DAY TWENTY

Current Electricity

Learning & Revision for the Day

- Electric Current
- Ohm's Law
- Resistance of Different Materials
- Series and Parallel Combinations of Resistors
- Temperature Dependence of Resistance
- Electric Energy and Power
- Electric Cell
- Potential Difference and emf of a Cell
- Kirchhoff's Laws
- Wheatstone's Bridge
- Meter Bridge
- Potentiometer
- Galvanometer
- Ammeter
- Voltmeter

Electric Current

Electric current is defined as the amount of charge flowing across any section of wire per unit time. If charge Δq passes through the area in time interval Δt at uniform rate, then current i is defined as

$$i = \frac{\Delta q}{\Delta t}$$

SI unit of electric current is ampere (A).

- Conventional direction of flow of current is taken to be the direction of flow of positive charge or opposite to the direction of flow of negative charge.
- Electric current is a scalar as it does not follow the vector law of addition.

Current Density

Current per unit area is termed as current density.

$$J = \frac{I}{A}\,(\text{Am}^{-2})$$

It is a vector quantity.

Drift Velocity

- Drift velocity is the average uniform velocity acquired by conduction electrons inside a metallic conductor on application of an external electric field.

  The drift velocity is given by the relation

$$\mathbf{v}_d = -\frac{e\,\mathbf{E}}{m}\tau$$

where, τ known as relaxation time.

- Drift velocity per unit electric field is called the **mobility** of the electrons. Thus, mobility,

$$\mu = \left|\frac{\mathbf{v}_d}{\mathbf{E}}\right| = \frac{e}{m}\tau$$

- In terms of drift speed, electric current flowing through a conductor is expressed as $I = nAev_d$
  where, A = cross-section area of conductor,
  n = number of conduction electrons per unit volume,
  v_d = drift velocity of electrons
  and e = charge of one electron.

Ohm's Law

Ohm's law states that the physical conditions such as temperature, mechanical strain, etc., are kept constant, the current (i) flowing through a conductor is directly proportional to the potential difference across its two ends.

i.e. $i \propto V$ or $V \propto i$ or $V = Ri$

or $\frac{V}{i} = R = a$ constant,

where R depends on the nature of material and it given dimension.

Electrical Resistance

Electrical resistance is defined as the ratio in the potential difference (v) across the ends of the conductor to the current (i) flowing through it,

i.e., $R = \frac{V}{i}$

The SI unit of electrical restristance is Ω (ohm) and its dimension is $[ML^2T^{-3}A^{-2}]$.

Electrical Resistivity

The resistance of a resistor (an element in a circuit with some resistance R) depends on its geometrical factors (length, cross-sectional area) as also on the nature of the substance of which the resistor is made. Electrical resistance of a rectangular slab depends on its length (l) and its cross-sectional area (A).

i.e., $R \propto l$

and $R \propto \frac{1}{A}$

Combining the two dependences, we get

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

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

where, ρ is a constant of proportionality called resistivity.

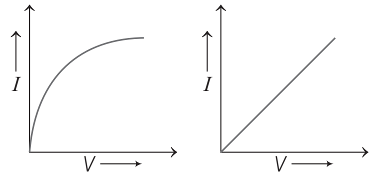
$$\rho = \frac{m}{ne^2\tau}$$

Resistance of Different Materials

A perfect conductor would have zero resistivity and a perfect insulator would have infinite resistivity. Though these are ideal limits, the electrical resistivity of substances has a very wide range. Metals have low resistivity of $10^{-8}\ \Omega$m to $10^{-6}\ \Omega$m, while insulators like glass or rubber have resistivity, some 10^{18} times (or even more) greater, Generally, good electrical conductors like metals are also good conductors of heat, while insulators like ceramic or plastic materials are also poor thermal conductors.

V-I Characteristics of Ohmic and Non-ohmic Conductors

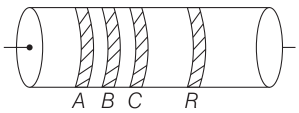
Substances obeying Ohm's law are called **Ohmic resistors**, e.g. metals and their alloys. Substances which do not obey Ohm's law are called **non-ohmic resistors**, e.g. electrolytes, gases, thermionic tubes, transistors, rectifiers, etc.



Non-ohmic resistors Ohmic resistors

Colour Code for Resistors

The electronic colour code is used to indicate the values or ratings of electronic components. The resistance value and tolerance can be determined from the standard resistor colour code. The following diagram shows a carbon resistor. A variation on the colour code is used for precision resistors which may have five colour bands.



Colour coded resistor

In that case, the first three bands indicate the first three digits of the resistance. Value and the fourth band indicates the number of zeros. In the five band code, the fifth band is gold for 1% resistors and silver for 2%.

Resistor	Code	Colour
Resistance value	0	Black (B)
First three bands	1	Brown(B)
1st band-1st digit	2	Red (R)
2nd band-2nd digit	3	Orange (O)
3rd band-number of zeros	4	Yellow (Y)
	5	Green (G)
	6	Blue (B)
	7	Violet (V)
	8	Grey (G)
	9	White (W)

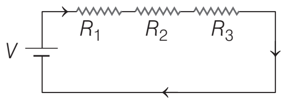
Shortcut to learn the series

B B R O Y Great Britain Very Good Wife.

Series and Parallel Combinations of Resistors

Series Combination

A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take. The current is the same through each resistor. The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors. Equivalent resistance of resistors in series

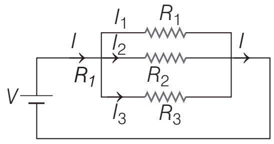


Three resistor in series

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

Parallel Combination

A parallel circuit is a circuit in which the resistors are arranged with their heads connected together and their tails connected together. The current in a parallel circuit breaks up, with some flowing along each parallel branch and recombining, when the branches meet again. The voltage across each resistor is parallel is the same.



Three resistor in parallel

The total resistance of a set of resistors in parallel is found by adding up the reciprocals of the resistance values, and then, taking the reciprocal of the total.

The equivalent resistance of resistors in parallel,

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

Temperature Dependence of Resistance

Resistance and resistivity of metallic conductors increases with increase in temperature. The relation is written as

$$R_\theta = R_0\,(1 + \alpha\theta + \beta\theta^2) \text{ and } \rho_\theta = \rho_0\,(1 + \alpha\theta + \beta\theta^2)$$

where, R_0 and ρ_0 are values of resistance and resistivity at $0°C$ and R_θ and ρ_θ at $\theta°C$. α and β are two constants whose value vary from metal to metal.

Electric Energy and Power

Whenever the electric current is passed through a conductor, it becomes hot after short time. This effect is known as **heating effect** of current or **Joule heating effect.**

$$H = W = I^2Rt \text{ joule} = \frac{I^2Rt}{418} \text{ cal}$$

The rate at which work is done by the source of emf in maintaining the effect of current in a circuit is called electric power of the circuit,

$$P = VI \text{ watt}$$

Other expressions for power,

$$P = I^2R \text{ watt} \Rightarrow \quad P = \frac{V^2}{R}$$

Electric Cell

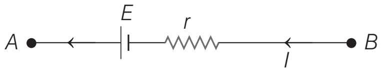
An electric cell is a device which maintains a continuous flow of charge (or electric current) in a circuit by a chemical reaction. In an electric cell, there are two rods of different metals called electrodes.

Internal Resistance of a Cell

Thus, when a current is drawn through a source, the potential difference between the terminal of the source is

$$V = E - ir$$

This can also be shown as below



$$V_A - E + Ir = V_B \text{ or } V_A - V_B = E - Ir$$

Following three special cases are possible

(i) If the current flows in opposite direction (as in case of charging of battery), then $V = E + Ir$

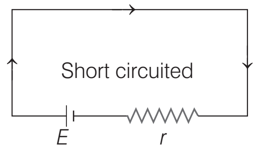
(ii) $V = E$, if the current through the cell is zero.

(iii) $V = 0$, if the cell is short circuited.

This is because current in the circuit,

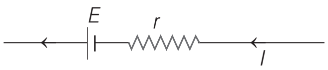
$$I = \frac{E}{r} \quad \text{or} \quad E = Ir$$

$$\therefore \quad E - Ir = 0 \text{ or } V = 0$$



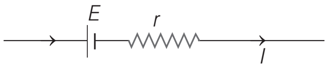
Thus, we can summarise, it was follows

⇒



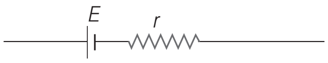
$$V = E - ir \text{ or } V < E$$

⇒

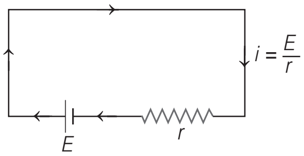


$$V = E + Ir \text{ or } V > E$$

⇒



$$V = E, \text{ if } I = 0$$



$V = 0$ is short circuited

Potential Difference and emf of a Cell

Electromotive force (emf) of a cell is the terminal potential difference of cell when it is in an **open circuit,** i.e. it is not supplying any current to the external circuit. However, when it is supplying a current to an external resistance, the voltage across the terminals of cell is called the **terminal voltage** or **terminal potential difference.**

If E be the emf and r the internal resistance of a cell and a resistance R is joined with it, then current in the circuit, $I = \dfrac{E}{R+r}$ and terminal potential difference,

$$V = IR = \frac{ER}{(R+r)} \text{ or } V = E - Ir$$

Internal resistance of cell, $r = \left(\dfrac{E-V}{V}\right)R = R\left(\dfrac{E}{V} - 1\right)$

Terminal voltage is more than emf of cell when cell is charged and it is given by $V = E + Ir$.

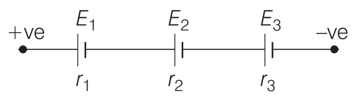
Combination of Cells in Series and in Parallel

A group of cells is called a battery. Two common grouping of cells are

1. Series Grouping

In series grouping, if all the cells are joined so as to supply current in the same direction, then resultant emf, $E_{eq} = E_1 + E_2 + E_3 + \ldots$

However, if one or more cells are joined so as to supply current in reverse direction, then emf of that/those cells is taken as negative, while calculating the equivalent emf.



