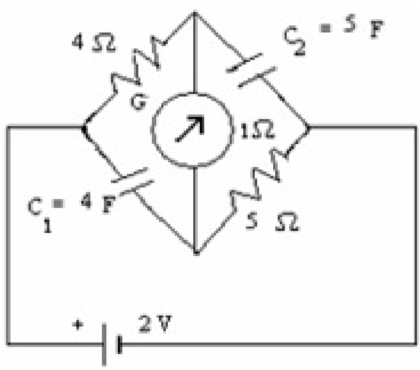
CBSE Test Paper-03

Class - 12 Physics (Current Electricity)

1. A milliammeter of range 10 mA has a coil of resistance 1 Ω.To use it as an ammeter of range 1 A, the required shunt must have a resistance of
   a. $\frac{1}{100\Omega}$
   b. $\frac{1}{9\Omega}$
   c. $\frac{1}{101\Omega}$
   d. $\frac{1}{99\Omega}$
2. In the circuit shown below, the cell is ideal, with emf = 2 V. The resistance of the coil of the galvanometer G is 1Ω



   a. 0.2 A current flows in G
   b. Potential difference cross C2 is 1.2 V
   c. Potential difference across C1 is 1 V
   d. No current flows in G
3. Orders of magnitude of random electron motion speed to drift speed are like
   a. $10^2 \mathrm{m/s}, 10^2 \mathrm{m/s}$
   b. $10^3 \mathrm{m/s}, 10^{-1 \mathrm{m/s}}$
   c. $10^4 \mathrm{m/s}, 10^{-2} \mathrm{m/s}$
   d. $10^6 \mathrm{m/s}, 10^{-4} \mathrm{m/s}$
4. A current passes through a wire of non-uniform cross section. Which of the following quantities are independent of the cross section?
   a. Current density
   b. Drift speed
   c. Free electron density
   d. The charge crossing in a given time interval

5. Meter Bridge is used to
   a. determine unknown emf e
   b. determine unknown voltage v
   c. determine unknown power P
   d. determine unknown resistance R
6. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more? Justify your answer.

7. Define the term drift velocity of charge carriers in a conductor and write its relationship with the current flowing through it.

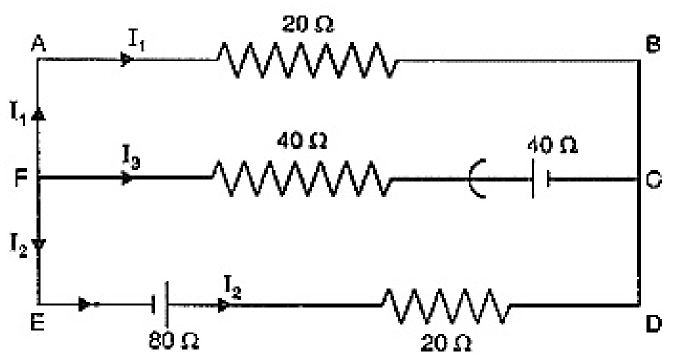
8. Define the term electrical conductivity of a metallic wire. Write its SI unit.

9. A wire of 'resistivity' ρ is stretched to twice its length. What will be its new resistivity?

10. i. Derive an expression for drift velocity of free electrons.
    ii. How does drift velocity of electrons in a metallic conductor vary with increase in temperature? Explain.

11. The network PQRS, shown in the circuit diagram, has the batteries of 4 V and 5 V and negligible internal resistance. A milliammeter of 20Ω resistance is connected between P and R. Calculate the reading in the milliammeter.

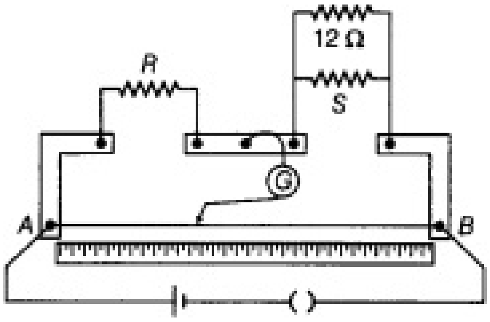
12. State Kirchhoff's rules of current distribution in an electrical network. Using these rules determine the value of the current I_1 in the electric circuit given below.



