2

CURRENT ELECTRICITY

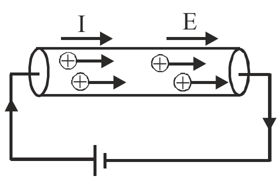
ELECTRIC CURRENT

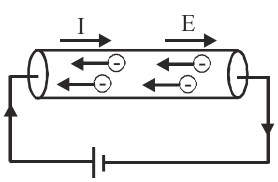
The time rate of flow of charge through any cross-section is called current. If Δq charge passes through a cross-section in time Δt then average current $I_{av} = \frac{\Delta q}{\Delta t}$

and instantaneous current $I = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt}$

Ampere : The current through a conductor is said to be one ampere if one coulomb of charge is flowing per second through a cross-section of wire.

The conventional direction of current is the direction of flow of positive charge or applied field. It is opposite to direction of flow of negatively charged electrons.





If n electrons pass through a point in a conductor in time t then current through the conductor is $I = \frac{q}{t} = \frac{ne}{t}$

Number of electrons flowing through conductor in t second is $n = \frac{I \times t}{e}$

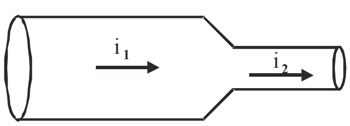
For 1 ampere of current

$$n = \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18} \text{ electrons/second}$$

Note :

(i) The conductor remains uncharged when current flows through it because the charge entering at one end per second is equal to charge leaving the other end per second.

(ii) For a given conductor current does not change with change in its cross-section because current is simply rate of flow of charge.



$i_1 = i_2$

(iii) If a charge q is moving in a circle of radius r with speed v then its time period is $T = 2\pi r/v$. The equivalent current

$$I = \frac{q}{T} = \frac{qv}{2\pi r}.$$

Current density : This is defined as current flowing per unit area held normal to direction of flow of current.

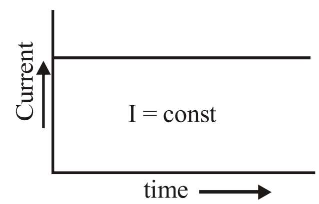
current density $J = \frac{I}{A} = \frac{nq}{At}$ and current $I = \int \vec{J} \cdot \vec{da}$

The direction of current density $\vec{J}$ is same as that of electric field $\vec{E}$. J is a vector with unit amp/m^2 and dimension
$M^0 L^{-2} T^0 A^1$.

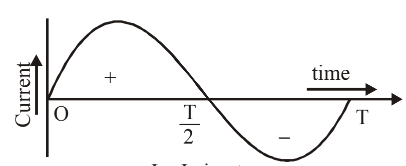
If there are n particles per unit volume each having a charge q and moving with velocity v then current through cross-sectional area A is $I = \frac{\Delta q}{\Delta t} = nqvA$

TYPES OF CURRENT

(a) **Direct Current :** The current whose magnitude and direction does not vary with time is called direct current (dc). The various sources are cells, battery, dc dynamo etc.



(b) **Alternating Current :** The current whose magnitude continuously changes with time and periodically changes its direction is called alternating current. It has constant amplitude and has alternate positive and negative halves. It is produced by ac dynamo.



$I = I_0 \sin\omega t$

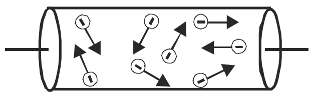
CONDUCTORS

Conductors are substances through which electric charges can flow easily. They are characterised by presence of a large number of free electrons (10^{29} electrons per m^3). The number density of free electrons in a conductor is same throughout the conductor. This is because free electrons experience repulsive force between them and conductor allows movement of free electrons. Thus, free electrons are evenly scattered throughout the volume of conductor.

These free electrons transport electric charge so are called as conduction electrons.

(a) Behaviour of conductor in absence of applied potential difference :

(i) The free electrons present in a conductor gain energy from temperature of surrounding and move randomly in a conductor.



(ii) The speed gained by virtue of temperature is called as thermal speed of an electron.

$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT$ so thermal speed

$v_{rms} = \sqrt{\frac{3kT}{m}}$ where m is mass of electron

At room temperature T = 300 K ; $v_{rms} = 10^5$ m/sec.

(iii) The average distance travelled by a free electron between two consecutive collisions is called as mean free path λ. ($\lambda \sim 10$ Å)

Mean free path $\lambda = \frac{\text{total distance travelled}}{\text{number of collisions}}$

(iv) The time taken by an electron between two successive collisions is called as relaxation time τ. ($\tau \sim 10^{-14}$ s)

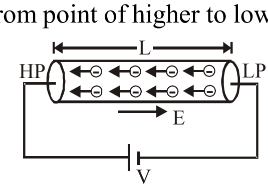
relaxation time $\tau = \frac{\text{total time taken}}{\text{number of collisions}}$

(v) The thermal speed can be written as $v_T = \frac{\lambda}{\tau}$

(vi) In absence of applied potential difference electrons have random motion. The average displacement and average velocity is zero. There is no flow of current due to thermal motion of free electrons in a conductor.

(b) Behaviour of conductor in presence of applied potential difference :

(i) When two ends of a conductors are joined to a battery then one end is at higher potential and another at lower potential. This produces an electric field inside the conductor from point of higher to lower potential i.e. $E = \frac{V}{L}$.



(ii) The field exerts an electric force on free electrons causing acceleration of each electron.

$\vec{F} = m\vec{a} = -e\vec{E}$ so acceleration $\vec{a} = \frac{-e\vec{E}}{m}$

(iii) The average velocity with which the free electrons are drifted towards the positive end of a conductor under the influence of an external electric field is called drift velocity v_d. Using $\vec{v} = \vec{u} + \vec{a}t$

we have, $\vec{v}_d = \frac{-e\vec{E}}{m}\tau$ ($v_d \sim 10^{-4}$ m/sec)

(iv) The direction of drift velocity for electrons in a metal is opposite to that of applied field E.

(v) Relation between current and drift velocity :

Let n be number density of free electrons and A be area of cross-section of conductor.

Number of free electrons in conductor of length L = nAL

Total charge on these free electrons $\Delta q = neAL$

Time taken by drifting electrons to cross conductor $\Delta t = L/v_d$

$\therefore$ Current $I = \frac{\Delta q}{\Delta t} = neAL\frac{v_d}{L} = neAv_d$

or $\mathbf{I = neAv_d}$.

The current flowing through a conductor is directly proportional to the drift velocity ($I \propto v_d$)

(vi) The current density

$$J = \frac{I}{A} = nev_d = ne\left(\frac{eE}{m}\right)\tau = \left(\frac{ne^2\tau}{m}\right)E$$

so $J \propto E$ or $J = \sigma E$

where $\sigma = \frac{ne^2\tau}{m}$ is specific conductivity of conductor which depends on temperature and nature of material.

$\vec{J} = \sigma\vec{E}$ **is microscopic form of Ohm's law.**

(vii) The drift velocity depends on nature of metal through τ, applied potential difference, length of conductor.

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

v_d is independent of radius or area of cross-section of a conductor.

(viii) The rise of temperature causes increase in v_{rms} and hence a decrease in λ and relaxation time τ causing a decrease in drift velocity.

(ix) Mobility of a charge carrier is defined as drift velocity acquired per unit electric field.

Mobility $\mu = \frac{v_d}{E} = \frac{e\tau}{m} = \frac{e}{m}\frac{m\sigma}{ne^2} = \frac{\sigma}{ne}$

The unit is $m^2 V^{-1} s^{-1}$ and dimensions are $M^{-1} T^2 A^1$

The mobility depends on applied potential difference, length of conductor, number density of charge carriers, current in conductor, area of cross-section of conductor.

Example 1 :

Though the drift velocity for electrons is small, an electric bulb lights up immediately as we turn the switch on. Why?

Sol. When switch is made on the electric field $\vec{E}$ responsible for setting up current propagates through wires at speed of light 3×10^8 m/s. So field is set up immediately in time L/c

(L = length , c = speed of light) causing electrons to drift and hence bulb lights up immediately.

Example 2 :

The magnitude J of the current density in a certain lab wire with a circular cross-section of radius R = 2.00mm is given by $J = (3.00 \times 10^8)\, r^2$, with J in amperes per square meter and radial distance r in meters. What is the current through the outer section bounded by r = 0.900 R and r = R ?

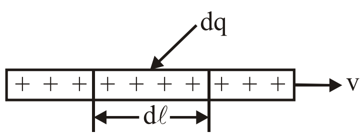
Sol. Assuming J is directed along the wire (with no radial flow) we integrate, starting

$$i = \int |\vec{J}|\, dA = \int_{9R/10}^{R} (kr^2)\, 2\pi r\, dr = \frac{1}{2} k\pi \left(R^4 - 0.656R^4\right)$$

where $k = 3.0 \times 10^8$ and SI units are understood. Therefore if R = 0.00200m. We obtain $i = 2.59 \times 10^{-3}$ A.

Example 3 :

Find the current associated with a moving straight wire of linear charge density $\lambda = 2\mu$ C/m and of cross-section $A = 2\text{mm}^2$, when the wire is pulled with a speed v = 2 m/s.



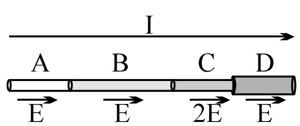
Sol. Let dq (= $\lambda\, d\ell$) passes through a given vertical plane in time dt. Then, $i = \frac{dq}{dt} = \frac{\lambda d\ell}{dt} = \ell v = 2 \times 10^{-3} \times 2 = 4$ mA

TRY IT YOURSELF - 1

Q.1 A hollow conducting sphere of inner radius R and outer radius 2R has resistivity 'ρ' a function of the distance 'r' from the centre of the sphere: $\rho = kr^2/R$. The inner and outer surfaces are painted with a perfectly conducting 'paint' and a potential difference ΔV is applied between the two surfaces. Then, as 'r' increases from R to 2R, the electric field inside the sphere

(A) increases (B) decreases
(C) remains constant (D) passes through a maxima

Q.2 Four wires A, B, C and D are made of different materials. They each carry the same current I. Wire B has twice the length of other wires. Wire C has twice the internal electric field of other wires. Wire D has twice the diameter of other wires. Other than these differences, all wires share identical characteristics. Rank the conductivities of these materials, from greatest to least.



(A) $\sigma_A = \sigma_B > \sigma_C > \sigma_D$ (B) $\sigma_A = \sigma_B = \sigma_C = \sigma_D$
(C) $\sigma_A = \sigma_B < \sigma_C = \sigma_D$ (D) $\sigma_A = \sigma_B > \sigma_C = \sigma_D$

Q.3 In which material do the conduction electrons have the largest mean time between collisions?

(A) Copper (B) Aluminium
(C) Nichrome (D) Tungsten

FOR Q.4.-Q.6

A small insect crawls in the direction of electron drift along bare copper wire that carries a current of 2.56 A. It travels with the drift speed of the electron in the wire of uniform cross section area 1mm^2. Number of free electrons for copper = 8×10^{22}/cc & resistivity of copper = $1.6 \times 10^{-8}\ \Omega$m.

Q 4 How much time would the caterpillar take to crawl 1.0 cm if it crawls at the drift speed of the electrons in the wire?

(A) 50 sec. (B) 5 sec.
(C) 5000 sec. (D) None of these

Q 5 What is order of the average time of collision for free electrons of copper?

(A) 10^{-13} sec. (B) 10^{-15} sec.
(C) 10^{-11} sec. (D) 10^{-8} sec.

Q 6 If the caterpillar starts from the point of zero potential at t = 0, it reaches a point of ______ potential after 10 sec.

(A) 80 μV (B) – 80 μV
(C) 160 μV (D) – 160 μV

Q.7 Copper contains 8.4×10^{28} free electrons/m^3. A copper wire of cross-sectional area 7.4×10^{-7} m^2 carries a current of 1 A. The electron drift speed is approximately:

(A) 3×10^8 m/s (B) 10^3 m/s
(C) 1m/s (D) 10^{-4} m/s

ANSWERS

(1) (C)	**(2)** (A)	**(3)** (A)
(4) (A)	**(5)** (A)	**(6)** (A)
(7) (D)		

RESISTANCE AND OHM'S LAW

The property of a substance due to which it opposes the flow of current through it is called resistance. It is a scalar quantity with unit volt/ampere called ohm (Ω) dimensions

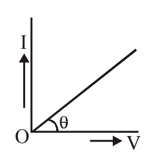
of $R = \frac{V}{I} = \frac{W}{qI} = \frac{M^1L^2T^{-2}}{ATA} = M^1L^2T^{-3}A^{-2}$

The reciprocal of resistance is called conductance $G = \frac{1}{R}$.

The SI unit is ohm^{-1} or mho or siemen (s) and its dimensions are $M^{-1}\, L^{-2}\, T^3\, A^2$.

The substances which obey ohm's law are called ohmic or linear conductor. The resistance of such conductors is independent of magnitude and polarity of applied potential difference. Here the graph between I and V is a straight line passing through the origin. The reciprocal of slope of straight line gives resistance

$$R = \frac{V}{I} = \frac{1}{\tan\theta} = \text{constant.}$$



e.g. silver, copper, mercury, carbon, mica etc.

The substances which do not obey ohm's law are called nonohmic or non linear conductors. The I–V curve is not a straight line. i.e. p n diode, transistors, thermionic valves, rectifiers etc.

Resistivity : In terms of microscopic quantities $E = \rho J$ so resistivity is numerically equal to ratio of magnitude of electric field to current density.

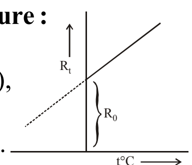
$\rho = \frac{RA}{L}$ so if $L = 1$ m, $A = 1\ m^2$ then $\rho = R$. Specific resistivity is numerically equal to resistance of substance having unit area of cross-section and unit length. It is a scalar with unit ohm-meter (Ω-m) and dimensions $M^1L^3T^{-3}A^{-2}$. The reciprocal of resistivity is called conductivity or specific conductance with units mho/m and dimensions

$M^{-1}\ L^{-3}\ T^3\ A^2$. $\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m} = ne\mu$

The resistivity is independent of shape and size of body and depends on nature of material of body. The resistivity is the property of material while resistance is property of object.

Dependence of resistance on temperature :

The temperatue dependence of resistance is given by $R = R_0(1 + \alpha\,\Delta\theta)$, where α is temperature coefficient of resistance & Δθ is change in temperature. The variation is graphically represented as.



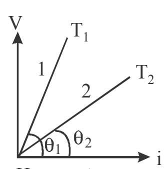
The temperature coefficient of resistance $\alpha = \frac{R - R_0}{R_0\Delta\theta}$ is defined as change in resistance per unit resistance at 0°C per degree rise of temperature.

For maximum metals $\alpha = \frac{1}{273}$ per °C

so, $R = R_0\left(1+\frac{\Delta\theta}{273}\right) = R_0\left(\frac{273+\Delta\theta}{273}\right) = R_0\frac{T}{273}$

So $R \propto T$ i.e. The resistance of pure metallic conductor is proportional to its absolute temperature.

At different temperature V-i curves are different.



Here $\tan\theta_1 > \tan\theta_2$
So $R_1 > R_2$
i.e., $T_1 > T_2$

Dependency of α on temperature :

If at temperature T_0 temperature coefficient of resistance is α_0 and at T_1 its α_1 then resistance R_0, R_1, R_2 at T_0, T_1, T_2 can be written as : $R_1 = R_0[1 + \alpha_0(T_1 - T_0)]$

$R_2 = R_0[1 + \alpha_0(T_2 - T_0)]$

$R_2 = R_1[1 + \alpha_1(T_2 - T_1)]$

Solving, $R_2 - R_1 = R_0\alpha_0(T_2 - T_1)$, and

$R_2 - R_1 = R_1\alpha_1(T_2 - T_1)$

So, $R_1\alpha_1 = R_0\alpha_0$ and $\alpha_1 = \frac{\alpha_0}{1+\alpha_0(T_1 - T_0)}$

Note :

(i) $R \propto L$ and $R \propto \frac{1}{A}$ so $R \propto \frac{L}{A}$ or $R = \rho\frac{L}{A}$

where ρ is called resistivity or specific resistance.

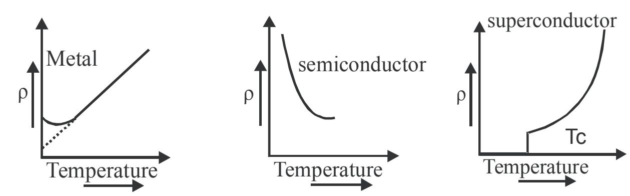
(ii) The fractional change in resistance without change in volume or mass are :

(a) When change in length is small (≤ 5%) fractional change in R is $\frac{\Delta R}{R} = \frac{2\Delta L}{L}$

(b) When change in radius is small (≤ 5%) fractional change in R is $\frac{\Delta R}{R} = \frac{-4\Delta r}{r}$

(c) When change in area is small (≤ 5%) fractional change in R is $\frac{\Delta R}{R} = \frac{-2\Delta A}{A}$

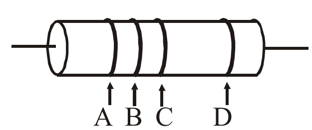
(iii) The temperature dependence of resistivity is given by relation $\rho = \rho_0(1 + \propto \Delta\theta)$ where ∝ is temperature coefficient of resistivity and Δθ is change is temperature. For metals ∝ is positive so resistivity increases with temperature while for non-metals ∝ is negative so resistivity decreases with temperature.



Colour code for carbon resistors :

Colour	Strip A	Strip B	Strip C	Strip D
Black	0	0	10^0	Tolerance
Brown	1	1	10^1	
Red	2	2	10^2	
Orange	3	3	10^3	
Yellow	4	4	10^4	
Green	5	5	10^5	
Blue	6	6	10^6	
Violet	7	7	10^7	
Grey	8	8	10^8	
White	9	9	10^9	
Gold	–	–	10^{-1}	± 5%
Silver	–	–	10^{-2}	± 10%
No colour	–	–	–	± 20%

Aid to memory BBROY Great Britain Very Good Wife.



The first two rings give first two significant figures of resistance. The third ring indicates the decimal multiplier i.e. the number of zeroes that will follow the two significant figures. The fourth ring shows tolerance or percentage accuracy.

Ohm's Law : If the physical state i.e. temperature, nature of material and dimensions of a conductor remain unchanged then the ratio of potential difference applied across its ends to current flowing through it remains constant.

$V \propto I$ or $V = IR$, where $R = \dfrac{V}{I}$ is resistance of conductor.

$$I = neAv_d = neA\frac{eE}{m}\tau = \left(\frac{ne^2\tau}{m}\right)AE = \left(\frac{ne^2\tau}{m}\right)A\frac{V}{L}$$

So $R = \dfrac{V}{I} = \left(\dfrac{m}{ne^2\tau}\right)\dfrac{L}{A}$

R is resistance of conductor.

Note :

(i) $V = IR$ defines resistance and hence it is applicable to all ohmic and nonohmic conductors. If R is constant or $V \propto I$ then it represents ohm's law.

(ii) The relation $R = \dfrac{V}{I}$ is macroscopic form while $\rho = \dfrac{E}{J}$ is microscopic form of ohms law.

Limitation of Ohm's law

Although Ohm's law has been found valid over a large class of materials, there do exist materials and devices used in electric circuits where the proportionality of V and I does not hold. The deviations broadly are one or more of the following types:

(a) V ceases to be proportional to I (Fig. a).

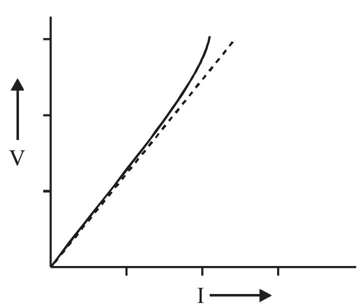


Figure (a) : The dashed line represents the linear Ohm's law. The solid line is the voltage V versus current I for a good conductor.

(b) The relation between V and I depends on the sign of V. In other words, if I is the current for a certain V, then reversing the direction of V keeping its magnitude fixed, does not produce a current of the same magnitude as I in the opposite direction (Fig. b). This happens, for example, in a diode.

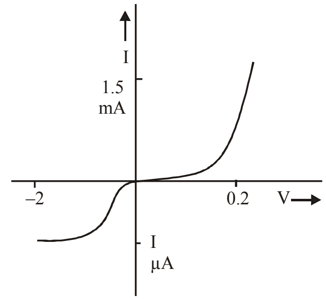


Figure (b) : Characteristic curve of a diode. Note the different scales for negative and positive values of the voltage and current.

(c) The relation between V and I is not unique, i.e., there is more than one value of V for the same current I (Fig. c). A material exhibiting such behaviour is GaAs.

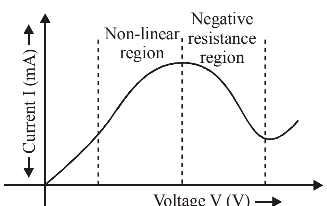
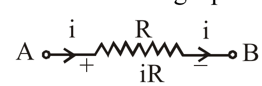


Figure (c) : Variation of current versus voltage for GaAs

Materials and devices not obeying Ohm's law in the form of $V = RI$, are actually widely used in electronic circuits.

ELECTRIC CURRENT IN RESISTANCE

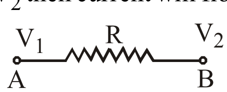
In a resistor current flows from high potential to low potential.



High potential is represented by positive (+) sign and low potential is represented by negative (–) sign.

$V_A - V_B = iR$

If $V_1 > V_2$ then current will flow from A to B



and $i = \dfrac{V_1 - V_2}{R}$

If $V_1 < V_2$ then current will flow from B to A

and $i = \dfrac{V_2 - V_1}{R}$

Example 4 :

Discuss the effect on the resistance R of wire when mass is kept constant and (a) length is increased n times (b) radius is increased n times (c) cross-sectional area is increased n times.

Sol. (a) $R = \dfrac{\rho L}{A} = \dfrac{\rho L}{A}\dfrac{xL}{xL} = \dfrac{\rho L^2}{V} = \dfrac{\rho L^2 d}{m}$

where d is density, m is mass and V is volume of wire. When length is increased n times the new resistance

$$R' = \frac{\rho(nL)^2 d}{m} \quad \therefore \frac{R'}{R} = \frac{(nL)^2}{L^2} = n^2 \quad \text{so } R' = n^2 R$$

(b) $R = \frac{\rho L}{A} = \frac{\rho L \times A}{A \times A} = \frac{\rho V}{A^2} = \frac{\rho m}{d\pi^2 r^4}$.

When radius is increased n times new resistance

$$R' = \frac{\rho m}{d\pi^2 (nr)^4} \quad \text{so} \quad \frac{R'}{R} = \frac{r^4}{(nr)^4} \quad \text{or} \quad R' = \frac{R}{n^4}$$

(c) $R = \frac{\rho L}{A} = \frac{\rho L \times A}{A \times A} = \frac{\rho V}{A^2} = \frac{\rho m}{dA^2}$

When area is increased n times new resistance

$$R' = \frac{\rho m}{d(nA)^2} \quad \text{so} \quad \frac{R'}{R} = \frac{A^2}{(nA)^2} \quad \text{or} \quad R' = \frac{R}{n^2}$$

Example 5 :

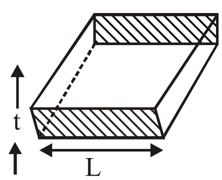
Consider a thin square sheet of side L and thickness t, made of a material of resistivity ρ. The resistance between two opposite faces, shown by the shaded areas in the figure is –

(A) directly proportional to L

(B) directly proportional to t

(C) independent of L

(D) independent of t



Sol. (C). $R = \frac{\rho L}{A}$; $R = \frac{\rho L}{tL} = \frac{\rho}{t}$

Independent of L.

Example 6 :

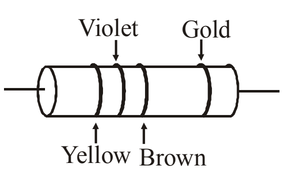
Draw a colour code for 42 k Ω ± 10% carbon resistance.

Sol. According to colour code colour for digit 4 is yellow, for digit 2 it is red, for 3 colour is orange and 10% tolerance is represented by silver colour.

So colour code should be yellow, red, orange and silver.

Example 7 :

What is resistance of following resistor.



Sol. Number for yellow is 4, Number of violet is 7

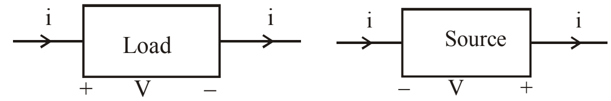
Brown colour gives multiplier 10^1, Gold gives a tolerance of ± 5%. So resistance of resistor is $47 \times 10^1\ \Omega \pm 5\%$

or $470 \pm 5\%\ \Omega$.

ELECTRICAL POWER

Energy liberated per second in a device is called its power. The electrical power P delivered or consumed by an electrical device is given by P = VI, where V = Potential difference across the device and I = current.

If the current enters the higher potential point of the device then the electric power is consumed by it (i.e. acts as load). If the current enters the lower potential point then the device supplies power (i.e. acts as source)



$$\text{Power} = \frac{V.dq}{dt} = VI \quad ; \; P = VI$$

If power is constant then energy = Pt

If power is variable then energy = $\int P\, dt$

Power consumed by a resistor, $P = I^2R = VI = \frac{V^2}{R}$

When a current is passed through a resistor energy is wasted in overcoming the resistance of the wire.

This energy is converted into heat.

$$W = VIt = I^2Rt = \frac{V^2}{R}t$$

The heat generated (in joules) when a current of I ampere flows through a resistance of R ohm for T second is given

by : $H = I^2RT \text{ Joule} = \frac{I^2RT}{4.2} \text{ Calorie}$

1 unit of electrical energy = 1 Kilowatt hour

= 1 KWh = 3.6×10^6 Joule

SOURCES OF EMF

Electrochemical Cell : An electrochemical cell is a device which by converting chemical energy into electrical energy maintains the flow of charge in a circuit. It usually consists of two electrode of different materials and an electrolyte. The electrode at higher potential is called anode and the one at lower potential is cathode.

Electromotive Force (EMF) : The emf of a cell is defined as work done by cell in moving a unit positive charge in the whole circuit including the cell once.

(1) emf E = W/q; SI unit is joule/coulomb or volt.

(2) emf is the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell.

(3) emf is the characteristic property of cell and depends on the nature of electrodes and electrolyte used in cell.

(4) emf is independent of quantity of electrolyte, size of electrodes and distance between the electrodes.

Internal Resistance of Cell : The opposition offered by the electrolyte of the cell to the flow of electric current through it is called the internal resistance of the cell. The internal resistance of cell depends on.

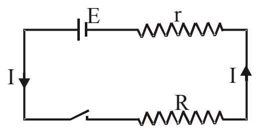
(1) Distance between electrodes (r ∝ d) larger is the separation between electrodes more is the length of electrolyte through which ions have to move so more is internal resistance.

(2) Conductivity or nature of electrolyte ($r \propto 1/\sigma$)

(3) Concentration of electrolyte ($r \propto c$)
(4) Temperature of electrolyte ($r \propto 1/T$)
(5) Nature and area of electrodes dipped in electrolyte ($r \propto 1/A$)

Terminal Potential Difference : The potential difference between the two electrodes of a cell in a closed circuit i.e. when current is being drawn from the cell is called terminal potential difference.

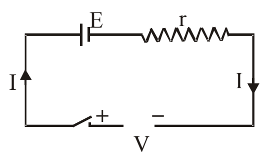
(a) When cell is discharging : When cell is discharging current inside the cell is from cathode to anode.



Current $I = \dfrac{E}{r+R}$ or $E = IR + Ir = V + Ir$ or $V = E - Ir$

When current is drawn from the cell potential difference is less than emf of cell. Greater is the current drawn from the cell smaller is the terminal voltage. When a large current is drawn from a cell its terminal voltage is reduced.

(b) When cell is charging : When cells is charging current inside the cell is from anode to cathode.



Current $I = \dfrac{V-E}{r}$ or $V = E + Ir$

During charging terminal potential difference is greater than emf of cell.

(c) When cell is in open circuit :

In open circuit $R = \infty$ $\quad \therefore\ I = \dfrac{E}{R+r} = 0$ $\quad$ So $V = E$

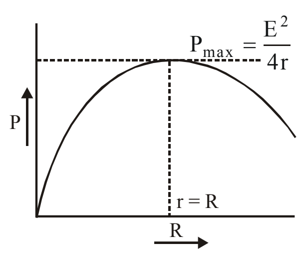
In open circuit terminal potential difference is equal to emf and is the maximum potential difference which a cell can provide.

(d) When cell is short circuited :

In short circuit $R = 0$, so $I = \dfrac{E}{R+r} = \dfrac{E}{r}$ and $V = IR = 0$

In short circuit current from cell is maximum and terminal potential difference is zero.

(e) Power transferred to load by cell :



$$P = I^2R = \frac{E^2R}{(r+R)^2}$$

so $P = P_{max}$ if $\dfrac{dP}{dR} = 0$

$P = P_{max}$ if $r = R$

Power transferred by cell to load is maximum when r = R

and $P_{max} = \dfrac{E^2}{4r} = \dfrac{E^2}{4R}$

Note :

1. The current inside a cell is due to motion of both positive and negative ions while outside it depends on nature of circuit elements like conductors, semiconductor, gas or electrolyte.

2. The cell is a source of constant emf and not of constant current because if resistance of circuit changes then current $I = E/r + R$ also changes but emf remains constant.

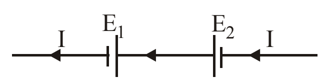
3. As $I = E/r$ so more current can be drawn from a cell with larger emf and smaller internal resistance. e.g. In lead acid accumulator $E = 2.05$ V and $r_{min} = 0.1\Omega$.

4. With use of cell its internal resistance increases appreciably but emf fall slightly. The current delivering ability is reduced.

5. A cell neither creates nor destroys charge but maintains the flow of charge by providing required energy.

6. The emf of cell is taken to be positive in a circuit if current inside a cell is from negative to positive i.e. during discharging otherwise negative.

$E = E_1 + E_2$



$E = E_2 - E_1$

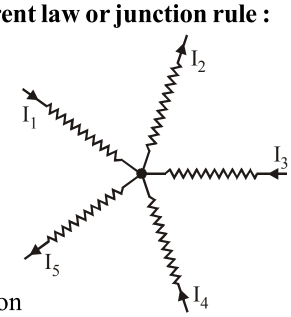
$E = E_1 - E_2$

7. Capacity of a battery is equal to product of current in ampere and time in hour for which a cell can operate. It depends on the amount of electrolyte and so an size of cell. e.g. capacity 8Ah means we can draw 8A current for one hour or 2A current for 4 hours.

KIRCHHOFF'S LAW

(a) Kirchhoff's first law or current law or junction rule :

In any electrical network, the algebraic sum of currents meeting at a junction is always zero i.e. $\Sigma I = 0$



$I_1 - I_2 + I_3 + I_4 - I_5 = 0$

or $I_1 + I_3 + I_4 = I_2 + I_5$

(i) The sum of currents flowing towards a junction is equal to sum of currents leaving the junction.

(ii) By convention the current directed towards the junction is positive while those directed away from the junction is taken as negative.

(iii) The first law is in accordance with conservation of charge.

(iv) The charges do not accumulate at a junction. The total charge entering a junction is equal to total charge leaving the junction.

(b) Kirchhoff's second law or voltage law or loop rule :

The algebraic sum of all the potential drops and emf's along any closed path in a network is zero. i.e. $\Sigma V = 0$

(i) The second law is in accordance with conservation of energy.

(ii) According to second law the electric energy given to the charge by a source of emf is lost in passing through resistance.

(iii) The change in potential in covering a resistance in the direction of current is negative (–IR) while in opposite direction it is positive.

$V_A - IR = V_B$ $\quad$ $V_B + IR = V_A$

$V_B - V_A = IR$ $\quad$ $V_A - V_B = IR$

The potential falls along direction of current. The potential fall is taken as negative while potential rise is taken as positive.

(iv) The emf of source is taken as positive when it is traversed from negative to positive terminal while it is taken as negative when it is traversed from positive to negative irrespective of the direction of current.

$V_A - E = V_B$ $\quad$ $V_B + E = V_A$

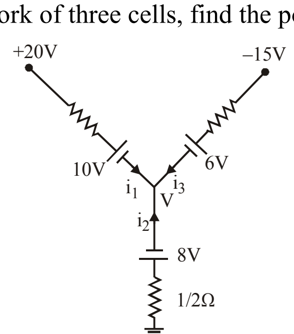
$V_B - V_A = -E$ $\quad$ $V_A - V_B = E$

(v) If there are n loops their will be (n – 1) equations according to loop rule.

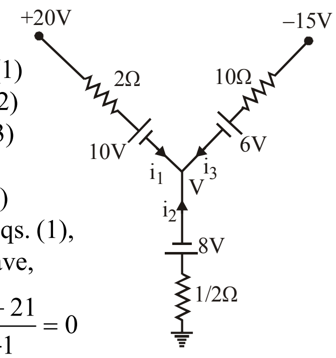
(vi) The algebraic sum of products of currents and resistances in a closed loop is equal to sum of emf's applied in the circuit i.e. $\Sigma E = \Sigma IR$

Example 8 :

In the network of three cells, find the potential V of their function.



Sol. Applying KCL for the individual branches.



$20 - i_1(2) + 10 = V$ ...... (1)

$0 - i_2(1/2) - 8 = V$ ...... (2)

$-15 - i_3(1) - 6 = V$ ...... (3)

$i_1 + i_2 + i_3 = 0$ ...... (4)

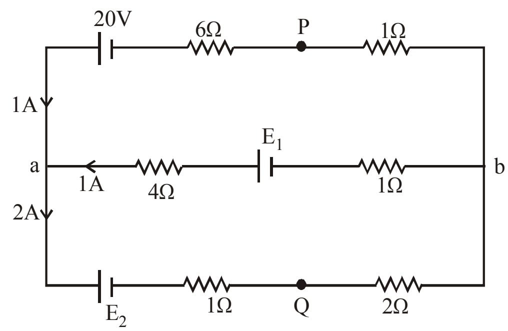
Putting i_1, i_2 and i_3 from eqs. (1), (2) and (3) in eq. (4) we have,

$$\frac{30-V}{2} + \frac{V+8}{-1/2} + \frac{V+21}{-1} = 0$$

or $\quad V = -\frac{44}{7}$ volt

Example 9 :

(a) Find the emfs E_1 and E_2 in the circuit of the following diagram and the potential difference between the points a and b.



(b) In the above circuit, the polarity of the battery E_1 be reversed, what will be the potential difference between a and b ?

Sol. (a) It is clear that 1A 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, $E_1 = 18V$

Also applying Kirchhoff's law to the loop PaQbP,

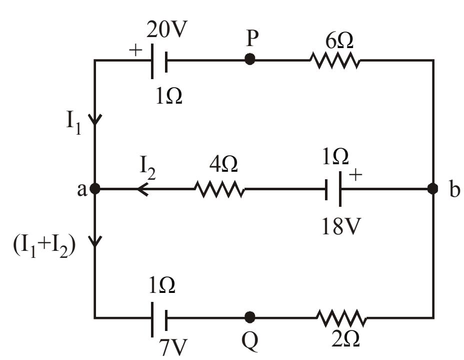
$20 - E_2 = 6 + 1 + (1 \times 2) + (2 \times 2) = 13$

Hence, $E_2 = 7V$

Thus the potential difference between the points a and b is $V_{ab} = 18 - 1 - 4 = 13V$

(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 $38 = 7I_1 - 5I_2$ ....(1)

Similarly for the loop abQa,

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

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

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

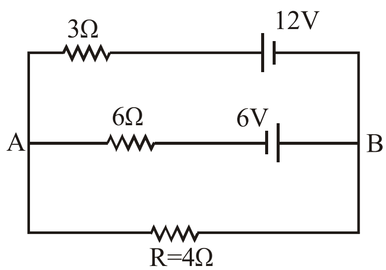
$$I_1 = 2.52 \text{ and } I_2 = -4.07\text{ A}$$

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

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

Example 10 :

Find current through $R = 4\Omega$. Also find $V_A - V_B$.



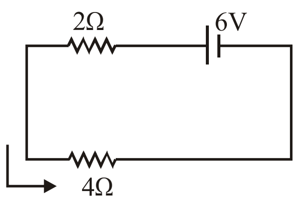
Sol. Applying parallel combination of batteries.

$$E_{eq} = \frac{+\frac{12}{3} - \frac{6}{6}}{\frac{1}{3} + \frac{1}{6}} = \frac{4-1}{1/2} = +6\text{V}$$

$R_{eq} = 2\Omega$

$$i = \frac{6}{2+4} = 1 \text{ amp.}$$

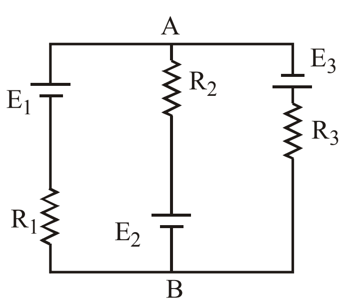
$V_A - V_B = iR = 2$ volt



Example 11 :

Find potential difference $(V_A - V_B)$ in the circuit shown

$E_1 = 1.5\text{V}, E_2 = 2.0\text{V}, E_3 = 2\text{V}, R_1 = 10\Omega, R_2 = 20\Omega, R_3 = 30\Omega$

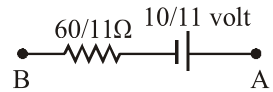


Sol. We can reduced the whole circuit into one battery and resistance.

$$E_{eq} = \frac{\frac{1.5}{10} + \frac{2.0}{20} - \frac{2.5}{30}}{\frac{1}{10} + \frac{1}{20} + \frac{1}{30}} = \frac{\frac{1}{6}}{\frac{11}{60}} = \frac{10}{11}\text{volt}$$

$$R_{eq} = \frac{60}{11}\Omega$$

$$V_A - V_B = \frac{10}{11} \text{ volt}$$



NODE VOLTAGE METHOD (NODAL ANALYSIS)

Another method of analysis of multiple-loop circuits is called the node voltage method. It is based on finding the voltages at each node in the circuit using Kirchoff's current law. A node is the junction of two or more components. In writing the current expression the assumption is made that the node potential is always higher than the other voltages appearing in the equation. In case it turns out not to be so, a negative value for the current would result. The general steps for the node voltage method of circuit analysis are as follows :

Step 1 : Determine the number of nodes.

Step 2 : Select one node as a reference. All voltages will be relative to the reference node. Assign voltage designations to each node where the voltage is unknown.

Step 3 : Assign currents at each node where the voltage is unknown, except at the reference node. The directions are arbitrary.

Step 4 : Apply Kirchhoff's current law to each node where currents are assigned.

Step 5 : Express the current equations in terms of voltages, and solve the equations for the unknown node voltages using Ohm's law.

We will use figure to illustrate the general approach to node voltage analysis. First, establish the nodes. In this case, there are four nodes, as indicated in the figure. Second, let's use node B as the reference. Think of it as the circuit's reference ground. Node voltages C and D are already known to be the source voltages. The voltages at node A is the only unknown, it is designated as V_A. Third, arbitrarily assign the branch currents at node A as indicated in the figure. Fourth, the Kirchhoff current equation at node A is $I_{R1} = I_{R2} + I_{R3}$

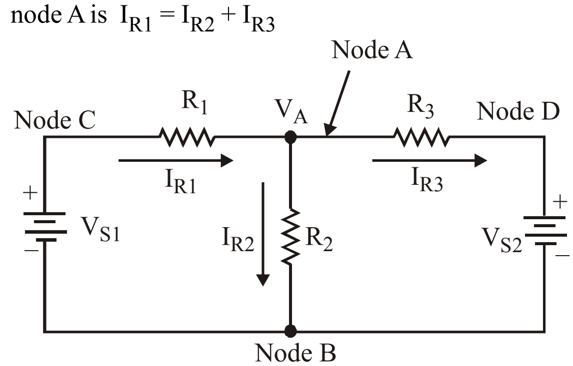


Figure : Circuit for node voltage analysis.

Fifth, express the currents in terms of circuit voltages using Ohm's law.

$$I_{R1} = \frac{V_1}{R_1} = \frac{V_{S1} - V_A}{R_1} \quad ; \quad I_{R2} = \frac{V_2}{R_2} = \frac{V_A}{R_2}$$

$$I_{R3}=\frac{V_3}{R_3}=\frac{V_A-V_{S2}}{R_3}$$

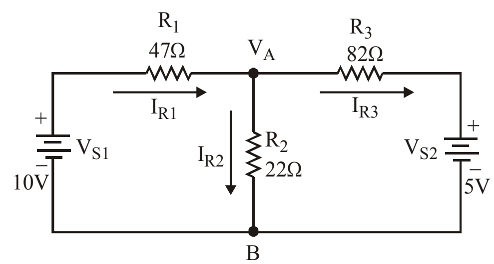
Substituting these terms into the current equation yields

$$\frac{V_{S1}-V_A}{R_1}=\frac{V_A}{R_2}+\frac{V_A-V_{S2}}{R_3}$$

The only unknown is V_A, so solve the single equation by combining and rearranging terms. Once the voltage is known, all branch currents can be calculated.

Example 12 :

Find the node voltage V_A in figure.



Sol. The reference node is chosen at B. The unknown node voltage is V_A, as indicated in figure. This is the only unknown voltage. Branch currents are assigned at node A as shown. The current equation is $I_{R1}=I_{R2}+I_{R3}$ Substitution for currents using Ohm's law gives the equation in terms of voltages.

$$\frac{10-V_A}{47}=\frac{V_A}{22}+\frac{V_A-5}{82}$$

Rearranging the terms yields

$$\frac{10}{47}-\frac{V_A}{47}-\frac{V_A}{22}+\frac{5}{82}-\frac{V_A}{82}=0$$

$$-\frac{V_A}{47}-\frac{V_A}{22}-\frac{V_A}{82}=-\frac{10}{47}-\frac{5}{82}$$

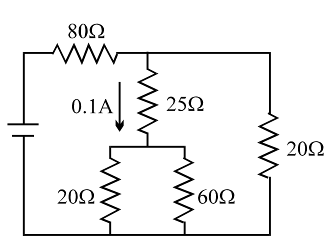
To solve for V_A, combine the terms on each side of the equation and find the common denominator.

$$\frac{1804V_A+3854V_A+1034V_A}{84,788}=\frac{1055}{3854}$$

$$\frac{6692V_A}{84,788}=\frac{1055}{3854}\ ;\quad V_A=\frac{(1055)\,(84,788)}{(6692)\,(3854)}=3.47V$$

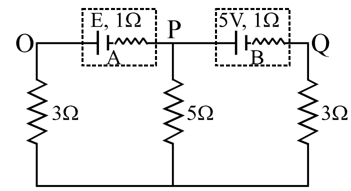
TRY IT YOURSELF - 2

Q.1 A current 0.1 A flows through the 25 Ω resistor as shown in the figure. Then :



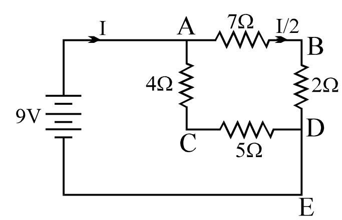
(A) current through the 80Ω resistor is 0.4A.
(B) current through the 60Ω resistor is 0.025A.
(C) emf of the battery is 28 V.
(D) emf of the battery is 24 V.

Q.2 Two batteries A and B and three resistors are connected. Internal resistance of both batteries is 1 Ω each as shown. EMF of battery B is 5 V The potential difference between P and Q is zero. Which of following is/are true.



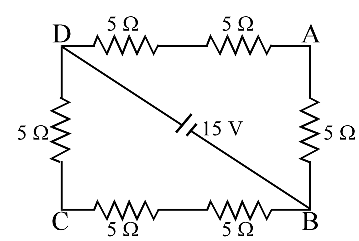
(A) the current through 5 Ω is 3 A
(B) the current through the battery A is 8 A
(C) the emf of the source A is 47 V
(D) the p.d. between O and P is 8 V

Q.3 What would be the potential at point B with respect to point C in the circuit?



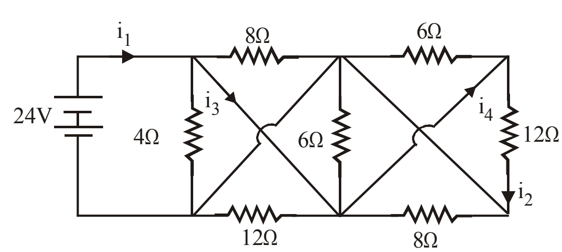
(A) +7V (B) +3V
(C) 0 V (D) –3 V

Q.4 In the circuit diagram shown in the figure. Which of the following is true



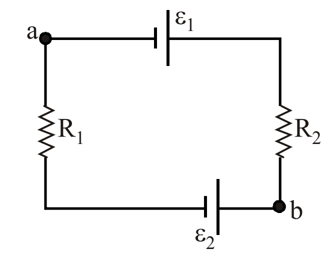
(A) The points A and C are at the same potential
(B) A is at a higher potential than C
(C) Magnitude of P.D. between A and C is 5 volt
(D) C is at higher potential than A

Q.5 For the circuit shown in figure



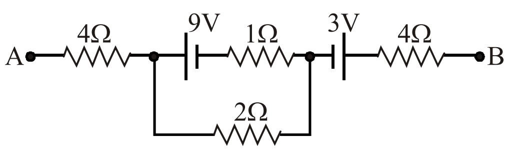
(A) i_1 = 24 A (B) i_2 = 2 A
(C) i_3 = 15 A (D) i_4 = 6A

Q.6 In figure ε_1 = 8V, ε_2 = 4V, and R_1 = 5Ω. If the potential difference between points b and a is measured to be 5 V, what is the value of the resistance R_2?



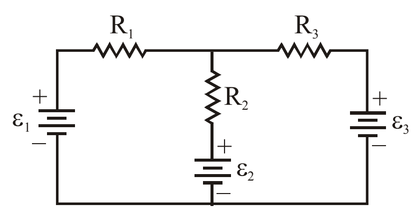
(A) 5Ω (B) 10Ω
(C) 15Ω (D) 20Ω

Q.7 In the circuit shown in figure, $(V_A - V_B)$ = 16V. The current passing through 2Ω resistor is



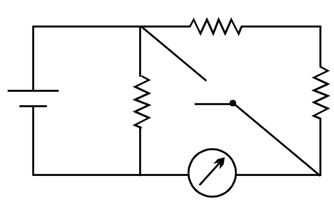
(A) 2.5 A (B) 3.0 A
(C) 3.5 A (D) 4.0 A

Q.8 In figure, take $\varepsilon_1 = 6.0$ V, $\varepsilon_2 = 1.5$ V and $\varepsilon_3 = 4.5$ V. Take $R_1 = 600\ \Omega$, $R_2 = 125\ \Omega$, $R_3 = 300\Omega$.



