CHAPTER 14

Current Electricity

Chapter Highlights

Electric current, Drift velocity, Ohm's law, Resistance, Effect of temperature on resistance, Grouping of resistance, Cell, Grouping of cell, Kirchhof's law, Wheat stone bridge, Meter bridge ammeter, Voltmeter, Potentiometer, Power, Heating effect of current

ELECTRIC CHARGE AND CURRENT

Electric charges in motion constitute electric current. Metals such as gold, silver, copper, aluminium, etc., called conductors, have large number of free electrons. These free electrons move around in all directions from atom to atom under normal conditions but when a potential difference is applied between two points (two ends preferably), the electrons move only in one direction. The electrons are negatively charged particles, and the conventional current is considered as the flow of positive charges. Hence the direction of flow of electrons is opposite to the direction of conventional current, which takes place in a direction from a point of higher potential to a point of lower potential.

The strength of the current is the rate at which the electric charges are flowing. If a charge Q coulomb passes through a given cross-section of the conductor in t second, the current I through the conductor is given by

$$I = \frac{Q}{t}\frac{\text{coulomb}}{\text{second}} = \frac{Q}{t}$$

The SI unit of current is ‘ampere’(A)

SOLVED EXAMPLES

1. An electrical device sends out 78 coulombs of charge through a conductor in 6 s. Find the current flow.

Solution:

Given that charge flowing $Q = 78$ C,

Time of flow $t = 6$ s

$$\text{The current } I = \frac{Q}{t} = \frac{78\text{ C}}{6\text{ s}} = 13\text{ A.}$$

2. What is the quantity of electricity required to provide a current of 10 A for 1 hour?

Solution:

Given that the current $I = 10$ A,

Time of flow $t = 1$ hour $= 3600$ s

The quantity of electricity = the amount of charge flowing

$$Q = It$$

$$= (10\text{ A})(3600\text{ s}) = 36000\text{ C.}$$

ELECTROMOTIVE FORCE AND VOLTAGE

Let us consider a water flow system as shown in Fig. 14.1. Suppose in the horizontal tube AB, we wish to maintain a steady flow of water. This requires a steady pressure difference between A and B. This is accomplished by maintaining the levels of water in the two reservoirs R_1 and R_2. An external source of energy (the pump P) serves the purpose. Water flows spontaneously from higher to lower pressure. The pump is meant to do the opposite, that is, take water from lower pressure to higher pressure. For this, the pump will need to work at a steady rate. Water cannot flow at a constant rate in an isolated tube.

A steady electric current in a conductor is maintained in an analogous way. In a conductor, positive charge will flow from higher potential (A) to lower potential (B), i.e., in the direction of electric field. To maintain a steady electric current, the conductor cannot be isolated to transport the positive charge from B back to A, i.e., from lower to higher potential and thus maintain a potential difference between A and B. The external device will need to do work for transporting positive charge from lower to higher potential.

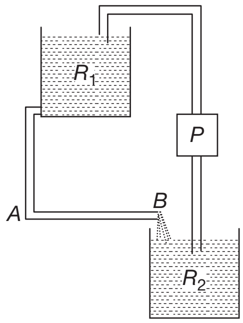


Fig. 14.1

Electromotive force is the maximum work done in taking a unit charge once around the closed circuit. The external device may be a cell, a battery, a generator, or dynamo.

Emf of a cell is defined as the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell.

The SI unit of emf of a cell is volt (V) or joule per coulomb. The emf of the cell is said to be 1 V, if 1 J of energy is supplied by the cell to drive 1 coulomb of charge once around the whole circuit.

In current electricity, dry cells or secondary cells or generators are employed to create a potential difference in order to cause an electric current flow in closed circuits just as a water pump is used to create pressure difference in order to drive water in water pipes.

The unit of potential difference is **volt**. The volt is defined as that potential difference between two points of a conductor carrying a current of one ampere when the power dissipated between these points is equal to one watt.

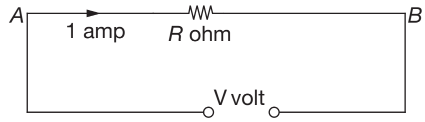
RESISTANCE

Electrical resistance may be defined as the property of a substance, which opposes the flow of an electric current through it.

The unit of resistance is **ohm**. Symbol is Ω. Ohm is that resistance between two points of a conductor when a potential difference of one volt is applied between these points produced in this conductor a current of one ampere.

OHM'S LAW

Ohm's law is the most fundamental of all the laws in electricity.



Statement: The current which flows in a conductor is proportional to the potential difference which causes its flow provided the temperature of the conductor is constant.

If a potential difference of V volt exists between the ends A and B of a conductor AB current of I ampere flows through the conductor and

$$V \propto I \text{ or } V = IR$$

where the constant R is the resistance of the conductor. In this Ohm's law relation, V is in volts, I is in amperes, and R is in ohms.

SOLVED EXAMPLE

3. The current in a conductor is 5 A when the voltage between the ends of the conductor is 12 V.
   (A) What is the resistance of the conductor?
   (B) What will be the current in the same conductor if the voltage is increased to 42 V?

Solution:

(A) Given that $I = 5$ A; $V = 12$ V; R =?

$$R = \frac{V}{I} = \frac{12 \text{ V}}{5 \text{ A}} = 2.4\ \Omega$$

(B) If the voltage applied becomes 42 V

$$I = \frac{V}{R} = \frac{42 \text{ V}}{2.4\ \Omega} = 17.5 \text{ A.}$$

RESISTIVITY

The resistance of a resistor depends on its geometrical factors as also on the nature of the substance of which the resistor is made. For a conductor of length l and cross-sectional area A, the resistance R is proportional to both l and R.

$$R \propto \frac{l}{A}$$

$$R = \rho \frac{l}{A}$$

where ρ is a constant of proportionality called resistivity. It depends only on the nature of the material of the resistor and its physical conditions such as temperature and pressure. The unit of resistivity is ohm m (Ω m). The inverse of ρ is called conductivity and is denoted by σ. The unit of σ is $(\Omega\ \text{m})^{-1}$ or ohm m^{-1} or siemen m^{-1}.

RELATION BETWEEN CURRENT AND DRIFT VELOCITY

Let us consider a conductor of length l and of uniform area of cross-section A. If n is the number of free electrons per unit volume of the conductor, then total number of free electrons in the conductor = Aln. Thus, charge on all the free electrons in the conductor is $q = Alne$. If a constant potential difference V be applied across the ends of the conductor with the help of a battery, then electric field set-up across the conductor is given by $E = \frac{V}{l}$, let v_d be the drift speed of the electrons.

Therefore, the time taken by the free electrons to cross the conductor

$$t = \frac{l}{V_d}$$

Hence current $\Rightarrow$ $I = \frac{q}{t} = \frac{Al\,ne}{l / v_d} = neAv_d$

or $\qquad I = \frac{ne^2 Av\tau}{lm}$ or $v = \frac{m}{ne^2\tau}\frac{l}{A} I = RI$

$\therefore \qquad R = \frac{m}{ne^2\tau}\frac{l}{A}$

Resistivity of the material $\rho = \frac{m}{ne^2\tau}$

MOBILITY OF ELECTRON

Mobility of electron (μ_e) is defined as the drift velocity of electron per unit electronic field applied.

$$\mu_e = \frac{v_d}{E} \Rightarrow v_d = \mu_e E$$

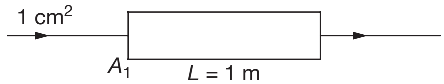
So, $\qquad I = neA\mu_e E$

SOLVED EXAMPLE

4. A certain rectangular block has dimensions 100 cm × 1 cm × 1 cm. Find the resistance of the block (A) across the square faces (B) across two opposite rectangular faces. The specific resistance of the material is 40×10^{-8} Ω m.

Solution:

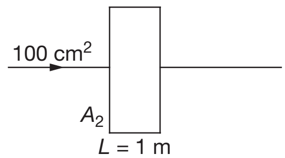
(A) Resistance of the block across the square faces



$$R = \frac{\rho \times L}{A} = \frac{(40 \times 10^{-8}\,\Omega\,\text{m})\ (1\,\text{m})}{1 \times 10^{-4}\,\text{m}^2}$$

$= 40 \times 10^{-4}$ Ω

(B) Resistance across the two opposite rectangular faces



$$R = \frac{\rho L}{A} \frac{(40 \times 10^{-8}\,\Omega\ \text{m})\ (10^{-2}\ \text{m})}{100 \times 10^{-4}\,\text{m}^2} = 40 \times 10^{-8}\ \Omega.$$

TEMPERATURE DEPENDENCE OF RESISTIVITY

In most metals, an increase in temperature increases the amplitude of vibration of lattices ions of the metal. Due to it, the collision of free electrons with ions/atoms while drifting becomes more frequent, resulting in a decrease in relaxation time τ.

The resistivity of all metallic conductors increases with temperature.

Resistivity of the material $\rho = \frac{m}{ne^2\tau}$

Over a limited temperature range that is not too large, the resistivity of a metallic conductor can often be represented approximately by a linear relation

$$\rho_T = \rho_0\left[1 + \alpha\left(T - T_0\right)\right]$$

Where ρ_0 is the resistivity at a reference temperature T_0 and ρ_T its value at temperature T. The factor α is called the temperature coefficient of resistivity.

TEMPERATURE DEPENDENCE OF RESISTANCE

If R_0 and R be the resistances of a conductor at 0°C and θ°C, then it is found that

$$R = R_0(1 + \alpha\theta)$$

where α is a constant called the temperature coefficient of resistance.

$$\alpha = \frac{R - R_0}{R_0 \cdot \theta}$$ and the unit of α is K^{-1} or $°C^{-1}$.

If R_1 and R_2 be the resistances of a conductor at temperatures θ_1° C and θ_2° C, then

$$R_1 = R_0(1 + \alpha\theta_1)$$

$$R_2 = R_0(1 + \alpha\theta_2) \text{ and } \alpha = \frac{R_2 - R_1}{R_1\theta_2 - R_2\theta_1}$$

SOLVED EXAMPLE

5. A metal wire of diameter 2 mm and of length 100 m has a resistance of 0.5475 Ω at 20°C and 0.805 Ω at 150°C. Find the values of (A) temperature coefficient of resistance (B) its resistance at 0°C (C) its resistivities at 0°C and 20°C.

Solution:

(A) If R_{20} and R_{150} be the resistances at temperatures 20°C and 150°C, respectively, and α be the temperature coefficient of resistance

$$R_{20} = 0.5475 = R_0(1 + \alpha \times 20) \quad (1)$$

$$R_{150} = 0.805 = R_0(1 + \alpha \times 150) \quad (2)$$

Now, $$\alpha = \frac{R_{150} - R_{20}}{R_{20} \times 150 - R_{150} \times 20} = \frac{0.805 - 0.5475}{0.5475 \times 150 - 0.805 \times 20}$$

or $\alpha = 3.9 \times 10^{-3}\ °C^{-1}$

(B) Substituting this value of α in Equation (1), $R_0 = 0.5079\ \Omega$

(C) Now $R_0 = \dfrac{\rho_0 L}{A}$, $0.5079 = \dfrac{\rho_0(100)}{\pi(1 \times 10^{-3})^2}$

or $\rho_0 = 1.596 \times 10^{-8}\ \Omega$.m

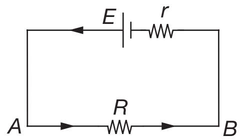
$$\rho_{20} = \rho_0(1 + \alpha \times 20)$$
$$= 1.596 \times 10^{-8}[1 + (3.9 \times 10^{-3} \times 20)]$$
$$= 1.720 \times 10^{-8}\ \Omega\text{.m.}$$

EMF OF A CELL AND ITS INTERNAL RESISTANCE

If a cell of emf E and internal resistance r be connected with a resistance R, the total resistance in the circuit is $(R + r)$.

The current through the circuit $I = \dfrac{E}{R + r}$

Potential difference across the ends A and B $= IR = \dfrac{ER}{R + r}$



Thus, although the emf of the cell is E, the effective potential difference it can deliver is less than E, and it is given by

$$V_{AB} = E - Ir$$

The quantity V_{AB} is called the terminal potential difference of the cell, and this is also the potential difference across the external resistance R.

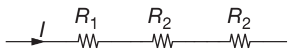
If $R \to \infty$, $V_{AB} \to E$, the emf of the cell.

GROUPING OF RESISTANCES

Resistors in Series

The series circuit is one in which the same current flows in all the components of the circuit. If resistors R_1, R_2, R_3, ... are connected in series, the equivalent (or effective) resistance of the combination is the sum of the resistances so connected.

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



In a series combination of resistors,

(i) the equivalent resistance is equal to the sum of the individual resistances,

(ii) the same current flows through all the components, and

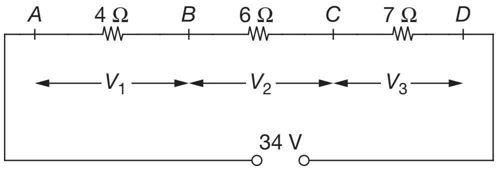
(iii) the sum of the separate voltage drops (IR drop) is equal to the applied voltage across the combination. If V be the applied voltage, V_1, V_2, V_3, ... be the IR drops across resistances R_1, R_2, R_3, ... respectively.

$$V = IR_1 + IR_2 + IR_3 + ... = V_1 + V_2 + V_3 + ...$$

SOLVED EXAMPLE

6. Three resistors of values 4 Ω, 6 Ω, and 7 Ω are in series and a potential difference of 34 V is applied across the grouping. Find the potential drop across each resistor.

Solution:



The current through the circuit $= \dfrac{34\text{ V}}{(4 + 6 + 7)\ \Omega} = 2\text{ A}$

Potential difference across 4 Ω resistor = IR = 2 A × 4 Ω = 8 V

Potential difference across 6 Ω resistor = 2 A × 6 Ω = 12 V

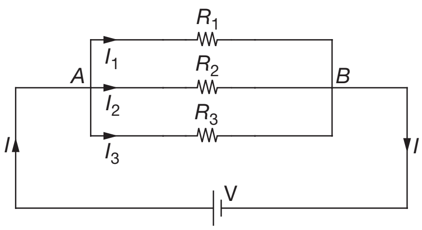
Potential difference across 7 Ω resistor = 2 A × 7 Ω = 14 V.

Resistors in Parallel

A parallel circuit of resistors is one in which the same voltage is applied across all the components.

If resistors R_1, R_2, R_3, ... are connected in parallel then reciprocal of the equivalent resistance is the sum of the reciprocals of the resistance of separate components.

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



(i) The total current taken from the supply is equal to the sum of the currents in separate branches.

(ii) The potential difference across each resistor is the same V volt which is the applied voltage.

(iii) The branch currents I_1, I_2, I_3, ... are in the ratio,

$$\frac{1}{R_1} : \frac{1}{R_2} : \frac{1}{R_3} : \ldots$$

(iv) The equivalent resistance is smaller than the smallest of the resistances in parallel.

SOLVED EXAMPLE

7. Two resistances 3 Ω and 2 Ω are in parallel connection and a potential difference of 12 V is applied across them. Find

(A) the equivalent resistance of the parallel combination,

(B) the circuit current, and

(C) the branch currents.

Solution:

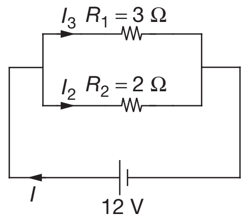
(A) Two resistors R_1 and R_2 are in parallel. Their equivalent resistance R is given by

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

or

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{2 \times 3}{2 + 3} = \frac{6}{5} = 1.2\ \Omega$$



(B) The circuit current $= \dfrac{\text{Circuit voltage}}{\text{Circuit resistance}}$

$$= \frac{12\text{ V}}{1.2\ \Omega} = 10\text{ A}$$

(C) The current through 2 Ω resistor

$$I_2 = I \times \frac{3}{2 + 3} = 10 \times \frac{3}{5} = 6\text{ A}$$

The current through 3 Ω resistor

$$I_3 = I \times \frac{2}{2 + 3} = 10 \times \frac{2}{5} = 4\text{ A}$$

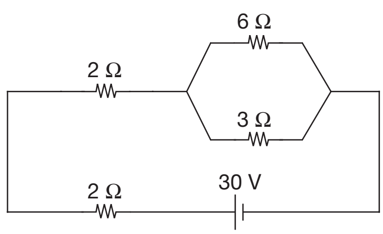
(Also $I_3 = I - I_2 = 10\text{ A} - 6\text{ A} = 4\text{ A}$).

Series-parallel Groupings

A series-parallel circuit is a combination of resistors in series as well as parallel connections. The following examples will illustrate the solutions of such problems.

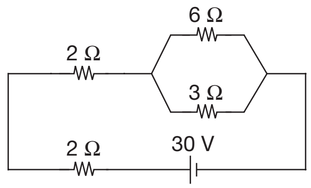
SOLVED EXAMPLES

8. Determine the current taken from the 30 V supply and the current through the 6 Ω resistor.



Solution:

As a first step to solution, let us reduce the parallel combination of 6 Ω and 3 Ω into a single resistance.



The parallel combination $= \frac{6 \times 3}{6 + 3}\ \Omega = 2\ \Omega$

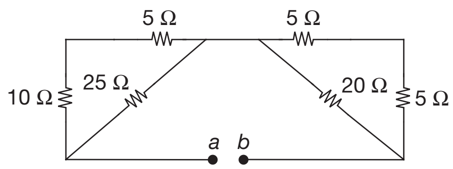
Now the circuit reduces to three resistors, each 2 ohm, in series to a 30 V supply.

Hence the circuit current $= \frac{30\ \text{V}}{6\ \Omega} = 5$ A

The current through 6 Ω resistor $= 5 \times \frac{3}{6+3}$ A

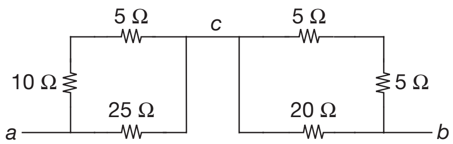
$= \frac{15}{9} = 1.7$ A.

9. Find the equivalent resistance of the circuit given across *ab*.



Solution:

As a first step, the circuit may be redrawn as follows.

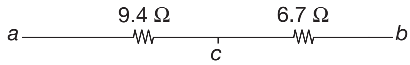


The left block is equivalent to 15 Ω and 25 Ω in parallel

That is, $\frac{25 \times 15}{25 + 15} = 9.4\ \Omega$

The right block is equivalent to 10 Ω and 20 Ω in parallel

That is, $\frac{10 \times 20}{10 + 20} = \frac{200}{30} = 6.7\ \Omega$



The circuit now reduces as two resistors in series i.e., 9.4 + 6. 7 = 16.1 Ω.

10. Figure 14.2 shows a cube made of wires each having a resistance *R*. The cube is connected into a circuit across a body diagonal *AB* as shown. Find the equivalent resistance of the network in this case.

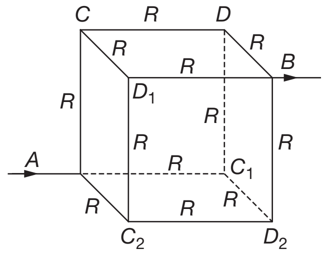
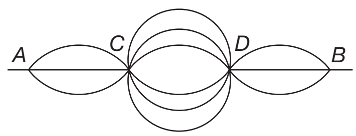


Fig. 14.2

Solution:

Let us search the points of same potential. Since the three edges of the cube from *A* viz., *AC*, AC_1, and AC_2 are identical in all respects, the circuit points *C*, C_1, and C_2 are at the same potential. Similarly for the point *B*, the sides *BD*, BD_1, and BD_2 are symmetrical and the points *D*, D_1, and D_2 are at the same potential.

Next let us bring together the points *C*, C_1 and C_2 and also *D*, D_1, and D_2.



Then the cube will look as follows.

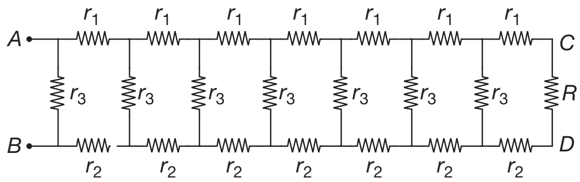
The resistance between *A* and $C = \frac{R}{3}$

The resistance between *C* and $D = \frac{R}{6}$

The resistance between *D* and $B = \frac{R}{3}$

The circuit is equivalent to $\frac{R}{3}$, $\frac{R}{6}$, and $\frac{R}{3}$ in series which is equal to $\frac{5}{6}$ R.

11. Study the following circuit. Values of r_1, r_2, and r_3 are 1 Ω, 2 Ω, and 3 Ω, respectively. A resistance *R* is connected across the points *C* and *D*. What should be the value of *R* for which the resistance of the network across *AB* is *R*?

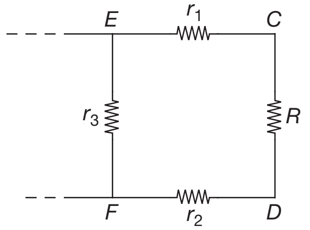


Solution:

Let us consider the extreme right square of the loop.

Resistance across $EF = (r_1 + R + r_2)$ and r_3 in parallel

$$= \frac{r_3 (r_1 + r_2 + R)}{(r_1 + r_2 + r_3 + R)}$$



This value should be equal to R, so that by the repeated operation of this type, we will be left with only one square which will be the left extreme one and it will have a value R.

i.e., $$\frac{r_3 (r_1 + r_2 + R)}{(r_1 + r_2 + r_3 + R)} = R$$

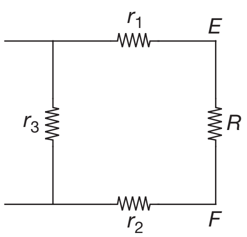
Substituting the numerical values,

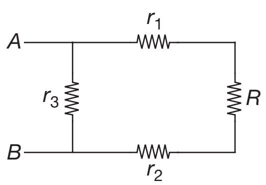
$$\frac{3(1 + 2 + R)}{(1 + 2 + 3 + R)} = R$$

(or) $$\frac{3(3 + R)}{(6 + R)} = R$$

$$9 + 3R = 6R + R^2$$

(or) $$R^2 + 3R - 9 = 0$$



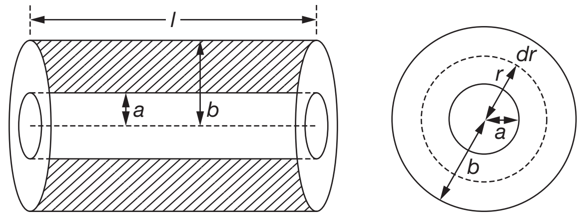


$$R = \frac{-3 \pm \sqrt{9 + 36}}{2}$$

$$= \frac{-3 \pm 3\sqrt{5}}{2}$$

$\therefore$ $$R = \frac{3(\sqrt{5} - 1)}{2}\ \Omega.$$

12. A homogeneous poorly conducting medium of resistivity ρ fills up the space between two thin coaxial ideally conducting cylinders. The radii of the cylinders are equal to a and b with $a < b$, the length of each cylinder is l. Neglecting the edge effects, find the resistance of the medium between the cylinders.



Solution:

The current will be conducted radially outwards from the inner conductor (say) to the outer. The area of cross-section for the conduction of the current is, therefore, the area of an elementary cylindrical shell, which varies with radius. The length of the conducting shell is measured radially from radius a to radius b.

Consider an elementary cylindrical shell of radius r and thickness dr. Its area of cross-section (normal to flow of current) = $(2\pi r l)$ and its length = dr.

Hence, the resistance of the elementary cylindrical shell of the medium is $dR = \dfrac{\rho dr}{2\pi r l} = \dfrac{\rho}{2\pi l}\left[\dfrac{dr}{r}\right]$

The resistance of the medium is obtained by integrating for r from a to b.

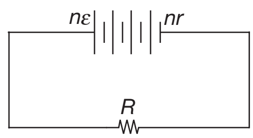
Hence, required resistance,

$$R = \frac{\rho}{2\pi l}\int_a^b \frac{dr}{r} = \frac{\rho}{2\pi l}\left[\log_e r\right]_a^b = \left(\frac{\rho}{2\pi l}\right)\log_e \frac{b}{a}.$$

GROUPING OF CELLS

Cells in Series

Let there be n cells each of emf ε, arranged in series. Let r be the internal resistance of each cell.



