efficient at 0°C and
2. Resistance at 0°C

S-09, S-13, 4 Marks

Soln. :

Given : $R_{20} = 16.5\ \Omega$, $R_{55} = 18\ \Omega$

Step 1 : Calculate α_{20} :

We know that,

$$R_2 = R_1 (1 + \alpha_1 \Delta t)$$

$$\therefore R_{55} = R_{20} [1 + \alpha_{20} (55 - 20)]$$

$$\therefore 18 = 16.5 [1 + (\alpha_{20} \times 35)]$$

$$\therefore \alpha_{20} = 2.6 \times 10^{-3} / °C$$

Step 2 : Calculate α_0 :

$$\alpha_2 = \frac{\alpha_1}{1 + \alpha_1 (t_2 - t_1)}$$

$$\therefore \alpha_{20} = \frac{\alpha_0}{1 + \alpha_0 (20 - 0)}$$

$$\therefore 2.6 \times 10^{-3} = \frac{\alpha_0}{1 + 20\alpha_0}$$

$$\therefore 2.6 \times 10^{-3} + 0.052\,\alpha_0 = \alpha_0$$

$$\therefore \alpha_0 = 2.74 \times 10^{-3} \quad \text{...Ans.}$$

Step 3 : Find R_0 :

$$\alpha_0 = \frac{(R_2 - R_1) / t_2 - t_1}{R_0}$$

$$\therefore \alpha_0 = \frac{(R_{55} - R_{20}) / (55 - 20)}{R_0}$$

$$\therefore 2.74 \times 10^{-3} = \frac{(18 - 16.5)}{35\,R_0}$$

$$\therefore R_0 = 15.63\ \Omega \quad \text{...Ans.}$$

Ex. 1.8.5 : The resistance of a coil at room temperature 25°C is 10 Ω. Calculate it's resistance when the coil temperature rises to 75°C. Given that the temperature of coefficient of material of the coil is 0.004/ °C. **S-10, 2 Marks**

Soln. :

Given : $R_{25} = 10\ \Omega$, $T_1 = 25^\circ C$, $\alpha = 0.004/^\circ C$

To find : R_{75}

Step 1 : Find R_0 :

$$R_{25} = R_0 [1 + \alpha_0 (T_1 - 0)]$$

$$10 = R_0 [1 + (0.004 \times 25)]$$

$$10 = R_0 [1.1]$$

$$\therefore \quad R_0 = 9.09\ \Omega$$ ...Ans.

Step 2 : Find R_{75} :

$$R_{75} = R_0 [1 + (\alpha_0 \times 75)]$$

$$= 9.09 [1 + 0.004 \times 75]$$

$$= 11.817\ \Omega$$ ...Ans.

Ex. 1.8.6 : A platinum coil has a resistance of 3.146 Ω at 40°C and 3.767 Ω at 100°C. Find the resistance at 0°C. **W-11, 4 Marks**

Soln. :

Given : $R_{40°} = 3.146\ \Omega,\ R_{100°} = 3.767\ \Omega$

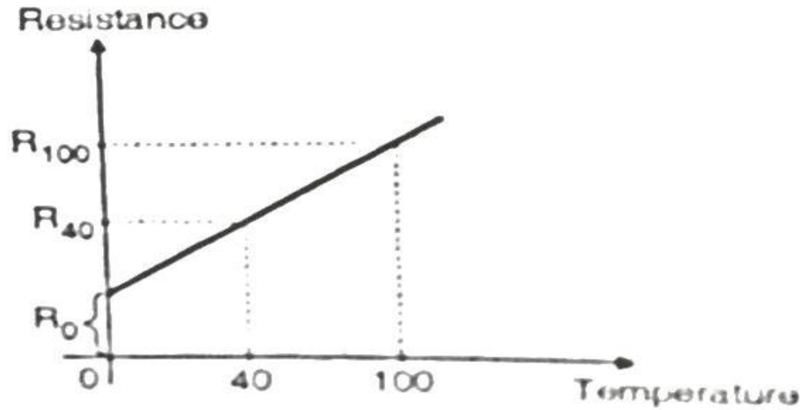
To find : R_0

The slope of the temperature versus resistance characteristics of Fig. P. 1.8.6 is

$$\text{Slope} = \frac{R_{100°} - R_{40°}}{100° - 40°} = \frac{3.767 - 3.146}{60}$$

$$= 0.01035\ \Omega/°C$$

$$\text{Also slope} = \frac{R_{40} - R_0}{40 - 0}$$



(A-2714(a)) Fig. P. 1.8.6

$$\therefore \quad 0.01035 = \frac{3.146 - R_0}{40}$$

$$\therefore \quad R_0 = 2.732\ \Omega$$

...Ans.

ILLUSTRATIVE EXAMPLES

Example 1 : The resistance of a copper wire of length 2 metre is 0.2 *ohms*. The diameter of the wire is 0.045 cm. Find its specific resistance.