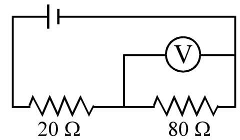
(A) Current in ε_1 is in upward direction
(B) Current in ε_2 is in downward direction
(C) Current in ε_3 is in downward direction
(D) Current in ε_1 is in downward direction

Q.9 In the circuit shown, the reading of the Ammeter is doubled after the switch is closed. Each resistor has a resistance = 1 Ω and the ideal cell has an e.m.f. = 10 V. Then, the Ammeter has a coil resistance equal to



(A) 2 Ω (B) 1 Ω
(C) 2.5 Ω (D) None

Q.10 In the given circuit, the emf of the cell is 2 V and its internal resistance is negligible. The resistance of the voltmeter is 80 Ω. The reading of the voltmeter will be



(A) 0.8 V (B) 1.6 V
(C) 1.33 V (D) 2.0 V

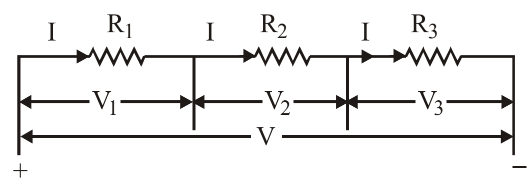
ANSWERS

(1) (BC)	**(2)** (ABC)	**(3)** (D)
(4) (CD)	**(5)** (ABCD)	**(6)** (C)
(7) (C)	**(8)** (AB)	**(9)** (A)
(10) (C)		

COMBINATION OF RESISTANCES

(a) Series Combination :

(i) Resistances are said to be connected in series between two points if they provide only a single path between two points.



(ii) Resistances are connected in series if same current flows through each resistance when some potential difference is applied across the combination.

(iii) Potential difference across each resistance is different and is directly proportional to its resistance $V \propto R$.
So $V_1 = I R_1$; $V_2 = I R_2$ and $V_3 = I R_3$

(iv) The series combination obeys law of conservation of energy. So $V = V_1 + V_2 + V_3 = I(R_1 + R_2 + R_3)$

Equivalent resistance $R_s = \dfrac{V}{I} = R_1 + R_2 + R_3$

(v) The equivalent resistance is equal to sum of individual resistances.

(vi) The equivalent resistance is greater than largest of individual resistance.

(vii) The resistances are connected in series (a) to increase the resistance and (b) to divide large potential difference across many resistances.

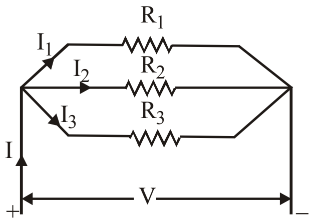
(viii) In n identical resistances R are connected in series then the equivalent resistance $R_s = nR$

(ix) This combination is used in resistance boxes and sometimes in decorative bulbs.

(x) In resistances connected in series if one resistance get open the current in whole circuit will become zero.

(b) Parallel Combination :

(i) Resistances are said to be connected in parallel between two points if it is possible to proceed from one point to another along different paths.



(ii) Resistances are said to be in parallel if potential across each resistance is same and equal to applied potential.

(iii) Current through each resistance is different and is inversely proportional to resistance of resistor. $I \propto 1/R$.

So, $I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}$ and $I_3 = \frac{V}{R_3}$

(iv) The parallel combination obeys the conservation of charge. So, $I = I_1 + I_2 + I_3 = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$

Reciprocal of equivalent resistance

$$\frac{1}{R_p} = \frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

(v) The reciprocal of equivalent resistance is equal to sum of reciprocal of individual resistances.

(vi) The equivalent resistance is smaller than smallest of individual resistance.

(vii) The resistances are connected in parallel to decrease resistance.

(viii) If n identical resistances R are connected in parallel then equivalent resistance $R_p = R/n$

(ix) This combination is used in household electrical applicances.

(x) In resistances connected in parallel if one resistance becomes open then also all others will work as usual.

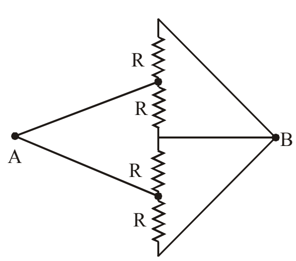
(xi) In case of two resistances in parallel

$$\frac{I_1}{I_2} = \frac{R_2}{R_1} \text{ and } I_1 + I_2 = I$$

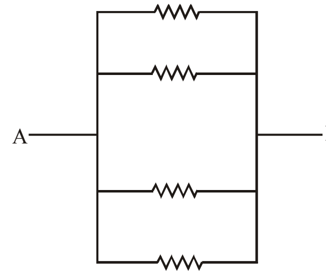
So $I_1 = \frac{R_2 I}{R_1 + R_2}$ and $I_2 = \frac{R_1 I}{R_1 + R_2}$

Example 13 :

Find the equivalent resistance across A and B.



Sol. The circuit can redrawn as

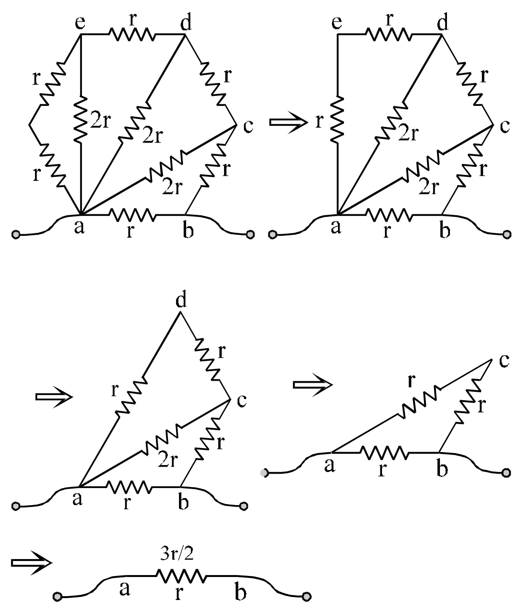


; $R_{AB} = R/4$

Example 14 :

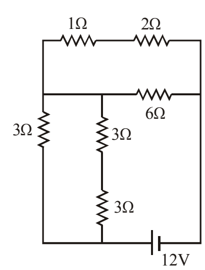
Find equivalent resistance between a and b.

Sol.

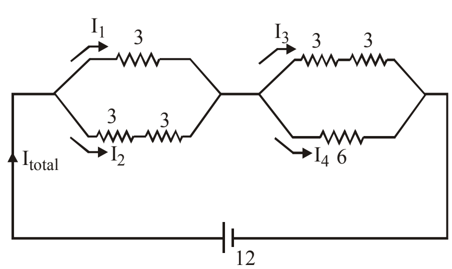


Example 15 :

Find current through each resistance.



Sol.

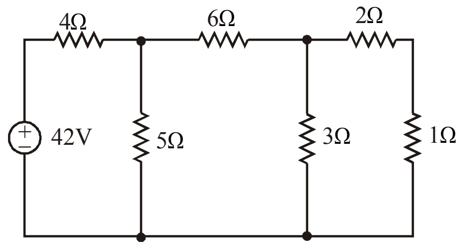


$R_{eq} = 2\Omega + 2\Omega = 4\Omega$

$I_{total} = 12/4 = 3$ amp.

Example 16 :

Find the current through 1Ω resistor. (figure).



Sol. Equivalent resistance across the 42V source is

$$R_{eq} = ([\{(1+2) \parallel 3\} + 6] \parallel 5) + 4]$$

$$= \frac{7.5 \times 5}{7.5 + 5} + 4 = 7\Omega$$

In figure, $I_{4\Omega} = \frac{42}{7} = 6A$;

Drop across 4Ω resistor = 24V

Potential across 5Ω resistor = 42 – 24 = 18V.

Current through 5Ω resistor is $I_{5\Omega} = \frac{18}{5} = 3.6A$

This current through 6Ω resistor ($I_{6\Omega}$) is 6 – 3.6 = 2.4A

∴ Drop across 6Ω resistor is 6 × 2.4V= 14.4V

Finally, the potential across 3Ω resistor is 18 – 14.4 = 3.6V

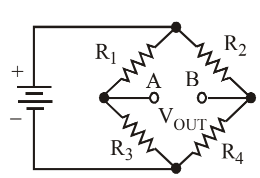
Thus current in 1Ω resistor is $\frac{3.6}{(2+1)} = 1.2A$

THE WHEATSTONE BRIDGE

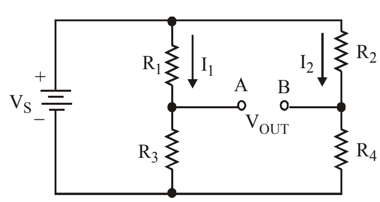
Bridge circuits are widely used in measurement devices and other applications that you will learn later. In this section, you will study the balanced resistive bridge, which can be used to measure unknown resistance values.

The circuit shown in figure (a) is known as a Wheatstone bridge. Figure (b) is the same circuit electrically, but it is drawn in a different way.

A bridge is said to be balanced when the voltage (V_{OUT}) across the output terminals A and B is zero, that is, $V_A = V_B$. In figure (b), if V_A equals V_B, then $V_{R1} = V_{R2}$ because the top sides of both R_1 and R_2 connect to the same point. Also $V_{R3} = V_{R4}$ because the bottom sides of both R_3 and R_4 connect to the same point. The voltage ratios can be written as $\frac{V_1}{V_3} = \frac{V_2}{V_4}$



(a)



(b)

Substituting by Ohm's law yields

$$\frac{I_1R_1}{I_1R_3} = \frac{I_2R_2}{I_2R_4}$$

The currents cancel to give

$$\frac{R_1}{R_3} = \frac{R_2}{R_4}$$

Solving for R_1 yields the following formula :

$$R_1 = R_3\left(\frac{R_2}{R_4}\right)$$

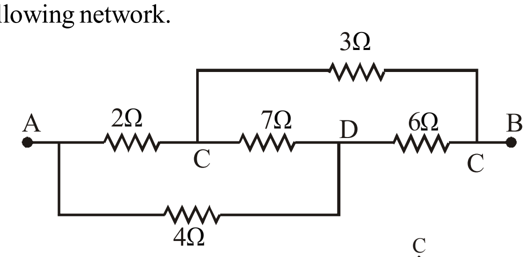
This formula can be used to determine an unknown resistance in a balanced bridge. First, make R_3 a variable resistor and call it R_V. Also, set the ratio R_2/R_4 to a known value. If R_V is adjusted until the bridge is balanced, the product of R_V and the ratio R_2/R_4 is equal to R_1, which is the unknown resistor (R_{UNK}).

$$R_{UNK} = R_V\left(\frac{R_2}{R_4}\right)$$

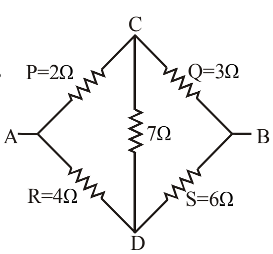
The bridge is balanced when the voltage across the output terminals equals zero ($V_A = V_B$). A galvanometer (a meter that measures small currents in either direction and is zero at center scale) is connected between the output terminals. Then R_V is adjusted until the galvanometer shows zero current ($V_A = V_B$), indicating a balanced condition. The setting of R_V multiplied by the ratio R_2/R_4 gives the value of R_{UNK}.

Example 17 :

Calculate the effective resistance between A and B in the following network.



Sol. The circuit can be redrawn as



Here $\frac{P}{Q} = \frac{R}{S} = \frac{2}{3}$

so bridge is balanced

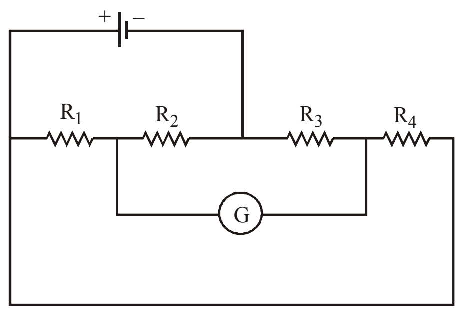
So the resistance between C and D is not useful.

Equivalent resistance = (P + Q) || (R + S)

$$R_{eq} = \frac{(P+Q)(R+S)}{P+Q+R+S} = \frac{(2+3)(4+6)}{2+3+4+6} = \frac{5 \times 10}{15} = \frac{10}{3}\Omega$$

Example 18 :

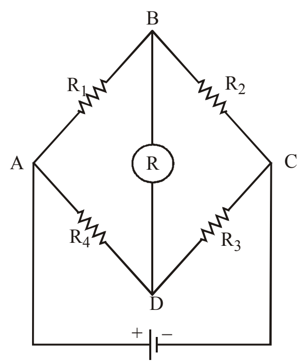
In the given circuit, the galvanometer G will show zero deflection if –



(A) $R_1R_2 = R_3R_4$ (B) $R_1R_3 = R_2R_4$

(C) $R_1R_4 = R_2R_3$ (D) None of the above

Sol. **(B).** Equivalent circuit



STAR-DELTA CONVERSIONS

The combination of resistances shown in fig. 1 (a) is called a star connection and that shown in fig. 1 (b) is called a delta connection.

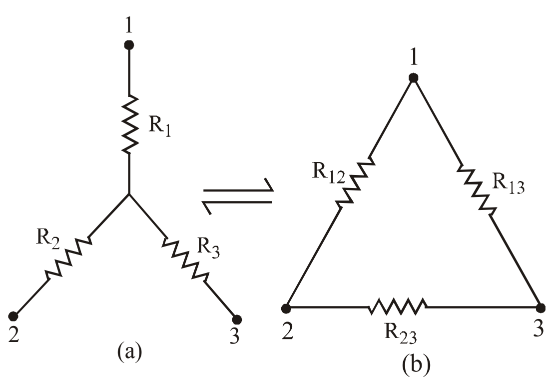


Fig. (a) Star, (b) Delta connections

These two arrangements are electrically equivalent for the resistance measured between any pair of terminals. A star connection can be replaced by a delta, and a delta can be replaced by a star.

Star to Delta Conversion :

If resistances R_1, R_2 and R_3 are known and connected in Star configuration (as in fig. (a))then it can be replaced by a delta configuration with following resistances :

$$R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3} \; ; \; R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1}$$

$$R_{13} = R_1 + R_3 + \frac{R_1R_3}{R_2}$$

Delta to Star Conversion : Consider fig. (a) and (b) again. If resistances R_{12}, R_{23} and R_{13} are known and connected in a delta configuration as in fig. (b), then it can be replaced by a star connection with the following resistances

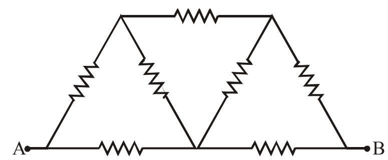
$$R_1 = \frac{R_{12}R_{13}}{R_{12} + R_{13} + R_{23}} \; ; \; R_2 = \frac{R_{23}R_{21}}{R_{12} + R_{13} + R_{23}}$$

$$R_3 = \frac{R_{31}R_{32}}{R_{12} + R_{13} + R_{23}}$$

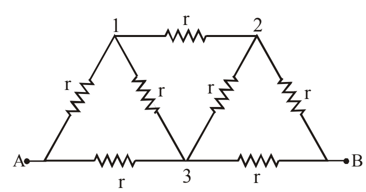
(Note : $R_{13} = R_{31}, R_{23} = R_{32}, R_{12} = R_{21}$)

Example 19:

Each resistance in the network is of r ohm. Then calculate the equivalent resistance between the terminals A and B.



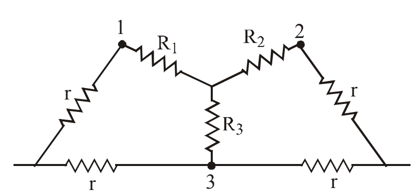
Sol. Consider the delta connection between points 1, 2, 3. Converting it into a star connection, the fig. now looks like fig., with resistances –

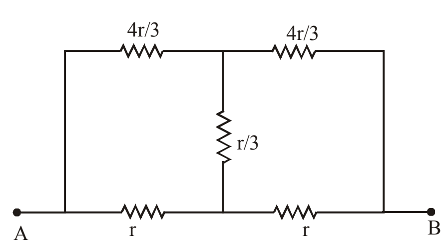


$$R_1 = \frac{r \times r}{r + r + r} = \frac{r}{3}, \quad R_2 = \frac{r}{3}, \quad R_3 = \frac{r}{3}$$

Thus fig. reduces to a balanced wheatstone bridge (fig.),

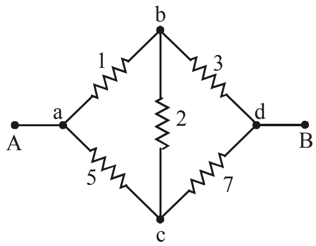
whose equivalent resistance is $R_{eq} = \frac{8}{7}r$





Example 20 :

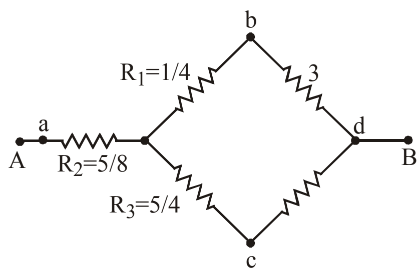
Consider the unbalanced wheatstone bridge shown in fig. Find the equivalent resistance between the points A and B. (all resistances are in ohm)



Sol. Consider one of the delta combination, say abc.

Then converting it into equivalent star combination, we find fig. A direct use of the conversion formula give

$$R_1 = \frac{1\times 2}{1+2+5} = \frac{1}{4}$$

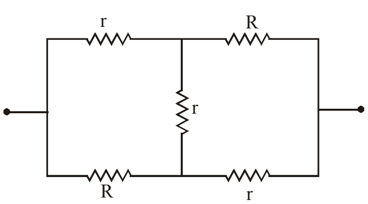


$$R_2 = \frac{5\times 1}{8} = \frac{5}{8}, \qquad R_3 = \frac{2\times 5}{8} = \frac{5}{4}$$

Thus R_{AB}, now can be calculated from the simplified figure. It gives $R_{AB} = \frac{5}{8} + \frac{13}{4} || \frac{13}{4} = \frac{5}{8} + \frac{429}{184} = \frac{544}{184}$

or $R_{AB} = 2.96\ \Omega$

Note :



$$R_{eq} = \frac{r\,(3R + r)}{3r + R}$$

PROBLEM SOLVING APPROACH (COMBINATION OF RESISTANCE)

Follow the following steps to evaluate equivalent resistance of a given circuit.

Step 1 : If resistance are arranged in series-parallel mixed grouping, we apply method of successive reduction to find equivalent resistance.

Step 2 : If not able to reduce the given network in series and parallel through simple successive reduction follow the steps:

(a) Find same potential points in network and considering same potential point as a single point.

(b) Redraw the circuit you will find resistance in series and parallel combination.

Step 3 : If not able to see same potential point try to observe if network contains balanced wheatstone bridge.

Step 4 : Even if not able to observe balanced wheatstone bridge try to observe symmetry in network and use plane cutting method.

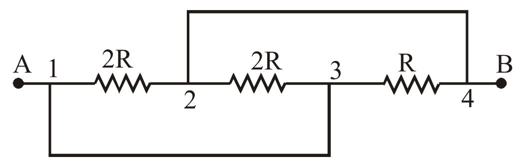
Step 5 : If not able to see symmetry try to observe star-delta in the network.

Step 6 : If network contain infinite resistance then use simple concept $\infty - 1 = \infty$.

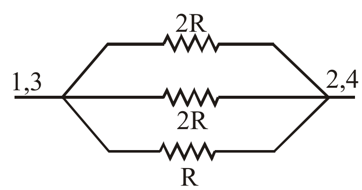
Step 7 : Even if not able to see star-delta use Kirchhoff's rule.

Example 21 :

Find equivalent resistance between the points A and B?



Sol. Point 1 and 3 are at same potential. Similarly point 2 and 4 are at same potential. Joining resistance between 1 and 2, 2 and 3, 3 and 4 we find that they all are in parallel.

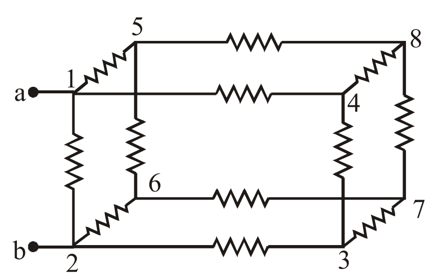


So equivalent resistance

$$\frac{1}{R_p} = \frac{1}{2R} + \frac{1}{2R} + \frac{1}{R} = \frac{2}{R} \text{ or } R_p = R/2$$

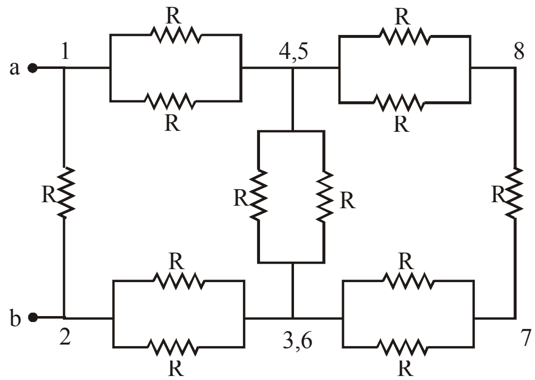
Example 22 :

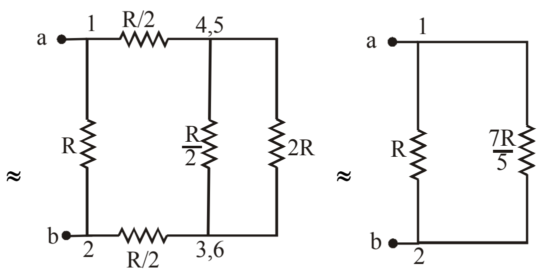
Twelve equal resistances R are used to generate shape of a cube. Calculate equivalent resistance across the side of cube?



Sol. By symmetry potential at point 4 and 5 is same. Similarly potential at point 3 and 6 is same (Looking from point a, b you can imagine a plane passing 4, 5, 6, 3 that will cut the cube into two symmetrical parts hence potential of 4, 5 is same and of 3, 6 also.

The equivalent circuits can be drawn as :





The equivalent resistance between a and b is

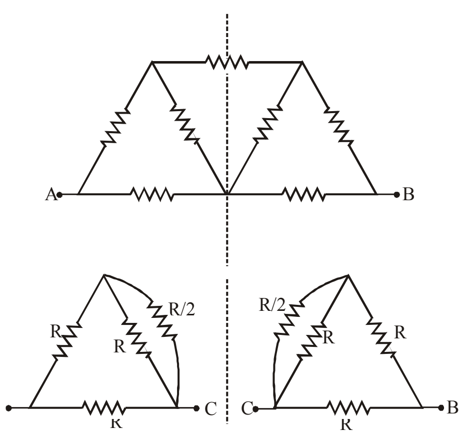
$$R_{eq} = \frac{R \times \frac{7}{5}R}{R + \frac{7}{5}R} = \frac{7}{12}R$$

Example 23 :

Seven resistors each of resistance R, are connected as shown in figure. Find the equivalent resistance between A and B

Sol. $R_{AB} = R_{AC} + R_{CB}$

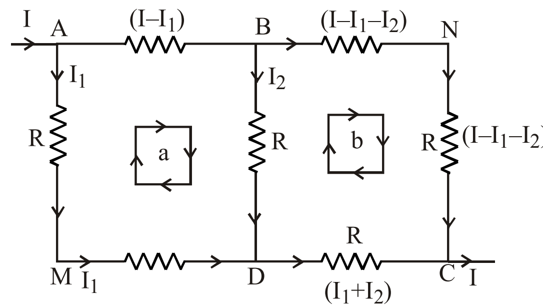
Line of symmetry, $R_{AB} = \frac{8}{7}R$



Example 24:

What is the equivalent resistance between points A and C in the circuit shown in figure.

Sol. Distribution of current in various branches of the circuit in



Accordance with Kirchhoff's I law is shown in figure. Applying Kirchhoff's II law to meshes a and b we have respectively :

$$-(I - I_1)R - I_2R + I_1R + I_1R = 0$$

i.e., $3I_1 - I_2 = I$ .... (1)

$$-(I - I_1 - I_2)R - (I - I_1 - I_2)R + (I_1 + I_2)R + I_2R = 0$$

$3I_1 + 4I_2 = 2I$ .... (2)

Solving eqs. (1) and (2) for I_1 and I_2

$I_1 = \frac{2}{5}I$ .... (3) and $I_2 = \frac{1}{5}I$ .... (4)

Now if $(R_{eq})_{AC}$ is the equivalent resistance between points A and C

$V = (R_{eq})_{AC} = I_1R + I_1R + (I_1 + I_2)R$

$= 3I_1R + I_2R$ .... (5)

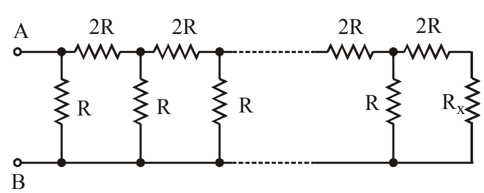
Substituting the values of I_1 and I_2 from eqs (3) and (4) in

eq. (5), $I(R_{eq})_{AC} = 3 \times \left(\frac{2}{5}I\right)R + \frac{1}{5}IR = \frac{7}{5}IR$

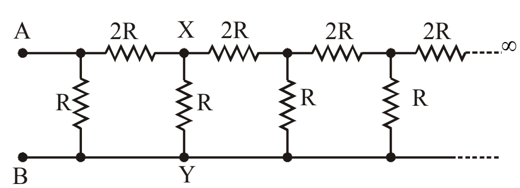
$$(R_{eq})_{AC} = \frac{7}{5}R$$

Example 25 :

At what value of the resistance R_x in the circuit shown in figure will the total resistance between points A and B be independent of the number of cells ?

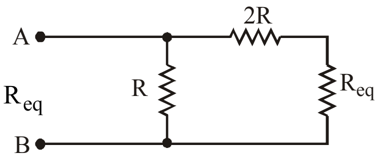


Sol. Problem is equivalent to



As $\infty - 1 \to \infty$

$R_{AB} = R_{XY} = R_{eq}$



$$\frac{(R_{eq} + 2R)}{R_{eq} + 2R + R} = R_{eq}$$

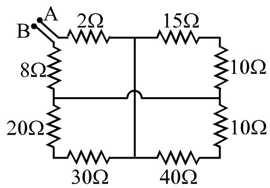
$$R_{eq}^2 + 2RR_{eq} - 2R^2 = 0$$

$$R_{eq} = (\sqrt{3} - 1)\,R$$

Hence if will put $R_X = R_{eq}$ total resistance between A and B will be independent on number of resistors.

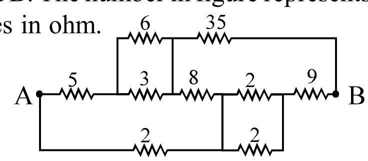
TRY IT YOURSELF - 3

Q.1 The equivalent resistance between points A and B is:



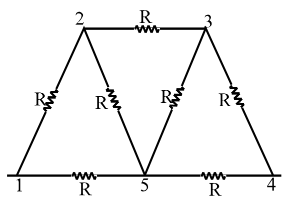
(A) 32.5 Ω
(B) 22.5 Ω
(C) 2.5 Ω
(D) 42.5 Ω

Q.2 Find the equivalent resistance of the circuit shown between points A and B. The number in figure represents respective resistances in ohm.



(A) (22/3) Ω
(B) (28/3) Ω
(C) 9Ω
(D) none

Q.3 The equivalent resistance between points 1 and 4 of the circuit is :



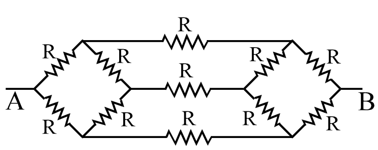
(A) $\frac{8}{7}R$ (B) $\frac{7}{8}R$

(C) $\frac{15}{4}R$ (D) none

Q.4 A given piece of wire of length *l*, and radius r and resistance R is stretched uniformly to wire of radius (r/2). Its new resistance is :

(A) 4 R (B) 8 R
(C) 16 R (D) 32 R

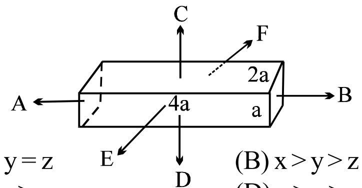
Q.5 The equivalent resistance between the terminal points A and B in the network shown in figure is



(A) $\frac{7R}{5}$ (B) $\frac{5R}{6}$

(C) $\frac{7R}{12}$ (D) $\frac{5R}{12}$

Q.6 A conductor with rectangular cross section has dimensions (a×2a×4a) as shown in figure. Resistance across AB is x, across CD is y and across EF is z. Then



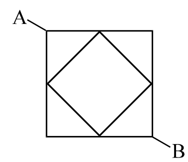
(A) x = y = z (B) x > y > z
(C) y > x > z (D) x > z > y

Q.7 A piece of conducting wire of resistance R is cut into 2n equal parts. Half the parts are connected in series to form a bundle and remaining half in parallel to form another bundle. These bundles are then connected to give the maximum resistance. The maximum resistance of the combination is

(A) $\frac{R}{2}\left(1 + \frac{1}{n^2}\right)$ (B) $\frac{R}{2}\left(1 + n^2\right)$

(C) $\frac{R}{2(1 + n^2)}$ (D) $R\left(n + \frac{1}{n}\right)$

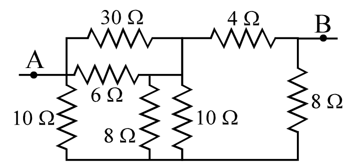
Q.8 A wire has linear resistance ρ (in Ohm/m). Find the resistance R b/w points A and B if the side of the "big" square is d.



(A) $\frac{\rho d}{\sqrt{2}}$ (B) $\sqrt{2}\rho d$

(C) $2\rho d$ (D) None

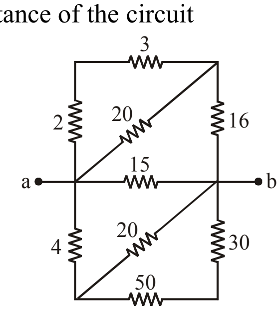
Q.9 Seven resistors are connected as shown in the diagram.



The equivalent resistance in ohms of this network between A and B is

(A) 6 (B) 8
(C) 12 (D) 20

Q.10 In Fig. denote the numerical values of resistors in SI. The total resistance of the circuit



(A) 12 ohms (B) 24 ohms.
(C) 15 ohms (D) 6 ohms

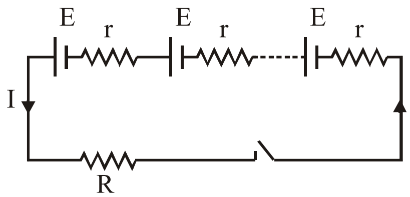
ANSWERS

(1) (B)	**(2)** (B)	**(3)** (A)
(4) (C)	**(5)** (A)	**(6)** (D)
(7) (A)	**(8)** (A)	**(9)** (A)
(10) (D)		

COMBINATION OF CELLS

In series grouping of cell's their emf's are additive or subtractive while their internal resistances are always additive. If dissimilar plates of cells are connected together their emf's are added to each other while if their similar plates are connected together their emf's are subtractive.

(A) Series grouping : In series grouping anode of one cell is connected to cathode of other cell and so on. In identical cells are connected in series



* Equivalent emf of the combination $E_{eq} = nE$

* Equivalent internal resistance $r_{eq} = nr$

* Main current = Current from each cell = $i = \dfrac{nE}{R + nr}$

* If out of n cells in series m cells be connected in an opposite manner, then the current will given by

$$i = \frac{\left[\sum_{i=1}^{(n-m)} E_i - \sum_{j=1}^{m} E_j\right]}{\sum_{i=1}^{n} r_i + R}$$

* Potential difference across each cell $V' = V/n$

* Power dissipated in the external circuit = $\left(\dfrac{nE}{R+nr}\right)^2 .R$

* Condition for maximum power $R = nr$ and $P_{max} = n\left(\dfrac{E^2}{4r}\right)$

$\left(\dfrac{dP}{dR} = 0, \text{ Maximum power transfer theorem}\right)$

* Total power consumed in the circuit

$^2/(R + r)$ [and not $E^2R/(R + r)^2$] and will be maximum ($= E^2/r$) when $R = \min = 0$ with $I = (E/r) = \max$. If $R = r$, $P = (E^2/2r)$ with $I = (E/2r)$

Note : It is a common misconception that "current in the circuit will be maximum when power consumed by the load is maximum."

Actually current $I = E/(R + r)$ is maximum ($= E/r$) when $R = \min = 0$ with $P_L = (E/r)^2 \times 0 = 0 = \min.$ while power consumed by the load $E^2R/(R + r)^2$ is maximum ($E^2/4r$) when

$R = r$ and $I = E/2r \neq \max (= E/r)$

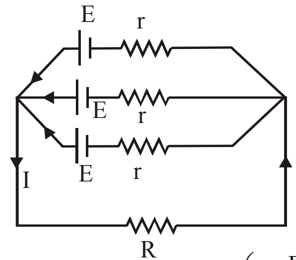
(B) Parallel grouping :

In parallel grouping all anodes are connected at one point and all cathode are connected together at other point. If n identical cells are connected in parallel.

* Equivalent emf $E_{eq} = E$

* Equivalent internal resistance $R_{eq} = r/n$

* Main current $i = \dfrac{E}{R + r/n}$



* Power dissipated in the circuit $P = \left(\dfrac{E}{R + r/n}\right)^2 .R$

* Condition for max. power is $R = r/n$ and $P_{max} = n\left(\dfrac{E^2}{4r}\right)$

Dissimilar cells in parallel :

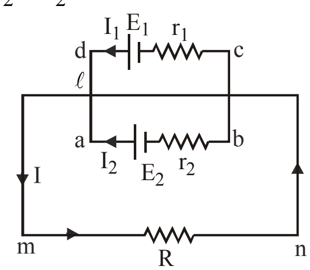
Let two cells of emf E_1 and E_2 and internal resistances r_1 & r_2 be connected in parallel to an external resistance R.

Applying loop rule to loop dℓ m n c d

$-IR - I_1 r_1 + E_1 = 0$ ......(1)

Applying loop rule to loop aℓ m n b a

$-IR - I_2 r_2 + E_2 = 0$ ......(2)



Applying first rule at junction ℓ

$I = I_1 + I_2$.

Multiply equation 1 by r_2 and eq. 2 by r_1 and put $I_2 = I - I_1$

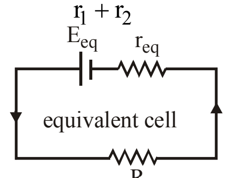
we get $-IR\, r_2 - I_1 r_1 r_2 + E_1 r_2 = 0$

and $-IR\, r_1 - (I - I_1) r_2 r_1 + E_2 r_1 = 0$

On adding these we get,

$$E_1 r_2 + E_2 r_1 = IR(r_1 + r_2) + Ir_1 r_2 = I(r_1 + r_2)\left[R + \frac{r_1 r_2}{r_1 + r_2}\right]$$

or $$I = \frac{(E_1 r_2 + E_2 r_1)/(r_1 + r_2)}{R + \dfrac{r_1 r_2}{r_1 + r_2}} = \frac{E_{eq}}{R + r_{eq}}$$



Two dissimilar cells in parallel are equivalent to a single cell of internal resistance $r_{eq} = \dfrac{r_1 r_2}{r_1 + r_2}$ and emf

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \frac{r_1 r_2}{r_1 + r_2}\left[\frac{E_1}{r_1} + \frac{E_2}{r_2}\right]$$

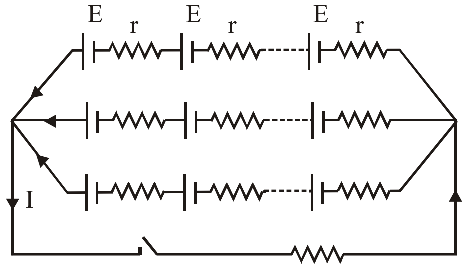
(C) Mixed Grouping :

If n identical cell's are connected in a row and such m row's are connected in parallel as shown.

* Equivalent emf of the combination $E_{eq} = nE$
* Equivalent internal resistance of the combination $r_{eq} = nr/m$
* Main current flowing through the load

$$i = \frac{nE}{R + (nr/m)} = \frac{mnE}{mR + nr}$$

* Potential difference across load $V = iR$
* Potential difference across each cell $V' = V/n$



* Current from each cell $i' = i/n$
* Condition for maximum power

$$R = \frac{nr}{m} \text{ and } P_{max} = (mn)\frac{E^2}{4r}$$

* In mixed grouping' as both current in the circuit and power transferred to the load are maximum under same condition it is preferred over series or parallel grouping of cells.
* Total number of cell = mn
* If N (= mn) and r/R = (m/n) are given then m = no. of rows and n = no. of cells contained in each row can be calculated for maximum current through R. It may be mentioned here, that the values of m and n should necessarily be positive integers. If, upon solving for m and n, the values come out to be fractions, then get the two set of integral values of m and n, one immediately lesser and the other greater than the obtained fractions. Next, check the value of i for these two set of m and n values, and then decide the values of m and n for i to be maximum.

Example 26 :

Twelve cells each having the same emf and negligible internal resistance are kept in a closed box. Some of the cells are connected in the reverse order. This battery is connected in series with an ammeter, an external resistance R and two cells of the same type as in the box. The current when they aid the battery is 3 ampere and when they oppose, it is 2 ampere. How many cells in the battery are connected in reverse order ?

Sol. Let n cells are connected in reverse order. Then emf of the battery is $E' = (12n - n)E - nE = (12 - 2n)E$

In case (i) $I = \frac{E' + 2E}{R} = 3$ or $E' + 2E = 3R$

or $(14 - 2n)E = 3R$ .... (1)

In case (ii) $I = \frac{E' - 2E}{R} = 2$ or $E' - 2E = 3R$

or $(10 - 2n)E = 2R$ .... (2)

Dividing (1) and (2) $\frac{14 - 2n}{10 - 2n} = \frac{3}{2}$ or $n = 1$

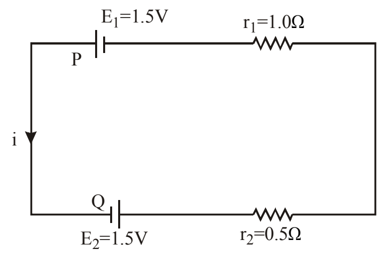
One cell is connected in reverse order.

Example 27 :

Two cells P and Q connected in series have each an emf of 1.5 V and internal resistances 1.0 Ω and 0.5Ω respectively. Find the current through them and the voltages across their terminals.

Sol. For a single closed loop, consisting of cells and resistors the current i flowing through it is given by

$$i = \frac{\Sigma E_i}{\Sigma r + \Sigma r_i} \quad \therefore\ i = \frac{1.5 + 1.5V}{1.0 + 0.5\Omega} = 1.5A$$



The voltage across the cell P is

$$V_p = E_1 - ir_1 = 1.5V - 1.5\,(1.0)V = \text{zero}$$

and Q is $V_Q = E_2 - ir_2 = 1.5V - 1.5\,(0.5)V = 0.75V$

GALVANOMETER

These are instruments used for detection and measurement of small currents. The moving coil galvanometer work on the principle that when a current carrying coil is placed in a magnetic field it experiences a torque.

The different type of moving coil galvanometers are

(a) Pivoted Galvanometer : It consists of a coil of fine insulated wire wound on a metallic frame. The coil is mounted on two jewelled pivots and is symmetrically placed between cylindrical pole pieces of a strong permanent horse-shoe magnet.

(b) Dead beat Galvanometer : Here coil is wound over the metallic frame to make it dead beat. On passing current the galvanometer shows a steady deflection without any oscillation. The damping is produced by eddy currents.

(c) Ballistic Galvanometer : This is used for measurement of charge. Here coil is wound on an insulating frame and oscillates on passing current.

In moving coil galvanometer the deflection produced is proportional to current flowing through galvanometer i.e. they have linear scale of measurement.

In equilibrium deflecting torque = restoring torque

i.e. $NIAB = C\theta$ or $I = \left(\frac{C}{NAB}\right)\theta$ or $I = K\theta$

where K is galvanometer constant.

Current Sensitivity : This is defined as the deflection produced in galvanometer when a unit current flows through it. Current sensitivity $CS = \frac{\theta}{I} = \frac{NAB}{C}$ radian/ampere

or division/ampere

(a) The sensitivity can be increased by increasing number of turns in coil (N), area of cross-section of coil (A), magnetic field B and decreasing torsional constant (C).

(b) The reciprocal of current sensitivity is called figure of merit.

Figure of merit $FM = \frac{I}{\theta} = \frac{C}{NAB}$

Voltage Sensitivity : This is defined as the deflection produced in galvanometer when a unit voltage is applied across its terminals.

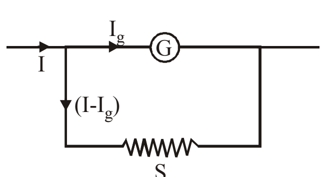
Voltage sensitivity $VS = \frac{\theta}{V} = \frac{\theta}{IR} = \frac{NAB}{CR}$ division/volt,

where R is resistance of coil.

Shunting a galvanometer reduces its current sensitivity.

AMMETER

An ammeter is a low resistance galvanometer used to measure strength of current in an electrical circuit. An ammeter is always connected in series in a circuit because when an ammeter is connected in series it does not appreciably change the resistance of circuit and hence the main current flowing through the circuit. In ideal ammeter has zero resistance. The reading of an ammeter is always less than actual current in the circuit because all practical ammeters have low finite resistance. Smaller is the resistance of an ammeter more accurate will be the reading. A galvanometer can be converted to an ammeter by connecting a low resistance shunt in parallel to coil of galvanometer.



Here, $I_g G = (I - I_g) S$ or $S = \frac{I_g}{I - I_g} G$

Here G is resistance of galvanometer and I_g is current required to produced full scale deflection of current.

The resistance of converted ammeter is $R_A = \frac{G.S}{G+S}$

The range of an ammeter is increased by reducing shunt resistance S.

If $I = N I_g$ then $S = \frac{I_g}{NI_g - I_g} G = \frac{G}{N-1}$

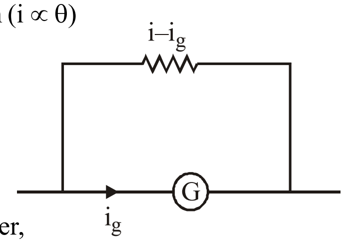
The range of an ammeter can be increased N times by reducing shunt to S = G/N – 1.

It is possible to increase the range of an ammeter because it lowers the resistance of ammeter further. The length of the shunt required $\ell = \pi r^2 S/\rho$ where r is radius of shunt wire and ρ is specific resistance of material of shunt wire. Reducing the shunt resistance may increase range but it reduces the sensitivity.

Example 28 :

The deflection of a moving coil galvanometer falls from 60 divisions to 12 divisions when a shunt of 12Ω is connected. What is the resistance of the galvanometer?

Sol. The current i in the galvanometer is directly proportional to the angle of deflection ($i \propto \theta$)



Then, $\frac{i_g}{i} = \frac{12}{60} = \frac{1}{5}$

or $i_g = \frac{i}{5}$ .... (1)

For shunted galvanometer,

$(i - i_g) S = i_g G$

$G = (i - i_g)\frac{S}{i_g}$ .... (2)

Putting i_g from eq. (1) in eq. (2) and S = 12 ohm.

G = 48 ohm

Example 29 :

What is the value of shunt which passes 10% of main current through a galvanometer of 99Ω?

Sol. $S = \frac{I_g G}{I - I_g}$ where $I_g = \frac{10}{100} I = 0.1 I$.

So, $S = \frac{0.1 I \times 99}{I(1-0.1)} = \frac{9.9}{0.9} = 11\ \Omega$

Example 30 :

A galvanometer of coil resistance 20 ohm, gives a full scale deflection with a current of 5 mA. What arrangements should be made in order to measure currents upto 1.0 A ?

Sol. The upper limiting value of current to be measured is to be increased by a factor.

$n = \frac{1.0A}{5A} = 200$

∴ The resistance of the shunt required will be

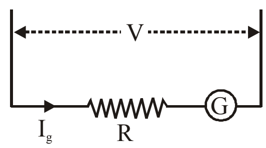
$S = \frac{G}{n-1} = \frac{20\Omega}{200-1} \approx 0.1\ \Omega$

Hence, a shunt of resistance 0.1Ω should be connected in parallel across the galvanometer coil.

VOLTMETER

A voltmeter is a high resistance galvanometer used to measure potential difference. A voltmeter is connected in parallel to a circuit element because when connected in parallel it draws least current from the main current. So it measures nearly accurate potential difference. An ideal voltmeter has infinite resistance. The reading of a voltmeter is always less than actual value because all practical voltmeter may have large but finite resistance. Greater is the resistance of voltmeter more accurate is its reading. A galvanometer is converted to a voltmeter by connecting a high resistance in series with coil of galvanometer.

$V = I_g(R+G)$ or $R = \dfrac{V}{I_g} - G$



The resistance of converted voltmeter is $R_v = R + G$

The range of a voltmeter is increased by increasing the series resistance.

If $V = NV_g = NI_g G$ then $R = \dfrac{NI_gG - G}{I_g} = (N-1)G$

The value of resistance required to increase range N times is $R = (N-1)G$.

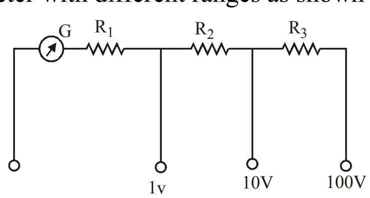
Example 31 :

A voltmeter having 100Ω resistance can measure a potential difference of 25V. What resistance R is required to be connected in series, to make it read voltages upto 250 V ?

Sol. The upper limiting value of voltage is to be increased by a factor $n = \dfrac{250V}{25V} = 10$; $R = (n-1)G = (10-1)\,100 = 900\,\Omega$

Example 32 :

The galvanometer G has internal resistance G = 50Ω and full scale deflection occurs at i = 1mA. Find the series resistors R_1, R_2 and R_3 needed to use the arrangement as a voltmeter with different ranges as shown in the figure.



Sol. For the range of $V_1 = 1$ volt,

$$i_g = \frac{V_1}{G+R_1} \;;\; 10^{-3} = \frac{1}{50+R_1} \quad \text{or} \quad R_1 = 950 \text{ ohm}$$

For the range of $V_2 = 10$ volt

$$i_g = \frac{V_2}{G+R_1+R_2} \;;\; 10^{-3} = \frac{10}{50+950+R_2}$$

or $R_2 = 9 \times 10^3$ ohm

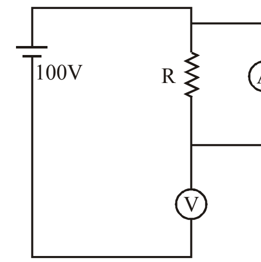
For the range of $V_3 = 100$ volt,

$$i_g = \frac{V_3}{G+R_1+R_2+R_3} \;;\; 10^{-3} = \frac{100}{50+950+9000+R_3}$$

or $R_3 = 90 \times 10^3$ ohm.

