PHYSICS

Crash Course for JEE Main 2020

CURRENT ELECTRICITY

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1. ELECTRIC CURRENT

$I_{av} = \frac{\Delta q}{\Delta t}$ and instantaneous current

$i = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt}$

2. ELECTRIC CURRENT IN A CONDUCTOR

$I = nAeV.$

$v_d = \frac{\lambda}{\tau},$

$$v_d = \frac{\frac{1}{2}\left(\frac{eE}{m}\right)\tau^2}{\tau} = \frac{1}{2}\frac{eE}{m}\tau,$$

$I = neAV_d$

3. CURRENT DENSITY

$$\vec{J} = \frac{dI}{ds}\vec{n}$$

4. ELECTRICAL RESISTANCE

$$I = neAV_d = neA\left(\frac{eE}{2m}\right)\tau = \left(\frac{ne^2\tau}{2m}\right)AE$$

$$E = \frac{V}{\ell} \quad \text{so} \quad I = \left(\frac{ne^2\tau}{2m}\right)\left(\frac{A}{\ell}\right)V = \left(\frac{A}{\rho\ell}\right)V = V/R \Rightarrow V = IR$$

ρ is called resistivity (it is also called specific resistance) and $\rho = \frac{2m}{ne^2\tau} = \frac{1}{\sigma}$, σ is called conductivity. Therefore current in conductors is proportional to potential difference applied across its ends. This is **Ohm's Law**.

Units:

$R \to \text{ohm}(\Omega)$, $\rho \to \text{ohm} - \text{meter}(\Omega - m)$

also called siemens, $\sigma \to \Omega^{-1}m^{-1}$.

®

Dependence of Resistance on Temperature :

$R = R_o(1 + \alpha\theta).$

Electric current in resistance

$$I = \frac{V_2 - V_1}{R}$$

5. ELECTRICAL POWER

$P = VI$

Energy = $\int p\,dt$

$P = I^2R = VI = \frac{V^2}{R}$.

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

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

9. KIRCHHOFF'S LAWS

9.1 Kirchhoff's Current Law (Junction law)

$\Sigma I_{in} = \Sigma I_{out}$

9.2 Kirchhoff's Voltage Law (Loop law)

$\Sigma IR + \Sigma EMF = 0$".

10. COMBINATION OF RESISTANCES :

Resistances in Series:

$R = R_1 + R_2 + R_3 + ... + R_n$ (this means R_{eq} is greater then any resistor)) and

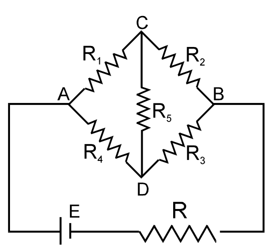
$V = V_1 + V_2 + V_3 + ... + V_n$.

$V_1 = \frac{R_1}{R_1 + R_2 + ... + R_n}V$; $V_2 = \frac{R_2}{R_1 + R_2 + ... + R_n}V$;

2. Resistances in Parallel :

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

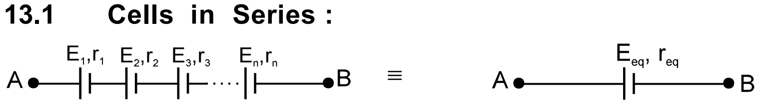
11. WHEATSTONE NETWORK : (4 TERMINAL NETWORK)



When current through the galvanometer is zero (null point or balance point) $\frac{P}{Q} = \frac{R}{S}$, then PS = QR

13. GROUPING OF CELLS

13.1 Cells in Series :

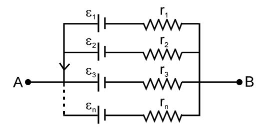


Equivalent EMF $E_{eq} = E_1 + E_2 + ... + E_n$ [write EMF's with polarity]