Solution :

Resistance of the wire $R = 0.2\ \Omega$

length of the wire, $l = 2$ m

Diameter of the wire, $d = 0.045$ cm

$$= 45 \times 10^{-5} m$$

Area of cross section,

$$a = \frac{\pi}{4} d^2$$

$$= \frac{\pi}{4}(45 \times 10^{-5})^2$$

$$= 1591 \times 10^{-10}\ M^2$$

Resistnace of the wire, $R = \rho \dfrac{l}{a}$

$$\rho = \frac{R\,a}{l}$$

$$= \frac{0.2 \times 1591 \times 10^{-10}}{2}$$

$$= 1590 \times 10^{-10}\ \Omega - m. \text{ (Ans)}$$

Example 2: Two wires of the same material are equal in length and their resistances are 100 and 400 Ωs respectively. find the ratio of their diameters.

Solution: As the material is same, their resistivity must be same. Given that,

$$R_1 = 100 \ \Omega, l_1 = 12 \ \text{m}, \quad R_2 = 400 \ \Omega$$

We have $$R_1 = \rho \frac{l_1}{a_1}$$

and $$R_2 = \rho \frac{l_2}{a_2}$$

$$\frac{R_1}{R_2} = \frac{a_2}{a_1}\left(\frac{l_1}{l_2}\right) = \frac{a_2}{a_1} \qquad (\because \ l_1 = l_2)$$

$$\frac{R_1}{R_2} = \frac{\frac{\pi}{4} d_2^2}{\frac{\pi}{4} d_1^2} = \left(\frac{d_2}{d_1}\right)^2$$

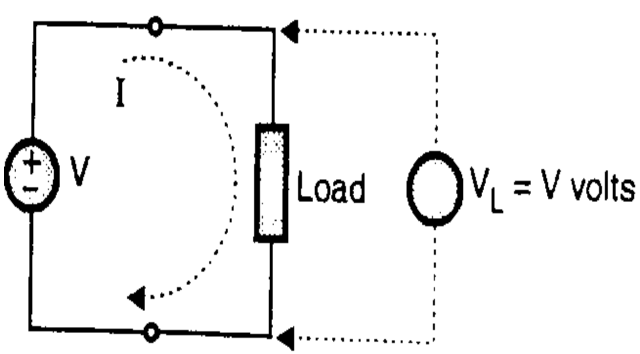
$$\frac{100}{400} = \left(\frac{d_2}{d_1}\right)^2$$

$$\therefore \quad \frac{d_2}{d_1} = \frac{1}{2} \text{ or } d_1 = 2d_2 \qquad \text{(Ans)}$$

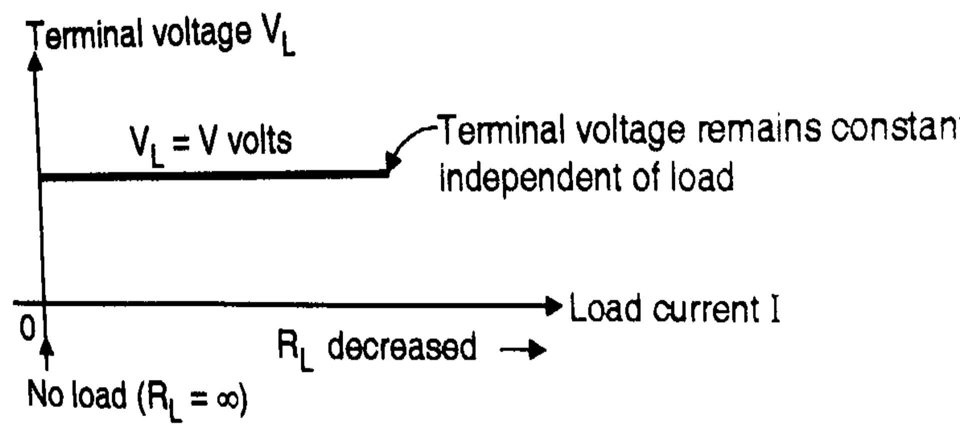
Voltage Source:

Ideal voltage sources:

- Internal Source resistance of ideal voltage source is zero, therefore terminal voltage remain constant equal to V volt without load or with load.
- As load resistance decrease, load current increases and terminal voltage is constant.
- Ideal voltage source does not exist



