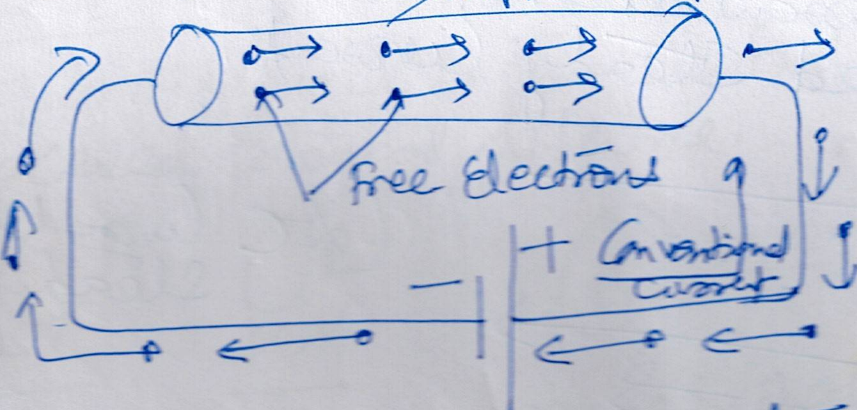
Unit - I

DC Circuits

Passive Circuit Components
R, L, C

Electrical Current.

The directed flow of free electrons (or charge) is called as electrical current. The Cu strip has large no of free electrons



When electric pressure or voltage is applied, free electrons being negatively charged will start moving towards positive terminal of the circuit. This directed flow of electrons is called electric current.

(1) Actual Direction of Current is from −ve terminal to positive terminal.

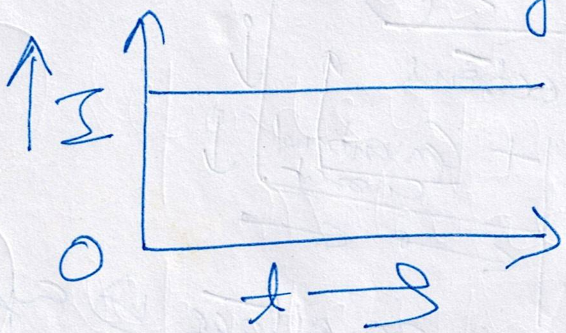
Before Electron theory, it was assumed that current flow from positive terminal of the ckt to −ve terminal of the ckt; This assumed direction is called Conventional Current.

Types of Current

(1) Steady Current (2) Varying Current
(3) Alternating Current

(1) Steady Current :-

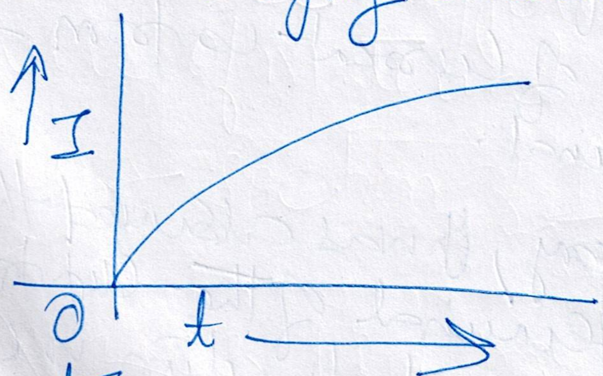
when magnitude of the current does not change with time. it is called Steady Current.



(DC Current)
Steady current

(2) Varying Current

Magnitude of current changes with time. It is called Varying current.



Inverter
Rectifier

(3) Alternating current

Whose magnitude continuously changes with time and direction changes periodically.