Equivalent internal resistance $r_{eq} = r_1 + r_2 + r_3 + r_4 + ... + r_n$

13.2 Cells in Parallel:

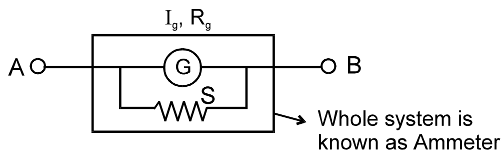
$$E_{eq} = \frac{\varepsilon_1/r_1 + \varepsilon_2/r_2 + ... + \varepsilon_n/r_n}{1/r_1 + 1/r_2 + ... + 1/r_n}$$ [Use emf with polarity]



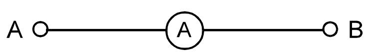
$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + ... + \frac{1}{r_n}$$

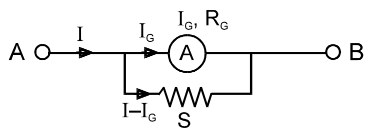
15. AMMETER

A shunt (small resistance) is connected in parallel with galvanometer to convert it into ammeter. An ideal ammeter has zero resistance



Ammeter is represented as follows -





If maximum value of current to be measured by ammeter is I then

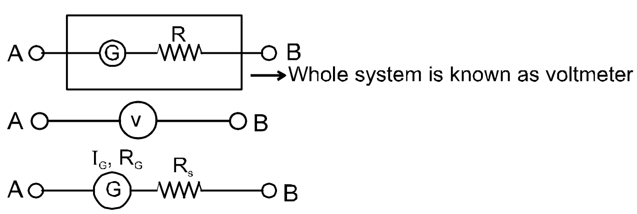
$I_G \cdot R_G = (I - I_G)S$

$$S = \frac{I_G . R_G}{I - I_G} \qquad S = \frac{I_G \times R_G}{I} \quad \text{when} \quad I >> I_G.$$

where I = Maximum current that can be measured using the given ammeter.

16. VOLTMETER

A high resistance is put in series with galvanometer. It is used to measure potential difference across a resistor in a circuit.



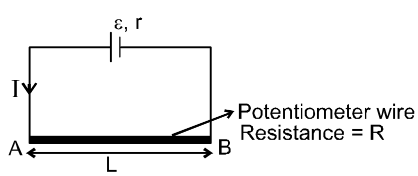
For maximum potential difference

$$V = I_G . R_S + I_G R_G$$

$$R_S = \frac{V}{I_G} - R_G \quad \text{If} \quad R_G << R_S \Rightarrow R_S \approx \frac{V}{I_G}$$

17. POTENTIOMETER

$$I = \frac{\varepsilon}{r + R}$$



$$V_A - V_B = \frac{\varepsilon}{R+r} . R$$

Potential gradient (x) → Potential difference per unit length of wire

$$x = \frac{V_A - V_B}{L} = \frac{\varepsilon}{R+r} . \frac{R}{L}$$

Application of potentiometer

(a) To find emf of unknown cell and compare emf of two cells.

In case I,

In figure (1) is joint to (2) then balance length = ℓ_1

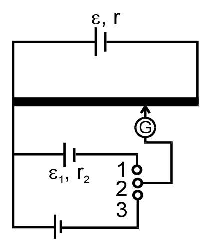
$\varepsilon_1 = x\ell_1$ ....(1)

in case II,

In figure (3) is joint to (2) then balance length = ℓ_2

$\varepsilon_2 = x\ell_2$ ....(2)

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{\ell_1}{\ell_2}$$



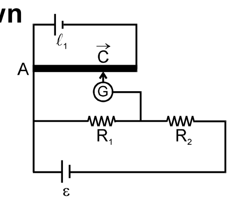
If any one of ε_1 or ε_2 is known the other can be found. If x is known then both ε_1 and ε_2 can be found

(b) To find current if resistance is known

$V_A - V_C = x\ell_1$

$IR_1 = x\ell_1$

$$I = \frac{x\ell_1}{R_1}$$

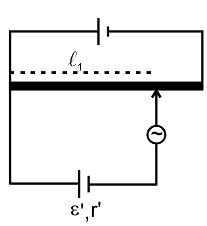


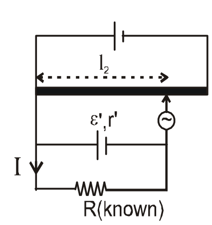
Similarly, we can find the value of R_2 also.

