Very Short Answer Questions (PYQ)

Q. 1. Define the term drift velocity of charge carriers in a conductor. Write its relationship with current flowing through it. [CBSE Delhi 2014]

Ans. Drift velocity is defined as the average velocity acquired by the free electrons in a conductor under the influence of an electric field applied across the conductor. It is denoted by vd.

Current, I = NeA. Vd

Q. 2. Define the term 'Mobility' of charge carries in a conductor. Write its SI unit. What is its relation with relaxation time? [CBSE Delhi 2014, (North) 2016]

Ans. Mobility is defined as the magnitude of the drift velocity acquired by it in a unit electric field.

$$\mu = \frac{|v_d|}{E} = \frac{\mathrm{eE}\,\tau}{\mathrm{mE}} = \frac{e\tau}{m} \qquad \Rightarrow \qquad \mu \propto \tau$$

Where τ is the average collision time for electrons.

The SI unit of mobility is m^2/Vs or $m^2\ V^{-1}s^{-1}$.

Q. 3. Define electrical conductivity of a conductor and give its SI unit. On what factors does it depend? [CBSE Delhi 2014, (East) 2016]

Ans. The reciprocal of resistivity (ρ) of a material is called its electrical conductivity (σ),

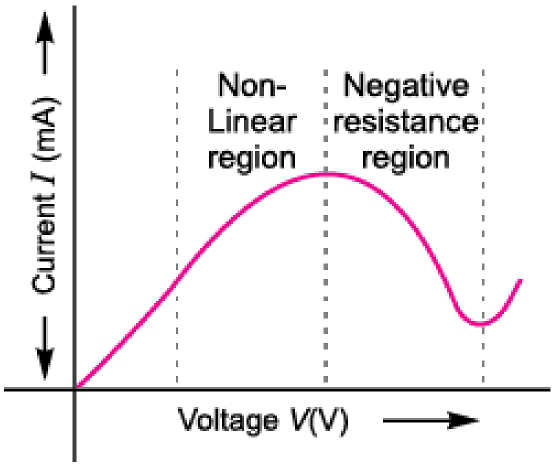
$$i.e., \qquad \sigma = \frac{1}{\rho}$$

SI unit of conductivity is mho m^{-1} (or siemen m^{-1}).

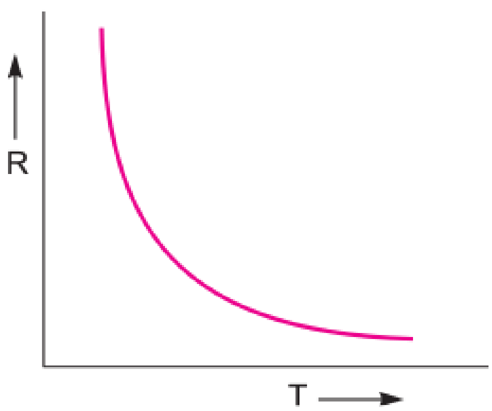
It depends upon number density, nature of material, relaxation time and temperature.

Q. 4. Plot a graph showing variation of current versus voltage for the material GaAs.
[CBSE Delhi 2014]

Ans. The variation of electric current with applied voltage for GaAs is as shown.



Q. 5. Plot a graph showing the variation of resistance of a conducting wire as a function of its radius, keeping the length of the wire and its temperature as constant.
[CBSE (F) 2013]



Ans. Resistance of a conductor of length l, and radius r is given by

$$R = \rho \frac{l}{\pi r^2}; \qquad \text{thus} \qquad R \propto \frac{1}{r^2}$$

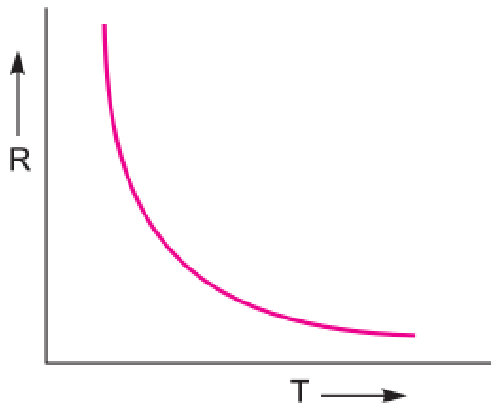
Q. 6. The emf of a cell is always greater than its terminal voltage. Why? Give reason.
[CBSE Delhi 2013]

Ans. (i) In an open circuit, the emf of a cell and terminal voltage are same.

(ii) In closed circuit, a current is drawn from the source, so, V = E – Ir, it is true/valid, because each cell has some finite internal resistance.

Q. 7. Show variation of resistivity of Si with temperature in a graph.
[CBSE Delhi 2014]

Ans.

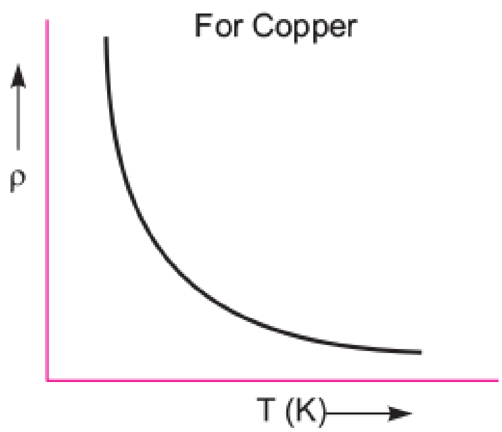


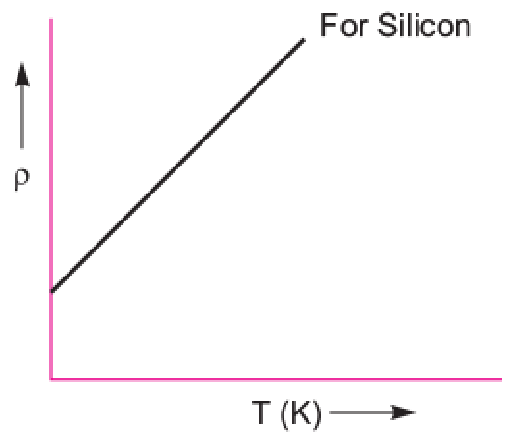
Resistivity of Si decreases rapidly with increasing temperatures.

Q. 8. Two materials Si and Cu, are cooled from 300 K to 60 K. What will be the effect on their resistivity? [CBSE (F) 2013]

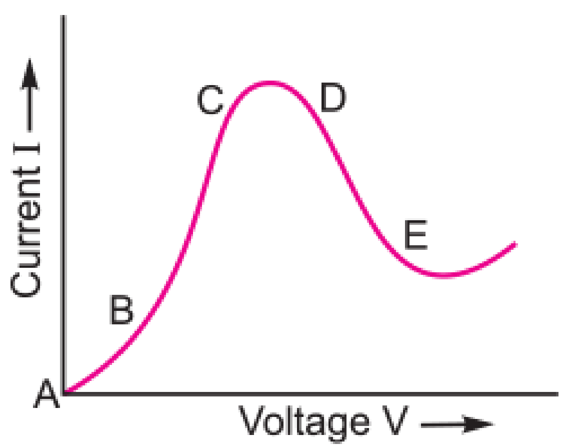
Ans. In silicon, the resistivity increases.

In copper, the resistivity decreases.





Q. 9. (i) Graph showing the variation of current versus voltage for a material GaAs is shown in the figure. Identify the region of negative resistance



(ii) Where Ohm's law is obeyed. [CBSE Delhi 2015]

Ans. (i) In region DE, material GaAs (Gallium Arsenide) offers negative resistance, because slope $<\frac{\Delta V}{\Delta I}<0.$

(ii) The region BC approximately passes through the origin, (or current also increases with the increase of voltage). Hence, it follows Ohm's law and in this region $\frac{\Delta V}{\Delta I}>0.$

Q. 10. Give an example of a material each for which temperature coefficient of resistivity is

(i) Positive,
(ii) Negative. [CBSE Sample Paper 2016]

Ans. (i) Copper (Cu) (Temperature coefficient of resistivity (α) is positive for metals and alloys.)

(ii) Silicon (Si) (For semiconductors, α is negative)

Q. 11. Define the current sensitivity of a galvanometer. Write its SI unit.
[CBSE (AI) 2013]

Ans. Ratio of deflection produced in the galvanometer and the current flowing through it is called current sensitivity. $S_i=\frac{\theta}{I}$

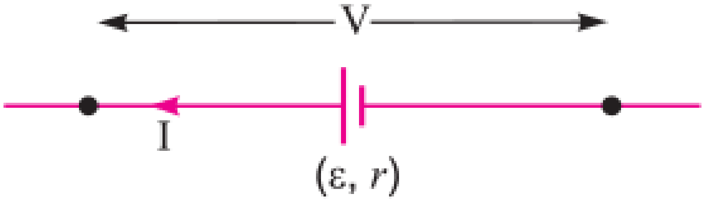
SI unit of current sensitivity Si is division/ampere or radian/ampere.

Q. 12. The emf of a cell always greater than its terminal voltage. Why? Give reason.
[CBSE Delhi 2013]

Ans. (i) In an open circuit, the emf of a cell and terminal voltage are same.

(ii) In closed circuit, a current is drawn from the source, so, V = E – Ir, it is true/valid, because each cell has some finite resistance.

Q. 13. A cell of emf 'E' and internal resistance 'r' draws a current 'I'. Write the relation between terminal voltage 'V' in terms of E, I and r. [CBSE Delhi 2013]



Ans. The terminal voltage V < E, so V = E – Ir

Q. 14. Distinguish between emf and terminal voltage of a cell. [CBSE Patna 2015]

Ans. The emf of a cell is equal to the terminal voltage, when the circuit is open.

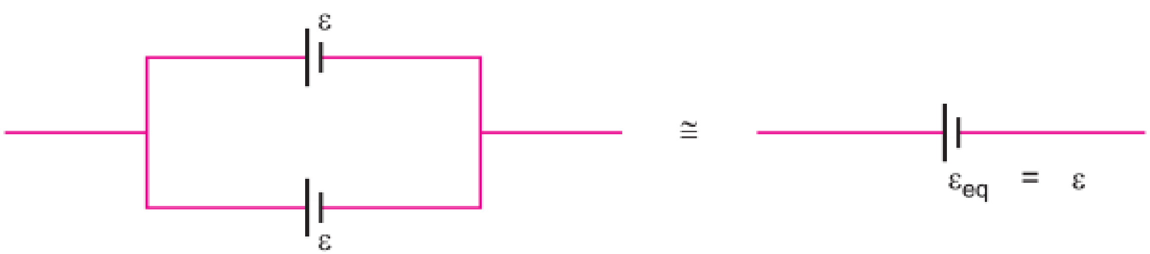
The emf of a cell is less than the terminal voltage, when the cell is being charged, i.e.,

V = E + ir

Q. 15. Two identical cells, each of emf E, having negligible internal resistance, are connected in parallel with each other across an external resistance R. What is the current through this resistance? [CBSE (AI) 2013]

Ans. $\text{Current, } I = \frac{E}{R}$

Concept: (i) emf of combination of two (or more cells) in parallel remain same.



(ii) Internal resistance is negligible i.e., zero.

$$\text{So, } I = \frac{\varepsilon_{eq}}{R + r_{eq}} = \frac{\varepsilon}{R} \qquad (r_{eq} = 0)$$

Q. 16. A resistance R is connected across a cell of emf ε and internal resistance r. A potentiometer now measures the potential difference between the terminals of the cell as V. Write the expression for 'r' in terms of ε, V and R. [CBSE Delhi 2011]

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

Q. 17. Two wires, one of copper and the other of manganin, have same resistance and equal thickness. Which wire is longer? Justify your answer. [CBSE Guwahati 2015]

Ans. Copper

Reason: Let l_1 and l_2 be lengths of copper and manganin wires having same resistance R and thickness i.e. area of cross-section (A).

Resistance of copper wire, $R = \frac{\rho_1 l_1}{A}$

Resistance of manganin wire $R = \frac{\rho_2 l_2}{A}$

$\Rightarrow$ $\rho_1 l_1 = \rho_2 l_2$ (As ρl = constant)

Since $\rho_1 <<< \rho_2$

So, $l_1 >>> l_1$

i.e., copper wire would be longer.

Q. 18. Two wires one of manganin and the other of copper have equal length and equal resistance. Which one of these wires will be thicker?
[CBSE (AI) 2012, (South) 2016] [HOTS]

Ans. Q. 18. Two wires one of manganin and the other of copper have equal length and equal resistance. Which one of these wires will be thicker?

[CBSE (AI) 2012, (South) 2016] [HOTS]

Ans. Resistance $R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}$

Resistivity ρ of manganin is much greater than that of copper, therefore to keep same resistance for same length of wire, the manganin wire must be thicker.

Q. 19. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more? Justify your answer. [CBSE (AI) 2017]

Ans. Nichrome wire gets heated up more.

Heat dissipated in a wire is given by

$H = I^2 Rt$

$H = I^2 \frac{\rho l}{A} t \qquad \left(\because R = \frac{\rho l}{A}\right)$

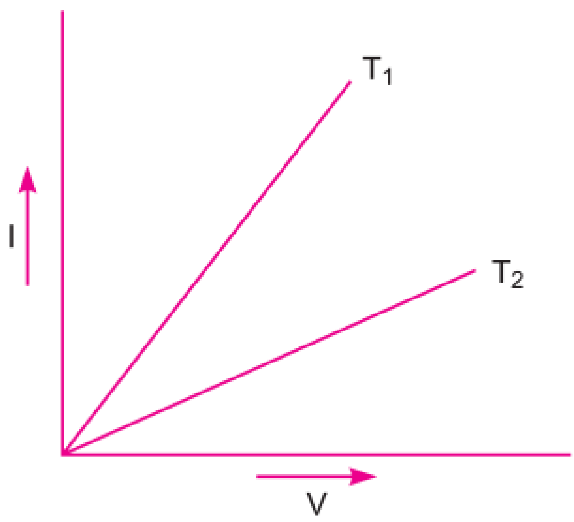
Here, radius is same, hence area (A) is same. Also, current (I) and length (l) are same.

$\therefore \quad H \propto r$

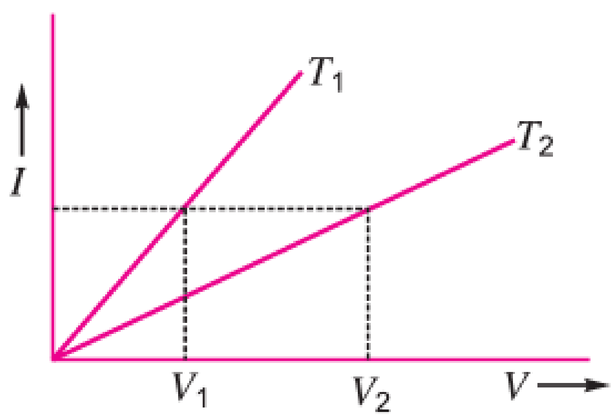
But $\quad \rho_{nichrome} > \rho_{copper}$

$\therefore \quad H_{nichrome} > H_{copper}$

Q. 20. I – V graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in the figure. Which of the two temperatures is lower and why?
[CBSE Allahabad 2015]



Ans. If a constant current I flows through the conductor, resistance at temperature T_1 and T_2 is



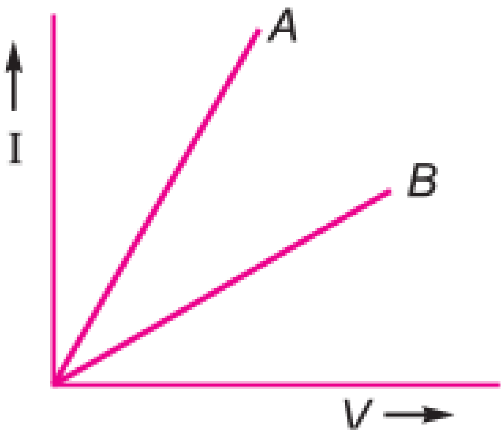
$$R_1 = \frac{V_1}{I}$$

and $$R_2 = \frac{V_2}{I}$$

Since $V_2 > V_1 \Rightarrow R_2 > R_1$

The resistance of the wire increases with rise of temperature. Hence, T_1 is lower than T_2.

Q. 21. Two metallic resistors are connected first in series and then in parallel across a d c supply. Plot of I –V graph is shown for the two cases. Which one represents a parallel combination of the resistors and why? [CBSE Bhubaneshwar 2015]



Ans. Line A represents the parallel combination.

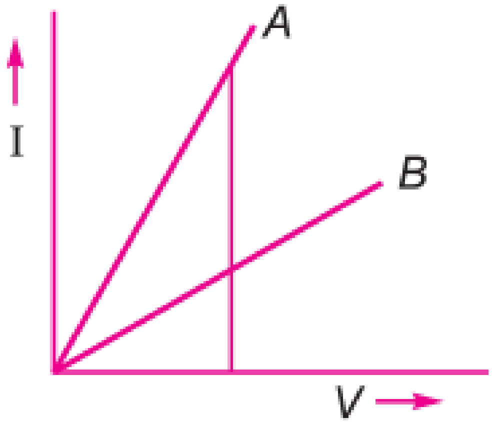
Reason: At a given potential difference V, current in the combination A

Is more than in the combination B.

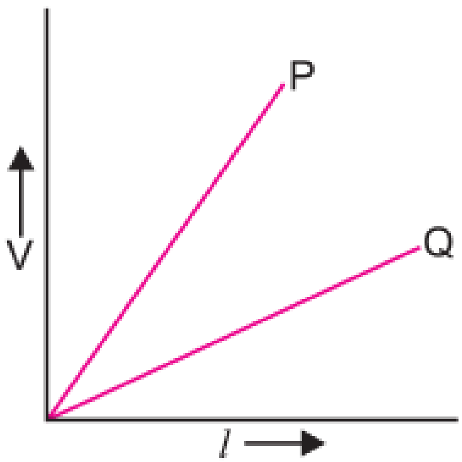
i.e., $I_A > I_B$

Since $R_A = \frac{V}{I_A}$ and $R_B = \frac{V}{I_B}$

$\Rightarrow$ $R_A < R_B$

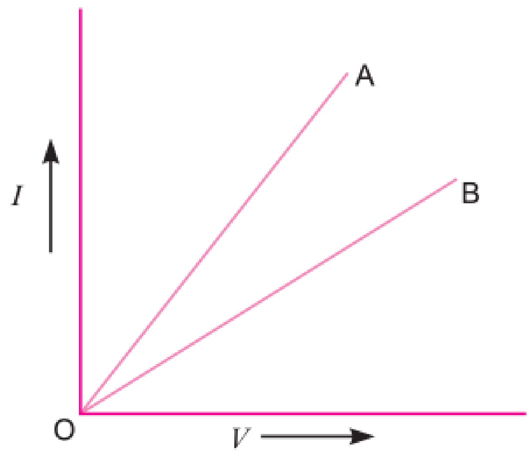


Q. 22. The variation of potential difference V with length l in the case of two potentiometer P and Q is as shown. Which of these two will you prefer for comparing the emfs of two primary cells and why? [CBSE (East) 2016] [HOTS]



Ans. For greater accuracy of potentiometer, the potential gradient (slope) $\frac{V}{l}$ must be as small as possible. In the graph given the slope $\frac{V}{l}$ is smaller for a potentiometer Q; hence we shall prefer potentiometer Q for comparing the emfs of two cells.

Q. 23. I – V graph for two identical conductors of different materials A and B is shown in the figure. Which one of the two has higher resistivity?
[CBSE (Chennai) 2015] [HOTS]



Ans. The resistivity of material B is higher.

Reason: If the same amount of the current flows through them, then $V_B > V_A$, and from Ohm's law $R_B > R_A$. Hence the resistivity of the material B is higher.

Very Short Answer Questions (OIQ)

Q. 1. Though we specify the direction of direct current by putting an arrow, why is it not considered a vector quantity?

Ans. Current is a scalar quantity because it does not obey the laws of vector addition.

Q. 2. Is current density a scalar or a vector quantity?

Ans. Current density is a vector quantity.

Q. 3. A steady current is flowing in a cylindrical conductor. Does electric field exist within the conductor?

Ans. Yes, electric field exists within the conductor because it is the electric field which imparts acceleration to electrons for the flow of current.

Q. 4. When a straight wire of resistance R is bent into U-shape, does its resistance change?

Ans. No, the resistance remains same, because length and cross-sectional area of the wire remain unchanged.

Q. 5. If the radius of a copper wire is doubled, will its specific resistance increase, decrease or remain same?

Ans. The specific resistance of a wire depends only on the material (at a given temperature). Therefore by changing the radius, the specific resistance of copper remains unchanged.

Q. 6. What is the effect of heating of a conductor on the drift velocity of free electrons?

Ans. $v_d = \frac{eE}{m}\tau$

By heating a conductor, the collisions of electrons occur more frequently; so relaxation time decreases and hence drift velocity decreases.

Q. 7. A uniform wire of resistance 50 Ω is cut into 5 equal parts. These parts are now connected in parallel. What is the value of equivalent resistance of the combination?

Ans. 2 ohms

Q. 8. What happens to the power dissipation if the value of electric current passing through a conductor of constant resistance is doubled?

Ans. Power $P = I^2Rt \propto I^2$

Clearly if current is doubled, the power dissipated becomes 4 times.

Q. 9. Define the term resistivity and write the SI unit.

Ans. The resistivity of a material of a conductor is defined as the resistance offered by a conductor of length 1 m and area of cross-section 1 m^2. Its SI unit is ohm × metre (Ω m).

Q. 10. A carbon resistor is marked in colour bands of red, black, orange and silver. What is the resistance and tolerance value of the resistor?

Ans. From colour-code table

Red	Black	Orange	Silver
↓	↓	↓	↓
2	0	3	±10%

$$R = 20 \times 10^3 \Omega \pm 10\% = 20\ k\Omega \pm 10\%$$

Q. 11. A wire of resistivity ρ is stretched to double its length. What will be its new resistivity?

Ans. New resistivity will be ρ (unchanged) because resistivity is independent of dimensions of conductor.

Q. 12. The metallic conductor is at temperature θ_1. The temperature of metallic conductor is increased to θ_2. How will the product of its resistivity and conductivity change?

Ans. Product $\rho\,\sigma = \rho.\frac{1}{\rho}\left(\text{since}\,\sigma = \frac{1}{\rho}\right)$

$\Rightarrow$ Product is independent of temperature.

Q. 13. Specific resistance of copper, silver and constantan are 1.18×10^{-6}, 1×10^{-6}, 45×10^{6} ohm cm respectively. Which is the best electrical conductor and why?

Ans. Smaller the resistivity of a substance, larger is its conductivity. The resistivity of silver is least so silver is the best conductor.

Q. 14. The potential difference applied across a given resistance is altered so that heat produced per second increases by a factor of 16. By what factor does the applied pd change?

Ans. Power $P = \frac{V^2}{R} \Rightarrow V \propto \sqrt{P}$ for given resistance. Hence, for making power 16-times, voltage should be made 4-times.

Q. 15. Two electric bulbs whose resistances are in the ratio 1 : 2 are connected in parallel to a source of constant voltage. What will be the ratio of power dissipation in these wires?

Ans.

Power $P = \frac{V^2}{R} \propto \frac{1}{R}$ for same voltage, the bulbs being in parallel.

$$\frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{2}{1}.$$

Thus, ratio of power dissipated is 2 : 1.

Q. 16. Two 120 V light bulbs, one of 25 W and the other of 200 W were connected in series across a 240 V line. One bulb burnt out almost instantaneously. Which one was burnt and why?

Ans. Resistance of bulb $R = \frac{V^2}{P} \propto \frac{1}{P};$ so 25 W bulb has higher resistance. In series current remains the same; so pd across 25 W bulb will be more than that across 200 W bulb; so 25 W bulb was burnt out immediately.

Q. 17. Two heating coils, one of fine wire and other of thick wire, made of the same material and of the same length are connected one by one to a source of electricity. Which coil will produce heat at a greater rate?

Ans.

$$Q \propto \frac{1}{R} \qquad \text{and} \qquad R = \frac{\rho l}{\pi r^2}$$

$$\therefore \qquad Q \propto \frac{\pi r^2}{\rho l}$$

Clearly, thick wire will produce heat at a greater rate.

Q. 18. For household electrical wiring, one uses Cu wires or Al wires. What considerations are kept in mind? [NCERT Exemplar]

Ans. Two considerations are required: (i) cost of metal, and (ii) good conductivity of metal. Cost factor inhibits silver. Cu and Al are the next best conductors.

Q. 19. Why are alloys used for making standard resistance coils? [NCERT Exemplar]

Ans. Alloys have:

(i) Low value of temperature coefficient and the resistance of the alloy does not vary much with rise in temperature.

(ii) High resistivity, so even a smaller length of the material is sufficient to design high standard resistance.

Q. 20. As the temperature of a conductor increases, both its resistivity as well as conductivity change. Will the ratio of its resistivity and conductivity increase, decrease or remain the same.

Ans. Increases.

Q. 21. The amount of electric charge passing through a cross-section of wire in time t is Q (t) = $At^2 + Bt + C$

Where A, B and C are constants having values 5, 4 and 1 respectively.

Calculate the value of electric current at t = 4s.

Ans.

We have, $Q(t) = \mathrm{At}^2 + \mathrm{Bt} + C$

$$\frac{\mathrm{dQ}}{\mathrm{dt}} = 2\mathrm{At} + B$$

$$= 2 \times 5 \times 4 + 4 \ (\text{at } t = 4\text{s})$$

$$I = 44 \text{ A.}$$

Q. 22. On increasing the current drawn from a cell, the net potential difference across its terminals is lowered, why?

Ans. The terminal potential difference V = E – Ir. Clearly if I is increased, the terminal potential difference falls.

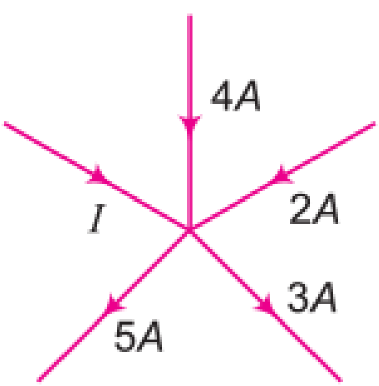
Q. 23. Is it possible that the terminal potential difference across the cell be zero? If yes, state the condition.

Ans. Yes, terminal potential difference V = IR. If external resistance R = 0, V = 0; i.e. terminal potential difference is zero, when cell is short circuited.

Q. 24. State the condition under which the terminal pd across a battery and its emf are equal.

Ans. The terminal pd across a battery is equal to its emf when battery is in open circuit, i.e., when no current is being drawn from the cell.

Q. 25. What is the value of I in the given current distribution?



Ans. I + 4 + 2 = 5 + 3

I = 2 A

Q. 26. When is a Wheatstone's bridge most sensitive?

Ans. The Wheatstone's bridge is most sensitive when all the four resistances of the bridge are equal.

Q. 27. Name the device used for measuring the internal resistance of a secondary cell.

Ans. Potentiometer.

