(Physics) **CURRENT ELECTRICITY**

**Strength of Electric Current**

The strength of electric current is defined as rate of flow of charge through any cross section of a conductor.

1. The instantaneous current is defined by the equation, $I = \underset{\Delta t \to 0}{\mathrm{Lt}} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$

Average current $i = \frac{q}{t}$

**Ampere :** If one coulomb of charge passes through a cross-section of the conductor per second then the current is one ampere.

$$1 \text{ ampere } = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

Current is a scalar quantity.

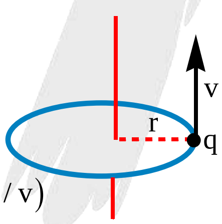
**Applications on electric current**

1. If the current is varying with time t, then the charge flowing in a time interval from $t_1$ to $t_2$ is

$$q = \int_{t_1}^{t_2} I dt$$

2. If n particles, each having a charge q, pass through a given cross-sectional area in time t, then the average current is $i = \frac{nq}{t}$

3. If a point charge q is revolving in a circle of radius r with speed v then its time period is




$T = (2\pi r / v)$

4. The average current associated with this revolving charge is $I = \frac{q}{T} = fq = \frac{\omega}{2\pi} q = \frac{vq}{2\pi r}$ where f is the frequency of revolution in Hz.

$\omega$ is the angular frequency in rad/sec

v is linear velocity of the charge q

r is the radius of the circular path

5. If in a discharge tube $n_1$ protons are moving from left to right in t seconds and $n_2$ electrons are moving simultaneously from right to left in t seconds, then the net current in any cross section of the discharge tube is $I = \frac{(n_1 + n_2)e}{t}$ (from left to right) here e is the magnitude of charge of electron (or) proton.

**DRIFT VELOCITY:** Drift velocity is the average velocity acquired by free electrons inside a metal by the application of an electric field which results in current.

Drift velocity $v_d = \frac{J}{ne} = \frac{I}{Ane}$

where, $J = I/A$ is current density,

n is number of free electrons per unit volume,

e is charge of electron

The drift velocity is related to relaxation time by $v_d = \frac{eE}{m}\tau$

**Note :**

1. The drift velocity of electrons is of the order of $10^{-4}\ m\,s^{-1}$.
2. Greater the electric field, greater will be the drift velocity $v_d \propto E$
3. The direction of drift velocity for electrons in a metal is opposite to that of the electric field applied $\vec{E}$

**Current Density** $(\vec{J})$**:** Current density at a point is defined as a vector having magnitude equal to current per unit area.

$$\vec{J} = \underset{\Delta s \to 0}{Lt} \frac{\Delta I}{\Delta s} = \frac{dI}{ds} n$$

If the normal to the area makes an angle $\theta$ with the direction of the current, then the current density is $J = \frac{\Delta I}{\Delta s \cos\theta}$, $dI = J ds \cos\theta$ (or) $dI = \vec{J} \cdot \vec{ds}$ i.e., $I = \int \vec{J} \cdot \vec{ds}$

SI unit of $\vec{J}$ is $Am^{-2}$

The dimensional formula of J is $\left[AL^{-2}\right]$

Current is the flux of current density.

**Relaxation time** $(\tau)$**:** It is the time interval between two successive collisions of electrons with positive ions in the metallic lattice.

The resistance of a conductor is given by $R = \frac{2m\ell}{ne^2\tau A}$

where n = number density of electrons

e = electron charge

m = mass of electron

$\tau$ = relaxation time.

**Mobility $(\mu)$ :** Mobility $(\mu)$ of a charge carrier (like electron) is defined as the average drift velocity resulting from the application of unit electric field strength.

$$\mu = \frac{\text{drift velocity}}{\text{electric field}}; \quad \therefore \quad \mu = \frac{|v_d|}{E}$$

Mobility depends on pressure and temperature.

**OHM'S LAW :** For a given conductor, at a given temperature the strength of electric current through it is directly proportional to the potential difference applied across at its ends.

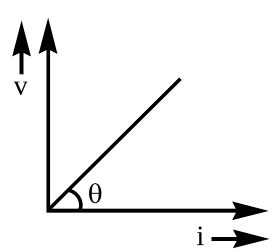
i.e., $I \alpha V \Rightarrow I = \frac{V}{R}; \quad V = IR$

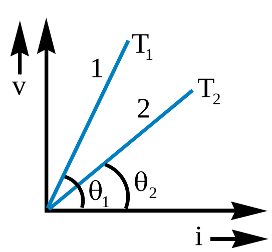
Where R is electrical resistance of the conductor

**Note :**

- Ohm's law is neither a basic law nor a deriavable one
- Ohm's law is just an emperical relation.
- Microscopically Ohm's law is expressed as $J = nev_d \Rightarrow J = \sigma E$ where $\sigma$ is the electrical conductivity of the material.
- The conductors which obey Ohm's law are called Ohmic conductors.

  Ex : all metals
- For Ohmic conductors V – i graph is a straight line passing through origin (metals).




(A) Slope of the line

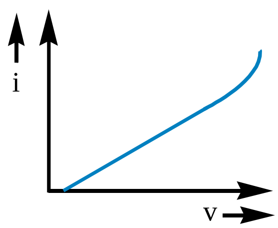
(B) Here $\tan\theta_1 > \tan\theta_2$

$\tan\theta = v/i = R$ ; $T_1 > T_2$ So $R_1 > R_2$ i.e

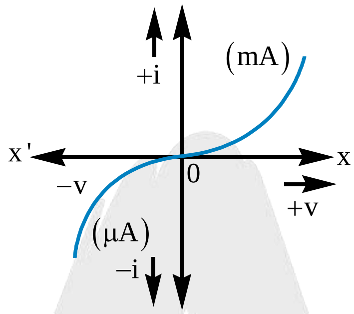
- The substances which do not obey Ohm's law are called non-Ohmic conductors.

  Ex : Thermistor, Electronic Valve, Semi-conductor devices, gases, crystal rectifier etc.

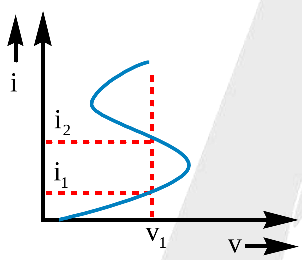
- The V – i graph for a non – Ohmic conductor is non-linear.



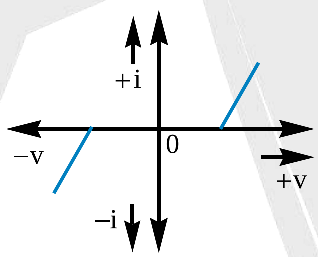

vaccum tube



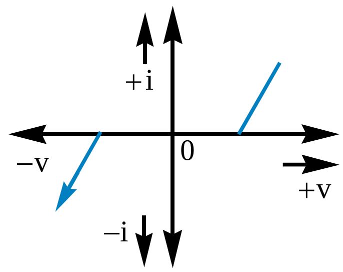

semi conductors




Thermistor

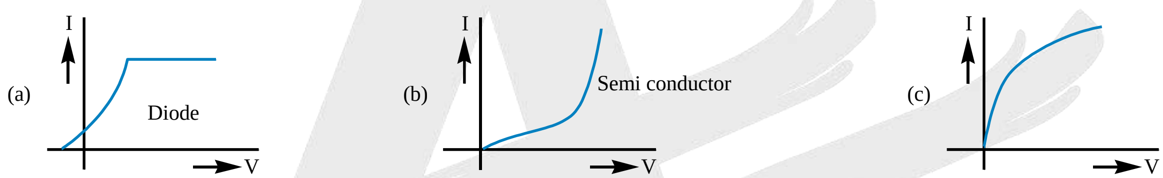



dil$H_2SO_4$ (Platinum Electrode)




Neon Gas (With tungsten Electrode)

**Non – Ohmic Circuit :** The circuits in which Ohm's law is not obeyed are called non-ohmic circuits. The V-I graph is a curve, e.g. torch bulb, electrolyte, semiconductors, thermonic valves etc. as shown by curves (a), (b), (c).




**Resistance-Definition :** The resistance of a conductor is defined as the ratio of the potential difference 'V' across the conductor to the current 'i' flowing through the conductor.

Resistance $R = \frac{V}{i}$

- The resistance of a conductor depends upon

  1) shape (dimensions) 2) nature of meterial

  3) impurities 4) Temperature
- The resistance of a conductor increases with impurities.
- The resistance of a semi conductor decreases with impurities.

**Factors Effecting the Resistance of A Conductor**

1. The resistance of the conductor is directly proportional to the length ( $\ell$ ) of the conductor i.e.

$$R \alpha \ell \quad (\text{or}) \quad \frac{R_1}{R_2} = \frac{\ell_1}{\ell_2}$$

For small changes in the length, $\frac{\Delta R}{R} = \frac{\Delta \ell}{\ell}$

2. The resistance of a conductor is inversely proportional to the area of cross-secton (A)

i.e., $R\alpha\frac{1}{A}$ (or) $R\propto\frac{1}{r^2}$; $\frac{R_1}{R_2}=\left(\frac{A_2}{A_1}\right)=\left(\frac{r_2^2}{r_1^2}\right)$

For small changes in area (or) radius we have $\frac{\Delta R}{R}=\frac{\Delta A}{A}=-\frac{2\Delta r}{r}$

3. As the temperature increases resistance of metallic conductors increases and that of semiconductors decreases.

**Conductance :** The reciprocal of resistance (R) is called conductance.

Conductance $G=\frac{1}{R}$.

The S.I unit of conductance is mho or siemen or ohm $^{-1}$.

**Resistivity :** As we know, that the resistance of the conductor is directly proportional to its length and inversely proportional to its area of cross section, we can write $R\propto\frac{\ell}{A}\Rightarrow R=\frac{\rho\ell}{A}$

where $\rho$ is specific resistance or resistivity of the material of the conductor.

**Note :**

1. Resistivity is the specific property of a material but Resistance is the bulk property of a conductor.
2. Resistivity is independent of dimensions of the conductor such as length, area of the cross section.
3. Resistivity depends on the nature of the material of the conductor, temperature and impurities.
4. Resistivity of any alloy is more than resistivity of its constituent elements.

(i) $R_{alloys}>R_{conductors}$ (ii) $\alpha_{metals}>\alpha_{alloys}$

**Special Cases :**

1. The alternate forms of resistance is $R=\rho\frac{\ell^2}{V}=\rho\frac{\ell^2 d}{m}=\frac{\rho V}{A^2}=\frac{\rho m}{d A^2}$

Where d is density of material of conductor

V is volume of the conductor

m is mass of the conductor

2. If a conductor is stretched or elongated or drawn or twisted, then the volume of the conductor is constant. Hence

a) $R=\frac{\rho\ell^2}{V}\Rightarrow R\alpha\ell^2$

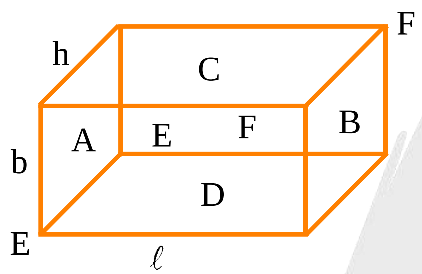
b) $R = \frac{\rho V}{A^2} \Rightarrow R \alpha \frac{1}{A^2} \alpha \frac{1}{r^4}$

c) In terms of mass of the wire $R \alpha \frac{\ell^2}{m}$ and $R \alpha \frac{m}{A^2} \alpha \frac{m}{r^4}$

3. For small changes in the length or radius during the stretching

$$\frac{\Delta R}{R} = 2\frac{\Delta \ell}{\ell} \quad ; \quad \frac{\Delta R}{R} = -2\frac{\Delta A}{A} = -4\frac{\Delta r}{r}$$

4. In case of a cuboid of dimensions $\ell \times b \times h$ is




Resistance across AB, $R_{AB} = \frac{\rho \ell}{b \times h}$.

Resistance across CD, $R_{CD} = \frac{\rho b}{\ell \times h}$

Resistance across EF, $R_{EF} = \frac{\rho h}{\ell \times b}$

If $\ell > b > h$, then

$R_{max} = \frac{\rho \ell}{b \times h}$ $\qquad$ $R_{min} = \frac{\rho h}{\ell \times b}$

5. If a wire of resistance R is stretched to 'n' times its original length, its resistance becomes $n^2 R$.

6. If a wire of resistance R is stretched until its radius becomes $\frac{1}{n}$ th of its original radius then its resistance becomes $n^4 R$.

7. When a wire is stretched to increase its length by x% (where x is very small) its resistance increases by 2x%.

8. When a wire is stretched to increase its length by x% (where x is large) its resistance increases by $\left(2x + \frac{x^2}{100}\right)$.

9. When a wire is stretched to reduce its radius by x% (where x is very small), its resistance increases by 4x%.

**Conductivity :** Conductivity is the measure of the ability of a material to conduct electric current through it. It is reciprocal of resistivity.

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

S.I unit : siemen/m : $\left(Sm^{-1}\right)$

For perfect insulators $\sigma = 0$

For perfect conductors, $\sigma$ is infinity.

**Temperature dependence of resistance :**

For conductors i.e metals resistance increases with rise in temperature

$$R_t = R_0\left(1+\alpha t+\beta t^2\right) \text{ for } t > 300°C$$

$$R_t = R_0\left(1+\alpha t\right) \text{ for } t < 300°C \text{ or } \alpha = \frac{R_t - R_0}{R_0 t} / °C$$

If $R_0$ = resistance of conductor at $0°C$

If $R_t$ = resistance of conductor at $t°C$ and $\alpha, \beta$ = temperature co-efficients of resistance

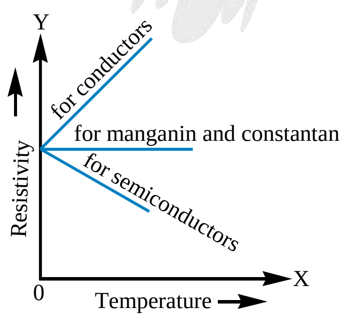
If $R_1$ and $R_2$ are the resistances at $t_1°C$ to $t_2°C$ respectively then

$$\frac{R_1}{R_2} = \frac{1+\alpha t_1}{1+\alpha t_2}$$

$$\therefore \quad \alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1}$$

**The value of $\alpha$ is different at different temperatures.**

At a given temperature $\alpha = \frac{1}{R_t}\left(\frac{dR}{dt}\right)$ at $t°C$



Graph shows the variation of resistivity with temperature for conductors, semiconductors and for alloys like manganin and constantan. Since the resistivity of manganin and constantan remains constant with respect to change in temperature, these materials are used for the bridge wires and resistance coils.

- The resistivity of manganin and constantan is almost independent of temperature.
- Two resistors having resistances $R_1$ and $R_2$ at $0°C$ are connected in series. The condition for the effective resistance in series in same at all temperatures

$$R_1 + R_2 = R'_1 + R'_2$$

$$R_1 + R_2 = R_1(1+\alpha_1 t) + R_2(1+\alpha_2 t)$$

$$R_1\alpha_1 = -R_2\alpha_2$$

**Variation of resistance of some materials**

| Material | Temperature coefficient of resistance $(\alpha)$ | Variation of resistance with temperature rise |
|---|---|---|
| Metals | Positive | Increases |
| Solid non-metal | Zero | Independent |
| Semi-conductor | Negative | Decreases |
| Electrolyte | Negative | Decreases |
| Ionized gases | Negative | Decreases |
| Alloys | Small positive value | Almost constant |

**Variation of Resistivity with temperature :**

- If $\rho_1$ is the resistivity of a material at temperature $t_1$ and $\rho_2$ is the resistivity of the same material at temperature $t_2$, then $\rho_2 = \rho_1\left[1+\alpha(t_2 - t_1)\right]$

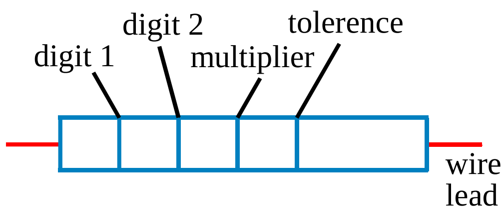
**Thermistor :** A thermistor is a heat sensitive and non-ohmic device.

- This is made of semiconductor compounds such as oxides of Ni, Fe, Co etc.
- This will have high positive or negative temperature coefficient of resistance.

- Thermistor with negative '$\alpha$' are used as resistance thermometers which can measure low temperature of order of 10K and small changes of the order of $10^{-3}$K.
- Having negative $\alpha$, these are widely used in measuring the rate of energy flow in microwave beam.
- Thermistor can also be used to serve as thermostat.

**Resistor Colour codes**

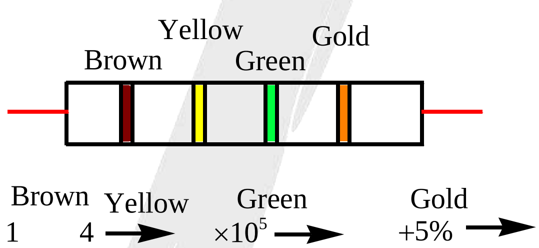
| Colour | Number | Multiplier | Tolerance (%) |
|---|---|---|---|
| Black | 0 | $\times 10^{\circ}$ | |
| Brown | 1 | $\times 10^{1}$ | |
| Red | 2 | $\times 10^{2}$ | |
| Orange | 3 | $\times 10^{3}$ | |
| Yellow | 4 | $\times 10^{4}$ | |
| Green | 5 | $\times 10^{5}$ | |
| Blue | 6 | $\times 10^{6}$ | |
| Violet | 7 | $\times 10^{7}$ | |
| Gray | 8 | $\times 10^{8}$ | |
| White | 9 | $\times 10^{9}$ | - |
| Gold | - | $\times 10^{-1}$ | $\pm$ 5% |
| Silver | - | $\times 10^{-2}$ | $\pm$ 10% |
| No colour | - | | $\pm$ 20% |




**Colour bands on a resistor : B.B.ROY** of **G**reat **B**ritain having **V**ery **G**ood **W**ife with **G**old and **S**ilver

- Resistors in the higher range are made mostly from carbon. Carbon resistors are compact, inexpensive and thus find extensive use in electronic circuits.

- Suppose the colours on the resistor as shown in figure are brown, yellow, green and gold as read from left to right. Using the table, find the resistance of the resistor.




$$=14\times10^{5}\left(1\pm\frac{5}{100}\right)\Omega$$

$$=(1.4\pm0.07)10^{6}\,\Omega=(1.4\pm0.07)\,\text{M}\Omega$$

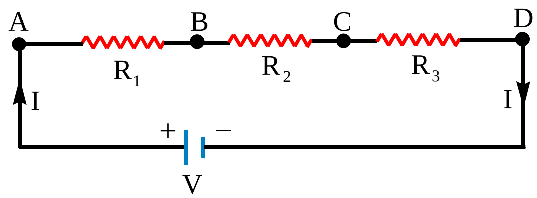
Sometimes tolerance is missing from the code there are only three bands. Then tolerance is 20%.

- Super Conductor : There are certain metals for which the resistance suddenly falls to zero below certain temperature called critical temperature.

- Critical temperature depends on the nature of material. The materials in this state are called super conductors.
- Without any applied emf steady current can be maintained in super conductors.

  Ex : Hg below 4.2 K or Pb below 8.2 K

**Resistances In Series :**




1. If resistors of resistances $R_1, R_2, R_3, .....$ are connected in series, the resultant resistance

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

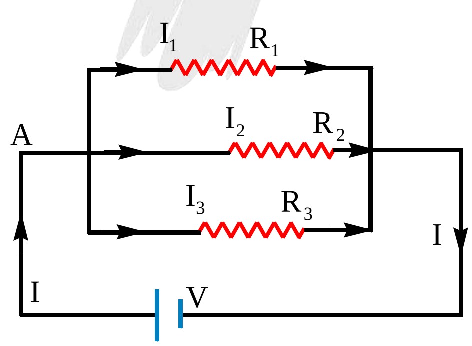
2. When resistances are connected in series, same current passes through each resistor. But the potential differences are in the ratio $V_1 : V_2 : V_3 ..... = R_1 : R_2 : R_3 .....$

3. When resistors are joined in series, the effective resistance is greater than the greatest resistance in the circuit.

4. When two resistances are connected in series then

   $V_1 = \frac{VR_1}{R_1 + R_2}$ and $V_2 = \frac{VR_2}{R_1 + R_2}$

**Resistances in Parallel**




1. If resistors of resistance $R_1, R_2, R_3, .........$ are connected in parallel, the resultant resistance R is given by $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ..........$

2. If resistances $R_1$ and $R_2$ are connected in parallel, the resultant resistance $R = \frac{R_1R_2}{R_1+R_2}$

3. When resistors are joined in parallel the potential difference across each resistor is same. But the currents are in the ratio $i_1 : i_2 : i_3 : .............. = \frac{1}{R_1} : \frac{1}{R_2} : \frac{1}{R_3} : ...........$

4. When two resistances are parallel then $I_1 = \frac{IR_2}{R_1+R_2}$ and $I_2 = \frac{IR_1}{R_1+R_2}$

**Note :**

1. When resistors are joined in parallel, the effective resistance is less than the least resistance in the circuit.

2. A wire of resistance 'R' is cut into 'n' equal parts and all of them are connected in parallel, equivalent resistance becomes $\frac{R}{n^2}$.

3. In 'n' wires of equal resistances are given, the number of combinations that can be made to give different resistances is $2^{n-1}$.

4. If 'n' wire of unequal resistances are given, the number of combinations that can be made to give different resistances is $2^n$ $(\text{If } n > 2)$.

5. If $R_s$ and $R_p$ be the resultant resistances of $R_1$ and $R_2$ when connected in series and parallel then $R_1 = \frac{1}{2}\left(R_s + \sqrt{R_s^2 - 4R_sR_p}\right)$

$$R_2 = \frac{1}{2}\left(R_s - \sqrt{R_s^2 - 4R_sR_p}\right)$$

6. If a uniform wire of resistance R is, stretched to 'm' times its initial length and bent into a regular polygon of 'n' sides

a) Resistance of the wire after stretching is $R_1 = m^2R \quad \left(R \,\alpha\, \ell^2\right)$

b) Resistance of each side $R_2 = \frac{m^2R}{n}$

c) Resistance across diagonally opposite points $R_0 = \left(\frac{\frac{n}{2}R_2}{2}\right) \Rightarrow R_0 = \frac{m^2R}{4}$

d) Resistance across one side

$R_3 = \frac{(n-1)}{n}$ $R_2 = \frac{(n-1)m^2R}{n^2}$

7. 12 wires each of resistance 'r' are connected to form a cube. Effective resistance across

a) Diagonally opposite corners $= \frac{5r}{6}$.

b) face diagonal $= \frac{3r}{4}$.

c) two adjacent corners $= \frac{7r}{12}$.