Potentiometer is ideal voltmeter because it does not draw any current from circuit, at the balance point.

(c) To find the internal resistance of cell.

I[st] arrangement 2[nd] arrangement





by first arrangement $\varepsilon' = x\ell_1$ ...(1)

by second arrangement $IR = x\ell_2$

$$I = \frac{x\ell_2}{R}, \qquad \text{also } I = \frac{\varepsilon'}{r'+R}$$

$$\therefore \quad \frac{\varepsilon'}{r'+R} = \frac{x\ell_2}{R} \quad \Rightarrow \quad \frac{x\ell_1}{r'+R} = \frac{x\ell_2}{R}$$

$$r' = \left[\frac{\ell_1 - \ell_2}{\ell_2}\right] R$$

(d)Ammeter and voltmeter can be graduated by potentiometer.
(e)Ammeter and voltmeter can be calibrated by potentiometer.

18. METRE BRIDGE (USE TO MEASURE UNKNOWN RESISTANCE)

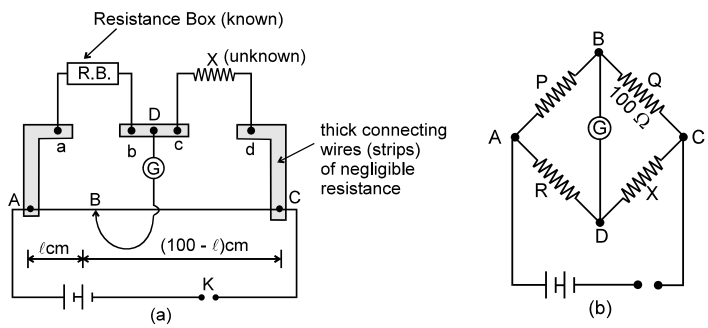
If AB = ℓ cm, then BC = $(100 - \ell)$ cm.

Resistance of the wire between A and B , R $\propto \ell$

[$\because$ Specific resistance ρ and cross-sectional area A are same for whole of the wire]

or $\quad R = \sigma\ell \quad$ ...(1)

where σ is resistance per cm of wire.



If P is the resistance of wire between A and B then

$P \propto \ell \quad \Rightarrow \quad P = \sigma(\ell)$

Similarly, if Q is resistance of the wire between B and C, then

$Q \propto 100 - \ell$

$\therefore \quad Q = \sigma(100 - \ell) \quad$ ....(2)

Dividing (1) by (2), $\quad \dfrac{P}{Q} = \dfrac{\ell}{100 - \ell}$

Applying the condition for balanced Wheatstone bridge, we get R Q = P X

$\therefore \quad x = R\dfrac{Q}{P} \quad$ or $\quad X = \dfrac{100 - \ell}{\ell} R$

Since R and ℓ are known, therefore, the value of X can be calculated.

SECTION-1 SCQ

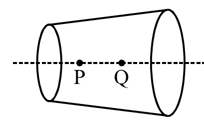
Q.1 Two wires each of radius of cross section r but of different materials are connected together end to end (in series). If the densities of charge carriers in the two wires are in the ratio 1 : 4, the drift velocity of electrons in the two wires will be in the ratio:

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

Q.2 An insulating pipe of cross-section area 'A' contains an electrolyte which has two types of ions→ their charges being –e and +2e. A potential difference applied between the ends of the pipe result in the drifting of the two types of ions, having drift speed = v (–ve ion) and v/4 (+ve ion). Both ions have the same number per unit volume = n. The current flowing through the pipe is

(A) nev A/2 (B) nev A/4 (C) 5nev A/2 (D) 3nev A/2

Q.3 A wire has a non-uniform cross-section as shown in figure. A steady current flows through it. The drift speed of electrons at points P and q is v_P and v_Q.



