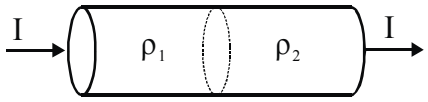
SECTION-I

Single Correct Answer Type 7 Q. [3 M (–1)]

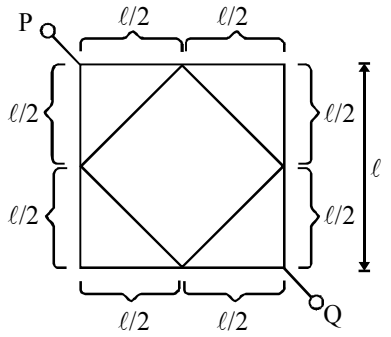
1. Two long straight cylindrical conductors with resistivities ρ_1 and ρ_2 respectively are joined together as shown in figure. If current I flows through the conductors, the magnitude of the total free charge at the interface of the two conductors is :-



(A) zero (B) $\frac{(\rho_1-\rho_2)I\varepsilon_0}{2}$ (C) $\varepsilon_0 I|\rho_1-\rho_2|$ (D) $\varepsilon_0 I|\rho_1+\rho_2|$

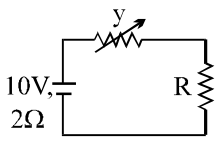
2. The resistance of a galvanometer is normally measured using :
(A) Post office box (B) Potentiometer
(C) Half deflection method (D) Meter bridge

3. If the wire has resistivity ρ and cross sectional area A, the equivalent resistance between P and Q is :-



(A) $\frac{\rho\ell}{\sqrt{2}A}$ (B) $\frac{\sqrt{2}\rho\ell}{A}$ (C) $\frac{2\rho\ell}{A}$ (D) $\frac{\rho\ell}{A}$

4. 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

5. ln 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

6. A circuit contains a battery of voltage V wired to three resistors of resistance R. Which of the following **cannot** be the power dissipated in the circuit (assuming negligible resistance for the wires)?

(A) $P=\frac{V^2}{(3R)}$ (B) $P=\frac{3V^2}{R}$ (C) $P=\frac{3V^2}{(2R)}$ (D) $P=\frac{2V^2}{(R)}$

7. Two batteries with e.m.f 12 V and 13 V are connected in parallel across a load resistor of 10 Ω. The internal resistances of the two batteries are 1 Ω and 2 Ω respectively. The voltage across the load lies between. **[JEE-Main 2018]**

(A) 11.5 V and 11.6 V (B) 11.4 V and 11.5 V

(C) 11.7 V and 11.8 V (D) 11.6 V and 11.7 V

Multiple Correct Answer Type 4 Q. [4 M (–1)]

8. Consider a wire in the shape of a circle carrying a current. Note that as the current progresses along the wire, the direction of current density vector changes in a particular manner, while the current remain unaffected. The agent that is essentially responsible for this is

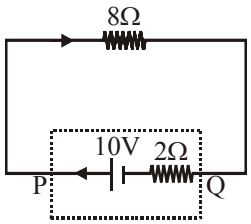
(A) Source of emf.

(B) electric field produced by charges accumulated on the surface of wire

(C) the charges just behind a given segment of wire which push them just the right way by repulsion

(D) the charges ahead

9. A battery of emf 10 volt and internal resistance 2Ω is connected to an external resistance 8Ω as shown in the figure :-



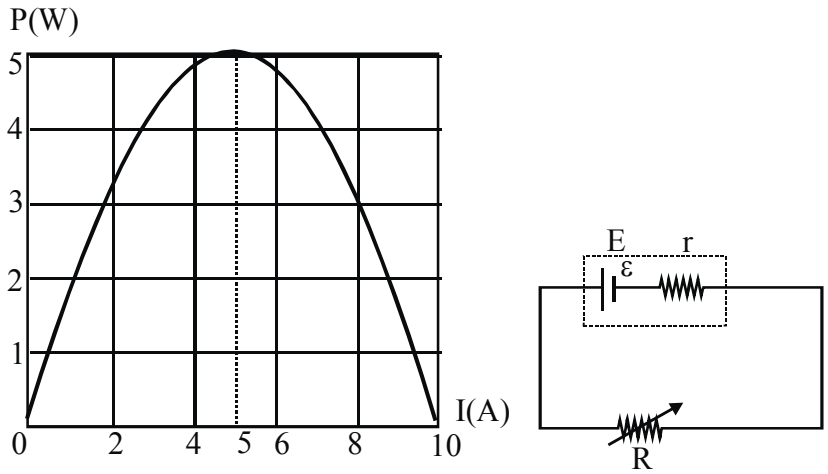
(A) Work done due to conservative electric field while a unit positive charge passes through battery from Q to P (along the arrow) is 8 Joule.