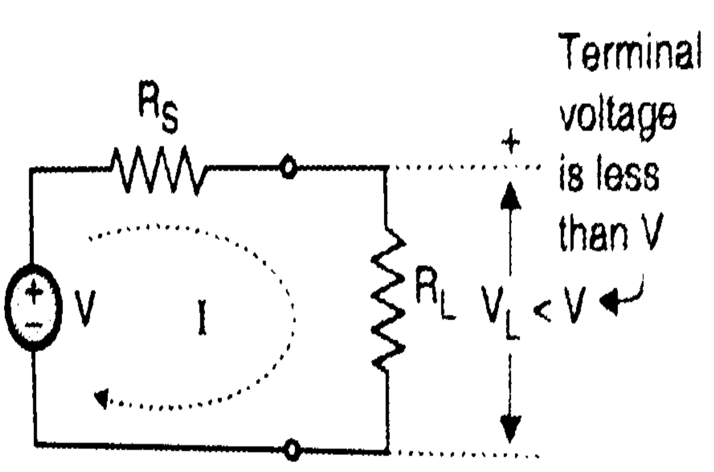
(c) Terminal voltage V_L = V Volts



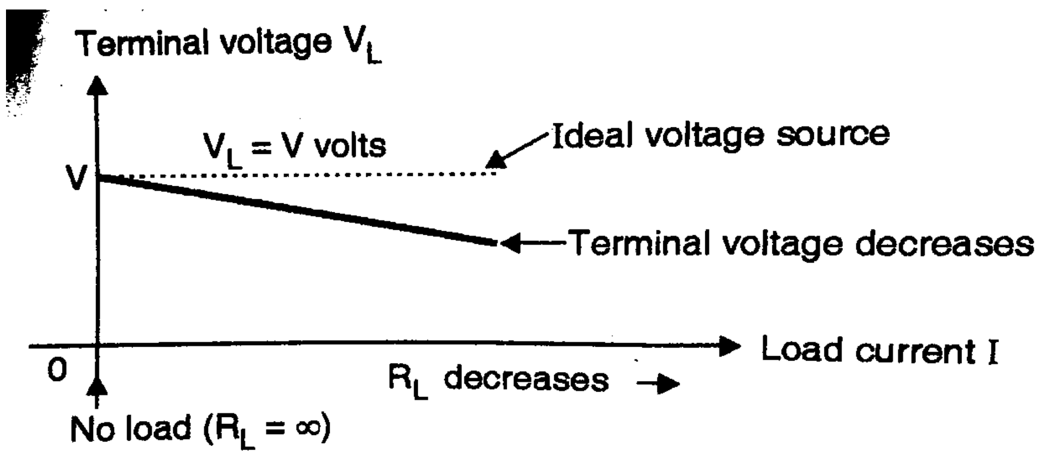
(A-73(a)) Fig. 1.10.2 : Terminal voltage of an ideal voltage source

❖ Practical voltage sources:

- It has internal source resistance Rs
- In no load condition current is zero therefore there is no voltage drop across internal source resistance. Therefore VL=V, at no load.
- In load condition as current flowing in circuit, some voltage drop across internal source resistance. Therefore terminal voltage is less than V, As load resistance decreases, so load current increases then terminal voltage getting decrease



(c) Terminal voltage with load

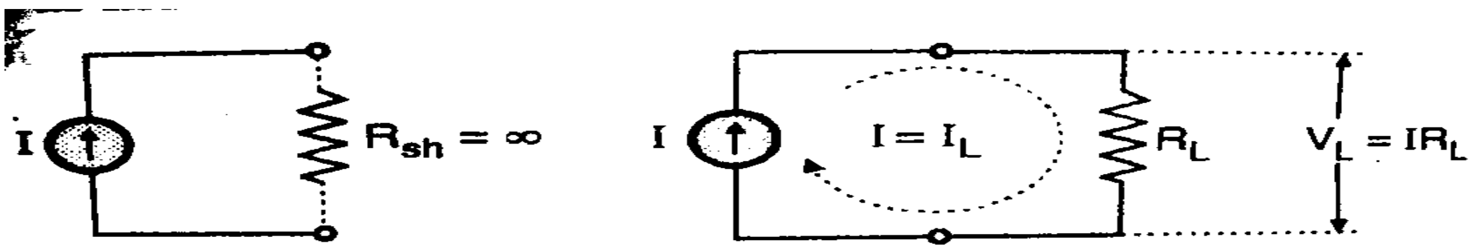


(A-75(a)) Fig. 1.10.4 : Variation of terminal voltage with change in load current

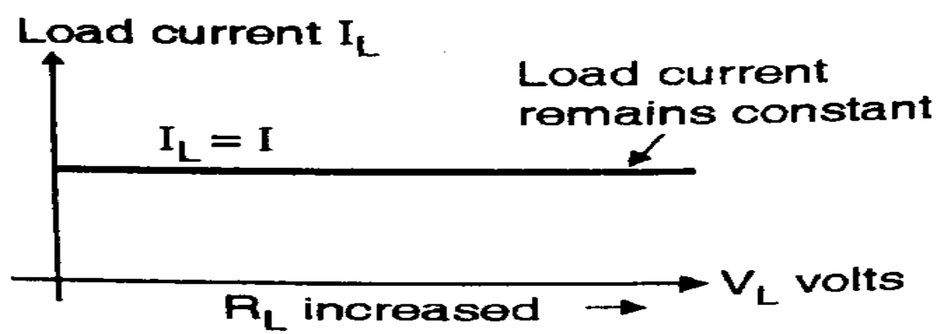
❖ Current Sources:

❖ Ideal current sources:

- Internal shunt resistance is infinite (Rsh=infinite means Ish=0)for the ideal current source.
- When the load resistance is connected between the output terminals a constant current flowing through the load, IL=I.
- As load resistance increases load current remains constant.