~~Technique~~

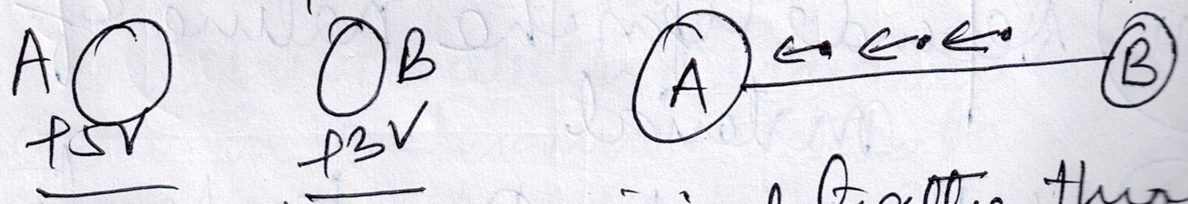
Electric Potential (V)

When a body is charged, work is done in charging it. This work is stored in form of potential Energy. The ability of the charged body to do work is called electric potential.

The capacity of a charged body to do work is called its Electric potential.

Potential Difference

The difference in the potentials of two charged bodies is called potential difference.



If two bodies are joined together through a conductor, electrons will flow from body B to body A till the same potential is attained.

Emf maintains potential difference while p.d causes current to flow.

Resistance

The opposition offered by a substance to the flow of electric current is called its resistance. A wire is said to have a resistance of 1 ohm if a p.d of 1 Volt across its ends causes 1 Amp to flow through it.

Factors upon the Resistance

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

(I) $R \propto l$ Directly proportional to its length

(II) $R \propto \frac{1}{a}$ Inversibly proportional to its area of X-section

(III) Depends upon the nature of material

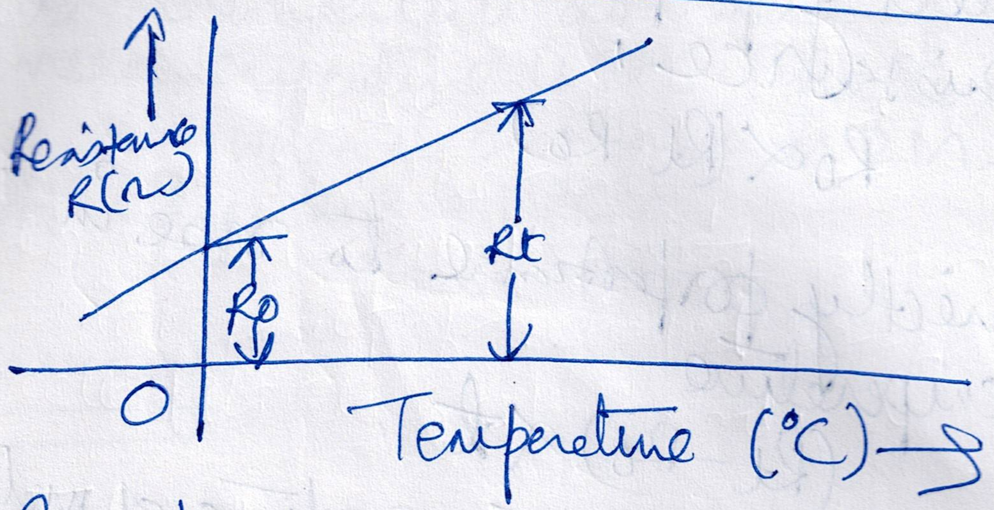
(IV) Depends upon the temperature

Specific Resistance of a material is the resistance offered by 1m length of wire of material having an area of cross section of $1 m^2$.

Conductance (Reciprocal)

~~Resistance of a conductor is called Conductance (G)~~

Effect of Temp on Resistance



(1) Resistance of pure metal increases with increase of temperature.

(2) Resistance of electrolytes, insulators and semiconductors decreases with the increase in temperature. Metals have -ve temp coefficient of Resistance.

(3) The resistance of alloys increases with rise of temp but increase is very small and irregular.

Temp Coefficient of Resistance

Consider a conductor having resistance R_0 at 0°C and R_t at t°C.