(B) Work done due to conservative electric field while a unit positive charge passes through battery from Q to P (along the arrow) is – 8 Joule.

(C) Work done due to conservative electric field while a unit positive charge passes through 8Ω along the arrow is –8 Joule.

(D) Work done due to non conservative electric field while a unit positive charge moves from Q to P (along the arrow) is 10 Joule.

10. Figure shows the net power dissipated in R versus the current in a simple circuit shown.



(A) The internal resistance of battery is 0.2Ω (B) The emf of battery is 2V

(C) R at which power is 5W is 2.5 Ω (D) At i = 2A, power is 3.2 W

11. Two identical moving coil galvanometer have 10 Ω resistance and full scale deflection at 2 μA current. One of them is converted into a voltmeter of 100 mV full scale reading and the other into an Ammeter of 1 mA full scale current using appropriate resistors. These are then used to measure the voltage and current in the Ohm's law experiment with R = 1000 Ω resistor by using an ideal cell. Which of the following statement(s) is/are **CORRECT** ? **[JEE Advanced-2019]**

(A) The measured value of R will be 978 Ω < R < 982 Ω.

(B) The resistance of the Voltmeter will be 100 kΩ.

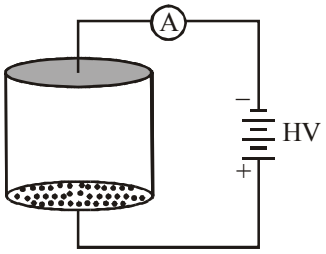
(C) The resistance of the Ammeter will be 0.02 Ω (round off to 2nd decimal place)

(D) If the ideal cell is replaced by a cell having internal resistance of 5 Ω then the measured value of R will be more than 1000 Ω.

Linked Comprehension Type (1 Para × 2Q.) [3 M (-1)]
(Single Correct Answer Type)

Paragraph for Questions No. 12 and 13

Consider an evacuated cylindrical chamber of height h having rigid conducting plates at the ends and an insulating curved surface as shown in the figure. A number of spherical balls made of a light weight and soft material and coated with a conducting material are placed on the bottom plate. The balls have a radius r <<h. Now a high voltage source (HV) is connected across the conducting plates such that the bottom plate is at $+V_0$ and the top plate at $-V_0$. Due to their conducting surface, the balls will get charged, will become equipotential with the plate and are repelled by it. The balls will eventually collide with the top plate, where the coefficient of restitution can be taken to be zero due to the soft nature of the material of the balls. The electric field in the chamber can be considered to be that of a parallel plate capacitor. Assume that there are no collision between the balls and the interaction between them is negligible. (Ignore gravity) **[JEE Advanced-2016]**



12. Which of the following statements is correct ?

(A) The balls will bounce back to the bottom plate carrying the opposite charge they went up with

(B) the balls will execute simple harmonic motion between the two plates

(C) The balls will bounce back to the bottom plate carrying the same charge they went up with

(D) The balls will stick to the top plate and remain there

13. The average current in the steady state registered by the ammeter in the circuit will be :

(A) Proportional to $V_0^{1/2}$ (B) Proportional to V_0^2

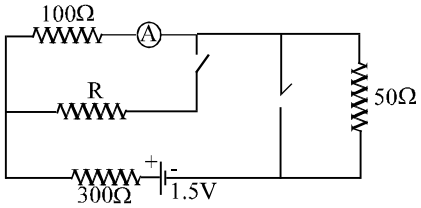
(C) Proportional to the potential V_0 (D) Zero

SECTION-II

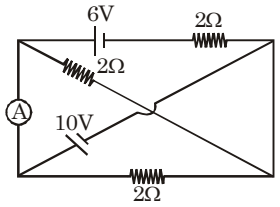
Numerical Answer Type Question **2 Q. [3(0)]**

(upto second decimal place)

1. In the circuit shown in figure the reading of ammeter is the same with both switches open as with both closed. Then find the resistance R. (ammeter is ideal)



2. An ideal ammeter is connected in a circuit as shown in circuit diagram. What will be the reading of ammeter (in S.I. units).