8. If two wires of resistivities $\rho_1$ and $\rho_2$, lengths $\ell_1$ and $\ell_2$ are connected in series, the equivalent resistivity $\rho = \frac{\rho_1\ell_1 + \rho_2\ell_2}{\ell_1 + \ell_2}$.

If $\ell_1 = \ell_2$ then $\rho = \frac{\rho_1 + \rho_2}{2}$.

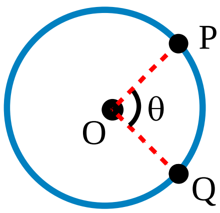
If $\ell_1 = \ell_2$ then conductivity $\sigma = \frac{2\sigma_1\sigma_2}{\sigma_1 + \sigma_2}$.

9. If two wires of resistivities $\rho_1$ and $\rho_2$, areas of cross section $A_1$ and $A_2$ are connected in parallel, the equivalent resistivity $\rho = \frac{\rho_1\rho_2(A_1 + A_2)}{\rho_1 A_2 + \rho_2 A_1}$.

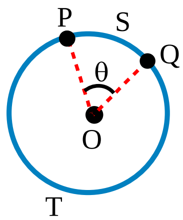
If $A_1 = A_2$ then $\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$ and conductivity $\sigma = \frac{\sigma_1 + \sigma_2}{2}$.

10. If 'n' wires each of resistance 'R' are connected to form a closed polygon, equivalent resistance across two adjacent corners is $R_{eff} = \left(\frac{n-1}{n}\right)R$

- P and Q are two points on a uniform ring of resistance R. The equivalent resistance between P and Q is




Resistance of section PSQ




$R_1 = \frac{R}{2\pi r} \cdot r\theta = \frac{R\theta}{2\pi}$ ; Resistance of section PTQ

$R_2 = \frac{Rr(2\pi - \theta)}{2\pi r}$; $\quad R_2 = \frac{R(2\pi - \theta)}{2\pi}$

As $R_1$ and $R_2$ are in parallel

So, $R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{R\theta}{4\pi^2}(2\pi - \theta)$

**JOULES LAW :** According to Joule's law, the current passing through a conductor produces heat.

$W = vit$

Now, work done, $W = (iR)it$

$$W = i^2 R t == \frac{v^2}{R} t = v i t$$

This work is converted into energy in the conductor.

$\therefore$ Thermal energy produced, $Q = i^2 R t$ in Joules

Or $Q = \dfrac{i^2 R t}{4.2}$ in cal.

As $H \propto i^2$, heating effect of current is common to both A.C and D.C.

Joules's effect is irreversible.

**Electrical Energy :**

- The electric energy consumed in a circuit is defined as the total workdone in maintaing the current in an electric circuit for a given time.

  Elecctrical Energy $= V i t = Pt = i^2Rt = \dfrac{V^2 t}{R}$

  S.I unit of electric energy is joule

  1 K.W.H. $= 36 \times 10^5$ J

**Electrical Power:** The rate at which work is done in maintaining the current in electric circuit.

Electrical power $P = \dfrac{W}{t} = Vi = i^2R = \dfrac{V^2}{R}$ watt or joule/sec

- Heat energy produced due to the electric current

$$H = \frac{W}{J} = \frac{Pt}{J} = \frac{E\,it}{J} = \frac{i^2Rt}{J} = \frac{E^2 t}{RJ}$$

$H = ms\Delta t$

Where $s = 4200$ J / Kg°C

Where J is mechanical equivalent of heat.

**Fuse wire :** A fuse wire is generally prepared from tin – lead alloy (63% tin + 37% lead). It should have high resistivity, low melting point.

Let R be the resistance of fuse wire.

We know that $R = \frac{\rho L}{\pi r^2}$

(L and r denote length and radius)

The heat produced in the fuse wire is $H = i^2 R = \frac{i^2 \rho L}{\pi r^2}$

If $H_0$ is heat loss per unit surface area of the fuse wire, then heat radiated per second is

$= H_0 2\pi r L$ At thermal equilibrium,

$$\frac{i^2 \rho L}{\pi r^2} = H_0 2\pi r L \quad (\text{or}) \quad H_0 = \frac{i^2 \rho}{2\pi^2 r^3}$$

According to Newton's law of cooling.

$H_0 = K\theta$

Where $\theta$ is the increase in temperature of fuse wire and K is a constant.

$$\theta = \frac{i^2 \rho}{2\pi^2 r^3 K}$$

Here $\theta$ is independent of length L of the fuse wire provided i remains constant.

For a given material of fuse wire $i^2 \alpha r^3$.

- If radiation losses are neglected, due to heating effect of current the temperature of fuse wire will increase continuously, and it melts in time 't' such that

$$H = ms\Delta\theta; \ \frac{I^2 Rt}{J} = ms(\theta_{mp} - \theta_r)$$

$$t = \frac{\pi^2 r^4 s(\theta_{mp} - \theta_r)J}{I^2 \rho}; \quad t \, \alpha \, r^4$$

i.e., in absence of radiation losses, the time in which fuse will melt is also independent on length and varies with radius as $r^4$.

**Note :**

a) If resistances are connected in series, i.e.., I is same

$P \alpha R$ with $V \alpha R$ [as V = IR]

i.e., in series, potential difference and power consumed will be more in larger resistance.

However, if resistances are connected in parallel, i.e.., V is same $P \alpha \frac{1}{R}$ with $I \alpha \frac{1}{R}$ [as V = IR]

i.e., in parallel, current and power consumed will be more in smaller resistance.

This in turn implies that more power is consumed in larger resistance if resistances are in series and in smaller resistance if resistances are in parallel.

b) A resistance R under a potential difference V dissipates power.

$$P = \left(V^2 / R\right)$$

So If the resistance is changed from R to (R/n) keeping V same, the power consumed will be

$$P^1 = \frac{V^2}{(R/n)} = n\frac{V^2}{R} = nP$$

i.e.., if for a given voltage, resistance is changed from R to (R/n), power consumed changes from P to nP.

c) If n equal resistances are connected in series with a voltage source, the power dissipated will be $P_s = \frac{V^2}{nR}$ $\left[\text{as } R_s = nR\right]$

and if the same resistances are connected in parallel with the same voltage source

$$P_p = \frac{V^2}{(R/n)} = \frac{nV^2}{R} \quad \left[\text{as } R_p = (R/n)\right]$$

So, $\frac{P_p}{P_s} = n^2$ i.e.., $P_p = n^2 P_s$.

i.e.., power consumed by n equal resistors in parallel is $n^2$ times that of power consumed in series if V remains same.

d) The resistance of a given electric appliance (e.g. bulb, heater, geyser or press) is constant and is given by, $R = \frac{V_s}{I} = \frac{V_s}{(W/V_s)} = \frac{V_s^2}{W} \quad \left[\text{as } I = \frac{W}{V}\right]$

Where $V_s$ and W are the voltage and wattage specified on the appliance.

So, if the applied voltage is different from specified, the 'actual power consumption' will be

$P = \frac{V_A^2}{R} = \left(\frac{V_A}{V_S}\right)^2 \times W \quad \left[\text{as } R = \frac{V_S^2}{W}\right]$.

**Bulbs connected in Series :**

- If Bulbs (or electrical appliances) are connected in series, the current through each resistance is same. Then power of the electrical appliance $P \propto R$ & $V \propto R$ $\left[\therefore \; P = i^2Rt\right]$

  i.e. In series combination; the potential difference and power consumed will be more in larger resistance.

- When the appliances of power $P_1, P_2, P_3 ....$ are in series, the effective power consumed (P) is

  $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + ........$ i.e., effective power is less than the power of individual appliance.

- If 'n' appliances, each of equal resistance 'R' are connected in series with a voltage source 'V', the power dissipated $'P_s'$ will be $P_S = \frac{V^2}{nR}$.

**Bulbs connected in parallel :**

- If Bulbs (or electrical appliances) are connected in parallel, the potential difference across each resistance is same. Then $P \propto \frac{1}{R}$ and $I \propto \frac{1}{R}$.

  i.e. The current and power consumed will be more in smaller resistance.

- When the appliances of power $P_1, P_2, P_3 ....$ are in parallel, the effective power consumed (P) is

  $P = P_1 + P_2 + P_3 + ........$

  i.e. the effective power of various electrical appliance is more than the power of individual appliance.

- If 'n' appliances, each of resistance 'R' are connected in parallel with a voltage source 'V', the power dissipated '$P_p$' will be $P_P = \dfrac{V^2}{(R/n)} = \dfrac{nV^2}{R}$

  $\dfrac{P_P}{P_S} = n^2$ or $P_P = n^2 P_S$

  This shows that power consumed by 'n' equal resistances in parallel is $n^2$ times that of power consumed in series if voltage remains same.

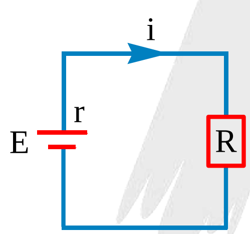
- In parallel grouping of bulbs across a given source of voltage, the bulb of greater wattage will give more brightness and will allow more current through it, but will have lesser resistance and same potential difference across it.

- For a given voltage V, if resistance is changed from 'R' to $\left(\dfrac{R}{n}\right)$, power consumed changes from 'P' to 'nP' $P' = \dfrac{V^2}{R'}$ where $R' = \dfrac{R}{n}$, then $P' = \dfrac{V^2}{(R/n)} = \dfrac{nV^2}{R} = nP$.

- If $t_1$, $t_2$ are the time taken by two different coils for producing same heat with same supply, then if they are connected in series to produce same heat, time taken $t = t_1 + t_2$

  If they are connected in parallel to produce same heat, time taken is $t = \dfrac{t_1 t_2}{t_1 + t_2}$.

**Maximum power transfer theorem**




Consider a device of resistance R connected to a source of e.m.f E and internal resistance r as shown.

Current in the circuit is $i = \left(\dfrac{E}{R+r}\right)$.

Power dissipated in the device is $P = i^2 R$

$$\Rightarrow \quad P = \frac{E^2R}{(R+r)^2}$$

For maximum power dissipated in the device $\frac{dP}{dR} = 0 \Rightarrow \frac{d}{dR}\left[\frac{E^2R}{(R+r)^2}\right] = 0$

On simplification, we can get R = r

So, the power dissipated in an external resistance is maximum if that resistance is equal to internal resistance of the source supplying the current to that device.

## CELLS

**Primary Cells :**

- Voltaic, Leclanche, Daniel and Dry cells are primary cells. They convert chemical energy into electrical energy. They can't be recharged. They supply small currents.

**Secondary Cells (or) Storage Cells :**

- Electrical energy is first converted into chemical energy and then the stored chemical energy is converted into electrical energy due to these cells.
- These cells can be reacharged.
- The internal resistance of a secondary cell is low where as the internal resistance of a primary cell is large.
- **EMF of a Cell :** The energy supplied by the battery to drive unit charge around the circuit is defined as electro motive force of the cell.

  EMF is also defined as the absolute potential difference between the terminals of a source when no energy is drawn from it. i.e., in the open circuit of the cell. It depends on the nature of electrolyte used in the cell.

  Unit : J/C or Volt
- **emf of a cell depends on**

  a) metal of electrodes

  b) nature of electrolyte

  c) temperature

- **emf of the cell is independent of**

  a) area of plate

  b) quantity of electrolyte

  c) distance between plate

  d) size of the cell

**Internal Resistance of a Cell**

- It is the resistance offered by the electrolyte of the cell.

**It depends on**

- Area of the electrodes used $\left(r \propto \frac{1}{A}\right)$
- Nature of electrolyte, concentration $(r \propto C)$
- Area of cross section of the electrolyte through which the current flows and age of the cell.
- Internal resistance of an ideal cell is zero.

**Lost volts :** It is the difference between emf and P.D. of a cell. It is used in driving the current between terminals of the cell.

Lost volts $E - V = ir$

**Note :** Formulae related with cells

$$i = \frac{E - V}{r} \quad \text{............ (A)}$$

$$r = \frac{E - V}{i} \quad \text{............ (B)}$$

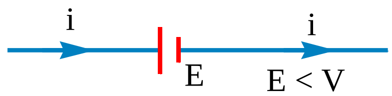
$$r = \left(\frac{E - V}{V/R}\right) = \left(\frac{E - V}{V}\right)R = \left(\frac{E}{V} - 1\right)R \quad \text{............ (C)}$$

- $V = iR = \frac{ER}{(R + r)}$
- Fractional energy useful $= \frac{V}{E} = \frac{R}{R + r}$
- % of fractional useful energy $= \left(\frac{V}{E}\right)100 = \left(\frac{R}{R + r}\right)100$
- Fractional energy lost, $\frac{V'}{E} = \frac{r}{R + r}$
- % of lost energy, $\left(\frac{V'}{E}\right)100 = \left(\frac{r}{R + r}\right)100$

- Internal resistance, $r = \left[\dfrac{E - V}{V}\right] R$

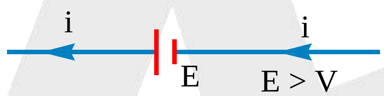
**DIFFERENT CONCEPTS CONCERNING A CELL**

- When the cell is charging, the EMF is less than the terminal voltage $(E < V)$ and the direction of current inside the cell is from positive terminal to the negative terminal.



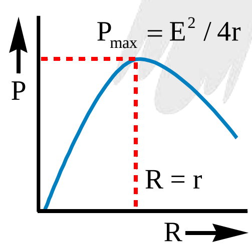

$V = E + i r$

- When the cell is discharging, the EMF is greater than the terminal voltage $(E > V)$ and the direction of current inside the cell is from negative terminal to the positive terminal.




$V = E - i r$; Hence $E > V$

- Power delivered will be maximum when R = r. So $P_{max} = \dfrac{E^2}{4r}$
- This statement in generalized form is called 'maximum power transfer theorem'



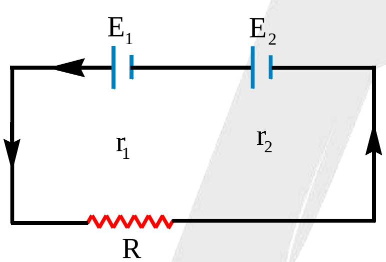

Here the % of energy lost and energy useful are each equal to 50%

**Back EMF :** When current flows through the electrolyte solution, electrolysis takes place with a layer of hydrogen and this hinders the flow of current. In the neighbourhood of both electrodes, the concentrations of ions get altered. This opposing EMF is called back EMF and the phenomenon is called Electrolytic polarisation. To reduce back emf manganese dioxide or potassium dichromate is added to electrolyte of cell.

**GROUPING OF CELLS**

1. Electric Cells in Series : When 'n' identical cells each of EMF 'E' and internal resistance 'r' are connected in series to an external resistance 'R', then

- Total emf of the combination = n E
- Effective internal resistance = n r
- Current through external resistance $i = \frac{nE}{R + nr}$
- If $R << nr$ then $i = \frac{E}{r}$ = current from one cell
- If $R >> nr$ then $i = \frac{nE}{R}$
- If two cells of different emf's are in series $E_{eq} = E_1 + E_2$ ; $r_{eq} = r_1 + r_2$; $i = \frac{E_1 + E_2}{r_1 + r_2 + R}$

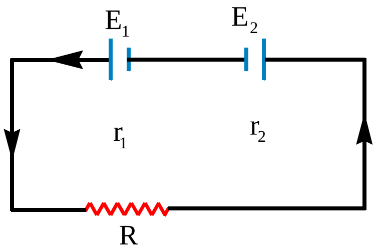



T.P.D across the first cell $V = E_1 - i r_1$

T.P.D across the second cell $V_2 = E_2 - i r_2$

- If one of the cell is in reverse connection $(E_1 > E_2)$ then $E_{eq} = E_1 - E_2$

$r_{eq} = r_1 + r_2$; $i = \frac{E_1 - E_2}{r_1 + r_2 + R}$




First cell is discharging then $V_1 = E_1 - i r_1$

Second cell is charging then $V_2 = E_2 + i r_2$

cell having less emf is in charging state.

**WRONGLY CONNECTED CELLS**

- By mistake if ‘m’ cells out of ‘n’ cells are wrongly connected to the external resistance ‘R’

  (a) total emf of the combination $= (n - 2m)E$

  (b) total internal resistance = n r

  (c) total resistance = R +n r

  (d) current through the circuit $i = \dfrac{(n-2m)E}{R + nr}$

**ELECTRIC CELLS IN PARALLEL**

1. Total emf of the combination = E

2. Effective internal resistance $= \dfrac{r}{n}$

3. Total resistance in the circuit $= R + \dfrac{r}{n}$

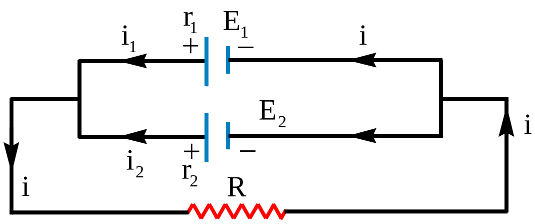
4. Current through the external resistance

   $$i = \frac{E}{R + \frac{r}{n}} = \frac{nE}{nR + r}$$

5. If $R >> \dfrac{r}{n}$, then $i = \dfrac{E}{R}$ = current from one cell

6. If $R << \dfrac{r}{n}$, then $i = \dfrac{nE}{r}$

7. If two cells of emf $E_1$ and $E_2$ having internal resistances $r_1$ and $r_2$ are connected in parallel to an external resistance 'R', then




the effective emf, $E = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

the effective internal resistance, $r_{eff} = \dfrac{r_1 r_2}{r_1 + r_2}$

current through the circuit, $i = \dfrac{E}{r_{eff} + R}$

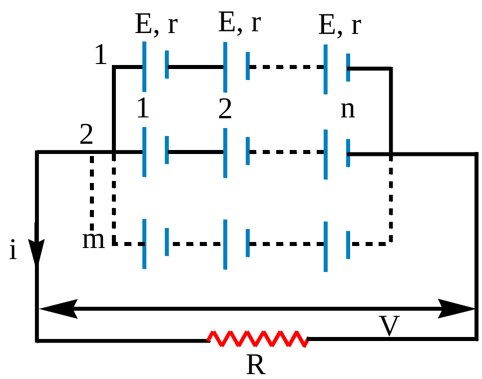
$i = i_1 + i_2$

$i_1 = \dfrac{E_1 - iR}{r_1}$ and $i_2 = \dfrac{E_2 - iR}{r_2}$

Potential difference across R, i.e., terminal potential of the cell is $V = iR = \dfrac{ER}{R + r_{eff}}$

8. When the cell $E_2$ is reversed in polarity then we should use - $E_2$ in all the above equations.

**Mixed Grouping:** If n identical cell's are connected in a row and such m rows are connected in parallel as then




9. Equivalent emf of the combination $E_{eq} = nE$

10. Equivalent internal resistance of the combination $r_{eq} = \frac{nr}{m}$

11. Main current flowing through the load $i = \frac{nE}{R + \frac{nr}{m}} = \frac{nmE}{mR + nr}$

12. Condition for maximum power $R = \frac{nr}{m}$ and $P_{max} = (nm)\frac{E^2}{4r}$

13. **Condition for maximum current**

$\frac{R}{n} + \frac{r}{m}$ = minimum

$$\frac{d}{dm}\left[\frac{mR}{N} + \frac{r}{m}\right] = 0; \left[n = \frac{N}{m}\right]$$

$$\frac{R}{N} - \frac{r}{m^2} = 0; \text{ i.e., } \frac{R}{n} = \frac{r}{m} \qquad (N = n \times m)$$

So in case of mixed grouping of cells, current in the circuit will be maximum when $\left(\frac{R}{n} = \frac{r}{m}\right)$

$$I_{max} = \frac{nE}{2R} = \frac{mE}{2r}$$

14. Total number of cells $= m \times n$

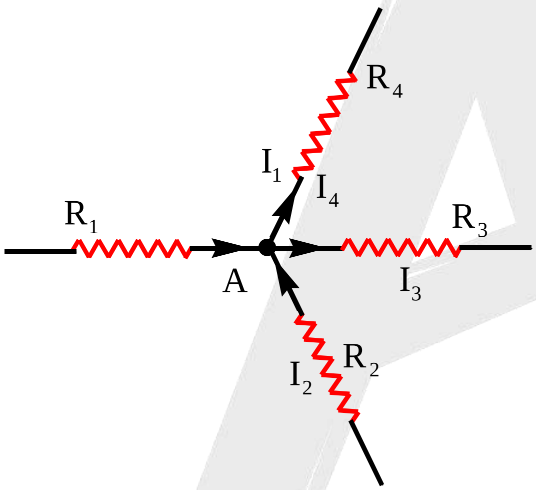
**KIRCHHOFF'S LAWS**

When the circuit is complicated to find current Kirchhoff's laws are formulated.

(i) Kirchhoff's First Law (Junction Law or Current Law) : It states that the sum of the currents flowing into a junction is equal to the sum of the currents flowing out of the junction.

Or

"The algebraic sum of currents at a junction is zero".




**Distribution of current at a junction in the circuit**

$I_1 + I_2 = I_3 + I_4$ or $I_1 + I_2 - I_3 - I_4 = 0$

If we take currents approaching point A in Figure as positive and that leaving the point as negative, then the above relation may be written as $I_1 + I_2 + (-I_3) + (-I_4) = 0$

$\sum I = 0$

**Note:** Kirchhoff's first law is accordance with law of conservation of charge, since no charge can accumulate at a junction.

**Kirchhoff's Second law (Loop law or potential law):**

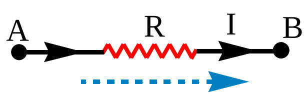
Kirchhoff's second law states that the algebraic sum of changes in potential around any closed loop is zero.

(Kirchhoff's second law) can be expressed as $\Sigma V = 0$

In terms of potential drops and emfs, the law is expressed as $\Sigma(iR) + \Sigma E = 0$

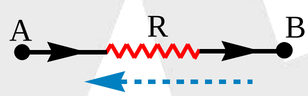
**Sign conventions:**

(a) The change in potential in traversing a resistance in the direction of current is $-IR$ while in the opposite direction $+IR$ as shown in the figure.




