VERY SHORT ANSWER QUESTIONS

(1 mark)

Previous Years' Questions

Q. 1. Out of two bulbs marked 25 W and 100 W, which has higher resistance?

[CBSE Delhi 2003]

Ans. Resistance of a bulb $R = \frac{V^2}{P} \propto \frac{1}{P}$ for same voltage.

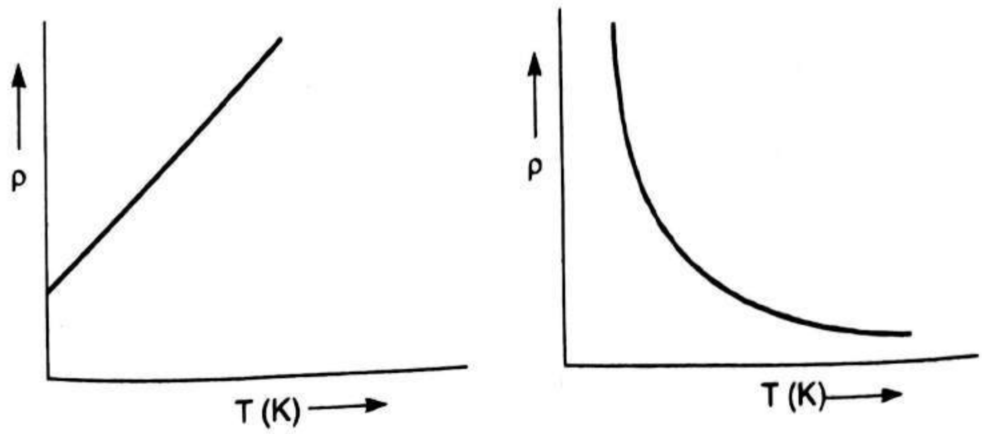
Smaller the power, higher is the resistance. Clearly 25 W bulb has higher resistance.

Q. 2. 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.

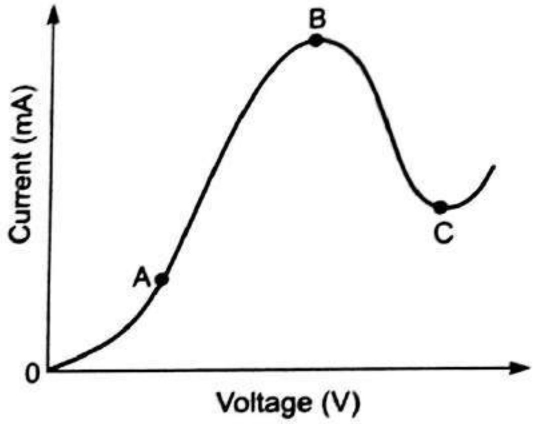
In copper, the resistivity decreases.



Q. 3. A wire of resistivity ρ is stretched to double its length. What will be its new resistivity? *[CBSE Delhi 2003]*

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

Q. 4. The graph shown in the figure represents a plot of current versus voltage for a given semiconductor. Identify the region, if any, over which the semiconductor has a negative resistance. **[CBSE (AI) 2013]**



Ans. In region BC *i.e.*, the region showing negative slope.

Concept: In figure draw two horizontal lines, as marked by dotted lines and use the formula

$R = \left(\frac{+\Delta V}{-\Delta I}\right)$ in the region, B to C = negative resistance.

Q. 5. 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, $I_A = I_B = I = neAv_d$

For same diameter, cross-sectional area is same

$A_A = A_B = A$

∴ $I_A = I_B \Rightarrow n_x eAv_x = n_y eAv_y$

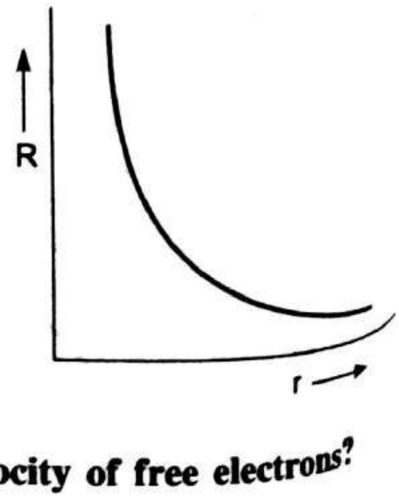
Given $n_x = 2n_y$

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

Q. 6. 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

$$R = \rho \frac{\ell}{\pi r^2}$$



Q. 7. 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. 8. Define the term resistivity and write the SI unit. *[CBSE Delhi 2005]*

Ans. The resistivity of the 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 S.I. unit is ohm × metre (Ωm).

Q. 9. Define electrical conductivity of a conductor and give its SI unit. *[CBSE Delhi 2008, 2005]*

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

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

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

Q. 10. What happens to the power dissipation if the value of electric current passing through a conductor of constant resistance is doubled? *[CBSE Delhi 2003]*

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

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

Q. 11. 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? *[CBSE Delhi 2003]*

Ans. For same voltage $Q = \frac{V^2}{R} t \propto \frac{1}{R}$

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

Q. 12. A carbon resistor is marked in colour bands of red, black, orange and silver. What is the resistance and tolerance value of the resistor? *[CBSE (AI) 2002]*

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. 13. 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? *[CBSE Delhi 2002C]*

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

= independent of temperature.

Q. 14. Write an expression for the resistivity of a metallic conductor showing its variation over a limited range of temperature. *[CBSE Delhi 2008C]*

Ans. If ρ_1 is the resistivity of temperature T_1 and ρ_2 that at temperature T_2, then

$$\rho_2 = \rho_1\,[1 + \alpha\,(T_2 - T_1)]$$

where α is temperature coefficient of resistivity.

Q. 15. 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]*

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 R, for same length of wire, the manganin wire must be thicker.

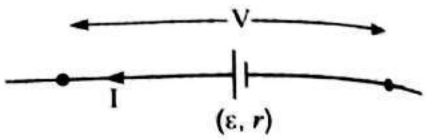
Q. 16. Specific resistance of copper, silver and constantan are 1.18×10^{-6}, 1×10^{-6}, 45×10^{-6} ohm cm respectively. Which is the best electrical conductor and why?

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

Q. 17. Name the device used for measuring the internal resistance of a secondary cell.

Ans. Potentiometer.

Q. 18. 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]***

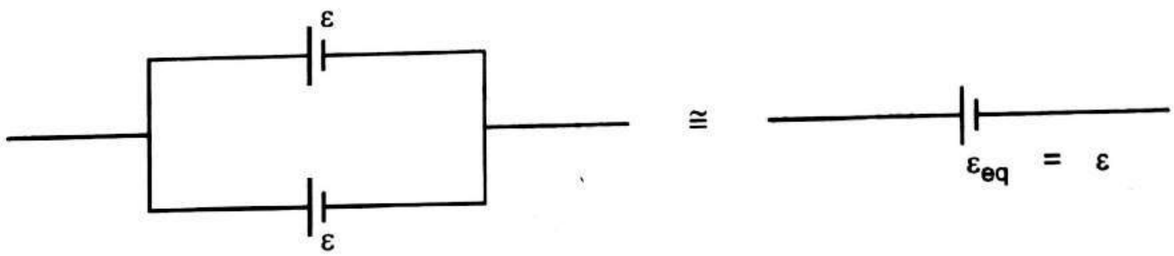


Ans. The terminal voltage V < E, so V = E − Ir

Q. 19. 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. Current, $I = \dfrac{E}{R}$

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



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

So, $I = \dfrac{\varepsilon_{eq}}{R + r_{eq}} = \dfrac{\varepsilon}{R}$ $\quad (r_{eq} = 0)$

Q. 20. Why do we prefer a potentiometer to measure the emf of a cell rather than a voltmeter?

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

Q. 21. 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, $I_S = \dfrac{E}{R_1 + R_2 + r}$

(*ii*) In parallel arrangement, current, $I_p = \dfrac{E}{\dfrac{R_1 R_2}{R_1 + R_2} + r}$

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

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

Q. 22. 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. 23. Define the current sensitivity of a galvanometer. Write its SI unit. ***[CBSE (AI) 2013]***

Ans. Ratio of deflection produced in the galvanometer to the current flowing through it.

$$\text{Current sensitivity } S_i = \frac{\theta}{I}$$

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

Q. 24. 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. 25. The applied p.d. across a given resistance is altered so that heat produced per second increases by a factor of 16. By what factor does the applied p.d. 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. 26. Two electric bulbs are marked 220 V, 60 W and 220 V, 100 W respectively. Which of the two has the greater resistance?

Ans. Power $P = \frac{V^2}{R} \Rightarrow R \propto \frac{1}{P}$ for same voltage. Smaller the power, larger the resistance; so 60 W bulb has greater resistance.

Q. 27. 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

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

Thus ratio of power dissipated is 2 : 1.

Q. 28. State the condition under which the terminal p.d. across a battery and its emf are equal.

[CBSE (AI) 2004]

Ans. The terminal p.d. 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. 29. A toaster produces more heat than a light bulb when connected in parallel to a 220 V mains. Which of the two has greater resistance?

Ans. Heat produced $P \propto \frac{1}{R}$ for the same voltage. Hence, light bulb has greater resistance.

Q. 30. Two heating coils, one of fine wire and other of thick wire, made of the same material and of the same length is connected one by one to a source of electricity. Which coil will produce heat at a greater rate?

Ans. $Q \propto \frac{1}{R}$ or, $R = \frac{\rho l}{\pi r^2}$

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

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

Q. 31. 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? *[CBSE (AI) 2004]*

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 p.d. across 25 W bulb will be more than that across 200 W bulb; so 25 W bulb was burnt out immediately.

Other Important Questions

Q. 32. 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_1 of the null point. One measures only their lengths along the straight segments (of lengths 1 metre each). This is easily done with the help of centimeter rulings or meter ruler and leads to accurate measurements.

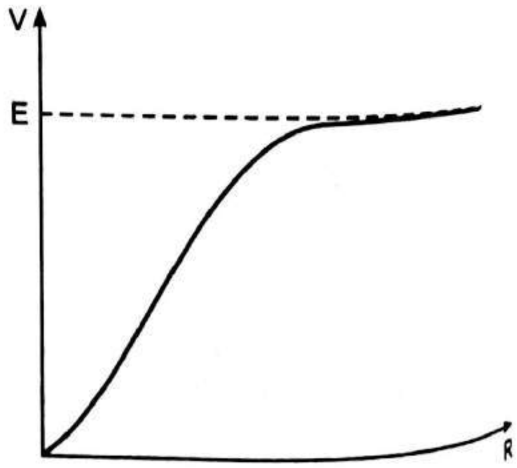
Q. 33. For wiring in the home, one uses Cu wires or Al wires. What considerations are involved in this? *[NCERT Exemplar]*

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. 34. Why are alloys used for making standard resistance coils? *[NCERT Exemplar]*

Ans. Alloys have low value of temperature co-efficient (less temperature sensitivity) of resistance and high resistivity.

Q. 35. A cell of emf *E* and internal resistance *r* is connected across an external resistance *R*. Plot a graph showing the variation of P.D. across *R*, verses *R*. *[NCERT Exemplar]*



Ans. $I = \frac{V}{R} = \frac{E}{R+r}$

$\therefore \quad V = \frac{ER}{R+r} = \frac{E}{1+\frac{r}{R}}$

When, $R = 0, V = 0$

And $R = \infty, V = \infty.$

Q. 36. You always specify the direction of current with an arrow; then why is the current a scalar quantity?

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

Q. 37. What are the charge carriers for current flow in a metallic conductor?

Ans. Free electrons are the charge carriers for current flow in a metallic conductor.

Q. 38. Is current density a scalar or a vector quantity?

Ans. Current density is a vector quantity.

Q. 39. 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. 40. When a straight wire of resistance R is bent in U-shape, does its resistance change?

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

Q. 41. 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 on the material (at a given temperature), therefore by changing the radius, the specific resistance of copper remains unchanged.

Q. 43. On increasing the current drawn from a cell, the 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. 44. 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. 45. State the condition for maximum current to be drawn from the cell.

Ans. Current drawn from a cell of emf E and internal resistance r in an external resistance R is

$$I = \frac{E}{R + r}$$

Clearly, for maximum current, the external resistance R should be zero *i.e.*, for maximum current the terminals of a cell must be short circuited.

Q. 46. When is a Wheatstone's bridge most sensitive?

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

Q. 47. A 25 watt and a 100 watt bulbs are joined in a series and connected to mains. Which bulb will glow brighter ?

Ans. The resistance of bulb, $R = V^2/P \propto 1/P$ for same V. Obviously the resistance of 25 watt bulb is 4 times that of 100 watt bulb. In series current I is the same, therefore Joule-heat produced ($I^2 R$) is proportional to resistance R. Hence the bulb having higher resistance (i.e., 25 watt bulb) glows brighter than 100 watt bulb when connected in series.

SHORT ANSWER QUESTIONS

(2, 3 marks)

Previous Years' Questions

Q. 1. Define the terms (*i*) drift velocity, (*ii*) relaxation time.

A conductor of length L is connected to a dc source of emf ε. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3L, how will the drift velocity change? *[CBSE Delhi 2011, (AI) 2013]*

Ans. (*i*) **Drift Velocity:** When a potential difference is applied across a conductor, the free electrons drift towards the direction of positive potential. The small average velocity of free electrons along the direction of positive potential is called the drift velocity.

(*ii*) **Relaxation Time:** The time of free travel of a free electron between two successive collisions of electron with lattice ions/atoms is called the **relaxation time.**

Drift velocity, $v_d = \frac{e\tau}{m}\frac{\varepsilon}{L} \alpha \frac{1}{L}$

When length L is made 3L, drift velocity becomes **one-third.**

Q. 2. How does drift velocity of electrons in a metallic conductor vary with the rise of temperature? *[CBSE Delhi 2002]*

Ans. Drift velocity $v_d = \frac{e\tau}{m}E$, where E is electric field strength. 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. 3. Write the mathematical relation between mobility and drift velocity of charge carriers in a conductor. Name the mobile charge carriers responsible for conductors 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 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. 4. **(*a*) You are required to select a carbon resistor of resistance 47 $k\Omega \pm 10\%$ 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. 5. How does the resistivity of (*i*) a conductor and (*ii*) a semiconductor vary with temperature? Give reason for each case. *[CBSE (AI) 2005]*

Ans. (*i*) The resistivity of a conductor increases with increase of temperature.