Example 33 :

A voltmeter of resistance 995Ω and an ammeter of resistance 10Ω is connected as shown to calculate the unknown resistance R which is connected to the ideal battery. Voltmeter reading is 99.5 volts. The value of resistance R is calculated as $\dfrac{\text{Voltmeter reading}}{\text{Ammeter reading}}$ by student A.



(i) Find his answer.

(ii) Also find the actual value of resistance.

Sol. (i) Voltage across number = 0.5 volts

Resistance = 10Ω

Ammeter reading = 0.05 A

$$R = \frac{\text{Voltmeter reading}}{\text{Ammeter reading}} = \frac{99.5}{0.05} = 1990\Omega$$

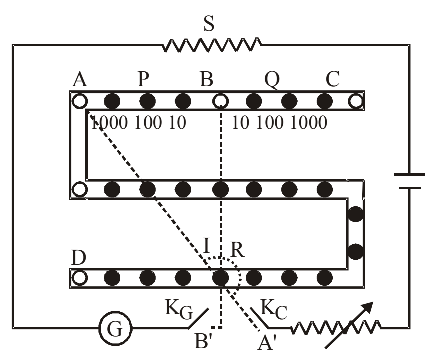
(ii) Current across voltmeter $= \dfrac{99.5}{995} = 0.1$ A

and current through ammeter = 0.05 A

∴ Current through R = 0.05 A and voltage across R = 0.5V

∴ $R = \dfrac{0.5}{0.05} = 10\Omega$

POST OFFICE BOX

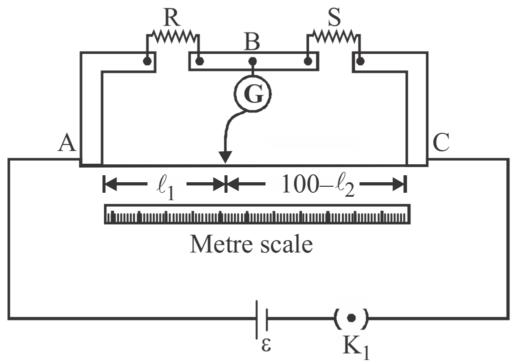


Post-office Box

It is so named because it has a shape of box and was designed to find resistance of electric cables and telegraph wires. It was used in post offices to determine resistance of transmission lines. It is based on principle of wheatstone bridge. Unknown resistance is $S = \dfrac{Q}{P}R$ and specific resistance is $\rho = \dfrac{\pi r^2 S}{L}$, where r is radius and L is length of wire. In PO box we first press cell key and then press galvanometer key to eliminate induced effects. It is used to find unknown resistance, specific resistance of a wire, internal resistance of cell, resistance of galvanometer etc.

METER BRIDGE

This is the simplest form of wheatstone bridge and is specially useful for comparing resistances more accurately. The construction of the metre 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 them a known resistance and in second an unknown resistance 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 from two resistances of the wheatstone bridge, wire used is of uniform material and cross-section.

The resistance can be found with the help of the following relation :

$$\frac{R}{S} = \frac{\sigma\ell_1}{\sigma\,(100-\ell_1)} \quad \text{or} \quad \frac{R}{S} = \frac{\ell_1}{100-\ell_1} \quad \text{or} \quad R = S\frac{\ell_1}{100-\ell_1}$$

where σ is the resistance per unit length of the wire and ℓ_1 is the length of the wire from one end where null point is obtained. The bridge is most sensitive when null point is somewhere near the middle point of the wire. This is due to end resistances.

Example 34 :

An unknown resistance S is placed on the left gap and known resistance of 60Ω in right gap of meter bridge. The null point is obtained at 40 cm from left end of bridge. Find the unknown resistance?

Sol. $S = R\frac{(100-L)}{L} = 60\frac{(100-60)}{60} = 40\Omega$

Example 35 :

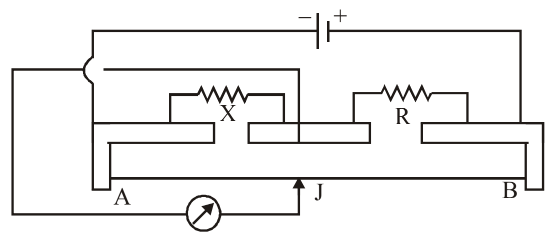
In a meterbridge the length of wire is 100 cm. At what point is balance point obtained if two resistances are in ratio 2 : 3?

Sol. $\frac{P}{Q} = \frac{L}{100-L} = \frac{2}{3}$

So $3L = 200 - 2L$ or $L = \frac{200}{5} = 40\,\text{cm}$.

Example 36 :

The figure shows a meter-bridge circuit, with AB = 100cm, X=12Ω and R = 18Ω, and the jockey J in the position of balance. If R is now made 8Ω, through what distance will J have to be moved to obtain balance ?



Sol. $\frac{12}{18} = \frac{\ell}{100-\ell} \Rightarrow \ell = 40\text{cm}$

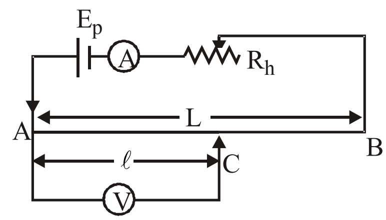
Now, $\frac{12}{8} = \frac{\ell'}{100-\ell'} \Rightarrow \ell' = 60\text{cm}$

Shifting balancing position = $\ell' - \ell$ = 20cm.

POTENTIOMETER

It is a device used to measure unknown potential difference accurately.

The potential drop across any section of wire of uniform cross-section and composition is proportional to length of that section if a constant current flows through it.



If I is the current in potentiometer wire AB of uniform cross-sectional area A, length L and specific resistance ρ then

unknown potential difference across AC is $V = \frac{I\rho\ell}{A}$ and

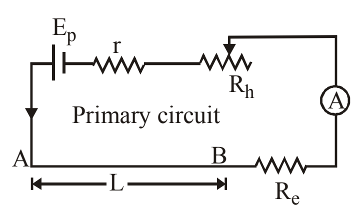
known potential difference across AB is $E_p = \frac{I\rho L}{A}$

At balance point unknown potential difference = known potential difference

or $\frac{V}{\ell} = \frac{E_p}{L}$ or $V = \left(\frac{E_p}{L}\right)\ell$ or $V = x\,\ell$ so $V \propto \ell$.

where $x = E_p/L$ = potential gradient i.e. fall of potential per unit length of potentiometer.

Potential gradient : The fall of potential per unit length of potentiometer wire is called potential gradient.



r = internal resistance of driving cell;
R_h = resistance of rheostat, R_e = external series resistance,
R is resistance of potentiometer wire,
L is length of potentiometer wire.
The current through primary circuit

$$I = \frac{E_p}{r + R_h + R_e + R}$$

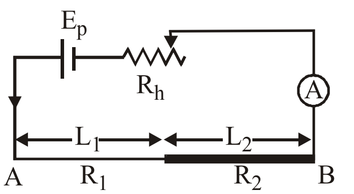
The potential gradient, $x = \frac{IR}{L} = \frac{E_p}{r + R_h + R_e + R}\left(\frac{R}{L}\right)$

Note :

(i) Keeping the thickness of potentiometer wire constant if the length is changed from L_1 to L_2 then ratio of potential gradient will be $\frac{x_1}{x_2} = \frac{L_2}{L_1}$

(ii) If two wires of length L_1 and L_2, resistances R_1 and R_2 are joined in series with a battery of emf E_p and a rheostat than the ratio of potential gradients can be calculated as $x_1 = \left(\frac{E_p}{R_1 + R_2}\right)\frac{R_1}{L_1}$ and $x_2 = \left(\frac{E_p}{R_1 + R_2}\right)\frac{R_2}{L_2}$

or $\frac{x_1}{x_2} = \frac{R_1}{R_2} \cdot \frac{L_2}{L_1}$



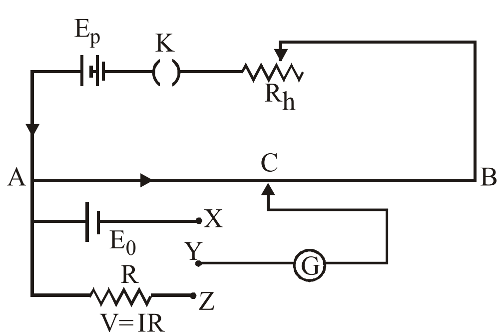
Sensitivity of Potentiometer :
Smaller the potential difference that can be measured with a potentiometer more is the sensitivity of the potentiometer. The sensitivity of potentiometer is inversely proportional to potential gradient ($S \propto 1/x$). The sensitivity can be increased by (a) Increasing length of potentiometer wire (b) For a potentiometer wire of fixed length potential gradient is decreased by reducing the current in circuit.

Uses of potentiometer

(a) Determination of unknown emf or potential difference

If unknown emf E_1 is balanced at length ℓ_1 then

$$E_1 = x\ell_1 = \left(\frac{E_0}{\ell_0}\right)\ell_1$$



If unknown potential difference V is balanced for length ℓ

then $V = x\ell = \left(\frac{E_0}{\ell_0}\right)\ell$

If the length of potentiometer wire is changed from L to L'

then the new balancing length is $\ell' = \left(\frac{L'}{L}\right)\ell$

If length is increased L' > L so $\ell' > \ell$ and if length is decreased L' < L so $\ell' < \ell$. So change in balancing length $\Delta\ell = (\ell' - \ell)$

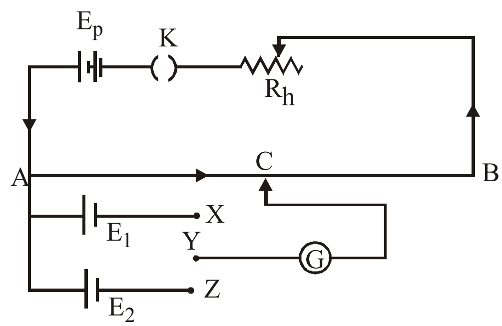
If the current flowing through resistance R is I then

$$V = IR = x\ell = \left(\frac{E_0}{\ell_0}\right)\ell \quad \text{so} \quad I = \frac{x\ell}{R} = \left(\frac{E_0}{\ell_0}\right)\frac{\ell}{R}$$

For determination of current we use a coil of standard resistance.

(b) Comparison of emfs of two cells :

Let E_1 emf be balanced at length ℓ_1 and E_2 emf be balanced at length ℓ_2 then $E_1 = x\ell_1$ and $E_2 = x\ell_2$ so $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$

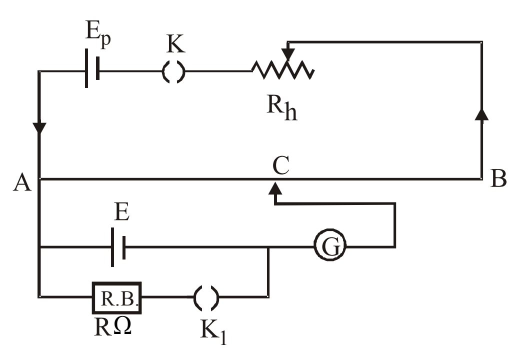


If two cells joined in series support each other (E_1 E_2)
then the balancing length is ℓ_1 so $E_1 + E_2 = x\ell_1$.

If two cells joined in series oppose each other (E_1 E_2)
then the balancing length is ℓ_2 so $E_1 - E_2 = x\ell_2$.

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{\ell_1}{\ell_2} \quad \text{or} \quad \frac{E_1}{E_2} = \frac{\ell_1 + \ell_2}{\ell_1 - \ell_2}$$

(c) Determination of internal resistance of cell



Keeping K_1 open the balancing length ℓ_1 gives emf of cell so $E = x\ell_1$.

Keeping K_1 closed the balancing length ℓ_2 for some resistance R gives potential difference so

$$V = x\ell_2 \; ; \; iR = x\,\ell_2$$

$$\frac{ER}{R+r} = \frac{E}{\ell_1}\ell_2 \; ; \; R + r = \frac{\ell_1}{\ell_2}R \; ; \; r = \left(\frac{\ell_1}{\ell_2} - 1\right)R$$

Example 37 :

The current flowing through the primary circuit is 2A and resistance per unit length is 0.2 Ω/m. If the potential difference across 10 ohm coil is balanced at 2.5 m then find current flowing through the coil.

Sol. The potential gradient $x = \frac{IR}{L} = 2 \times 0.2 = 0.4$ V/m

Unknown potential $V = x\ell = I'R$

so $$I' = \frac{x\ell}{R} = \frac{0.4 \times 2.5}{10} = 0.1\text{A}$$

Example 38 :

A uniform potential gradient is established across a potentiometer wire. Two cells of emf E_1 and E_2 connected to support and oppose each other are balanced over $\ell_1 = 6$m and $\ell_2 = 2$m. Find E_1/E_2.

Sol. $E_1 + E_2 = x\ell_1 = 6x$ and $E_1 - E_2 = 2x$

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{6}{2} \quad \text{or} \quad \frac{E_1}{E_2} = \frac{2}{1}$$

Example 39 :

In the primary circuit of a potentiometer a battery of 2V and a rheostat of 22Ω are connected. If the length of potentiometer wire is 10m and its resistance is 18Ω then find the potential gradient in wire.

Sol. The potential gradient

$$x = \left(\frac{E}{r + R + R_h + R_e}\right)\frac{R}{L} \; ; \; r = R_e = 0\Omega.$$

So $$x = \left(\frac{2}{0 + 18 + 22 + 0}\right)\frac{18}{10} = 0.09 \text{ V/m}$$

Example 40 :

No current flows if the terminals of a cell are joined with 125 cm length of potentiometer wire. If a 20Ω resistance is connected in parallel to cell balancing length is reduced by 25 cm. Find internal resistance of cell.

Sol. $$r = \frac{\ell_1 - \ell_2}{\ell_2} \times R = \frac{125 - 100}{100} \times 20 = 5\Omega$$

Example 41 :

The length of potentiometer wire is 40cm. Zero deflection in galvanometer is obtained at point F. Find the balancing length AF.

Sol. Let x be potential gradient and V_1 and V_2 be potential difference across 8Ω and 12Ω respectively.

$$\frac{V_1}{V_2} = \frac{8}{12} = \frac{x\ell}{x(40 - \ell)} \quad \text{or} \quad \frac{\ell}{40 - \ell} = \frac{2}{3} \quad \text{or} \quad \ell = 16 \text{ cm}$$

Example 42 :

If the current in the primary circuit of a potentiometer wire is 0.2 A, specific resistance of material of wire is 40×10^{-8} Ωm and area of cross-section is 0.8×10^{-6} m^2. Calculate potential gradient?

Sol. Potential gradient

$$x = \frac{V}{L} = \frac{IR}{L} = \frac{I\rho}{A} = \frac{0.2 \times 40 \times 10^{-8}}{0.8 \times 10^{-6}} = 0.1 \text{ volt/m}$$

TRY IT YOURSELF - 4

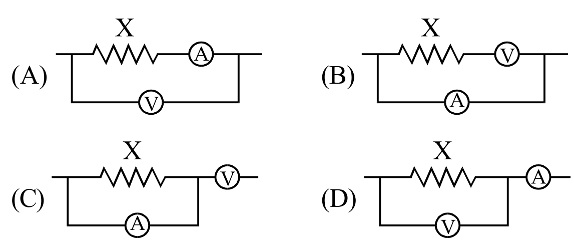
Q.1 An ammeter and a voltmeter are joined in series to a cell. Their readings are A and V respectively. If a resistance is now joined in parallel with the voltmeter,

(A) both A and V will increase
(B) both A and V will decrease
(C) a will decrease, V will increase
(D) A will increase, V will decrease

Q.2 A voltmeter and an ammeter are joined in series to an ideal cell, giving readings V and A respectively. If a resistance equal to the resistance of the ammeter is now joined in parallel to the ammeter,

(A) V will not change
(B) V will increase slightly
(C) A will become exactly half of its initial value
(D) A will become slightly more than half of its initial value.

Q.3 Which of the following is the most suitable arrangement for measuring the unknown resistance X which has resistance in the range 0 to 10Ω. Resistance of ammeter 1Ω, resistance of voltmeter 10kΩ.



Q.4 In the measurement of resistance by a meter bridge, the known and unknown resistances are interchanged to eliminate

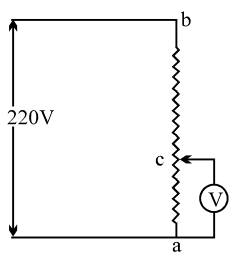
(A) index errors
(B) random errors
(C) end error
(D) error due to thermo-electric effect

Q.5 Two ammeters, 1 and 2, have different internal resistances: r_1(known) and r_2(unknown). Each ammeter has scale such that the angular deviation of the needle from zero is proportional to the current. Initially, the ammeters are connected in series and then to a source of constant voltage. The deviations of the needles of the ammeters are θ_1 and θ_2, respectively. The ammeters are then connected in parallel and then to the same voltage source. This time, the deviations of the needles are θ_1' and θ_2', respectively. r_2 in terms of r_1, θ_1, θ_2, θ_1' and θ_2' is

(A) $r_1 \dfrac{\theta_1\theta'_1}{\theta_2\theta'_2}$ (B) $r_1 \dfrac{\theta_2\theta'_1}{\theta_1\theta'_2}$

(C) $r_1 \dfrac{\theta_2\theta'_2}{\theta_1\theta'_1}$ (D) $r_1 \dfrac{\theta_1\theta_2}{\theta'_1\theta'_2}$

Q.6 A potential difference of 220 V is maintained across a 12000 ohm rheostat, as shown in the figure. The voltmeter has a resistance of 6000 ohm and point c is at one-fourth of the distance from a to b. Therefore the reading of the voltmeter will be

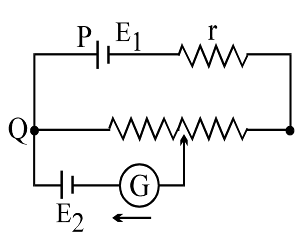


(A) 32 V (B) 36 V
(C) 40 V (D) 42 V

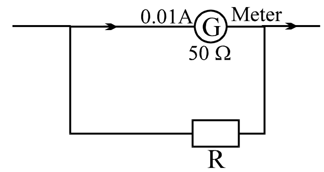
Q.7 A galvanometer of resistance 100 Ω contains 100 division. It gives a deflection of one division on passing a current of 10^{-4} A. Find the resistance in ohms to be connected to it, so that it becomes a voltmeter of range 10V.
(A) (500/9) Ω (B) 500 Ω
(C) (100/9) Ω (D) 900 Ω

Q.8 A galvanometer has a resistance of 96 Ω and full scale deflection of 100 μA. It can be used as ammeter provided a resistance is added to it. Pick up the correct range and resistance combination(s)
(A) 1.3 mA range with 25 KΩ resistance in parallel
(B) 1.3 mA range with 8 Ω resistance in parallel
(C) 2.5 mA range with 2.5 Ω resistance in parallel.
(D) 2.5 mA range with 4Ω resistance in parallel

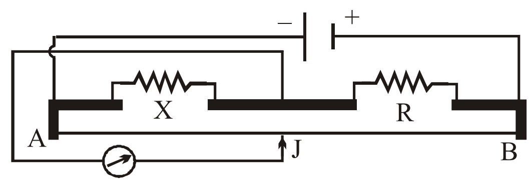
Q.9 In the potentiometer circuit of given figure the galvanometer reveals a current in the direction shown wherever the sliding contact touches the wire. This could be caused by
(A) E_1 being too low
(B) r being too high
(C) a break in PQ
(D) E_2 being too low



Q.10 The figure is a galvanometer (current for maximum deflection is 0.01 A & coil resistance is 50 Ω) is to be converted into an ammeter of range 0 – 8 A. Calculate the value of resistor R.
(A) 39950 Ω
(B) 15.98 Ω
(C) 0.160 Ω
(D) 0.062 Ω

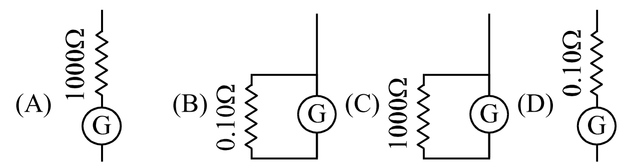


Q.11 The figure shows a meter-bridge circuit, X = 12 Ω and R = 18 Ω. The jockey J is at the null point. If R is made 8 Ω, through what distance will the jockey J have to be moved to obtain null point again.

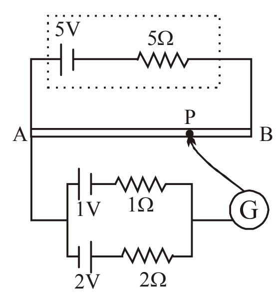


(A) 10 cm (B) 20 cm
(C) 30 cm (D) 40 cm

Q.12 A galvanometer with an internal resistance of 100 Ω will show a full scale deflection with a current of 10mA. Which of the following circuits would turn this galvanometer into an ammeter which will read 10A at full scale ?

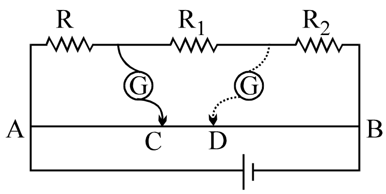


Q.13 A battery of emf ε_0 = 5V and internal resistance 5Ω is connected across a long uniform wire AB of length 1 m and resistance per unit length 5 Ωm^{-1}. Two cells of ε_1 = 1V and ε_2 = 2V are connected as shown in the figure.



(A) The null point is at A
(B) If the Jockey is touched to point B the current in the galvanometer will be going towards B
(C) When Jockey is connected to point A no current is flowing through 1 V battery
(D) The null point is at distance of 8/15 m from A.

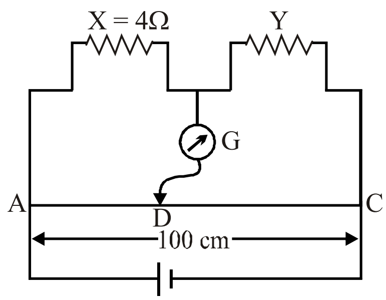
Q.14 The diagram shows a modified meter bridge, which is used for measuring two unknown resistance at the same time. When only the first galvanometer is used, for obtaining the balance point, it is found at point C. Now the first galvanometer is removed and the second galvanometer is used, which gives balance point at D. Using the details given in the diagram, find out the value of R_1 and R_2.



AB=L; AC=L/4 and AD=2L/3

(A) $R_1 = 5R/3$ (B) $R_2 = 4R/3$
(C) $R_1 = 4R/3$ (D) $R_2 = 5R/3$

Q.15 Figure shows a metre bridge, wire AC has uniform cross-section. The length of wire AC is 100 cm. X is a standard resistor of 4Ω and Y is a coil. When Y is immersed in melting ice the null point is at 40 cm from point A. When the coil Y is heated to 100°C, a 78 Ω resistor has to be connected in parallel with Y in order to keep the bridge balanced at the same point.



Temperature coefficient of resistance of the coil is :
(A) $6.3 \times 10^{-4}\, K^{-1}$ (B) $4.3 \times 10^{-4}\, K^{-1}$
(C) $8.3 \times 10^{-4}\, K^{-1}$ (D) $2.3 \times 10^{-4}\, K^{-1}$

Q.16 The wire of the potentiometer has resistance 4 ohms and length 80 cm . It is connected to a cell of e.m.f. 2 volts and internal resistance 1 ohm . If a cell of e.m.f. 1 volts is balanced by it, the balancing length will be :
(A) 40 cm (B) 50 cm
(C) 60 cm (D) 70 cm

ANSWERS

(1) (D)	**(2)** (BD)	**(3)** (D)
(4) (C)	**(5)** (B)	**(6)** (C)
(7) (D)	**(8)** (BD)	**(9)** (ABC)
(10) (D)	**(11)** (B)	**(12)** (B)
(13) (AB)	**(14)** (AB)	**(15)** (C)
(16) (B)		

HEATING EFFECT OF CURRENT

Cause of heating : The potential difference applied across the two ends of conductor sets up electric field. Under the effect of electric field, electrons accelerate and as they move, they collide against the ions and atoms in the conductor, the energy of e^- transferred to the atoms and ions appears as heat.

Joule's law of heating : When a current I is made to flow through a resistance R for time t, heat Q is produced such

that $Q = I^2Rt$; $Q = P \times t = VIt = \frac{V^2}{R}t$

Heat produced in conductor does not depend upon the direction of current.

SI unit : Joule ; Practical units : 1 kilowatt hour (kWh)
1 kWh = 3.6×10^6 joule = 1 unit
1 BTU (British thermal unit) = 1055 J
1 kWh = 1 B.O.T.U. (Board of Trade Unit) = 3412 BTU

Power : $P = VI = \frac{V^2}{R} = I^2R$, SI unit : Watt

The watt-hour meter placed on the premises of every consumer records the electrical energy consumed.

Rated power (of an electric device) : The voltage of operation needed is known as the rated voltage and the corresponding power consumed is called as the rated power. Suppose, R is the electrical resistance of an electric device, with V_r and P_r its is rated voltage and wattage

respectively. Clearly, $P_r = \frac{V_r^2}{R}$ .... (1)

Now, if the device is subjected to a voltage of V, then, the power consumption P will be

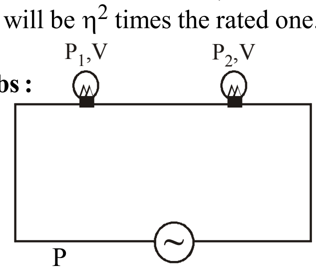
$$P = \frac{V^2}{R} \quad .... (2)$$

The resistance R being the property of the electric device, is independent of the applied voltage.

Dividing eq. (2) by eq. (1), $P = \left(\frac{V}{V_r}\right)^2 P_r$

Thus, if the voltage be η times the rated one, then the actual power consumption will be η^2 times the rated one.

Series combination of bulbs :
Total power consumed



$P_{total} = \frac{P_1P_2}{P_1 + P_2}$

If n bulbs are identical $P_{total} = \frac{P}{n}$

In series combination of bulbs Brightness

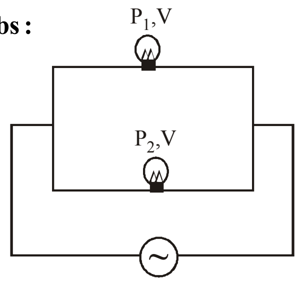
$\propto$ Power consumed by bulb $\propto V \propto R \propto \frac{1}{P_{rated}}$

Bulb of lesser wattage will shine more

For same current $P = I^2R$

$P \propto R \; R \uparrow \Rightarrow P \uparrow$

Parallel combination of bulbs :



Total power consumed

$P_{total} = P_1 + P_2$

If n bulbs are identical

$P_{total} = nP$

In parallel combination of bulbs Brightness

$\propto$ Power consumed by bulb

$\propto I \propto 1/R$

Bulb of greater wattage will shine more

For same V more power will be consumed in smaller resistance $P \propto 1/R$.

Note :

1. Two identical heater coils gives total heat H_S when connected in series and H_P when connected in parallel than

$\frac{H_P}{H_S} = 4$ [In this, it is assumed that supply voltage is same]

2. If a heater boils m kg water in time T_1 and another heater boils the same water in T_2, then both connected in series will boil the same water in time $T_s = T_1 + T_2$ and if in parallel

$T_p = \frac{T_1T_2}{T_1 + T_2}$ [Use time taken $\propto$ Resistance]

3. Instruments based on heating effect of current, works on both A.C. and D.C. Equal value of A.C. (RMS) and D.C. produces, equal heating effect. Thats why brightness of bulb is same whether it is operated by A.C. or same value D.C.

Electric fuse : Commercially it is a device employed to save the different electrical appliances used in a house such as fan, bulb, T.V., tape recorder etc. in circumstances of abrupt increase of currents entering through the main supply. The usual currents supposed to activate household appliances lies within 0-5.0 A. An electric fuse consists of a simple wire made of an alloy of tin and lead, having low melting point and high resistivity.

Let a fuse wire be of length ℓ and radius r, made of a substance of resistivity ρ.

If i be the current passing through the fuse wire, then the rate of heat generation will be $\frac{dH}{dt} = i^2R = i^2\left(\frac{\rho\ell}{\pi r^2}\right)$

The heat dissipated to the surrounding varies directly as the surface area of the wire. If P be the thermal power generated per unit area, then the total rate of heat loss is

$$\frac{dE}{dt} = P(2\pi r\ell)$$

In the steady state the rate of heat generated due to Joule's effect becomes equal to the rate of heat loss to the surrounding.

$$i^2\left(\frac{\rho\ell}{\pi r^2}\right) = P(2\pi r\ell) \quad \text{or} \quad i = \left[\frac{P(2\pi^2r^3)}{\rho}\right]^{1/2}$$

Example 43 :

An electric heater and an electric bulb are rated 500W, 220V and 100W, 220V respectively. Both are connected in series to a 220V a.c. mains. Calculate power consumed by (i) heater (ii) bulb.

Sol. $P = \frac{V^2}{R}$ or $R = \frac{V^2}{P}$

For heater resistance, $R_h = \frac{(220)^2}{500} = 96.8\,\Omega$

For bulb resistance, $R_L = \frac{(220)^2}{100} = 484\,\Omega$

Current in the circuit when both are connected in series

$$I = \frac{V}{R_L + R_h} = \frac{220}{484 + 96.8} = 0.38\text{ A}$$

(i) Power consumed by heater

$= I^2R_h = (0.38)^2 \times 96.8 = 13.98\text{ W}$

(ii) Power consumed by bulb

$= I^2R_L = (0.38)^2 \times 484 = 69.89\text{ W}$

Example 44 :

How much time heater will take to increase the temperature of 100g water by 50°C if resistance of heating coil is 484Ω and supply voltage is 220V a.c.

Sol. Heat given by heater = heat taken by water

$\Rightarrow \frac{V^2}{R}t = ms\,J\Delta\theta \Rightarrow \frac{220 \times 220}{484}t$

$= (100 \times 10^{-3})(4.2 \times 10^3)(50)$

$\Rightarrow t = 210$ sec.

Example 45 :

Forty electric bulbs are connected in series across a 220V 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 ?

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

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

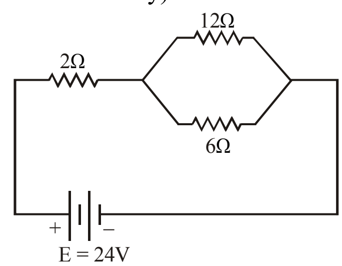
When one of the bulbs is fused, the resistance of the remaining 39 bulbs in series = 39r and the power of the system when connected to the same supply

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

$\therefore$ Power of 39 bulbs in series is greater.

Example 46 :

Find the heat generated in each of the resistors shown in fig. in a time interval of 1 hour. (Ignore the internal resistance of the battery)



Sol. The resistances 12Ω and 6Ω are connected in parallel, having an equivalent resistance of

$$\frac{(12\Omega)\,(6\Omega)}{(12+6)\,\Omega}=4\Omega$$

This 4Ω resistance is in series with the 2Ω resistance yielding an equivalent resistance of $4\Omega + 2\Omega = 6\Omega$.

$\therefore$ Current drawn from the battery $=\dfrac{24V}{6\Omega}=4A$

$\therefore$ Heat produced in the 2Ω resistance is,

$H=i^2Rt=(4A)^2\,(2\Omega)\,(3600\text{ s})=115.2\text{ kJ}$

Since 12Ω and 6Ω resistors are in parallel, hence the total current of 4A gets distributed in them in the inverse ratio of their respectively resistances.

$\therefore$ Current through the 12Ω and 6Ω resistances will be respectively.

$$4A\left(\frac{6\Omega}{12+6\Omega}\right)=1.33\text{ A} \quad \text{and} \quad 4A\left(\frac{12\Omega}{12+6\Omega}\right)=2.67\text{ A}$$

The heat generated in the 12Ω resistor will be

$H=i^2Rt=(1.33\text{ A})^2\,(12\Omega)\,(3600\text{ s})=76.4\text{ kJ}$

and heat generated in the 6Ω resistor will be

$H=(2.67A)^2\,(6\Omega)\,(3600\text{ s})=154\text{ kJ}$

Example 47 :

Two bulbs A and B each with a rated voltage of 220V, have rated powers of 25W and 100W respectively. They are connected in series across a voltage supply of 440V. Find, which of the two bulbs will fuse.

Sol. The ratio of resistances of the bulbs A and B is,

$$\frac{R_A}{R_B}=\frac{(P_r)_B}{(P_r)_A}=\frac{100}{25}=\frac{4}{1}$$

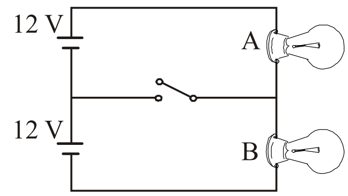
Since, the two bulbs are in series, so the voltage across the two will be in direct proportion to their respective resistances. $V_A=\left(\dfrac{4}{4+1}\right)440V=352\text{ V}$

and $V_B=\left(\dfrac{1}{4+1}\right)440V=88\text{ V}$

The voltage across the bulb A exceeds the rated voltage and hence it will fuse.

TRY IT YOURSELF - 5

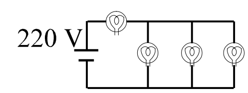
Q.1 Two light bulbs shown in the circuit have ratings A (24 V, 48 W) and B (24 V and 36 W) as shown. When the switch is closed.



(A) the intensity of light bulb A decreases & of B increases
(B) the intensity of light bulb A as well as B increases.
(C) the intensity of light bulb A as well as B decreases
(D) the intensity of light bulb A increases & of B decreases

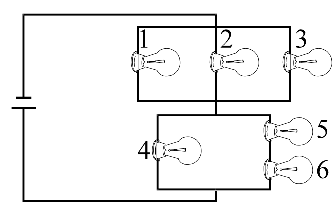
Q.2 Two wires A and B of same material and mass, have their lengths in the ratio 1:2. On connecting them, one at a time to the same source of potential, the rate of heat dissipation in B is found to be 5 W. What is the rate of heat dissipation in A.
(A) 40W (B) 20W
(C) 10W (D) 100W

Q.3 Four identical bulbs each rated 100 watts, 220 volts are connected across a battery as shown. The power consumed by them is:



(A) 75 watt
(B) 400 watt
(C) 300 watt
(D) 400/3 watt

Q 4 Six identical light bulbs are connected to a battery to form the circuit shown. Which light bulb(s) glow the brightest?



(A) 1, 2 and 3 (B) 5 and 6
(C) 1, 2, 3 and 4 (D) 4 only

FOR Q 5-7

A car battery with a 12 V emf and an internal resistance of 0.04 Ω is being charged wtih a current of 50 A

Q.5 The potential difference V across the terminals of the battery are
(A) 10 V (B) 12 V
(C) 14 V (D) 16 V

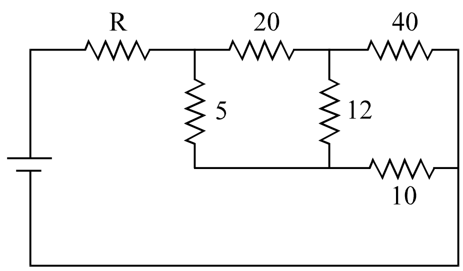
Q.6 The rate at which energy is being dissipated as heat inside the battery is:
(A) 100 W (B) 500 W
(C) 600 W (D) 700 W

Q.7 Rate of energy conversion from electrical to chemical is:
(A) 100 W (B) 500 W
(C) 600 W (D) 700 W

Q.8 The same mass of copper is drawn into two wires A and B or radii r and 3r respectively. They are connected in series, and electric current is passed. The ratio of the heat produced in A and B is
(A) 1 : 9 (B) 1 : 81
(C) 81 : 1 (D) 9 : 1

Q.9 The wattage rating of a light bulb indicates the power dissipated by the bulb if it is connected across 110V DC potential difference. If a 50W and 100 W bulb are connected in series to a 110V DC source, how much power will be dissipated in the 50W bulb.
(A) 50 W (B) 100 W
(C) 22 W (D) 11 W

Q.10 What should be the value of R so that the electric power consumed by it is maximum:



(A) 12 Ω (B) 24 Ω
(C) 6 Ω (D) none of these

ANSWERS

(1) (D)	**(2)** (B)	**(3)** (A)
(4) (D)	**(5)** (C)	**(6)** (A)
(7) (C)	**(8)** (C)	**(9)** (C)
(10) (A)		

USEFUL TIPS

* Average current $I_{av} = \frac{\Delta Q}{\Delta t}$

* Instantaneous current

$$I_{in} = \frac{dQ}{dt} \quad (\because Q = \int I \cdot dt)$$

* Due to rotatory motion of charge $I = \frac{qv}{2\pi R}$
where, v = tangential speed, R = radius of the circle)

* $EMF = \frac{\text{Work done}}{\text{charge}}$

* $V = IR$ (R = resistance)

* Dynamic resistance $R = \frac{dV}{dI}$

* Resistance (R) of a conductor of length L and uniform cross-section area A is $R = \frac{\rho L}{A}$.
(ρ = resistivity of the conductor)

* Electrical conductivity $\sigma = \frac{1}{\rho}$

* Conductance $G = \frac{1}{\text{Resistance}}$ 1 (unit: siemen)

* Drift velocity $v_d = \frac{e\tau E}{m}$
(τ = relaxation time, m = mass of electron, E = electric field, e = electronic charge)

* $I = nev_dA$

* Current density vector $\vec{J} = \frac{I}{A}$ $(\because i = \int \vec{J} \cdot d\vec{A})$

$$\therefore \quad \vec{J} = ne\vec{v}_d$$

* $\rho = \frac{m}{ne^2\tau}$; $\vec{J} = \sigma\vec{E}$; $\vec{E} = \rho\vec{J}$; $\mu = \frac{\vec{v}_d}{E} = \frac{e\tau}{m} \cdot \sigma = ne\mu$

* Temperature dependence of resistivity
$\rho = \rho_0 [1 + \alpha_\rho T]$ (ρ_0 and α_p are constants,
α_p : thermal coefficient of resistivity)
For small temperature changes $\rho_T = \rho_0 [1 + \alpha_\rho (T - T_0)]$
Resistance also follows the same dependence on temperature i.e. $R = R_0 [1 + \alpha_R T]$ and
$R_T = R_0 [1 + \alpha_R (T - T_0)]$
(α_R : thermal coefficient of resistance)

* In case of a cell getting discharged (current coming out), terminal voltage across it is
$V = E - Ir$ (ε = emf; r = internal resistance).

* In case of charging of a cell (current going in)
$V = E + Ir$

* In Meter Bridge (Based on Wheatstone Bridge) the unknown resistance $X = \frac{R\ell}{(100 - \ell)}$
(R = known resistance, I = balancing length)

* In potentiometer

(i) $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$ (comparison of EMF)

(ii) $E = \frac{\ell V_S}{L}$ (absolute value of EMF)

(iii) $r = \left(\frac{\ell_1}{\ell_2} - 1\right) R$ (internal resistance of cell measured)

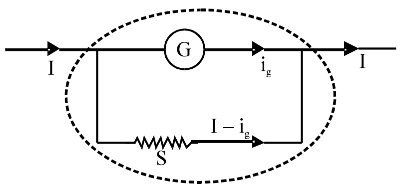
* The sensitivity of a potentiometer is increased by decreasing potential gradient along the potentiometer wire.

* For a cylindrical wire resistance $R \propto (\text{length})^2$;

$R \propto \frac{1}{(\text{radius})^4}$, $R \propto \frac{1}{(\text{cross section area})^2}$

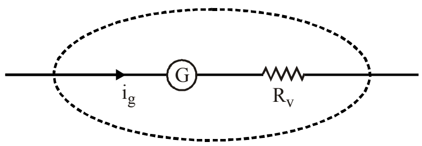
* A galvanometer is converted into an ammeter by connecting a very small resistance (called shunt) in parallel to the galvanometer. Same method is used to increase the range of an ammeter. If the range of an ammeter is to be increased N times then a small resistance

$S = \frac{R_A}{N-1}$ is connected in parallel to the ammeter (R_A : resistance of the ammeter).



* Shunting of a galvanometer decreases its sensitivity.

* A galvanometer is converted into a voltmeter by connecting a very large resistance in series to it. If the range of a voltmeter is to be increased N times then a resistance $R = (N-1) R_V$ is connected in series to the voltmeter (R_V = resistance of the voltemeter).



* Human body, though has a large resistance of the order of 10 kΩ is very sensitive to minute currents even of the order of 1 mA. Electrocution produces disorders in the nervous system of the body and hence one fails to control the movement of the body. It is incorrect to say that an electrocuted person gets stuck to the electric line. Actually due to loss of nervous control an electrocuted person can't get rid of the electric line. The cause of death in electrocution is not the heating effects of current rather its interferance with the current of nervous system which makes heart beat irregular and cease.

* Tungsten is used in bulb mainly because it has very high melting point (3380°C). Low resistivity of it is the secondary consideration.

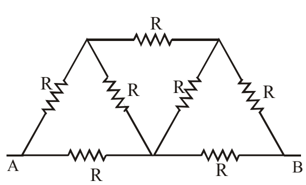
* Nichrome alloy is used in heating devices because it is much cheaper then tungsten. Even if it has lower melting point (800°C) it works well as heating devices.

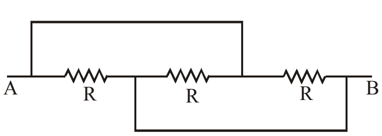
* In series connection a bulb of less wattage will give light more than the bulb of greater wattage.

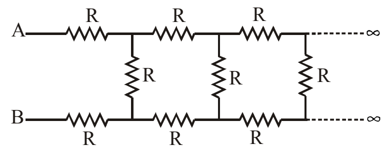
* When a (40 W, 220 V) and a (100 W, 220 V) bulbs are connected in series to a 440 V supply then 40 W bulb will fuse.

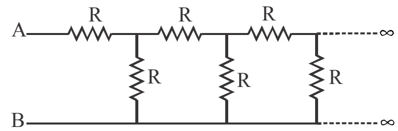
* Long distance power transmission is done at higher voltage to keep the current and power losses low.

* **Equivalent resistance of some typical circuits**

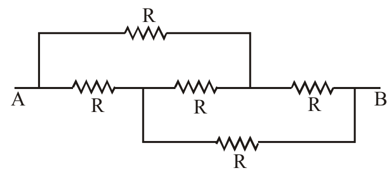
(a)  $R_{AB} = \frac{8}{7}R$

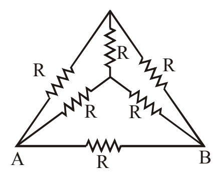
(b)  $R_{AB} = \frac{R}{3}$

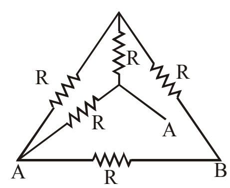
(c)  $R_{AB} = R(\sqrt{3}+1)$

(d) 

$R_{AB} = \frac{R}{2}(1+\sqrt{5})$

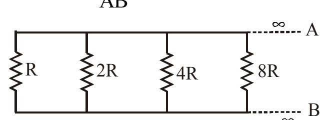
(e)  $R_{AB} = R$

(f)  $R_{AB} = \frac{R}{2}$

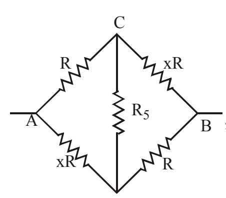
(g)  $R_{AB} = R$

(h) 

$R_{AB} = 2R$

(i) 

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

(j) 

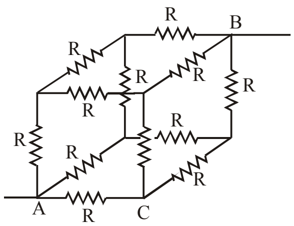
, If $x = 0$, $R_{AB} = \frac{R}{3}$

For $x \neq 0$ and $x = 1, 2, 3, ...$

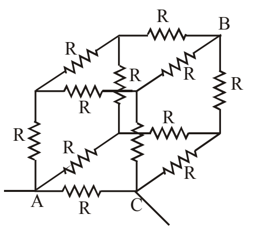
$R_{AB} = \frac{(3x+1)R}{(x+3)}$. If $x = 1$, $R_{AB} = \frac{(3+1)R}{(1+3)} = R$, become balanced Wheatstone's bridge.

If $x = 2$, $R_{AB} = \frac{7}{5}R$, if $x = 3$, $R_{AB} = \frac{5}{3}R$

If $x = \infty$, $R_{AB} = 3R$

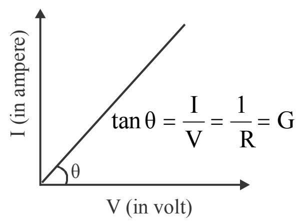
(k) 

$R_{AB} = \frac{5}{6}R$

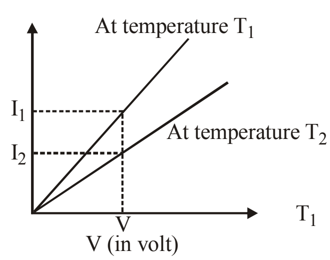
(*l*) 

$R_{AC} = \frac{7}{12}R$

* **Some important graphs**

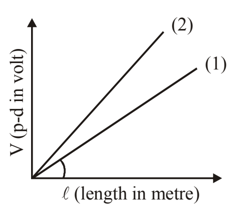
(a) 

VI graph for Ohmic resistor

(b) 

$T_1 < T_2$
$R_1 < R_2$
$I_1 > I_2$ for same V

VI graph for metallic conductor at temperature T_1 and T_2.

(c) 

V - ℓ Characteristic of potentiometer

Sensitivity $= \frac{\ell}{V} = \cot\theta$

Potential gradient $\frac{V}{\ell} = \tan\theta$

ADDITIONAL EXAMPLES

Example 1 :

In case of hydrogen atom an electron moves in an orbit of radius 5×10^{-11} m with a speed of 2.2×10^6 m/s. Calculate equivalent current.

Sol. The equivalent current

$$I = \frac{qv}{2\pi r} = \frac{1.6\times10^{-19}\times2.2\times10^{6}}{2\times3.14\times5\times10^{-11}} = 1.12 \text{ mA}$$

Example 2 :

How many electrons flow through the filament of a 120 volt, 60 W electric lamp in one second?

Sol. Electric current $I = \frac{\text{Power}}{\text{voltage}}$ or $I = \frac{60}{120} = 0.5$ A

$$n = \frac{I.t}{e} = \frac{0.5\times1}{1.6\times10^{-19}} = 3.125\times10^{18}$$

Example 3 :

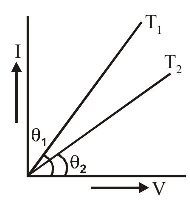
A potential difference V is applied to a copper wire of diameter d and length L. What is effect on drift speed when V, L and d are doubled?

Sol. Drift velocity $v_d = \frac{eE}{m}\tau = \frac{eV}{mL}\tau$

As $v_d \propto V$ so on doubling V drift velocity is doubled.
As $v_d \propto 1/L$ so on doubling L drift velocity is halved.
As v_d is independent of d so no change on doubling the diameter.