$V_A - IR = V_B$

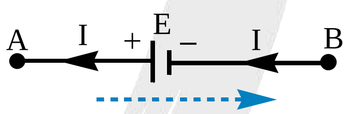
$V_A - V_B = IR$




$V_B + IR = V_A$

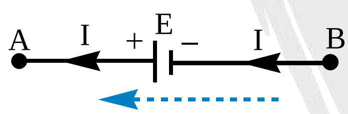
$V_A - V_B = IR$

(b) The change in potential in traversing an emf source from negative to positive is +E while in the opposite direction $-E$ irrespective of the direction of current in the circuit as shown in the figure.




$V_A - E = V_B$

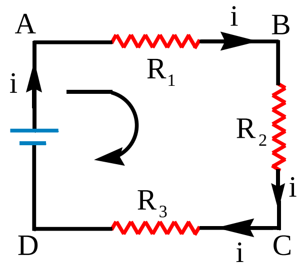
$V_A - V_B = E$




$V_B + E = V_A$

$V_A - V_B = E$

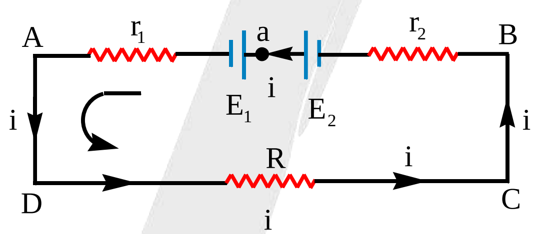
**Example - 1:**




Apply the Kirchhoff's second law to the loop ABCDA, then

$$-iR_1 - iR_2 - iR_3 + E = 0, \quad \therefore i = \frac{E}{(R_1 + R_2 + R_3)}$$

**Example – 2:**




Apply the kirchoff's second law to the loop ADCBA, then

$$-iR - ir_2 + E_2 - E_1 - ir_1 = 0$$

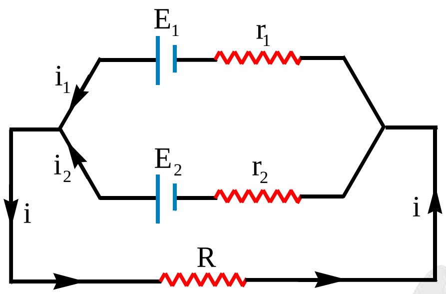
$$i(r_1 + R + r_2) = E_2 - E_1 \Rightarrow i = \frac{E_2 - E_1}{r_1 + r_2 + R}$$

**Note:**

1. This law represents "Conservation of energy"

2. If there are n meshes in a circuit, the number of independent equations in accordance with loop rule will be $(n-1)$.

Application : This is the most general case of parallel grouping in which E and r of different cells are different and the positive terminals cells are connected as shown




Kirchhoff's second law in different loops gives the following equations,

$E_1 - iR - i_1 r_1 = 0$

or $i_1 = \frac{E_1}{r_1} - \frac{iR}{r_1}$ .........(1)

$E_2 - iR - i_2 r_2 = 0$

$i_2 = \frac{E_2}{r_2} - \frac{iR}{r_2}$ .........(2)

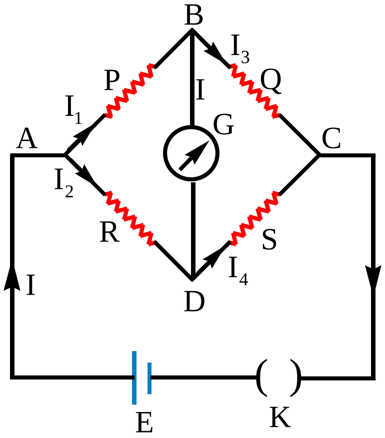
Adding equations (1), (2) we get

$i_1 + i_2 = (E_1/r_1) + (E_2/r_2) - iR(1/r_1 + 1/r_2)$

or $i[1 + R(1/r_1 + 1/r_2)] = (E_1/r_1) + (E_2/r_2)$

$\therefore \quad i = \frac{(E_1/r_1) + (E_2/r_2)}{1 + R(1/r_1 + 1/r_2)}$

**Wheatstone Bridge:**




**Condition for balancing of bridge:**

Applying Kirchhoff's first law at junction B and D we get $I_1 - I_3 - I_G = 0$; and $I_2 + I_G - I_4 = 0$

Applying Kirchhoff's second law for closed loop ABDA, $-I_1P - I_GG + I_2R = 0$

Applying Kirchhoff's second law for closed loop BCDB, $-I_3Q + I_4S + I_GG = 0$

The values of P, Q, R, S are adjusted such that $I_G$ become zero. At this stage the bridge is set to be in balance condition.

i.e., In balanced condition of bridge $I_G = 0$

$\Rightarrow$ In balanced condition the above equations respectively become

$I_1 = I_3$ .....(1)

And $I_2 = I_4$ .....(2)

$I_1P = I_2R$ .....(3)

$I_3Q = I_4S$ .....(4)

Dividing equation (3) by equation (4)

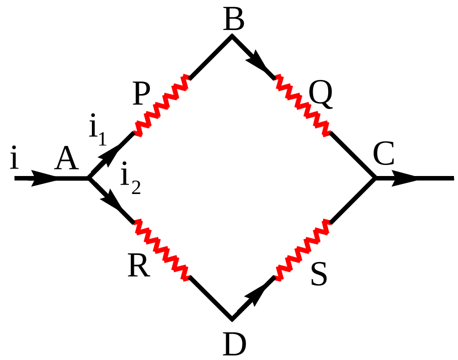
$$\frac{I_1P}{I_3Q} = \frac{I_2R}{I_4S}$$

Using equations (1) and (2) we get

$$\frac{P}{Q} = \frac{R}{S} \quad .....(5)$$

This is the balancing condition for Wheat stone bridge.

**Application: Direction of current in an unbalanced Wheatstone's bridge:**




$$V_{AB} = V_A - V_B = i_1 P = i\frac{(R+S)P}{P+Q+R+S}$$

$$V_{AD} = V_A - V_D = i_2 R = i\frac{(P+Q)R}{P+Q+R+S}$$

$$(V_B - V_D) = \frac{i}{P+Q+R+S}\left[(P+Q)R-(R+S)P\right]$$

$$= \frac{i}{P+Q+R+S}\left[QR-PS\right]$$

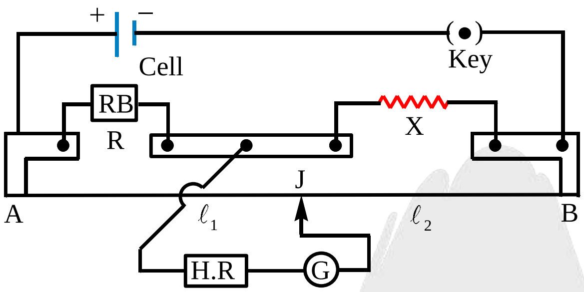
If $QR > PS$, $V_B > V_D$ $\Rightarrow$ current flows from B to D

If $QR < PS$, $V_B < V_D$ $\Rightarrow$ current flows from D to B

$QR = PS$, $V_B = V_D \Rightarrow$ balanced bridge

**Meter bridge:**

1. It works on the principle of Wheatstone Bridge $\left(\frac{P}{Q}=\frac{R}{S}\right)$




2. When the Meter bridge is balanced then

$\frac{R}{X}=\frac{\ell_1}{\ell_2}=\frac{\ell_1}{100-\ell_1}$, where $\ell_1$ is the balancing length from the left end.

**Note:**

1. If resistance in the left gap increases or resistance in the right gap decreases, balancing point shifts towards right side
2. If resistance in the left gap decreases or resistance in the right gap increases, balancing point shifts towards left.
3. If a cm, b cm are the end corrections at A and B, then $\frac{R}{X}=\frac{\ell_1+a}{\ell_2+b}$
4. Meter bridge is more sensitive if $\ell_1 = 50\,\text{cm}$
5. The resistance of copper strip is called end resistance

**Potentiometer:**

Potentiometer is an instrument which can measure accurately the emf of a source or the potential difference across any part of an electric circuit without drawing any current.

**Principle:**

The principle of potentiometer states that when a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.

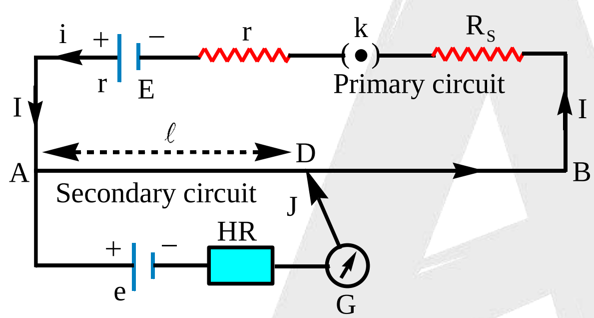
The principle of potentiometer requires that

(i) Potentiometer wire should be of uniform area of cross-section and

(ii) Current through the wire should remain constant

**Theory of potentiometer:**

The end of the potentiometer wire AB are connected to a standard cell of emf E or a source of emf E that supplies constant current. The current through the potentiometer wire can be varied by means of a series resistance $R_s$ which is adjustable.




Let r be the internal resistance of the cell of emf E connected across the potentiometer wire of length L and resistance R. The current through the potentiometer wire is $I = \dfrac{E}{r + R + R_S}$

The potential of the wire decreases from the end A to the end B. The potential fall or potential drop across a length $\ell$ of the potentiometer wire is V = Current x Resistance of length $\ell$ of the potentiometer wire $= I \times \left(\dfrac{R}{L}\right)\ell$

If the resistance per unit length of the wire, $\dfrac{R}{L}$ is denoted by $\rho$, the potential drop across the wire is $V = I \times \rho \times \ell$

$\frac{V}{\ell}$ is called potential drop per unit length of the potentiometer wire or potential gradient of the wire. It is given by $\frac{V}{\ell} = I\rho \quad = \left(\frac{E}{r+R+R_S}\right)\frac{R}{L}$

Thus, the unknown voltage V is measured when no current is drawn from it.

1) When specific resistance (S) of potentiometer wire is given then potential gradient

$X = \frac{IS}{A} = \frac{IS}{\pi r^2}$ where A = area of cross – section of potentiometer wire r = Radius of potentiometer wire.

2) When two wires of length $L_1$ and $L_2$ and resistance $R_1$ and $R_2$ are joined together to form the potentiometer wire, then $\frac{x_1}{x_2} = \frac{R_1}{L_1}\frac{L_2}{R_2}$

**Potential gradient depends on**

a) Resistance per unit length of the potentiometer wire $(\rho = R / L)$

b) Radius of cross section of the potentiometer wire, when the series resistance is included in the circuit and cell in the primary circuit is not ideal.

c) Current flowing through potentiometer wire

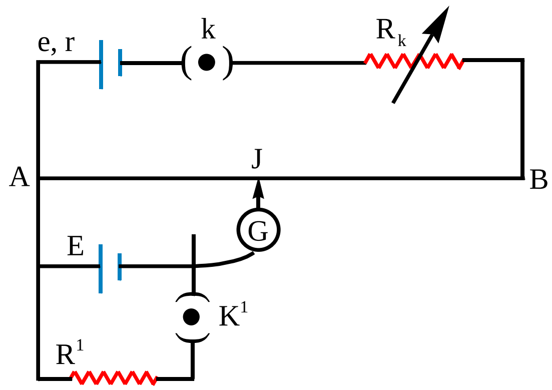
d) emf of the cell in primary circuit

e) Series resistance in the primary circuit

f) Total length (L) and resistance (R) of the potentiometer wire

g) If cell in primary circuit is ideal and in the absence of series resistance potential gradient **only depends on emf of cell** in primary circuit and length of potentiometer wire

**To Determine the Internal Resistance of A Primary Cell:**




1. Initially in secondary circuit key K' remains open and balancing length $(\ell_1)$ is obtained. Since cell E is in open circuit so it's emf balances on length $\ell_1$

   i.e., $E = x\ell_1$ ....(i)

2. Now key K' is closed so cell E comes in closed circuit. If the process of balancing is repeated again keeping constant then potential difference V balances on length $\ell_2$

   i.e., $V = x\ell_2$ ....(ii)

3. By using formula internal resistance

   $$r = \left(\frac{E}{V} - 1\right).R'$$

   Where E = emf of cell in secondary circuit

   V = Terminal voltage

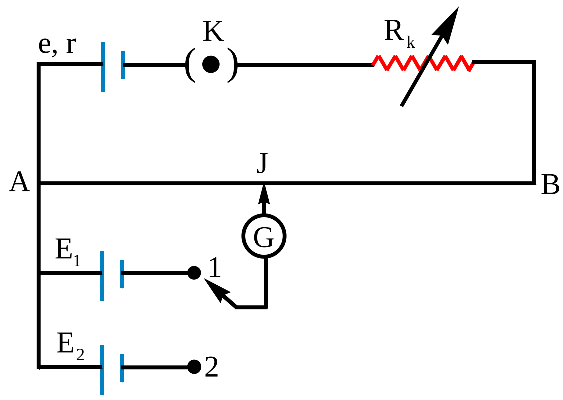
   i.e., p.d on R, $r = \left(\frac{\ell_1 - \ell_2}{\ell_2}\right)R'$

   $$\because \frac{E}{V} = \frac{\ell_1}{\ell_2}, \qquad \frac{E}{V} - 1 = \frac{\ell_1}{\ell_2} - 1$$

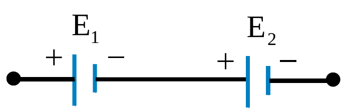
**Comparison of emf's of two cells:**

1. Let $\ell_1$ and $\ell_2$ be the balancing length with the cell $E_1$ and $E_2$ respectively, then $E_1 = x\ell_1$ and

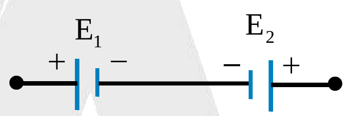
   $$E_2 = x\ell_2 \Rightarrow \frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$$




2. Let $E_1 > E_2$ and both are connected in series. If balancing length is $\ell_1$ when cells assist each other and it is $\ell_2$ when they oppose each other as shown then:




$(E_1 + E_2) = x\ell_1$

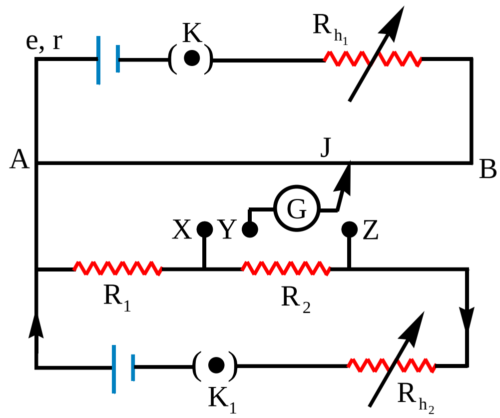



$(E_1 - E_2) = x\ell_2$

$$\Rightarrow \frac{E_1 + E_2}{E_1 - E_2} = \frac{\ell_1}{\ell_2} \qquad \text{(or)} \qquad \frac{E_1}{E_2} = \frac{\ell_1 + \ell_2}{\ell_1 - \ell_2}$$

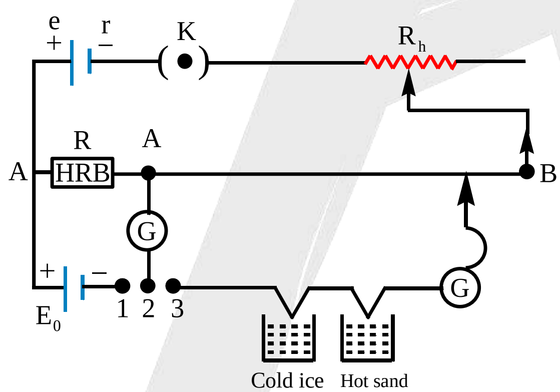
**Comparison of resistances :**

Let the balancing length for resistance $R_1$ (when XY is connected) be $\ell_1$ and let balancing length for resistance $R_1 + R_2$ (when YZ is connected) be $\ell_2$. Keeping X constant




Then $iR_1 = x\ell_1$ and $i(R_1 + R_2) = x\ell_2 \Rightarrow \frac{R_2}{R_1} = \frac{\ell_2 - \ell_1}{\ell_1}$

**To determine thermo emf :**



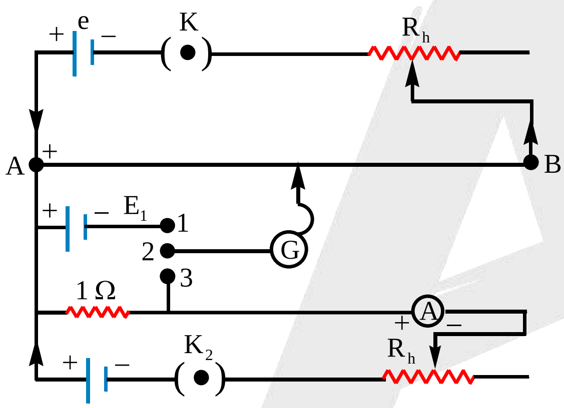

- The value of thermo-emf in a thermocouple for ordinary temperature difference is very low $\left(10^{-6}\ \text{volt}\right)$. For this the potential gradient x must be also very low $\left(10^{-4}\ \text{V/m}\right)$. Hence a high resistance high resistance (R) is connected in series with the potentiometer wire in order to reduce current in the primary circuit
- The potential difference across R must be equal to the emf of standard cell

i.e. $iR = E_0$ $\therefore \ i = \dfrac{E_0}{R}$

- The small thermo emf produced in the thermocouple $e = x\ell$
- $x = i\rho = \dfrac{iR}{L}$ $\therefore \ e = \dfrac{iR'\ell}{L}$

where L = Length of potentiometer wire, $\rho$ = resistance per unit length, $\ell$ = balancing length of e and $R^{|}$ = Resistance of potentiometer wire

**Calibration of an Ammeter :** Checking the correctness of ammeter readings with the help of potentiometer is called calibration of ammeter.

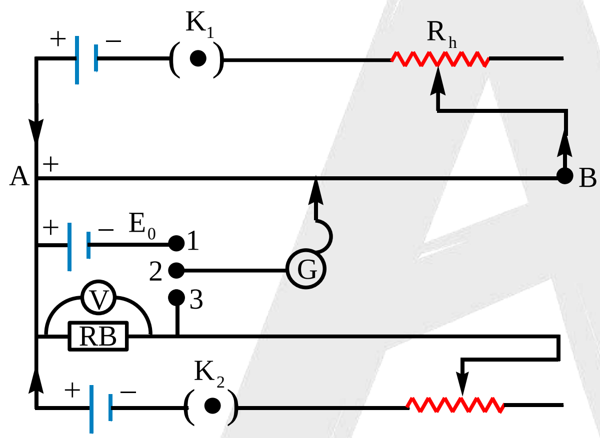



- For the calibration of an ammeter, 1 Ω resistance coil is specially used in the secondary circuit of the potentiometer, because the potential difference across 1 Ω is equal to the current following through it i.e V = i
- If the balancing length for the emf $E_0$ is $\ell_0$ then $E_0 = x\ell_0 \Rightarrow x = \dfrac{E_0}{\ell_0}$ (Process of standardization)
- Let $i'$ current flows through 1 Ω resistance giving potential difference as $V' = i'(1) = x\ell_1$ where $\ell_1$ is the balancing length. So error can be found as $\Delta i = i - i' = i - x\ell_1 = i - \dfrac{E_0}{\ell_0} \times \ell_1$

Here i is ammeter reading

**Calibration of voltmeter :**

- Checking the correctness of voltmeter readings with the help of potentiometer is called calibration of voltmeter.
- If $\ell_0$ is balancing length for $E_0$ the emf of standard cell by connecting 1 and 2 of bi-directional key, then $x = E_0 / \ell_0$



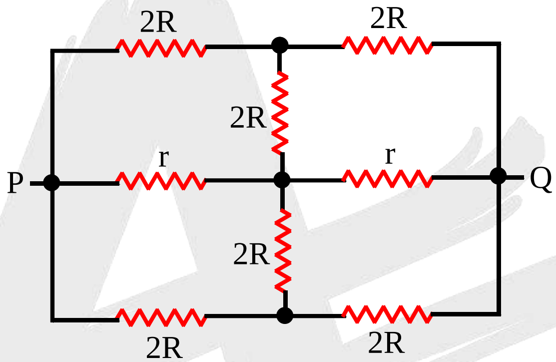

- The balancing length $\ell_1$ for unknown potential difference $V'$ is given by (closing 2 and 3)

$$V' = x\ell_1 = \left(\frac{E_0}{\ell_0}\right)\ell_1$$

If the voltmeter reading is V then the error will be $(V - V')$ which may be +ve, -ve or zero.

## EXCERCISE-1

1. The effective resistance between points P and Q of the electrical circuit shown in the figure is $\frac{\alpha Rr}{R+r}$. Find $\alpha$ ?



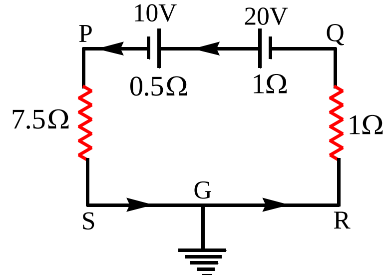

2. An electric current of 5 A is passed through a circuit containing three wires arranged in parallel. If the lengths and radii of the wires are in the ratio 2 : 3 : 4 and 3 : 4 : 5, respectively, then the ratio of current passing through the wires would be :

(A) $54:64:75$ (B) $9:16:25$ (C) $4:9:16$ (D) $75:54:64$

3. A circuit consists of a resistance R connected to n similar cells. If the current in the circuit is the same whether the cells are connected in series or in parallel, then the internal resistance r of each cell is given by :

(A) $r=\frac{R}{n}$ (B) $r=nR$ (C) $r=R$ (D) $r=\frac{1}{R}$

4. In the circuit shown :




(A) The potential at P is 7.5 V (B) The potential at Q is −1 V

(C) The potential at R is zero (D) The potential at S is zero

5. The electron in a hydrogen atom moves in a circular orbit of radius $5\times10^{-11}$ m with a speed of $0.6\pi\times10^{6}$ m / s. Then :

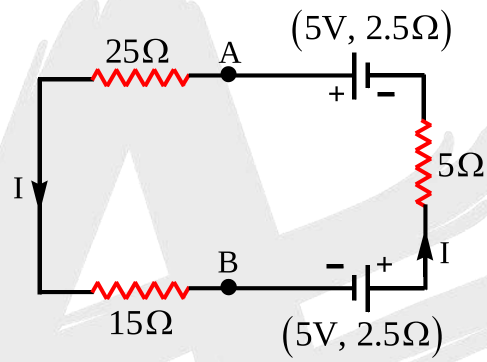
(A) The frequency of revolutions of the electron is $6\times10^{15}$ rev / s

(B) The electron carries $-1.6\times10^{-19}$ C around the loop

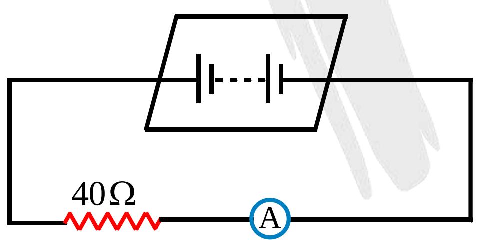
(C) The current in the orbit is 1.96 mA

(D) The current flow in the opposite direction to the direction of motion of electron

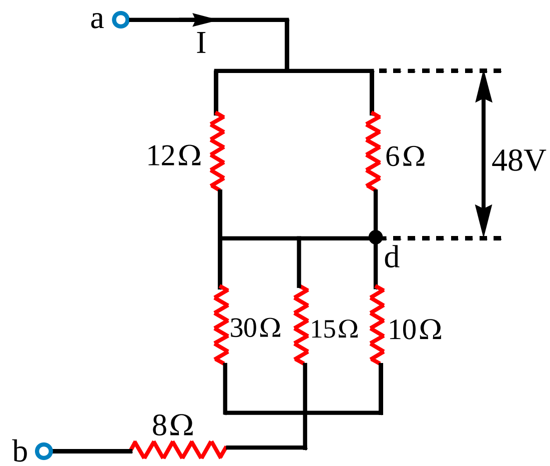
6. Find the potential difference in volt between points A and B in the circuit shows in figure.