Reason: When temperature increases, the rate of collisions of free electrons of conductor with ions of lattice increases, so relaxation time decreases. As a result, the resistivity $\left(\rho = \frac{m}{ne^2\tau} \propto \frac{1}{\tau}\right)$ increases.

(*ii*) The resistivity of a semiconductor decreases with the rise of temperature.

Reason: 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 $\left(\rho \propto \frac{1}{n}\right)$, so resistivity of semiconductor decreases with the rise of temperature.

Q. 6. Write the mathematical relation for the resistivity of a material in terms of relaxation time, number density, and 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. ***[CBSE Delhi 2007]***

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 the temperature of a semiconductor increases, the covalence bonds break and charge carriers (electrons and holes) become free *i.e.,* charge carrier density (n) increases with rise of temperature, so resistivity of a semiconductor decreases with rise of temperature.

Q. 7. 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. ***(CBSE Delhi 2008)***

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

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

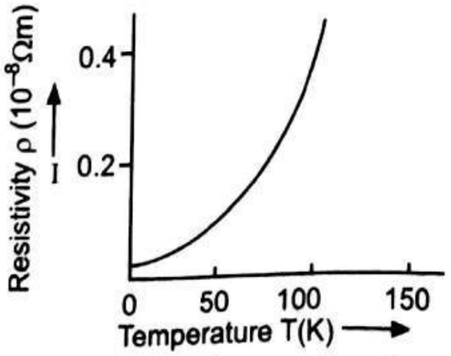
Thus, resistivity of a material is numerically equal to the resistance of the conductor having unit length and unit cross-sectional area.

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

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

where ρ_T is the resistivity at a temperature T and ρ_0 is the same at a reference temperature T_0. α is called the *temperature co-efficient of resistivity.*

The relation of Eq. (*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. 8. Using the mathematical expression for the conductivity of a material, explain how it varies with temperature for (*i*) semiconductor (*ii*) good conductors. *[CBSE (AI) 2008]*

Ans. Conductivity of a material, $\sigma = \dfrac{ne^2\tau}{m}$

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

τ = relaxation time n = number density of charge carriers

(*i*) **In the case of a semiconductor;** 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.

(*ii*) **In the case of good conductors;** when temperature increases, the number of collisions of electrons with ion-lattice increases, so relaxation time decreases, so conductivity of good conductor decreases with rise of temperature.

Q. 9. 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 $v_d = -\dfrac{eV\tau}{ml} \propto \dfrac{1}{l}$

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

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

New resistance

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

$$R' = 9R$$

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

Q. 10. A cylindrical metallic wire is stretched to increase its length by 10%. Calculate the percentage increase in its resistance. *[CBSE Delhi 2007]*

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 , $A = \dfrac{V}{l}$ = 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 $l' = l + \dfrac{10}{100}l = 1.1\,l \Rightarrow \dfrac{l'}{l} = 1.1$

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

% increase in resistance

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

Q. 11. 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) series and (ii) parallel across the same voltage supply. *[CBSE (AI) 2011]*

Ans. (i) **In series combinations**

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

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

$$R = \frac{V_2}{P}, \quad R_1 = \frac{V^2}{P_1} \text{ and } R_2 = \frac{V^2}{P_2}$$

∴ From equation (i)

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

(ii) **In parallel combination**

Net resistance $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

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

$$\Rightarrow \qquad P = P_1 + P_2$$

Q. 12. 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: *[CBSE Delhi 2012]*

(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.

Ans. (i) $i = \frac{\varepsilon}{r}$

where $\varepsilon = emf$

r = Internal resistance

In this situation, effective resistance of circuit is minimum so current is maximum.

So, $i = 4.2$ A

(ii) $i = \frac{\varepsilon}{R_1 + r}$

Here, effective resistance is more than (i) and (iv) but less than (iii).

So, $i = 1.05$ A

(iii) $i = \frac{\varepsilon}{r + R_1 + R_2}$

In this situation effective resistance is maximum so current is minimum.

So, $i = 0.42$ A

(iv) $i = \dfrac{\varepsilon}{r + \dfrac{R_1 R_2}{R_1 + R_2}}$

In this situation, the effective resistance is more than (*i*) but less than (*ii*) and (*iii*).

Hence, $i = 1.4$ A

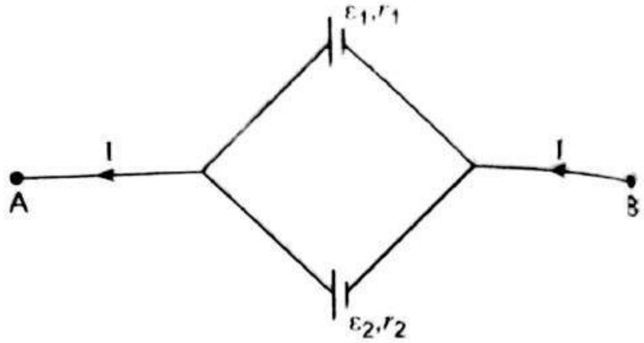
Q. 13. Two cells of emfs $\varepsilon_1, \varepsilon_2$ and internal resistance r_1 and r_2 respectively are connected in parallel as shown in the figure. ***[CBSE (F) 2012]***

Deduce the expressions for

(*i*) the equivalent e.m.f. of the combination,

(*ii*) the equivalent resistance of the combination, and

(*iii*) the potential difference between the points *A* and *B*.



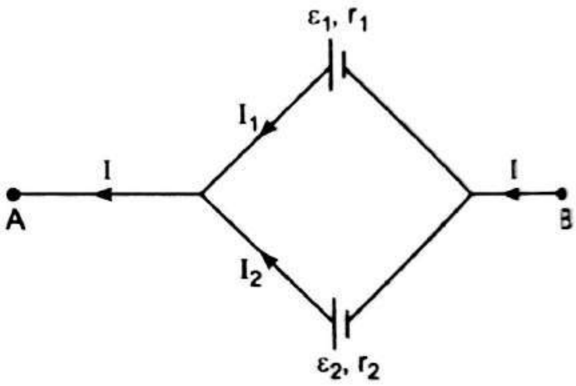
Ans. Here, $I = I_1 + I_2$ ...(*i*)

Let V = Potential difference between A and B.

For cell ε_1

Then, $V = \varepsilon_1 - I_1 r_1 \Rightarrow I_1 = \dfrac{\varepsilon_1 - V}{r_1}$

Similarly, for cell ε_2 $\quad I_2 = \dfrac{\varepsilon_2 - V}{r_2}$



Putting these values in equation (*i*)

$$I = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2}$$

or $$I = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

or $$V = \left(\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right) \quad ...(ii)$$

Comparing the above equation with the equivalent circuit of emf 'ε_{eq}' and internal resistance 'r_{eq}' then,

$$V = \varepsilon_{eq} - I r_{eq} \quad ...(iii)$$

Then

(*i*) $\varepsilon_{eq} = \dfrac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$ $\qquad$ (*ii*) $r_{eq} = \dfrac{r_1 r_2}{r_1 + r_2}$

(*iii*) The potential difference between A and B

$$V = \varepsilon_{eq} - I r_{eq}$$

Q. 14. State Kirchhoff's rules of current distribution in an electrical network. ***[CBSE Delhi 2013, 200***

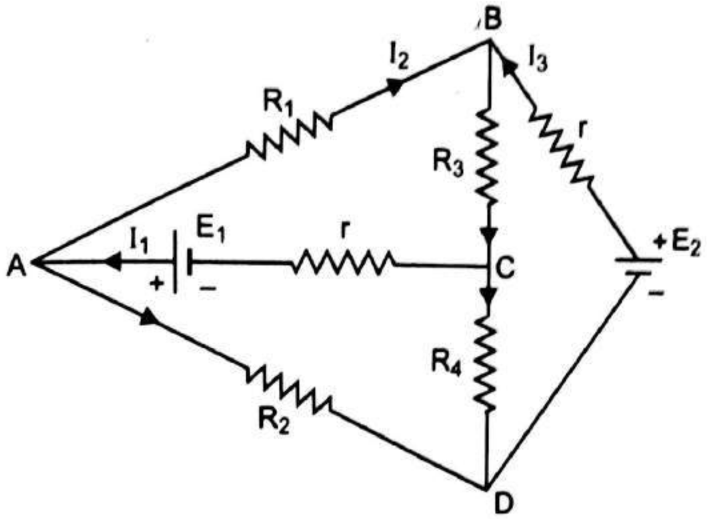
Ans. Kirchhoff's Laws:

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

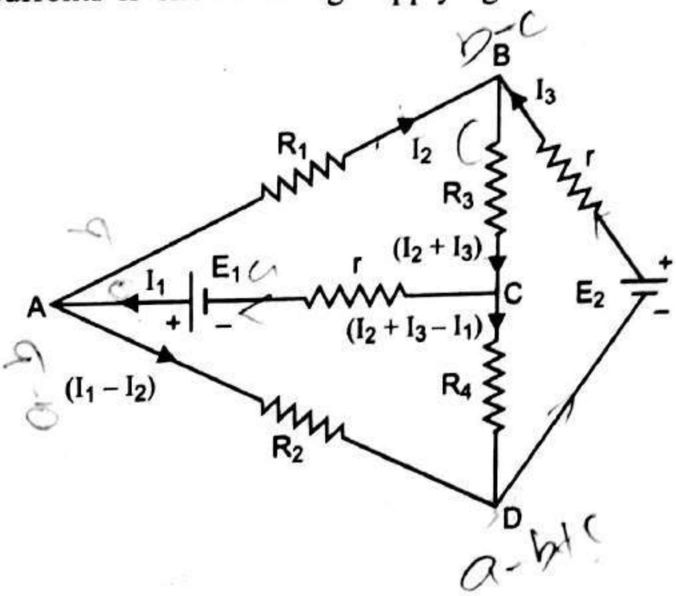
$$\Sigma I = 0$$

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

Q. 15. Use Kirchhoff's rules to write the three equations that may be used to obtain the values of three unknown currents in the branches (shown) of the given circuit. *[CBSE (AI) 2008C]*



Ans. The distribution of currents is shown in fig. Applying Kirchhoff's II law in loop *ABCA*.



$$-I_2R_1 - (I_2 + I_3)R_3 - I_1r + E_1 = 0$$

$$\Rightarrow \quad I_1r + I_2(R_1 + R_3) + I_3R_3 = E_1 \quad \ldots(i)$$

Applying Kirchhoff's II law to loop *ACDA*

$$-E_1 + I_1r - (I_2 + I_3 - I_1)R_4 + (I_1 - I_2)R_2 = 0$$

$$\Rightarrow \quad I_1(r + R_2) - (R_2 + R_4)I_2 - I_3R_4 = E_1 \quad \ldots(ii)$$

In loop BE_2DB

$$I_3r - E_2 + (I_2 + I_3 - I_1)R_4 + (I_2 + I_3)R_3 = 0$$

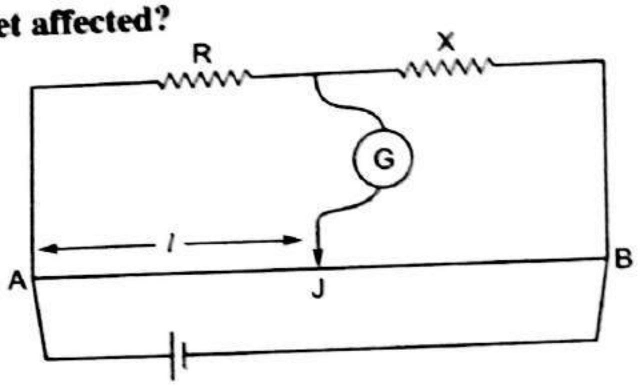
$$\Rightarrow \quad -I_1R_4 + I_2(R_3 + R_4) + I_3(r + R_3 + R_4) = E_2 \quad \ldots(iii)$$

Equations (*i*), (*ii*) and (*iii*) are required equations.

Q. 16. **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) $\frac{R}{X} = \frac{rl}{r(100-l)}$

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

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

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

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

From (i) and (ii), $\frac{100-l}{l} = \frac{l'}{100-l'}$

$$\Rightarrow \quad l' = (100-l)$$

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

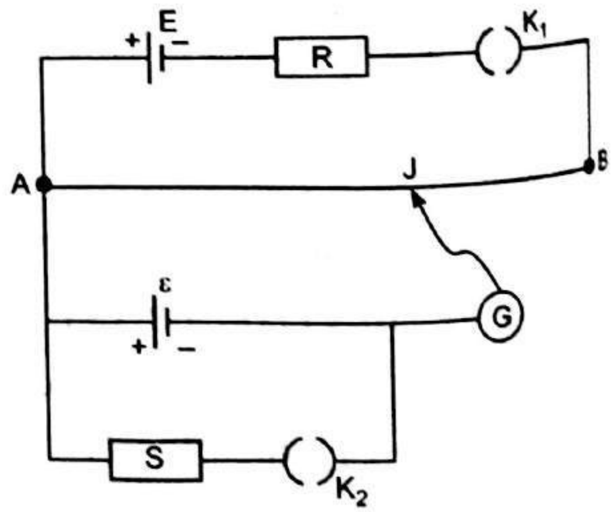
Q. 17. **Two students 'X' and 'Y' perform an experiment on potentiometer separately using the circuit given:** **[CBSE (F) 2012]**

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

(i) 'X' increases the value of resistance R in the set-up by keeping the key K_1 closed and the key K_2 open?

(ii) 'Y' decreases the value of resistance S in the set-up, while the key K_2 remain open and the key K_1 closed?

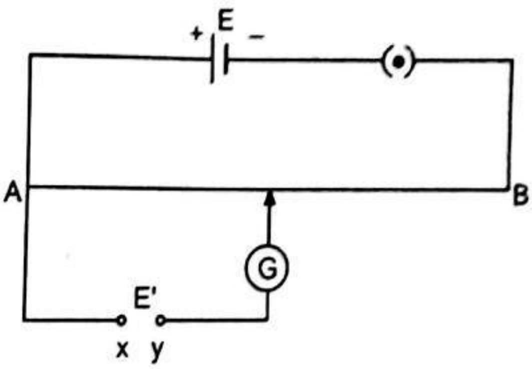
Justify.