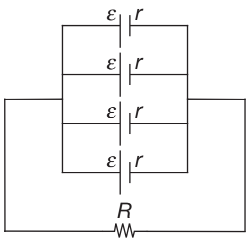
The total emf is $n\varepsilon$ and the total internal resistance is nr. If R be the external load, the current I through the circuit

$$I = \frac{n\varepsilon}{R + nr}. \qquad (14.1)$$

Cells in Parallel

If m cells each of emf ε and internal resistance r be connected in parallel and if this combination be connected to an external resistance R, then the emf of the circuit = ε.

The internal resistance of the circuit = the resistance due to m resistances each of r in parallel $= \frac{r}{m}$.



Now the current through the external resistor

$$R = \frac{\varepsilon}{R + \frac{r}{m}} = \frac{m\varepsilon}{mR + r}.$$

Mixed Grouping of Cells

Let n identical cells be arranged in series and let m such rows be connected in parallel. Obviously, the total number of cells is nm.

The emf of the system = $n\varepsilon$

The internal resistance of the system $= \frac{nr}{m}$

The current through the external resistance R

$$I = \frac{n\varepsilon}{R + \frac{nr}{m}} = \frac{mn\varepsilon}{mR + nr}.$$

SOLVED EXAMPLE

13. Six cells are connected (A) in series, (B) in parallel, and (C) in 2 rows each containing 3 cells. The emf of each cell is 1.08 V and its internal resistance is 1 Ω. Calculate the currents that would flow through an external resistance of 5 Ω in the three cases.

Solution:

(A) The cells in series.

Given that $\varepsilon = 1.08$ V, $n = 6$, $r = 1\ \Omega$, $R = 5\ \Omega$

The total emf = $n\varepsilon = 6 \times 1.08$ V

The total internal resistance $nr = 6 \times 1 = 6\ \Omega$

The current in the circuit $I_S = \frac{n\varepsilon}{R + nr} = \frac{6 \times 1.08}{5 + 6}$ = 0.589 A.

(B) The cells in parallel.

Here $\varepsilon = 1.08\ V$, $m = 6$, $r = 1\ \Omega$, $R = 5\ \Omega$

$$I_p = \frac{m\varepsilon}{mR + r} = \frac{6 \times 1.08}{6 \times 5 + 1} = \frac{6.48}{31} = 0.209 \text{ A}.$$

(C) The cells in multiple arc with $n = 3$, $m = 2$

$$I = \frac{mn\varepsilon}{mR + nr} = \frac{6 \times 1.08}{(2 \times 5) + (3 \times 1)}$$

$$= \frac{6.48}{13} = 0.498 \text{ A}.$$

ARRANGEMENT OF CELLS FOR MAXIMUM CURRENT

Considering the above case, it is required to find the condition for maximum current if the product mn is given.

In this case, the product mn, ε, r, and R are constants and m and n alone can be varied to get I maximum.

For I_{max} denominator $(mR + nr)$ should be minimum in Equation (14.1). This happens when $mR = nr$ or $R = \frac{nr}{m}$.

Hence the current through the external resistance R is maximum when it is equal to internal resistance of the battery $\frac{nr}{m}$.

If cells of different emf and internal resistance are in parallel, there is no simple formula to give the total emf and the internal resistance, and any calculations involving circuits in such cases can be done with the help of Kirchhoff's laws, which will be discussed later.

SOLVED EXAMPLE

14. How would you arrange 20 cells each of emf 1.5 V and internal resistance 1 Ω to give the maximum current through an external resistance of 5 Ω? Also find this current.

Solution:

Let n cells be in series and let there be m such groups in parallel.

Total number of cells $mn = 20$

The external resistance $R = 5\ \Omega$

The internal resistance of each cell $r = 1\ \Omega$

The condition for maximum current is $R = \frac{nr}{m}$

or, $$5 = \frac{n \times 1}{m} = \frac{n}{m}$$

or $n = 5\,m$

Now $mn = m\,(5m) = 20$

or $m^2 = 4$

$m = 2\; n = 100$

To get the maximum current, the cells have to be arranged in 2 rows, each row consisting of 10 cells in series.

The maximum current

$$= \frac{mn\varepsilon}{mR + nr} = \frac{20 \times 1.5}{2 \times 5 + 10 \times 1} = \frac{30}{20} = 1.5 \text{ A.}$$

KIRCHHOFF'S LAW

If several resistors and cells are connected such that they cannot be reduced to simple series and parallel arrangements, Ohm's law becomes insufficient to solve the problem.

First Law

Accordingly, 'The algebraic sum of currents meeting at a junction is zero'.

i.e. $\sum I = O$

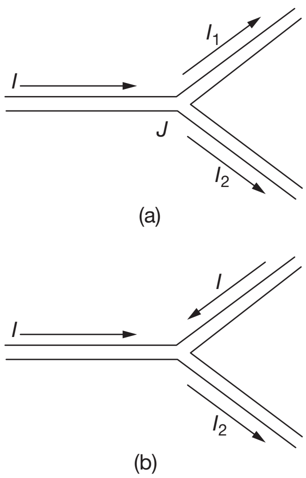


Fig. 14.3

Treating the current to be positive, if it is reaching a junction and negative if leaving it, we have

$$I - I_1 - I_2 = 0$$

or $I = I_1 + I_2$ (for Fig. 14.3 (A))

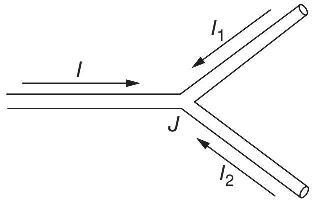
For Fig. 14.3 (B), we have

$$I + I_1 - I_2 = 0$$

or $I + I_1 = I_2$

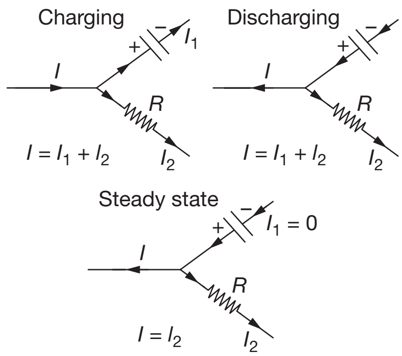
Important Points Regarding First Law

1. This law implies that current reaching a junction is equal to the current leaving the junction.
2. If a current comes out to be negative, actual direction of current at the junction is opposite to that assumed.



In the above diagram, $I + I_1 + I_2 = 0$ can be satisfied only if at least one current is negative, i.e., leaving the junction.

3. This law is simply a statement of 'conservation of charge'. If current reaching a junction is not equal to the current leaving, charge will not be conserved.
4. This law is also applicable to a capacitor treating the resistance of capacitor to be zero during charging or discharging and infinite in steady state.



5. This law is also known as junction rule or current law (KCL) or node theorem.

Second Law

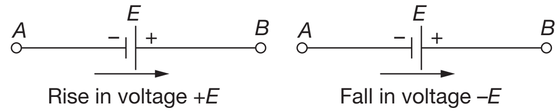
Accordingly, 'The algebraic sum of all potential differences in closed loop is zero', that is,

$$\sum v = 0$$

Important Points Regarding Second Law

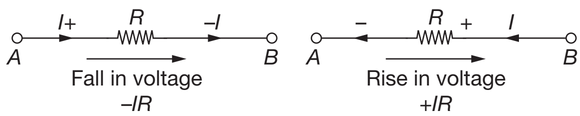
1. **Determination of sign**
   (A) Sign of Battery EMF: A rise in voltage should be given a +ve sign and a fall in voltage a –ve sign. Keeping this in mind, it is clear that as we go from the negative terminal of a battery to its positive terminal, there is a rise in potential; hence, this voltage should be given a +ve sign. If, on the other

hand, we go from +ve terminal to the –ve terminal, then there is a fall in potential, hence this voltage should be preceded by a negative sign.



It is important to not that the sign of the battery emf is independent of the direction of the current through that branch.

(B) Sign of IR drop: If we go through a resistor in the same direction as the current, then there is a fall in potential because current flows from a higher to a lower potential. Hence, this voltage fall should be taken as negative. However, if we go in a direction opposite to that of the current, then there is a rise in voltage. Hence, this voltage rise should be given a positive sign.



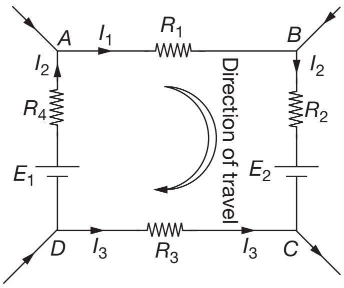


Fig. 14.4

Consider the closed path *ABCDA* (as shown in Fig. 14.4). As we travel around the mesh in the clockwise direction, different voltage drops will have the following signs.

I_1R_1 is –ve (fall in potential)
I_2R_2 is –ve (fall in potential)
I_3R_3 is +ve (rise in potential)
I_4R_4 is –ve (fall in potential)
E_2 is –ve (fall in potential)
E_1 is +ve (rise in potential)
Using Kirchhoff's voltage law, we get

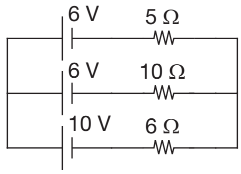
$$-I_1R_1 - I_2R_2 + I_3R_3 - I_4R_4 - E_2 + E_1 = 0$$

or $$I_1R_1 + I_2R_2 - I_3R_3 + I_4R_4 = E_1 - E_2$$

2. This law represents 'conservation of energy'. If the sum of potential changes around a closed loop is not zero, unlimited energy could be gained by repeatedly carrying a charge around a loop.

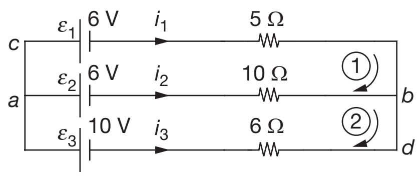
SOLVED EXAMPLES

15. Find the current in the resistors of the circuit given. The internal resistances of the batteries are included in the external resistances.



Solution:

The circuit given cannot be simplified further because it contains resistors not in simple series or parallel connection. Hence, Kirchhoff's rules have to be applied. Since the currents have not been marked, we have to do that first. No special care need be taken to indicate the exact current directions since those chosen incorrectly will simplify to give negative numerical values.



Applying the junction rule to junction a,

$$i_1 + i_2 + i_3 = 0 \quad (1)$$

Taking the loop *acba,*

IR drop across 5 Ω = $+5i_1$

IR drop across 10 Ω = $-10i_2$

emf of $\varepsilon_1 = +6$ V

emf of $\varepsilon_2 = -6$ V

Applying the loop rule,

$$5i_2 - 10i_2 = +6 - 6 = 0 \text{ or } i_1 - 2i_2 = 0 \quad (2)$$

Considering the loop *abda,*

$$10i_2 - 6i_3 = 10 - 6$$

$$10i_2 - 6i_3 = 4$$

$$5i_2 - 3i_3 = 2 \quad (3)$$

To find the unknowns i_1, i_2 , and i_3, solve the three Equations (1), (2), and (3). We get

$$i_1 = \frac{2}{7}\text{ A},\ i_2 = \frac{1}{7}\text{ A}$$

$$i_3 = -\frac{3}{7}\text{ A}.$$

The direction of flow of i_3 is opposite to that marked in the circuit.

16. A convention is often employed in circuit diagrams where the battery (or other power source) is not shown explicitly but the points connected to the source are indicated by voltage and ground, respectively. The following two circuit diagrams are drawn on this convention. Assume the battery resistance is negligible.

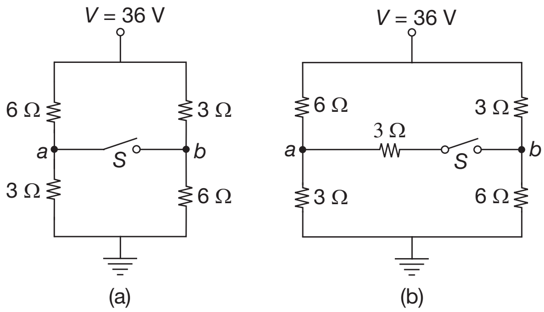


Fig. 14.5

(A) In Fig. 14.5 (A), what is the potential difference V_{ab} when the switch S is open?

(B) What is the current through switch S when it is closed?

(C) In Fig. 14.5 (B), what is the potential difference V_{ab} when switch S is open?

(D) What is the current through switch S when it is closed?

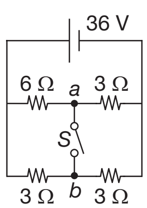
(E) What is the equivalent resistance in the circuit (b), when (i) switch S is open and (ii) switch S is closed?

Solution:

The given circuit is equivalent to

(A) Potential at the point $a = V_a = 36 - \left(\frac{6}{9} \times 36\right) = 12\text{ V}$

Potential at the point $b = V_b = 36 - \left(\frac{3}{9} \times 36\right) = 24\text{ V}$



Hence V_{ab} = Potential difference between a and b

$= V_a - V_b = 12 - 24 = -12\text{ V}$

(B) When the switch S is closed, the currents and potentials will readjust to new values.
The equivalent circuit is now

Let the current distributions be I_1 and I_2 as shown. Let the current in the switch be i_{ab} from a to b and x the resistance of switch. Then for the loop $QabQ$,

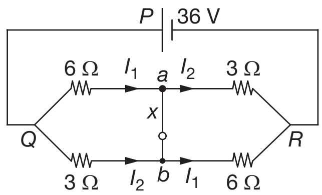


Fig. 14.6

$$6I_1 + I_{ab}\,x - 3I_2 = 0 \qquad (1)$$

For the loop $PQaRP$, $36 = 6I_1 + 3I_2$ (2)

Also $\qquad i_{ab} = I_1 - I_2$ (3)

From (1) and (3), we get, $\dfrac{I_1}{I_2} = \dfrac{3+x}{6+x}$ (4)

Proceeding to the limit $x \to 0$ without $i_{ab} \to \infty$, from (4), we get

$$\frac{I_1}{I_2} = \frac{1}{2}$$

or $\qquad I_2 = 2I_1$

Substituting in (2), we get

$$I_1 = 3\,A \text{ and } I_2 = 6\text{ A}.$$

Hence, the current through the switch $i_{ab} = I_1 - I_2 = -3\text{ A}$

The current flows in the switch from b to a.

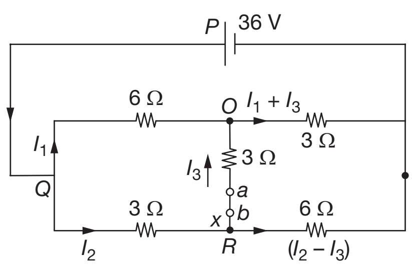
(C) In Fig. 14.6 (b) we have a resistance of 3 Ω added to the switch circuit. However, this will **NOT** affect the current and potential distributions when the switch S is open.
Hence the potential difference $V_{ab} = -12$ V (as in the case (a) above).

(D) When the switch S is closed, the currents and potentials will redistribute to new values. Let the currents be I_1, I_2, and I_3 as shown.
For the loop $QROQ$,

$$6I_1 - (3 + x)\,I_3 - 3I_2 = 0 \qquad (5)$$

For the loop $PQOSP$,

$$36 = 6I_1 + 3(I_1 + I_3) = 9I_1 + 3I_3$$



or $$3I_1 + I_3 = 12 \quad (6)$$

For the loop *QRSOQ*,

$$3I_2 + 6(I_2 - I_3) - 3(I_1 + I_3) - 6I_1 = 0$$

or $$9I_1 - 9I_2 + 9I_3 = 0$$

or $$I_1 - I_2 + I_3 = 0 \quad (7)$$

Solving (5), (6), and (7) for I_1, I_2, and I_3, we get

$$I_1 = \frac{24}{7} = 3.43 \text{ A},$$

$$I_2 = \frac{36}{7} = 5.14 \text{ A}$$

and $$I_3 = \frac{12}{7} = 1.71 \text{ A}.$$

Hence, the current that flows through the switch when it is closed = 1.71 A (flowing from *b* to *a*).

(E) When the switch *S* is open in circuit diagram (b) the total current in the circuit = the same total current as in circuit diagram (a) with switch *S* open. Hence, equivalent resistance is the same as in case (a) above, and

$$R_{eq} = \frac{9 \times 9}{9 + 9} = \frac{81}{18} = 4.5 \ \Omega$$

When the switch *S* is closed in diagram (b), the total current drawn from the battery is

$$I = I_1 + I_2 = \frac{24}{7} + \frac{36}{7} = \frac{60}{7} \text{ A}.$$

Hence, the equivalent resistance in the circuit is

$$R_{eq} = \frac{E}{I} = \frac{36}{60/7} = \frac{21}{5} = 4.2 \ \Omega.$$

17. (A) Find the emfs ε_1 and ε_2 in the circuit of the following diagram and the potential difference between the points *a* and *b*.

(B) If in the above circuit, the polarity of the battery ε_1 is reversed, what will be the potential difference between *a* and *b*?

Solution:

(A) It is clear that 1 A current flows in the circuit from *b* to *a*.

Applying Kirchhoff's law to the loop *PabP*,

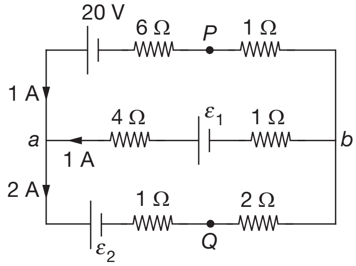
$$20 - E_1 = 6 + 1 - 4 - 1 = 2$$

Hence, $$E_1 = 18 \text{ V}$$

Also applying Kirchhoff's law to the loop *PaQbP*,

$$20 - E_2 = 6 + 1 + (1 \times 2) + (2 \times 2) = 13$$

Hence, $$E_2 = 7 \text{ V}$$



Thus, the potential difference between the points *a* and *b* is

$$V_{ab} = 18 - 1 - 4 = 13 \text{ V}.$$

(B) On reversing the polarity of the battery E_1, the current distributions will be changed.

Let the currents be I_1 and I_2 as shown.

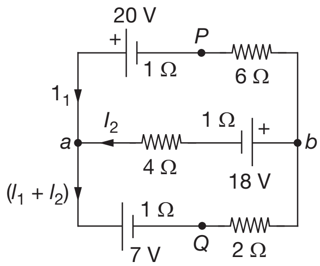
Applying Kirchhoff's law for the loop *PabP*,

$$20 + E_1 = (6 + 1)\,I_1 - (4 + 1)\,I_2$$

or $$38 = 7I_1 - 5I_2 \quad (1)$$

Similarly, for the loop *abQa*,

$$4I_2 + I_2 + 18 + 2(I_1 + I_2) + (I_1 + I_2) + 7 = 0$$



or $$3I_1 + 8I_2 = -25 \quad (2)$$

Solving (1) and (2) for I_1 and I_2, we get

$$I_1 = 2.52 \text{ and } I_2 = -4.07 \text{ A}$$

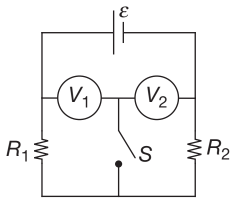
Hence, $$V_{ab} = -5 \times (4.07) + 18$$

$$= -20.35 + 18 = -2.35 \text{ V}.$$

18. In the circuit V_1 and V_2 are two voltmeters of resistances 3000 Ω and 2000 Ω, respectively. The resistances $R_1 = 2000\ \Omega$ and $R_2 = 3000\ \Omega$ and the emf of the battery $\varepsilon = 200$ V. The battery has negligible internal resistance. Find the readings of the voltmeters V_1 and V_2 when

(A) the switch *S* is open and

(B) the switch *S* is closed.



Solution:

(A) When S is open

V_1 and V_2 in series have a resistance

$$= 3000 + 2000 = 5000\ \Omega$$

R_1 and R_2 in series have a resistance

$$= 2000 + 3000 = 5000\ \Omega$$

5000 Ω and 5000 Ω in parallel are equivalent to

$$\frac{5000 \times 5000}{10000} = 2500\ \Omega$$

$$\text{Circuit current} = \frac{200}{2500} = \frac{2}{25}\ \text{A}$$

Current in the branch of V_1 and V_2

$$= \frac{1}{2}\left(\frac{2}{25}\right) = \frac{1}{25}\ \text{A}$$

Potential difference across $V_1 = \left(\frac{1}{25}\ \text{A}\right)(3000\ \Omega)$

$= 120$ V

Potential across across $V_1 = \left(\frac{1}{25}\ \text{A}\right)(2000\ \Omega)$

$= 80$ V

∴ The voltmeters V_1 and V_2 read 120 V and 80 V, respectively.

Similarly, V_2 and R_2 in parallel have an equivalent resistance of 1200 Ω.

As these two equivalent resistances are same

Potential difference across AS = potential difference across SB

∴ Potential difference across AS = 100 V

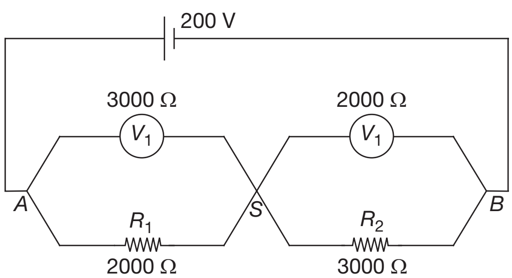
This is registered by V_1 SB

Similarly, potential difference across = 100 V

This is registered by V_1

Similarly, potential difference across SB = 100 V

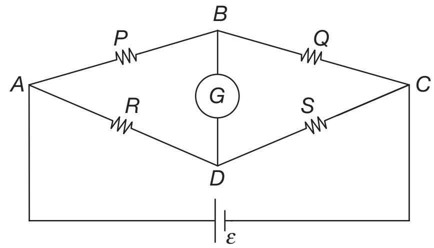
This is registered by V_2.



ELECTRICAL DEVICES

Wheatstone Bridge

For measurement of a resistance, a network made up of four resistance arms P, Q, R, and S is arranged as shown. Arms AB and BC having resistances P and Q, respectively, are known as ratio arms.



A galvanometer G is connected across B and D. A battery is connected across A and C. When the values of resistances P, Q, R, and S are such that no current flows through the galvanometer G, the bridge is said to be balanced. In that case, B and D are at the same potential and we have the condition

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

Usually, S is an unknown resistance and P, Q, and R are known.

Temperature measurement using wheatstone bridge

A platinum wire about 50 cm in length is wound on a non-conducting rod with a non-inductive winding. This platinum wire in connected in the arm CD of wheatstone bridge circuit as shown in Fig. 14.7.

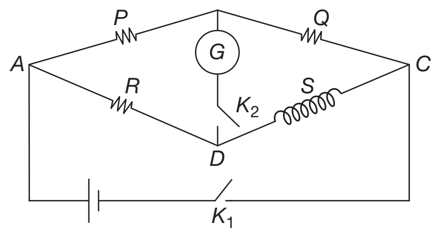


Fig. 14.7

Working and Theory

1. Keeping the platinum wire S at 0°C the arms P and Q are made equal. The value of R is adjusted so that on closing key K_1 and K_2 the galvanometer shown no deflection. If R_0 is the resistance of platinum wire at 0°C, then

$$R_0 = \frac{RQ}{P} \qquad (1)$$

2. Keeping the platinum wire into steam at 100°C and repeating the same procedure as in step 1, we get

$$R_{100} = \frac{R'Q}{P}$$

[R' = resistance of arm R]

3. Keeping the platinum wire into the bath whose temperature t°C is to be determined and repeating the step 1, we get

$$R_t = \frac{R''Q}{P}$$

[R'' = resistance of arm R]

If α is the temperature coefficient of resistance of platinum wire at t°C, then

$$R_{100} = R_0\left(1+\alpha\times100\right)$$

$$\alpha = \frac{R_{100}-R_0}{R_0\times100} \qquad (14.2)$$

Also $$R_t = R_0\left(1+\alpha t\right)$$

$$\alpha = \frac{R_t - R_0}{R_0\times t} \qquad (14.3)$$

From (14.2) and (14.3),

$$\frac{R_t - R_0}{R_0\times t} = \frac{R_{100}-R_0}{R_0\times100}$$

$$t = \frac{R_t - R_0}{R_{100}-R_0}\times100 \quad = \frac{R''-R}{R'-R}\times100$$

METER BRIDGE

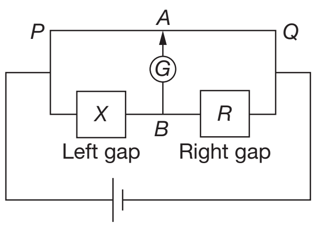
The wheatstone network is used to determine unknown resistances. The meter bridge is an instrument based on the balancing condition of wheatstone network.

