Date: 20/10/2021

Q1. Power P is to be delivered to a device via transmission cables having resistance R_C. If V is the voltage across R and I the current through it, find the power wasted and how can it be reduced.

Q2. Why are alloys used for making standard resistance coils?

Q3. What are the advantages of the null-point method in a Wheatstone bridge? What additional measurements would be required to calculate $R_{unknown}$ by any other method?

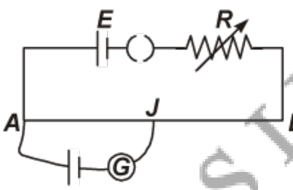
Q4. For wiring in the home, one uses Cu wires or Al wires. What considerations are involved in this?

Q5. The relaxation time τ is nearly independent of applied E field whereas it changes significantly with temperature T. First fact is (in part) responsible for Ohm's law whereas the second fact leads to variation of Á with temperature. Elaborate why?

Q6. Is the motion of a charge across junction momentum conserving? Why or why not?

Q7. What is the advantage of using thick metallic strips to join wires in a potentiometer?

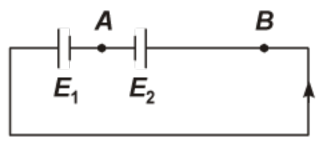
Q8. AB is a potentiometer wire (as shown in figure). If the value of R is increased, in which direction will the balance point J shift?



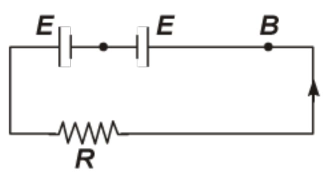
Q9. First a set of n equal resistors of R each are connected in series to a battery of e.m.f. E and internal resistance R. A current I is observed to flow. Then the n resistors are connected in parallel to the same battery. It is observed that the current is increased 10 times. What is 'n'?

Q10. A cell of e.m.f. 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.

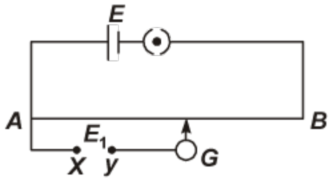
Q11. The circuit in figure shows two cells connected in opposition to each other. Cell E_1 is of e.m.f. 6V and internal resistance 2 Ω; the cell E_2 is of e.m.f. 4 V and internal resistance 8 Ω. Find the potential difference between the points A and B.



Q12. Two cells of same e.m.f. E but internal resistance r_1 and r_2 are connected in series to an external resistor R (as shown in figure). What should be the value of R so that the potential difference across the terminals of the first cell becomes zero.



Q13. While doing an experiment with potentiometer (as shown in figure) it was found that the deflection is one sided and (a) the deflection decreased while moving from one end A of the wire to the end *B*; (b) the deflection increased. while the jockey was moved towards the end *B*.



(a) Which terminal +or –ve of the cell E_1, is connected at *X* in case (i) and how is E_1 related to *E* ?

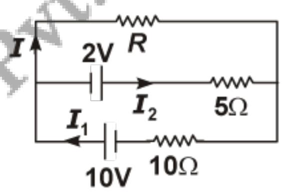
(b) Which terminal of the cell E_1 is connected at *X* in case (1 in 1)?

Q14. Two conductors are made of the same material and have the same length. Conductor *A* is a solid wire of diameter 1 mm. Conductor *B* is a hollow tube of outer diameter 2 mm and inner diameter 1 mm. Find the ratio of resistance R_A to R_B.

Q15. A room has A.C. run for 5 hours a day at a voltage of 220 V. The wiring of the room consists of Cu of 1 mm radius and a length of 10 m. Power consumption per day is 10 commercial units. What fraction of it goes in the joule heating in wires? What would happen if the wiring is made of aluminium of the same dimensions?

$[\rho_{cu} = 1.7 \times 10^{-8}_{\Omega m}, \quad \rho_{Al} = 2.7 \times 10^{-8}_{\Omega m}]$

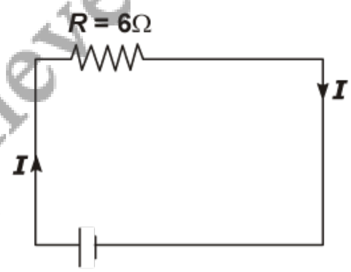
Q16. Two cells of voltage 10 V and 2 V and internal resistances 10 Ω and 5 Ω respectively, are connected in parallel with the positive end of 10 V battery connected to negative pole of 2 V battery (as shown in figure). Find the effective voltage and effective resistance of the combination.