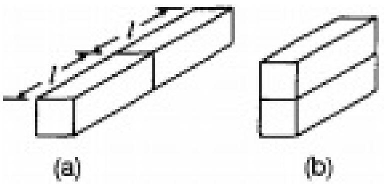
13. Three resistors R_1, R_2 and R_3 are connected in parallel, across a source of emf E and negligible internal resistance. Obtain a formula for the equivalent expressions for the

current through each of the three resistors.

14. In a meter bridge, the null point is found at a distance of 40 cm from A. If a resistance of 12Ω is connected in parallel with S, then null point occurs at 50.0 cm from A. Determine the values of R and S.



15. Two identical slabs, of a given metal, are joined together, in two different ways, as shown in figures (a) and (b).



What is the ratio of the resistances of these two combinations?

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Answers

1. d. $\frac{1}{99\Omega}$

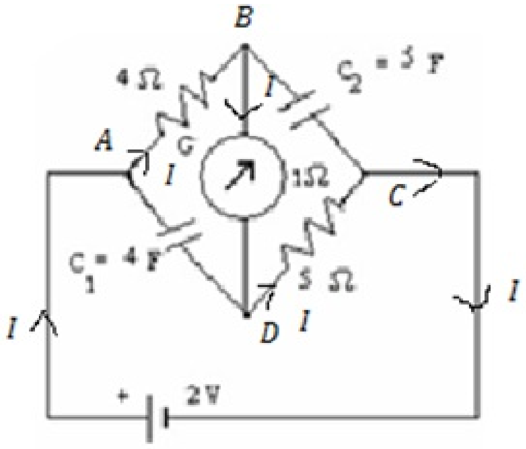
   Explanation: $S = \frac{I_S}{I - I_S} G$

   $= \frac{10 \times 10^{-3}}{1 - 10 \times 10^{-3}} \times 1 = \frac{1}{99} \Omega$

   (Theory in chapter 4 – magnetic effect of current)

2. a. 0.2 A current flows in G.

   Explanation: In steady state, no current flows through the capacitors.



   (B) The current flows along ABGDCA. The resistances 4Ω, 1 Ω and 5 Ω are in series. Total resistance of the circuit = R= 4+1+5=10 Ω. Current I = V/R= 2/10 = 0.2 A. The current through the galvanometer is 0.2 A

3. d. $10^6 \mathrm{m/s}, 10^{-4} \mathrm{m/s}$

   Explanation: The random velocities of electrons is of the order 10^5 to 10^6 m/s, while the drift velocities are of the order 0.1mm/s (10^{-4}m/s)

4. c. Free electron density

   Explanation: Free electron density,

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

   $\Rightarrow J = neV_d$

   n is number density, e is electronic charge and V_d is electron drift velocity.

5. d. determine unknown resistance R

   Explanation: With a known resistance in one of the gaps, the meter bridge is used to determine the value of an unknown resistance by the formula,

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

where l is the null point.

6. Resistivity of materials is the resistance to the flow of an electric current with some materials resisting the current flow more than others.

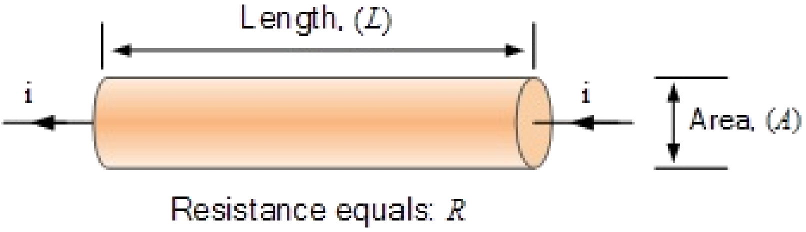
   For same length and same radius, resistance of wire

   $R \propto \rho$ [where, = ρ : resistivity]

   As, $\rho_{\text{nichrome}} > \rho_{\text{copper}}$

   Hence, resistance of nichrome section is more.

   In series, same current flows through both sections and heat produced = I^2Rt. So, more heat is produced in nichrome section of wire.