The resistances R_1 and R_2 are two parts of a long wire PQ (usually 1 m long). The portion PA of the wire offers resistance R_1 and the portion QA offers resistance R_2. The sliding contact at A is adjusted so that galvanometer reads zero.

For no deflection $\frac{R_1}{R_2} = \frac{X}{R}$

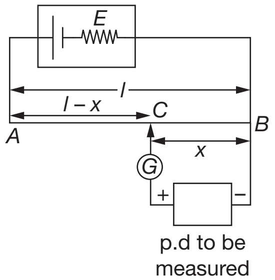
$$\Rightarrow \qquad X = R\left[\frac{R_1}{R_2}\right] = R\frac{l_1}{l_2}$$

If R is a known resistance, then X can be measured by measuring the length l_1 and l_2



Potentiometer

We already know that when a voltmeter is used to measure potential difference, its finite resistance causes it to draw a current from the circuit. Hence the potential difference which was to be measured is changed due to the presence of the instrument. Potentiometer is an instrument which allows the measurement of potential difference without drawing current from the circuit. Hence, it acts as an infinite-resistance voltmeter.



The resistance between A and B is a uniform wire of length l, with a sliding contact C at a distance x from B. The sliding contact is adjusted until the galvanometer G reads zero. The no deflection condition of galvanometer ensures that there is no current through the branch containing G and the potential difference to be measured. The length x for no deflection is called as the balancing length.

$V_{CB} = V$ potential difference to be measured.

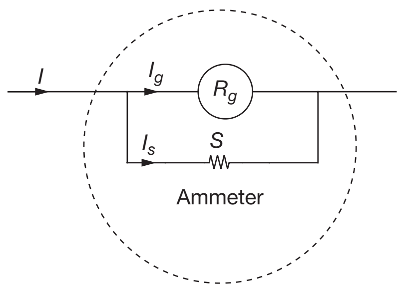
If λ is the resistance per unit length of AB.

$$V = V_{CB} = \frac{x}{l}V_{AB} = \left(\frac{V_{AB}}{l}\right)x$$

Ammeter

An ammeter is a modified form of suspended coil galvanometer. While galvanometers can permit only very small currents to pass through them, ammeters can allow, depending upon their construction, much heavy currents to flow through them.

A suitable shunt resistance S (of very small value compared to R_g) in parallel with that of galvanometer of resistance R_g achieves this objective.



If the ammeter is designed to measure a maximum current I (full-scale deflection current), then the shunt S required for the purpose is given by

$$I_g \cdot R_g = (I - I_g)S$$

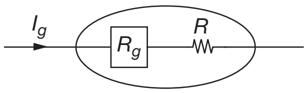
where I_g is the maximum permissible current through the galvanometer.

The resistance of ammeter is small (smaller than that of the shunt S) and for current measuring purposes, it is included in series in a circuit. An ideal ammeter has zero resistance.

Voltmeter

Voltmeter is also a modified form of galvanometer. It is used to measure potential differences.

A suitable high resistance R is included in series with the galvanometer of resistance R_g to enable the instrument to measure voltages. If the maximum range of the voltmeter is V_0 and the maximum permissible current through the galvanometer is I_g, then the value of R is given by

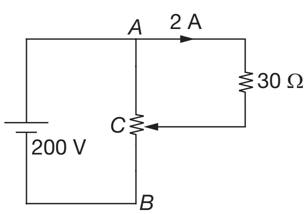


$$I_g = \frac{V_0}{R + R_g}$$

To measure the potential difference across two points in a circuit, the voltmeter is connected parallel with it. An ideal voltmeter has infinite resistance.

SOLVED EXAMPLES

19. A potential divider of resistance 500 Ω is used to obtain variable voltages from a supply main of 200 V. Determine the position of the tapping point C to get a current of 2 A through a resistance of 30 Ω connected across A and C as shown.



Solution:

Let the resistance of the potential divider between A and C be R Ω.

The potential difference across the 30 Ω resistor = 2 A × 30 Ω = 60 V

∴ the voltage drop across AC of the potential divider = 60 V

$$\text{Current flowing through } R = \frac{60}{R} \text{ A}$$

Now, the voltage drops across BC = 200 V – 60 V = 140 V

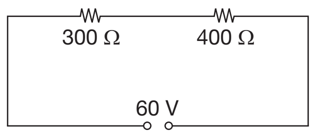
$$\text{The current through } BC = \frac{140}{(500 - R)} \text{ A}$$

$$\text{Now,} \quad \frac{140}{(500 - R)} = \frac{60}{R} + 2$$

Solving R = 434.7 Ω

Hence, the tapping point C lies in such a position that the length AC is $\frac{434.7}{500}$ = 0.8694 of the length AB.

20. In the circuit shown a voltmeter reads 30 V when it is connected across the 400 Ω resistance. Calculate what the same voltmeter would read when it is connected across the 300 Ω resistance.



Solution:

The voltmeter is in parallel with 400 Ω resistance.

Let its resistance be R Ω.

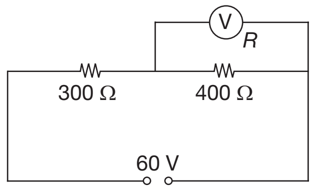
It is clear that the resistances R and 400 Ω combining in parallel produce equivalent resistance of value of 300 Ω so that the potential drop across this equivalent resistance is half of 60 V.

$$\therefore \quad \frac{R \times 400}{R + 400} = 300$$

$$400\,R = 300\,R + 120000$$

$$100\,R = 120000$$

$$R = 1200\ \Omega$$



Next, the same voltmeter is connected across the 300 Ω resistance. Now the equivalent resistance of 300 Ω and 1200 Ω of voltmeter in parallel connection will be

$$\frac{300 \times 1200}{300 + 1200} = 240\ \Omega$$

The total circuit resistance = 240 + 400 = 640

Potential drop across 240 Ω $= \dfrac{240}{640} \times 60\ \text{V} = 22.5$ V.

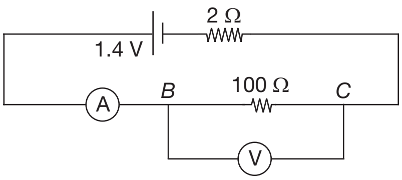
21. A battery of emf 1.4 V and internal resistance 2 Ω is connected to a resistor of 100 Ω resistance through an ammeter. The resistance of the ammeter is $\dfrac{4}{3}$ Ω. A voltmeter has also been connected to find the potential difference across the resistor.

(A) Draw the circuit diagram.
(B) The ammeter reads 0.02 A. What is the resistance of the voltmeter?
(C) The voltmeter reads 1.1 V. What is the error in the reading?

Solution:

(A) The circuit diagram is shown.
(B) Let the resistance of the voltmeter be R Ω. The equivalent resistance of voltmeter (R Ω) and 100 Ω in parallel is $\dfrac{100 \times R}{100 + R} = \dfrac{100R}{100 + R}$

The resistance of the ammeter $= \dfrac{4}{3}$ Ω



The total resistance of the circuit $= \dfrac{100R}{100 + R} + \dfrac{4}{3} + 2\ \Omega$

The current in the circuit as read by the ammeter = 0.02 A

Now, $$0.02 = \frac{1.4}{\dfrac{100R}{100 + R} + \dfrac{4}{3} + 2}$$

or, $$\frac{100R}{100 + R} + \frac{4}{3} + 2 = \frac{1.4}{0.02} = 70$$

$$\frac{100R}{100 + R} = 70 - \frac{10}{3} = \frac{200}{3}$$

$$300R = 200R + 20000$$

$$100R = 20000$$

$$R = 200\ \Omega$$

Resistance of the voltmeter = 200 Ω

(C) The effective resistance between B and C $= \dfrac{100 \times 200}{100 + 200} = \dfrac{200}{3}$ Ω

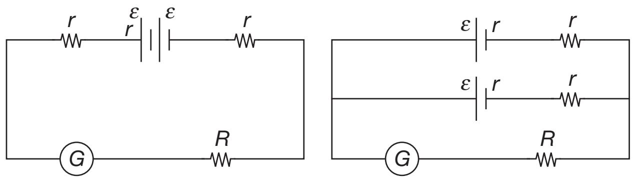
The potential drop across this resistance = circuit current $\times \dfrac{200}{3} = 0.02 \times \dfrac{200}{3} = \dfrac{4}{3}$ V = 1.33 V

The reading of the voltmeter = 1.1 V

The error in the reading of the voltmeter = 1.1 – 1.33 = – 0.23 V.

22. A galvanometer together with an unknown resistance in series is connected across two identical batteries each of 1.5 V. When the batteries are connected in series, the galvanometer records a current of 1 ampere, and when the batteries are in parallel, the current is 0.6 ampere. What is the internal resistance of the battery?

Solution:



Emf of each cell is $\varepsilon = 1.5$ V

Let the internal resistance of each cell be r.

Let the resistance of the galvanometer be G.

Let the unknown resistance in series with the galvanometer be R.

(A) Let the cells be in series.

The emf of the circuit = $2\varepsilon = 3$ V

The resistance of the circuit = $(R + G + 2r)$ Ω

The current in the circuit $\dfrac{3}{R + G + 2r} = 1$ A (given) (1)

(B) When the cells are in parallel, the emf of the circuit = $\varepsilon = 1.5$ V

The resistance of the circuit = $R + G + \dfrac{r \cdot r}{r + r}$

$$= \left(R + G + \frac{r}{2}\right)\Omega$$

The current in the circuit $\dfrac{1.5}{R + G + \dfrac{r}{2}} = 0.6$ A (2)

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

$$R + G + 2r = 3$$

and $R + G + \frac{r}{2} = \frac{1.5}{0.6} = 2.5$

Subtracting these two equations, we get

$$\frac{3}{2}r = 0.5 \Rightarrow r = \frac{1}{3}\,\Omega$$

Internal resistance of each cell $= \frac{1}{3}\,\Omega$.

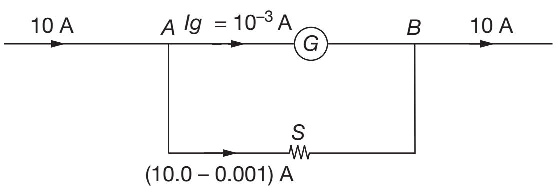
23. (A) A galvanometer having a coil of resistance of 100 Ω gives a full-scale deflection when a current of one milliampere is passed through it. What is the value of the resistance, which can convert this galvanometer into ammeter giving a full-scale deflection for a current of 10 amperes?

(B) A resistance of the required value is available, but it will get burnt if the energy dissipated in it is greater than 1 W. Can it be used for the above described conversion of the galvanometer?

(C) When this modified galvanometer is connected across the terminals of a battery, it shows a current of 4 A. The current drops to 1 ampere when a resistance of 1.5 Ω is connected in series with the modified galvanometer. Find the emf and the internal resistance of the battery.

Solution:

(A) The value of shunt resistance.



Let the shunt resistance required be S Ω. The galvanometer permits the full-scale deflection current of $I_g = 1 \times 10^{-3}$. A through it when the circuit is 10 A.

Then, $(10 - 0.001)\,S = 0.001 \times 100$

$$S = \frac{\frac{0.1}{9999}}{1000} = \frac{100}{9999} \approx \frac{1}{100}\,\Omega$$

(B) Power dissipated by the shunt $= i^2R$

$$= (9999 \times 10^{-3})^2 \times \frac{100}{9999}$$

$$= 9999 \times 10^{-6} \times 100$$

$$= 0.9999 \text{ W}$$

This is less than the maximum power of 1 W, which the resistor can dissipate. Hence, the resistance can be safely used.

(C) Emf of the battery and its internal resistance: The combined resistance of the galvanometer and the shunt is given by $\dfrac{\frac{1}{100} \times 100}{\frac{1}{100} + 100}\,\Omega \approx \frac{1}{100}\,\Omega$

This combined resistance and the internal resistance of the battery in series give a total resistance of $\left(\frac{1}{100} + r\right)$ ohm to the circuit.

If ε be the emf of the battery, then

$$\frac{\varepsilon}{r + 0.01} = 4 \text{ A} \qquad (1)$$

Now with an additional resistance of 1.5 Ω in series

$$\frac{\varepsilon}{r + 0.01 + 1.5} = 1 \text{ A} \qquad (2)$$

From Equations (1) and (2), we get $\frac{r + 1.51}{r + 0.01} = 4$

$$3\,r = 1.47$$

Internal resistance $r = 0.49$ Ω
Substituting this value of r in Equation (1),

$$\varepsilon = 4 \times 0.5 = 2 \text{ V}.$$

HEATING EFFECT OF CURRENT

Joule's Law of Electrical Heating

When an electric current flows through a conductor, electrical energy is used in overcoming the resistance of the wire. If the potential difference across a conductor of resistance R is V volt, and if a current of I ampere flows, the energy expended in time t seconds is given by

$$W = VIt \text{ J}$$

$$= I^2Rt \text{ J}$$

$$= \frac{V^2}{R}t \text{ J}$$

The electrical energy so expended is converted into heat energy and this conversion is called the heating effect of electric current.

The heat generated in joules when a current of I ampere flows through a resistance of R ohm for t seconds is given by

$$H = I^2Rt \text{ J}$$

This relation is known as Joule's law of electrical heating.

Electrical Power

The energy liberated per second in a device is called its power. The electrical power P delivered by an electrical device is given by

$$\left.\begin{aligned} P &= VI \quad \text{W} \\ &= I^2R \text{ W} \\ &= \frac{V^2}{R} \quad \text{W} \end{aligned}\right\}$$

The power P is in watts when I is in amperes, R is in ohms and V is in volts.

The practical unit of power is 1 kW = 1000 W.

The formula for power $P = I^2R = VI = \frac{V^2}{R}$ is true only when all the electrical power is dissipated as heat and not converted into mechanical work, and so on, simultaneously.

Unit of Electrical Energy consumption

1 unit of electrical energy = 1 kilo watt-hour = 1 kWh $= 36 \times 10^5$ J

$$\text{Number of units consumed} = \frac{\text{watt} \times \text{hour}}{1000} = \text{kWh}$$

SOLVED EXAMPLES

24. What is the resistance of the filament of a bulb rated at (100 W – 250 V)? What is the current through it when connected to 250 V line? What will be the power if it is connected to a 200 V line?

Solution:

$$\text{Power } P = VI = \frac{V^2}{R}$$

$$\text{Resistance } R = \frac{V^2}{P} = \frac{250 \times 250}{100} = 625\ \Omega$$

$$\text{The current through the lamp} = \frac{P}{V} = \frac{100}{250}\ \frac{\text{W}}{\text{V}} = 0.4 \text{ A}$$

The power of the lamp when it is connected to a 200 V line is

$$P = \frac{V^2}{R} = \frac{200 \times 200}{625} = 64 \text{ W.}$$

25. Forty electric bulbs are connected in series across a 220 V supply. After one bulb is fused, the remaining 39 are connected again in series across the same supply. In which case will there be more illumination and why?

Solution:

Let r be the resistance of each bulb and 40 bulbs in series will have a resistance of 40 r Ω. When connected across a supply voltage V, the power of the system with 40 bulbs will be

$$P_{40} = \frac{V^2}{40r}$$

When one of the bulbs is fused, the resistance of the remaining 39 bulbs in series = 39 r and the power of the system when connected to the same supply

$$P_{39} = \frac{V^2}{39r}$$

$$\text{It is clear that } \frac{V^2}{39r} > \frac{V^2}{40r}$$

∴ power of **39 bulbs** in series is greater.

26. A fuse made of lead wire having an area of cross-section 0.2 mm^2. On short circuiting, the current in the fuse wire reaches 30 A. How long after the short circuiting will the fuse begin to melt?

Specific heat capacity of lead = 134.4 J kg^{-1} K^{-1}
Melting point of lead = 327°C
Density of lead = 11340 kg/m^3
Resistivity of lead = 22×10^{-8} Ω-m
Initial temperature of the wire = 20°C
Neglect heat loss.

Solution:

If L be the length of the wire, its resistance

$$R = \frac{\rho L}{A} = \frac{(22 \times 10^{-8})L}{(0.2 \times 10^{-6}) \text{ m}^2}$$

Heat produced in the wire in 1 s = $I^2R = (30)^2 R$ J

Heat required to raise the temperature of the wire to 327°C

$$Q = ms\Delta T$$

$$= (LAd)\ (134.4)\ (307) \text{ J}$$

Time required to melt the wire

$$= \frac{Q}{I^2R} = \frac{LAd \times 134.4 \times 307}{I^2 \times \rho L} \times A$$

$$= \frac{A^2}{I^2} \cdot \frac{d}{\rho} \times 134.4 \times 307$$

$$= \frac{\left(0.2 \times 10^{-6}\right)^2}{900} \times \frac{11340}{22 \times 10^{-8}} \times 134.4 \times 307$$

$$= 0.0945 \text{ s.}$$

27. An electric kettle has two heating coils. When one of the coils is switched on, the kettle begins to boil in 6 min and when the other is switched on, the boiling begins in 8 min. In what time will the boiling begin if both coils are switched on simultaneously (A) in series and (B) in parallel?

Solution:

Let the resistance of the two coils be R_1 and R_2, respectively. Let the supply voltage be V. Let Q be the heat required to boil the kettle.

Using the first coil, let t_1 be the time taken. Now

$$Q = \frac{V^2}{R_1} \times t_1; \; t_1 = 6 \text{ min} \qquad (1)$$

Using the second coil, let t_2 be the time taken

$$Q = \frac{V^2}{R_2} \times t_2; \quad t_2 = 8 \text{ min} \qquad (2)$$

Now $\dfrac{V^2}{R_1} \times t_1 = \dfrac{V^2}{R_2} \times t_2$

or $\dfrac{R_1}{R_2} = \dfrac{t_1}{t_2} = \dfrac{6}{8} = \dfrac{3}{4}$

$$R_2 = \frac{4}{3} R_1 \qquad (3)$$

(A) When the two coils are in series to the supply

$$Q = \frac{V^2}{R_1 + R_2} \times T_1 = \frac{V^2}{R_1 + \frac{4}{3} R_1} T_1 = \frac{V^2}{\frac{7}{3} R_1} T_1 \qquad (4)$$

where T_1 is the time taken.

From (1) and (4), we get

$$\frac{V^2}{R_1} \times 6 \times 60 = \frac{V^2}{R_1} \times \frac{3}{7} T_1$$

$$6 \times 60 = \frac{3}{7} T_1$$

$$T_1 = \frac{6 \times 60 \times 7}{3} \text{ s}$$

$$= 14 \text{ min}$$

(B) When the two coils are in parallel connection, the equivalent resistance

$$= \frac{R_1 R_2}{R_1 + R_2} = \frac{\frac{4}{3} R_1^2}{\frac{7}{3} R_1} = \frac{4}{7} R_1$$

$\therefore$ heat developed in T_2 is

$$Q = \frac{V^2}{\frac{4}{7} R_1} \cdot T_2 \qquad (5)$$

From (1) and (5),

$$\frac{7}{4} \frac{V^2}{R_1} \cdot T_2 = \frac{V^2}{R_1} \times t_1$$

$$T_2 = t_1 \times \frac{4}{7} = \frac{24}{7} \text{ min} = 3\frac{3}{7} \text{ min}.$$

BRAIN MAP

CURRENT ELECTRICITY

1. Electric current

$$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

2. Ohm's law

$V = IR$

Where R is called the resistance

3. (a) Resistance

$$R = \rho \frac{l}{A}$$

(b) Effect of temperature

$$R = R_0 (1 + \alpha\theta)$$

(c) Grouping of resistors

(i) When reistors are in series

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

(ii) When resistors are in parallel

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

4. Kirchhoff's law

(a) 1st law:

at any junction of circuit elements

$\Sigma I = 0$

(b) 2nd law:

around any close loop

$\Sigma V = 0$

5. (a) When a cell of emf (ε) is in a circuit

(i) $I = \dfrac{E}{R + r}$

Where r is internal resistance of the cell

(ii) $V_{AB} = E - Ir$

(b) Grouping of cells

(i) When cells are in series

$$I = \frac{nE}{R + nr}$$

(ii) When cells are in parallel

$$I = \frac{m\varepsilon}{mR + r}$$

(iii) Cells are in multiple arc

$$I = \frac{mn\varepsilon}{mR + r}$$

(iv) For maximum current $mR = nr$

6. Voltmeter is used in parallel in a circuit and should have very high resistance.

7. Ammeter is used in series in a circuit and should have very small resistance.

8. Potentiometer is a method of measurement involves a condition of no current flows and e.m.f.s are compared independent of the interval resistance of the source.

9. Wheatstone bridge

is an arrangement of four resistances used for measuring one of them in temrs of others.

For a balance wheat Stone bridge $\dfrac{P}{Q} = \dfrac{R}{S}$

10. Heating effect of current

(i) Joules law

$H = I^2Rt$

(ii) Electrical power

$p = VI = I^2R = V^2/R$

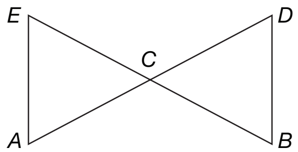
EXERCISES

Single Option Correct Type

1. If resistance of each wire in the network shown is r, the equivalent resistance between A and C is equal to

(A) r (B) $\frac{r}{2}$

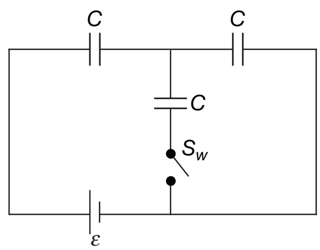
(C) $\frac{2r}{3}$ (D) $\frac{3r}{2}$



2. In the circuit shown, each capacitor has capacitance C. The EMF of the battery is ε and the S_w is closed. The total heat generated in the wire once the switch S_w is opened is

(A) $C\varepsilon^2$ (B) $\frac{C\varepsilon^2}{6}$

(C) $\frac{C\varepsilon^2}{12}$ (D) No heat will be dissipated



3. In the circuit shown in Fig. 14.8, equivalent resistance between A and B is

(A) 8 Ω (B) 15 Ω

(C) $\frac{3}{2}$ Ω (D) 2 Ω

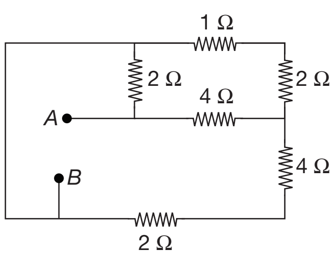


Fig. 14.8

4. The resistance of hexagon circuit between A and B represented in Fig. 14.9 is

(A) r (B) 0.5 r (C) 2 r (D) 3 r

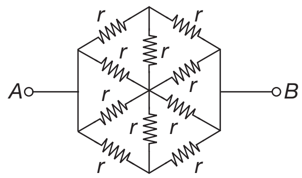
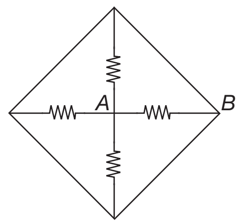


Fig. 14.9

5. In the given circuit, each resistor has resistance R. The equivalent resistance between A and B is

(A) $\frac{R}{4}$ (B) $4R$

(C) $\frac{3R}{4}$ (D) $\frac{4R}{3}$



6. A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be (Assuming potential difference is same in both cases).

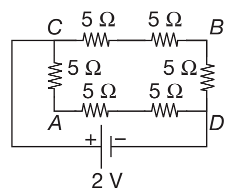
(A) One-fourth (B) Halved

(C) Doubled (D) Four times

7. In the circuit shown, the potential difference between points C and B will be

(A) (8/9) V (B) (4/3) V

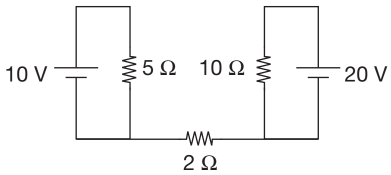
(C) (2/3) V (D) 4 V



8. The current through 2 Ω resistor is

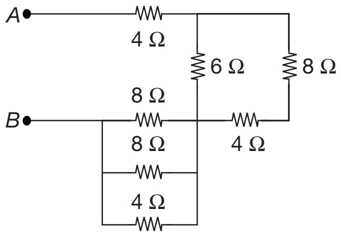
(A) Zero (B) 1 A

(C) 2 A (D) 4 A



9. The equivalent resistance between points A and B in the circuit shown is

(A) 4 Ω (B) 6 Ω
(C) 10 Ω (D) 8 Ω



10. There are n similar resistors each of resistance R. The equivalent resistance comes out to be x when connected in parallel. If they are connected in series, the resistance comes out to be

(A) x/n^2 (B) n^2x (C) x/n (D) nx

11. In the balanced wheatstone bridge circuit, as shown in the Fig. 14.10, when the key is pressed, what will be the change in the reading of the galvanometer?

