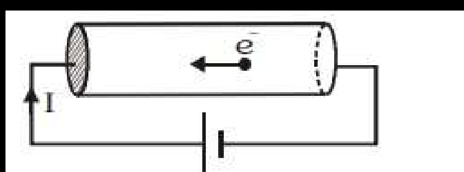
ELECTRIC CURRENT

Electric charges in motion constitute an electric current. Any medium having practically free electric charges, free to migrate is a conductor of electricity. The electric charge flows from higher potential energy state to lower potential energy state.



Positive charge flows from higher to lower potential and negative charge flows from lower to higher. If a charge ΔQ crosses an area in time Δt then the average electric current through the area, during this time as

- Average current $I_{av} = \dfrac{\Delta Q}{\Delta t}$
- Instantaneous current $I = \lim\limits_{\Delta t \to 0} \dfrac{\Delta Q}{\Delta t} = \dfrac{dQ}{dt}$

Solid Conductor

$\leftarrow e$

$I \rightarrow$

$I \rightarrow$

$+ve \rightarrow$

$\leftarrow e$

$+Q$ high V $\longrightarrow$ low V

- Current is a fundamental quantity with dimension $[M^0L^0T^0A]$
- Current is a scalar quantity with its SI unit **ampere.**

Ampere : The current through a conductor is said to be one ampere if one coulomb of charge is flowing per second through a cross–section of wire.

- The conventional direction of current is the direction of flow of positive charge or applied field. It is opposite to direction of flow of negatively charged electrons.

- The conductor remains uncharged when current flows through it because the charge entering at one end per second is equal to charge leaving the other end per second.
- If n particles per unit volume having a charge q and moving with velocity v then current through cross sectional area A is $I = \frac{\Delta q}{\Delta t} = nqvA$.
- If a charge q is moving in a circle of radius r with speed v then its time period is $T = 2\pi r/v$.

  The equivalent current $I = q/T = qv/2\pi r$

$I = \dfrac{Q_{flow}}{time}$

$$\boxed{I_{avg} = \frac{\Delta Q}{\Delta t}}$$

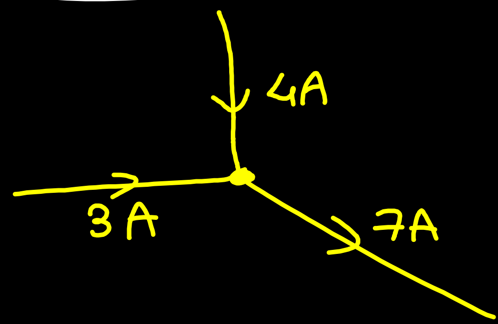
$$\boxed{I = \frac{dQ}{dt}}$$

Current

Unit Ampere

[A] or [I]

I scalar



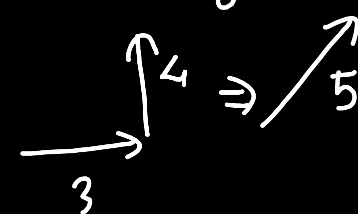
Vector

① directⁿ

② mag

③ follow vector law of addition

$\vec{a} = 3\hat{i} + 4\hat{j}$



$$I = \frac{dQ}{dt}$$

$$\boxed{Q_{flow} = \int_{ini}^{final} I \, dt}$$

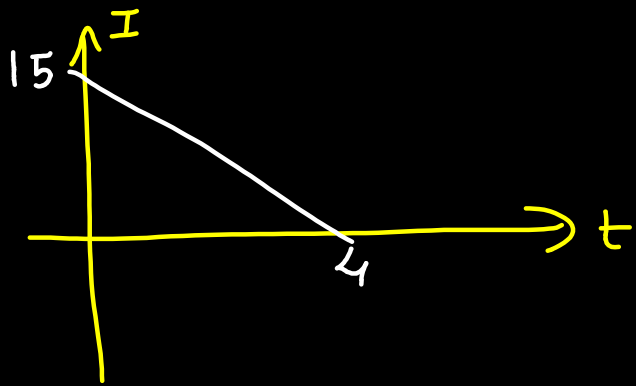
$$\boxed{Q_{flown} = I_{avg} \, \Delta t}$$

Q/ $I = 3 + 4t$. Find total charge flow from conductor from $t = 0$ to $t = 4s$. ??

$$Q = \int I \, dt = \int (3 + 4t) dt$$

$$= 3t + \frac{4t^2}{2} = \left[3t + 2t^2\right]_0^4 = HL - LL$$

$$44 - 0 = \underline{44 \text{ coulomb}}$$



Find Q_{flown} from $t=0$ to $t=4s$?

$\int I\,dt \rightarrow$ area under I v/s t

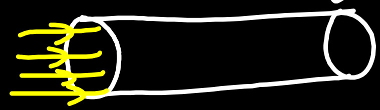
$$\frac{1}{2}(4)(15) = 30$$

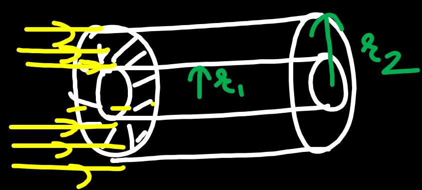
$$\Delta Q_{flow} = \int_0^4 I\,dt$$

$$= 30 \text{ coul.}$$

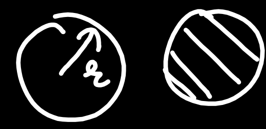
Current Density

Solid cylinder



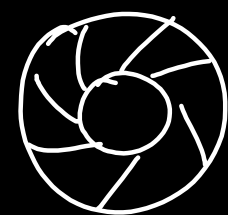


Crossection View



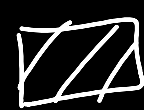
$A = \pi r^2$

$J = \frac{I}{\pi r^2}$



$A = \pi r_2^2 - \pi r_1^2$

$J = \frac{I}{\pi(r_2^2 - r_1^2)}$



$A = (l)(b)$.

$J = \frac{I}{(b)(l)}$.

Current Density (J)

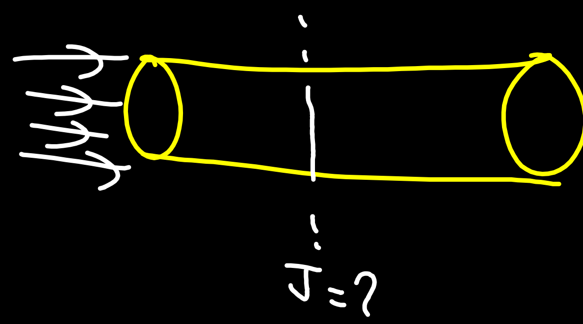
$$J = \left(\frac{I}{\text{area}}\right)$$

(area $\perp$'ur to I flow)

J → vector

$$\boxed{\vec{J} = \left(\frac{I}{\text{area}}\right)\hat{n}}$$

$\hat{n}$ → unit vector along current direction.



CLASSIFICATION OF MATERIALS ACCORDING TO CONDUCTIVITY

(i) Conductor

In some materials, the outer electrons of each atom or molecules are only weakly bound to it. These electrons are almost free to move throughout the body of the material and are called free electrons. They are also known as conduction electrons. When such a material is placed in an electric field, the free electrons move in a direction opposite to the field. Such materials are called conductors.

(ii) Insulator

Another class of materials is called insulators in which all the electrons are tightly bound to their respective atoms or molecules. Effectively, there are no free electrons. When such a material is placed in an electric field, the electrons may slightly shift opposite to the field but they can't leave their parent atoms or molecules and hence can't move through long distances. Such materials are also called dielectrics.

(iii) Semiconductor

In semiconductors, the behavior is like an insulator at low levels of temperature. But at higher temperatures, a small number of electrons are able to free themselves and they respond to the applied electric field. As the number of free electrons in a semiconductor is much smaller than that in a conductor, its behavior is in between a conductor and an insulator and hence, the name semiconductor. A freed electron in a semiconductor leaves a vacancy in its normal bound position. These vacancies also help in conduction.

Behavior of conductor in absence of applied potential difference :

In absence of applied potential difference electrons have random motion. The average displacement and average velocity is zero. The speed gained by virtue of temperature is called as thermal speed of an electron

So thermal speed $v_{ms} = \sqrt{\frac{3kT}{m}}$ where m is mass of electron

At room temperature $T = 300$ K, $v_{ms} = 10^5$ m/s

- Mean free path λ: $(\lambda \sim 10\text{Å}) \cdot \lambda = \frac{\text{total distance travelled}}{\text{number of collisions}}$

- Relaxation time : The time taken by an electron between two successive collisions is called as relaxation time τ: $(\tau \tilde{} 10^{-14}$ s), Relaxation time : $\tau = \frac{\text{total time taken}}{\text{number of collisions}}$

Behavior of conductor in presence of applied potential difference:

When two ends of a conductors are joined to a battery then one end is at higher potential and another at lower potential. This produces an electric field inside the conductor from point of higher to lower potential

$E = \frac{V}{L}$ where V = emf of the battery, L = length of the conductor.

The field exerts an electric force on free electrons causing acceleration of each electron.

Acceleration of electron $\vec{a} = \frac{\vec{F}}{m} = \frac{-e\vec{E}}{m}$

DRIFT VELOCITY

Drift velocity is defined as the velocity with which the free electrons get drifted towards the positive terminal under the effect of the applied external electric field. In addition to its thermal velocity, due to acceleration givenby applied electric field, the electron acquires a velocity component in a direction opposite to the direction of the electric field. The gain in velocity due to the applied field is very small and is lost in the next collision.

Relation between current and drift velocity

Let n= number density of free electrons and A = area of cross section of conductor.

Number of free electrons in conductor of length L = nAL , total charge on these free electron Δq= neAL

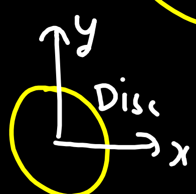
Time taken by drifting electrons to cross Conductor $\Delta t = \frac{L}{v_d}$ therefore current

I = $\frac{\Delta q}{\Delta t}$ = neAL $\left(\frac{v_d}{L} \right)$ = neAv_d

$$\boxed{\vec{J}\cdot\vec{area} = I}$$

$$\boxed{\int \underline{J}\,\underline{dA} = I}$$

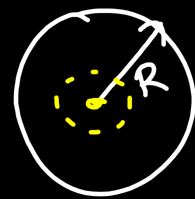
$\vec{area}$ → magnitude = area
→ direction ⊥'ue to surface



$$\vec{area} = \pi r^2 \hat{k}$$

Q

Crossection



$J = 5r$

Find total I flowing through this crossection??

$dA = (\text{length})(\text{thick})$

$= (2\pi r \; dr)$

$$I = \int J\,dA = \int 5r\; 2\pi r\, dr = 10\pi \int r^2\, dr$$

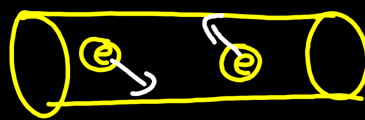
$$= \frac{10\pi}{3} r^3 \Big]_0^R = \frac{10\pi R^3}{3}$$

$$\boxed{I = \frac{dQ}{dt}}$$

$$\int dQ = \int I\,dt$$

$$\frac{I}{A} = J$$

$$I = \int J\,dA$$



$\overrightarrow{\text{avg velocity}} = 0$

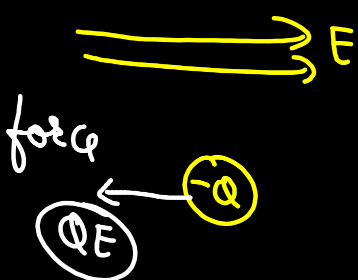
net displ of charge $= 0$

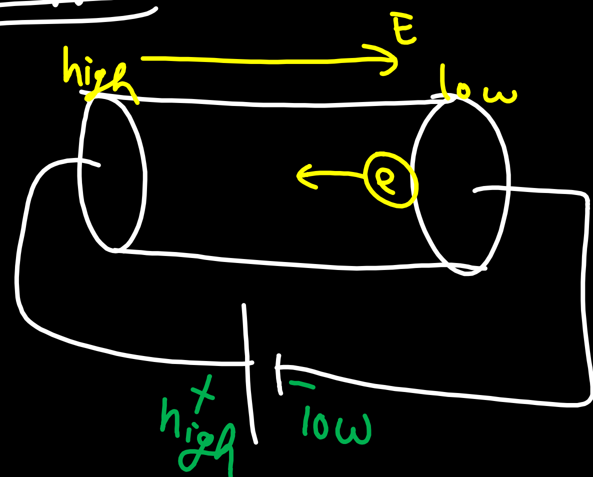
No Battery

$$V_{rms} = \sqrt{\frac{3KT}{m}} \rightarrow 10^5\ m/s \text{ (order)}$$

$$\boxed{\frac{1}{2}mV_{rms}^2 = \frac{3}{2}KT}$$

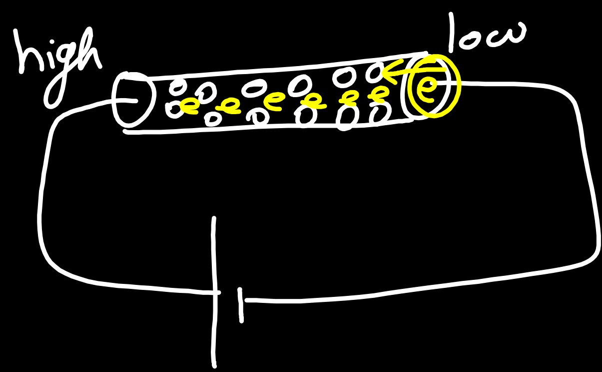
Potential diff





Drift vel

Random motion + Drift vel



$1e \longrightarrow e$ charge

$Ne \longrightarrow Ne$

$$I = \frac{Q}{t} = \frac{Ne}{t} = \frac{n(Vol)e}{t}$$

$$= nA\left(\frac{l}{t}\right)e$$

$$= nAe\,\underline{\underline{V_d}}$$

$n \rightarrow$ no. of free e^- per volume

per $1m^3$

Prop metal

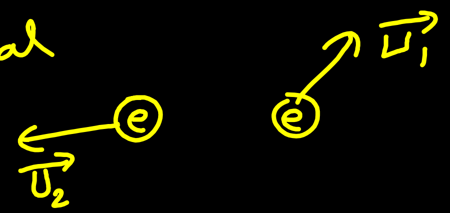
$$n = \frac{N}{Vol}$$

$$\boxed{I = neAV_d}$$

neAv

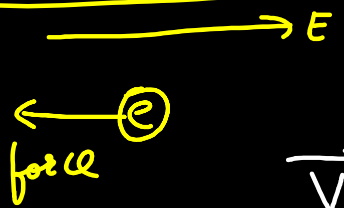
venA

initial



net addition $= \vec{U_1} + \vec{U_2} + \ldots - \vec{U_3}$

$= 0$

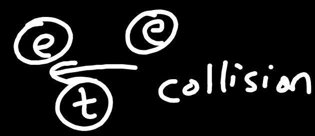


force $= QE$

acc $= \dfrac{eE}{m}$

$$\vec{V} = \vec{U} + \vec{a}t$$

$$\vec{V} = \vec{U_1} + \frac{eE}{m}t$$



$$\vec{V_1} = \vec{U_1} + \vec{a}t_1$$

$$\vec{V_2} = \vec{U_2} + \vec{a}t_2$$

$$\vdots$$

$$\vec{V_n} = \vec{U_n} + \vec{a}t_n$$

$$\frac{(\vec{V_1} + \ldots \vec{V_n})}{n} = 0 + \vec{a}\frac{(t_1 + t_2 + \ldots t_n)}{n}$$

$$\boxed{V_{drift} = \frac{eE}{m}\tau}$$

Unacademy Atoms

$$\boxed{I = neAv_d}$$

$$\frac{I}{A} = nev_d$$

$$\boxed{v_d = \frac{eE}{m}\tau}$$

mean relxation time

$$\boxed{J = nev_d}$$

$$J = ne\left(\frac{eE}{m}\tau\right)$$

$$\sigma = \frac{ne^2\tau}{m}$$

$$\boxed{J = \frac{ne^2\tau}{m}E}$$

$$\boxed{J = \sigma E}$$

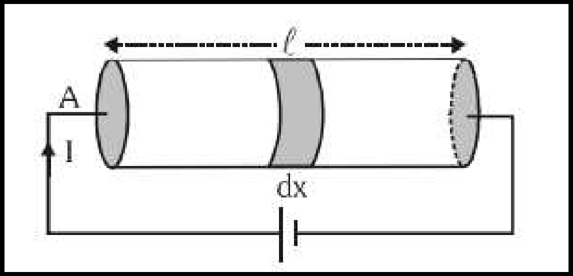
σ = conductivity

$$\rho = \frac{1}{\sigma}$$

resistivity.

RELATION BETWEEN CURRENT DENSITY, CONDUCTIVITY AND ELECTRIC FIELD

Let the number of free electrons per unit volume in a conductor = n



Total number of electrons in dx distance = n (Adx)

Total charge dQ = n(Adx)e

Current $\mathrm{I} = \frac{\mathrm{dQ}}{\mathrm{dt}} = \mathrm{nAe}\frac{\mathrm{dx}}{\mathrm{dt}} = \mathrm{neAv}_{\mathrm{d}}$, Current density $\mathrm{J} = \frac{\mathrm{I}}{\mathrm{A}} = \mathrm{nev}_{\mathrm{d}}$

$$= ne\left(\frac{eE}{m}\right)\tau \because v_d = \left(\frac{eE}{m}\right)\tau \Rightarrow J = \left(\frac{ne^2\tau}{m}\right)E \Rightarrow J = \sigma E, \text{ where conductivity } \sigma = \frac{ne^2\tau}{m}$$

σ depends only on the material of the conductor and its temperature.

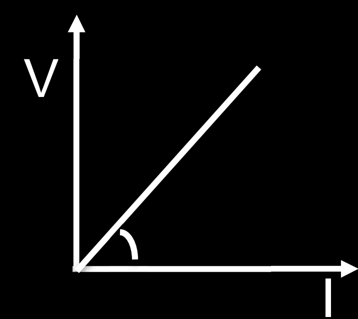
In vector form $\vec{\mathrm{J}} = \sigma\vec{E}$ Ohm's law (at microscopic level)

RELATION BETWEEN POTENTIAL DIFFERENCE AND CURRENT (Ohm's Law)

If the physical conditions of the conductor (length, temperature, mechanical strain etc.) remains same, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends i.e. I µ V Þ V = IR where R is a proportionality constant, known as electric resistance. *Ohm's law (at macroscopic level)*

- Ohm's law is not a universal law. The substances, which obey ohm's law are known as ohmic.
- Graph between V and I for a metallic conductor is a straight line as shown.

$$\text{Slope of the line} = \tan\theta = \frac{V}{I} = R$$



mobility $(\mu) = \dfrac{\text{drift vel}}{E}$

$$= \frac{V_d}{E}$$

$$= \frac{eE/m\,\tau}{E}$$

$$\mu = \frac{e\tau}{m}$$

$$\boxed{I = \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}}$$

$$\boxed{\int I\,dt = I_{avg}\,\Delta t = \Delta Q_{flown}}$$

$$\boxed{I = neAV_d}$$

$$\boxed{J = \frac{I}{A} = neV_d = \sigma E = \frac{ne^2\tau E}{m}}$$

$$\boxed{I = \int J\,dA}$$

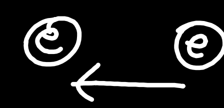
$$\boxed{V_d = \frac{eE}{m}\tau}$$

$$\boxed{\mu = \frac{V_d}{E} = \frac{e\tau}{m}}$$

$$\boxed{\sigma = \frac{ne^2\tau}{m}}$$

$$\boxed{\rho = \frac{1}{\sigma}}$$

V_d = order of 10^{-4} m/s

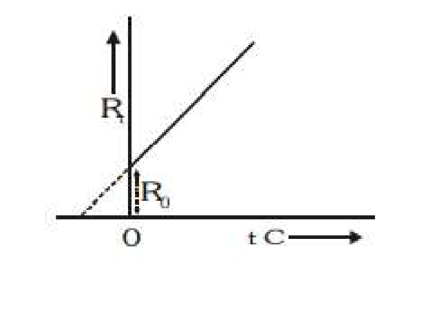


RESISTANCE

The resistance of a conductor is the opposition which the conductor offers to the flow of charge. Resistance is the property of a conductor by virtue of which it opposes the flow of current in it.
Unit : ohm, volt/ampere, Dimension $= ML^2\ T^{-3}\ A^{-2}$

Resistance depends on :

- Length of the conductor ($R \propto \ell$)
- Area of cross-section of the conductor $R \propto \frac{1}{A}$
- Nature of material of the conductor $R = \frac{\rho\ell}{A}$
- Temperature $R_t = R_0(1 + \alpha\Delta t)$
  Where R_t = Resistance at tC, R_0 = Resistance at 0 C
  Δt = Change in temperature, α = Temperature coefficient of resistance



- [For metals : α positive for semiconductors and insulators : α negative]
  Resistance of the conductor decreases linearly with decrease in temperature and becomes zero at a specific temperature. This temperature is called critical temperature. At this temperature conductor becomes a superconductor.

RESISTIVITY

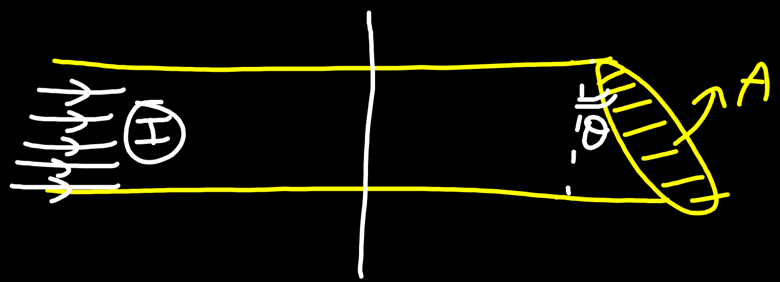
Resistivity : r=RA/l if l = 1m , A = 1m^2 then r = R

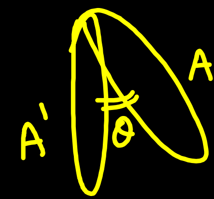
The specific resistance of a material is equal to the resistance of the wire of that material with unit cross – section area and unit length.

Resistivity depends on (i) Nature of material (ii) Temperature of material r does not depend on the size and shape of the material because it is the characteristic property of the conductor material.