Under normal range of temp, increase in resistance $(R_t - R_0)$

(1) Directly proportional to initial resistance,

$$R_0 \propto (R_t - R_0)$$

(2) Directly proportional to rise in temperature

$$(R_t - R_0) \propto t$$

(3) Depends upon the nature of material

$$(R_t - R_0) \propto R_0$$

$$R_t = R_0(1 + \alpha_0 t)$$

α_0 is constant & temp coefficient of Resistance at 0°C. It depends upon the nature of material and temperature.

$$R_t = R_0(1 + \alpha_0 t)$$

$$\boxed{\alpha_0 = \frac{R_t - R_0}{R_0 \times t}}$$

Temp Coefficient of Resistance of conductor is the increase in resistance per ohm original resistance per °C rise in temp.

Q1. A coil has a resistance of 18Ω when its mean temp is 20°C and of 20Ω when its mean temperature is 50°C. Find its mean temp rise when its resistance is 21Ω and the surrounding temp is 15°C.

Summary

(1) Those substance whose resistances increases with rise in temperature will have +ve temp coefficient of Resistance

(2) Those substance whose resistance decreases with increase in temp have -ve temp coefficient of Resistance

(3) If a conductor has resistances R_0, R_1 and R_2 at $0°C, t_1°C, t_2°C$

$$R_1 = R_0(1 + \alpha_0 t_1)$$

$$R_2 = R_0(1 + \alpha_0 t_2)$$

$$\Rightarrow \boxed{\frac{R_2}{R_1} = \frac{1 + \alpha_0 t_2}{1 + \alpha_0 t_1}}$$

This relation is utilised in ~~above~~ rise of temperature of the winding of an electrical machine. The resistance of the wdg is measured before and after the test runs

After the operation of the machine for a given period, let these values be R_2 and t_2.

Since R_1 & R_2 can be measured,
t_1 (Ambient temperature)
$\alpha_0 \rightarrow$ known
t_2 can be calculated.

$$\boxed{\text{Average rise in temp of winding} = (t_2 - t_1)^\circ C.}$$

If R_0 & α_0 are resistance and temp coefficient at $0^\circ C$, α_0
then its resistance $R_1 = R_0(1 + \alpha_0 t)$

If α_0, α_1 and α_2 are temp coefficients at $0^\circ C$, $t_1^\circ C$ and $t_2^\circ C$
then,

$$\alpha_1 = \frac{\alpha_0}{1 + \alpha_0 t_1}, \quad \alpha_2 = \frac{\alpha_0}{1 + \alpha_0 t_2}$$

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

R_1 and R_2 are resistances at $t_1^\circ C$ and $t_2^\circ C$
α_1 is the temp coefficient at $t_1^\circ C$

$$R_2 = R_1[1+\alpha_1(t_2-t_1)]$$

Sol^n $R_0 \to 0°C$

$$18 = R_0(1+\alpha_0 20)$$
$$20 = R_0(1+\alpha_0 50)$$

$$\frac{20}{18} = \frac{1+50\alpha_0}{1+20\alpha_0} \qquad \alpha_0 =$$

$$\Rightarrow 20(1+20\alpha_0) = 18(1+50\alpha_0)$$
$$\Rightarrow 20+400\alpha_0 = 18+900\alpha_0$$
$$\Rightarrow 500\alpha_0 = 2$$
$$\Rightarrow \alpha_0 = \frac{\cancel{2}}{\cancel{500}} \frac{1}{250} = \underline{0.004/°C}$$

If t°C is the temp of the coil at 21°C,

$$21 = R_0(1+0.004t), \quad \frac{21}{18} = \frac{R_0(1+0.004t)}{R_0(1+0.004 \times 20)}$$
$$\Rightarrow t = 65°C$$

Temp rise $= t - 15 = 65 - 15 = 50°C$

Q2 The resistance of the field coils of dynamo is 173Ω at 16°C. After working for 6 hours on full-load, the resistance of the coil increases to 212Ω.