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. 18. 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. ***[CBSE (AI) 2007]***

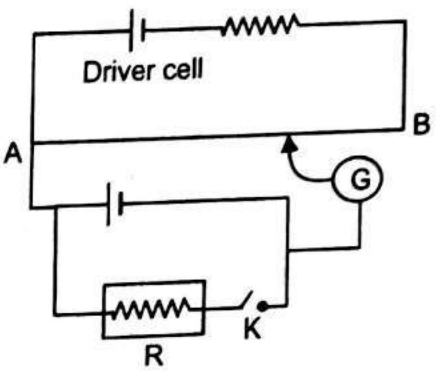
Ans. The two possible faults in the circuit may be (*i*) emf E' is greater than emf E.

(*ii*) Terminal X of unknown emf is negative (while it must 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. 19. The following circuit shows the use of potentiometer to measure the internal resistance of a cell



(*i*) When the key K 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?

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.

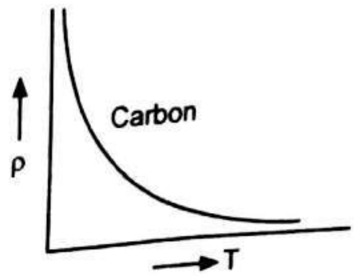
(*ii*) With increase of R, the terminal p.d. across cell E increases and hence balancing length $l = \frac{V}{k} \propto V$ increases. So the balance point is shifted to the right.

Q. 20. 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]***

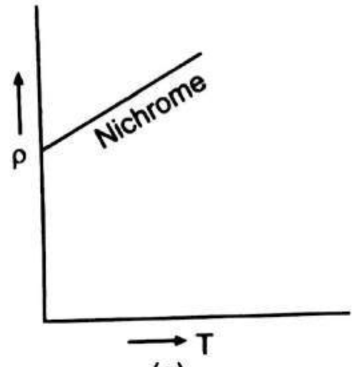
Ans. The resistivity of a typical semiconductor (carbon) decreases with increase of temperature. The graph is shown in figure.



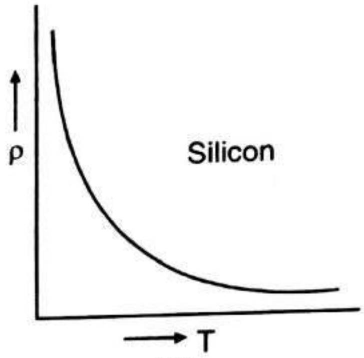
Explanation: In semiconductor the number density of free electrons (n) increases with increase in temperature (T) and consequently the relaxation period decreases. But the effect of increase in n has higher impact than decrease of τ. So, resistivity decreases with increase in temperature.

Q. 21. Draw the graphs showing the variation of resistivity with temperature for (*i*) nichrome and (*ii*) silicon.

Ans. The variation of resistivity of nichrome and silicon with temperature are shown in figures (*a*) and (*b*).



(*a*)

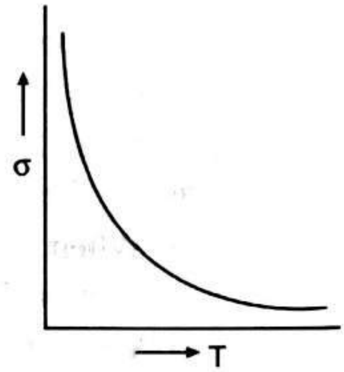


(*b*)

Q. 22. Explain the variation of conductivity with temperature for (*i*) a metallic conductor and (*ii*) ionic conductors. *[CBSE Delhi 2008, 2004 C, (AI) 2004]*

Ans. (*i*) Conductivity of a metallic conductor $\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$.

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. Figure represents the variation of conductivity of metal with temperature. Initially the variation of conductivity with temperature is linear and then it is non-linear.



(*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.

Other Important Questions

Q. 23. 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. The average velocity of random motion of electrons in any direction is zero, hence current is zero.

Q. 24. What is the change in resistance of an Eureka wire when its radius is halved and the length is reduced to one-fourth of its original value.

Ans. We have $$R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2} \quad ...(i)$$

New radius $r' = r/2$

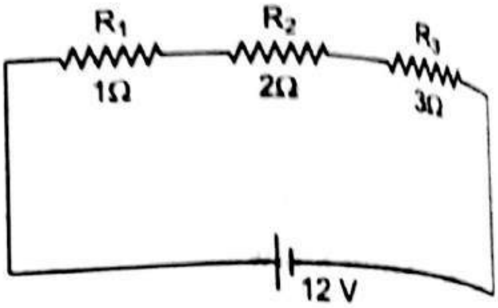
New length $l' = l/4$

$\therefore$ New resistance $$R' = \frac{\rho l'}{\pi r'^2} = \frac{\rho (l/4)}{\pi (r/2)^2} = \frac{\rho l}{\pi r^2} \quad ...(ii)$$

$\therefore$ Comparing (*i*) and (*ii*), we note that the resistance of wire remains unchanged.

NUMERICALS

NCERT Numericals



1. (a) Three resistors 1 Ω, 2 Ω and 3 Ω are connected in series. What is the total resistance of the combination. (b) If the combination is connected to a battery of emf 12 V and negligible internal resistance, obtain the potential drop across each resistor.

Sol. (a) In series combination total resistance

$$R = R_1 + R_2 + R_3$$
$$= 1 + 2 + 3 = 6\,\Omega$$

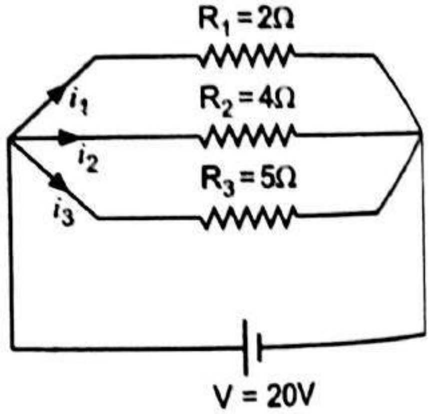
(b) In series current in each resistor is the same current in circuit $I = \frac{V}{R} = \frac{12}{6} = 2\,A$

Potential difference across $R_1 = 1\,\Omega$, $V_1 = IR_1 = 2 \times 1 = 2$ V

Potential difference across $R_2 = 2\,\Omega$, $V_2 = IR_2 = 2 \times 2 = 4$ V

Potential difference across $R_3 = 3\,\Omega$, $V_3 = IR_3 = 2 \times 3 = 6$ V

2. (a) Three resistors 2 Ω, 4 Ω and 5 Ω are connected in parallel. What is the total resistance of the combination? (b) If the combination is connected to a battery of emf 20 V and negligible internal resistance, determine the current through each resistor and the total current drawn from the battery.



Sol. (a) In parallel combination, net resistance R is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
$$= \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{10 + 5 + 4}{20}$$

$$\Rightarrow \quad R = \frac{20}{19}\,\Omega$$

(b) In parallel combination, the potential difference across each resistance remains the same.

Current in $R_1 = 2\,\Omega$ is $I_1 = \frac{V}{R_1} = \frac{20}{2} = 10$ A

Current in $R_2 = 4\,\Omega$ is $I_2 = \frac{V}{R_2} = \frac{20}{4} = 5$ A

Current in $R_3 = 5\,\Omega$ is $I_3 = \frac{V}{R_3} = \frac{20}{5} = 4$ A

∴ Total current drawn from battery

$$I = I_1 + I_2 + I_3 = 10 + 5 + 4 = 19 \text{ A}$$

3. A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6.0×10^{-7} m^2 and its resistance is measured to be 5.0 Ω. What is the resistivity of the material at the temperature of the experiment?

Sol. Given $l = 15$ m, $A = 6.0 \times 10^{-7}$ m^2, $R = 5.0\,\Omega$

We have, $\quad R = \frac{\rho l}{A}$

$\therefore$ Resistivity $\rho = \frac{RA}{l} = \frac{5.0 \times 6.0 \times 10^{-7}}{15} = 2.0 \times 10^{-7}\ \Omega m$

4. The number density of conduction electrons in a copper conductor is $8.5 \times 10^{28}\ m^{-3}$. How long an electron take does to drift from one end of a wire, 3.0 m long, to its other end? The area of cross-section of the wire is $2.0 \times 10^{-6}\ m^2$ and it is carrying a current of 3.0 A.

Sol. Current in wire, $I = neAv_d$

Given $n = 8.5 \times 10^{28}\ m^{-3}$, $e = 1.6 \times 10^{-19}$ C, $I = 3.0$ A, $A = 2.0 \times 10^{-6}\ m^2$, $l = 3.0$ m

$\therefore$ **Drift velocity** $v_d = \frac{I}{neA} = \frac{3.0}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 2.0 \times 10^{-6}} = 1.1 \times 10^{-4}$ m/s

$\therefore$ Time, $t = \frac{l}{v_d} = \frac{3.0}{1.1 \times 10^{-4}} = \mathbf{2.72 \times 10^4\ s = 7\ h\ 33\ min.}$

5. Two wires of equal length, one of aluminium and the other of copper have the same resistance. Which of the two wires is lighter ? Hence explain why aluminium wires are preferred for overhead power cables ($\rho_{Al} = 2.63 \times 10^{-8}\Omega m$, $\rho_{Cu} = 1.72 \times 10^{-8}\Omega m$, Relative density of Al = 2.7; Cu = 8.9).

Sol. The resistance of wire of length l and cross-sectional area A is given by

$$R = \frac{\rho l}{A} \Rightarrow A = \frac{\rho l}{R} \qquad \ldots(i)$$

mass of wire, m = volume × density = Ald

Substituting the value of A from (i)

$$m = \left(\frac{\rho l}{R}\right) ld \Rightarrow m = \frac{\rho l^2 d}{R}$$

As length and resistance of two wires are same,

So, $m \propto \rho d$

$$\frac{m_{Al}}{m_{Cu}} = \frac{\rho_{Al}\, d_{Al}}{\rho_{Cu}\, d_{Cu}} = \left(\frac{2.63 \times 10^{-8}}{1.72 \times 10^{-8}} \times \frac{2.7 \times 10^3}{8.9 \times 10^3}\right) = 0.46$$

This indicates that aluminium wire is 0·46 times lighter than copper wire. That is why aluminium wires are preferred for overhead power of cables.

6. At room temperature (27.0° C), the resistance of a heating element is 100 Ω. What is the temperature of the element if the resistance is found to be 117 Ω, given that the temperature coefficient of the material of the resistor is 1.70×10^{-4}/° C.

Sol. Given, $R_{27} = 100\,\Omega$, $R_t = 117\,\Omega$, $t = ?$, $\alpha = 1.70 \times 10^{-4}/°C$

Temperature Coefficient $\alpha = \frac{R_t - R_{27}}{R_{27}(t - 27)}$, temperature t is unknown

$$\Rightarrow \quad t - 27 = \frac{R_t - R_{27}}{R_{27} \cdot \alpha} = \frac{117 - 100}{100 \times 1.70 \times 10^{-4}} = 1000$$

$$\Rightarrow \quad t = 1000 + 27 = \mathbf{1027°C}$$

7. A silver wire has a resistance 2.1Ω at 27.5° C and a resistance of 2.7 Ω at 100°C. Determine the temperature coefficient of the resistivity of silver.

Sol. Given, $R_1 = 2.1\,\Omega$, $t_1 = 27.5°C$, $R_2 = 2.7\,\Omega$, $t_2 = 100°C$, $\alpha = ?$

Temperature coefficient of resistance,

$$\alpha = \frac{R_2 - R_1}{R_1 (t_2 - t_1)}$$

$$= \frac{2.7 - 2.1}{2.1 (100 - 27.5)} = \frac{0.6}{2.1 \times 72.5} = 0.0039\ (^\circ C)^{-1}$$

8. A heating element using nichrome connected to a 230 V supply draws an initial current of 3.2 A which settles after a few seconds at a steady value of 2.8 A. What is the steady temperature of the heating element if the room temperature is 27°C? Temperature coefficient of resistance of nichrome averaged over the temperature range involved is 1.7×10^{-4} per °C. ***(CBSE Delhi 2005)***

Sol. Resistance of heating element at room temperature $t_1 = 27^\circ C$ is

$$R_1 = \frac{V}{I_1} = \frac{230}{3.2}\ \Omega$$

Resistance of heating element at steady state temperature $t_2^\circ C$ is

$$R_2 = \frac{V}{I_2} = \frac{230}{2.8}\ \Omega$$

Temperature coefficient of resistance $\alpha = \frac{R_2 - R_1}{R_1 \times (t_2 - t_1)}$

$$\therefore\ t_2 - t_1 = \frac{R_2 - R_1}{R_1 . \alpha} = \frac{\left(\frac{230}{2.8}\right) - \left(\frac{230}{3.2}\right)}{\frac{230}{3.2} \times 1.7 \times 10^{-4}} = \frac{3.2 - 2.8}{2.8 \times 1.7 \times 10^{-4}} = \frac{0.4}{2.8 \times 1.7 \times 10^{-4}} = 840.3^\circ C$$

$\therefore$ Steady state temperature, $t_2 = 840.3 + t_1 = 840.3 + 27 = \mathbf{867.3^\circ C}$

9. What conclusion can you draw from the following observations on a resistor made of alloy manganin?

Current (*I*) A	**Voltage (*V*) V**	$R = \frac{V}{I}$ **Not given**	**Current**	**Voltage**	$R = \frac{V}{I}$ **Not given**
0.2	3.94	19.7 Ω	3.0	59.2	19.73 Ω
0.4	7.87	19.675 Ω	4.0	78.8	19.7 Ω
0.6	11.8	19.67 Ω	5.0	98.6	19.72 Ω
0.8	15.7	19.62 Ω	6.0	118.5	19.75 Ω
1.0	19.7	19.7 Ω	7.0	138.2	19.74 Ω
2.0	39.4	19.7 Ω	8.0	158.0	19.75 Ω

Sol. On calculating resistances from given observations, we note the resistance of manganin is same equal to **19.7 Ω** from all observations. This shows that manganin obeys Ohm's law and moreover, its resistivity is nearly independent of temperature (with increase of current, temperature of wire increases but resistance is independent of current).