Specific use of conducting materials :

- The **heating element** of devices like heater, geyser, press etc. are made of **micro ohm** because it has high resistivity and high melting point. It does not react with air and acquires steady state when red hot at 800 C.
- **Fuse wire** is made of **tin lead alloy** because it has low melting point and low resistivity. The fuse is used in series, and melts to produce open circuit when current exceeds the safety limit.
- **Resistances** of resistance box are made of **manganin** or **constantan** because they have moderate resistivity and very small temperature coefficient of resistance. The resistivity is nearly independent of temperature.
- The **filament of bulb** is made up of **tungsten** because it has low resistivity, high melting point of 3300 K and gives light at 2400 K. The bulb is filled with inert gas because at high temperature it reacts with air forming oxide.
- The **connection wires** are made of **copper** because it has low resistance and resistivity.





$$\cos\theta = \frac{A'}{A}$$

$$A\cos\theta = A'$$

$$J = ?$$

$$J = \frac{I}{A'} = \frac{I}{A\cos\theta}$$

Temp $\uparrow\uparrow\uparrow$ $\quad$ $\tau \downarrow\downarrow\downarrow$

$\sigma \downarrow\downarrow\downarrow$

$\rho \uparrow\uparrow\uparrow$

Temp $\uparrow$ conductor $R \uparrow\uparrow$ (collision increase)

Temp $\uparrow\uparrow$ Semiconductor Resistance $\downarrow\downarrow$

Resistance & Ohm's law

$$\boxed{J = \sigma E}$$ microscopic Ohm's law

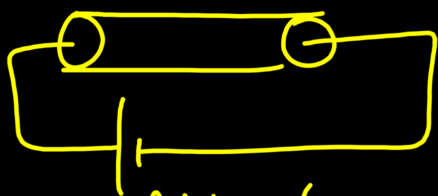
$$\vec{J} = \sigma \vec{E}$$

$$\Delta V = E \ell$$

$$\frac{\Delta V}{\ell} = E$$

$$\left(\frac{I}{A}\right) = \left(\frac{1}{\rho}\right)\left(\frac{\Delta V}{\ell}\right)$$

$$I = \frac{A}{\rho \ell} \Delta V \implies I = \frac{\Delta V}{\left(\frac{\rho \ell}{A}\right)} = \frac{\Delta V}{\text{Resistance}}$$



$\Delta V \rightarrow$ (pot. diff)

$I \propto \Delta V$

$I = \left(\frac{1}{R}\right)\Delta V$

$\boxed{\Delta V = IR}$

$J = \sigma E$

$\Delta V = IR$

$\boxed{R = \frac{\rho l}{A}}$

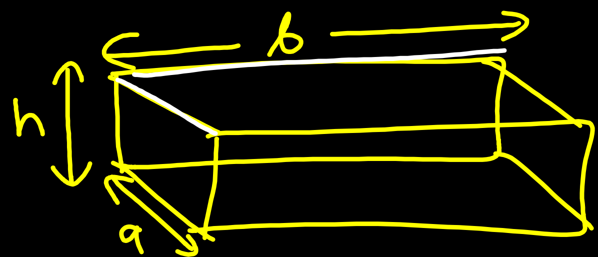
$\rho \rightarrow$ depends on material

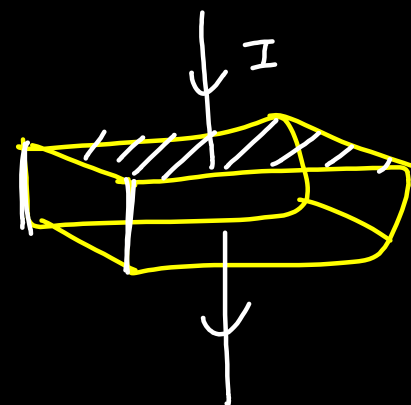
$R \rightarrow$ material, geometry.

$l \longrightarrow$ along directⁿ of current

$A \longrightarrow$ ⊥'ar to I directⁿ.

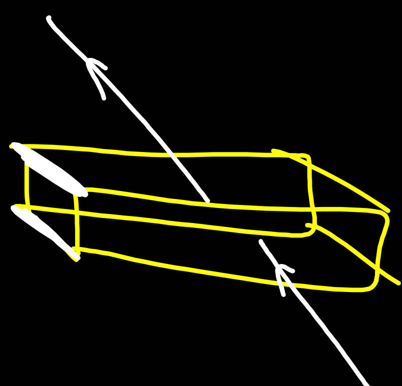
$\underset{I}{\longrightarrow} \quad \longrightarrow$



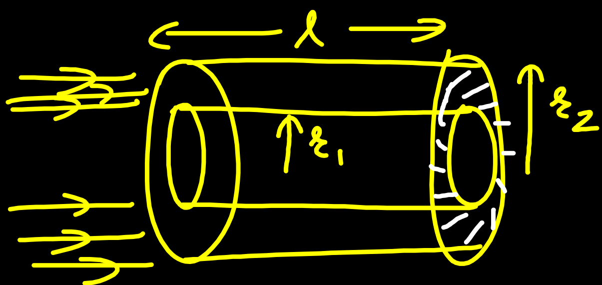


$$\frac{\rho(h)}{(ab)} = R$$

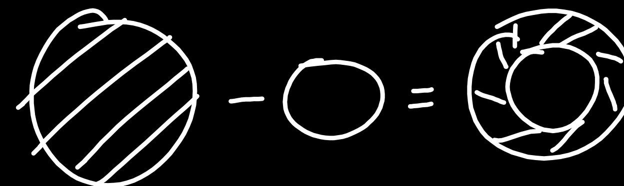
$$\frac{\rho(b)}{(ha)} = R$$



$$\frac{\rho(a)}{(hb)} = R$$



$\cancel{\pi(r_2 - r_1)^2}$



$\pi r_2^2 - \pi r_1^2 =$

$$R = \frac{\rho\, l}{\pi (r_2)^2 - \pi (r_1)^2}$$

Basic

Series

R_1 R_2

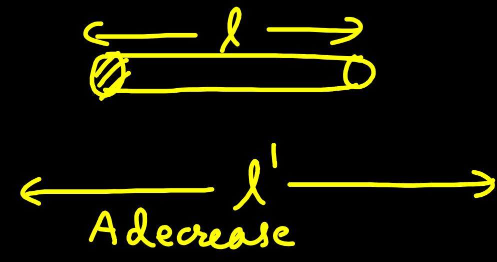
$R_{eq} = R_1 + R_2$

Parallel

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Streching

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



Volume constant

$V = A l.$

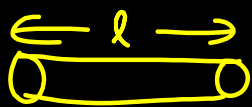
$$\frac{V}{l} = A$$

$$l = \frac{V}{A}$$

$$R = \frac{\rho l^2}{Vol}$$

$$R = \frac{\rho \, Vol}{A^2} = \frac{\rho \, Vol}{(\pi r^2)^2} = \frac{\rho \, Vol}{\pi^2 r^4}$$

Streching



l double

$R' \longrightarrow 4$ time.

#

radius half

$R' \longrightarrow 16$ times.

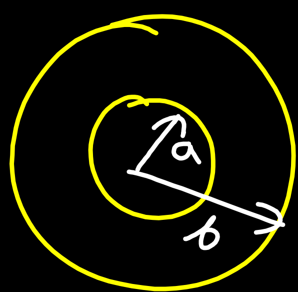
$l \rightarrow 1\%$ change

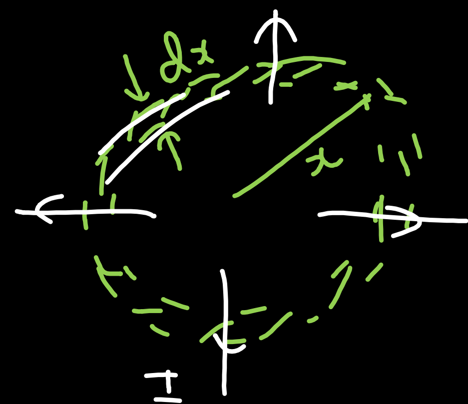
$R' \longrightarrow 2\%$ change.

$$\boxed{\begin{array}{l} y = x^2 \\ \%y = 2\%x \\ \text{when} \\ \% \text{ small} \end{array}}$$

Resistance in radial flow (integration)

① Sphere



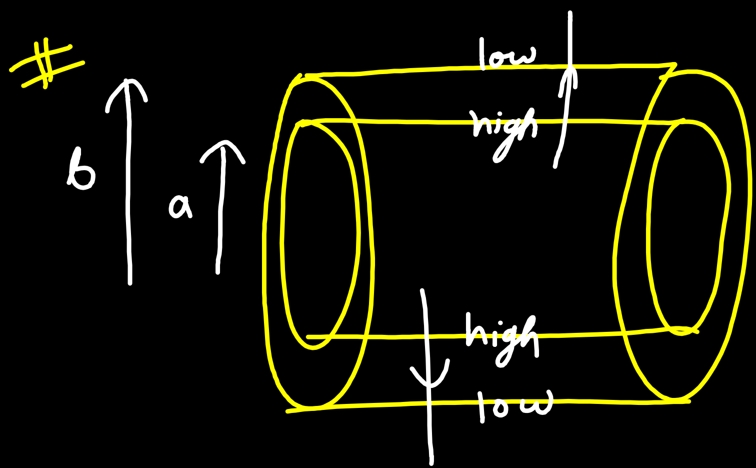


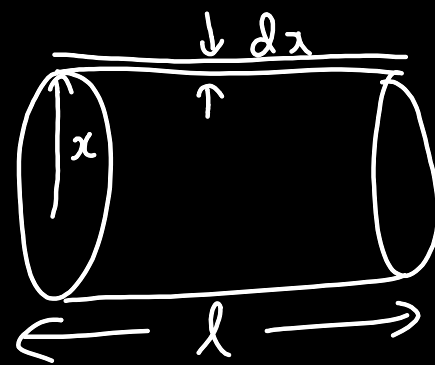
shell

$$R = \int_a^b \frac{\rho\,(dx)}{(4\pi x^2)}$$

$$R = \frac{\rho}{4\pi}\int x^{-2}\,dx$$

$$\Rightarrow R = \frac{\rho}{4\pi}\,\frac{x^{-1}}{-1} = \frac{-1\,\rho}{4\pi}\left(\frac{1}{x}\right)_a^b = \frac{-\rho}{4\pi}\left(\frac{1}{b}-\frac{1}{a}\right) = \frac{\rho(b-a)}{4\pi ab} = R$$

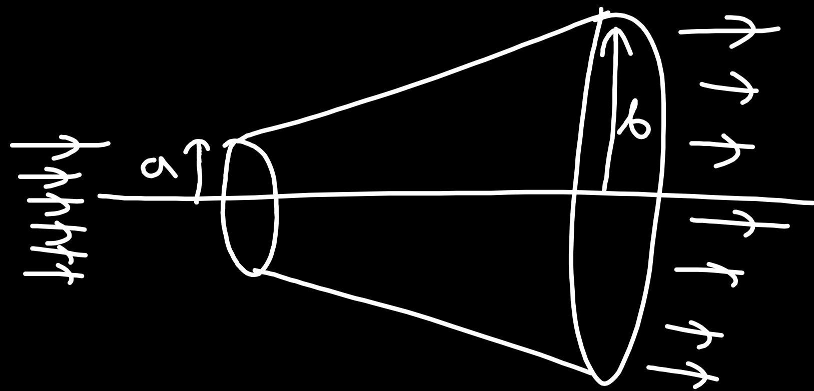




$$R = \int_a^b \frac{\rho\,(dx)}{(2\pi x l)}$$

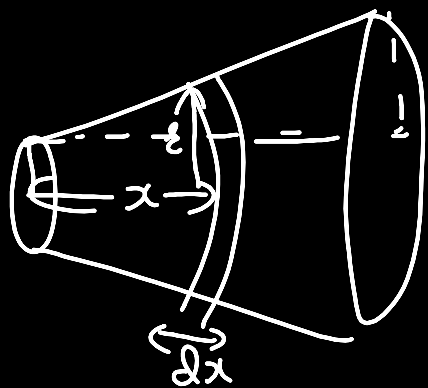
$$R = \frac{\rho}{2\pi l}\int \frac{dx}{x} = \frac{\rho}{2\pi l}\log_e x \Big]_a^b = \frac{\rho}{2\pi l}\log_e\left(\frac{b}{a}\right)$$

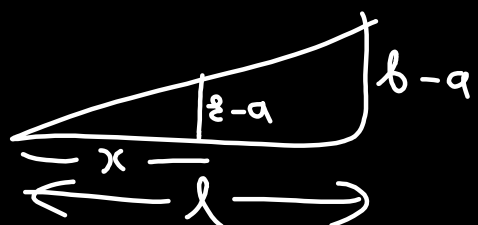
Resistance of frustrum (jee advanced 2022)



Area → ellipse area $\pi a b$

$$R = \frac{\rho l}{(\pi a b)}$$

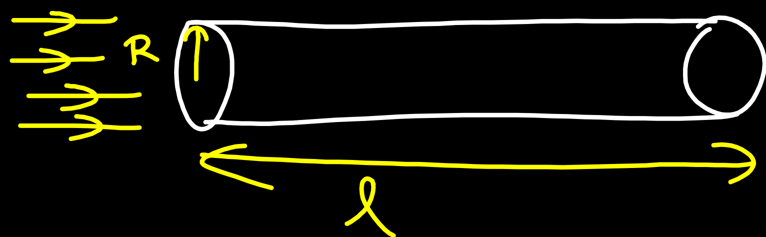


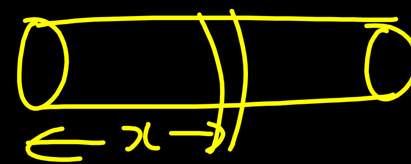


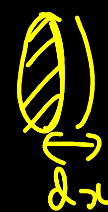
$$\int \frac{\rho\, dx}{\pi r^2} = R$$

ρ varies along x

$\left(\rho = \rho_0 x \quad \text{Suppose}\right)$







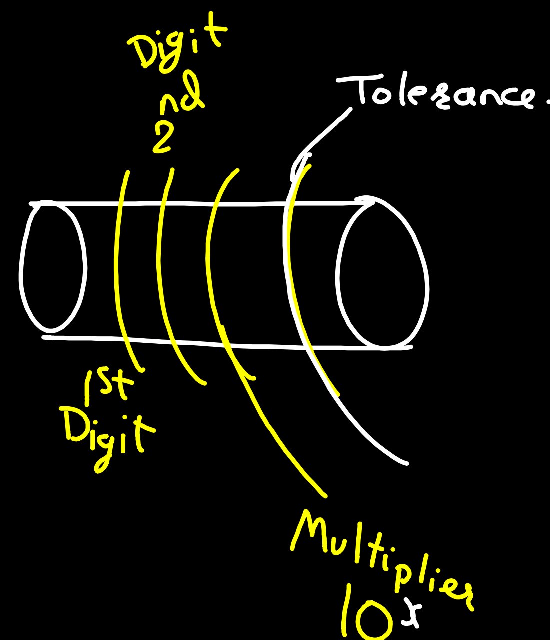
$$R = \int \frac{\rho \, dx}{\pi r^2}$$

Colour Coding

Colour	Strip A	Strip B	Strip C	Strip D
Black	0 10^0	0	10^0	Tolerance
Brown	1 10^1	1	10^1	
Red	2 10^2	2	10^2	
Orange	3 10^3	3	10^3	
Yellow	4 10^4	4	10^4	
Green	5 10^5	5	10^5	
Blue	6 10^6	6	10^6	
Violet	7 10^7	7	10^7	
Grey	8 10^8	8	10^8	
White	9 10^9	9	10^9	
Gold	–	–	10^{-1}	± 5%
Silver	–	–	10^{-2}	± 10%
No Colour	–	–	–	± 20%

Carbon Resistance Color Code Table

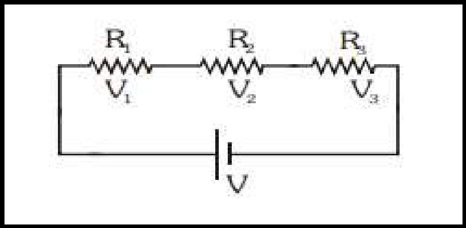
B B ROY Great Britain has Very Good Wife marge Sona Chandi



COMBINATION OF RESISTORS

Unacademy Atoms

Series Combination



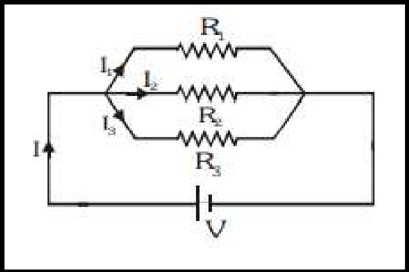
- Same current passes through each resistance
- Voltage across each resistance is directly proportional to it's value

V1 = IR1, V2 = IR2 , V3 = IR3

Sum of the voltage across resistance is equal to the voltage applied across the circuit.

$v = v_1 + v_2 + v_3$ => IR= $IR_1 + IR_2 + IR_3$ => $R = R_1 + R_2 + R_3$ Where R = equivalent resistance

Parallel Combination



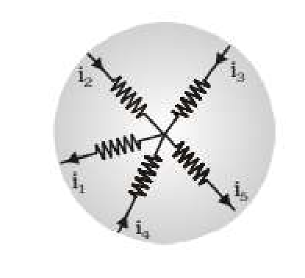
- There is same drop of potential across each resistance.
- Current in each resistance is inversely proportional to the value of resistance. $I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}$
- Current flowing in the circuit is sum of the currents in individual resistance.

$$I = I_1 + I_2 + I_3 \Rightarrow \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \Rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

KIRCHHOFF'S LAW

There are two laws given by Kirchhoff for determination of potential difference and current in different branches of any complicated network. **Law of conservation of charge is a consequence of continuity equation**

- **First law (Junction Law or Current Law)**
  In an electric circuit, the algebraic sum of the current meeting at any junction in the circuit is zero or Sum of the currents entering the Junction is equal to sum of the current leaving the Junction.
  $\Sigma i = 0$



$$i_1 - i_2 - i_3 - i_4 + i_5 = 0 \Rightarrow i_1 + i_5 = i_2 + i_3 + i_4$$

This is based on law of conservation of charge.

- **Second law (loop rule or potential law)**
  In any closed circuit the algebraic sum of all potential differences and e.m.f is zero. $\Sigma E - \Sigma IR = 0$ while moving from negative to positive terminal inside the cell, e.m.f is taken as positive while moving in the direction of current in a circuit the potential drop (i.e. IR) across resistance is taken as positive.
  This law is based on law of conservation of energy.

Notes :

- If a wire is stretched to n times of it's original length, its new resistance will be n^2 times.
- If a wire is stretched such that it's radius is reduced to $\frac{1}{n}$ th of it's original values, then resistance will increases n^4 times similarly resistance will decrease n^4 time if radius is increased n times by contraction.
- To get maximum resistance, resistance must be connected in series and in series the resultant is greater than largest individual.
- To get minimum resistance, resistance must be connected in parallel and the equivalent resistance of parallel combination is lower than the value of lowest resistance in the combination.
- Ohm's law is not a fundamental law of nature. As it is possible that for an element :-
  (i) V depends on I non linearly (e.g. vacuum tubes)
  (ii) Relation between V and I depends on the sign of V for the same value
  [Forward and reverse Bias in diode]
  (iii) The relation between V and I is non unique. That is for the same I there is more then one value of V.

In general :

(i) Resistivity of alloys is greater than their metals.

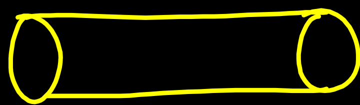
(ii) Temperature coefficient of alloys is lower than pure metals.

(iii) Resistance of most of non metals decreases with increase in temperature.

(e.g. Carbon)

(iv) The resistivity of an insulator (e.g. amber) is greater then the metal by a factor of 10^{22}

- Temperature coefficient (α) of semi conductor including carbon (graphite), insulator and electrolytes is negative.



Temp $\uparrow$ Resis $\uparrow$

$$\boxed{R = R_0(1 + \alpha \Delta T)}$$

$$\rho = \rho_0(1 + \alpha \Delta T)$$

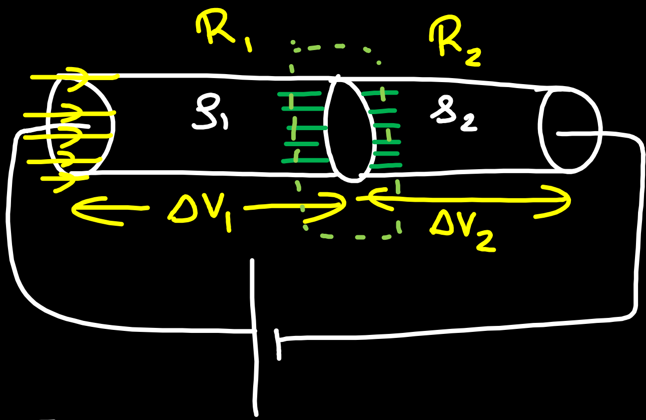
Break 20min

Resume 5:35pm

Kirchhoff's Law
& circuit Solving

Register
Free Special Class
Use Code AT24
Link in description.

Charge accumulalated at Juction



$J = \sigma E$

$E = \frac{J}{\sigma}$

$E = \rho J$

$J = \frac{I}{A}$

$E_1 = \rho_1 J$

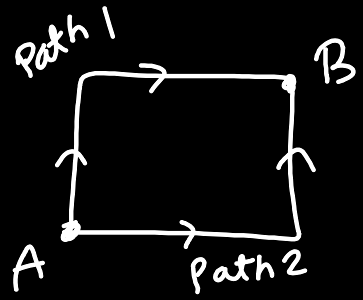
$E_2 = \rho_2 J$

Net flux $= \frac{Q_{enclosed}}{\varepsilon_0}$

$(E_1)A - (E_2 A) = \frac{Q_{en}}{\varepsilon_0}$

$\rho_1 JA - \rho_2 JA$

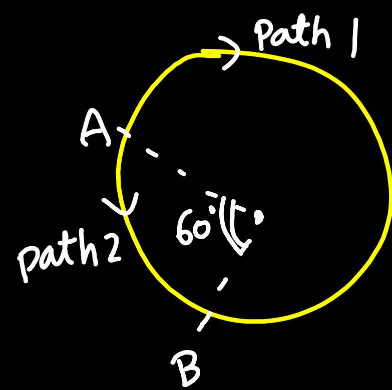
$\varepsilon_0 I (\rho_1 - \rho_2) = Q_{en}$



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

Path 1 $\quad R_1 = \frac{\rho(2l)}{A}$

Path $\quad R_2 = \frac{\rho(2l)}{A}$



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

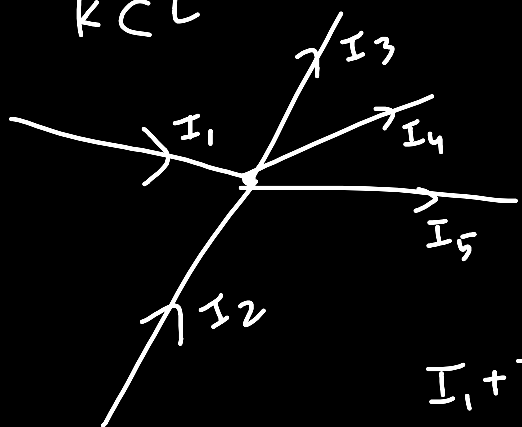
$$R_2 = \frac{\rho\left(\frac{\pi}{3} l\right)}{A}$$

$$R_1 = \frac{\rho\left(\frac{5\pi}{3} l\right)}{A}$$

Kirchhoff's Law & Circuit Solving

① K Junction L (Current law)

KCL



$I_1 + I_2 = I_3 + I_4 + I_5$

Cons. of charge

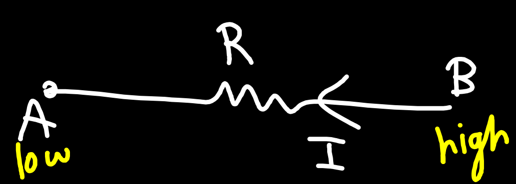
② KVL (voltage law)