Cal (1) temp of the coils (2) Mean rise of the of copper is 0.00426/°C at 0°C

Let t°C be the final temp,

$$\frac{R_{16}}{R_t} = \frac{R_0(1+\alpha_0 16)}{R_0(1+\alpha_0 t)}$$

$$t = 72.5°C$$

(ii) Rise in temp = 72.5 − 16 = 56.5°C

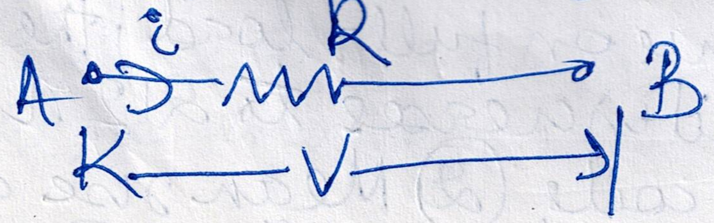
Basic law of Electricity

Ohm's law

The ratio of potential difference (V) between the ends of a conductor to the current (I) flowing between them is constant provided the physical conditions (eg. temperature etc) do not change.

$$\frac{V}{I} = \text{constant} = R$$

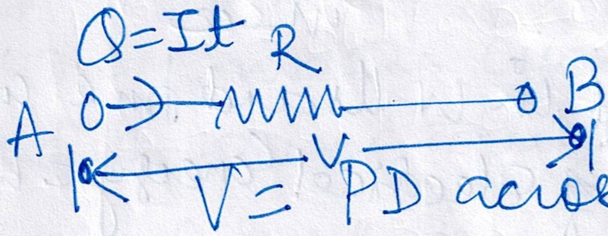
R is the resistance of the conductor between two points considered.



Power

The rate at which work is done in electric circuit is called as electric power.

$$\text{Electric power} = \frac{\text{Workdone in electric ckt}}{\text{time}}$$



V = PD across AB.

I = current in Amperes

R = Resistance of AB in Ω.

t = time in sec for which current flows.

$$P = \frac{\text{work}}{t} = \frac{VIt}{t} = VI$$

$$P = VI = I^2R = \frac{V^2}{R}.$$

Unit of Electrical Power = The basic unit of Electrical power is Joules/second.

Electrical Energy

The total work done in an electrical circuit is called electrical energy

Electrical Energy = Electric Power × time

$$= VIt = I^2Rt.$$

$$= \frac{V^2}{R}t$$

(1) If power is ~~taken~~ expressed in watts and time in sec, the unit of Electrical Energy will be watt-sec.

Energy in watt-sec = Power in watt × time in sec

(2) If power is expressed in watts and time in hours, unit of Electrical Energy = watt × hour

(3) If power is expressed in kW and time in hours, unit of Electrical Energy = Power in kW × time in hours.

One kilowatt-hour (kWh) of electrical Energy is expended in a circuit of 1 kW (1000 watts) of power is supplied for 1 hours.

(1) Electric Power $P = I^2 R = \frac{V^2}{R}$ Watts

Electrical Energy Consumed

$$W = I^2 R t = \frac{V^2}{R} t.$$

↑ Formula applied to Resistors & Devices.

(11) Electric Power = VI Watts.
Electrical Energy Consumed
$W = VIt$ Jaul

Q1 A 100V lamp has a hot resistance of 250Ω. Find the current taken by the lamp and its power rating. Calculate the energy it will consume in 24 hours.

$V = IR$
$I = \frac{100}{250} = 0.4A$

Power Rating $P = VI = 100 \times 0.4 = 40W$
Energy Consumption in 24h = Power × time
$= 40 \times 24$
$= 960$ Watt-hours

Q2 ~~A heating element supplies 300KJ in~~
A 10 watt resistor has a value of 120Ω. What is the rated current through the resistor? $P = I^2R$ (Rated Power)

Rated Current, $I = \sqrt{\frac{P}{R}} = \sqrt{\frac{10}{120}}$
$= 0.2887A$

Q3 The following are the details of the [illegible]
circuit connected through a supply meter.