SECTION-III

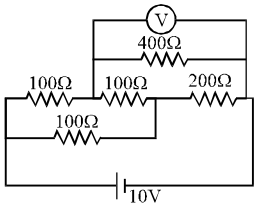
Numerical Grid Type (Ranging from 0 to 9) **1 Q. [4 M (0)]**

1. The coil of a heater has resistance of 5Ω and is powered from a source of internal resistance 20Ω. With what resistance (in Ω) should the coil be shunted to reduce the amount of power dissipated in it to one ninth of the value without shunt resistance ?

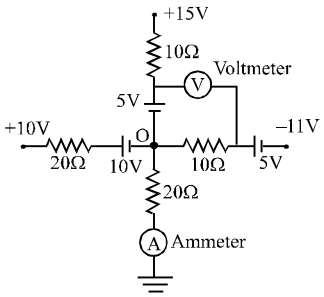
Subjective Type **9 Q. [4 M (0)]**

1. The total momentum of electrons in a straight wire of length ℓ carrying a current I is _ _ _ _ _ _ (mass of electron = m_e, charge of electron = e)

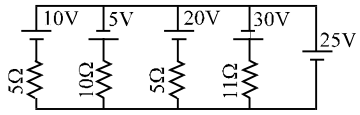
2. An electrical circuit is shown in the figure. Calculate the potential difference across the resistance of 400 ohm, as will be measured by the voltmeter V of resistance 400 ohm, either by applying Kirchhoff's rules or otherwise.



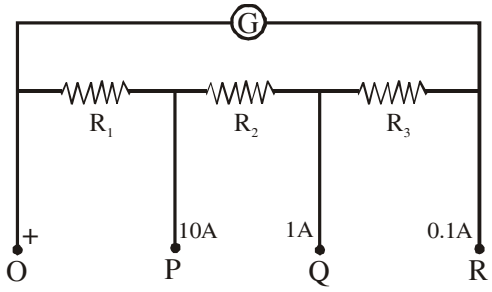
3. The potential of certain points in the circuit are maintained at the values indicated. The Voltmeter and Ammeter are ideal. Find the potential of the cross junction point in the circuit (at center O) and the readings of Voltmeter and Ammeter. All cells are ideal.



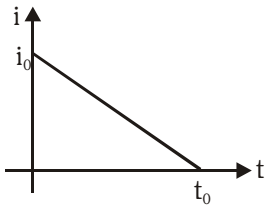
4. Find the current through 25V cell & power supplied by 20V cell in the figure shown.



5. The resistance of the galvanometer G in the circuit is 25Ω. The meter deflects full scale for a current of 10mA. The meter behaves as an ammeter of three different ranges. The range is 0–10A, if the terminals O and P are taken; range is 0–1 A between O and Q; range is 0–0.1 A between O and R. Calculate the resistance R_1, R_2 and R_3.



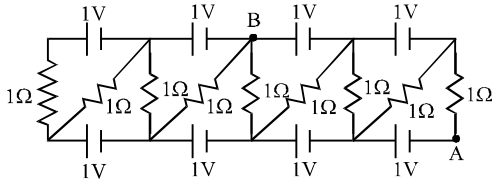
6. Relation between current in conductor and time is shown in figure then determine.
(i) Total charge flow through the conductor
(ii) Write expression of current in terms of time
(iii) If resistance of conductor is R then total heat dissipated across resistance R is



7. (a) The current density across a cylindrical conductor of radius R varies according to the equation $J = J_0\left(1-\frac{r}{R}\right)$, where r is the distance from the axis. Thus the current density is a maximum J_0 at the axis r = 0 and decreases linearly to zero at the surface r = R. Calculate the current in terms of J_0 and the conductor's cross sectional area is $A = \pi R^2$.

(b) Suppose that instead the current density is a maximum J_0 at the surface and decreases linearly to zero at the axis so that $J = J_0\frac{r}{R}$. Calculate the current.

