Current Electricity and Capacitance

SOLUTIONS

EXERCISE - O

1. **Ans. (D)**

$$i_+ = n(2e)\frac{Av}{4} = \frac{neAv}{2}$$

$i_- = n(e)\ Av = neAv$

$i_{net} = i_+ + i_-$

2. **Ans. (C)**

$$V_d = \frac{I}{neA}$$

$$V_d \propto \frac{I}{A}$$

3. **Ans. (C)**

Apply Gauss's law : $\frac{q_{in}}{\varepsilon_0}$ = (Outgoing flux – Incoming flux)

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

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

4. **Ans. (D)**

$$R = \frac{R_1R_2}{R_1+R_2}$$

$$= \frac{R(1+\alpha_1\Delta T)(1+\alpha_2\Delta T)}{2+(\alpha_1+\alpha_2)\Delta T}$$

$$= \frac{R\left[1+(\alpha_1+\alpha_2)\Delta T+\alpha_1\alpha_2(\Delta T)^2\right]}{2+(\alpha_1+\alpha_2)\Delta T}$$

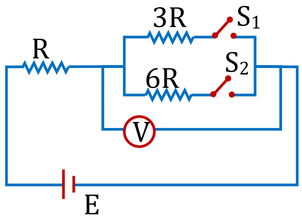
$$\simeq \frac{R}{2}\left[2 - \frac{1}{\left(1+\left(\frac{\alpha_1+\alpha_2}{2}\right)\Delta T\right)}\right]$$

$$= \frac{R}{2}\left[2 - \left(1 + \left(\frac{\alpha_1+\alpha_2}{2}\right)\Delta T\right)^{-1}\right]$$

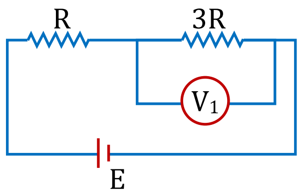
$$= \frac{R}{2}\left(1 + \frac{\alpha_1+\alpha_2}{2}\Delta T\right)$$

$$\Rightarrow \alpha_{eq} = \frac{\alpha_1+\alpha_2}{2}$$

5. **Ans. (A)**



S_1 closed

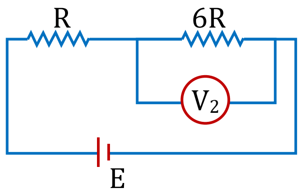


$V_1 = (3R)\,i$

$$i = \frac{E}{4R}$$

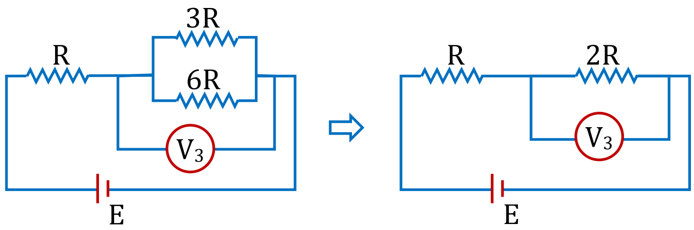
$$V_1 = \frac{3E}{4}$$

S_2 closed



$$i = \frac{E}{7R}$$

$$V_2 = (6R)\left(\frac{E}{7R}\right) = \frac{6}{7}E$$

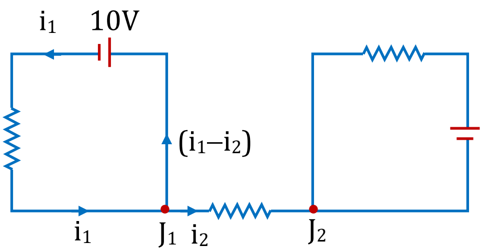


S_1 and S_2 closed

$$V_3 = \left(\frac{E}{3R}\right)2R = \frac{2E}{3}$$

So, $V_2 > V_1 > V_3$

6. **Ans. (B)**



No current can go through 2Ω resistor because according to junction law, the incoming current should be equal to outgoing current.

At junction J_1

Current going to battery = $(i_1 - i_2)$

Current coming out of battery = i_1

$$i_1 = (i_1 - i_2)$$

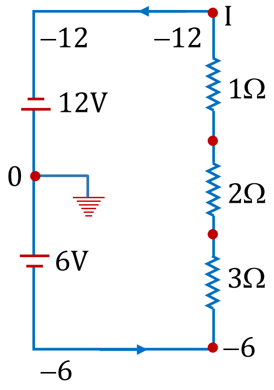
Hence, $i_2 = 0$

7. Ans. (A)

$\varepsilon = 10$

$$r = \frac{\varepsilon}{i} = \frac{10}{2} = 5\Omega$$

8. Ans. (C)



Current $I = \dfrac{12-6}{6} = 1A$

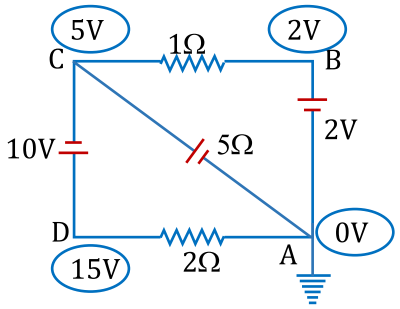
Also assign 0 volt at point which earthed