7. 10 identical cells each of 10 volt emf and internal resistance $2\ \Omega$ are arranged in series to form a battery but some cells are attached in reverse order by mistake. This battery is used to fix the current in given circuit. Ammeter is ideal and gives reading 1 A. Find number of cells in reverse order.

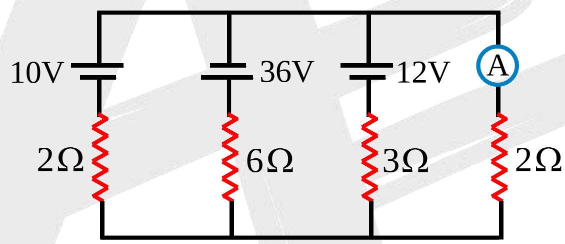



8. The potential difference across the 6 ohm resistance in the given circuit is 48 V. The potential difference across a to b is $51\times\alpha$ Volt. Then find the value of $\alpha$.

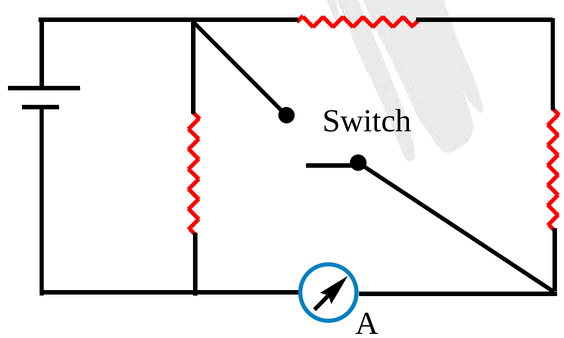



9. Two heaters operating on 220 V, can individually supply a certain amount of heat in 10 min and 15 min separately. If both of them are operated simultaneously in parallel on 220 V, then in how many minutes, will the same amount of heat will be delivered?

10. Find the current shown by ammeter (ideal) in ampere.

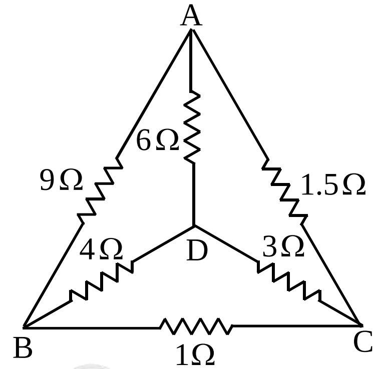



11. In the circuit shown, the reading of the Ammeter is doubled after the switch is closed. Each resistor has a resistance = 1 Ω and the ideal cell has an e.m.f. = 10 V. Then the ammeter has a resistance $(\text{in } \Omega)$ equal to :



12. A network of resistance is formed as follows:

$AB = 9\Omega;\ BC = 1\Omega;\ CA = 1.5\Omega$ forming a delta and $AD = 6\Omega;\ BD = 4\Omega$ and $CD = 3\Omega$ forming a star.



(a)

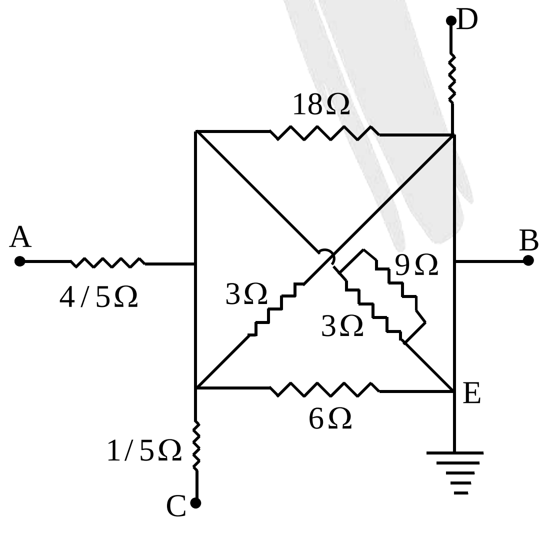
(A) The network resistance between A and B is $R_{AB} = \frac{18}{11}\Omega$

(B) The network resistance between B and C is $R_{BC} = \frac{441}{550}\Omega$

(C) The network resistance between C and A is $R_{CA} = \frac{550}{621}\Omega$

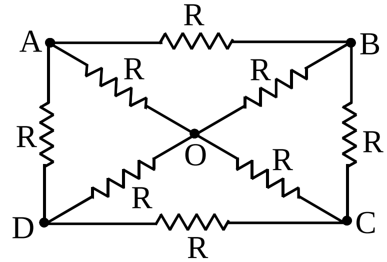
(D) The network resistance between C and A is $R_{CA} = \frac{621}{550}\Omega$

13. In figure shown, if a battery is connected between points A and B, emf $E = 18\,V$, what is current through it?



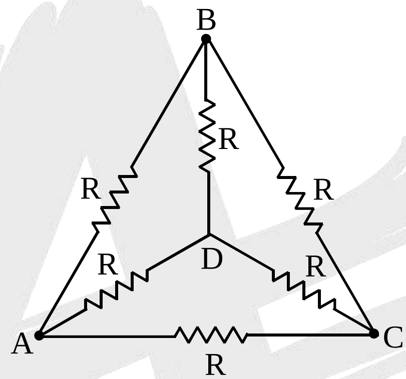

(A) 5 A (B) 10 A (C) 15 A (D) 20 A

14. Calculate effective resistance between points A and C for the networks shown.




(A) $\frac{R}{3}$ (B) $\frac{4R}{3}$ (C) $\frac{5R}{3}$ (D) $\frac{2R}{3}$

15. Calculate the effective resistance between points A and C, by applying symmetry principle.




(A) $\frac{R}{8}$ (B) $\frac{R}{4}$ (C) $\frac{R}{2}$ (D) R

16. Find effective resistance between points A and B of an infinite chain of resistors joined as shown in figure (a)

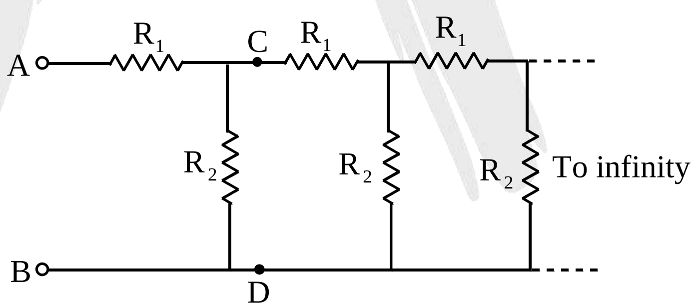
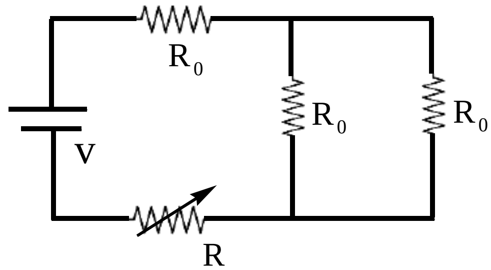


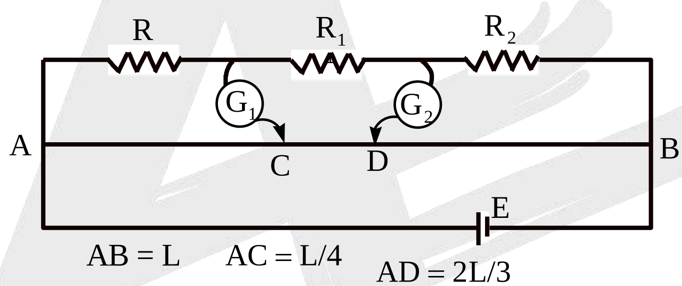

Figure (A)

(A) 0.6 R (B) 1.6 R (C) 2.6 R (D) 3.6 R

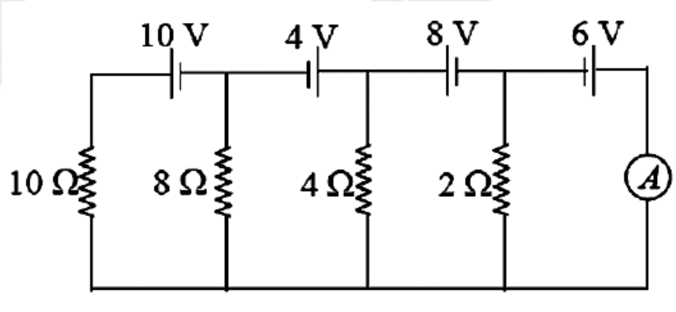
17. In the circuit shown, the value of R for which power dissipated in it will be maximum is $\left(\frac{aR_O}{b}\right)$ then $(a+b)$ is? (take a, b values in between the integers 2 and 9) (consider the battery is ideal)



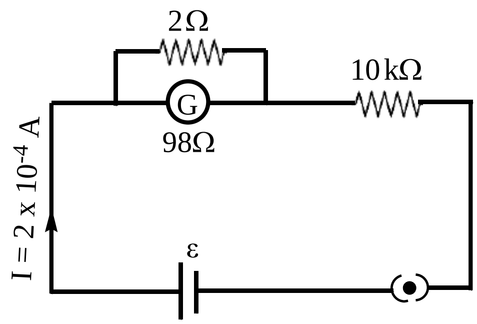

18. The diagram shows a modified meter bridge, which is used for measuring two unknown resistances at the same time. When only galvanometer $G_1$ is used for obtaining the balancing point, it is found at point C. Now the galvanometer $G_1$ is removed and the second galvanometer $G_2$ is used, which gives balance point at D. using the details given in the diagram $R_1$ value is found to be $\frac{KR}{3}$, then K is (consider the cell is idea)




19. If the reading of the ideal ammeter connected in the given circuit $n\left(\frac{13}{20}\right)$ ampere, find the value of n. Assume that the cells have negligible internal resistance.

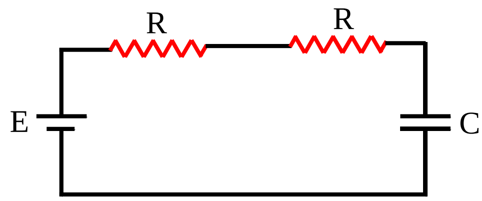



20. A galvanometer of resistance $98\Omega$ is connected in a circuit as shown in figure. It has 40 divisions on both sides of zero and it is showing full scale deflection in the given situation. The figure of merit of galvanometer is (in $\mu A$ / division )


2Ω
10kΩ
G
98Ω
I = 2 x 10-4 A
ε

## EXCERCISE-2

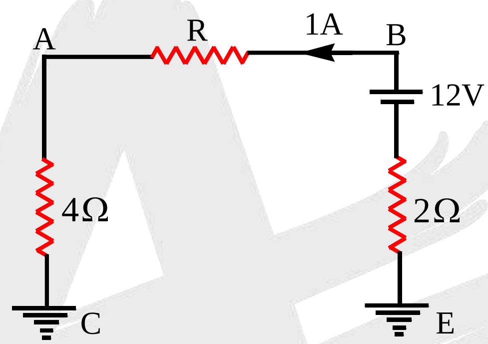
1. The time constant T for the shown circuit containing resistance and capacitor, is $\alpha RC$. Find $\alpha$ ?




2. If a copper wire is stretched to make it 0.1% longer, the percentage change in its resistance is :

(A) 0.2% increase (B) 0.2 decrease (C) 0.1% increase (D) 0.1% decrease

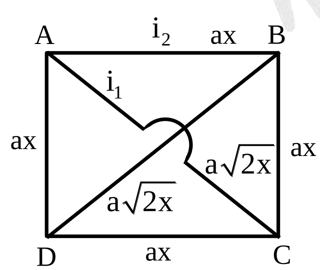
3. Referring to the adjoining circuit, find effective resistance (in $\Omega$) between points B and A is



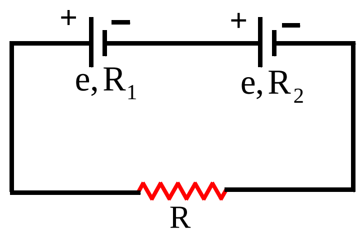

4. A cell of e.m.f. E and internal resistance r is connected in series with an external resistance nr. Then, the ratio of the terminal potential difference to e.m.f. is :

(A) $\frac{1}{n}$ (B) $\frac{1}{n+1}$ (C) $\frac{n}{n+1}$ (D) $\frac{n+1}{n}$

5. ABCD is a square of side a meters and is made of wires of resistance x ohms/meter. Similar wires are connected across the diagonals AC and BD. The effective resistance between the corners A and C is $ax\left(2-\sqrt{\alpha}\right)$. Find $\alpha$ ?




6. Two cells of the same e.m.f. e but different internal resistances $r_1$ and $r_2$ are connected in series with an external resistance R. The potential drop across the first cell is found to be zero. The external resistance R is :




(A) $r_1 - r_2$ (B) $\frac{r_1}{r_2}$ (C) $r_1 r_2$ (D) $r_1 + r_2$

7. Three electric bulbs rated 40, 60 and 100 watts respectively are connected in parallel with 230 volts d.c. mains. The current (in amp) through the 60 W bulb and the effective resistance (in ohm) of the circuit will be respectively, approximately :

(A) 0.23 A (B) 329 $\Omega$ (C) 0.26 A (D) 265 $\Omega$

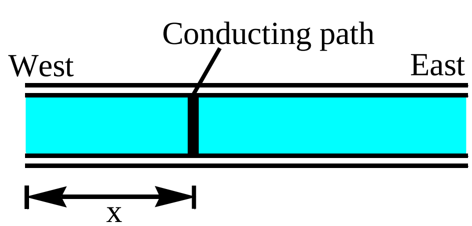
8. Electric field, in a straight solid uniform cylindrical conductor of radius R = 2 cm is along the axis of the cylinder and is given by E = K r where $K = 1\times10^{8}$ and r is the distance from the axis of the cylinder. If current in the cylinder is $I = 16\pi$ micro ampere and find the specific conductivity

(A) $3\times10^{-8}$ siemen (B) $1.5\times10^{-8}$ siemen (C) $3\times10^{8}$ siemen (D) $1.5\times10^{8}$ siemen

9. There is a cylindrical wire whose temperature coefficient of resistivity is $6\times10^{-3}$ /degree and co-efficient of linear expansion is $1\times10^{-3}$ /degree. Find the value of temperature co-efficient of resistance is

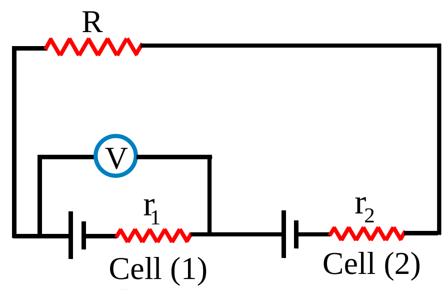
(A) $5\times10^{-2}$ / degree (B) $5\times10^{-3}$ / degree (C) $5\times10^{2}$ / degree (D) $5\times10^{3}$ / degree

10. A 10-km-long underground cable extends east to west and consists of two parallel wires, each of which has resistance $13\ \Omega/\text{km}$. An electrical short develops at distance x from the west end when conducting path of resistance R connects the wires (figure). The resistance of the wires and the short is then $100\ \Omega$ when the measurement is made from the east end, $200\ \Omega$ when it is made from the west end. What is the value of R?

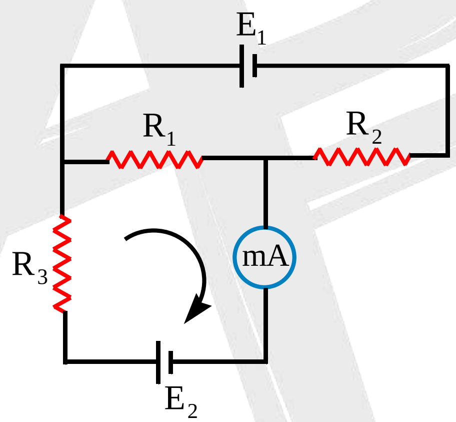



(A) 5 $\Omega$ (B) 10 $\Omega$ (C) 15 $\Omega$ (D) 20 $\Omega$

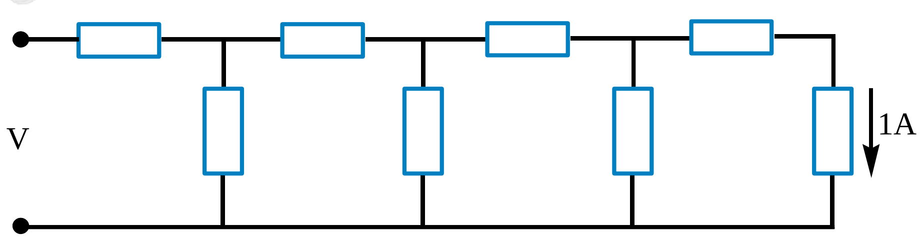
11. In the circuit shown, cells are of equal emf but of different internal resistances $r_1 = 6\ \Omega$ and $r_2 = 4\ \Omega$. It is found that reading of ideal voltmeter across cell (1) is zero, then find value of external resistance R in ohm?




12. The circuit shown in the figure contains three resistors $R_1 = 100\ \Omega$, $R_2 = 50\ \Omega$ and $R_3 = 20\ \Omega$ and cells of emf's $E_1 = 2\,V$ and $E_2$. The ammeter indicates a current of 50 mA. Find the emf (in V) of the second cell. (The internal resistance of the ammeter and of the cell should be neglected.)

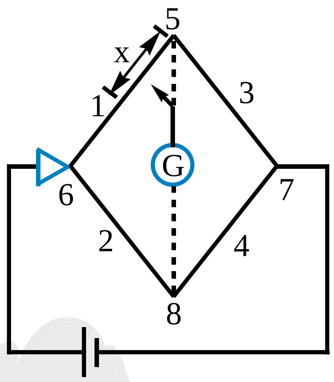



13. Each element in the finite chain of resistors shown in the figure is $1\ \Omega$. A current of 1 A flows through the final element. The potential difference V across the input terminals of the chain is $(30 + n)$ volt. Find n.

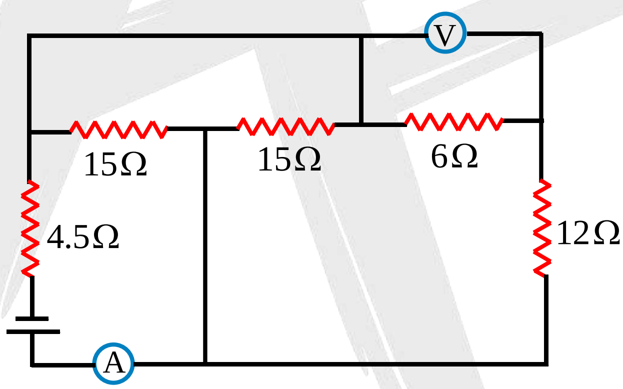



14. A cell of emf 1.5 V and internal resistance $0.5\ \Omega$ is connected to a nonlinear conductor in which current varies with voltage as $V^2 = I$. Calculate the current dranw from cell (in ampere).

15. Four wires of equal length 2 m are arranged as shown in the figure. Wires 2, 3 and 4 are of equal cross sectional area and wire 1 is of half the cross section of these wires. The distance (in m) pointer at point 5 must be moved to get null point is given by x. Find 12x.

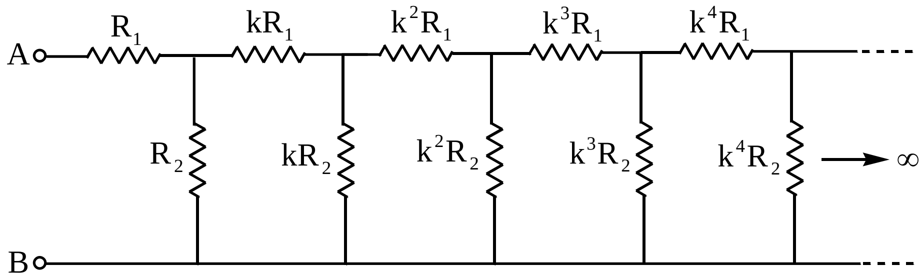



16. A galvanometer of coil resistance $1\,\Omega$ is converted into voltmeter by using a resistance of $5\,\Omega$ in series and another identical galvanometer is converted into ammeter by using a shunt of $1\,\Omega$. Now ammeter and voltmeter connected in circuit as shown, find the ratio of reading of voltmeter (in volts) and ammeter (in amperes).




17. A voltmeter with a resistance of $R_1 = 100\ \Omega$ connected to the terminals of a cell shows a potential difference of 2 V. When this cell is connected across a resistance of $R = 1\,\Omega$, an ammeter connected to the circuit shows a current I = 1 A. Find the emf of the cell ( in V) if the resistance of the ammeter is $R_2 = 1\,\Omega$.

18. The circuit diagram shown consists of a large number of elements (each element has two resistors $R_1$ and $R_2$). The resistances of the resistors in each subsequent element differs by a factor of $k = \frac{1}{2}$ from the resistances of the resistors in the previous elements. Find the equivalent resistance between A and B shown in figure.