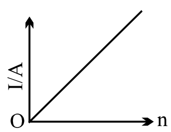
(A) $v_P = v_Q$ (B) $v_P < v_Q$

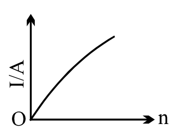
(C) $v_P > v_Q$ (D) Data insufficient

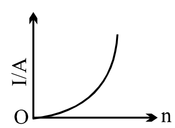
Q.4 A storage battery is connected to a charger for charging with a voltage of 12.5Volts. The internal resistance of the storage battery is 1Ω. When the charging current is 0.5 A, the emf of the storage battery is:

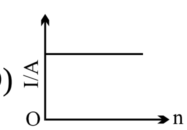
(A) 13 Volts (B) 12.5 Volts (C) 12 Volts (D) 11.5 Volts

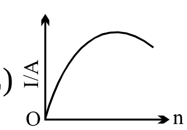
Q.5 A battery consists of a variable number n of identical cells having internal resistance connected in series. The terminals of the battery are short circuited and the current I measured.
Which one of the graph below shows the relationship between I and n ?

(A) 

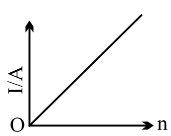
(B) 

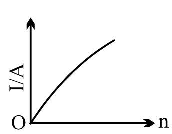
(C) 

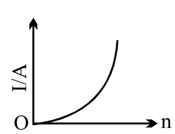
(D) 

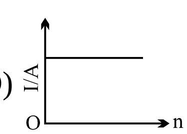
(E) 

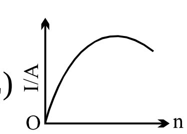
Q.6 In **previous problem**, if the cell had been connected in parallel (instead of in series) which of the above graphs would have shown the relationship between total current I and n ?

(A) 

(B) 

(C) 

(D) 

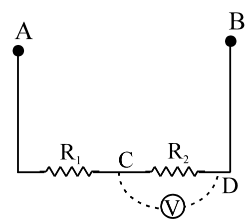
(E) 

Q.7 A wire of cross-section area A, length L_1, resistivity ρ_1 and temperature coefficient of resistivity α_1 is connected to a second wire of length L_2, resistivity ρ_2, temperature coefficient of resistivity α_2 and the same area A, so that wire carries same current. Total resistance R is independent of temperature for small temperature change if (Thermal expansion effect is negligible)

(A) $\alpha_1 = -\alpha_2$ (B) $\rho_1 L_1 \alpha_1 + \rho_2 L_2 \alpha_2 = 0$

(C) $L_1 \alpha_1 + L_2 \alpha_2 = 0$ (D) None

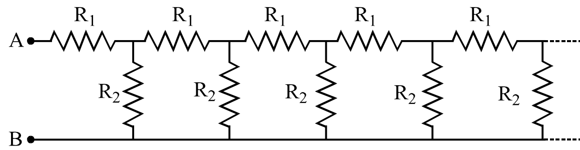
Q.8 Resistances R_1 and R_2 each 60Ω are connected in series as shown in figure. The Potential difference between A and B is kept 120 volt. Then what will be the reading of voltmeter connected between the point C & D if resistance of voltmeter is 120Ω.



(A) 48 V (B) 24 V

(C) 40V (D) None

Q.9 Consider an infinte ladder network shown in figure. A voltage V is applied between the points A and B. This applied value of voltage is halved after each section.

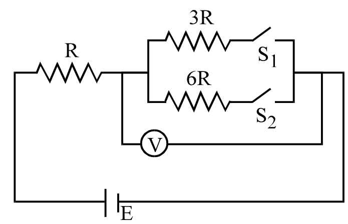


(A) $R_1/R_2 = 1$ (B) $R_1/R_2 = 1/2$ (C) $R_1/R_2 = 2$ (D) $R_1/R_2 = 3$

Q.10 A brass disc and a carbon disc of same radius are assembled alternatively to make a cylindrical conductor. The resistance of the cylinder is independent of the temperature. The ratio of thickness of the brass disc to that of the carbon disc is [α is temperature coefficient of resistance & Neglect linear expansion]