7. The drift velocity is the average velocity that a particle, such as an electron, attains in a material due to an electric field. It can also be referred to as axial drift velocity. In general, an electron will propagate randomly in a conductor at the Fermi velocity. An applied electric field will give this random motion a small net flow velocity in one direction. It can also be defined as the average velocity acquired by the free electrons along the length of a metallic conductor under a potential difference applied across the conductor.

   Its **relationship is expressed** as

   $v_d = \frac{I}{neA}$

   where, I is current flowing through the conductor, n is concentration of free electrons, e is electronic charge and A is cross-sectional area.

8. The electrical conductivity (σ) of a metallic wire is defined as the ratio of the current density to the electric field it creates. Its SI unit is mho per metre $(\Omega - m)^{-1}$.

   (σ) = J/E

   (σ) = I/AE

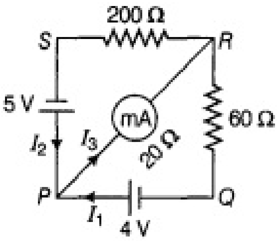
9. Resistivity ρ remains unaffected.

10. When a conductor is subjected to an electric field E, each electron experiences a force:

   i. F = - eE, and free electron acquires an
      acceleration, a= F/m = - eE/m ... (i)
      where, m = mass of electron, e = electronic charge and E = electric field.
      Free electron starts accelerating and gains velocity and collide with atoms and molecules of the conductor. The average time difference between two consecutive collisions is known as relaxation time of electron and can be calculated as -
      $\overline{\tau} = \frac{\tau_1+\tau_2+\ldots+\tau_n}{n}$ ...(ii)
      where, $\tau_1,\ \tau_2 \ldots .\ \tau_n$ are the average time difference(relaxation time) between 1st, 2nd, ...nth collisions.
      $\therefore$ v_1, v_2, ... v_n, are velocities gained by electron in 1st, 2nd, ..., nth collisions with initial thermal velocities u_1, u_2, ..., u_n, respectively.
      $\therefore \quad v_1 = u_1 + a\tau_1$
      Similarly,
      $$\begin{aligned} v_2 &= u_2 + a\tau_2 \\ \vdots \quad & \quad \vdots \quad \quad \vdots \\ v_n &= u_n + a\tau_2 \end{aligned}$$
      The drift speed v_d may be defined as
      $v_d = \frac{v_1+v_2+\ldots+v_n}{n}$
      $v_d = \frac{(u_1+u_2+\ldots+u_n)+a(\tau_1+\tau_2+\ldots+\tau_n)}{n}$
      $v_d = \frac{(u_1+u_2+\ldots+u_n)}{n} + \frac{a(\tau_1+\tau_2+\ldots+\tau_n)}{n}$
      $v_d = 0 + a\tau$ [$\because$ Average thermal velocity in n collisions = 0]
      $v_d = -(eE/m)\tau$ [from Eq. (i)]
      This is the required expression of drift speed of free electrons which shows it is directly proportional to relaxation time.

   ii. As the temperature of a conductor is increased, the thermal agitation increases and the collisions become more frequent. The average time τ between the successive collisions decreases and hence the drift speed decreases. Thus, the conductivity decreases and the resistivity of the conductor increases.

11. The given diagram is shown below



Applying Kirchhoff's second law i.e. KVL to the loop PRSP,

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

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

For loop PRQP,

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

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

Applying Kirchhoff's first law i.e. KCL we get,

$I_3 = I_1 + I_2$ ....(iii)

From Eqs. (i) and (iii), we have

$4I_1 + 44I_2 = 1$....(iv)

Also from eqs. (ii) and (iii) , we have

$20I_1 + 5I_2 = 1$....(v)

On solving eqs (iii), (iv) and (v) we get

$$I_3 = \frac{11}{172} A = \frac{11000}{172} \mathrm{mA}$$
$$I_2 = \frac{4000}{215} \mathrm{mA}, I_1 = \frac{39000}{860} \mathrm{mA}$$

$\therefore$ The reading in the millimeter will be $\frac{11000}{172} \mathrm{mA}$