Three cell in series

The equivalent internal resistance of the cell,

$$r_{eq} = r_1 + r_2 + r_3 + \ldots$$

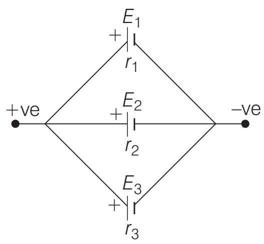
If n cells, each of emf E and internal resistance r, are joined in series, then

$$E_{eq} = nE \quad \text{and} \quad r_{eq} = nr$$

2. Parallel Grouping

In parallel grouping, if positive terminals of all cells have been joined at one point and all negative terminals at another point, then

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \ldots$$



Three cell in parallel

The equivalent emf of the parallel grouping is given by

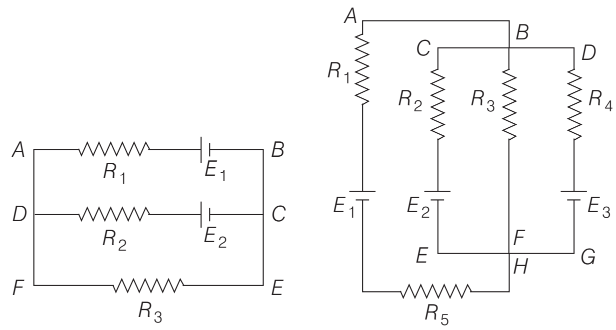
$$\frac{E_{eq}}{r_{eq}} = \frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3} + \ldots$$

If n cells, each of emf E and internal resistance r, all joined in parallel, then $\quad r_{eq} = \dfrac{r}{n}$

But $\quad E_{eq} = E$

Kirchhoff's Laws

Many electric circuits cannot be reduced to simple series parallel combinations. For example, two circuits that cannot be so broken down are shown in figure



(a) (b)

However, it is always possible to analyze such circuits by applying two rules, devised by Kirchhoff.

Junction Rule

The algebraic sum of the currents at any junction is zero.

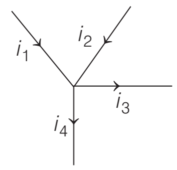


Illustration of Junction Rule

i.e. $\quad \sum_{\text{junction}} i = 0$

This law can also be written as, "the sum of all the currents directed towards a point in circuit is equal to the sum of all the currents directed away from that point."

Thus, in figure, $\quad i_1 + i_2 = i_3 + i_4$

The junction rule is bases on **conservation of electric charge.**

Loop Rule

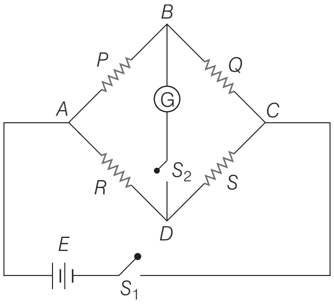
The algebraic sum of the potential difference in any loop including those associated emf's and those of resistive elements, must be equal to zero. That is, $\sum_{\text{closed loop}} \Delta V = 0$

This law represent **conservation of energy.**

Applying Kirchhoff's law for the following circuit, we have Resulting equation is $V_{r_1} + V_{r_2} + V_{r_3} - 10 = 0$.

Wheatstone's Bridge

For measuring accurately any resistance Wheatstone bridge is widely used. There are two known resistors, are variable resistor and one unknown resistors, one variable resistor and one unknown resistor connected in bridge form as shown.

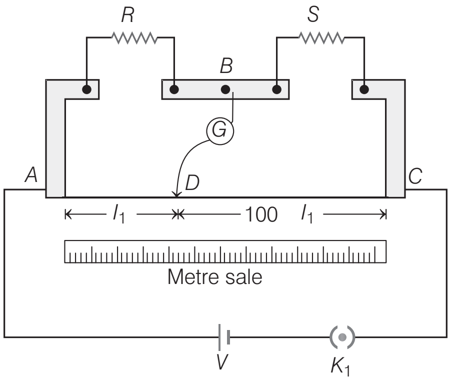


Wheatstone's Bridge

Meter Bridge
(Special Case of Wheatstone Bridge)

This is the simplest form of Wheastone bridge and is specially useful for comparing resistances more accurately. The construction of the meter bridge is shown in the figure. It consists of one metre resistance wire clamped between two metallic strips bent at right angles and it has two points for connection.

There are two gaps; in one of whose value is to be determined is connected. The galvanometer is connected with the help of jockey across BD and the cell is connected across AC. After making connections, the jockey is moved along the wire and the null point is found. Wheatstone bridge, wire used is of uniform material and cross-section. the resistance can be found with the help of the following relation

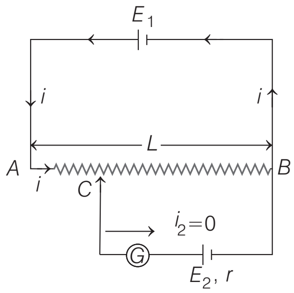


Meter Bridge

$$\frac{R}{S} = \frac{l_1}{(100 - l_1)} \quad \text{or} \quad R = S\,\frac{l_1}{100 - l_1}$$

Potentiometer

Principle Potentiometer is an ideal device to measure the potential difference between two points. It consists of a long resistance wire AB of uniform cross-section in which a steady direct current is set up by means of a battery.



Potentiometer

Potential gradient,

$$k = \frac{\text{Potential difference across } AB}{\text{Total length}}$$

$$= \frac{V_{AB}}{L} = \frac{iR_{AB}}{L} = i\lambda$$

where, $\lambda = \frac{R_{AB}}{L}$ = resistance per unit length of potentiometer wire.

The emf of source balanced between points B and C

$$E_2 = kl = i\,\frac{R_{CB}}{l} \times l = iR_{CB}$$

Here, AB is a long uniform resistance wire (length AB may be ranging from 1 m to 10 m). E_0 is a battery whose emf is known supplying a constant current I for flow through the potentiometer wire. If R be the total resistance of potentiometer wire and L its total length, then potential gradient, i.e. fall in potential per unit length along the potentiometer will be

$$k = \frac{V}{L} = \frac{IR}{L} = \frac{E_0 R}{(R_0 + R)\,L}$$

where, E_0 = emf of battery,

R_0 = resistance inserted by means of rheostat R_h

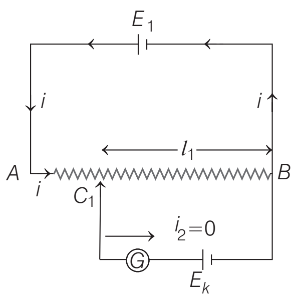
k = potential gradient.

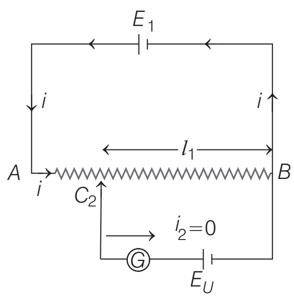
$L \rightarrow$ balancing length

$J \rightarrow$ jockey.

Applications of Potentiometer

(i) To find emf of an unknown battery





We calibrate the device by replacing E_2 by a source of known emf E_k and then by unknown emf E_u. Let the null points are obtained at lengths l_1 and l_2. Then,

$$E_K = i(\rho l_1) \quad \text{and} \quad E_U = i\,(\rho l_2)$$

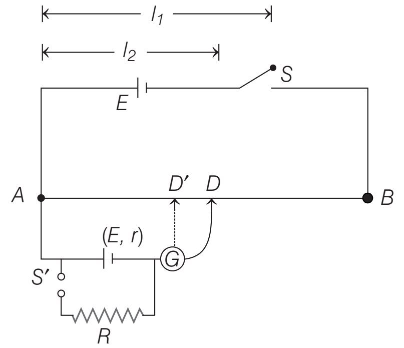
Here, ρ = resistance of wire AB per unit length

$$\therefore \qquad \frac{E_K}{E_U} = \frac{l_1}{l_2} \text{ or } E_U = \left(\frac{l_2}{l_1}\right) E_K$$

So, by measuring the lengths l_1 and l_2, we can find the emf of an unknown battery.

(ii) To find the internal resistance of a cell

Firstly, the emf E of the cell is balanced against a length $AD = l_1$. For this, the switch S' is left opened and S is closed. A known resistance R is then connected to the cell as shown. The terminal voltage V is now balanced against a smaller length $AD' = l_2$. Here, now switch is opened and S' is closed.



Then, $$\frac{E}{V} = \frac{l_1}{l_2}$$

Since, $$\frac{E}{V} = \frac{R + r}{R} \qquad \{\because E = i(R + r) \text{ and } V = iR\}$$

or $$\frac{R + r}{R} = \frac{l_1}{l_2} \Rightarrow r = \left(\frac{l_1}{l_2} - 1\right) R$$

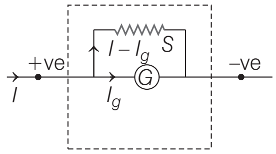
Galvanometer

It is a sensitive instrument used to detect and measure very small currents even of the order of few micro ampere.

Figure of merit of a galvanometer is defined as the current which gives one division deflection in galvanometer.

Ammeter

An ammeter is a device used to measure current directly in ampere or its submultiples.



Ammeter

A galvanometer may be converted into an ammeter of rating I by connecting a suitable low resistance (known as shunt S) in parallel with the galvanometer. Value of shunt resistance,

$$S = \frac{GI_g}{I - I_g}$$

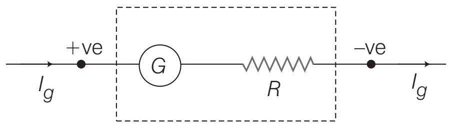
where, I_g = maximum safe current (full scale deflection current) which can be passed through galvanometer,
I = range of ammeter, G = resistance of galvanometer.

If $I = nI_g$, then shunt $S = \dfrac{G}{(n - 1)}$

The equivalent resistance of ammeter $= \dfrac{GS}{G + S}$.

Voltmeter

A voltmeter is a device used to measure potential difference across a circuit element in volts.



Voltmeter

A galvanometer may be converted into a voltmeter by connecting a suitable high resistance R in series with galvanometer. Value of series resistance,

$$R = \frac{V}{I_g} - G$$

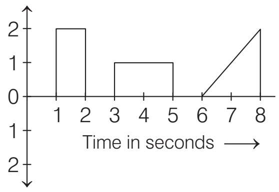
where, V = range of voltmeter.

The equivalent resistance of voltmeter $= G + R$.