(A) $\left|\frac{\alpha_C \rho_C}{\alpha_B \rho_B}\right|$ (B) $\left|\frac{\alpha_C \rho_B}{\alpha_B \rho_C}\right|$ (C) $\left|\frac{\alpha_B \rho_C}{\alpha_C \rho_B}\right|$ (D) $\left|\frac{\alpha_B \rho_B}{\alpha_C \rho_C}\right|$

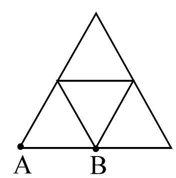
Q.11 In the circuit shown in figure reading of voltmeter is V_1 when only S_1 is closed, reading of voltmeter is V_2 when only S_2 is closed. The reading of voltmeter is V_3 when both S_1 and S_2 are closed then



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

Q.12 One end of a Nichrome wire of length 2L and cross-sectional area A is attatched to an end of another Nichrome wire of length L and cross-sectional area 2A. If the free end of the longer wire is at an electric potential of 8.0 volts, and the free end of the shorter wire is at an electric potential of 1.0 volt, the potential at the junction of the two wires is equal to
(A) 2.4 V (B) 3.2 V (C) 4.5 V (D) 5.6 V

Q.13 In the diagram resistance between any two junctions is R. Equivalent resistance across terminals A and B is



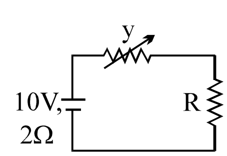
(A) $\frac{11R}{7}$ (B) $\frac{18R}{11}$ (C) $\frac{7R}{11}$ (D) $\frac{11R}{18}$

Q.14 Two bulbs rated (25 W – 220V) and (100W – 220V) are connected in series to a 440 V line. Which one is likely to fuse?
(A) 25 W bulb (B) 100 W bulb (C) both bulbs (D) none

Q.15 Rate of dissipation of Joule's heat in resistance per unit volume is (symbols have usual meaning)
(A) σ E (B) σ J (C) J E (D) None

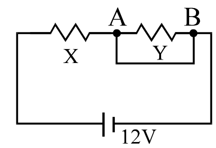
Q.16 Two bulbs one of 200 volts, 60 watts & the other of 200 volts, 100 watts are connected in series to a 200 volt supply. The power consumed will be
(A) 37.5 watt (B) 160 watt (C) 62.5 watt (D) 110 watt

Q.17 In the figure shown the power generated in y is maximum when y = 5Ω. Then R is



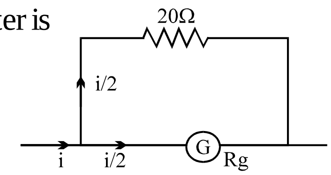
(A) 2 Ω (B) 6 Ω
(C) 5 Ω (D) 3 Ω

Q.18 When an ammeter of negligible internal resistance is inserted in series with circuit it reads 1A. When the voltmeter of very large resistance is connected across X it reads 1V. When the point A and B are shorted by a conducting wire, the voltmeter measures 10 V across the battery. The internal resistance of the battery is equal to



(A) zero
(B) 0.5 Ω
(C) 0.2 Ω
(D) 0.1 Ω

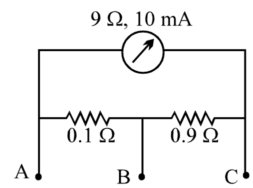
Q.19 In a galvanometer, the deflection becomes one half when the galvanometer is shunted by a 20Ω resistor. The galvanometer resistance is



(A) 5Ω (B) 10Ω
(C) 40Ω (D) 20Ω

Q.20 A galvanometer has a resistance of 20Ω and reads full-scale when 0.2 V is applied across it. To convert it into a 10 A ammeter, the galvanometer coil should have a
(A) 0.01Ω resistor connected across it (B) 0.02Ω resistor connected across it
(C) 200Ω resistor connected in series with it (D) 2000 Ω resistor connected in series with it

Q.21 A milliammeter of range 10 mA and resistance 9 Ω is joined in a circuit as shown. The metre gives full-scale deflection for current I when A and B are used as its terminals, i.e., current enters at A and leaves at B (C is left isolated). The value of I is