→ algebric sum of all ΔV in loop is 0

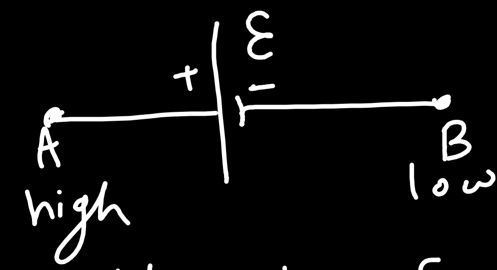
Circuit elements

$$\Delta V = IR$$

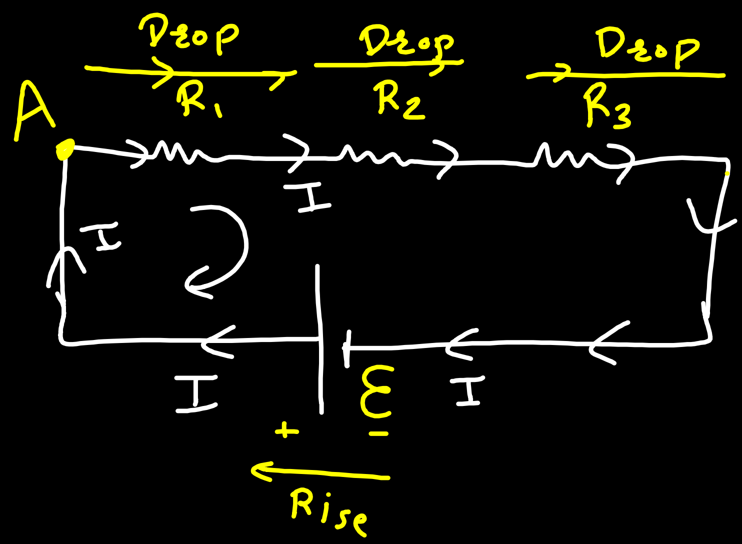
$$V_A - V_B = IR$$



$$V_A - V_B = -IR$$



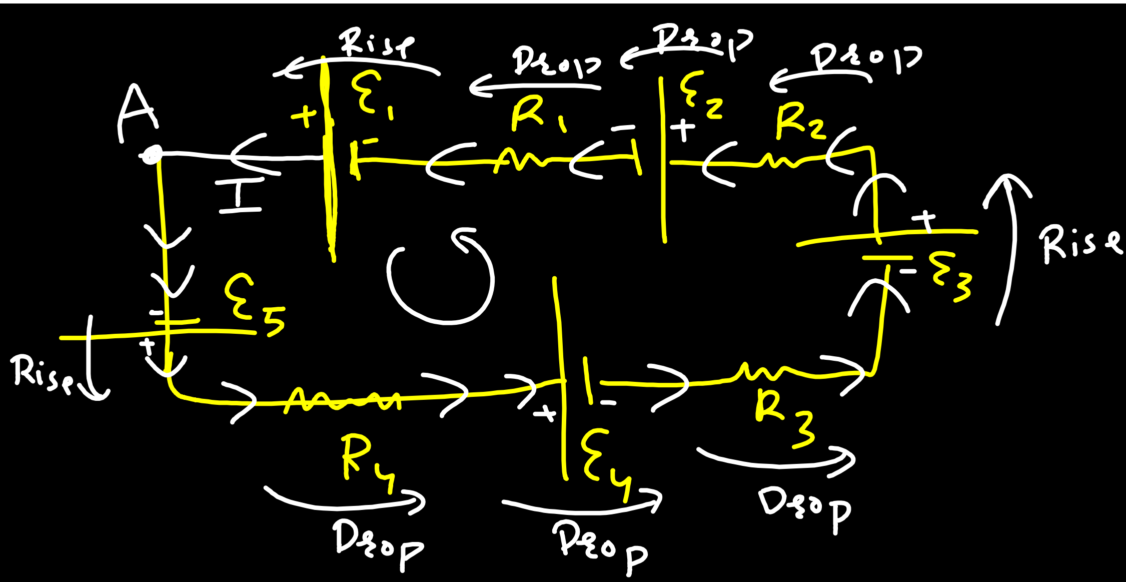
$$V_A - V_B = \mathcal{E}$$



$$V_A - IR_1 - IR_2 - IR_3 + \varepsilon = V_A$$

$$-IR_1 - IR_1 - IR_3 + \varepsilon = 0$$

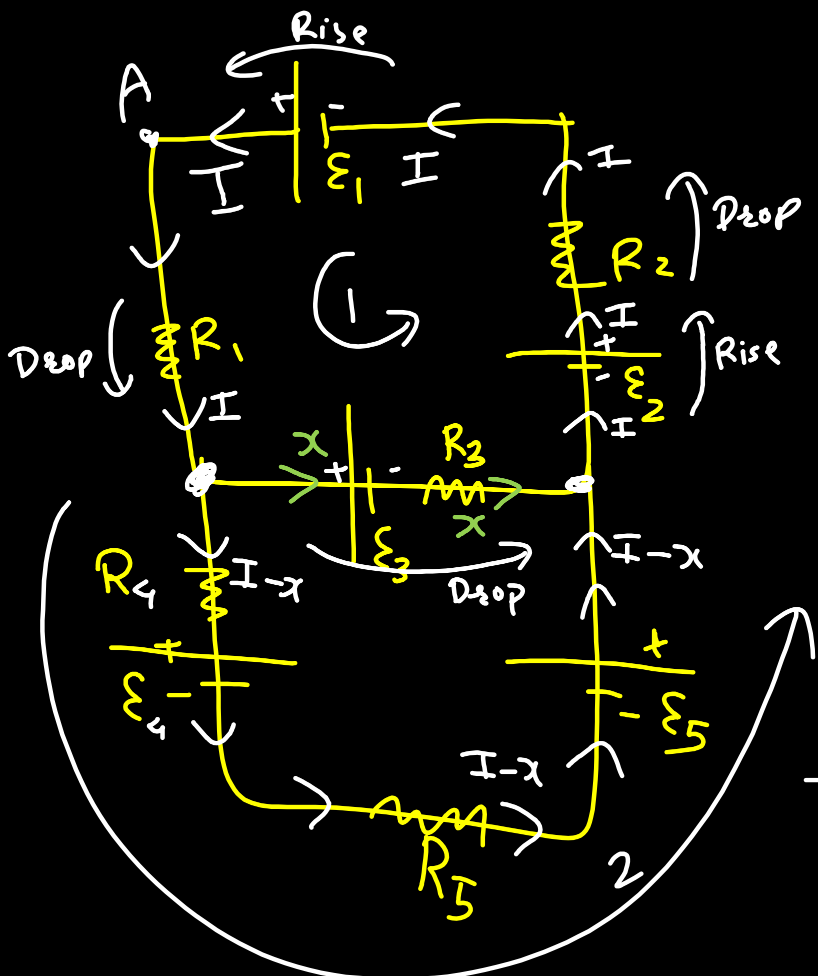
$$\varepsilon = IR_1 + IR_2 + IR_3$$



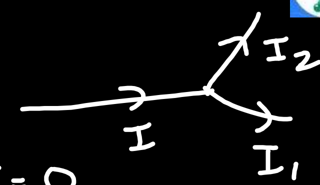
$$+\varepsilon_5 - IR_4 - \varepsilon_4 - IR_3 + \varepsilon_3 - IR_2 - \varepsilon_2 - IR_1 + \varepsilon_1 = 0$$

$$\varepsilon_5 + \varepsilon_3 + \varepsilon_1 = \varepsilon_4 + \varepsilon_2 + I(R_1 + R_2 + R_3 + R_4)$$

Variable I & x



$$-IR_1 - \varepsilon_3 - xR_3 + \varepsilon_2 - IR_2 + \varepsilon_1 = 0$$



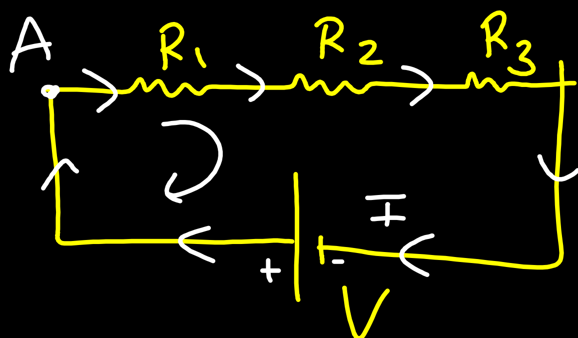
$$I_1 + I_2 = I$$

$$\boxed{\varepsilon_1 + \varepsilon_2 = \varepsilon_3 + I(R_1 + R_2) + xR_3}$$

$$-IR_1 - (I-x)R_4 - \varepsilon_4 - (I-x)R_5 + \varepsilon_5 + \varepsilon_2 - IR_2 + \varepsilon_1 = 0$$

Combination of Resistors

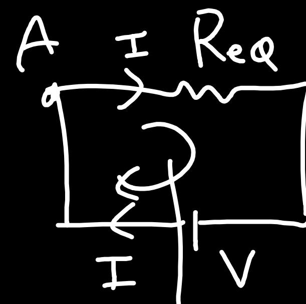
Series Connection



$$-IR_1 - IR_2 - IR_3 + V = 0$$

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

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

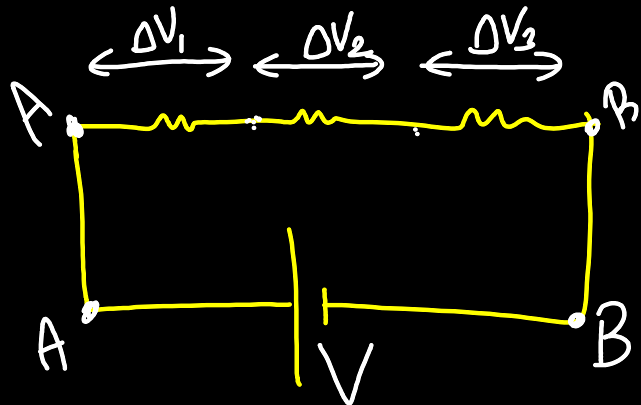


$$-IR_{eq} + V = 0$$

$$V = IR_{eq}$$

$$\frac{V}{R_{eq}} = I$$

$$R_{eq} = R_1 + R_2 + R_3$$



$\Delta V_1 = I R_1$

$\Delta V_2 = I R_2$

$\Delta V_3 = I R_3$

Series

I same

$R_{eq} = R_1 + R_2 + \ldots$

(greater than greatest)

$$\boxed{V = \Delta V_1 + \Delta V_2 + \Delta V_3}$$

$\Delta V_1 : \Delta V_2 : \Delta V_3 \Rightarrow R_1 : R_2 : R_3$

Power lost in $R_1 = I^2 R_1$

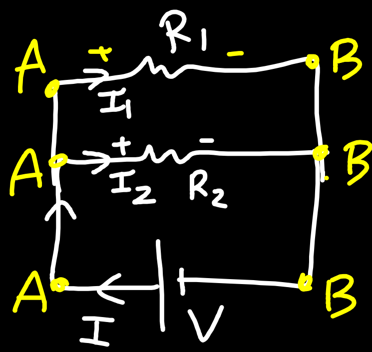
Power dissipated in R $= I^2 R = \frac{(\Delta V)^2}{R}$

$$\boxed{\begin{aligned} \text{Heat} &= (P)\,t \\ H &= I^2 R t \end{aligned}}$$

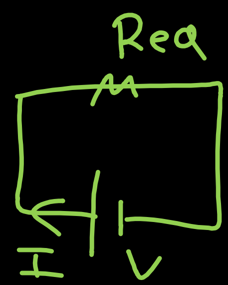
$$\text{Heat} = \int I^2 R\,dt$$

Parallel Connection $\longrightarrow$ # ΔV across both R same

Same points ke bich Connection



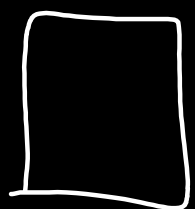
$\Longrightarrow$



$$V = I R_{eq}$$

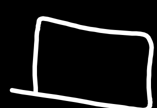
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

R_{eq} is Smaller than Smallest.



$$-I_1R_1 + V = 0$$

$$I_1 = V/R_1$$

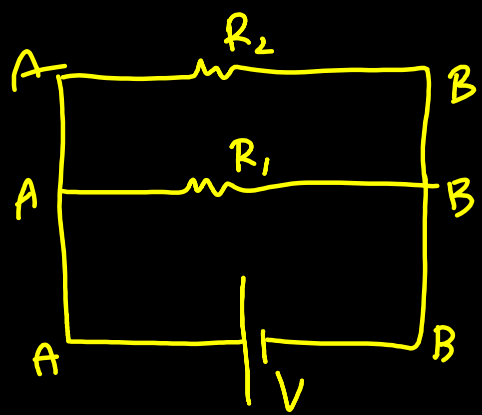


$$-I_2R_2 + V = 0$$

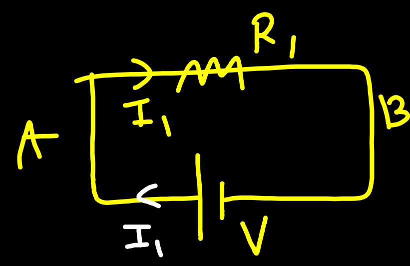
$$I_2 = V/R_2$$

$$I = I_1 + I_2$$

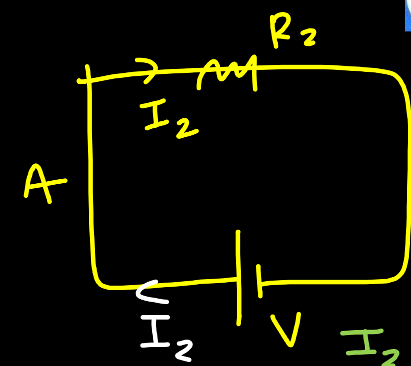
$$\frac{V}{R_1} + \frac{V}{R_2} = \frac{V}{R_{eq}}$$



$\Rightarrow$



$+$



$I_1 = V/R_1$ $\quad$ $I_1R_1 = V$

$I_2 = V/R_2$

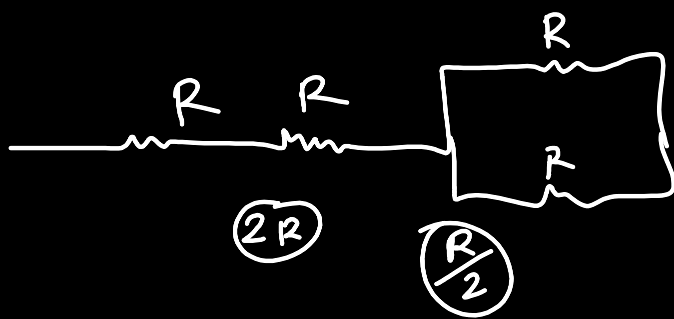
$V = I_2R_2$

finally total from battery $= I_1 + I_2$

(Superposition)

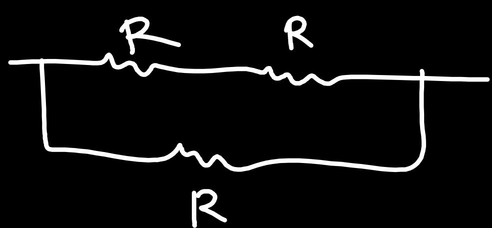
$I_{net} = V/R_1 + V/R_2$

Q



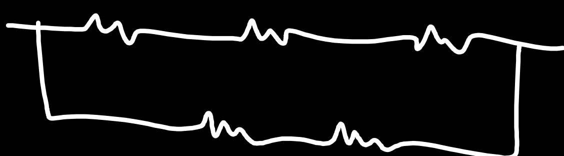
$= \frac{5R}{2}$

Q



$= \frac{2R}{R} = \frac{2R\,\cancel{R}}{3\cancel{R}} = \frac{2R}{3}$

Q



$3R$

$2R$

$= \frac{6R}{5}$

Series (all equal)

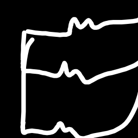
$R_{eq} = 3R$

Parallel

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

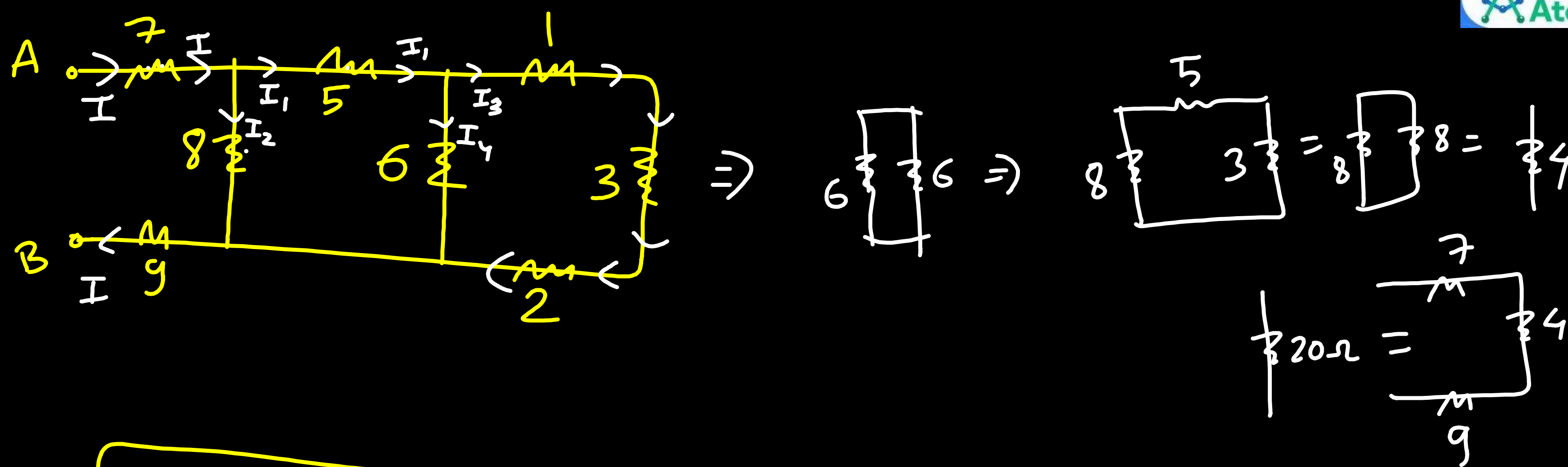
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \cdots$

if all equal



$R_{eq} = R/3$

Q



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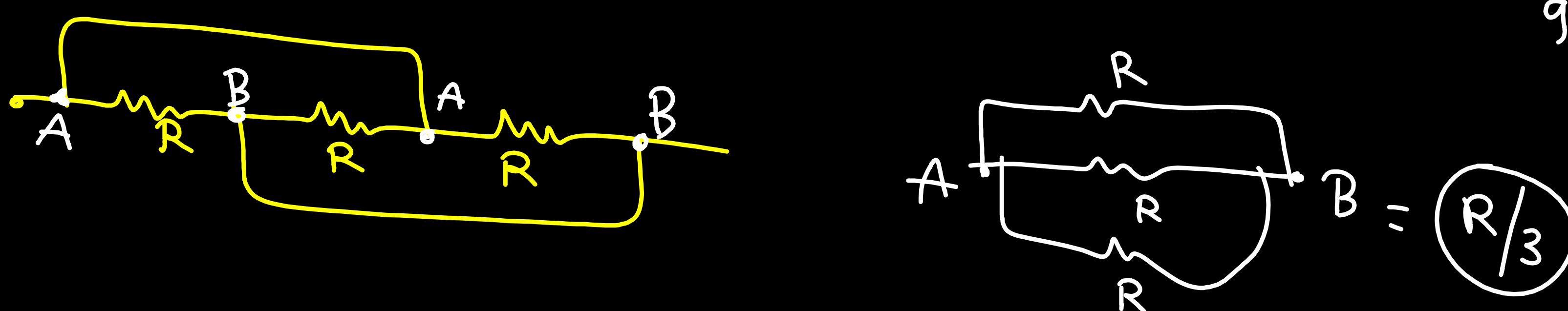
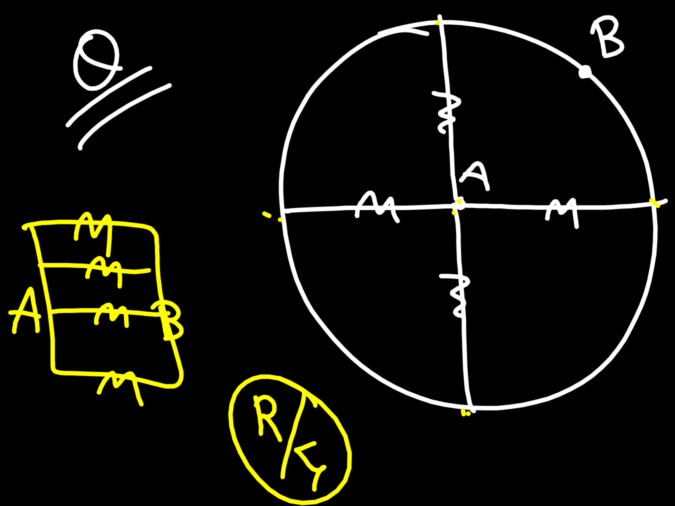
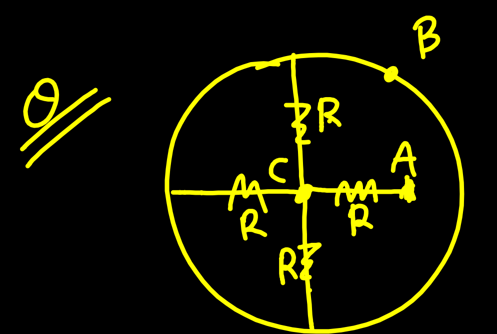


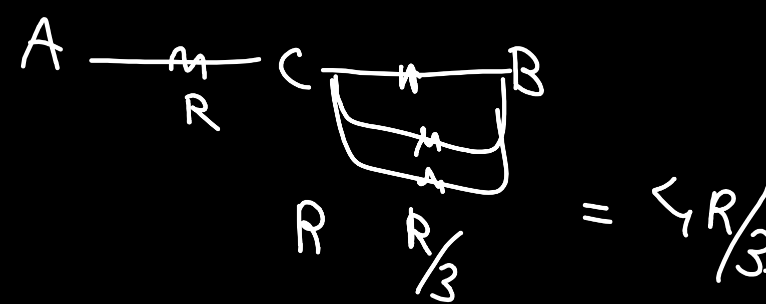
EQuipotential/Naming

\# Points ko Name Karo

\# Apne acc. Naya Circuit Banao







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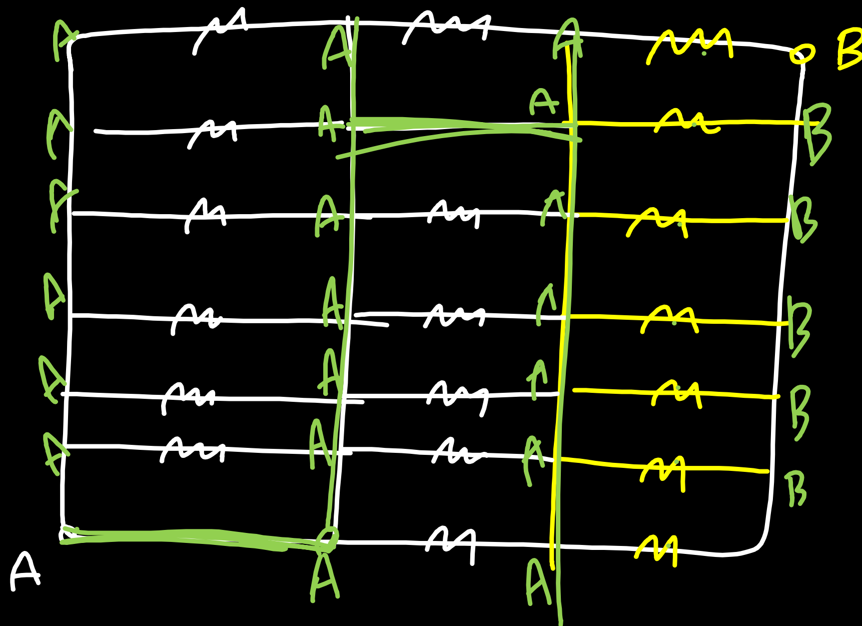
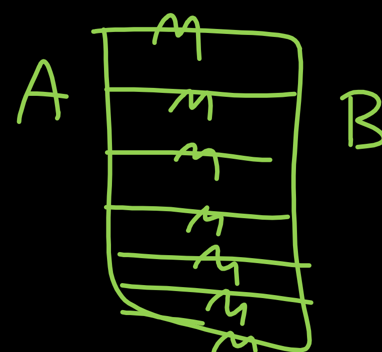