(A) No change (B) Increased
(C) Decreased (D) Zero

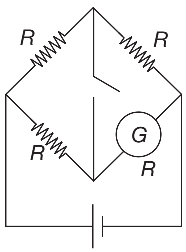


Fig. 14.10

12. In the circuit shown in Fig. 14.11, the reading of voltmeter will be

(A) 0.8 V (B) 1.33 V
(C) 1.6 V (D) 2.00 V

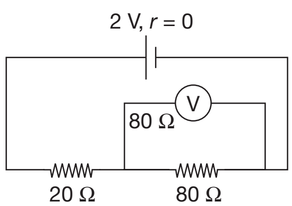


Fig. 14.11

13. In the circuit shown in Fig. 14.12

(A) current in wire AF is 1 A
(B) current in wire CD is 1 A
(C) current in wire BE is 2 A
(D) None of the above

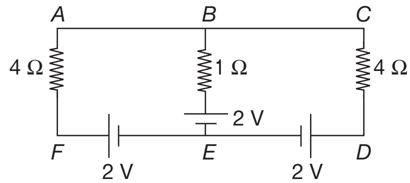
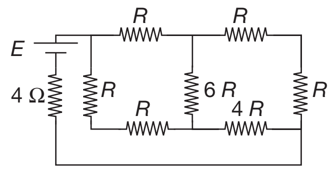


Fig. 14.12

14. A battery of internal resistance 4 Ω is connected to the network of resistance as shown. In order to give the maximum power to the network, the value of R should be

(A) $\frac{4}{9}$ Ω (B) $\frac{8}{9}$ Ω
(C) 2 Ω (D) 18 Ω

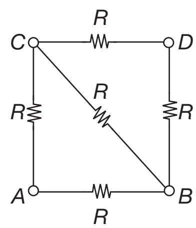


15. A cell of emf E is connected across a resistance R. The potential difference between the terminals of the cell is found to be V. The internal resistance of the cell must be

(A) $\frac{2(E-V)V}{R}$ (B) $\frac{2(E-V)R}{E}$
(C) $\frac{(E-V)R}{V}$ (D) $(E-V)R$

16. The resistance across AB is

(A) $\frac{5}{8}R$ (B) $\frac{7}{8}R$
(C) 1 R (D) 2 R



17. The equivalent resistance of the network shown in Fig. 14.13 between the base terminals is

(A) 3 Ω (B) $3\frac{1}{2}$ Ω

(C) $2\frac{2}{3}$ Ω (D) 2 Ω

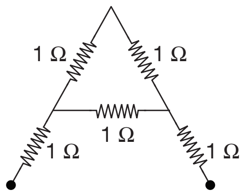
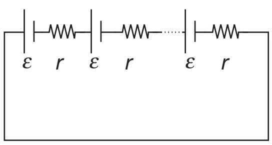


Fig. 14.13

18. n identical cells, each of emf ε and internal resistance r, are joined in series to form a closed circuit as shown. The potential difference across any one cell is

(A) Zero (B) ε

(C) $\frac{\varepsilon}{n}$ (D) $\frac{n-1}{n}\varepsilon$



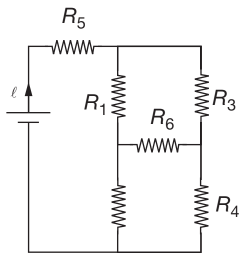
19. In the given circuit, it is observed that the current I is independent of the value of the resistance R_6. Then the resistance value must satisfy

(A) $R_1R_2R_5 = R_3R_4R_6$

(B) $\frac{1}{R_5}+\frac{1}{R_6}=\frac{1}{(R_1+R_2)}+\frac{1}{(R_3+R_4)}$

(C) $R_1R_4 = R_2R_3$

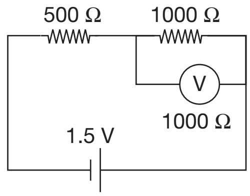
(D) $R_1R_3 = R_2R_4 = R_5R_6$



20. The resistances 500 Ω and 1000 Ω are connected in series with a battery of 1.5 V. The voltage across the 1000 Ω resistance is measured by a voltmeter having a resistance of 1000 Ω. The reading in the voltmeter would be

(A) 1.5 V (B) 1.0 V

(C) 0.75 V (D) 0.5 V



21. A set of n identical resistors, each of resistance R Ω, when connected in series, has an effective resistance of x ohm. When the resistors are connected in parallel, the effective resistance is y ohm. What is the relation between R, x, and y?

(A) $R = \frac{xy}{(x+y)}$ (B) $R = (y-x)$

(C) $R = \sqrt{xy}$ (D) $R = (x+y)$

22. In the circuit shown in Fig. 14.14, the current through

(A) the 3 Ω resistor is 0.50 A.
(B) the 3 Ω resistor is 0.25 A.
(C) the 4 Ω resistor is 0.50 A.
(D) the 4 Ω resistor is 0.25 A.

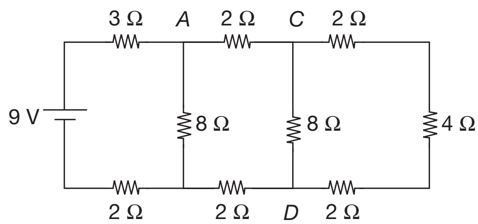


Fig. 14.14

23. In the arrangement of resistances shown in Fig. 14.15, the potential difference between the points B and D will be zero when the unknown resistance X is

(A) 4 Ω.
(B) 2 Ω.
(C) 3 Ω.
(D) EMF of the cell is needed to find out X.

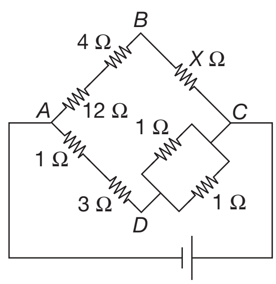
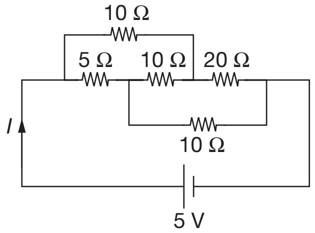


Fig. 14.15

24. The current drawn from the 5 V source will be

(A) 0.33 A (B) 0.5 A
(C) 0.67 A (D) 0.17 A



25. Five cells, each of EMF E and internal resistance r are connected in series. If due to oversight, one cell is connected wrongly, then the equivalent EMF and internal resistance of the combination, is

(A) $5E$ and $5r$ (B) $3E$ and $3r$
(C) $3E$ and $5r$ (D) $5E$ and $3r$

26. Five equal resistors, each equal to R are connected as shown in Fig. 14.16, then the equivalent resistance between points A and B is

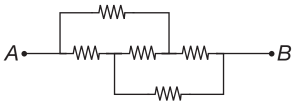


Fig. 14.16

(A) R (B) $5R$ (C) $R/5$ (D) $2R/3$

27. A wire with resistance 12 Ω is bent in the form of a circle. The effective resistance between the two points on any diameter of the circle is

(A) 12 Ω (B) 24 Ω (C) 6 Ω (D) 3 Ω

28. When cells are connected in series

(A) the EMF increases.
(B) the potential difference decreases.
(C) the current capacity increases.
(D) the current capacity decreases.

29. Which of the following has the maximum resistance?

(A) Voltmeter
(B) Millivoltmeter
(C) Ammeter
(D) Milliammeter

30. A conductor with rectangular cross-section has dimensions ($a \times 2a \times 4a$) as shown in Fig. 14.17. Resistance across AB is x, across CD is y, and across EF is z. Then

(A) $x = y = z$ (B) $x > y > z$
(C) $y > z > x$ (D) $x > z > y$

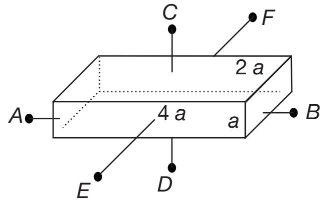


Fig. 14.17

31. A wire l = 8 m long of uniform cross-sectional area A = 8 mm^2 has a conductance of G = 2.45 Ω^{-1}. The resistivity of material of the wire will be

(A) 2.1×10^{-7} Ωm
(B) 3.1×10^{-7} Ωm
(C) 4.1×10^{-7} Ωm
(D) 5.1×10^{-7} Ωm

32. A galvanometer of resistance 400 Ω can measure a current of 1mA. To convert it into a voltmeter of range 8 V, the required resistance is

(A) 4600 Ω (B) 5600 Ω
(C) 6600 Ω (D) 7600 Ω

33. An ammeter reads up to 1 A. Its internal resistance is 0.81 Ω. To increase the range to 10 A, the value of the required shunt is

(A) 0.03 Ω (B) 0.3 Ω
(C) 0.9 Ω (D) 0.09 Ω

34. The resistance of the series combination of two resistances is S. When they are joined in parallel, the total resistance is P. If $S = nP$, then the minimum possible value of n is

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

35. A wire of resistance 4 Ω is stretched to twice its original length. What is the resistance of the wire now?

(A) 1 Ω (B) 14 Ω (C) 8 Ω (D) 16 Ω

36. The net resistance between points P and Q in the circuit shown in Fig. 14.18 is

(A) $R/2$ (B) $2R/5$
(C) $3R/5$ (D) $R/3$

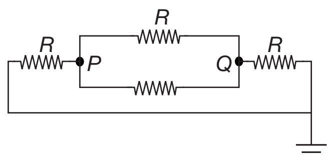
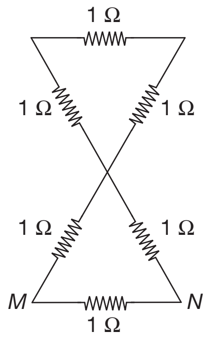


Fig. 14.18

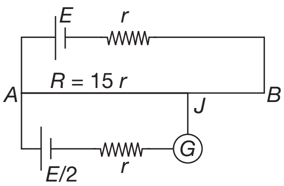
37. The equivalent resistance between points M and N is

(A) 2 Ω (B) 3 Ω
(C) 2/3 Ω (D) None of the above



38. The potentiometer wire *AB* is 600 cm long. At what distance from *A* should the jockey *J* touch the wire to get zero deflection in the galvanometer?

(A) 320 cm (B) 120 cm
(C) 20 cm (D) 450 cm



39. The EMF of the battery shown in Fig. 14.19 is

(A) 6 V (B) 12 V
(C) 18 V (D) 8 V

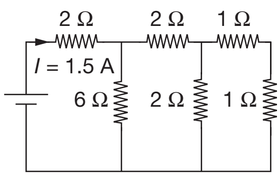


Fig. 14.19

40. In Fig. 14.20, the steady state current in 2 Ω resistance is

(A) 1.5 A (B) 0.9 A
(C) 0.6 A (D) Zero

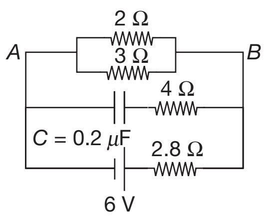


Fig. 14.20

41. The charge on the capacitor in Fig. 14.21 is

(A) 2 μC (B) 2/3 μC
(C) 4/3 μC (D) Zero

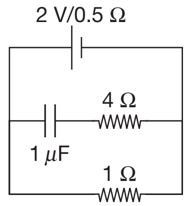


Fig. 14.21

42. Each of the resistance in the network shown in Fig. 14.22 below is equal to *R*. The resistance between the terminals *A* and *B* is

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

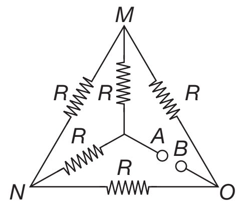


Fig. 14.22

43. Kirchhoff's second law is based on the law of conservation of

(A) Momentum (B) Charge
(C) Energy (D) Sum of mass and energy

44. The current *i* in Fig. 14.23 is

(A) $\frac{1}{5}$A (B) $\frac{1}{10}$A
(C) $\frac{1}{15}$A (D) $\frac{1}{45}$A

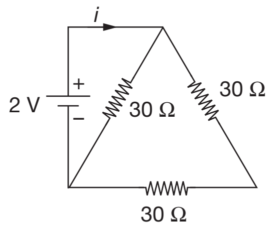


Fig. 14.23

45. The time constant of an *RC* circuit shown in Fig. 14.24 is

(A) 3 *RC* (B) 2/3 *RC*
(C) 6 *RC*/5 (D) 2 *RC*

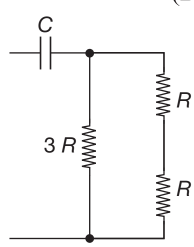
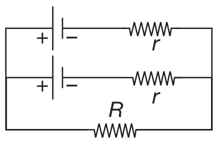


Fig. 14.24

46. What is the current through the resistor R in the circuit shown below? The EMF of each cell is E_m and internal resistance is r

(A) $\dfrac{E_m}{2R+r}$ (B) $\dfrac{E_m}{2r+R}$

(C) $\dfrac{2E_m}{R+2r}$ (D) $\dfrac{2E_m}{2R+r}$



47. Current I_3 in the given circuit shown in Fig. 14.25 is

(A) $\dfrac{5}{11}$ A (B) $\dfrac{7}{11}$ A

(C) $\dfrac{2}{11}$ A (D) None of these

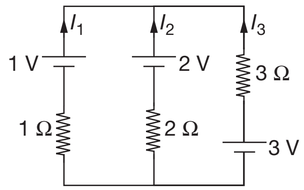


Fig. 14.25

48. Six resistors each of resistance R are connected as shown in Fig. 14.26. What is the effective resistance between points A and B?

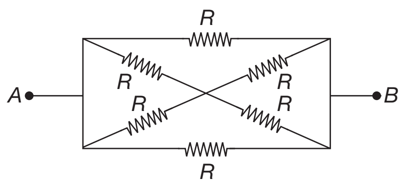


Fig. 14.26

(A) $\dfrac{R}{3}$ (B) R (C) $3R$ (D) $6R$

49. The current at which a fuse wire melts does not depend on its

(A) Cross-sectional area
(B) Length
(C) Resistivity
(D) Density

50. In the circuit shown in Fig. 14.27, the heat produced in the 5 Ω resistor due to a current flowing in it is 10 calories per second. The heat produced in the 4 Ω resistor is

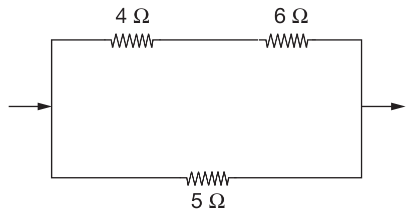


Fig. 14.27

(A) 1 cal s^{-1} (B) 2 cal s^{-1}
(C) 3 cal s^{-1} (D) 4 cal s^{-1}

51. In the circuit shown in Fig. 14.28, the current through

(A) the 3 Ω resistor is 0.50 A
(B) the 3 Ω resistor is 0.25 A
(C) the 4 Ω resistor is 0.50 A
(D) the 4 Ω resistor is 0.25 A

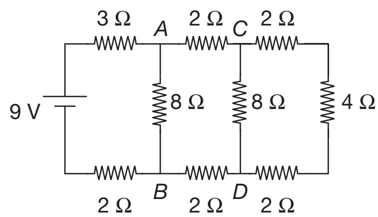


Fig. 14.28

52. Figure 14.29 shows currents in a part of an electrical circuit. The current i is

(A) 1 A (B) 1.3 A
(C) 1.7 A (D) 3.7 A

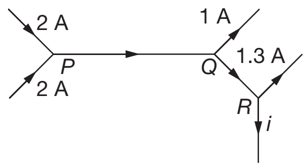


Fig. 14.29

53. The meter bridge circuit shown in Fig. 14.30 is balanced when jockey J divides wire AB in two parts AJ and BJ in the ratio of 1: 2. The unknown resistance Q has value

(A) 1 Ω (B) 3 Ω
(C) 4 Ω (D) 7 Ω

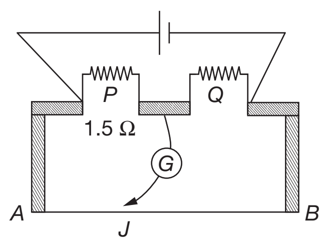


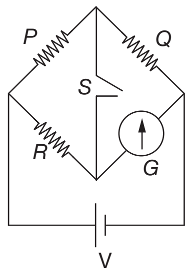
Fig. 14.30

54. n identical cells, each of emf ε and internal resistance r, are joined in series to form a closed circuit. The potential difference across any one cell is

(A) Zero (B) ε (C) $\frac{\varepsilon}{n}$ (D) $\frac{n-1}{n}\varepsilon$

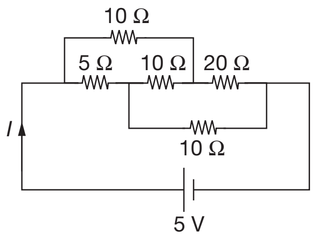
55. In the circuit shown, $P \neq R$, the reading of the galvanometer is same with switch S open or closed. Then

(A) $I_R = I_G$ (B) $I_P = I_G$
(C) $I_Q = I_G$ (D) $I_Q = I_R$



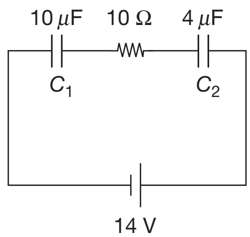
56. The current I drawn from the 5 V source will be

(A) 0.33 A (B) 0.5 A
(C) 0.67 A (D) 0.17 A



57. In the steady state in the circuit shown

(A) potential difference across C_1 is 4 V.
(B) potential difference across 10 Ω is 2V.
(C) potential difference across C_2 is 4 V.
(D) charge on C_1 or C_2 is 0 μC.



58. Find the current supplied by the battery as shown in Fig. 14.31.

(A) 1.5 A (B) 5 A
(C) 1.2 A (D) 2.4 A

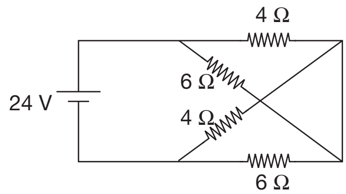
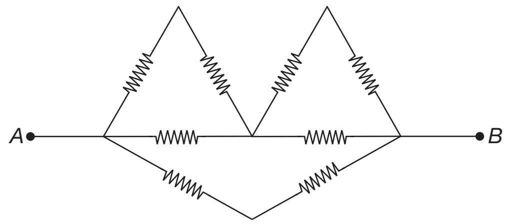


Fig. 14.31

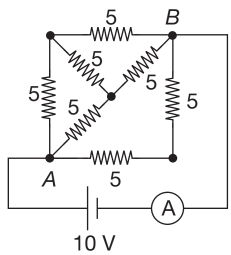
59. What is the equivalent resistance between A and B? (Each resistor has resistance R)

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



60. The ammeter will read the value of current

(A) 3 A (B) $\frac{10}{3}$ A
(C) 30 A (D) $\frac{100}{3}$ A



61. Each cell has EMF ε and internal resistance r as in Fig. 14.32. Find the current through resistance R

(A) $\frac{4\varepsilon}{r}$ (B) $\frac{3\varepsilon}{r}$
(C) $\frac{\varepsilon}{r}$ (D) Zero

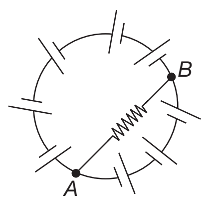


Fig. 14.32

62. If EMF in a thermocouple is $\varepsilon = \alpha T + \beta T^2$, then the neutral temperature of the thermocouple is

(A) $-\beta/(2\alpha)$ (B) $-2\beta/\alpha$

(C) $-\alpha/(2\beta)$ (D) $-2\alpha/\beta$

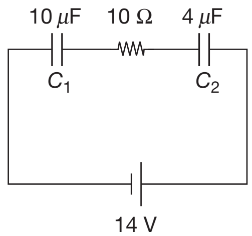
63. The charge flowing through a resistance R varies with time t as $Q = at - bt^2$. The total heat produced in R from $t = 0$ to the time when value of Q becomes again zero is

(A) $\frac{a^3R}{6b}$ (B) $\frac{a^3R}{3b}$

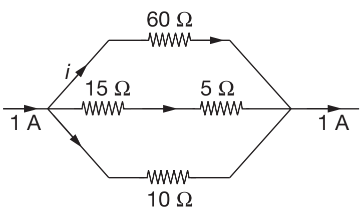
(C) $\frac{a^3R}{2b}$ (D) $\frac{a^3R}{b}$

64. In the steady state in the circuit shown,

(A) Potential difference across C_1 is 4 V.
(B) Potential difference across 10 Ω is 2V.
(C) Potential difference across C_2 is 4 V.
(D) Charge on C_1 or C_2 is 0 μC.



65. The charge flowing through a resistance R varies with time t as $Q = at - bt^2$. The total heat produced in R from $t = 0$ to the time when value of Q becomes again zero is



(A) $\frac{a^3R}{6b}$ (B) $\frac{a^3R}{3b}$

(C) $\frac{a^3R}{2b}$ (D) $\frac{a^3R}{b}$

66. The current–voltage (I-V) graphs for a given metallic wire at two different temperatures T_1 and T_2 as shown in Fig. 14.33. It follows from the graphs that

(A) $T_1 > T_2$
(B) $T_1 < T_2$
(C) $T_1 = T_2$
(D) T_1 is greater or less than T_2 depending on whether the resistance R of the wire is greater or less than the ratio V/I.