10. The earth's surface has a negative surface charge density of 10^{-9} Cm^{-2}. The potential difference of 400 kV between the top of atmosphere and the surface result (due to the low conductivity of lower atmosphere) in a current of only 1800 A over the entire globe. If there were no mechanism of sustaining atmospheric electric field, how much time (roughly) would be required to neutralise the earth's surface ? (This never happens in practice because there is a

mechanism to replenish electric charges, namely the continual thunder storms and lightning in different parts of the globe. Radius of earth $= 6.37 \times 10^6$ m).**

Sol. Given $\sigma = 10^{-9}\ Cm^{-2}$, $I = 1800$ A, $R = 6.37 \times 10^6$ m

Surface area of globe, $A = 4\pi R^2$

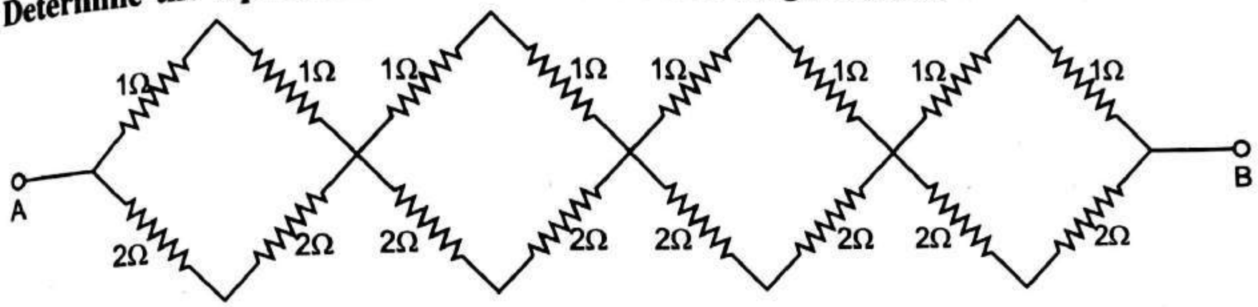
$$= 4 \times 3.14 \times (6.37 \times 10^6)^2 = 5.1 \times 10^{14}\ m^2$$

Total charge on globe, $Q = \sigma . A = 10^{-9} \times 5.1 \times 10^{14} = \mathbf{5.1 \times 10^5\ C}$

Charge $Q = It$, given $t = \frac{Q}{I} = \frac{5.1 \times 10^5}{1800} = \mathbf{283\ s}$

$$= 4 \text{ min } 43 \text{ s}$$

11. Determine the equivalent resistance of the following network.



Sol. The given network consists of a series combination of 4 equivalent units.

Resistance of Each Unit: Each unit has 2 rows. The upper row contains two resistances 1 Ω, 1 Ω in series and the lower row contains two resistances 2 Ω, 2 Ω in series. These two are mutually connected in parallel.

Resistance of upper row, $R_1 = 1 + 1 = 2\,\Omega$

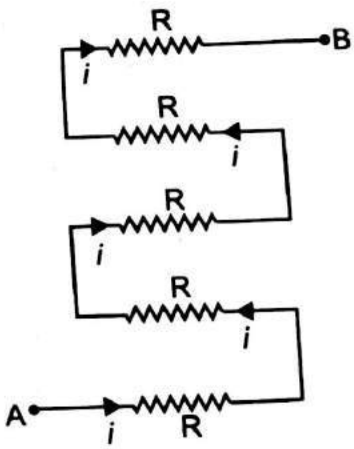
Resistance of lower row, $R_2 = 2 + 2 = 4\,\Omega$

$\therefore$ Resistance of each unit R' is given by

$$\frac{1}{R'} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R' = \frac{R_1 R_2}{R_1 + R_2} = \frac{2 \times 4}{2 + 4} = \frac{4}{3}\,\Omega$$

$\therefore$ Equivalent resistance between A and B

$$R_{AB} = R' + R' + R' + R' = 4R' = 4 \times \frac{4}{3} = \frac{16}{3}\,\Omega$$



12. Determine the equivalent resistance of the network shown in fig.

Sol. When a battery is connected between A and B, the current in all the 5 resistances passes undivided; so all the five resistances are connected in series, so equivalent resistance

$$R_{eq} = R + R + R + R + R = 5\,R$$

13. The storage battery of a car has an emf of 12 V. If the internal resistance of the battery is 0·4Ω, what is the maximum current that can be drawn from the battery?

Sol. Current drawn from battery of emf E, internal resistance r, resistance of external current R, is

$$I = \frac{E}{R + r}$$

For maximum current, external resistance, $R = 0$

$\therefore$

$$I = \frac{E}{r} = \frac{12}{0 \cdot 4} = 30 \text{ A}$$

14. A battery of emf 10 V and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 0·5 A, what is the resistance of the resistor ? What is the terminal voltage of the battery when the circuit is closed ?

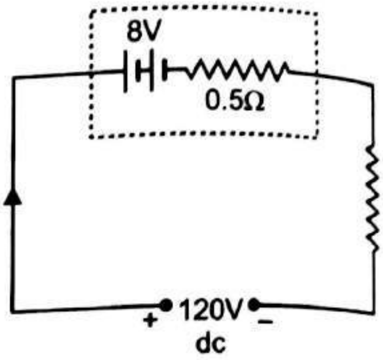
Sol. Given $E = 10$ V, $r = 3\,\Omega$, $I = 0{\cdot}5$ A.

Total resistance of circuit $R + r = \frac{E}{I} = \frac{10}{0{\cdot}5} = \mathbf{20\,\Omega}$

External resistance $R = 20 - r = 20 - 3 = \mathbf{17\,\Omega}$

Terminal voltage $V = IR = 0{\cdot}5 \times 17 = \mathbf{8{\cdot}5\ V}$

15. A storage battery of emf 8 V and internal resistance 0.5 Ω is being charged by a 120 V d.c. supply using a series resistor of 15.5 Ω. What is the terminal voltage of the battery during charging? What is the purpose of having a series resistor in the charging circuit?



Sol. When battery is being charged by a 120 V d.c. supply, the current in battery is in opposite direction of the normal connections of battery of supplying current. So the potential difference across battery

$$V = E + Ir \qquad \text{...}(i)$$

Given $E = 8$ volt, $r = 0{\cdot}5\,\Omega$

Current in circuit $I = \frac{120 - 8}{15{\cdot}5 + 0{\cdot}5} = \frac{112}{16} = 7$ A

$\therefore \quad V = 8 + 7 \times 0{\cdot}5 = 11{\cdot}5$ volt

Series resistance limits the current drawn from external d.c. source. In the absence of series resistance the current may exceed the safe-value permitted by storage battery.

16. Six lead-acid type of secondary cells each of emf 2·0 V and internal resistance 0·015 Ω are joined in series to provide a supply to a resistance of 8·5 Ω. What are the current drawn from the supply and its terminal voltage ?

Sol. Given $E = 2{\cdot}0$ V, $n = 6$, $r = 0{\cdot}015\,\Omega$, $R = 8{\cdot}5\,\Omega$

When cells are in series,

Current $\quad I = \frac{nE}{R + nr} = \frac{6 \times 2{\cdot}0}{8{\cdot}5 + 6 \times 0{\cdot}015} = \frac{12}{8{\cdot}59} = \mathbf{1{\cdot}4\ A}$

Terminal voltage $V = IR = 1{\cdot}4 \times 8{\cdot}5 = \mathbf{11{\cdot}9\ V}$

17. A secondary cell after a long use has an emf of 1.9 V and a large internal resistance of 380 Ω. What maximum current can be drawn from the cell ? Could the cell drive the starting motor of a car?

Sol. Current drawn from cell $I = \frac{E}{R + r}$

For maximum current $R = 0$

$\therefore$ Maximum current, $I_{max} = \frac{E}{r} = \frac{1{\cdot}9}{380}$ A $= 0{\cdot}005$ A

For driving the starting motor of a car a large current of the order of 100 A is required, therefore, the cell cannot drive the starting motor of the car.

18. Determine the current in each branch of the network shown in fig.

Sol. According to Kirchhoff's *first* law, the current in various branches of circuit are shown in figure.

Applying Kirchhoff's second law to mesh $ABDA$.

$$-10I_1 - 5I_3 + 5I_2 = 0$$

$$\Rightarrow \quad 2I_1 - I_2 + I_3 = 0 \qquad \ldots(i)$$

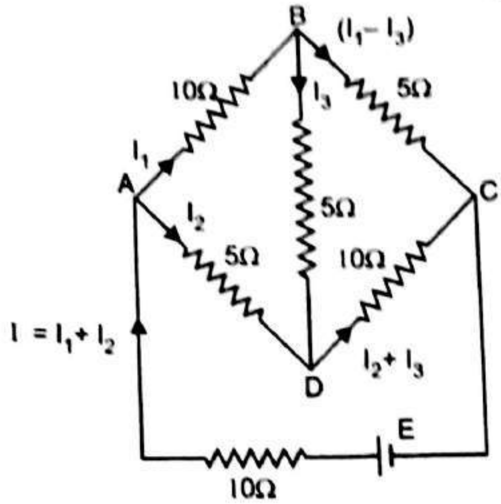
Applying Kirchhoff's second law to mesh $BCDB$

$$-5(I_1 - I_3) + 10(I_2 + I_3) + 5I_3 = 0$$

$$\Rightarrow \quad 5I_1 - 10I_2 - 20I_3 = 0$$

$$\Rightarrow \quad I_1 - 2I_2 - 4I_3 = 0 \qquad \ldots(ii)$$

Applying Kirchhoff's second law to mesh $ADCEA$



$$-5I_2 - 10(I_2 + I_3) + 10 - 10(I_1 + I_2) = 0$$

$$\Rightarrow \quad 2I_1 + 5I_2 + 2I_3 = 2 \qquad \ldots(iii)$$

From (i) $\quad I_2 = 2I_1 + I_3 \qquad \ldots(iv)$

From (ii) $\quad I_1 = 2I_2 + 4I_3 \qquad \ldots(v)$

$\therefore$ Substituting I_1 in (iv), we have

$$I_2 = 2(2I_2 + 4I_3) + I_3 \Rightarrow I_2 = -3I_3$$

From (v) $\quad -3I_3 = 2I_1 + I_3 \Rightarrow I_1 = -2I_3$

Now from (iii), $\quad -4I_3 - 15I_3 + 2I_3 = 2 \Rightarrow I_3 = -\frac{2}{17} A$

$$\therefore \quad I_1 = +\frac{4}{17} A, \qquad I_2 = \frac{6}{17} A, \qquad I = I_1 + I_2 = \frac{10}{17} A$$

Current in branch $AB = I_1 = \frac{4}{17} A$,

Current in branch $AC = I_1 - I_3 = \frac{6}{17} A$

Current in branch $AD = I_2 = \frac{6}{17} A$

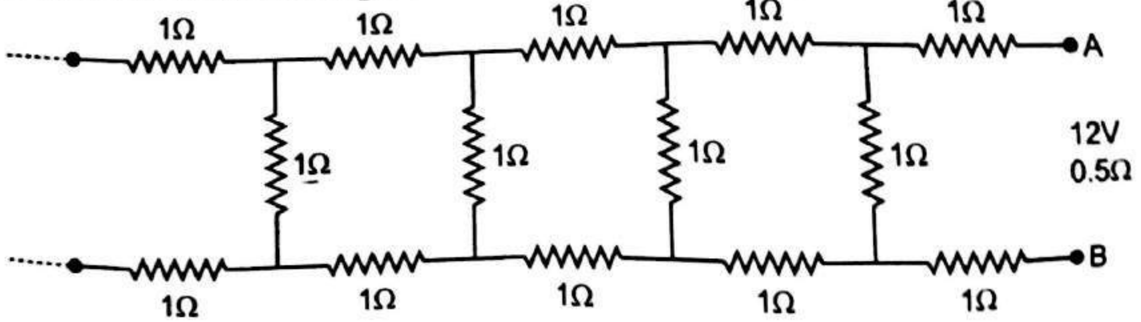
Current in branch $DC = I_2 + I_3 = \frac{4}{17} A$

Current in branch $BD = I_3 = -\frac{2}{17} A$

i.e., Current in branch $BD = \frac{2}{17} A$ and is direction is from D to B.

Current in cell $= I_1 + I_2 = \frac{10}{17} A$.

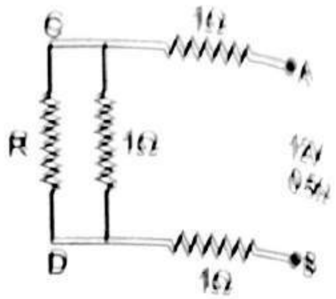
19. Determine the current drawn from a 12 V supply with internal resistance 0·5 Ω by the infinite network shown in fig. Each resistor has 1 Ω resistance.



Sol. Let R be equivalent resistance between A and B.

As $\infty \pm 1 = \infty$, resistance between C and D is the same as between A and B, then equivalent resistance of R and $1\,\Omega$ in parallel

$$R_1 = \frac{R \times 1}{R + 1}$$



$\therefore$ Net resistance between A and B will be

$$R_{AB} = R_1 + 1 + 1$$

Therefore, by hypothesis $R_1 + 1 + 1 = R$

$$\Rightarrow \quad \frac{R}{R+1} + 2 = R$$

$$\Rightarrow \quad R + 2(R+1) = R(R+1)$$

$$\Rightarrow \quad 3R + 2 = R^2 + R$$

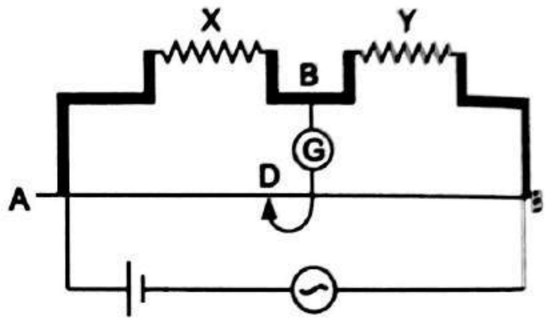
$$\Rightarrow \quad R^2 - 2R - 2 = 0$$

$$\Rightarrow \quad R = \frac{2 \pm \sqrt{4 - 4 \times 1 \times (-2)}}{2} = \frac{2 \pm \sqrt{12}}{2} = (1 + \sqrt{3})\,\Omega$$

$$= 1 + 1.732 = 2.732\,\Omega$$

Current drawn $I = \frac{12}{2.732 + 0.5} = \frac{12}{3.232} = \mathbf{3.7\,A}$

20. **(a) In a meter bridge the balance point is found to be at 39.5 cm from the end A, when the resistance *Y* is of 12.5 Ω. Determine the resistance of *X*. Why are the connections between resistors in a Wheatstone or meter bridge made of thick copper strips?**



(b) Determine the balance point of the bridge if *X and Y* are interchanged.