(A) $X = \dfrac{(R_1 - R_2) + \sqrt{R_1^2 + R_2^2 + 6R_1R_2}}{2}$

(B) $X = \dfrac{(R_1 + R_2) + \sqrt{R_1^2 + R_2^2 + 6R_1R_2}}{2}$

(C) $X = \dfrac{(R_1 - R_2) + \sqrt{R_1^2 + R_2^2 - 6R_1R_2}}{2}$

(D) $X = \dfrac{(R_1 - R_2) + \sqrt{R_1^2 - R_2^2 + 6R_1R_2}}{2}$

19. Two resistors with temperature coefficients of resistance $\alpha_1$ and $\alpha_2$ have resistances $R_{01}$ and $R_{02}$ at $0°C$. Find the temperature coefficient of the compound resistor consisting of the two resistors connected, (a) in series (b) in parallel

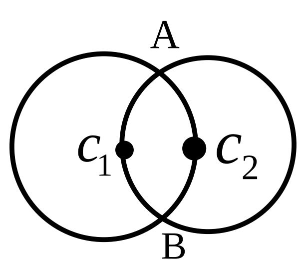
(A) The temperature coefficient of the compound resistor connected in series is $\alpha = \dfrac{R_{01}\alpha_1 + R_{02}\alpha_2}{R_{01} + R_{02}}$

(B) The temperature coefficient of the compound resistor connected in series is $\alpha = \dfrac{R_{01}\alpha_1 - R_{02}\alpha_2}{R_{01} + R_{02}}$

(C) The temperature coefficient of the compound resistor connected in parallel is $\alpha = \dfrac{\alpha_1 R_{02} + \alpha_2 R_{01}}{R_{01} + R_{02}}$

(D) The temperature coefficient of the compound resistor connected in parallel is $\alpha = \dfrac{\alpha_1 R_{02} - \alpha_2 R_{01}}{R_{01} + R_{02}}$

20. Two circular rings of identical radii and uniform resistance of each ring is $36\Omega$, are placed in such a way that they cross each other's center at $C_1$ and $C_2$ as shown in figure. An ideal cell of emf 20 volts is connected between A and B. The power delivered by cell is



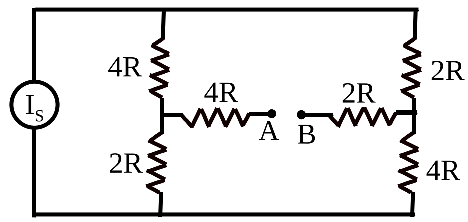

A) 80 W

B) 100 W

C) 120 W

D) 200 W

21. Consider the circuit shown below. $I_S$ is constant current source, meaning that no matter what device is connected between points A and B, the current provided by the constant current source is always $(I_S)$ the same




A) If an ideal voltmeter is connected between A and B, the reading of voltmeter is $l_S R$

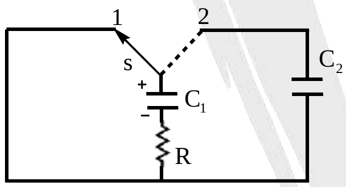
B) If an ideal voltmeter is connected between A and B, the reading of volume is $2l_S R$

C) If an ideal ammeter is connected between A and B, the reading of ammeter is $\frac{l_S}{9}$

D) If an ideal ammeter is connected between A and B, the reading of ammeter is $\frac{l_S}{6}$

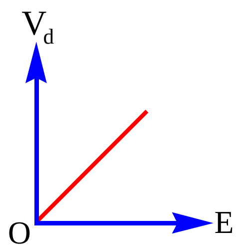
22. A charged capacitor $C_1$ is discharged through a resistance R by putting switch S in position 1 of circuit shown in the figure. When discharge current reduces to $i_o = 1A$, the switch is suddenly shifted to position 2. Let this be t=0. Calculate the total amount of heat liberated in resistance R starting from this instant (i.e from t=0 onwards) (express the answer in micro joule)

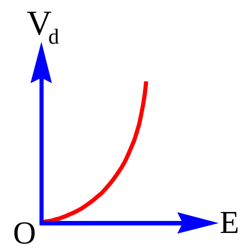
( $C_1 = 6\mu F, C_2 = 3\mu F, i_o = 1A, R = 10\Omega$ )

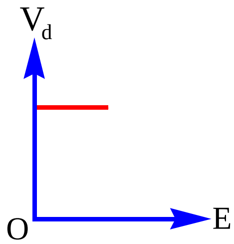


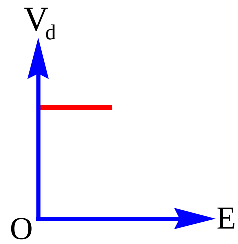

**EXCERCISE-3**

1. If E denotes electric field in a uniform conductor and $v_d$ the corresponding drift velocity of free electrons in the conductor, then which of the following graph is correct ?

(A) 


(B) 

(C) 


(D) 


2. When a galvanometer is shunted with a $4\ \Omega$ resistance, the deflection is reduced to 1/5. If the galvanometer is further shunted with a $2\ \Omega$ wire, the new deflection will be (assuming the main current remains the same) :

(A) $\frac{5}{13}$ of the deflection when shunted with $4\ \Omega$ only

(B) $\frac{8}{13}$ of the deflection when shunted with $4\ \Omega$ only

(C) $\frac{3}{4}$ of the deflection when shunted with $4\ \Omega$ only

(D) $\frac{3}{13}$ of the deflection when shunted with $4\ \Omega$ only

3. If two bulbs of 25 W and 100 W rated at 200 volts are connected in series across a 440 volts supply, then :

(A) 100 watt bulb will fuse

(B) 25 watt bulb will fuse

(C) None of the bulb will fuse

(D) both the bulbs will fuse

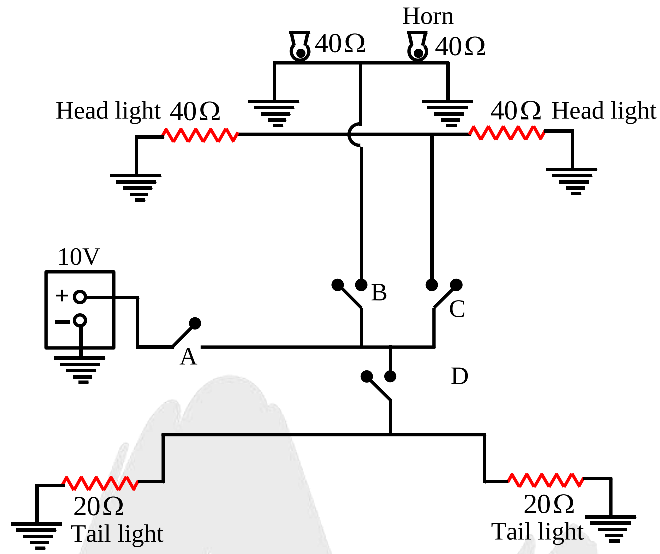
4. A cell of e.m.f. E and internal resistance r supplies currents for the same time t through external resistances $R_1$ and $R_2$ respectively. If the heat produced in both cases is the same, then the internal resistance is given by :

(A) $\frac{1}{r}=\frac{1}{R_1}+\frac{1}{R_2}$ (B) $r=\frac{R_1+R_2}{2}$ (C) $r=\sqrt{R_1 R_2}$ (D) $r=R_1+R_2$

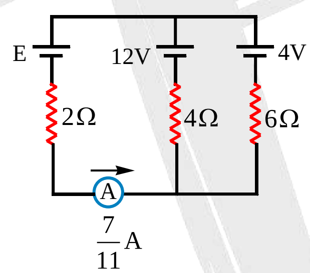
5. Total momentum of electrons in a straight wire of length $\ell$ carrying a current I is P. If mass of electron is doubled keeping its charge constant and length of the wire is also doubled keeping current constant, find the new value of momentum becomes

(A) 2P (B) 3P (C) 4P (D) 5P

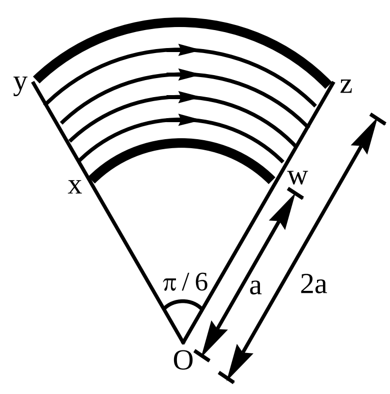
6. Figure shows an automobile circuit. How much power (in watt) is dissipated by the automobile circuit when switches A, B, C and D are all closed.



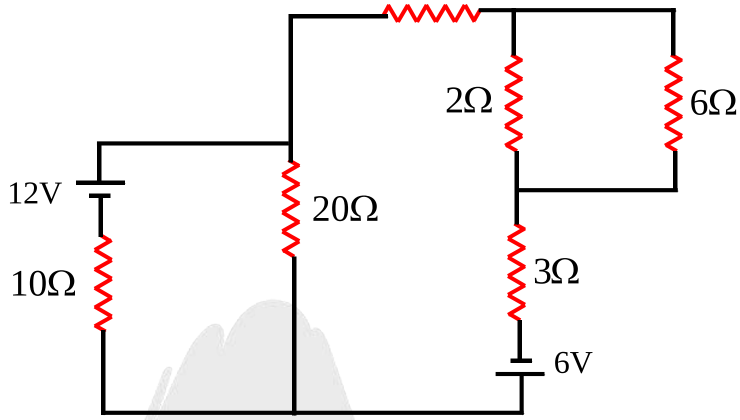

7. For the circuit shown in the figure. Find the emf (in V) of the unknown battery E. The ammeter represented by the symbol A can be considered perfect (i.e. no resistance) and it reads the current in the wire to be $\frac{7}{11}$ A in the direction shown.



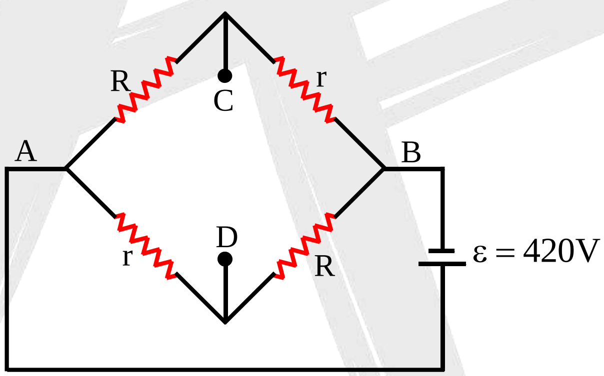

8. Calculate the resistance $(\text{in } \Omega)$ of the conduting strip xyzw having uniform conductivity $\sigma = \frac{\pi}{6}$ mho/metre, thickness $t = \frac{1}{\ln 2}$ m, current flows along the strip as shown by arrow in figure :



9. In the circuit indicated, find the current through both the batteries $i_1$ and $i_2$. If $|i_1|+|i_2|=i$ then find the value of $\frac{5i}{6}$.




10. A perfect voltmeter is connected between C and D gives reading 140 V. When we replace it with an ideal ammeter, its reading is 21 A. Now, we connect a resistor r between C and D. If the current I is flowing through this r between C and D. Find the value of I.




(A) 6 A (B) 3 A (C) 12 A (D) 9 A

Now, using KVL and KCL, we can determine the current through r between C and D = 12 A

11. A rod of length L and cross-section area A lies along the x-axis between x = 0 and x = L. the material obeys Ohm's Law and its resistivity varies along the rod according to,

$\rho(x)=\rho_0 e^{-x/t}$

The end of the rod at x = 0 is at a potential $V_0$ and it is zero at x = L

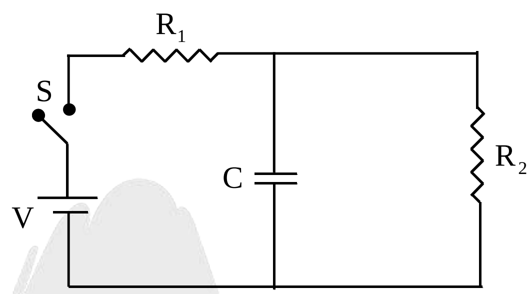
(A) The total resistance of the rod is $\frac{\rho_0 L}{A}\left(1-e^{-1}\right)$

(B) The current in the wire is $\frac{V_0 A}{\rho_0 L}\left(\frac{e}{e-1}\right)$

(C) The electric potential V(x) in the rod as a function of x is $\frac{V_0\left(e^{-x/L}-e^{-1}\right)}{1-e^{-1}}$

(D) The electric potential V(x) in the rod as a function of x is $\frac{V_0\left(e^{-x/L}+e^{-1}\right)}{1-e^{-1}}$

12. At t = 0, switch S is closed. The charge on the capacitor is varying with time as $Q=Q_0\left(1-e^{-\alpha t}\right)$.



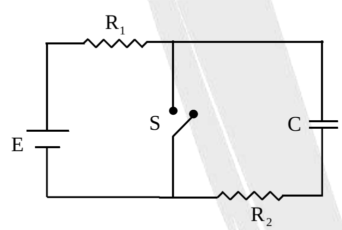

(A) The value of $Q_0$ is $\frac{CVR_2}{R_1-R_2}$

(B) The value of $Q_0$ is $\frac{CVR_2}{R_1+R_2}$

(C) The value of $\alpha$ is $\frac{R_1-R_2}{CR_1R_2}$

(D) The value of $\alpha$ is $\frac{R_1+R_2}{CR_1R_2}$

13. In the circuit in figure, suppose the switch has been open for a very long time. At time t = 0, it is suddenly closed.




(A) The time constant before the switch is closed is $\left(R_1+R_2\right)C$

(B) The time constant after the switch is closed $R_2C$

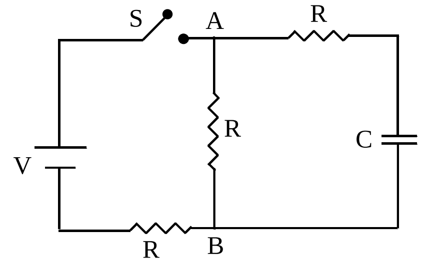
(C) The current through the switch as a function of time after the switch is closed is

$$\frac{E}{R_1}+\left(\frac{E}{R_2}\right)e^{-t/R_2C}$$

(D) The current through the switch as a function of time after the switch is closed is

$$\frac{E}{R_1}-\left(\frac{E}{R_2}\right)e^{-t/R_2C}$$

14. In the circuit shown in figure, the battery is an ideal one, with emf V. the capacitor is initially uncharged. The switch S is closed at time t = 0.




(A) The charge Q on the capacitor at time t is $\frac{CV}{2}\left(1-e^{-\frac{2t}{3RC}}\right)$

(B) The charge Q on the capacitor at time t is $\frac{CV}{2}\left(1+e^{-\frac{2t}{3RC}}\right)$

(C) The current in AB at time t is $\frac{V}{2R}$ as $t \to \infty$

(D) The current in AB at time t is $\frac{V}{R}$ as $t \to \infty$

15. A leaky parallel plane capacitor is filled completely with a material having dielectric constant k = 5 and electrical conductivity $\sigma = 7.4\times10^{-12}\,\Omega^{-1}\,m^{-1}$. If the charge on the plane at instant t = 0 is $q = 8.85\,mC$, then calculate the leakage current at the instant t = 12s.

(A) $0.142\,\mu A$ (B) $0.198\,\mu A$ (C) $0.298\,\mu A$ (D) $0.398\,\mu A$

16. A battery has an open circuit potential difference of 6V between its terminals. When a load resistance of $60\,\Omega$ is connected across the battery, the total power dissipated by the battery is 0.4 W.

(A) The load resistance R is $30\,\Omega$

(B) The maximum power dissipated in R is 0.3 W

(C) The total power supplied by the battery load R connected is 0.6W

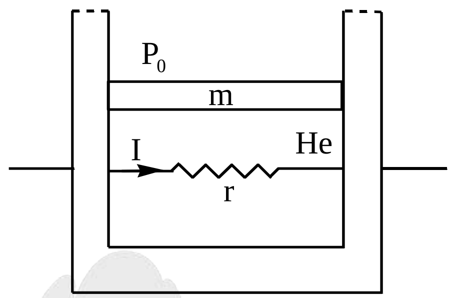
(D) The total power supplied by the battery load R connected is 1.2W

17. A conductor has a temperature independent resistance R and a total heat capacity C. at the moment $t = 0$ it is connected to a dc voltage V. find the time dependence of the conductor's temperature T assuming the thermal power dissipated into surrounding space to vary as $q = k(T - T_0)$ where k is a constant, $T_0$ is the environmental temperature (equal to conductor's temperature at the initial moment).

(A) $T = T_0 + \frac{V^2}{kR}\left[1+e^{\frac{Kt}{C}}\right]$ (B) $T = T_0 + \frac{V^2}{2kR}\left[1+e^{\frac{Kt}{C}}\right]$

(C) $T = T_0 + \frac{V^2}{kR}\left[1-e^{\frac{Kt}{C}}\right]$ (D) $T = T_0 - \frac{V^2}{kR}\left[1-e^{\frac{Kt}{C}}\right]$

18. A resistance coil of resistance r connected to an external battery, is placed inside an adiabatic cylinder fitted with a frictionless piston of mass m and same area A. initially cylinder contains one mole of ideal gas He. A current I flows through the coil such that temperature of gas varies as $T = T_0 + at + bt^2$, keeping pressure constant with time t. atmosphere pressure above piston is $P_0$



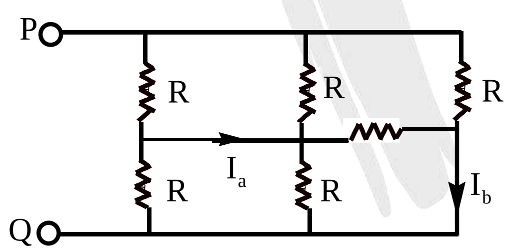

(A) The Current I flowing through the coil as function of time is $\sqrt{\frac{5R}{2r}(2bt+a)}$

(B) The Current I flowing through the coil as function of time is $\sqrt{\frac{5R}{2r}(2bt-a)}$

(C) The Speed of piston as function of time is $\frac{R}{PA}(2bt+a)$

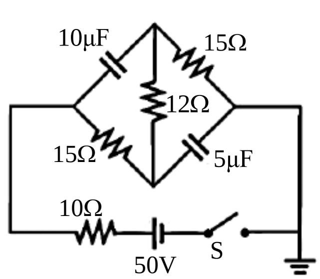
(D) The Speed of piston as function of time is $\frac{R}{PA}(2bt-a)$

19. Points P and Q of the circuit shown are connected to a battery and current is set up. Then $I_b / I_a$ will be




A) 2 B) 7 C) 4 D) not defined

20. All capacitors were initially uncharged



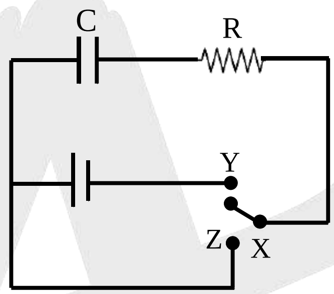
A) Battery current just after closing of switch S is 3.42 A

B) Battery current just after closing of switch S is 0.962 A

C) Battery current after long time of closing of switch S is 3.42 A

D) Battery current after long time of closing of switch S is 0.962 A

21. In the circuit shown, that contains a capacitor $C$ and a resistor $R$, the capacitor $C$ is uncharged initially. When the terminal $X$ is joined to the terminal $Y$ for a long time, it is observed that a heat $H_1$ is produced in the resistor. When the terminal $X$ is joined to the terminal $Z$, again for a long time, it is observed that a heat $H_2$ is produced in the resistor. Also, energy supplied by the battery during the process of charging is $H$. Then

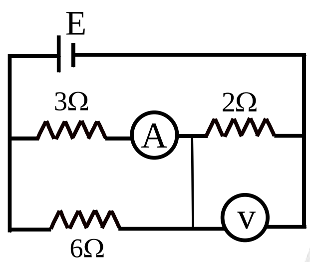
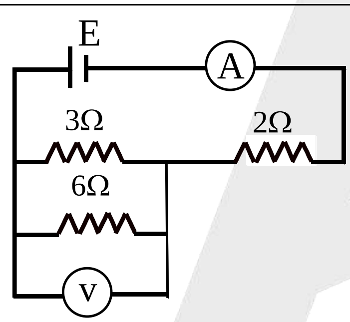
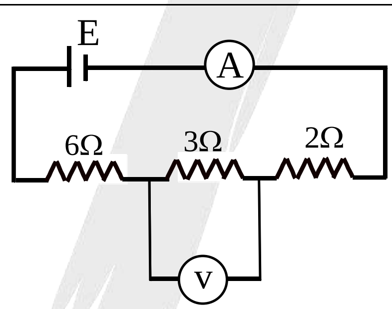
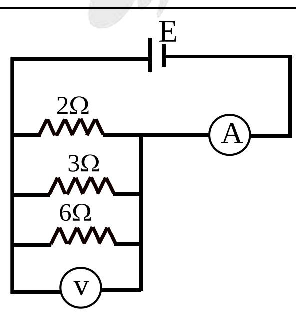



(A) $H_1 = H_2 = \frac{H}{2}$ (B) $H_1 + H_2 = 2H$ (C) $H_1 + H_2 = H$

(D)The maximum energy stored in $C$ at any time is $H_1$

**Answer Q.22, Q.23 and Q.24 by appropriately matching the information given in the three columns of the following table.**

Three resistors $2\Omega, 3\Omega$ and $6\Omega$ are connected to a cell in different ways. The cell (E), ammeter (A) and Voltmeter (V) are ideal. For the circuits in column I, the possible readings of the ammeter and that of the voltmeter as given in column II and III respectively.

| COLUMN - I | | COLUMN – II | | COLUMN -III | |
|---|---|---|---|---|---|
| I) |  | i) | 1A | P) | 2V |
| II) |  | ii) | 2A | Q) | 3V |
| III) |  | iii) | 3A | R) | 4V |
| IV |  | iv) | 4A | S) | 6V |

22. For which of the following the emf of the cell equal to 4V?

A) I, i, S B) III, i, P C) IV, iv, R D) II, i, R

23. When the equivalent resistance of the circuit is $4\Omega$. Choose the circuit with the readings of ammeter and the voltmeter.