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 The plot represents the flow of current through a wire at three different times. The ratio of charges flowing through the wire at different times is (see figure)



(a) 2 : 1 : 2 (b) 1 : 3 : 3 (c) 1 : 1 : 1 (d) 2 : 3 : 4

2 Consider a current carrying wire (current I) in the shape of a circle. Note that as the current progresses along the wire, the direction of J (current density) changes in an exact manner, while the current I remains unaffected. The agent that is essentially responsible for is

(a) source of emf
(b) electric field produced by charges accumulated on the surface of wire
(c) the charges just behind a given segment of wire which push them just the right way by repulsion
(d) the charges ahead

3 Across a metallic conductor of non-uniform cross-section, a constant potential difference is applied. The quantity which remains constant along the conductor is → CBSE AIPMT 2015

(a) current density (b) current
(c) drift velocity (d) electric field

4 Which of the following characteristics of electrons determines the current in a conductor?

(a) Drift velocity alone (b) Thermal velocity alone
(c) Both drift velocity and thermal velocity
(d) Neither drift velocity nor thermal velocity

5 Charge passing through a conductor of cross-section area $A = 0.3\ m^2$ is given by $q = 3t^2 + 5t + 2$ in coulomb, where t is in second. What is the value of drift velocity at $t = 2s$? (Take, $n = 2 \times 10^{25}/m^3$)

(a) 0.77×10^{-5} m/s (b) 1.77×10^{-5} m/s
(c) 2.08×10^{5} m/s (d) 0.57×10^{5} m/s

6 A resistor of 6 kΩ with tolerance 10% and another of 4 kΩ with tolerance 10% are connected in series. The tolerance of combination is about

(a) 5% (b) 10% (c) 12% (d) 15%

7 A carbon resistor of (47 ± 4.7) kΩ is to be marked with rings of different colours for its identification. The colour code sequence will be → NEET 2018

(a) Yellow - Green - Violet - Gold
(b) Yellow - Violet - Orange - Silver
(c) Violet - Yellow - Orange - Silver
(d) Green - Orange - Violet - Gold

8 When a wire of uniform cross-section a, length l and resistance R is bent into a complete circle, resistance between two of diametrically opposite points will be

(a) $\frac{R}{4}$ (b) $\frac{R}{8}$ (c) $4R$ (d) $\frac{R}{2}$

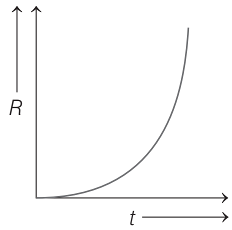
9 A wire of resistance 4Ω is stretched to twice its original length. The resistance of stretched wire would be → NEET 2013

(a) 2 Ω (b) 4 Ω (c) 8 Ω (d) 16Ω

10 6 Ω and 12 Ω resistors are connected in parallel. This combination is connected in series with a 10 V battery and 6 Ω resistor. What is the potential difference between the terminals of the 12 Ω resistor?

(a) 4 V (b) 16 V (c) 2 V (d) 8 V

11 The resistance R_t of a conductor varies with temperature t as shown in figure. If the variation is represented by $R_t = R_0(1 + \alpha t + \beta t^2)$. Then,



(a) α and β both negative
(b) α is positive and β is negative
(c) α and β both are positive
(d) α is negative and β is negative

12 An electric kettle has two heating coils. When one of the coils is connected to an AC source, the water in the kettle boils in 10 min. When the other coil is used the water boils in 40 min. If both the coils are connected in parallel, the time taken by the same quantity of water to boil will be

(a) 8 min (b) 4 min (c) 25 min (d) 15 min

13 Three equal resistors connected in series across a source of emf together dissipate 10 W power. If the same resistors are connected in parallel across the same source, the power dissipated will be

(a) 90 W (b) $\frac{10}{3}$ W (c) 30 W (d) 10 W

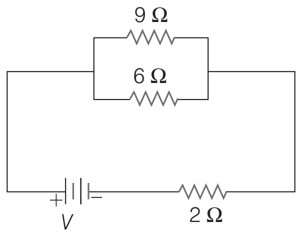
14 Two cities are 150 km apart. Electric power is sent from one city to another city through copper wires. The fall of potential per km is 8 V and the average resistance per km is 0.5 Ω. The power loss in the wire is → CBSE AIPMT 2014

(a) 19.2 W (b) 19.2 kW
(c) 19.2 J (d) 12.2 kW

15 If voltage across a bulb rated 220 V-100 W drops by 2.5% of its rated value, the percentage of the rated value by which the power would decrease is → CBSE AIPMT 2012

(a) 20% (b) 2.5% (c) 5% (d) 10%

16 If power dissipated in the 9 Ω resistor in the circuit shown is 36W, the potential difference across the 2 Ω resistor is ➜ CBSE AIPMT 2011

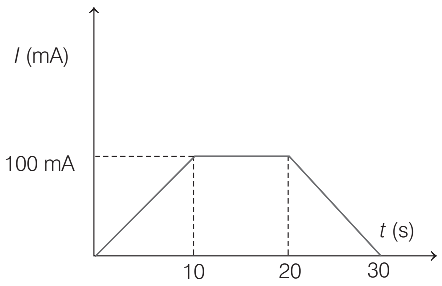


(a) 8 V (b) 10 V (c) 2 V (d) 4 V

17 A resistance coil and a battery are given. In which of the following cases, the heat generated is maximum?

(a) When the coil is directly connected to the battery as such
(b) When the coil is divided into two equal parts and both parts are connected to the battery in parallel
(c) When the coil is divided into four equal parts which are connected to the battery in parallel
(d) When only half the coil is connected to the battery

18 In a copper voltmeter, the mass deposited in 30 s is m gram. If the current-time graph as shown in the figure, the ECE of copper, in gC^{-1}, will be



(a) m (b) $\frac{m}{2}$ (c) 0.6 m (d) 0.1 m

19 A 5.0 A current is set up in an external circuit by a 6.0 V storage battery for 60 min. The chemical energy of the battery is reduced by

(a) 1.08×10^4 J (b) 1.08×10^{-4} J
(c) 1.8×10^4 J (d) 1.8×10^{-4} J

20 Two heater coils separately take 10 min and 5 min to boil a certain amount of water. If both the coils are connected in series, the time taken will be

(a) 2.5 min (b) 3.33 min
(c) 7.5 min (d) 15 min

21 The number of dry cells each of emf 1.5 V and internal resistance 0.5 Ω that must be joined in series with a resistance of 20 Ω, so as to send a current of 0.6 A through the circuit is

(a) 2 (b) 8
(c) 10 (d) 12

22 When the resistance of 9 Ω is connected at the ends of a battery, its potential difference decreases from 40 V to 30 V. The internal resistance of the battery is

(a) 6 Ω (b) 3 Ω (c) 9 Ω (d) 15 Ω

23 A 50 V battery is connected across 10 Ω resistor. The current is 4.5 A. The internal resistance of the battery is

(a) zero (b) 0.5 Ω (c) 1.1 Ω (d) 5.0 Ω

24 The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10 Ω is ➜ NEET 2013

(a) 0.2 Ω (b) 0.5 Ω (c) 0.8 Ω (d) 1.0 Ω

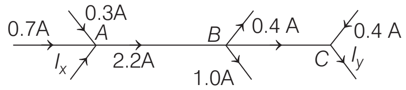
25 A current of 2 A flows through a 2 Ω resistor when connected across a battery. The same battery supplies a current of 0.5 A when connected across a 9 Ω resistor. The internal resistance of the battery is ➜ CBSE AIPMT 2011

(a) $\frac{1}{3}$ Ω (b) $\frac{1}{4}$ Ω (c) 1 Ω (d) 0.5 Ω

26 A cell of emf 1.5 V having a finite internal resistance is connected to a load resistance of 2 Ω. For maximum power transfer, the internal resistance of the cell should be

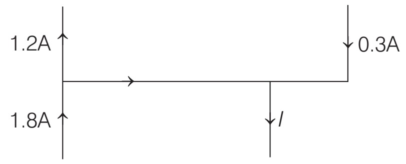
(a) 4 Ω (b) 0.5 Ω
(c) 2 Ω (d) None of these

27 In figure, values of I_x and I_y are respectively



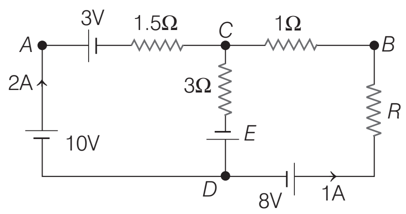
(a) 1 A, 1A (b) 1.2 A, 1.2 A
(c) 0.8 A, 0.8 A (d) 1 A, 1.2 A

28 In figure, value of current I is



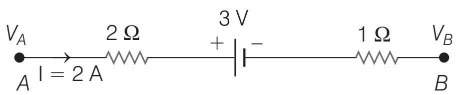
(a) 1.5 A (b) 0.4 A (c) 0.9 A (d) 0.7 A

29 In figure E is equal to



(a) 5 V (b) 4 V (c) 3 V (d) 2 V

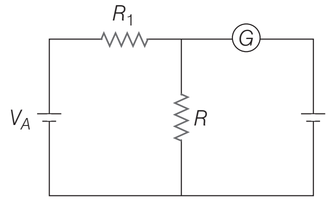
30 The potential difference $(V_A - V_B)$ between the points A and B in the given figure is ➜ NEET 2016



(a) −3 V (b) +3 V
(c) +6 V (d) +9 V

31 In the circuit shown, the cells A and B have negligible resistances. For $V_A = 12$ V, $R_1 = 500\ \Omega$ and $R = 100\ \Omega$, the galvanometer (G) shows no deflection. The value of V_B is

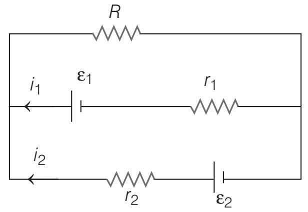
➙ CBSE AIPMT 2012



(a) 4 V (b) 2 V (c) 12 V (d) 6 V

32 See the electrical circuit shown in this figure. Which of the following equations is a correct equation for it ?

➙ CBSE AIPMT 2009



(a) $\varepsilon_1 - (i_1 + i_2)R - i_1 r_1 = 0$ (b) $\varepsilon_2 - i_2 r_2 - \varepsilon_1 - i_1 r_1 = 0$
(c) $-\varepsilon_2 - (i_1 + i_2) R + i_2 r_2 = 0$ (d) $\varepsilon_1 - (i_1 + i_2)R + i_1 r_1 = 0$

33 Consider the following two statements:

I. Kirchhoff's junction law follows from the conservation of charge.
II. Kirchhoff's loop law follows from the conservation of energy.