Example 4 :

The I-V curves at two different temperatures T_1 and T_2 are shown. (a) Is the specimen ohmic (b) At which temperature is resistance higher and (c) which temperature is greater?



Sol. **(a)** I-V curve is linear and passes through origin so specimen is ohmic

(b) $R = \frac{V}{I} = \frac{1}{\tan\theta}$.

From graph $\theta_1 > \theta_2$ so $\tan\theta_1 > \tan\theta_2$ or $R_1 < R_2$.
The resistance R_2 at temperature T_2 is greater.

(c) The resistance increases with temperature so $T_2 > T_1$ because $R_2 > R_1$.

Example 5 :

If a copper wire is stretched to make it 0.1% longer what is percentage change in its resistance.

Sol. $R = \frac{\rho L}{A} = \frac{\rho L^2}{V}$ taking log we get

$\log R = \log\rho + 2\log L - \log V$

differentiating we get $\frac{\Delta R}{R} = \frac{2\Delta L}{L} = 2(0.1\%) = 0.2\%$.

The resistance increases by 0.2%.

Example 6 :

At what temperature would the resistance of a copper conductor be doubled of its value at 0°C. Does this same temperature hold for all copper conductors regardless of . . . . $\alpha_{Cu} = 4.0 \times 10^{-3}/°C$.

Sol. $R = R_0(1 + \alpha\Delta\theta)$

so $\frac{R_2}{R_1} = \frac{R_0[1+\alpha(t_2-0)]}{R_0[1+\alpha(t_1-0)]} = \frac{1+\alpha t_2}{1+\alpha t_1}$

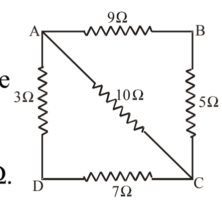
Given $R_2 = 2R_1$ and $t_1 = 0$

so $2 = 1 + \alpha t_2$ or $t_2 = \frac{1}{\alpha} = \frac{1}{4\times10^{-3}} = 250°C$

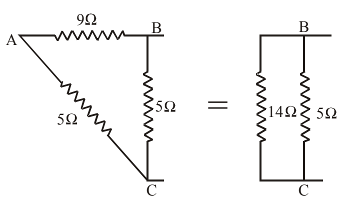
Here $t_2 = \frac{1}{\alpha}$ does not include dimensions of conductor so it is valid for all copper conductors of all shape and size.

Example 7 :

Five resistors are connected as shown. Find equivalent resistance between the points B and C.



Sol. Resistance of arm ADC = 3 + 7 = 10Ω.



This is in parallel to 10Ω of arm AC. Their parallel combination gives equivalent resistance of 5Ω.
So effective resistance between B and C

$$R_{eq} = \frac{14\times5}{14+5} = \frac{70}{19} = 3.684\Omega$$

Example 8 :

When two resistances are joined in series their resistance is 40Ω and when they are joined in parallel the resistance is 7.5Ω. Find the individual resistances?

Sol. Let the two resistances be R_1 and R_2

When connected in series $R_1 + R_2 = 40$ ....(1)

When connected in parallel $\frac{R_1R_2}{R_1+R_2} = 7.5$

so $R_1R_2 = 7.5 \times 40 = 300$

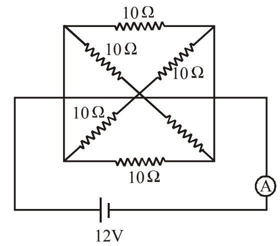
$(R_1 - R_2)^2 = (R_1+R_2)^2 - 4R_1R_2 = 40^2 - 4\times300 = 400$

So $R_1 - R_2 = 20\,\Omega$ ....(2)

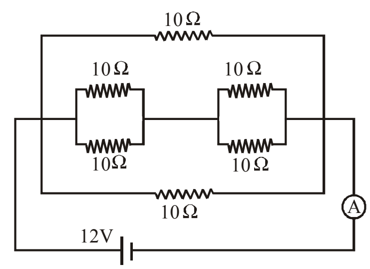
Solving 1 and 2 we have $R_1 = 30\,\Omega$ and $R_2 = 10\,\Omega$.

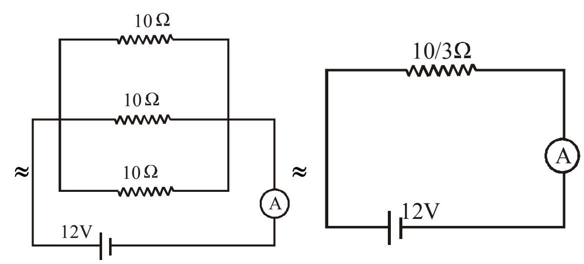
Example 9 :

Calculate the current shown by ammeter A in the circuit shown in fig.



Sol. The equivalent circuits can be drawn as





The equivalent resistance of circuit is $R_{eq} = \frac{10}{3}\Omega$

The current $I = \frac{E}{R_{eq}} = \frac{12}{10/3} = 3.6\ A$

Example 10 :

How will you connect 24 cells each of internal resistance 1Ω so as to get maximum power output across a load of 10Ω?

Sol. For maximum power output $\frac{R}{n} = \frac{r}{m}$ and $n \times m = p = 24$

So $R = \frac{n}{m}r = \frac{pr}{m^2}$ or $m^2 = \frac{pr}{R} = \frac{24\times1}{10}$

or $m = \sqrt{2.4} = 1.56$

(a) If m = 1 then $n = \frac{p}{m} = 24$

so $P_1 = \frac{RE^2}{\left(\frac{R}{n}+\frac{r}{m}\right)^2} = \frac{10E^2}{\left(\frac{10}{24}+1\right)^2} = 5E^2$

(b) If m = 2 then $n = \frac{p}{m} = \frac{24}{2} = 12$

so $P_2 = \frac{10E^2}{\left(\frac{10}{12}+\frac{1}{2}\right)^2} = 5.6E^2$

So to get maximum output power cells must be arranged in two rows having 12 cells in each row.

Example 11 :

Three identical cells each of emf 2V and unknown internal resistance are connected in parallel. This combination is connected to a 5Ω resistor. If the terminal voltage across the cells is 1.5 V, what is internal resistance of each cell.

Sol. In parallel combination of three cells $I = \frac{E}{R + r/3}$

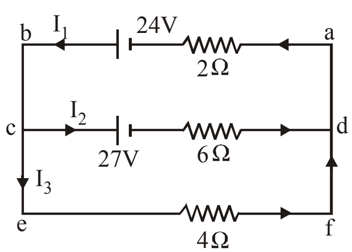
Terminal potential difference

$V = IR = \frac{ER}{R + r/3}$ or $\frac{r}{3} = \frac{ER - RV}{V}$

or $r = 3\left(\frac{ER - RV}{V}\right) = 3\left(\frac{2 \times 5 - 5 \times 1.5}{1.5}\right) = 5\Omega$

Example 12 :

Determine currents I_1, I_2 and I_3?



Sol. Using II law in loop abcda

$-2I_1 + 24 - 27 - 6I_2 = 0$

or $2I_1 + 6I_2 = -3$ ......(1)

Using II law in loop cdfec we get

$-27 - 6I_2 + 4I_3 = 0$

or $-6I_2 + 4I_3 = 27$ ......(2)

From junction rule at c we get

$I_1 = I_2 + I_3$ ......(3)

From 2 and 3 we get

$-6I_2 + 4(I_1 - I_2) = 27$

or $4I_1 - 10I_2 = 27$ ......(4)

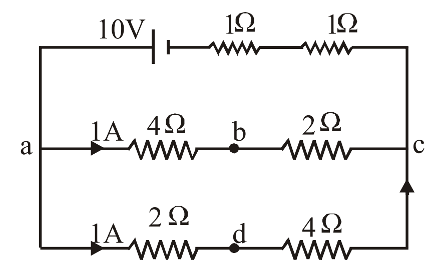
Solving 1 and 4 we get

$I_1 = 3A, I_2 = -1.5\,A$ so $I_3 = I_1 - I_2 = 4.5\,A$

Negative I_2 means the direction should have been opposite to shown in figure.

Example 13 :

Calculate potential difference between points d and b in the circuit.



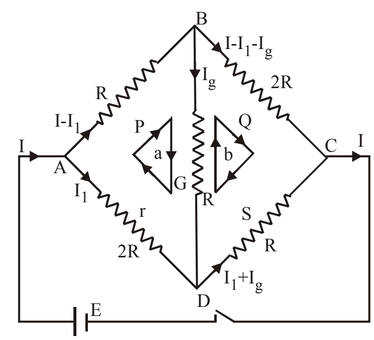
Sol. Using voltage rule from b to d via c we get

$V_b - 1 \times 2 + 4 \times 1 = V_d$

or $V_d - V_b = 2$ volt.

Example 14 :

Calculate effective resistance between A and C?



Sol. Here $\frac{P}{Q} = \frac{R}{2R} = \frac{1}{2}$ and $\frac{r}{S} = \frac{2R}{R} = \frac{2}{1}$

So $\frac{P}{Q} \neq \frac{r}{S}$ so bridge is unbalanced

Applying Kirchhoff's law to

Loop a $-(I - I_1)R - I_g R + I_1 \times 2R = 0$

or $3I_1 - I_g = I$ ......(1)

Loop b $-(I - I_1 - I_g)\,2R + (I_1 + I_g)\,R + I_g R = 0$ or

$3I_1 + 4I_g = 2I$ ......(2)

Solving 1 and 2 we get $I_1 = \frac{2I}{5}$ and $I_g = I/5$

If R_{eq} is equivalent resistance between AC then

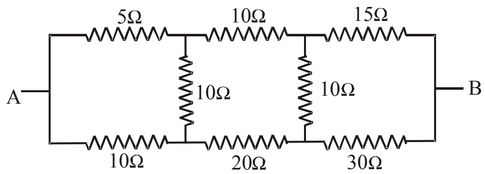
$V = I R_{eq} = I_1 \times 2R + (I_1 + I_g) R$

$= \frac{4}{5}IR + \frac{3}{5}IR = \frac{7}{5}IR$

so $R_{eq} = \frac{7}{5}R$

Example 15 :

Calculate the effective resistance between A and B in following network.



Sol. Ratio of upper resistances 5 : 10 : 15 = 1 : 2 : 3

Ratio of lower resistances 10 : 20 : 30 = 1 : 2 : 3

The ratio is same so resistance in middle are nonuseful.

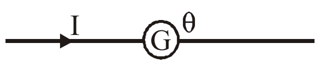
Equivalent resistance = (5 + 10 + 15) || (10 + 20 + 30)

$$\text{So } R_{eq} = \frac{30 \times 60}{30 + 60} = 20\,\Omega$$

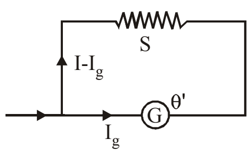
Example 16 :

If a shunt of resistance G/n is connected to a galvanometer then find change in current sensitivity?

Sol. The current sensitivity of a galvanometer, $I_S = \theta/I$



Current sensitivity of a shunted galvanometer $I'_S = \theta'/I$



$$I \propto \theta \text{ and } I_g \propto \theta', \text{ So } \frac{I_g}{I} = \frac{\theta'}{\theta}$$

$$I'_S = \frac{\theta'}{I} = \frac{1}{I}\frac{I_g}{I}\theta = \frac{I_g}{I}\left(\frac{\theta}{I}\right) = \frac{I_g}{I} I_S$$

For shunted galvanometer $(I - I_g)\,S = I_g G$

$$\text{or } \quad (I - I_g)\frac{G}{n} = I_g G \quad \text{so} \quad I_g = \frac{I}{1+n}$$

$$I'_S = \left(\frac{I_g}{I}\right) I_S = \frac{I_S}{1+n}$$

This shows that $I'_S < I_S$

The current sensitivity is reduced by shunting of galvanometer.

Example 17 :

A galvanometer of resistance 12 Ω shows full scale deflection for a current of 2.5 mA. How will you convert it to ammeter of range 7.5 A and voltmeter of range 10 volt. Find resistance of meter.

Sol. Shunt resistance required for ammeter

$$S = \frac{I_g}{I - I_g} G = \frac{2.5 \times 10^{-3}}{7.5 - 2.5 \times 10^{-3}} \times 12 = 4\text{m}\Omega$$

Resistance of ammeter, $\dfrac{1}{R_a} = \dfrac{1}{G} + \dfrac{1}{S}$

$$\text{or} \quad R_a = \frac{GS}{G+S} = \frac{4 \times 10^{-3} \times 12}{4 \times 10^{-3} + 12} = 4\text{m}\Omega$$

Series resistance required for voltmeter

$$R = \frac{V}{I_g} - G = \frac{10}{2.5 \times 10^{-3}} - 12 = 3988\,\Omega$$

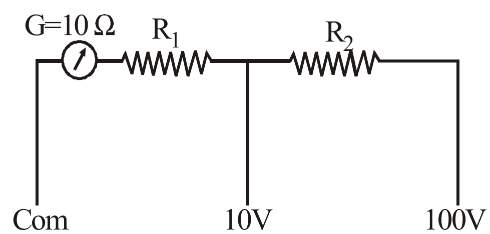
Resistance of voltmeter

$R_V = R + G = 3988 + 12 = 4000\,\Omega$.

Example 18 :

A galvanometer whose resistance is 10Ω is converted to a voltmeter of range 10V and 100V by connecting resistances R_1 and R_2 in series. if I_g = 10 mA find R_1 and R_2.

Sol. The potential difference across $G + R_1$ is 10 volt.



So $I_g(G + R_1) = 10$ or $10 \times 10^{-3}(10 + R_1) = 10$

or $R_1 = 990\,\Omega$.

The potential difference across $G + R_1 + R_2$ is 100 volt

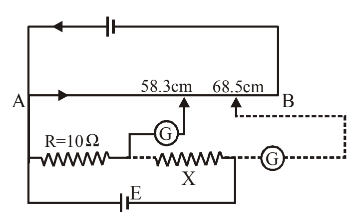
So $I_g(G + R_1 + R_2) = 100$

or $10 \times 10^{-3}(10 + 990 + R_2) = 100$

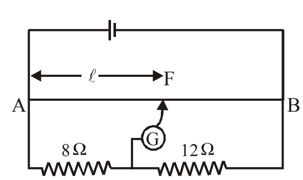
or $R_2 = 9000\,\Omega$.

Example 19 :

Figure shows use of potentiometer for comparison of two resistances. The balance point with standard resistance R = 10Ω is at 58.3 cm, while that with unknown resistance X is 68.5 cm. Find X.



Sol.



Let E_1 and E_2 be potential drops across R and X so

$$\frac{E_2}{E_1}=\frac{IX}{IR}=\frac{X}{R} \quad \text{or} \quad X=\frac{E_2}{E_1}R$$

$$\text{But } \frac{E_2}{E_1}=\frac{\ell_2}{\ell_1} \quad \text{so} \quad X=\frac{\ell_2}{\ell_1}R=\frac{68.5}{58.3}\times 10=11.75\Omega$$

Example 20 :

A battery of emf 2V is connected in series with a resistance box and a 10m long potentiometer with resistance 1Ω/m. A 10 mV potential difference is balanced across the entire length of wire. Calculate the current flowing in wire and resistance in resistance box.

Sol. Potential gradient

$$x=\frac{E}{r+R+R_e}\left(\frac{R}{L}\right)=\frac{2}{0+10+R_e}\times 1=\frac{2}{10+R_e}$$

Potential difference $V = x\ell$

$$\text{or} \quad 10\times 10^{-3}=\frac{2}{10+R_e}\times 10 \quad \text{or} \quad R_e=1990\,\Omega.$$

$$\text{Current flowing } I=\frac{E}{R+R_e}=\frac{2}{10+1990}=1\text{mA}$$

Example 21 :

While measuring the potential difference between the terminals of a resistance wire the balance point is obtained at 78.4 cm. The same potential difference is measured as 1.2 V with voltmeter. If standard cell of emf 1.018 V is balanced at 63.2 cm then find error in reading of voltmeter.

Sol. $E_0 = x\ell_0$ and $V = x\ell$ or $V=\frac{E_0}{\ell_0}\ell$

$$V=\frac{1.018\times 78.4}{63.2}=1.26\text{ volt}. \text{ So error} = 1.2-1.26=-0.06\text{V}$$

Example 22 :

A heater coil is rated 100W, 200V. It is cut into two identical parts. Both parts are connected together in parallel, to the same source of 200V. Calculate the energy liberated per second in the new combination.

Sol. $\because\ P=\frac{V^2}{R} \quad \therefore\ R=\frac{V^2}{P}=\frac{(220)^2}{100}=400\Omega$

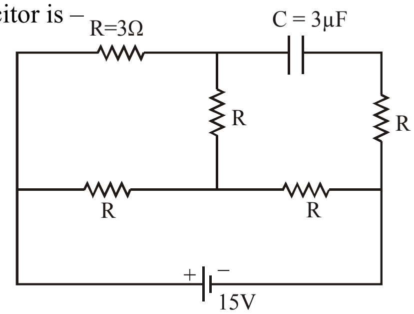
Resistance of half piece = 400/2 = 200Ω

$$\text{Resistance of pieces connected in parallel}=\frac{200}{2}=100\Omega$$

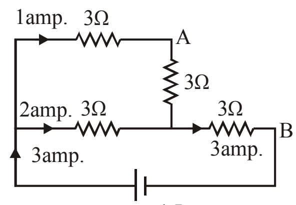
$$\text{Energy liberated/second}=P=\frac{V^2}{R}=\frac{200\times 200}{100}=400\text{W}$$

Example 23 :

In the circuit shown, the cell is ideal, with emf = 15V. Each resistance is of 3 Ω. The potential difference across the capacitor is –



Sol. At steady state capacitor as open circuit



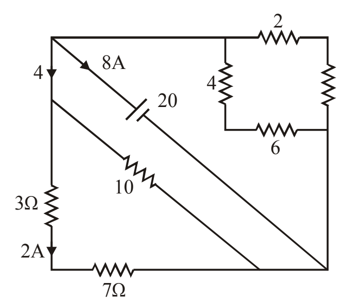
$$I=\frac{15}{[(3+3)\,||\,3]+3}=3\text{ amp.}$$

$$V_B+3\times 3+3\times 1=V_A;\quad V_A-V_B=12\text{ volt.}$$

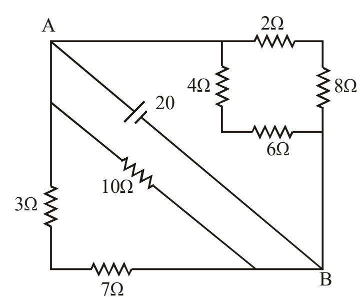
Example 24 :

Find the potential difference across 7Ω resistor and the current flowing through the battery.

Sol. $R_{AB}=\frac{5}{2}\Omega,\ i_{total}=\frac{20}{5/2}=8A$



$$\Delta V_{7\Omega}=7\times 2=14V$$



Example 25 :

Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5kg water by 40 K. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter 2d. The way these wires are connected is given in the options. How much time in minutes will it take to raise the temperature of the same amount of water by 40K?

(A) 4 if wires are in parallel (B) 2 if wires are in series
(C) 0.5 if wires are in parallel (D) Both (B) and (C)

Sol. **(D).** $t = \frac{H}{P} = \frac{HR}{V^2} \Rightarrow t \propto R$

$$R = \frac{\rho\ell}{A} \;;\; R' = \frac{\rho\ell}{4A} \quad (\text{as } d' = 2d)$$

When wires are in series,

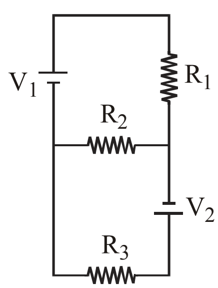
$$R_1 = R' + R' = 2R' = \frac{R}{2} \Rightarrow t' = \frac{t}{2} = 2\text{min.}$$

When wires are in parallel,

$$R_2 = \frac{R'}{2} = \frac{R}{8} \Rightarrow t' = \frac{t}{8} = 0.5 \text{ min.}$$

Example 26 :

Two ideal batteries of emf V_1 and V_2 and three resistances R_1, R_2 and R_3 are connected as shown in the figure. The current in resistance R_2 would be zero if –



(A) $V_1 = V_2$ and $R_1 = R_2 = R_3$
(B) $V_1 = V_2$ and $R_1 = 2R_2 = R_3$
(C) $2V_1 = V_2$ and $2R_1 = R_2 = R_3$
(D) All of these

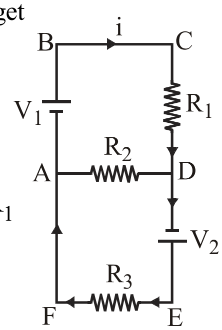
Sol. **(D).** Using KVL, in ABCDEFA, we get

$$-iR_1 + V_2 - iR_3 + V_1 = 0$$

$$\Rightarrow \quad i = \frac{V_1 + V_2}{R_1 + R_3}$$

Using KVL in ABCDA,

$0 + V_1 - iR_1 = 0 \Rightarrow i = V_1/R_1$



$$\Rightarrow \frac{V_1}{R_1} = \frac{V_1 + V_2}{R_1 + R_3}$$

$$\Rightarrow V_1R_1 + V_1R_3 = V_1R_1 + V_2R_1$$

$$\Rightarrow \frac{V_1}{R_1} = \frac{V_2}{V_3}$$

Example 27 :

A galvanometer gives full scale deflection with 0.006 A current. By connecting it to a 4990Ω resistance, it can be converted into a voltmeter of range 0 – 30 V. If connected to a $\frac{2n}{249}\Omega$ resistance, it becomes an ammeter of range 0 – 1.5 A. Find the value of n.

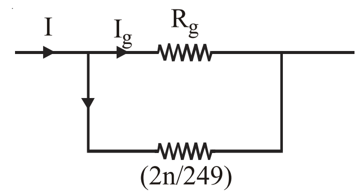
Sol. **5.** $I_g = 0.006\text{ A}, R = 4990\,\Omega$

$V = 30\text{ V} = I_g(R_g + R)$

$30 = 0.006(R_g + 4990)$

$$\frac{30 \times 1000}{6} = R_g + 4990$$

$R_g = 10\Omega$



$$0.006 \times 10 = (1.5 - 0.006) \times \frac{2n}{249}$$

$$\Rightarrow \frac{0.06}{1.5} = \frac{2n}{249} \Rightarrow 2n = \frac{0.06 \times 249}{1.494} = 10$$

$\Rightarrow n = 5$

QUESTION BANK

CHAPTER 2 : CURRENT ELECTRICITY

EXERCISE - 1 [LEVEL-1]

PART - 1 : ELECTRIC CURRENT

Q.1 The SI unit of the current density is
(A) ampere (A)
(B) ampere/metre^2 or (A/m^2)
(C) A-kg^3
(D) has no unit

Q.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 $\vec{J}$ (current density) changes in an exact manner, while the current I remains unaffected. The agent that is essentially responsible for it 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 right way by repulsion.
(D) the charges ahead.

Q.3 1 ampere current is equivalent to
(A) 6.25×10^{18} electrons s^{-1}
(B) 2.25×10^{18} electrons s^{-1}
(C) 6.25×10^{14} electrons s^{-1}
(D) 2.25×10^{14} electrons s^{-1}

Q.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 nor thermal velocity.

Q.5 In a conductor 4 coulombs of charge flows for 2 seconds. The value of electric current will be
(A) 4 volts (B) 4 amperes
(C) 2 amperes (D) 2 volts

Q.6 A metallic block has no potential difference applied across it, then the mean velocity of free electrons is (T = absolute temperature of the block)
(A) Proportional to T
(B) Proportional to $\sqrt{T}$
(C) Zero
(D) Finite but independent of temperature

Q.7 There is a current of 1.344 amp in a copper wire whose area of cross-section normal to the length of the wire is 1mm^2. If the number of free electrons per cm^3 is 8.4×10^{22}, then the drift velocity would be
(A) 1.0 mm/sec (B) 1.0 m/sec
(C) 0.1mm/sec (D) 0.01mm/sec

Q.8 20μA current flows for 30 seconds in a wire, transfer of charge will be
(A) 2×10^{-4} C (B) 4×10^{-4} C
(C) 6×10^{-4} C (D) 8×10^{-4} C

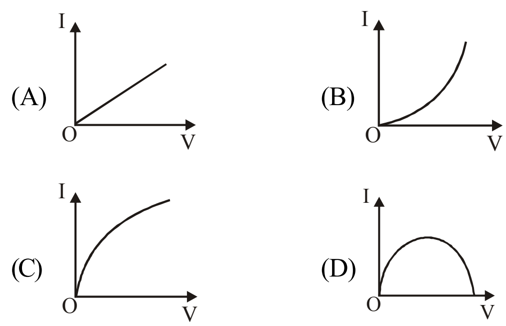
Q.9 At room temperature, copper has free electron density of 8.4×10^{28} per m^3. The copper conductor has a cross-section of 10^{-6} m^2 and carries a current of 5.4 A. The electron drift velocity in copper is
(A) 400 m/s (B) 0.4 m/s
(C) 0.4 mm/s (D) 72 m/s

Q.10 A steady current i is flowing through a conductor of uniform cross-section. Any segment of the conductor has
(A) Zero charge
(B) Only positive charge
(C) Only negative charge
(D) Charge proportional to current i

PART - 2 : OHM'S LAW

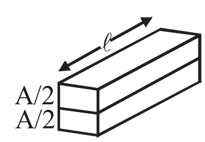
Q.11 Resistance R is –
(A) inversely proportional to A.
(B) directly proportional to A.
(C) does not depend on A.
(D) proportional to A$^{1/2}$.
(where, A = area of cross-section)

Q.12 Which of the following I–V graph represents ohmic conductors?



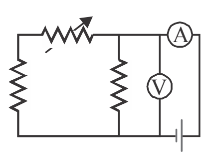
Q.13 Ohm's law is true
(A) For metallic conductors at low temperature
(B) For metallic conductors at high temperature
(C) For electrolytes when current passes through them
(D) For diode when current flows

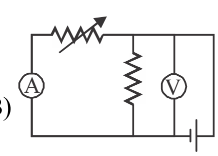
Q.14 In the given figure, for a given voltage V across the full cross section of slab, if I is the current through the entire slab, then the current flowing through each of the two half slabs is

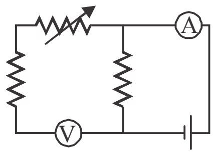


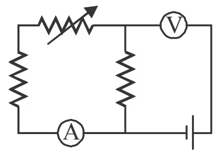
(A) I/2 (B) I
(C) I/4 (D) (3/4) I

Q.15 Express which of the following set-up can be used to verify Ohm's law?

(A)


(B)


(C) 

(D) 

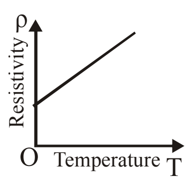
PART - 3 : RESISTIVITY

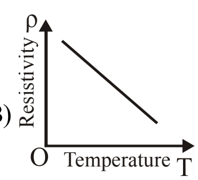
Q.16 ρ (resistivity) depends on
(A) current
(B) voltage
(C) length
(D) material of the conductor

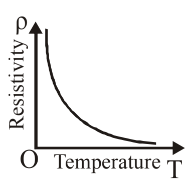
Q.17 Arrange the following materials in increasing order of their resistivity,
Nichrome, copper, Germanium, Silicon
(A) Copper < Nichrome < Germanium < Silicon
(B) Germanium < Copper < Nichrome < Silicon
(C) Nichrome < Copper < Germanium < Silicon
(D) Silicon< Nichrome < Germanium < Copper

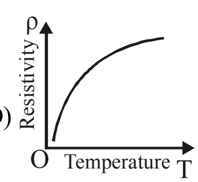
Q.18 In equation $J = \sigma E$, σ is called the –
(A) conductivity (B) resistivity
(C) both (A) and (B) (D) neither (A) nor (B)
(here, J = current density, E = electric field)

Q.19 The temperature dependence of the resistivity of semiconductor is given by

(A) 

(B) 

(C) 

(D) 

Q.20 In equation, $\rho_T = \rho_0 [1 + \alpha (T - T_0)]$, α is called
(A) temperature coefficient of resistivity
(B) temperature coefficient of conductivity
(C) both (A) and (B)
(D) None of the above
(Here, ρ_T is resistivity at temperature T,
ρ_0 = resistivity at reference temperature T_0)

Q.21 Order of resistivities of metals is –
(A) $10^{-8}\ \Omega m$ (B) $10^{-6}\ \Omega m$
(C) $10^{-8}\ \Omega m$ to $10^{-6}\ \Omega m$ (D) $10^{8}\Omega$ to $10^{6}\ \Omega$ m

Q.22 Which of the following relation is correct for conductivity σ of solid conductor?

(A) $\sigma = \frac{ne^2}{m}\tau$ (B) $\sigma = \frac{2ne^2}{m}\tau$

(C) $\sigma = \frac{ne^2}{2m}\tau$ (D) $\sigma = \frac{ne^2}{4m}\tau$

Q.23 If E is the magnitude of uniform electric field in the conductor whose length is ℓ, then the potential difference V across its ends is
(A) $2E\ell$ (B) $E\ell/2$
(C) $E\ell$ (D) $E\ell/4$

Q.24 Mobility (μ) of charge carrier in conductor is defined as

(A) $\mu = \frac{|v_d|}{E}$ (B) $\mu = \frac{-|v_d|}{E}$

(C) $\mu = \frac{|v_d|}{I}$ (D) $\mu = \frac{-|v_d|}{I}$

Q.25 With increase in temperature the conductivity of
(A) metals increases and of semiconductor decreases.
(B) semiconductors increases and of metals decreases.
(C) in both metals and semiconductors increases.
(D) in both metal and semiconductor decreases.

Q.26 Over a limited range of temperature, that is not too large, the resistivity of a metallic conductor is approximately given by
(A) $\rho_T = \rho_0 [1 + \alpha (T - T_0)]$
(B) $\rho_T = 2\rho_0 [1 + \alpha (T - T_0)]$
(C) $\rho_T = 4\rho_0 [1 + \alpha (T - T_0)]$
(D) $\rho_T = \rho_0 [2 + \alpha (T - T_0)]$

Q.27 The resistivity of a wire
(A) Increases with the length of the wire
(B) Decreases with the area of cross-section
(C) Decreases with the length and increases with the cross-section of wire
(D) None of the above statement is correct

Q.28 For which of the following the resistance decreases on increasing the temperature –
(A) Copper (B) Tungsten
(C) Germanium (D) Aluminium

Q.29 If n, e, τ and m respectively represent the density, charge relaxation time and mass of the electron, then the resistance of a wire of length ℓ and area of cross-section A will be

(A) $\frac{m\ell}{ne^2\tau A}$ (B) $\frac{m\tau^2 A}{ne^2\ell}$

(C) $\frac{ne^2\tau A}{2m\ell}$ (D) $\frac{ne^2 A}{2m\tau\ell}$

Q.30 What length of the wire of specific resistance $48 \times 10^{-8}\ \Omega$ m is needed to make a resistance of $4.2\ \Omega$ (diameter of wire = 0.4 mm)
(A) 4.1 m (B) 3.1 m
(C) 2.1 m (D) 1.1 m

Q.31 The following four wires are made of the same material and are at the same temperature. Which one of them has highest electrical resistance –
(A) Length = 50 cm, diameter = 0.5 mm
(B) Length = 100 cm, diameter = 1 mm
(C) Length = 200 cm, diameter = 2 mm
(D) Length = 300 cm, diameter = 3 mm

Q.32 The electric resistance of a certain wire of iron is R. If its length and radius are both doubled, then
(A) The resistance will be doubled and the specific resistance will be halved.
(B) The resistance will be halved and the specific resistance will remain unchanged.
(C) The resistance will be halved and the specific resistance will be doubled.
(D) The resistance and the specific resistance, will both remain unchanged.

Q.33 Two wires that are made up of two different materials whose specific resistance are in the ratio 2 : 3, length 3 : 4 and area 4 : 5. The ratio of their resistances is
(A) 6 : 5 (B) 6 : 8
(C) 5 : 8 (D) 1 : 2

PART - 4 : ELECTRIC ENERGY, POWER

Q.34 A boy has two spare light bulbs in his drawer. One is marked 240 V and 100 W and the other is marked 240 V and 60 W He tries to decide which of the following assertions are correct?
(A) The 60 W light bulb has more resistance and therefore burns less brightly.
(B) The 60 W light bulb has less resistance and therefore burns less brightly.
(C) The 100 W bulb has more resistance and therefore burns more brightly.
(D) The 100 W bulb has less resistance and therefore burns less brightly.

Q.35 When a current flows through a conductor its temperature
(A) May increase or decrease
(B) Remains same
(C) Decreases
(D) Increases

Q.36 Lamps used for household lighting are connected in
(A) Series (B) Parallel
(C) Mixed circuit (D) None

Q.37 An electric heater is connected to the voltage supply. After few seconds, current get its steady value then its initial current will be
(A) equal to its steady current.
(B) slightly higher than its steady current.
(C) slightly less than its steady current.
(D) zero

PART - 5 : COMBINATION OF RESISTORS

Q.38 Two resistors of resistance R_1 and R_2 having $R_1 > R_2$ are connected in parallel. For equivalent resistance R, the correct statement is
(A) $R_1 > R_2 + R_2$ (B) $R_1 < R < R_2$
(C) $R_2 < R < (R_1 + R_2)$ (D) $R < R_1$

Q.39 A wire of resistance R is divided in 10 equal parts. These parts are connected in parallel, the equivalent resistance of such connection will be
(A) 0.01 R (B) 0.1 R
(C) 10 R (D) 100 R

Q.40 The equivalent resistance of resistors connected in series is always
(A) Equal to the mean of component resistors
(B) Less than the lowest of component resistors
(C) In between the lowest and the highest of component resistors.
(D) Equal to sum of component resistors

Q.41 n equal resistors are first connected in series and then connected in parallel. What is the ratio of the maximum to the minimum resistance –
(A) n (B) $1/n^2$
(C) n^2 (D) 1/n

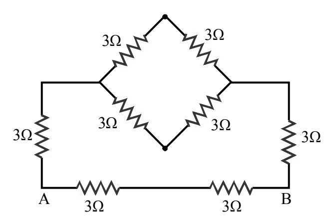
Q.42 A uniform wire of 16Ω is made into the form of a square. Two opposite corners of the square are connected by a wire of resistance 16Ω. The effective resistance between the other two opposite corners is –
(A) 32Ω (B) 20Ω
(C) 8Ω (D) 4Ω

Q.43 The effective resistance of two resistors in parallel is (12/7) Ω. If one of the resistors is disconnected the resistance becomes 4 Ω. The resistance of the other resistor is
(A) 4 Ω (B) 3 Ω
(C) (12/7) Ω (D) (7/12) Ω

Q.44 Two resistance wires on joining in parallel the resultant resistance is (6/5)Ω. One of the wire breaks, the effective resistance is 2 ohms. Resistance of the broken wire is
(A) (3/5)Ω (B) 2Ω
(C) (6/5) Ω (D) 3Ω

Q.45 Three resistances of one ohm each are connected in parallel. Such connection is again connected with 2/3Ω resistor in series. The resultant resistance will be
(A) (5/3) Ω (B) (3/2) Ω
(C) 1Ω (D) (2/3) Ω

Q.46 Equivalent resistance between A and B will be



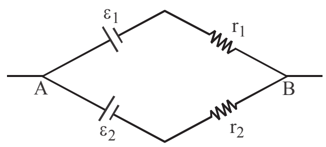
(A) 2 ohm (B) 18 ohm
(C) 6 ohm (D) 3.6 ohm

Q.47 Two resistors are connected (a) in series (b) in parallel. The equivalent resistance in the two cases are 9Ω and 2Ω respectively. Then the resistances of the component resistors are
(A) 2Ω and 7Ω (B) 3Ω and 6Ω
(C) 3Ω and 9Ω (D) 5Ω and 4Ω

PART - 6 : CELLS, EMF, INTERNAL RESISTANCE, COMBINATION OF CELLS

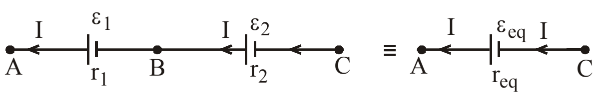
Q.48 Inside cell, the electrolyte through which a current flows has a finite resistance r, this r is called the –
(A) chemical resistance (B) resistivity
(C) conductivity (D) internal resistance of cell

Q.49 Two batteries of emf ε_1 and ε_2 ($\varepsilon_2 > \varepsilon_1$) and internal resistances r_1 and r_2 respectively are connected in parallel as shown in figure.



(A) The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2, i.e. $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$.
(B) The equivalent emf ε_{eq} is smaller than ε_1.
(C) The ε_{eq} is given by $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ always.
(D) ε_{eq} is independent of internal resistances r_1 and r_2.

Q.50 Consider first two cells in series as shown in figure the potential difference between the terminals A and C of the combination is

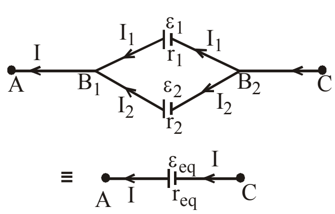


(A) $V_{AC} = \varepsilon_1 - Ir_1$ (B) $V_{AC} = \varepsilon_2 - Ir_2$
(C) $V_{AC} = \varepsilon_{eq} - Ir_{eq}$ (D) $V_{AC} = 2\varepsilon_{eq} - Ir_{eq}$

Q.51 In parallel combination of n cells, we obtain
(A) more voltage (B) more current
(C) less voltage (D) less current

Q.52 The battery of a trunk has an emf of 24 V. If the internal resistance of the battery is 0.8Ω. What is the maximum current that can be drawn from the battery?
(A) 30A (B) 32A
(C) 33 A (D) 34A

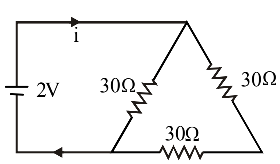
Q.53 Consider a parallel combination of the cells in the figure.



The potential difference across its terminal B_1 and B_2 is
(A) $V = \varepsilon_{eq} - Ir_{eq}$ (B) $V = \varepsilon_2 - Ir_2$
(C) $V = 2\varepsilon_{eq} - Ir_{eq}$ (D) $V = \varepsilon_1 - 2Ir_1$

Q.54 If n cells each of emf ε and internal resistance r are connected in parallel, then the total emf and internal resistances will be
(A) ε, r/n (B) ε, nr
(C) nE, r/n (D) nε, nr

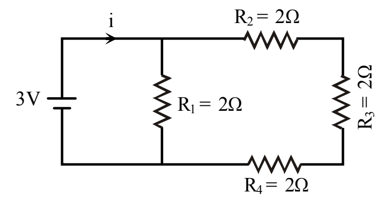
Q.55 The current in the adjoining circuit will be



(A) 1/45 amp. (B) 1/15 amp.
(C) 1/10 amp. (D) 1/5 amp.

Q.56 A cell of negligible resistance and e.m.f. 2 volts is connected to series combination of 2, 3 and 5 ohm. The potential difference in volts between the terminals of 3 ohm resistance will be –
(A) 0.6 (B) 2/3
(C)3 (D) 6

Q.57 What is the current(i) in the circuit as shown in figure



(A) 2 A (B) 1.2 A
(C) 1 A (D) 0.5 A

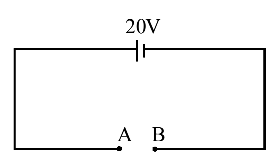
Q.58 A cell of emf 1.5V having a finite internal resistance is connected to a load resistance of 2Ω. For maximum power transfer the internal resistance of the cell should be –
(A) 4 ohm (B) 0.5 ohm
(C) 2 ohm (D) None

Q.59 By a cell a current of 0.9 A flows through 2 ohm resistor and 0.3 A through 7 ohm resistor. The internal resistance of the cell is
(A) 0.5 Ω (B) 1.0 Ω
(C) 12 Ω (D) 2.0 Ω

Q.60 The e.m.f. of a cell is E volts and internal resistance is r ohm. The resistance in external circuit is also r ohm. The p.d. across the cell will be –
(A) E/2 (B) 2E
(C) 4E (D) E/4

Q.61 For driving a current of 2 A for 6 minutes in a circuit, 1000J of work is to be done. The e.m.f. of the source in the circuit is
(A) 1.38 V (B) 1.68 V
(C) 2.04 V (D) 3.10 V

Q.62 In the shown circuit, what is the potential difference across A and B



(A) 50 V (B) 45 V
(C) 30 V (D) 20 V

Q.63 To draw maximum current from a combination of cells, how should the cells be grouped
(A) Series
(B) Parallel
(C) Mixed
(D) Depends upon the relative values of external and internal resistance

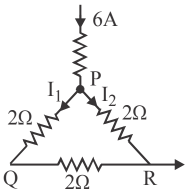
Q.64 The n rows each containing m cells in series are joined in parallel. Maximum current is taken from this combination across an external resistance of 3Ω resistance. If the total number of cells used are 24 and internal resistance of each cell is 0.5Ω then
(A) m = 8, n = 3 (B) m = 6, n = 4
(C) m = 12, n = 2 (D) m = 2, n = 12

Q.65 To get the maximum current from a parallel combination of n identical cells each of internal resistance r in an external resistance R, when

(A) R >> r (B) R << r
(C) R = r (D) None

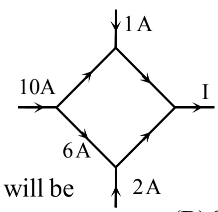
PART - 7 : KIRCHHOFF'S LAWS

Q.66 A current of 6A enters one corner P of an equilateral triangle PQR having 3 wires of resistances 2Ω each and leaves by the corner R. Then the currents I_1 and I_2 are



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

Q.67 The figure shows a network of currents. The magnitude of currents is shown here.



The current I will be

(A) 3 A (B) 9 A
(C) 13 A (D) 19 A

PART - 8 : GALVANOMETER, AMMETER AND VOLTMETER

Q.68 A galvanometer can be converted into an ammeter by connecting

(A) Low resistance in series
(B) High resistance in parallel
(C) Low resistance in parallel
(D) High resistance in series

Q.69 10^{-3} amp is flowing through a resistance of 1000Ω. To measure the correct potential difference, the voltmeter is to be used of which the resistance should be –

(A) 0Ω (B) 500Ω
(C) 1000Ω (D) >> 1000Ω

Q.70 The current flowing through a coil of resistance 900 ohms is to be reduced by 90%. What value of shunt should be connected across the coil

(A) 90Ω (B) 100Ω
(C) 9Ω (D) 10Ω

Q.71 An ammeter gives full deflection when a current of 2amp. flows through it. The resistance of ammeter is 12 ohms. If the same ammeter is to be used for measuring a maximum current of 5 amp., then the ammeter must be connected with a resistance of –

(A) 8 ohms in series (B) 18 ohms in series
(C) 8 ohms in parallel (D) 18 ohms in parallel

PART - 9 : WHEATSTONE BRIDGE, POST OFFICE BOX

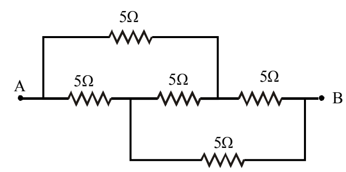
Q.72 In a wheatstone bridge if the battery and galvanometer are interchanged then the deflection in galvanometer will

(A) change in previous direction
(B) not change
(C) change in opposite direction
(D) none of these.

Q.73 Four resistances of 3Ω, 3Ω, 3Ω and 4Ω respectively are used to form a Wheatstone bridge. The 4Ω resistance is short circuited with a resistance R in order to get bridge balanced. The value of R will be

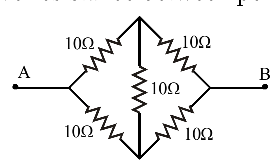
(A) 10Ω (B) 11Ω
(C) 12Ω (D) 13Ω

Q.74 Effective resistance between A and B is –



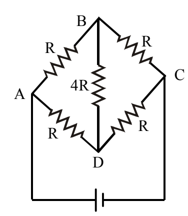
(A) 15 Ω (B) 5 Ω
(C) (5/2) Ω (D) 20 Ω

Q.75 The effective resistance between points A & B is



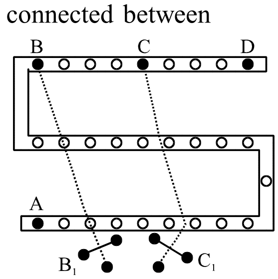
(A) 10Ω (B) 20Ω
(C) 40Ω (D) None of these

Q.76 Five resistors of given values are connected together as shown in the figure. The current in the arm BD will be



(A) Half the current in the arm ABC
(B) Zero
(C) Twice the current in the arm ABC
(D) Four times the current in the arm ABC

Q.77 For the post office box arrangement to determine the value of unknown resistance, the unknown resistance should be connected between



(A) B and C (B) C and D
(C) A and D (D) B_1 and C_1

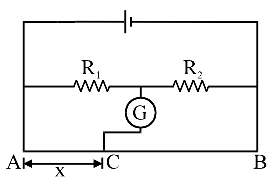
PART - 10 : METER BRIDGE

Q.78 A wire connected in the left gap of a meter bridge balance a 10Ω resistance in the right gap to a point, which divides the bridge wire in the ratio 3 : 2. If the length of the wire is 1 m. The length of one ohm wire is
(A) 0.057 m (B) 0.067 m
(C) 0.37 m (D) 0.134 m

Q.79 In an experiment of meter bridge, a null point is obtained at the centre of the bridge wire. When a resistance of 10 ohm is connected in one gap, the value of resistance in other gap is
(A) 10Ω (B) 5Ω
(C) (1/5)Ω (D) 500Ω

Q.80 Two resistances are connected in two gaps of a metre bridge. The balance point is 20 cm from the zero end. A resistance of 15 ohms is connected in series with the smaller of the two. The null point shifts to 40 cm. The value of the smaller resistance in ohms is
(A) 3 (B) 6
(C) 9 (D) 12

Q.81 In the given circuit, no current is passing through the galvanometer. If the cross-sectional diameter of AB is doubled then for null point of galvanometer the value of AC would



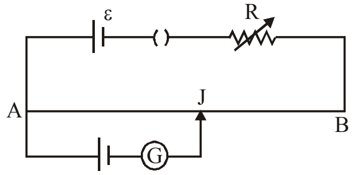
(A) x (B) x/2
(C) 2x (D) none

PART - 11 : POTENTIOMETER

Q.82 In a potentiometer of 10 wires, the balance point is obtained on the 7^{th} wire. To shift the balance point to 9^{th} wire, we should
(A) decrease resistance in the main circuit.
(B) increase resistance in the main circuit.
(C) decrease resistance in series with the cell whose emf is to be measured.
(D) increase resistance in series with the cell whose emf is to be determined.