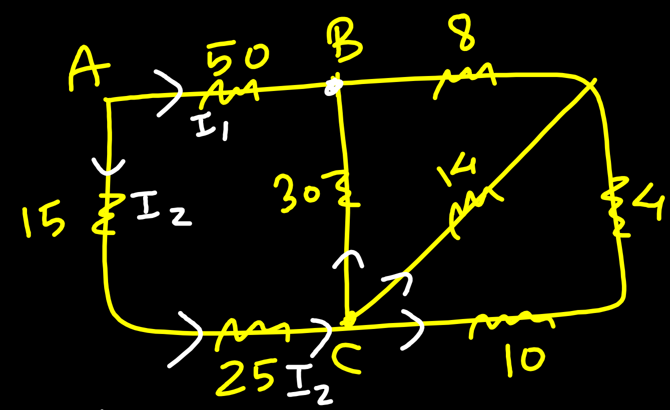
all r

r/7



Short circuit

Q



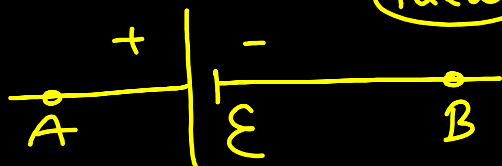
A & B eq $R_{eq} = 25\Omega$

H.W. A & C eq $R_{eq} = 24\Omega$

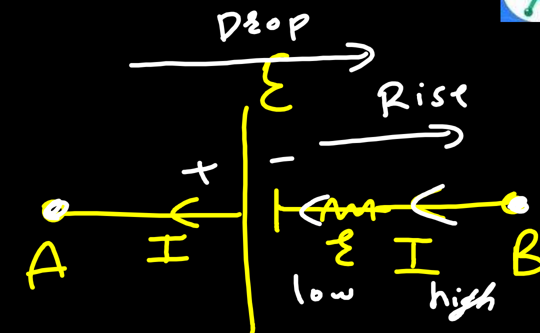
H.W. B & C " $R_{eq} = 9\Omega$

Internal Resistance of Cell/Battery

ideal

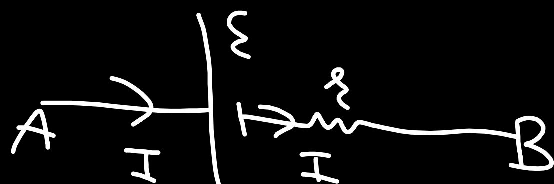
① 

$$\boxed{V_A - V_B = \varepsilon}$$

② 

$$V_A - \varepsilon + Ir = V_B$$

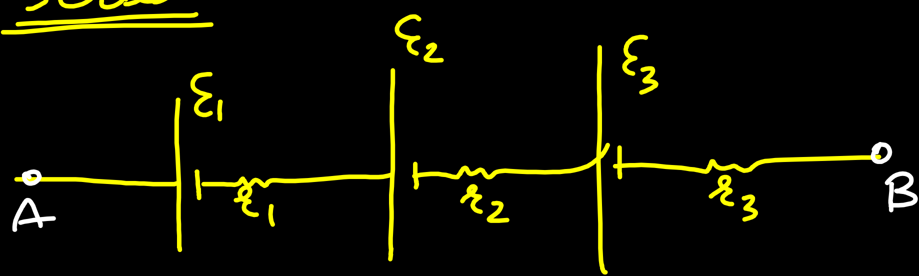
$$\boxed{V_A - V_B = \varepsilon - Ir}$$

③ 

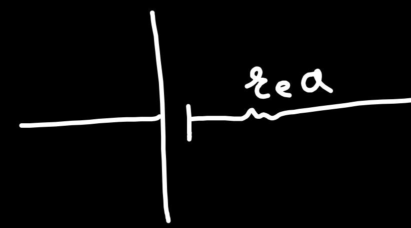
$$\boxed{V_A - V_B = \varepsilon + Ir}$$

Combination of Cells

① Series



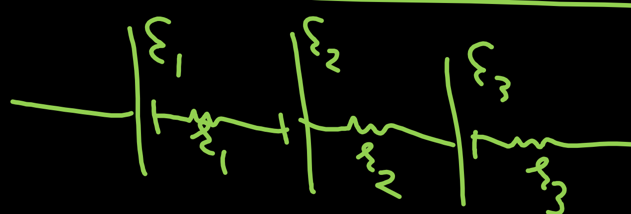
$\Rightarrow$



$$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \dots$$

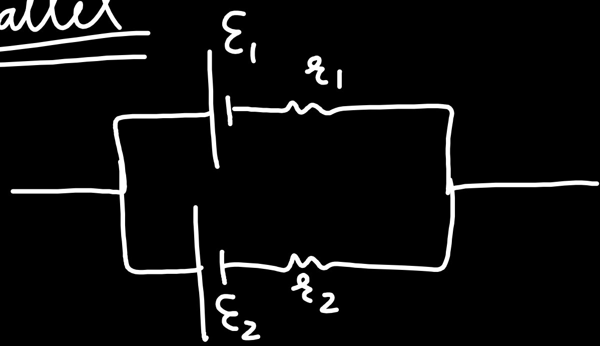
$$r_{eq} = r_1 + r_2 + r_3 + \dots$$

if anyone of Opp Polarity

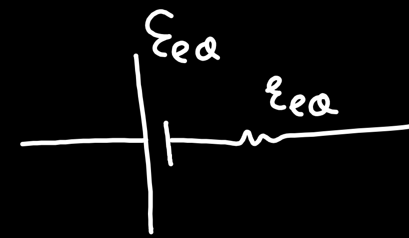


$$\boxed{\begin{aligned} \varepsilon_{eq} &= \varepsilon_1 - \varepsilon_2 + \varepsilon_3 \\ r_{eq} &= r_1 + r_2 + r_3 \end{aligned}}$$

② Parallel



$\Rightarrow$



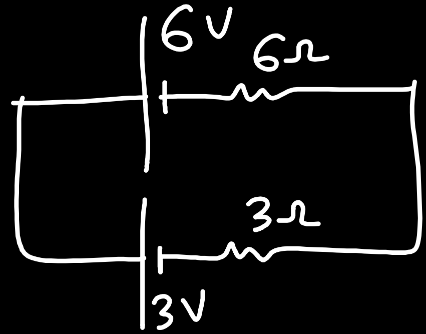
$$\varepsilon_{eq} = \frac{\left(\frac{\varepsilon_1}{r_1}+\frac{\varepsilon_2}{r_2}+\frac{\varepsilon_3}{r_3}+\cdots\right)}{\left(\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}+\cdots\right)}$$

$$\frac{1}{r_{eq}} = \frac{1}{r_1}+\frac{1}{r_2}+\cdots$$

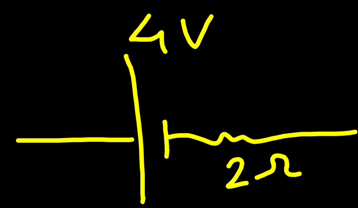
$\Rightarrow$ if any one opp polarity

$$\varepsilon_{eq} = \frac{\frac{\varepsilon_1}{r_1}-\frac{\varepsilon_2}{r_2}+\frac{\varepsilon_3}{r_3}}{\left(\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}\right)}$$

Q



$\Rightarrow$

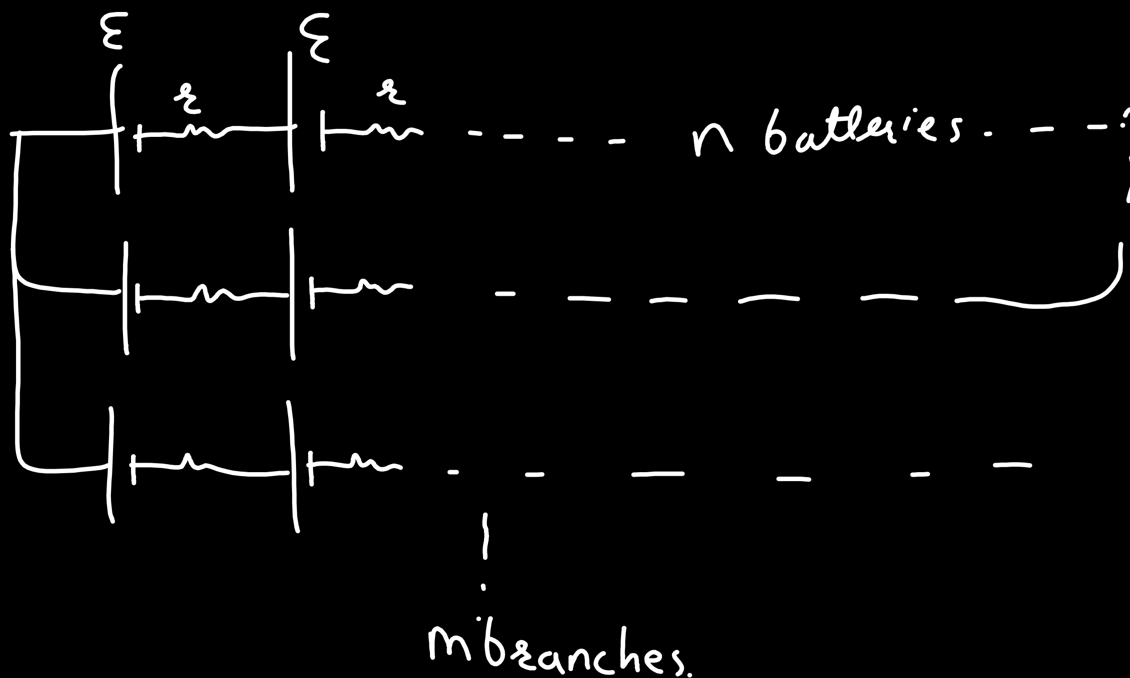


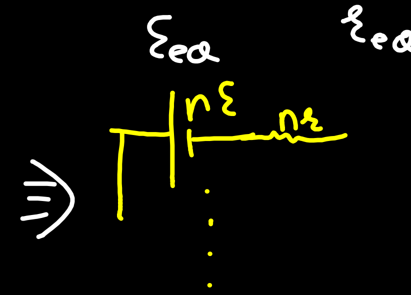
$$\varepsilon_{eq} = \frac{\left(\frac{6}{6}+\frac{3}{3}\right)}{\left(\frac{1}{6}+\frac{1}{3}\right)} = \frac{(1+1)}{1/2} = 4$$

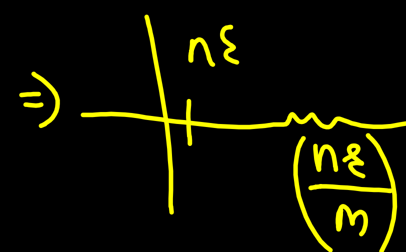
$$\frac{1}{r_{eq}} = \frac{1}{6}+\frac{1}{3} = \frac{3}{6} = \frac{1}{2}$$

$$r_{eq} = 2\Omega$$

Q//





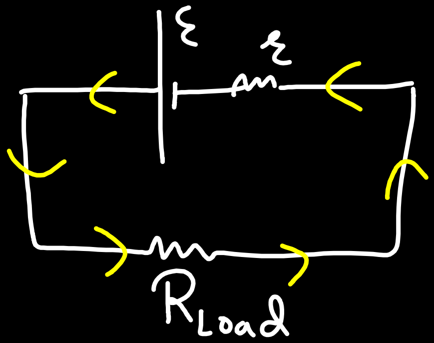


$$\varepsilon_{eq} = \frac{\left(\frac{n\varepsilon}{nr} + \frac{n\varepsilon}{nr} + \dots m\text{ times}\right)}{\left(\frac{1}{nr} + \frac{1}{nr} + \dots m\text{ times}\right)} = \frac{\frac{m\varepsilon}{\cancel{r}}}{\frac{\cancel{m}}{n\cancel{r}}} = n\varepsilon$$

$$R_{Load} = \frac{nr}{m}$$

for max Power.

Maximum Power Theorem



$$R_{Load} = r_{internal}$$

$$R_{eq} I = V$$

$$I = \frac{V}{R_{eq}} = \frac{\varepsilon}{R + r}$$

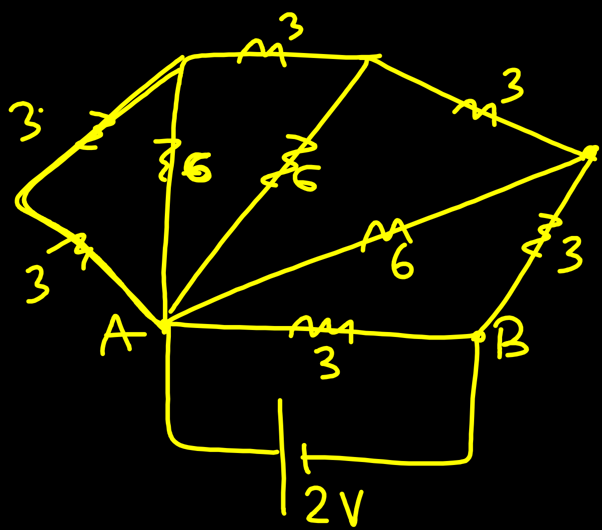
$$P = I^2 R_{Load}$$

$$P = \left(\frac{\varepsilon}{R + r}\right)^2 R$$

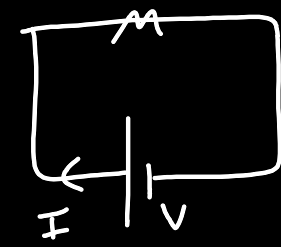
$$\frac{dP}{dR} = 0$$

Circuit Solving

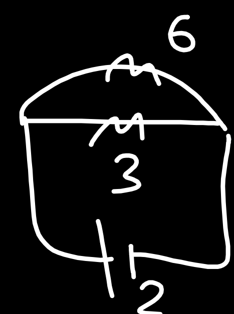
Circuit Reduction using EQR concept

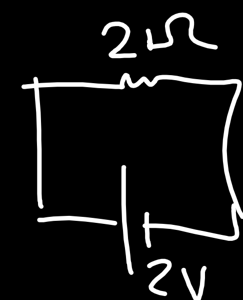


$\Rightarrow$



$$I = \frac{V}{R_{eq}}$$

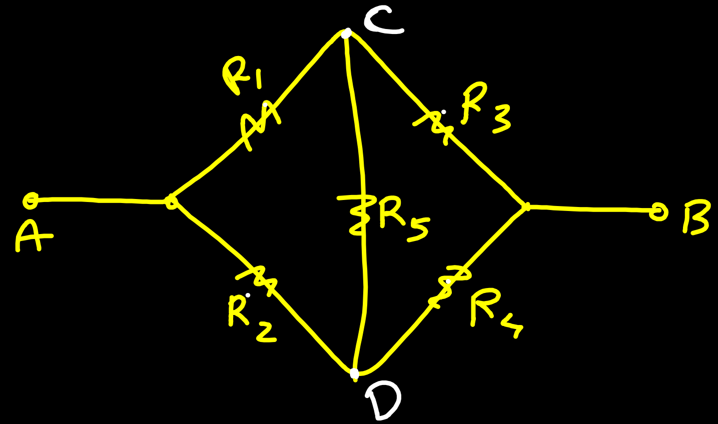




$$I = \frac{2}{2} = 1A$$

$$R_{eq} = \frac{\cancel{6}^{\,2}\times\cancel{3}^{\,1}}{\cancel{9}_{\,3}}$$

#WheatStone Bridge

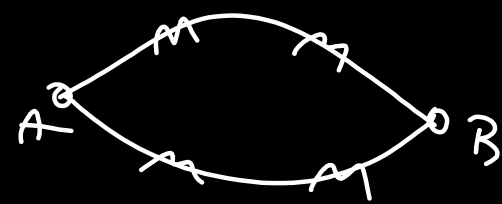


$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

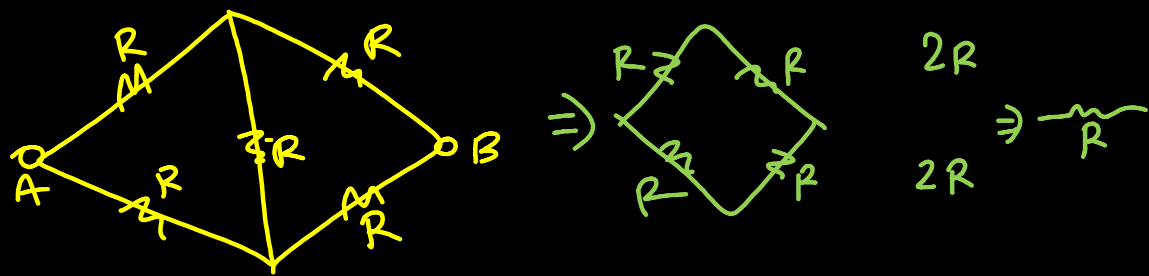
than $V_C = V_D$

& no current flow in R_5

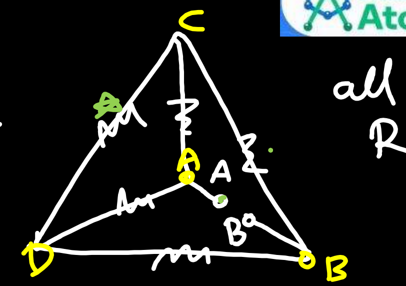
we can remove R_5



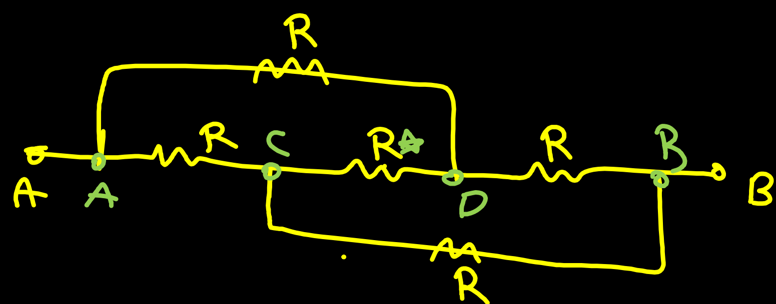
Q



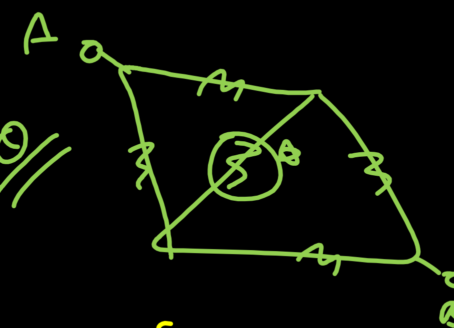
Q

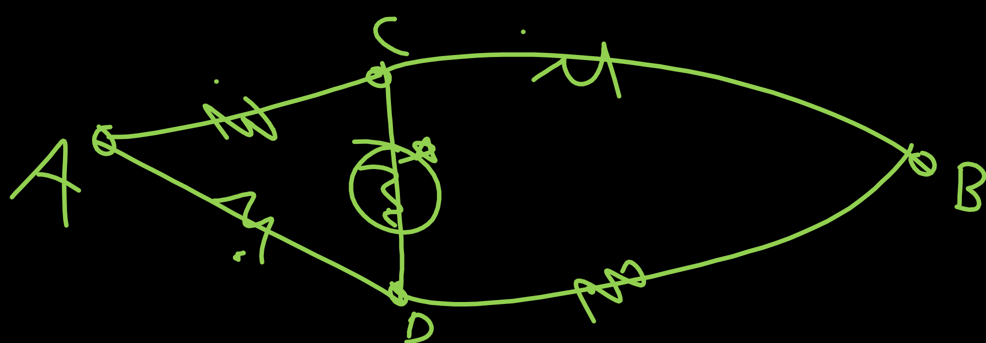


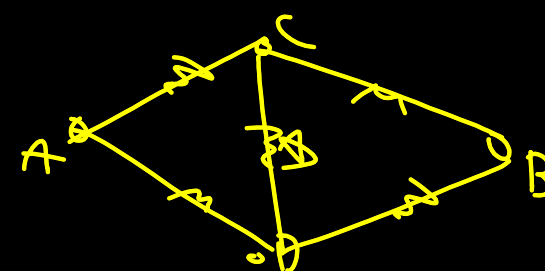
Q



Q

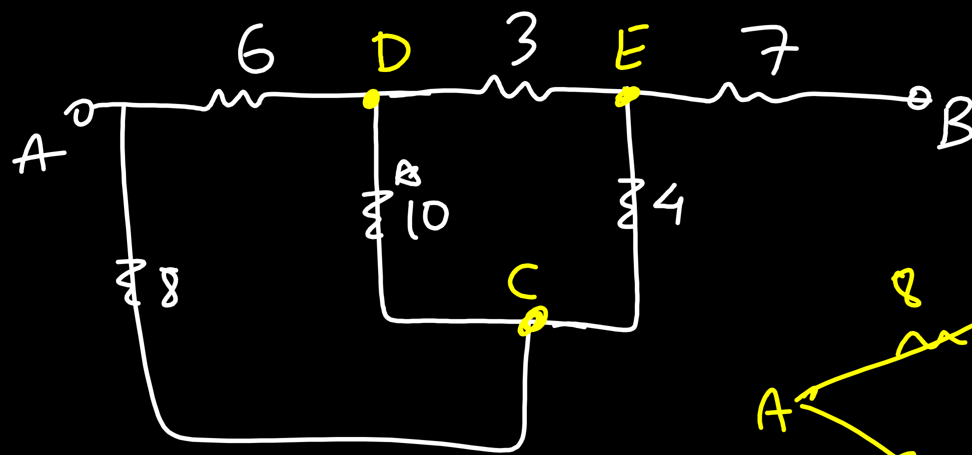


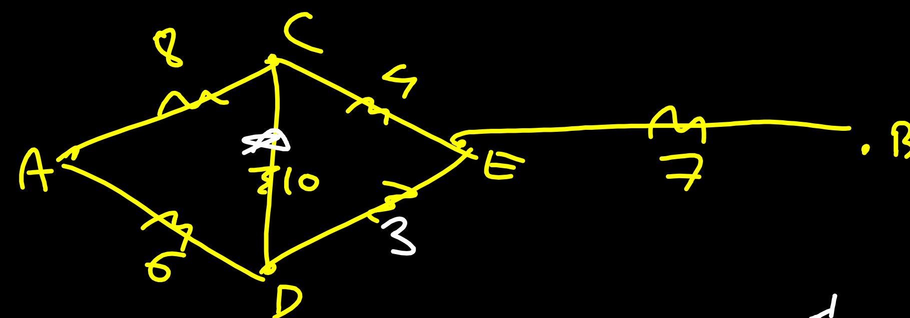




R

Q



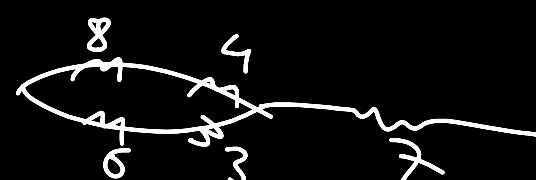


$$\frac{12\times\cancel{9}\,3}{\cancel{21}\,7}$$

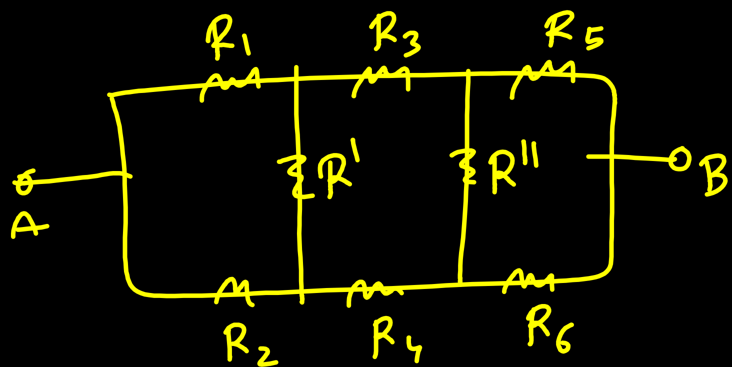
$$\frac{36}{7}$$

12

9

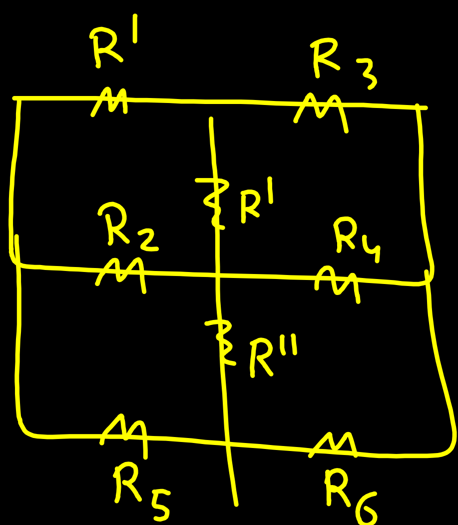


$$\frac{36}{7}+7=\frac{85}{7}\,\Omega$$



$$\frac{R_1}{R_2} = \frac{R_3}{R_4} = \frac{R_5}{R_6}$$

than we can remove R' & R''