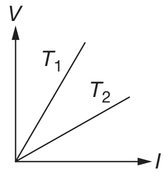
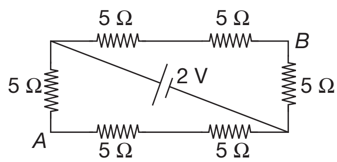


Fig. 14.33

67. The potential difference between points A and B in the following circuit diagram will be

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



68. The current in the arm CD in the circuit shown in Fig. 14.34 will be

(A) $i_1 + i_2$ (B) $i_2 + i_3$
(C) $i_1 + i_3$ (D) $i_1 - i_2 + i_3$

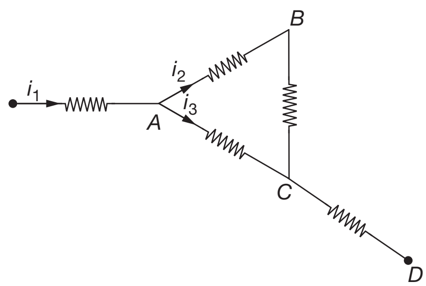
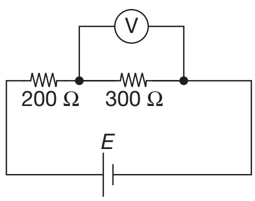


Fig. 14.34

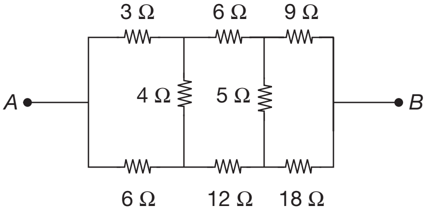
69. In the given circuit, resistance of voltmeter is 400 Ω and its reading is 20 V. Find the value of EMF of battery

(A) $\frac{130}{3}$ V (B) 65 V
(C) 40 V (D) 33.6 V



70. In the given circuit, find the equivalent resistance between points *A* and *B*.

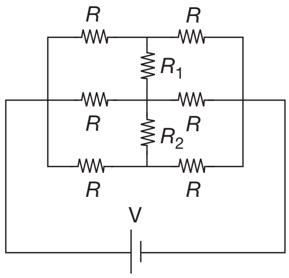
(A) 18 Ω (B) 12 Ω (C) 20 Ω (D) 27 Ω



71. In the given circuit diagram, current through the battery is $\frac{3V}{2R}$, if and only if

(A) $R_1 = R_2 = R$ (B) $R_1 > R_2$

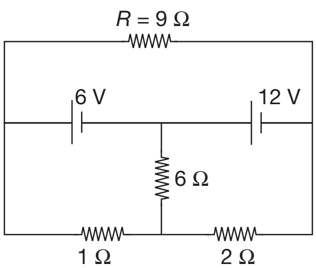
(C) $R_1 < R_2$ (D) Always



72. In the given circuit diagram, Find the value of current in resistance *R*.

(A) 2 A (B) $\frac{3}{2}$ A

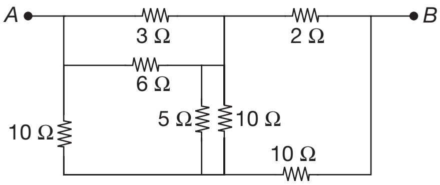
(C) 1 A (D) 4 A



73. In the given circuit, the equivalent resistance between point *A* and *B* is

(A) $\frac{10}{3}$ Ω (B) $\frac{5}{3}$ Ω

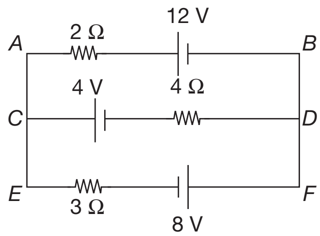
(C) $\frac{24}{57}$ Ω (D) $\frac{57}{24}$ Ω



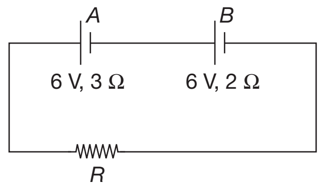
74. The current in branch *CD* of given circuit is,

(A) Zero (B) 1 A

(C) 2 A (D) 3 A



75. Two sources of EMF 6V and internal resistance 3 Ω and 2 Ω are connected to an external resistance *R* as shown. If potential difference across source *A* is zero, then value of *R* is

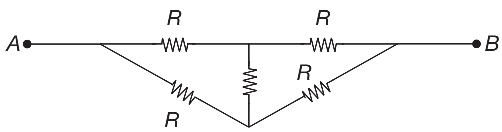


(A) 1 Ω (B) 2 Ω (C) 3 Ω (D) 4 Ω

76. The equivalent resistance between points *A* and *B* is

(A) 2*R* (B) $\frac{3}{4}R$

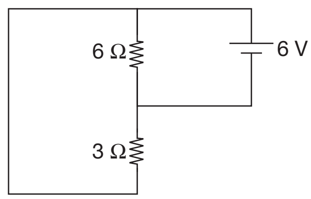
(C) $\frac{4}{3}R$ (D) $\frac{3}{5}R$



77. In the circuit shown, current through 3 Ω resistance is

(A) 1 A (B) 2 A

(C) 3 A (D) 4 A



78. The circuit as shown in Fig. 14.35. The ratio of current i_1 / i_2 is

(A) 2 (B) 8 (C) 0.5 (D) 4

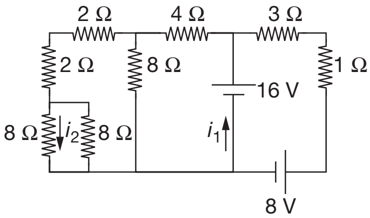


Fig. 14.35

79. In the circuit shown in Fig. 14.36, reading of voltmeter is V_1 when only S_1 is closed, reading of voltmeter is V_2 when only S_2 is closed and reading of voltmeter is V_3 when both S_1 and S_2 are closed. Then

(A) $V_3 > V_2 > V_1$ (B) $V_2 > V_1 > V_3$
(C) $V_3 > V_1 > V_2$ (D) $V_1 > V_2 > V_3$

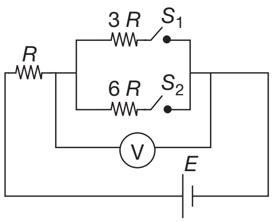


Fig. 14.36

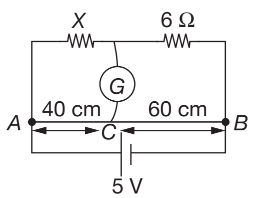
80. The resistance of a wire is 10 Ω. Its length is increased by 10% by stretching. The new resistance will now be nearly

(A) 12 Ω (B) 1.2 Ω
(C) 13 Ω (D) 11 Ω

81. The same mass of copper is drawn into two wires 1 mm and 2 mm thick. Two wires are connected in series and current is passed through them. Heat produced in the wire is in the ratio

(A) 2 : 1 (B) 1 : 16
(C) 4 : 1 (D) 16 : 1

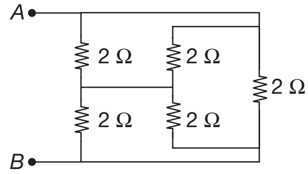
82. In the circuit shown, a meter bridge is in its balanced state. The meter bridge wire has a resistance 0.1 Ω/cm. The value of unknown resistance X and the current drawn from the battery of negligible resistance is



(A) 6 Ω, 5 A (B) 4 Ω, 0.1 A
(C) 4 Ω, 1.0 A (D) 12 Ω, 0.5 A

83. Find the equivalent resistance across AB

(A) 1 Ω (B) 2 Ω (C) 3 Ω (D) 4 Ω



84. The reading of the ammeter in Fig. 14.37 shown is

(A) $\frac{1}{8}$ A (B) $\frac{3}{4}$ A

(C) $\frac{1}{2}$ A (D) 2 A

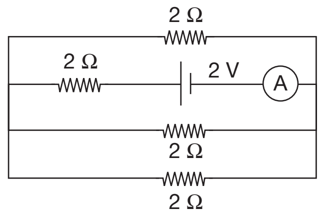
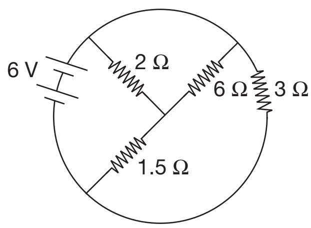


Fig. 14.37

85. The total current supplied to the circuit by the battery is

(A) 1 A (B) 2 A (C) 4 A (D) 6 A

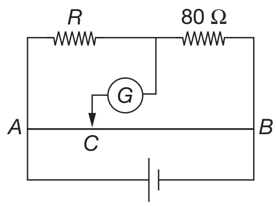


86. The magnitude of i in ampere unit is

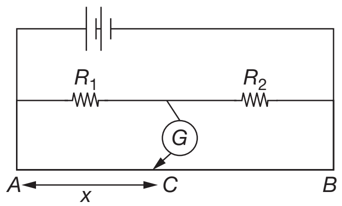
(A) 0.1 (B) 0.3 (C) 0.6 (D) 0.4

87. AB is a wire of uniform resistance. The galvanometer G shows zero current when the length $AC = 20$ cm and $CB = 80$ cm. The resistance R is equal to

(A) 2 Ω (B) 8 Ω (C) 20 Ω (D) 40 Ω



88. In the shown arrangement of the experiment of the meter bridge, if AC corresponding to null deflection of galvanometer is x, what would be its value if the radius of the wire AB is doubled?



(A) x (B) $x/4$ (C) $4x$ (D) $2x$

89. Two cells with the same EMF E and different internal resistances r_1 and r_2 are connected in series to an external resistance R. The value of R for the potential difference across the first cell to be zero is

(A) $\sqrt{r_1 r_2}$ (B) $r_1 + r_2$

(C) $r_1 - r_2$ (D) $\frac{r_1 + r_2}{2}$

90. A battery of internal resistance 4 Ω is connected to the network of resistances as shown in Fig. 14.38. In order for the maximum power to be delivered to the network, the value of R in Ω should be

(A) $\frac{4}{9}$ (B) 2 (C) $\frac{8}{3}$ (D) 18

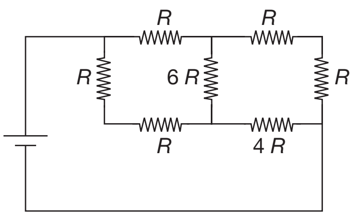
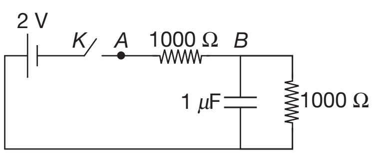


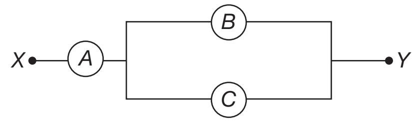
Fig. 14.38

91. In the adjoining circuit, when the key K is pressed at time t = 0, which of the following statements about current I in the resistor AB is true?

(A) $I = 2$ mA at all t
(B) I oscillates between 1 mA and 2 mA
(C) $I = 1$ mA at all t
(D) At $t = 0$, $I = 2$ mA and with time it goes to 1 mA



92. A, B, and C are voltmeters of resistances R, 1.5R, and 3R, respectively. When some potential difference is applied between X and Y, the voltmeter readings are V_A, V_B, and V_C, respectively.



(A) $V_A = V_B = V_C$ (B) $V_A \neq V_B = V_C$
(C) $V_A = V_B \neq V_C$ (D) $V_B \neq V_A = V_C$

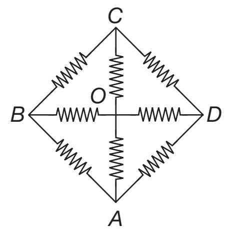
93. A galvanometer of resistance 19.5 Ω gives full-scale deflection when a current of 0.5 A is passed through it. It is desired to convert it into an ammeter of full-scale current 20 A. Value of shunt is

(A) 0.5 Ω (B) 1 Ω (C) 1.5 Ω (D) 2 Ω

94. In the arrangement shown, the magnitude of each resistance is 2Ω. The equivalent resistance between O and A is given by

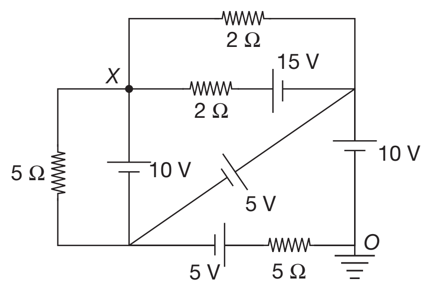
(A) $\frac{14}{15}$ Ω (B) $\frac{7}{15}$ Ω

(C) $\frac{4}{3}$ Ω (D) $\frac{5}{6}$ Ω



95. In the circuit shown, if point O is earthed, the potential of point X is equal to

(A) 10 V (B) 15 V
(C) 25 V (D) 12.5 V



96. Figure 14.39 shows a network of a capacitor and resistors. The charge on capacitor in steady state is

(A) 4 μC (B) 6 μC
(C) 10 μC (D) 16 μC

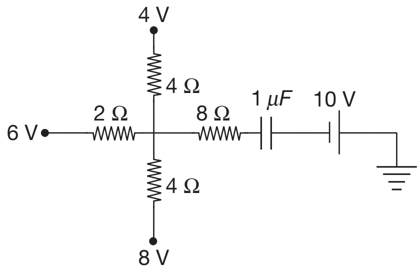


Fig. 14.39

97. A parallel plate capacitor is connected with a resistance R and a cell of EMF ε as shown in Fig. 14.40. The capacitor is fully charged. Keeping the right plate fixed, the left plate is moved slowly towards further left with a variable velocity v such that the current flowing through the circuit is constant. Then the variation of v with separation x between the plates is represented by a curve.

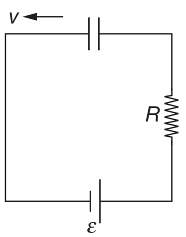
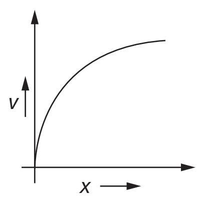
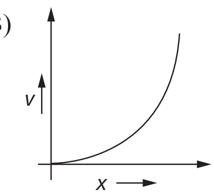


Fig. 14.40

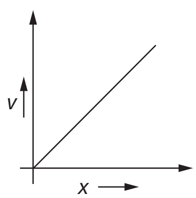
(A)



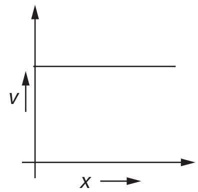
(B)



(C)



(D)



98. The electric potential variation around a single closed loop containing an ideal battery and one or more resistors as shown in Fig. 14.41. If current of 1A flows in the circuit, the circuit cannot have

(A) two resistors and two batteries.
(B) one resistor and three batteries.
(C) maximum net EMF of 6 V.
(D) three resistors and one battery.

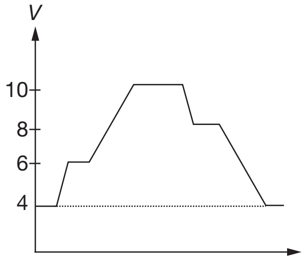


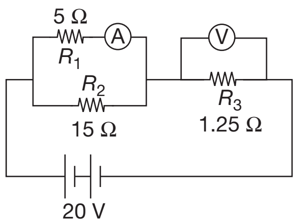
Fig. 14.41

99. An ammeter is obtained by shunting a 30 Ω galvanometer with a 30 Ω resistance. What additional shunt should be connected across it to double the range?

(A) 15 Ω (B) 10 Ω
(C) 5 Ω (D) None of these

100. An ideal ammeter and an ideal voltmeter are connected as shown. The ammeter and voltmeter reading for $R_1 = 5\ \Omega$, $R_2 = 15\ \Omega$, $R_3 = 1.25\ \Omega$, and $E = 20$ V are given as

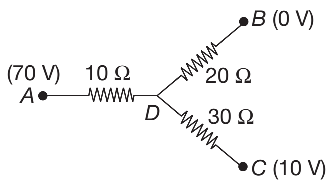
(A) 6.25 A, 3.75 V
(B) 3.00 A, 5 V
(C) 3.75 A, 3.75 V
(D) 3.75 A, 6.25 V



More than One Option Correct Type

101. In the network shown, points A, B, and C are at potentials of 70 V, zero, and 10 V, respectively.

(A) Point D is at a potential of 40 V.
(B) The currents in the sections AD, DB, DC are in the ratio 3 : 2 : 1
(C) The currents in the sections AD, DB, DC are in the ratio 1 : 2 : 3
(D) The network draws a total power of 200 W



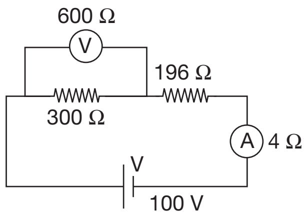
102. In the given circuit diagram, resistance of voltmeter is 600 Ω and resistance of ammeter is 4 Ω, then

(A) reading of voltmeter 66.66 V.

(B) reading of voltmeter 50 V.

(C) reading of ammeter $\frac{1}{2}$ A.

(D) reading of ammeter $\frac{1}{4}$ A.



103. The internal resistance of the cell shown in Fig. 14.42 is negligible. On closing the key K, the ammeter reading changes from 0.25 A to 5/12 A, then

(A) $R_1 = 10$ Ω.
(B) $R_1 = 15$ Ω.
(C) the power drawn from the cell increases.
(D) the current through R decreases by 40%.

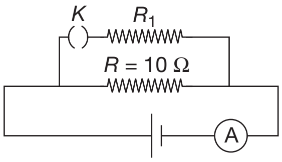


Fig. 14.42

104. In the circuit shown in Fig. 14.43.

(A) The current through NP is 0.5 A
(B) The value of $R_1 = 40$ Ω
(C) The value of $R = 14$ Ω
(D) The potential difference across $R = 49$ V

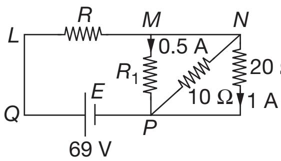


Fig. 14.43

105. A voltmeter and an ammeter are connected in series to an ideal cell of EMF E. The voltmeter reading is V, and the ammeter reading is I.

(A) $V < E$
(B) The voltmeter resistance is V/I
(C) The potential difference across the ammeter is $(E - V)$
(D) Voltmeter resistance plus ammeter resistance $= E/I$.

106. A dielectric slab of thickness d is inserted in a parallel plate capacitor whose negative plate is at $x = 0$ and positive plate is at $x = 3d$. The slab is equidistant from the plates. The capacitor is given some charge. As x goes from 0 to $3d$,

(A) the magnitude of the electric field remains the same.
(B) the direction of the electric field remains the same.
(C) the electric potential increases continuously.
(D) the electric potential increases at first, then decreases and again increases.

107. Two heaters designed for the same voltage V have different power ratings. When connected individually across a source of voltage V, they produce H amount of heat each in time t_1 and t_2, respectively. When used together across the same source, they produce H amount of heat in time t,

(A) if they are in series, $t = t_1 + t_2$.

(B) if they are in series, $t = 2(t_1 + t_2)$.

(C) if they are in parallel, $t = 2(t_1 - t_2)$.

(D) if they are in parallel, $t = \dfrac{t_1 t_2}{2(t_1 + t_2)}$.

108. In the given Fig. 14.44, A cell of EMF 3.4 V and internal resistance 3 Ω is connected to an ammeter having resistance 2 Ω and external resistance 100 Ω. When a voltmeter connected across 100 Ω resistance, the reading of ammeter is 0.04 A. Then,

(A) the reading of voltmeter is 3.2 V.
(B) the reading of voltmeter is 2 V.
(C) the value of resistance of voltmeter is 400 Ω.
(D) the value of resistance of voltmeter is 300 Ω.

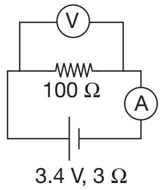


Fig. 14.44

109. A positively charged conducting ball B is placed inside a cavity of a positively charged conductor A. A and B are isolated from each other. If the charges on A and B be Q and q ($Q > q$), respectively, then

(A) the charge on the outer surface of conductor A is $Q + q$.
(B) potential of B is greater than potential of A.

(C) when B touches the surface of A, then potential of A and B become same.
(D) no charge is left on B when it touches the surface of A.

110. A part of the circuit is shown in Fig. 14.45
(A) power dissipated in 3 Ω resistance is 27 W.
(B) $V_C - V_B = 20$ V.
(C) $V_C - V_D = 20$ V.
(D) power dissipated in 6 Ω resistance is 36 W.

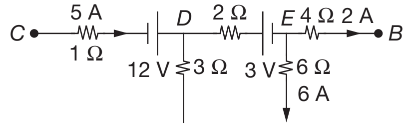


Fig. 14.45

Passage Based Questions

Passage 1

In the circuit shown in Fig. 14.46, E, F, G, H are cells of EMF 2, 1, 3, and 1 V, respectively, and their internal resistances are 2, 1, 3, and 1 Ω, respectively.

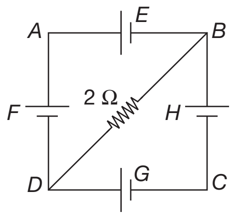


Fig. 14.46

111. The potential difference between D and B is
(A) $\frac{10}{13}$ V (B) $\frac{12}{13}$ V (C) $\frac{13}{13}$ V (D) $\frac{14}{13}$ V

112. The potential difference across the terminals of cell E is
(A) $\frac{17}{13}$ V (B) $\frac{20}{13}$ V (C) $\frac{23}{13}$ V (D) $\frac{24}{13}$ V

113. The potential difference across the terminals of cell H is
(A) $\frac{17}{13}$ V (B) $\frac{20}{13}$ V (C) $\frac{23}{13}$ V (D) $\frac{24}{13}$ V

Passage 2

The average bulk resistivity of the human body (apart from the surface resistance of the skin) is about 5 Ω *m*. The conducting path between the hands can be represented approximately as a cylinder 1.6 m long and 0.1 m diameter. The skin resistance may be made negligible by soaking the hands in salt water. A lethal shock current needed is 100 mA. Note that a small amount of potential difference could be fatal if the skin is damp.

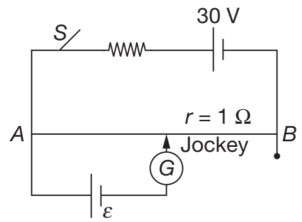
114. What is the resistance between the hands?
(A) 10^2 Ω (B) 10^3 Ω
(C) 10^4 Ω (D) None of these

115. What potential difference is needed between the hands for a lethal shock current?
(A) 100 V (B) 10 V
(C) 120 V (D) 150 V

116. The power dissipated in the body is
(A) 1 W (B) 0.1 W
(C) 100 W (D) 10 W

Passage 3

A potentiometer is a device used for measuring EMF and internal resistance of a cell. It consists of two circuits, one is main circuit in which there is a cell of given emf ε' and given resistance R which is connected across a wire of length 100 cm and having resistance r and another circuit having unknown EMF ε and galvanometer. For a given potentiometer, if $\varepsilon' = 30$V, $r = 1$ Ω, and resistance R varies with time t given by $R = 2t$. The jockey can move on wire with constant velocity 10 cm/s and switch S is closed at $t = 0$



117. If jockey starts moving from A at $t = 0$ and balancing point found at $t = 1$ s then the value of ε is
(A) 1 V (B) 2 V (C) 3 C (D) 4 V

118. If jockey starts moving from A at $t = 1$ sec, then the balancing point will be obtained at
(A) $t = 3$ s (B) $t = 5$ s
(C) $t = 4$ s (D) $t = 9$ s

119. If balancing length is found to be 70 cm, then the time after which jockey starts moving from A is
(A) 1 s (B) 2 s
(C) 3 s (D) 4 s

Passage 4

Figure 14.47 shows the circuit of a potentiometer. The length of the potentiometer wire AB is 50 cm. The EMF E_1 of the battery is 4 V, having negligible internal resistance. Value of R_1 and R_2 are 15 Ω and 5 Ω, respectively. When both the keys are open, the null point is obtained at a distance of 31.25 cm from A, but when both the keys are closed, the balance length reduces to 5 cm only. Given $R_{AB} = 10\ \Omega$

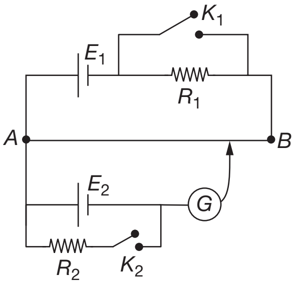


Fig. 14.47

120. The EMF of the cell E_2 is

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

121. The internal resistance of the cell E_2 is

(A) 4.5 Ω (B) 5.5 Ω
(C) 6.5 Ω (D) 7.5 Ω

122. The balance length when key K_2 is open and K_1 is closed is given by

(A) 10.5 cm (B) 11.5 cm
(C) 12.5 cm (D) 13.5 cm

123. The balance length when key K_1 is open and K_2 is closed is given by

(A) 10.5 cm (B) 11.5 cm
(C) 12.5 cm (D) 25 cm

Passage 5

A capacitor of capacitance $C = 0.1\text{F}$ is charged by a battery of EMF $E_1 = 100$ V and internal resistance $r_1 = 1\ \Omega$ by putting switch S in position 1 as shown in Fig. 14.48.

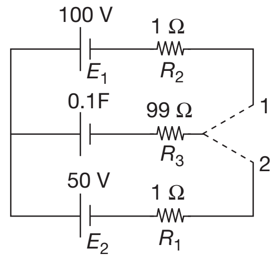


Fig. 14.48

124. Find out heat generated in $R_3 = 99\ \Omega$ till steady state

(A) 500 J (B) 495 J
(C) 1000 J (D) 485 J

125. Now switch is thrown to position 2. Find the work done on the battery till steady state

(A) 250 J (B) 300 J
(C) 275 J (D) 325 J

126. Find the energy stored in the capacitor when switch is shifted to position 2 at steady state

(A) 125 J (B) 150 J
(C) 175 J (D) 200 J

127. Find the heat generated across $R_1 = 1\ \Omega$ in steady state in position 2

(A) 1.25 J (B) 125 J
(C) 2.5 J (D) 7.5 J

Match the Column Type

128. In the circuit shown in Fig. 14.49,

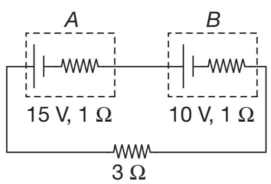


Fig. 14.49

Column-I	Column-II
(A) Potential difference across battery A	1. A
(B) Potential difference across battery B	2. B
(C) Power is supplied by battery	3. 14 V
(D) Power is consumed by battery	4. 11 V
	5. 1 V

129. Five batteries whose EMF and internal resistance are as shown in Fig. 14.50.

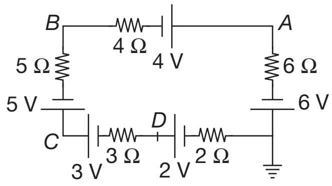


Fig. 14.50

Column-I	Column-II
(A) Potential of point *A*	1. – 5V
(B) Potential of point *B*	2. 1 V
(C) Potential of point *C*	3. – 3V
(D) Potential of point *D*	4. 2.5V
	5. 1.5 V

130. Consider two identical cells each of EMF *E* and internal resistance *r* connected to a load resistance *R*

Column-I	Column-II
(A) For maximum power transferred to load if cells are connected in series	1. $\frac{E^2}{4r}$
(B) For maximum power transferred to load if cells are connected in parallel	2. $\frac{E^2}{2r}$
(C) For series combination of cells	3. $E_{eq} = E, r_{eq} = \frac{r}{2}$
(D) For parallel combination of cells	4. $E_{eq} = 2E, r_{eq} = 2r$

131. In the circuit shown in Fig. 14.51, $R_1 = R_2 = R_3 = 3\ \Omega$ and EMF of each cell is $E = 4$V and negligible internal resistance. All ammeters are ideal.