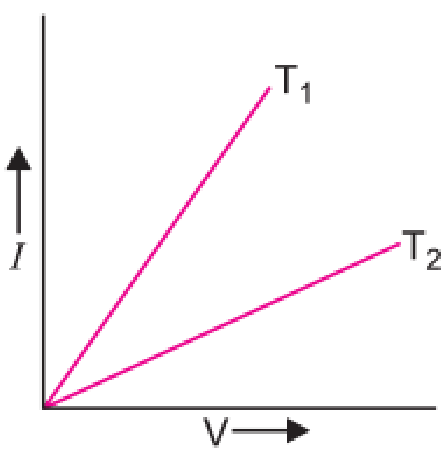
Q. 28. Why do we prefer a potentiometer to measure the emf of a cell rather than a voltmeter?

Ans. A voltmeter has a finite resistance and draws current from a cell, therefore voltmeter measures terminal potential difference rather than emf, while a potentiometer at balance condition, does not draw any current from the cell; so the cell remains in open circuit. Hence potentiometer reads the actual value of emf.

Q. 29. What is the advantage of using thick metallic strips to join wires in a potentiometer? [NCERT Exemplar]

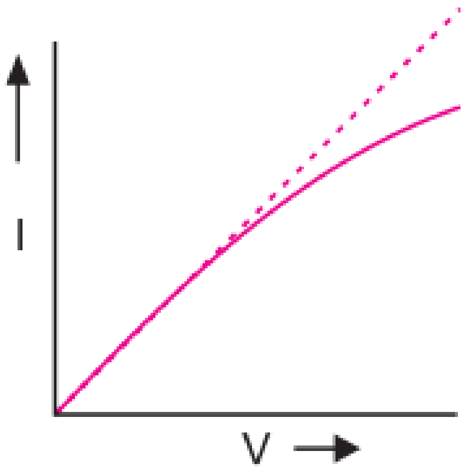
Ans. The metal strips have low resistance and need not be counted in the potentiometer length l of the null point. One measures only their lengths along the straight segments (of length l metre each). This is easily done with the help of centimeter rulings or meter ruler and leads to accurate measurements.

Q. 30. I-V graph for a metallic wire at two different temperatures T1 and T2 is shown in the figure. Which of these two temperatures is higher and why? [HOTS]



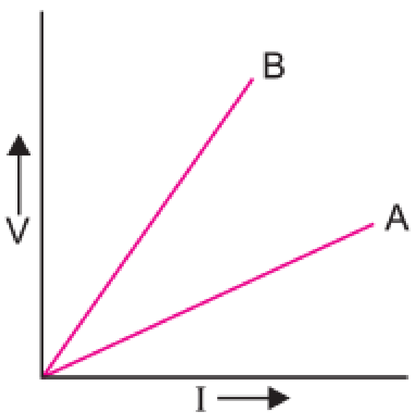
Ans. The slope of given graph, gives $\frac{V}{I} = \frac{1}{R}$. Smaller the slope, larger the resistance. As resistance of a metal increases with the increase of temperature, resistance at temperature T_2 is higher.

Q. 31. The I-V characteristics of a resistor are observed to deviate from a straight line for higher values of current as shown in the adjoining figure why?
[HOTS]



Ans. At higher value of current, sufficient heat is produced which raises the temperature of resistor and so causes increase in resistance.

Q. 32. V-I graphs for parallel and series combinations of two metallic resistors are shown in figure. Which graph represents parallel combination? Justify your answer.
[HOTS]



Ans. Graph 'A' represents parallel combination.

Reason: In series combination the effective resistance, $R = \frac{V}{I}$ is more than parallel combination.

The slope of a line of V-I graph represents resistance. The slope of B is more than A. Therefore B represents series combination and A represents parallel combination.

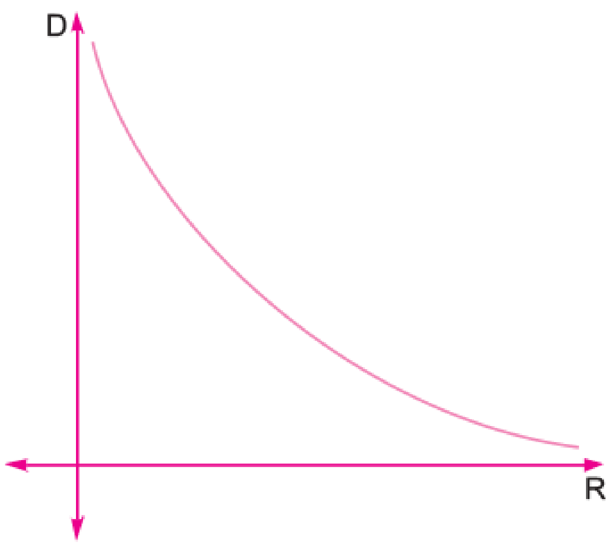
Q. 33. Draw a graph to show a variation of resistance of a metal wire as a function of its diameter keeping its length and material constant. [CBSE Sample Paper 2017]

Ans.

$$R = \rho \frac{1}{A} \quad \Rightarrow \quad \rho \frac{l}{\pi r^2} = \rho \frac{4l}{\pi D^2}$$

$$i.e. \quad R \, \alpha \frac{1}{D^2} \quad \Rightarrow \quad R \text{ is inversely proportional to diameter}$$

Hence, graph of resistance (R) versus diameter (D) is of the following form.



Q. 34. Current is allowed to flow in a metallic wire at a constant potential difference. When the wire becomes hot, cold water is poured on half of its portion. By doing so, its other half portion becomes still more hot. Explain its reason. [HOTS]

Ans. When cold water is poured on half the wire, the resistance of this portion decreases, and hence the current $I = \frac{V}{R}$ in whole wire increases and so the other half portion becomes still more hot.

Short Answer Questions – I (PYQ)

Q. 1. Define the terms

(i) Drift velocity,
(ii) Relaxation time. **[CBSE Delhi 2011, (AI) 2013]**

Ans. (i) Drift Velocity: The average velocity acquired by the free electrons of a conductor in a direction opposite to the externally applied electric field is called drift velocity. The drift velocity will remain the same with lattice ions/atoms.

(ii) Relaxation Time: The average time of free travel of free electrons between two successive collisions is called the relaxation time.

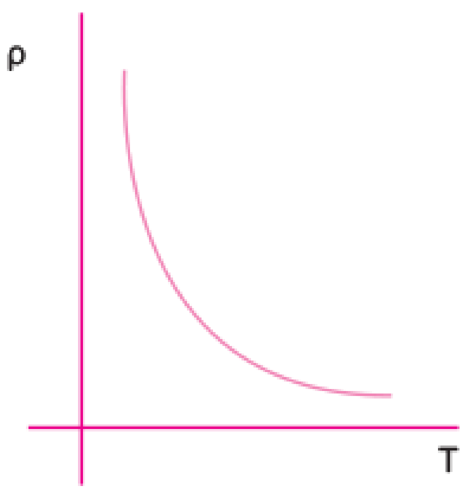
Q. 2. Sketch a graph showing the variation of resistivity of carbon with temperature.

OR

Plot a graph showing temperature dependence of resistivity for a typical semiconductor. How is this behaviour explained? [CBSE Delhi 2012, (F) 2011]

Ans. The resistivity of a typical semiconductor (carbon) decreases with increase of temperature. The graph is shown in figure.

Explanation: In semiconductor the number density of free electrons (n) increases with increase in temperature (T) and consequently the relaxation period decreases. But the effect of increase in n has higher impact than decrease of τ. So, resistivity decreases with increase in temperature.



Q. 3. (a) You are required to select a carbon resistor of resistance 47 kΩ ± 10% from a large collection. What should be the sequence of colour bands used to code it?

(b) Write the characteristics of manganin which make it suitable for making standard resistance. [CBSE (F) 2011]

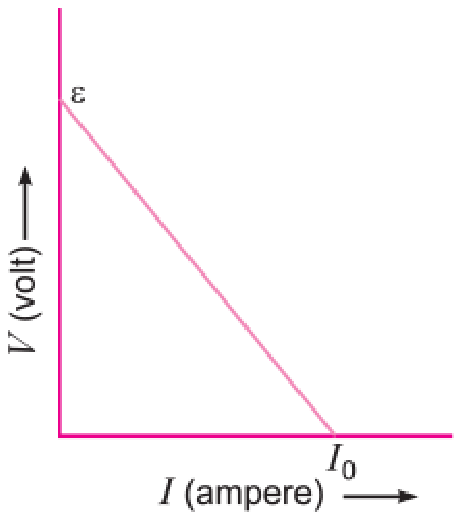
Ans. (a) Resistance $= 47\ k\Omega \pm 10\% = 47 \times 10^3 \Omega \pm 10\%$

Sequence of colour should be: Yellow, Violet, Orange and Silver

(b) (i) Very low temperature coefficient of resistance.

(ii) High resistivity

Q. 4. Plot a graph showing variation of voltage Vs the current drawn from the cell. How can one get information from this plot about the emf of the cell and its internal resistance? [CBSE (F) 2016]



Ans.

$$V = \varepsilon - \mathrm{Ir} \Rightarrow r = \frac{\varepsilon - V}{I}$$

At $I = 0,\ V = \varepsilon$

When $V = 0, \quad I = I_0,\ r = \frac{\varepsilon}{I_0}$

The intercept on y-axis gives the emf of the cell. The slope of graph gives the internal resistance.

Q. 5. Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2Ω and 0.3Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. [CBSE Delhi 2016]

Ans.

$$E_1 = 1.5V, \qquad r_1 = 0.2\Omega$$

$$E_2 = 2.0V, \qquad r_2 = 0.3\Omega$$

emf of equivalent cell

$$E = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \left(\frac{1.5 \times 0.3 + 2 \times 0.2}{0.2 + 0.3}\right) = \frac{0.45 + 0.40}{0.5} V = 1.7V$$

Internal resistance of equivalent cell

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} \quad \Rightarrow \quad r = \frac{r_1 r_2}{r_1 + r_2} = \left(\frac{0.2 \times 0.3}{0.2 + 0.3}\right)\Omega = \frac{0.06}{0.5}\Omega = 0.12\ \Omega$$

Q. 6. When 5 V potential difference is applied across a wire of length 0.1 m, the drift speed of electrons is 2.5 × 10^{-4} m/s. If the electron density in the wire is 8 × 10^{28} m^{-3}, calculate the resistivity of the material of wire. [CBSE (North) 2016]

Ans.

We know $I = \text{neAv}_d,\ I = \frac{V}{R}$ and $R = \rho \frac{l}{A}$

So $\quad \frac{V}{R} = \text{neAv}_d$

$$\frac{V}{\text{nev}_d\ l} = \frac{\text{RA}}{l} \quad \Rightarrow \quad \rho = \frac{V}{\text{nev}_d\ l}$$

$$\rho = \frac{5}{8 \times 10^{28} \times 1.6 \times 10^{-19} \times 2.5 \times 10^{-4} \times 0.1} \Omega m = 1.56 \times 10^{-5} \Omega \text{m}$$

$$\approx 1.6 \times 10^{-5} \Omega m$$

Q. 7. Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires. [CBSE (AI) 2011]

Ans. In series current is same,

So, $I_A = I_B = I = \text{neAv}_d$

For same diameter, cross-sectional area is same

$$A_A = A_B = A$$

$\therefore \quad I_A = I_B \quad \Rightarrow \quad n_x \, \text{eAv}_x = n_y \, \text{eAv}_y$

Given $n_x = 2n_y \quad \Rightarrow \quad \frac{v_x}{v_y} = \frac{n_y}{n_x} = \frac{n_y}{2n_y} = \frac{1}{2}$

Q. 8. A conductor of length 'l' is connected to a dc source of potential 'V'. If the length of the conductor is tripled by gradually stretching it, keeping 'V' constant, how will (i) drift speed of electrons and (ii) resistance of the conductor be affected? Justify your answer. [CBSE (F) 2012]

Ans.

(*i*) We know that $v_d = -\frac{\text{eV}\,\tau}{\text{ml}} \propto \frac{1}{l}$

When length is tripled, the drift velocity becomes one-third.

(*ii*) $R = \rho\frac{l}{A}, \qquad l' = 3l$

New resistance

$$R' = \rho\frac{l'}{A'} = \rho \times \frac{3l}{A/3} = 9R \qquad \Rightarrow \qquad R' = 9R$$

Hence, the new resistance will be 9 times the original.

Q. 9. A potential difference V is applied across the ends of copper wire of length l and diameter D. What is the effect on drift velocity of electrons if [CBSE Ajmer 2015]

(i) V is halved
(ii) l is doubled.
(iii) D is halved.

Ans.

$$\text{Drift velocity, } v_d = \frac{I}{\text{neA}} = \frac{V/R}{\text{neA}} = \frac{V}{\text{neA}\left(\frac{\rho l}{A}\right)} = \frac{V}{\text{ne}\,\rho\, l}$$

i. As $v_d \propto V$, when V is halved the drift velocity is halved.

ii. As $v_d \propto \frac{1}{l}$, when l is doubled the drift velocity is halved.

iii. As v_d is independent of D, when D is halved drift velocity remains unchanged.

Q. 10. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0 × 10^{-7} m^2 carrying a current of 1.5 A. Assume the density of conduction electrons to be 9 × 10^{28} m^{-3}. [CBSE (AI) 2014]

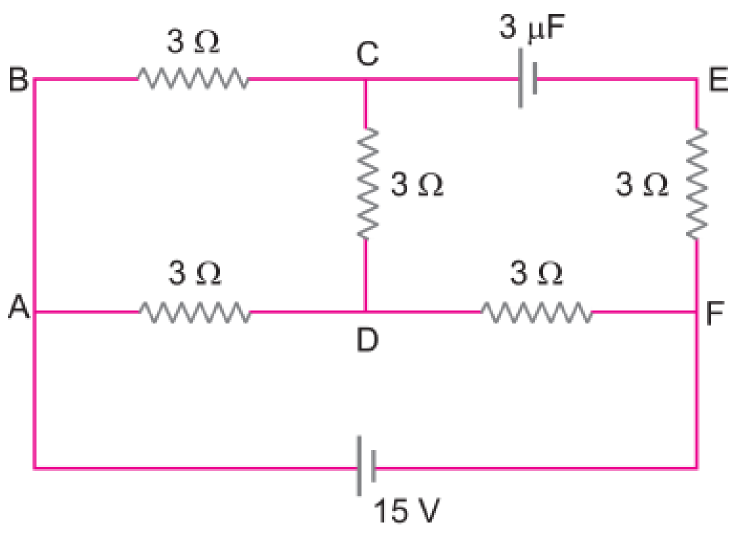
Ans. Flow of current in the conductor due to drift velocity of the free electrons is given by

$I = neAv_d$

$$v_d = \frac{I}{\text{neA}} = \frac{1.5}{9\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}$$

$$= 1.048\times10^{-3} m/s \simeq 1\,\text{mm}/s$$

Q. 11. In the circuit shown in the figure, find the total resistance of the circuit and the current in the arm CD. [CBSE (F) 2014]



Ans. It can be seen that resistances BC and CD are in series and their combination is in parallel with AD.

$$\text{Then } \frac{1}{R_P} = \frac{1}{6} + \frac{1}{3} \quad \Rightarrow \quad R_P = 2\Omega$$

Total resistance of circuit is 2+ 3 = 5Ω

(Due to capacitor, resistor 3Ω in EF will not be counted)

$$\text{Total current} = \frac{15}{5} = 3A.$$

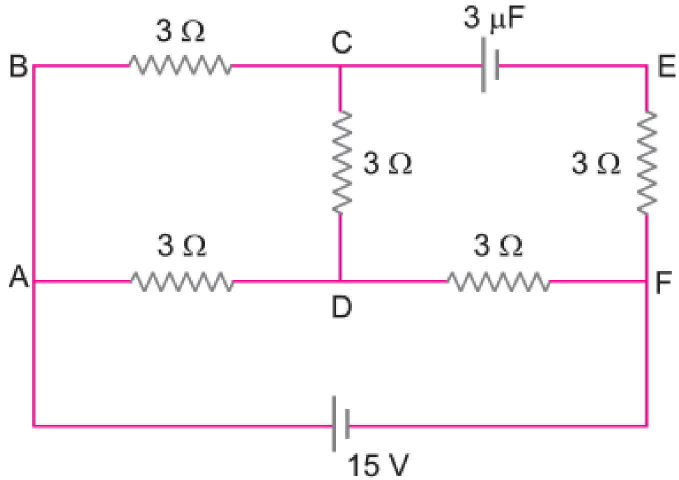
This current gets divided at junction A.

Voltage across DF = 3 Ω × 3 A = 9 V and Voltage across AD = 15 – 9 = 6 V

$$I \text{ across } CD = \frac{6\ V}{3+3} = 1\ A$$

Hence, current through arm CD = 1 A.

Q. 12. Use Kirchhoff's laws to determine the value of current I1 in the given electrical circuit. [CBSE Delhi 2007]



Ans. From Kirchhoff's first law at junction C

$$I_3 = I_1 + I_2 \quad \text{...(i)}$$

Applying Kirchhoff's second law in mesh CDFEC

$$40I3 – 40 + 20I1 = 0 \text{ or } 20\ (2I3 + I1) = 40$$

$$\Rightarrow \quad I_1 + 2I_3 = 2 \quad \text{...(ii)}$$

Applying Kirchhoff's second law to mesh ABFEA

$$80 – 20I_2 + 20I_1 = 0$$

$$\Rightarrow \quad 20\ (I_1 – I_2) = – 80$$

$$\Rightarrow \quad I_2 – I_1 = 4 \quad \text{...(iii)}$$

Substituting value of I3 from (i) in (ii), we get

$$I_1 + 2(I_1 + I_2) = 2 \quad \Rightarrow \quad 3I_1 + 2I_2 = 2 \quad \ldots(iv)$$

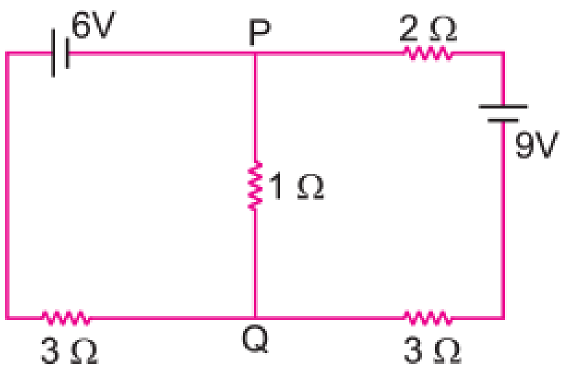
Multiplying equation (iii) by 2, we get

$$2I_2 - 2I_1 = 8 \quad \ldots(v)$$

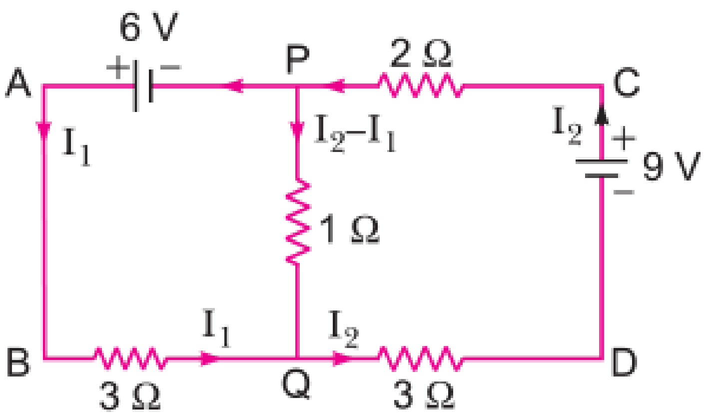
Subtracting (v) from (4), we get

$$5I_1 = -6 \Rightarrow I_1 = -\frac{6}{5}A = -1.2\ A$$

Q. 13. Find the magnitude and direction of current in 1Ω resistor in the given circuit.
[CBSE (South) 2016]



Ans.



For the mesh APQBA

$$-6 - 1(I_2 - I_1) + 3I_1 = 0$$

Or $$-I_2 + 4I_1 = 6 \quad \ldots(1)$$

For the mesh PCDQP

$$2I_2 - 9 + 3I_2 + 1(I_2 - I_1) = 0$$

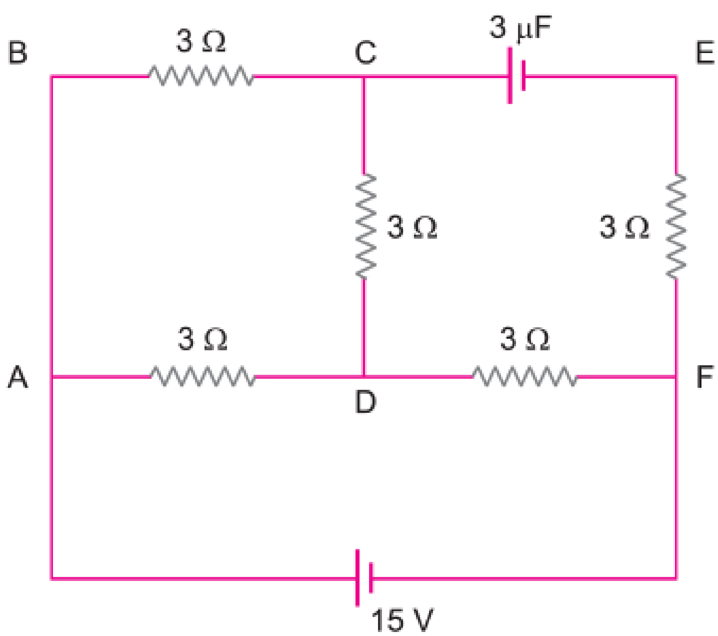
Or $$6I_2 - I_1 = 9 \quad \ldots(2)$$

Solving (1) and (2), we get

$$I_1 = \frac{45}{23} A \qquad \text{and} \qquad I_2 = \frac{42}{23} A$$

$$\therefore \quad \text{Current through the } 1\ \Omega \text{ resistor } = (I_2 - I_1) = \frac{-3}{23} A$$

Q. 14. In the circuit shown in the figure, find the total resistance of the circuit and the current in the arm AD. [CBSE (AI) 2014]



Ans. Since BC and CD are in series,

So, R_{BCD} = 3 Ω + 3 Ω = 6 Ω

Also AD is parallel with the combination of BC and CD.

$\therefore \quad \frac{1}{Rp} = \frac{1}{6} + \frac{1}{3} = \frac{6+3}{6 \times 3}$

$R_p = 2\ \Omega$

Then DF is in series,

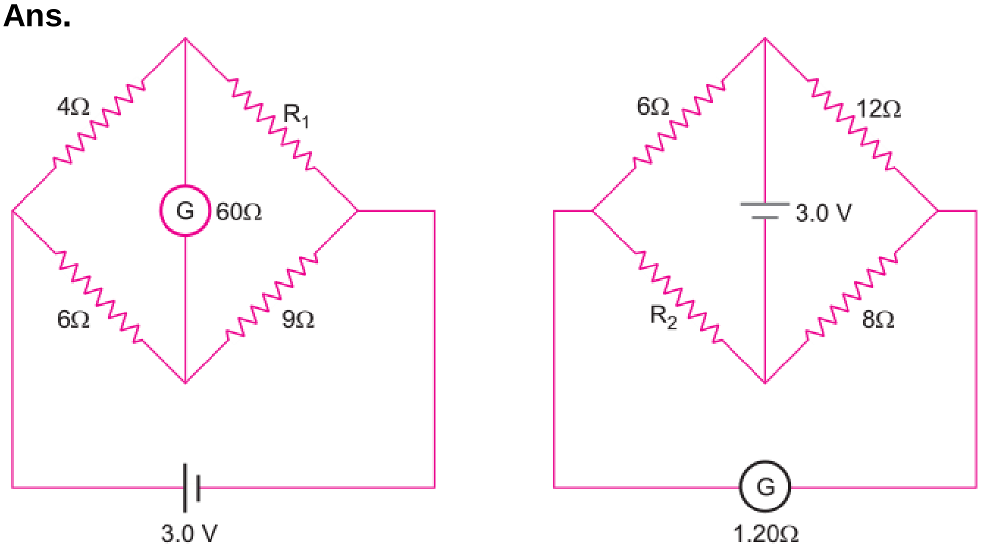
$R_{eq} = 2 + 3 = 5\ \Omega$

Net current $I = \frac{V}{R_{eq}} = \frac{15}{5} = 3A$

$\therefore \quad I_{AD} = 2A.$

Q. 15. Figure shows two circuits each having a galvanometer and a battery of 3 V. When the galvanometers in each arrangement do not show any deflection, obtain the ratio $\frac{R_1}{R_2}$. [CBSE (AI) 2013]

Ans.



Ans. For balanced Wheatstone bridge, if no current flows through the galvanometer

$$\frac{4}{R_1} = \frac{6}{9}$$

$$\Rightarrow \qquad R_1 = \frac{4 \times 9}{6} = 6\,\Omega$$

For another current

$$\frac{6}{12} = \frac{R_2}{8} \quad \Rightarrow \quad R_2 = \frac{6 \times 8}{12} = 4\,\Omega$$

$$\therefore \qquad \frac{R_1}{R_2} = \frac{6}{4} = \frac{3}{2}$$

Q. 16. A potentiometer wire of length 1 m has a resistance of 10 Ω. It is connected to a 6 V battery in series with a resistance of 5Ω. Determine the emf of the primary cell which gives a balance point at 40 cm. [CBSE Delhi 2014]

Ans. Here, $l = 1\text{m}$, $R_1 = 10$, $V = 6\text{V}$, $R_2 = 5\Omega$

Current flowing in potentiometer wire,

$$I = \frac{V}{R_1 + R_2} = \frac{6}{10+5} = \frac{6}{15} = 0.4\,A$$

Potential drop across the potentiometer wire

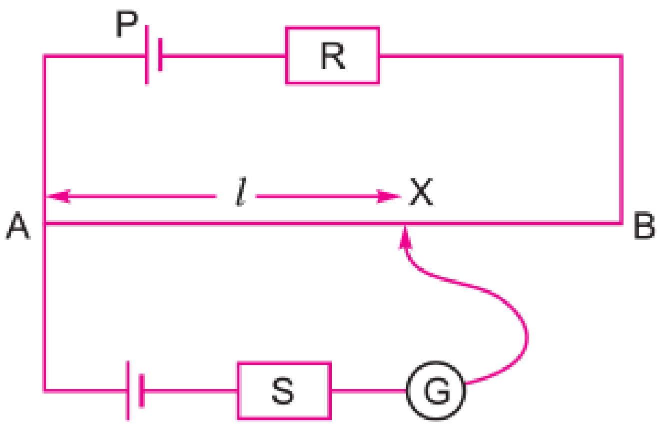
$$V' = IR = 0.4 \times 10 = 4\text{V}$$

Potential gradient, $K = \frac{V'}{l} = \frac{4}{1} = 4\,V/m$

Emf of the primary cell $= Kl = 4 \times 0.4 = 1.6$ V

Q. 17. In the potentiometer circuit shown, the null point is at X. State with reason, where the balance point will be shifted when:

(a) Resistance R is increased, keeping all other parameters unchanged;
(b) Resistance S is increased, keeping R constant. [CBSE Bhubaneshwar 2015]



Ans. Let l be the balance length of the segment AX on the potentiometer wire for given resistance R and S.

(a) If resistance R is increased, the current flow in the main circuit (or wire AB) will decrease. From relation K = $\frac{\rho I}{L}$ the potential gradient along the wire AB will decrease. To balance the emf of the cell, the point X will shift toward the point B, i.e.,

$$\varepsilon = kl = k'l'$$

If $k' < k$, so $l' > l$

(b) For the given resistance R, the potential gradient along the wire remain same. Balance length 'l' remain constant. $\varepsilon = kl$

And no current flows in the resistance S. If resistance S is increased/decreased there is no change in the balance length.