(c) What happens if the galvanometer and cell are interchanged at the balance point of the bridge? Would the galvanometer show any current?

Sol. (*a*) The condition of balance of Wheatstone's bridge is

$$\frac{X}{Y} = \frac{l}{100 - l}$$

Given $l = 39.5$ cm

$$\Rightarrow \quad X = \frac{l}{100 - l} Y = \frac{39.5}{60.5} \times 12.5\,\Omega = 8.2\,\Omega$$

The connections between resistors in a meter bridge are made of thick copper strips to minimise the resistance of connection wires, because these resistances have not been accounted in the formula.

(*b*) When X and Y are interchanged, then l and $(100 - l)$ will also be interchanged, so new balancing length $l' = 100 - l = 100 - 39.5 = 60.5$ cm

(*c*) If the galvanometer and the cell are interchanged, the position of balance point remains unchanged, but the sensitivity of the bridge changes. Now the galvanometer shows a constant deflection.

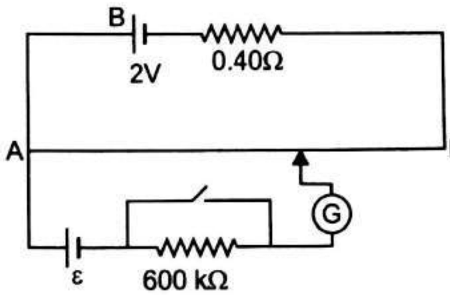
21. In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35.0 cm length of wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell ?

Sol. Given $\varepsilon_1 = 1.25$ V, $l_1 = 35.0$ cm, $l_2 = 63.0$ cm, $\varepsilon_2 = ?$

We have $$\frac{\varepsilon_2}{\varepsilon_1} = \frac{l_2}{l_1}$$

$$\Rightarrow \quad \varepsilon_2 = \left(\frac{l_2}{l_1}\right) \cdot \varepsilon_1 = \left(\frac{63.0}{35.0}\right) \times 1.25 \text{ V} = \mathbf{2.25 \text{ V}}$$

22. Figure shows a potentiometer with a cell of 2.0 V and internal resistance of 0.40 Ω 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 current is 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 ε 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?

Sol. (*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 = $1 \cdot 02$ V

l_s = balancing with length standard cell = $67 \cdot 3$ cm

l = balancing length with cell of unknown emf = $82 \cdot 3$ cm

∴ Unknown emf $$\varepsilon = \frac{(82 \cdot 3 \text{ cm})}{(67 \cdot 3 \text{ cm})} \times 1 \cdot 02 \text{ V} = 1 \cdot 25 \text{ V}$$

(*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.

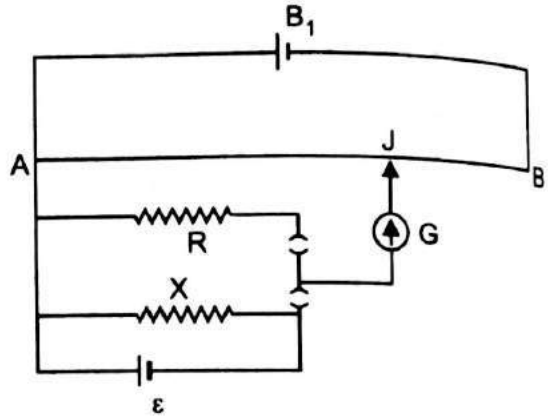
(*c*) The balance point is not affected by the presence of high resistance because in balanced-position there is no current in cell-circuit (secondary circuit).

(*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 (ε) of secondary circuit.

(f) No, the circuit will have to be modified by putting variable resistance (R) in series with the driver cell B; 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.

23. Figure shows a potentiometer circuit for comparison of two resistances. The balance point with a standard resistance $R = 10\cdot0\,\Omega$ 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.



Sol. In first case resistance R is in parallel with cell ε, so p.d. across $R = \varepsilon$

i.e., $\varepsilon = RI$ ...(*i*)

In second case X is in parallel with cell ε, so p.d. across $X = \varepsilon$

i.e., $\varepsilon = XI$ ...(*ii*)

Let k be the potential gradient of potentiometer wire. If l_1 and l_2 are the balancing length corresponding to resistance R and X 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

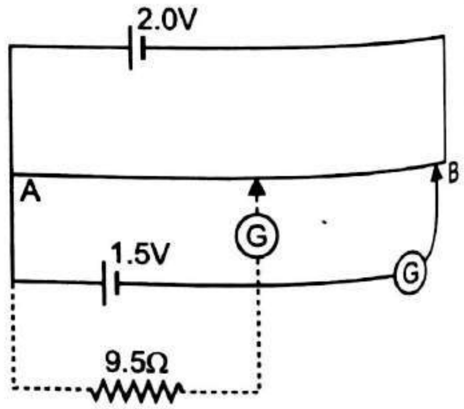
$$\frac{X}{R} = \frac{l_2}{l_1} \Rightarrow X = \frac{l_2}{l_1}R$$

Here $R = 10\cdot0\,\Omega$, $l_1 = 58\cdot3$ cm, $l_2 = 68\cdot5$ cm

$$\therefore \quad X = \frac{68\cdot5}{58\cdot3} \times 10\cdot0 = 11\cdot75\,\Omega$$

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 emf (ε).

24. Fig. shows a $2\cdot0\,V$ potentiometer used for the determination of internal resistance of a 1.5 V cell. The balance point of the cell in open circuit is 76.3 cm. When a resistor of 9.5 Ω is used in the external circuit of the cell, the balance point shifts to 64.8 cm length of the potentiometer wire. Determine the internal resistance of the cell.



Sol. Internal resistance of the cell

$$r = \left(\frac{\varepsilon}{V} - 1\right)R = \left(\frac{l_1}{l_2} - 1\right)R$$

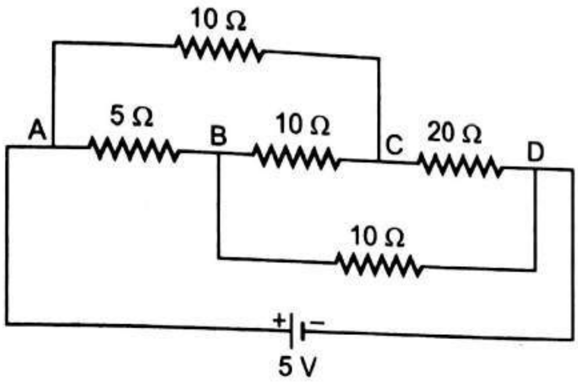
Here, $l_1 = 76\cdot3$ cm, $l_2 = 64\cdot8$ cm, $R = 9\cdot5\,\Omega$

$$\therefore \quad r = \left(\frac{76\cdot3}{64\cdot8} - 1\right) \times 95\,\Omega = \frac{(76\cdot3 - 64\cdot8)}{64\cdot8} \times 9\cdot5\,\Omega = \frac{11\cdot5 \times 9\cdot5}{64\cdot8} = 1\cdot7\,\Omega$$

Previous Years' Numericals

1. Calculate the value of the current drawn from a 5 V battery in the circuit as shown.

[CBSE (F) 2013]



Sol. In case of balanced Wheatstone bridge, no current flows through the resistor 10Ω between points B and C.

The resistance of arm ACD, $R_{S_1} = 10 + 20 = 30\Omega$

The resistance of arm ABD, $R_{S_2} = 5 + 10 = 15\Omega$

Equivalent resistance $R_{eq} = \dfrac{R_{S_1} \times R_{S_2}}{R_{S_1} + R_{S_2}}$

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

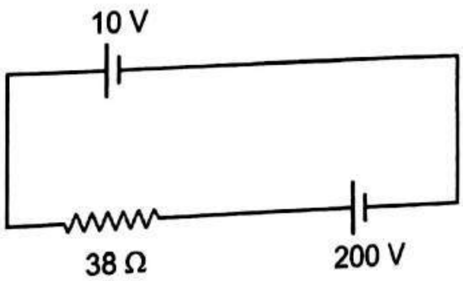
$= 10\Omega$

Current drawn from the source,

$$I = \frac{V}{R_{eq}} = \frac{5}{10} = \frac{1}{2}A = 0\cdot5A$$

2. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in the figure. Find the value of the current in circuit.

[CBSE Delhi 2013]



Sol. If cells are in oppositions

$E_{net} = E_1 - E_2$

$= (200 - 10)$ V

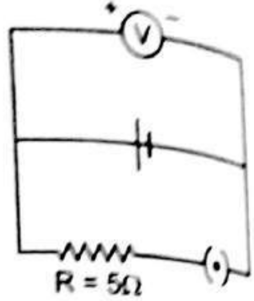
$= 190$ V

Current $I = \dfrac{E_{net}}{R_{eq}} = \dfrac{190}{38} = 5A$

$I = \dfrac{V}{R}$

$I = \dfrac{E_{net}}{R}$

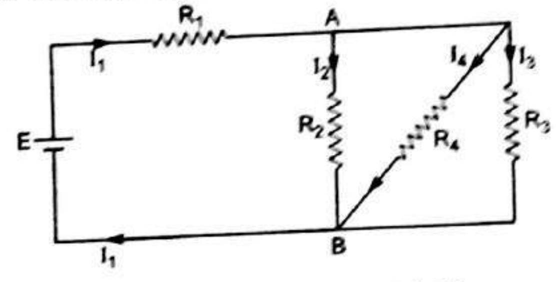
3. **The reading on a high resistance voltmeter, when a cell is connected across it, is 2·2 V. When the terminals of the cell are also connected to a resistance of 5 Ω as shown in the circuit, the voltmeter reading drops to 1·8 V. Find the internal resistance of the cell.** *[CBSE (AI) 2010]*



Sol. Given $E = 2.2\text{ V},\ V = 1.8\text{ V},\ R = 5\ \Omega$

$\therefore$ Internal resistance, $r = \left(\dfrac{E}{V} - 1\right)R = \left(\dfrac{2.2}{1.8} - 1\right) \times 5\Omega = \dfrac{10}{9}\Omega = 1.1\Omega$

4. **In the circuit shown, $R_1 = 4\ \Omega$, $R_2 = R_3 = 15\ \Omega$, $R_4 = 30\ \Omega$ and $E = 10$ V. Calculate the equivalent resistance of the circuit and the current in each resistor.** *[CBSE (Delhi) 2011]*



Sol. 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

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

$\Rightarrow \qquad R = 6\Omega$

R_1 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 I_2, I_3 and I_4.

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

Also, $I_2 R_2 = I_3 R_3 = I_4 R_4$

$\Rightarrow \quad I_2 \times 15 = I_3 \times 15 = I_4 \times 30$

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

Substituting values of I_2, I_3 in (2), we get

$2I_4 + 2I_4 + I_4 = 1$ A $\qquad \Rightarrow \mathbf{I_4 = 0.2\ A}$

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

Thus, $\qquad I_1 = 1\text{A},\ I_2 = I_3 = 0.4\text{A}$ and $I_4 = 0.2\text{A}$

5. **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.** *[CBSE (AI) 2007; 2005]*

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

Value of second digit (black ring) = 0

Multiplier (yellow ring) = 10^4

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

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

6. 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.

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

From relation,

$$R_T = R_{27}\,[1 + \alpha (T_2 - 300)]$$

$\Rightarrow$ $$1.2R = R\,[1 + 2.0 \times 10^{-4}\,(T_2 - 300)]$$

$\Rightarrow$ $$1 + 2.0 \times 10^{-4}\,(T_2 - 300) = 1.2$$

or $$2.0 \times 10^{-4}\,(T_2 - 300) = 0.2$$

$$T_2 - 300 = \frac{0.2}{2.0 \times 10^{-4}}$$

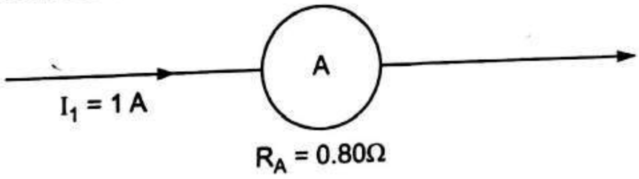
$$T_2 = 1000 + 300 = \mathbf{1300\ K}$$

7. An ammeter of resistance 0.80 Ω can measure current upto 1.0 A.

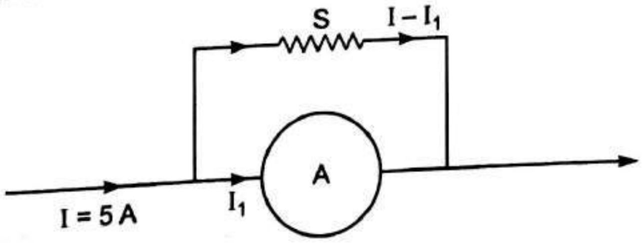
(i) What must be the value of shunt resistance to enable the ammeter to measure current upto 5.0 A?

(ii) What is the combined resistance of the ammeter and the shunt? ***[CBSE Delhi 2013]***

Sol. (i) Fig. shows an ammeter of resistance 0.80 Ω that measure current of 1.0



If a shunt 'S' is connected in parallel, a current $(I - I_1)$ flows through 'S'.