8. Find the potential difference $V_A - V_B$ for the circuit shown in the figure.



9. A galvanometer (coil resistance 99Ω) is converted into a ammeter using a shunt of 1 Ω and connected as shown in the figure (i). The ammeter reads 3A. The same galvanometer is converted into a voltmeter by connected a resistance of 101Ω in series. This voltmeter is connected as shown in figure (ii). Its reading is found to be 4/5 of the full scale reading. Find

(i) internal resistance r of the cell

(ii) range of the ammeter and voltmeter

(iii) full scale deflection current of the galvanometer

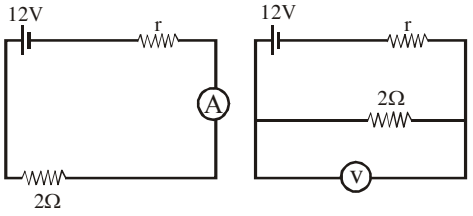


Fig. (i) Fig. (ii)

ANSWER KEY **GR # CURRENT ELECTRICITY**

SECTION-I

Single Correct Answer Type **7 Q. [3 M (–1)]**

1. Ans. (C) **2. Ans. (C)** **3. Ans. (A)** **4. Ans. (D)**

5. Ans. (C) **6. Ans. (D)** 7. Ans. (A)

Multiple Correct Answer Type **4 Q. [4 M (–1)]**

8. Ans. (B) **9. Ans. (B, D)** **10. Ans. (A, B,D)** **11. Ans. (A,C)**

Linked Comprehension Type **(1 Para × 2Q.) [3 M (-1)]**

(Single Correct Answer Type)

12. Ans. (A) **13. Ans. (B)**

SECTION-II

Numerical Answer Type Question **2 Q. [3(0)]**

(upto second decimal place)

1. Ans. 600Ω **2. Ans. 7.00**

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) **1 Q. [4 M (0)]**

1. Ans. 2

Subjective Type **9 Q. [4 M (0)]**

1. Ans. $p = I m_e l/e$ **2. Ans.** 20/3 V **3. Ans.** $x = \frac{4}{3}$ V, $12\frac{1}{3}$ V, $\frac{1}{15}$ A

4. Ans. 12A, –20W **5. Ans.** $R_1 = 0.0278\Omega$, $R_2 = 0.25\Omega$, $R_3 = 2.5\Omega$

6. Ans. (i) $\frac{1}{2}i_0t_0$ (ii) $i = i_0\left(1-\frac{t}{t_0}\right)$ (iii) $\frac{Rt_0i_0^2}{3}$ **7. Ans.** (a) $J_0A/3$; (b) $2J_0A/3$

8. Ans. $-\frac{22}{9}$ V **9. Ans.** (i) 1.01Ω (ii) 0-5 A, 0-10V, (ii) 0.05 A

SOLUTIONS
SECTION-I

Single Correct Answer Type **7 Q. [3 M (–1)]**

1. Ans. (C)

Sol. Apply Gauss's law : $\frac{q_{in}}{\varepsilon_0}$ = (outgoing flux - incoming flux)

$$V = IR = \frac{I\rho\ell}{A} \Rightarrow \frac{V}{\ell}A = I\rho \Rightarrow EA - I\rho$$

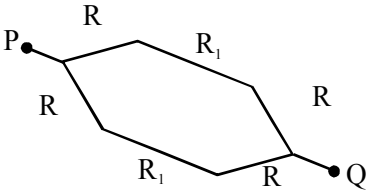
$$\Rightarrow \frac{q_{in}}{\varepsilon_0} = I\left|\rho_1 - \rho_2\right| \Rightarrow q_{in} = I\varepsilon_0\left|\rho_1 - \rho_2\right|$$

2. Ans. (C)

3. Ans. (A)

Sol. $R = \frac{\rho\ell/2}{A}$

$$R_1 = \frac{2R}{1+\sqrt{2}}$$



$$R_{eq} = R + \frac{R_1}{2} = R\frac{\left(2+\sqrt{2}\right)}{1+\sqrt{2}}$$

$$= R\sqrt{2} = \frac{\rho\ell}{\sqrt{2}A}$$

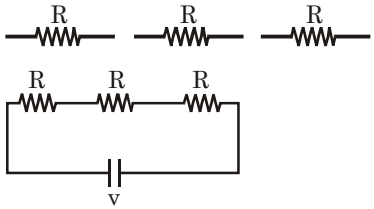
4. Ans. (D)

Sol. $5 = R + 2 \Rightarrow R = 3\Omega$

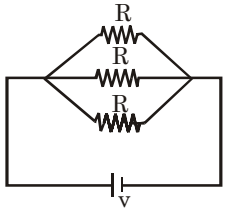
5. Ans. (C)

6. Ans. (D)

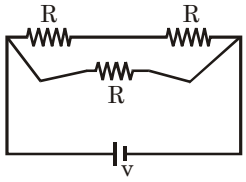
Sol.