Q.83 Two cells of emf's approximately 5V and 10V are to be accurately compared using a potentiometer of length 400 cm.
(A) The battery that runs the potentiometer should have voltage of 8V.
(B) The battery of potentiometer can have a voltage of 15V and R adjusted so that the potential drop across the wire slightly exceeds 10V.
(C) The first portion of 50 cm of wire itself should have a potential drop of 10V.
(D) Potentiometer is usually used for comparing resistances and not voltages.

Q.84 AB is a wire of potentiometer with the increase in the value of resistance R, the shift in the balance point J will be –

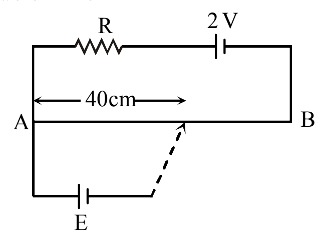


(A) towards B
(B) towards A
(C) remains constant
(D) first towards B then back towards A.

Q.85 A cell of internal resistance 1.5Ω and of e.m.f. 1.5 volt balances 500 cm on a potentiometer wire. If a wire of 15Ω is connected between the balance point and the cell, then the balance point will shift
(A) To zero (B) By 500 cm
(C) By 750 cm (D) None

Q.86 In a potentiometer circuit there is a cell of e.m.f. 2 volt, a resistance of 5 ohm and a wire of uniform thickness of length 1000 cm and resistance 15ohm. The potential gradient in the wire is –
(A) $\frac{1}{500}$ V / cm (B) $\frac{3}{2000}$ V / cm
(C) $\frac{3}{5000}$ V / cm (D) $\frac{1}{1000}$ V / cm

Q.87 AB is a potentiometer wire of length 100 cm and its resistance is 10 ohms. It is connected in series with a resistance R = 40 ohms and a battery of e.m.f. 2V and negligible internal resistance. If a source of unknown e.m.f. E is balanced by 40 cm length of the potentiometer wire, the value of E is



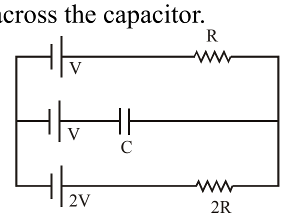
(A) 0.8 V (B) 1.6 V
(C) 0.08 V (D) 0.16 V

Q.88 A potentiometer consists of a wire of length 4 m and resistance 10 Ω. It is connected to cell of emf 2 V. The potential difference per unit length of the wire will be
(A) 0.5 V/m (B) 10 V/m
(C) 2 V/m (D) 5 V/m

Q.89 When two cells of emf E_1 and E_2 are separately balanced in a potentiometer experiment, the difference in balancing lengths is found to be 0.5 m. If the difference in emf's of the two cells is 0.4 volt, then the potential gradient is-
(A) 0.4 V/m (B) 0.6 V/m
(C) 0.8 V/m (D) 1.25 V/m

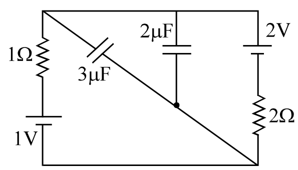
PART - 12 : CHARGING AND DISCHARGING OF CAPACITOR

Q.90 In the given circuit, with steady current, find the potential drop across the capacitor.



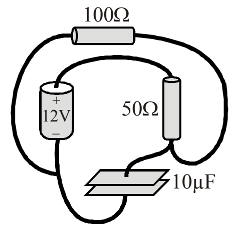
(A) V (B) V/2
(C) V/3 (D) 2V

Q.91 In the circuit shown, the charge on the 3μF capacitor at steady state will be



(A) 6 μC (B) 4 μC
(C) 2/3 μC (D) 3 μC

Q.92 In the circuit shown in the figure,

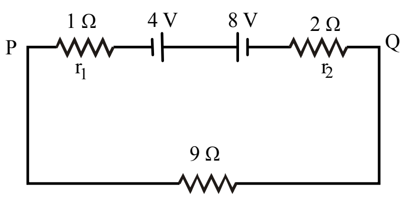


(A) In steady state, there is no current in the 100 Ω resistor.
(B) In steady state, the current in 100 Ω resistor is 0.08A.
(C) In steady state, there is no current in the 50 Ω resistor.
(D) In steady state, the current in 50 Ω resistor is 0.04 A.

EXERCISE - 2 (LEVEL-2)

Choose one correct response for each question.

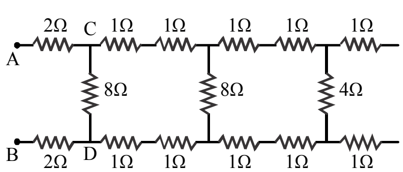
Q.1 Two batteries of e.m.f. 4V and 8 V with internal resistances 1 Ω and 2 Ω are connected in a circuit with a resistance of 9 Ω as shown in figure. The current and potential difference between the points P and Q are



(A) (1/3) A and 3V (B) (1/6) A and 4V
(C) (1/9) A and 9V (D) (1/2) A and 12V

Q.2 A potential difference of V is applied at the ends of a copper wire of length l and diameter d. On doubling only d, drift velocity
(A) Becomes two times (B) Becomes half
(C) Does not change (D) Becomes one fourth

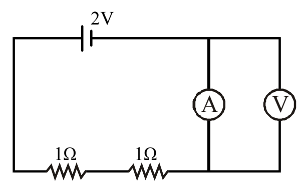
Q.3 In the figure shown, the total resistance between A and B is



(A) 12Ω (B) 4Ω
(C) 6Ω (D) 8Ω

Q.4 A 10 m long wire of 20Ω resistance is connected with a battery of 3 volt e.m.f. (negligible internal resistance) and a 10 Ω resistance is joined to it is series. Potential gradient along wire in volt per meter is
(A) 0.02 (B) 0.3
(C) 0.2 (D) 1.3

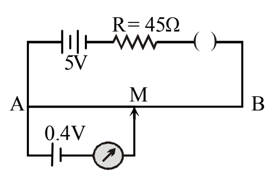
Q.5 In the circuit shown, A and V are ideal ammeter and voltmeter respectively. Reading of the voltmeter will be



(A) 2 V (B) 1 V
(C) 0.5 V (D) Zero

Q.6 A current of two amperes is flowing through a cell of e.m.f. 5 volts and internal resistance 0.5ohm from negative to positive electrode. If the potential of negative electrode is 10V, the potential of positive electrode will be
(A) 5 V (B) 14 V
(C) 15 V (D) 16 V

Q.7 In given figure, the potentiometer wire AB has a resistance of 5 Ω and length 10 m. The balancing length AM for the emf of 0.4 V is

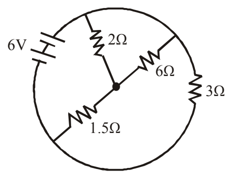


(A) 0.4 m (B) 4 m
(C) 0.8 m (D) 8 m

Q.8 Three equal resistors connected in series across a source of emf together dissipate 10 watt of power. What would be the power dissipated if the same resistors are connected in parallel across the same source of emf
(A) 45 watt (B) 90 watt
(C) 80 watt (D) 40 watt

Q.9 When cell of emf and internal resistance r, is connected to the ends of a resistance R, then current through resistance is I. If the same cell is connected to the ends of a resistance R/2 then the current would be-
(A) less than I
(B) I
(C) greater then I but less than 2I
(D) greater than 2I

Q.10 The total current supplied to the circuit by the battery is–



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

Q.11 The resistance of the wire in the platinum resistance thermometer at ice point is 5Ω and at steam point is 5.25Ω. When the thermometer is inserted in an unknown hot bath its resistance is found to be 5.5Ω. The temperature of the hot bath is
(A) 100°C (B) 200°C
(C) 300°C (D) 350 °C

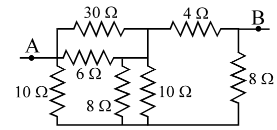
Q.12 A battery having 12 V emf and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 1 A, then the resistance of resistor and lost voltage of the battery when circuit is closed will be –
(A) 7Ω, 7V (B) 8Ω, 8V
(C) 9Ω, 9V (D) 9Ω, 10V

Q.13 A metal rod of length 10cm and a rectangular crosssection 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 × 1/2cm faces.
(D) same irrespective of the three faces.

Q.14 A wire with 15Ω resistance is stretched by one tenth of its original length and kept volume of wire is constant. Then its resistance will be
(A) 15.18 Ω (B) 81.15 Ω
(C) 51.18 Ω (D) 18.15 Ω

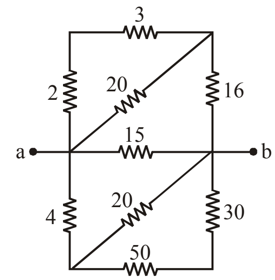
Q.15 A hollow conducting sphere of inner radius R and outer radius 2R has resistivity 'ρ' a function of the distance 'r' from the centre of the sphere: $\rho = kr^2/R$. The inner and outer surfaces are painted with a perfectly conducting 'paint' and a potential difference ΔV is applied between the two surfaces. Then, as 'r' increases from R to 2R, the electric field inside the sphere
(A) increases
(B) decreases
(C) remains constant
(D) passes through a maxima

Q.16 Seven resistors are connected as shown in the diagram. The equivalent resistance in ohms of this network between A and B is



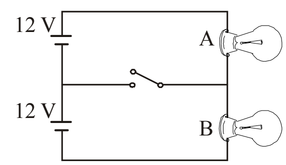
(A) 6 (B) 8
(C) 12 (D) 20

Q.17 In Fig. denote the numerical values of resistors in SI. The total resistance of the circuit



(A) 12 ohms (B) 24 ohms.
(C) 15 ohms (D) 6 ohms

Q.18 Two light bulbs shown in the circuit have ratings A (24 V, 48 W) and B (24 V and 36 W) as shown. When the switch is closed.



(A) the intensity of light bulb A decreases & of B increases.
(B) the intensity of light bulb A as well as B increases.
(C) the intensity of light bulb A as well as B decreases.
(D) the intensity of light bulb A increases & of B decreases.

FOR Q.19-Q.21

A car battery with a 12 V emf and an internal resistance of 0.04 Ω is being charged wtih a current of 50 A

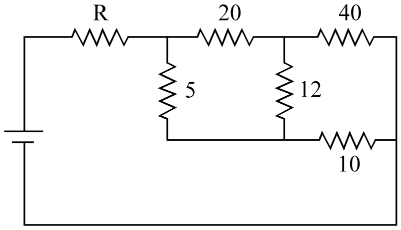
Q.19 The potential difference V across the terminals of the battery are
(A) 10 V (B) 12 V
(C) 14 V (D) 16 V

Q.20 The rate at which energy is being dissipated as heat inside the battery is:
(A) 100 W (B) 500 W
(C) 600 W (D) 700 W

Q.21 Rate of energy conversion from electrical to chemical is:
(A) 100 W (B) 500 W
(C) 600 W (D) 700 W

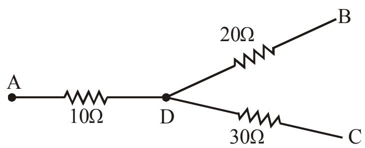
Q.22 The wattage rating of a light bulb indicates the power dissipated by the bulb if it is connected across 110V DC potential difference. If a 50W and 100 W bulb are connected in series to a 110V DC source, how much power will be dissipated in the 50W bulb.
(A) 50 W (B) 100 W
(C) 22 W (D) 11 W

Q.23 What should be the value of R (internal resistance) so that the electric power consumed by it is maximum:



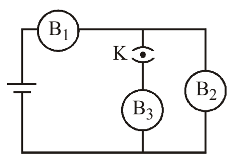
(A) 12 Ω (B) 24 Ω
(C) 6 Ω (D) none of these

Q.24 In the circuit given here, the points A, B and C are 70 V, zero, 10 V respectively. Then –



(A) the point D will be at a potential of 60 V
(B) the point D will be at a potential of 20 V
(C) currents in the paths AD, DB and DC are in the ratio of 1 : 2 : 3
(D) currents in the paths AD, DB and DC are in the ratio of 3 : 2 : 1

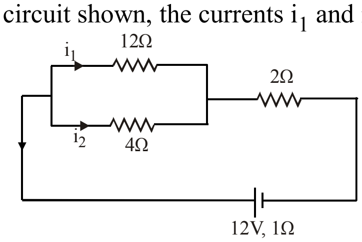
Q.25 B_1, B_2 and and B_3 are the three identical bulbs connected to a battery of steady emf with key K closed. What happens to the brightness of the bulbs B_1 and B_2 when the key is opened ?



(A) Brightness of the bulbs B_1 increases & that of B_2 decreases.
(B) Brightness of the bulbs B_1 and B_2 increases
(C) Brightness of the bulbs B_1 decreases & that of B_2 increases.
(D) Brightness of the bulbs B_1 & B_2 decreases.

Q.26 A battery of e.m.f. E has an internal resistance 'r'. A variable resistance R is connected to the terminals of the battery. A current I is drawn from the battery. V is the terminal P.D. If R alone is gradually reduced to zero, which of the following best describes I and V?
(A) I approaches zero, V approaches E
(B) I approaches E/r, V approaches zero
(C) I approaches E/r, V approaches E
(D) I approaches infinity, V approaches E

Q.27 In the circuit shown, the currents i_1 and i_2 are –

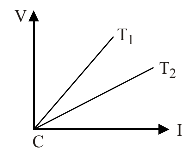


(A) $i_1 = 3$ A, $i_2 = 1$ A (B) $i_1 = 1$ A, $i_2 = 3$ A
(C) $i_1 = 0.5$ A, $i_2 = 1.5$ A (D) $i_1 = 1.5$ A, $i_2 = 0.5$ A

Q.28 A conductor wire having 10^{29} free electrons/m^3 carries a current of 20 A. If the cross-section of the wire is 1 mm^2, then the drift velocity of electrons will be –
(A) 6.25×10^{-3} m/s (B) 1.25×10^{-5} m/s
(C) 1.25×10^{-3} m/s (D) 1.25×10^{-4} m/s

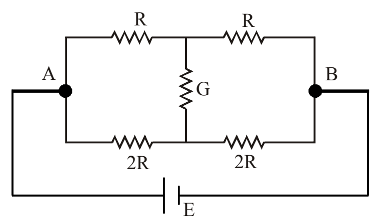
Q.29 A resistor has a colour code of green, blue, brown and silver. What is its resistance?
(A) 5600Ω ± 10% (B) 560Ω ± 5%
(C) 560Ω ± 10 % (D) 56 Ω ± 5%

Q.30 The voltage V and current I graphs for a conductor at two different temperatures T_1 and T_2 are shown in the figure. The relation between T_1 and T_2 is



(A) $T_1 = 1/T_2$ (B) $T_1 = T_2$
(C) $T_1 < T_2$ (D) $T_1 > T_2$

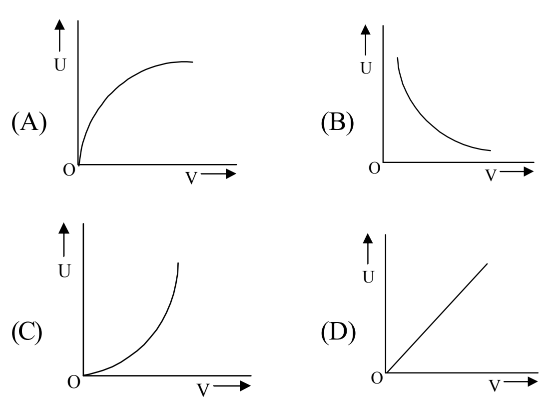
Q.31 Consider the following statements regarding the network shown in the figure.



(a) The equivalent resistance of the network between points A and B is independent of value of G.
(b) The equivalent resistance of the network between points A and B is (4/3) R.
(c) The current through G is zero.

Which of the above statements is/are TRUE?
(A) (a), (b) and (c) (B) (b) and (c)
(C) (b) alone (D) (a) alone

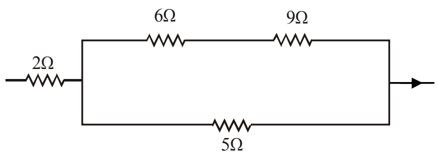
Q.32 Which of the following graphs correctly represents the variation of heat energy (U) produced in a metallic conductor in a given time as a function of potential difference (V) across the conductor?



Q.33 A current of 2A is passing through a metal wire of cross sectional area $2 \times 10^6 m^2$. If the number density of free electrons in the wire is $5 \times 10^{26} m^{-3}$, the drift speed of electrons is – (Given $e = 1.6 \times 10^{-19}$ C)

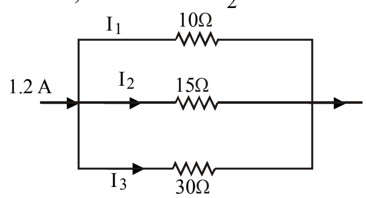
(A) 1/40 m/s (B) 1/80 m/s
(C) 1/32 m/s (D) 1/16 m/s

Q.34 In this circuit, when certain current flows, the heat produced in 5Ω is 4.05 J in a time t. The heat produced in 2Ω coil in the same time interval is –



(A) 1.44 (B) 2.88
(C) 2.02 (D) 5.76

Q.35 In this circuit, the value of I_2 is –

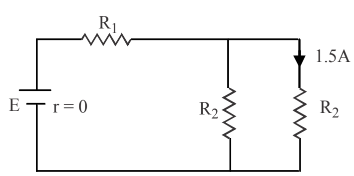


(A) 0.3 A (B) 0.4 A
(C) 0.6 A (D) 0.2 A

Q.36 Three conductors draw currents of 1A, 2A and 3A respectively, when connected in turn across a battery. If they are connected in series and the combination is connected across the same battery, the current drawn will be

(A) (2/7) A (B) (3/7) A
(C) (4/7) A (D) (6/11) A

Q.37 In the circuit, $R_1 = R_2$. The value of E and R_1 are
(E – EMF, R_1 – resistance)

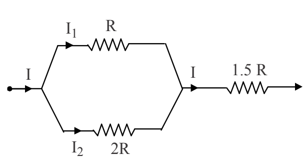


(A) 180 V, 60 Ω (B) 120 V, 60 Ω
(C) 180 V, 40 Ω (D) 120 V, 10 Ω

Q.38 Masses of three wires of copper are in the ratio of 1:3 : 5 and their lengths are in the ratio of 5 : 3 : 1. The ratio of their electrical resistances is

(A) 1 : 3 : 5 (B) 5 : 3 : 1
(C) 1 : 15 : 125 (D) 125 : 15 : 1

Q.39 In the circuit diagram, heat produces in R, 2R and 1.5 R are in the ratio of –



(A) 4 : 2 : 3 (B) 8 : 4 : 27
(C) 2 : 4 : 3 (D) 27 : 8 : 4

Q.40 Two resistors of resistances 2Ω and 6Ω are connected in parallel. This combination is then connected to a battery of emf 2V and internal resistance 0.5Ω. What is the current flowing through the battery?

(A) 4 A (B) (4/3) A
(C) (4/17) A (D) 1 A

Q.41 The equivalent resistance of two resistors connected in series is 6Ω and their parallel equivalent resistance is (4/3)Ω. What are the values of resistances?

(A) 4Ω, 6Ω (B) 8Ω, 1Ω
(C) 4Ω, 2Ω (D) 6Ω, 2Ω

Q.42 In a potentiometer experiment of a cell of emf 1.25 V gives balancing length of 30 cm. If the cell is replaced by another cell, balancing length is found to be 40 cm. What is the emf of second cell?

(A) ≈ 1.57 V (B) ≈ 1.67 V
(C) ≈ 1.47 V (D) ≈ 1.37V

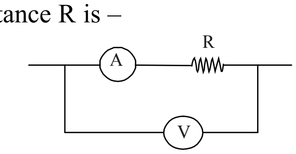
Q.43 Three resistances 2Ω , 3Ω and 4Ω are connected in parallel. The ratio of currents passing through them when a potential difference is applied across its ends will be –

(A) 5 : 4 : 3 (B) 6 : 3 : 2
(C) 4 : 3 : 2 (D) 6 : 4 : 3

Q.44 Four identical cells of emf E and internal resistance r are to be connected in series. Suppose if one of the cell is connected wrongly, the equivalent emf and effective internal resistance of the combination is

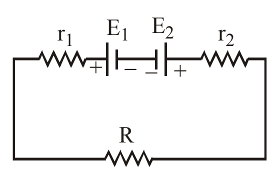
(A) 2E and 4r (B) 4E and 4r
(C) 2E and 2r (D) 4E and 2r

Q.45 In the circuit shown below, the ammeter and the voltmeter readings are 3 A and 6 V respectively. Then the value of the resistance R is –



(A) < 2Ω (B) 2Ω
(C) ≥ 2Ω (D) > 2Ω

Q.46 Two cells of emf E_1 and E_2 are joined in opposition (such that $E_1 > E_2$). If r_1 and r_2 be the internal resistance and R be the external resistance, then the terminal potential difference



(A) $\frac{E_1 - E_2}{r_1 + r_2} \times R$ (B) $\frac{E_1 + E_2}{r_1 + r_2} \times R$

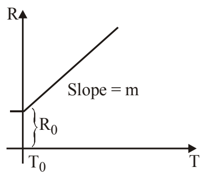
(C) $\frac{E_1 - E_2}{r_1 + r_2 + R} \times R$ (D) $\frac{E_1 + E_2}{r_1 + r_2 + R} \times R$

Q.47 The resistance of the bulb filament is 100 Ω at a temperature of 100°C. If its temperature co-efficient of resistance be 0.005 per C, its resistance will become 200Ω at a temperature

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

Q.48 In Wheatstones network P = 2Ω , Q = 2Ω , R = 2Ω and S = 3Ω. The resistance with which S is to shunted in order that the bridge may be balanced is
(A) 4Ω (B) 1Ω
(C) 6Ω (D) 2Ω

Q.49 Variation of resistnace of the conductor with temperature is as shown. The temperature coefficient (α) of the conductor

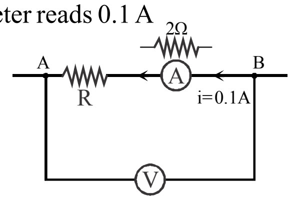


(A) m/R_0 (B) m^2R_0
(C) mR_0 (D) R_0/m

Q.50 An ammeter gives full scale deflection when current of 1.0 A is passed in it. To convert it into 10 A range ammeter, the ratio of its resistance and shunt resistance will be
(A) 1 : 9 (B) 1 : 10
(C) 1 : 11 (D) 9 : 1

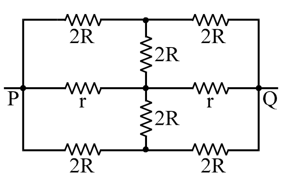
Q.51 In a circuit 5 percent of total current passes through a galvanometer. If resistance of the galvanometer is G then value of the shunt is –
(A) 19 G (B) 20 G
(C) G/20 (D) G/19

Q.52 If resistance of voltmeter is 10000Ω and resistance of ammeter is 2Ω then find R when voltmeter reads 12V and ammeter reads 0.1 A



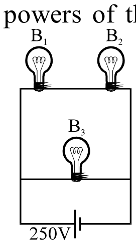
(A) 118 Ω (B) 120 Ω
(C) 124 Ω (D) 114Ω

Q.53 The effective resistance between the points P and Q of the electrical circuit shown in the figure is



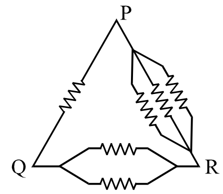
(A) 2Rr/(R + r) (B) 8R(R + r)/(3R + r)
(C) 2r + 4R (D) 5R/2 + 2r

Q.54 A 100 W bulb B_1, and two 60 W bulbs B_2 and B_3, are connected to a 250 V source, as shown in the figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3 respectively. Then



(A) $W_1 > W_2 = W_3$
(B) $W_1 > W_2 > W_3$
(C) $W_1 < W_2 = W_3$
(D) $W_1 < W_2 < W_3$

Q.55 Six equal resistances are connected between points P, Q and R as shown in the figure. Then the net resistance will be maximum between



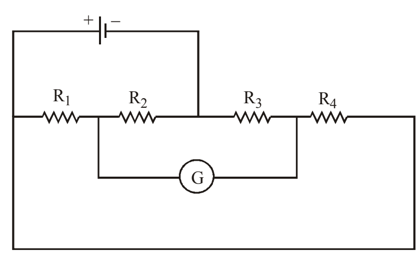
(A) P and Q (B) Q and R
(C) P and R (D) any two points

Q.56 The charge q flowing through a wire varies with time t as $q = (0.1 + 0.2t + 0.3t^2)$C where t is in second. Find the current through the wire initially and at t = 2s.
(A) 0.2A, 1.4A (B) 0.5A, 1.4A
(C) 0.1A, 2.2A (D) 0.4A, 1.8A

Q.57 If certain number of bulbs rated as (P_1 watt, V volt), (P_2 watt, V volt)..... are connected in series across a potential difference of V volt, then power P consumed by all bulbs is given as
(A) $P = P_1 + P_2 + P_3 + ...$ (B) $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} .....$
(C) $P^2 = P_1^2 + P_2^2 + P_3^2 ....$ (D) None of these

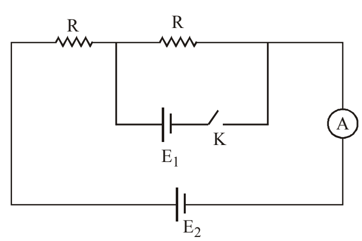
Q.58 The resistivity of most conductors increases with temperature. A possible reason is that, in a conductor –
(A) the electron density changes with temperature
(B) the charge on each electron changes with temperature
(C) the time between collision changes with temperature
(D) the mass of the electron changes with temperature

Q.59 In the given circuit, the galvanometer G will show zero deflection if –



(A) $R_1R_2 = R_3R_4$ (B) $R_1R_3 = R_2R_4$
(C) $R_1R_4 = R_2R_3$ (D) None of the above

Q.60 In the given circuit, when key K is open, reading of ammeter is I. Now key K is closed then the correct statement –

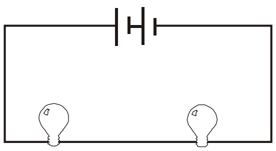


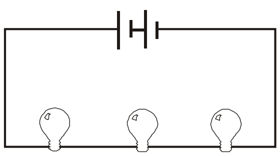
(A) If $E_1 < IR$, reading of the ammeter is less than I
(B) If $IR < E_1 < 2IR$, reading of the ammeter is greater than I
(C) If $E_1 = 2IR$, reading of the ammeter will be zero
(D) Reading of ammeter will not change

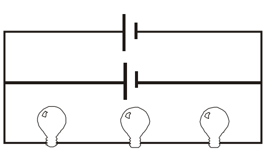
Q.61 In a meter bridge experiment, we try to obtain the null point at the middle. This –
(A) reduces systematic error as well as random error
(B) reduces systematic error but not the random error
(C) reduces random error but not the systematic error
(D) reduces neither systematic error nor the random error

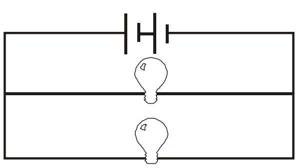
Q.62 Two heaters A and B are in parallel across the supply voltage. Heater A produces 500kJ in 20 minutes and B produces 1000 kJ in 10 minutes. The resistance of A is 100Ω. If the same heaters are connected in series across the same voltage, the heat produced in 5 minutes will be
(A) 200 kJ (B) 100 kJ
(C) 50 kJ (D) 10 kJ

Q.63 In the diagrams, all light bulbs are identical, all cells are ideal and identical. In which circuit (a, b, c, d) will the bulbs be dimmest?

(A) 

(B) 

(C) 

(D) 

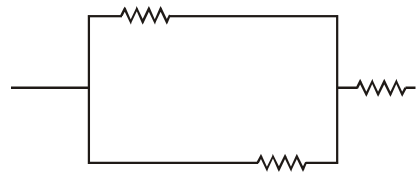
Q.64 The total momentum of electrons in a straight wire of length 1000m carrying a current of 70A is closest to –
(A) 40×10^{-8} N-sec (B) 30×10^{-8} N-sec
(C) 50×10^{-8} N-sec (D) 70×10^{-8} N-sec

Q.65 Two resistance of equal magnitude R and having temperature coefficient α_1 and α_2 respectively are connected in parallel. The temperature coefficient of the parallel combination is, approximately –

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

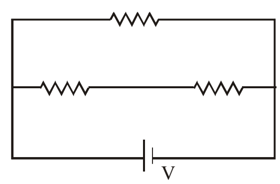
(C) $\dfrac{\alpha_1 - \alpha_2}{2}$ (D) $\dfrac{\alpha_1 + \alpha_2}{2}$

Q.66 Each of 3 resistors in figure has a resistance of 2Ω and can dissipate a maximum of 18 W without becoming excessively heated. Find the maximum power the circuit can dissipate.



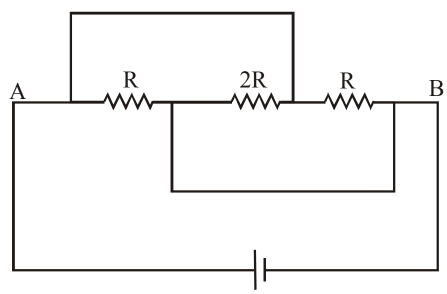
(A) 17W (B) 20 W
(C) 27W (D) 10W

Q.67 Three identical resistors are connected across a voltage source V so that one of them is in parallel with two others which are connected in series as shown. The power dissipated through the first one, compared to the power dissipated by each of the other two, is approximately



(A) the same (B) half as much
(C) twice as much (D) four times as much

Q.68 In the figure shown the current flowing through 2 R is –



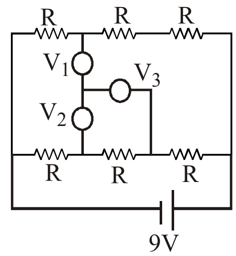
(A) from left to right (B) from right to left
(C) no current (D) none of these

Q.69 In an atom electrons revolves around the nucleus along a path of radius 0.72 Å making 9.4×10^{18} revolution per second. The equivalent current is ($e = 1.6 \times 10^{-19}$ C)
(A) 1.2 A (B) 1.5 A
(C) 1.4 A (D) 1.8 A

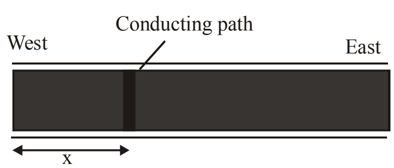
EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)

NOTE : The answer to each question is a NUMERICAL VALUE.

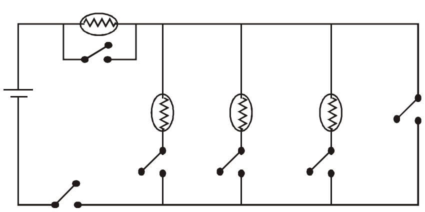
Q.1 In the circuit shown below, all the three voltmeters are identical and have very high resistance (but not ∞). Each resistor has the same resistance. The voltage of the ideal battery shown is 9V. Find the reading of voltmeter V_3 (in volts).



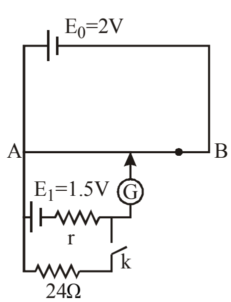
Q.2 A 10 km long underground cable extends east to west and consists of two parallel wires, each of which has resistance 13Ω/km. A short develops at distance x from the west end when a conducting path of resistance R connects the wires (figure). The resistance of the wires and the short is then 100Ω when the measurement is made from the east and, 200Ω when it is made from the west end. What is the value of R (in ohm).



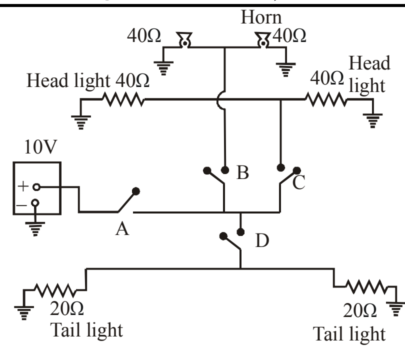
Q.3 In the circuit shown what is the maximum number of switches that must be closed to turn on the lights –



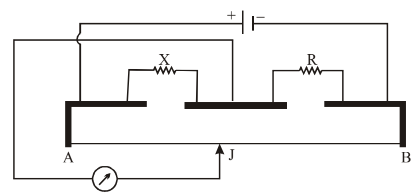
Q.4 For the arrangement of the potentiometer shown in the figure, the balance point is obtained at a distance 75cm. from A when the key k is open. The second balance point is obtained at 60cm. from A when the key k is closed. Find the internal resistance (in Ω) of the battery E_1.



Q.5 Figure shows an automobile circuit. How much power (in watt) is dissipated by the automobile circuit when switches A, B, C and D are all closed.

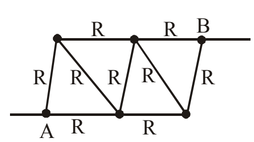


Q.6 The figure shows a meter-bridge circuit, X = 12Ω and R = 18Ω. The jockey J is at the null point. If R is made 8Ω, through the jockey J have to be moved by 4 × A cm. to obtain null point again then find the value of A.

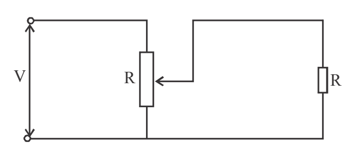


Q.7 A hank of uninsulated wire consisting of seven and a half turns is stretched between two nails hammered into a board to which the ends of the wire are fixed. The resistance of the circuit between the nails is determined with the help of electrical measuring instruments. Determine the proportion in which the resistance will change if the wire is unwound so that the ends remain to be fixed to the nails.

Q.8 The resistance R_{AB} between points A and B of the frame formed by nine identical wires of resistance R each (figure) is $\frac{15}{X}R$. Find the value of X.



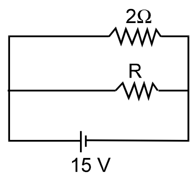
Q.9 The voltage across a load is controlled by using the circuit diagram shown in figure. The resistance of the load and of the potentiometer is R. The load is connected to the middle of the potentiometer. The input voltage is constant and equal to V. the voltage across the load will change by a factor of k = 10/X if its resistance is doubled. Find the value of X.



Q.10 When two identical batteries of internal resistance 1Ω each are connected in series across a resistor R, the rate of heat produced in R is J_1. When the same batteries are connected in parallel across R, the rate is J_2. If $J_1 = 2.25\ J_2$ the value of R in Ω is :

EXERCISE - 4 [PREVIOUS YEARS JEE MAIN QUESTIONS]

Q.1 If energy consumption of this circuit is 150 watt then find the value of resistance – **[AIEEE-2002]**



(A) 2 Ω (B) 4 Ω
(C) 6 Ω (D) 8 Ω

Q.2 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. The $P_2 : P_1$ is – **[AIEEE-2002]**
(A) 1 (B) 4
(C) 2 (D) 3

Q.3 If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter a – **[AIEEE-2002]**
(A) Low resistance in parallel.
(B) High resistance in parallel.
(C) High resistance in series.
(D) Low resistance in series.

Q.4 The length of a wire of a potentiometer is 100 cm, and the e.m.f. of its stand and cell is E volt. It is employed to measure the e.m.f. of battery whose internal resistance is 0.5Ω. If the balance point is obtained at $\ell = 30$ cm from the positive end the e.m.f. of the battery is **[AIEEE-2003]**

(A) $\frac{30\,E}{(100-0.5)}$ (B) $\frac{30(E-0.5i)}{(100)}$,

where i is the current in the potentiometer wire

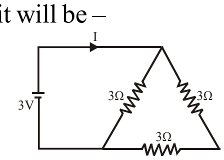
(C) $\frac{30\,E}{100}$ (D) $\frac{30\,E}{100.5}$

Q.5 An ammeter reads upto 1 ampere. Its internal resistance is 0.81 ohm. To increase the range to 10A the value of the required shunt is – **[AIEEE-2003]**
(A) 0.3 Ω (B) 0.9 Ω
(C) 0.09 Ω (D) 0.03 Ω

Q.6 The length of a given cylindrical wire is increased by 100%. Due to the consequent decrease in diameter the change in the resistance of the wire will be **[AIEEE-2003]**
(A) 100% (B) 50%
(C) 300% (D) 200%

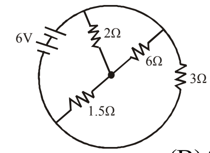
Q.7 A 220 volt, 1000 watt bulb is connected across a 110 volt mains supply. The power consumed will be **[AIEEE-2003]**
(A) 500 watt (B) 250 watt
(C) 1000 watt (D) 750 watt

Q.8 A 3 volt battery with negligible internal resistance is connected in a circuit as shown in the figure. The current I in the circuit will be – **[AIEEE-2003]**



(A) 1.5 A (B) 2 A
(C) 1/3 A (D) 1 A

Q.9 The total current supplied to the circuit by the battery is– **[AIEEE-2004]**



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

Q.10 The resistance of the series combination of two resistance is S. When they are joined in parallel the total resistance is P. If S = n P then the minimum possible value of n is – **[AIEEE-2004]**
(A) 4 (B) 3
(C) 2 (D) 1

Q.11 An electric current is passed through a circut 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 wires will be – **[AIEEE-2004]**
(A) 3 (B) 1/3
(C) 8/9 (D) 2

Q.12 The thermistors are usually made of – **[AIEEE-2004]**
(A) Metals with low temperature coefficient of resistivity.
(B) Metals with high temperature coefficent of resistivity.
(C) metal oxides with high temperature coefficient of resistivity.
(D) Semiconducting meterials having low temperature coefficient of resistivity.

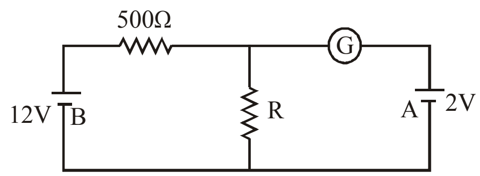
Q.13 Time taken by a 836 W heater to heat one litre of water from 10°C to 40°C is – **[AIEEE-2004]**
(A) 50 s (B) 100 s
(C) 150 s (D) 200 s

Q.14 In a metre bridge experiment null point is obtained at 20cm from one end of the wire when resistance X is balanced against another resistance Y. If X < Y, then where will be the new position of the null point from the same end, if one decides to balance a resistance of 4X against Y **[AIEEE-2004]**
(A) 50 cm (B) 80 cm
(C) 40 cm (D) 70 cm

Q.15 In a potentiometer experiment the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2Ω, the balancing length becomes 120cm. The internal resistance of the cell is – **[AIEEE-2005]**
(A) 1 Ω (B) 0.5 Ω
(C) 4 Ω (D) 2 Ω

Q.16 A moving coil galvanometer has 150 equal divisions. Its current sensitivity is 10 divisions per milliampere and voltage sensitivity is 2 divisions per millivolt. In order that each division reads 1 volt, the resistance in ohms needed to be connected in series with the coil will be – **[AIEEE-2005]**
(A) 10^3 (B) 10^5 (C) 99995 (D) 9995

Q.17 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 **[AIEEE-2005]**



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

Q.18 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 – **[AIEEE-2005]**

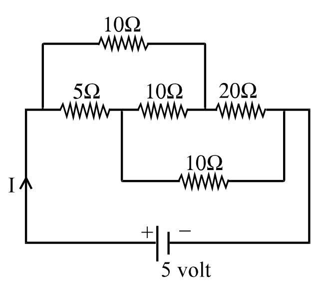
(A) $R = R_2 \times (R_1 + R_2)/(R_2 - R_1)$ (B) $R = R_2 - R_1$
(C) $R = R_1R_2/(R_1 + R_2)$ (D) $R = R_1R_2/(R_2 - R_1)$

Q.19 An energy source will supply a constant current into the load if its internal resistance is – **[AIEEE-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

Q.20 A material 'B' has twice the specific resistance of 'A'. A circular wire made of 'B' has twice the diameter of a wire made of 'A'. then for the two wires to have the same resistance, the ratio ℓ_B/ℓ_A of their respective lengths must be – **[AIEEE 2006]**
(A) 1/4 (B) 2
(C) 1 (D) 1/2

Q.21 The Kirchhoff's first law $(\Sigma i = 0)$ and second law $(\Sigma iR = \Sigma E)$, where the symbols have usual meanings, are respectively based on – **[AIEEE 2006]**
(A) conservation of momentum, conservation of charge
(B) conservation of charge, conservation of energy
(C) conservation of charge, conservation of momentum
(D) conservation of energy, conscrvation of charge

Q.22 The current I drawn from the 5 volt source will be – **[AIEEE 2006]**



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

Q.23 In a Wheatstone's bridge, three resistances P, Q and R are connected in the three arms and the fourth arm is formed by two resistances S_1 and S_2 connected in parallel. the condition for the bridge to be balance will be – **[AIEEE 2006]**

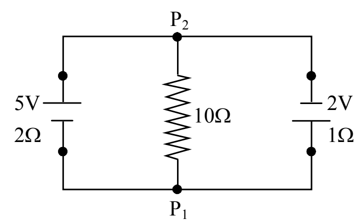
(A) $\frac{P}{Q} = \frac{R(S_1 + S_2)}{2S_1S_2}$ (B) $\frac{P}{Q} = \frac{R}{S_1 + S_2}$

(C) $\frac{P}{Q} = \frac{2R}{S_1 + S_2}$ (D) $\frac{P}{Q} = \frac{R(S_1 + S_2)}{S_1S_2}$

Q.24 An electric bulb is rated 220 volt – 100 watt. The power consumed by it when operated on 110 volt will be – **[AIEEE 2006]**
(A) 25 watt (B) 50 watt
(C) 75 watt (D) 40 watt

Q.25 The resistance of wire is 5 ohm at 50ºC and 6 ohm at 100ºC. The resistance of the wire at 0ºC will be **[AIEEE 2007]**
(A) 2 ohm (B) 1 ohm
(C) 4 ohm (D) 3 ohm

Q.26 A 5 V battery with internal resistance 2 Ω and a 2V battery with internal resistance 1Ω are connected to a 10Ω resistor as shown in the figure.
[AIEEE-2008]
The current in the 10 Ω resistor is -
(A) 0.03 A P_1 to P_2
(B) 0.03 A P_2 to P_1
(C) 0.27 A P_1 to P_2
(D) 0.27 A P_2 to P_1

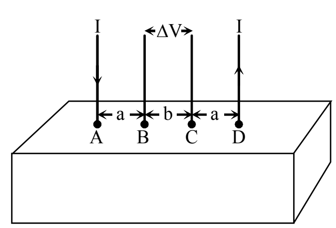


Directions :

Q. No. 27 & 28 are based on the following paragraph.

Consider a block of conducting material of resistivity 'ρ' shown in the figure. Current 'I' enters at 'A' and leaves from 'D'. We apply superposition principle to find voltage 'ΔV' developed between 'B' and 'C'. The calculation is done in the following steps:

(i) Take current 'I' entering from 'A' and assume it to spread over a hemispherical surface in the block.
(ii) Calculate field E(r) at distance 'r' from A by using Ohm's law E = ρj, where j is the current per unit area at 'r'.
(iii) From the 'r' dependence of E(r), obtain the potential V(r) at r.
(iv) Repeat (i), (ii) and (iii) for current 'I' leaving 'D' and superpose results for 'A' and 'D'.



Q.27 For current entering at A, the electric field at a distance 'r' from A is - **[AIEEE-2008]**

(A) $\frac{\rho I}{r^2}$ (B) $\frac{\rho I}{2\pi r^2}$

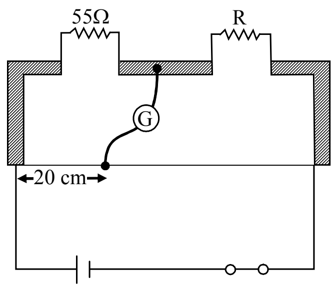
(C) $\frac{\rho I}{4\pi r^2}$ (D) $\frac{\rho I}{8\pi r^2}$

Q.28 ΔV measured between B and C is - **[AIEEE-2008]**

(A) $\frac{\rho I}{a} - \frac{\rho I}{(a+b)}$ (B) $\frac{\rho I}{2\pi a} - \frac{\rho I}{2\pi(a+b)}$

(C) $\frac{\rho I}{2\pi(a-b)}$ (D) $\frac{\rho I}{\pi a} - \frac{\rho I}{\pi(a+b)}$

Q.29 Shown in the figure below is a meter-bridge set up with null deflection in the galvanometer. **[AIEEE 2008]**



The value of the unknown resistor R is

(A) 220 Ω (B) 110 Ω

(C) 55 Ω (D) 13.75 Ω

Q.30 **Statement-1 :** The temperature dependence of resistance is usually given as $R = R_0(1 + \alpha\Delta t)$. The resistance of a wire changes from 100Ω to 150Ω when its temperature is increased from 27°C to 227°C. This implies that $\alpha = 2.5 \times 10^{-3}$/°C.

Statement-2 : $R = R_0(1 + \alpha\Delta t)$ is valid only when the change in the temperature Δt is small and $\Delta R = (R - R_0) << R_0$. **[AIEEE-2009]**

(A) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is true. Statement-2 is true; Statement-2 is not a correct explanation for Statement-1

(C) Statement-1 is true, Statement-2 is false.

(D) Statement-1 is false, Statement-2 is true.

Q.31 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 **[AIEEE 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) $\frac{\alpha_1+\alpha_2}{2}, \frac{\alpha_1+\alpha_2}{2}$

Q.32 If a wire is stretched to make it 0.1% longer, its resistance will : **[AIEEE 2011]**

(A) increase by 0.05% (B) increase by 0.2%

(C) decrease by 0.2% (D) decrease by 0.05%

Q.33 Two electric bulbs marked 25W-220V and 100W-220 V are connected in series to a 440 V supply. Which of the bulbs will fuse. **[AIEEE 2012]**

(A) both (B) 100W

(C) 25W (D) neither

Q.34 The supply voltage to room is 120V. The resistance of the lead wires is 6Ω. A 60W bulb is already switched on. What is the decrease of voltage across the bulb, when a 240W heater is switched on in parallel to the bulb ? **[JEE MAIN 2013]**

(A) zero Volt (B) 2.9 Volt

(C) 13.3 Volt (D) 10.04 Volt

Q.35 **Statement -1 :** Higher the range, greater is the resistance of ammeter. **[JEE MAIN 2013]**

Statement -2 : To increase the range of ammeter, additional shunt needs to be used across it.

(A) Statement-1 is fasle, Statment -2 is true, Statement - 2 is the correct explanation of Statement-1.

(B) Statement -1 is true, Statment-2 is true, Statement-1 is not the correct explanation of Statement-2.

(C) Statement-1 is true, Statment-2 is false.

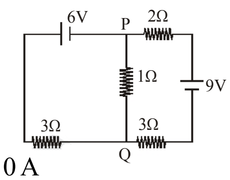
(D) Statement-1 is fasle, Statment-2 is true.