For parallel combination of resistors

$$I_1 \cdot R_A = (I - I_1)\,S$$

$$1 \times 0.80 = (5 - 1)\,S$$

$$\therefore\ S = \frac{0.8}{4} = 0.2\,\Omega$$

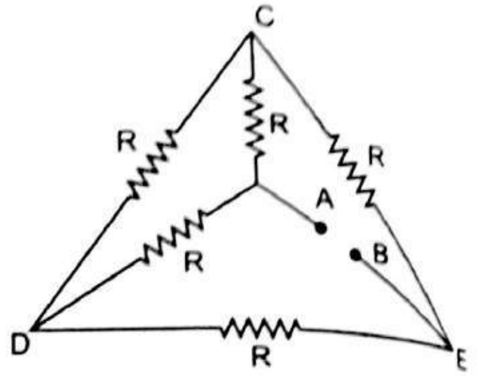
(ii) Combined resistance of the ammeter and the shunt

$$\frac{1}{R} = \frac{1}{R_A} + \frac{1}{S} \quad \Rightarrow \quad R = \frac{R_A \times S}{R_A + S} = \frac{0.8 \times 0.2}{0.8 + 0.2}$$

$$= 0.16\ \Omega$$

8. **(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 $R = 2\,\Omega$. *[CBSE (AI) 2008]*



Sol. (i) The equivalent circuit is shown in fig. It is 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

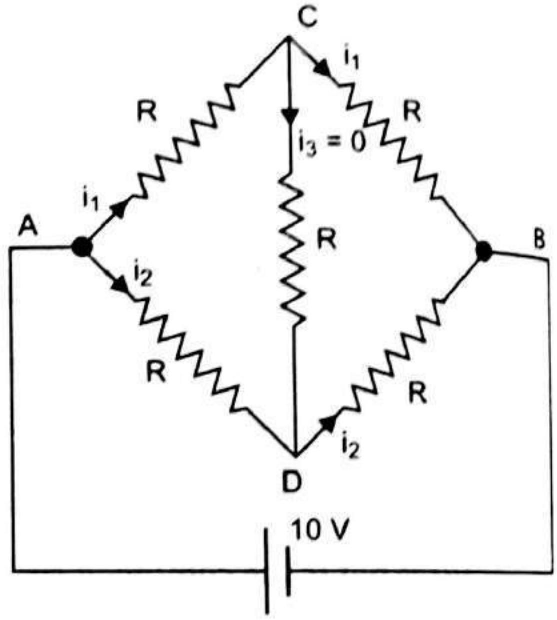
$$\frac{1}{R_{AB}} = \frac{1}{2R} + \frac{1}{2R} = \frac{2}{2R}$$

$\Rightarrow$ $R_{AB} = R = 2\,\Omega$

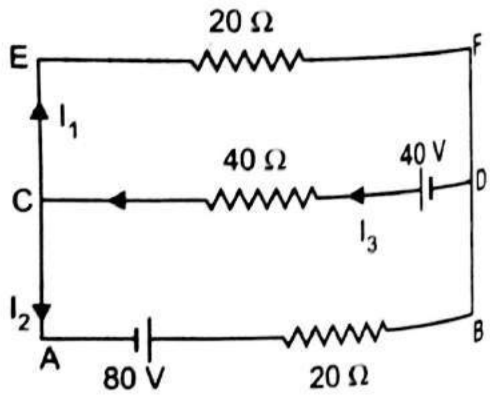
(ii) In arm CD, there **is no current,** $I_{CD} = 0$, Current through arm ACB,

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

$$= \frac{10}{2R} = \frac{10}{2 \times 2} = \frac{10}{4} = \mathbf{2{\cdot}5\ A}$$



9. **Use Kirchhoff's laws to determine the value of current I_1 in the given electrical circuit.** *[CBSE Delhi 2007]*



Sol. From Kirchhoff's first law at junction C

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

Applying Kirchhoff's second law in mesh $CDFEC$

$$40I_3 - 40 + 20I_1 = 0 \text{ or } 20(2I_3 + I_1) = 40$$

$\Rightarrow$ $I_1 + 2I_3 = 2$ ...(ii)

Applying Kirchhoff's second law to mesh $ABFEA$

$$80 - 20I_2 + 20I_1 = 0$$

$\Rightarrow$ $20(I_1 - I_2) = -80$

$\Rightarrow$ $I_2 - I_1 = 4$ ...(iii)

Substituting value of I_3 from (i) in (ii), we get

$$I_1 + 2(I_1 + I_2) = 2$$

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

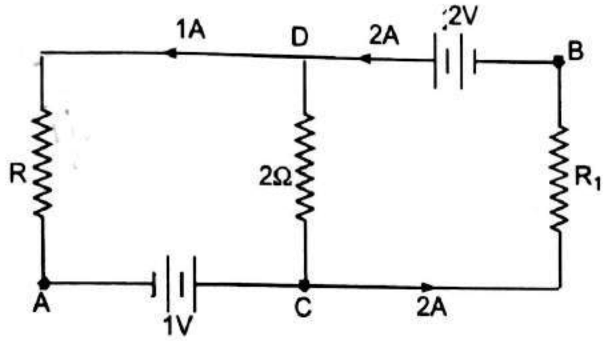
Multiplying equation (iii) by 2, we get

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

Subtracting (v) from (4), we get

$$5I_1 = -6 \quad \Rightarrow \quad I_1 = -\frac{6}{5}\text{ A} = -\mathbf{1{\cdot}2\ A}$$

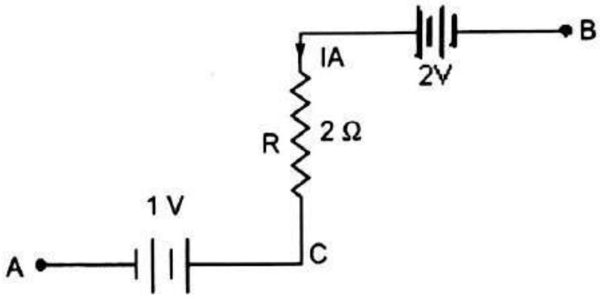
10. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. *[CBSE (AI) 2011]*



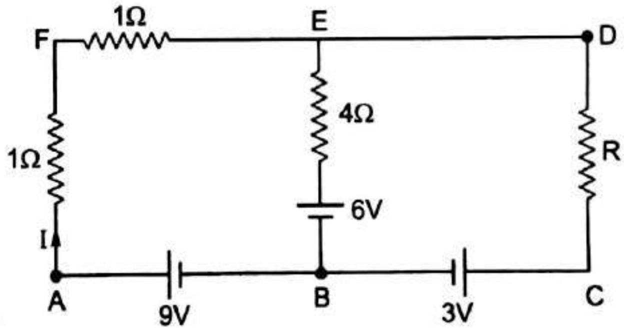
Sol. Current in 2 Ω resistor is 1A. Applying Kirchhoff's II law $V_A + 1 + 2\times 1 - 2 = V_B$.

As $V_A = 0$

$\therefore \quad V_B = 1 + 2 - 2 = 1\text{V}$.



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



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

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

$$\Rightarrow \quad I = 1.5\text{ A} \qquad \ldots(i)$$

For loop BCDEB

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

$$\therefore \quad IR = 3$$

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

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

12. 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, 2008C]*

Sol. 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

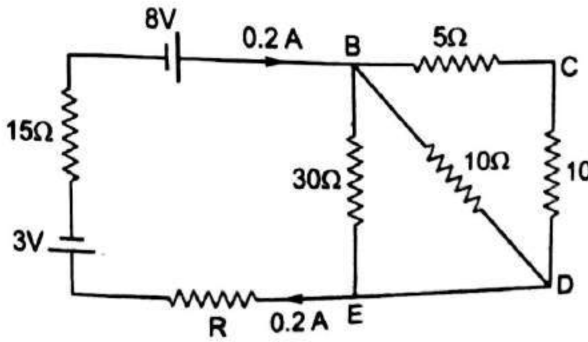
$$5\times 0.2 + R\times 0.2 + 15\times 0.2 = 8 - 3$$

$$\Rightarrow \quad R = 5\Omega$$

Hence

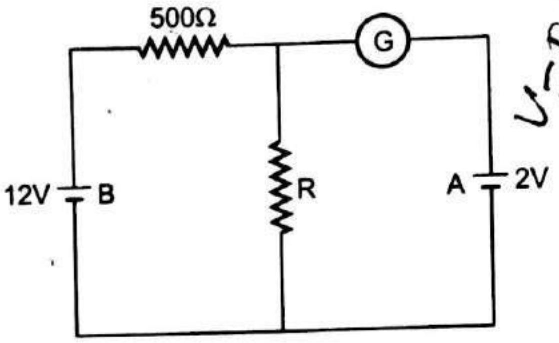
$$V_{BE} = IR_{BE}$$

$$= 0.2\times 5 = 1\text{ volt}$$



13. 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]



V = IR

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

Current in the circuit $I = \dfrac{\varepsilon}{R_1 + R_2} = \dfrac{12.0V}{500 + R}$

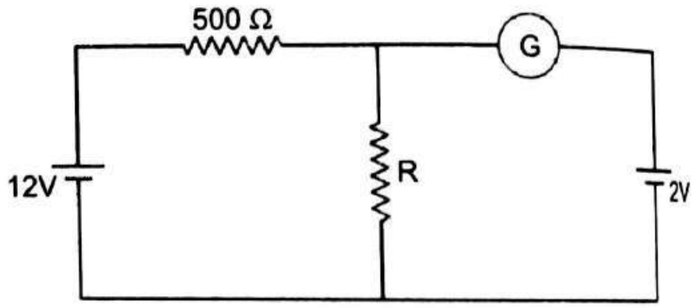
and $V = IR = 2.0V$

$$\left(\frac{12.0V}{500 + R}\right) R = 2.0$$

$$12R = 1000 + 2R$$

$$10R = 1000$$

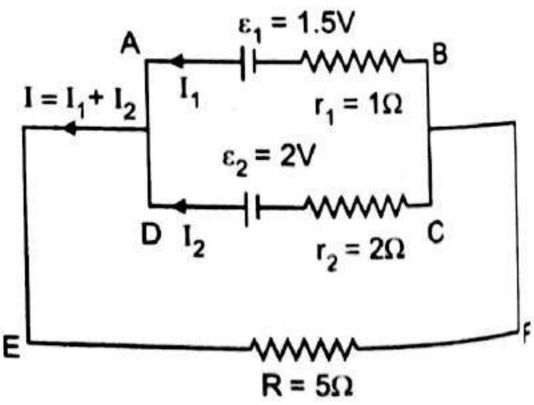
$$\Rightarrow R = 100\ \Omega$$



14. 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 5 Ω.

(i) Draw the circuit diagram.

(ii) Using Kirchhoff's laws, calculate the current through each branch of the circuit and potential difference across 5 Ω resistor. *[CBSE (AI) 2005]*



Sol. (*a*) The circuit is shown in figure.

(*b*) Supppose I_1 and I_2 are current drawn from cells E_1 and E_2 respectively, then according to Kirchhoff's junction law, current in $R = 5\,\Omega$ is $I = I_1 + I_2$.

Applying Kirchhoff's second law to mesh $ABFEA$

$$1 \times I_1 + 1{\cdot}5 - 5(I_1 + I_2) = 0$$

$$\Rightarrow \quad 6I_1 + 5I_2 = 1{\cdot}5 \qquad \ldots(i)$$

Applying Kirchhoff's second law to mesh $CDEFC$

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

$$\Rightarrow \quad 5I_1 + 7I_2 = 2 \qquad \ldots(ii)$$

Solving equation (1) and (2), we get

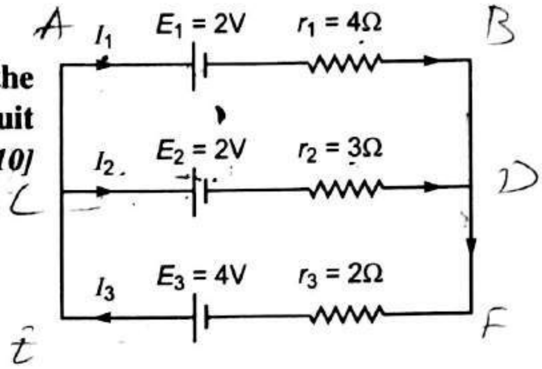
$$I_1 = \frac{1}{34}A,\ I_2 = \frac{9}{34}A$$

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

Potential difference across $R = 5\,\Omega$ resistor

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

of electronic charge e is estimated as $1\cdot6 \times 10^{-19}$ C.



15. State Kirchhoff's rules. Use these rules to write the expressions for the currents I_1, I_2 and I_3 in the circuit diagram shown. ***[CBSE (AI) 2010]***

Sol. From Kirchhoff's first law

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

For applying Kirchhoff's second law to mesh $ABDC$

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

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

Applying Kirchoff's II law to mesh $ABCEA$

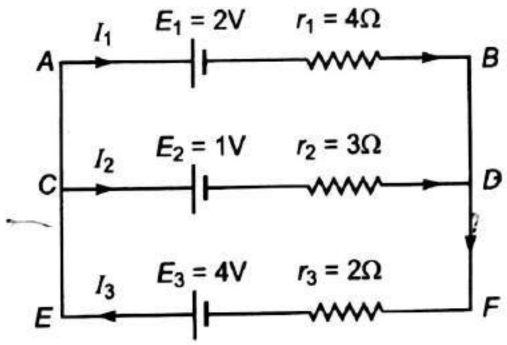
$$-2 - 4I_1 - 2I_3 + 4 = 0$$

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

Using (1) we get

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

$$\text{or} \qquad 3I_1 + I_2 = 1 \qquad \ldots(iii)$$



Solving (*ii*) and (*iii*), we get

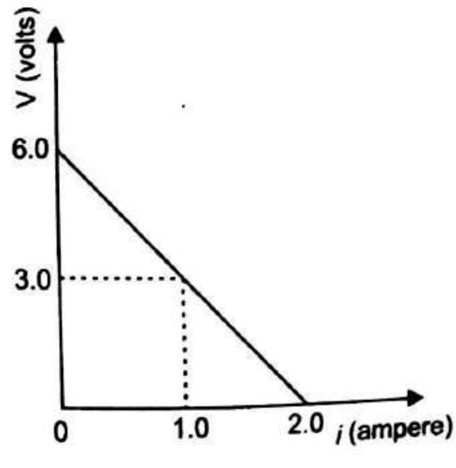
$$I_1 = \frac{2}{3}A, \quad I_2 = 1 - 3I_1 = \frac{7}{13}A$$

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

16. The following graph shows the variation of terminal potential difference V, across a combination of three cells in series to a resistor, versus current i :

(*i*) calculate the emf of each cell.