$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

& $$\frac{R_2}{R_5} = \frac{R_4}{R_6}$$

$$\frac{R_1}{R_3} = \frac{R_2}{R_4} = \frac{R_5}{R_6}$$

R' & R'' removed

Break after 20 min

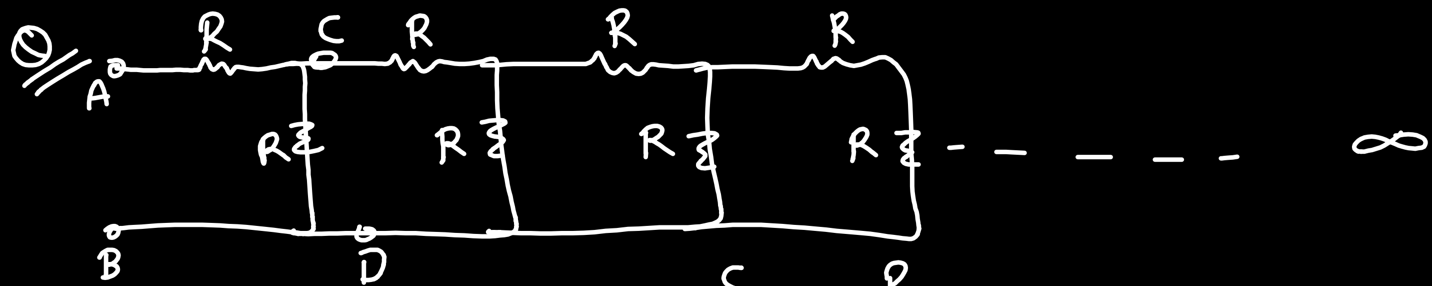
8:25 Resume

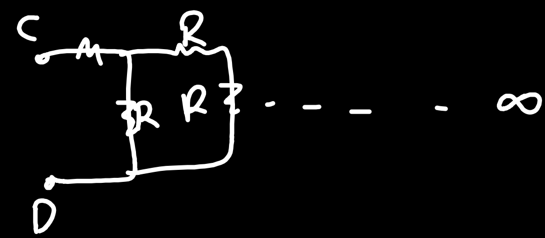
Enroll in Free Special Class tomorrow

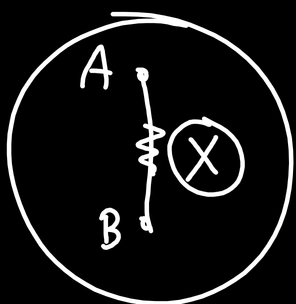
Use Code AT24

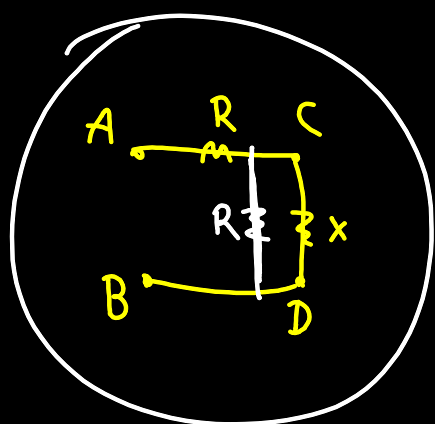
Link in Comment & description

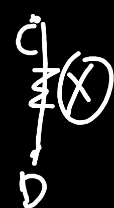
∞ Ladder Problems











Concept

$(\infty - 1) = \infty$

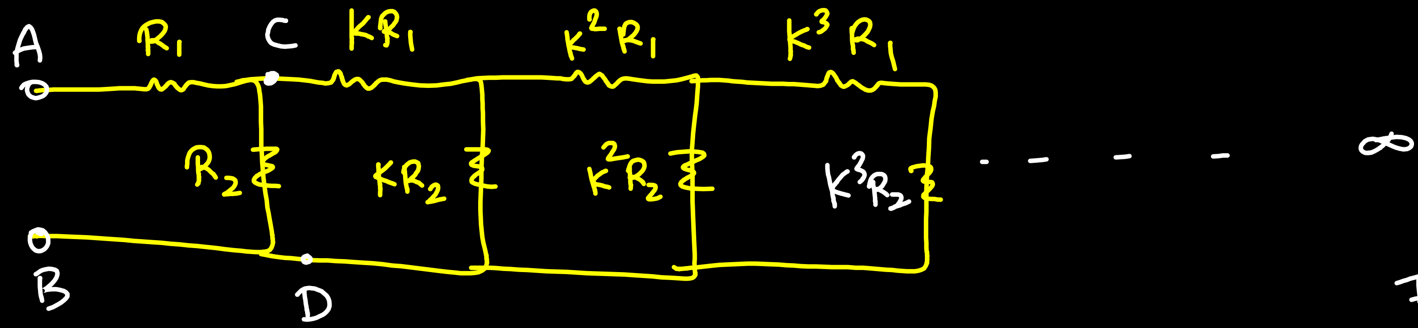
$$\frac{XR}{X+R} + R = X$$

$$\left(\frac{XR}{X+R}\right) = (X - R)$$

$$X^2 - XR - R^2 = 0$$

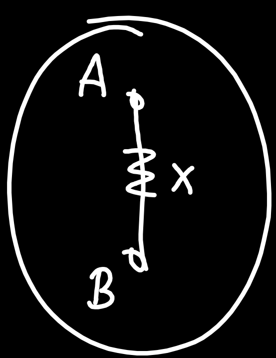
$$X = \frac{(\sqrt{5}+1)R}{2}$$

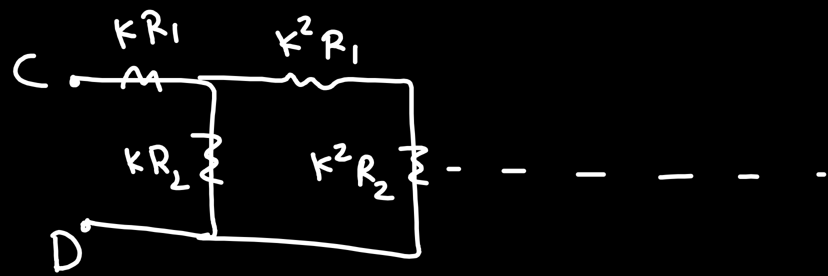
Q

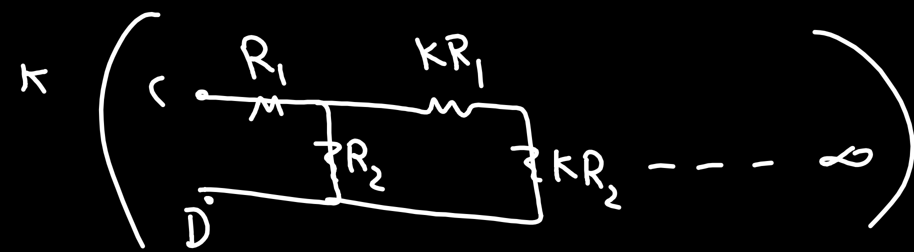


If AB $R_{eq} = X$

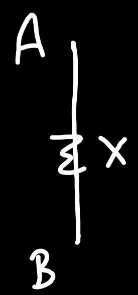
CD $R_{eq} = (X)K$

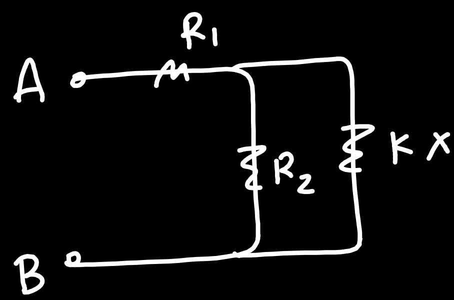






$K(X)$



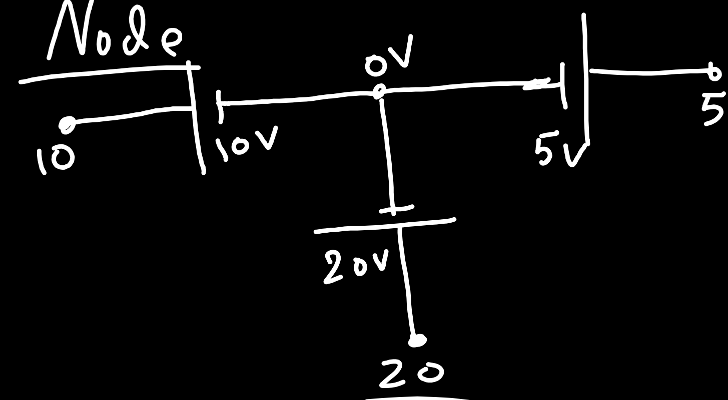


$$\boxed{X = R_1 + \frac{(kX)R_2}{kX + R_2}}$$

Solve.

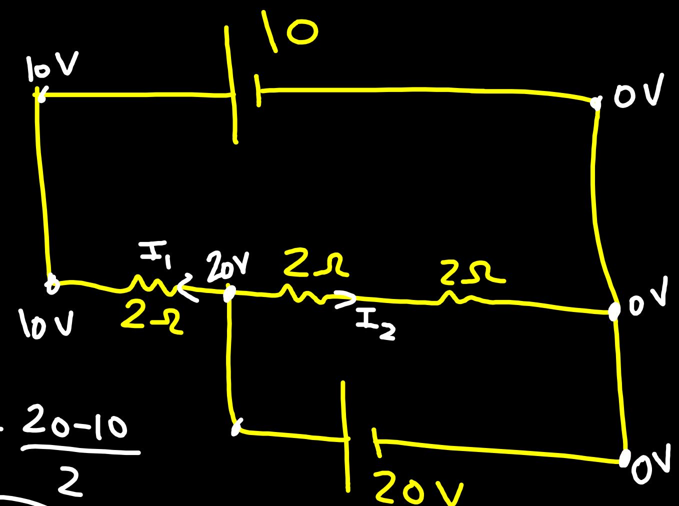
Nodal Analysis

Node



$$I = \frac{\Delta V}{R_{eq}}$$

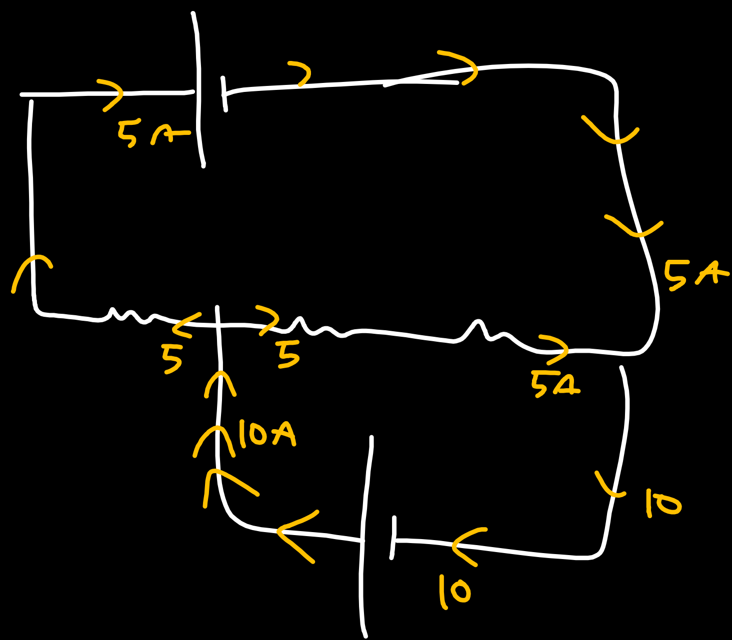
Q



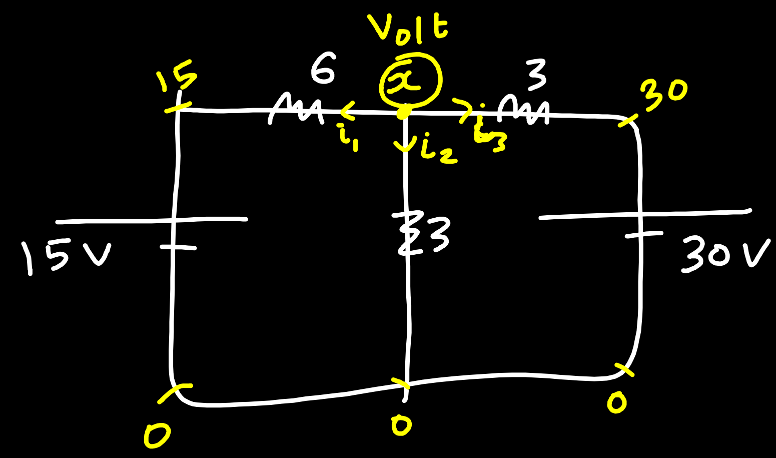
$$I_1 = \frac{20-10}{2}$$

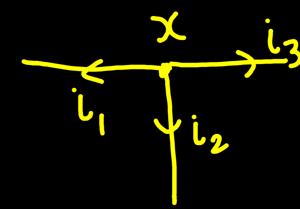
$$I_1 = 5A$$

$$I_2 = \frac{20-0}{4} = 5A$$


5A
5
5
5A
5A
10A
10
10

Q//





$$i_1 = \frac{x-15}{6}$$

$$i_2 = \frac{x-0}{3}$$

$$i_3 = \frac{x-30}{3}$$

$$i_1 + i_2 + i_3 = 0$$

$$\frac{x-15}{6} + \frac{x}{3} + \frac{x-30}{3} = 0$$

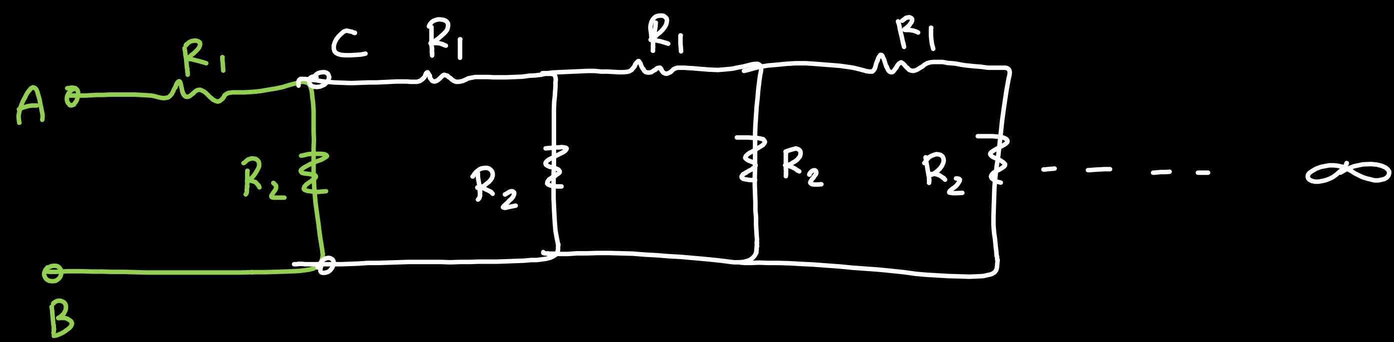
$$\frac{x-15}{6} + \frac{2x-30}{3} = 0$$

$$x - 15 + 4x - 60$$

$$5x = 75$$

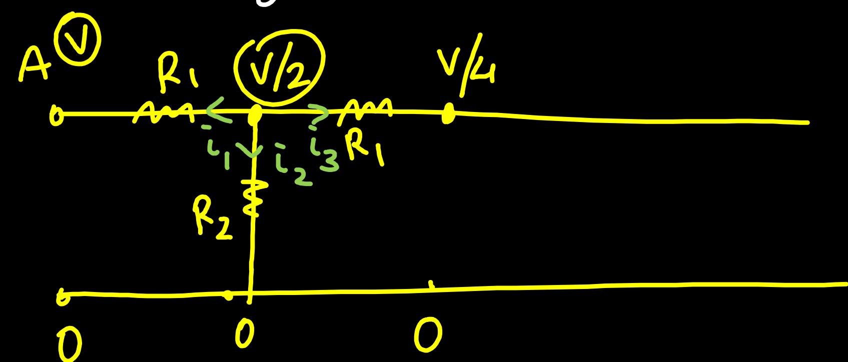
$$x = 15$$

Q



After every section voltage is halved. $\Delta V_{AB} = V$

Find $\frac{R_1}{R_2} = ?$



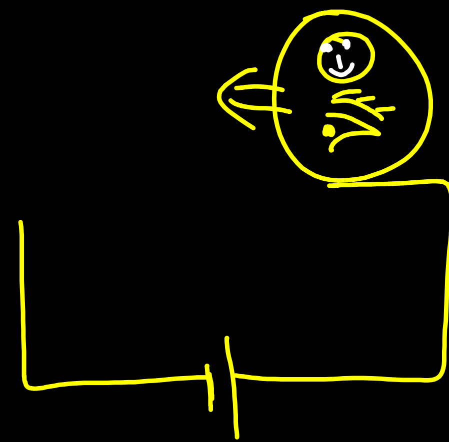
$$i_1 + i_2 + i_3 = 0$$

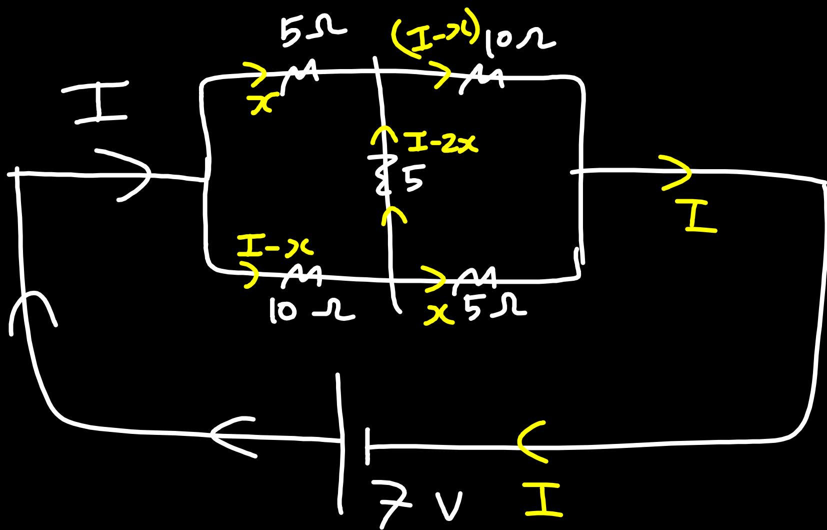
$$\frac{\left(\frac{V}{2} - V\right)}{R_1} + \frac{\left(\frac{V}{2} - 0\right)}{R_2} + \frac{\left(\frac{V}{2} - \frac{V}{4}\right)}{R_1} = 0$$

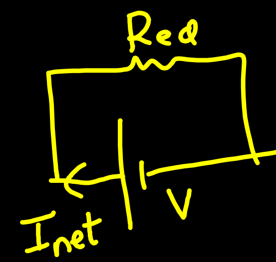
$$\frac{R_1}{R_2} = \frac{1}{2}$$

time/ajitlulla

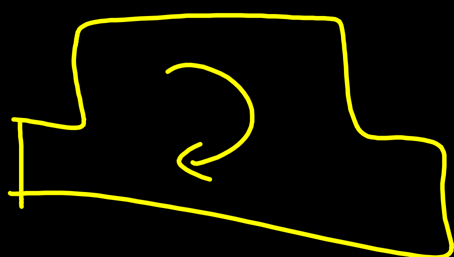
Battery Symmetry







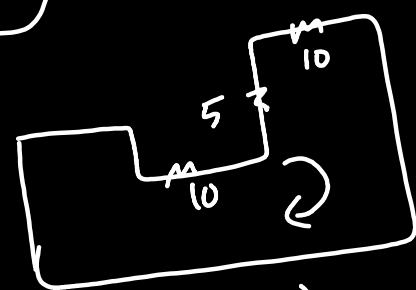
$$I_{net} = \frac{V}{R_{eq}}$$



$$-x5 - (I-x)10 + 7 = 0$$

$$7 = 5x + 10I - 10x$$

$$7 = 10I - 5x$$



$$-(I-x)10 - (I-2x)5 - (I-x)10 + 7 = 0$$

$$7 = 25I - 30x$$

$$7 = 10I - 5x \Big] \times 6$$

$$7 = 25I - 30x$$

$$42 = 60I - 30x$$

$$- \quad 7 = {}^{-}25I \; {}^{-}{-}30x$$

$$35 = 35I$$

$$1 = I$$

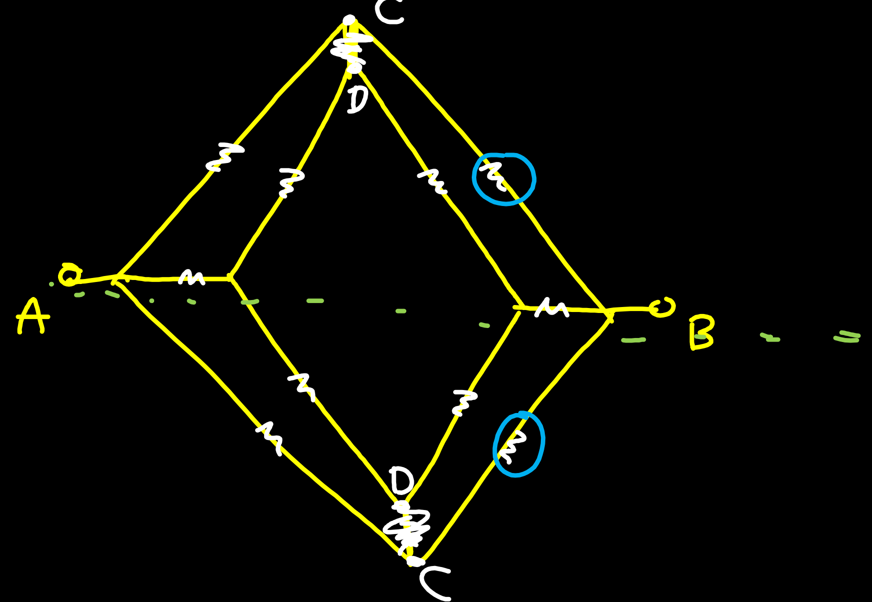
$$I = \frac{V}{R_{eq}} = \frac{7}{R_{eq}} = 1$$

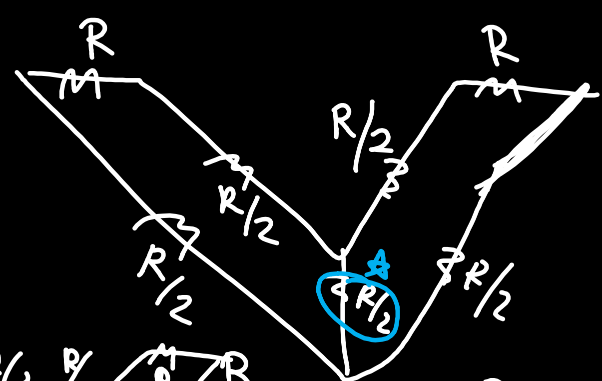
$$R_{eq} = 7\Omega$$

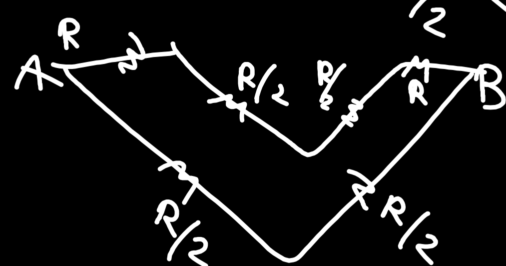
AB line itself is line of Symmetry (Req is required about AB)

→ Can be Folded about AB

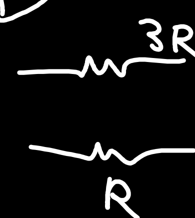
→ mirror image points have Same potential.