(a) Symbol (b) Operation with load connected

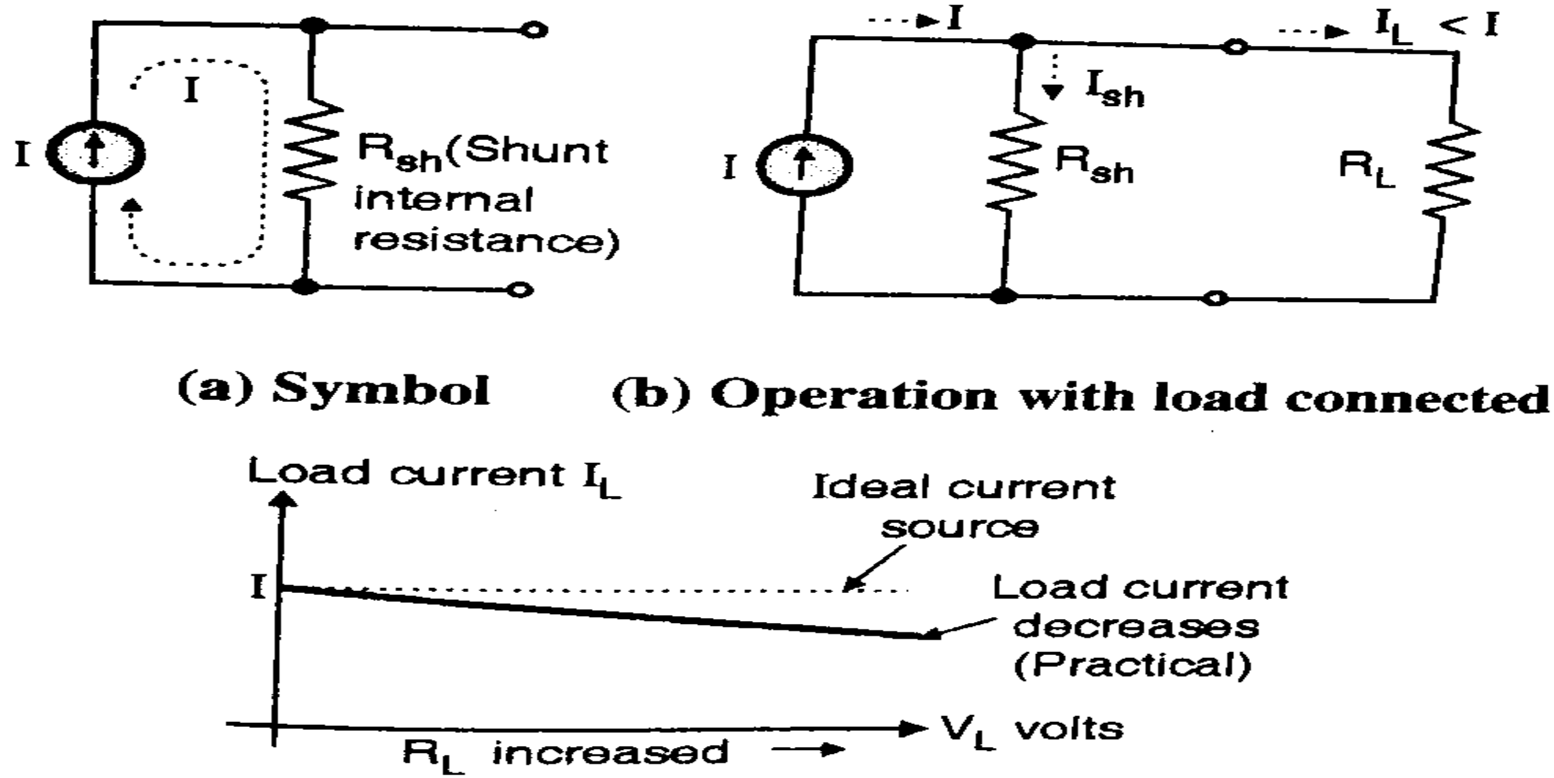


(c) Load current remains constant

(A-76) Fig. 1.10.5 : Ideal current source

❖ Practical current sources:

- It has finite internal shunt (parallel)resistance.
- Due to the presence of shunt internal resistance , the source current I gets divided between shunt resistance and load resistance. Hence load current is less than I. As load resistance increases load current decreases