12. For electrical network, Kirchhoff's rules are as follows:
    i. Junction rule: At any junction, the sum of the currents entering the function is equal to the sum of currents leaving the junction.
    $\therefore \sum = 0$
    ii. Loop rule: The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero.
    $\therefore \sum IR + \sum E = 0$
    According to Kirchhoff's rule, $I_1 + I_2 = I_3$
    Applying loop rule to both the lower and upper loops, we get
    $40 I_3 + 20 I_1 = 40$ (In loop ABCF)
    $40 I_3 + 20 I_2 = 80 + 40$ (In loop CDEF)

By addition of two equations, we get

80 I_3 + 20(I_1 + I_2) = 160

or 80 I_3 + 20 I_3 = 160

or $I_3 = \frac{160}{100} = 1.6A$

gain, $40 \times 1.6 + 20\ I_1 = 40$

or 20 I_1 = 40 - 64 = -24

or $I_1 = -\frac{24}{20} = 1.2A$

13. Let the equivalent resistance of parallel combination of R_1, R_2 and R_3 is R.

$\therefore \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R} = \frac{R_2R_3+R_1R_3+R_1R_2}{R_1R_2R_3}$

$R = \frac{R_1R_2R_3}{R_1R_2+R_2R_3+R_3R_1}$

$\therefore$ Potential differences across each resistance is equal to E.

$\therefore$ Current in R_1, I_1 = E/R_1

Current in R_2, I_2 = E/R_2

Current in R_3, I_3 = E/R_3

14. Meter bridge is based on the principle of Wheatstone bridge and it is used to find the resistance of an unknown conductor or to compare two unknown resistance.

A meter bridge consists of a wire of length 1m i.e. 100cm.

At balance condition:

$\frac{R}{S} = \frac{l}{100-l}$, where ' l ' is distance from one end to the null point.

i) Applying the condition of balanced Wheatstone bridge,

In a meter bridge, the null point is found at a distance of 40 cm from A.

l = 40cm

$\frac{R}{S} = \frac{l}{100-l} = \frac{40}{100-40} = \frac{40}{60} = \frac{2}{3}$

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

The equivalent resistance of resistors when connected in parallel combination is given by

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

The equivalent resistance of 12Ω and $S\Omega$ in parallel combination is

$\frac{1}{R_{eq}} = \frac{1}{12} + \frac{1}{S}$

$R_{eq} = \frac{12S}{12+S}\Omega$

In a meter bridge, A resistance of 12Ω is connected in parallel with S, then null point occurs at 50.0 cm from A.

l=50cm

Again, applying the condition

$$\frac{R}{(12S/12+S)} = \frac{50}{50} = 1$$

$$\Rightarrow \quad R = \frac{12S}{12+S} \text{ ...(ii)}$$

From Eqs. (i) and (ii), we get

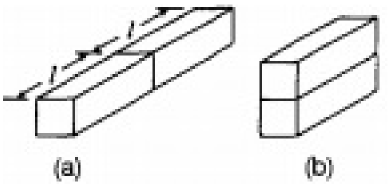
$$\frac{2}{3}S = \frac{12S}{12+S}$$

$$12 + S = 18 \Rightarrow S = 6\Omega$$

$$R = \frac{2}{3}S = \frac{2}{3} \times 6 = 4\Omega$$

$$R = 4\Omega$$

15. Let the resistance each of the conductor is' R '.



Case I: According to Fig. (a), the resistances are connected in series combination, so equivalent resistance of slab is calculated by using the formula,

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

let the equivalent resistance in the Case I is R_1.

$R_1 = R + R = 2R$

Case II: According to Fig. (b), the resistances are connected in parallel combination, so equivalent resistance of slab is calculated by using the formula,

$$\frac{1}{Req} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} .. + \frac{1}{R_n}$$

let the equivalent resistance in the Case II is R_2

$$\frac{1}{R_2} = \frac{1}{R} + \frac{1}{R}$$

$$\Rightarrow \frac{1}{R_2} = \frac{2}{R}$$

$$\Rightarrow R_2 = \frac{R}{2}$$

Ratio of the equivalent resistance in two combinations is calculated below.

$$\therefore \quad \frac{R_1}{R_2} = \frac{2R}{(R/2)} = 4$$

$$\therefore R_1 = 4R_2$$