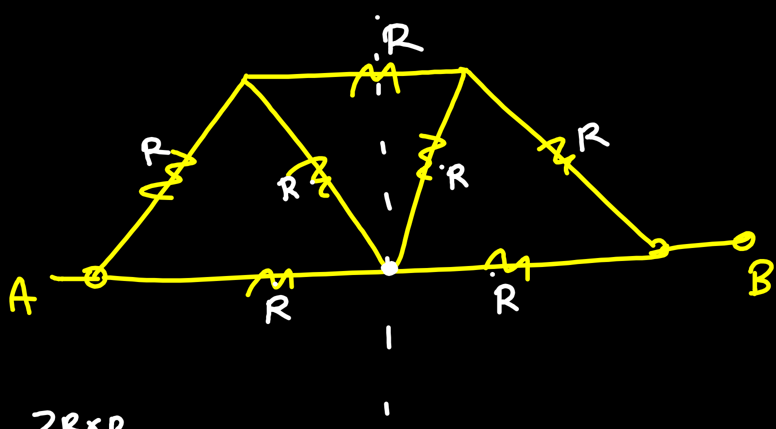


$\Rightarrow$

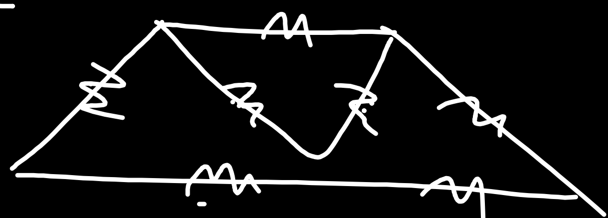


$= \frac{3R}{4}$

$\perp$'ve line of Symmetry



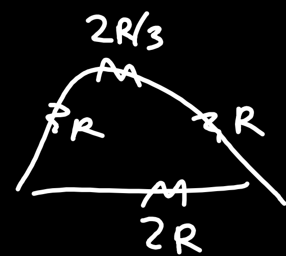
$\frac{2R \times R}{3R}$

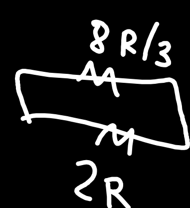


$1+1+\frac{2}{3}$

$2+\frac{2}{3}$

$\Rightarrow$



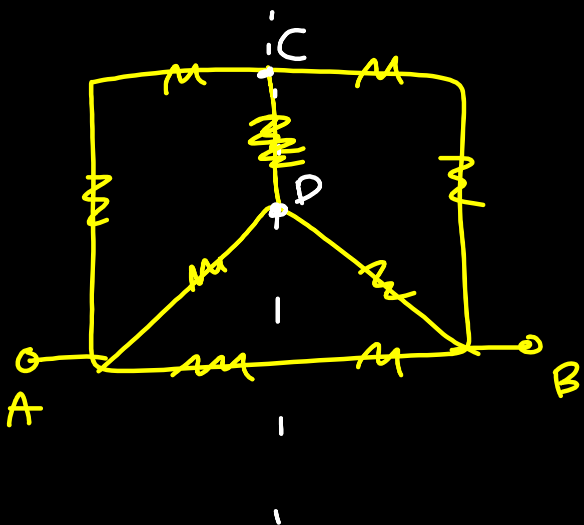


$= \frac{\frac{8R}{\cancel{3}} \times 2R}{\frac{14R}{\cancel{3}}} = \frac{8R}{7}$

→ Connection Removal

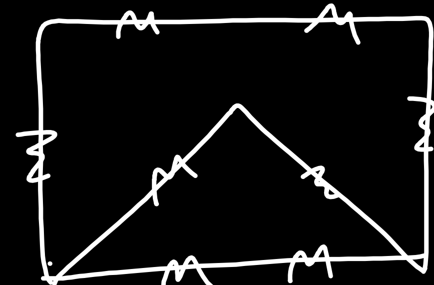
→ mirror image resistors have same I but sense is always +ve to -ve

→ Points lying on this line of symmetry have same Voltage.



$$V_C = V_D$$

$\Rightarrow$



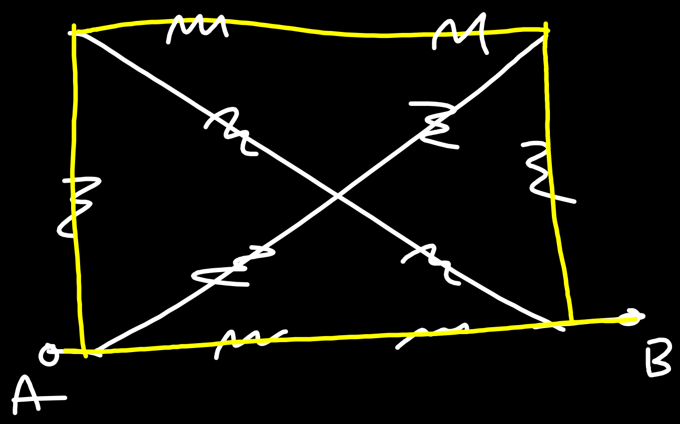
4R

2R

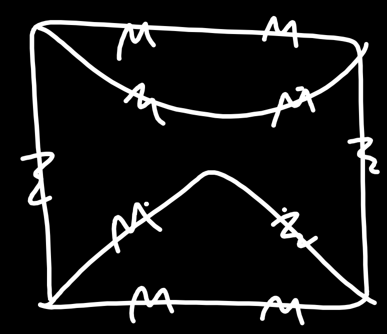
2R

$$\frac{1}{R_{eq}} = \frac{1}{2R} + \frac{1}{2R} + \frac{1}{4R}$$

$$R_{eq} = \frac{4R}{5}$$

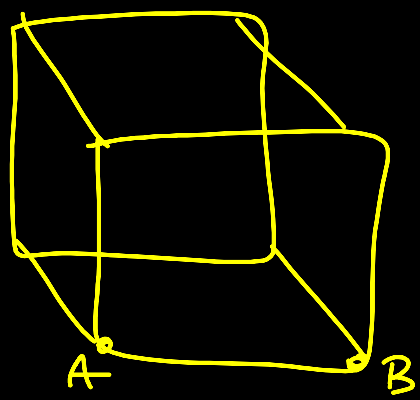

A
B

=



Cube

1234567



edge

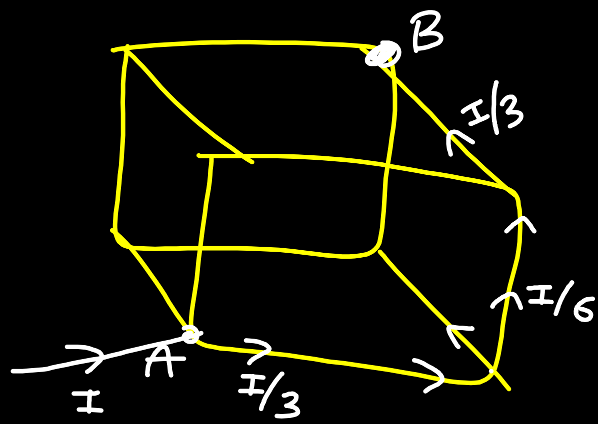
face digonal

body digonal.

$\frac{7}{12}R$ $\frac{3}{4}R$ $\frac{5}{6}R$

$\frac{7R}{12}$ $\frac{3R}{4}$ $\frac{5R}{6}$

Body Digonal



A to B

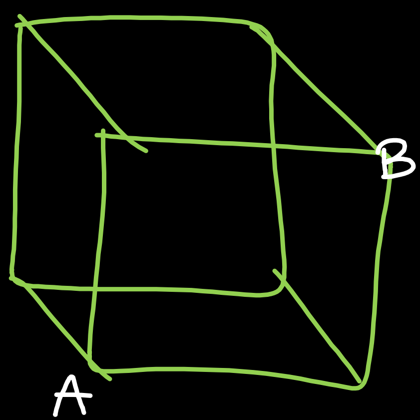
$$-\frac{I}{3}R - \frac{I}{6}R - \frac{I}{3}R + V = 0$$

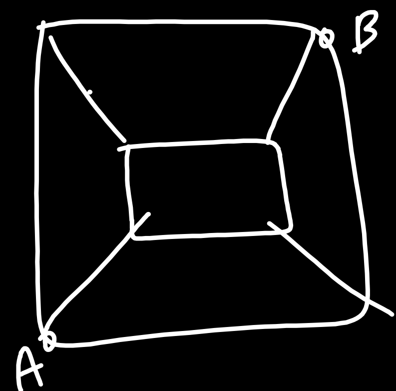
$$V = \left(\frac{5R}{6}\right) I$$

$$V = I R_{eq}$$

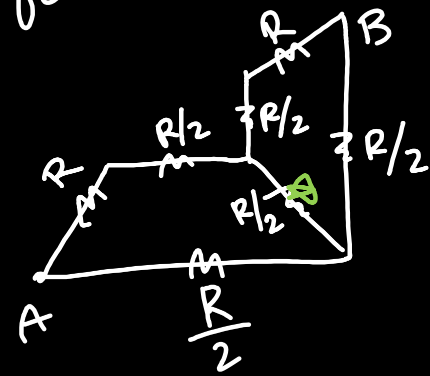
$$R_{eq} = \frac{5R}{6}$$

Face Diagonal

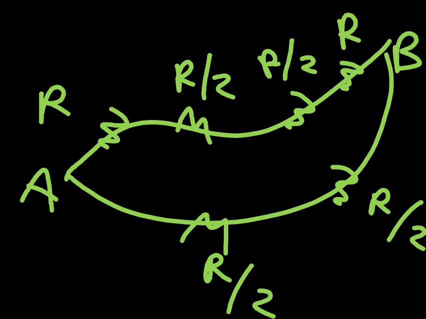




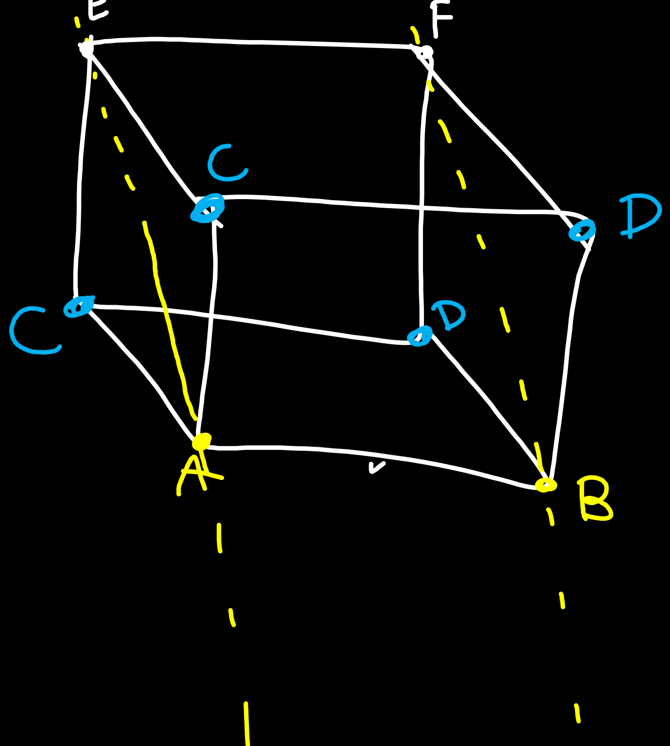
fold about AB



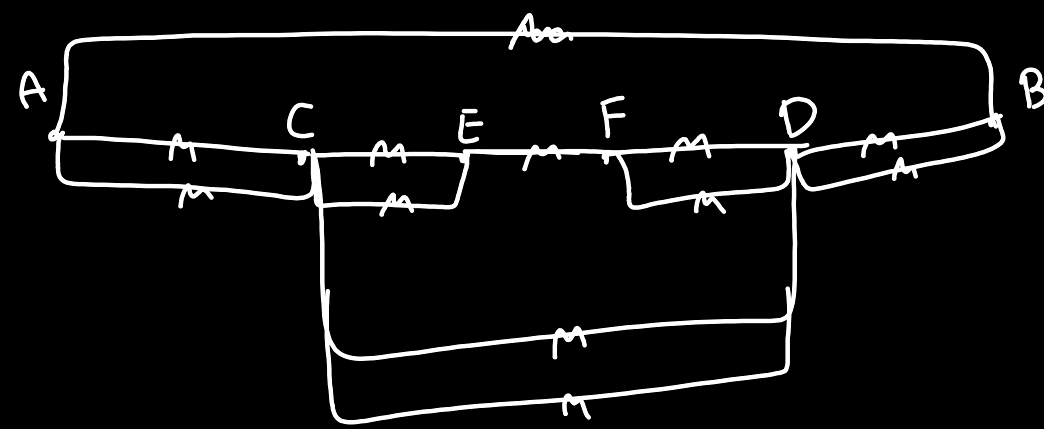
$$\frac{3R}{4} =$$



Edge

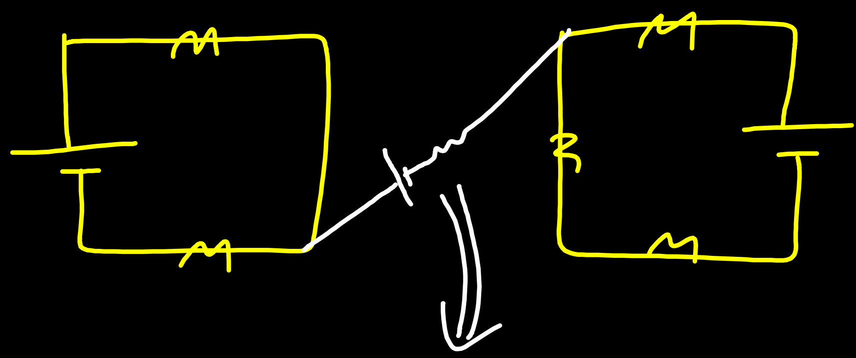


(plane of Symmetry Passing through AB)
mirror images have same Voltage.



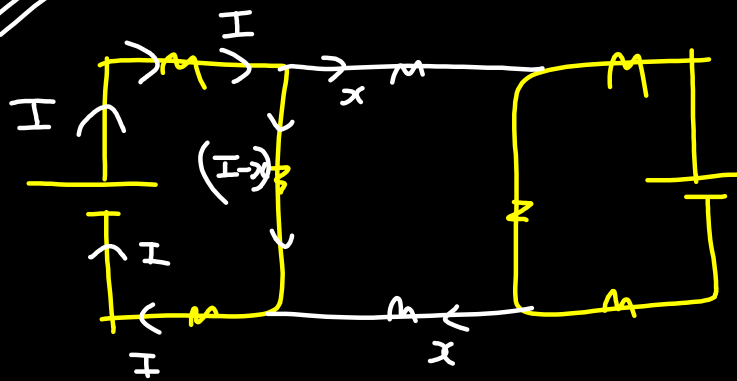
$$= \frac{7R}{12}$$

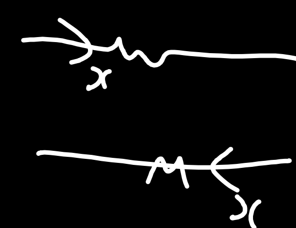
Two independent circuits Connected by single or two wires.



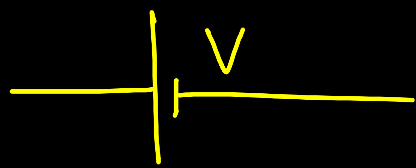
I in this is 0

Q//



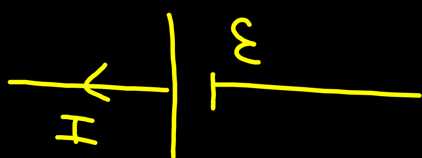


Heating Effect



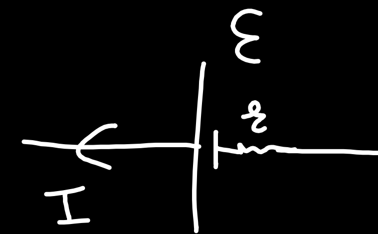
WD by battery $= QV$

$= (Q\,\Delta V)$

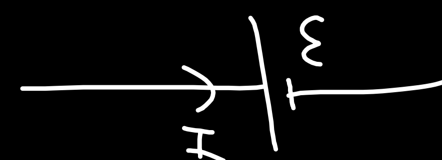


Power by battery $= (I)(\varepsilon_{mf})$

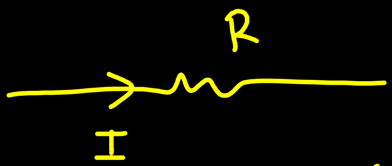
$= \underline{\underline{VI}}$



Power by battery $= I\left(\varepsilon - Ir\right)$



Power consumed by battery $= \varepsilon I$

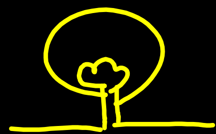


Power lost/dissipated $= I^2R = \dfrac{(\Delta V)^2}{R}$

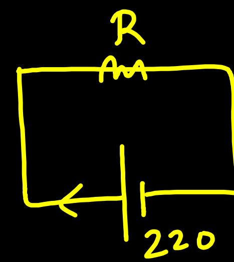
$$\Delta V = IR$$

$$\text{Heat} = (P)t$$
$$= I^2Rt$$
$$= \int I^2R\,dt$$

Bulb



100 Watt
220 Volt



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

$$100 = \frac{(220)^2}{R}$$

$$\boxed{R = \frac{(220)^2}{100}}$$

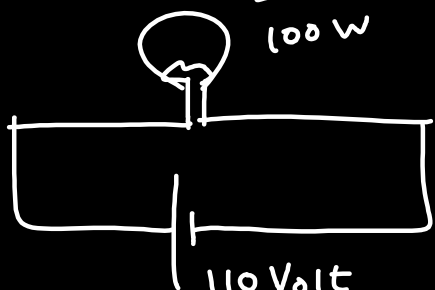
→ if 220 Volt is applied P is 100 Watt

→ max voltage it can handle is 220 volt

→ rating से resistance आता है।

Q.

220V
100 W



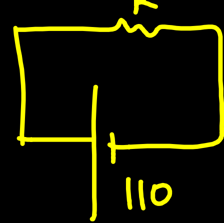
110 Volt

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

$\boxed{R = \frac{V_0^2}{P_0}}$

Find Power dissipated by bulb??

R



110

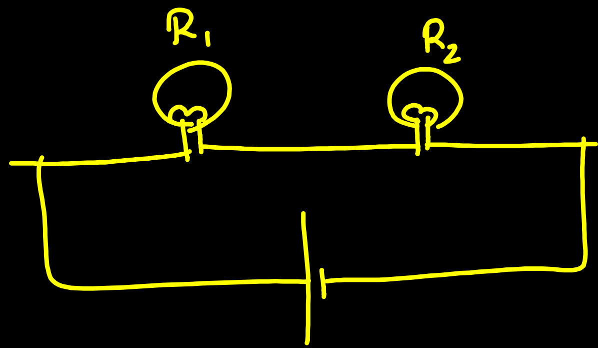
$P = \frac{(110)^2}{R}$

Ans. $\Rightarrow \frac{\cancel{110}\,\cancel{110}}{\cancel{484}} = \boxed{25\,W}$

$R = \frac{(220)^2}{100}$

$R = \frac{484\cancel{00}}{1\cancel{00}}$

Q.

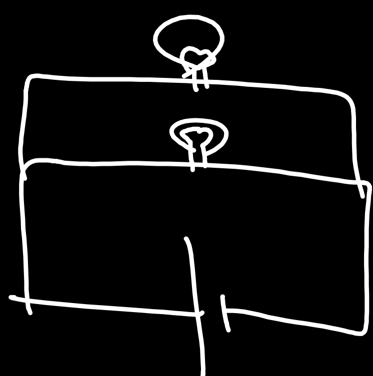


which glows more brighter

$$Power = I^2 R$$

Jiska R more Woh Jyada bright

Q.

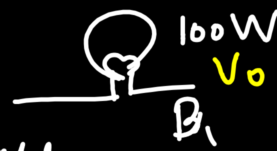


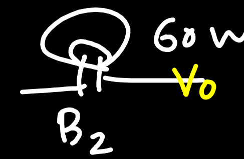
$$P = \frac{V^2}{R}$$

Jiska R less uska bright more

Home

Parallel



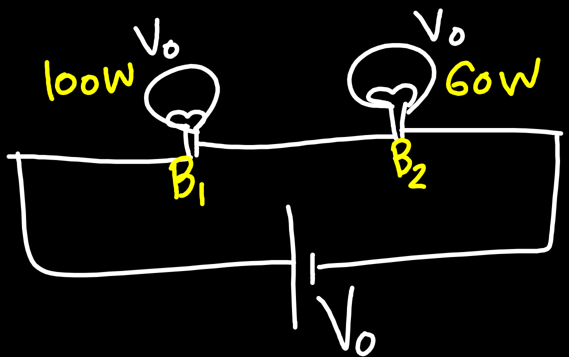


B_1 glows more bright

Series

B_2 glows brighter

Q// Series



Power $= I^2R$

more R more bright

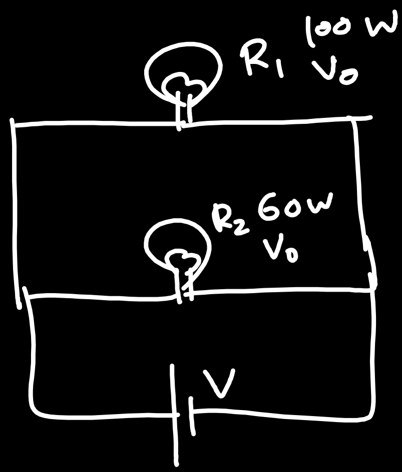
B_2 " "

$R = \frac{V_0^2}{P_0}$

bulb with less Power rating glow more relatively than other one.

$R_1 = \frac{V_0^2}{100}$ $\quad R_2 > R_1$

$R_2 = \frac{V_0^2}{60}$



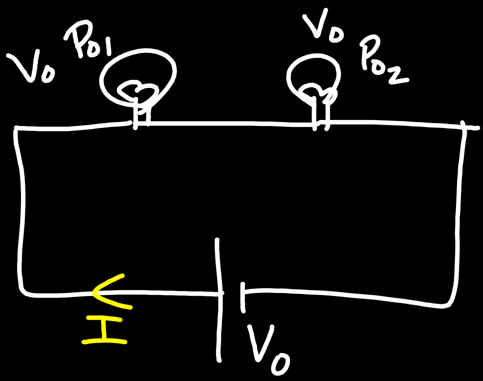
$R_2 > R_1$

$$\text{Power} = \frac{V_0^2}{R}$$

B_1 more bright

in Parallel Connection more Power rating more bright.

#



$$I = \frac{V_0}{R_1 + R_2}$$

$$R_1 = \frac{V_0^2}{P_{01}}$$

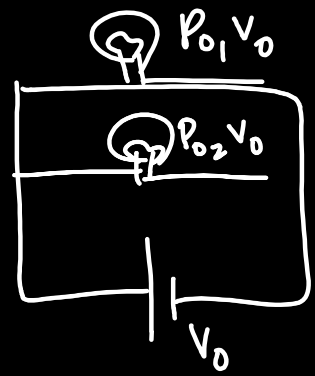
$$R_2 = \frac{V_0^2}{P_{02}}$$

$$\boxed{P_{net\ consumed} = \frac{P_{01} P_{02}}{P_{01} + P_{02}}}$$

$$P_{net} = I^2 R_1 + I^2 R_2$$

$$= I^2 (R_1 + R_2)$$

$$= \frac{V_0^2}{R_1 + R_2}$$



$$P_{net} = \frac{V_0^2}{R_1} + \frac{V_0^2}{R_2}$$

$$R_1 = \frac{V_0^2}{P_{0_1}}$$

$$R_2 = \frac{V_0^2}{P_{0_2}}$$

$$P_{net} \text{ consumed} = P_{0_1} + P_{0_2}$$

Q. An electric kettle has two heating coils.

One boils water in 3 min

other " " " 6 min

Find time to boil

① if both are connected in series.