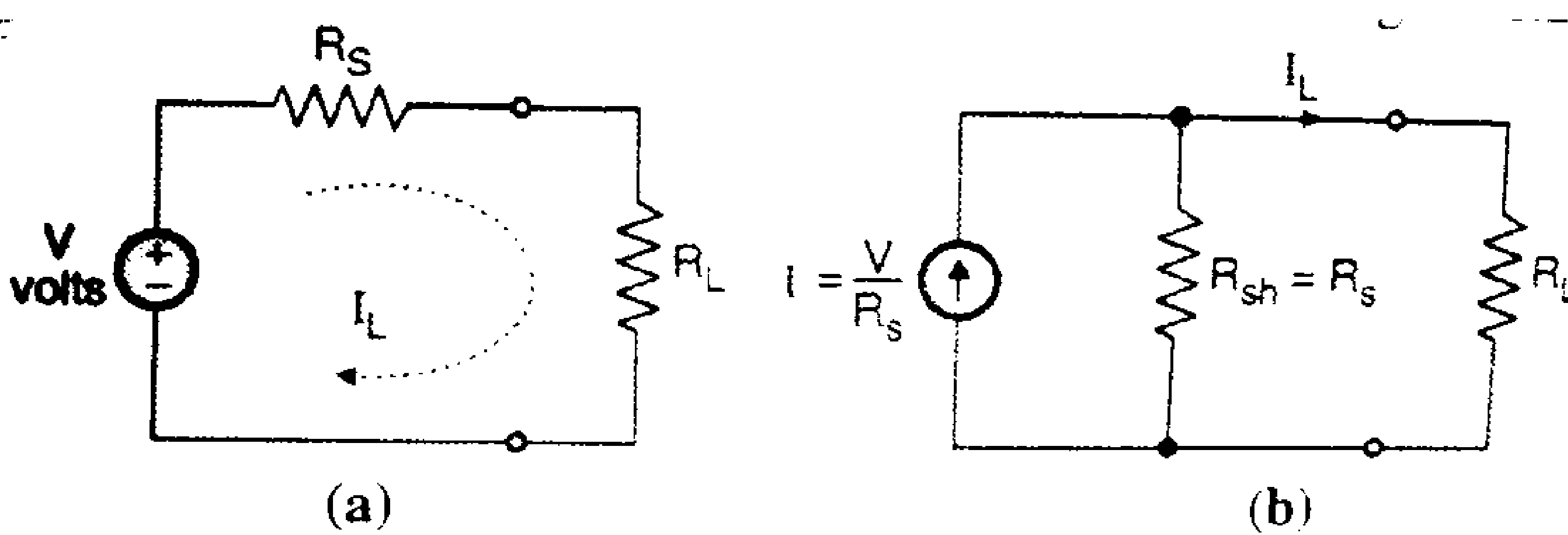
(a) Symbol (b) Operation with load connected

(c) Variation of load current with change in load

(A-77) Fig. 1.10.6 : Practical current source

❖ Source transformation

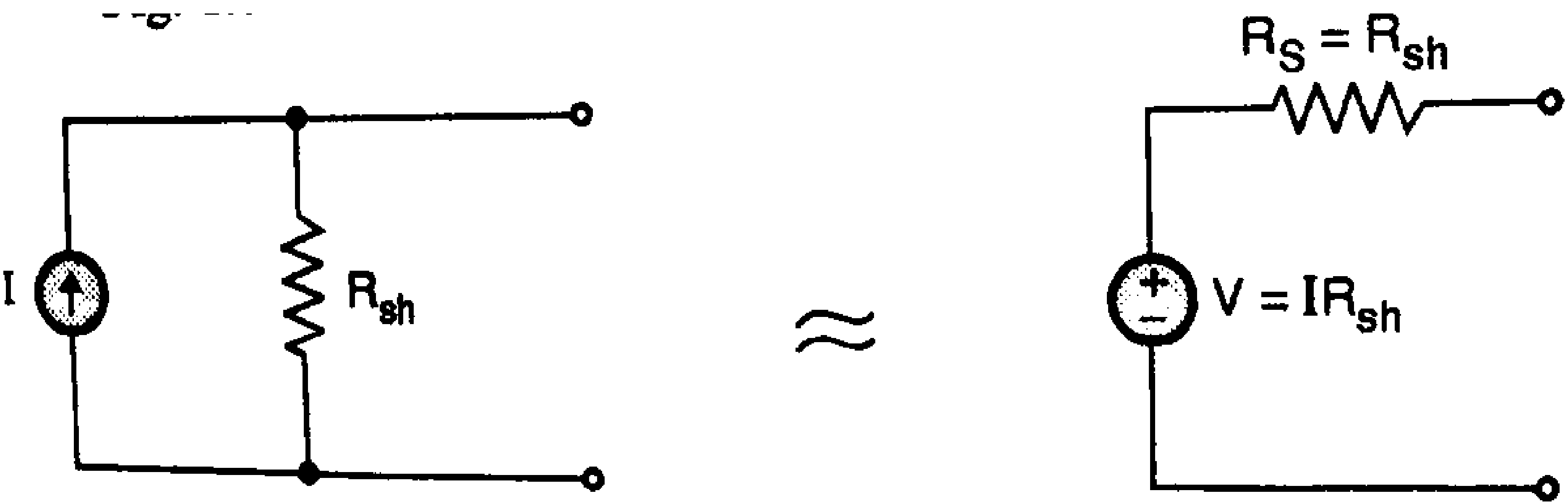
Voltage source to current source transformation:



(A-134) **Fig. 1.11.2 : Voltage source transformed into current source**

❖ Source transformation

Current source to voltage source transformation:



(a) Current source (b) Equivalent voltage source

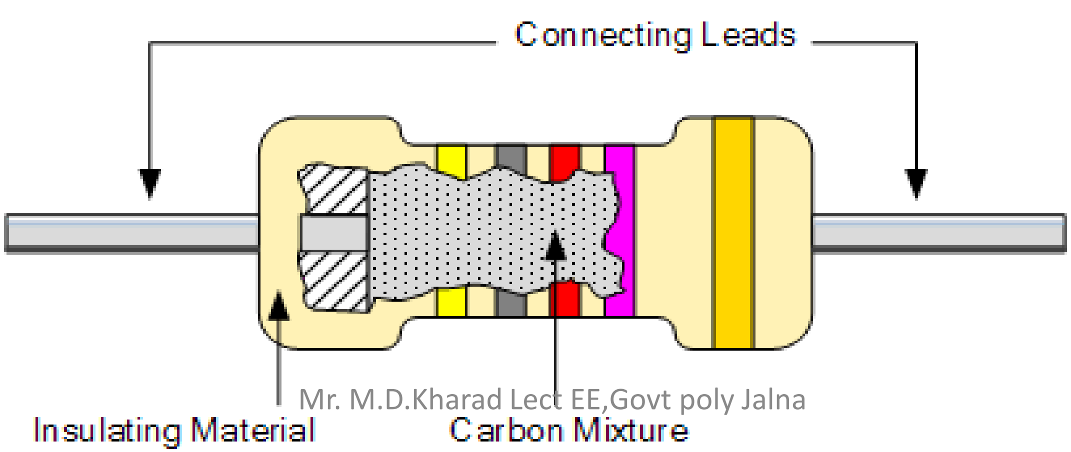
(A-135) Fig. 1.11.3 : Current source transformed into voltage source

Types of Resistor

- Linear resistors
  - Fixed resistors
    - Carbon composition
    - Wire wound
    - Film type
  - Variable resistors
    - Potentiometer
    - Trimmers
    - Rheostates
- Non linear resistors
  - Thermistors
  - Light dependent resistors
  - Varistors

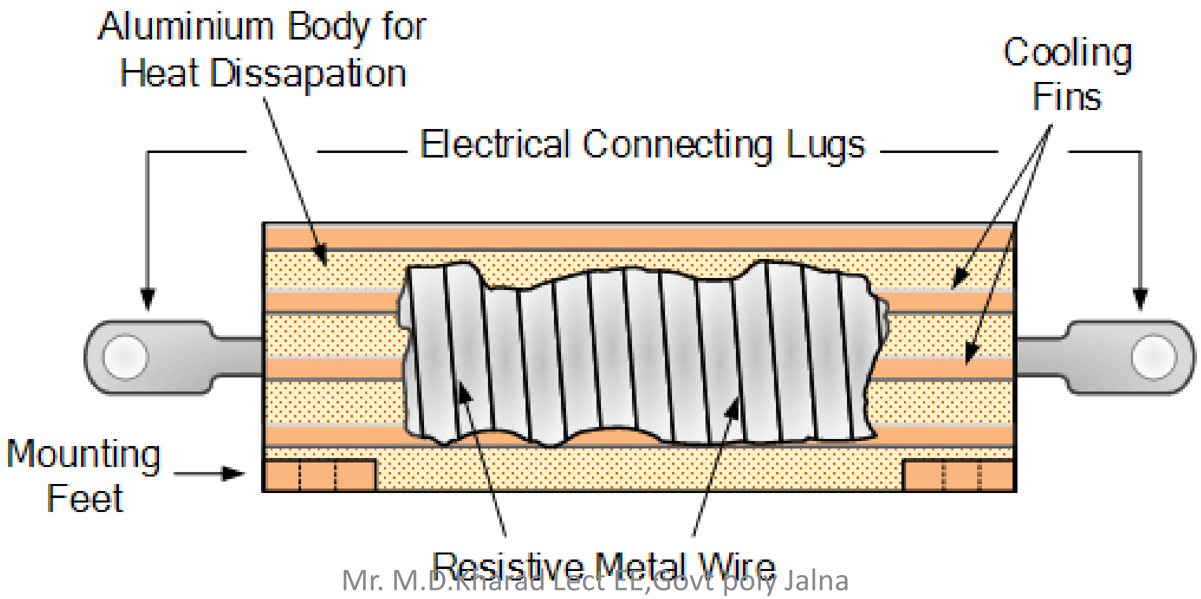
❖ Carbon composition resistor:

- This resistance manufactured with insulated and noninsulated form where noninsulated provides better heat dissipation.
- Carbon black, resin blinder, refractory fillings are first graded and mixed in proper proportion and shifted then resultant black powder compressed in to the shape of resistor and then curved in solid unit.
- Tolerance +- 5%, +- 10% or 20% so actual value differs from printed value. Available in power rating 0.2,0.5,1,2W
- Wide temp. range -55degC to 150degC, Capable for operating 800V
- **Application:** potential divider, in transistor, amplifier, radio, TV, High frequency, low power.