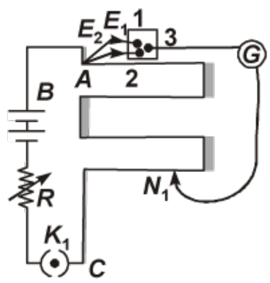
Q17. Let there be *n* resistors R_1 ...... R_n with R_{max} = max (R_1 ...... R_n) and R_{min} = min {R_1 ...... R_n}. Show that when they are connected in parallel, the resultant resistance $R_P < R_{min}$ and when they are connected in series, the resultant resistance $R_S > R_{max}$. Interpret the result physically.

Q18. (a) Consider circuit (as shown in figure). How much energy is absorbed by electrons from the initial state of no current (ignore thermal motion) to the state of drift velocity?

(b) Electrons give up energy at the rate of RI^2 per second to the thermal energy. What time scale would one associate with energy in problem (a)? *n* = no of electron/volume = $10^{29}/m^3$, length of circuit = 10 cm, cross-section = $A = (1\text{ mm})^2$.



Q19. In an experiment with a potentiometer, V_B = 10 V. *R* is adjusted to be 50 Ω (as shown in figure). A student wanting to measure voltage E_1 of a battery (approx. 8V) finds no null point possible. He then diminishes *R* to 10 Ω and is able to locate the null point on the last (4th) segment of the potentiometer. Find the resistance of the potentiometer wire and potential drop per unit length across the wire in the second case.



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S1. The power consumption in transmission lines is given by $P = I^2R_C$, where R_C is the resistance of transmission lines. The power is given by

$$P = VI$$

The given power can be transmitted in two ways namely (i) at low voltage and high current or (ii) high voltage and low current. In power transmission at low voltage and high current more power is wasted as $P \propto I^2$ whereas power transmission at high voltage and low current facilitates the power transmission with minimal power wastage.

The power wastage can be reduced by transmitting power at high voltage.

S2. Alloys have small value of temperature coefficient of resistance with less temperature sensitivity.

This keeps the resistance of the wire almost constant even in small temperature change. The alloy also has high resistivity and hence high resistance, because for given length and cross-section area of conductor. (L and A are constant).

$$R \propto \rho.$$

S3. The advantage of null point method in a Wheatstone bridge is that the resistance of galvanometer does not affect the balance point and there is no need to determine current in resistances and galvanometer and the internal resistance of a galvanometer. R_{unknown} can be calculated applying Kirchhoff 's rules to the circuit. We would need additional accurate measurement of all the currents in resistances and galvanometer and internal resistance of the galvanometer.

S4. 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.

S5. Relaxation time is inversely proportional to the velocities of electrons and ions. The applied electric field produces the insignificant change in velocities of electrons at the order of 1 mm/s, whereas the change in temperature (T), affects velocities at the order of 10^2 m/s.

This decreases the relaxation time considerably in metals and consequently resistivity of metal or conductor increases as.

$$\rho = \frac{1}{\sigma} = \frac{m}{ne^2\tau}.$$

S6. When an electron approaches a junction, in addition to the uniform $\boldsymbol{E}$ facing it normally. It keep the drift velocity fixed as drift velocity depend on E by the relation drift velocity

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

This result into accumulation of charges on the surface of wires at the junction. These produce additional electric field. These fields change the direction of momentum.

Thus, the motion of a charge across junction is not momentum conserving.

S7. 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 meter each). This is easily done with the help of centimeter rulings or meter ruler and leads to accurate measurements.

S8. With the increase of R, the current in main circuit decreases which in turn, decreases the potential difference across AB and hence potential gradient (k) across AB decreases.

Since, at neutral point, for given e.m.f. of cell, I increases as potential gradient (k) across AB has decreased because

$$E = kI$$

Thus, with the increase of I, the balance point neutral point will shift towards B.

S9.

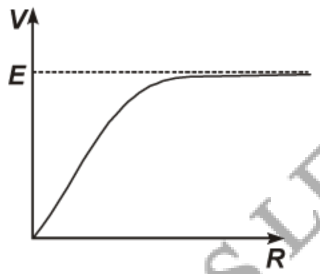
$$I = \frac{E}{R + nR} \qquad \text{[When resistors are connected in series]}$$

$$\frac{E}{R + \frac{R}{n}} = 10I \qquad \text{[When resistors are connected in parallel]}$$

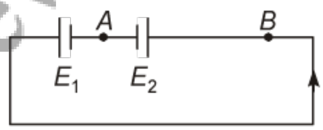
$$\frac{1+n}{1+\frac{1}{n}} = 10 \quad \Rightarrow \quad \frac{1+n}{n+1}n = 10$$

$$n = 10.$$

S10.