Q.36 In a large building, there are 15 bulbs of 40 W, 5 bulbs of 100 W, 5 fans of 80 W and 1 heater of 1kW. The voltage of the electric mains is 220 V. The minimum capacity of the main fuse of the building will be **[JEE MAIN 2014]**

(A) 12 A (B) 14 A

(C) 8 A (D) 10 A

Q.37 In the circuit shown, the current in the 1 Ω resistor is



[JEE MAIN 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

Q.38 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} m/s. If the electron density in the wire is 8×10^{28} m^{-3}, the resistivity of the material is close to **[JEE MAIN 2015]**

(A) 1.6×10^{-7} Ωm (B) 1.6×10^{-6} Ωm

(C) 1.6×10^{-5} Ωm (D) 1.6×10^{-8} Ωm

Q.39 A galvanometer having a coil resistance of 100Ω 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 : **[JEE MAIN 2016]**

(A) 2Ω (B) 0.1Ω (C) 3Ω (D) 0.01Ω

Q.40 Which of the following statements is false?

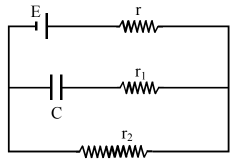
(A) In a balanced Wheatstone bridge if the cell and the galvanometer are exchanged, the null point is disturbed. **[JEE MAIN 2017]**

(B) A rheostat can be used as a potential divider

(C) Kirchhoff's II law represents energy conservation

(D) Wheatstone bridge is the most sensitive when all the four resistances are of the same order of magnitude

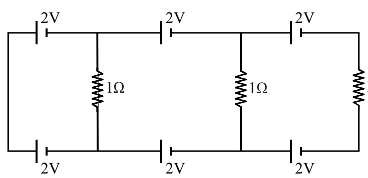
Q.41 In the given circuit diagram when the current reaches steady state in the circuit, the charge on the capacitor of capacitance C will be : **[JEE MAIN 2017]**



(A) $CE\dfrac{r_1}{(r_2+r)}$ (B) $CE\dfrac{r_2}{(r+r_2)}$

(C) $CE\dfrac{r_1}{(r_1+r)}$ (D) CE

Q.42 In the given circuit the current in each resistance is: **[JEE MAIN 2017]**



(A) 0.25 A (B) 0.5A
(C) 0 A (D) 1 A

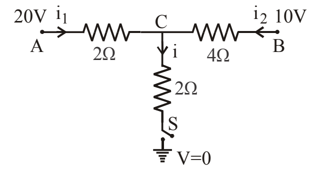
Q.43 When a current of 5mA is passed through a galvanometer having a coil of resistance 15Ω , it shows full scale deflection. The value of the resistance to be put in series with the galvanometer to convert it into a voltmeter of range 0-10V is : **[JEE MAIN 2017]**
(A) $2.045 \times 10^3\ \Omega$ (B) $2.535 \times 10^3\ \Omega$
(C) $4.005 \times 10^3\ \Omega$ (D) $1.985 \times 10^3\ \Omega$

Q.44 Two batteries with e.m.f. 12 V and 13 V are connected in parallel across a load resistor of 10Ω. The internal resistances of the two batteries are 1Ω and 2Ω respectively. The voltage across the load lies between **[JEE MAIN 2018]**
(A) 11.4 V and 11.5 V (B) 11.7 V and 11.8 V
(C) 11.6 V and 11.7 V (D) 11.5 V and 11.6 V

Q.45 In a potentiometer experiment, it is found that no current passes through the galvanometer when the terminals of the cell are connected across 52 cm of the potentiometer wire. If the cell is shunted by a resistance of 5Ω, a balance is found when the cell is connected across 40 cm of the wire. Find the internal resistance of the cell. **[JEE MAIN 2018]**
(A) 2Ω (B) 2.5Ω
(C) 1Ω (D) 1.5Ω

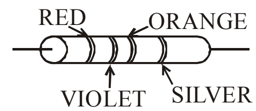
Q.46 On interchanging the resistances, the balance point of a meter bridge shifts to the left by 10 cm. The resistance of their series combination is 1 kΩ. How much was the resistance on the left slot before interchanging the resistances? **[JEE MAIN 2018]**
(A) 550 Ω (B) 910 Ω
(C) 990 Ω (D) 505 Ω

Q.47 When the switch S, in the circuit shown, is closed, then the value of current i will be : **[JEE MAIN 2019 (JAN)]**



(A) 3 A (B) 5 A
(C) 4 A (D) 2 A

Q.48 A resistance is shown in the figure. Its value and tolerance are given respectively by: **[JEE MAIN 2019 (JAN)]**

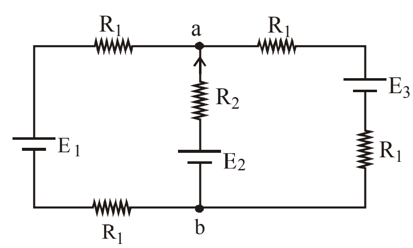


(A) 27 KΩ, 20% (B) 270 KΩ, 5%
(C) 270 KΩ, 10% (D) 27 KΩ, 10%

Q.49 A copper wire is stretched to make it 0.5% longer. The percentage change in its electrical resistance if its volume remains unchanged is: **[JEE MAIN 2019 (JAN)]**
(A) 2.5% (B) 0.5%
(C) 1.0% (D) 2.0%

Q.50 Drift speed of electrons, when 1.5 A of current flows in a copper wire of cross section 5 mm^2, is v. If the electron density in copper is 9×10^{28} /m^3 the value of v in mm/s is close to (Take charge of electron to be $=1.6 \times 10^{-19}$ C) **[JEE MAIN 2019 (JAN)]**
(A) 0.2 (B) 3
(C) 2 (D) 0.02

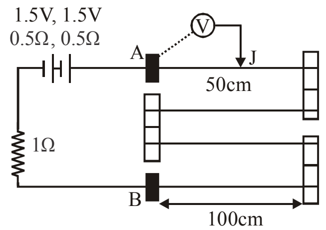
Q.51 For the circuit shown, with $R_1 = 1.0\Omega$, $R_2 = 2.0\Omega$, $E_1 = 2$ V and $E_2 = E_3 = 4$ V, the potential difference between the points 'a' and 'b' is approximately (in V) : **[JEE MAIN 2019 (APRIL)]**



(A) 2.7 (B) 3.3
(C) 2.3 (D) 3.7

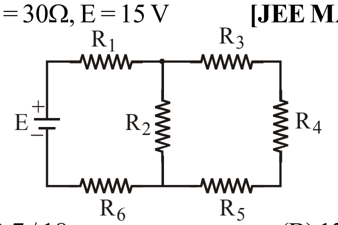
Q.52 A 200 Ω resistor has a certain color code. If one replaces the red color by green in the code, the new resistance will be : **[JEE MAIN 2019 (APRIL)]**
(A) 100 Ω (B) 400 Ω
(C) 500 Ω (D) 300 Ω

Q.53 In the circuit shown, a four-wire potentiometer is made of a 400 cm long wire, which extends between A and B. The resistance per unit length of the potentiometer wire is r = 0.01 Ω/cm. If an ideal voltmeter is connected as shown with jockey J at 50 cm from end A, the expected reading of the voltmeter will be : **[JEE MAIN 2019 (APRIL)]**



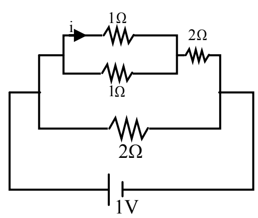
(A) 0.20 V (B) 0.25 V
(C) 0.75 V (D) 0.50V

Q.54 In the figure shown, what is the current (in Ampere) drawn from the battery ? You are given:
$R_1 = 15\Omega, R_2 = 10\Omega, R_3 = 20\Omega, R_4 = 5\Omega, R_5 = 25\Omega,$
$R_6 = 30\Omega, E = 15$ V **[JEE MAIN 2019 (APRIL)]**



(A) 7 / 18 (B) 13 / 24
(C) 9 / 32 (D) 20 / 3

Q.55 The current 'i' in the given circuit is
[JEE MAIN 2020 (JAN)]



(A) 0.2A (B) 0.3A
(C) 0.5A (D) 0.25A

Q.56 In a building there are 15 bulbs of 45 W, 15 bulbs of 100 W, 15 small fans of 10 W and 2 heaters of 1 kW. The voltage of electric main is 220 V. The minimum fuse capacity (rated value) of the building will be:
[JEE MAIN 2020 (JAN)]
(A) 5 A (B) 20 A
(C) 25 A (D) 15 A

Q.57 A battery of unknown emf connected to a potentiometer has balancing length 560 cm. If a resistor of resistance 10Ω is connected in parallel with the cell the balancing length change by 60 cm. If the internal resistance of the cell is (n/10) Ω, the value of 'n' is
[JEE MAIN 2020 (JAN)]

Q.58 The length of a potentiometer wire is 1200 cm and it carries a current of 60 mA. For a cell of emf 5V and internal resistance of 20Ω, the null point on it is found to be a 1000cm. The resistance of whole wire is :
[JEE MAIN 2020 (JAN)]
(A) 120 Ω (B) 60 Ω
(C) 80 Ω (D) 100 Ω

Q.59 Four resistances of 15Ω, 12Ω, 4Ω and 10Ω respectively in cyclic order to form Wheatstone's network. The resistance that is to be connected in parallel with the resistance of 10Ω to balance the network is ________Ω.
[JEE MAIN 2020 (JAN)]

Q.60 In a meter bridge experiment S is a standard resistance. R is a resistance wire. It Is found that balancing length is $\ell = 25$ cm. If R is replaced by a wire of half length and half diameter that of R of same material, then the balancing distance ℓ' (in cm) will now be________.
[JEE MAIN 2020 (JAN)]

EXERCISE - 4 [PREVIOUS YEARS AIPMT / NEET QUESTIONS]

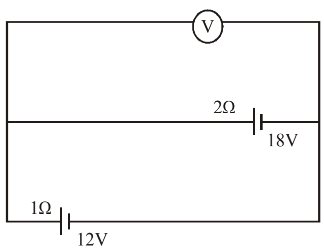
Q.1 When a wire of uniform cross-section a, length ℓ and resistance R is bent into a complete circle, resistance between any two of diametrically opposite points will be **[AIPMT 2005]**

(A) R/4 (B) 4R
(C) R/8 (D) R/2

Q.2 A 5A fuse wire can withstand a maximum power of 1W in circuit. The resistance of the fuse wire is **[AIPMT 2005]**

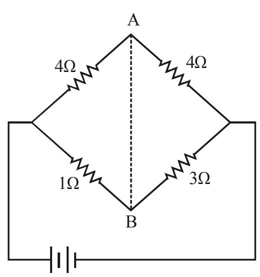
(A) 0.2Ω (B) 5Ω
(C) 0.4 Ω (D) 0.04 Ω

Q.3 Two batteries, one of emf 18 volt and internal resistance 2Ω and the other of emf 12 volt and internal resistance 1Ω, are connected as shown. The voltmeter V will record a reading of – **[AIPMT 2005]**



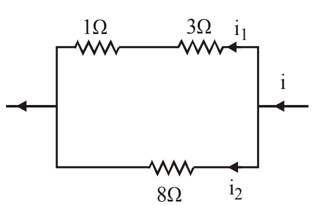
(A) 30 volt (B) 18volt
(C) 15 volt (D) 14 volt

Q.4 In the circuit shown, if a conducting wire is connected between points A and B, the current in this wire will – **[AIPMT 2006]**



(A) Flow in the direction which will be decided by the value of V
(B) be zero
(C) flow from B to A
(D) flow from A to B

Q.5 Power dissipated across the 8Ω resistor in the circuit shown here is 2 watt. The power dissipated in watt units across the 3Ω resistor is – **[AIPMT 2006]**

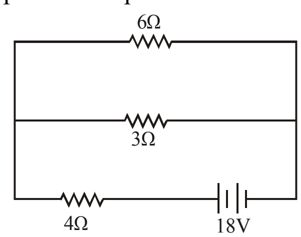


(A) 1.0 (B) 0.5
(C) 3.0 (D) 2.0

Q.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 – **[AIPMT 2006]**

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

Q.7 The total power dissipated in watts in the circuit shown here is – **[AIPMT 2007]**



(A) 40 (B) 54
(C) 4 (D) 16

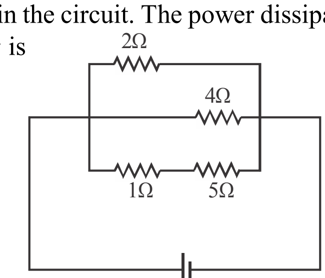
Q.8 Three resistances P, Q, R each of 2Ω and an unknown resistance S form the four arms of a Wheatstone bridge circuit. When a resistance of 6Ω is connected in parallel to S the bridge gets balanced. What is the value of S ? **[AIPMT 2007]**

(A) 3Ω (B) 6Ω
(C) 1Ω (D) 2Ω

Q.9 The resistance of an ammeter is 13Ω and its scale is graduated for a current upto 100 amps. After an additional shunt has been connected to this ammeter it becomes possible to measure currents upto 750 amperes by this meter. The value of shunt-resistance is – **[AIPMT 2007]**

(A) 2Ω (B) 0.2Ω
(C) 2kΩ (D) 20Ω

Q.10 A current of 3 amp flows through the 2 ohm resistor shown in the circuit. The power dissipated in the 5 ohm resistor is **[AIPMT 2008]**



(A) 5 watt (B) 4 watt
(C) 2 watt (D) 1 watt

Q.11 An electric kettle takes 4A current at 220 V. How much time will it take to boil 1 kg water from temperature 20°C? The temperature of boiling water is 100°C **[AIPMT 2008]**

(A) 4.2 min (B) 6.3 min
(C) 8.4 min (D) 12.6 min

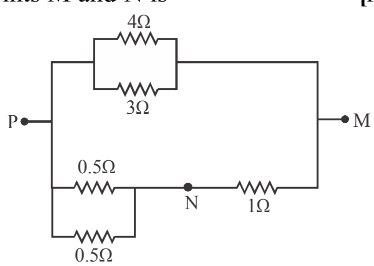
Q.12 A cell can be balanced against 110 cm and 100 cm of potentiometer wire, respectively with and without being short circuited through a resistance of 10 ohm. Its internal resistance is **[AIPMT 2008]**

(A) Zero (B) 1.0 ohm
(C) 0.5 ohm (D) 2.0 ohm

Q.13 A wire of a certain material is stretched slowly by ten per cent. Its new resistance and specific resistance become respectively **[AIPMT 2008]**

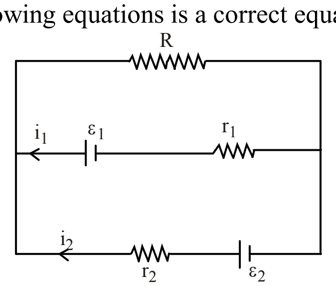
(A) 1.1 times, 1.1 times (B) 1.2 times, 1.1 times
(C) 1.21 times, same (D) Both remain the same

Q.14 In the circuit shown, the current through the 4 ohm resistor is 1 amp when the points P and M are connected to a d.c. voltage source. The potential difference between the points M and N is – **[AIPMT 2008]**



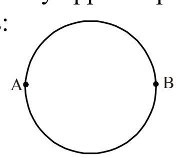
(A) 3.2 volt (B) 1.5 volt
(C) 1.0 volt (D) 0.5 volt

Q.15 See the electric circuit shown in this Figure. Which of the following equations is a correct equation for it? **[AIPMT 2009]**



(A) $\varepsilon_2 - i_2r_2 - \varepsilon_1 - i_1r_1 = 0$ (B) $-\varepsilon_2 - (i_1 + i_2) R + i_2r_2 = 0$
(C) $\varepsilon_1 - (i_1 + i_2) R + i_1r_1 = 0$ (D) $\varepsilon_1 - (i_1 + i_2) R - i_1r_1 = 0$

Q.16 A wire of resistance 12 ohms per meter 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: **[AIPMT 2009]**



(A) 3Ω (B) 6πΩ
(C) 6Ω (D) 0.6πΩ

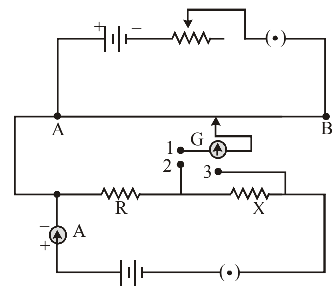
Q.17 A galvanometer having a coil resistance of 60Ω shows full scale deflection when a current of 1.0 amp passes through it. It can be converted into an ammeter to read currents upto 5.0 amp by – **[AIPMT 2009]**

(A) putting in series a resistance of 15Ω
(B) putting in series a resistance of 240Ω
(C) putting in parallel a resistance of 15Ω
(D) putting in parallel a resistance of 240Ω

Q.18 A student measures the terminal potential difference (V) of a cell (of emf E 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, then, respectively, equal: **[AIPMT 2009]**

(A) – r and E (B) r and – E
(C) – E and r (D) E and – r

Q.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 (i) 1 and 2 (ii) 1 and 3, is plugged in, are found to be at length ℓ_1 cm and ℓ_2 cm respectively. The magnitudes, of the resistors R and X, in ohms, are then, equal, respectively, to



[AIPMT (PRE) 2010]

(A) $k(\ell_2 - \ell_1)$ and $k\ell_2$ (B) $k\ell_1$ and $k(\ell_2 - \ell_1)$
(C) $k(\ell_2 - \ell_1)$ and $k\ell_1$ (D) $k\ell_1$ and $k\ell_2$

Q.20 A galvanometer has a coil of resistance 100 ohm and gives a full scale deflection for 30mA current. If it is to work as a voltmeter of 30 volt range, the resistance required to be added will be **[AIPMT (PRE) 2010]**

(A) 900 Ω (B) 1800 Ω
(C) 500 Ω (D) 1000 Ω

Q.21 Consider the following two statements.

(a) Kirchhoff's junction law follows from the conservation of charge.
(b) Kirchhoff's loop law follows from the conservation of energy. **[AIPMT (PRE) 2010]**

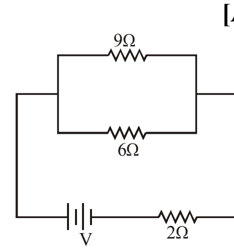
Which of the following is correct?

(A) Both (a) and (b) are wrong
(B) (a) is correct and (b) is wrong
(C) (a) is wrong and (b) is correct
(D) Both (a) and (b) are correct

Q.22 A current of 2A flows through a 2Ω resistor when connected across a battery. The same battery supplies a current of 0.5 A when connected across a 9Ω resistor. The internal resistance of the battery is **[AIPMT (PRE) 2011]**

(A) 1 Ω (B) 0.5 Ω
(C) 1/3 Ω (D) 1/4 Ω

Q.23 If power dissipated in the 9Ω resistor in the circuit shown is 36 Watt, the potential difference across the 2Ω resistor is – **[AIPMT (PRE) 2011]**



(A) 2 Volt (B) 4 Volt
(C) 8 Volt (D) 10 Volt

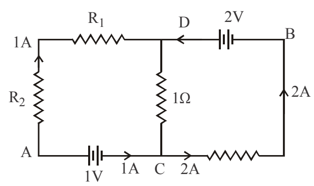
Q.24 A galvanometer of resistance, G is shunted by a resistance S ohm. To keep the main current in the circuit unchanged, the resistance to be put in series with the galvanometer is: **[AIPMT (MAINS) 2011]**

(A) $\frac{S^2}{(S+G)}$ (B) $\frac{SG}{(S+G)}$ (C) $\frac{G^2}{(S+G)}$ (D) $\frac{G}{(S+G)}$

Q.25 A thermocouple of negligible resistance produces an e.m.f. of 40 µV/°C in the linear range of temperature. A galvanometer of resistance 10 ohm whose sensitivity is 1µA/div, is employed with the thermocouple. The smallest value of temperature difference that can be detected by the system will be : **[AIPMT (MAINS) 2011]**

(A) 0.5°C (B) 1°C
(C) 0.1°C (D) 0.25°C

Q.26 In the circuit shown in the fig if potential at point A is taken to be zero the potential at point B **[AIPMT (MAINS) 2011]**

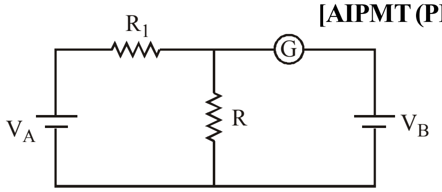


(A) –1V (B) +2V
(C) –2V (D) +1V

Q.27 A milli voltmeter of 25 milli volt range is to be converted into an ammeter of 25 ampere range. The value (in ohm) of necessary shunt will be : **[AIPMT (PRE) 2012]**

(A) 0.001 (B) 0.01
(C) 1 (D) 0.05

Q.28 In the circuit shown the cells A and B have negligible resistances. For $V_A = 12V$, $R_1 = 500\Omega$ and $R = 100\Omega$ the galvanometer (G) shows no deflection. The value of V_B **[AIPMT (PRE) 2012]**

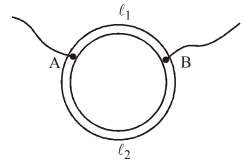


(A) 4V (B) 2V
(C) 12V (D) 6V

Q.29 If voltage across a bulb rated 220 Volt-100 Watt drops by 2.5% of its rated value, the percentage of the rated value by which the power would decrease is : **[AIPMT (PRE) 2012]**

(A) 20 % (B) 2.5 %
(C) 5 % (D) 10 %

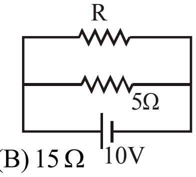
Q.30 A ring is made of a wire having a resistance $R_0 = 12\Omega$. Find the points A and B as shown in the figure, at which a current carrying conductor should be connected so that the resistance R of the sub circuit between these points is equal to (8/3)Ω. **[AIPMT (PRE) 2012]**



(A) $\frac{\ell_1}{\ell_2} = \frac{5}{8}$ (B) $\frac{\ell_1}{\ell_2} = \frac{1}{3}$

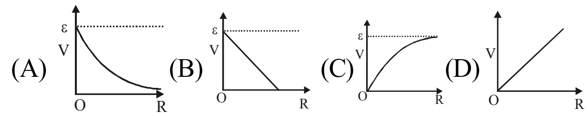
(C) $\frac{\ell_1}{\ell_2} = \frac{3}{8}$ (D) $\frac{\ell_1}{\ell_2} = \frac{1}{2}$

Q.31 The power dissipated in the circuit shown in the figure is 30 Watts. The value of R is : **[AIPMT (MAINS) 2012]**



(A) 20 Ω (B) 15 Ω
(C) 10 Ω (D) 30 Ω

Q.32 Cell having an emf ε and internal resistance r is connected across a variable external resistance R. As the resistance R is increased, the plot of potential difference V across R is given by : **[AIPMT (MAINS) 2012]**



Q.33 A wire of resistance 4Ω is stretched to twice its original length. The resistance of stretched wire would be – **[NEET 2013]**

(A) 16Ω (B) 2Ω
(C) 4Ω (D) 8Ω

Q.34 The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10Ω is **[NEET 2013]**

(A) 1.0 Ω (B) 0.2 Ω
(C) 0.5 Ω (D) 0.8 Ω

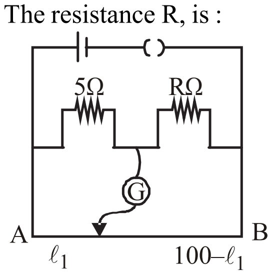
Q.35 The resistances of the four arms P,Q, R and S in a Wheatstone's bridge are 10 ohm, 30 ohm, 30 ohm and 90ohm, respectively. The e.m.f. and internal resistance of the cell are 7 volt and 5ohm respectively. If the galvanometer resistance is 50ohm, the current drawn from the cell will be – **[NEET 2013]**

(A) 2.0 A (B) 1.0 A
(C) 0.2 A (D) 0.1 A

Q.36 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 volt and the average resistance per km is 0.5 Ω. The power loss in the wire is **[AIPMT 2014]**

(A) 19.2 W (B) 19.2 kW
(C) 19.2 J (D) 12.2 kW

Q.37 The resistances in the two arms of the meter bridge are 5Ω and RΩ , respectively. When the resistance R is shunted with an equal resistance, the new balance point is at $1.6\ell_1$. The resistance R, is : **[AIPMT 2014]**



(A) 10Ω (B) 15Ω
(C) 20Ω (D) 25Ω

Q.38 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 2.0V 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) 9.5Ω, the 'balancing lengths', on the potentiometer wire are found to be 3m and 2.85m, respectively. The value of internal resistance of the cell is **[AIPMT 2014]**

(A) 0.25Ω (B) 0.95Ω
(C) 0.5Ω (D) 0.75Ω

Q.39 In an ammeter 0.2% of main current passes through the galvanometer. If resistance of galvanometer is G, the resistance of ammeter will be – **[AIPMT 2014]**

(A) $\frac{1}{499}G$ (B) $\frac{499}{500}G$ (C) $\frac{1}{500}G$ (D) $\frac{500}{499}G$

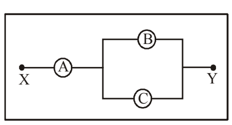
Q.40 Across a metallic conductor of non-uniform cross section a constant potential difference is applied. The quantity which remains constant along the conductor is – **[AIPMT 2015]**

(A) current (B) drift velocity
(C) electric field (D) current density

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

(A) 40 Ω (B) 44 Ω
(C) 48 Ω (D) 32 Ω

Q.42 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 : **[AIPMT 2015]**



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

Q.43 A potentiometer wire of length L and a resistance r are connected in series with a battery of e.m.f. E_0 and a resistance r_1. An unknown e.m.f. E is balanced at a length ℓ of the potentiometer wire. The e.m.f. E will be given by– **[RE-AIPMT 2015]**

(A) $\frac{LE_0 r}{(r+r_1)\,\ell}$ (B) $\frac{LE_0 r}{\ell r_2}$

(C) $\frac{E_0 r}{(r+r_1)}\cdot\frac{\ell}{L}$ (D) $\frac{E_0 \ell}{L}$

Q.44 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 – **[RE-AIPMT 2015]**

(A) $\frac{\sigma_1\sigma_2}{\sigma_1+\sigma_2}$ (B) $\frac{2\sigma_1\sigma_2}{\sigma_1+\sigma_2}$ (C) $\frac{\sigma_1+\sigma_2}{2\sigma_1\sigma_2}$ (D) $\frac{\sigma_1+\sigma_2}{\sigma_1\sigma_2}$

Q.45 A circuit contains an ammeter, a battery of 30 V and a resistance 40.8 ohm all connected in series. If the ammeter has a coil of resistance 480 ohm and a shunt of 20 ohm, the reading in the ammeter will be – **[RE-AIPMT 2015]**

(A) 1 A (B) 0.5 A
(C) 0.25 A (D) 2 A

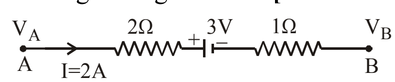
Q.46 The charge flowing through a resistance R varies with time t as $Q = at - bt^2$, where a and b are positive constants. The total heat produced in R is – **[NEET 2016 PHASE 1]**

(A) $\frac{a^3R}{6b}$ (B) $\frac{a^3R}{3b}$ (C) $\frac{a^3R}{2b}$ (D) $\frac{a^3R}{b}$

Q.47 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's is **[NEET 2016 PHASE 1]**

(A) 5 : 1 (B) 5 : 4
(C) 3 : 4 (D) 3 : 2

Q.48 The potential difference $(V_A - V_B)$ between the points A and B in the given figure is **[NEET 2016 PHASE 2]**



(A) –3 V (B) +3 V
(C) +6 V (D) +9 V

Q.49 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 PHASE 2]**

(A) 230 Ω (B) 46 Ω
(C) 26 Ω (D) 13 Ω

Q.50 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) R/n (B) n^2R (C) R/n^2 (D) nR

Q.51 A potentiometer is an accurate and versatile device to make electrical measurements of E.M.F. because the method involves – **[NEET 2017]**

(A) Potential gradients
(B) A condition of no current flow through the galvanometer
(C) A combination of cells, galvanometer and resistances
(D) Cells

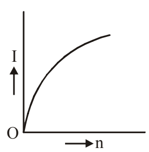
Q.52 A carbon resistor of (47 ± 4.7) kΩ is to be marked with rings of different colours for its identification. The colour code sequence will be **[NEET 2018]**

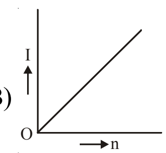
(A) Yellow – Green – Violet – Gold
(B) Yellow – Violet – Orange – Silver
(C) Violet – Yellow – Orange – Silver
(D) Green – Orange – Violet – Gold

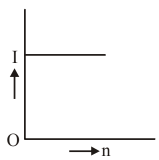
Q.53 A set of 'n' equal resistors, of value 'R' each, are connected in series to a battery of emf 'E' and internal resistance 'R'. The current drawn is I. Now, the 'n' resistors are connected in parallel to the same battery. Then the current drawn from battery becomes 10 I. The value of 'n' is **[NEET 2018]**

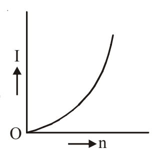
(A) 20 (B) 11 (C) 10 (D) 9

Q.54 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) 

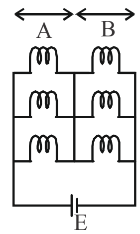
(C) 

(D) 

Q.55 Current sensitivity of a moving coil galvanometer is 5div/mA and its voltage sensitivity (angular deflection per unit voltage applied) is 20 div/V. The resistance of the galvanometer is **[NEET 2018]**

(A) 250 Ω (B) 25 Ω
(C) 40 Ω (D) 500 Ω

Q.56 Six similar bulbs are connected as shown in the figure with a DC source of emf E and zero internal resistance. The ratio of power consumption by the bulbs when (i) all are glowing and (ii) in the situation when two from section A and one from section B are glowing, will be : **[NEET 2019]**

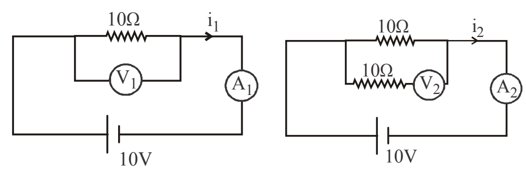


(A) 4 : 9 (B) 9 : 4
(C) 1 : 2 (D) 2 : 1

Q.57 Which of the following acts as a circuit protecting device? **[NEET 2019]**

(A) Conductor (B) Inductor
(C) Switch (D) Fuse

Q.58 In the circuits shown below, the readings of voltmeters and the ammeters will be **[NEET 2019]**



Circuit 1 Circuit 2

(A) $V_2 > V_1$ and $i_1 = i_2$ (B) $V_1 = V_2$ and $i_1 > i_2$
(C) $V_1 = V_2$ and $i_1 = i_2$ (D) $V_2 > V_1$ and $i_1 > i_2$

ANSWER KEY

EXERCISE - 1

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	B	B	A	A	C	B	C	C	C	A	A	A	A	A	A	D	A	A	C	A	C	A	C	A	B
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	A	D	C	A	D	A	B	C	A	D	B	A	D	A	D	C	D	B	D	C	D	B	D	A	C
Q	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
A	B	A	A	A	C	A	A	C	A	A	A	D	D	C	B	A	C	C	D	B	C	B	C	B	A
Q	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92								
A	B	C	B	A	C	A	D	B	A	D	B	B	A	C	C	B	B								

EXERCISE - 2

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	A	C	D	C	D	B	D	B	C	C	B	C	A	D	C	A	D	D	C	A	C	C	A	D	C
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	B	C	C	C	D	A	C	B	B	B	D	C	D	B	D	C	B	D	A	A	C	B	C	A	D
Q	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69						
A	D	A	A	D	A	A	B	C	B	C	A	B	C	A	D	C	D	B	B						

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10
A	2	20	4	6	20	5	225	11	9	4

EXERCISE - 4

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	C	B	C	C	C	C	B	A	C	A	B	D	C	A	D	D	B	B	B	B	B	D	D	A	D
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	B	B	B	A	A	D	B	C	D	D	A	B	C	D	A	B	C	D	D	D	A	B	D	C	D
Q	51	52	53	54	55	56	57	58	59	60															
A	B	C	B	C	A	B	12	D	10	40															

EXERCISE - 5

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
A	A	D	D	C	C	D	B	A	A	A	B	B	C	A	D	D	C	A	B	A	D	C	D	C	D	D	A	B	C	D
Q	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58		
A	C	C	A	C	C	B	B	C	C	A	D	D	C	B	B	A	D	D	C	B	B	B	C	C	A	B	D	C		

CURRENT ELECTRICITY
TRY IT YOURSELF - 1

(1) **(C).**

$$E = \rho \frac{i}{A}$$

$$E = \frac{kr^2}{R}\frac{i}{\pi r^2}$$

$$E = \frac{ki}{\pi R}$$

(2) **(A).**

$E_C = 2E_A = 2E_B = 2E_D$ ...(1)

$d_D = 2d_A = 2d_B = 2d_C$ ...(2)

from (1) & (2), we get

$$\frac{1}{4E_C d_C^2} = \frac{1}{8E_A d_A^2} = \frac{1}{8E_B d_B^2} = \frac{1}{2E_D d_D^2}$$

$$\therefore \quad \frac{\sigma_C}{4} = \frac{\sigma_A}{8} = \frac{\sigma_B}{8} = \frac{\sigma_D}{2}$$

So, (A)

(3) **(A).**

$i = neA\,V_d$

$$i = \frac{i}{A} = nE\,(s\delta)$$

$$\sigma E = ne\left(\frac{eE}{m}\delta\right)$$

$$\delta = \frac{\sigma m}{ne^2} \qquad \Rightarrow \delta \,\alpha\, \sigma$$

(4) **(A).**

(5) **(A).**

(6) **(A).**

(i) $J = \frac{I}{A}$

$J = Nev_2$

$$v_d = \frac{I}{ANe} = \frac{2.56}{10^{-6} \times 8 \times 10^{28} \times 1.6 \times 10^{-19}}$$

$= 2 \times 10^{-4}$

Hence $t = 10^{-2}/2 \times 10^{-4} = 50$ sec

(ii) $\frac{1}{\rho} = \frac{Ne_2\tau}{m}$

hence $\tau = \frac{m}{\rho Ne^2}$

$$= \frac{9.1 \times 10^{-19}}{\left(1.6 \times 10^{-8} \times 8 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.66 \times 10^{-4}\right)}$$

$\cong 10^{-13}$ sec.

(iii) $S = 2 \times 10^{-4} \times 10 = 2 \times 10^{-3}$

$$E = \rho J = 1.6 \times 10^{-8} \times \frac{2.56}{10^{-6}}$$

$v = Es = 80\ \mu V$]

(7) **(D).**

TRY IT YOURSELF - 2

(1) **(BC).**

(2) **(ABC).**

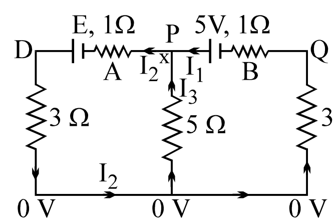
$V_{PQ} = 5 - I_1(1) = 0 \quad \Rightarrow \quad I_1 = 5A$

$x = 3(I_1) = -15$ V

$\Rightarrow I_3 = 3A$

$\therefore I_2 = 5 + 3 = 8$ A

$\Rightarrow V_0 = 8(3) = 24$ V



$V_0 - V_P = 24 - (-15) = 39$ V

Also, $V_0 - V_P = E - I_2(1)$

$\Rightarrow \quad 39 = E - 8(1)$

$\Rightarrow \quad E = 47$ V

(3) **(D).**

$$R_{AD} = \frac{9}{2}\ \Omega$$

$$I = \frac{9}{R_{AD}} = 2\text{ A}$$

Current equally divides in ABD & ACD as $R_{ABD} = R_{ACD}$

$V_B = V_A - R_{AB}(I/2) = V_A - 7$

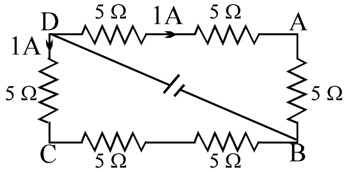
$V_C = V_A - R_{AC}(I/2) = V_A - 4$

$V_{BC} = V_B - V_C = -3V$]

(4) **(CD).**

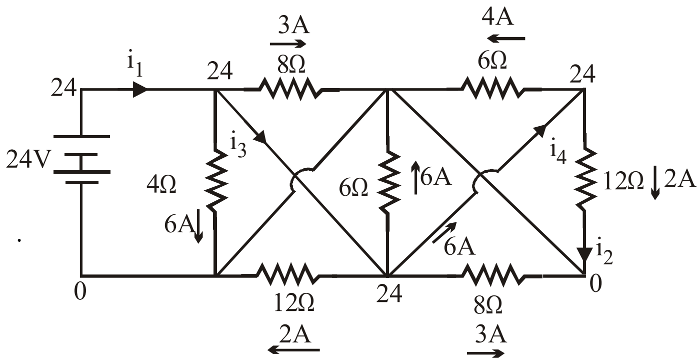
Current in the circuit $\quad I = \frac{15}{15} \times 2$

$I = 2$ Amp

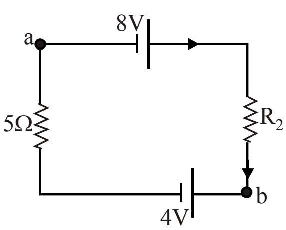


$V_D = +15$
$V_D - 10 \times 1 = V_A$
$V_A = 15 – 10 = 5\text{ V}$
$V_C = 15 - 5 \times 1 = 10\text{ V}$

(5) **(ABCD).**



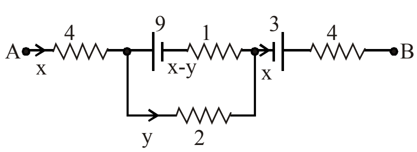
(6) **(C).** $V_b - V_a = 5.5$



$5i + 4 = 5$
$i = 0.2$

$$i = \frac{8-4}{5+R_2} \quad \Rightarrow \quad 5 + R_2 = \frac{4}{0.2}$$

(7) **(C).**



$16 = 4x + 9 + (x - y) \cdot 1 - 3 + 4x$
$16 = 9x - y + 9$

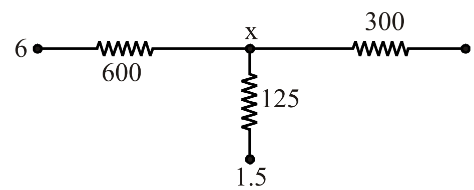
$9x - y = 7$ ......(i)

$2y = 9 + (x - y)$
$3y - x = 9$ ......(ii)

from (i) and (ii)
$9(3y - 9) - y = 7$
$27y - 81 - y = 7$
$26y = 88$

$$y = \left(\frac{88}{26}\right)$$

(8) **(AB).**



$$\frac{x-6}{600} + \frac{x-1.5}{125} + \frac{x-4.5}{300} = 0$$

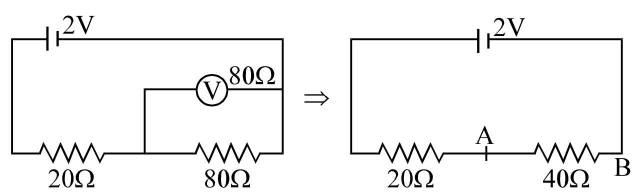
$1.5 < x < 4.5$

(9) **(A).**
Ohm's law $V = iR$
$\Rightarrow V \propto i$ (for ammeter)

$$\therefore \frac{V_2}{V_1} = \frac{i_2}{i_1} = 2 \Rightarrow \quad 10 = 2 \times 10 \times \frac{R}{2+R}$$

$\Rightarrow R = 2\,\Omega$

(10) **(C).**



reading of the voltmeter = Potential difference across AB =

$$\frac{40}{20+40} \times 2 = 1.33\text{ V}$$

TRY IT YOURSELF - 3

(1) **(B).**
(2) **(B).**

(3) **(A).**
(4) **(C).**
(5) **(A).**
(6) **(D).**

$R_{AB} = \dfrac{\rho \times 4a}{2a^2}$; $R_{CD} = \dfrac{\rho \times a}{8a^2}$; $R_{EF} = \dfrac{\rho \times 2a}{4a^2}$
x y z

x > z > y

(7) **(A).**

Resistance of each part $= \dfrac{R}{2n}$

For 'n' such parts connected in series, equivalent resistances, say $R_1 = n\left[\dfrac{R}{2n}\right] = \dfrac{R}{2}$

Similarly, equivalent resistance say R_2 for another set of n identical respectively in parallel would be

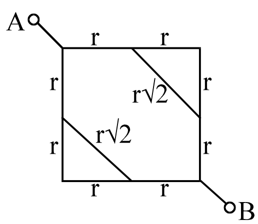
$$\frac{1}{n}\left(\frac{R}{2n}\right) = \frac{R}{2n^2}$$

For getting maximum of R_1 & R_2, they should be connected in series & hence,

$$R_{eq} = R_1 + R_2 = \frac{R}{2}\left(1 + \frac{1}{n^2}\right)$$

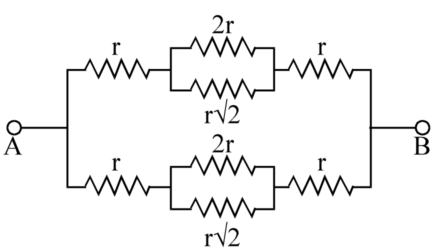
(8) **(A).**

The circuit is equivalent to



Let each half side has resistance r (= ρd/2)

∴

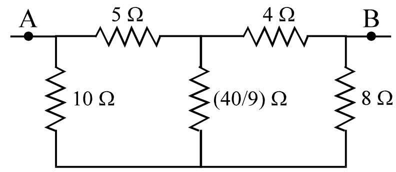


$$\therefore \quad R = \frac{1}{2}\left[2r + \frac{(2r)(r\sqrt{2})}{(2+\sqrt{2})r}\right] = r\sqrt{2} \text{ (on solving)}$$

$\therefore \quad R = \rho d/\sqrt{2}$

(9) **(A).**

The given circuit is equivalent to



As 10 × 4 = 5 × 8 this is balanced Wheatstone network

Therefore $R = \dfrac{(5+4)\times(10+8)}{9+18} = 6$ ohm

(10) **(D).** $\dfrac{1}{20} + \dfrac{1}{20} + \dfrac{1}{15} = \dfrac{6+4}{60} = 6\Omega$

TRY IT YOURSELF - 4

(1) **(D).**
(2) **(BD).**
(3) **(D).**
(4) **(C).**
(5) **(B).** In first case

$i = k_1\theta_1, i = k_2\theta_2$

$\therefore \quad k_1\theta_1 = k_2\theta_2$ ...(1)

In second case

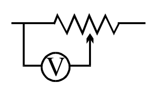
$v_1 = v_2$

$\Rightarrow \quad k_1\theta'_1 r_1 = k_2\theta'_2 r_2$ ...(2)

from (1) & (2), we get $r_2 = r_1 \dfrac{\theta_2\theta'_1}{\theta_1\theta'_2}$

(6) **(C).**

R_{eq} till ac $= \dfrac{6000 \times 3000}{6000+3000} = 2000\,\Omega$



$R = 2000 + 9000 = 11000\,\Omega$

$\Rightarrow \quad i = \dfrac{220}{11000} = 0.02$ A

$\Rightarrow \quad V = 2000 \times 0.02 = 40$ V

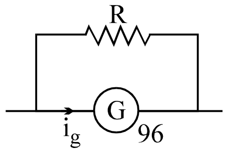
(7) **(D).**

$i_g = 100 \times 10^{-4} = 0.01$ A

$10 = 0.01\,(R + 100) \quad \Rightarrow \quad R = 900\,\Omega$

(8) **(BD).**

$(i - i_g)R = i_g \times 96$



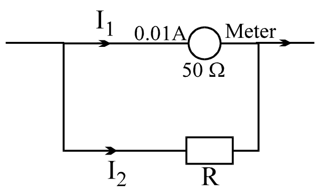
$(i - 10^{-4})R = 96 \times 10^{-4}$

(9) (ABC).

Potential drop across wire $V = \left(\dfrac{E_1}{r + R_1}\right)R_1$

R_1 : Resistance of wire
for the direction shown of current $E_2 > V$
so correct options are (A), (B) & (C)

(10) (D).



$I_2 = 8A$ (app) as I_1 is very-very small
$r_g I_1 = I_2 R$

$$R = \frac{r_g I_1}{I_2} = \frac{0.01 \times 80}{8} = 0.062\,\Omega$$

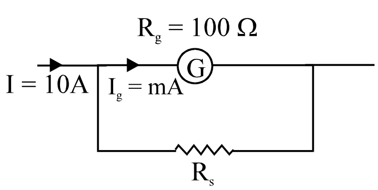
(11) (B).

If ℓ_1 = length from one end then $\dfrac{\ell_1}{1-\ell_1} = \dfrac{X}{R} = \dfrac{12}{18}$

and ℓ'_1 = length from one end in second case $\dfrac{\ell'_1}{1-\ell'_1} = \dfrac{X}{R'}\;\dfrac{12}{8}$

So shift = 20 cm

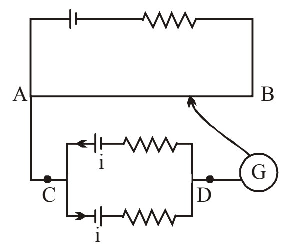
(12) (B).



$I_g R_g \approx I R_s$

$$R_s = \frac{I_g R_g}{I} = \frac{10 \times 10^{-3} \times 100}{10} = 0.1\,\Omega$$

(13) (AB).



For null point current flow in the loop CD only.

$$i = \frac{3V}{2\Omega + 1\Omega} = 1\,A$$

$V_{CD} = 1V - 1\,(1) = 0$
$\therefore$ option (A) is correct
is $V_A > V_B$
When Jockey touches to B current flow from A to B to increase the P.D. acros the secondary circuit.
$\therefore$ option (B) is correct

(14) (AB).

$$\frac{R}{R_1 + R_2} = \frac{L/4}{3L/4}$$

$3R = (R_1 + R_2)$

$$\frac{R + R_1}{R_2} = \frac{2/3}{1/3}$$

$3R = R_2 + R_1$
$R = 2R_2 - R_1$
$4R = 3R_2$

$$R_1 = \frac{5R}{3}\;;\; R_2 = \frac{4R}{3}$$

(15) (C).

$$\frac{x}{R_0} = \frac{\ell}{100 - \ell}$$

Since null point remains unchanged

$\dfrac{x}{R'} = \dfrac{40}{60} \quad \Rightarrow \quad R' = 6\Omega$

and $6 = \dfrac{78 R_t}{R_t + 78} \quad \Rightarrow \quad R_t = 6.5\,\Omega$

$$\alpha = \frac{R_t - R_0}{R_0 t} = 8.3 \times 10^{-4}\,k^{-1}$$

(16) (B).