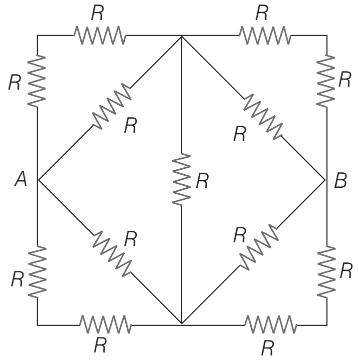
Which of the following is correct? ➙ CBSE AIPMT 2010

(a) Both I and II are wrong (b) I is correct and II is wrong
(c) I is wrong and II is correct (d) Both I and II are correct

34 The resistance of each arm of the Wheatstone's bridge is 10 Ω. A resistance of 10 Ω is connected in series with galvanometer, then the equivalent resistance across the battery will be

(a) 10 Ω (b) 15 Ω (c) 20 Ω (d) 40 Ω

35 Thirteen resistances each of resistance R ohm are connected in the circuit as shown in the figure below. The effective resistance between A and B is



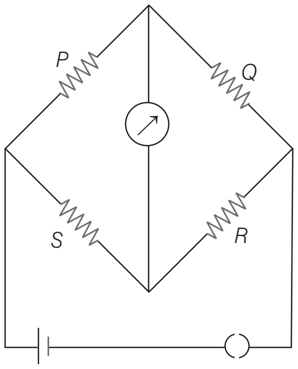
(a) $R\,\Omega$ (b) $\frac{2R}{3}\,\Omega$ (c) $\frac{4R}{3}\,\Omega$ (d) $2R\,\Omega$

36 The resistances of the four arms P, Q, R and S in a Wheatstone bridge are 10 Ω, 30 Ω, 30 Ω and 90 Ω, respectively. The emf and internal resistance of the cell are 7 V and 5 Ω, respectively. If the galvanometer resistance is 50 Ω, the current drawn from the cell will be

➙ NEET 2013

(a) 1.0 A (b) 0.2 A (c) 0.1 A (d) 2.0 A

37 In the Wheatstone's bridge shown in figure, where $P = 2\ \Omega$, $Q = 3\ \Omega$, $R = 6\ \Omega$ and $r = 8\ \Omega$. In order to obtain balance, shunt resistance across S must be



(a) 2 Ω (b) 3 Ω
(c) 6 Ω (d) 8 Ω

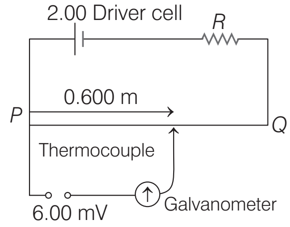
38 In a meter bridge, the balancing length from the left end (standard resistance of one ohm is in the right gap) is found to be 20 cm. The value of the unknown resistance is

(a) 0.8 Ω (b) 0.5 Ω
(c) 0.4 Ω (d) 0.25 Ω

39 For a cell of emf 2V, a balance is obtained for 50 cm of the potentiometer wire. If the cell is shunted by a 2 Ω resistor and the balance is obtained across 40 cm of the wire, then the internal resistance of the cell is

(a) 0.025 Ω (b) 0.50 Ω
(c) 0.80 Ω (d) 1.00 Ω

40 Figure shows a simple potentiometer circuit for measuring a small emf produced by a thermocouple.



The meter wire PQ has a resistance of 5 Ω and the driver cell an emf of 2.00 V. If a balance point is obtained 0.600 m along PQ when measuring an emf of 6.00 mV, what is the value of resistance R ?

(a) 95 Ω (b) 995 Ω
(c) 195 Ω (d) 1995 Ω

41 A potentiometer wire has length 4 m and resistance 8 Ω. The resistance that must be connected in series with the wire and an accumulator of emf 2 V, so as to get a potential gradient 1 mV per cm on the wire is
➔ CBSE AIPMT 2015

(a) 32 Ω (b) 40 Ω
(c) 44 Ω (d) 48 Ω

42 A potentiometer circuit has been set up for finding the internal resistance of a given cell. The main battery, used across the potentiometer wire, has an emf of 2.0 V and a negligible internal resistance. The potentiometer wire itself is 4 m long. When the resistance R connected across the given cell, has values of

(i) infinity
(ii) 9.5 Ω

The 'balancing length', on the potentiometer wire are found to be 3 m and 2.85 m, respectively.

The value of internal resistance of the cell is
➔ CBSE AIPMT 2014

(a) 0.25 Ω
(b) 0.95 Ω
(c) 0.5 Ω
(d) 0.75 Ω

43 A potentiometer is an accurate and versatile device to make electrical measurement of emf because the method involves
➔ NEET 2017

(a) cells
(b) potential gradients
(c) a condition of no current flow through the galvanometer
(d) a combination of cells, galvanometer and resistances

44 A potentiometer wire of length L and a resistance r are connected in series with a battery of emf E_0 and a resistance r_1. An unknown emf is balanced at a length l of the potentiometer wire. The emf E will be given by
➔ CBSE AIPMT 2015

(a) $\frac{LE_0 r}{l\, r_1}$
(b) $\frac{E_0\, r}{(r + r_1)} \cdot \frac{l}{L}$
(c) $\frac{E_0\, l}{L}$
(d) $\frac{LE_0\, r}{(r + r_1)\, l}$

45 Two cells of emfs approximately 5 V and 10 V are to be accurately compared using a potentiometer of length 400 cm.

(a) The battery that runs the potentiometer should have voltage of 8 V
(b) The battery of potentiometer can have a voltage of 15 V and R adjusted, so that the potential drop across the wire slightly exceeds 10 V
(c) The first portion of 50 cm of wire itself should have a potential drop of 10 V
(d) Potentiometer is usually used for comparing resistances and not voltages

46 A galvanometer of resistance 100 Ω gives full scale deflection for 10 mA current. What should be the value of shunt, so that it can measure a current of 100 mA?

(a) 11.11 Ω (b) 9.9 Ω
(c) 1.1 Ω (d) 4.4 Ω

47 A circuit contains an ammeter, a battery of 30 V and a resistance 40.8 Ω all connected in series. If the ammeter has a coil of resistance 480 Ω and a shunt of 20 Ω, then reading in the ammeter will be ➔ CBSE AIPMT 2015

(a) 0.5 A (b) 0.25 A
(c) 2 A (d) 1 A

48 A millivoltmeter of 25 mV range is to be converted into an ammeter of 25 A range. The value (in ohm) of necessary shunt will be ➔ CBSE AIPMT 2012

(a) 0.001 (b) 0.01 (c) 1 (d) 0.05

49 The range of a voltmeter of resistance G Ω is V volt. The resistance required to be connected in series with it in order to convert it into a voltmeter of range nW volt, will be

(a) $(n-1)G$ (b) G/n
(c) nG (d) $G/(n-1)$

50 A 100 V voltmeter of internal resistance 20 kΩ in series with a high resistance R is connected to 110 V line. The voltmeter reads 5V, the value of R is

(a) 210 kΩ (b) 315 kΩ
(c) 420 kΩ (d) 4440 kΩ

51 A galvanometer has a coil of resistance 100 Ω and gives a full scale deflection for 30 mA current. If it is to work as a voltmeter of 30 V range, the resistance required to be added will be ➔ CBSE AIPMT 2010

(a) 900 Ω (b) 1800 Ω (c) 500 Ω (d) 1000 Ω

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

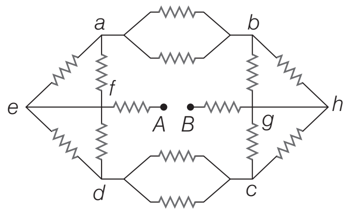
1 A cylindrical conductor AB of non-uniform area of cross-section carries a current of 5 A. The radius of the conductor at one end A is 0.5 cm. The current density at the other end of the conductor is half of the value at A. The radius of the conductor at the end B is nearly

(a) 1.4 cm (b) 0.7 cm
(c) 0.6 cm (d) None of these

2 A metal rod of the length 10 cm and a rectangular cross-section of 1 cm × 1/2 cm is connected to a battery across opposite faces. The resistance will be

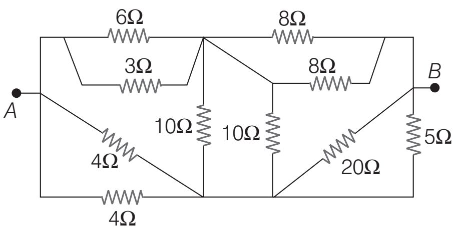
(a) maximum when the battery is connected across 1 cm × 1/2 cm faces
(b) maximum when the battery is connected across 10 cm × 1 cm faces
(c) maximum when the battery is connected across 10 cm × 1/2 cm faces
(d) same irrespective of the three faces

3 Each of the resistors showing in figure has resistance R. Find the equivalent resistance between A and B.



(a) $\frac{7R}{4}$ (b) $\frac{5R}{4}$
(c) $\frac{9R}{4}$ (d) $\frac{11R}{4}$

4 The effective resistance between A and B in figure is



(a) 2 Ω (b) 3 Ω (c) 5 Ω (d) 6 Ω

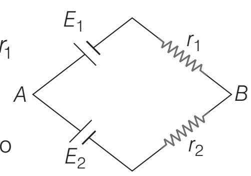
5 Two lamps P and Q are connected in parallel in an electric circuit. Lamp P glows brighter than lamp Q. If R_P and R_Q are their respective resistances, then

(a) $R_P > R_Q$ (b) $R_P < R_Q$
(c) $R_P = R_Q$ (d) None of these

6 Two cells having the same emf, are connected in series through an external resistance R. Cells have internal resistances r_1 and r_2 ($r_1 > r_2$), respectively. When the circuit is closed, the potential difference across the first cell is zero. The value of R is

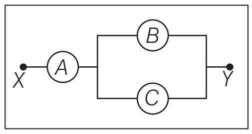
(a) $r_1 - r_2$ (b) $\frac{r_1 + r_2}{2}$ (c) $\frac{r_1 - r_2}{2}$ (d) $r_1 + r_2$

7 Two batteries of emf E_1 and E_2 ($E_2 > E_1$) and internal resistances r_1 and r_2 respectively are connected in parallel as shown in figure.



(a) The equivalent emf E_{eq} of the two cells is between E_1 and E_2, i.e. $E_1 < E_{eq} < E_2$
(b) The equivalent emf E_{eq} is smaller than E_1
(c) The E_{eq} is given by $E_{eq} = E_1 + E_2$ always
(d) E_{eq} is independent of internal resistances r_1 and r_2

8 A, B and C are voltmeters of resistance R, $1.5R$ and $3R$ respectively as shown in the figure. When some potential difference is applied between X and Y, the voltmeter readings are V_A, V_B and V_C, respectively. Then, ➜ CBSE AIPMT 2015



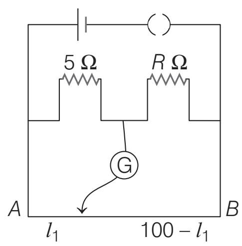
(a) $V_A = V_B = V_C$ (b) $V_A \neq V_B = V_C$
(c) $V_A = V_B \neq V_C$ (d) $V_A \neq V_B \neq V_C$

9 A filament bulb (500 W, 100 V) is to be used in a 230 V main supply. When a resistance R is connected in series, it works perfectly and the bulb consumes 500 W. The value of R is ➜ NEET 2016

(a) 230 Ω (b) 46 Ω (c) 26 Ω (d) 13 Ω

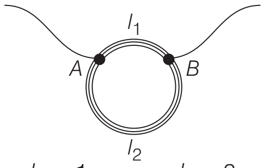
10 The resistance in the two arms of the meter bridge are 5 Ω and R Ω, respectively.