(*ii*) for what current i, will the power dissipation of the circuit be maximum? ***[CBSE (AI) 2008]***



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

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

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

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

From fig., when $i = 0$, $V = 6\cdot0$ V

∴ From (*i*),

$$6 = 3\varepsilon - 0 \qquad \Rightarrow \qquad \varepsilon = \frac{6}{3} = 2\text{ V}$$

i.e., emf of each cell, ε = 2 V

(*ii*) For maximum power dissipation, the effective internal resistance of cells must be equal to external resistance.

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From fig., when $V = 0, i = 2\cdot0$ A.

$\therefore$ Equation (*i*) gives

$$0 = 3\varepsilon - 2\cdot0(r_{int}) \Rightarrow \qquad r_{int} = \frac{3\varepsilon}{2\cdot0} = \frac{3\times2}{2\cdot0} = 3\,\Omega$$

$\therefore$ For maximum power, external resistance,

$$R = r_{int} = 3\,\Omega$$

Current in circuit, $i = \dfrac{3\varepsilon}{R + r_{int}} = \dfrac{3\times2}{3+3} = \mathbf{1\cdot0\ A}$

(*i*) Thus, emf of each cell, $\varepsilon = 2$ V

and (*ii*) For maximum power dissipation, current in circuit = **1·0 A**

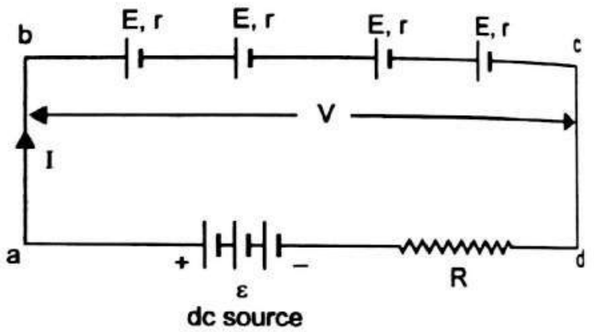
17. *n*-identical cells, each of emf ε, internal resistance r connected in series are charged by a dc source of emf ε′, using a resistance *R*.

(*i*) Draw the circuit arrangement.

(*ii*) Deduce expressions for (*a*) the charging current and (*b*) the potential difference across the combination of cells. ***[CBSE Delhi 2008]***

Sol. (*i*) The circuit arrangement is shown in fig.

(*ii*) 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

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

$$\Rightarrow \qquad V = \varepsilon' - IR$$

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

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

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

18. A series battery of 6 lead accumulators each of emf 2·0 V and internal resistance of 0·5Ω is charged by a 100 V dc supply. What series resistance should be used in the charging circuit in order W limit the current to 8 A? Using the required resistor, obtain (*i*) the power supplied by dc source and (*ii*) the power dissipated as heat. ***[CBSE (AI) 2005]***

Sol. Net emf of lead accumulators, $\varepsilon = 6\times2\cdot0 = 12\cdot0$ V

Net internal resistance $r_{in} = 6\times0\cdot5 = 3\,\Omega$

Charging current $I = 8$ A

Charging voltage, $\varepsilon' = 100$ volt

If *R* is series resistance, then

$$I = \frac{\varepsilon' - \varepsilon}{R + r_{in}}$$

$$\Rightarrow \quad 8 = \frac{100 - 12}{R + 3} \quad \Rightarrow \quad 8(R + 3) = 88$$

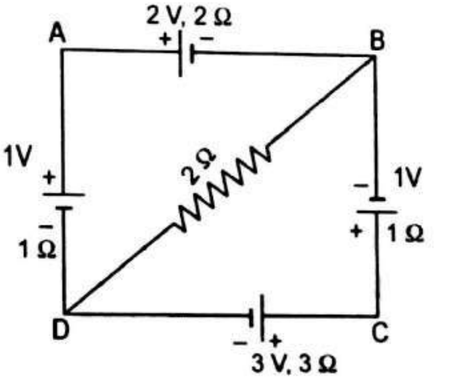
$$\text{or} \quad 8R = 88 - 24 \quad \Rightarrow \quad R = \frac{88 - 24}{8} = \frac{64}{8} = \mathbf{8\,\Omega}$$

Power supplied by dc source = $\varepsilon' I = 100 \times 8 =$ **800 W**

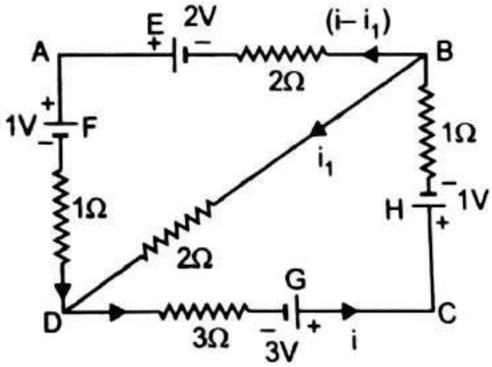
Power dissipated as heat $= I^2 \, (R + r_{in})$

$$= (8)^2 \, (8 + 3) = 64 \times 11 \text{ W} = \mathbf{704 \text{ W}}$$

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



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



Applying Kirchhoff's second law to mesh *BADB*,

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

$$\Rightarrow \quad 3i - 5i_1 = 1 \qquad \ldots(i)$$

Applying Kirchhoff's law to mesh *DCBD*,

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

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

$$\text{or} \quad 2i + i_1 = 1 \qquad \ldots(ii)$$

Multiplying equation (*ii*) with 5, we get

$$10i + 5i_1 = 5 \qquad \ldots(iii)$$

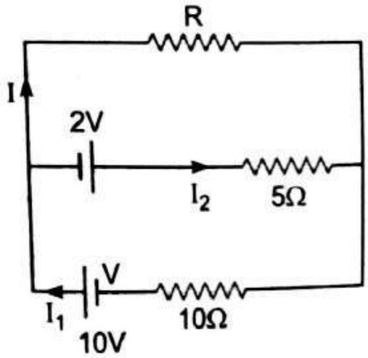
Adding (*i*) and (*iii*), we get

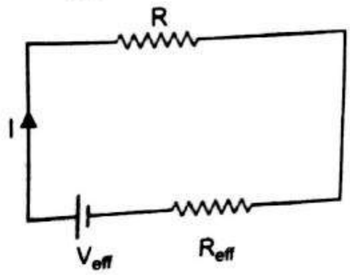
$$13i = 6 \quad \Rightarrow \quad i = \frac{6}{13} \text{ A}$$

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

Potential difference between *B* and *D* is

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





20. Two cells of voltage 10V and 2V and internal resistances 10Ω and 5W respectively, are connected in parallel with the positive end of 10V battery connected to negative pole of 2V battery (Fig. 3.8). Find the effective voltage and effective resistance of the combination. ***[NCERT Exemplar]***

Sol. Applying Kirchhoff's junction rule:

$$I_1 = I + I_2$$

Kirchhoff's loop rule gives:

$$10 = IR + 10I_1 \quad ...(i)$$

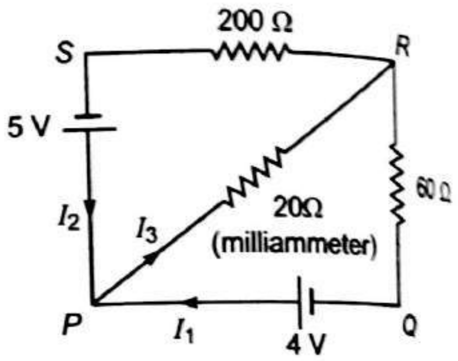
$$2 = 5I_2 - RI = 5(I_1 - I) - RI$$

$$4 = 10I_1 - 10I - 2RI \quad ...(ii)$$

From (*i*) – (*ii*) we have $6 = 3RI + 10I$ or, $2 = I\left(R + \frac{10}{3}\right)$

$2 = (R + R_{eff})I$ comparing with $V_{eff} = (R + R_{eff})I$ and $V_{eff} = 2V$; $R_{eff} = \frac{10}{3}\Omega$

21. State Kirchhoff's rules. Apply these rules to the loops *PRSP* and *PRQP* to write the expressions for the currents I_1, I_2, and I_3 in the given circuit. *[CBSE (AI) 2010]*



Sol. From Kirchhoff's I law $I_3 = I_1 + I_2$ ...(*i*)

Applying Kirchhoff's II law to loop *PRSP*

$$-20I_3 - 200I_2 + 5 = 0$$

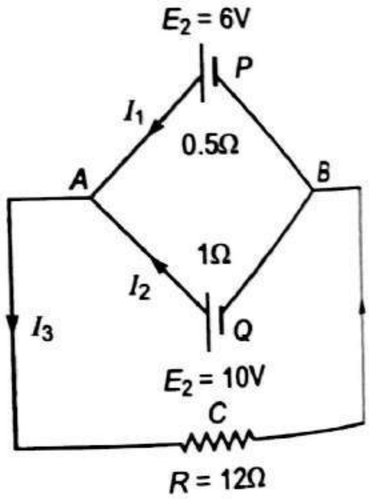
$$\Rightarrow \quad 40I_2 + 4I_3 = 1 \quad ...(ii)$$

Applying Kirchhoff's II law to loop *PRQP*

$$-20I_3 - 60I_1 + 4 = 0$$

$$\Rightarrow \quad 15I_1 + 5I_3 = 1 \quad ...(iii)$$

22. State Kirchhoff's rules. Apply Kirchhoff's rules to the loops *ACBPA* and *ACBQA* to write the expressions for the currents I_1, I_2 and I_3 in the network.



Sol. From Kirchhoff's law

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

Applying Kirchhoff's II law to loop *ACBPA*

$$-12I_3 - 0.5I_1 + 6 = 0$$

$$0.5I_1 + 12I_3 = 6 \quad ...(ii)$$

Applying Kirchhoff's II law to loop *ACBQA*

$$-12I_3 - 1I_2 + 10 = 0$$

$$I_2 + 12I_3 = 10 \quad ...(iii)$$

23. Two cells of emf 1 *V*, 2 *V* and internal resistances 2 Ω and 1 Ω 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?

Sol. For parallel combination,

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

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

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,

$r_1 = 2\,\Omega$, $r_2 = 1\,\Omega$, $R_{ext} = R$

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

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

$$= \frac{(1\times 1 + 2\times 2)/(2+1)}{R + (2\times 1)/(2+1)} = \frac{5/3}{R + \frac{2}{3}} = \frac{5}{3R+2} \qquad \ldots(ii)$$

Given $I_1 = I_2$

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

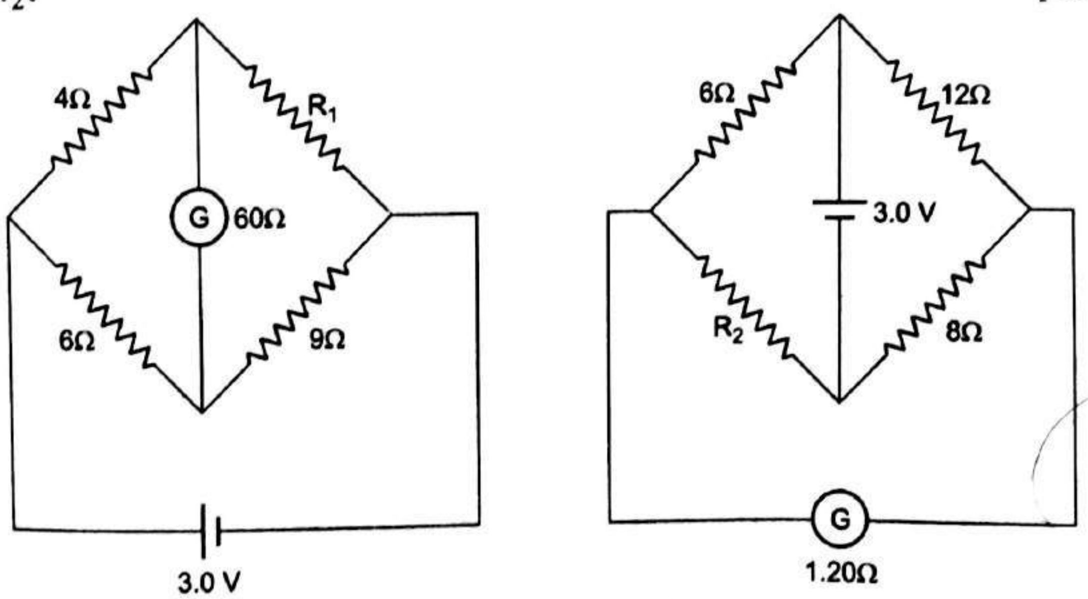
$$4R = 9$$

$$\Rightarrow \quad R = \frac{9}{4} = \mathbf{2\cdot 25\,\Omega}$$

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.

24. 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 R_1 / R_2. ***[CBSE (AI) 2013]***



Sol. For balanced Wheatone bridge, if no current flows through the galvanometer

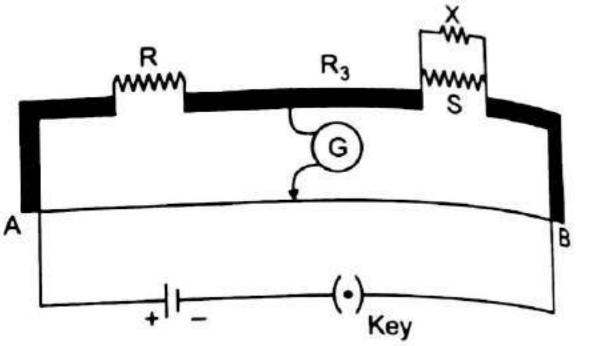
$$\frac{4}{R_1} = \frac{6}{9} \Rightarrow R_1 = \frac{4\times 9}{6} = 6\,\Omega$$

For another current

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

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

25. When two known resistances R and S are connected in the left and right gaps of a meter bridge, the balance point is found at a distance l_1 from the zero end of the meter bridge wire. An unknown resistance X is now connected in parallel to the resistance S and the balance point is now found at a distance l_2 from the zero end of the meter bridge wire. Obtain a formula for X in terms of l_1, l_2 and S.