Power dissipated in circuit = $\frac{v^2}{3R}$



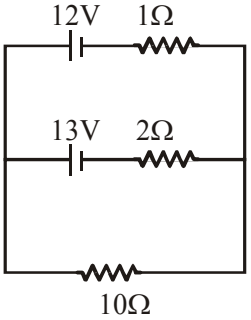
Power dissipated in circuit = $\frac{v^2}{R/3}$



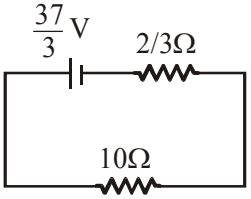
Power dissipated in circuit = $\frac{v^2}{2R/3}$

7. Ans. (A)

Sol. $\frac{\frac{12}{1}+\frac{13}{2}}{\frac{1}{1}+\frac{1}{2}}=\frac{37}{3}$ volt



$r_{eq}=\frac{2\times1}{2+1}=\frac{2}{3}\Omega$



Now its equivalent circuit is :

$i=\frac{37/3}{10+\frac{2}{3}}=\frac{37}{32}$

$\therefore\ V_{10\Omega}=i\times10=\frac{37}{32}\times10=\frac{370}{32}=11.56$ volt

Hence (1)

Multiple Correct Answer Type 4 Q. [4 M (–1)]

8. Ans. (B)

9. Ans. (B, D)

Sol. $i=\frac{10}{2+8}=1A$

$\int\left(\vec{E}_C+\vec{E}_{N.C}\right).\overrightarrow{d\ell}=iR$

Across 8Ω $E_{N.C}=0$

$\int\vec{E}_C.\overrightarrow{d\ell}=8\ J/C$

(1) $\int\vec{E}_C.\overrightarrow{d\ell}=8\ J$

Since $\int_{loop} E_C \cdot d\ell = 0$

So work done by conservative electric field while an unit charge goes from Q to P is –8 joule.
Now across the battery, we have

(1) $\int \left(\vec{E}_{N.C}\right).\overrightarrow{d\ell} = \varepsilon = 10\,\text{joule}$

$\therefore$ (B), (D)

10. Ans. (A, B,D)

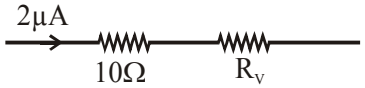
Sol. Power is maximum when r = R

$\Rightarrow P_{max} = I^2 \times (r)$ $\quad P_{max} = 5W$

$\Rightarrow r = \frac{1}{5} = 0.2\ \Omega$

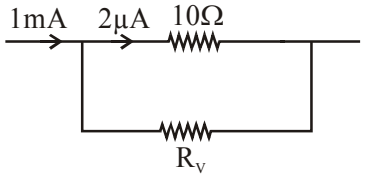
11. Ans. (A,C)

Sol.

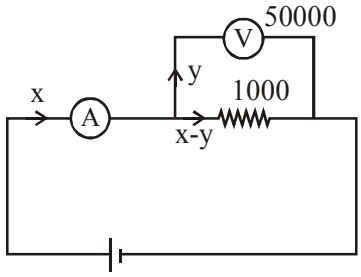


$0.1 = 2 \times 10^{-6}\,(10 + R_V)$

$\therefore R_V = 49990\ \Omega$



$2 \times 10^{-6} \times 10 = 10^{-3}\, R_A \ \therefore R_A = 0.02\ \Omega$



$y\ 50000 = (x - y)\ 1000$

$\therefore 51y = x$

$\text{Reading} = \frac{y\,50000}{x} \simeq 980$

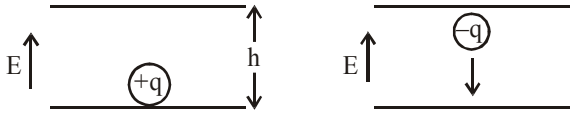
Linked Comprehension Type (1 Para × 2Q.) [3 M (-1)]
(Single Correct Answer Type)

12. Ans. (A)

Sol. Balls placed on +ve plate become positive charge and move upward due to electric field.
These balls on colliding with negative plate become negatively charged and move opposite to the direction of electric field.