When the resistance R is shunted with an equal resistance, the new balance point is at $1.6 l_1$. The resistance R, is ➜ CBSE AIPMT 2014



(a) 10 Ω (b) 15 Ω
(c) 20 Ω (d) 25 Ω

11 A ring is made of a wire having a resistance $R_0 = 12\Omega$. Find the points A and B, as shown in the figure, at which a current carrying conductor should be connected, so that the resistance R of the sub circuit between these points is equal to $\frac{8}{3}\Omega$. ➜ CBSE AIPMT 2012



(a) $\frac{l_1}{l_2}=\frac{5}{8}$ (b) $\frac{l_1}{l_2}=\frac{1}{3}$ (c) $\frac{l_1}{l_2}=\frac{3}{8}$ (d) $\frac{l_1}{l_2}=\frac{1}{2}$

12 When a copper voltmeter is connected with a battery of emf 12 V. 2g of copper is deposited in 30 min. If the same voltmeter is connected across a 6 V battery, then the mass of copper deposited in 45 min would be

(a) 1 g (b) 1.5 g (c) 2 g (d) 2.5 g

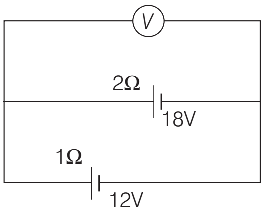
13 The resistance of a wire is R ohm. If it is melted and stretched to n times its original length, its new resistance will be ➜ NEET 2017

(a) nR (b) $\frac{R}{n}$ (c) n^2R (d) $\frac{R}{n^2}$

14 A potentiometer wire is 100 cm long and a constant potential difference is maintained across it. Two cells are connected in series first to support one another and then in opposite direction. The balance points are obtained at 50 cm and 10 cm from the positive end of the wire in the two cases. The ratio of emf is ➜ NEET 2016

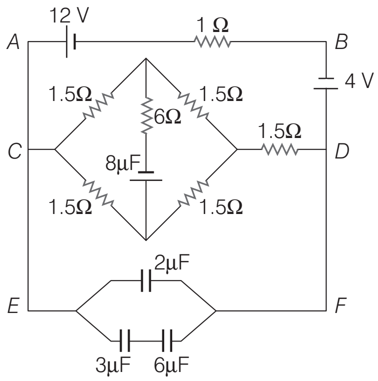
(a) 5 : 4 (b) 3 : 4 (c) 3 : 2 (d) 5 : 1

15 Two batteries, one of emf 18 V and internal resistance 2 Ω and the other of emf 12 V and internal resistance 1 Ω, are connected as shown in figure. The voltmeter V will record a reading of



(a) 15 V (b) 30 V (c) 14 V (d) 18 V

16 In the given circuit, find the potential difference across 6 μF capacitor in steady state.



(a) 4 V (b) 2 V (c) 6 V (d) None of above

17 Two metal wires of identical dimensions are connected in series. If σ_1 and σ_2 are the conductivities of the metal wires respectively, the effective conductivity of the combination is ➜ CBSE AIPMT 2015

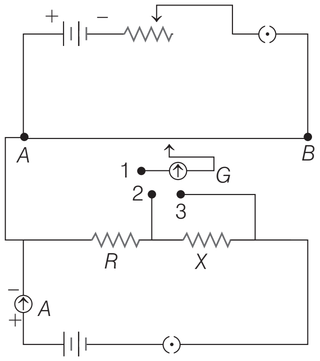
(a) $\frac{2\,\sigma_1\,\sigma_2}{\sigma_1+\sigma_2}$ (b) $\frac{\sigma_1+\sigma_2}{2\,\sigma_1\,\sigma_2}$

(c) $\frac{\sigma_1+\sigma_2}{\sigma_1\,\sigma_2}$ (d) $\frac{\sigma_1\,\sigma_2}{\sigma_1+\sigma_2}$

18 In an ammeter 0.2% of main current passes through the galvanometer. If resistance of galvanometer is G, the resistance of ammeter will be ➜ CBSE AIPMT 2014

(a) $\frac{1}{499}G$ (b) $\frac{499}{500}G$ (c) $\frac{1}{500}G$ (d) $\frac{500}{499}G$

19 A potentiometer circuit is set up as shown. The potential gradient across the potentiometer wire, is k volt/cm and the ammeter present in the circuit, reads 1.0 A when two way key is switched OFF. The balance points, when the key between the terminals (a) 1 and 2 (b) 1 and 3, is plugged in, are found to be at lengths l_1 cm and l_2 cm, respectively. The magnitudes, of the resistors R and X in ohm are then equal respectively to ➜ CBSE AIPMT 2010



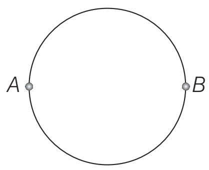
(a) $k(l_2-l_1)$ and kl_2 (b) kl_1 and $k(l_2-l_1)$

(c) $k(l_2-l_1)$ and kl_1 (d) kl_1 and kl_2

20 A student measures the terminal potential difference (V) of a cell (of emf ε and internal resistance r) as a function of the current (I) flowing through it. The slope and intercept of the graph between V and I respectively, equal to ➜ CBSE AIPMT 2009

(a) ε and $-r$ (b) $-r$ and ε (c) r and $-$ε (d) $-$ε and r

21 A wire of resistance $12\,\Omega\,m^{-1}$ is bent to form a complete circle of radius 10 cm. The resistance between its two diametrically opposite points A and B as shown in the figure is ➜ CBSE AIPMT 2009



(a) 0.6 π Ω (b) 3 Ω (c) 6 π Ω (d) 6 Ω

22 The charge following through a resistance R varies with time t as $Q=at-bt^2$, where a and b are positive constants. The total heat produced in R is ➜ NEET 2016

(a) $\frac{a^3R}{3b}$ (b) $\frac{a^3R}{2b}$ (c) $\frac{a^3R}{b}$ (d) $\frac{a^3R}{6b}$

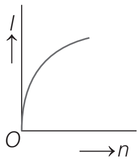
23 In producing chlorine by electrolysis 100 kW power at 125 V is being consumed. How much chlorine per minute is liberated (Take, ECE of chlorine is 0.367×10^{-6} kg C^{-1}) ➜ CBSE AIPMT 2010

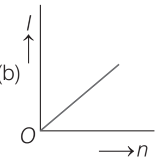
(a) 1.76×10^{-3} kg
(b) 9.67×10^{-3} kg
(c) 17.61×10^{-3} kg
(d) 3.67×10^{-3} kg

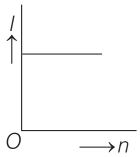
24 A set of n equal resistors, of value R each, are connected in series to a battery of emf E and internal resistance R. The current drawn is I. Now, the n resistors are connected in parallel to the same battery. Then, the current drawn from battery becomes $10I$. The value of n is ➜ NEET 2018

(a) 20 (b) 11
(c) 10 (d) 9

25 A battery consists of a variable number n of identical cells (having internal resistance r each) which are connected in series. The terminals of the battery are short-circuited and the current I is measured. Which of the graphs shows the correct relationship between I and n? ➜ NEET 2018

(a)


(b)


(c)


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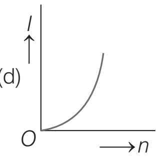


ANSWERS

SESSION 1

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

SESSION 2

1 (b)	**2** (a)	**3** (d)	**4** (b)	**5** (b)	**6** (a)	**7** (a)	**8** (a)	**9** (c)	**10** (b)
11 (d)	**12** (b)	**13** (c)	**14** (c)	**15** (c)	**16** (b)	**17** (a)	**18** (c)	**19** (c)	**20** (b)
21 (a)	**22** (d)	**23** (c)	**24** (c)	**25** (c)					

Hints and Explanations

SESSION 1

1 Charge = Area under the current-time graph

$q_1 = 2 \times 1 = 2, q_2 = 1 \times 2 = 2$

and $q_3 = \frac{1}{2} \times 2 \times 2 = 2$

$\therefore q_1 : q_2 : q_3 = 2 : 2 : 2 = 1 : 1 : 1$

2 The current density is a vector quantity. Its direction is given by the direction of flow of positive charge in the circuit. The same is possible due to electric field produced by charges accumulated on the surface of wire.

3 The area of cross-section of conductor is non-uniform, so current density will be different, but the numbers of flow of electron will be same, so current will be constant.

4 Current, $I = nAev_d$, i.e. $I \propto v_d$.

Therefore, current in a conductor is determined by drift velocity alone.

5 Given, $A = 0.3\ \text{m}^2$, $n = 2 \times 10^{25}/\text{m}^3$,

$q = 3t^2 + 5t = +2\,\text{C}$

$\therefore I = \frac{dq}{dt} = \frac{d}{dt}(3t^2 + 5t + 2) = 6t + 5$

At $t = 2\,s$, $I = 6 \times 2 + 5 = 17$

$\therefore$ Drift velocity, $v_d = \frac{I}{neA}$

$= \frac{17}{2 \times 10^{25} \times 1.6 \times 10^{-19} \times 0.3}$

$= \frac{17}{0.96 \times 10^{-6}} = 1.77 \times 10^{-5}$ m/s

6 In series combination,

$R = R_1 + R_2 = 6 + 4 = 10\ \text{k}\Omega$

Error in combination,

$\Delta R = \Delta R_1 + \Delta R_2 = \frac{10}{100} \times 6 + \frac{10}{100} \times 4$

$= 0.6 + 0.4 = 1$

$\therefore \frac{\Delta R}{R} = \frac{1}{10} = 10\%$

7 Given, $R = (47 \pm 4.7)\ \text{k}\Omega$

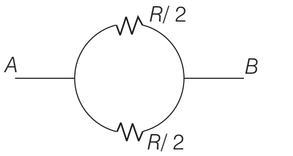
$= 47 \times 10^3 \pm 10\%\ \Omega$

As per the colour code for carbon resistors, the colour assigned to numbers

4 – Yellow
7 – Violet
3 – Orange

For $\pm 10\%$ accuracy, the colour is silver. Hence, the bands of colours on carbon resistor in sequence are yellow, violet, orange and silver.