(1) Six lamps of 40W each working for 4hrs/[illegible]
(2) 02 flourescent tubes 125 Watt each working f[illegible]
2hours/day
(3) one 1000Watt heater working for 3hours per day

If each unit of energy costs 70p, what will [illegible]
the electricity bill for the month of June?
and July

(1) Total wattage of lamp = $40 \times 6 = 240$ watt
(2) Total wattage of tubes = $125 \times 2 = 250$ watt
(3) Wattage of heater = 1000 watts

Energy consumed by Appliances/day

$(240 \times 4) + (250 \times 02) + 1000 = 4460$
$= 4.46$ kWh.

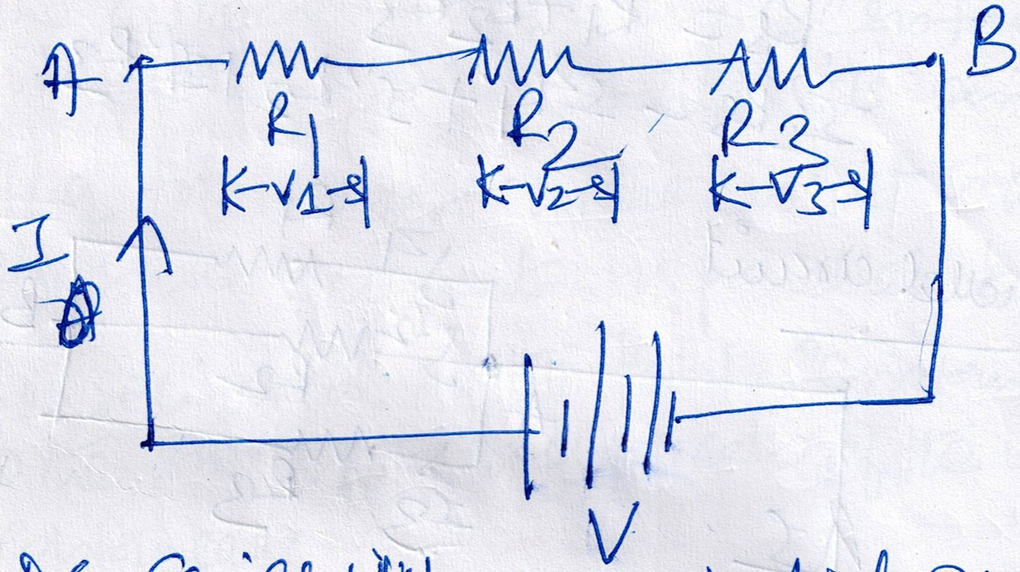
~~June~~ = Energy consumed for 30days
$4.46 \times 30 = 133.8$ kw[illegible]

Bill of the month
$= 0.7 \times 133.8 = 93.66$/-

DC Ckt

1. Series Circuit
2. Parallel Circuit
3. Series-Parallel Circuit

DC Series Circuit



A DC series ckt is one in which resistances are connected end to end so that there is only one path for current to flow is called DC series ckt.