Potential gradient $= \dfrac{V_{AB}}{L_{AB}} = \dfrac{iR_{AB}}{L_{AB}}$

$$= \frac{\left(\frac{2V}{1+4}\right)4}{80\,\text{cm}} = \frac{1}{50}\ \text{v/cm},$$

So balancing length for 1V is 50 cm

TRY IT YOURSELF - 5

(1) **(D).** For a bulb

$R = \dfrac{v^2}{W}$ and $W_B < W_A$

So, $R_B > R_A$ and $V_A = \dfrac{24\times 3}{7} < 12\,V$

$V_B = \dfrac{24\times 4}{7} > 12\,V$

After closing the switch
$V_A = V_B = 12V$, So, V_A increases
But V_B decreases
hence, P_A increases and P_B decreases

(2) **(B).**

(3) **(A).**

(4) **(D).**

(5) **(C).** $V = E + IR = 12 + 50\,(0.04) = 14\,V$

(6) **(A).** $P = I^2R = (50)^2\,(0.04) = 100\,W$

(7) **(C).**
Rate of energy conversion from electrical to chemical is EI
$= 12(50) = 600\,W$

(8) **(C).**
Let R_A and R_B are resistances

$R_A = \rho\dfrac{l_A}{A_A}$ & $R_B = \rho\dfrac{l_B}{A_B}$

$\dfrac{R_A}{R_B} = \dfrac{l_A}{l_B} \times \dfrac{A_B}{A_A} = \left(\dfrac{A_B}{A_A}\right)^2$ $[\because l_A A_A = l_B A_B$

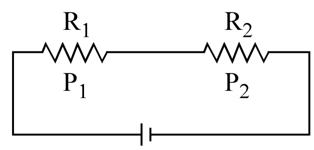
$\Rightarrow \dfrac{A_B}{A_A} = \dfrac{l_A}{l_B} = \dfrac{(\pi\times 9r^2)^2}{(\pi r^2)^2} = \dfrac{81}{1}$

In series $H_A : H_B = R_A : R_B = 81 : 1$

(9) **(C).**

$R = \dfrac{V^2}{P}$ $\therefore R_1 = \dfrac{110\times 110}{50}$

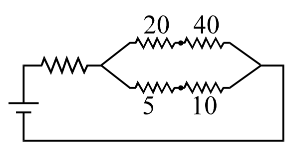
$R_2 = \dfrac{110\times 110}{100}$



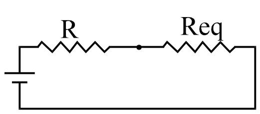
$I = \dfrac{110}{3R} = \dfrac{110\times 100}{3\times 110\times 110} = \dfrac{10}{33}$ amp.

$P_1 = I^2 \times R_1 = \dfrac{10}{33}\times\dfrac{10}{33}\times\dfrac{110\times 110}{50} = \dfrac{200}{9} \approx 22\,W$

(10) **(A).**



$\Rightarrow$



Here $R_{eq} = 12$
For maximum P ; $R = R_{eq} = 12$

CHAPTER-2 : CURRENT ELECTRICITY
EXERCISE-1

(1) **(B).** The SI unit of current density is A/m^2.

$J = \frac{I}{A}$ (SI unit of current I is ampere, A and SI unit of area of cross-section area A is m^2)

$\Rightarrow J = \frac{A}{m^2} \Rightarrow J = Am^{-2}$.

(2) **(B).** The direction of current density is the direction of flow of positive charge in the circuit which is possible due to electric field produced by charges accumulated on the surface of wire.

(3) **(A).** Q = It
Also Q = ne [$e = 1.6 \times 10^{-19}$ C] $\therefore$ ne = I t

or $n = \frac{It}{e} = \frac{1A \times 1s}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}$ electrons s^{-1}

(4) **(A).** Current is conductor $I = neAv_d \Rightarrow I \propto v_d$
Hence, current in a conductor is determined by drift velocity and does not depend upon thermal velocity.

(5) **(C).** $i = \frac{q}{t} = \frac{4}{2} = 2$ ampere

(6) **(B).** In the absence of external electric field mean velocity of free electron (V_{rms}) is given by

$$V_{rms} = \sqrt{\frac{3KT}{m}} \Rightarrow V_{rms} \propto \sqrt{T}$$

(7) **(C).** $v_d = \frac{i}{nAe} = \frac{1.344}{10^{-6} \times 1.6 \times 10^{-19} \times 8.4 \times 10^{22}}$

$$= \frac{1.344}{10 \times 1.6 \times 8.4} = 0.01 cm/s = 0.1 mm/s$$

(8) **(C).** $Q = it = 20 \times 10^{-6} \times 30 = 6 \times 10^{-4}$ C

(9) **(C).** $V_d = \frac{i}{nAe} = \frac{5.4}{8.4 \times 10^{28} \times 10^{-6} \times 1.6 \times 10^{-19}}$

$$= 0.4 \times 10^{-3} \text{ m/sec} = 0.4 \text{mm/sec}.$$

(10) **(A).** As steady current is flowing through the conductor, hence the number of electrons entering from one end and outgoing from the other end of any segment is equal. Hence charge will be zero.

(11) **(A).** In general, the resistance R is inversely proportional to the cross-sectional area, $R \propto 1/A$

(12) **(A).** Ohm's law V = I R is an equation of straight line. Hence I – V characteristics for ohmic conductors is also a straight line and its slope gives resistance of the conductor.

(13) **(A).** Because with rise in temperature resistance of conductor increase, so graph between V and i becomes non linear.

(14) **(A).** For a given voltage V across the slab, if I is the current through the entire slab, then clearly the current flowing through each of the two half-slabs is I/2.

(15) **(A).** Ammeter is always connected in series and voltmeter in parallel.

(16) **(D).** ρ (resistivity) depends on the material of the conductor.

(17) **(A).**

Materials	Resistivity (ρ) (Ω m at 0°C)
Copper (Cu)	1.7×10^{-8}
Nichrome (alloy of Ni, Fe, Cr)	100×10^{-8}
Germanium	0.46
Silicon	2300

(18) **(A).** The potential difference V across the end of a conductor can be expressed as $V = E\,I$ .... (1)

and $V = IR = \left(\frac{I\rho\ell}{A}\right)(\Rightarrow V = J\rho\ell$ ..... (2)

From Eqs. (1) and (2), $E\ell = J\rho\ell$

$\Rightarrow E = J\rho \Rightarrow J = \frac{1}{\rho} \cdot E \Rightarrow J = \sigma E$

where, $\sigma = 1/\rho$ is called the conductivity (reciprocal of resistivity).

(19) **(C).** The graph (A) is true for conductors whose resistivity increases with temperature. But for semiconductors, resistivity decreases as the number of conducting electrons increase with rise of temperature.

(20) **(A).** α is called the temperature coefficient of resistivity. For metals, α is positive.

(21) **(C).** Metal have low resistivities in the range of 10^{-8} Ωm to 10^{-6} Ωm

(22) **(A).** On comparing equations

$$I\Delta t = \frac{ne^2A}{m}\tau\,\Delta t\,|E| \text{ and } I = JA,$$

we get exactly Ohm's law, if we identify, the conductivity $\sigma = \frac{ne^2}{m}\tau$.

We thus see that a very simple picture of electrical conduction reproduces Ohm's law. We have, of course, made assumptions that τ and n are constants, independent of E.

(23) **(C).** We know that $|E| = -\frac{dV}{d\ell}$.
The potential difference V across its ends is $E\ell$.

(24) **(A).** Mobility μ defined as the magnitude of the drift velocity per unit electric field $\mu = \frac{|v_d|}{E}$.

(25) **(B).** Semiconductors having negative temperature coefficient of resistivity whereas metals are having positive temperature coefficient of resistivity with increase in temperature the resistivity of metal increases whereas resistivity of semiconductor decreases.

(26) **(A).** The resistivity of a material is found to be dependent on the temperature. Different materials do not exhibit the same dependence on temperatures. Over a limited range of temperatures, that is not too large, the resistivity of a metallic conductor is approximately given by, $\rho_r = \rho_0\,[1+\alpha\,(T-T_0)$
where, ρ_r is the resistivity at a temperature T and ρ_0 at a reference temperature T_0. α is called the temperature coefficient of resistivity.

(27) **(D).** Resistivity is the property of the material. It does not depend upon size and shape.

(28) **(C).** For semiconductors, resistance decreases on increasing the temperature.

(29) **(A).** $R = \rho\frac{\ell}{A} = \frac{m}{ne^2\tau}.\frac{\ell}{A}$

(30) **(D).** $\ell = \frac{R\pi r^2}{\rho} = \frac{4.2\times 3.14\times(0.2\times10^{-3})^2}{48\times10^{-8}} = 1.1\text{m}$

(31) **(A).** $R \propto \frac{\ell}{r^2}$. For highest resistance $\frac{\ell}{r^2}$ should be maximum, which is correct for option (A)

(32) **(B).** $R \propto \frac{1}{r^2} \Rightarrow \frac{R_2}{R_1} = \frac{\ell_2}{\ell_1}\times\frac{r_1^2}{r_2^2} = \left(\frac{2}{1}\right)\times\left(\frac{1}{2}\right)^2 = \frac{1}{2}$

$\Rightarrow R_2 = \frac{R_1}{2}$, specific resistance doesn't depend upon length, and radius.

(33) **(C).** Resistance $= \rho\frac{\ell}{A}$

$\therefore \frac{R_1}{R_2} = \frac{\rho_1}{\rho_2}\times\frac{\ell_1}{\ell_2}\times\frac{A_2}{A_1} = \frac{2}{3}\times\frac{3}{4}\times\frac{5}{4} = \frac{5}{8}$

(34) **(A).** When the same potential difference, that is the voltage, is applied as in houses, $\text{Power} = VI = \frac{V^2}{R}$.
The smaller resistance consumes greater power. Here 100 W bulb has less resistance. It should glow more brightly. The 60 W bulb has more resistance and therefore statement (A) is correct.

(35) **(D).** Heating effect of current.

(36) **(B).** Because all the lamps have same voltage.

(37) **(A).** When the heater is connected to the supply its initial current will be slightly higher than its steady value but due to heating effect of the current the temperature will rise. This causes an increase in resistance and a slight decrease in current to steady current.

(38) **(D).** Equivalent resistance of parallel resistors is always less than any of the member of the resistance system.

(39) **(A).** Each part will have a resistance r = R/10
Let equivalent resistance be r_R then

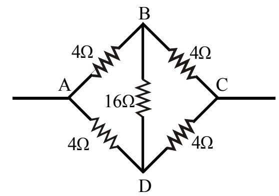
$\frac{1}{r_R} = \frac{1}{r}+\frac{1}{r}+\frac{1}{r}$...........10 times

$\therefore \frac{1}{r_R} = \frac{10}{r} = \frac{10}{R/10} = \frac{100}{R} \Rightarrow r_R = \frac{R}{100} = 0.01R$

(40) **(D).** $R_{series} = R_1 + R_2 + R_3 + \ldots\ldots$

(41) **(C).** $R_{max} = nR$ and $R_{min} = R/n \Rightarrow \frac{R_{max}}{R_{min}} = n^2$

(42) **(D).** According to the principle of Wheatstone's bridge, the effective resistance between the given points is 4Ω.



(43) **(B).** $\frac{7}{12} = \frac{1}{4}+\frac{1}{R} \Rightarrow R = 3\Omega$

(44) **(D).** Suppose resistance of wires are R_1 and R_2 then

$\frac{6}{5} = \frac{R_1R_2}{R_1+R_2}$.

If R_2 breaks then $R_1 = 2\Omega$

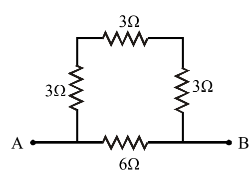
Hence, $\frac{6}{5} = \frac{2\times R_2}{2+R_2} \Rightarrow R_2 = 3\Omega$.

(45) **(C).** Resistance of 1 ohm group $= \frac{R}{n} = \frac{1}{3}\Omega$

This is in series with $\frac{2}{3}\Omega$ resistor.

$\therefore$ Total resistance $= \frac{2}{3}+\frac{1}{3} = \frac{3}{3}\Omega = 1\Omega$

(46) **(D).** The circuit reduces to



$R_{AB} = \frac{9\times6}{9+6} = \frac{9\times6}{15} = \frac{18}{5} = 3.6\Omega$

(47) **(B).** $R_1 + R_2 = 9$ and $\frac{R_1R_2}{R_1+R_2} = 2 \Rightarrow R_1R_2 = 18$

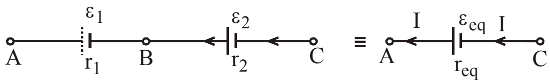
$R_1 - R_2 = \sqrt{(R_1+R_2)^2 - 4R_1R_2} = \sqrt{81-72} = 3$

$R_1 = 6\Omega, R_2 = 3\Omega$

(48) **(D).** The electrolyte through which a current flows has a finite resistance r, called the internal resistance. This is due to collision among ions.

(49) **(A).** The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2, i.e. $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$.

(50) (C).



Consider first two cells in series, where one terminal of the two cells is joined together leaving the other terminal in either cell free.

ε_1, ε_2 are the emf's of the two cells and r_1, r_2 their internal resistances, respectively.

Let V (A), V (B), V (C) be the potentials at points A, B, and C shown in figure. Then, V(A) – V(B) is the potential difference between the positive and negative terminals of the first cell.

Hence, $V_{AB} \equiv V(A) - V(B) = \varepsilon_1 - Ir_1$

Similarly, $V_{BC} \equiv V(B) - V(C) = \varepsilon_2 - Ir_2$

Hence, the potential difference between the terminals A and C of the combination is

$V_{AC} \equiv V(A) - V(C) = [V(A) - V(B)] + [V(B) - V(C)]$

$= (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$

If we wish to replace the combination by a single cell between A and C of emf ε_{eq} and internal resistance r_{eq}, we would have $V_{AC} = \varepsilon_{eq} - I\,r_{eq}$

Comparing the last two equations, we get

$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ and $r_{eq} = r_1 + r_2$

(51) (B). In parallel combination of cells the voltage across the terminals is same and resistance is minimum. Therefore from V = IR. The current drawn from cell combination will be more.

(52) (A). Here, $\varepsilon = 24$ V and $r = 0.8\ \Omega$

For the maximum current from the battery,

$\varepsilon = I r$ ($\because R = 0$)

$$\therefore \quad I = \frac{\varepsilon}{r} = \frac{24}{0.8} = 30\text{ A}$$

(53) (A). Consider a parallel combination of the cells. I_1 and I_2 are the currents leaving the positive electrodes of the cells. At the point B_1, I_1 and I_2 flow in whereas the current I flows out. Since, as much charge flows in as out, we have $I = I_1 + I_2$

Let V (B_1) and V(B_2) be the potentials at B_1 and B_2, respectively. Then, considering the first cell, the potential difference across its terminals is

$V(B_1) - V(B_2)$

Hence, $V \equiv V(B_1) - V(B_2) = \varepsilon_1 - I_1 r_1$

$$\Rightarrow I_1 = \frac{\varepsilon_1 - V}{r_1}$$

Points B_1 and B_2 are connected exactly, similarly to the second cell. Hence, considering the second cell, we also have

$$V \equiv V(B_1) - V(B_2) = \varepsilon_2 - I_2 r_2 \Rightarrow I_2 = \frac{\varepsilon_2 - V}{r_2}$$

Combining the last three equations

$$I = I_1 + I_2 = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2} = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

Hence, V is given by, $V = \dfrac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} - I\dfrac{r_1 r_2}{r_1 + r_2}$

If we want to replace the combination by a single cell, between B_1 and B_2 of emf ε_{eq} and internal resistance r_{eq}, we would have

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

(54) (A). In the parallel combination,

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \ldots + \frac{\varepsilon_n}{r_n}\ ;\ \frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \ldots + \frac{1}{r_n}$$

($\because \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = \ldots = \varepsilon_n = \varepsilon$ and $r_1 = r_2 = r_3 = \ldots r_n = r$)

$$\therefore \quad \frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon}{r} + \frac{\varepsilon}{r} + \ldots + \frac{\varepsilon}{r} = n\frac{\varepsilon}{r} \qquad \ldots (1)$$

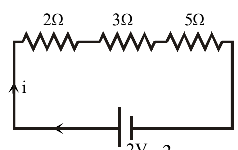
$$\frac{1}{r_{eq}} = \frac{1}{r} + \frac{1}{r} + \ldots + \frac{1}{r} = \frac{n}{r}\ ;\ r_{eq} = \frac{r}{n} \ldots (2)$$

From eq. (1) and (2), $\varepsilon_{eq} = n\dfrac{\varepsilon}{r} \times r_{eq} = n \times \dfrac{\varepsilon}{r} \times \dfrac{r}{n} = \varepsilon$

(55) (C). $R_{equivalent} = \dfrac{(30+30)30}{(30+30)+30} = \dfrac{60 \times 30}{90} = 20\Omega$

$$\therefore i = \frac{V}{R} = \frac{2}{20} = \frac{1}{10}\text{ ampere}$$

(56) (A). Current supplied by cell



$$i = \frac{2}{2+3+5} = \frac{1}{5}\text{A}$$

$V = iR = 3/5 = 0.6$

(57) (A). Equivalent resistance of the circuit $R = \dfrac{3}{2}\Omega$

$\therefore$ Current through the circuit $i = \dfrac{V}{R} = \dfrac{3}{3/2} = 2\text{A}$

(58) (C). For maximum power,

External resistance = Internal resistance.

(59) (A). $0.9(2+r) = 0.3(7+r) \Rightarrow 6 + 3r = 7 + r \Rightarrow r = 0.5\ \Omega$

(60) (A). Since both the resistors are same, therefore potential difference = V + V = E ⇒ V = E/2

(61) (A). $P = \dfrac{W}{t} = Vi \Rightarrow V = \dfrac{W}{it} = \dfrac{1000}{2 \times 6 \times 60} = 1.38\text{ V}$

(62) (D). Because cell is in open circuit.

(63) (D). Maximum current will be drawn from the circuit if resultant resistance of all internal resistances is equal to the value of external resistance if the arrangement is mixed. In series, R >> nr and in parallel, the external resistance is negligible.

(64) (C). Total cells = m × n = 24 .... (i)

For maximum current in the circuit

$$R = \frac{mr}{n} \Rightarrow 3 = \frac{m}{n} \times (0.5) \Rightarrow m = 6n \qquad \ldots (ii)$$

On solving equation (i) and (ii), we get m = 12, n = 2

(65) **(B).** Cells are joined in parallel when internal resistance is higher then a external resistance. (R << r)

$$i = \frac{E}{R + \frac{r}{n}}$$

(66) **(A).** Applying Kirchhoff's first law at the junction P, we get $6 = I_1 + I_2$ ... (1)
Applying Kirchhoff's second law to the closed loop PQRP, we get
$-2I_1 - 2I_1 + 2I_2 = 0$ or $2I_1 + 2I_1 - 2I_2 = 0$
or, $4I_1 - 2I_2 = 0$ ... (2)
Solve (i) and (ii), we get $I_1 = 2\,A, I_2 = 4\,A$.

(67) **(C).** On applying Kirchoff's current law, i = 13A.

(68) **(C).** To convert a galvanometer into an ammeter a low value resistance is to be connected in parallel to it called shunt.

(69) **(D).** Resistance of voltmeter should be greater than the external circuit resistance. An ideal voltmeter has infinite resistance.

(70) **(B).** $\because\ i_g = (100-90)\%$ of $i = i/10$

$\Rightarrow$ Required shunt $S = \frac{G}{(n-1)} = \frac{900}{(10-1)} = 100\Omega$

(71) **(C).** $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{5}{2} = 1 + \frac{12}{S} \Rightarrow S = 8\Omega$. (In parallel).

(72) **(B).** The deflection in galvanometer will not be changed due to interchange of battery and the galvanometer.

(73) **(C).** The bridge will be balanced when the shunted resistance is of the value of 3Ω

$\therefore\ 3 = \frac{4 \times R}{4 + R}$; $12 + 3R = 4R$ $\therefore$ $R = 12$

(74) **(B).** The given fig. is balance wheat stone bridge.

(75) **(A).** This is a balanced Wheatstone bridge. Therefore no current will flow from the diagonal resistance 10Ω

$\therefore$ Equivalent resistance $= \frac{(10+10)\times(10+10)}{(10+10)+(10+10)} = 10\Omega$

(76) **(B).** This is a balanced Wheatstone bridge circuit.
So potential at B and D will be same and no current flows through 4R resistance.

(77) **(C).** BC, CD and BA are known resistance. The unknown resistance is connected between A & D.

(78) **(B).** Here, $\frac{R}{S} = \frac{3}{2}$, $S = 10\Omega$ $\therefore$ $R = \frac{3}{2} \times S = \frac{3}{2} \times 10 = 15\,\Omega$

As the length of wire is 1 m.
$\therefore$ Length of one ohm wire = 1/15 = 0.067 m

(79) **(A).** Wheatstone bridge is balanced, therefore

$$\frac{P}{Q} = \frac{R}{S} \text{ or } 1 = \frac{10}{S} \Rightarrow S = 10 \text{ ohm}$$

(80) **(C).** Let S be larger and R be smaller resistance connected in two gaps of meter bridge.

$\therefore$ $S = \left(\frac{100-\ell}{\ell}\right) R = \frac{100-20}{20} R = 4R$ .....(i)

When 15Ω resistance is added to resistance R, then

$S = \left(\frac{100-40}{40}\right)(R+15) = \frac{6}{4}(R+15)$ ..(ii)

From equations (i) and (ii) R = 9Ω

(81) **(A).** The ratio $\frac{AC}{CB}$ will remain unchanged.

(82) **(D).** To shift the balance point on higher length, the potential gradient of the wire is to be decreased. The same can be obtained by decreasing the current of the main circuit, which is possible by increasing the resistance in series of potentiometer wire.

(83) **(B).** The balance point can be obtained only if the potential difference across the wire is greater than the emf's to be compared (or measured). Therefore, option (B) is correct.

(84) **(A).** Due to increase in resistance R the current through the wire will decrease and hence the potential gradient also decreases, which results in increase in balancing length. So J will shift towards B.

(85) **(D).** Balance point has some fixed position on potentiometer wire. It is not affect by the addition of resistance between balance point and cell.

(86) **(B).** Potential gradient $x = \frac{V}{L} = \frac{iR}{L}$

$\Rightarrow$ $x = \frac{2}{(15+5)} \times \frac{15}{10} = \frac{3}{2000}$ volt / cm

(87) **(D).** $E = \frac{e}{(R + R_h + r)} \frac{R}{L} \times \ell$

$= \frac{2}{(10+40+0)} \times \frac{10}{1} \times 0.4 = 0.16V$

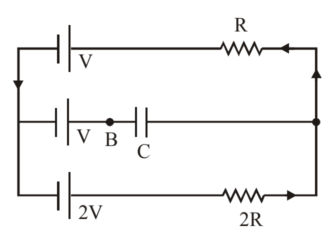
(88) **(A).** Potential difference per unit length

$= \frac{V}{L} = \frac{2}{4} = 0.5\,V/m$

(89) **(C).** $E_1 = \phi\ell_1, E_2 = \phi\ell_2$ $\therefore$ $E_1 - E_2 = \phi(\ell_1 - \ell_2)$

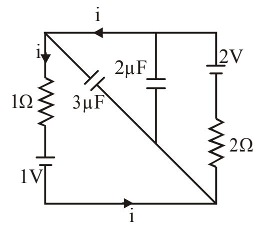
Thus, $\phi = \frac{E_1 - E_2}{\ell_1 - \ell_2} = \frac{0.4}{0.5} = 0.8$ V/m

(90) **(C).** In steady state, the current I flowing in the circuit will be $I = \frac{2V - V}{R + 2R} = \frac{V}{3R}$



Next, $V_A - \frac{V}{3R}.R - V + V = V_B \Rightarrow V_A - V_B = \frac{V}{3}$

(91) **(B).** Let the current in the circuit is i.
Applying Kirchhoff's loop law is outer circuit and go in anticlockwise.



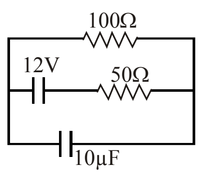
$$-i-1-2i+2=0 \Rightarrow -3i=-1 \Rightarrow i=\frac{1}{3}A$$

$\therefore$ In the circuit consisting of 3μF,
if PD across 3μF is V.

$$-\frac{1}{3}\times 1-1+V=0\ ;\ V=1+\frac{1}{3}=\frac{4}{3}V$$

$$q=CV=\frac{4}{3}\times 3\mu F=4\mu C$$

(92) **(B).**

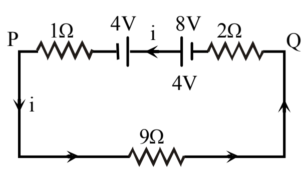


$$i=\frac{12}{150}=\frac{4}{50}=0.08\,A$$

EXERCISE-2

(1) **(A).** Applying Kirchoff's voltage law in the given loop.

$$-2i+8-4-1\times i-9i=0 \Rightarrow i=\frac{1}{3}A$$



Potential difference across PQ $=\frac{1}{3}\times 9=3V$

(2) **(C).** Drift velocity $v_d=\frac{V}{\rho l n e}$

v_d does not depend upon diameter.

(3) **(D).** The last two resistance are out of circuit. Now 8Ω is in parallel with $(1+1+4+1+1)\Omega$.

$$\therefore R=8\Omega\,||\,8\Omega=\frac{8}{2}=4\Omega \Rightarrow R_{AB}=4+2+2=8\Omega$$

(4) **(C).** Potential gradient

$$x=\frac{e}{(R+R_h+r)}.\frac{R}{L}=\frac{3}{(20+10+0)}\times\frac{20}{10}=0.2$$

(5) **(D).** Zero (No potential difference across voltmeter).

(6) **(B).** $V_2-V_1=E-ir=5-2\times 0.5=4\text{volt}$

$$\Rightarrow V_2=4+V_1=4+10=14\text{ volt}$$

(7) **(D).** $E=\frac{e}{(R+R_h+r)}.\frac{R}{L}\times\ell$

$$\Rightarrow 0.4=\frac{5}{(5+45+0)}\times\frac{5}{10}\times\ell \Rightarrow \ell=8\text{ m}$$

(8) **(B).** Let R be the resistance of each resistor.
When they are connected in series, the total resistance = R + R + R = 3R ohm.
$\therefore$ Power dissipated $W_1=E^2/3R$,
where E = emf of the source.
When the resistors are connected in parallel, their effective resistance is given by

$$\frac{1}{R'}=\frac{1}{R}+\frac{1}{R}+\frac{1}{R}=\frac{3}{R}\text{ or } R'=\frac{R}{3}$$

$\therefore$ Power dissipated $W_2=\frac{E^2}{R/3}=\frac{3E^2}{R}$

Now $\frac{W_1}{W_2}=\frac{3E^2}{R}=\frac{3R}{E^2}=9$

or $W_2=9W_1=9\times 10=90$ watt $(\because W_1=10\text{ watt})$.

(9) **(C).** In the first case I = E/(r + R) and in the second case
I' = E/(r + R/2) = 2E/(2r + R)
Using E = I (r + R), we get

$$I'=I\left(\frac{2r+2R}{2r+R}\right)=I\left(1+\frac{R}{2r+R}\right)$$

Thus the term in bracket is greater than 1 but less than 2. Thus 2I > I' > I

(10) **(C).** $R_{circuit}=1.5\Omega \Rightarrow I=4A$

(11) **(B).** Here, $R_0=5\Omega, R_{100}=5.25\Omega, R_t=5.5\Omega$
$R_t=R_0(1+\alpha t)\,;\,R_{100}=R_0(1+100\alpha)$

$$\alpha=\frac{R_{100}-R_0}{R_0\times 100} \quad .....(1)$$

Let the temperature of hot bath be t °C

$$R_t=R_0(1+\alpha t)\,;\ \alpha=\frac{R_t-R_0}{R_0\times t} \quad .....(2)$$

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

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

$$t=\frac{R_t-R_0}{R_{100}-R_0}\times 100=\frac{5.5-5}{5.25-5}\times 100$$

$$=\frac{0.5}{0.25}\times 100=200°C$$

(12) **(C).** Here, ε = 12V, r = 3Ω and I = 1A
V = I R = ε – Ir

$$\therefore R=\frac{\varepsilon-Ir}{I}=\frac{12-1\times 3}{1}=12-3=9\Omega$$

and V = I R = 1 × 9 = 9 V

(13) **(A).** As $R = \rho \dfrac{\ell}{A}$, resistance is maximum when ℓ is large and A is least. For the given dimensions of wire, resistance will be maximum for
$\ell = 10$ cm and A = 1 cm × ½ cm.

(14) **(D).** If the wire is stretched by $(1/10)^{th}$ of its original length then the new length of wire become

$$\ell_2 = \ell + \frac{\ell}{10} = \frac{11\ell}{10} \qquad \text{..... (1)}$$

As the volume of wire remains constant then

$$\pi r_1^2 \ell = \pi r_2^2 \ell_2 = \pi r_2^2 \left(\frac{11\ell}{10}\right) \quad \text{(using (1))}$$

$$\Rightarrow \quad r_2^2 = \frac{10}{11} r_1^2 \qquad \text{... (2)}$$

Now the resistance of stretched wire.

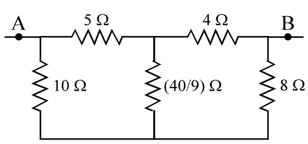
$$R_2 = \frac{\rho\left(\frac{11}{10}\ell\right)}{\pi r_2^2} = \frac{\left(\frac{11}{10}\right)\rho\ell}{\pi \times \frac{10}{11} r_1^2}$$

$$= \left(\frac{11}{10}\right)^2 \times \frac{\rho\ell}{\pi r_1^2} \quad \left(\because R_1 = \frac{\rho\ell}{\pi r_1^2} = 15\Omega\right)$$

$$\Rightarrow \quad R_2 = \left(\frac{11}{10}\right)^2 \times 15 = 18.15\,\Omega$$

(15) **(C).** $E = \rho \dfrac{i}{A}$; $E = \dfrac{kr^2}{R}\dfrac{i}{\pi r^2} = \dfrac{ki}{\pi R}$

(16) **(A).** The given circuit is equivalent to



As 10 × 4 = 5 × 8
this is balanced Wheatstone network

Therefore $R = \dfrac{(5+4)\times(10+8)}{9+18} = 6$ ohm

(17) **(D).** $\dfrac{1}{R} = \dfrac{1}{20} + \dfrac{1}{20} + \dfrac{1}{15} = \dfrac{6+4}{60}$

(18) **(D).** For a bulb, $R = \dfrac{V^2}{W}$ and $W_B < W_A$

So, $R_B > R_A$ and $V_A = \dfrac{24\times 3}{7} < 12$ V

$V_B = \dfrac{24\times 4}{7} > 12$ V

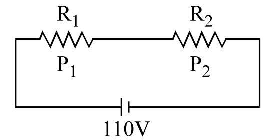
After closing the switch
$V_A = V_B = 12$V, So, V_A increases
But V_B decreases, hence, P_A increases and P_B decreases

(19) **(C).** V = E + IR = 12 + 50 (0.04) = 14 V

(20) **(A).** $P = I^2R = (50)^2\,(0.04) = 100$ W

(21) **(C).** Rate of energy conversion from electrical to chemical is EI = 12(50) = 600 W

(22) **(C).** $R = \dfrac{V^2}{P}$ $\quad \therefore\ R_1 = \dfrac{110\times 110}{50}$



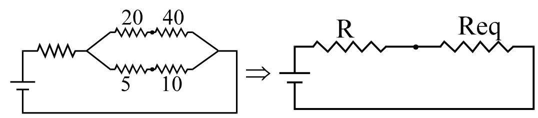
$R_2 = \dfrac{110\times 110}{100}$

$I = \dfrac{110}{3R} = \dfrac{110\times 100}{3\times 110\times 110} = \dfrac{10}{33}$ amp.

$P_1 = I^2 \times R_1 = \dfrac{10}{33}\times\dfrac{10}{33}\times\dfrac{110\times 110}{50}$

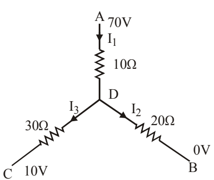
$= \dfrac{200}{9} \approx 22$ W

(23) **(A).**



Here $R_{eq} = 12$
For maximum P ; $R = R_{eq} = 12$

(24) **(D).** According to KCL, $I_1 = I_2 + I_3$



$$\frac{V_A - V_D}{10} = \frac{V_D - 0}{20} + \frac{V_D - V_C}{30}$$

or $70 - V_D = \dfrac{V_D}{2} + \dfrac{V_D - 10}{3}$

$6(70 - V_D) = 3V_D + 2(V_D - 10)$
$420 - 6V_D = 3V_D + 2V_D - 20$
$440 = 11\,V_D \Rightarrow V_D = 40V$

$I_1 = \dfrac{70-40}{10} = 3A,\ I_2 = \dfrac{40-0}{20} = 2A,$

$I_3 = \dfrac{40-10}{30} = 1A$

(25) **(C).** Circuit resistance increases,
Current decreases in B_1

(26) **(B).** $I = \dfrac{E}{R+r}$ when R decreases to 0, I = E/r
V = IR when R decreases to 0, V = 0

(27) **(C).** $R = \dfrac{12\times 4}{12+4} + 2 = 5\Omega$; $I = \dfrac{E}{R+r} = \dfrac{12}{6} = 2A$

$I_1 + I_2 = 2A$
$I \propto 1/R\ \therefore\ I_1 = 0.5A,\ I_2 = 1.5\,A$

(28) **(C).** $v_d = \dfrac{I}{nAe} = \dfrac{20}{10^{29}\times 10^{-6}\times 1.6\times 10^{-19}}$

$= 1.25 \times 10^{-3}\ ms^{-1}$.

(29) **(C).** R = 56 × 10 ± 10% = 560 ± 10%

(30) **(D).** Slope of V – I graph = Resistance
Resistance ∝ temperature
$R_1 > R_2 \Rightarrow T_1 > T_2$

(31) **(A).** Balanced wheatstone bridge

$$R_{eff} = \frac{(P+Q)\,(R+S)}{(P+Q+R+S)} = \frac{4}{3}R$$

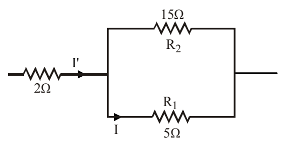
(32) **(C).** $P = \frac{V^2}{R}$; $\frac{U}{t} = \frac{V^2}{R}$; $U \propto V^2$

(33) **(B).** $i = neAv_d$

$$v_d = \frac{i}{neA} = \frac{2}{5\times10^{26}\times1.6\times10^{-19}\times2\times10^{-6}}$$

$$= \frac{1}{5\times10\times1.6} = \frac{1}{80}\,m/s$$

(34) **(B).** $I = \frac{I'R_2}{R_1+R_2}$



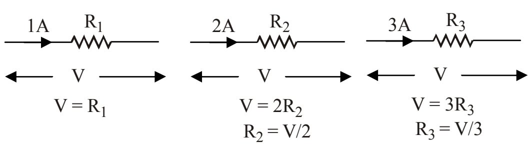
$$I = \frac{I'\times15}{20} = \frac{3}{4}I'$$

Heat produced $H = I^2Rt$

$$\frac{H'}{H} = \frac{(I')^2\times2}{\left(\frac{3}{4}I'\right)^2\times5} = \frac{32}{45} \therefore\ H' = \frac{32}{45}\times4.05 = 2.88\text{ J}$$

(35) **(B).** $I_2 = \frac{IR_1}{R_1+R_2} = \frac{1.2\times\left(\frac{30}{4}\right)}{15+\frac{30}{4}} = \frac{9}{\frac{90}{4}} = \frac{4}{10} = 0.4\text{ A}$

(36) **(D).**



When they are connected in series and connected across the same battery then,

$V = I\,[R_1+R_2+R_3]$

$$V = I\left[V+\frac{V}{2}+\frac{V}{3}\right] \Rightarrow V = IV\left[1+\frac{1}{2}+\frac{1}{3}\right]$$

$$1 = I\left[\frac{6+3+2}{6}\right] \Rightarrow I = \frac{6}{11}A$$

(37) **(C).** $E = \frac{3R}{2}\times3$.

Only option (C) satisfy the relation.

(38) **(D).** $m_1 : m_2 : m_3 = 1:3:5$

$\ell_1 : \ell_1 : \ell_2 = 5:3:1$

$$R_1 : R_2 : R_3 = \frac{\ell_1}{A_1} : \frac{\ell_2}{A_2} : \frac{\ell_3}{A_3} \qquad d = \frac{m}{V} = \frac{m}{A\ell}$$

$$R_1 : R_2 : R_3 = \frac{\ell_1^2}{m_1} : \frac{\ell_2^2}{m_2} : \frac{\ell_3^2}{m_3}$$

$$A = \frac{m}{d\ell};\ A \propto \frac{m}{\ell} = \frac{25}{1} : \frac{9}{3} : \frac{1}{5} = 125:15:1$$

(39) **(B).** $I_1 = \frac{I\times2R}{3R} = \frac{2I}{3}$;

$$H_1 = I_1^2R = \frac{4I^2}{9}\times R\ ;\ I_2 = \frac{I\times R}{3R} = \frac{I}{3}$$

$$H_2 = I_2^2(2R) = \frac{I^2}{9}\times2R$$

$H_3 = I^2\times1.5\,R$

$$H_1 : H_2 : H_3 = \frac{4I^2}{9}\times R : \frac{I^2}{9}\times2R : I^2\times1.5R$$

$$= \frac{4}{9} : \frac{2}{9} : 1.5 = 4:2:13.5 = 8:4:27$$

(40) **(D).** $R_p = \frac{R_1R_2}{R_1+R_2} = \frac{2\times6}{2+6} = 1.5\Omega$

$$I = \frac{E}{R_p+r} = \frac{2}{1.5+0.5} = 1\text{ A}$$

(41) **(C).** $R_1+R_2 = 6$

$$\frac{R_1R_2}{R_1+R_2} = \frac{4}{3} \Rightarrow R_1R_2 = 8 \Rightarrow R_1 = 2,\ R_2 = 4\Omega$$

(42) **(B).** $E_1 \propto L_1$, $E_2 \propto L_2$

$$\frac{E_1}{E_2} = \frac{L_1}{L_2} \Rightarrow \frac{1.25}{E_2} = \frac{30}{40} \Rightarrow E_2 = \frac{5}{3} = 1.67\text{ V}$$

(43) **(D).** $V = iR$; $i \propto \frac{1}{R}$; $i_1 : i_2 : i_3 = \frac{1}{R_1} : \frac{1}{R_2} : \frac{1}{R_3} = \frac{1}{2} : \frac{1}{3} : \frac{1}{4}$

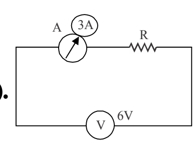
$= 6:4:3$

(44) **(A).** Total internal resistance does not change

$R' = 4r$; $E' = E\,[n-2m]$

m = Wrong connection $= E\,[4-2] = 2E$

(45) **(A).**



; $V = iR$; $R = 6/3 = 2\Omega$

If the Ammeter ad voltmeter have resistance [R < 2]

(46) **(C).** $I = \frac{\text{Net emf}}{\text{Total resistance}} = \frac{E_1-E_2}{R+r_1+r_2}$

$$V = IR \Rightarrow V = \frac{(E_1-E_2)\,R}{R+r_1+r_2}$$

(47) **(B).** $\alpha = \frac{R_2-R_1}{R_1(t_2-t_1)} \Rightarrow 0.005 = \frac{200-100}{100\,(t_2-100)}$

$t_2 = 300°\,C$

(48) **(C).** $\frac{P}{Q} = \frac{R}{\frac{SX}{S+X}} \Rightarrow \frac{2}{2} = \frac{2}{\frac{3\times X}{3+X}} \Rightarrow \frac{3X}{3+X} = 2$

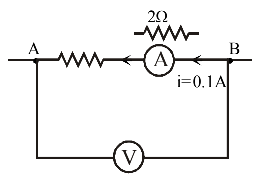
$3X = 6 + 2X \Rightarrow X = 6$

(49) **(A).** $R = R_0(1+\alpha T)$

(50) **(D).** $S = \frac{i_g G}{(i - i_g)} \Rightarrow \frac{G}{S} = \frac{i - i_g}{i_g} = \frac{10-1}{1} = \frac{9}{1}$

(51) **(D).** $\frac{i_g}{i} = \frac{S}{G+S} \Rightarrow \frac{5}{100} = \frac{S}{G+S} \Rightarrow \quad S = \frac{G}{19}$

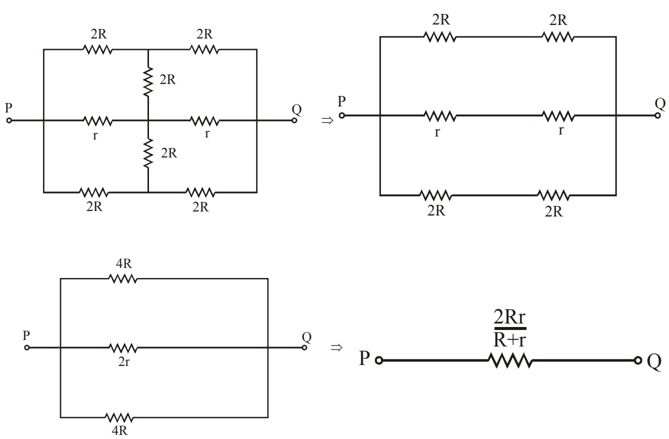
(52) **(A).** According to following figure



Reading of voltmeter = Potential difference between A and B = i (R + 2)

$\Rightarrow$ $12 = 0.1\,(R+2) \Rightarrow R = 118\,\Omega$.

(53) **(A).** The circuit can be redrawn as follows :



(54) **(D).** $P = \frac{V^2}{R}$ so, $R = \frac{V^2}{P}$

$\therefore \quad R_1 = \frac{V^2}{100}$ and $R_2 = R_3 = \frac{V^2}{60}$

Now, $W_1 = \frac{(250)^2}{(R_1+R_2)^2}.R_1$,

$W_2 = \frac{(250)^2}{(R_1+R_2)^2}.R_2$ and $W_3 = \frac{(250)^2}{R_3}$

$W_1 : W_2 : W_3 = 15 : 25 : 64$

$W_1 < W_2 < W_3$

(55) **(A).** $R_{PQ} = \frac{5}{11}r$, $R_{QR} = \frac{4}{11}r$ and

$R_{PR} = \frac{3}{11}r \quad \therefore \quad R_{PQ}$ is maximum.

Therefore correct option is (A).

(56) **(A).** The instantaneous current is

$i = \frac{dq}{dt} = \frac{d}{dt}(0.3t^2 + 0.2t + 0.1)$

or $\quad i = (0.6t + 0.2)$ C/s

Initially, $t = 0$,

$\therefore$ Initial current is $i = 0.6\,(0) + 0.2\text{ A} = 0.2\text{ A}$

At t = 2s, the current is

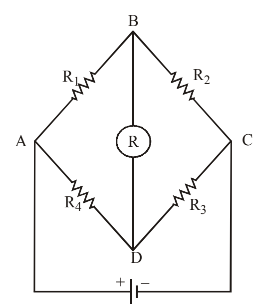
$i = 0.6\,(2) + 0.2\text{ A} = 1.4\text{ A}$

(57) **(B).** $P = \frac{V^2}{\frac{V^2}{P_1} + \frac{V^2}{P_2} + \frac{V^2}{P_3} + ...}$

(58) **(C).** $v_d = \frac{qE}{m}\tau$ ($\tau \to$ relaxation time)

$J = nevd = \sigma E \quad \therefore \sigma \propto \tau$

(59) **(B).** Equivalent circuit



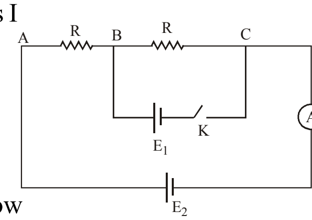
(60) **(C).** When K is open

current in ammeter is I

$\therefore$ $E_2 = 2\,IR$

When key K is closed and for E_1=2IR the current in branch, BC = 2 I

So no current will flow from A to B



(61) **(A).** $R_x = \frac{(R_0)(x)}{1-x}$

$\ln R_x = \ln R_0 + \ln x - \ln(1-x)$

$\frac{dR_x}{R_x} = 0 + \frac{dx}{x} + \frac{dx}{1-x}$

$\frac{dR_x}{R_x}$ is minimum for $x = \frac{1}{2}$

So, random error is minimum

(62) **(B).** $V^2 = \dfrac{500 \times 100 \times 10^3}{20 \times 60}$

$\dfrac{V^2}{R_1} t = 500 \;;\; \dfrac{V^2}{R_2}\left(\dfrac{t}{2}\right) = 1000$

$\dfrac{2R_2}{R_1} = \dfrac{1}{2} \;;\; R_2 = 25\Omega$

$\dfrac{V^2}{125} \times 5 \times 60 \Rightarrow \dfrac{500 \times 10^3}{25 \times 2 \times 6} \times 60 = 10^5$

(63) **(C).** Power $= I^2R$.
Brightness order, $d > a > b > c$

(64) **(A).** No. of electron in the wire $= nA\ell$ ($n = e^-$ density) and momentum $(nA\ell)\, m_e V_d$

$= neAV_d \dfrac{\ell m_e}{e} = \dfrac{i\ell m_e}{e} = \dfrac{70 \times 1000}{1.6 \times 10^{-19}} \times 9.1 \times 10^{-31}$

$= 40 \times 10^{-8}$.

(65) **(D).** $R_{eq} = \dfrac{R\,(1+\alpha_1\Delta T).R\,(1+\alpha_2\Delta T)}{R\,(1+\alpha_1\Delta T) + R\,(1+\alpha_2\Delta T)}$

$= \dfrac{R\,(1+\alpha_1\Delta T)\,(1+\alpha_2\Delta T)}{2 + (\alpha_1+\alpha_2)\,\Delta T}$

$= \dfrac{R\,(1+\alpha_2\Delta T+\alpha_1\Delta T)}{2 + (\alpha_1+\alpha_2)\,\Delta T}$ (neglect $\alpha_1\alpha_2$)

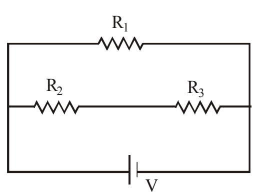
$\approx \dfrac{R}{2}\left(1 + \left(\dfrac{\alpha_2+\alpha_1}{2}\right)\Delta T\right)$

(66) **(C).** $P_{max} = (i_{max})^2 R \;;\; 18 = i^2_{max} \times 2$

$i_{max} = 3A$ Here $Req = 3\Omega$.

Maximum power of circuit $= i^2_{max} R_{eq} = 3^2 \times 3 = 27W$

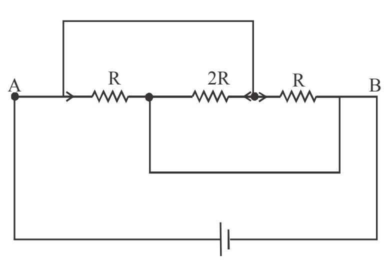
(67) **(D).**



$P_1 = \dfrac{V^2}{R}$

$P_3 = P_2 = \dfrac{(V/2)^2}{R} = \dfrac{V^2}{4R}, \quad \dfrac{P_1}{P_2} = 4$

(68) **(B).** In figure all resistance are connected in parallel.