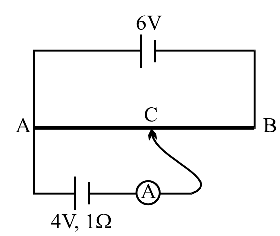


(A) 100 mA (B) 900 mA (C) 1 A (D) 1.1 A

Q.22 A galvanometer coil has a resistance 90 Ω and full scale deflection current 10 mA. A 910Ω resistance is connected in series with the galvanometer to make a voltmeter. If the least count of the voltmeter is 0.1V, the number of divisions on its scale is
(A) 90 (B) 91 (C) 100 (D) none

Q.23 In a balanced wheat stone bridge, current in the galvanometer is zero. It remains zero when:
[1] battery emf is increased [2] all resistances are increased by 10 ohms
[3] all resistances are made five times [4] the battery and the galvanometer are interchanged
(A) only [1] is correct (B) [1], [2] and [3] are correct
(C) [1], [3] and [4] are correct (D) [1] and [3] are correct

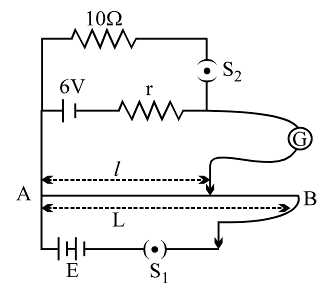
Q.24 A 6 V battery of negligible internal resistance is connected across a uniform wire of length 1 m. The positive terminal of another battery of emf 4V and internal resistance 1 Ω is joined to the point A as shown in figure. The ammeter shows zero deflection when the jockey touches the wire at the point C. The AC is equal to



(A) 2/3 m (B) 1/3 m
(C) 3/5 m (D) 1/2 m

Q.25 A potentiometer wire has length 10 m and resistance 10Ω. It is connected to a battery of EMF 11 volt and internal resistance 1 Ω, then the potential gradient in the wire is
(A) 10 V/m (B) 1 V/m (C) 0.1 V/m (D) none

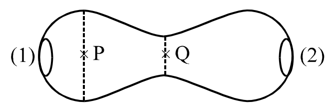
Q.26 In the arrangement shown in figure when the switch S_2 is open, the galvanometer shows no deflection for $l = L/2$. When the switch S_2 is closed, the galvanometer shows no deflection for $l = 5L/12$. The internal resistance (r) of 6 V cell, and the emf E of the other battery are respectively



(A) 3Ω, 8V
(B) 2Ω, 12V
(C) 2Ω, 24V
(D) 3Ω, 12V

SECTION-2 MCQ

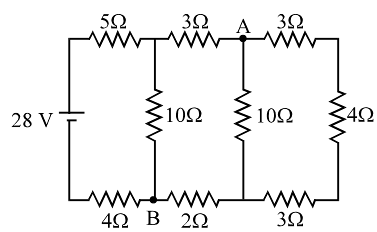
Q.27 A metallic conductor of irregular cross-section is as shown in the figure. A constant potential difference is applied across the ends (1) and (2). Then :



(A) the current at the cross-section P equals the current at the cross-section Q
(B) the electric field intensity at P is less than that at Q.
(C) the rate of heat generated per unit time at Q is greater than that at P
(D) the number of electrons crossing per unit area of cross-section at P is less than that at Q.

Q.28 A current passes through an ohmic conductor of nonuniform cross section. Which of the following quantities are independent of the cross-section?
(A) the charge crossing in a given time interval.
(B) drift speed
(C) current density
(D) free-electron density

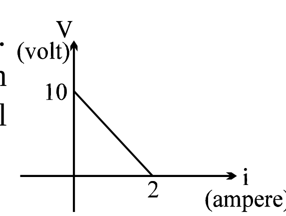
Q.29 Consider the circuit shown in the figure



(A) the current in the 5 Ω resistor is 2 A
(B) the current in the 5 Ω resistor is 1 A
(C) the potential difference $V_A - V_B$ is 10 V
(D) the potential difference $V_A - V_B$ is 5 V