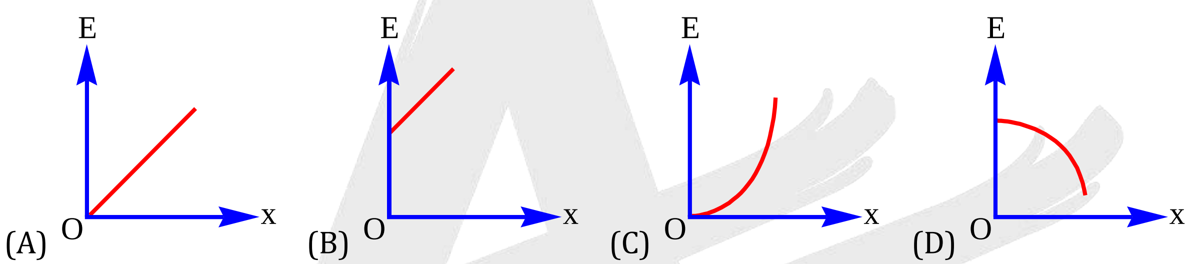
A) II, iii, S B) I, iii, S C) I, i, R D) II, iv, P

24. Which of the following is correct match for the circuit with total resistance $1\Omega$?

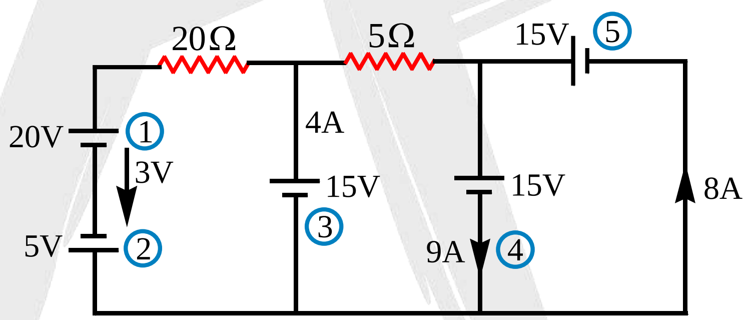
A) III, iii, Q B) III, ii, R C) III, i, S D) III, ii, S

**EXCERCISE-4**

1. A cylindrical conductor has uniform cross-section. Resistivity of its material increases linearly from left end to right end. If a constant current is flowing through it and at a section of distance x from left end, then magnitude of electric field intensity is E. Which of the following graphs is correct?

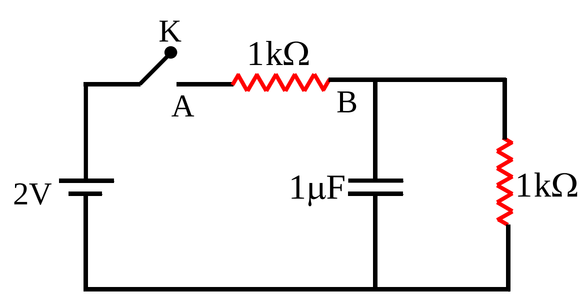



2. In the given network, the batteries getting charged are :




(A) 2, 3 and 5 (B) 1, 3 and 5 (C) 1 and 4 (D) 1, 2 and 5

3. When the key K is pressed at time t = 0, which of the following statements about the current I, in the resistor AB of the given circuit is true ?




(A) It is 2 mA at all times

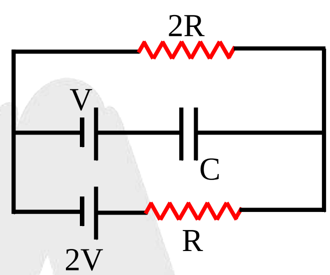
(B) It is oscillates between 1 mA and 2 mA

(C) It is 1 mA at all times

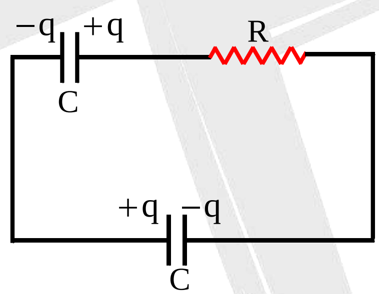
(D) At t = 0, I = 2 mA and with time it finally reduces to 1 mA

4. Two electric bulbs rated $P_1$ and $P_2$ watt at V volt are connected in series across V volt mains, then their total power consumption P is $\frac{\alpha P_1 P_2}{\beta(P_1+P_2)}$. Find $\alpha+\beta$

5. In the circuit shown, the voltage drop across the 2R resistor must be $\frac{\alpha V}{\beta}$. Find $\alpha+\beta$?




6. Two capacitors, having equal capacitance C, are having same charges q on each plate. They are connected across a resistor R as shown in the figure. What is the total heat generated in the resistor upto the instant when the steady state has reached?

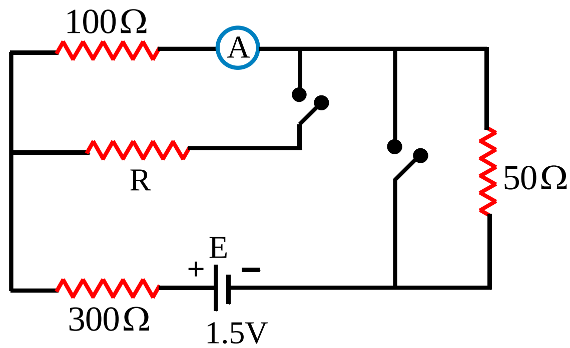



(A) $\frac{q^2}{2C}$ (B) $\frac{q^2}{C}$ (C) Zero (D) $\frac{2q^2}{C}$

7. A beam of fast moving electrons having cross-sectional area $A = 1\ \text{cm}^2$ falls normally on a flat surface. The electrons are absorbed by the surface and the average pressure exerted by the electrons on this surface is found to be P = 9.1 Pa. If the electrons are moving with a speed $v = 8\times10^7$ m/s, then find the effective current through any cross-section of the electron beam. (Mass of electron $= 9.1\times10^{-31}$ kg)

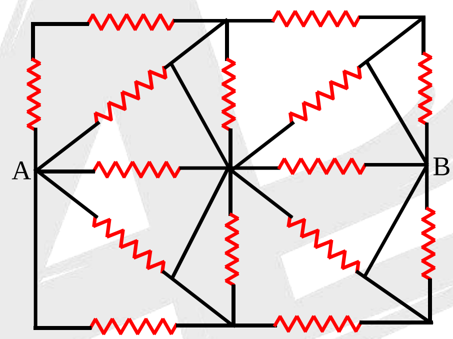
(A) 1 A (B) 2 A (C) 3 A (D) 4 A

8. In the circuit shown, the reading of the ammeter (ideal) is the same with both switches open as with both closed. Find the value of resistance R



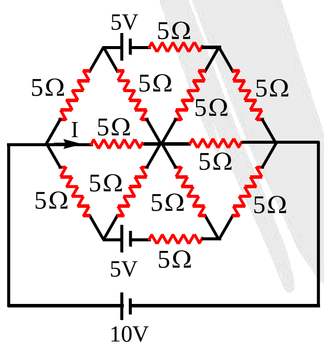

(A) 200 Ω (B) 400 Ω (C) 600 Ω (D) 800 Ω

9. In the given circuit all resistor are identical. Their resistance is equal to $20\ \Omega$. Find the equivalent resistance between A and B in $\Omega$.

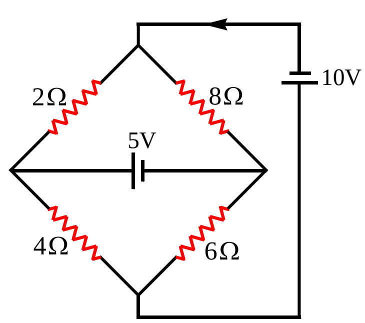



(A) 9 Ω (B) 6 Ω (C) 3 Ω (D) 1 Ω

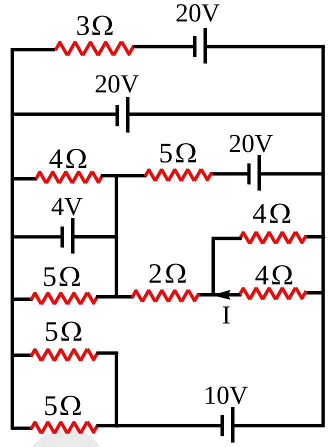
10. In the given circuit find the value of I in amperes.



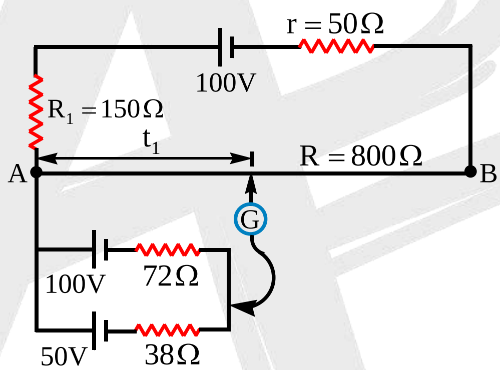

11. The current supplied to the circuit by 10 V cell is I ampere. Assume both cells as ideal find 4I.



12. In the circuit shown, find the value of current I in amp.

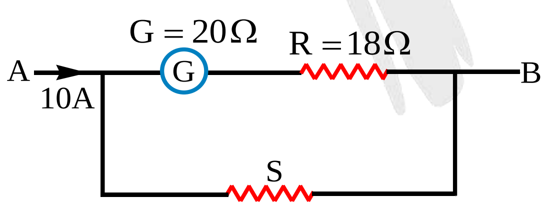



13. In the circuit shown length of A is 100 cm. Then find the value of $\ell_1$. Where $\ell_1$ corresponds to null point.




(A) 80 cm (B) 60 cm (C) 40 cm (D) 20 cm

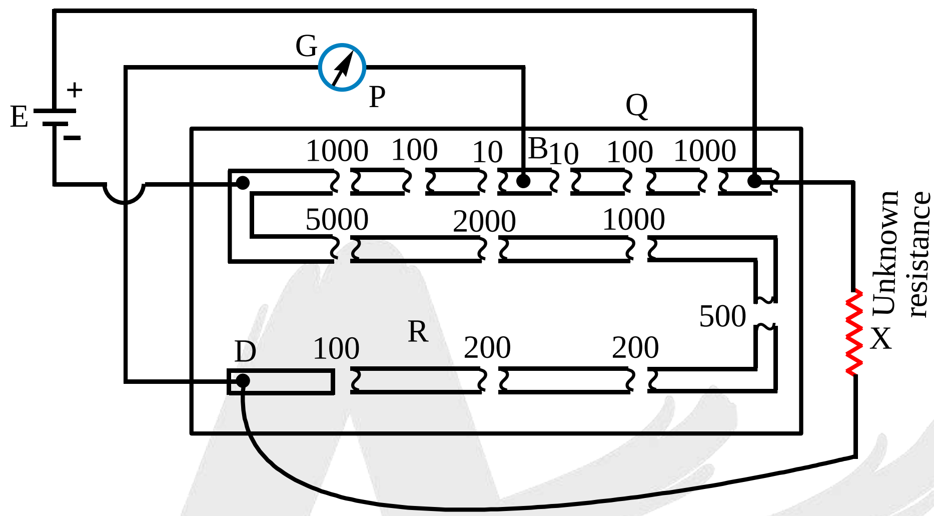
14. Full scale deflection current for galvanometer is 1 Amp. What should be the value of shunt resistance so that galvanometer shows half scale deflection?



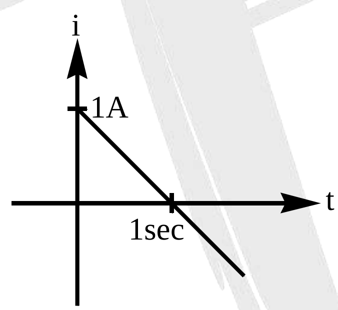

(A) $1\,\Omega$ (B) $2\,\Omega$ (C) $3\,\Omega$ (D) $4\,\Omega$

15. A galvanometer of resistance $40\ \Omega$, shunted by a resistance of $50\ \Omega$ gives a deflection of 50 divisions when joined in series with a resistance of $\frac{1000}{9}$ and a 2 volt battery, what is the current sensitivity of galvanometer (in div/mA)?

16. In the figure shown below, the maximum possible unknown resistance X (in $\Omega$), that can be measured by the post office box are $X_{max}$ is given by $R \times 10^5\,\Omega$, then R is : (in this experiment, we take out only one plug in arm AB and only one plug in arm BC, but in arm AD we can take out many plugs).

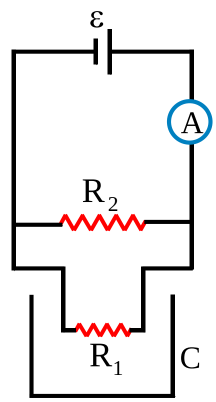



17. Current through $3\,\Omega$ resistor is shown in graph. Find the heat produced in the resistor in first 2 sec



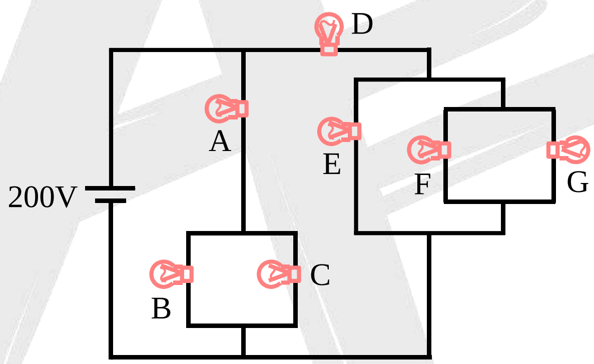

(A) 1 J (B) 2 J (C) 3 J D) 4 J

18. The coil of a calorimeter C has a resistance of $R_1 = 60\,\Omega$. The coil $R_1$ is connected to the circuit as shown in figure. What is the rise in temperature of 240 grams of water poured into the calorimeter when it is heated for 7 minutes during which a current flows through the coil and the ammeter shows 3 A? The resistance $R_2 = 30\,\Omega$. [Disregard the resistances of the battery and the ammeter, and the heat losses and heat capacity of the calorimeter and the resistor and specific heat of water $= 4200\ J/kg^\circ C$]



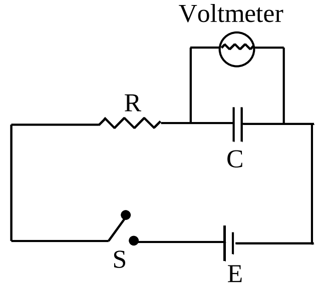

(A) 15°C (B) 20°C (C) 25°C (D) 30°C

19. Circuit shows seven identical bulbs (A to G) connected through a battery of emf 200 V. The bulbs are rated as 200 V, 100 Watt. The power dissipated in the bulb which glow brightest is given by P watt. Fill the value of $\frac{2}{3}\sqrt{P}$.




20. A non-ideal cell with emf $(\varepsilon)$ and internal resistance (r) is connected with an external resistance (R). The efficiency in energy transfer by cell to external resistance is $\eta = \frac{1}{3}$. Now, an unknown resistance (x) is connected in parallel to the external resistance (R), the new efficiency is $\eta = \frac{1}{6}$. Then find the ratio of $\left(\frac{3x}{R}\right)$.

21. A digital voltmeter of internal resistance r is used to measure the voltage across a capacitor after the switch in figure is closed. Because the meter has finite resistance, part of the current supplied by the battery passes through the meter.



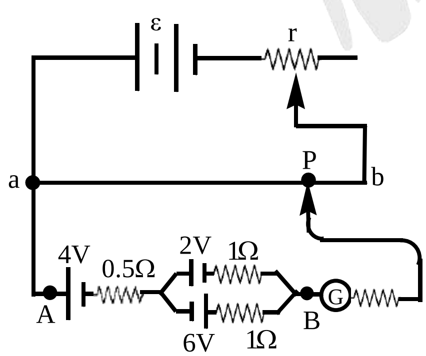

(A) Apply Kirchhoff's rules to this circuit, and use the fact that $I_C = \frac{dq}{dt}$, then that this leads to the difference equation $R_{eq}\frac{dq}{dt} + \frac{q}{C} = \frac{r}{R+r}E$ where $R_{eq} = \frac{rR}{R+r}$

(B) The solution to this differential equation is $q = \frac{CEr}{R+r}\left(1-e^{-\frac{t}{R_{eq}C}}\right)$ and that the voltage across the capacitor as a function of time is $V_C = \frac{Er}{R+r}\left(1-e^{-\frac{t}{R_{eq}C}}\right)$

(C) If the capacitor is fully charged, and the switch is then opened, the voltage across the capacitor is $\frac{Er}{R+r}e^{-\frac{t}{rc}}$

(D) If the capacitor is fully charged, and the switch is then opened, the voltage across the capacitor is $\frac{Er}{R+r}e^{\frac{t}{rc}}$

22. A potentiometer as shown in figure in which three batteries between A & B are connected when the point P is the null point, measured by the potentiometer arrangement. Then choose correct statement(s)



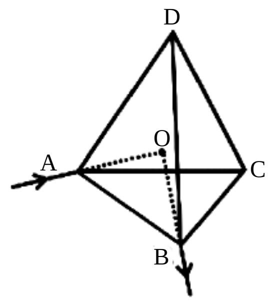

A) Current passing through 6 V battery is 4A

B) Current passing through 2 V battery is 4A

C) $V_A - V_B = 2V$

D) $V_A - V_B = 6V$

23. A regular tetrahedron frame is made up of homogenous resistance wire of uniform cross section. Current I enters vertex A through a long, straight wire directed towards the centre O of the tetrahedron and is conducted away through vertex B in the same way, as illustrated in the figure. Choose **CORRECT** statement(s)



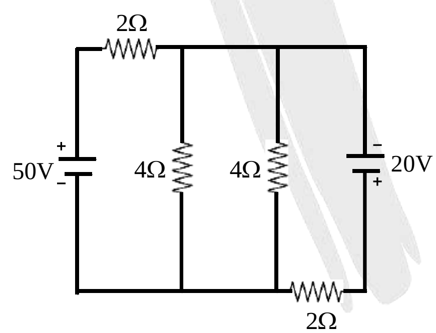

A) There is no current through wire DC because point D and C are equipotential

B) Current through wire AB is I/2

C) Current through wire AC is I/4

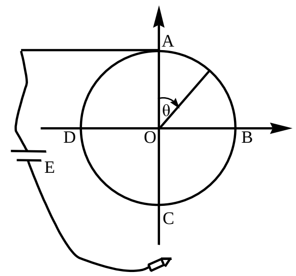
D) Net magnetic field at point O is zero

24. For the circuit containing two batteries and four resistors, connected as follows. Then, mark all correct one –




A) Power of 2 Ω resistor is 800 W
B) Power of 4 Ω resistor is 25 W
C) Power of 2 Ω resistor is 450 W
D) Power of 4 Ω resistor is 50 W

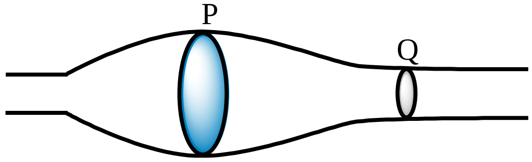
25. The figure shows a circular loop made of a wire. The resistivity of the material varies as a function of $\theta$ such that $\rho = \rho_0 \sin^2\theta$. The positions of the jockey such that the magnetic field at the centre (O) due to the current in the loop is zero, will be




A) $\theta = \frac{\pi}{2}$ B) $\theta = \pi$ C) $\theta = \frac{3\pi}{2}$ D) $\theta = \frac{\pi}{4}$

## EXCERCISE-5

1. A source of constant potential difference is connected across a conductor having irregular cross-section as shown. Then :




(A) electric field intensity at P is greater than that at Q

(B) rate of electrons crossing per unit area of cross-section at P is less than that at Q

(C) the rate of generation of heat per unit length at P is greater than at Q

(D) mean kinetic energy of free electrons at P is greater than that at Q

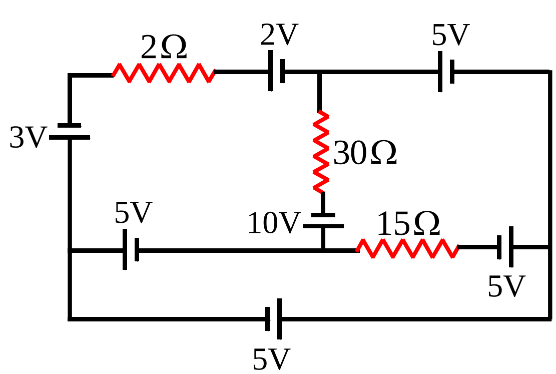
2. An electric current of 16 A exists in a metal wire of cross-section $10^{-6}\,m^2$ and length 1m. Assuming one free electron per atom. The drift speed of the free electrons in the wire is $\alpha \times 10^{-3}\,m/s$. Find $\alpha$ ?

(Density of metal $= 5\times10^3\,kg/m^3$, atomic weight = 60)

3. A long cylinder with uniformly charged surface and cross-sectional radius a = 1.0 cm moves with a constant velocity v = 10 m/s along its axis. An electric field strength at the surface of the cylinder is equal to E = 0.9 kV/cm. Find the resulting convection current, that is, the current caused by mechanical transfer of a charge. $\left(\in_0 = 8.85\times10^{-12}\,C^2/N\text{-}m^2\right)$

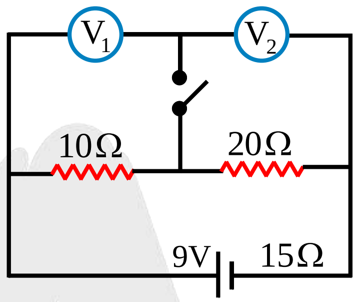
(A) 0.5 μA (B) 1 μA (C) 1.5 μA (D) 2 μA

4. In the circuit shown, current through the resistance $2\Omega$ is $i_1$ and current through the resistance $30\Omega$ is $i_2$. Find the ratio $\frac{i_1}{i_2}$.

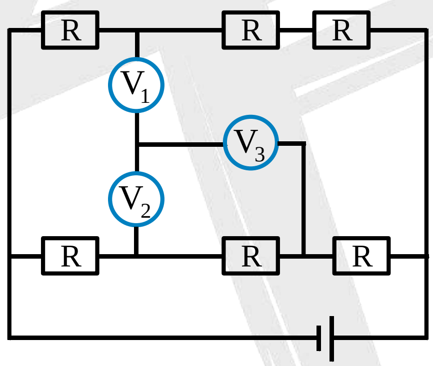



(A) 1 : 3 (B) 3 : 1 (C) 1 : 9 (D) 9 : 1

5. In the circuit shown in the figure the electromotive force of the battery is 9 V and its internal resistance is $15\ \Omega$. The two identical voltmeters can be considered ideal. Let $V_1$ and $V'_1$ reading of 1st voltmeter when switch is open and closed respectively. Similarly, $V_2$ and $V'_2$ be the reading of 2nd voltmeter when switch is open and closed respectively. Then find the value of $\dfrac{V'_2 - V_2}{V_1 - V'_1}$.