Q. 18. State the underlying principle of a potentiometer. Write two factors by which current sensitivity of a potentiometer can be increased. Why is a potentiometer preferred over a voltmeter for measuring the emf of a cell? [CBSE Patna 2015]

Ans. Principle: The potential drop across a part of the potentiometer wire is directly proportional to the length of that part of the wire of uniform cross section.

$$V = kl$$

Where k is potential gradient.

Current sensitivity of potentiometer wire is also known as potential gradient, and it can be increased.

(i) By increasing the total length of the wire, keeping terminal voltage constant.

(ii) By connecting a suitable extra resistance R in series with the potentiometer. So, less amount of the current flows through the potentiometer wire.

Reasons: At the balance point, there is no net current drawn from the cell, and cell is in open circuit condition. Voltmeter has some resistance, when connected across the cell. Some current is drawn, as a result emf of the cell decreases. Hence, emf of the cell cannot be measured by the voltmeter.

Q. 19. Answer the following:

(i) Why are the connections between the resistors in a meter bridge made of thick copper strips?

(ii) Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire?

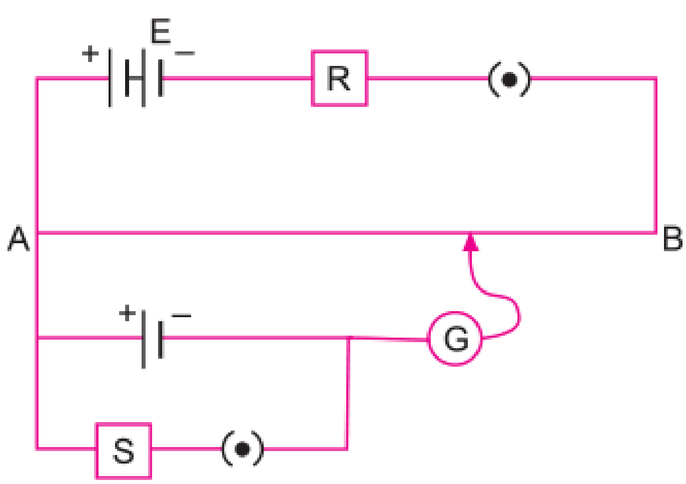
(iii) Which material is used for the meter bridge wire and why?
[CBSE (AI) 2014] [HOTS]

Ans. (i) A thick copper strip offers a negligible resistance, so does not alter the value of resistances used in the meter bridge.

(ii) If the balance point is taken in the middle, it is done to minimise the percentage error in calculating the value of unknown resistance.

(iii) Generally alloys magnin/constantan/nichrome are used in Meter Bridge, because these materials have low temperature coefficient of resistivity.

Q. 20. Two students X and Y perform an experiment on potentiometer separately using the circuit diagram shown here. Keeping other things unchanged (i) X increases the value of resistance R. (ii) Y decreases the value of resistance S in the set up. How would these changes affect the position of the null point in each case and why?
[CBSE (South) 2016] [HOTS]

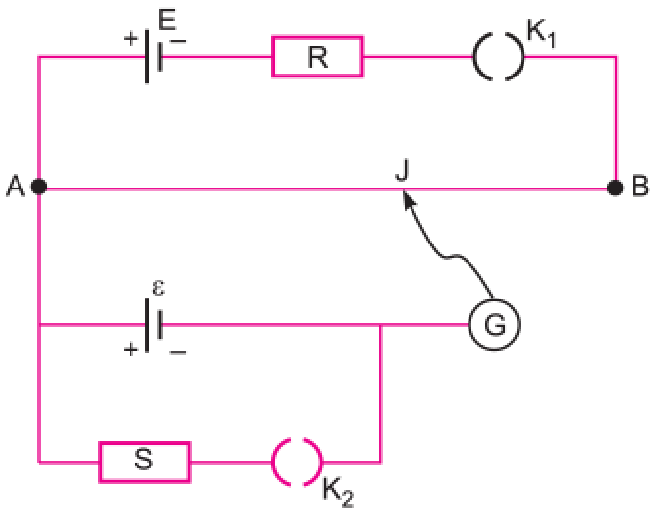


Ans. (i) By increasing resistance R, the current in main circuit decreases, so potential gradient decreases. Hence a greater length of wire would be needed for balancing the same potential difference. So, the null point would shift towards right (i.e., towards B).

(ii) By decreasing resistance S, the terminal potential difference V = ε – Ir, where I = $\frac{\varepsilon}{(r+S)}$ $V = \frac{\varepsilon}{1+\frac{r}{S}}$ across cell decreases, so balance is obtained at small length i.e., point will be obtained at smaller length. So, the null point would shift towards left (i.e., towards A).

Q. 21. Two students 'X' and 'Y' perform an experiment on potentiometer separately using the circuit given.

Keeping other parameters unchanged, how will the position of the null point be affected if



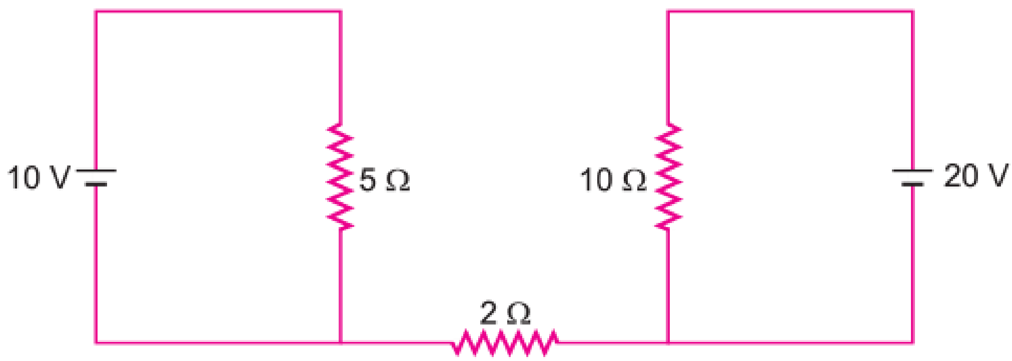
(i) 'X' increases the value of resistance R in the set-up by keeping the key K1 closed and the key K2 open?

(ii) 'Y' decreases the value of resistance S in the set-up, while the key K2 remain open and the key K1 closed? Justify your answer in each case. [CBSE (F) 2012] [HOTS]

Ans. (i) By increasing resistance R the current through AB decreases, so potential gradient decreases. Hence a greater length of wire would be needed for balancing the same potential difference. So the null point would shift towards B.

(ii) By decreasing resistance S, the current through AB remains the same, potential gradient does not change. As K_2 is open so there is no effect of S on null point.

Q. 22. What will be the value of current through the 2Ω resistance for the circuit shown in the figure? Give reason to support your answer. [CBSE (F) 2013] [HOTS]

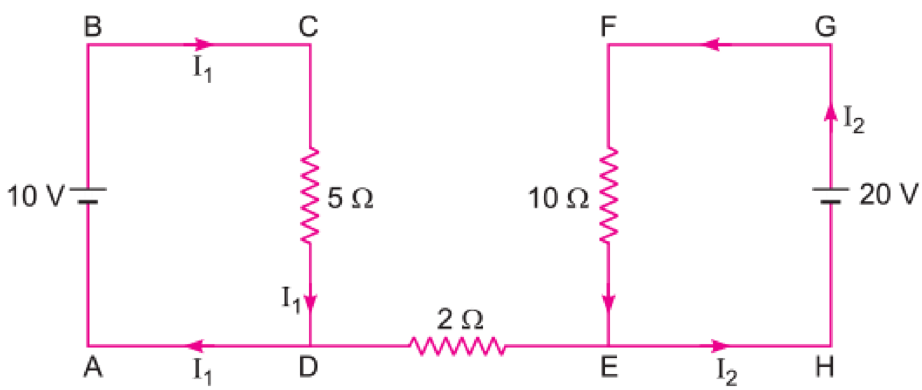


Ans. No current will flow through 2Ω resistor, because in a closed loop, total p.d. must be zero. So

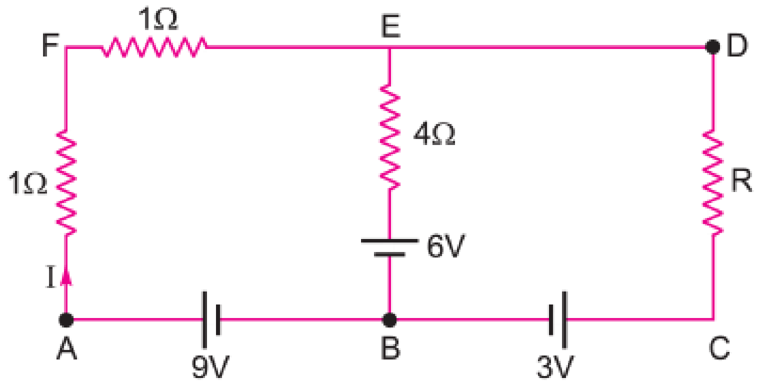
$$10V - 5I_1 = 0 \quad ...(1)$$

$$20V - 10I_2 = 0 \quad ...(2)$$

And resistor 2Ω is not part of any loop ABCD and EFGH



Q. 23. Using Kirchoff's rules determine the value of unknown resistance R in the circuit so that no current flows through 4Ω resistance. Also find the potential difference between A and D.   [CBSE Delhi 2012] [HOTS]



Ans. Applying Kirchhoff's loop rule for loop ABEFA,

$$-9 + 6 + 4 \times 0 + 2I = 0$$

$I = 1.5$ A ...(i)

For loop BCDEB

$3 + IR + 4 \times 0 - 6 = 0$

$\therefore$ $IR = 3$

Putting the value of I from (i) we have

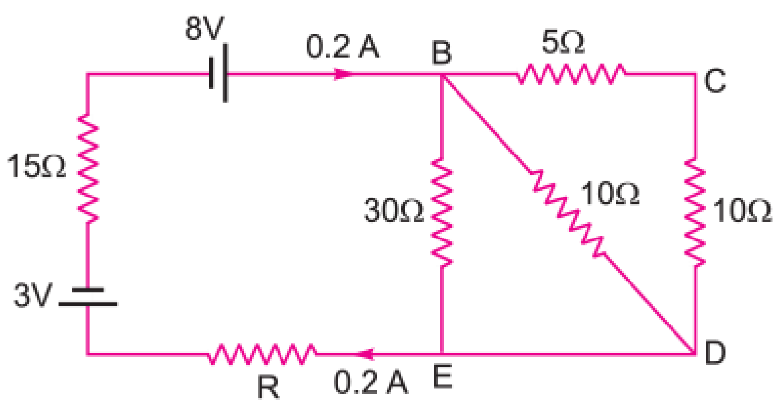
$$\frac{3}{2} \times R = 3 \quad \Rightarrow \quad R = 2\,\Omega$$

Potential difference between A and D through path $ABCD$

$$9 - 3 - IR = V_{AD}$$

or $$9 - 3 - \frac{3}{2} \times 2 = V_{AD} \quad \Rightarrow \quad V_{AD} = 3V$$

Q. 24. Calculate the value of the resistance R in the circuit shown in the figure so that the current in the circuit is 0.2 A. What would be the potential difference between points B and E? [CBSE (AI) 2012] [HOTS]



Ans.

Here, $R_{BCD} = 5\Omega + 10\Omega = 15\ \Omega$

Effective resistance between B and E

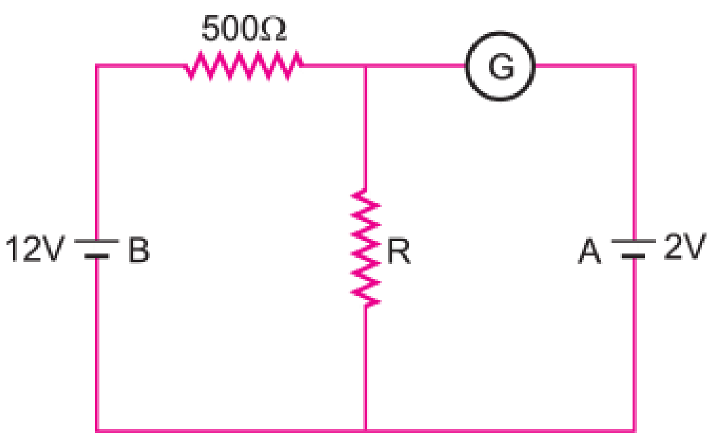
$$\frac{1}{R_{BE}} = \frac{1}{30} + \frac{1}{10} + \frac{1}{15} \quad \Rightarrow \quad R_{BE} = 5\Omega$$

Applying Kirchhoff's Law

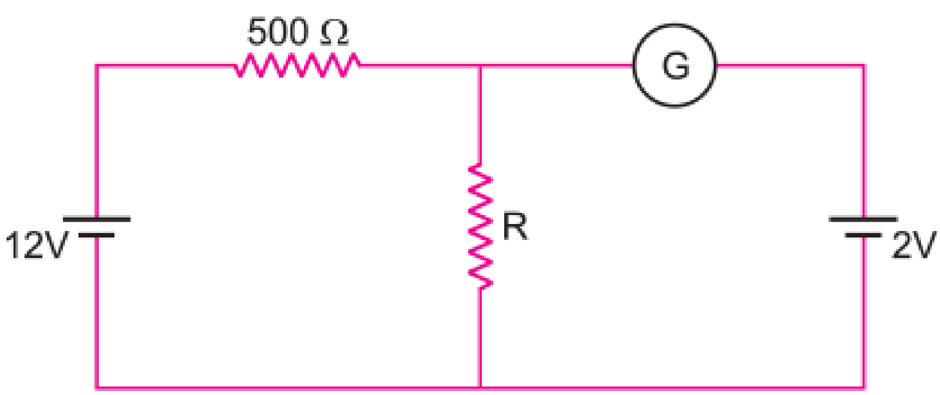
$$5 \times 0.2 + R \times 0.2 + 15 \times 0.2 = 8 - 3 \quad \Rightarrow \quad R = 5\ \Omega$$

Hence, $V_{BE} = IR_{BE} = 0.2 \times 5 = 1$ volt

Q. 25. In the circuit shown in the figure, the galvanometer 'G' gives zero deflection. If the batteries A and B have negligible internal resistance, find the value of the resistor R. [CBSE (F) 2013] [HOTS]



Ans. If galvanometer G gives zero deflection, than current of source of 12 V flows through R, and voltage across R becomes 2 V.



Current in the circuit $I = \frac{\varepsilon}{R_1 + R_2} = \frac{12}{500 + R}$

and $V = IR = 2$

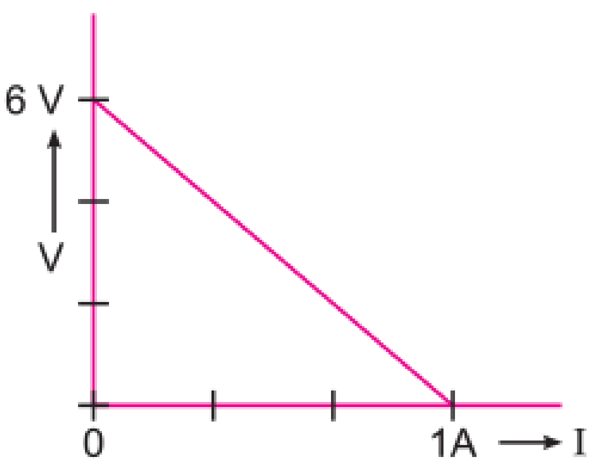
$$\left(\frac{12.0\ V}{500 + R}\right)R = 2$$

$$12R = 1000 + 2R$$

$$10R = 1000$$

$\Rightarrow$ $R = 100\ \Omega$

Q. 26. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is shown alongside. What is the emf and internal resistance of each cell? [CBSE (Central) 2016] [HOTS]



Ans.

We know that for a circuit

$$V = E_{eq} - Ir_{eq} \quad \text{...}(i)$$

From graph, when $I = 0$ A, then $V = 6$ V and when $I = 1$ A then $V = 0$ V

Putting, $V = 6$ V and $I = 0$ A in eq. (i)

$$6 = E_{eq} - 0.\, r_{eq} \quad \Rightarrow \quad E_{eq} = 6 \text{ V}$$

$$E_{eq} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 \quad \Rightarrow \quad \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = \varepsilon = \frac{E}{3} = 2 \text{ V}$$

And, when $I = 1$ A, and $V = 0$ V

$$0 = 6 - 1.\, r_{eq} \quad \Rightarrow \quad r_{eq} = 6\ \Omega$$

$$r_{eq} = r_1 + r_2 + r_3 \Rightarrow \quad r_1 = r_2 = r_3 = r = \frac{R}{3} = 2 \text{ ohm}$$

Short Answer Questions – I (OIQ)

Q. 1. Write the mathematical relation between mobility and drift velocity of charge carriers in a conductor. Name the mobile charge carriers responsible for conduction of electric current in (i) an electrolyte (ii) an ionised gas.

Ans. The mathematical relation between mobility and drift velocity of charge carriers in a conductor is given by

$$\mu = \frac{|v_d|}{E} = \frac{\text{magnitude of the drift velocity}}{\text{electric field}}$$

(i) In an electrolyte, the mobile charge carriers are both positive and negative ions.

(ii) In an ionised gas, the mobile charge carriers are electrons and positive ions.

Q. 2. Name the charge carriers of electric current in

(i) Silver foil
(ii) Hydrogen discharge tube
(iii) Germanium semiconductor
(iv) Wire made of alloy nichrome
(v) Superconductor

Ans. (i) Charge carriers in silver foil are **free electrons.**

(ii) Charge carriers in hydrogen discharge tube are **electrons** (e–) and **positive hydrogen ions** (H+).

(iii) Charge carriers in germanium semiconductor are **electrons** (e–) and **holes** (o+)

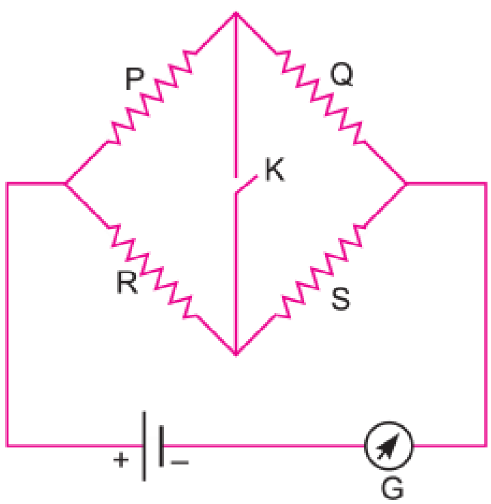
(iv) Charge carriers in nichrome wire are **electrons.**

(v) Charge carriers in superconductor are **electrons.**

Q. 3. Electrons are continuously in motion within a conductor but there is no current in it unless some source of potential is applied across its ends. Give reason.

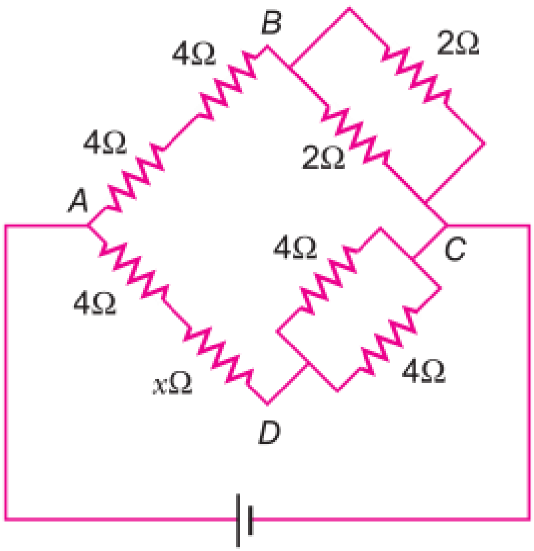
Ans. In the absence of any external source the motion of electrons in a conductor is random and electrons collide continuously with the positive ions of metal. This causes a random change in direction of motion. The average velocity of random motion of electrons in any direction is zero, hence current is zero.

Q. 4. In a Wheatstone's bridge experiment, a student by mistake, connects key (K) in place of galvanometer and galvanometer (G) in place of key (K). What will be the test for the balance of the bridge?



Ans. When the bridge is balanced, there will be no current in key, therefore a constant current will flow in the galvanometer. In balanced position, there will be a constant deflection in galvanometer and hence no change in its deflection on pressing the key.

Q. 5. The given circuit represents a balanced Wheatstone's bridge. Calculate the value of resistance x.



Ans. In the balanced condition,

$$\frac{P}{Q} = \frac{R}{S}$$

$$\therefore \qquad \frac{4+4}{1} = \frac{4+x}{2} \qquad \Rightarrow \qquad x = 12\Omega$$

Q. 6. Why is Wheatstone bridge (Metre Bridge) method not suitable for measurement of very low and very high resistances?

Ans. Because, in order to ensure sensitivity of the bridge, all other resistances used should either have low value or very high value. This also requires a galvanometer of very low resistance or very high resistance and introduces error in the results.

Q. 7. Two electric bulbs have the following specifications.

(i) 100 W at 220 V
(ii) 1000 W at 220 V.

Which bulb has higher resistance? What is the ratio of their resistances?

Ans. The resistance of filament,

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

At constant voltage V, the resistance

$$R \propto \frac{1}{P}$$

That is the resistance of filament of 100 W bulb is greater than that of 1000 W bulb.

$$\text{The ratio of resistances} = \frac{R_1}{R_2} = \frac{P_2}{P_1} = \frac{1000}{100} = \frac{10}{1} = 10 : 1$$

Q. 8. Two heated wires of the same dimensions are first connected in series and then in parallel to a source of supply. What will be the ratio of heat produced in the two cases?

Ans.

$$Q = \frac{V^2}{R} t \propto \frac{1}{R}$$

For same voltage

$$\frac{Q_{\text{series}}}{Q_{\text{parallel}}} = \frac{R_{\text{parallel}}}{R_{\text{series}}} = \frac{(R.R)/(R+R)}{R+R} = \frac{R/2}{2R} = \frac{1}{4}$$

Q. 9. A heater coil is cut in two parts and only one of them is used in the heater. What is the ratio of the heat produced by this half coil to that by the original coil if the voltage applied is the same?

Ans. For same p.d. the heat produced per second

$$H = \frac{V^2}{R} \propto \frac{1}{R}.$$

As the one part of heater coil has resistance R_2=R/2 being the resistance of original coil; therefore the ratio of heat produced

$$\frac{H_2}{H_1} = \frac{R_1}{R_2} = \frac{R}{R/2} = 2 : 1$$

Q. 10. Two wires A and B of the same material and having same length, have their cross sectional areas in the ratio 1 : 6. What would be the ratio of heat produced in these wires when same voltage is applied across each? [CBSE Sample Paper 2017]

Ans.

$A_A : A_B = 1 : 6$

$$H = V^2t/R \qquad \text{and} \qquad R = \frac{\rho l}{A}$$

$$H_A = \frac{V^2t}{\rho l/A_A}; \qquad H_B = \frac{V^2t}{\rho l/A_B}$$

$$= \frac{H_A}{H_B} = \frac{V^2t \times A_A}{\rho l} \times \frac{\rho l}{V^2\,\mathrm{t}\mathrm{A}_B} \quad \Rightarrow \quad \frac{H_A}{H_B} = \frac{A_A}{A_B} = 1{:}6$$

Q. 11. A (i) series (ii) parallel combination of two given resistors is connected, one by one, across a cell. In which case will the terminal potential difference, across the cell have a higher value?

Ans. Terminal potential difference across a cell

$$V = \varepsilon - Ir$$

i. In series arrangement, current, $I_S = \frac{E}{R_1 + R_2 + r}$

ii. In parallel arrangement, current, $I_P = \frac{E}{\frac{R_1R_2}{R_1+R_2} + r}$

Obviously, $I_P > I_S$, so $V_P < V_S$

That is **series arrangement will have higher terminal potential difference.**

Q. 12. A voltage of 30 V is applied across a carbon resistor with first, second and third rings of blue, black and yellow colours respectively. Calculate the value of current in mA, through the resistor.

Ans. Value of first digit (blue ring) = 6

Value of second digit (black ring) = 0

Multiplier (yellow ring) = 10^4

∴ Resistance, $R = 60 \times 10^4\ \Omega$, Voltage, $V = 30$ V

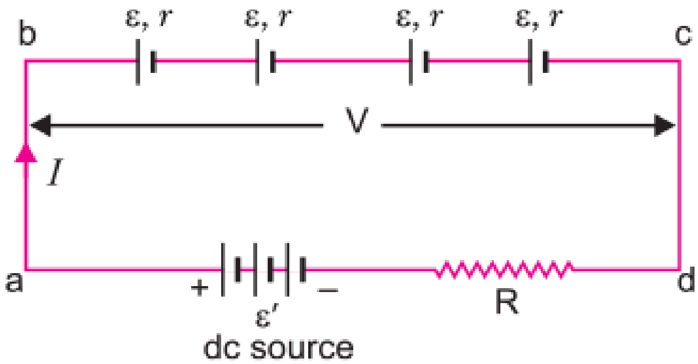
$$\text{Current } I = \frac{V}{R} = \frac{30}{60 \times 10^4} = 0.5 \times 10^{-4}\ A = 0.05\ \text{mA}.$$

Q. 13. n-identical cells, each of emf ε, internal resistance r connected in series are charged by a dc source of emf ε' using a resistance R.

(i) Draw the circuit arrangement.

(ii) Deduce expressions for (a) the charging current and (b) the potential difference across the combination of cells.

Ans. The circuit arrangement is shown in figure.



Applying Kirchhoff's second law to the circuit abcda

$-n\varepsilon - I(nr) - IR + \varepsilon' = 0$

$$\Rightarrow \qquad I = \frac{\varepsilon' - n\varepsilon}{R + nr}$$

(a) Charging current, $I = \dfrac{\varepsilon' - n\varepsilon}{R + nr}$ ...(i)

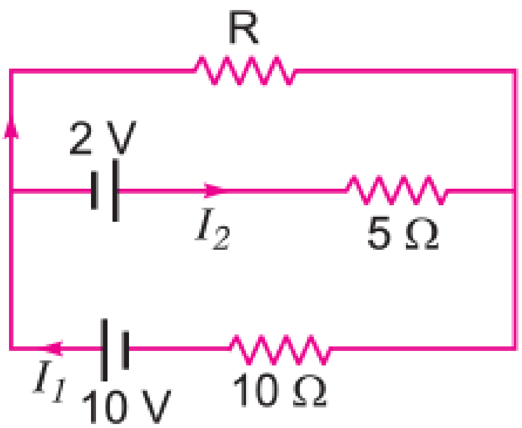
(b) Potential difference across the combination V is given by

$$-V - IR + \varepsilon' = 0$$

$$\Rightarrow \quad V = \varepsilon' - IR \qquad \Rightarrow \quad V = \varepsilon' - \frac{(\varepsilon' - n\varepsilon)}{R + nr}$$

$$\Rightarrow \quad V = \frac{\varepsilon'(R + nr) - \varepsilon' + n\varepsilon}{R + nr} \qquad \Rightarrow \quad V = \frac{\varepsilon'(R + nr - 1) + n\varepsilon}{R + nr}$$

Q. 14. Two cells of emf 10 V and 2 V and internal resistance 10 Ω and 5Ω respectively, are connected in parallel as shown. Find the effective voltage across R.
[CBSE Sample Paper 2016]

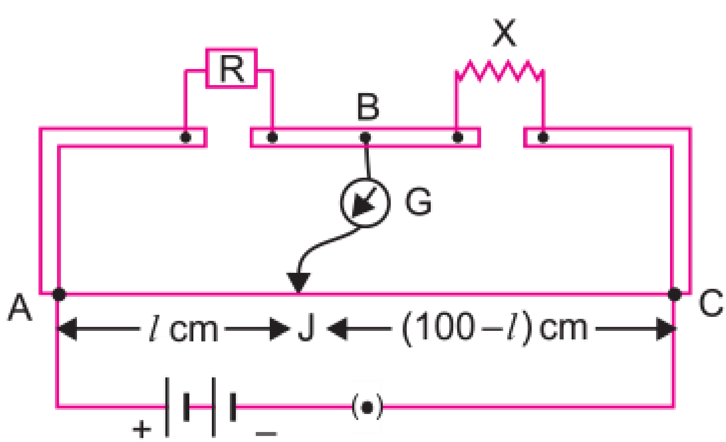


Ans.