S11. $\because \; I = \dfrac{E}{R+r}$ $\qquad I = \dfrac{6-4}{2+8} = 0.2\,\text{A}$



P.D. across $E_1 = 6 - 0.2 \times 2 = 5.6\,\text{V}$

P.D. across $E_2 = V_{AB} = 4 + 0.2 \times 8 = 5.6\,\text{V}$

Point B is at a higher potential than A.

S12.

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

$$V_1 = E - Ir_1 = \frac{2E}{r_1 + r_2 + R} r_1 = 0$$

or

$$E = \frac{2Er_1}{r_1 + r_2 + R}$$

$$1 = \frac{2r_1}{r_1 + r_2 + R}$$

$$r_1 + r_2 + R = 2r_1$$
$$R = r_1 - r_2.$$

S13. (a) The deflection in galvanometer is one sided and the deflection decreased, while moving from one end '*A*' of the wire to the end '*B*', thus imply that current in auxiliary circuit (lower circuit containing primary cell) decreases, while potential difference across *A* and jockey increases.

This is possible only when positive terminal of the cell E_1, is connected at *X* and $E_1 > E$.

(b) The deflection in galvanometer is one sided and the deflection increased, while moving from one end *A* of the wire to the end *B*, this imply that current in auxiliary circuit (lower circuit containing primary cell) increases, while potential difference across A and jockey increases.

This is possible only when negative terminal of the cell E_1, is connected at *X*.

S14.

$$R_A = \frac{\rho l}{\pi(10^{-3} \times 0.5)^2}$$

$$R_B = \frac{\rho l}{\pi[(10^{-3})^2 - (0.5 \times 10^{-3})^2]}$$

$$\frac{R_A}{R_B} = \frac{(10^{-3})^2 - (0.5 \times 10^{-3})^2}{(.5 \times 10^{-3})^2} = 3 : 1$$

S15. Power consumption = 2 units/hour = 2 kW = 2000 J/s

$$I = \frac{P}{V} = \frac{2000}{220} = 9\text{A}$$

Power loss in wire = RI^2 J/s

$$= \rho = \frac{l}{A} I^2 = 1.7 \times 10^{-8} \times \frac{10}{\pi \times 10^{-6}} \times 81 \text{ J/s}$$

$$= 4 \text{ J/s}$$

The fractional loss due to the joule heating in first wire

$$= \frac{4}{2000} \times 100 = 0.2\%$$

$$\text{Power loss in Al wire} = 4\frac{\rho_{Al}}{\rho_{Cu}} = 1.6 \times 4 = 6.4 \text{ J/s} = \frac{6.4}{2000} \times 100 = 0.32\%$$

S16. **Applying Kirchhoff's junction rule:**

$$I_1 = I + I_2$$

Kirchhoff's loop rule gives:

$$V = V_1 + V_2 \qquad \text{[Potential across closed loop is zero]}$$

$$10 = IR + 10I_1 \qquad \text{... (i)}$$

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

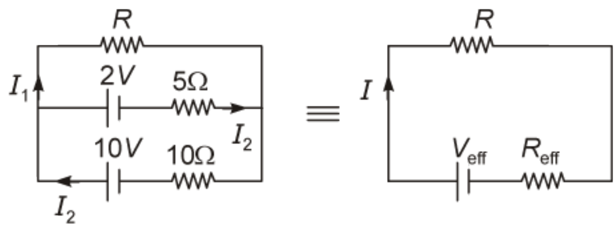
$$4 = 10I_1 - 10I - 2RI \qquad \text{... (ii)}$$

(i) – (ii) $\Rightarrow$ $6 = 3RI + 10I$ or $2 = I\left(R + \frac{10}{3}\right)$

$$2 = (R + R_{eff})I$$

Comparing with $V_{eff} = (R + R_{eff})I$ and $V_{eff} = 2\,V$

$$R_{eff} = \frac{10}{3}\,\Omega.$$



S17. When all resistances are connected in parallel, the resultant resistance R_p is given by

$$\frac{1}{R_P} = \frac{1}{R_1} + ... + \frac{1}{R_n}$$

On multiplying both sides by R_{min}, we have

$$\frac{R_{min}}{R_P} = \frac{R_{min}}{R_1} + \frac{R_{min}}{R_2} + ... + \frac{R_{min}}{R_n}$$

Here, in R.H.S., there exist ne term $\frac{R_{min}}{R_{min}} = 1$ and other terms are positive, so we have

$$\frac{R_{min}}{R_P} = \frac{R_{min}}{R_1} + \frac{R_{min}}{R_2} + ... + \frac{R_{min}}{R_n} > 1$$

This shows that the resultant resistance $R_p < R_{min}$.