$$V_1 = IR_1,\ V_2 = IR_2,\ V_3 = IR_3$$

$$V = V_1 + V_2 + V_3$$

$$= IR_1 + IR_2 + IR_3$$

$$= I(R_1 + R_2 + R_3)$$

$$\Rightarrow \frac{V}{I} = (R_1 + R_2 + R_3)$$

$$R_s = (R_1 + R_2 + R_3)$$

The main Characteristics of DC series

(1) The current in each resistor is same

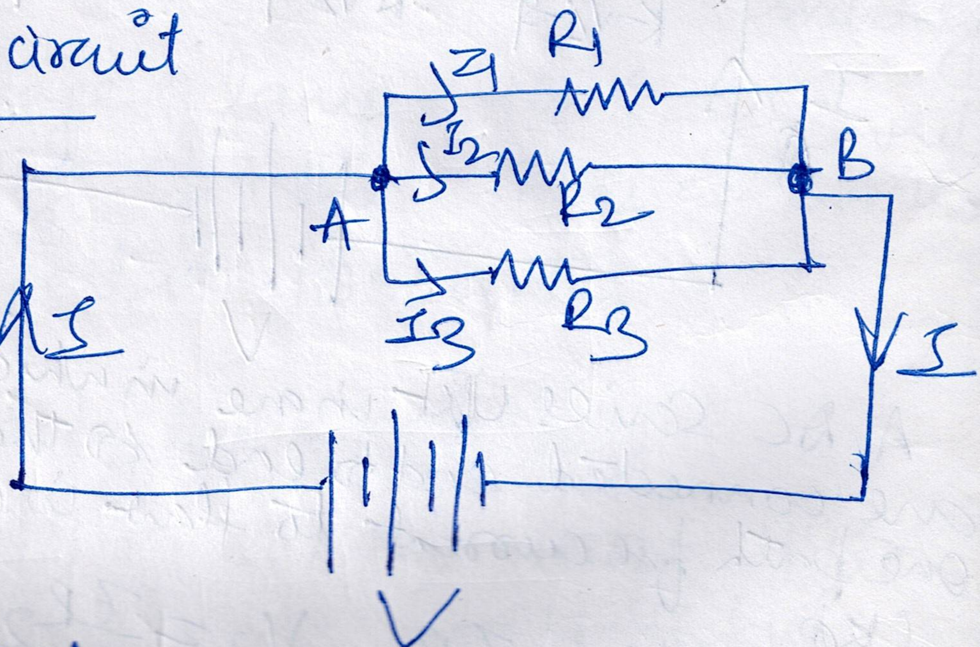
(2) The total resistance = sum of individual Resistances

(3) The total power dissipated in the Ckt is equal to the sum of power dissipated in individual resistances

$$R_S = R_1 + R_2 + R_3$$

$$I^2 R_S = I^2 R_1 + I^2 R_2 + I^2 R_3$$

DC parallel circuit



When one end of the each resistance is joined to a common point and the other end of each resistance is joined to another common point so that there are as many paths for current to flow as the no of Resistances.

$$I_1 = V/R_1, \; I_2 = V/R_2, \; I_3 = V/R_3$$

$$I = I_1 + I_2 + I_3$$

$$= V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\boxed{\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

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Manifestures of Parallel circuit

(1) The voltage across each resistor is same.

(2) The current through any resistance is inversibly proportional to its resistance

(3) The total current in the circuit is equal to the sum of currents in parallel branches.

(4) The reciprocal of the total Resistance is equal to the sum of the reciprocals of the individual resistances.

(5) No of ||lel branches is increased, the total resistance of the ckt is decreased

(6) The total resistance of the ckt is always less than the smallest of the resistances.

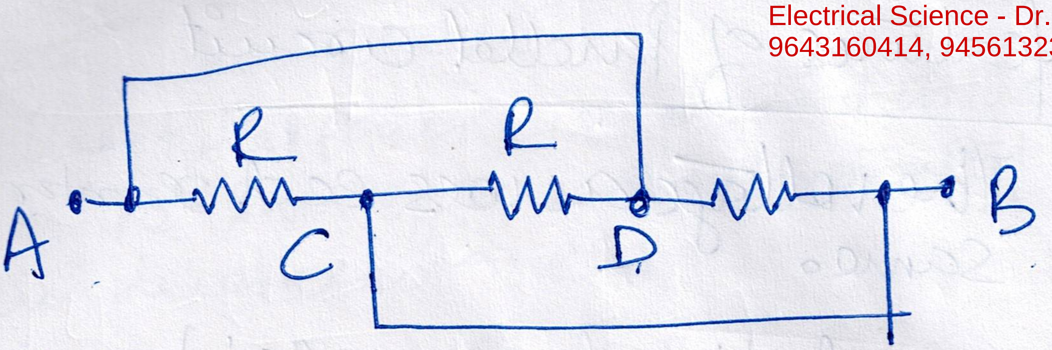
(7) If n resistances, each of the resistances connected in parallel, $\boxed{R_p = R/n}$.