[CBSE Delhi 2010, CBSE (AI) 2009, 2004C]

Sol. In first case

$$\frac{R}{S}=\frac{l_1}{100-l_1} \quad \ldots(i)$$

When X and S are in parallel, let resistance

$$S'=\frac{XS}{X+S}$$

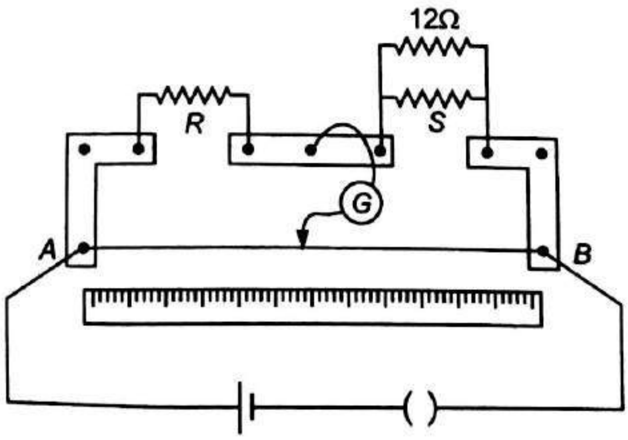
In second case $$\frac{R}{\left(\frac{XS}{X+S}\right)}=\frac{l_2}{100-l_2} \quad \ldots(ii)$$

Dividing (*ii*) by (*i*), we get

$$\frac{X+S}{X}=\frac{l_1}{l_2}\left(\frac{100-l_1}{100-l_2}\right)$$

$$\Rightarrow \qquad X=\frac{S}{\frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)-1}$$

26. In a meter bridge, the null point is found at a distance of 40 cm from A. If a resistance of $12\,\Omega$ is connected in parallel with S, the null point occurs at $50\cdot0$ cm from A. Determine the values of R and S. ***[CBSE Delhi 2010]***



Sol. In first case $l_1=40$ cm

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

In second case when S and $12\,\Omega$ are in parallel balancing length $l_2=50$ cm, so

$$S'=\frac{12S}{12+S} \quad \ldots(ii)$$

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

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

Substituting this value in (ii), we get

$$S' = \frac{12 \times \left(\frac{3}{2}R\right)}{12 + \left(\frac{3}{2}R\right)} = \frac{18R}{12 + \frac{3}{2}R}$$

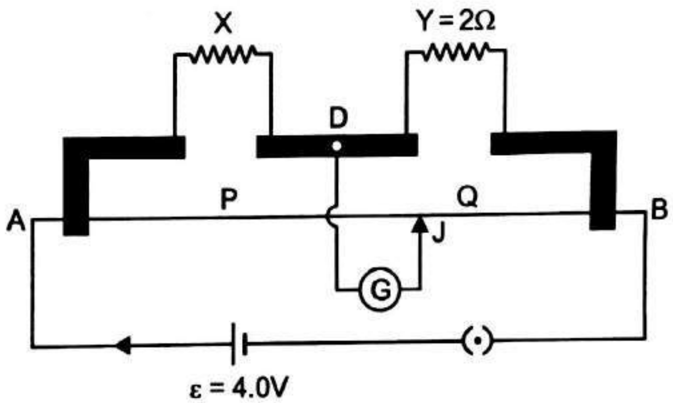
Also from equation (iii), $S' = R$

$$\therefore \quad \frac{18R}{12 + \frac{3}{2}R} = R \Rightarrow 18 = 12 + \frac{3}{2}R$$

$$\Rightarrow \quad \frac{3}{2}R = 6 \quad \text{or} \quad R = 4\,\Omega$$

$$\therefore \quad S = \frac{3}{2}R = \mathbf{6\,\Omega}$$

27. In a practical Wheatstone bridge circuit, wire AB is 2m long. When resistance $Y = 2\cdot0\,\Omega$ 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 $AB = 0\cdot01\,\Omega/\text{cm}$. Also calculate the current drawn by the cell of emf 4·0 V and negligible internal resistance.



Sol. P = Resistance of wire AJ

$= (1.20 \times 100\,\text{cm}) \times (0.01\,\Omega/\text{cm}) = 1.20\,\Omega$

Q = Resistance of wire BJ

$= [(2 - 1.20)\,\text{m} \times 100] \times$ resistance per cm

$= 0.80 \times 100\,\text{cm} \times 0.01\,\Omega = 0.80\,\Omega$

$Y = 2.0\,\Omega$, $X = ?$

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

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

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)

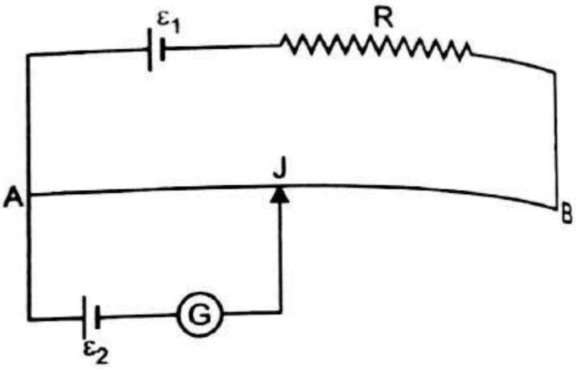
$$R_2 = 2 \times 100 \times 0.01 = 2.0\,\Omega$$

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

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

current drawn from battery $\quad I = \frac{\varepsilon}{R_{AB}} = \frac{4.0}{10/7} = \mathbf{2.8\ A}$

28. In the given circuit diagram AB is a uniform wire of resistance $10\,\Omega$ and length 1 m. It is connected to a series arrangement of cell ε_1, of emf $2 \cdot 0$ V and negligible internal resistance and a resistor R terminal A is also connected to an electrochemical cell ε_2 of emf 100 mV and a galvanometer G. In this set-up a balancing point is obtained at 40 cm mark from A. Calculate the value of resistance R. If R_2 were to have an emf of 300 mV, where will you expect the balancing point to be.



Sol. If k is potential gradient and l_1 the balancing length for cell ε_2, then we have

$$\varepsilon_2 = kl_1$$

$$\Rightarrow \quad 100\,\text{mV} = k \times 40\,\text{cm}$$

$$\Rightarrow \quad k = \frac{100}{40}\,\text{mV/cm} = 2 \cdot 5 \times 10^{-3}\ \text{V/cm} = 0 \cdot 25\ \text{V/m} \qquad ...(i)$$

Current in primary circuit

$$I = \frac{\varepsilon_1}{R + R_{AB}} \qquad \text{where } R_{AB} \text{ is resistance of wire } AB$$

$$I = \frac{2 \cdot 0}{R + 10}$$

Potential difference across wire AB, $V_{AB} = I \times R_{AB} = \dfrac{2 \cdot 0}{R + 10} \times 10 = \dfrac{20}{R + 10}$

$\therefore$ Potential gradient $\quad k = \dfrac{V_{AB}}{L_{AB}} = \dfrac{20/(R+10)}{1} = \dfrac{20}{R + 10} \qquad ...(ii)$

Comparing (*i*) and (*ii*), we get

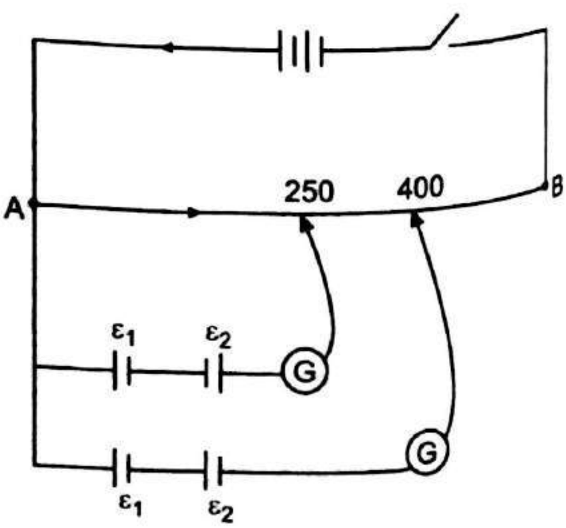
$$\frac{20}{R + 10} = 0 \cdot 25 \Rightarrow R + 10 = \frac{20}{0 \cdot 25}\,\Omega = \mathbf{80\,\Omega}$$

$$R = 80 - 10 = \mathbf{70\,\Omega}$$

Balancing length when $\varepsilon_2 = 300\,\text{mV} = 300 \times 10^{-3}\ \text{V} = 0 \cdot 3\ \text{V}$ is

$$\varepsilon_2' = kl_2 \Rightarrow 0 \cdot 3 = 0 \cdot 25 \times l_2 \Rightarrow l_2 = \frac{0 \cdot 3}{0 \cdot 25} = \mathbf{1 \cdot 2\ m}$$

29. 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. *[CBSE Delhi 2005]*



Sol. 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

$$\varepsilon_1 - \varepsilon_2 = kl_1$$

$$\varepsilon_1 + \varepsilon_2 = kl_2$$

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

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

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

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

30. 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?

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

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

When heaters are connected in series, current in circuit, $I = \dfrac{V}{R_1 + R_2} = \dfrac{200}{\frac{400}{3} + \frac{400}{6}} = 1\ A$

$\therefore$ Heat produced in 200 V, 300 W heater per second

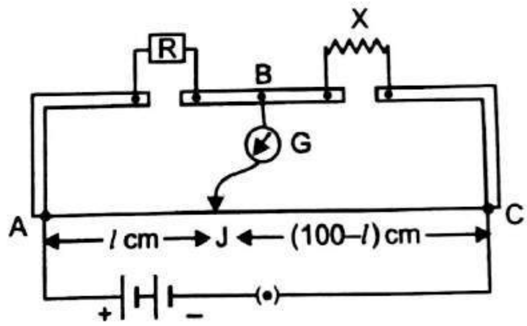
$$Q_1 = I^2 R_1 = (1)^2 \times \frac{400}{3} = 133\cdot 33\ Js^{-1}$$

Heat produced in 200 V, 600 W heater per second

$$Q_2 = I^2 R_2 = (1)^2 \times \frac{400}{6} = \mathbf{66\cdot 66\ Js^{-1}}$$

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

31. A resistance $R = 4\,\Omega$ is connected to one of the gaps in a meter bridge, which uses a wire of length 1 *m*. An unknown resistance $X > 4\,\Omega$ 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. ***[CBSE (AI) 2008]***



Sol. From 'meter bridge' formula

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

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

Given $R = 4\,\Omega$

$\therefore \quad X = \dfrac{(100 - l)}{l} \times 4\,\Omega \quad \ldots(i)$

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

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

Equating (*i*) and (*ii*)

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

Solving we get $l = 40$ cm

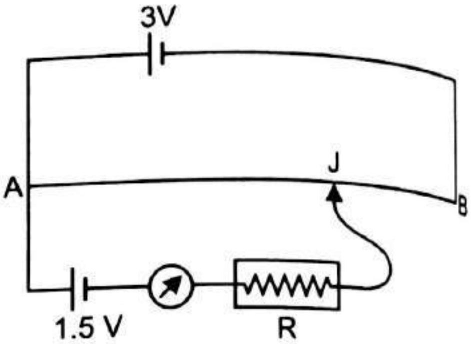
$\therefore$ Unknown resistance, $X=\frac{100-l}{l}\times 4\,\Omega=\frac{100-40}{40}\times 4\,\Omega \Rightarrow X=6\,\Omega$

33. 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 emf 1.5 *V* is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell by a cell of unknown emf, the balance point shifts to 80 *cm*.

(*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 your answer.



[CBSE Delhi 2008]

Sol. (*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 $\varepsilon_1 = 1\cdot 5\ V, l_1 = 60$ cm, $l_2 = 80$ cm

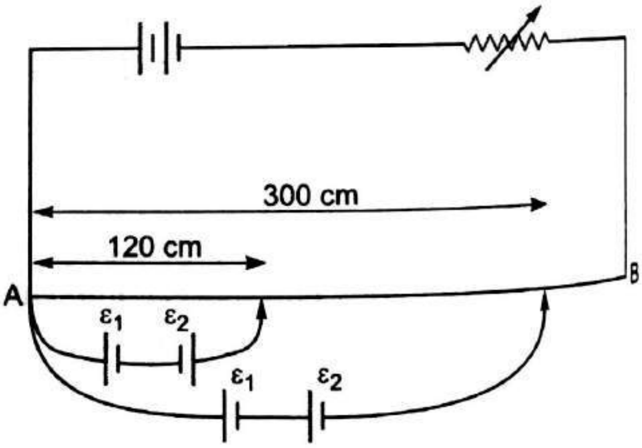
$$\therefore \quad \varepsilon_2=\frac{80}{60}\times 1\cdot 5\ V=\mathbf{2\cdot 0\ V}$$

(*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 1·5 *V*.

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

34. In the figure a long uniform potentiometer wire *AB* is having a constant potential gradient along its length. The null points for the two primary cells of emfs ε_1 and ε_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end A. Find (*i*) $\varepsilon_1 / \varepsilon_2$ and (*ii*) position of null point for the cell ε_1.

How is the sensitivity of a potentiometer increased? ***[CBSE Delhi 2012]***



Sol. (*i*) Let k = potential gradient in *V/cm*

$$\varepsilon_1+\varepsilon_2=300k \qquad ...(i)$$

$$\varepsilon_1-\varepsilon_2=120k \qquad ...(ii)$$

We can solve, $\frac{\varepsilon_1}{\varepsilon_2}=\frac{7}{3}$

(*ii*) From equation (*i*)

$$\varepsilon_1+\varepsilon_2=300k$$

$$\therefore \quad \varepsilon_1+\frac{3}{7}\varepsilon_1=300k \Rightarrow \quad \varepsilon_1=210k$$

Therefore, balancing length for cell ε_1 is 210 *cm*.

(*iii*) By decreasing potential gradient