13. Ans. (B)

Sol.



$$h = \frac{1}{2}at^2 \qquad [\text{as } u = 0]$$

$$\sqrt{\frac{2hm}{qE}} = \text{time} \Rightarrow \text{time} = \sqrt{\frac{2m}{q\Delta V}}$$

$$E = \frac{V_0}{h}$$

$$<\text{current}> = \frac{\text{charge}}{\text{time}} = \frac{q\sqrt{qV_0}}{\sqrt{2mh^2}}$$

$$q \propto V_0$$

$$< I > \propto V_0^{\,2}$$

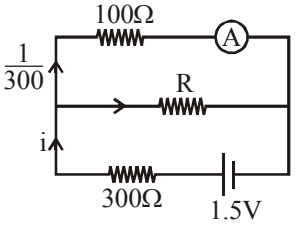
SECTION-II

Numerical Answer Type Question **2 Q. [3(0)]**

(upto second decimal place)

1. **Ans.** 600Ω

Sol. $i_1 = \frac{1.5}{450} = \frac{10}{3} \times 10^{-3} = \frac{1}{300}\text{A}$



$$+1.5 - 300i - 100 \times \frac{1}{300} = 0$$

$$R\left(i - \frac{1}{300}\right) = 100 \times \frac{1}{300}$$

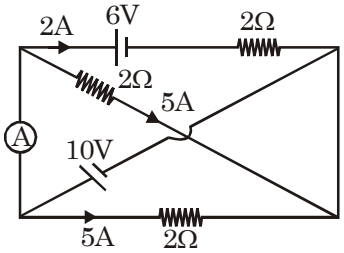
$$i = \frac{716}{300}$$

$$R\left(\frac{7}{6} - 1\right) = 100$$

$R = 600\ \Omega$

2. **Ans. 7.00**

Sol. From diagram



Current through ammeter

= (2 + 5) = 7A

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) **1 Q. [4 M (0)]**

1. Ans. 2

Sol. $P_i = \left(\frac{V}{5+20}\right)^2 \times 5$

$$P_f = \left[\left(\frac{\frac{V}{5R}}{5+R} + 20\right) \times \frac{5R}{5+R}\right]^2 \frac{1}{5}$$

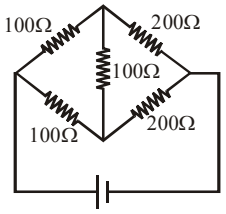
$$\Rightarrow P_f = \frac{P_i}{9}$$

Subjective Type **9 Q. [4 M (0)]**

1. Ans. $p = I m_e l/e$

2. Ans. 20/3 V

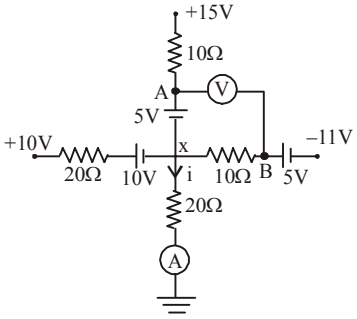
Sol.



Wheat stone bridge

3. Ans. $x = \frac{4}{3}V,\ 12\frac{1}{3}V,\ \frac{1}{15}A$

Sol. $\frac{x+10-10}{20} + \frac{x+5-15}{10} + \frac{x-(-6)}{10} + \frac{x-0}{20} = 0$



$$\frac{3x}{10} = 1 - \frac{6}{10}$$

$$x = \frac{4}{3}V$$

$$V_A = x + 5 = \frac{4}{3} + 5 = \frac{19}{3}V$$

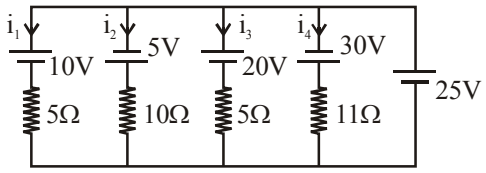
$$V_B = -11 + 5 = -6$$

$$V_A - V_B = \frac{19}{3} + 6 = \frac{37}{3} = 12\frac{1}{3}V$$

$$i = \frac{x-0}{20} = \frac{4}{3\times 20} = \frac{1}{15}A$$

4. **Ans.** 12A, –20W

Sol.