The effective voltage across R is given by $\varepsilon_{eq} = \dfrac{\left(\frac{\varepsilon_1}{r_1}+\frac{\varepsilon_2}{r_2}\right)}{\left(\frac{1}{r_1}+\frac{1}{r_2}\right)} = \dfrac{\left(\frac{10}{10}-\frac{2}{5}\right)}{\left(\frac{1}{10}+\frac{1}{5}\right)}$

$\Rightarrow$ $$\varepsilon_{eq} = 2\ \mathrm{V}$$

Q. 15. A resistance R = 4Ω is connected to one of the gaps in a meter bridge, which uses a wire of length 1 m. An unknown resistance X > 4Ω is connected in the other gap as shown in the figure. The balance point is noticed at 'l' cm from the positive end of the battery. On interchanging R and X, it is found that the balance point further shifts by 20 cm (away from the end A). Neglecting the end correction calculate the value of unknown resistance 'X' used.



Ans.

From 'meter bridge' formula

$$\frac{R}{X} = \frac{l}{100 - l} \quad \Rightarrow \quad X = \frac{100 - l}{l} R$$

Given $R = 4\Omega$

$$\therefore \qquad X = \frac{(100 - l)}{l} \times 4\Omega \qquad \ldots(i)$$

On interchanging R and X, the balance point is obtained at a distance $(l+20)$ cm from end A, so

$$\frac{X}{R} = \frac{l+20}{100 - (l+20)} \quad \Rightarrow \quad X = \frac{l+20}{80 - l} \times 4\Omega \qquad \ldots(ii)$$

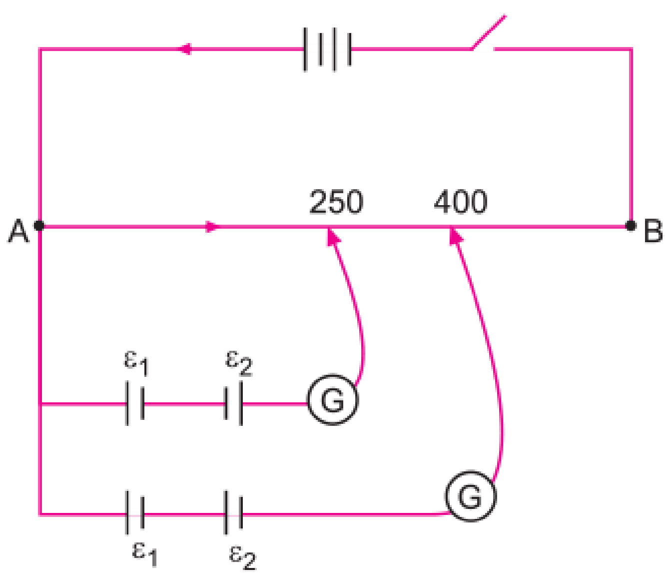
Equating (i) and (ii)

$$\frac{(100 - l)}{l} \times 4 = \frac{l+20}{80 - l} \times 4$$

Solving we get $l = 40$ cm

$$\therefore \quad \text{Unknown resistance, } X = \frac{100 - l}{l} \times 4\Omega = \frac{100 - 40}{40} \times 4\Omega \quad \Rightarrow \quad X = 6\Omega$$

Q. 16. Two primary cells of emfs wire ε_1 and ε_2 ($\varepsilon_1 > \varepsilon_2$) are connected to a potentiometer wire AB as shown in fig. If the balancing lengths for the two combinations of the cells are 250 cm and 400 cm, find the ratio of ε_1 and ε_2.



Ans. In first combination ε_1 and ε_2 are opposing each other while in second combination ε_1 and ε_2 are adding each other, so

$$\varepsilon_1 - \varepsilon_2 = kl_1$$
$$\varepsilon_1 + \varepsilon_2 = kl_2$$

$$\frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2} = \frac{l_1}{l_2}$$

$$\Rightarrow \quad \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2} = \frac{250}{400} \quad \Rightarrow \quad \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2} = \frac{5}{8}$$

$$\Rightarrow \quad 8\varepsilon_1 - 8\varepsilon_2 = 5\varepsilon_1 + 5\varepsilon_2 \Rightarrow 3\varepsilon_1 = 13\varepsilon_2$$

$$\therefore \quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{13}{3} \quad \therefore \quad \varepsilon_1 : \varepsilon_2 = 13 : 3$$

Q. 17. A cylindrical metallic wire is stretched to increase its length by 10%. Calculate the percentage increase in its resistance. [HOTS]

Ans. When the same wire is stretched, its length increases but cross-sectional area decreases. The change in resistance is due to both increase in length and decrease in cross-sectional area.

Volume $V = lA$ = constant, $A = \frac{V}{l}$ = constant

$$\therefore \quad R = \frac{\rho l}{A} = \frac{\rho l^2}{V} \propto l^2$$

$$\therefore \quad \frac{R'}{R} = \left(\frac{l'}{l}\right)^2$$

Given $\quad l' = l + \frac{10}{100}l = 1.1\,l \quad \Rightarrow \quad \frac{l'}{l} = 1.1$

$$\frac{R'}{R} = (1.1)^2 = 1.21$$

% increase in resistance

$$\frac{R' - R}{R} \times 100\% = \left(\frac{R'}{R} - 1\right) \times 100\% = (1.21 - 1) \times 100\% = 21\%$$

Q. 18. You are given n resistors each of resistance r. They are first connected to get the minimum possible resistance. In the second case, these are again connected differently to get the maximum possible resistance. Calculate the ratio between minimum and maximum values of resistance so obtained. [HOTS]

Ans. For minimum possible resistance, the resistors should be connected in parallel

$$\frac{1}{r_P} = \frac{1}{r} + \frac{1}{r} + ... \; n \text{ times}$$

or $$\frac{1}{r_P} = \frac{n}{r}$$

or $$r_P = \frac{r}{n}$$

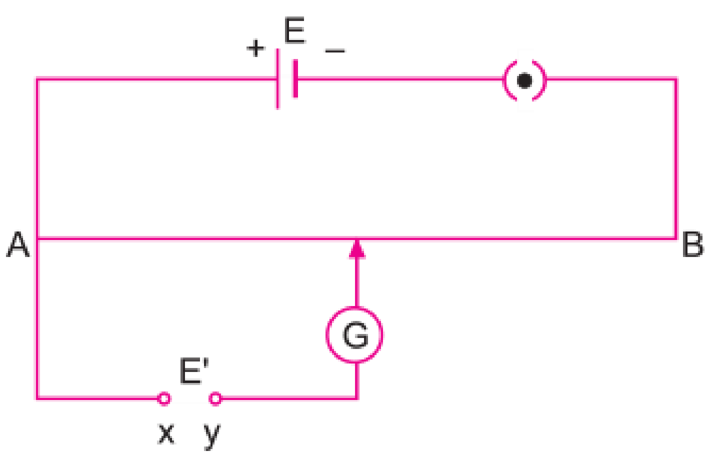
For maximum possible resistance, the resistors should be connected in series

$$r_s = r + r + ... \; n \text{ times}$$

or $$r_s = nr$$

$$\text{Ratio } \frac{r_P}{r_s} = \frac{r}{n} \times \frac{1}{\text{nr}} = \frac{1}{n^2}$$

Q. 19. For the potentiometer circuit shown in the given figure, points X and Y represent the two terminals of an unknown emf E'. A student observed that when the jockey is moved from the end A to the end B of the potentiometer wire, the deflection in the galvanometer remains in the same direction.



What may be the two possible faults in the circuit that could result in this observation?

If the galvanometer deflection at the end B is (i) more, (ii) less than at the end A, which of the two faults, listed above, would be there in the circuit? Give reason in support of your answer in each case. [HOTS]

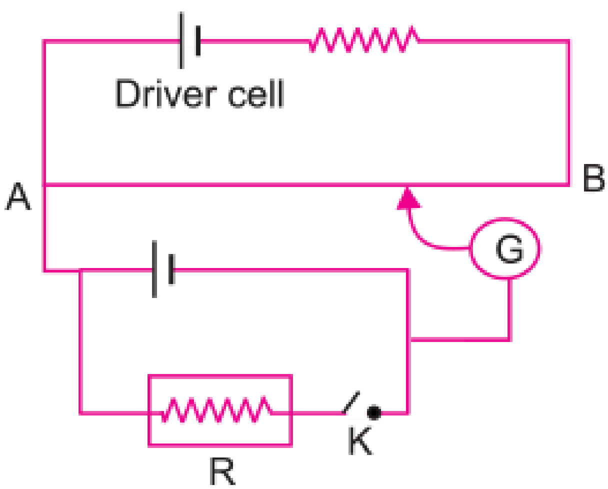
Ans. The two possible faults in the circuit may be (i) emf E′ is greater than emf E.

(ii) Terminal X of unknown emf is negative (while it should be positive).

If galvanometer deflection at end B is more than that at end A, then terminal X is negative, because in this case net current in galvanometer along AB due to both cells is additive.

If galvanometer deflection at end B is less than that at end A, then E′> E, because net current in galvanometer due to both cells' emfs E and E′ is subtractive.

Q. 20. The following circuit shows the use of potentiometer to measure the internal resistance of a cell



(i) When the key is open, how does the balance point change, if the current from the driver cell decreases?

(ii) When the key K is closed, how does the balance point change if R is increased keeping current from the driver cell constant? [HOTS]

Ans. (i) When current through driver cell decreases, the potential gradient across potentiometer wire decreases; so the balancing length $l = \frac{E}{k}$ increases, so balance point is shifted to the right.

(ii) With increase of R, the terminal p.d. across cell E increases and hence balancing length l = $\frac{V}{k} \propto V$ increases. So the balance point is shifted to the right.

Q. 21. First a set of n equal resistors of R each are connected in series to a battery of emf E and internal resistance R. A current I is observed to flow. Then the n resistors are connected in parallel to the same battery. It is observed that the current is increased 10 times. What is n? [NCERT Exemplar] [HOTS]

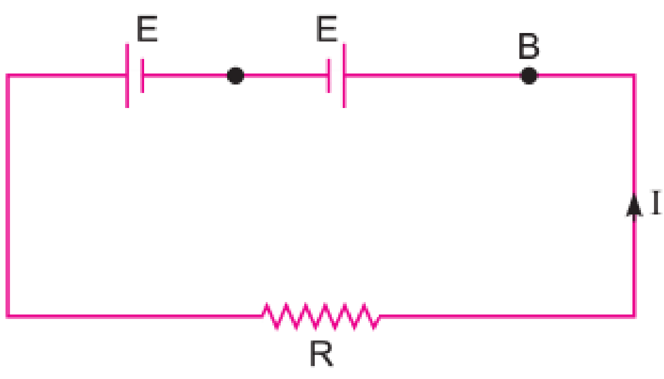
Ans.

When n resistors are in series, $I = \frac{E}{R + nR}$;

When n resistors are in parallel, $\frac{E}{R + \frac{R}{n}} = 10I$

$$\frac{1+n}{1+\frac{1}{n}} = 10 \Rightarrow \frac{1+n}{n+1} n = 10 \quad \Rightarrow \quad n = 10.$$

Q. 22. Two cells of same emf E but internal resistance r1 and r2 are connected in series to an external resistor R (Fig.). What should be the value of R so that the potential difference across the terminals of the first cell becomes zero. [NCERT Exemplar] [HOTS]



Ans.

$$I = \frac{E+E}{R+r_1+r_2}$$

$$V_1 = E - \mathrm{Ir}_1 = E - \frac{2E}{r_1+r_2+R} r_1 = 0$$

or $$E = \frac{2\,\mathrm{Er}_1}{r_1+r_2+R}$$

$\Rightarrow$ $$r_1 + r_2 + \mathrm{R} = 2r_1 \qquad \Rightarrow \qquad R = r_1 - r_2$$

Q. 23. Calculate the temperature at which the resistance of a conductor becomes 20% more than its resistance at 27°C. The value of the temperature coefficient of resistance of the conductor is 2.0 × 10^{-4}/K. [HOTS]

Ans.

Given $R_{27} = R\ (\text{say}),\ R_T = R + \frac{20}{100} R = 1.2R,\ T_1 = 27 + 273 = 300\ K$

From relation,

$$R_T = R_{27}\left[1 + \alpha\left(\mathrm{T}_2 - 300\right)\right]$$

$\Rightarrow$ $$1.2R = R\left[1+2.0\times10^{-4}\left(T_2 - 300\right)\right]$$

$\Rightarrow$ $$1 + 2.0\times10^{-4}\left(T_2 - 300\right) = 1.2$$

or $$2.0\times10^{-4}\left(T_2 - 300\right) = 0.2$$

$$T_2 - 300 = \frac{0.2}{2.0\times10^{-4}}$$

$$T_2 = 1000 + 300 = \mathbf{1300\ K}$$

Q. 24. The potential difference across a resistor 'r' carrying current 'I' is Ir.

(i) Now if the potential difference across 'r' is measured using a voltmeter of resistance 'RV', show that the reading of voltmeter is less than the true value.

(ii) Find the percentage error in measuring the potential difference by a voltmeter.

(iii) At what value of RV, does the voltmeter measures the true potential difference?
[CBSE Sample Paper 2016] [HOTS]

Ans. (i)

$$V = Ir \text{ (without voltmeter } R_V\text{)}$$

$$V' = \frac{\mathrm{Ir}\mathrm{R}_V}{r+R_V} = \frac{\mathrm{Ir}}{1+\frac{r}{R_V}}$$

$$V' < V$$

(ii)

Percentage error

$$\left(\frac{V-V'}{V}\right) \times 100 = \left(\frac{r}{r+R_V}\right) \times 100$$

(iii) $R_V \longrightarrow \infty,\ V' = Ir = V$

Short Answer Questions – II (PYQ)

Q. 1. Answer the following questions:

(i) Derive an expression for drift velocity of free electrons.

(ii) How does drift velocity of electrons in a metallic conductor vary with increase in temperature? Explain. [CBSE (Central) 2016]

Ans. (i) When a potential difference is applied across a conductor, an electric field is produced and free electrons are acted upon by an electric force (Fe). Due to this, electrons accelerate and keep colliding with each other and acquire a constant (average) velocity vd called drift velocity.

Electric force on electron $F_e = -eE$

If m is the mass of electron, then its acceleration

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

Now, $v = u + at$

Here, $u = 0, t = \tau$ (relaxation time), $\vec{v} = \vec{v}_d$

$$\vec{v_d} = 0 - \frac{e\vec{E}}{m}\tau$$

$$\Rightarrow \qquad \vec{v_d} = -\frac{e\tau}{m}\vec{E}$$

(ii) With rise of temperature, the rate of collision of electrons with ions of lattice increases, so relaxation time decreases. As a result the drift velocity of electrons decreases with the rise of temperature.

Q. 2. (a) State Kirchhoff's rules and explain on what basis they are justified.

(b) Two cells of emfs E_1 and E_2 and internal resistances r_1 and r_2 are connected in parallel. Derive the expression for the (i) emf and (ii) internal resistance of a single equivalent cell which can replace this combination. [CBSE Patna 2015]

Ans. (a) Kirchhoff's Laws

(i) First law (or junction law): The algebraic sum of currents meeting at any junction is zero, i.e.,

∑I = 0

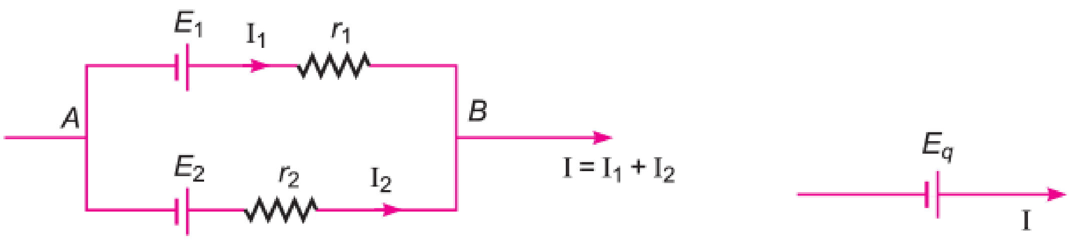
This law is based on conservation of charge.

(ii) Second law (or loop law): The algebraic sum of potential differences of different circuit elements of a closed circuit (or mesh) is zero, i.e.,

∑V = 0

This law is based on conservation of energy.

(b)



(a) (b)

Let I1 and I2 be the currents leaving the positive, terminals of the cells, and at the point B

$I = I_1 + I_2$ …(i)

Let V be the potential difference between points A and B of the combination of the cells, so

$V = E_1 - I_1r_1$ …(ii) (across the cells)

And $V = E_2 - I_2r_2$ …(iii)

From equation (i), (ii) and (iii), we get

$$I = \frac{(E_1 - V)}{r_1} + \frac{(E_2 - V)}{r_2}$$

$$= \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \quad ...(iv)$$

Fig. (b) Shows the equivalent cell, so for the same potential difference

$$V = E_{eq} - I_{rq}$$

or $$I = \frac{E_{eq}}{r_q} - \frac{V}{r_q} \quad \ldots(v)$$

On comparing Eq. (iv) and (v), we get

$$\frac{E_{eq}}{r_q} = \frac{E_1}{r_1} + \frac{E_2}{r_2}$$

and $$\frac{1}{r_q} = \frac{1}{r_1} + \frac{1}{r_2} \quad \Rightarrow \quad r_q = \frac{r_1 r_2}{r_1 + r_2}$$

On further solving, we have

$$E_{eq}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = \frac{E_1}{r_1} + \frac{E_2}{r_2}$$

$$\Rightarrow \quad E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

Q. 3. Plot a graph showing the variation of current density (J) versus the electric field (E) for two conductors of different materials. What information from this plot regarding the properties of the conducting material, can be obtained which can be used to select suitable materials for use in making (i) standard resistance and (ii) connecting wires in electric circuits?

Electron drift speed is estimated to be of the order of mms^{-1}. Yet large current of the order of few amperes can be set up in the wire. Explain briefly.
[CBSE Panchkula 2015]

Ans. As we know that the drift velocity of the free electrons in a conducting material is given by

$$v_d = \frac{-\,eE}{m}\tau \quad \ldots(1)$$

And the flow of the current due to drifting electrons

$$I = neAv_d \quad \ldots(2)$$

From relation (1) and (2), we get

$$I = neA\left(\frac{eE}{m}\tau\right) = \frac{ne^2\ A}{m}\tau\ .\ E$$

$$\text{Current density, } |J| = \frac{I}{A}$$

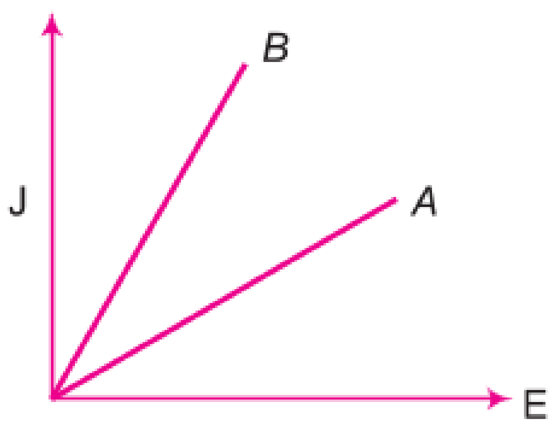
$$|J| = \frac{n\ e^2\ A}{m}\ E$$

$$\Rightarrow \qquad |J| = \frac{1}{\rho}\ E$$

$$\left[\text{where}, \rho = \frac{m}{ne^2\ P}\right]$$

⇒ Current density, $J \propto E$

Where represents the slope of J-E graph.



Let ρA the resistivity of the standard resistance A and ρ_B is the resistivity of the connective wire, i.e., $\rho_B < \rho_A$. So the graph of J vs E can be given as shown alongside.

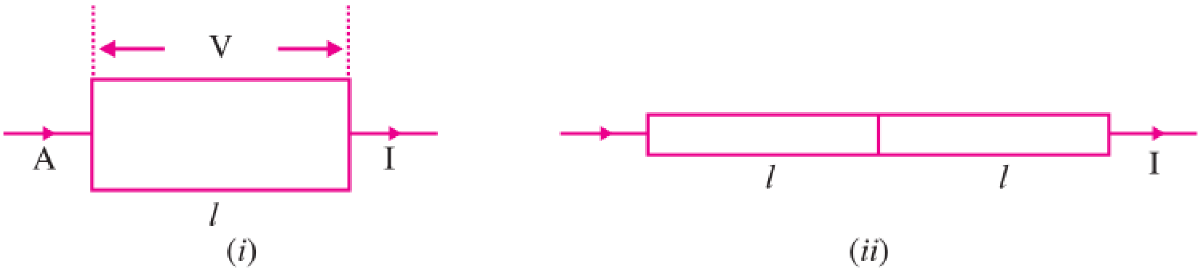
Information regarding current flow:

(i) When the circuit is closed, an electric field gets established through the conductor with the speed of light.

(ii) Localised electrons at all places inside the conductor begins to drift instantly and current flow occurs immediately.

(iii) In the relation i = neAvd, the free electron number density is of order of 10^{29} m^{-3}, even drift velocity is of order of few mm/sec or 10^{-3} m/sec, the current flow becomes of order of few ampere. I = neAvd, Here, drift velocity V_d is very small (in the order of mm s^{-1}), but electron number density (n) is very large. Hence, large current can be set up in the wire.

Q. 4. A metal rod of square cross-sectional area A having length l has current I flowing through it when a potential difference of V volt is applied across its ends (figure (i)). Now the rod is cut parallel to its length into two identical pieces and joined as shown in figure (ii). What potential difference must be maintained across the length 2l so that the current in the rod is still I? [CBSE (F) 2016]



Ans. Let resistance of metal rod having cross sectional area A and length l be R_1

$$\Rightarrow \qquad R_1 = \rho\frac{l}{A}$$

Also, resistance of metal rod having cross sectional area A/2 and length 2l

$$R_2 = \rho\frac{2l}{\frac{A}{2}} \qquad \left[\because R = \rho\frac{l}{A}\right]$$

$$= 4\ R_1$$

Let V′ be potential difference maintained across rod. When the rod is cut parallel and rejoined by length, the length of the conductor becomes 2l and area decreases by A/2.

For maintaining same current,

$$I = \frac{V}{R_1} = \frac{V'}{R_2}$$

$$I = \frac{V}{R_1} = \frac{V'}{4R_1} \quad \Rightarrow \quad V' = 4V$$

The new potential applied across the metal rod will be four times the original potential (V).

Q. 5. Two metallic wires, P_1 and P_2 of the same material and same length but different cross-sectional areas, A_1 and A_2 are joined together and connected to a source of emf. Find the ratio of the drift velocities of free electrons in the two wires when they are connected (i) in series, and (ii) in parallel. [CBSE (F) 2017]

Ans. We know that,

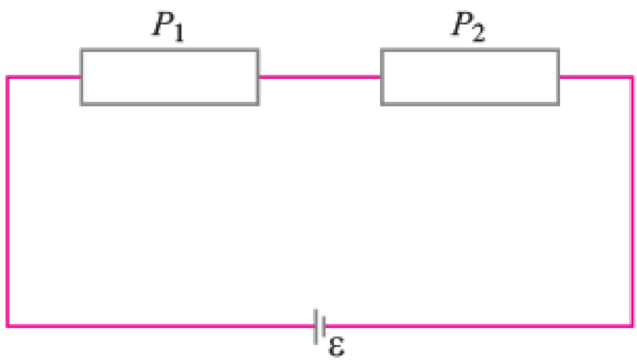
$$I = \text{neA}\ v_d \qquad \Rightarrow \qquad v_d = \frac{I}{\text{neA}}$$

Let R_1 and R_2 be resistances of P_1 & P_2 and A_1 & A_2 are their cross sectional areas respectively.

$$\therefore \qquad R_1 = \rho\frac{l}{A_1} \quad \text{and} \quad R_2 = \rho\frac{l}{A_2}$$

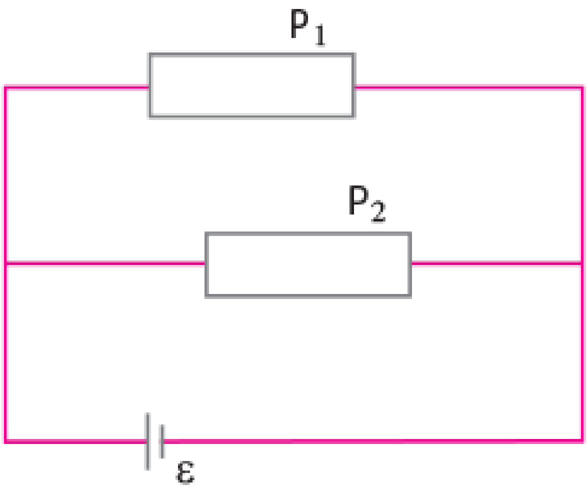
When connected in series,

$$\therefore \qquad \frac{v_{d_1}}{v_{d_2}} = \frac{\dfrac{\varepsilon}{\left(\dfrac{\rho l}{A_1}+\dfrac{\rho l}{A_2}\right)\text{neA}_1}}{\dfrac{\varepsilon}{\left(\dfrac{\rho l}{A_1}+\dfrac{\rho l}{A_2}\right)\text{neA}_2}} = \frac{A_2}{A_1}$$



When, connected in parallel,

$$\frac{v_{d_1}}{v_{d_2}} = \frac{\dfrac{\dfrac{\varepsilon}{\rho l} \cdot \dfrac{1}{neA_1}}{A_1}}{\dfrac{\dfrac{\varepsilon}{\rho l} \cdot \dfrac{1}{neA_2}}{A_2}} = 1$$



Q. 6. Two heating elements of resistance R_1 and R_2 when operated at a constant supply of voltage, V, consume powers P_1 and P_2 respectively. Deduce the expressions for the power of their combination when they are, in turn, connected in

(i) In series combination
(ii) In parallel combination

Ans. In series combination

Net resistance, $R = R_1 + R_2$ ...(i)

As heating elements are operated at same voltage V, we have

$$R = \frac{V^2}{P}, \quad R_1 = \frac{V^2}{P_1} \text{ and } R_2 = \frac{V^2}{P_2}$$

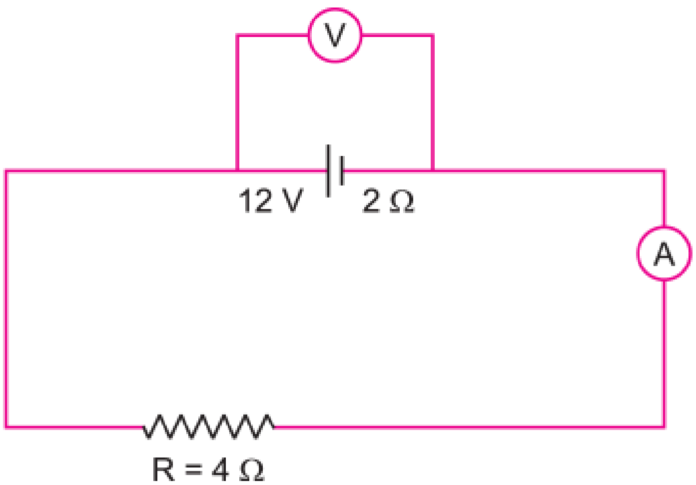
$\therefore$ From equation (i)

$$\frac{V^2}{P} = \frac{V^2}{P_1} + \frac{V^2}{P_2} \Rightarrow \frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$$

Q. 7. Answer the following questions:

(i) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?