② " " " " " parallel

$t = 9$ min

$t = \frac{3 \times 6}{3+6} = \frac{\cancel{3} \times \cancel{6}^{2}}{\cancel{9}\,3} = 2$ min

$H = Pt$

$H = P_1 t_1$ $\qquad P_1 = H/t_1$

$H = P_2 t_2$ $\qquad P_2 = H/t_2$

Series

$$P_{net} = \frac{P_1 P_2}{P_1 + P_2}$$

$$H = \left(\frac{P_1 P_2}{P_1 + P_2}\right) t_{net}$$

$$t_1 + t_2 = t_{net}$$

Series

$$R = R_1 + R_2$$

$$t = t_1 + t_2$$

$$P = \frac{P_1 P_2}{P_1 + P_2}$$

||

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

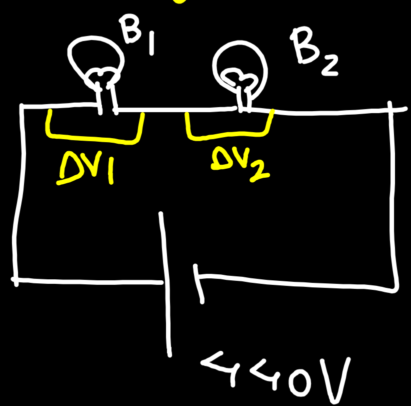
$$t = \frac{t_1 t_2}{t_1 + t_2}$$

$$P = P_1 + P_2$$

Q// Two electric bulbs rated 25W-220V & 100W-220V are connected in series with 440V. Which of them will fuse.

$\Delta V_1 = I(4R)$

$\Delta V_2 = I(R)$



$R_1 = \frac{V_0^2}{P_0} = \frac{(220)^2}{25}$

$= \frac{\cancel{48400}^{4}}{\cancel{25}}$

$R_1 = (22)^2 4$

$4R$

$R_2 = \frac{(220)^2}{100}$

$= 484$

$R_2 = (22)^2$

R

B_1: $4V$ $\quad$ $B2$: V

$4V + V = 440$

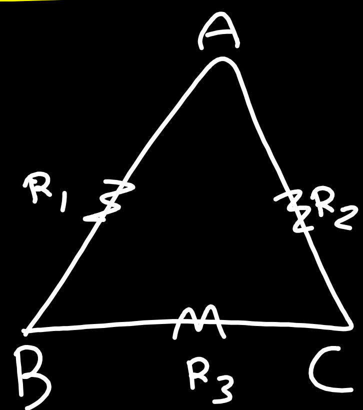
$V = \frac{\cancel{440}^{88}}{\cancel{5}} = 88 \text{ Volt}$

$\Delta V_1 = 4 \times 88$

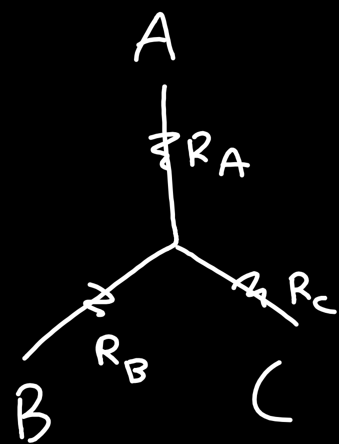
$$\begin{array}{r} 388 \\ \hline 352 \end{array}$$

Ans = B, will fuse

Star- Delta Conversion



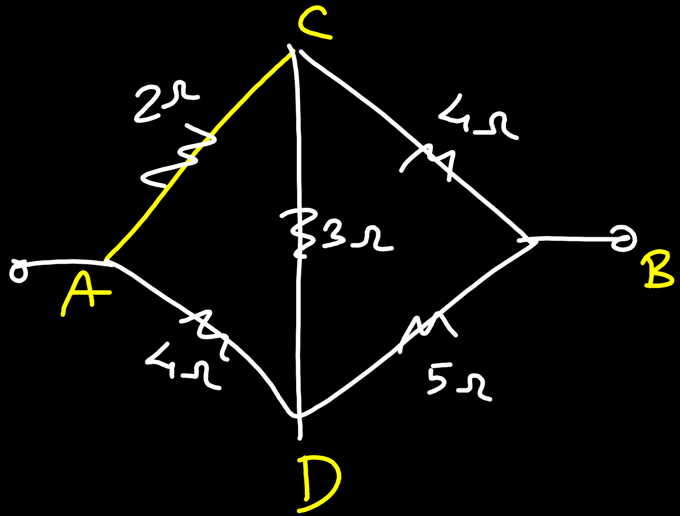
$\Rightarrow$

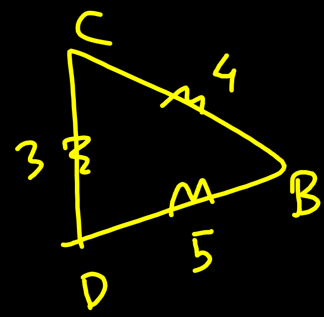


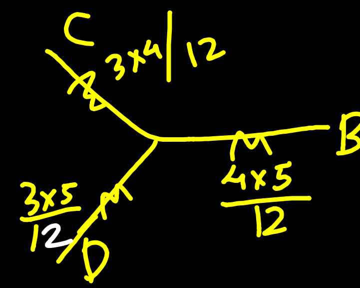
$$R_A = \frac{R_1 R_2}{R_1 + R_2 + R_3}$$

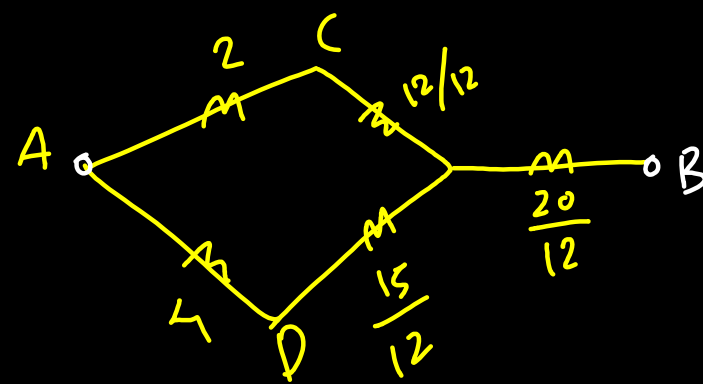
$$R_B = \frac{R_1 R_3}{\Sigma R}$$

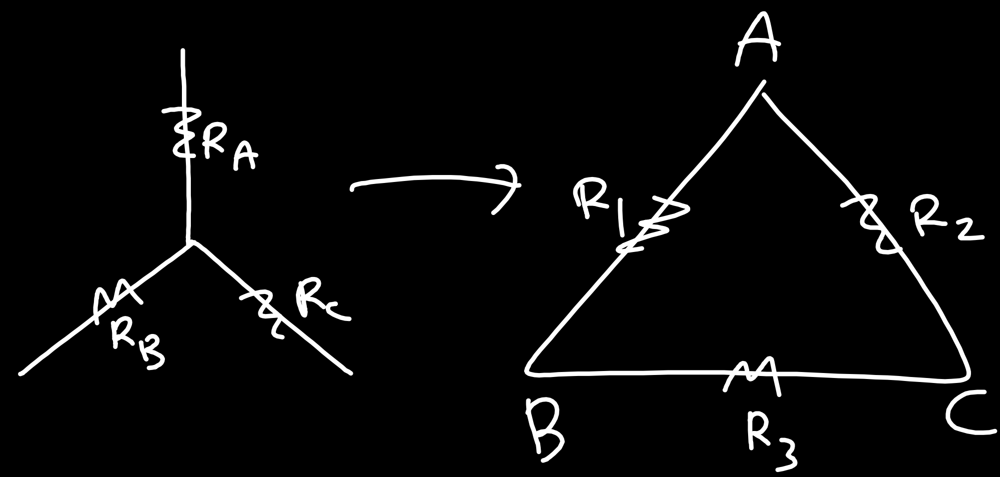
$$R_C = \frac{R_2 R_3}{\Sigma R}$$


C
2Ω
4Ω
3Ω
A
B
4Ω
5Ω
D


C
4
3
B
D
5


C
3x4/12
B
3x5/12
4x5/12
D


2
C
12/12
A
B
20/12
15/12
4
D



$$R_1 = \frac{R_A R_B + R_B R_c + R_c R_A}{R_c}$$

$$R_2 = \frac{\Sigma R_1 R_2}{R_B}$$

$$R_3 = \frac{\Sigma R_1 R_2}{R_A}$$

Next Session

→ Instruments

→ RC Circuits

A current of 10 A exists in a wire of cross sectional area of 5 mm^2 with a drift velocity of 2×10^{-3} ms^{-1}. The number of free electrons in each cubic meter of the wire is

Jee 2021

$e = 1.6 \times 10^{-19}$

$n = ?$

$I = 10$

$A = 5 mm^2 = 5 \times 10^{-6} m^2$

$I = n e A V_d$

$V_d = 2 \times 10^{-3} m/s$

(a) 2×10^6 (b) 625×10^{25} (c) 2×10^{25} (d) 1×10^{23}

A cylindrical wire of radius 0.5 mm and conductivity 5×10^7 S/m is subjected to an electric field of 10mV/m. The expected value of current in the wire will be $x^3\pi$mA. The value of x is 5

Jee 2021

$r = 0.5\,mm$

$r = 0.5 \times 10^{-3}\,m$

$\sigma = 5 \times 10^7\,S/m$

$E = 10 \times 10^{-3}\,V/m$

$\boxed{J = \sigma E}$

J find

$J = \frac{I}{A}$

$I = J(A)$

$= (J \pi r^2)$

$$I = J\,A$$

$$= (\sigma E)\,\pi r^2$$

$$= 5 \times 10^{7} \times 10 \times 10^{-3} \times \pi\,(0.5 \times 10^{-3})^{2}$$

$$x^3\,\pi\,\text{mA} = 125\,\pi \times 10^{-3}\,\text{A}$$

$$x^3 = 125$$

$$x = 5$$

A current of 5 A passes through a copper conductor (resistivity) $= 1.7 \times 10^{-8} \Omega m$) of radius of cross-section 5 mm. Find the mobility of the charges if their drift velocity is 1.1×10^{-3} m/s. [10 Apr. 2019 I]

(a) $1.8 \ m^2/Vs$

(b) $1.5 \ m^2/Vs$

(c) $1.3 \ m^2/Vs$

(d) $1.0 \ m^2/Vs$

$I = 5$

$\rho = 1.7 \times 10^{-8}$

$r = 5 \times 10^{-3} m$

$V_d = 1.1 \times 10^{-3}$

$\mu = \frac{V_d}{E} = \frac{e\tau}{m}$

$$J = \sigma E$$

$$\frac{I}{A} = \sigma E$$

$$\frac{I}{A} = \frac{1}{\rho} E$$

$$\frac{I\rho}{A} = E$$

$$\mu = \frac{V_d}{E}$$

$$= \frac{V_d A}{I\rho}$$

$$= \frac{1.1 \times 10^{-3} \times \pi (5 \times 10^{-3})^2}{5 \times 1.7 \times 10^{-8}}$$

$$\approx \frac{171}{170} \approx 1$$

In a conductor, if the number of conduction electrons per unit volume is $8.5 \times 10^{28}\ m^{-3}$ and mean free time is 25 *fs* (femto second), it's approximate resistivity is: ($m_e = 9.1 \times 10^{-31}$ kg) **[9 Apr. 2019 II]**

(a) $10^{-6}\ \Omega m$ (b) $10^{-7}\ \Omega m$

(c) $10^{-8}\ \Omega m$ (d) $10^{-5}\ \Omega m$

H.W

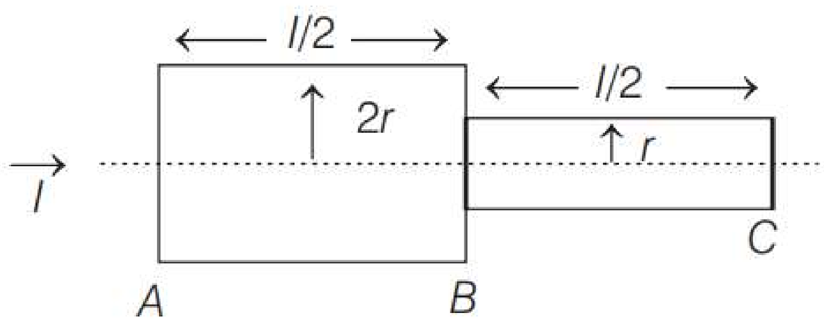
$n = 8.5 \times 10^{28}$

$\tau = 25 \times 10^{-15}$

$\sigma = \frac{ne^2\tau}{m}$

$\rho = \frac{m}{ne^2\tau}$

Two bars of radius r and $2r$ are kept in contact as shown. An electric current I is passed through the bars. Which one of following is correct ? **(2006)**



(a) Heat produced in bar BC is 4 times the heat produced in bar AB

(b) Electric field in both halves is equal

(c) Current density across AB is double that of across BC

(d) Potential difference across AB is 4 times that of across BC

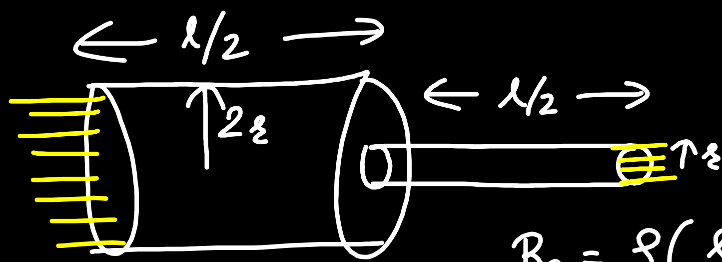
$H_2 = 4H_1$

$\frac{I^2R}{2} = 4\frac{I^2R}{8}$

$E = \frac{\Delta V}{l}$

$E_1 = \frac{(I\,R/8)}{l/2}$

$E_2 = \frac{(I\,R/2)}{l/2}$



$$R_1 = \frac{\rho(l/2)}{\pi(2r)^2}$$

$$R_1 = \frac{\rho l}{8\pi r^2} = R/8$$

$$H = I^2 R_1$$

$$H_1 = \frac{I^2 R}{8}$$

$$R_2 = \frac{\rho(l/2)}{\pi r^2}$$

$$= \frac{\rho l}{2\pi r^2}$$

$$R_2 = R/2$$

$$I^2 R_2$$

$$H_2 = \frac{I^2 R}{2}$$

$$J_1 = \frac{I}{\pi(2r)^2} = \frac{I}{4\pi r^2}$$

$$J_2 = \frac{I}{\pi r^2}$$

$$\Delta V = IR$$

$$\Delta V_1 = \frac{IR}{8}$$

$$\Delta V_2 = \frac{IR}{2}$$

$$\text{Heat} = I^2 R$$

$$\Delta V = IR$$

$$\Delta V = E(l)$$

$$\text{heat} = I^2 R$$

Series = I same

$$J = \frac{I}{A}$$

Space between two concentric conducting spheres of radii a and $b\,(b > a)$ is filled with a medium of resistivity ρ. The resistance between the two spheres will be

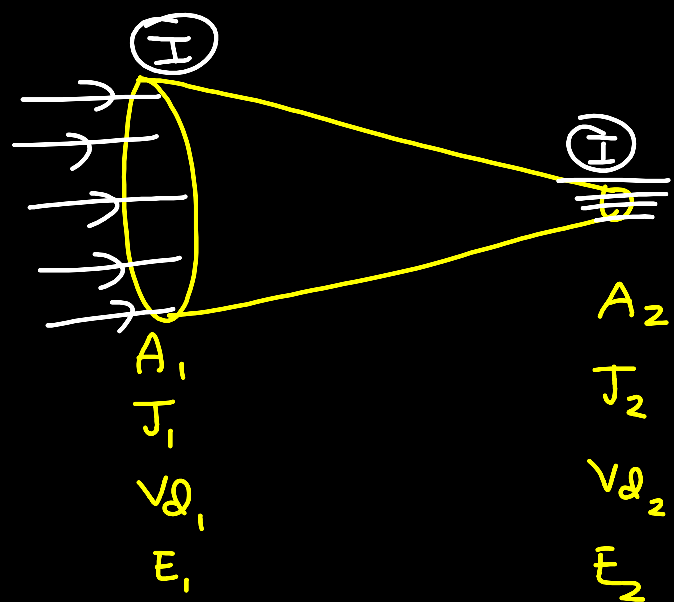
(2019 Main)

(a) $\frac{\rho}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$

(b) $\frac{\rho}{4\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$

(c) $\frac{\rho}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$

(d) $\frac{\rho}{4\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$



$A_1 > A_2$

$J_1 < J_2$

$v_1 < v_2$

$E_1 < E_2$

$$J = \frac{I}{A}$$

$$I = I$$

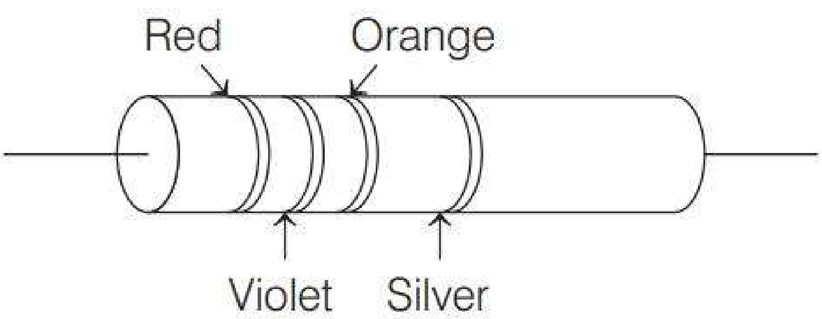
$$\cancel{n}\cancel{e} A_1 v_{d_1} = \cancel{n}\cancel{e} A_2 v_{d_2}$$

$$A_1 v_1 = A_2 v_2$$

$$v \propto \frac{1}{\text{area}}$$

$$J = \sigma E$$

A resistance is shown in the figure. Its value and tolerance are given respectively by **(2019 Main)**



(a) 270 Ω, 5% (b) 27 k Ω, 20%

(c) 27 k Ω, 10% (d) 270 k Ω, 10%

Red Violet Oran Silver

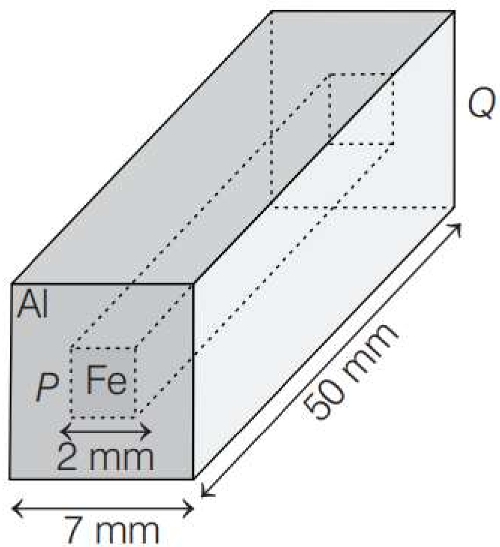
2 7 10^3 10%

$27 \times 10^3 \pm 10\%$

B 0
B 1
R 2
O 3
Y 4

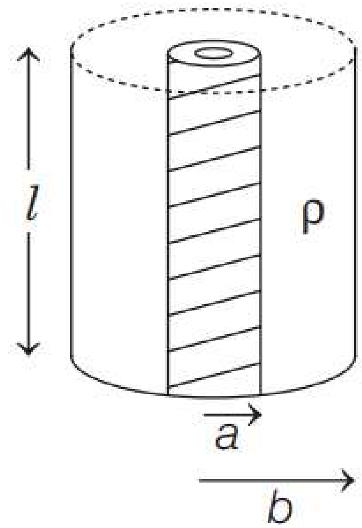
G 5
B 6
V 7

In an aluminium (Al) bar of square cross section, a square hole is drilled and is filled with iron (Fe) as shown in the figure. The electrical resistivities of Al and Fe are $2.7 \times 10^{-8}\ \Omega\text{m}$ and $1.0 \times 10^{-7}\ \Omega\text{m}$, respectively. The electrical resistance between the two faces P and Q of the composite bar is **(2015 Adv.)**



(a) $\frac{2475}{64}\mu\,\Omega$ (b) $\frac{1875}{64}\mu\,\Omega$ (c) $\frac{1875}{49}\mu\,\Omega$ (d) $\frac{2475}{132}\mu\,\Omega$

A torch battery of length l is to be made up of a thin cylindrical bar of radius a and a concentric thin cylindrical shell of radius b is filled in between with an electrolyte of resistivity ρ (see figure). If the battery is connected to a resistance R, the maximum joule's heating in R will takes place for



(2020 Main)

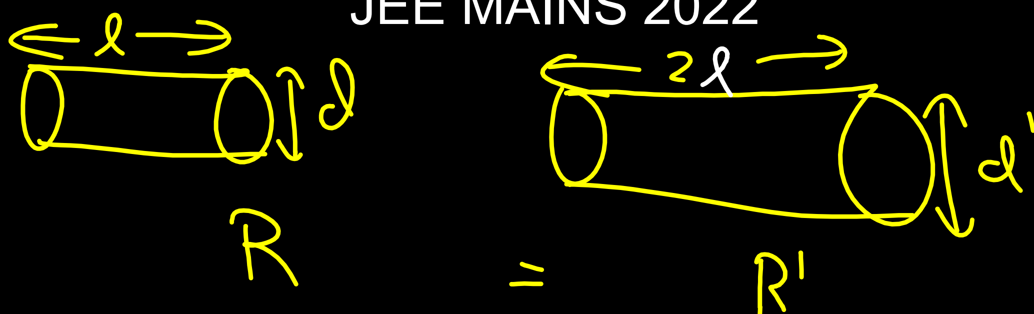
(a) $R = \frac{\rho}{2\pi l}\left(\frac{b}{a}\right)$ (b) $R = \frac{4\rho}{\pi l}\ln\left(\frac{b}{a}\right)$

(c) $R = \frac{\rho}{\pi l}\ln\left(\frac{b}{a}\right)$ (d) $R = \frac{2\rho}{\pi l}\ln\left(\frac{b}{a}\right)$

Eight copper wire of length l and diameter d are joined in parallel to form a single composite conductor of resistance R. If a single copper wire of length $2l$ have the same resistance (R) then its diameter will be ________ d.

H.W.

JEE MAINS 2022



Two metallic wires of identical dimensions are connected is series. If σ_1 and σ_2 are the conductivities of the these wires respectively, the effective conductivity of the combination is :

(A) $\dfrac{\sigma_1 \sigma_2}{\sigma_1 + \sigma_2}$ (B) $\dfrac{2\sigma_1 \sigma_2}{\sigma_1 + \sigma_2}$

(C) $\dfrac{\sigma_1 + \sigma_2}{2\sigma_1 \sigma_2}$ (D) $\dfrac{\sigma_1 + \sigma_2}{\sigma_1 \sigma_2}$

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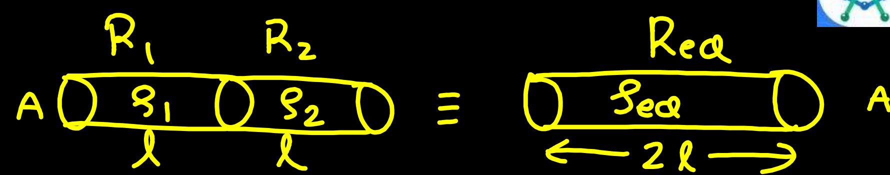
$$R = \frac{\rho l}{A}$$

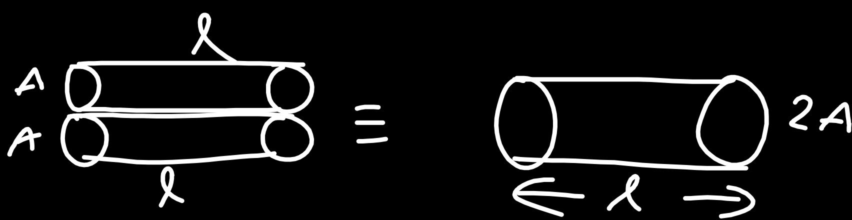


$$R_1 + R_2 = R_{eq}$$

$$\frac{\rho_1 \cancel{l}}{\cancel{A}} + \frac{\rho_2 \cancel{l}}{\cancel{A}} = \frac{(\rho_{eq}) 2\cancel{l}}{\cancel{A}}$$

$$\frac{1}{\sigma_1} + \frac{1}{\sigma_2} = \frac{1}{\sigma_{eq}} 2$$

$$\sigma_{eq} = \frac{2\sigma_1 \sigma_2}{\sigma_1 + \sigma_2}$$



$$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_{eq}}$$

A wire of 1Ω has a length of 1 m. It is stretched till its length increases by 25%. The percentage change in resistance to the nearest integer is

a. 56% b. 25% c. 12.5% d. 76%

$$R = \frac{\rho l^2}{Vol}$$

$$\% \text{ change} = \frac{\text{final} - \text{ini}}{\text{ini}} \times 100$$

$$\text{final} = (\text{initial}) + (\% \text{ of initial})$$

$$= l + 25\% \text{ of } l$$

$$= l + .25 l$$

$$= 1.25 l$$

$$= \frac{\rho (1.25)^2 l^2}{Vol} = \frac{1.56 \rho l^2}{Vol}$$

An electric current is passed through a circuit containing two wires of the same material, connected in parallel. If the lengths and radii are in the ratio of $\frac{4}{3}$ and $\frac{2}{3}$, then the ratio of the current passing through the wires will be [2004]

(a) 8/9 (b) 1/3 (c) 3 (d) 2

H.W.