(8) Total Resistance $R_p = \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

$= \frac{R_2 + R_1}{R_1 R_2}$

$$R_p = \frac{R_1R_2}{R_1+R_2} = \frac{\text{Product}}{\text{Sum}}$$

Q.

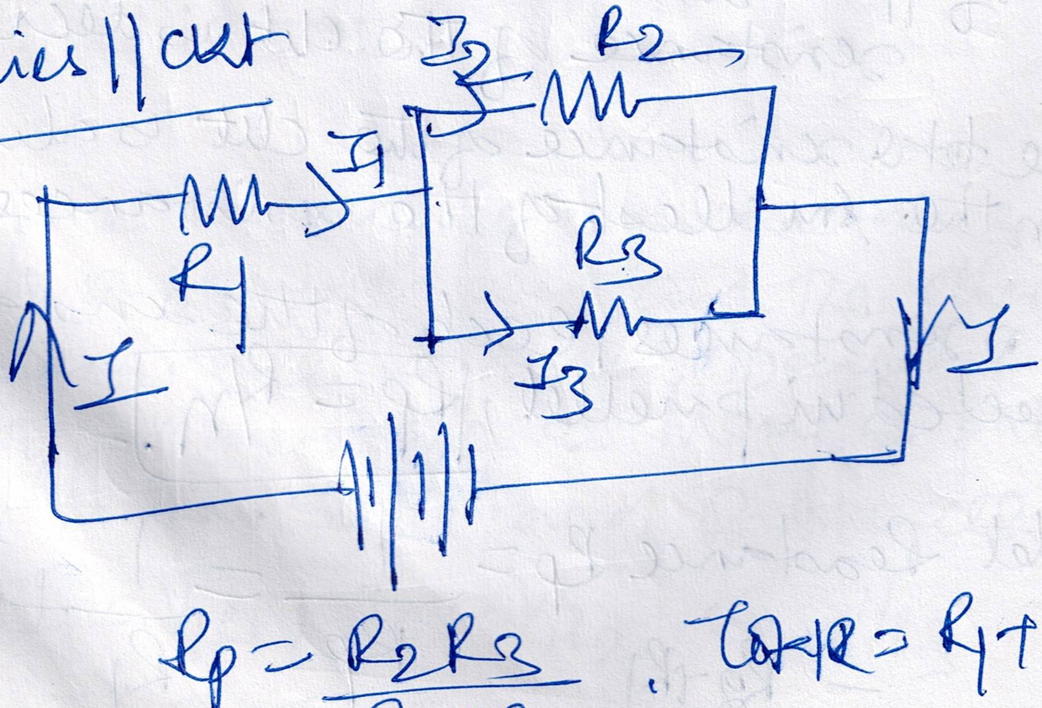


Three equal resistors are connected. Find the equivalent resistance between A and B.