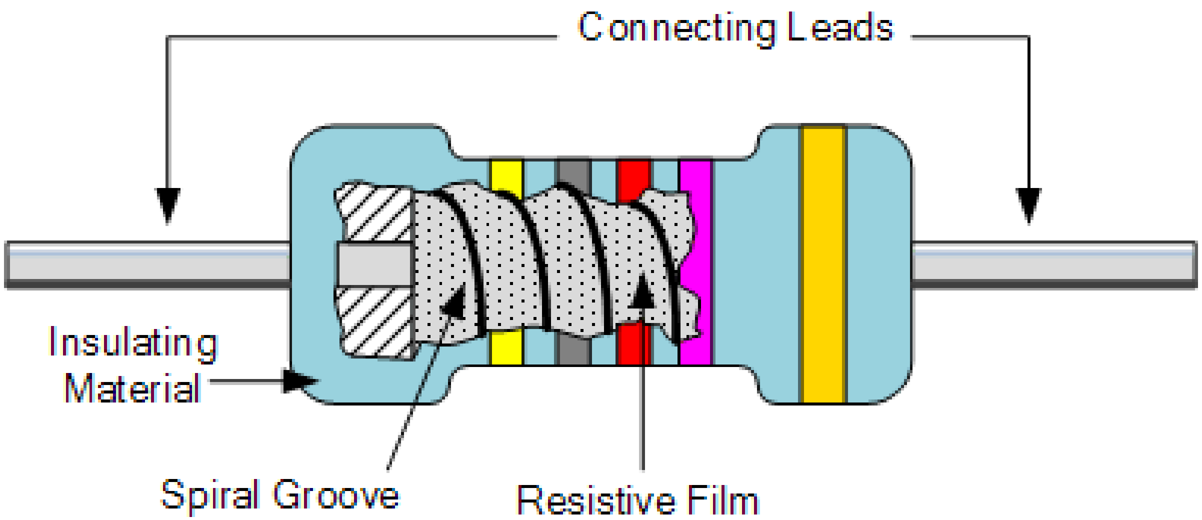
❖ Wire wound resistors:

- Power handling capacity is higher
- Resistance wire wound on a ceramic rod or tube
- End connection wires are welded to ends of windings.
- Due to wound wire it has large inductance, hence not used in high frequency applications.
- **Applications:** low frequency high power, Radio, TV, power Amplifier, Zener voltage regulator.



❖ Film type:

- Film type resistors are classified as two types
- Carbon film resistor and Metal film resistor.
- Manufacturing consists of thin film of resistive material such as carbon, metal or metal oxide film.
- Film is deposited on glass or ceramic rod using evaporation, spraying or dipping. thickness is depends on desired value. end caps are fitted in the end after spiraling process is completed.
- **Application:** medical instruments, instrumental applications.