$i_1 = \frac{15}{5} = 3A$ $\quad i_2 = \frac{30}{10} = 3A$ $\quad i_3 = \frac{5}{5} = 1A$

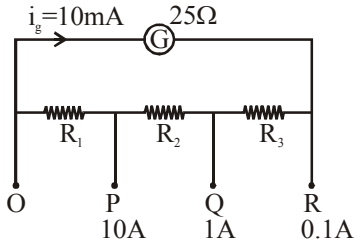
$i_4 = \frac{55}{11} = 5A$

$i_{25} = i_1 + i_2 + i_3 + i_4 = 12\ A$

$P_{20} = -20i_3 = -20 \times 1 = -20W$

5. **Ans.** $R_1 = 0.0278\Omega$, $R_2 = 0.25\Omega$, $R_3 = 2.5\Omega$

Sol.



For O–r $(0.1 - i_g)(R_1 + R_2 + R_3) = i_g \times 25$

for O-Q $(1 - i_g)(R_1 + R_2) = i_g (25 + R_3)$

for O-P $(10 - i_g) R_1 = i_g (25 + R_2 + R_3)$

6. **Ans.** (i) $\frac{1}{2} i_0 t_0$ (ii) $i = i_0\left(1 - \frac{t}{t_0}\right)$ (iii) $\frac{Rt_0 i_0^2}{3}$

Sol. (i) Total charge = Area under the i-t graph.

$= \frac{1}{2} i_0 t_0$

(ii) $\frac{i}{i_0} + \frac{t}{t_0} = 1 \Rightarrow i = i_0\left(1 - \frac{t}{t_0}\right)$

(iii) $H = \int i^2 R\, dt$

$= \int_0^{t_0} i_0^2\left(1 - \frac{t}{t_0}\right)^2 \cdot R dt$

7. **Ans.** (a) $J_0 A/3$; (b) $2J_0 A/3$

Sol. (a) $I = \int J_0\left(1 - \frac{r}{R}\right) \cdot 2\pi r dr$

$= J_0 \cdot 2\pi \cdot \left[\int_0^R r dr - \int_0^R \frac{r^2}{R} \cdot dr\right]$

$$= J_0 \cdot 2\pi \cdot \left[\frac{R^2}{2} - \frac{1}{R} \cdot \frac{R^3}{3} \right]$$

$$= J_0 \cdot 2\pi \left[\frac{R^2}{2} - \frac{R^2}{3} \right] = J_0 \cdot 2\pi \cdot \frac{R^2}{6}$$

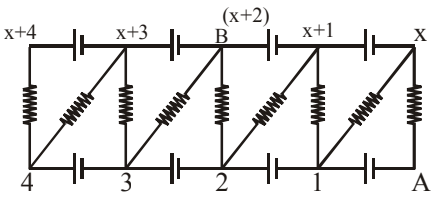
8. **Ans.** $-\frac{22}{9}V$

Sol. $\frac{x+4-4}{1} + \frac{(x+3-4)}{1} + \frac{x}{1} + \frac{(x+2-3)}{1} + \frac{x}{1} + \frac{x+1-2}{1} + \frac{x}{1} + \frac{x-1}{1} + \frac{x}{1} = 0$

$5x + 4(x - 1) = 0$

$9x - 4 = 0$

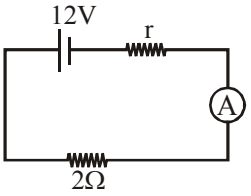
$x = \frac{4}{9}V$



$V_A - V_B = -(x + 2 - 0) = -\frac{22}{9}V$

9. **Ans.** (i) 1.01Ω (ii) 0-5 A, 0-10V, (ii) 0.05 A

Sol. (i) $r_A = \frac{1 \times 99}{100} = 0.99A$

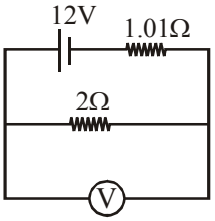


$$3 = \frac{12}{r + 2 + 0.99}$$

$\Rightarrow r + 2.99 = 4$

$r = 1.01\ \Omega$

(ii) $r_v = 99 + 101 = 200\ W$



$$i = \frac{12}{1.01 + \frac{2 \times 200}{200}} = 4A$$

$V = 8V$

Range of voltmeter = $\frac{5}{4} \times 8 = 10V$

Range of ammeter = 5A

(ii) $1(5 - i_g) = 99\, i_g$

$5 = 100\, i_g$

$i_g = 0.05\ A$