$$\frac{1}{R_{AB}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = R/3$$

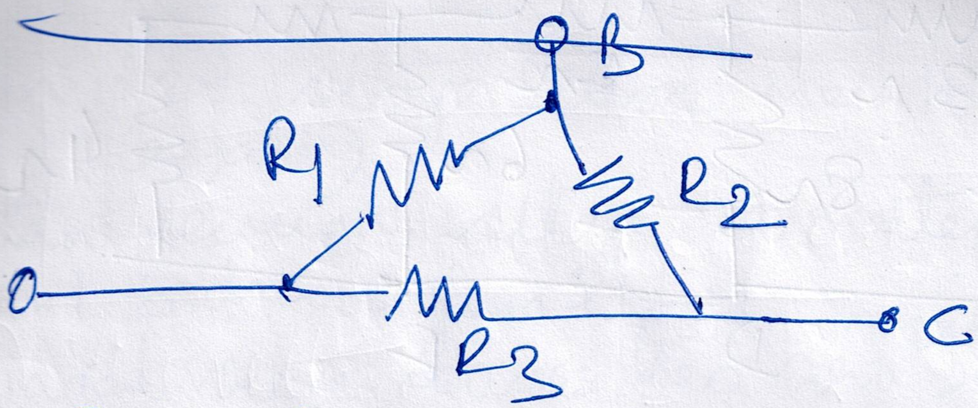
$$\boxed{R_{AB} = R/3}$$

DC Series || ckt



$$R_p = \frac{R_2R_3}{R_2+R_3}, \quad \text{Total } R = R_1 + \frac{R_2R_3}{R_2+R_3}$$

Equivalent Resistance



The Equivalent resistance of the ckt or n/w between its any two points is that single resistance which can replace the entire ckts between those points.

A&B

① $R_{AB} = R_1 \,||\, (R_2 + R_3)$

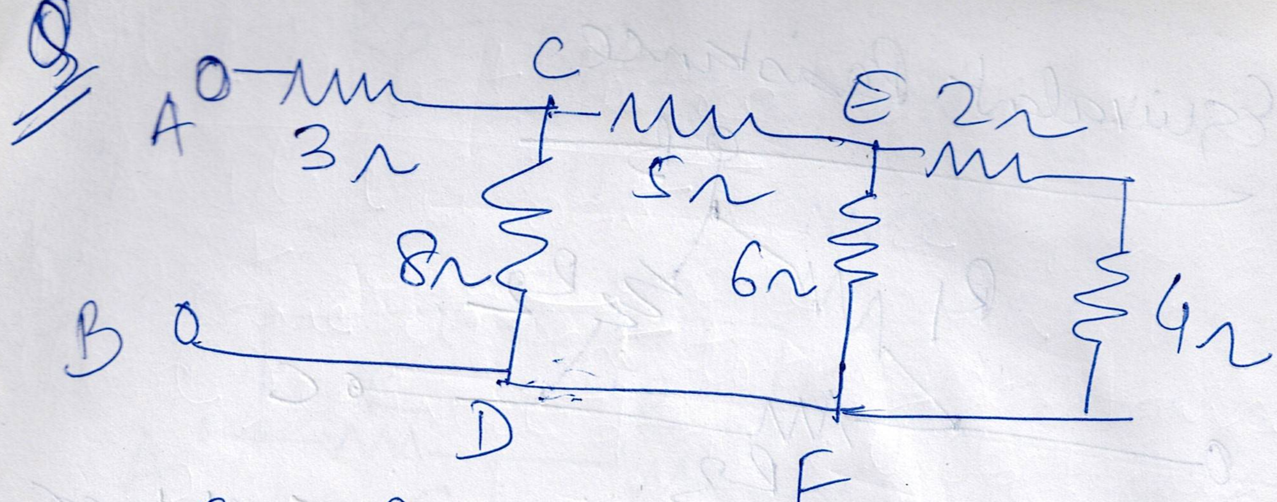
$$= \frac{R_1(R_2+R_3)}{R_1+R_2+R_3}$$

② $R_{AC} = R_3 \,||\, (R_1 + R_2)$

$$= \frac{R_3(R_1+R_2)}{R_1+R_2+R_3}$$

③ $R_{BC} = R_2 \,||\, (R_1 + R_3) = \frac{R_2(R_1+R_3)}{R_1+R_2+R_3}$

Q



$$R_{EF} = \frac{(4+2)\times 6}{(4+2)+6} = 3\Omega.$$

$$R_{CD} = \frac{(5+3)\times 8}{(5+3)+8} = 4\Omega$$

$$R_{AB} = 3+4 = 7\Omega.$$

Voltage and Current Source

Voltage source :- Source of Energy that establishes a potential diff. across its terminals

Current Sources :- A source of Energy that provides current source.