$\Delta V = IR$

$\Delta V_1 = \Delta V_2$

$I_1 R_1 = I_2 R_2$

Two conductors have the same resistance at 0°C but their temperature coefficients of resistance are α_1 and α_2. The respective temperature coefficients of their series and parallel combinations are nearly **[2010]**

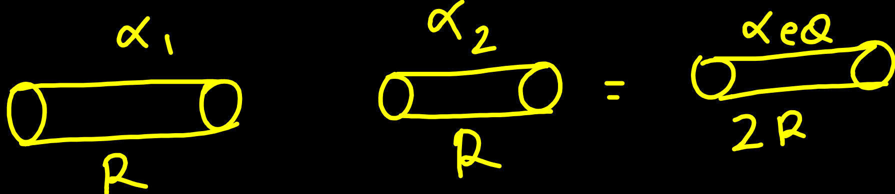
(a) $\frac{\alpha_1+\alpha_2}{2}, \alpha_1+\alpha_2$

(b) $\alpha_1+\alpha_2, \frac{\alpha_1+\alpha_2}{2}$

(c) $\alpha_1+\alpha_2, \frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}$

(d) $\frac{\alpha_1+\alpha_2}{2}, \frac{\alpha_1+\alpha_2}{2}$

$R_t = R_0(1+\alpha\Delta T)$



$$R(1+\alpha_1\Delta T) + R(1+\alpha_2\Delta T) = 2R(1+\alpha_{eq}\Delta T)$$

$$\cancel{R} + R\alpha_1\Delta T + \cancel{R} + R\alpha_2\Delta T = 2\cancel{R} + 2R\alpha_{eq}\Delta T$$

$$\frac{\alpha_1+\alpha_2}{2} = \alpha_{eq}$$

$(1+x)^n = 1+nx$

$x <<< 1$

$$\frac{1}{(1+\alpha\Delta T)} = (1+\alpha\Delta T)^{-1}$$

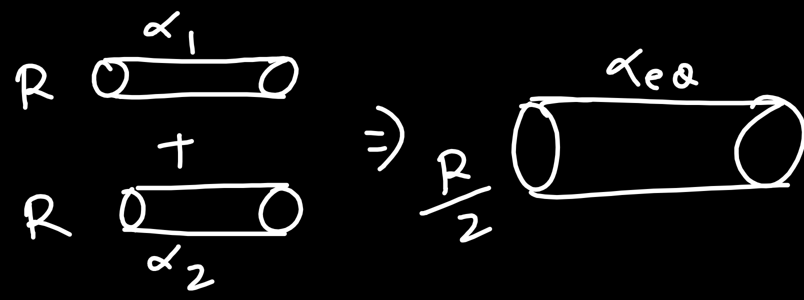
$\Downarrow$

$(1-\alpha\Delta T)$

Unacademy Atoms

$$\frac{1}{R}+\frac{1}{R}=\frac{1}{R_{eq}}$$

$$R/2 = R_{eq}$$



$$\frac{1}{R_1}+\frac{1}{R_2}=\frac{1}{R_{eq}}$$

$$\frac{1}{R(1+\alpha_1\Delta T)}+\frac{1}{R(1+\alpha_2\Delta T)}=\frac{1}{\left(\frac{R}{2}\right)(1+\alpha_{eq}\Delta T)}$$

Binomial approx.

$$(1-\alpha_1\Delta T)+(1-\alpha_2\Delta T)=2(1-\alpha_{eq}\Delta T)$$

$$\frac{\alpha_1+\alpha_2}{2}=\alpha_{eq}$$

The resistance of a wire is 5 ohm at 50°C and 6 ohm at 100°C. The resistance of the wire at 0°C will be (2007)

(a) 3 ohm (b) 2 ohm (c) 1 ohm (d) 4 ohm

H.W.

0°C R_0

50°C

$R_t = R_0(1+\alpha \Delta T)$

$5 = R_0(1+\alpha 50)$

$6 = R_0(1+\alpha 100)$

A metal wire of resistance 3 Ω is elongated to make a uniform wire of double its previous length. This new wire is now bent and the ends joined to make a circle. If two points on the circle make an angle 60° at the centre, the equivalent resistance between these two points will be: **[9 Apr. 2019 II]**

(a) $\frac{12}{5}\Omega$ (b) $\frac{5}{2}\Omega$ (c) $\frac{5}{3}\Omega$ (d) $\frac{7}{2}\Omega$

The resistance of the series combination of two resistances is S. when they are joined in parallel the total resistance is P. If $S = nP$ then the minimum possible value of n is

(2004)

(a) 2 (b) 3 (c) 4 (d) 1

$AM \geq GM$

$R_1 + R_2 = R_{eq}$

$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_{eq}}$

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

$(R_1 + R_2) = n\left(\frac{R_1 R_2}{R_1 + R_2}\right)$

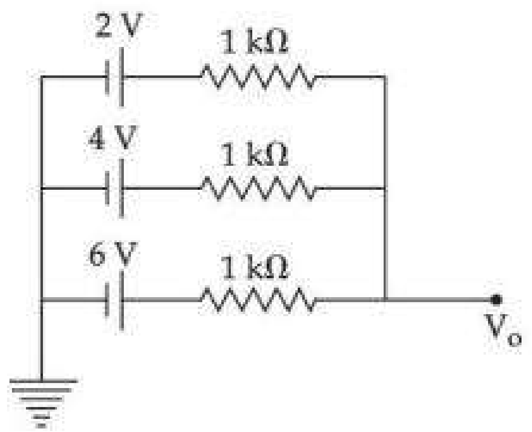
$\frac{(R_1 + R_2)^2}{R_1 R_2} = n$

$\frac{R_1 + R_2}{2} \geq \sqrt{R_1 R_2}$

$\frac{(R_1 + R_2)^2}{R_1 R_2} \geq 4$

The series combination of two batteries, both of the same emf 10 V, but different internal resistance of 20Ω and $5\ \Omega$, is connected to the parallel combination of two resistors 30Ω and R Ω. The voltage difference across the battery of internal resistance 20Ω is zero, the value of R (in Ω) is [NA. 8 Jan. 2020 II]

In the given figure, the value of V_0 will be ____ V.



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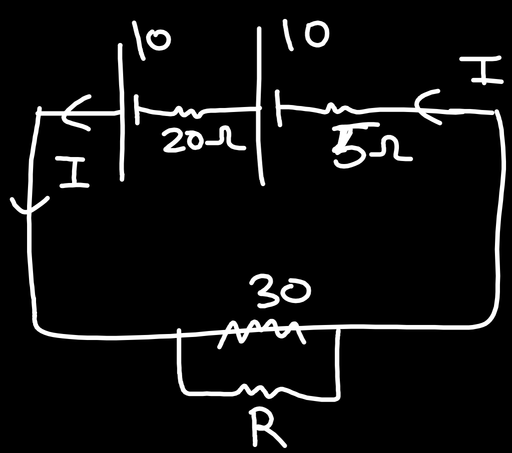
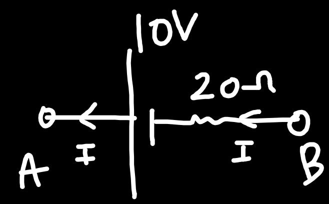
The series combination of two batteries, both of the same emf 10 V, but different internal resistance of 20Ω and 5 Ω, is connected to the parallel combination of two resistors 30Ω and R Ω. The voltage difference across the battery of internal resistance 20Ω is zero, the value of R (in Ω) is [NA. 8 Jan. 2020 II]





$$\varepsilon - Ir = 0$$

$$10 - I(20) = 0$$

$$I = 1/2$$

$$I = \frac{V_{net}}{R_{eq}} = \frac{20}{25 + \frac{30R}{30+R}}$$

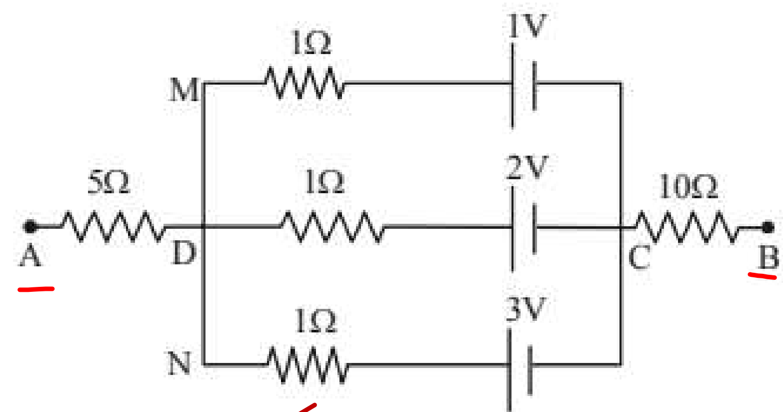
$$\frac{1}{2} = \frac{20}{25 + \frac{30R}{30+R}}$$

$$25 + \frac{30R}{30+R} = 40$$

$$2R = 30 + R$$

$$R = 30$$

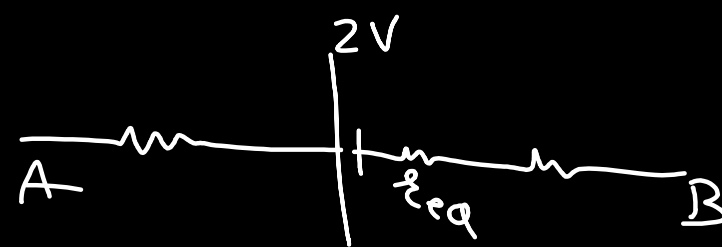
In the circuit shown, the potential difference between A and B is : [11 Jan. 2019 II]



(a) 1V (b) 2V (c) 3V (d) 6V

$$\varepsilon_{eq} = \frac{\frac{1}{1} + \frac{2}{1} + \frac{3}{1}}{\left(\frac{1}{1} + \frac{1}{1} + \frac{1}{1}\right)}$$

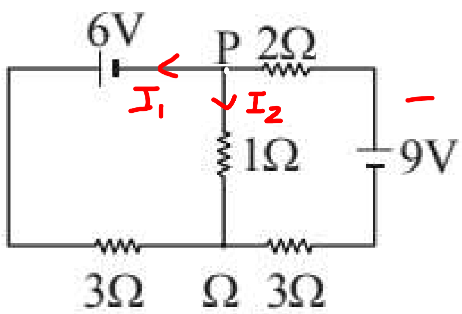
$$= \frac{6}{3} = 2$$

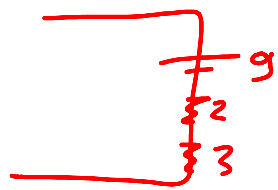


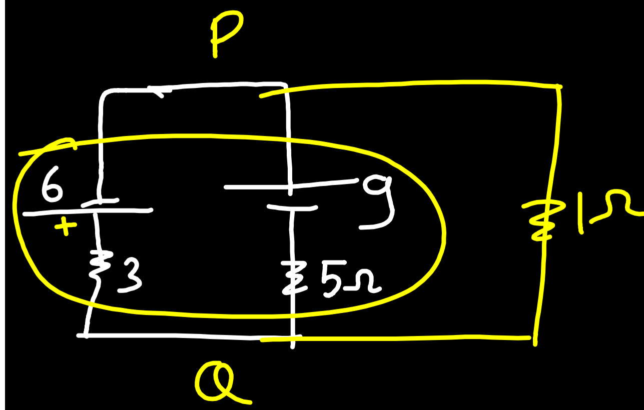
2V

In the circuit shown, the current in the 1Ω resistor is:

[2015]







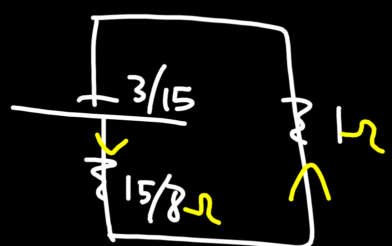
(a) 0.13 A, from Q to P (b) 0.13 A, from P to Q

(c) 1.3A from P to Q (d) 0A

$$\varepsilon_{eq} = \frac{\left(\frac{6}{3} - \frac{9}{5}\right)}{\left(\frac{1}{3}+\frac{1}{5}\right)} = \frac{1/5}{8/15} = 3/8$$

$$\frac{1}{r_{eq}} = \frac{1}{3}+\frac{1}{5} = \frac{8}{15}$$

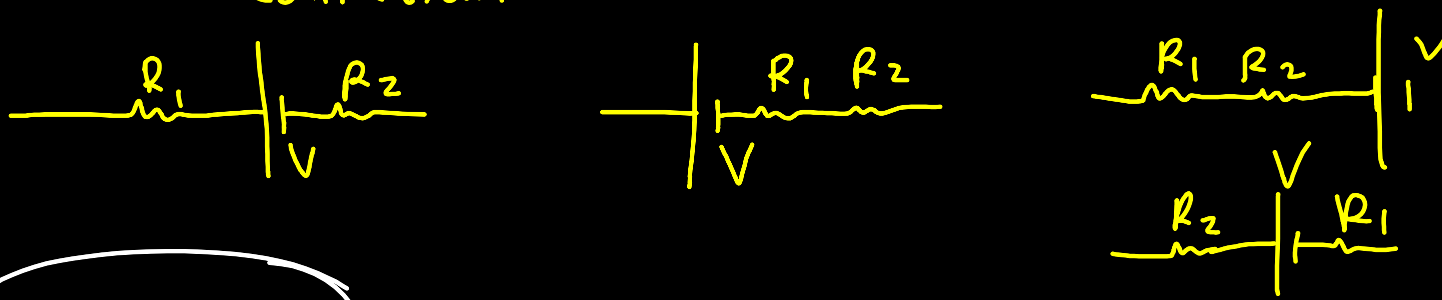
$$r_{eq} = \frac{15}{8}$$



$$I = \frac{V_{net}}{R_{net}} = \frac{3/8}{1+15/8}$$

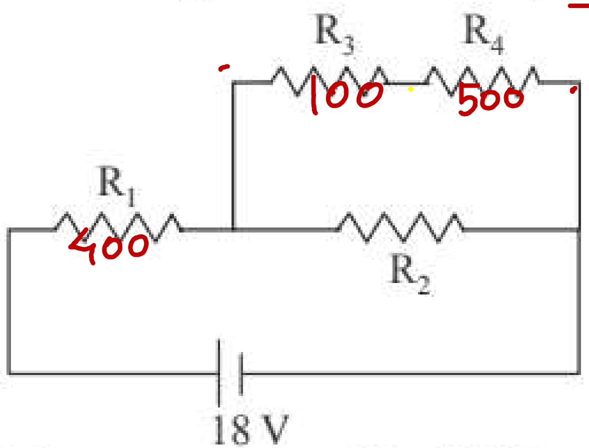
$$= \frac{3}{23} \approx$$

elements Ko aage piche displace Kar Sakte ho if in Series Connetion.



KCL & KVL

In the given circuit the internal resistance of the 18 V cell is negligible. If $R_1 = 400\Omega$, $R_3 = 100\ \Omega$ and $R_4 = 500\ \Omega$ and the reading of an ideal voltmeter across R_4 is 5 V, then the value of R_2 will be: **[9 Jan. 2019 II]**



If ΔV across R_4 $= 5V$

$R_2 = ?$

(a) 300 Ω (b) 450 Ω

(c) 550 Ω (d) 230 Ω

$\Delta V_4 = I_4 R_4$

$5 = I_4\, 500$

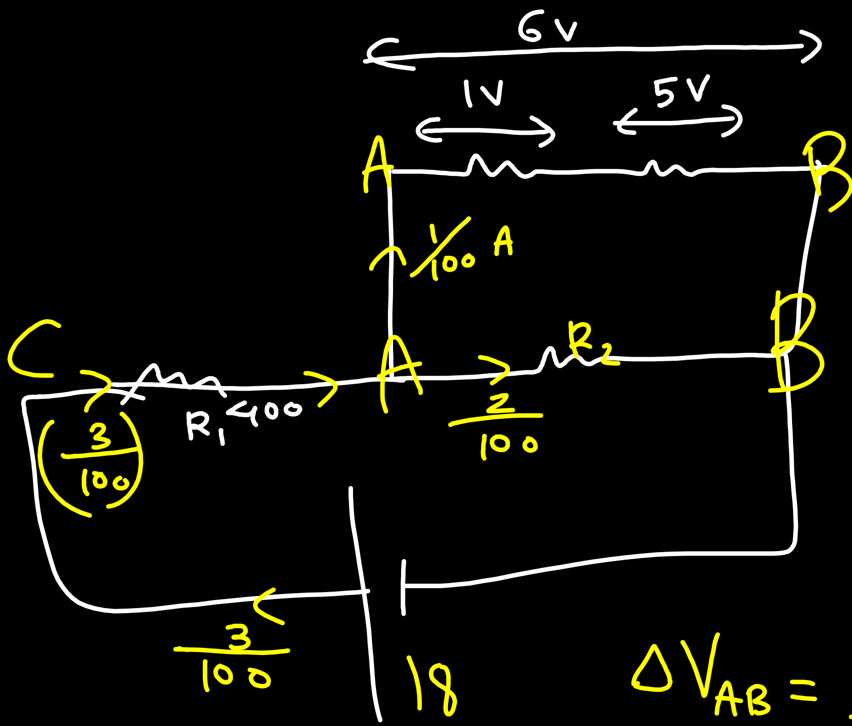
$\frac{1}{100} = I$

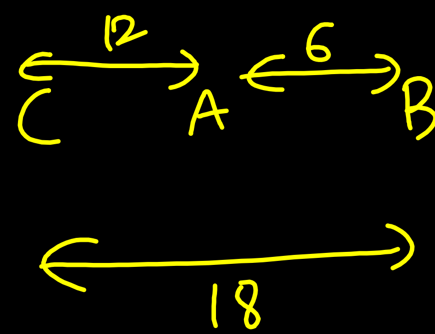
R_3

$\frac{1}{100}$ 100

$\Delta V_3 = IR$

$= 1V$





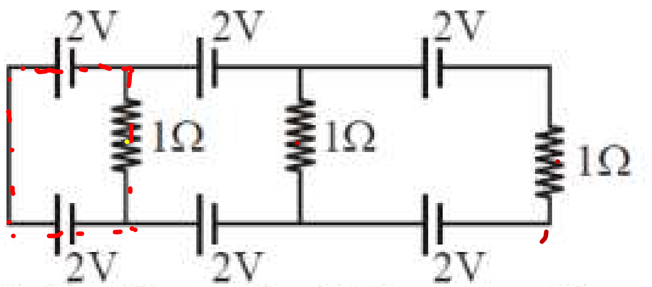
$$\Delta V_{AB} = \frac{2}{100} R_2 = 6$$

$$\Delta V_1 = I R_1$$

$$12 = I \, 400$$

$$\frac{3}{100} = I$$

$$R_2 = 300$$



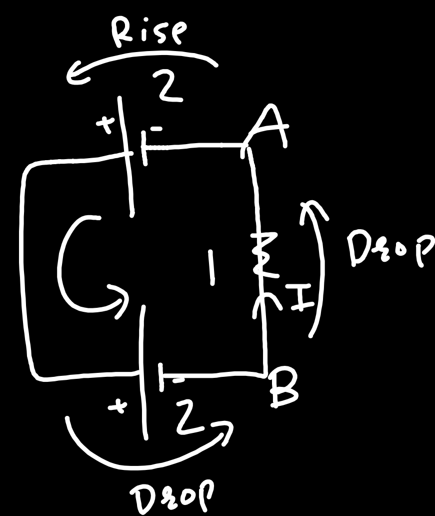
In the above circuit the current in each resistance is

[2017]

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

I distribute

Points Naming

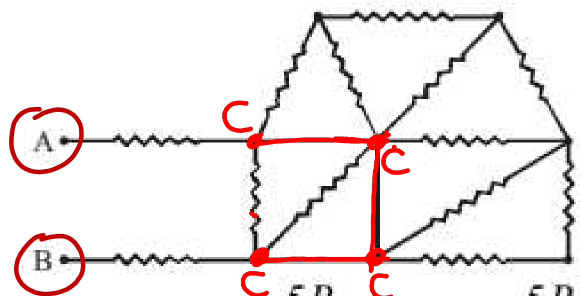


$$+\cancel{2}-\cancel{2}-I(1\Omega)=0$$

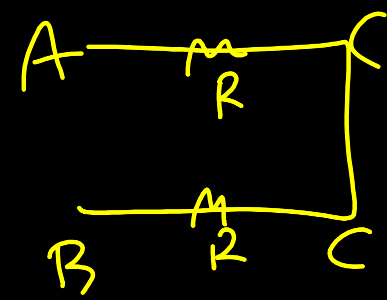
$$I=0$$

In the given circuit all resistances are of value R ohm each. The equivalent resistance between A and B is :

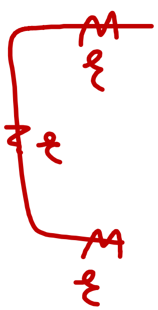
[Online April 15, 2018]

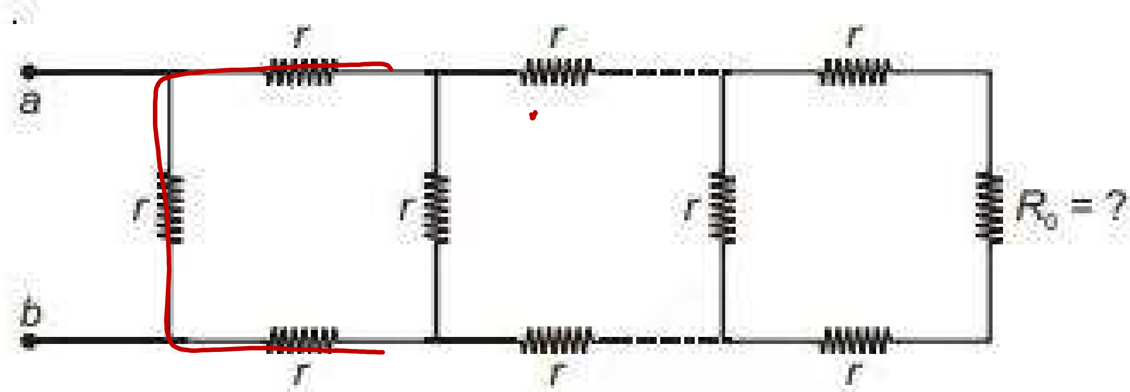


(a) $2R$ (b) $\frac{5R}{2}$ (c) $\frac{5R}{3}$ (d) $3R$



In the circuit shown there are n repetitions of the same loop. What resistance R_0 should be connected across the end points so that the equivalent resistance between a and b may be independent of n? What is this equal to?

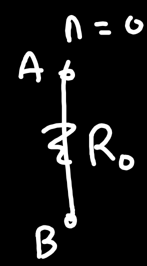


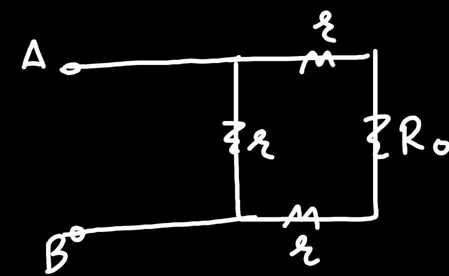


$n=0$

$n=1$

$n=2$





$$R_0 = \frac{(R_0+2r)r}{(R_0+2r)+r}$$

$$R_0 = (\sqrt{3}-1)r$$