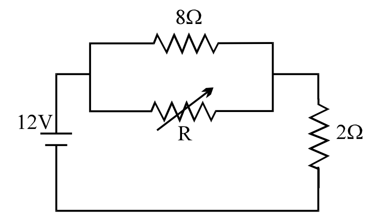
Q.30 Two identical fuses are rated at 10A. If they are joined
(A) in parallel, the combination acts as a fuse of rating 20A
(B) in parallel, the combination acts as a fuse of rating 5A
(C) in series, the combination acts as a fuse of rating 10A.
(D) in series, the combination acts as a fuse of rating 20A.

Q.31 A battery of emf E and internal resistance r is connected across a resistance R. Resistance R can be adjusted to any value greater than or equal to zero. A graph is plotted between the current (i) passing through the resistance and potential difference (V) across it. Select the correct alternative(s).



(A) internal resistance of battery is 5Ω
(B) emf of the battery is 20V
(C) maximum current which can be taken from the battery is 4A
(D) V- i graph can never be a straight line as shown in figure.

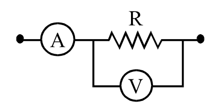
Q.32 The value of the resistance R in figure is adjusted such that power dissipated in the 2Ω resistor is maximum. Under this condition



(A) R = 0
(B) R = 8Ω
(C) power dissipated in the 2 Ω resistor is 72 W
(D) power dissipated in the 2 Ω resistor is 8 W

Q.33 Mark out the correct options.
(A) An ammeter should have small resistance. (B) An ammeter should have large resistance.
(C) A voltmeter should have small resistance. (D) A voltmeter should have large resistance.

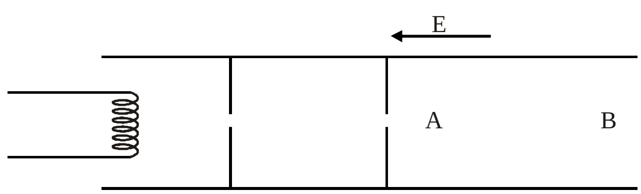
Q.34 In the circuit shown the readings of ammeter and voltmeter are 4A and 20V respectively. The meters are non ideal, then R is :



(A) 5Ω (B) less than 5Ω
(C) greater than 5Ω (D) between 4Ω & 5Ω

Q.35 A micrometer has a resistance of 100Ω and a full scale range of 50μA. It can be used as a voltmeter or a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination(s).
(A) 50 V range with 10 kΩ resistance in series. (B) 10 V range with 200 kΩ resistance in series.
(C) 5 mA range with 1 Ω resistance in parallel. (D) 10 mA range with 1 kΩ resistance in parallel.

Q.36 Electrons are emitted by a hot filament and are accelerated by an electric field as shown in figure. The two stops at the left ensure that the electron beam has a uniform cross-section. Match the entries of column-I with column-II as electron move from A to B :

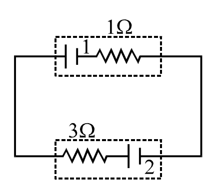


	Column-I		**Column-II**
(A)	Speed of an electron	(P)	Increases
(B)	Number of free electrons per unit volume	(Q)	Decreases
(C)	Current density	(R)	Remains same
(D)	Electric potential	(S)	any of the above is possible

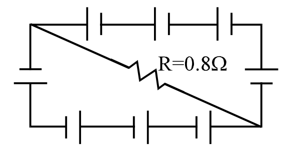
SECTION-3 INTEGER TYPE

Q.37 A current I flows through a uniform wire of diameter d when the mean electron drift velocity is V. The same current will flow through a wire of diameter d/2 made of the same material if the mean drift velocity of the electron is "xV". Find the value of x.

Q.38 In the figure shown, battery 1 has emf = 6 V and internal resistance = 1 Ω. Battery 2 has emf = 2V and internal resistance = 3 Ω. The wires have negligible resistance. What is the potential difference across the terminals of battery 2 ?