(ii) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings. [CBSE AI 2017]



Ans. (i)

Heat generated $H = I_2\ Rt = \frac{V^2 t}{R}$

Given, $H' = 9H$

$\therefore \qquad \frac{V'^2 t}{R} = 9 \times \frac{V^2 t}{R}$

$\Rightarrow \qquad V^2 = 9 \times V^2 \qquad \Rightarrow \qquad V' = \sqrt{9} \times V$

$\therefore \qquad V = 3V$

$\therefore$ Potential difference increases by a factor of $\sqrt{9}$ *i.e.*, 3.

(ii) Given: emf E = 12 V

Internal resistance r = 2 Ω

External resistance r = 4 Ω

Ammeter Reading,

$$I = \frac{E}{R+r} = \frac{12}{4+2} = \frac{12}{6}$$

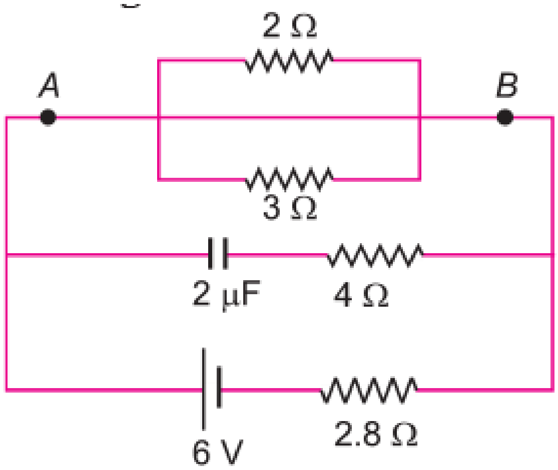
∴ $I = 2$ A

Voltmeter Reading,

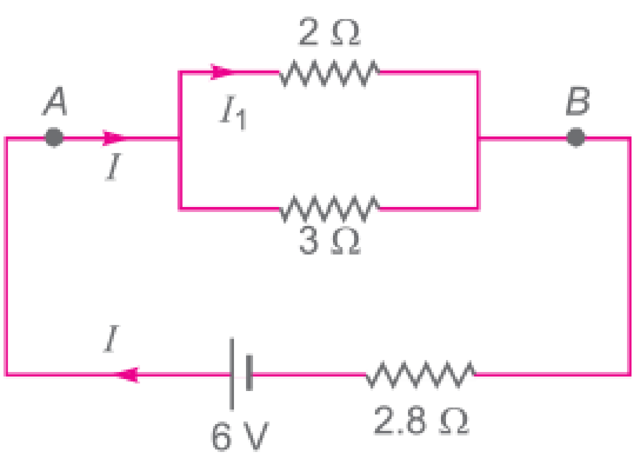
$V = E - Ir = 12 - (2 \times 2)$

∴ $V = 8$ V

Q. 8. Calculate the steady current through the 2 Ω resistor in the circuit shown below.
[CBSE (F) 2010]



Ans. In steady state there is no current in capacitor branch, so equivalent circuit is shown in fig.



Net resistance of circuit,

$$R_{eq} = \frac{2\times3}{2+3} + 2.8 = 1.2 + 2.8 = 4\ \Omega$$

Net emf, $E = 6$ V

Current in circuit, $I = \frac{E}{R_{eq}} = \frac{6}{4} = 1.5\ A$

Potential difference across parallel combination of 2 Ω and 3 Ω resistances.

$$V = IR' = 1.5 \times 1.2 = 1.8\ \text{V}$$

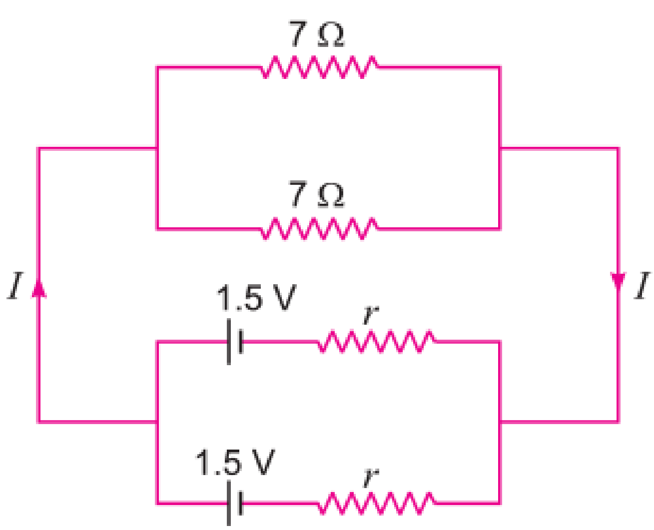
Current in 2 Ω resistance

$$I_1 = \frac{V'}{R_1} = \frac{1.8}{2} = 0.9A$$

Q. 9. Two identical cells of emf 1.5 V each joined in parallel supply energy to an external circuit consisting of two resistances of 7Ω each joined in parallel. A very high resistance voltmeter reads the terminal voltage of cells to be 1.4 V. Calculate the internal resistance of each cell. [CBSE (North) 2016]

Ans. Here, E = 1.5 V, V = 1.4 V

Resistance of external circuit = Equivalent resistance of two resistances of 7Ω connected in parallel



or $$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{7\times 7}{7+7}\Omega = 3.5\Omega$$

Let r′ be the total internal resistance of the two cells, then

$$r' = \left(\frac{E-V}{V}\right)R = \left(\frac{1.5-1.4}{1.4}\right)3.5 = 0.25\Omega$$

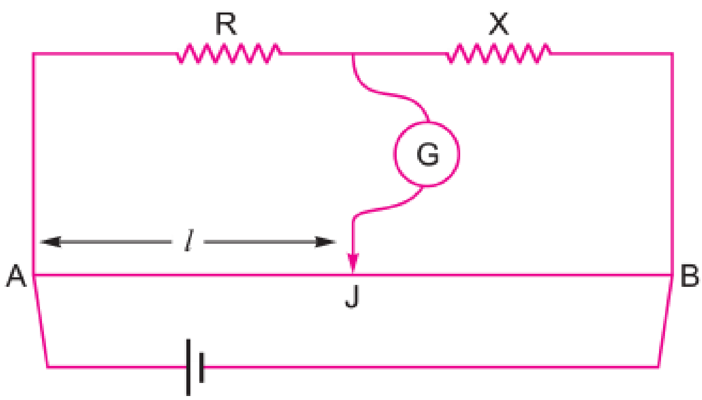
As the two cells of internal resistance r each have been connected in parallel, so

$$\frac{1}{r'} = \frac{1}{r} + \frac{1}{r} \Rightarrow \frac{1}{0.25} = \frac{2}{r} \Rightarrow r = 0.25\times 2 = 0.5\Omega$$

Q. 10. In the meter bridge experiment, balance point was observed at J with AJ = l.

(i) The values of R and X were doubled and then interchanged. What would be the new position of balance point?

(ii) If the galvanometer and battery are interchanged at the balance position, how will the balance point get affected? [CBSE (AI) 2011]



Ans.

$$(i) \quad \frac{R}{X} = \frac{rl}{r(100-l)}$$

$$\Rightarrow \quad \frac{R}{X} = \frac{l}{100-l} \quad \quad ...(i)$$

When both R and X are doubled and then interchanged, the new balance length becomes l' given by

$$\frac{2X}{2R} = \frac{l'}{(100-l')} \quad \quad ...(ii)$$

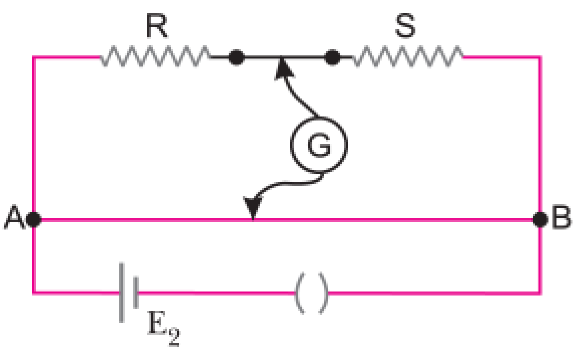
$$\Rightarrow \quad \frac{X}{R} = \frac{l'}{100-l'}$$

From (i) and (ii),

$$\frac{100-l}{l} = \frac{l'}{100-l'} \quad \quad \Rightarrow l' = (100 - l)$$

(ii) If galvanometer and battery are interchanged, there is no effect on the balance point.

Q. 11. In a meter bridge shown in the figure, the balance point is found to be 40 cm from end A. If a resistance of 10 Ω is connected in series with R, balance point is obtained 60 cm from A. Calculate the value of R and S. [CBSE Patna 2015]



Ans.

$$\frac{R}{S} = \frac{40}{60} \quad \Rightarrow \quad 3R = 2S \quad \Rightarrow \quad R = \frac{2S}{3} \qquad ...(i)$$

$$\frac{R+10}{S} = \frac{60}{40} \quad \Rightarrow \quad 2R + 20 = 3S \qquad ...(ii)$$

From equation (i) and (ii), we get

$$2 \times \frac{2S}{3} + 20 = 3S$$

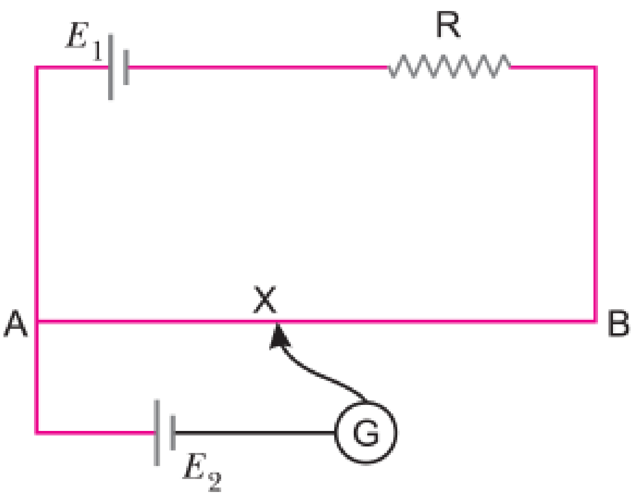
$$\Rightarrow \qquad S = 12 \text{ ohm}$$

From equation (i), we get

$$R = \frac{2 \times 12}{3}$$

$$\Rightarrow \qquad R = 8 \text{ ohm}$$

Q. 12. In the circuit diagram shown, AB is a uniform wire of resistance 15 Ω and length 1 m. It is connected to a cell E1 of emf 2 V and negligible internal resistance and a resistance R. The balance point with another cell E2 of emf 75 mV is found at 30 cm from end A. Calculate the value of the resistance R. [CBSE Chennai 2015]



Ans. Current drawn from the cell, E_1 = 2 V

$$I = \frac{E_1}{15 + R} = \frac{2}{15+R}$$

Potential drop across the wire AB

$$V_{AB} = I \times 15 = \frac{2\times15}{15+R} = \frac{30}{15+R}$$

Since wire length is 1 m or 100 cm.

So, potential gradient along the wire,

$$K = \frac{V_{AB}}{100 \text{ cm}} = \frac{30}{100(15+R)}$$

At the balance point

$$E_2 = kl_2$$

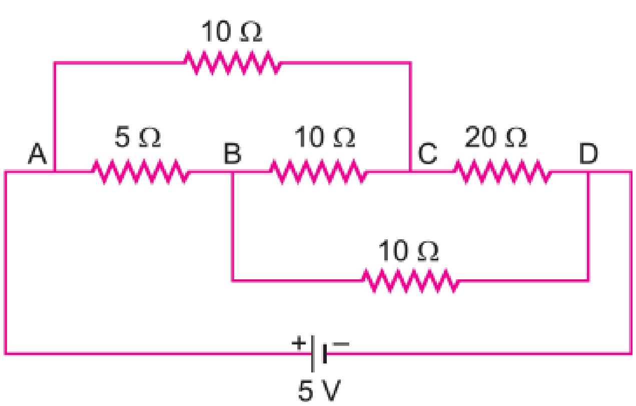
$$75 \text{ mV} = \frac{30}{100(15+R)} \times 30 \text{ cm}$$

$$75 \times 10{-}3 \times 100\ (15 + R) = 900$$

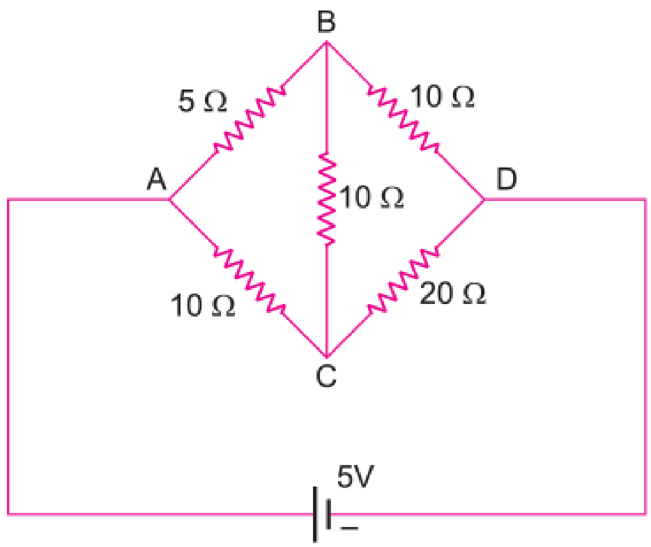
$$15 + R = \frac{9000}{75}$$

$\therefore$ $R = 120 - 15 = 105$ ohm

Q. 13. Calculate the value of the current drawn from a 5 V battery in the circuit as shown. [CBSE (F) 2013]



Ans. The equivalent wheat stone bridge for the given combination is shown in figure alongside.



The resistance of arm ACD, R_{S1} =10 + 20 = 30Ω

Also, the resistance of arm ABD, R_{S2} = 5+ 10= 15Ω

Since the condition $\frac{R}{Q} = \frac{R}{S}$ is satisfied, it is a balanced bridge.

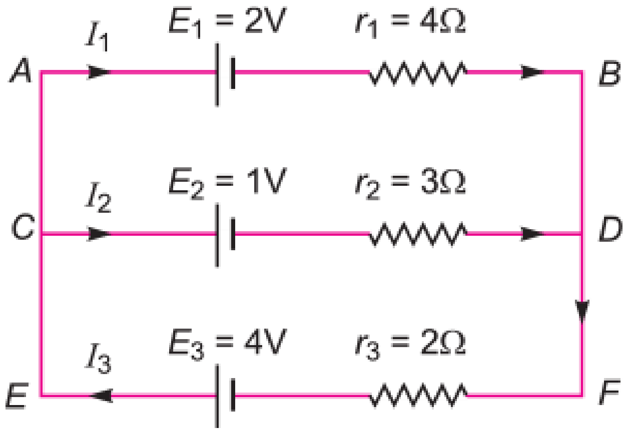
No current flows along arm BC.

∴ Equivalent resistance $\frac{R_{S_1} \times R_{S_2}}{R_s + R_{s_2}}$

$$= \frac{30 \times 15}{30+15} = \frac{30 \times 15}{45}$$

Current drawn from the source, I = $I = \frac{V}{R} = \frac{5}{10} = \frac{1}{2} A = 0.5\ A$

Q. 14. State Kirchhoff's rules. Use these rules to write the expressions for the currents I1, I2 and I3 in the circuit diagram shown. [CBSE (AI) 2010]



Ans. Kirchhoff's Rules:

(i) The algebraic sum of currents meeting at any junction is zero, i.e.,

$$\sum I = 0$$

(ii) The algebraic sum of potential differences across circuit elements of a closed circuit is zero, i.e., $\sum V = 0$

From Kirchhoff's first law

$$I_3 = I_1 + I_2 \qquad \ldots(i)$$

For applying Kirchhoff's second law to mesh ABDC

$$-2 - 4I_1 + 3I_2 + 1 = 0$$

$\Rightarrow$ $$4I_1 - 3I_2 = -1 \qquad \ldots(ii)$$

Applying Kirchoff's II law to mesh ABCEA

$$-2 - 4I_1 - 2I_3 + 4 = 0$$

$\Rightarrow$ $$4I_1 + 2I_3 = 2 \text{ or } 2I_1 + I_3 = 1$$

Using (i) we get

$\Rightarrow$ $$2I_1 + (I_1 + I_2) = 1$$

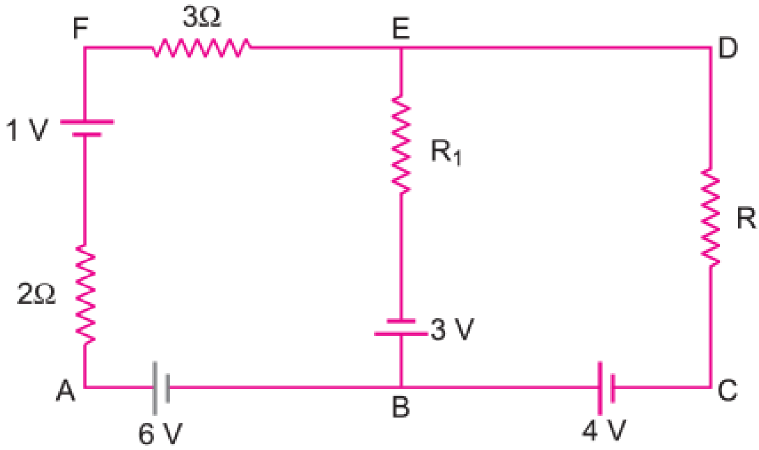
Or $$3I_1 + I_2 = 1 \qquad \ldots(iii)$$

Solving (ii) and (iii), we get

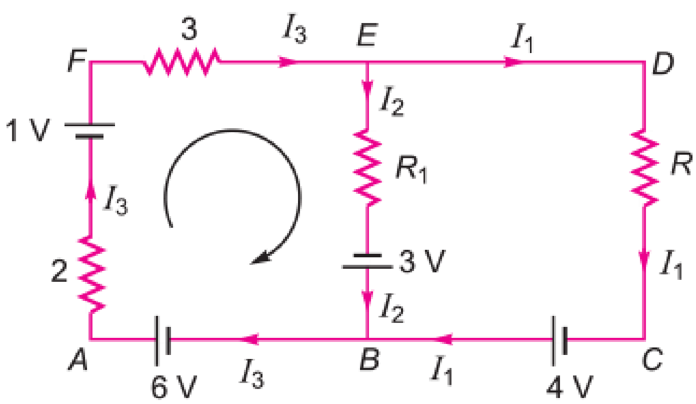
$$I_1 = \frac{2}{13}\ A,\ I_2 = 1 - 3I_1 = \frac{7}{13}\ A$$

so, $$I_3 = I_1 + I_2 = \frac{9}{13} A$$

Q. 15. Use Kirchhoff's rules to determine the potential difference between the points A and D when no current flows in the arm BE of the electric network shown in the figure.
[CBSE Allahabad 2015]



Ans.



According to Kirchhoff's junction rule at E or B

$$I_3 = I_2 + I1$$

Since I2 = 0 in the arm BE as given in the question

⇒ $I_3 = I_1$

Using loop rule in the loop AFEBA

$$+6V - 2I_3 + 1V - 3I_3 - I_2 R_1 + 3V = 0$$

⇒ $2I_3 + 3I_3 + I_2R_1 = 10V$

Since $I_2=0$, so

$$5I_3 = 10V$$

⇒ $I_3 = 2$ A

∴ $I_3 = I_2 = 2$ A

The potential difference between A and D, along the branch AFED of the closed circuit.

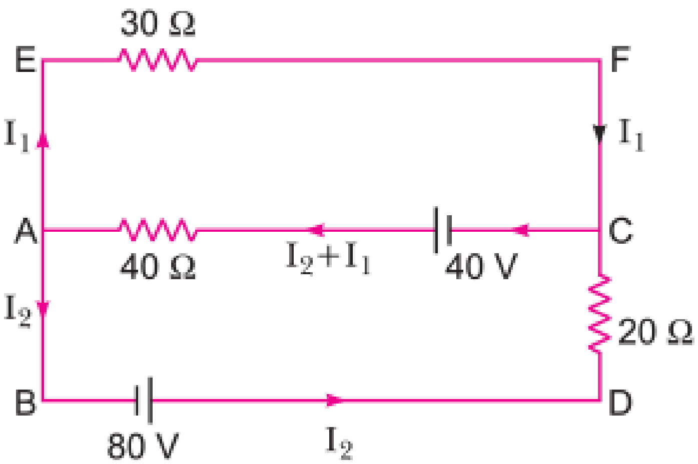
$$VA - 2I_3 + 1V - 3I_3 - V_D = 0$$

⇒ $$V_A - V_D = 2I_3 - 1 + 3I_3$$

$$= 2 \times 2 - 1 + 3 \times 2 = 9 \text{ V}$$

Q. 16. Answer the following questions:

(i) Using Kirchhoff's rules, calculate the current in the arm AC of the given circuit.



(ii) On what principle does the meter bridge work? Why are the metal strips used in the bridge? [CBSE South 2016]

Ans. (i) For the mesh EFCAE

$$-30I_1 + 40 - 40(I_1+I_2) = 0$$

Or $7I_1 - 4I_2 = -4$

Or $7I_1 + 4I_2 = 4$ ...(i)

For the mesh ACDBA

$$40(I_1 + I_2) - 40 + 20I_2 - 80) = 0$$

Or $40(I_1 + 60I_2 - 120 = 0$

Or $2I_1 + 3I_2 = 6$ ...(ii)

Solving (i) and (ii), we get

$$I_1 = \frac{-12}{13} A$$

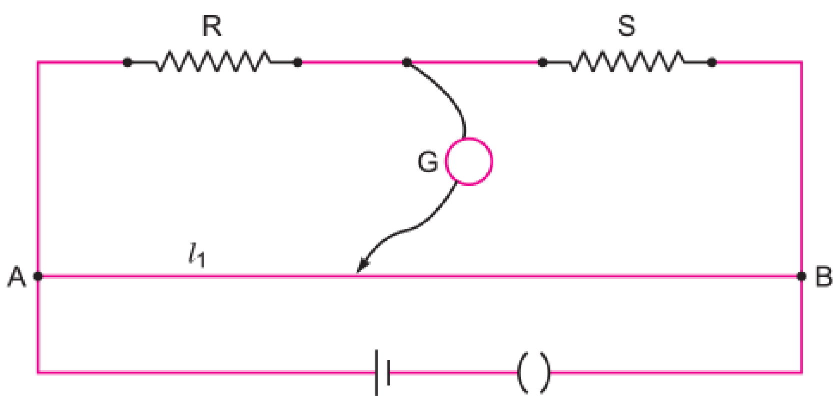
$$I_2 = \frac{34}{13} A$$

$\therefore$ Current through arm $\quad AC = I_1 + I_2 = \frac{22}{13} A$

Q. 17. Answer the following questions:

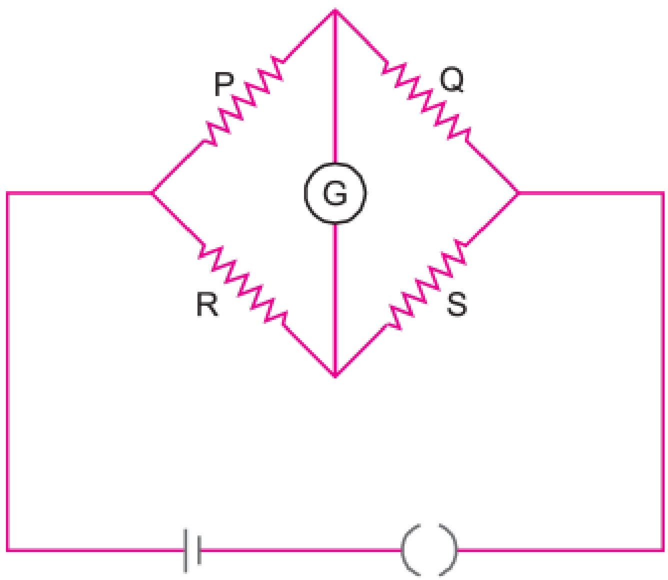
(i) Write the principle of working of a metre bridge.

(ii) In a metre bridge, the balance point is found at a distance l1 with resistances R and S as shown in the figure.



An unknown resistance X is now connected in parallel to the resistance S and the balance point is found at a distance l_2. Obtain a formula for X in terms of l_1, l_2 and S.
[CBSE (AI) 2017]

Ans. (i)



Working of a meter bridge is based on the principle of balanced Wheatstone bridge.

According to the principle, the balancing condition is

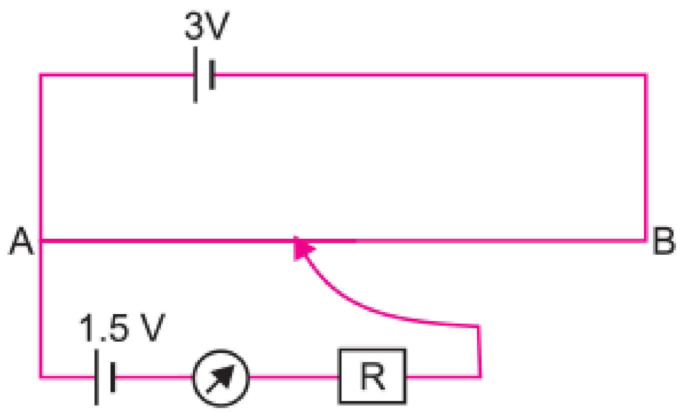
$$\frac{P}{Q} = \frac{R}{S} \text{ (When } I_g = 0\text{)}$$

For balancing lengths in a meter bridge,

$$\frac{P}{Q} = \frac{R}{S} \quad \Rightarrow \quad \frac{l}{100 - l} = \frac{R}{S}$$

$$\therefore \quad S = \frac{100 - l}{l} R$$

Q. 18. A potentiometer wire of length 1 m is connected to a driver cell of emf 3 V as shown in the figure. When a cell of 1.5 V emf is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell and using a cell of unknown emf, the balance point shifts to 80 cm. [CBSE Delhi 2008]



(i) Calculate unknown emf of the cell.