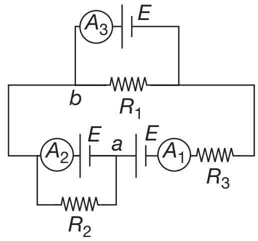


Fig. 14.51

Column-I	Column-II
(A) Reading of ammeter A_1 in ampere is	1. $\frac{4}{3}$
(B) Reading of ammeter A_2 in ampere is	2. $\frac{8}{3}$
(C) Reading of ammeter A_3 in ampere is	3. 4
(D) Potential difference between points *a* and point *b* in volt is	4. Zero
	5. 2

Assertion–Reason Type

132. Assertion: If a current flows through a wire of non-uniform cross section, potential difference per unit length of wire in direction of current is same throughout the length of wire.

Reason: In above assertion, current through wire is same at all cross-section.

(A) A (B) B (C) C (D) D

133. Assertion: In a meter bridge, if its wire is replaced by another wire having same length, same material but twice the cross-sectional area the accuracy decreases.

Reason: Accuracy of meter bridge depends on the length of wire.

(A) A (B) B (C) C (D) D

134. Assertion: In L–C–R series circuit, a sinusoidal voltage is applied. Maximum value of potential drop across capacitor may be greater than, maximum value of applied voltage.

Reason: The average power dissipated in pure inductor is $\frac{1}{2}LI^2$, where *L* is inductance and *I* is maximum value of current through inductor.

(A) A (B) B (C) C (D) D

135. Assertion: Combination of two resistors in parallel produces less power than when they are connected in series on connecting the combination to an external mains supply.

Reason: $P = i^2R$

(A) A (B) B (C) C (D) D

136. **Assertion:** In a simple battery circuit, the point at the lowest potential is positive terminal of the battery.

Reason: The current flows towards the point of the lower potential in the circuit, but it does not flow in a cell from positive to the negative terminal.

(A) A (B) B (C) C (D) D

137. **Assertion:** The value of shunt which passes 10% of the main current through the galvanometer of resistance 99 Ω is 11 Ω.

Reason: If an ammeter is connected in series with a resistance, the value of reading of ammeter is greater than the actual current in resistance.

(A) A (B) B (C) C (D) D

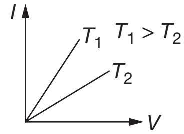
138. **Assertion:** With increase in temperature, resistance of a wire increases.

Reason: With increase in temperature, length and area of cross-section of wire changes but resistivity remains constant.

(A) A (B) B (C) C (D) D

139. **Assertion:** Current versus potential difference I – V graph for a conductor at two different temperatures T_1 and T_2 are shown is correct.

Reason: Resistance of a conductor increases with rise in temperature.



(A) A (B) B (C) C (D) D

140. **Assertion:** Three identical very large metallic plates having charges Q, $-Q$, and $3Q$, respectively are placed parallel. If middle is earthed through a switch, then charge flow through the switch is $-Q$.

Reason: In above assertion, final charge on middle plate is $-4Q$.

(A) A (B) B (C) C (D) D

141. **Assertion:** Insertion of dielectric slab between the plates of a charged capacitor (connected with the battery) increases the energy density.

Reason: The dipole moments in the dielectric interact with each other so as to give it additional energy.

(A) A (B) B (C) C (D) D

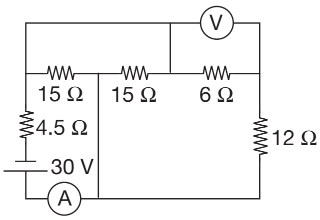
142. **Assertion:** Current is passed through a steel wire which gets dull red. A half of the wire is immersed in cold water. The portion of wire outside water becomes brighter.

Reason: The resistance of whole wire increases when immersed in cold water.

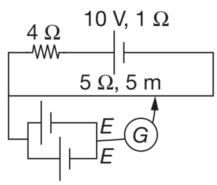
(A) A (B) B (C) C (D) D

Integer type

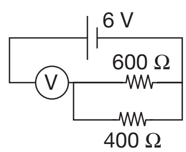
143. A galvanometer of coil resistance 1 Ω is converted into voltmeter by using a resistance of 5 Ω in series and same galvanometer is converted into ammeter by using a shunt of 1 Ω. Now ammeter and voltmeter connected in circuit as shown, find the reading of voltmeter and ammeter.



144. A resistance of 4 Ω and a wire of length 5 m and resistance 5 Ω are joined in series and connected to a cell of EMF 10 V and internal resistance 1 Ω. A parallel combination of two identical cells is balanced across 300 cm of the wire. The EMF of each cell is



145. The measurement of voltmeter (ideal) in the following circuit is



146. In the part of a circuit shown in Fig. 14.52, the potential difference between points G and H ($V_G - V_H$) will be

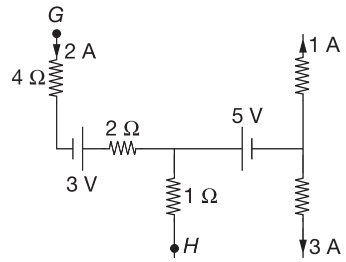
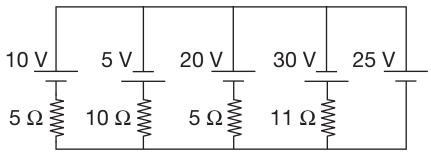


Fig. 14.52

147. In the circuit shown, current through 30 V cell is



148. Figure 14.53 shows a network of eight resistors numbered 1 to 8, each equal to 2 Ω, connected to a 3 V battery of negligible internal resistance. The current in the circuit is

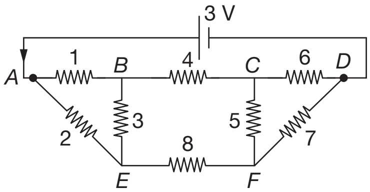
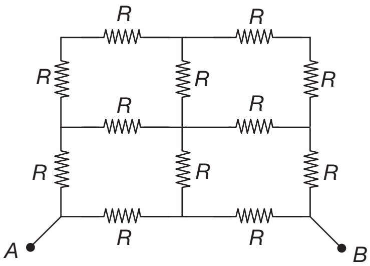
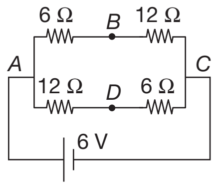


Fig. 14.53

149. Find the equivalent resistance in Ω between point A and B in the given circuit. If value of $R = 4$ Ω.



150. What is the potential difference between points B and D?



151. Figure 14.54 shows a RC circuit with a parallel plate capacitor. Before switching on the circuit, plate A of the capacitor has a charge $-Q_0$, while plate B has no net charge. Now, at $t = 0$, the circuit is switched on. How much time (in second) will elapse before the net charge on plate A becomes zero. (Given $C = 1\mu$F, $Q_0 = 1\mu$C, $\varepsilon = 1000$ V and $R = \dfrac{2\times10^6}{\ln 3}\,\Omega$)

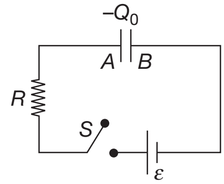


Fig. 14.54

152. Find the effective value or RMS value of an alternating current that changes according to the law. (All quantities are in SI unit and symbols have their usual meaning.)

$I = 10$, when $0 < t < \dfrac{T}{8}$; $I = 0$, when $\dfrac{T}{8} < t < \dfrac{T}{2}$

$I = -10$, when $\dfrac{T}{2} < t < \dfrac{5}{8}T$; $I = 0$,

when $\dfrac{5}{8}T < t < T$; $I = 10$, when $T < t < \dfrac{9}{8}T$.

153. An infinite ladder network consisting of 1 Ω and 2 Ω resistors is shown in Fig. 14.55.

Find the effective resistance of the network across AB (Neglect the internal resistance of the battery).

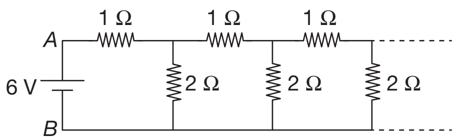


Fig. 14.55

Previous Years' Questions

154. Figure 14.56 shows three resistor configurations, R_1, R_2, and R_3, connected to 3 V battery. If the power dissipated by the configurations R_1, R_2, and R_3 is P_1, P_2, and P_3, respectively, then **[2008]**

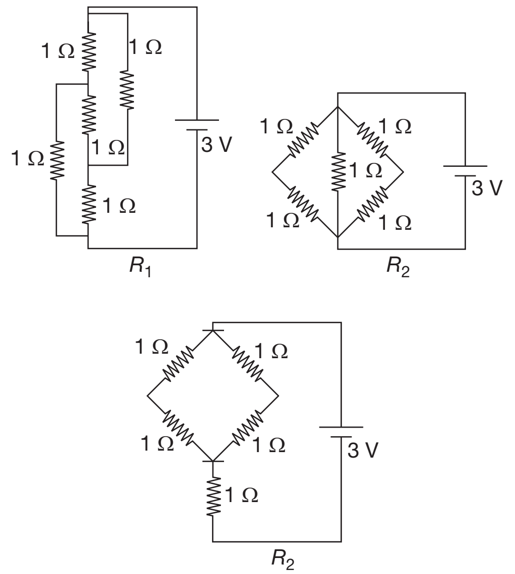


Fig. 14.56

(A) $P_1 > P_2 > P_3$ (B) $P_1 > P_3 > P_2$

(C) $P_2 > P_1 > P_3$ (D) $P_3 > P_2 > P_1$

155. Two conductors have the same resistance at 0°C but their temperature coefficients of resistance are α_1 and α_2. The respective temperature coefficients of their series and parallel combinations are nearly **[2010]**

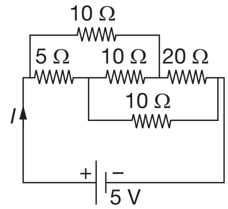
(A) $\frac{\alpha_1+\alpha_2}{2}, \alpha_1+\alpha_2$ (B) $\alpha_1+\alpha_2, \frac{\alpha_1+\alpha_2}{2}$

(C) $\alpha_1+\alpha_2, \frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}$ (D) $\frac{\alpha_1+\alpha_2}{2}, \frac{\alpha_1+\alpha_2}{2}$

156. The resistance of a wire is 5 Ω at 50°C and 6 Ω at 100°C. The resistance of the wire at 0°C will be **[2007]**

(A) 2 Ω (B) 1 Ω
(C) 4 Ω (D) 3 Ω

157. The current drawn from the 5 V source will be **[2006]**



(A) 0.33 A (B) 0.5 A
(C) 0.67 A (D) 0.17 A

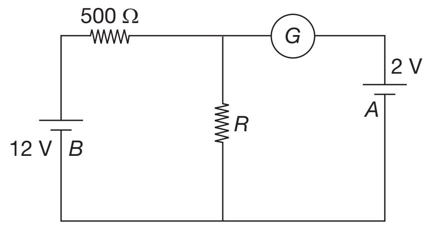
158. The resistance of a bulb filament is 100 Ω at a temperature 100°C. If its temperature coefficient of resistance be 0.005/°C, its resistance will become 200 Ω at a temperature of **[2006]**

(A) 300°C (B) 400°C
(C) 500°C (D) 200°C

159. An electric bulb is rated 220 V – 100 W. The power consumed by it when operated on 110 V will be **[2006]**

(A) 75 W (B) 40 W
(C) 25 W (D) 50 W

160. In the circuit, the galvanometer *G* shows zero deflection. If the batteries *A* and *B* have negligible internal resistance, the value of the resistor *R* will be **[2005]**



(A) 200 Ω (B) 100 Ω
(C) 500 Ω (D) 1000 Ω

161. Two sources of equal EMF are connected to an external resistance *R*. The internal resistances of the two sources are R_1 and R_2 $(R_2 > R_1)$. If the potential difference across the source having internal resistance R_2 is zero, then **[2005]**

(A) $R = \frac{R_2 \times (R_1 + R_2)}{(R_2 - R_1)}$ (B) $R = R_2 - R_1$

(C) $R = \frac{R_1 R_2}{(R_1 + R_2)}$ (D) $R = \frac{R_1 R_2}{(R_2 - R_1)}$

162. An energy source will supply a constant current into the load, if its internal resistance is **[2005]**

(A) Equal to the resistance of the load.
(B) Very large as compared to the load resistance.
(C) Zero.
(D) Non-zero but less than the resistance of the load.

163. In a potentiometer experiment, the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 cm. The internal resistance of the cell is **[2005]**

(A) 1Ω (B) 0.5 Ω (C) 4 Ω (D) 2Ω

164. The resistance of the series combination of two resistances is S. When they are joined in parallel, the total resistance is P. If $S = nP$, then the minimum possible value of n is **[2004]**

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

165. An electric current is passed through a circuit containing two wires of the same material, connected in parallel. If the lengths and radii of the wires are in the ratio of 4/3 and 2/3, then the ratio of the currents passing through the wire will be **[2004]**

(A) 3 (B) 1/3 (C) 8/9 (D) 2

166. In a metre bridge experiment, null point is obtained at 20 cm from one end of the wire when resistance X is balanced against another resistance Y. If $X < Y$, then where will the new position of the null point be from the same end, if one decides to balance a resistance of $4X$ against Y? **[2004]**

(A) 50 cm (B) 80 cm
(C) 40 cm (D) 70 cm

167. A 3 V battery with negligible internal resistance is connected in a circuit as shown in Fig. 14.57. The current I in the circuit will be **[2003]**

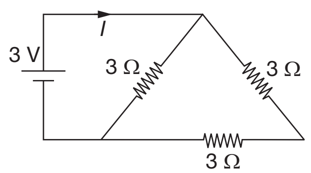


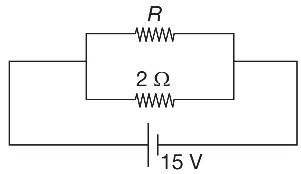
Fig. 14.57

(A) 1 A (B) 1.5 A (C) 2 A (D) $\frac{1}{3}$ A

168. A wire when connected to 220 V mains supply has power dissipation P_1. Now the wire is cut into two equal pieces which are connected in parallel to the same supply. Power dissipation in this case is P_2. Then $P_2 : P_1$ is **[2002]**

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

169. If in the circuit, power dissipation is 150 W, then R is **[2002]**



(A) 2 Ω (B) 6Ω (C) 5 Ω (D) 4 Ω

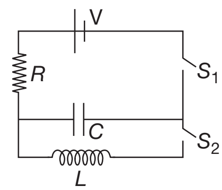
170. In an LCR circuit, as shown below, both switches are open initially. Now switch S_1 is closed, S_2 is kept open. (q is charge on the capacitor and $\tau = RC$ is capacitive time constant). Which of the following statement is correct? **[2013]**

(A) At $t = \tau$, $q = CV/2$

(B) At $t = 2\tau$, $q = CV(1 - e^{-2})$

(C) At $t = \frac{\tau}{2}$, $q = CV(1 - e^{-1})$

(D) Work done by the battery is half of the energy dissipated in the resistor



171. The supply voltage to a room is 120 V. The resistance of the lead wires is 6 Ω. A 60 W bulb is already switched on. What is the decrease of voltage across the bulb, when a 240 W heater is switched on in parallel to the bulb? **[2013]**

(A) 2.9 V (B) 13.3 V
(C) 10.04 V (D) Zero V

172. This question has statement I and statement II. Of the four choices given after the statements, choose the one that best describes the two statements. **[2013]**

Statement-I: Higher the range, greater is the resistance of ammeter.
Statement-II: To increase the range of ammeter, additional shunt needs to be used across it.

(A) Statement-I is true, Statement-II is true, Statement-II is **not** the correct explanation of Statement-I.
(B) Statement-I is true, Statement-II is false.
(C) Statement-I is false, Statement-II is true.
(D) Statement-I is true, Statement-II is true, Statement-II is **correct** explanation of Statement-I.

173. In Fig. 14.58 shows an experimental plot for discharging of a capacitor in an R-C circuit. The time constant of this circuit lies between **[2012]**

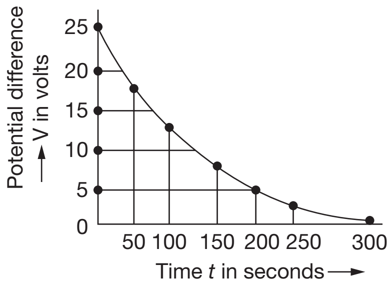


Fig. 14.58

(A) 150 s and 200 s (B) 0 and 50 s
(C) 50 s and 100 s (D) 100 s and 150 s

174. Two electric bulbs marked 25W-220 V and 100W-220 V are connected in series to a 440 V supply. Which of the bulbs will fuse? **[2012]**

(A) Both (B) 100 W
(C) 25 W (D) Neither

175. Resistance of a given wire is obtained by measuring the current flowing in it and the voltage difference applied across it. If the percentage errors in the measurement of the current and the voltage difference are 3% each, then error in the value of resistance of the wire is **[2012]**

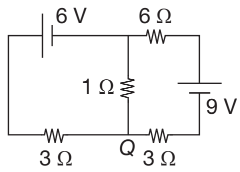
(A) 6% (B) Zero (C) 1% (D) 3%

176. In a large building, there are fifteen bulbs of 40 W, five bulbs of 100 W, five fans of 80 W and one heater of 1 kW. The voltage of the electric mains is 220 V. The minimum capacity of the main fuse of the building will be **[2014]**

(A) 8 A (B) 10 A (C) 12 A (D) 14 A

177. In the circuit shown, the current in the resistor is **[2015]**

(A) 0 A
(B) 0.13 A, from Q to P
(C) 0.13 A, from P to Q
(D) 1.3 A, from P to Q



178. When 5 V potential difference is applied across a wire of length 0.1 m, the drift speed of electrons is 2.5×10^{-4} ms^{-1}. If the electron density in the wire is 8×10^{28} m^{-3}, the resistivity of the material is close to **[2015]**

(A) 1.6×10^{-7} Ω m (B) 1.6×10^{-6} Ω m
(C) 1.6×10^{-5} Ω m (D) 1.6×10^{-8} Ω m

179. A galvanometer having a coil resistance of 100 Ω gives a full scale deflection, when a current of 1 mA is passed through it. The value of the resistance, which can convert this galvanometer into ammeter giving a full scale deflection for a current of 10 A, is **[2016]**

(A) 2Ω (B) 0.1Ω
(C) 3Ω (D) 0.01Ω

180. The temperature dependence of resistances of Cu and Si (not doped) in the temperature range 300-400 K, is best described by **[2016]**

(A) linear increase for Cu, exponential increase for Si.
(B) linear increase for Cu, exponential decrease for Si.
(C) linear decrease for Cu, linear decrease for Si.
(D) linear increase for Cu, linear increase of Si.

ANSWER KEYS

Single Option Correct Type

1. (C)	**2.** (D)	**3.** (C)	**4.** (B)	**5.** (A)	**6.** (C)	**7.** (B)	**8.** (A)	**9.** (C)	**10.** (B)
11. (A)	**12.** (B)	**13.** (D)	**14.** (C)	**15.** (C)	**16.** (A)	**17.** (C)	**18.** (A)	**19.** (C)	**20.** (C)
21. (C)	**22.** (D)	**23.** (B)	**24.** (B)	**25.** (C)	**26.** (A)	**27.** (D)	**28.** (A)	**29.** (A)	**30.** (D)
31. (C)	**32.** (D)	**33.** (D)	**34.** (A)	**35.** (D)	**36.** (B)	**37.** (C)	**38.** (A)	**39.** (A)	**40.** (B)
41. (C)	**42.** (A)	**43.** (C)	**44.** (B)	**45.** (C)	**46.** (D)	**47.** (A)	**48.** (A)	**49.** (B)	**50.** (B)

51. (A) **52.** (C) **53.** (B) **54.** (A) **55.** (A) **56.** (B) **57.** (A) **58.** (C) **59.** (C) **60.** (A)
61. (D) **62.** (C) **63.** (A) **64.** (A) **65.** (B) **66.** (A) **67.** (C) **68.** (B) **69.** (A) **70.** (B)
71. (D) **72.** (A) **73.** (A) **74.** (A) **75.** (A) **76.** (D) **77.** (B) **78.** (B) **79.** (B) **80.** (A)
81. (D) **82.** (C) **83.** (A) **84.** (B) **85.** (C) **86.** (A) **87.** (C) **88.** (A) **89.** (C) **90.** (B)
91. (D) **92.** (A) **93.** (A) **94.** (A) **95.** (B) **96.** (D) **97.** (B) **98.** (D) **99.** (A)
100. (B) and (A)

More than One Option Correct Type

101. (A), (B) and (D) **102.** (B) and (D) **103.** (B) and (C) **104.** (B), (C) and (D)
105. (A), (B), (C) and (D) **106.** (B) and (C) **107.** (A) **108.** (A) and (C)
109. (A), (B), (C) and (D) **110.** (A) and (B)

Passage Based Questions

Passage 1

111. (A) **112.** (D) **113.** (A)

Passage 2

114. (B) **115.** (B) **116.** (B)

Passage 3

117. (A) **118.** (C) **119.** (C)

Passage 4

120. (A) **121.** (D) **122.** (C) **123.** (C)

Passage 5

124. (D) **125.** (A) **126.** (A) **127.** (A)

Match the Column Type

128. (A) $\rightarrow$ 3; (B) $\rightarrow$ 4; (C) $\rightarrow$ 1; (D) $\rightarrow$ 2
129. (A) $\rightarrow$ 3, (B) $\rightarrow$ 1, (C) $\rightarrow$ 4, (D) $\rightarrow$ 2
130. (A) $\rightarrow$ (2) ; (B) $\rightarrow$ (2) ; (C) $\rightarrow$ (4) ; (D) $\rightarrow$ (3)
131. (A) $\rightarrow$ 1; (B) $\rightarrow$ 2; (C) $\rightarrow$ 4; (D) $\rightarrow$ 3

Assertion-Reason Type

132. (D) **133.** (D) **134.** (C) **135.** (D) **136.** (D) **137.** (C) **138.** (C) **139.** (D) **140.** (D) **141.** (A)
142. (C)

Integer Type

143. 3 V **144.** 3 V **145.** 6 V **146.** 7 V **147.** 5 A **148.** 1 A **149.** 5 Ω **150.** 2 V **151.** 2 s **152.** 5 A
153. 2 Ω

Previous years' Questions

154. (C) **155.** (D) **156.** (C) **157.** (B) **158.** (B) **159.** (C) **160.** (B) **161.** (B) **162.** (C) **163.** (D)
164. (A) **165.** (B) **166.** (A) **167.** (B) **168.** (B) **169.** (B) **170.** (B) **171.** (C) **172.** (C) **173.** (D)
174. (C) **175.** (A) **176.** (C) **177.** (B) **178.** (C) **179.** (D) **180.** (B)

HINTS AND SOLUTIONS

Single Option Correct Type

1. For point A and C, loop BCD shorted

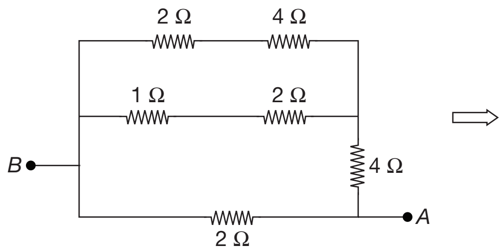
   Hence, $R_{AC} = \dfrac{r \times 2r}{3r} = \dfrac{2}{3}r$

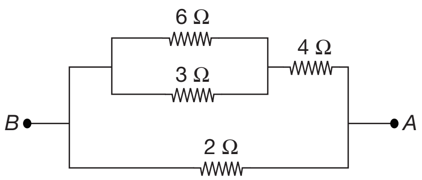
   The correct option is (C)

2. As the charge distribution remains same on opening the switch, no charge will flow in the circuit. So heat dissipated is zero.