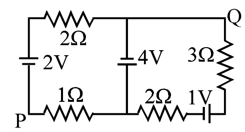


Q.39 A circuit is comprised of eight identical batteries and a resistor R = 0.8Ω. Each battery has an emf of 1.0 V and internal resistance of 0.2Ω. The voltage difference across any of the battery is

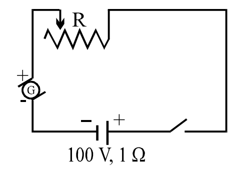


Q.40 A wire of length L and 3 identical cells of negligible internal resistances are connected in series. Due to the current, the temperature of the wire is raised by ΔT in time t. N number of similar cells is now connected in series with a wire of the same material and cross section but of length 2L. The temperature of the wire is raised by the same amount ΔT in the same time t. The value of N is :

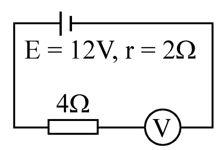
Q.41 In the circuit shown, what is the potential difference V_{PQ}?



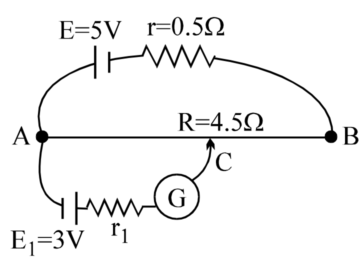
Q.42 The battery in the diagram is to be charged by the generator G. The generator has a terminal voltage of 120 volts when the charging current is10 amperes. The battery has an emf of 100 volts and an internal resistance of 1 ohm. In order to charge the battery at 10 amperes charging current, the resistance R should be set at



Q.43 By error, a student places moving-coil voltmeter V (nearly ideal) in series with the resistance in a circuit in order to read the current, as shown. The voltmeter reading will be 4x volts. Find the value of x ?



Q.44 In the given potentiometer circuit length of the wire AB is 3 m and resistance is R = 4.5 Ω. The length AC for no deflection in galvanometer is.



SECTION-4 MATCH THE COLUMN

Q.45 The following table gives the lengths of four copper rods at the same temperature, their diameters, and the potential differences between their ends.

Rod	Length	Diameter	Potential Difference
1	L	3d	V
2	2L	d	3V
3	3L	2d	2V
4	3L	d	V

Correctly match the physical quantities mentioned in the left column with the rods as marked.

(A) Greatest Drift speed of the electrons.	(p) Rod 1
(B) Greatest Current	(q) Rod 2
(C) Greatest rate of thermal energy produced	(r) Rod 3
(D) Greatest Electric field	(s) Rod 4

Q.46 Match the statements in Column I with the current element in Column II.

	Column - I	**Column - II**
(A)	Current always flows from higher potential to lower potential	(p) A Resistor
(B)	Energy dissipated in an element is always zero	(q) Ideal cell/Battery
(C)	Current flow through the element is always zero	(r) Non-Ideal cell/Battery
(D)	Potential difference may/will be zero	(s) Short-circuited resistor

ANSWER KEY

SCQ

Q.1	C	Q.2	D	Q.3	C	Q.4	C	Q.5	D
Q.6	A	Q.7	B	Q.8	A	Q.9	B	Q.10	A
Q.11	A	Q.12	A	Q.13	D	Q.14	A	Q.15	C
Q.16	A	Q.17	D	Q.18	C	Q.19	D	Q.20	B
Q.21	C	Q.22	C	Q.23	C	Q.24	A	Q.25	B
Q.26	B								

MCQ

Q.27	A,B,C,D	Q.28	A,D	Q.29	A	Q.30	A,C	Q.31	A
Q.32	A,C	Q.33	A,D	Q.34	C	Q.35	B,C		

Q.36 (A) P (B) Q (C) R (D) P

INTEGER

Q.37	4	Q.38	5	Q.39	0	Q.40	6	Q.41	+ 2V
Q.42	1.0 Ω	Q.43	3	Q.44					

MATCH THE COLUMN

Q.45 (A) q, (B) p , (C) p, (D) q

Q.46 (A) p ; (B) q, s ; (C) s ; (D) p, r, s