8 When wire is bent to form a complete circle, then



$$2\pi r = R \Rightarrow r = \frac{R}{2\pi}$$

Resistance of each semi-circle

$$= \pi r = \frac{\pi R}{2\pi} = \frac{R}{2}$$

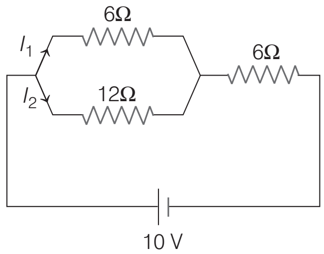
Thus, net resistance in parallel combination of two semi-circular

resistances, $R' = \dfrac{\frac{R}{2} \times \frac{R}{2}}{\frac{R}{2} + \frac{R}{2}} = \dfrac{\frac{R^2}{4}}{R} = \dfrac{R}{4}$

9 When a wire is stretched, both its area and length changes. So, the new resistance of wire,

$$R' = n^2 R = 2^2 \times 4 = 16\,\Omega$$

10



$$\therefore \quad R = \frac{6 \times 12}{6 + 12} = \frac{6 \times 12}{18} = 4\,\Omega$$

Total resistance,

$R_{eq} = 6 + 4 = 10\,\Omega$

$\therefore$ Current, $I = \dfrac{V}{R} = \dfrac{10}{10} = 1$ A

The current in 12 Ω resistor is

$$I_2 = I\left(\frac{R_1}{R_1 + R_2}\right) = 1 \times \left(\frac{6}{6 + 12}\right)$$

$$\Rightarrow I_2 = \frac{1}{3}$$

The potential difference in 12 Ω resistor,

$$V = I_2 \times R = \frac{1}{3} \times 12 = 4\text{ V}$$

11 Graph indicates that resistance increases with increase in temperature, so α and β both are positive.

12 $H = \dfrac{V^2}{R} t \Rightarrow \dfrac{H}{V^2} = \dfrac{t}{R} = \text{constant}$

$\therefore \quad t \propto R$

$\because \quad R_p = \dfrac{R_1 R_2}{R_1 + R_2}$

$\therefore \quad t_p = \dfrac{t_1 t_2}{t_1 + t_2} = \dfrac{10 \times 40}{10 + 40} = 8$ min

13 In series, $10 = \dfrac{V^2}{3R} \Rightarrow \dfrac{V^2}{R} = 30$

In parallel, $P = \dfrac{V^2}{\left(\frac{R}{3}\right)} = 3 \times 30 = 90$ W

14 Resistance $= 150 \times 0.5 = 75\,\Omega$

$\therefore \quad I = \dfrac{\Delta V}{\Delta R} = \dfrac{8}{0.5} = 16$ A

Therefore, power,

$$P = I^2 R = (16)^2 \times 75\text{ W}$$

$$= 19200 = 19.2\text{ kW}$$

15 Power, $P = \dfrac{V^2}{R}$

For small variation, $\dfrac{\Delta P}{P} \times 100\%$

$$= \frac{2\Delta V}{V} \times 100\% = 2 \times 2.5 = 5\%$$

Therefore, power would decrease by 5%.

16 Electric power, $P = i^2 R$

$\therefore$ Current, $i = \sqrt{\dfrac{P}{R}}$

For resistance of 9 Ω,

$$i_1 = \sqrt{\frac{36}{9}} = \sqrt{4} = 2\text{ A}$$

and $\quad i_2 = \dfrac{i_1 \times R}{6} = \dfrac{2 \times 9}{6} = 3$ A

$\because \quad I = i_1 + i_2 = 2 + 3 = 5$ A

So, $V_2 = IR_2 = 5 \times 2 = 10$ V

17 Since, battery supplies constant emf.

So, power, $P = \dfrac{V^2}{R}$ or Power $\propto \dfrac{1}{R}$

So, R should be minimum to generate maximum heat. In option (c), resistance would be minimum. So, heat generated would be maximum.

18 $\therefore$ Average current,

$$I = \frac{50 + 100 + 50}{3} = \frac{200}{3}\text{ mA}$$

$$\because \quad z = \frac{m}{It} = \frac{3m}{200 \times 10^{-3} \times 30} = \frac{m}{2}$$

19 $\therefore$ Chemical energy reduced $= VIt$

$= 6 \times 5 \times 6 \times 60 = 10800 = 1.08 \times 10^4$ J

20 H is same, therefore $t \propto R$

$$\because \quad H = \frac{V^2}{R} t$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{10}{5} = 2$$

When the coils are connected in series,

$R_{eff} = R_1 + R_2 = 3R_2$

$$\frac{t}{5} = \frac{3R_2}{R_2}$$

$$\therefore \quad t = 15\text{ min}$$

21 For n identical cells (series grouping),

$$I = \frac{nE}{nr + R} \Rightarrow 0.6 = \frac{n \times 1.5}{n \times 0.5 + 20}$$

This gives, $n = 10$

22 The internal resistance of battery is given by

$$r = \left[\frac{E}{V} - 1\right]R = \left[\frac{40}{30} - 1\right] \times 9$$

$$= \frac{9 \times 10}{30} = 3\,\Omega$$

23 By applying kirchhoff's loop law, we get

$$E = I(R + r)$$

So, $\quad 50 = 4.5(10 + r)$

$$4.5\,r = 50 - 45 = 5$$

$$\Rightarrow \quad r = \frac{5}{4.5} = 1.1\,\Omega$$

24 Current in the circuit,

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

$\Rightarrow \quad 2.1 = 0.2(10 + r)$

$\Rightarrow \quad r = 10.5 - 10 = 0.5\,\Omega$

25 Current, $I = \dfrac{E}{R + r}$

$$2 = \frac{E}{2 + r} \quad \text{...(i)}$$

and $\quad 0.5 = \dfrac{E}{9 + r} \quad$ ...(ii)

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{2}{0.5} = \frac{9 + r}{2 + r} \Rightarrow 4 = \frac{9 + r}{2 + r} \Rightarrow 3r = 1$$

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

26 For maximum power, external resistance = internal resistance

$$2\,\Omega = 2\,\Omega$$

27 At the node A, $I_x + 0.7 + 0.3 = 2.2$

i.e. $\quad I_x = 1.2$ A

At the node B, 2.2 A enters the node, while the other three currents leave the node. The unknown current at B is

$$2.2 - (1.0 + 0.4) = 0.8\text{ A}$$

Then, at the node C, $0.8 + 0.4 = I_y$

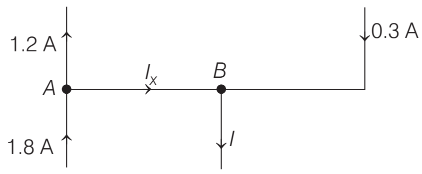
i.e. $\quad I_y = 1.2$ A

28 At the node A, $1.8 = 1.2 + I_x$

i.e. $\quad I_x = 0.6$ A

Then, at the node B,

$$I_x + 0.3 = I = 0.6 + 0.3 = 0.9\text{ A}$$

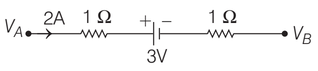


29 By Kirchhoff's first law, current in branch CD is 3A.

Applying KCL to the loop $ACDA$,

$$2 \times 1.5 + 3 \times 2 = 10 - 3 + E$$
$$9 = 7 + E$$
or $$E = 2\text{ V}$$

30



Applying KVL,

$$V_A + \Sigma V = V_B + 2 \times 2 + 2 \times 1$$
$$V_A - V_B - 3 = 4 + 2;\ V_A - V_B = 9\text{ V}$$

31 **Concept** If potential difference across $R\ \Omega$ resistor is equal to potential difference of cell B, galvanometer shows no deflection.

Applying Kirchhoff's law,

$$500I + 100I = 12$$

So, $$I = \frac{12 \times 10^{-2}}{6}$$
$$= 2 \times 10^{-2}\text{ A}$$

Hence, $$V_B = 100(2 \times 10^{-2})$$
$$= 2\text{ V}$$

32 The algebraic sum of the changes in potential in complete transversal of a mesh (closed loop) is zero, i.e. $\Sigma V = 0$

So, $\varepsilon_1 - (i_1 + i_2)R - i_1 r_1 = 0$

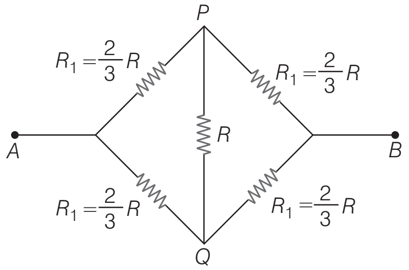
33 Kirchhoff's junction law follows from the conservation of charge.

Kirchhoff's loop law follows from the conservation of energy.

34 To keep a resistance in series with a balanced galvanometer is not meaningful. The bridge would stay balanced. Therefore, net resistance across the battery

$$= \left(\frac{1}{10+10} + \frac{1}{10+10}\right)^{-1}$$
$$= 10\Omega$$

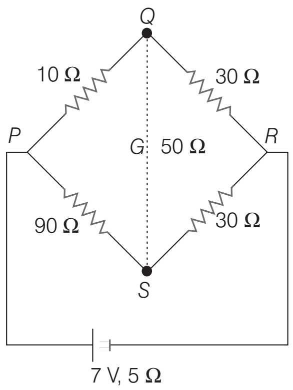
35 Equivalent circuit will be



Now, above circuit is a Wheatstone's bridge. By solving, we get

$$R_{AB} = \frac{2}{3}R\,\Omega$$

36 Effective resistance,



$$\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{...(i)}$$

Then, $R_1 = 10 + 30$

$\Rightarrow$ $R_1 = 40$

Now, $R_2 = 90 + 30 = 120$

$R_2 = 120$

By Eq. (i), we get

$$\frac{1}{R_{\text{eff}}} = \frac{1}{40} + \frac{1}{120}$$

$$\Rightarrow \quad R_{\text{eff}} = \frac{40 \times 120}{120 + 40} = \frac{4800}{160}$$
$$= 30\ \Omega$$

In the balancing condition,

$$\therefore \text{Current, } I = \frac{7}{(30+5)} \quad \left[\because I = \frac{E}{R+r}\right]$$
$$= \frac{7}{35} = 0.2\text{ A}$$

37 For a balanced wheat stone's bridge,

$$\frac{P}{Q} = \frac{x}{R} \Rightarrow x = 4\ \Omega$$

and $\frac{1}{S} + \frac{1}{r} = \frac{1}{x} \Rightarrow \frac{1}{8} + \frac{1}{r} = \frac{1}{4}$, gives

$r = 8\ \Omega$

38 For a meter bridge,

$$\frac{P}{Q} = \frac{l_1}{l_2} \Rightarrow P = \frac{20}{80} \times 1 = 0.25\ \Omega$$

39 Internal resistance of the cell,

$$r = \left(\frac{l_1 - l_2}{l_2}\right)R = \frac{50-40}{40} \times 2 = 0.50\ \Omega$$

40 The voltage per unit length on the meter wire PQ is

$$\frac{6.00\text{ mV}}{0.60\text{ m}} \text{ or } 10\text{ mVm}^{-1}$$

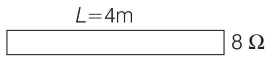
Hence, potential across the meter wires PQ is 10 mV^{-1} (1 m) = 10 mV. Current drawn from the driver cell is

$$I = \frac{10\text{ mV}}{5\ \Omega} = 2\text{ mA}$$

Resistance of the resistor R is

$$R = \frac{2\text{V} - 10\text{mV}}{2\text{ mA}} = \frac{1990\text{ mV}}{2\text{ mV}} = 995\ \Omega$$

41



Since, 1 cm$\rightarrow$ 1 mV

$\therefore$ 100 cm$\rightarrow$ 100 mV

$\Rightarrow$ 400 cm$\rightarrow$ 400 mV = 0.4 V

Change in potential,

$$\Delta V = 0.4 = \frac{2}{8+R} \times 8$$

$$\Rightarrow 8 + R = \frac{16}{0.4} = \frac{160}{4} = 40 \Rightarrow R = 32\Omega$$

42 Internal resistance of a cell,

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

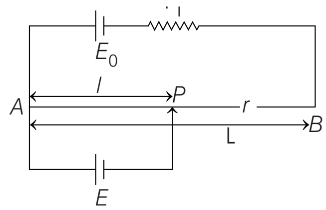
$$\therefore \left(\frac{3}{2.85} - 1\right) 9.5\ \Omega = \frac{0.15}{2.85} \times 9.5\ \Omega = 0.5\ \Omega$$

43 When a cell is balanced against potential drop across a certain length of potentiometer wire, no current flows through the cell.