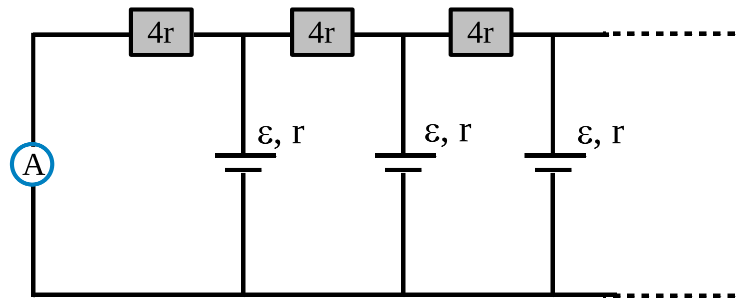



6. In the circuit shown below, all three voltmeters are identical and nearly ideal. Each resistor has the same given resistance R. Voltage V is also given to be 9 V. Find the reading of voltmeter $V_3$

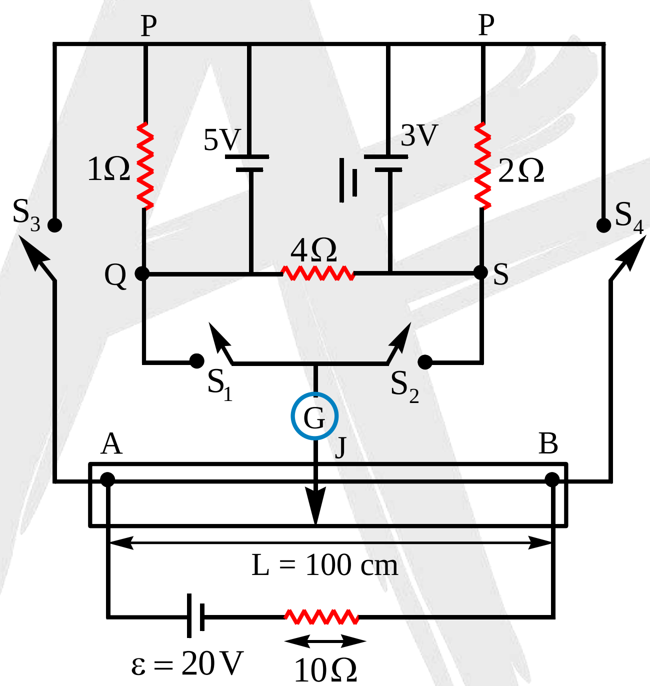



(A) 1V (B) 2V (C) 3V (D) 4V

7. The circuit shown in the diagram extends to the right into infinity. Each battery has the emf $\varepsilon$ (unknown) and the internal resistance r. Each resistor has the resistance 4r. The reading of the ideal ammeter shown in the diagram is $I = \dfrac{\varepsilon}{\left(2 + 2\sqrt{\alpha}\right) r}$. Fill the value of $\alpha$.

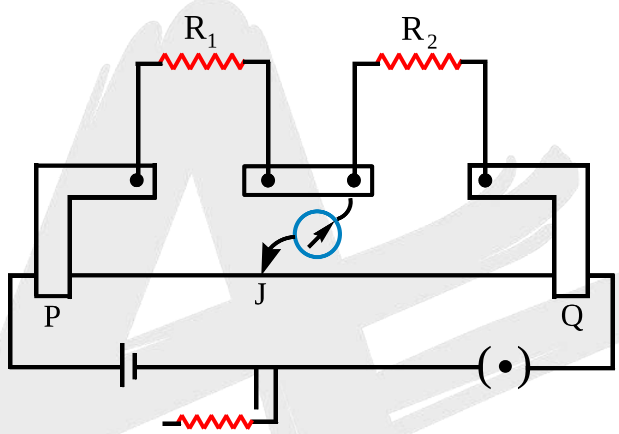



8. Figure shows a potentiometer connected to an external circuit. At an instant either switch $S_1$ and $S_3$ is closed or $S_2$ and $S_4$ is closed. When switch $S_1$ and $S_3$ is closed null point is attained at $J_1(AJ_1 = \ell_1)$ and when $S_2$ and $S_4$ is closed it is attained at $J_2(BJ_2 = \ell_2)$. Find the value of $\left(\frac{\ell_1}{\ell_2}\right)$.



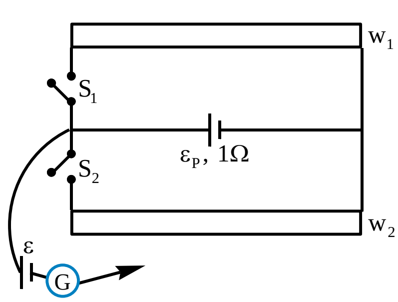

(A) $\frac{5}{3}$ (B) $\frac{3}{5}$ (C) $\frac{2}{3}$ (D) $\frac{3}{2}$

9. The circuit diagram given in the figure shows the experimental setup for the measurement of unknown resistance by using a meter bridge. The wire connected between the points P and Q (PQ = 100 cm) has uniform cross-sectional area and its resistivity is directly proportional to the distance from point P. Null point is obtained with the jockey J with $R_1$ and $R_2$ in the given position. On interchanging the positions $R_1$ and $R_2$ in the gaps the jockey has to be displaced through a distance $\Delta$ from the previous position along the wire to establish the null point. If the ratio of $\frac{R_1}{R_2} = 3$, find the value of $\Delta$. Ignore any end corrections. [Take $\sqrt{3} = 1.7$]



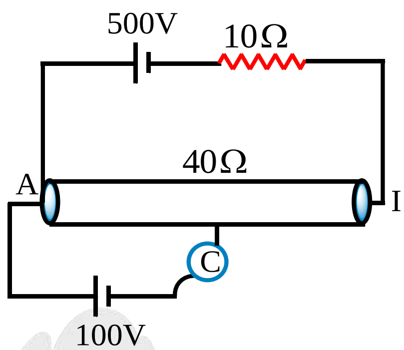

(A) 15 cm (B) 25 cm (C) 35 cm (D) 45 cm

10. Two potentiometer wires $w_1$ and $w_2$ of equal length $\ell$, connected to a battery of emf $\varepsilon_0$ and internal resistance $1\,\Omega$ through two switches $S_1$ and $S_2$. A battery of emf $\varepsilon$ is balanced on these potentiometer wires one by one. If potentiometer wire $w_1$ is of resistance $2\,\Omega$ and balancing length is $\frac{\ell}{2}$ on it, when only $S_1$ is closed and $S_2$ is open. On closing $S_2$ and opening $S_1$ the balancing length on $w_2$ is found to be $\frac{2\ell}{3}$, find the resistance of potentiometer wire $w_2$ is



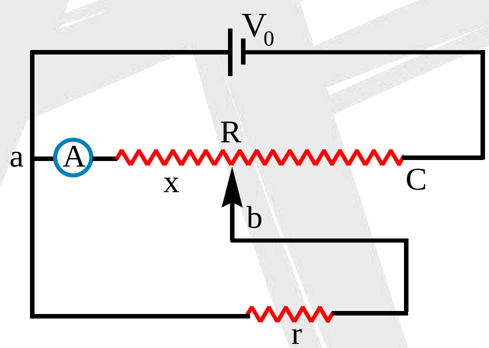

(A) $1\,\Omega$ (B) $2\,\Omega$ (C) $3\,\Omega$ (D) $4\,\Omega$

11. A uniform shape potentiometer wire AB (100 cm long) has specific resistance $\rho = kx$ where x is position of point from starting end A. Then at which position null point of wire will come from left end A for given circuit? Resistance of AB wire is $40\ \Omega$.



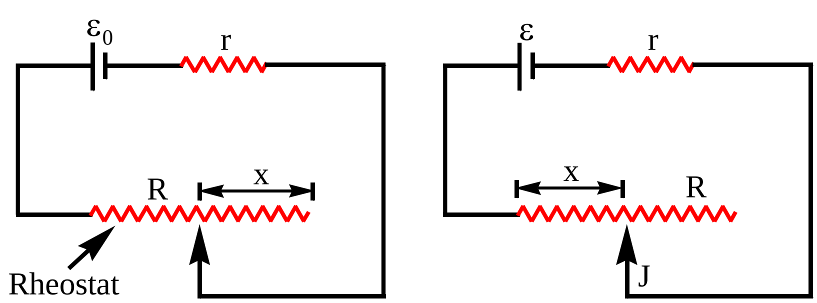

(A) 25 cm (B) 15 cm (C) 50 cm (D) 35 cm

12. A constant voltage $V_0 (=12\ V)$ is applied to a potential divider of resistance $R (= 4\ \Omega)$, connected to an ideal ammeter. A cnstant resistance $r (= 2\ \Omega)$ is connected to the sliding contact of the potential divider (as shown). Find the minimum current measured by ammeter.

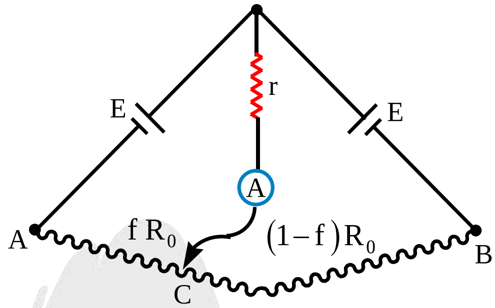



(A) 1 A (B) 2 A (C) 3 A (D) 4 A

13. In the given figure same power is consumed by rheostat (R) in both cases, then find the minimum ratio of $\left(\frac{R}{r}\right)$. Assume total length of R as unity.

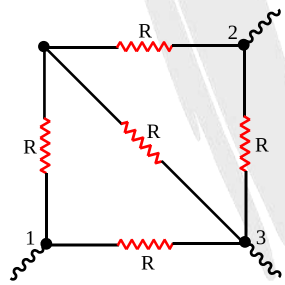


14. In figure, the uniform-resistance wire between A and B has a total resistance $R_0$. The contact at C can divide the wire into resistors f $R_0$ and $(1-f)R_0$. Consider the ideal ammeter for any $0<f<1$. Assume that the batteries are identical and have negligible internal resistance. For what value of f is the ammeter reading is minimum.




(A) $\frac{1}{2}$ (B) $\frac{1}{4}$ (C) $\frac{1}{6}$ (D) $\frac{1}{8}$

15. The resistances in a burner of an electric stove are connected together in an arrangement shown in figure. This arrangement is connected to the supply mains at points 1 and 2, and after a certain time, 500 grams of water are heated to the boiling point. How much water can be heated to the boiling point in the same time interval when the arrangement of resistances is connected to the supply mains at points 1 and 3? The initial temperature of the water is the same in both cases. Neglect all heat loses.

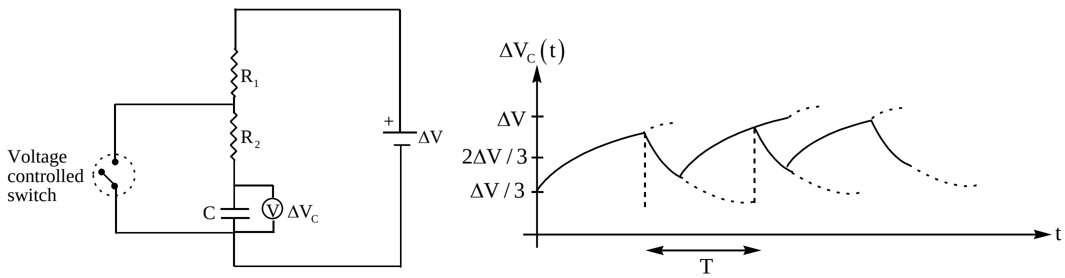



(A) 200 gm (B) 400 gm (C) 600 gm (D) 800 gm

16. An electric kettle has two windings. When one of them is switched on, the water in the kettle begins to boil in 15 minutes, and when the other is switched on it takes 30 minutes for water to boil. If the two windings are joined in series and switched on, find the time water in the kettle begin to boil. Assuming no heat loss to the surrounding.

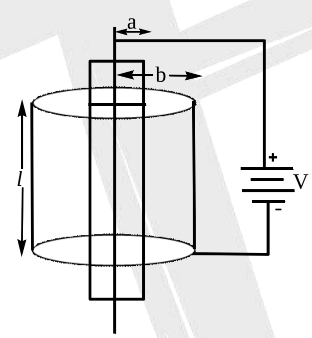
(A) 15 min (B) 30 min (C) 45 min (D) 55 min

17. The switch in figure closes when $\Delta V_C > \frac{2\Delta V}{3}$ and opens when $\Delta V_C < \frac{\Delta V}{3}$. The voltmeter reads a voltage as plotted in figure. What is the period T of the waveform in terms of $R_1$, $R_2$ and C?



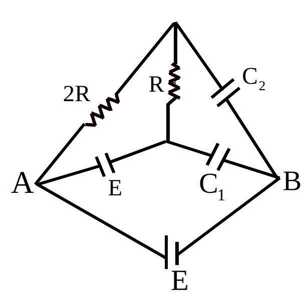

(A) $(R_1 + 2R_2)C\log_e 2$
(B) $(2R_1 + R_2)C\log_e 2$
(C) $(3R_1 + R_2)C\log_e 2$
(D) $(R_1 + 3R_2)C\log_e 2$

18. A metal rod of radius a is concentric with a metal cylindrical shell of radius b and length $l$. The space between rod and cylinder is tightly packed with a high resistance material of resistivity $\rho$. A battery having a terminal voltage V is connected across the combination as shown. Neglect resistance of rod. Then the current $I$ in the circuit is:



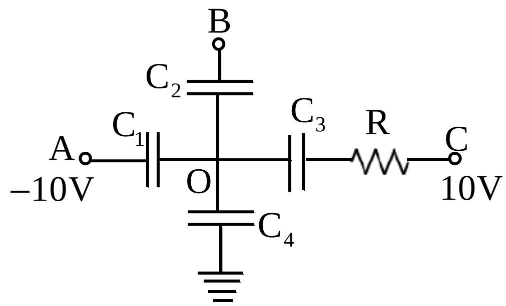

A) $\frac{lV}{\rho}$
B) $\frac{2\pi lV}{\rho(\ln b - \ln a)}$
C) $\frac{4\pi lV}{\rho(\ln b - \ln a)}$
D) $\frac{lV}{4\pi\rho(\ln b - \ln a)}$

19. If energy stored in the capacitor $C_1$ and $C_2$ are same, then find the value of $\frac{C_1}{C_2}$.




A) $\frac{36}{25}$
B) $\frac{1}{36}$
C) $\frac{9}{4}$
D) $\frac{25}{36}$

20. As shown in figure there is a part of large network in which potentials of some of the points are shown. Each capacitor has a capacitance $6\mu F$. Which of the following statements is/are true?



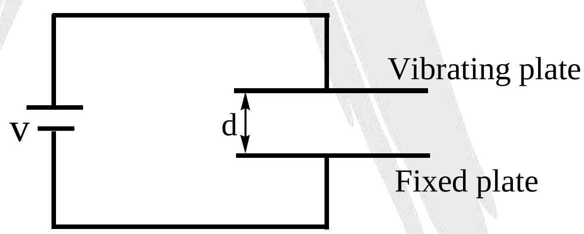

(A) If $V_O$ is potential at O and $V_B$ is potential at B then $4V_0 = V_B$

(B) From the given information, potential of both the points O and B cannot be determined.

(C) If charge on capacitor $C_2$ were also specified, potential of point O can be determined but that of B cannot be determined.

(D) If charge on capacitor $C_2$ were also specified, potentials of both the points O and B can be determined.

21. An air-filled parallel plate capacitor with the plate area A is connected to a battery with an emf V volt and negligible internal resistance. One of the plates vibrates so that the distance between plates varies as $d = d_0 + a\cos\omega t$ (where $a << d_0$). The capacitor breaks down when the instantaneous current reaches to the value 'I'. Choose the CORRECT option(s)



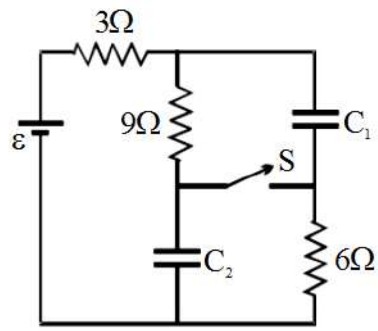

A) The maximum possible amplitude vibrations 'a' is $\frac{Id_0^2}{VA\omega\varepsilon_0}$

B) The maximum possible amplitude vibrations 'a' is $\frac{2Id_0^2}{VA\omega\varepsilon_0}$

C) The instantaneous current in circuit is $\frac{\varepsilon_0 VA\omega a}{(d_0 + a\cos\omega t)^2}\sin\omega t$

D) The instantaneous current in circuit is $\frac{\varepsilon_0 VA\omega a}{2(d_0 + a\cos\omega t)^2}\sin\omega t$

22. In the circuit shown there is steady state with the switch closed. The switch is opened at $t = 0$. Choose the correct option(s). (Given: $\varepsilon = 24V, C_1 = 3F$ and $C_2 = 2F$)




A) The voltage across $C_1$ before the switch is open is 12V.

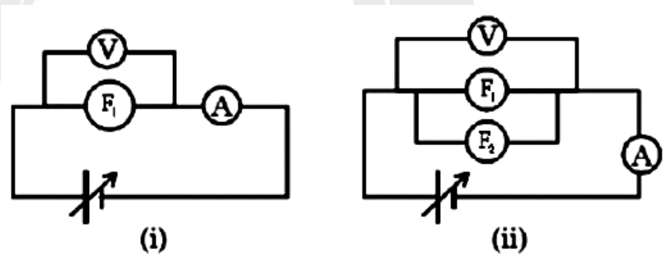
B) The voltage across $C_1$ after a long time after the switch is open is 12V

C) The voltage across $C_2$ after a long time after the switch is open is 24V

D) The voltage across $C_2$ before the switch is open is 8V

**Paragraph For Questions 23 and 24**

A fuse $F_1$ is connected across an ideal source of variable voltage and the voltage is increased gradually. The fuse blows out just when the reading of the voltmeter and ammeter reaches 1.0 V and 1.0 A respectively (see figure (i)). The experiment is repeated with another fuse $F_2$ and the reading of the voltmeter and ammeter when it blows out is 2.4 V and 1.2 A respectively. The ammeter & voltmeter are ideal




23. Now these two fuses are connected in parallel as shown in figure(ii). Voltage is increased gradually. Find the reading of the ammeter and voltmeter just before when any one of the fuses blows out.

A) $R_A = 2.2A, R_V = 2.4V$  B) $R_A = 1.5A, R_V = 2V$

C) $R_A = 1.5A, R_V = 1V$  D) $R_A = 1A, R_V = 1V$

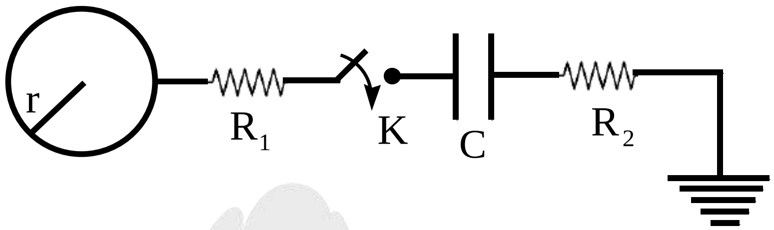
24. If we continue to increase the voltage, the reading just before next fuse will blow out are

A) 1V, 1A  B) 2.4 V, 1.2 A  C) 1.4 V, 2.2 A  D) 2.4 V, 0.2 A

**Paragraph for Question Nos. 25 to 26**

A charged spherical shell of radius r is connected to a capacitor C through two resistances $R_1$ and $R_2$ as shown in figure. Initially charge on sphere is $Q_0$, capacitor and sphere are far enough so that they do not influence each other.

25. Charge on capacitor C after long time as switch K gets closed.




A) $\dfrac{4\pi\in_0 rQ_0}{C+4\pi\in_0 r}$ B) $Q_0$ C) $\dfrac{CQ_0}{C+4\pi\in_0 r}$ D) can't find

26. Heat energy developed across resistor $R_1$ after long time interval as switch gets closed.

A) $\dfrac{Q_0^2 C}{8\pi\in_0 r\left(C+4\pi\in_0 r\right)}\left(\dfrac{R_1}{R_1+R_2}\right)$ B) $\dfrac{R_1 Q_0^2 4\pi\in_0 r}{C\left(R_1+R_2\right)\left(C+4\pi\in_0 r\right)}$

C) $\dfrac{Q_0^2}{2C}$ D) $\dfrac{Q_0^2 R_1 C}{4\pi\in_0 r\left(C+4\pi\in_0 r\right)\left(R_1+R_2\right)}$

## <u>Proficiency Test-1</u>

1. Current-voltage characteristics of two elements A and B are as shown. [Figure (a) and (b)] Which of the following graphs represents current-voltage characteristics for their series combination?

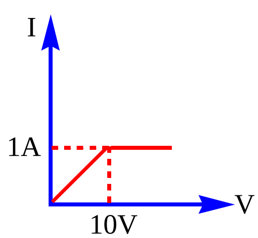


Figure (a)

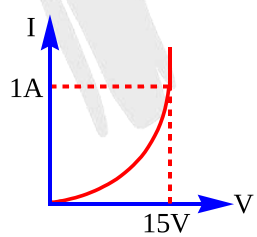
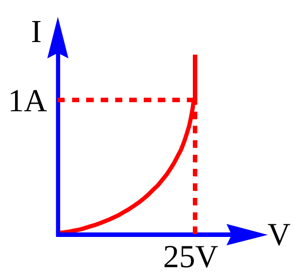
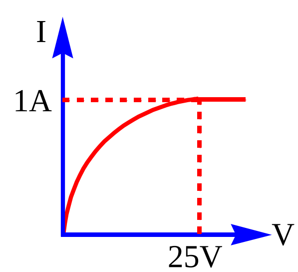


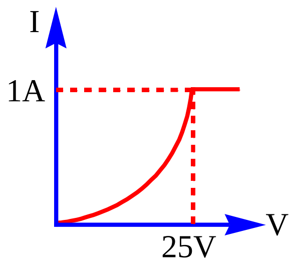
Figure (b)

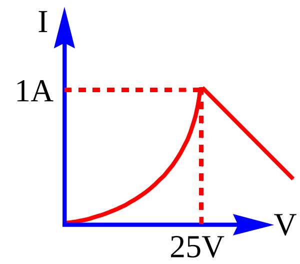


(A)

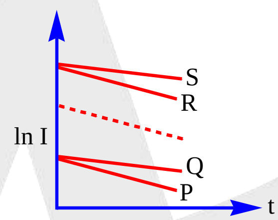


(B)

(C) 

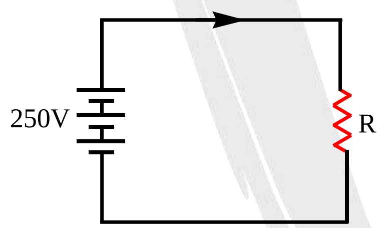

(D) 


2. A capacitor is charged using an external battery with a resistance x in series. The dashed line shows the variation of ln I with respect to time. If the resistance is changed to 2x, the new graph will be :

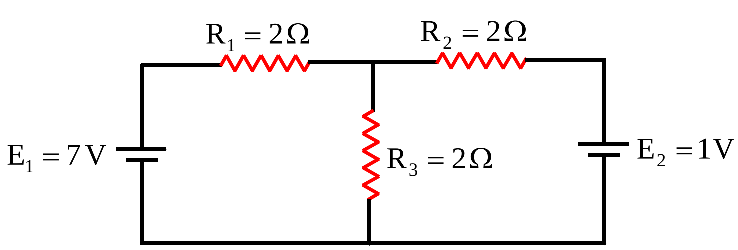



(A) P (B) Q (C) R (D) S

3. In the given circuit, the resistance R has a value that depends on the current. Specifically, R is 20 ohms when I is zero and the increase in resistance (in ohms) is numerically equal to one-half of the current in amperes. What is the value of current I (in A) in the circuit?