Thus, in parallel combination, the equivalent resistance of resistors is less than the minimum resistance available in combination of resistors. Now, series combination, the equivalent resistant is given by

$$R_s = R_1 + ... + R_n$$

Here, in R.H.S., there exist one term having resistance R_{max}.

So, we have

or $$R_s = R_1 + ... + R_{max} + ... + ... + R_n$$

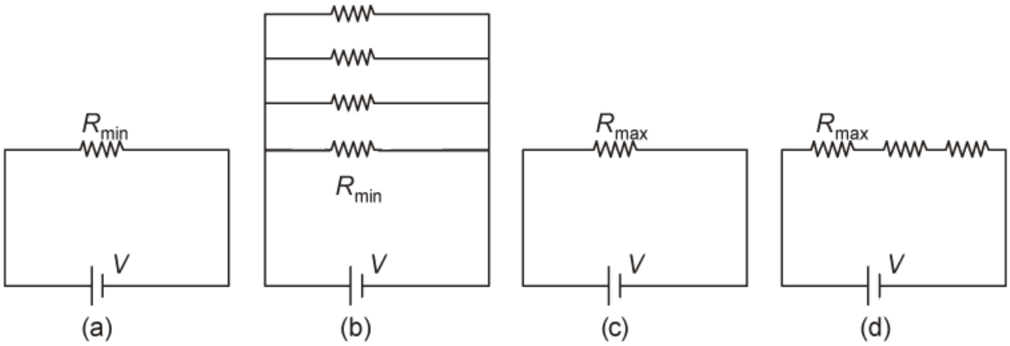
$$R_s = R_1 + ... + R_{max} + ... + R_n = R_{max} + ... (R_1 + ... +) R_n$$

or $$R_s \geq R_{max}$$

$$R_s = R_{max}(R_1 + ... + R_n)$$

Thus, in series combination, the equivalent resistance of resistors is greater than the maximum resistance available in combination of resistors. Physical interpretation

In Fig. (b), R_{min} provides an equivalent route as in Fig. (a) for current. But in addition there are $(n - 1)$ routes by the remaining $(n - 1)$ resistors. Current in Fig. (b) is greater than current in Fig. (a). Effective Resistance in Fig. (b) < R_{min}. Second circuit evidently affords a greater resistance.



In Fig. (d), R_{max} provides an equivalent route as in Fig. (c) for current. Current in Fig (d) current in Fig. (c). Effective resistance in Fig. (d) > R_{max}. Second circuit evidently affords a greater resistance.

S18. (a)

$$I = \frac{6}{6} = 1\text{ A} = nev_d A$$

$$v_d = \frac{1}{10^{20} \times 1.6 \times 10^{-19} \times 10^{-6}} = \frac{1}{1.6} \times 10^{-4}\text{ m/s}$$

Total kinetic energy of all electrons

$$\text{K.E.} = \frac{1}{2} m_e v_d^2 \times nAl$$

$$= \frac{1}{2} \times 9.1 \times 10^{-31} \times \frac{1}{2.56} \times 10^{-8} \times 10^{29} \times 10^{-6} \times 10^{-1} = 2 \times 10^{-17}\text{ J}$$

(b) Ohmic loss = $RI^2 = 6 \times 1^2 = 6$ J/s

All of KE of electrons would be lost in $\frac{2 \times 10^{-17}}{6}$ s $= 10^{-17}$ s.

S19. Let R' be the resistance of the potentiometer wire.

$$\frac{10 \times R'}{50 + R'} < 8 \quad = \quad 10R' < 400 + 8R'$$

$$2R' < 400 \quad \text{or} \quad R' < 200\,\Omega.$$

$$\frac{10 \times R'}{10 + R'} > 8 \;\Rightarrow\; 2R' > 80 \;\Rightarrow\; R' > 40$$

$$\frac{10 \times \frac{3}{4} R'}{10 + R'} < 8 \;\Rightarrow\; 7.5R' < 80 + 8R'$$

$$R' > 160 \;\Rightarrow\; 160 < R' < 200.$$

Any R' between 160 Ω and 200 Ω will achieve.

Potential drop across 400 cm of wire > 8 V.

Potential drop across 300 cm of wire < 8 V.

$$\phi \times 400 > 8\,V \ (\times \rightarrow \text{potential gradient})$$
$$\phi \times 300 < 8\,V$$

$$\phi > 2\,V/m$$
$$< 2\frac{2}{3}\,V/m.$$