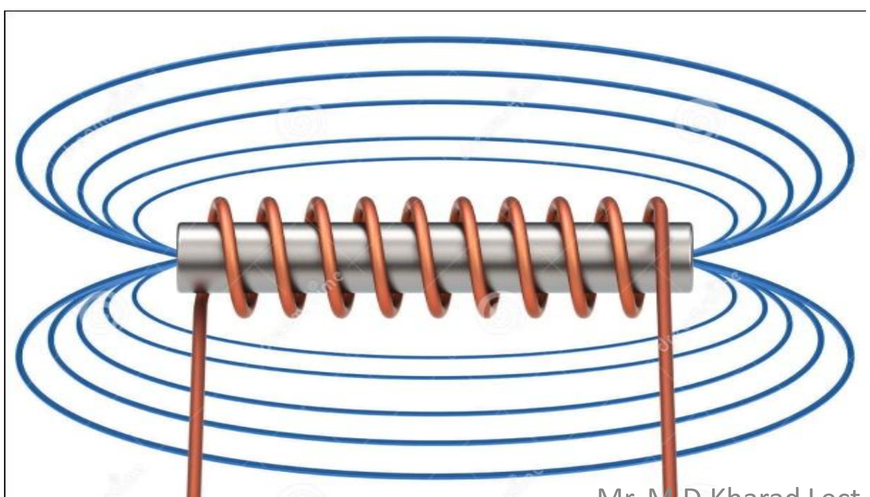


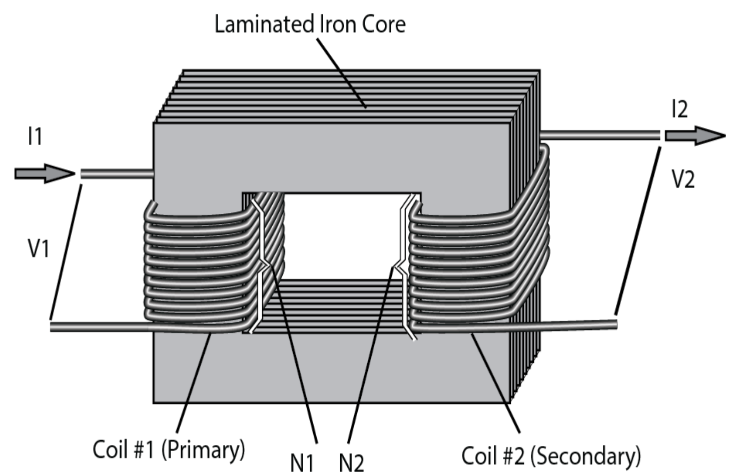
❖ Heating Effect of Electric current:

- When electric current flowing through a conductor, heat is produced in it due to collision between moving electrons and stationary atoms. Hence electrical energy is converted in to heat energy. Consider conductor of R ohm and potential difference V and I current flows for t seconds then work done
- W= V*i*t joules = i*R*i*t = i^{2*}R*t joules
- Heat produced in the conductor is directly proportional to the square of the current and time for which current flows
- **Heating effect application:** It is utilized in Electric iron, Water heater, Hot plates, Electric lamp, Electric cooker, Hair dryer, Room heater, Electric oven, Electric furnace, Electric fuse, Electric heat treatment process etc.

❖ Magnetic Effect of Electric current:

- Whenever electric current passing through a conductor or coil, a magnetic field get developed across it, and coil starts acting as electromagnet.
- The coil is wound on piece of some magnetic material such as iron, then and current flowing from coil the this piece acts as magnet.
- Electromagnet losses its magnetic property as soon as current becomes zero.
- **Magnetic effect applications :** It is utilized in Electric motor, Electric bell, Electromagnet, Measuring instrument, Alternator, Various electric appliances, Electric hoist etc.





❖ Chemical Effect of Electric current:

- Whenever the DC current is passing through a chemical solution, the solution decomposed in to the constituent substances. This process is chemical effect of electric current.
- Electrolytes: electrolytes are the liquids which allows the electric current to pass through them.
- Ionization: it is the process of splitting up of the molecular in to positive and negative ions.
- **Chemical effect applications:** It is utilized in Electro-plating, Battery charging, Electro-refining, Fuel cells, Production of chemicals, Electro-typing, Electrolytic process etc.

1) Define resistance. Also write down its formula.
2) In a circuit containing resistance of 60 Ω connected across a voltage sources of 20 V and current is allowed to pass for 50 sec. Calculate: (i) Work done in Joules (ii) Heat energy produced in kcal .
3) A coil has resistance of 3.146 Ω at temperature of 40degC and 3.767 at 100degC. Find resistance of coil at 0degC and temperature coefficient of resistance at 40degC.
4) Convert given voltage source of Fig. no. 3 into equivalent current source and given current source of Fig. no. 4 into equivalent voltage source.

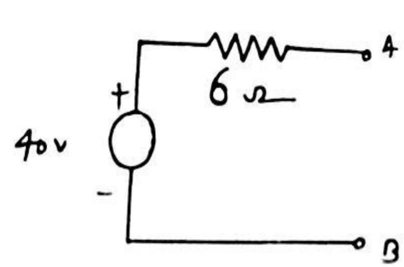


Fig. No. 3

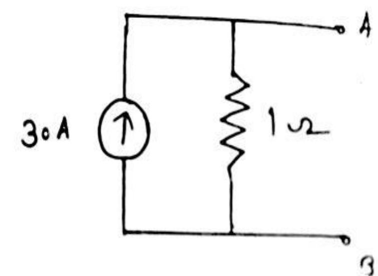


Fig. No. 4

5) Compare alternating and direct current.
6) Define emf and resistance.
7) State the different types of resistors.
8) State the concept of internal voltage drop.
9) State the following effects of currents: (i) Heating effect, (ii) Magnetic effect.
10) The field coil of a generator has 14.1 ohm at 25degC and 18.2ohm at 32degC. Find the temperature coefficient of resistance at 0degC and resistance at 0degC.

Assignment-1

11) Define Ideal voltage source and Practical voltage source. Draw it's symbol and characteristics.
12) Write any four application of heating effect of electric current.
13) List four types of resistors. Give one application of each.
14) Draw circuit for ideal and practical voltage source. Convert a 20 V voltage source with 2.5 ohm internal resistance into equivalent current source.
15) A field winding has resistance of 220 ohm at 25(i) 0O C (ii) 50 OC. take αo = 0.004per degree Celsius
16) What is terminal voltage explain in brief.
17) Define potential difference and give its unit.
18) Define temperature coefficient of resistance. State its unit.
19) How to convert practical voltage source to practical current source. Draw equivalent current source for given circuit.
20) State the laws of resistance and derive unit of resistivity.