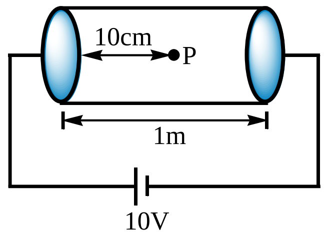



4. In the given electric circuit power supply by battery $E_1$ and $E_2$ are a and b respectively. Find the value of $b^2$.



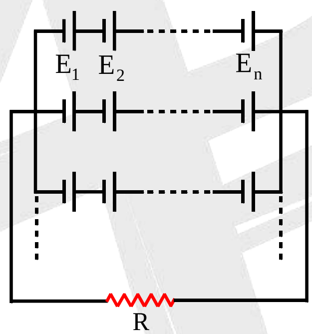

5. A cylindrical solid of length 1m and radius 1m is connected across a source of emf 10 V and negligible internal resistance shown in figure. The resistivity of the rod as a function of x (x

measured from left end) is given by $\rho = bx$ [where b is a positive constant]. Find the electric field (in SI unit) at point P at a distance 10 cm from left end.



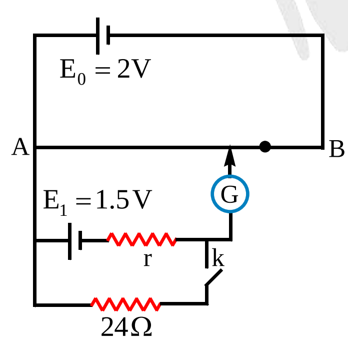

(A) 2 V/m (B) 4 V/m (C) 6 V/m (D) 8 V/m

6. 324 identical galvanic cells, each of internal resistance $9\ \Omega$ are arranged as several in-series groups of cells connected in parallel. The arrangement has been laid out so that power output in an externally connected resistance of value $4\ \Omega$ is maximum. If n cells are connected in every series group that form parallel combination, then find value of n.



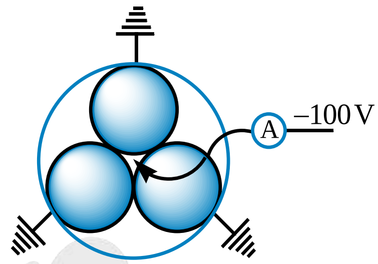

(A) 3 (B) 6 (C) 9 (D) 12

7. For the arrangement of the potentiometer shown in the figure, the balance point is obtained at a distance 75 cm from A when the key k is open. The second balance point is obtained at 60 cm from A when the key k is closed. Find the internal resistance of the battery $E_1$.



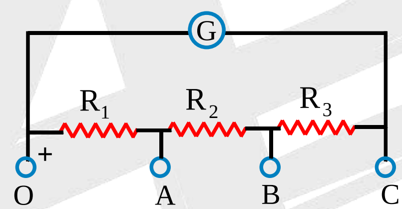

(A) $2\ \Omega$ (B) $4\ \Omega$ (C) $6\ \Omega$ (D) $8\ \Omega$

8. Consider the four rings shown. The bigger ring has radius $R = \left(\frac{24+12\sqrt{3}}{\sqrt{3}\,\pi}\right)$ and all rings made-up of wire having resistance $10\ \Omega$ per unit length of wire and all other wire has negligible resistance. Find reading of ammeter




(A) 3 A (B) 4 A (C) 5 A (D) 6 A

9. The following figure shows a circuit diagram of an ammeter of three different ranges. The specification of the ammeter is

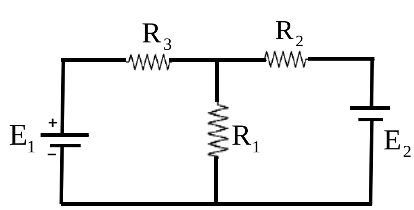



| Range (in amp.) | 10 | 5 | 1 |
|---|---|---|---|
| Terminals taken | O and A | O and B | O and C |

The resistance of the galvanometer coil is $99\ \Omega$. The range of the galvanometer is 10 mA. Find the $\left(\frac{R_3}{R_1+R_2}\right)$.

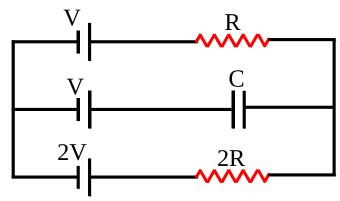
(A) 2 (B) 4 (C) 6 (D) 8

10. $R_1 = 5\Omega, R_2 = 2\Omega, R_3 = 3\Omega$ and $E_1 = 2E_2 = 10V$ internal resistance is zero. The power generated in $R_1$ is $0.8x\ J/s$ find $x = ?$

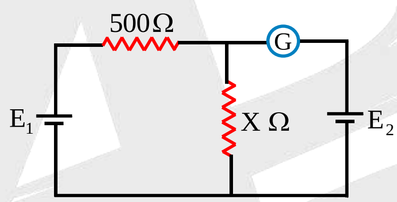


## Proficiency Test-2

1. In the given circuit, with steady current, the potential drop across the capacitor must be $\frac{\alpha V}{\beta}$. Find $\alpha + \beta$?




2. In the adjoining circuit, the battery $E_1$ has an e.m.f. of 12 volts and zero internal resistance while the battery $E_2$ has an emf of 2 volts. If the galvanometer G reads zero, then the value of the resistance X (in ohms) is :




3. In a gas discharge tube, if $3 \times 10^{18}$ electrons are flowing per sec from left to right and $2 \times 10^{18}$ protons are flowing per second from right to left of a given cross-section, the magnitude and direction of current through the cross-section :

(A) 0.48 A, left to right  (B) 0.48 A, right

(C) 0.80 A, left to right  (D) 0.80 A, right to left

4. To measure a potential difference across a resistor of resistance R $\Omega$, a voltmeter of resistance $R_v$ is used. To measure the potential with a minimum accuracy of 95%, then $R \geq nR$. Find n?

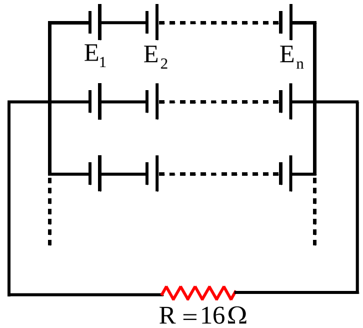
5. A battery of 10 volt is connected to a resistance of 20 ohm through a variable resistance R. The amount of charge which has passed in the circuit in 4 minutes, if the variable resistance R is increased at the rate of 5 ohm/min, is :

(A) 120 coulomb  (B) $120 \log_e 2$ coulomb

(C) $\frac{120}{\log_e 2}$ coulomb  (D) $\frac{60}{\log_e 2}$ coulomb

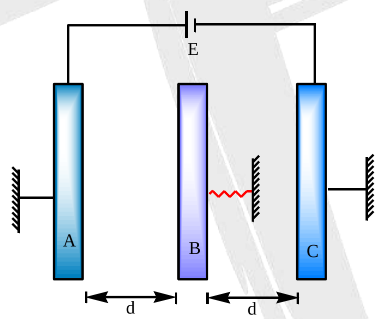
6. 300 numbers of identical galvanic cells, each of internal resistance $9\ \Omega$ are arranged as several in-series groups of cells connected in parallel. The arrangement has been laid out so that power

output in an externaly connected resistance of value $16\ \Omega$ is maximum. If n number of cells are connected in every series group that form parallel combination, then find value of n.

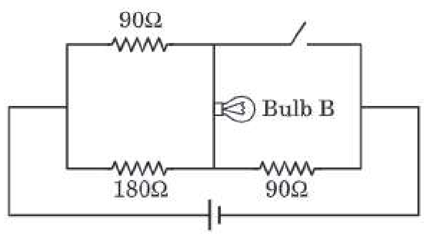



(A) 5 (B) 15 (C) 25 (D) 35

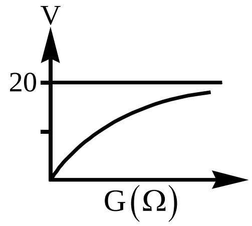
7. A, B, C are three identical neutral conducting plates, A and C are rigidly attached to fixed supports whereas plate B is attached to a spring having constant K. The supports and spring are very small in size and their effect on induced charges on plates A, B, C is negligible. The seperations between plates are d as shown. If plate B is displaced by $x\left(x < d\right)$ in the plane and released it is found that plate B under goes SHM. If K = 2 N/m, mass of plate B is 8 kg, emf of battery = 2 V and system is in gravity free space, the time period of B is found to be $T = \alpha\pi$. Find value of $\alpha$.

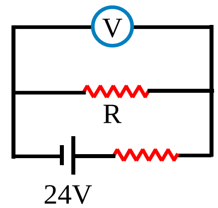



8. In the circuit shown, the bulb B glows equally bright whether the switch is closed or open. If the resistance of bulb is $R\,\Omega$. Find the value of $\frac{R}{5}\Omega$.



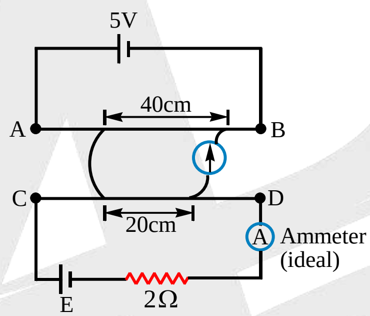

9. A cell of internal resistance $1\,\Omega$ is connected across a resistor. A voltmeter having variable resistance G is used to measure potential difference across resistor. The plot of voltmeter reading V against G is shown. Find the value of external resistance R




(A) $2\,\Omega$ (B) $3\,\Omega$ (C) $5\,\Omega$ (D) 6

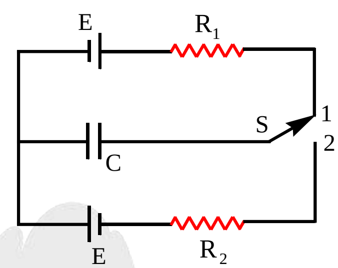
10. AB and CD are two uniform resistance wires of lengths 100 cm and 80 cm respectively. The connections are shown in the figure. The cell of emf 5 V is ideal while the other cell of emf E has internal resistance $2\,\Omega$. A length of 20 cm of wire CD is balanced by 40 cm of wire AB. Find the emf E, if the reading of the ideal ammeter is 2A. The other connecting wires have negligible resistance.




(A) 3 volt (B) 6 volt (C) 9 volt (D) 12 volt

## Proficiency Test-3

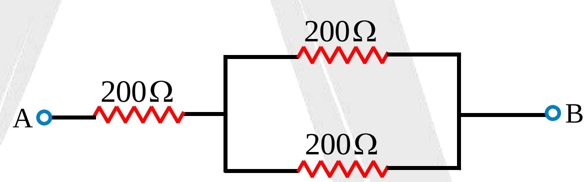
1. In the circuit shown, switch S is placed in position 1 till the capacitor is charged to half of the maximum possible charge in this situation. Now, the switch S is placed in position 2. The maximum energy lost by the circuit after switch S is placed in position 2 is $\frac{\alpha CE^2}{\beta}$. Find $\alpha+\beta$?




2. An isolated conducting sphere has a 10 cm radius. Two wires are connected to it, one carries a current of 1.000002 A into it and the other carries a current of 1.000000 A out of it. How long would it take for the sphere to increase its potential by 900 V as compared to its initial value?

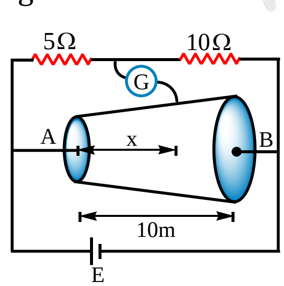
(A) 2 ms (B) 3 ms (C) 4 ms (D) 5 ms

3. Three $200\ \Omega$ resistors are connected as shwon in figure. The maximum power that can be dissipated in any one of the resistor is 50 W. Find the total power dissipated in the circuit for maximum voltage across the terminals A and B.

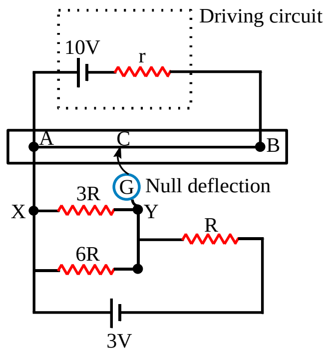



(A) 25 W (B) 50 W (C) 65 W (D) 75 W

4. Raduys if wire AB of length 10 m changes from r to 2r. At what distance (x in m) from A, a jockey be contacted to give no deflection in galvanometer?

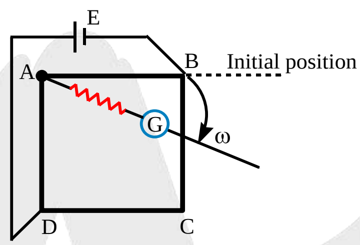



5. In the potentiometer circuit shown here, a potentiometer wire AB of length 100 cm and resistance $8\ \Omega$ is used. While measuring potential difference between points X and Y balancing length (AC) is obtained to be equal to 25 cm. What is internal resistance r of the driving circuit?



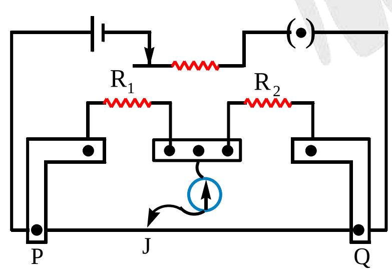

(A) 0.5 Ω (B) 1 Ω (C) 1.5 Ω (D) 2 Ω

6. ABCD is a square frame made from different wires of same length and each having different uniform resistance per unit length. Resistances of wires forming sides AB, BC, CD and DA are $100\ \Omega$, $400\ \Omega$, $500\ \Omega$ and $200\ \Omega$ respectively. An ideal cell is connected across B and D. A straight conducting wire containing a resistance and a galvanometer in series starts rotating about pivoted point A from initial position as shown with uniform angular velocity $\omega = \frac{\pi}{360}\ \text{rad/sec}$. One end of the straight wire (rotating) is pivoted at A and other end always in sliding contact with a side of the square. The time after start when galvanometer shows zero deflection is




(A) 61 sec (B) 41 sec (C) 74 sec (D) 84 sec

7. The circuit diagram given in the figure shows the experimental setup for the measurement of unknown resistance by using a meter bridge. The wire connected between the points P and Q has non-uniform resistance such that the resistance per unit length varies directly as the distance from the point P. Null point is obtained with the jockey J with $R_1$ and $R_2$ in the given position. On interchanging the positions of $R_1$ and $R_2$ in the gaps, the jockey has to be displaced through a distance x from the prevous position along the wire to establish the null point. If the ratio of $\frac{R_1}{R_2} = 3$. Find the value of $\Delta$. (length of wire PQ = 1 m)



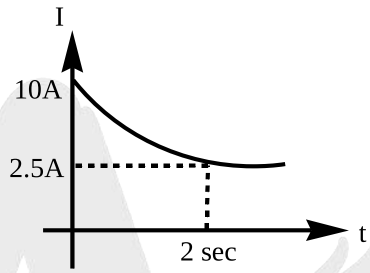

(A) 50 (B) $50\left(2\sqrt{3}\right)$ (C) $50\left(\sqrt{5}-2\right)$ (D) $50\left(\sqrt{3}-1\right)$

8. A curved rectangular bar forms a resistor. The curved sides are concentric circular arcs. If $\rho$ is the resistivity of the material of the bar, $l_0$ is the length inner arc of radius $r_0$, $(r_0+b)$ is the radius of the

outer arc, and a is the width of the bar. The electric resistance of the bar across its rectangular ends is

A) $\dfrac{\rho l_0}{a r_0}$ B) $\dfrac{\rho l_0}{a r_0 In\left[1+\dfrac{b}{r_0}\right]}$ C) $\dfrac{2\rho l_0}{a r_0 In\left[1+\dfrac{b}{r_0}\right]}$ D) None of these

9. The figure shows, a graph of the current in a discharging R-C circuit, the resistance of resistor is 10 Ω




A) The initial potential difference across capacitor is 100 volt

B) The capacitance of the capacitor is $\dfrac{1}{10\ln 2}F$

C) The total heat produced in the circuit is $\dfrac{500}{\ln 2}J$

D) The thermal power in the resistor will becoming $\dfrac{1}{e}$ times of initial value with a time constant $\dfrac{1}{2\ln 2}$sec

10. A metal sphere of radius a is surrounded by a concentric metal sphere of inner radius of b, where $b > a$.The space between the spheres is filled with a material whose electrical conductivity $\sigma$ varies with the electric field strength E as $\sigma = kE$ where k is a constant. A potential difference V is maintained between spheres.

A) current is $4\pi r^2 kE^2$, where $(a < r < b)$

B) current is $2\pi r^2 kE^2$, where $(a < r < b)$

C) potential difference between spheres is $V = \sqrt{\dfrac{I}{4\pi k}}\,\ell n\left(\dfrac{b}{a}\right)$ where I is total current

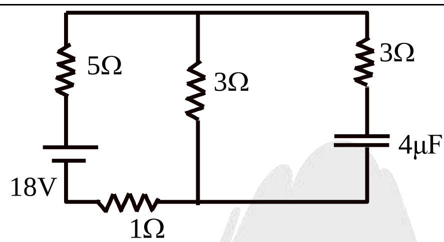
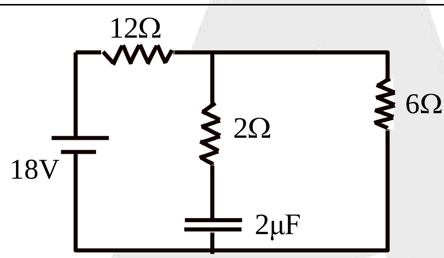
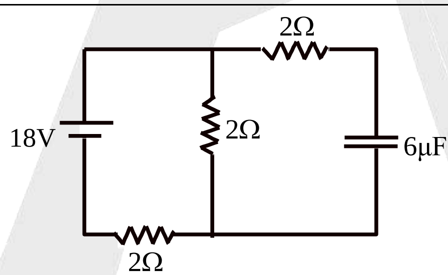
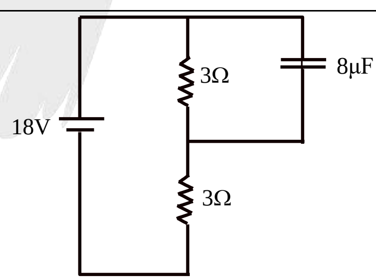
D) potential difference between spheres is $V = \sqrt{\dfrac{I}{2\pi k}}\,\ell n\left(\dfrac{b}{a}\right)$ where I is total current

**Answer Q.11, Q.12 and Q.13 by appropriately matching the information given in the three columns of the following table.**

**COLUMN – I** Circuit with initially uncharged capacitor.

**COLUMN – II** Time constant of the charging circuit in $\mu s$

**COLUMN –III** Steady state charge on the capacitor in $\mu c$

| COLUMN - I | | COLUMN – II | | COLUMN -III | |
|---|---|---|---|---|---|
| I) |  | i) | 10 μs | P) | 24 μc |
| II) |  | ii) | 18 μs | Q) | 12 μc |
| III) |  | iii) | 12 μs | R) | 72 μc |
| IV) |  | iv) | 20 μs | S) | 54 μc |

11. Which of the following is correct matching for the circuit with time constant 12μs

A) IV, (iii), P B) II, (iii), Q C) I, (iii), P D) III, (iii) Q

12. Which of the following is correct matching for the circuit with time constant 20μs

A) I, (iv), P B) III, (iv), R C) II, (iv), P D) IV, (iv) S

13. Which of the following is correct matching for the circuit in which steady state charge on the capacitor is 54μc

A) II, i, S B) IV, i, S C) IV, ii, S D) III, ii, S

# CURRENT ELECTRICITY

## EXERCISE – 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2 | A | C | ABCD | ABD | 8 | 2 | 4 | 6 | 1 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 2 | ABD | B | D | C | B | 5 | 5 | 3 | 0.1 |

## EXERCISE – 2

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2 | A | 6 | C | 2 | A | CD | A | B | D |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 2 | 4 | 4 | 1 | 6 | 1 | 2 | A | AC | B |
| 21 | 22 | | | | | | | | |
| AC | 100 | | | | | | | | |

## EXERCISE – 3

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| A | A | B | C | C | 20 | 6 | 1 | 2 | C |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| ABC | BD | ABC | AC | B | ABC | C | AC | B | AD |
| 21 | 22 | 23 | 24 | | | | | | |
| ACD | C | A | D | | | | | | |

## EXERCISE – 4

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| B | C | D | 2 | 7 | B | B | C | A | 1 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 9 | 2 | A | B | 6 | 9 | B | C | 5 | 2 |
| 21 | 22 | 23 | 24 | 25 | | | | | |
| ABC | ABC | ABCD | ABC | ABC | | | | | |

## EXERCISE – 5

# CURRENT ELECTRICITY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| B | 2 | A | D | 1 | B | 2 | A | C | A |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| C | B | 2 | A | D | C | A | B | D | ABD |
| 21 | 22 | 23 | 24 | 25 | 26 | | | | |
| AC | ACD | C | B | C | A | | | | |

## PROFICIENCY TEST – 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| C | B | 10 | 1 | A | D | C | C | B | 13 |

## PROFICIENCY TEST – 2

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 3 | 100 | D | 19 | B | C | 4 | 6 | C | D |

## PROFICIENCY TEST – 3

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 17 | D | D | 2 | D | C | D | B | ABCD | AC |
| 11 | 12 | 13 | | | | | | | |
| B | A | D | | | | | | | |