(ii) Explain with reason, whether the circuit works, if the driver cell is replaced with a cell of emf 1 V.

(iii) Does the high resistance R, used in the secondary circuit affect the balance point? Justify our answer.

Ans. (i)

Unknown emf ε_2 is given by

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{l_2}{l_1} \quad \Rightarrow \quad \varepsilon_2 = \frac{l_2}{l_1}\varepsilon_1$$

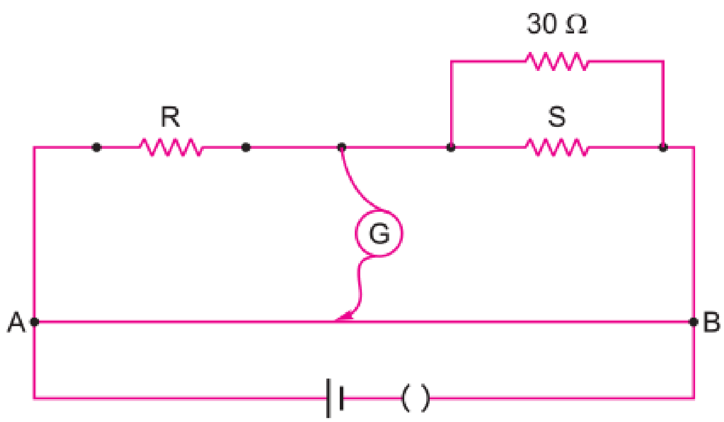
Given $\varepsilon_1 = 1.5$ V, $l_1 = 60$ cm, $l_2 = 80$ cm

$$\therefore \quad \varepsilon_2 = \frac{80}{60} \times 1.5V = 2.0V$$

(ii) The circuit will not work if emf of driver cell is 1 V (less than that of cell in secondary circuit), because total voltage across wire AB is 1 V which cannot balance the voltage V.

(iii) No, since at balance point no current flows through galvanometer G i.e., cell remains in open circuit.

Q. 19. In a meter bridge with R and S in the gaps, the null point is found at 40 cm from A. If a resistance of 30Ω is connected in parallel with S, the null point occurs at 50 cm from A. Determine the values of R and S. [CBSE East 2016]



Ans.

In first case l_1 =40cm

$$\frac{R}{S} = \frac{l_1}{100-l_1} \Rightarrow \frac{R}{S} = \frac{40}{60} = \frac{2}{3} \qquad \ldots(i)$$

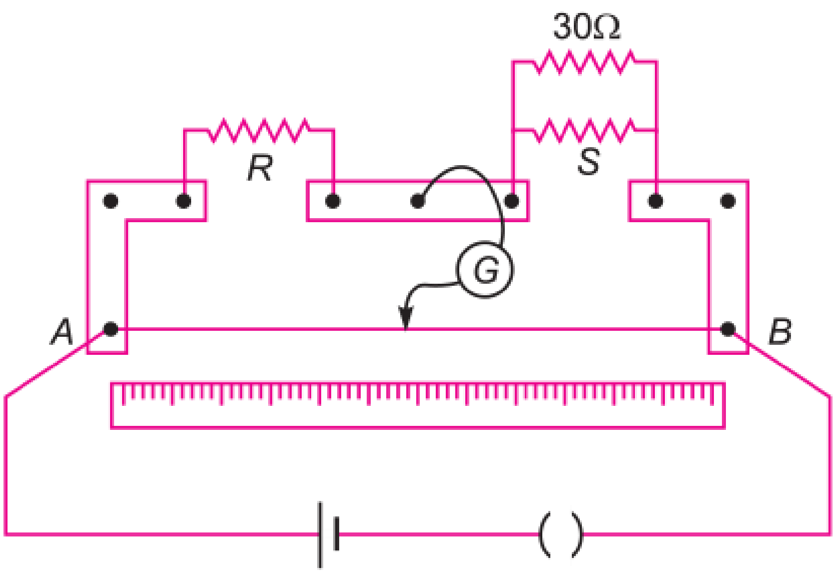
In second case when S and 30Ω are in parallel balancing length l_2=50 cm, so

$$S' = \frac{30S}{30+S} \qquad \ldots(ii)$$

$$\frac{R}{S'} = \frac{50}{100-50} = 1 \Rightarrow S' = R \qquad \ldots(iii)$$

From (i) $\quad S = \frac{3}{2}R$

Substituting this value in (ii), we get



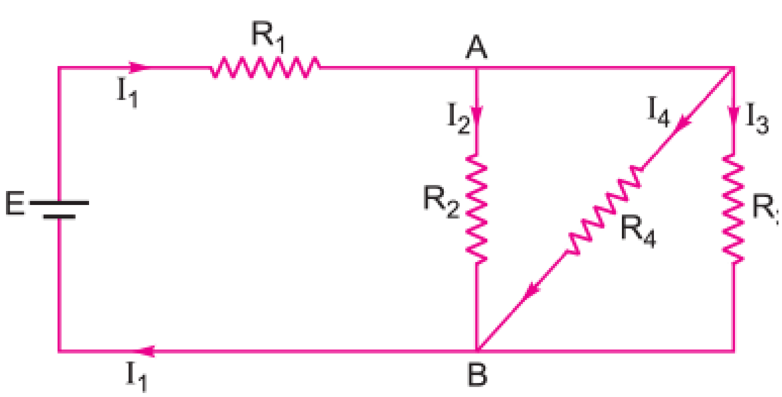
$$S' = \frac{30\times\left(\frac{3}{2}R\right)}{30+\left(\frac{3}{2}R\right)} = \frac{45R}{30+\frac{3}{2}R}$$

Also from equation (iii), $S' = R$

$$\therefore \quad \frac{45R}{30+\frac{3}{2}R} = R \quad \Rightarrow \quad 45 = 30 + \frac{3}{2}R$$

$$\Rightarrow \quad \frac{3}{2}R = 15 \quad \text{or} \quad R = 10\,\Omega \quad \Rightarrow \quad S = \frac{3}{2}\times R = \frac{3}{2}\times 10 = 15\,\Omega$$

Q. 20. In the circuit shown, R1 = 4Ω , R2 = R3 = 15Ω, R4 = 30Ω and E = 10 V. Calculate the equivalent resistance of the circuit and the current in each resistor. [CBSE Delhi 2011] [HOTS]



Ans. Given $R_1 = 4\Omega$, $R_2 = R_3 = 15\Omega$, $R_4 = 30\Omega$, $E = 10$ V.

Equivalent Resistance:

R_2, R_3 and R_4 are in parallel, so their effective resistance (R) is given by

$$\frac{1}{R} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{15} + \frac{1}{15} + \frac{1}{30}$$

$\Rightarrow$ $R = 6\Omega$

R1 is in series with R, so equivalent resistance

$R_{eq} = R + R_1 = 6 + 4 = 10\ \Omega$.

Currents:

$$I_1 = \frac{E}{R_{eq}} = \frac{10}{10} = 1\ \text{A} \qquad ...(i)$$

This current is divided at A into three parts I2, I3 and I4.

$\therefore$ $I_2 + I_3 + I_4 = 1$ A ....(ii)

Also, $I_2 R_2 = I_3 R3 = I4R4$

$\Rightarrow$ $I_2 \times 1_5 = I_3 \times 1_5 = I_4 \times 30$

$\Rightarrow$ $I_2 = I_3 = 2I_4$ ...(iii)

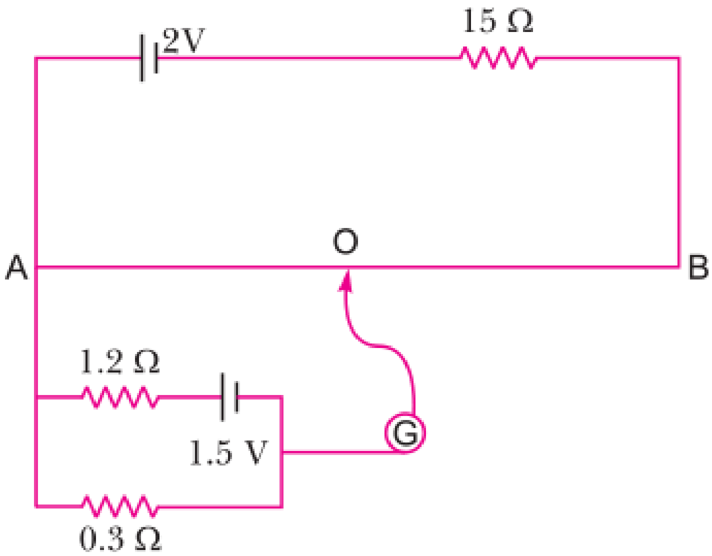
Substituting values of I2, I3 in (ii), we get

$2I_4 + 2I_4 + I_4 = 1$ A $\Rightarrow$ I4 = 0.2 A

$\therefore$ $I_2 = I_3 = 2 \times 0.2 = 0.4$ A

Thus, $I_1 = 1$A, $I_2 = I_3 = 0.4$A and $I_4 = 0.2$A

Q. 21. In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10Ω. Calculate the potential gradient along the wire and balance length AO.
[CBSE Delhi 2016] [HOTS]



Ans. Current flowing in the potentiometer wire

$$I = \frac{E}{R_{\text{total}}} = \frac{2.0}{15+10} = \frac{2}{25} A$$

Potential difference across the wire $\frac{2}{25} \times 10 = \frac{20}{25} = 0.8V$

Potential gradient $k = \frac{V_{\text{AB}}}{l_{\text{AB}}} = \frac{0.8}{1.0} = 0.8V/m$

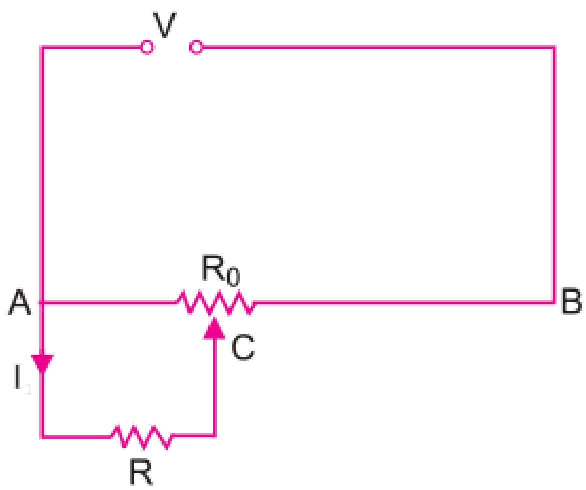
Now, current flowing in the circuit containing experimental cell,

$$\frac{1.5}{1.2+0.3} = 1\ A$$

Potential difference across length $AO = 0.3 \times 1 = 0.3$ V

Length AO $= \frac{0.3}{0.8}m = \frac{0.3}{0.8} \times 100$ cm $= 37.5$ cm

Q. 22. A resistance of R draws current from a potentiometer. The potentiometer wire, AB, has a total resistance of R0. A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of potentiometer wire. [CBSE Delhi 2017]



Ans. Effective resistance between points A and C is given by

$$\frac{1}{R_1} = \frac{1}{R} + \frac{1}{\frac{R_0}{2}} = \frac{\frac{R_0}{2} + R}{R.\frac{R_0}{2}}$$

$$R_1 = \frac{R\frac{R_0}{2}}{\frac{R_0}{2} + R}$$

Effective resistance between points A and B is given by

$$R_2 = \left(\frac{R\frac{R_0}{2}}{\frac{R_0}{2}+R}\right) + \frac{R_0}{2}$$

Current drawn from the voltage source, $I = \frac{V}{R_2}$

$$I = \frac{V}{\left(\frac{R\frac{R_0}{2}}{R+\frac{R_0}{2}}\right)+\frac{R_0}{2}} = \frac{V}{R\frac{R_0}{2R+R_0}+\frac{R_0}{2}}$$

Let current through R be I_1

$$I_1 = \frac{I\left(\frac{R_0}{2}\right)}{R+\frac{R_0}{2}}$$

Voltage across R is given by $V_1 = I_1 R$

$$= \frac{IR_0}{2\left(R+\frac{R_0}{2}\right)} . R$$

$$= \frac{R\ R_0}{2\left(R+\frac{R_0}{2}\right)} \cdot \frac{V}{\left(\frac{R\ R_0}{2R\ +\ R_0}\right)+\frac{R_0}{2}}$$

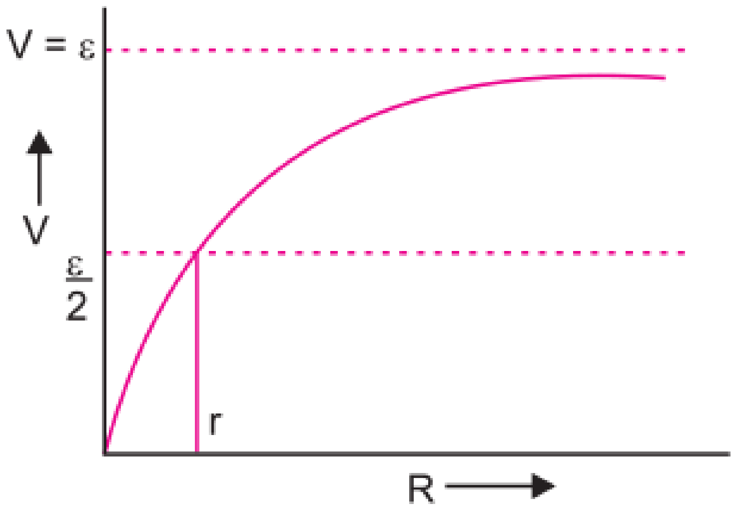
$$= \frac{R\ R_0}{2\left(\frac{2R\ +R_0}{2}\right)} \times \frac{V}{\frac{2R\ R_0+R_0(2R\ +\ R_0)}{2(2R\ +R_0)}}$$

$$= \frac{R\ R_0}{2R\ +\ R_0} \times \frac{2V(2R+R_0)}{R_0(2R\ +\ 2R\ +R_0)} = \frac{2\,\mathrm{RV}}{R_0+4R}$$

Q. 23. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the

current I.
[CBSE Delhi 2015] [HOTS]

Ans.



(i) Current in circuit $I=\frac{\varepsilon}{R+r}$

Terminal potential difference

$$V = \text{IR} = \left(\frac{\varepsilon}{R+r}\right)R$$

$$=\frac{\varepsilon}{(R+r)/R} = \frac{\varepsilon}{1+\frac{r}{R}}$$

When R increases r/R decreases, so terminal potential difference increases with the increase of R.

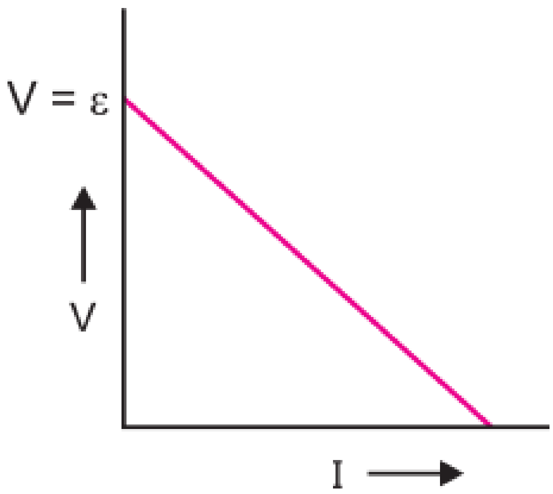
When $R = 0,\ V \longrightarrow 0$

When $R = r,\ V = \frac{\varepsilon}{2}$

When $R \longrightarrow \infty$ (open circuit), $V = \varepsilon$

The graph of terminal potential difference V versus R is shown in figure.

(ii) $V = E - Ir \qquad \Rightarrow \quad I = \frac{E-V}{r}$



Short Answer Questions – II (OIQ)

Q. 1. Define resistivity of a conductor. Plot a graph showing the variation of resistivity with temperature for a metallic conductor. How does one explain such a behaviour, using the mathematical expression of the resistivity of a material?

Ans.

We know that, $R = \rho \frac{l}{A}$

If $l = 1, A = 1 \Rightarrow \rho = R$

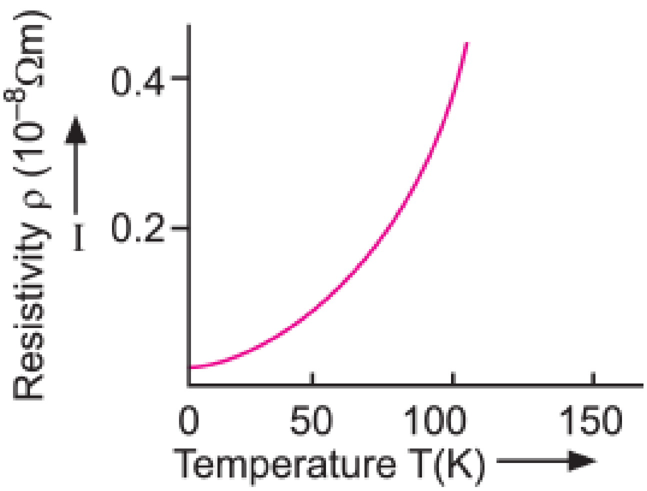
Thus, resistivity of a material is numerically equal to the resistance of the conductor having unit length and unit cross-sectional area.

The resistivity of a material is found to be dependent on the temperature. Different materials do not exhibit the same dependence on temperature. Over a limited range of temperatures, that is not too large, the resistivity of a metallic conductor is approximately given by,

$$\rho_T = \rho_0[1 + \alpha(T - T_0)] \qquad \ldots(i)$$

Where ρ_T is the resistivity at a temperature T and ρ_0 is the same at a reference temperature T0, α is called the temperature co-efficient of resistivity.

Relation (i) implies that a graph of ρ_T plotted against T would be a straight line. At temperatures much lower than 0°C, the graph, however, deviates considerably from a straight line (Fig.).



Resistivity ρ_T of metallic conductor as a function of temperature T

Q. 2. Write the mathematical relation for the resistivity of a material in terms of relaxation time, number density, mass and charge of charge carriers in it. Explain using this relation, why the resistivity of a metal increases and that of a semiconductor decreases with rise in temperature.

Ans. Resistivity of a material, $\rho = \frac{m}{ne^2 \tau}$

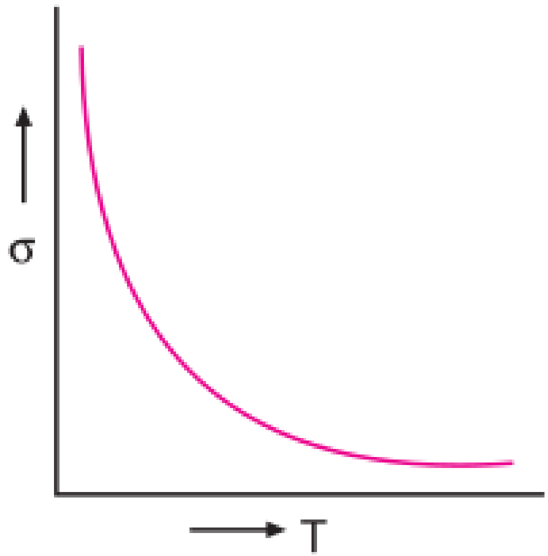
Where m is mass, e is charge on charge carrier, n is number density and τ is relaxation time.

For a metallic conductor: When temperature of a metal increases, the number of collisions of electrons with ion-lattice increases, so relaxation time decreases, as resistivity $\rho \propto \frac{1}{\tau}$, so resistivity of material increases with rise of temperature.

For a semiconductor: When temperature increases, the covalent bonds between valence electrons of atoms of semiconductor break, so more charge carriers (electrons and holes) becomes free. In other words the number density of charge carriers increases $\rho \propto \frac{1}{n}$, so resistivity of semiconductor decreases with the rise of temperature.

Q. 3. Explain the variation of conductivity with temperature for (i) a metallic conductor, (ii) ionic conductors and (iii) semiconductors.

Ans. Conductivity of a metallic conductor σ = $\frac{1}{\rho} = \frac{ne^2 \tau}{m}$.



Where m = mass of charge carrier, e = charge on each carrier

τ = relaxation time, n = number density of charge carriers

(i) With rise of temperature, the collision of electrons with fixed lattice ions/atoms increases so that relaxation time (τ) decreases. Consequently, the conductivity of metals decreases with rise of temperature.

(ii) Conductivity of ionic conductor increases with increase of temperature because with increase of temperature, the ionic bonds break releasing positive and negative ions which are charge carriers in ionic conductors.

(iii) In the case of a semiconductors, when temperature increases, covalent bonds break and charge carriers (electrons and holes) become free i.e., n increases, so conductivity increases with rise of temperature.

Q. 4. Two heater coils made of same material are connected in parallel across the mains. The length and diameter of the wire of one of coils are double that of the other. Which one of them will produce more heat?

Ans. We have resistance of one wire

$$R_1 = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2} = \frac{4\ \rho l}{\pi D^2}$$

Where l is length and D is diameter of the wire. The resistance of second wire of double the length and double the diameter is,

$$R_2 = \frac{4\rho\,(2l)}{\pi\,(2D)^2} = \frac{4\rho\, l}{\pi\, D^2}.\frac{1}{2},\ i.e.,\ R_2 = \frac{R_1}{2}$$

Heat produced per second

$$H = \frac{V^2}{R} \propto \frac{1}{R}$$

As second coil has resistance equal to half of first coil, therefore **heat produced in second coil is double than that in first coil.**

Q. 5. Two heaters are marked 200 V, 300 W and 200 V, 600 W. If the heaters are connected in series and the combination connected to a 200 V dc supply, which heater will produce more heat?

Ans.

Resistance of heaters $R_1 = \frac{V^2}{P_1} = \frac{(200)^2}{300} = \frac{400}{3}\Omega$

$$R_2 = \frac{V^2}{P_2} = \frac{(200)^2}{600} = \frac{400}{6}\Omega$$

When heaters are connected in series, current in circuit,

$$I = \frac{V}{R_1+R_2} = \frac{200}{\frac{400}{3}+\frac{400}{6}} = 1\ A$$

Heat produced in 200 V, 300 W heater per second

$$Q_1 = I^2R_1 = (1)^2 \times \frac{400}{3} = 133.33\ \text{Js}^{-1}$$

Heat produced in 200 V, 600 W heater per second

$$Q_2 = I^2R_2 = (1)^2 \times \frac{400}{6} = 66.66\ \text{Js}^{-1}$$

Clearly heat produced in 300 W heater is more that produced in 600 W heater.

Q. 6. Two cells of emf 1 V, 2 V and internal resistances 2Ω and 1Ω respectively are connected in (i) series. (ii) Parallel. What should be the external resistance in the circuit so that the current through the resistance be the same in the two cases? In which case is more heat generated in the cells?

Ans. For parallel combination,

$$\text{Net emf, } \varepsilon = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_2}{r_1 + r_2}$$

$$\text{Net internal resistance, } r_{\text{int}} = \frac{r_1 r_2}{r_1 + r_2}$$

For series combination,

Net emf, $\varepsilon = \varepsilon_1 + \varepsilon_2$

Net internal resistance $r_{int} = r_1 + r_2$

Given, $\varepsilon_1 = 1$ V, $\varepsilon_2 = 2$ V, and $r_1 = 2\ \Omega$, $r_2 = 1\ \Omega$, $R_{ext} = R$

$$\therefore \quad \text{Current, } I_1 = \frac{\varepsilon_1 + \varepsilon_2}{r_1 + r_2 + R} = \frac{1+2}{2+1+R} = \frac{3}{3+R}\ A \quad \ldots(i)$$

$$\text{Current, } \quad I_2 = \frac{(\varepsilon_1 r_2 + \varepsilon_2 r_1)/(r_1 + r_2)}{R + \{(r_1 r_2/(r_1 + r_2)\}} \ldots(ii)$$

$$= \frac{(1\times1+2\times2)/(2+1)}{R+(2\times1)/(2+1)} = \frac{5/3}{R+\frac{2}{3}} = \frac{5}{3R+2}$$

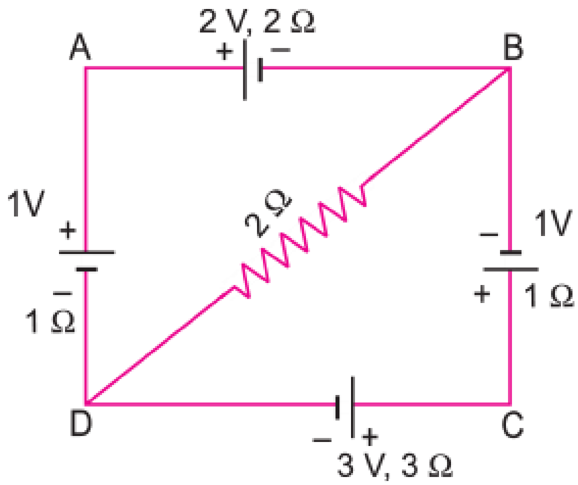
$$\text{Given } I_1 = I_2$$

$$\therefore \quad \frac{3}{3+R} = \frac{5}{3R+2} \text{ or } 9R + 6 = 15 + 5\ R$$

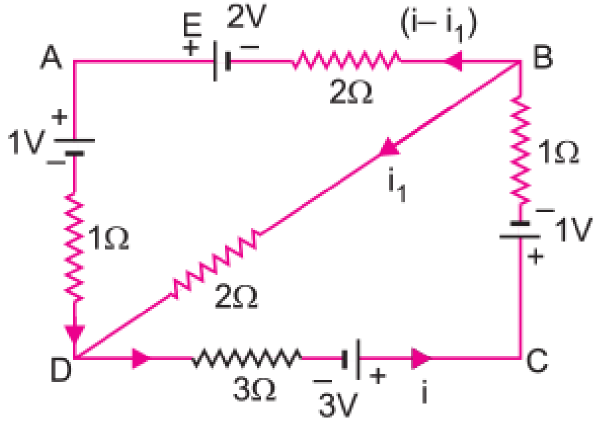
$$4R = 9 \qquad \Rightarrow R = \frac{9}{4} = 2.25\ \Omega$$

Heat generated in external resistance (I^2R) is same in both cases but heat generated in cells ($I^2\ r_{int}$) is more in series than that in parallel combination of cells.

Q. 7. For the circuit shown here, calculate the potential difference between points B and D.



Ans. According to Kirchhoff's first law the distribution of currents is shown in fig.