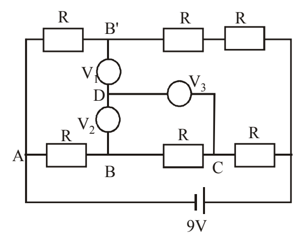
(69) **(B).** Radius of electron orbit $r = 0.72$ Å $= 0.72 \times 10^{-10}$ m
Frequency of revolution of electron in orbit of given atom $\nu = 9.4 \times 10^{18}$ rev/s, (where T is time period of revolution of electron in orbit). Then equivalent current is $I = \dfrac{e}{T} = e\,\nu = 1.6 \times 10^{-19} \times 9.4 \times 10^{18}$
$= 1.504$ A

EXERCISE-3

(1) **2.** Taking potential at A to be zero potential at B = 3V and potential at B' = 3V and potential at C = 6V
Let V_D be potential of point D then sum of charged reaching point D is zero

$\dfrac{V_B - V_D}{R_{V_2}} + \dfrac{V_{B'} - V_D}{R_{V_1}} + \dfrac{(V_C - V_D)}{R_{V_3}} = 0$

$[R_{V_2} = R_{V_1} = R_{V_3} = R']$

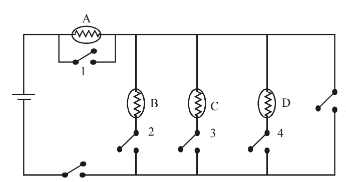


$\Rightarrow \dfrac{3 - V_D}{R'} + \dfrac{3 - V_D}{R'} + \dfrac{6 - V_D}{R'} = 0$

$\Rightarrow 12 - 3V_D = 0 \;;\; V_D = 4$ volts reading of $V_3 = 2$ volts

(2) **20.** $13\,(2x) + R = 200 \;;\; 13\,(2\,(10 - x) + R = 100$
$260 + 2R = 300 \;;\; R = 20\Omega$

(3) **4.**



Closing switch 1 will short circuit bulb A, closing switch 5 will short circuit BCD so these switches need not be closed.

(4) **6.** Let λ is resistance per unit length of wire AB. When k is opened $I\,(\lambda x_1) = E_1$ ....(1)
k is closed
$I\,\lambda x_2 = E_1 - ir$ ....(2)

$i = \dfrac{E_1}{R + r}$ ....(3)

$\Rightarrow r = \left(\dfrac{x_1}{x_2} - 1\right) R = \left(\dfrac{0.75}{0.60} - 1\right) 24 \Rightarrow r = 6\Omega$

(5) **20.** All the elements of circuit are in parallel arrangement

$\dfrac{1}{R_{eq}} = \dfrac{1}{40} \times \dfrac{1}{40} \times \dfrac{1}{40} \times \dfrac{1}{40} \times \dfrac{1}{20} \times \dfrac{1}{20} = \dfrac{4}{40} \times \dfrac{2}{40}$

$R_{eq} = 5\Omega$. Power $= V^2/R = 20W$

(6) **5.** If ℓ_1 = length from one end then

$$\frac{\ell_1}{1-\ell_1}=\frac{X}{R}=\frac{12}{18} \;;\quad \ell_1=\frac{12}{30}\text{m}=40\text{cm}.$$

and ℓ'_1 = length from one end in second case

$$\frac{\ell'_1}{1-\ell'_1}=\frac{X}{R'}=\frac{12}{8} \;;\quad \ell'_1=\frac{12}{20}\text{m}=60\text{cm}.\ \text{So shift}=20\text{ cm}$$

(7) **225.** Let the resistance of half the turn be R. Then in the former case, we have fifteen resistors of resistance R connected in parallel, the total resistance being R/15.
In the latter case, we have the same fifteen resistors connected in series, the total resistance being 15R. Therefore, as a result of unwinding, the resistance of the wire will increase by a factor of 225.

(8) **11.** In order to simplify the solution, we present the circuit in a more symmetric form (figure a).

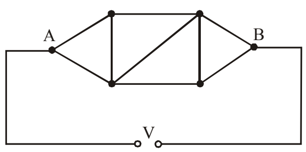


figure (a)

The obtained circuit cannot be simplified by connecting or disconnecting junctions (or by removing some conductors) so as to obtain parallel- or series- connected subcircuits. However, any problem involving a direct current has a single solution, which we shall try to "guess" by using the symmetry of the circuit and the similarity of the currents in the circuit.
Let us apply a voltage V to the circuit and mark currents through each element of the circuit. We shall require not nine values of current (as in the case of arbitrary resistances of circuit elements) but only five values I_1, I_2, I_3, I_4, and I_5 (figure b).

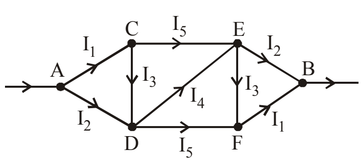


figure (b)

For such currents, Kirchhoff's first rule for the junction C

$I_1 = I_3 + I_5$

and for the junction D, $I_2 + I_3 = I_4 + I_5$

will automatically be observed for the junctions E and F (this is due to the equality of the resistances of all resistors of the circuit). Let us now write Kirchhoff's second rule in order to obtain a system of five independent equations:

$(I_2 + I_5 + I_1)R = V$

$(I_3 + I_4)R = I_5R$

$(I_1 + I_3)R = I_2R$, where R is the resistance of each resistor. Solving this system of five equations, we shall express all the currents in terms of I_1 :

$$I_2=\frac{6}{5}I_1,\ I_3=\frac{I_1}{5},\ I_4=\frac{3}{5}I_1,\ I_5=\frac{4}{5}I_1$$

Besides, $V=\left(I_1+\frac{4}{5}I_1+\frac{6}{5}I_1\right)R$.

Consequently, $\frac{V}{3I_1}=R$

Considering that the resistance R_{AB} of the circuit satisfies the equation $R_{AB}=\frac{V}{I_1+I_2}$, we obtain

$$R_{AB}=\frac{V}{I_1+I_2}=\frac{V}{I_1+(6/5)I_1}=\frac{5}{11}\frac{V}{I_1}$$

Taking into account the relation obtained above, we get the following expression for the required resistance :

$$R_{AB}=\frac{15}{11}R$$

(9) **9.** The potentiometer with the load is equivalent to a resistor of resistance $R_1=\frac{R}{2}+\frac{RR/2}{R+R/2}=\frac{5}{6}R$

Hence the total current in the circuit will be

$$I_1=\frac{V}{(5/6)R}=\frac{6}{5}\frac{V}{R}$$

The voltage across the load will be $V_{11}=V-I_1\frac{R}{2}=\frac{2}{5}V$

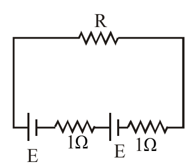
If the resistance of the load becomes equal to 2R, the total current will be $I_2=\frac{V}{\frac{R}{2}+\frac{(R/2)(2R)}{R/2+2R}}=\frac{10}{9}\frac{V}{R}$

The voltage across the load will become

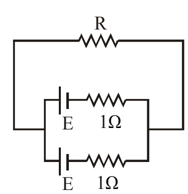
$$V_{21}=V-I_2\frac{R}{2}=\frac{4}{9}V$$

Thus, the voltage across the load will change by a factor of $k=V_{21}/V_{11}$: $k=\frac{V_{21}}{V_{11}}=\frac{10}{9}$

(10) **4.**



$$i=\frac{2E}{2+R} \;;\quad J_1=\left(\frac{2E}{2+R}\right)^2 R$$



$$E_{eq}=\frac{\frac{E}{1}+\frac{E}{1}}{\frac{1}{1}+\frac{1}{1}}=E$$

$$r_{eq}=\frac{1}{2}\Rightarrow\ i=\frac{E}{\frac{1}{2}+R}=\frac{2E}{2R+1}$$

$$J_2 = \left(\frac{2E}{1+2R}\right)^2 R$$

Given, $J_1 = \frac{9}{4}J_2 \Rightarrow \left(\frac{2E}{2+R}\right)^2 R = \frac{9}{4}\left(\frac{2E}{1+2R}\right)^2 R$

$\Rightarrow \frac{2}{2+R} = \frac{3}{1+2R} \Rightarrow 2+2R = 6+3R \Rightarrow R = 4\Omega$

EXERCISE-4

(1) **(C).** $P = \frac{V^2}{R_{eq}}$; $150 = \frac{(15)^2}{\left(\frac{2R}{R+2}\right)} \Rightarrow R = 6\Omega$

(2) **(B).** Same supply so V = constant

$\therefore \quad P = \frac{V^2}{R} \propto \frac{1}{R}$; $\frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{R/4}{R} = \frac{1}{4}$

$P_2 : P_1 = 4$

(3) **(C).** High resistance in series.

(4) **(C).** Potential gradient $x = \frac{E}{100}$ volt per cm

emf of unknown battery $= x\ell = \frac{30}{100}E$

(5) **(C).** $S = \frac{I_g R_g}{I - I_g}$

(6) **(C).** Volume constant so $R \propto \ell^2$

$\ell' = 2\ell \Rightarrow R' = 4R$

$\therefore$ Change in resistance = 300%

(7) **(B).** $P = \frac{V^2}{R} \propto V^2$; Power consumed = 250 watt

(8) **(A).** $R = 2\Omega \;\; \therefore \;\; I = \frac{V}{R} = \frac{3}{2} = 1.5A$

(9) **(C).** $R_{circuit} = 1.5\Omega \;\; \Rightarrow I = 4A$

(10) **(A).** S = nP

$$(R_1 + R_2) = n\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

$$n = \frac{(R_1+R_2)^2}{R_1 R_2} = \frac{R_1}{R_2} + \frac{R_2}{R_1} + 2$$

$$n_{min} = \left(\frac{R_1}{R_2} + \frac{R_2}{R_1}\right)_{min} + 2 = 2 + 2 = 4$$

(11) **(B).** In parallel $I \propto \frac{1}{R} \propto \frac{r^2}{\ell}$

$$\frac{I_1}{I_2} = \frac{r_1^2}{r_2^2} \times \frac{\ell_2}{\ell_1} = \left(\frac{2}{3}\right)^2 \times \frac{3}{4} = \frac{1}{3}$$

(12) **(D).** Semiconducting materials having how temperature coefficient of resistivity.

(13) **(C).** $836 \times t = ms\,(\Delta\theta)$

$$t = \frac{1 \times 4200 \times (40-10)}{836} = 150 \text{ sec.}$$

(14) **(A).** $\frac{X}{Y} = \frac{20cm}{80cm} \Rightarrow 4X = Y$

So 4X and Y will balance at 50 cm.

(15) **(D).** $r = \left(\frac{\ell_1 - \ell_2}{\ell_2}\right) R = 2\Omega$

(16) **(D).** $I_g = 15mA,\ V_g = 75mV \Rightarrow R_g = \frac{V_g}{I_g} = 5\Omega$

Required range of voltmeter = 150V

$\therefore \quad R = \frac{V}{I_g} - R_g = 9995\Omega$

(17) **(B).** Galvanometer shows zero if dro across R is 2V

$\therefore \quad \left(\frac{R}{500+R}\right)(12V) = 2V \Rightarrow R = 100\Omega$

(18) **(B).** $I = \frac{2E}{R + R_1 + R_2}$; $V_{R_2} = E - IR_2$

$0 = E - IR_2$; $0 = E - \left(\frac{2E}{R+R_1+R_2}\right)(R_2)$

$\Rightarrow R = R_2 - R_1$

(19) **(B).** $I = \frac{E}{R+r}$

if $r >> R \Rightarrow$ Variation in R does not affect the current.

(20) **(B).** Given $\rho_B = 2\rho_A,\ r_B = 2r_A$

If $R_A = R_B$

$$\Rightarrow \frac{\rho_A \ell_A}{\pi r_A^2} = \frac{\rho_B \ell_B}{\pi r_B^2} \Rightarrow \frac{\ell_B}{\ell_A} = \frac{\rho_A}{\rho_B}.\frac{r_B^2}{r_A^2} = \frac{1}{2} \times (2)^2 = 2$$

(21) **(B).** Conservation of charge, conservation of energy.

(22) **(D).** Balanced wheat stone bridge, $R = 10\Omega$

$\therefore \quad I = \frac{5}{10} = 0.5A$

(23) **(D).** $\frac{P}{Q} = \frac{R}{\left(\frac{S_1 S_2}{S_1 + S_2}\right)}$

(24) **(A).** $P = \frac{V^2}{R} \propto V^2$; Power consumed = 25 watt.

(25) **(D).** $R_t = R_0(1 + \alpha t)$

$5 = R_0(1 + \alpha \times 50)$ ....(i)

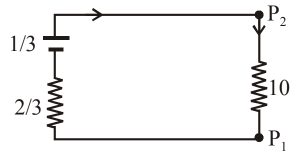
$6 = R_0(1 + \alpha \times 100)$ ....(ii)

Solving $\alpha = 1/200,\ R_0 = 4\Omega$

(26) **(B).** Convert two parallel cells into a single cell

$$E_{net} = \frac{E_1 r_2 - E_2 r_1}{r_1 + r_2} = \frac{1}{3} \text{volt}$$

$$r_{net} = \frac{r_1 r_2}{r_1 + r_2} = \frac{2}{3}\Omega$$



$$I = \frac{1/3}{10 + \frac{2}{3}} = 0.03\text{A}$$

$(P_2 \text{ to } P_1)$

(27) **(B).** $E = \rho I = \rho \frac{I}{2\pi r^2}$

(28) **(B).** $\Delta V = -\int E\, dr = -\int_{a+b}^{a} \frac{\rho I}{2\pi r^2} dr$

$$= \frac{\rho I}{2\pi a} - \frac{\rho I}{2\pi(a+b)}$$

(29) **(A).** $\frac{55}{R} = \frac{20}{80} \Rightarrow R = 220\Omega$

(30) **(A).** $150 = 100\,(1 + \alpha \times 200)$

$$\alpha = \frac{50}{200 \times 100} = \frac{1}{400} = 2.5 \times 10^{-3} / {}^\circ\text{C}$$

(31) **(D).** Let R_0 be the initial resistance of both conductors

∴ At temperature θ their resistance will be,

$R_1 = R_0\,(1 + \alpha_1\,\theta)$ and $R_2 = R_0\,(1 + \alpha_2\,\theta)$

For, series combination, $R_s = R_1 + R_2$

$R_{s0}\,(1+\alpha_s\theta) = R_0\,(1 + \alpha_1\,\theta) + R_0\,(1 + \alpha_2\,\theta)$

where $R_{s0} = R_0 + R_0 = 2R_0$

∴ $2R_0\,(1+\alpha_s\theta) = 2R_0 + R_0\,\theta\,(\alpha_1 + \alpha_2)$

or $\alpha_s = \frac{\alpha_1 + \alpha_2}{2}$

For parallel combination, $R_p = \frac{R_1 R_2}{R_1 + R_2}$

$$R_{p0}(1+\alpha_p\theta) = \frac{R_0(1+\alpha_1\theta)\,R_0(1+\alpha_2\theta)}{R_0(1+\alpha_1\theta) + R_0(1+\alpha_2\theta)},$$

where $R_{p0} = \frac{R_0 R_0}{R_0 + R_0} = \frac{R_0}{2}$

$$\therefore \frac{R_0}{2}(1+\alpha_p\theta) = \frac{R_0^2(1+\alpha_1\theta+\alpha_2\theta\alpha_1\alpha_2\theta)}{R_0(2+\alpha_1\theta+\alpha_2\theta)}$$

As α_1 and α_2 are small quantities

∴ $\alpha_1\,\alpha_2$ is negligible

or $\alpha_p = \frac{\alpha_1 + \alpha_2}{2 + (\alpha_1 + \alpha_2)\,\theta} = \frac{\alpha_1 + \alpha_2}{2}[1 - (\alpha_1 + \alpha_2)\,\theta]$

As $(\alpha_1 + \alpha_2)^2$ is negligible

∴ $\alpha_p = \frac{\alpha_1 + \alpha_2}{2}$

(32) **(B).** $R = \frac{\rho \ell}{A}$ ($\because V = A\ell$ const).

$V = A\ell$

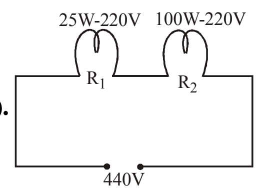
By differentiation, $0 = \ell\, dA + A\, d\ell$

By differentiation, $dR = \frac{\rho\,(A d\ell - \ell dA)}{A^2}$

$$dR = \frac{2\rho d\ell}{A^2} \text{ or } \frac{dR}{R} = 2\frac{d\ell}{\ell}$$

So, $\frac{dR}{R}\% = 2\frac{d\ell}{\ell}\% = 2 \times 0.1\% = 0.2\%$

(33) **(C).**



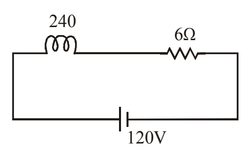
As $R_1 = \frac{220}{25} \times 220$ and $R_2 = \frac{220}{100} \times 220$

$$R = R_1 + R_2 = 220 \times 220 \left(\frac{1}{25} + \frac{1}{100}\right) = 220 \times 220\,\frac{1}{20}$$

$$\therefore I_{live} = \frac{440}{\frac{220 \times 220}{20}} = \frac{40}{220}\text{A}$$

∴ 1st bulb (25W) will fuse only.

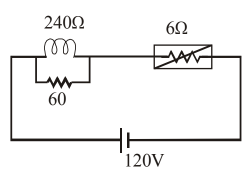
(34) **(D).** $P = \frac{V^2}{R}$



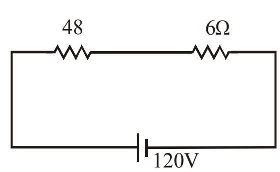
$$R = \frac{120 \times 120}{60} = 240\Omega$$

$R_{eq} = 240 + 6 = 246\Omega$

$V_1 = \frac{240}{246} \times 120 = 117.073$ volt



$V_2 = \frac{48}{54} \times 120 = 106.66$ Volt



$V_1 - V_2 = 10.04$ Volt

(35) **(D).** Statements 1 is false and Statement 2 is true.

(36) **(A).**

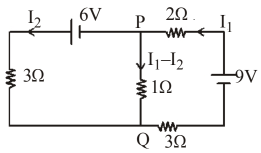
Item	**No.**	**Power**
40 W bulb	15	600 Watt
100 W bulb	5	500 Watt
80 W fan	5	400 Watt
1000 W heater	1	1000 Watt

Total Wattage = 2500 Watt

So, current capacity

$$i = \frac{P}{V} = \frac{2500}{220} = \frac{125}{11} = 11.36 \simeq 12 \text{ amp.}$$

(37) **(B).** From KVL,



$9 = 6I_1 - I_2$ ...(1)

$6 = 4I_2 - I_1$ ...(2)

Solving, $I_1 - I_2 = -0.13$ A

(38) **(C).** $V = IR = I\rho\frac{\ell}{A}$; $\rho = \frac{VA}{I\ell} = \frac{VA}{\ell neAv_d} = \frac{V}{\ell \times n \times e \times v_d}$

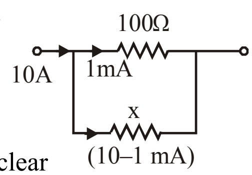
$$\rho = \frac{5}{0.1 \times 2.5 \times 10^{-19} \times 1.6 \times 10^{-19} \times 8 \times 10^{28}}$$

$= 1.6 \times 10^{-5}\ \Omega$m

(39) **(D).** (1mA) (100) = (10 – 1 ma) x

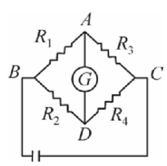
$10^{-1} = 10$ x

$$x = \frac{1}{100} = 0.01\,\Omega$$



(40) **(A).** From the given figure it is clear that if galvanometer is connected between AD and cell between BC , then

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \quad \text{....(i)}$$

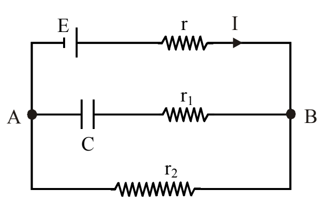


If cell and galvanometer are interchanged, then for balance

$$\frac{R_1}{R_3} = \frac{R_2}{R_4} \quad \text{....(ii)}$$

Since equations (i) and (ii) are same, null point is undisturbed if cell and galvanometer are interchanged.

(41) **(B).**



At steady state current through the capacitor = 0

$$I = \frac{E}{r + r_2}$$

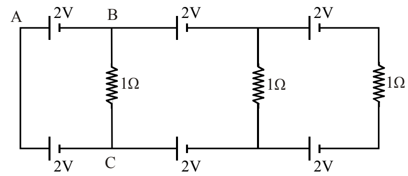
P.d. across AB = Q/C

$$E - Ir = \frac{Q}{C} \Rightarrow E - \frac{Er}{r + r_2} = \frac{Q}{C} \Rightarrow Q = CE\frac{r_2}{r + r_2}$$

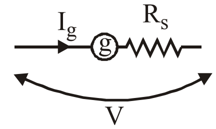
(42) **(C).** If $V_A = V \Rightarrow V_B = V - 2$ and $V_C = V - 2$

Potential difference across each resistor = 0

⇒ Current across each resistor = 0



(43) **(D).** $I_g = 5$mA



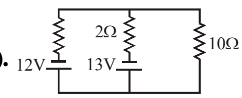
$V = I_g(R_g + R_s)$

$10 = 5 \times 10^{-3}(15 + R_s)$

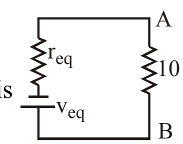
$15 + R_s = 2 \times 10^3 = 2000$

$R_s = 1985 = 1.985 \times 10^3\ \Omega$

(44) **(D).**



Equivalent circuit is

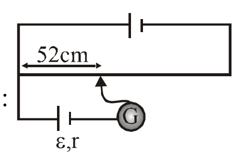


Where, $r_{eq} = \frac{1 \times 2}{1 + 2} = \frac{2}{3}$; $v_{eq} = \frac{\left(\frac{V_1}{r_1} + \frac{V_2}{r_2}\right)}{\frac{1}{r_1} + \frac{1}{r_2}} = 12.33$

$$v_{AB} = V_{eq}\frac{10}{10 + r_{eq}} = 11.55 \text{ volts}$$

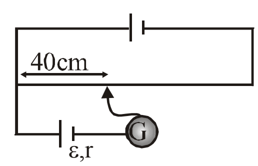
(45) **(D).** Let potential difference per unit length of potentiometer wire be x.

In case-I :



$\varepsilon = (52)(x)$ ...(i)

In case-II :



$i = \frac{\varepsilon}{r + 5}$; $\varepsilon - ir = (40)(x)$

$$\varepsilon - \left(\frac{\varepsilon}{r+5}\right) r = 40x \Rightarrow \varepsilon\left(\frac{5}{r+5}\right) = 40x \quad \text{...(ii)}$$

From (i) & (ii)

$$52x = 40x\left(\frac{r+5}{5}\right) \; ; \quad r = 5\left(\frac{13}{10} - 1\right) = \frac{15}{10} = 1.5\,\Omega$$

(46) **(A).** Let the resistances in left and right slot be r and $1000 - r$ respectively

Initial : $r(100 - x) = (1000 - r)(x)$ ....(1)

After interchanging:

$(1000 - r)[100 - (x - 10)] = r(x - 10)$

$(1000 - r)(110 - x) = r(x - 10)$ ....(2)

From (1) : $100r - rx = 1000x - rx \Rightarrow r = 10x$

From (2): $(1000 - r)\left(110 - \frac{r}{10}\right) = r\left(\frac{r}{10} - 10\right)$

$(1000 - r)(1100 - r) = r^2 - 100r$

$1000 \times 1100 - 2100r + r^2 = r^2 - 100r$

$\Rightarrow \quad r = \frac{1000 \times 1100}{2000} = 550\ \Omega$

(47) **(B).** Voltage at C = x ; KCL : $i_1 + i_2 = i$

$\frac{20 - x}{2} + \frac{10 - x}{4} = \frac{x - 0}{2} \Rightarrow x = 10$ and $i = 5$ amp.

(48) **(D).** Colour code : Red violet orange silver

$R = 27 \times 10^3\ \Omega \pm 10\% = 27\ K\Omega \pm 10\%$

(49) **(C).** $R = \frac{\rho\ell}{A}$ and volume $(V) = A\ell$.

$R = \frac{\rho\ell^2}{V} \Rightarrow \frac{\Delta R}{R} = \frac{2\Delta\ell}{\ell} = 1\%$

(50) **(D).** $I = n\,e\,A\,v_d$

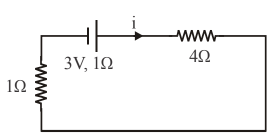
$\Rightarrow v_d = \frac{I}{neA} = \frac{1.5}{9 \times 10^{28} \times 1.6 \times 10^{-19} \times 5 \times 10^{-6}} = 0.02$ mm/s

(51) **(B).** $E_{eq} = \frac{\frac{E_1}{2R_1} + \frac{E_2}{R_2} + \frac{E_3}{2R_1}}{\frac{1}{2R_1} + \frac{1}{R_2} + \frac{1}{2R_1}} = \frac{5}{\frac{3}{2}} = \frac{10}{3} = 3.3$

(52) **(C).** When red is replaced with green 1st digit changes to 5 so new resistance will be 500Ω.

(53) **(B).** Resistance of wire AB = $400 \times 0.01 = 4\Omega$

$i = 3/6 = 0.5$ A

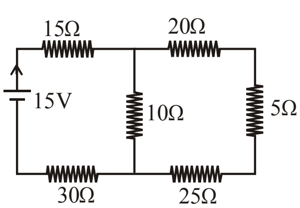


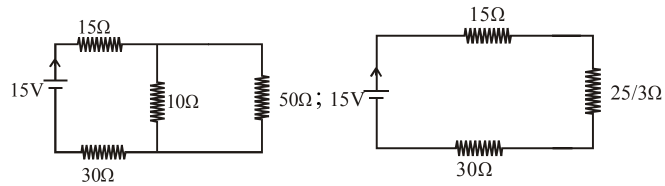
Now voltmeter reading

= i (Resistance of 50cm length)

= (0.5A) (0.01×50) = 0.25 volt

(54) **(C).**

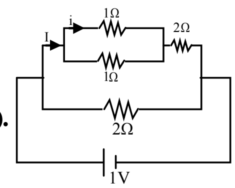




$R_{eq} = 15 + \frac{25}{3} + 30 = \frac{45 + 25 + 90}{3} = \frac{160}{3}$

$I = \frac{E}{R_{eq}} = \frac{15 \times 3}{160} = \frac{9}{32}$ amp.

(55) **(A).**



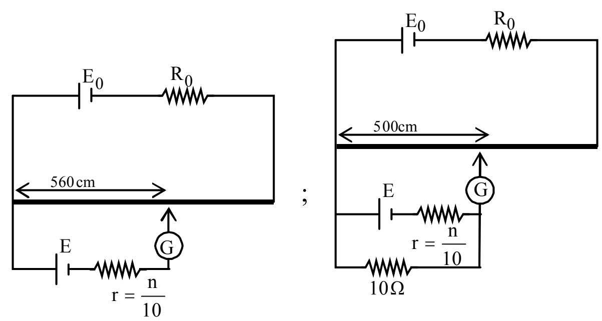
$I = \frac{1}{2.5} = 0.4A$; $i = \frac{1}{2} = 0.2$ A

(56) **(B).** Total power is

$(15 \times 45) + (15 \times 100) + (15 \times 10) + (2 \times 1000) = 4325$ W

So current is $= \frac{4325}{220} = 19.66$. Ans is 20 Amp.

(57) **12.**



Let the emf of cell is ε internal resistance is 'r' and potential gradient is x.

Only cell connected : $\varepsilon = 560\,x$ ......(1)

After connecting the resistor

$\frac{\varepsilon \times 10}{10 + r} = 500x$ .....(2)

From eq. (1) and (2)

$\frac{560 \times 10}{10 + r} = 500s$; $56 = 50 + 5r$; $r = \frac{6}{5} = 1.2\Omega$; n = 12

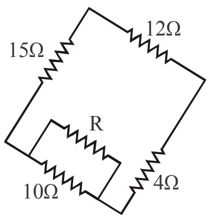
(58) **(D).** $5 = \lambda\,\ell$

where λ is potential gradient & L is total length of wire.

$5 = \frac{\Delta V}{L}\ell$; $\Delta V = \frac{5 \times L}{\ell} = 5 \times \frac{12}{10} = 6V = 60mA \times R$

$R = 100\ \Omega$

(59) **10.00**



Let the resistance to be connected is R.
For balanced wheatstone bridge,

$$15 \times 4 = 12 \times \frac{10R}{10+R} \Rightarrow R = 10\Omega$$

(60) **40.00.** In balancing, $\frac{R}{S} = \frac{25}{75}$.

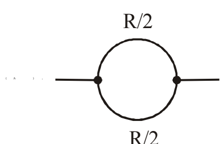
New resistance $R' = \frac{\rho\ell}{A} = \frac{\rho \times (\ell/2)}{A/4} = \frac{\rho\ell}{2} \times 4A$; $R' = 2R$

$$\frac{2R}{S} = \frac{\ell'}{100-\ell'} \;;\; 2 \times \frac{1}{3} = \frac{\ell'}{100-\ell'} = 3\ell' = 200 - 2\ell'$$

$5\ell' = 200 \Rightarrow \ell' = 40$

EXERCISE-5

(1)



$$R_{eq} = \frac{R_1R_2}{R_1+R_2} = \frac{\left(\frac{R}{2}\cdot\frac{R}{2}\right)}{\frac{R}{2}+\frac{R}{2}} = \frac{R}{4}$$

(2) **(D).** Power, $P = i^2R$
where, i = currrent in circuit, R = resistance
$R = P/i^2$
Given P = 1W, i = 5A ; $R = 1/(5)^2 = 0.04\,\Omega$

(3) **(D).** $V = \frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}}{\frac{1}{r_1}+\frac{1}{r_2}} = \frac{\frac{18}{2}+\frac{12}{1}}{\frac{1}{2}+\frac{1}{1}} = 14V$

(Since the cells are in parallel).

(4) **(C).** Current will flow from B to A
Potential drop over the resistance 4Ω will be more due to higher value of resistance.
So, potential at A will be less as compared with at B.
Hence, current will flow from B to A.

(5) **(C).** Power = V.I = I^2R

$$i_2 = \sqrt{\frac{Power}{R}} = \sqrt{\frac{2}{8}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

Potential over 8Ω = Ri_2 = 8 × (1/2) = 4V
This is the potential over parallel.

So, $i_1 = \frac{4}{4} = 1$

Powero f 3Ω = $i_1^2 R$ = 1 × 1 × 3 = 3W

(6) **(D).** Current in the circuit $= \frac{E+E}{r_1+r_2+R} = \frac{2E}{r_1+r_2+R}$

P.D. across first cell $= E - ir_1 = E - \frac{2E \times r_1}{(r_1+r_2)+R}$

Now, $E = \frac{2Er_1}{(r_1+r_2)+R}$

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

(7) **(B).** Power dissipated $P = \frac{V^2}{R} = \frac{(18)^2}{6} = 54W$

(8) **(A).** $\frac{6S}{6+S} = 2; S = 3\Omega$

(9) **(A).** $S = \frac{I_gG}{I-I_g} = \frac{100 \times 13}{750-100} = 2\Omega$

(10) **(A).** Voltage across 2 ohm, v = 3 × 2 = 6 volt

So current across 5 ohm $= \frac{6v}{1\Omega+5\Omega} = 1A$

Power across 5 ohm = $P = I^2R$
$= (1)^2 \times 5$ ohm = 5 watt

(11) **(B).** V I t = ms ΔT ⇒ $t = \frac{ms\Delta T}{VI} = \frac{1 \times 4200 \times 80}{220 \times 4}$
= 381.8 sec. = 6.3 min

(12) **(B).** $E \propto \ell_1$;

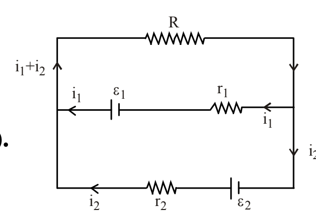
$$\frac{ER}{r+R} \propto \ell_2 \;;\; \frac{r+R}{R} = \frac{\ell_1}{\ell_2} \;;\; \frac{r}{R}+1 = 1.1 \;;\; r = 1 \text{ ohm}$$

(13) **(C).** Specific resistance remain same while resistance change.

(14) **(A).** V_{PM} = 1A × 4 ohm = 4 volt

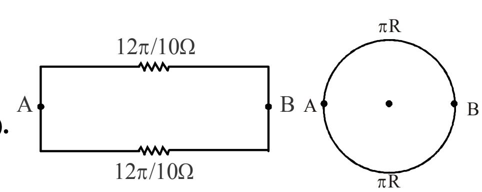
$$V_{MN} = \frac{1\Omega}{1\Omega+0.25\Omega} \times 4\text{volt} = 3.2\text{volt}$$

(15) **(D).**



$$\varepsilon_1 - (i_1+i_2)R - i_1r_1 = 0$$

(16) **(D).**



Circumference of circle $= 2 \times \pi \frac{10}{100} = \frac{2\pi}{10} = \frac{\pi}{5}$

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

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

$\therefore$ Equivalent resistance $= \dfrac{\frac{12\pi}{10} \times \frac{12\pi}{10}}{\frac{12\pi}{10} + \frac{12\pi}{10}} = \frac{6\pi}{10} = 0.6\pi\Omega$

(17) **(C).** $G = 60\Omega, I_g = 1.0\,A, I = 5\,A$

$I_g G = (I - I_g)\,S$; $S = \frac{I_g G}{I - I_g} = \frac{1}{5-1} \times 60 = 15\Omega$

putting 15Ω in parallel.

(18) **(A).** $V + ir = E\,;\, V = V_A - V_B = E - ir$

$\frac{\partial V}{\partial i} = -r,\ i = 0, v = E$

$\therefore$ Slope $= -r$, intercept $= E$

(19) **(B).** When the key between the terminals 1 and 2 is plugged in, then Pd. across $R = IR = k\ell_1$ where k is the potneital gradient across the potentiometer wire.
When the key between the terminals 1 and 3 is plugged in, then Pd. across $(R + X) = I\,(R + X) = k\ell_2$

$R = \frac{k\ell_1}{I} = \frac{k\ell_1}{1} = k\ell_1\Omega$; $R + X = \frac{k\ell_2}{I}$

$X = k\ell_2 - R = k\ell_2 - k\ell_1 = k\,(\ell_2 - \ell_1)\,\Omega$

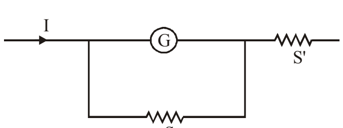
(20) **(A).** Here, Resistance of galvanometer, $G = 100\Omega$
Current for full scale deflection,
$I_g = 30mA = 30 \times 10^{-3}\,A$
Range of voltmeter, $V = 30V$
To convert the galvanometer into an voltmeter of a given range, a resistance R is connected in series
$30 = I_g\,(R + G), R = 900\,\Omega$

(21) **(D).** Kirchoff's junction law or Kirchhoff's first law is based on the conservation of charge.
Kirchhoff's loop law or Kirchhoff's second law is based on the conservation of energy.

(22) **(C).** $2 = \frac{\varepsilon}{2 + r}$; $0.5 = \frac{\varepsilon}{9 + r}$ or $\frac{2}{0.5} = \frac{9 + r}{2 + r}$ $\therefore$ $r = \frac{1}{3}\Omega$

(23) **(D).** Current in 9Ω is 2A, so that in 6Ω is 3A. Total current is $2 + 3 = 5A$. Potential drop $= 5 \times 2 = 10V$

(24) **(C).** $G = \frac{GS}{G+S} + S'$; $S' = \frac{G^2}{G+S}$

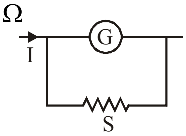


(25) **(D).** 1division $\equiv 1\mu A$; Voltage $= iR = 1 \times 10 = 10\mu V$

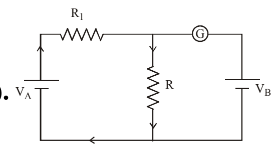
$40\mu V \rightarrow 1°C$; $10\mu V \rightarrow \frac{1}{4}°C = 0.25°C$

(26) **(D).** Current from D to C = 1 A
$\therefore$ $V_D - V_C = 2 \times 1 = 2V$
$V_A = 0 \therefore V_C = 1V, \therefore V_D - V_C = 2$
$\Rightarrow$ $V_D - 1 = 2$ $\therefore V_D = 3V$
$\therefore$ $V_D - V_B = 2$ $\therefore 3 - V_B = 2$ $\therefore V_B = 1V$

(27) **(A).** $\frac{GS}{G+S} = \frac{V_G}{I} = \frac{25 \times 10^{-3}}{25} = 0.001\,\Omega$
$S << G$ so, $S = 0.001\,\Omega$



(28) **(B).**



Since deflection in galvanometer is zero so current will flow as shown in the above diagram.

Current $I = \frac{V_A}{R_1 + R} = \frac{12}{500 + 100} = \frac{12}{600}$

So, $V_B = IR = \frac{12}{600} \times 100 = 2V$

(29) **(C).** Resistance of bulb is constant

$P = \frac{v^2}{R} \Rightarrow \frac{\Delta p}{p} = \frac{2\Delta v}{v} + \frac{\Delta R}{R}$; $\frac{\Delta p}{p} = 2 \times 2.5 + 0 = 5\%$

(30) **(D).** We knows $R \propto l$
Here, $R_1 + R_2 = 12\Omega$

and $\frac{R_1 \times R_2}{R_1 + R_2} = \frac{8}{3}\Omega \Rightarrow R_1R_2 = 32\Omega$

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

Again, $R_1 = \frac{12 l_1}{l_1 + l_2}$ and $R_2 = \frac{12 l_2}{l_1 + l_2}$. Hence, $\frac{l_1}{l_2} = \frac{1}{2}$.

(31) **(C).** $P = \frac{v^2}{R_{eq}}$; $v = 10$ V; $R_{eq} = \left(\frac{5R}{5+R}\right)$

$P = 30W$; $30 = \frac{(10)^2}{\left(\frac{5R}{5+R}\right)}$; $\frac{5R}{5+R} = \frac{10}{3}$

$\Rightarrow$ $15R = 50 + 10R \Rightarrow 5R = 50 \Rightarrow R = 10\Omega$

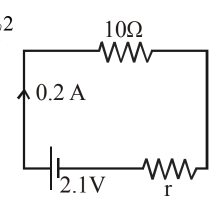
(32) **(C).** $I = \left(\frac{\varepsilon}{R + r}\right)$; $V = IR = \left(\frac{\varepsilon}{R + r}\right)R$; $V = \frac{\varepsilon}{\left(1 + \frac{r}{R}\right)}$

when $R = 0, V = 0$; $R = \infty, v = \varepsilon$

(33) **(A).** $R = \frac{\rho\ell}{A} = \frac{\rho\ell^2}{A\ell} \Rightarrow R \propto \ell^2$

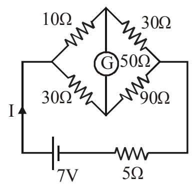
(34) **(C).** $I = \frac{E}{r + R}$

$\Rightarrow$ $r = 0.5\,\Omega$



(35) **(C).** Total resistance of

Wheatstone bridge $=\dfrac{(40)(120)}{40+120}=30\Omega$



Current through cell $=\dfrac{7V}{(5+30)\,\Omega}=\dfrac{1}{5}A=0.2\text{ A}$

(36) **(B).** Resistance $=150\times 0.5=75\,\Omega$

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

$P=I^2R=(16)^2\times 75\text{ W }=19200=19.2\text{ kW}$

(37) **(B).** Initially, $\dfrac{5}{\ell_1}=\dfrac{R}{100-\ell_1}$ .... (1)

Finally, $\dfrac{5}{1.6\ell_1}=\dfrac{R}{2\,(100-1.6\ell_1)}$ .... (2)

$\Rightarrow \dfrac{R}{1.6\,(100-\ell_1)}=\dfrac{R}{2\,(100-1.6\ell_1)}$

$\Rightarrow 1.6\ell_1=40\Rightarrow \ell_1=25$

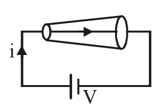
From eq. (1), $\dfrac{5}{25}=\dfrac{R}{75}\ \Rightarrow R=15\Omega$

(38) **(C).** $r=\left(\dfrac{\ell_1}{\ell_2}-1\right)R=\left(\dfrac{3}{2.85}-1\right)9.5\Omega$

$=\dfrac{0.15}{2.85}\times 9.5\Omega=0.5\Omega$

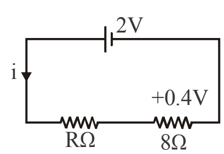
(39) **(C).** $n=\dfrac{I}{I_s}=\dfrac{100}{0.2}=500\ ;\ R_A=\dfrac{G}{n}=\dfrac{G}{500}$

(40) **(A).** Current remains same.

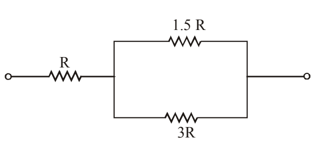


(41) **(D).** Total potential difference across potentio meter wire $=10^{-3}\times 400\text{ volt}=0.4\text{ volt}$

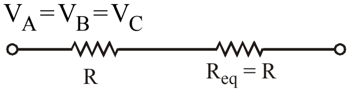
$0.4=\dfrac{2}{R+8}\times 8\Rightarrow\ R=32\Omega$



(42) **(D).**



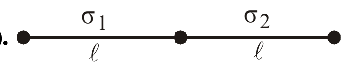
$V_A=V_B=V_C$



(43) **(C).** Potential gradient $x=\dfrac{ir}{L}=\dfrac{E_0}{(r_1+r)}\dfrac{r}{L}$

emf $E=x\ell=\dfrac{E_0r}{(r_1+r)}\dfrac{l}{L}$

(44) **(B).**



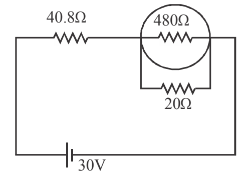
$R_{eq}=R_1+R_2$

$\dfrac{2\ell}{\sigma_{eq}A}=\dfrac{\ell}{\sigma_1A}+\dfrac{\ell}{\sigma_2A}\Rightarrow \sigma_{eq}=\dfrac{2\sigma_1\sigma_2}{\sigma_1+\sigma_2}$

(45) **(B).** $R_{eff}=40.8+\dfrac{480\times 20}{480+20}$

$=40.8+19.2=60\Omega$

$I=\dfrac{V_{eff}}{R_{eff}}=0.5\text{ A}$



(46) **(A).** $Q=at-bt^2$; $I=\dfrac{dQ}{dt}=a-2bt$

Current will exist till, $t=a/2b$

$P=\int_0^t I^2R\,dt=\int_0^{a/2b}(a-2bt)^2R\,dt$

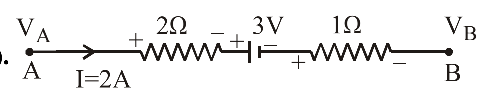
$=\int_0^{a/2b}(a^2+4b^2t^2-4abt)\,R\,dt$

$=\left[a^2t+4b^2\dfrac{t^3}{3}-4ab\dfrac{t^2}{2}\right]_0^{a/2b}R=\dfrac{a^3R}{6b}$

(47) **(D).** Potentiometer $E\propto I$

$\dfrac{E_1+E_2}{E_1-E_2}=\dfrac{50}{10}=\dfrac{5}{1}\ ;\ \dfrac{E_1}{E_2}=\dfrac{5+1}{5-1}=\dfrac{6}{4}=\dfrac{3}{2}$

(48) **(D).**



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

(49) **(C).** $I=\dfrac{P}{V}=\dfrac{500}{100}=5A$

Voltage across resistance R will be

$230-100=130\text{ V}\ ;\ R=\dfrac{130}{5}=26\Omega$

(50) **(B).** $R=\dfrac{\rho\ell}{A}=\dfrac{\rho\ell^2}{\text{volume}}\Rightarrow R\propto\ell^2\ ;\ R_2=n^2R_1$

(51) **(B).** In zero deflection condition, potentiometer draws no current.

(52) **(B).** $(47\pm 4.7)\,k\Omega=47\times 10^3\pm 10\%$

$\therefore$ Yellow – Violet – Orange – Silver

(53) **(C).** $I = \dfrac{E}{nR + R}$ .... (1)

$10\,I = \dfrac{E}{\dfrac{R}{n} + R}$ .... (2)

Dividing (2) by (1), $10 = \dfrac{(n+1)\,R}{\left(\dfrac{1}{n}+1\right) R}$

After solving the equation, n = 10

(54) **(C).** $I = \dfrac{ne}{nr} = \dfrac{e}{r}$

So, I is independent of n and I is constant.

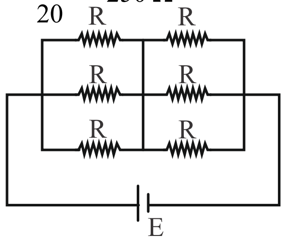
(55) **(A).** Current sensitivity, $I_s = \dfrac{NBA}{C}$

Voltage sensitivity, $V_s = \dfrac{NBA}{CR_G}$

So, resistance of galvanometer

$R_G = \dfrac{I_s}{V_s} = \dfrac{5 \times 1}{20 \times 10^{-3}} = \dfrac{5000}{20} = 250\ \Omega$

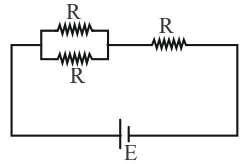
(56) **(B).** (i) All bulbs are glowing



$R_{eq} = \dfrac{R}{3} + \dfrac{R}{3} = \dfrac{2R}{3}$

Power $(P_i) = \dfrac{E^2}{R_{eq}} = \dfrac{3E^2}{2R}$ ...(1)

(ii) Two from section A and one from section B are glowing.



$R_{eq} = \dfrac{R}{2} + R = \dfrac{3R}{2}$; Power $(P_f) = \dfrac{2E^2}{3R}$ ...(2)

$\dfrac{P_i}{P_f} = \dfrac{3E^2}{2R}\,\dfrac{3R}{2E^2} = 9:4$

(57) **(D).** Fuse wire has less melting point so when excess current flows, due to heat produced in it, it melts.

(58) **(C).** For ideal voltmeter, resistance is infinite and for the ideal ammeter, resistance is zero.

$V_1 = i_1 \times 10 = \dfrac{10}{10} \times 10 = 10 \text{ volt}$

$V_2 = i_2 \times 10 = \dfrac{10}{10} \times 10 = 10 \text{ volt}$

$V_1 = V_2$

$i_1 = i_2 = \dfrac{10V}{10\Omega} = 1A$