$\therefore$ emf of cell = potential drop across balance length of potentiometer wire.

So, potentiometer is a more accurate device for measuring emf of a cell or no current flows through the cell during measurement of emf.

44 Consider a potentiometer wire of length L and a resistance r are connected in series with a battery of emf E_0 and a resistance r_1 as shown in figure. Current in wire $AB = \dfrac{E_0}{r_1 + r}$



Potential gradient,

$$x = \frac{Ir}{L} = \left[\frac{E_0}{r_1 + r}\right]\frac{r}{L}$$

emf produced across E will be given by

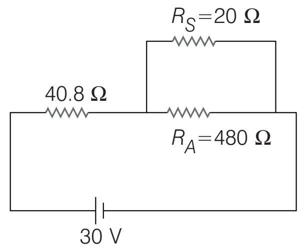
$$E = x \cdot l = \left[\frac{E_0 r}{r_1 + r}\right]\frac{l}{L}$$

45 In a potentiometer experiment, the emf of a cell can be measured, if the potential drop along the potentiometer wire is more than the emf of the cell to be determined. As values of emfs of two cells are approximately 5 V and 10 V, therefore the potential drop along the potentiometer wire must be more than 10 V. Hence, option (b) is correct.

46 $\therefore$ Shunt resistance,

$$S = \frac{GI_g}{I - I_g} = \frac{100 \times 10}{100 - 10} = \frac{100}{9} = 11.11\ \Omega$$

47 Effective resistance of a circuit,



$$R_{\text{eff}} = 40.8 + \frac{480 \times 20}{480 + 20}$$

$$= 40.8 + 19.2 = 60\ \Omega$$

So, current flowing across ammeter,

$$I = \frac{V}{R} = \frac{30}{60} = \frac{1}{2} = 0.5\ \text{A}$$

Hence, reading of ammeter = 0.5 A

48 The full scale deflection current,

$$i_g = \frac{25\ \text{mV}}{G}\ \text{A}$$

where, G is the resistance of the meter.

The value of shunt required for converting it into ammeter of range 25 A is, $S = \dfrac{i_g G}{i - i_g}$

$$\Rightarrow \quad S = i_g \frac{G}{i} \qquad (\text{as } i >> i_g)$$

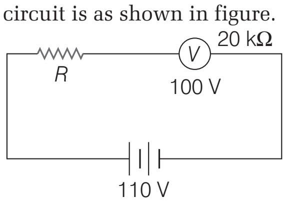
So that, $S \approx \dfrac{25\ \text{mV}}{G} \cdot \dfrac{G}{i} = \dfrac{25\ \text{mV}}{25}$

$$= 0.001\ \Omega$$

49 Potential, $V = I_g G \Rightarrow nV = I_g (G + R)$

On dividing, $R = (n - 1)G$

50 The circuit is as shown in figure.



Potential difference across voltmeter = 5R

∴ Current in the circuit

$$= \frac{5}{20 \times 10^3} = 0.25 \times 10^{-3}\ \text{A}$$

Voltage across R_1,

$$V_1 = 110 - 5 = 105\ \text{V}$$

Hence, $R = \dfrac{V_1}{I} = \dfrac{105}{0.25 \times 10^{-3}}$

$$= 420 \times 10^3 = 420\ \text{k}\Omega$$

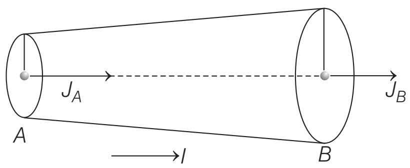
51 Required resistance to convert a galvanometer into voltmeter of 30 V is given by, $R = \dfrac{V}{i_g} - G$

Symbols have their usual meaning

$$= \frac{30}{30 \times 10^{-3}} - 100 = 900\ \Omega$$

SESSION 2

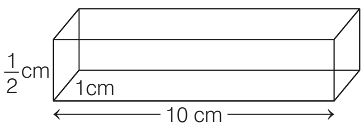
1 Given, $J_B = \dfrac{J_A}{2}$



i.e. $\quad I(\pi r_A^2) = I(\pi r_B^2)/2$

$$r_B = (r_A)\sqrt{2} = 0.5 \times 1.414 = 0.7\ \text{cm}$$

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



(a) When the battery is connected across 1 cm × 1/2 cm faces, then $l = 10$ cm; $A = 1 \times 1/2\ \text{cm}^2$,

$$R_1 = \frac{\rho \times 10}{1 \times 1/2} = 20\rho\Omega$$

(b) When the battery is connected across 10 cm × 1 cm faces, then $l = 1/2$ cm, $A = 10 \times 1\ \text{cm}^2$,

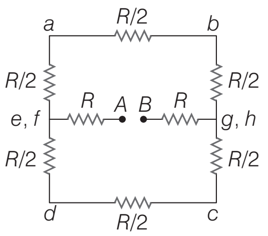
$$R_2 = \frac{\rho \times 1/2}{10 \times 1}$$

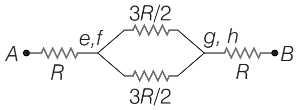
$$= \frac{\rho}{20}\Omega$$

(c) When the battery is connected across 10 cm × 1/2 cm faces, then $l = 1$ cm, $A = 10 \times 1/2\ \text{cm}^2$,

$$R_3 = \frac{\rho \times 1}{(10 \times 1/2)} = \frac{\rho}{5}\Omega$$

3 The figure can be redrawn as follows

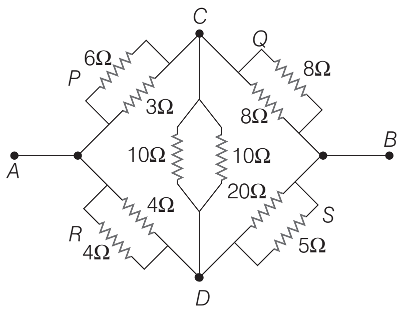


⇒ 

$$R_{AB} = R + \frac{3R}{4} + R$$

$$= \frac{11R}{4}$$

4 Figure is equivalent to the one shown below. It is a Wheatstone's bridge in which



$$P = \frac{6 \times 3}{6 + 3} = 2\ \Omega, Q = \frac{8}{2} = 4\ \Omega,$$

$$R = \frac{4}{2} = 2\ \Omega \text{ and } S = \frac{20 \times 5}{20 + 5} = 4\ \Omega$$

We find that $\dfrac{P}{Q} = \dfrac{2}{4} = \dfrac{R}{S}$

i.e. The bridge is balanced. Effective resistance between A and B is

$$R_{AB} = \frac{(P + Q)(R + S)}{P + Q + R + S} = \frac{(2 + 4)(2 + 4)}{2 + 4 + 2 + 4}$$

$$= \frac{6 \times 6}{12} = 3\ \Omega$$

5 Power, $Q = \dfrac{V^2}{R} t$ or $\dfrac{Q}{t} = P \propto \dfrac{1}{R}$

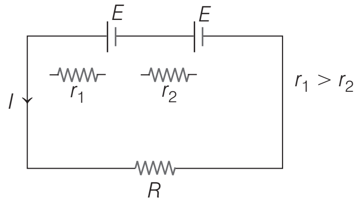
$$\Rightarrow \quad \frac{P_P}{P_Q} = \frac{R_Q}{R_P} > 1$$

$$\therefore \quad R_P < R_Q$$

6 Net resistance of the circuit

$= r_1 + r_2 + R$

Net emf in series = $E + E = 2E$



Therefore, from Ohm's law, current in the circuit,

$$I = \frac{\text{net emf}}{\text{net resistance}}$$

$$\Rightarrow \quad I = \frac{2E}{r_1 + r_2 + R} \qquad \ldots\text{(i)}$$

It is given that, as circuit is closed.

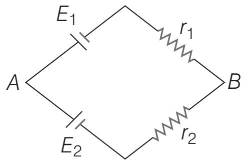
For first call, i.e. $E - Ir_1 = 0$

$$\Rightarrow \quad I = \frac{E}{r_1} \qquad \ldots\text{(ii)}$$

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

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

7 Refer figure the equivalent internal resistance of two cells between A and B is



$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{r_1 + r_2}{r_1 r_2}$$

or $\quad r_{eq} = \dfrac{r_1 r_2}{r_1 + r_2} \qquad$ ...(i)

If E_{eq} is the equivalent emf of the two cells in parallel between A and B, then

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

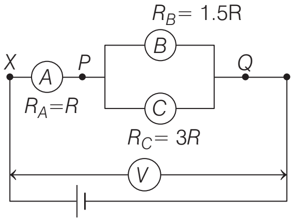
$$\therefore \quad E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 r_2} \times r_{eq}$$

$$= \frac{(E_1 r_2 + E_2 r_1)}{r_1 r_2} \times \frac{r_1 r_2}{(r_1 + r_2)}$$

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

This shows that whatever may be the values of r_1 and r_2, the value of E_{eq} is between E_1 and E_2. As $E_2 > E_1$, so $E_1 < E_{eq} < E_2$.

8 $\dfrac{1}{R'} = \dfrac{1}{R_B} + \dfrac{1}{R_C}$



$$\frac{1}{R'} = \frac{1}{1.5R} + \frac{1}{3R}$$

$$\frac{1}{R'} = \frac{2+1}{3R} \Rightarrow R' = R$$

$\therefore \quad V_{XP} = V_A = iR$

and $\quad V_{PQ} = V_B = V_C = iR$

$\qquad V_A = V_B = V_C$

9 If a rated voltage and power are given,

then $P_{rated} = \dfrac{V_{rated}^2}{R}$

$\therefore$ Current in the bulb,

$$i = \frac{P}{V} \qquad (\because P = Vi)$$

$$i = \frac{500}{100} = 5 \text{ A}$$

$\therefore$ Resistance of bulb,

$$R_b = \frac{100 \times 100}{500} = 20\ \Omega$$

$\because$ Resistance R is connected in series.