Applying Kirchhoff's second law to mesh BADB,

$$-2(i - i_1) + 2 - 1 - 1.\ (i - i_1) + 2i_1 = 0$$

$\Rightarrow$ $3i - 5i1 = 1$ …(i)

Applying Kirchhoff's law to mesh DCBD,

$$-3i + 3 - 1 - 1\times i - 2i_1 = 0$$

$\Rightarrow$ $4i + 2i_1 = 2$

Or $2i + i_1 = 1$ …(ii)

Multiplying equation (ii) with 5, we get

$10i + 5i1 = 5$ …(iii)

Adding (i) and (iii), we get

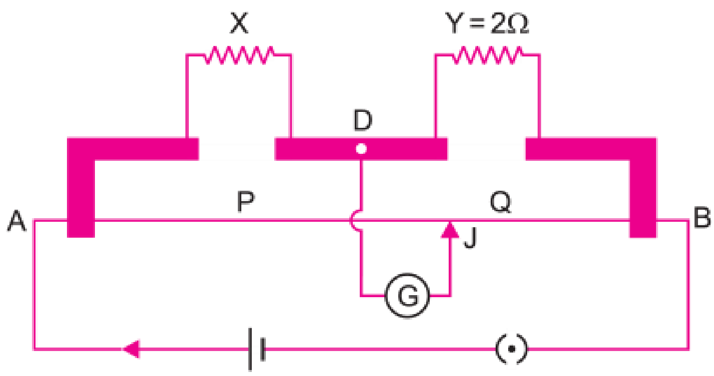
$$13i = 6 \Rightarrow \quad i = \frac{6}{13} A$$

From (ii), $i_1 = 1 - 2i = 1 - \frac{12}{13} = \frac{1}{13} A$

Potential difference between B and D is

$$V_B - V_D = i_1 \times 2 = \frac{2}{13} V$$

Q. 8. In a practical Wheatstone bridge circuit, wire AB is 2 m long. When resistance Y = 2.0W and jockey is in position J such that AJ = 1.20 m, there is no current in galvanometer, find the value of unknown resistance X. The resistance per unit length of wire AB = 0.01 W/cm. Also calculate the current drawn by the cell of emf 4.0 V and negligible internal resistance.



Ans. P = Resistance of wire AJ

= (1.20 × 100 cm) × (0.01Ω/cm) = 1.20 Ω

Q = Resistance of wire BJ

= [(2–1.20) m×100] ×resistance per cm

= 0.80 × 100 cm × 0.01 Ω = 0.80Ω

Y = 2.0 Ω, X=?

When no current flows through the galvanometer, the bridge is balanced so

$$\frac{P}{Q} = \frac{X}{Y} \Rightarrow X = \frac{P}{Q} Y \quad \text{or} \quad X = \frac{1.20}{0.80} \times 2.0 = 3.0 \ \Omega$$

Total resistance of X and Y connected in series

$R_1 = X + Y = 3.0 + 2.0 = 5.0\ \Omega$

Total resistance of P and Q connected in series (or wire AB)

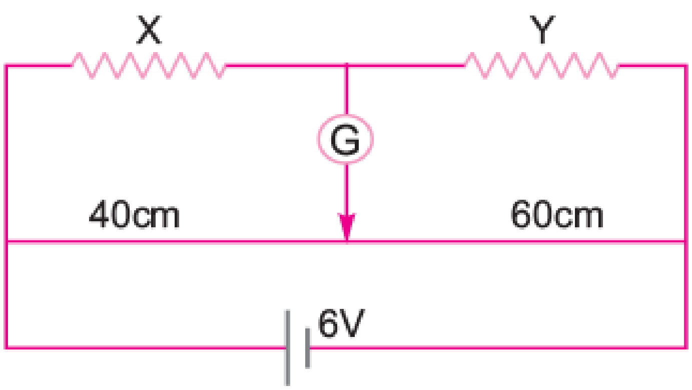
$R_2 = 2 \times 100 \times 0.01 = 2.0\Omega$

The resistance R_1 and R_2 are in parallel, so effective resistance between terminals A and B of bridge is

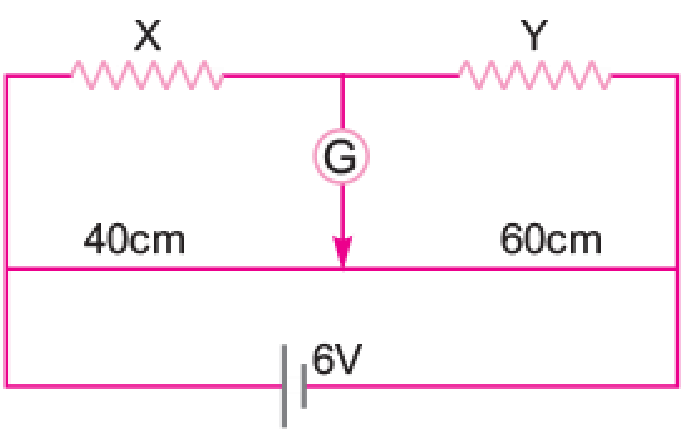
$$R_{AB} = \frac{R_1\, R_2}{R_1 + R_2} = \frac{5.0 \times 2.0}{5.0 + 2.0} = \frac{10}{7}\ \Omega$$

$$\text{Current drawn from battery } I = \frac{\varepsilon}{R_{AB}} = \frac{4.0}{10/7} = 2.8\text{A}$$

Q. 9. In the given circuit, a metre bridge is shown in the balanced state. The metre bridge wire has a resistance of 1 Ω cm^{-1}. Calculate the unknown resistance X and the current drawn from the battery of a negligible internal resistance if the magnitude of Y is 6Ω. If at the balancing point, we interchange the position of galvanometer and the cell, how it will affect the position of the galvanometer?



Ans. At balanced state



$$\frac{X}{Y} = \frac{40}{60} = \frac{2}{3} \Rightarrow \quad X = \frac{2}{3}Y = \frac{2}{3}?6$$

$\therefore \qquad X = 4\Omega$

4Ω and 6Ω are in series, the equivalent resistance is given by

R_{eq} = 4Ω + 6Ω = 10Ω

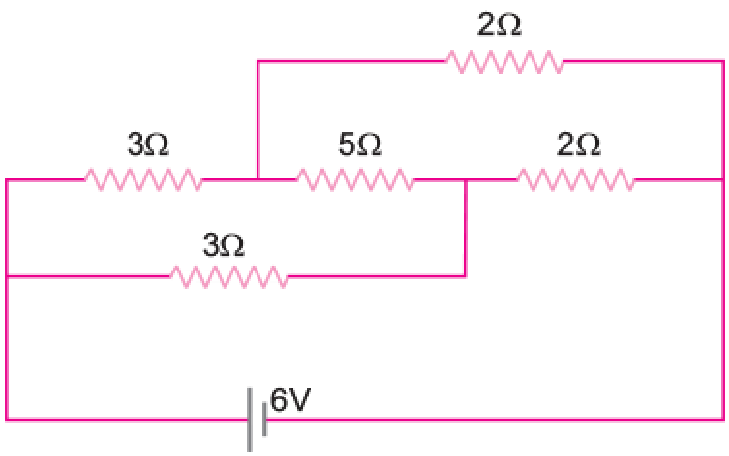
4Ω and 6Ω are in series R_{eq} = 10Ω

Resistance of bridge wire = 1 ohm/cm × 100 cm = 100Ω

10Ω and 100Ω are in parallel, = 1000/110Ω = 9.09Ω, Current = $\frac{6}{9.09}$

There will be no change in the balancing length if we interchange position of galvanometer and cell.

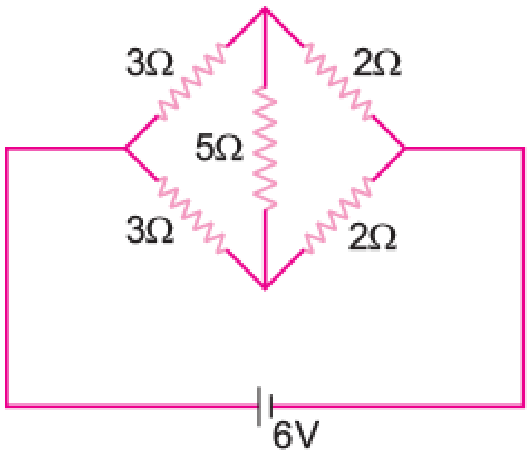
Q. 10. Calculate the current drawn from the battery in the given network shown here. State Kirchhoff's loop law and name the law on which it is based.



Ans. The equivalent circuit is as shown in figure alongside.

[∴ Bridge is in balanced condition, no current flows through 5Ω resistance]

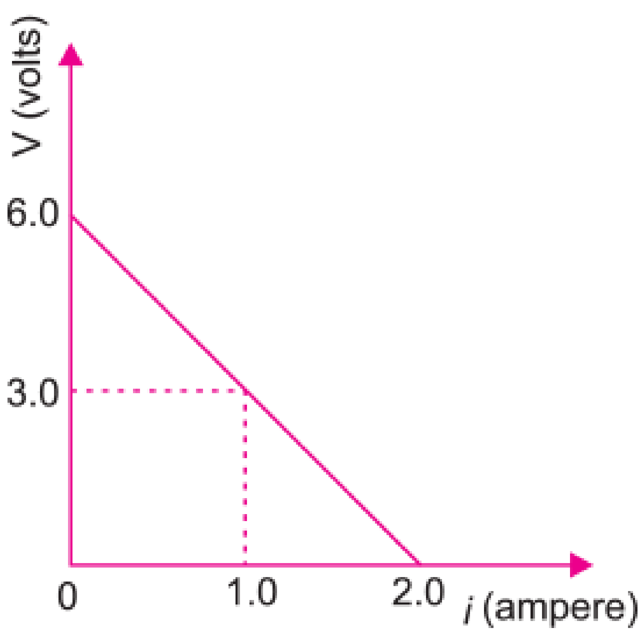
$\frac{1}{R} = \frac{1}{5} + \frac{1}{5}$ R = 5Ω



$$\text{Current in the circuit} = \frac{6}{2.5}A = 2.4A$$

Kirchhoff's Loop Law: The algebraic sum of potential differences of different circuit elements of a closed circuit (or mesh) is zero. This law is based on law of conservation of energy.

Q. 11. The graph shown here shows the variation of terminal potential difference V, across a combination of three cells in series to a resistor, versus current i: [HOTS]



(i) Calculate the emf of each cell.

(ii) For what current i, will the power dissipation of the circuit be maximum?

Ans. (i) Let ε be emf and r the internal resistance of each cell. The equation of terminal potential difference

$V = \varepsilon_{eff} - i\, r_{int}$ becomes

$V = 3\varepsilon - i\, r_{int}$ ...(i)

Where r_{int} is effective (total) internal resistance.

From fig., when $i = 0$, $V = 6.0$ V

$$\therefore \quad \text{From } (i),\ 6 = 3\varepsilon - 0 \quad \Rightarrow \quad \varepsilon = \frac{6}{3} = 2 \text{ V}$$

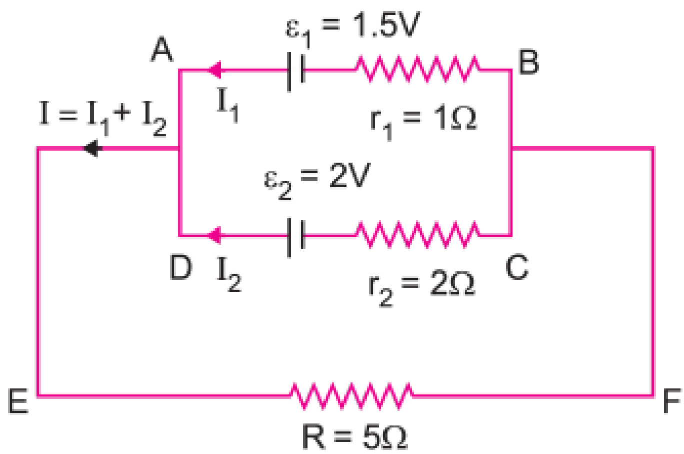
i.e., emf of each cell, $\varepsilon = 2$ V

Thus, emf of each cell, $\varepsilon = 2$V

Q. 12. Two cells of emf 1.5 V and 2 V and internal resistance 1Ω and 2Ω respectively are connected in parallel to pass a current in the same direction through an external resistance of 5Ω.

(i) Draw the circuit diagram.

(ii) Using Kirchhoff's laws, calculate the current through each branch of the circuit and potential difference across 5Ω resistor.



Ans. (i) The circuit is shown in figure.

(ii) Suppose I_1 are I_2 current drawn from cells ε1 and ε2 respectively, then according to Kirchhoff's junction law, current in R = 5Ω $I = I_1 + I_2$.

Applying Kirchhoff's second law to mesh ABFEA

$$1 \times I_1 + 1.5 - 5(I_1 + I_2) = 0$$

$\Rightarrow \quad 6I_1 + 5I_2 = 1.5$ ...(i)

Applying Kirchhoff's second law to mesh CDEFC

$$-2I_2 + 2 - 5(I_1 + I_2) = 0$$

⇒ $5I_1 + 7I_2 = 2$ …(ii)

Solving equation (i) and (ii), we get

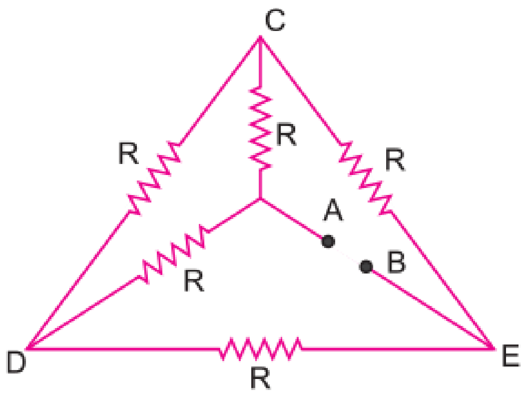
$$I_1 = \frac{1}{34} A,\ I_2 = \frac{9}{34} A$$

$$I = I_1 + I_2 = \frac{1}{34} + \frac{9}{34} = \frac{10}{34} A$$

Potential difference across R=5Ω resistor

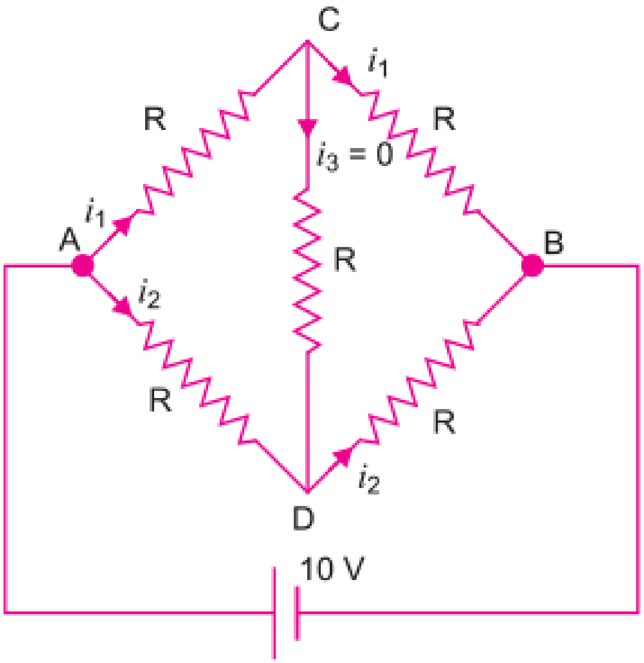
$$(I_1 + I_2)\,R = \frac{10}{34} \times 5 = \frac{25}{17} \text{ volt}$$

Q. 13. (i) Calculate the equivalent resistance of the given electrical network between points A and B.



(ii) Also calculate the current through CD and ACB if a 10 V dc source is connected between points A and B and the value of R = 2Ω.

Ans.



(i) The equivalent circuit is shown in fig. It is a balanced Wheatstone bridge. So, the resistance connected between C and D is ineffective.

Resistance of arm ACB, $R_1 = R + R = 2R$

Resistance of arm ADB, $R_2 = R + R = 2R$

Equivalent resistance between A and B, R_{AB} is given by

$$\frac{1}{R_{\mathrm{AB}}} = \frac{1}{2R} + \frac{1}{2R} = \frac{2}{2R}$$

⇒ $R_{AB} = R = 2\Omega$

(ii) In arm CD, there is no current, $I_{CD} = 0$,

Current through arm ACB

$$i_1 = \frac{V}{R_1}$$

$$= \frac{10}{2R} = \frac{10}{2\times2} = \frac{10}{4} = 2.5A$$

Long Answer Questions

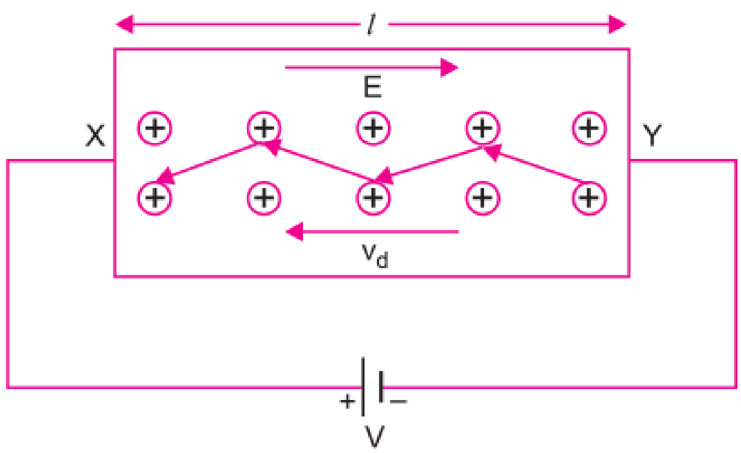
Q. 1. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time of electrons. [CBSE Delhi 2009]

OR

Explain how the average velocity of free electrons in a metal at constant temperature, in an electric field, remains constant even though the electrons are being constantly accelerated by this electric field.

Ans. Consider a metallic conductor XY of length l and cross-sectional area A. A potential difference V is applied across the conductor XY. Due to this potential difference an electric field $\vec{E}$ is produced in the conductor. The magnitude of electric field strength $E = \frac{V}{l}$ and its direction is from Y to X.

This electric field exerts a force on free electrons; due to which electrons are accelerated.



The electric force on electron $\vec{F} = -e\vec{E}$ (where e = +1.6 × 10^{-10} coulomb).

If is the mass of electron, then its acceleration

$$\vec{a} = \frac{\vec{F}}{m} = -\frac{e\vec{E}}{m} \qquad \ldots(i)$$

This acceleration remains constant only for a very short duration, since there are random forces which deflect the electron in random manner. These deflections may arise as

(i) Ions of metallic crystal vibrate simple harmonically around their mean positions. Different ions vibrate in different directions and may be displaced by different amounts.

(ii) Direct collisions of electrons with atoms of metallic crystal lattice.

In any way after a short duration called relaxation time, the motion of electrons become random. Thus, we can imagine that the electrons are accelerated only for a short duration. As average velocity of random motion is zero, if we consider the average motion of an electron, then its initial velocity is zero, so the velocity of electron after time τ (i.e., drift velocity $\underset{V}{\rightarrow}$ d) is given by the relation $\underset{V}{\rightarrow} = \underset{U}{\rightarrow} + \underset{at}{\longrightarrow}$

$$\left(\text{here } \vec{u} = 0,\ v = \vec{v}_d, t = \tau,\ \vec{a} = -\frac{e\vec{E}}{m}\right)$$

$$\vec{v}_d = 0 - \frac{e\vec{E}}{m}\tau \quad \Rightarrow \quad \vec{v}_d = -\frac{e\tau}{m}\vec{E}$$

At given temperature, the relaxation time τ remains constant, so drift velocity remains constant.

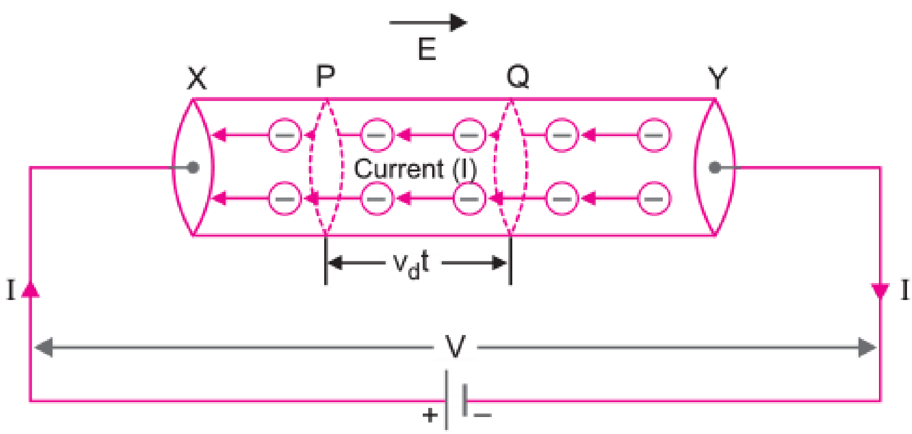
Q. 2. Establish a relation between electric current and drift velocity.
[CBSE (AI) 2013]

OR

Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

Ans. Relation between electric current and drift velocity:

Consider a uniform metallic wire XY of length l and cross-sectional area A. A potential difference V is applied across the ends X and Y of the wire. This causes an electric field at each point of the wire of strength



$$E = \frac{V}{l}. \qquad \dots(i)$$

Due to this electric field, the electrons gain a drift velocity v_d opposite to direction of electric field. If q be the charge passing through the cross-section of wire in t seconds, then

Current in wire $I = \frac{q}{t}$ ...(ii)

The distance traversed by each electron in time t = average velocity × time = v_d t

If we consider two planes P and Q at a distance v_d t in a conductor, then the total charge flowing in time t will be equal to the total charge on the electrons present within the cylinder PQ.

The volume of this cylinder = cross sectional area × height

= A v_d t

If n is the number of free electrons in the wire per unit volume, then the number of free electrons in the cylinder = n (Av_d t)

If charge on each electron is – e (e = 1.6 ×10^{-19}C), then the total charge flowing through a cross-section of the wire

q = (nA_vd t) (– e) =–neA_vd t ..(iii)

∴ Current flowing in the wire,

$$I = \frac{q}{t} = \frac{-v}{t}$$

i.e., current I = – neA_vd ...(iv)

This is the relation between electric current and drift velocity. Negative sign shows that the direction of current is opposite to the drift velocity.

Numerically I = – neA_vd ...(v)

∴ Current density, $J = \frac{I}{A} = d$

⇒ J ∝ vd.

That is, current density of a metallic conductor is directly proportional to the drift velocity.

Q. 3. Deduce Ohm's law using the concept of drift velocity.

OR

Define the term 'drift velocity' of charge carriers in a conductor. Obtain the expression for the current density in terms of relaxation time. [CBSE (F) 2014]

OR

Define relaxation time of the free electrons drifting in a conductor. How is it related to the drift velocity of free electrons? Use this relation to deduce the expression for the electrical resistivity of the material. [CBSE (AI) 2012]

OR

(i) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend?

(ii) Why alloys like constantan and manganin are used for making standard resistors? [CBSE Delhi 2016]

Ans. Relaxation time of free electrons drifting in a conductor is the average time elapsed between two successive collisions.

Deduction of Ohm's Law: Consider a conductor of length l and cross-sectional area A. When a potential difference V is applied across its ends, the current produced is I. If n is the number of electrons per unit volume in the conductor and vd the drift velocity of electrons, then the relation between current and drift velocity is

$$I = -neAv_d \qquad \ldots(i)$$

Where – e is the charge on electron ($e = 1.6 \times 10^{-19}$ C)

Electric field produced at each point of wire, $E = \frac{V}{l}$ (ii)

If τ is relaxation time and E is electric field strength, then drift velocity

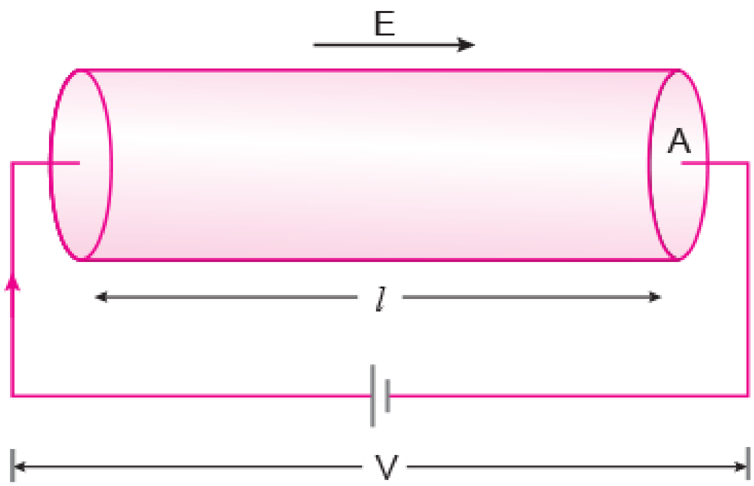
$$v_d = -\frac{e\tau E}{m} \qquad \text{(iii)}$$

Substituting this value in (i), we get

$$I = -neA\left(-\frac{e\tau}{m}E\right) \quad \text{or} \quad I = -\frac{ne^2\tau}{m}AE \qquad \ldots(iv)$$

As $E = \frac{V}{l}$ [From (ii)]

$$I = \frac{ne^2 tA}{m}\frac{V}{l} \quad \text{or} \quad \frac{V}{I} = \frac{m}{ne^2 t}\cdot\frac{l}{A} \qquad \ldots(v)$$



Current density $J\left(=\frac{I}{A}\right) = \frac{\mathrm{ne}^2\,\tau}{\mathrm{ml}}V.$

This is relation between current density J and applied potential difference V.

Under given physical conditions (temperature, pressure) for a given conductor

$$\frac{m}{\mathrm{ne}^2\,\tau}\cdot\frac{l}{A} = \text{Constant}$$

∴ This constant is called the resistance of the conductor (i.e. R).

i.e. $$R = \frac{m}{ne^2\tau}\cdot\frac{l}{A}$$ (iv)

From (v) and (vi); $\frac{V}{I} = R$

(vii)

This is Ohm's law. From equation (vi) it is clear that the resistance of a wire depends on its length (l), cross-sectional area (A), number of electrons per m^3 (n) and the relaxation time (τ)

Expression for resistivity:

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

$(viii)$

Comparing (vi) and (viii), we get

Resistivity of a conductor $$\rho = \frac{m}{ne^2\tau}$$ ……(ix)

Clearly, resistivity of a conductor is inversely proportional to number density of electrons and relaxation time.

Resistivity of the material of a conductor depends upon the relaxation time, i.e., temperature and the number density of electrons.

This is because constantan and manganin show very weak dependence of resistivity on temperature.

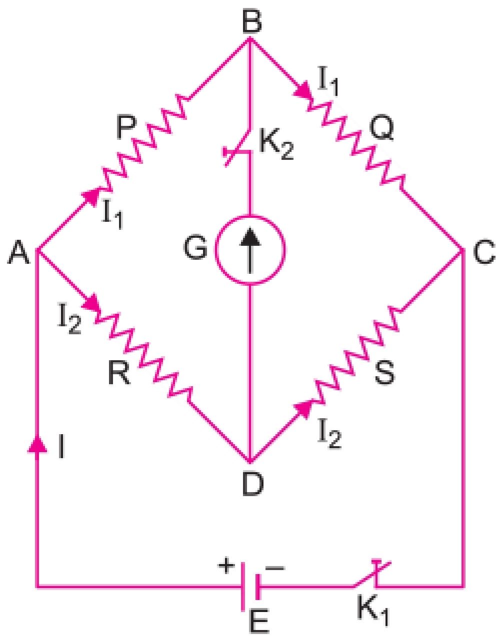
Q. 4. Derive condition of balance of a Wheatstone bridge.

OR

Draw a circuit diagram showing balancing of Wheatstone bridge. Use Kirchhoff's rules to obtain the balance condition in terms of the resistances of four arms of wheat stone Bridge. [CBSE Delhi 2013, 2015]

Ans. Condition of balance of a Wheatstone bridge:

The circuit diagram of Wheatstone bridge is shown in fig.



P, Q, R and S are four resistance forming a closed bridge, called Wheatstone bridge. A battery is connected across A and C, while a galvanometer is connected between B and D. When the bridge is balanced, there is no current in galvanometer.