   The correct option is (D)

3. Equivalent circuit diagram of the circuit is





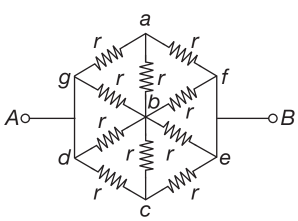
   So $R_{eq} = \dfrac{3}{2}\ \Omega$

   The correct option is (C)

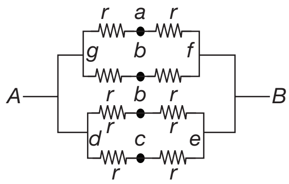
4. From Fig. 14.59 (a) it is evident that the potential difference between points a, b, and c is zero. The equivalent circuit is as shown in Fig. 14.59 (b).

   $$r_{gf} = r_{de} = \frac{2r \times 2r}{2r + 2r} = r$$

   $$\therefore \quad r_{AB} = \frac{2r \times 2r}{2r + 2r} = \frac{r}{2}$$



(a)



(b)

Fig. 14.59

   The correct option is (B)

5. The correct option is (A)

6. $H \propto \dfrac{1}{R}$

   R becomes half, so heat generate will be doubled.

   The correct option is (C)

7. $I = \dfrac{V}{R_e} = \dfrac{2}{15}$ A (I is current in each branch)

   $V_C - V_B = \dfrac{4}{3}$ V

   The correct option is (B)

8. The correct option is (A)

9. The correct option is (C)

10. In parallel $\dfrac{1}{x} = \dfrac{n}{R}$ and series $R_{\text{eff}} = nR = n^2x$

    The correct option is (B)

11. Under balanced condition $\dfrac{P}{Q} = \dfrac{R}{S}$

    Here resistances are in same proportion

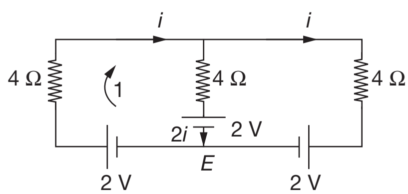
    Hence, there will not be any deflection in galvanometer on pressing the key. It remains same.

    The correct option is (A)

12. The correct option is (B)

13. By KVL in loop 1 $2 - 4i - 8i - 2 = 0$

    $\Rightarrow \quad i = 0$



    The correct option is (D)

14. Given circuit is balance wheat stone bridge hence no current will flow through 6 Ω resistance. So equivalent resistance will be $2R$ Ω.

For maximum power $2R = 4 \Rightarrow R = 2\ \Omega$

The correct option is (C)

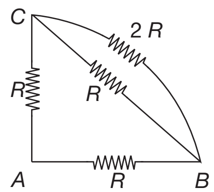
15. As $V = E - I.r$ and $I = \dfrac{E}{R+r} \Rightarrow r = \dfrac{(E-V)R}{V}$

The correct option is (C)

16. The circuit can be rearranged.

Now $2R$ and R are parallel

$$\frac{1}{R_{AB}} = \frac{1}{R+\frac{2R}{3}} + \frac{1}{R} = \frac{3}{5R} + \frac{1}{R} \quad \therefore R_{AB} = \frac{5}{8}R$$



The correct option is (A)

17. $R_{eq} = 1 + \dfrac{1\times 2}{1+2} + 1 = 1\dfrac{2}{3} + 1 = \dfrac{8}{3}$

The correct option is (C)

18. $I = \dfrac{n\varepsilon}{nr} = \dfrac{\varepsilon}{r}, \quad V = \varepsilon - Ir = 0$

The correct option is (A)

19. This is condition for balance wheatstone bridge

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow R_1R_4 = R_2R_3$$

The correct option is (C)

20. The correct option is (C)

21. For series connection, $x = nR$

For parallel connection, $y = \dfrac{R}{n}$

Therefore, $xy = nR \times \dfrac{R}{n} = R^2$.

The correct option is (C)

22. The equivalent resistance between points A and B to the right of AB is 4 Ω. Therefore, total resistance = 3 + 4 + 2 = 9 Ω. Current I = 9 V/9 Ω = 1 A. This current is equally divided in the 8 Ω resistor between A and B and the remainder 8 Ω resistor. Hence, current in AC = 0.5 A. This current is equally divided between the 8 Ω resistor in CD and the circuit to the right of CD. Therefore, current in the 4 Ω resistor = 0.25 A.

The correct option is (D)

23. $\dfrac{16}{X} = \dfrac{4}{1/2}, X = 2$

The correct option is (B)

24. $\dfrac{10}{20} = \dfrac{5}{10}$. So it is a balance wheatstone bridge.

$$R_e = \frac{30\times 15}{45} = 10\ \Omega,\ I = \frac{5}{10} = \frac{1}{2}\text{ A}$$

The correct option is (B)

25. $EMF = (4-1)E = 3E$. Internal resistance = $5r$

The correct option is (C)

26. It is a case of wheatstone bridge.

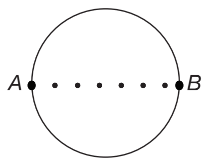
The correct option is (A)

27. $R_{total} = 12\ \Omega$

$R_{AB\text{ upper}} = 6\ \Omega = R_{AB\text{ lower}}$

Combination $\dfrac{1}{R_{eff}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

$$\frac{1}{R_{eff}} = \frac{1}{6} + \frac{1}{6} \quad \therefore R_{eff} = 3\ \Omega$$



The correct option is (D)

28. The correct option is (A)

29. The correct option is (A)

30. $R = \dfrac{\rho 1}{A},\ x = \rho\dfrac{4(a)}{(a)(2a)} = \dfrac{2\rho}{a}$,

$$y = \frac{\rho(a)}{(4a)(2a)} = \frac{\rho}{8a} \text{ then } x > z > y$$

$$= \frac{\rho(2a)}{(4a)(a)} = \frac{\rho}{2a}$$

The correct option is (D)

31. $\rho = \dfrac{RA}{l} = \dfrac{A}{Gl} = \dfrac{8\times 10^{-6}}{2.45\times 8} = 4.1\times 10^{-7}\ \Omega\text{ m}$

The correct option is (C)

32. $i_g(G+R) = V,\ 10^{-3}(400+R) = 8,\ R = 7600\ \Omega$

The correct option is (D)

33. $S = \dfrac{I_gG}{I-I_g} = \dfrac{1\times 0.81}{(10-1)} \Rightarrow 0.09\ \Omega$

The correct option is (D)

34. For two resistances R_1 and R_2

$S = R_1 + R_2$ (in series), $P = \dfrac{1}{R_1} + \dfrac{1}{R_2}$ (in parallel)

According to $S = nP$, $R_1 + R_2 = n\left(\dfrac{R_1R_2}{R_1+R_2}\right)$

If n is minimum, $R_1 = R_2 = R$ then $n = 4$

The correct option is (A)

35. Volume of wire remains constant $A_1 l_1 = A_2 l_2$, $A_1 l_1 = A_2 (2l_1)$

So, $A_1 = 2A_2$, $R_1 = \rho \frac{l_1}{A_1}$, $R_2 = \rho \frac{l_2}{A_2}$, $\frac{R_1}{R_2} = \frac{l_1}{l_2} \frac{A_2}{A_1}$,

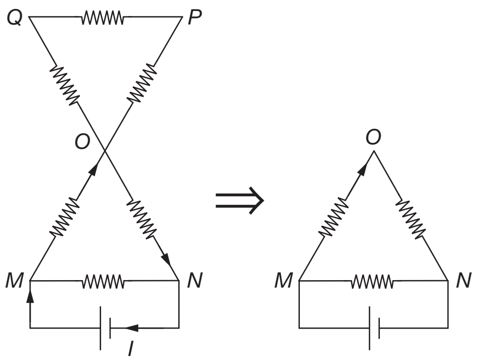
$R_2 = 16\ \Omega$

The correct option is (D)

36. The correct option is (B)

37. When a battery is connected between points M and N. NO current is found is PQO. Hence, this section may be removed from the circuit.

$$R_{\text{eff}} = \frac{2 \times 1}{(2+1)} = \frac{2}{3}\ \Omega$$



The correct option is (C)

38. In case of zero deflection in galvanometer,

$$V_{AJ} = \frac{E}{2},\ iR_{AJ} = \frac{E}{2},\ \left(\frac{E}{15r+r}\right)\left(\frac{15r}{600}\right)AJ = \frac{E}{2}$$

$AJ = 320$ cm

The correct option is (A)

39. According to KVL, $E - ir = 0$ (r is effective resistance in circuit)

$E - 4 \times 1.5 = 0$

$E = 6$ V

The correct option is (A)

40. In steady state, current through battery $I = \frac{6}{2.8 + 1.2} = 1.5$ A

$I_2 = \frac{3}{2+3} \times 1.5 = 0.9$ A

The correct option is (B)

41. $I_{\text{net}} = \frac{2}{r+1} = \frac{2}{(3/2)} = \frac{4}{3}$ A.

$V_T = 2 - \frac{4}{2} \times 0.5 = \frac{4}{3}$ V.

$Q = CV = 1\mu\text{F} \times \frac{4}{3}\text{V} = \frac{4}{3}\mu\text{C}$.

The correct option is (C)

42. Resistance between M and N can be removed (Balanced whetstone bridge)

$R_{\text{eff}} = R$

The correct option is (A)

43. A charge if taken around a closed loop work done is zero

The correct option is (C)

44. $R_{\text{eff}} = 20\ \Omega$, $i = \frac{E}{R_{\text{eff}}} = \frac{1}{10}$ A

The correct option is (B)

45. $R_{\text{eff}} = \frac{2R \times 3R}{2R + 3R} = \frac{6}{5}R$, $\tau = C.R_{\text{eff}} = \frac{6RC}{5}$

The correct option is (C)

46. $R_{\text{eff}} = R + \frac{r}{2} = \frac{2R + r}{2}$, $E_{\text{eff}} = E_m$, $I = \frac{E_{\text{eff}}}{R_{\text{eff}}} = \frac{2E_m}{2R + r}$

The correct option is (D)

47. Applying Kirchhoff's law, $I_3 = \frac{5}{11}$ A

The correct option is (A)

48. The correct option is (A)

49. The correct option is (B)

50. Let I be current through 5 Ω

$$I^2 \times 5 = 10 \qquad (1)$$

Current through 4 Ω will be $\frac{I}{2}$

Heat produced in 4 Ω resistance $= \frac{I^2}{4} \times 4 = 2$

The correct option is (B)

51. The correct option is (A)

52. The correct option is (C)

53. $\frac{1.5}{R_{AJ}} = \frac{R_Q}{R_{JB}}$, $R_Q = \frac{R_{JB}}{R_{AJ}} = \frac{2}{1} \times 1.5$, $R_Q = 3\ \Omega$

The correct option is (B)

54. Current in circuit $i = \frac{n\varepsilon}{nr} = \frac{\varepsilon}{r}$

The equivalent circuit of one cell is shown in Fig. 14.60 potential difference across the cell $= V_A - V_B = -\varepsilon + ir$ $= -\varepsilon + \frac{\varepsilon}{r}.r = 0$

The correct option is (A)

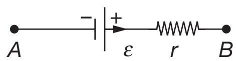


Fig. 14.60

55. As $P \neq R$ and reading of galvanometer is same, wheatbridge must be balanced and in that case, $I_R = I_G$

The correct option is (A)

56. $\frac{10}{20}=\frac{5}{10}$.

Thus, it is a balance wheatstone bridge.

$R_e=\frac{30\times 15}{45}=10\ \Omega$, $I=\frac{5}{10}=\frac{1}{2}$ A

The correct option is (B)

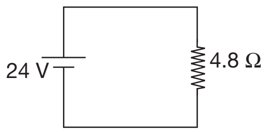
57. $\frac{q}{10}+\frac{q}{4}=14 \Rightarrow q=40\ \mu$C.

Potential difference across $C_1=\frac{40}{10}=4$ V

The correct option is (A)

58. Circuit becomes simple, then

$20\,i=24 \Rightarrow i=1.2$ A



The correct option is (C)

59. In Fig. 14.61, $R_{\text{eff}}=\frac{4R}{5}$

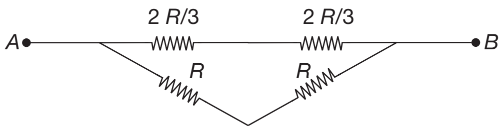


Fig. 14.61

The correct option is (C)

60. $R_{AB}=\frac{10}{3}$ (use wheatstone bridge)

$I=\frac{10}{\frac{10}{3}}=3$ A

The correct option is (A)

61. Potential difference between A and B is zero; the current through R is zero.

The correct option is (D)

62. For neutral temperature, $\frac{d\varepsilon}{dT}=0 \Rightarrow \alpha+2\beta T=0$

Then, $T=-\frac{\alpha}{2\beta}$

The correct option is (C)

63. $H=dH=\int_0^{a/2b}(a+2bt)\,dt$

The correct option is (A)

64. $\frac{q}{10}+\frac{q}{4}=14 \Rightarrow q=40\ \mu$C

Potential difference across $C_1=\frac{40}{10}=4$ V

The correct option is (A)

65. $H=\int_0^{a/b} I^2R\,dt=\int_0^{a/b}(a-2bt)^2R\,dt=\frac{a^3R}{3b}$

The correct option is (B)

66. The correct option is (A)

67. The correct option is (C)

68. The correct option is (B)

69. Current in voltmeter, $I=\frac{20}{400}=\frac{1}{20}$ A.

Current in $300\Omega=\frac{1}{15}$ A.

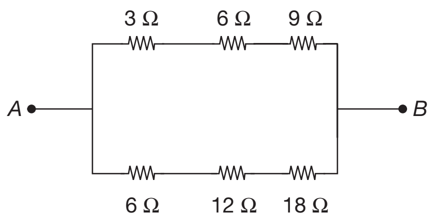
Current in $200\Omega=\frac{1}{20}+\frac{1}{15}=\frac{35}{300}=\frac{7}{60}$

$E=200\times\frac{7}{60}+20=\frac{130}{3}$ V

The correct option is (A)

70. Equivalent circuit is

$R_{\text{eq}}=12\Omega$



The correct option is (B)

71. Current through the battery is independent on R_1 and R_2.

The correct option is (D)

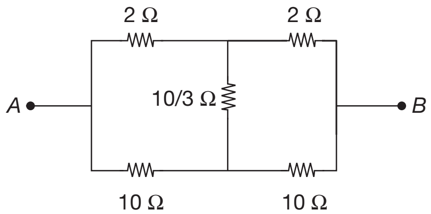
72. Potential difference across $R=18$ V

So $I=\frac{18}{9}=2$ A

The correct option is (A)

73. Equivalent circuit is balanced wheatstone bridge as shown

$R_{AB}=\frac{10}{3}\ \Omega$



The correct option is (A)

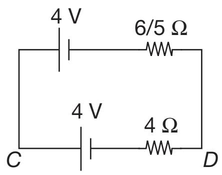
74. The equivalent EMF of 12 V and 8 V battery = $\dfrac{\dfrac{12}{2}-\dfrac{8}{3}}{\dfrac{1}{2}+\dfrac{1}{3}}$

$$= \frac{36-16}{3+2} = 4\text{ V}$$

$$r_{eq} = \frac{2\times 3}{2+3} = \frac{6}{5}\ \Omega$$

The equivalent circuit is

$\therefore$ $I = 0$



The correct option is (A)

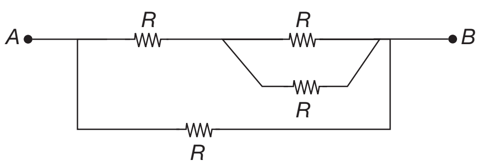
75. $I = \dfrac{12}{5+R}$ and $6-3\left(\dfrac{12}{5+R}\right)=0$

$6 = \dfrac{36}{5+R} \Rightarrow R = 1\ \Omega$

The correct option is (A)

76. Circuit can be rearranged as follows

$$R_{eq} = \frac{\left(\dfrac{3R}{2}\right)R}{\dfrac{3R}{2}+R} = \frac{3R}{5}$$



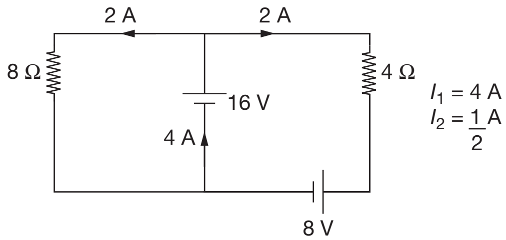
The correct option is (D)

77. Current through battery $i = \dfrac{6}{\dfrac{(6\times 3)}{(6+3)}} = 3\text{ A}$

Current through 3 Ω is $i = (3)\dfrac{6}{3+6} = 2\text{ A}$

The correct option is (B)

78. The simplified circuit can be drawn as



The correct option is (B)

79. In series, potential difference $\propto R$

When only S_1 is closed, $V_1 = \dfrac{3}{4}E = 0.75E$

When only S_2 is closed, $V_2 = \dfrac{6}{7}E = 0.86E$

And when S_1 and S_2 are closed, combined resistance of $6R$ and $3R$ is $2R$.

$\therefore \quad V_3 = \dfrac{2}{3}E = 0.67E$

$\therefore \quad V_2 > V_1 > V_3$

The correct option is (B)

80. Since $R \propto l^2$

$\Rightarrow$ If length is increased by 10%, resistance increases by almost 20%

Hence, new resistance $R' = 10 + 20\%$ of $10 = 10 + \dfrac{20}{100}\times 10 = 12\ \Omega$

The correct option is (A)

81. $H = i^2RT = i^2\left(\dfrac{\rho l}{A}\right)t = \dfrac{i^2\rho Vt}{A^2}$ (V = volume)

$$\Rightarrow \quad H \propto \frac{1}{r^4}$$

$$\Rightarrow \quad \frac{H_1}{H_2} = \left(\frac{r_2}{r_1}\right)^4 = \left(\frac{2}{1}\right)^4 = \frac{16}{1}$$

The correct option is (D)

82. Resistance of the part AC

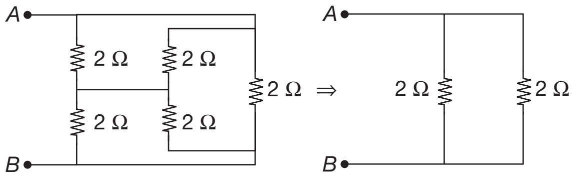
$R_{AC} = 0.1 \times 40 = 4\ \Omega$ and $R_{CB} = 0.1 \times 60 = 6\ \Omega$

In balanced condition, $\dfrac{X}{6} = \dfrac{4}{6} \Rightarrow X = 4\ \Omega$

Equivalent resistance R_{eq} = 5 Ω so current drawn from battery $i = \dfrac{5}{5} = 1\text{ A}$

The correct option is (C)

83.



$$R_{AB} = \frac{2\times 2}{2+2} = 1\ \Omega$$

The correct option is (A)

84. The correct option is (B)

85. Net resistance = $\frac{3}{2}$ Ω

Then by Kirchhoff's law $6 = \frac{3}{2} i,\ i = 4$ A

The correct option is (C)

86. The correct option is (A)

87. By balanced wheatstone bridge $\frac{R}{20} = \frac{80}{80} \Rightarrow R = 20\ \Omega$

The correct option is (C)

88. The correct option is (A)

89. Current in the circuit is $I = \frac{2E}{R + r_1 + r_2}$, $V_1 = E - Ir_1 = 0$

$$\Rightarrow \quad E - \frac{2Er_1}{R + r_1 + r_2} = 0 \Rightarrow R = r_1 - r_2$$

The correct option is (C)

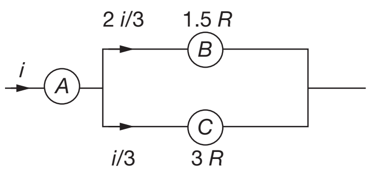
90. The correct option is (B)

91. The correct option is (D)

92. $V_A = iR$

$$V_B = \left(\frac{2i}{3}\right)1.5R = iR$$

$$V_C = \left(\frac{i}{3}\right)(3R) = iR$$



The correct option is (A)

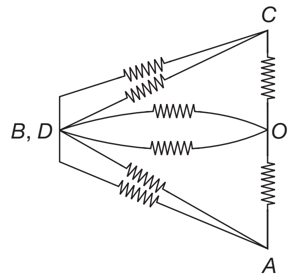
93. $19.5 \times 0.5 = S\,(20 - 0.5)$

$S = 0.5\ \Omega$

The correct option is (A)

94. From symmetry. *B* and *D* are points having same potential; so, redrawing the network as

$$R_{OA} = \frac{14}{15}\ \Omega$$



The correct option is (A)

95. $V_0 + 10 - 5 + 10 = V_x \Rightarrow V_x = 15$ V

The correct option is (B)

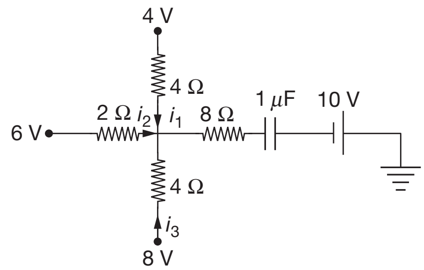
96. Let the potential of the junction be V. Then

$$\frac{6-V}{2} + \frac{4-V}{4} + \frac{8-V}{4} = 0$$

$$12 - 2V + 4 - V + 8 - V = 0$$

$$24 = 4\text{V}$$

$$V = 6\ \text{V}$$



Potential drop across capacitor

$$= 6 - (-10)$$

$$= 16\text{V}$$

Charge on capacitor = 16 μ**C**

The correct option is (D)

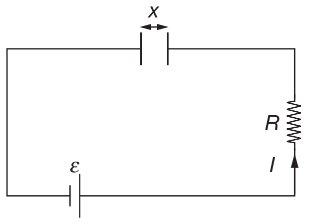
97. $$q = C(\varepsilon - IR) = \frac{\varepsilon_0 A}{x}(\varepsilon - IR) \quad (1)$$

$$x = \frac{\varepsilon_0 A(\varepsilon - IR)}{q} \quad (2)$$

On differentiation of Equation (2) from (1),

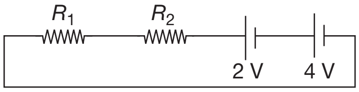
$$v = \frac{Ix^2}{\varepsilon_0 A(\varepsilon - IR)}$$

The correct option is (B)

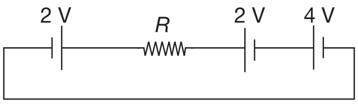


98. The possible circuit of close loop corresponding to graph are

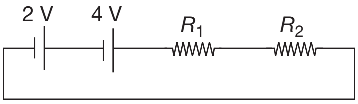
(A)



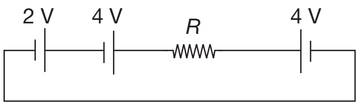
(B)



(C)



(D)



The correct option is (D)

99. For ammeter, $S = \frac{I_g}{I - I_g} \times G$

$\Rightarrow \frac{G}{S} = \left(\frac{I}{I_g} - 1\right) \Rightarrow I = 2I_g$

New range is doubled, i.e., $4I_g$

Now shunt required, $S = \frac{I_g}{4I_g - I_g} \times G = 10\ \Omega$

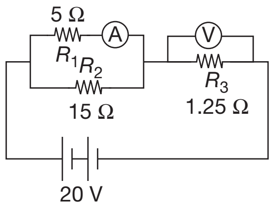
This can be obtained by shunting the earlier shunt of 30 Ω with an additional shunt of 15 Ω.