$\therefore \quad$ Current, $i = \dfrac{E}{R_{net}} = \dfrac{230}{R + R_b}$

$$\Rightarrow \quad R + 20 = \frac{230}{5} = 46$$

$$\therefore \quad R = 26\ \Omega$$

10 Initially, $\dfrac{5}{l_1} = \dfrac{R}{100 - l_1} \qquad$ ...(i)

Finally, $\dfrac{5}{1.6 l_1} = \dfrac{R}{2(100 - 1.6 l_1)} \qquad$ ...(ii)

$$\Rightarrow \quad \frac{R}{1.6\,(100 - l_1)} = \frac{R}{2(100 - 1.6 l_1)}$$

$$\Rightarrow \quad 160 - 1.6 l_1 = 200 - 3.2 l_1$$

$$\Rightarrow \quad 1.6 l_1 = 40 \Rightarrow l_1 = 25$$

From Eq. (i), we get $\dfrac{5}{25} = \dfrac{R}{75}$

$$\Rightarrow \quad R = 15\ \Omega$$

11 We know, $R \propto l$

Here, $\quad R_1 + R_2 = 12\ \Omega$

and $\quad \dfrac{R_1 \times R_2}{R_1 + R_2} = \dfrac{8}{3}\ \Omega$

$$\Rightarrow \quad R_1 R_2 = 32\ \Omega$$

We get, $R_1 = 8\ \Omega$ and $R_2 = 4\ \Omega$

Again, $\quad R_1 = \dfrac{12\, l_1}{l_1 + l_2}$

and $R_2 = \dfrac{12\, l_2}{l_1 - l_2}$

Hence, $\quad \dfrac{l_1}{l_2} = \dfrac{1}{2}.$

12 Mass, $m = ZIt \Rightarrow m = \dfrac{ZVt}{R}$

or $\quad m \propto Vt$

$$\therefore \quad \frac{m_1}{m_2} \propto \frac{V_1 t_1}{V_2 t_2}$$

Here, $m_1 = 2\text{g}, V_1 = 12$ V,

$\quad t_1 = 30$ min, $V_2 = 6$ V

and $\quad t_2 = 45$ min

$$\frac{2}{m_2} = \frac{12 \times 30}{6 \times 45}$$

$$\Rightarrow \quad m_2 = 1.5\text{ g}$$

The mass of copper deposited = 1.5 g.

13 Volume of material remains same in stretching.

As volume remains same, $A_1 l_1 = A_2 l_2$

Now, given $l_2 = n l_1$

$\therefore$ New area, $A_2 = \dfrac{A_1 l_1}{l_2} = \dfrac{A_1}{n}$

Resistance of wire after stretching,

$$R_2 = \rho \frac{l_2}{A_2} = \rho \cdot \frac{n l_1}{A_1 / n}$$

$$= \left(\rho \frac{l_1}{A_1}\right) \cdot n^2 = n^2 \cdot R$$

$$\left[\because R = \left(\rho \frac{l_1}{A_1}\right)\right]$$

14 According to question, emf of the cell is directly proportional to the balancing length i.e.

$$E \propto l \qquad \text{...(i)}$$

Now, in the first case, cells are connected in series to support one another i.e.

Net $\quad$ emf $= E_1 + E_2$

From Eq. (i), $E_1 + E_2 = 50$ cm (given) $\qquad$ ...(ii)

Again cells are connected in series in opposite direction i.e.

Net emf $= E_1 - E_2$

From Eq. (i), $E_1 - E_2 = 10 \qquad$ ...(iii)

From Eqs. (ii) and (iii)

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{50}{10}$$

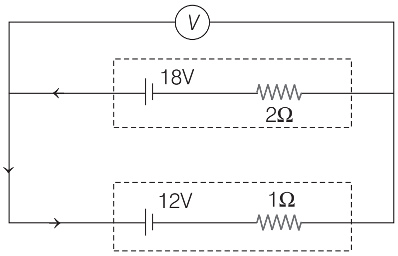
$$\Rightarrow \quad \frac{E_1}{E_2} = \frac{5+1}{5-1} = \frac{6}{4} = \frac{3}{2}$$

15 It is clear that the two cells oppose each other, hence the effective emf in closed circuit is 18 − 12 = 6 V and net resistance is 1 + 2 = 3 Ω (because in the closed circuit, the internal resistances of two cells are in series).

The current in circuit will be in direction of arrow shown in figure.

$$I = \frac{\text{effective emf}}{\text{total resistance}} = \frac{6}{3} = 2 \text{ A}$$

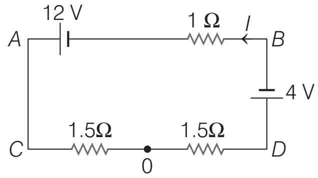
The potential difference across V will be same as the terminal voltage of either cell.



Since, current is drawn from the cell of 18 V, hence

$$V_1 = E_1 - I r_1$$
$$= 18 - (2 \times 2) = 18 - 4 = 14 \text{ V}$$

16 The given circuit in steady state reduces to



$$I = \frac{12 - 4}{4} = 2 \text{ A}$$

$$V_{CD} = 3 \times 2 = 6 \text{ V}$$

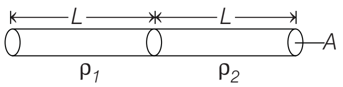
Now, change on 6 μF capacitor is

$$\frac{6\text{ V}}{\left(\frac{1}{3}+\frac{1}{6}\right)\frac{1}{\mu\text{F}}} = 12\ \mu\text{C}$$

Potential difference across 6 μF capacitor is

$$\frac{12\ \mu\text{C}}{6\ \mu\text{F}} = 2\text{ V}$$

17 Net resistance of a metal wire having resistivity ρ, we have



$$R_1 = \rho_1 \frac{L}{A}$$

Similarly, $R_2 = \rho_2 \frac{L}{A}$

Then, net effective resistance of two metal wires,

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

$$\Rightarrow \rho\frac{2L}{A} = \rho_1 \frac{L}{A} + \rho_2 \frac{L}{A}$$

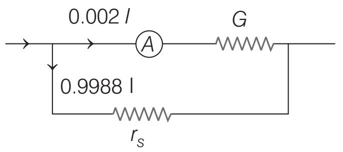
$$\Rightarrow 2\rho = \rho_1 + \rho_2$$

As, conductivity $\sigma = \frac{1}{\rho}$, we have

$$\frac{2}{\sigma} = \frac{1}{\sigma_1} + \frac{1}{\sigma_2} \Rightarrow \frac{2}{\sigma} = \frac{\sigma_1 + \sigma_2}{\sigma_1 \sigma_2}$$

⇒ Net effective conductivity of combined wires, $\sigma = \frac{2\sigma_1\sigma_2}{\sigma_1 + \sigma_2}$

18 For ammeter,



$$0.002I \times G = 0.998I \times r_s$$

$$r_s = \frac{0.002}{0.998} G$$

$$\Rightarrow r_s = 0.002004G = \frac{1}{499} \times G$$

Equivalent resistance of ammeter,

$$\frac{1}{R} = \frac{1}{G} + \frac{1}{r_s}$$

$$\therefore \frac{1}{R} = \frac{1}{G} + \frac{1}{G/499} \Rightarrow R = \frac{G}{500}$$

19 The balancing length for R (when 1, 2 are connected) be l_1 and balancing length for $R + X$ (when 1, 3 is connected) is l_2.

Then, $iR = kl_1$ and $i\,(R + X) = kl_2$

Given, $i = 1\text{A}$

$\therefore$ $R = kl_1$ ...(i)

$R + X = kl_2$ ...(ii)

Also, subtracting Eq. (i) from Eq. (ii), we get $X = k(l_2 - l_1)$

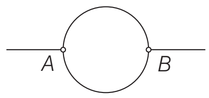
20 According to Ohm's law

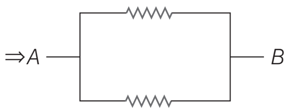
$$\frac{dV}{dI} = -r \text{ and } V = \varepsilon$$

if $I = 0$ [as $V + Ir = \varepsilon$]

So, slope of the graph $= -r$ and intercept $= \varepsilon$

21





Circumference of circle

$$= 2\pi r = 2 \times \pi \times \frac{10}{100} = \frac{2\pi}{10} = \frac{\pi}{5}$$

Resistance of wire $= 12 \times \frac{\pi}{5} = \frac{12\pi}{5}$

Resistance of each section $= \frac{12\pi}{10}\ \Omega$

∴ Equivalent resistance

$$= \frac{\frac{12\pi}{10} \times \frac{12\pi}{10}}{\frac{12\pi}{10} + \frac{12\pi}{10}} = \frac{6\pi}{10} = 0.6\ \pi\ \Omega$$

22 Given, charge, $Q = at - bt^2$ ...(i)

∵ We know that, current, $I = \frac{dQ}{dt}$

So, Eq. (i) can be written as

$$I = \frac{d}{dt}(at - bt^2) \Rightarrow I = a - 2bt \quad \text{...(ii)}$$

For maximum value of t, till the current exist is given by $\Rightarrow a - 2bt = 0$

$$\therefore \quad t = \frac{a}{2b} \quad \text{...(iii)}$$

∵ The total heat produced (H) can be given as

$$H = \int_0^t I^2 R\, dt$$

$$= \int_0^{a/2b} (a - 2bt)^2\, R \cdot dt \quad \left(\because t = \frac{a}{2b}\right)$$

$$= \int_0^{a/2b} (a^2 + 4b^2t^2 - 4abt)\, Rdt$$

$$H = \left[a^2 t + 4b^2 \frac{t^3}{3} - \frac{4abt^2}{2}\right]_0^{a/2b} R$$

Solving above equation, we get

$$\Rightarrow \quad H = \frac{a^3 R}{6b}$$

23 Mass of the substance deposited at the cathode is given by $m = Zit$

(Z = electrochemical equivalent)

$$= Z\left(\frac{W}{V}\right) t$$

$$= 0.367 \times 10^{-6} \times \frac{100 \times 10^3}{125} \times 60$$

$$= 17.61 \times 10^{-3}\ \text{kg}$$

24 When n equal resistors of resistance R are connected in series, then the current drawn is given as

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

where, nR = equivalent resistance of n resistors in series and r = internal resistance of battery.

Given, $r = R$

$$\Rightarrow \quad I = \frac{E}{nR + R} = \frac{E}{R(n+1)} \quad \text{...(i)}$$

Similarly, when n equal resistors are connected in parallel, then the current drawn is given as

$$I' = \frac{E}{\frac{R}{n} + R}$$

where, $\frac{R}{n}$ = equivalent resistance of n resistors in parallel.

Given, $I' = 10I$

$$\Rightarrow 10I = \frac{E}{\frac{R}{n} + R} = \frac{nE}{(n+1)R} \quad \text{...(ii)}$$

Substituting the value of I from Eq. (i) in Eq. (ii), we get

$$10\left(\frac{E}{R(n+1)}\right) = \frac{nE}{R(n+1)}$$

$$\Rightarrow \quad n = 10$$

25 If n identical cells are connected in series, then

Equivalent emf of the combination,

$$E_{eq} = nE$$

Equivalent internal resistance,

$$r_{eq} = nr$$

$$\therefore \text{ Current, } I = \frac{E_{eq}}{r_{eq}} = \frac{nE}{nr}$$

$$\text{or} \quad I = \frac{E}{r} = \text{constant}$$

Thus, current (I) is independent of the number of cells (n) present in the circuit.

Therefore, the graph showing the relationship between I and n would be as shown below.