Derivation of Formula: Let the current flowing in the circuit in the balanced condition be I. This current on reaching point A is divided into two parts I_1 and I_2. As there is no current in galvanometer in balanced condition, current in resistances P and Q is I_1 and in resistances R and S it is I_2.

Applying Kirchhoff's I law at point A

$$I - I_1 - I_2 = 0 \quad \text{or} \quad I = I_1 + I_2 \qquad ...(i)$$

Applying Kirchhoff's II law to closed mesh ABDA

$$-I_1 P + I_2 R = 0 \quad \text{or} \quad I_1 P = I_2 R \qquad ...(ii)$$

Or

Applying Kirchhoff's II law to mesh BCDB

$$-I_1 Q + I_2 S = 0 \quad \text{or} \quad I_1 Q = I_2 S \qquad ...(iii)$$

Dividing equation (ii) by (iii), we get

$$\frac{I_1 P}{I_1 Q} = \frac{I_2 R}{I_2 S} \quad \text{or} \quad \frac{P}{Q} = \frac{R}{S} \qquad ...(iv)$$

This is the **condition of balance of Wheatstone bridge.**

Q. 5. Using the principle of Wheatstone Bridge, describe the method to determine the specific resistance of a wire in the laboratory. Draw the circuit diagram and write the formula used.

Write any two important precautions you would observe while performing the experiment.

OR

Draw a circuit diagram of a Metre Bridge and write the mathematical relation used to determine the value of an unknown resistance. Why cannot such an arrangement be used for measuring very low resistance? [CBSE East 2016]

OR

(a) State, with the help of a suitable diagram, the principle on which the working of a meter bridge is based.

(b) Answer the following:

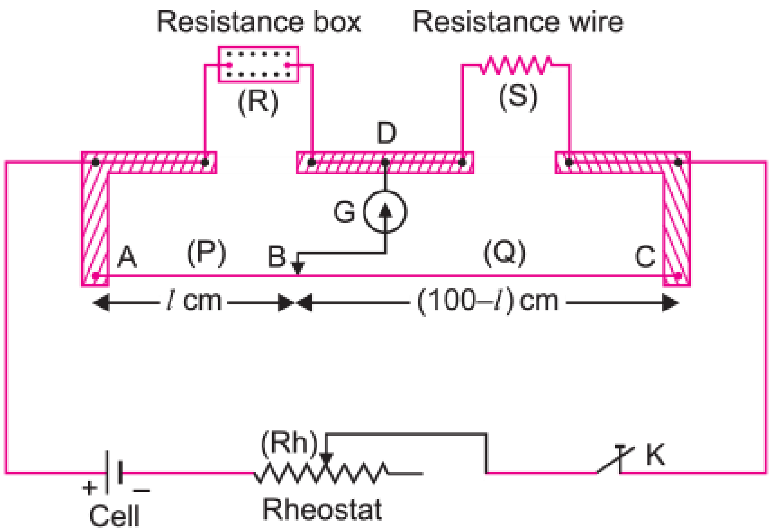
(i) Why are the connections between resistors in a meter bridge made of thick copper strips?

(ii) Why is it generally preferred to obtain the balance point near the middle of the bridge wire in meter bridge experiments? [CBSE (F) 2013]

Ans. Metre Bridge: Special Case of Wheatstone Bridge

It is a practical device based on the principle of Wheatstone bridge to determine the unknown resistance of a wire.

If ratio of arms resistors in Wheatstone bridge is constant, then no current flows through the galvanometer (or bridge wire).



Construction: It consists of a uniform 1 metre long wire AC of constantan or manganin fixed along a scale on a wooden base (fig.) The ends A and C of wire are joined to two L-shaped copper strips carrying connecting screws as shown. In between these copper strips, there is a third straight copper strip having three connecting screws. The middle screw D is connected to a sensitive galvanometer. The other terminal of galvanometer is connected to a sliding jockey B. The jockey can be made to move anywhere parallel to wire AC.

Circuit: To find the unknown resistance S, the circuit is complete as shown in fig. The unknown resistance wire of resistance S is connected across the gap between points C and D and a resistance box is connected across the gap between the points A and D. A cell, a rheostat and a key (K) is connected between the points A and C by means of connecting screws. In the experiment when the sliding jockey touches the wire AC at any point, then the wire is divided into two parts. These two parts AB and BC act as the resistances P and Q of the Wheatstone bridge. In this way the resistances of arms AB, BC, AD and DC form the resistances P, Q, R and S of Wheatstone bridge. Thus the circuit of metre bridge is the same as that of Wheatstone bridge.

Method: To determine the unknown resistance, first of all key K is closed and a resistance R is taken out from resistance box in such a way that on pressing jockey B at end points A and C, the deflection in galvanometer is on both the sides. Now jockey is slided on wire at such a position that on pressing the jockey on the wire at that point, there is no deflection in the galvanometer G. In this position, the points B and D are at the same potential; therefore the bridge is balanced. The point B is called the null point. The length of both parts AB and BC of the wire are read on the scale. The condition of balance of Wheatstone bridge is

$$\frac{P}{Q} = \frac{R}{S}$$

$\Rightarrow$ Unknown resistance,

$$S = \left(\frac{Q}{P}\right) R$$

$\ldots(i)$

To Determine Specific Resistance:

If r is the resistance per cm length of wire AC and l cm is the length of wire AB, then length of wire BC will be (100 – l) cm

∴ P = resistance of wire AB = lr

Q = resistance of wire BC = (100 – l)r

Substituting these values in equation (i), we get

$$S = \frac{(100-l)\,r}{l\,r} \times R \quad \text{or} \quad S = \frac{100-l}{l} R$$

$\ldots(ii)$

As the resistance (R) of wire (AB) is known, the resistance S may be calculated.

A number of observations are taken for different resistances taken in resistance box and S is calculated each time and the mean value of S is found.

$$\text{Specific resistance } \rho = \frac{SA}{l} = \frac{S\pi r^2}{L}$$

Knowing resistance S, radius r by screw gauge and length of wire L by metre scale, the value of ρ may be calculated.

If a small resistance is to be measured, all other resistances used in the circuit, including the galvanometer, should be low to ensure sensitivity of the bridge. Also the resistance of thick copper strips and connecting wires (end resistences) become comparable to the resistance to be measured. This results in large error in measurement.

Precautions:

(i) In this experiment the resistances of the copper strips and connecting screws have not been taken into account. These resistances are called end-resistances. Therefore very small resistances cannot be found accurately by Metre Bridge. The resistance S should not be very small.

(ii) The current should not flow in the metre bridge wire for a long time, otherwise the wire will become hot and its resistance will be changed.

(iii) The resistivity of copper is several times less than the resistivity of the experimental alloy wire. As such area of thick copper strips is more, so copper strips almost offer zero resistance in the circuit.

(iv) If any one resistance in wheat stone bridge is either very small (or very large) in respect of other, then balance point might be very close to terminal A or terminal B. So generally balance point is taken in the middle of the bridge wire.

Q. 6. Answer the following questions:

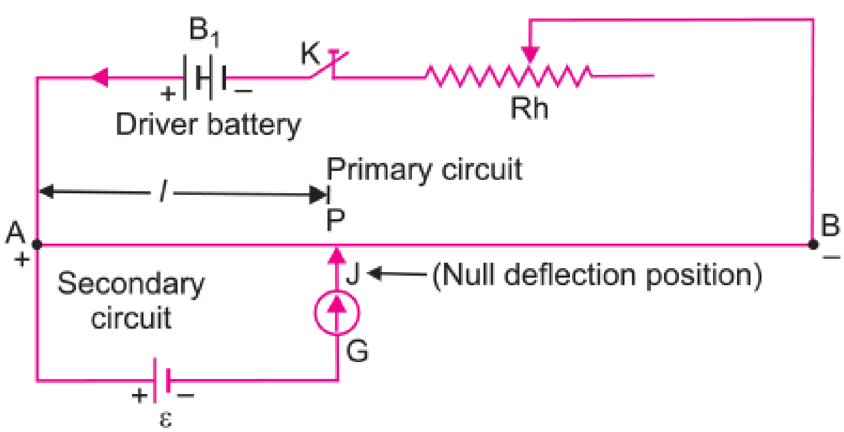
(i) State the principle of working a potentiometer. [CBSE Delhi 2010, 2016]

(ii) Draw a circuit diagram to compare the emf of two primary cells. Write the formula used. How can the sensitivity of a potentiometer be increased?

(iii) Write two possible causes for one sided deflection in the potentiometer experiment. [CBSE Delhi 2013]

Ans. (i) Principle of Potentiometer: When a constant current flows through a wire of uniform area of cross-section, the potential drop across any length of the wire is directly proportional to the length.

Circuit Diagram. It consists of a long resistance wire AB of uniform cross-section. Its one end A is connected to the positive terminal of battery B1 whose negative terminal is connected to the other end B of the wire through key K and a rheostat (Rh). The battery B1 connected in circuit is called the driver battery and this circuit is called the **primary circuit.** By the help of this circuit a definite potential difference is applied across the wire AB; the potential falls continuously along the wire from A to B. **The fall of potential per unit length of wire is called the potential gradient.** It is denoted by 'k'. A cell is connected such that its positive terminal is connected to end A and the negative terminal to a jockey J through the galvanometer G. This circuit is called the **secondary circuit.**



In primary circuit the rheostat (Rh) is so adjusted that the deflection in galvanometer is on one side when jockey is touched on wire at point A and on the other side when jockey is touched on wire at point B.

The jockey is moved and touched to the potentiometer wire and the position is found where galvanometer gives no deflection. Such a point P is called null deflection point.

VAB is the potential difference between points A and B and L metre be the length of wire, then the potential gradient

$$k = \frac{V_{AB}}{L}$$

If the length of wire AP in the null deflection position be l, then the potential difference between points A and P,

$$V_{AP} = kl$$

∴ The emf of cell, $\varepsilon = V_{AP} = kl$

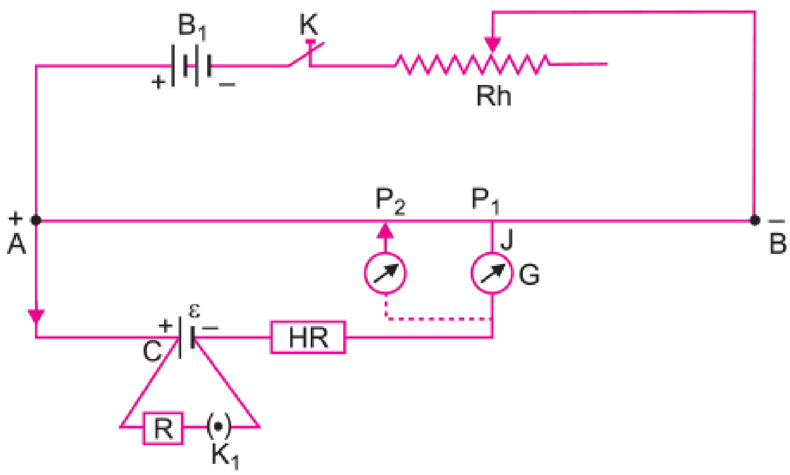
In this way the emf of a cell may be determined by a potentiometer.

Q. 7. Draw the circuit diagram of a potentiometer which can be used to determine the internal resistance (E) of a given cell of emf. Describe a method to find the internal resistance of a primary cell. [CBSE (AI) 2013; (F) 2011, 2016]

Ans. Determination of Internal Resistance of Potentiometer.

Circuit: A battery B_1 a rheostat (Rh) and a key K is connected across the ends A and B of the potentiometer wire such that positive terminal of battery is connected to point A. This completes the primary circuit.

Now the given cell C is connected such that its positive terminal is connected to A and negative terminal to jockey J through a galvanometer. A resistance box (R) and a key K_1 are connected across the cell. This completes the secondary circuit.



Method:

Initially key K is closed and a potential difference is applied across the wire AB. Now rheostat Rh is so adjusted that on touching the jockey J at ends A and B of potentiometer wire, the deflection in the galvanometer is on both sides. Suppose that in this position the potential gradient on the wire is k.

Now key K_1 is kept open and the position of null deflection is obtained by sliding and pressing the jockey on the wire. Let this position be P_1 and $AP_1 = l_1$

In this situation the cell is in open circuit, therefore the terminal potential difference will be equal to the emf of cell, i.e.,

$$\text{emf } \varepsilon = kl_1 \qquad \text{...(i)}$$

Now a suitable resistance R is taken in the resistance box and key K_1 is closed. Again, the position of null point is obtained on the wire by using jockey J. Let this position on wire be P_2 and $AP_2 = l_2$.

In this situation the cell is in closed circuit, therefore the terminal potential difference (V) of cell will be equal to the potential difference across external resistance R, i.e.,

$$V = kl_2 \qquad \text{...(ii)}$$

Dividing (i) by (ii), we get $\frac{\varepsilon}{V} = \frac{l_1}{l_2}$

$\therefore$ Internal resistance of cell, $r = \left(\frac{\varepsilon}{V} - 1\right) R = \left(\frac{l_1}{l_2} - 1\right) R$

From this formula r may be calculated.

Q. 8. Answer the following questions:

A cell of emf E and internal resistance r is connected to two external resistances R_1 and R_2 and a perfect ammeter. The current in the circuit is measured in four different situations:

(i) Without any external resistance in the circuit.

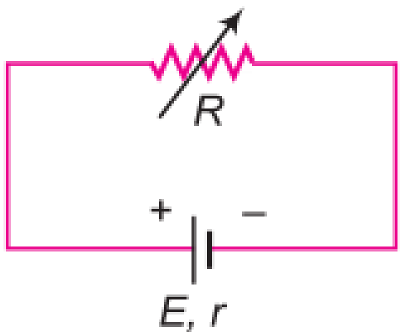
(ii) With resistance R_1 only

(iii) With R_1 and R_2 in series combination

(iv) With R_1 and R_2 in parallel combination.

The currents measured in the four cases are 0.42 A, 1.05 A, 1.4 A and 4.2 A, but not necessarily in that order. Identify the currents corresponding to the four cases mentioned above.

(ii) A variable resistor R is connected across a cell of emf E and internal resistance 'r' as shown in the figure.

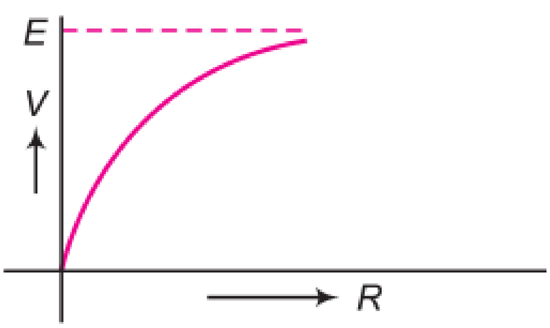


Plot a graph showing the variation of

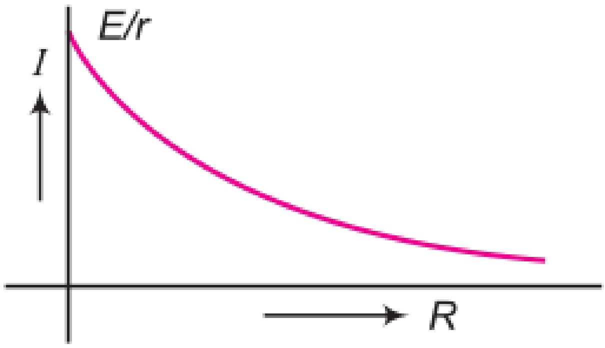
(i) Terminal voltage V and
(ii) The current I, as a function of R. **[CBSE Delhi 2012] [HOTS]**

Ans. $V = E - Ir = E - \frac{E}{R+r} r$

i. $V = R \frac{E}{R+r}$



ii. $I = \frac{E}{R+r}$

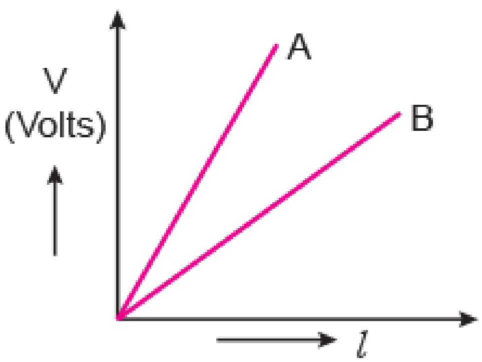


r = Internal resistance

Q. 9. Answer the following questions:

(1) (i) State the principle on which a potentiometer works. How can a given potentiometer be made more sensitive?

(ii) In the graph shown below for two potentiometers, state with reason which of the two potentiometer, A or B, is more sensitive.



(2) Two metallic wires, P1 and P2 of the same material and same length but different cross-sectional areas, A1 and A2 are joined together and connected to a source of emf. Find the ratio of the drift velocities of free electrons in the two wires when they are connected (i) in series, and (ii) in parallel. [CBSE (A) 2017]

Ans. (1) Principle: When a constant current flows through a wire of uniform area of cross section, the potential drop across any length of the wire is directly proportional to the length.

To make it more sensitive, the value of potential gradient K is kept least possible. Smaller the value of K, greater is the length (l) for the null deflection, and so greater will be the accuracy of measurement.

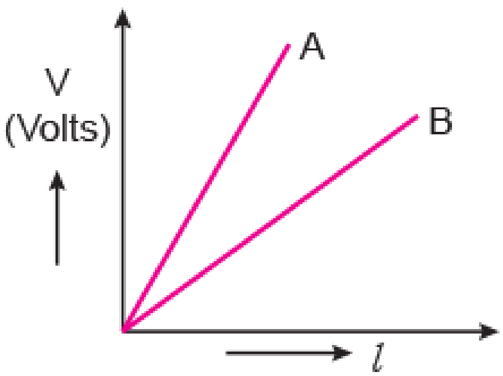
Potential gradient = v/l

∴ Potential gradient of wire A is more than wire B

So, wire B is more sensitive then A.

Q. 10. Explain with the help of a circuit diagram how the value of unknown resistance can be determined using a Wheatstone Bridge. Give the formula used.

Ans. Determination of Unknown resistance by Wheatstone Bridge. The circuit diagram is completed as shown in fig. P and Q are each 10Ω resistance, RB is a resistance box and X is unknown resistance to be measured. B is battery with key K_1 (in series, G is galvanometer with key K_2 in series.)



The battery key K_1 is pressed first and smallest resistance in RB is introduced by pressing galvanometer by K_2, the deflection in galvanometer is noted. Now resistance in RB is introduced, by pressing galvanometer key the deflection should be on other side. This is the main precaution before starting the experiment.

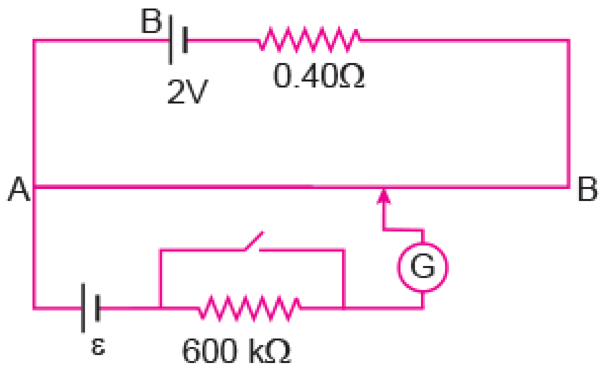
Now suitable value of resistance in RB is chosen so that on pressing the galvanometer key, there is no deflection in galvanometer. This resistance R is noted. Now formula used is

$$\frac{P}{Q} = \frac{R}{X}$$

⇒ Unknown resistance

$$X = \frac{Q}{P}R \text{ can be calculated.}$$

Q. 11. Figure shows a potentiometer with a cell of 2.0 V and internal resistance of 0.40Ω maintaining a potential drop across the resistor wire AB. A standard cell which maintains a constant emf of 1.02 V (for very moderate currents upto a few mA) gives a balance point at 67.3 cm length of the wire. To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then replaced by a cell of unknown emf and the balance point found similarly, turns out to be at 82.3 cm length of the wire.



(a) What is the value of ε?

(b) What purpose does the high resistance of 600 kΩ have?

(c) Is the balance point affected by this high resistance?

(d) Is the balance point affected by the internal resistance of the driver cell?

(e) Would the method work in the above situation if the driver cell of the potentiometer had an emf of 1.0 V instead of 2.0 V?

(f) Would the circuit work well for determining extremely small emf, say of the order of few mV (such as the typical emf of a thermo couple)? If not, how would you modify the circuit?

Ans. (a) For same potential gradient of potentiometer wire, the formula for comparison of emfs of cells is

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{l_2}{l_1} \quad \Rightarrow \quad \frac{\varepsilon}{\varepsilon_s} = \frac{l}{l_s}$$

$$\varepsilon = \frac{l}{l_s}\varepsilon_s$$

ε_s = emf of standard cell = 1.02 V

l_s = balancing with length standard cell = 67.3 cm

l = balancing length with cell of unknown emf = 82.3 cm

$$\therefore \text{ Unknown emf } \varepsilon = \frac{(82.3 \quad \text{cm})}{(67.3 \quad \text{cm})} \times 1.02\ V = 1.25\ V$$

(b) The purpose of high resistance is to reduce the current through the galvanometer. When jockey is far from the balance point, this saves the standard cell from being damaged.

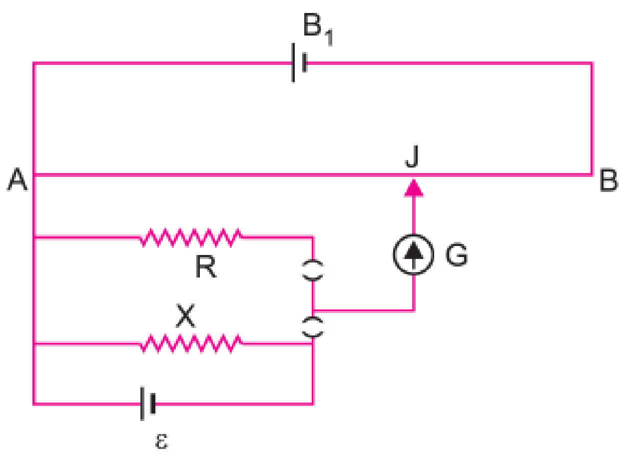
(c) The balance point is not affected by the presence of high resistance because in balanced-position there is no current in cell-circuit (secondary circuit).

(d) No, the balance point is not affected by the internal resistance of driver cell, because we have already set the constant potential gradient of wire.

(e) No, since for the working of potentiometer the emf of driver cell must be greater than emf of secondary circuit.

(f) No, the circuit will have to be modified by putting variable resistance (R) in series with the driver cell the value of R is so adjusted that potential drop across wire is slightly greater than emf of secondary cell, so that the balance point may be obtained at a longer length. This will reduce the error and increase the accuracy of measurement.

Q. 12. Figure shows a potentiometer circuit for comparison of two resistances. The balance point with a standard resistance R = 10.0Ω is found to be 58.3 cm, while that with the unknown resistance X is 68.5 cm. Determine the value of X. What might you do if you failed to find a balance point with the given cell ε.



Ans. In first case, resistance R is in parallel with cell ε, so p.d. across R = ε

i.e., $\varepsilon = RI$ ...(i)

In second case, X is in parallel with cell so p.d. across X = ε

i.e., $\varepsilon = XI$ ...(ii)

Let k be the potential gradient of potentiometer wire. If l1 and l2 are the balancing length corresponding to resistance respectively, then

$\varepsilon = kl_1$ ...(iii)

$\varepsilon = kl_2$ ...(iv)

From (i) and (iii) $RI = kl_1$ ...(v)

From (ii) and (iv) $XI = kl_2$ ...(vi)

Dividing (vi) by (v), we get

$$\frac{X}{R} = \frac{l_2}{l_1} \Rightarrow X = \frac{l_2}{l_1} R$$

Here, R = 10.0 Ω, l_1 = 58.3 cm, l_2 = 68.5 cm

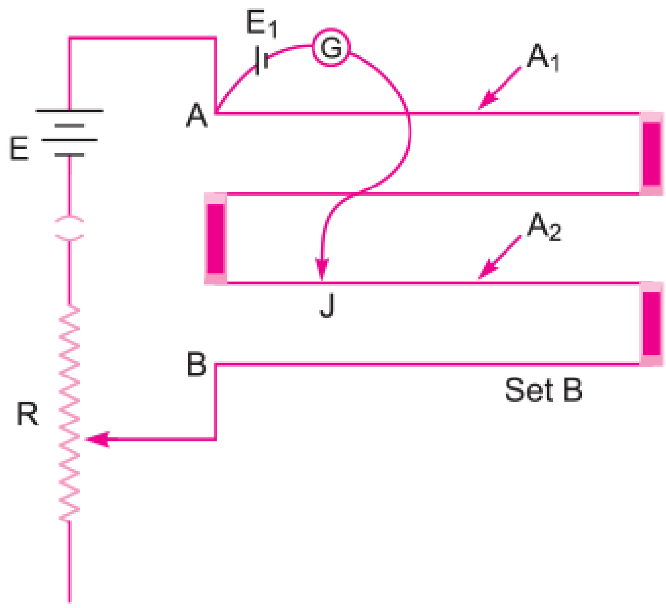
$$\therefore \qquad X = \frac{68.5}{58.3} \times 10.0 = 11.75\,\Omega$$

If we fail to find the balance point with the given cell ε, then we shall take the driver battery (B_1) of higher emf than given emf (ε).

Q. 13. You are given two sets of potentiometer circuits to measure the emf E_1 of a cell.

Set A: consists of a potentiometer wire of a material of resistivity ρ_1, area of cross-section A_1 and length l.

Set B: consists of a potentiometer of two composite wire of equal lengths l/2 each, of resistivity ρ_1, ρ_2 and area of cross-section A_1, A_2 respectively.



Find the relation between resistivity of the two wires with respect to their area of cross section, if the current flowing in the two sets is same.

Compare the balancing length obtained in the two sets. [CBSE Sample Paper 2016]

Ans.

(i) $I = \frac{\varepsilon}{R+\frac{\rho_1 l}{A_1}}$ for set A and $I = \frac{\varepsilon}{R+\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2}}$ for set B

Equating the above two expressions, we have

$$\frac{\varepsilon}{R+\frac{\rho_1 l}{2A_1}} = \frac{\varepsilon}{R+\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2}}$$

$$\Rightarrow \quad R+\frac{\rho_1 l}{A_1} = R+\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2} \quad \Rightarrow \quad \frac{\rho_1 l}{A_1} - \frac{\rho_1 l}{2A_1} = \frac{\rho_2 l}{2A_2}$$

$\ldots(i)$

$$\Rightarrow \quad \frac{\rho_1}{A_1} = \frac{\rho_2}{A_2}$$

(ii) Potential gradient of the potentiometer wire for set A, $K = I\frac{\rho_1}{A_1}$

Potential drop across the potentiometer wire in set B

$$V = I\left(\frac{\rho_1 l}{2A_1}+\frac{\rho_2 l}{2A_2}\right) \quad \Rightarrow \quad V = \frac{1}{2}\left(\frac{\rho_1}{A_1}+\frac{\rho_2}{A_2}\right) I$$

$$K' = \frac{I}{2}\left(\frac{r_1}{A_1}+\frac{r_2}{A_2}\right),$$

using the condition (i), we get

$K' = I\frac{\rho_1}{A_1}$, which is equal to K.

Therefore, balancing length obtained in the two sets is same.