The correct option is (A)

100. (A) R_{eq} of the circuit $= \frac{R_1 \times R_2}{R_1 + R_2} + R_3$

$$= \frac{5 \times 15}{5 + 15} + \frac{125}{100} = \frac{75}{20} + \frac{5}{4} = 5\ \Omega$$

$$I = \frac{E}{R_{eq}} = \frac{20}{5} = 4\text{ A}$$



Current in $R_1 = \frac{IR_2}{R_1 + R_2} = 3$ A

P.D. across $R_3 = IR_3 = 5$ V

The correct option is (B)

(B) $I = \frac{6}{R_{AB} + 1} = \frac{6}{2 + 1} = 2$ A

$R_{AB} = \frac{6 \times 3}{6 + 3} = 2\ \Omega$

Current through 3 Ω resistors $I' = \frac{(I \times 6)}{9} = \frac{4}{3}$ A

(mC) $\Delta T = I^2 Rt$

$2000 \times \Delta T = \left(\frac{4}{3}\right)^2 \times 3 \times 15 \times 60$

$\Delta T = 2.4°\text{C}$

The correct option is (A)

More than One Option Correct Type

101. Let V_D be the potential of D, then

$$\frac{V_A - V_D}{10} + \frac{V_B - V_D}{20} + \frac{V_C - V_D}{30} = 0 \Rightarrow V_D = 40\text{ V}$$

Also, ratio of current in *AD*, *DB,* and *DC* are

$$\frac{70 - 40}{10} : \frac{40}{20} : \frac{40 - 10}{30}$$

That is, 3 : 2 : 1

Also total power network draws, $P = \sum I^2 R = 200$ W

The correct option is (A), (B) and (D)

102. $R_{eq} = 400\ \Omega$, $I = \frac{100}{400} = \frac{1}{4}$ A

Potential difference across voltmeter $= \frac{1}{4} \times 200\ \Omega = 50$ V

The correct option is (B) and (D)

103. The correct option is (B) and (C)

104. Current across *NP*, $I_{NP} \times 10 = 20 \times 1$ or $I_{NP} = 2$ A

Across *MP*, $0.5R_1 = 20$ or $R_1 = 40\ \Omega$

Total current $= 2 + 0.5 + 1.0 = 3.5\ \Omega$

$$3.5 = \frac{69}{R + \frac{40}{4}}$$ yields $R = 4\ \Omega$

The correct option is (B) (C) and (D)

105 For non-ideal ammeter and voltmeter, there will be potential difference across both.

The correct option is (A), (B), (C) and (D)

106. Electric potential increased continuously but electric field strength decreases in dielectric but direction is same from $x = 0$ to $x = 3d$.

The correct option is (B) and (C)

107. $$H = \frac{V^2}{R_1}t_1 = \frac{V^2}{R_2}t_2 \quad (1)$$

$$H = \left(\frac{V^2}{R_1 + R_2}\right)t \text{ for series} \quad (2)$$

$$H = \left[\frac{V^2}{R_1} + \frac{V^2}{R_2}\right]t \text{ for parallel} \quad (3)$$

$\therefore\ t_1 + t_2 = t$ from (1) and (2), $t = \frac{t_1 t_2}{t_1 + t_2}$ from (1) and (3)

The correct option is (A)

108. $R_{eq} = 5 + \frac{100R}{100 + R}$, $I = \frac{3.4}{R_{eq}} = 0.04$, $R = 400\ \Omega$

Reading of voltmeter $= \left(400 \times \frac{0.04}{500}\right)(100) = 3.2$ V

The correct option is (A) and (C)

109. (A) Due to induction, charge on outer surface is $Q + q$

(B) Potential at B is sum of potential of B and A

(C) Charge flows till potential of A and B will be same

(D) All charge will be on the outer surface of A

The correct option is (A) (B) (C) and (D)

110. Current in 3 Ω resistance is 3 A

Power dissipated in 3 Ω = $i^2 R = 27$ W

$V_C - 5 \times 1 + 12 - 8 \times 2 - 3 - 4 \times 2 = V_B$

$V_C - V_B = 20$ V

$V_C - V_D = 7$ V

Power dissipated in 6 Ω = 216 W

The correct option is (A) and (B)

Passage Based Questions

Passage 1

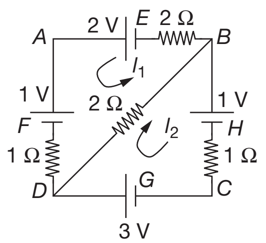
Applying KVL in loop $ADBA$,

$$5I_1 + 2I_2 = 1 \quad (1)$$

Appling KVL in loop $BDCB$,

$$3I_2 + I_1 = 1 \quad (2)$$

From equation (1) and (2), $I_1 = \frac{1}{13}$ A, $I_2 = \frac{4}{13}$ A



111. $$V_{DB} = (I_1 + I_2)R = \left(\frac{1}{13} + \frac{4}{13}\right)^2 = \frac{10}{13} \text{ V}$$

The correct option is (A)

112. $$(V_T)_E = \varepsilon - I_1 r = 2 - \left(\frac{1}{13}\right)^2 = \frac{24}{13} \text{ V}$$

The correct option is (D)

113. $$(V_T)_H = \varepsilon + I_2 r = 1 + \left(\frac{4}{13}\right)1 = \frac{17}{13} \text{ V}$$

The correct option is (A)

Passage 2

114. $$R = \rho\frac{l}{a} = \frac{5 \times 1.6}{\pi(0.05)^2} = 10^3\ \Omega$$

The correct option is (B)

115. $V = IR = 100 \times 10^{-3} \times 10^3 = 100$ V

The correct option is (B)

116. $P = VI = 10$ W

The correct option is (B)

Passage 3

117. $$\varepsilon = \frac{30}{(2t+1)}\frac{10t}{100}(1) = \frac{3t}{2t+1} = 1\text{V (at } t = 1 \text{ s)}$$

The correct option is (A)

118. $$\varepsilon = \frac{3(t-1)}{2t+1} = 1 \Rightarrow t = 4 \text{ s}$$

The correct option is (C)

119. $$\varepsilon = \frac{30 \times 0.7}{2(t+7)+1} = 1 \Rightarrow t = 3 \text{ s}$$

The correct option is (C)

Passage 4

120. As $E_2 = \left(\dfrac{E_1}{R_1 + R_{AB}}\right)\dfrac{R_{AB}}{L_{AB}} \times l = 1\text{V}$

The correct option is (A)

121. $E_2 - \dfrac{E_2}{R_2 + r}.r = \dfrac{E_1}{50} \times 5 \Rightarrow r = 7.5\ \Omega$

The correct option is (D)

122. As $\dfrac{4}{50} \times l = 1 \Rightarrow l = 12.5$ cm

The correct option is (C)

123. As $\dfrac{1.6}{50} \times l = \dfrac{2}{5} \Rightarrow l = 12.5$ cm

The correct option is (C)

Passage 5

124. When switch in position 1 and steady state is reached

$q_0 = CE_1 = 10$ C

W_1 = Energy supplied by battery $= q_0E_1 = 1000$ J

Energy stored on the capacitor $U_1 = \dfrac{q_0^2}{2C} = 500$ J

$H_1 = W_1 - U_1 = 500$ J

$H_{99\Omega} = \dfrac{99}{100} \times 500 = 495$ J

The correct option is (D)

125. Position (2), in steady state

$q = 5$C

$W_2 = E_2(q_0 - q) = 250$ J

The correct option is (A)

126. $U_2 = \dfrac{q^2}{2C} = 125$ J

The correct option is (A)

127. $H_2 = U_1 - (U_2 + W_2) = 125$ J

Heat generated across 1 $\Omega = \dfrac{125}{100} \times 1 = 1.25$ J

The correct option is (A)

Match the Column Type

128. (A) → 3; (B) → 4; (C) → 1; (D) → 2

129. $I = \dfrac{2+3-5+4+6}{2+3+5+4+6} = \dfrac{1}{2}$ A

$V_D = 2 - \dfrac{1}{2} \times 2 = 1$ V

$V_C = V_D + 3 - \dfrac{1}{2} \times 3 = 2.5$ V

$V_B = V_C - 5 - \dfrac{1}{2} \times 5 = -5$ V

$V_A = V_B + 4 - \dfrac{1}{2} \times 4 = -3$ V

(A) → 3, (B) → 1, (C) → 4, (D) → 2

130. (A) → (2); (B) → (2); (C) → (4); (D) → (3)

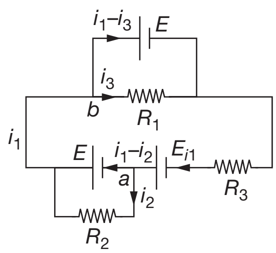
131. On solving by KVL we get, $i_1 = \dfrac{E}{R}, i_2 = -\dfrac{E}{R}$

$i_3 = \dfrac{E}{R}$

$\Rightarrow\ i_1 - i_2 = \dfrac{2E}{R}$ and $i_1 - i_3 = 0$

So reading of ammeter A_1 is $E/R = \dfrac{4}{3}$

A_2 is $2E/R = \dfrac{8}{3}$, A_3 is zero, and $\Delta V_{ab} = 4$ V.



(A) → 1; (B) → 2; (C) → 4; (D) → 3

Integer Type

143. $R_{\text{voltmeter}} = 6\ \Omega$, $R_{\text{ammeter}} = 0.5\ \Omega$

$R_{\text{eq}} = 10\ \Omega$

$I = \dfrac{30}{10} = 3\text{A}$

Reading of voltmeter = 1 × 3 = 3 V.

144. $E = \pi l = \dfrac{Vl}{L} = \dfrac{iR}{L} \times l \Rightarrow E = \dfrac{E}{R + R_h + r} \times \dfrac{R}{L} \times l$

$\Rightarrow E = \dfrac{10}{5+4+1} \times \dfrac{5}{5} \times 3 = 3\text{V}$

145. If the voltmeter is ideal then given circuit is an open circuit, so reading of voltmeter is equal to the EMF of cell, i.e., 6 V

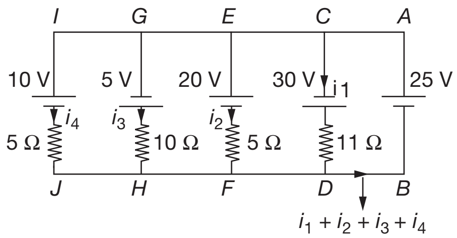
146. $V_G - 2\times 4 + 3 - 2\times 2 + 2\times 1 = V_H$

$V_G - V_H = 7\text{V}$

147. Applying KVL in loop ABCDA, ABFEA, ABHGA, and ABJIA we get,

$$30 - i_1 \times 11 = -25 \quad (1)$$
$$20 + i_2 \times 5 = 25 \quad (2)$$
$$5 - i_3 \times 10 = -25 \quad (3)$$
$$10 + i_4 \times 5 = 25 \quad (4)$$

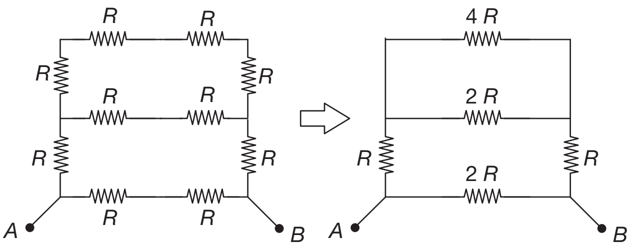
$$i_1 = 5\text{A},$$



148. No current will flow through 3 and 5.

So, $R_{eq} = \frac{6\times 6}{6+6} = 3\ \Omega,\ i = \frac{V}{R_{eq}} = \frac{3}{3} = 1\text{ A}$

149. The equivalent circuit is



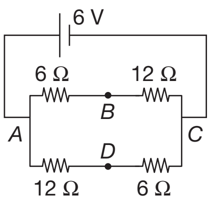
$$\Rightarrow \quad R_{eq} = \frac{\frac{10R}{3}\times 2R}{\frac{10}{3}R + 2R} = \frac{5}{4}R = 5\ \Omega$$

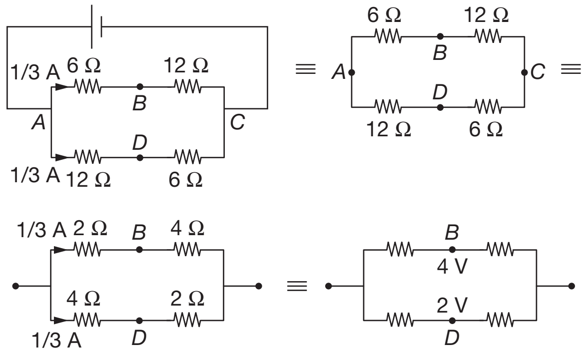
150. $\frac{1}{R} = \frac{1}{18} + \frac{1}{18} = \frac{2}{18} = \frac{1}{9}$

$R = 9\ \Omega$

$I = \frac{6}{9}\text{ A} = \frac{2}{3}\text{ A}$

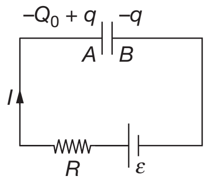
Thus, this current gets equally divided between the two arms.





$\therefore \quad V_B - V_D = (4-2)\text{V} = 2\text{V}$

151. Let at any time t charge flown through the plate B to plate A is q and instantaneous current is I.



From loop theorem $\left(\frac{2q - Q_0}{2C}\right) + IR - \varepsilon = 0$

$$\Rightarrow \quad R\frac{dq}{dt} = \frac{-2q + 2\varepsilon C + Q_0}{2C}$$

$$\Rightarrow \quad \frac{dq}{2\varepsilon C + Q_0 - 2q} = \frac{dt}{2RC}$$

Now for charge on plate A to be zero, $q = Q_0$.

Integrating $\int_0^{Q_0} \frac{dq}{2\varepsilon C + Q_0 - 2q} = \int_0^t \frac{dt}{2RC}$

$$= \quad t = RC\ln\left[\frac{2\varepsilon C + Q_0}{2\varepsilon C - Q_0}\right]$$

Putting the value of C, Q_0, ε, and R

We get $t = 2$ s.

152. We solve this problem using the fact that the effective value of as alternating current is the value of a direct current that produces the same quantity of heat in a conductor the alternating current during the same time.

The heat produced by the AC current during time period from 0 to T is

$$H = 10^2 R\frac{T}{8} + 0 + 10^2 R\frac{T}{8} + 0$$

$$H = 10^2 R\frac{T}{4} \quad (1)$$

In the same time interval, 0 to T heat produced by constant direct current I, would have been

$H' = I^2RT$ (2)

$H = H' \Rightarrow I^2RT = 10^2 R\frac{T}{4}$

$\Rightarrow \quad I = \frac{10}{2}$

effective value or RMS value of required current is 5 A

153. 2 Ω

Previous Years' Questions

154. The correct option is (C)

155. Let R_0 be the resistance of both conductors at $0°C$.

Let R_1 and R_2 be their resistance at $t°C$, then

$R_1 = R_0(1+\alpha_1 t)$

$R_2 = R_0(1+\alpha_2 t)$

Let R_s be the resistance of the series combination of two conductors at $t°C$, then

$R_s = R_1 + R_2$

$R_{s0}(1+\alpha_s t) = R_0(1+\alpha_1 t) + R_0(1+\alpha_2 t)$

where $R_{s0} = R_0 + R_0 = 2R_0$

$\therefore \; 2R_0\left(1+\alpha_s t\right) = 2R_0 + R_0 t\left(\alpha_1+\alpha_2\right)$

$2R_0 + 2R_0\alpha_s t = 2R_0 + R_0 t\left(\alpha_1+\alpha_2\right)$

$\therefore \; \alpha_s = \frac{\alpha_1+\alpha_2}{2}$

Let R_p be the resistance of the parallel combination of two conductors at $t°C$. Then

The correct option is (D)

156. Given $R_{50} = 5\ \Omega,\ R_{100} = 6\ \Omega$

$R_t = R_0(1+\alpha t)$

Where R_t = resistance of wire at $t°C$, R_0 = resistance of wire at $0°C, \alpha$ = temperature coefficient of resistance.

$\therefore R_{50} = R_0[1+\alpha 50]$

and $R_{100} - R_0[1+\alpha 100]$

or $R_{50} - R_0 = R_0\alpha(50)$ (1)

$R_{100} - R_0 = R_0\alpha(100)$ (2)

Divide (1) by (2), we get

$\frac{5-R_0}{6-R_0} = \frac{1}{2}$ or $10 - 2R_0 = 6 - R_0$

or $R_0 = 4\ \Omega$

The correct option is (C)

157. The equivalent circuit is a balanced wheatstone bridge. Hence, no current flows through arm *BD*.

AB and *BC* are in series

$\therefore \; R_{ABC} = 5 + 10 = 15\ \Omega$

AD and *DC* are in series

$\therefore \; R_{ADC} = 10 + 20 = 30\ \Omega$

ABC and *ADC* are in parallel

or $R_{eq} = \frac{15\times 30}{15+30} = 10\ \Omega$

$\therefore$ current $I = \frac{5}{10} = 0.5\,A$

The correct option is (B)

158. $\therefore R_{100} = R_0[1+0.005\ (100)]$

or $100 = R_0[1+0.005\times 100]$ (1)

$200 = R_0[1+0.005t]$ (2)

from (1) and (2),

$t = 400°C$

The correct option is (B)

159. Resistance of the bulb

$(R) = \frac{V^2}{P} = \frac{(220)^2}{100} = 484\ \Omega$

Power across 110 V $= \frac{(110)^2}{484}$

$\therefore$ Power $= \frac{110\times 110}{484} = 25$ W

The correct option is (C)

160. For zero deflection in galvanometer,

$I_1 = I_2$

or $\frac{12}{500+R} = \frac{2}{R}$

$\Rightarrow \; 12R = 100 + 2R \Rightarrow R = 100\ \Omega$

The correct option is (B)

161. $I = \frac{2E}{R_1 + R_2 + R}$

$\because \; E - IR_2 = 0$

$\therefore \; E = IR_2$

or $E = \frac{2ER_2}{R_1+R_2+R}$

or $R_1 + R_2 + R = 2R_2$

or $R = R_2 - R_1$

The correct option is (B)

162. If internal resistance is zero, the energy sources will supply a constant current.

The correct option is (C)

163. The internal resistance of a cell is given by

$$= R\left(\frac{l_1 - l_2}{l_2}\right)$$

$$\therefore\ r = 2\left[\frac{240-120}{120}\right] = 2\ \Omega$$

The correct option is (D)

164. In series combination, $S = (R_1 + R_2)$

In parallel combination, $P = \dfrac{R_1R_2}{(R_1+R_2)}$

$\because\ S = nP$

$$\therefore\ (R_1+R_2) = n\frac{R_1R_2}{(R_1+R_2)} \quad \therefore\ (R_1+R_2)^2 = nR_1R_2$$

For minimum value, $R_1 = R_2 = R$

$\therefore\ (R\times R)^2 = n(R\times R) \Rightarrow 4R^2 = nR^2$

or $n = 4$

The correct option is (A)

165. Potential difference is same when the wires are put in parallel

$$V = I_1R_1 = I_1 \times \frac{\rho l_1}{\pi r_2^2}$$

Again $V = I_2R_2 = I_2 \times \dfrac{\rho l_2}{\pi r_2^2}$

$$\therefore\ \frac{I_1\times \rho l_1}{\pi r_1^2} = \frac{I_2 \times \rho l_2}{\pi r_2^2} \Rightarrow \frac{I_1}{I_2} = \frac{1}{3}$$

The correct option is (B)

166. For meter bridge experiment,

$$\frac{R_1}{R_2} = \frac{l_1}{l_2} = \frac{l_1}{(100 - l_1)}$$

In the first case, $\dfrac{X}{Y} = \dfrac{20}{100-20} = \dfrac{1}{4}$

In the second case,

$$\frac{4X}{Y} = \frac{l}{(100-l)}$$

$$l = 50 \text{ cm}$$

The correct option is (A)

167. Equivalent resistance $= \dfrac{(3+3)\times 3}{(3+3)+3} = \dfrac{18}{19} = 2\ \Omega$

$\therefore$ current $I = \dfrac{V}{R} = \dfrac{3}{2} = 1.5$ A

The correct option is (B)

168. $P_1 = \dfrac{V^2}{R}$

When connected in parallel,

$$R_{eq} = \frac{\left(\frac{R}{2}\right)\times\left(\frac{R}{2}\right)}{\frac{R}{2}+\frac{R}{2}} = \frac{R}{4}$$

$$\therefore\ P_2 = \frac{V^2}{\frac{R}{4}} = 4\frac{V^2}{R} = 4P_1$$

$$\therefore\ \frac{P_2}{P_1} = 4$$

The correct option is (B)

169. Power $= \dfrac{V^2}{R}$

$$\therefore\ 150 = \frac{(15)^2}{R} + \frac{(15)^2}{2} = \frac{225}{R} + \frac{225}{2}\ 6\ \Omega$$

The correct option is (B)

170. Charge on the capacitor at time t

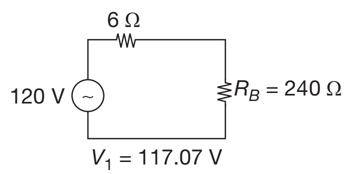
$Q = Q_0(1 - e^{-t/\tau})$, where $Q_0 = CV$

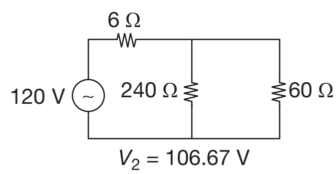
So At $t = 2\tau$ $\quad Q = CV(1 - e^{-2})$

The correct option is (B)

171. Resistance of bulb $R_B = 240\ \Omega$

Resistance of heater $R_H = 60\ \Omega$





$\Delta V = V_1 - V_2 = 10.4$ V

The correct option is (C)

172. $i = \dfrac{i_g\,(G+S)}{S} = i_g\left(1 + \dfrac{G}{S}\right)$

The resistance of ammeter is $\frac{GS}{G+S}$.

The correct option is (C)

173. $V = V_0 e^{-t/\tau}$ at $t = \tau$

$$= \frac{25}{e} = \frac{25}{2.71} = 9.2$$ and it lies between 100 and 150 s.

The correct option is (D)

174. $R_1 = \frac{(220)^2}{25}$ $R_2 = \frac{(220)^2}{100}$

$$i = \frac{440}{(220)^2\left(\frac{1}{25}+\frac{1}{100}\right)} = \frac{2}{220}\cdot\frac{100}{5} = \frac{2}{11}\text{ A}$$

$$\therefore \quad P_1 = \left(\frac{2}{11}\right)^2 \cdot \frac{(220)^2}{25} = 64\text{ W} > 25\text{ W}$$

$$P_2 = \left(\frac{2}{11}\right)^2 \cdot \frac{(220)^2}{100} = 16\text{ W}$$

∴ bulb of 25 W – 220 V will fuse.

The correct option is (C)

175. $R = (V/I) \Rightarrow (dR/R) = (dV/V + dI/I)$

$= (3+3)\% = 6\%$

The correct option is (A)

176. Total power (P) = 15 × 40 + 5 × 100 + 5 × 80 + 1000 = 2500 W

Main supply voltage = 220 V

$$\Rightarrow \text{current} = \frac{2500}{220} = 11.3\text{ A}$$

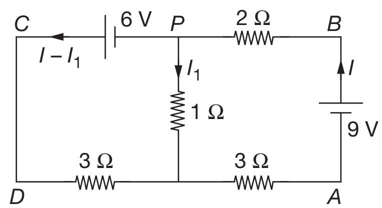
⇒ minimum capacity = 12 A

The correct option is (C)

177. From *KVL* in loop *ABPQA*

$$2I + I_1 + 3I = 9$$

$$5I + I_1 = 9 \qquad (1)$$



From KVL in loop PCDQP

$3(I - I_1) - I_1 = 6$

$3I - 4I_1 = 6$ (2)

Solving (1) and (2)

$$I_1 = -\frac{3}{23}\text{ A} = -0.13\text{ A}$$

∴ Current in branch *PQ* is 0.13 A from *Q* to *P*

The correct option is (B)

178. $I = neAv_d$

$$R = \frac{V}{neAv_d}$$

$$\rho = \frac{V}{nev_d \cdot \ell}$$

$$\rho = \frac{5}{8\times10^{28}\times1.6\times10^{-19}\times2.5\times10^{-4}\times(0.1)}$$

$$\rho = 1.6\times10^{-5}\,\Omega\text{m}$$

The correct option is (C)

179. $GI_g = (I - I_g)s$

$$S = \left(\frac{I_g}{I - I_g}\right)G$$

$$S = \left(\frac{10^{-3}}{10 - \frac{1}{10^3}}\right)\times 100$$

$S = 0.01\,\Omega$ (approx.)

The correct option is (D)

180. T = 300 K to 400 K

For Cu, $R = R_0(1+\alpha t)$ therefore linear

For Si, exponential decrease.

The correct option is (B)