So, $V_A = -12$, $V_D = -6V$

$V_c = -9V$, $V_B = -11V$

9. Ans. (A)

Distributing potentials as shown in figure

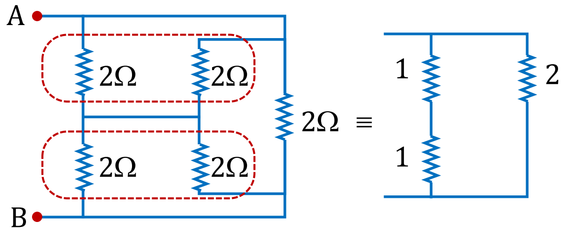


As all potentials are known currents in resistances can be given as

$$I_{1\Omega} = \frac{5-2}{1} = 3A \quad \text{(left to right)}$$

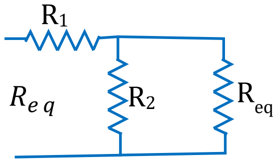
and $I_{2\Omega} = \dfrac{15-0}{2} = 7.5A$ (left to right)

10. Ans. (A)



$R_{eq} = 1$

11. Ans. (B)

$\Rightarrow R_{eq}$ 

$$\Rightarrow \quad R_{eq} = \frac{R_2.R_{eq}}{R_2 + R_{eq}} + R_1$$

and $R_1 = \frac{R_2.R_{eq}}{R_2 + R_{eq}}$ (as applied value of voltage is halved after each section)

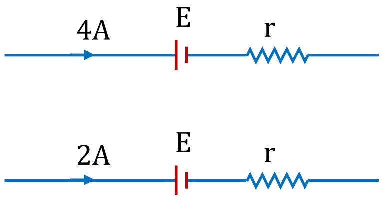
$R_{eq} = 2R_1$

$$= \frac{R_2.R_{eq}}{R_2 + R_{eq}} + R_1 = 2R_1$$

$$= \frac{R_2.2R_1}{R_2 + 2R_1} + R_1 = 2R_1$$

$$\Rightarrow \quad \frac{R_1}{R_2} = 1/2$$

12. Ans. (C)



$E + 4r = 12$

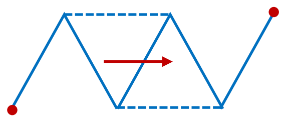
$E - 2r = 9$

$\Rightarrow \quad E = 10\ V$ and $r = 0.5\Omega$

13. Ans. (A)

Initial resistance $R_1 = 5\Omega$

For final resistance we have condition of balanced Wheatstone bridge



Final resistance $R_2 = 1 + \frac{2}{2} + 1 = 3$

$\Delta R = R_1 - R_2 = 2\Omega$

14. Ans. (A)

(a) $R_{eq} = \left(\frac{1}{16} + \frac{1}{8} + \frac{1}{16}\right)^{-1} + 1 = 5\Omega$

(b) $I = \frac{60}{4+1} = 12\ A$

Hence 12 A will flow through the cell.

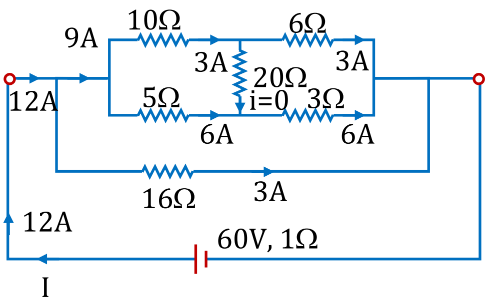
By using current distribution law.

Current in resistance 10Ω and $6\Omega = 3A$

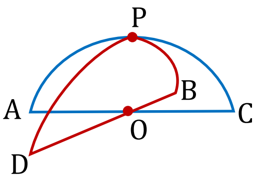
Current in resistance 5Ω and $3\Omega = 6A$

Current in resistance $20\Omega = 0$

Current in resistance $16\Omega = 3A$



15. Ans. (D)

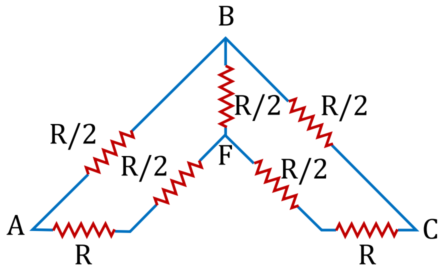


$$R_{eff} = \frac{1}{4}\left[\frac{\pi a}{2} r + ar\right]$$

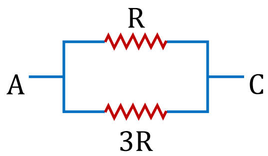
$$= \frac{1}{4} ar\left[\frac{\pi + 2}{2}\right] = \left[\frac{\pi + 2}{8}\right] ar$$

16. Ans. (B)

By folding symmetry along $A - C$ we have



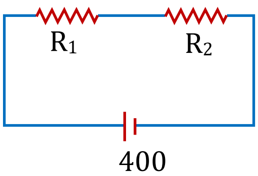
Now by condition of balanced wheat stone Bridge eliminate $R/2$ between B and F



$$R_{eq} = \frac{3R}{4}$$

17. Ans. (A)

$$R_1 = \frac{220^2}{25},\ R_2 = \frac{220^2}{100}$$

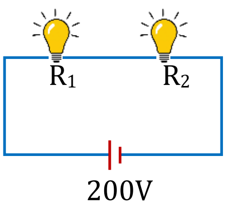


$$P_1 = \left(\frac{400}{R_1 + R_2}\right)^2 \times R_1$$

$$P_2 = \left(\frac{400}{R_1 + R_2}\right)^2 \times R_2$$

18. Ans. (A)

$$R_1 = \frac{200^2}{60}$$



$$R_2 = \frac{200^2}{100}$$

$$P = \frac{200^2}{(R_1 + R_2)} = \frac{200^2}{\frac{200^2}{60} + \frac{200^2}{100}} = \frac{100 \times 60}{160}$$

19. Ans. (B)

$$P_1 = \frac{V^2 A}{\rho \ell}$$

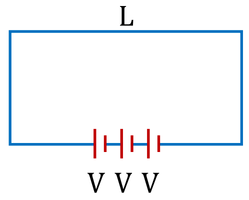
$$P_2 = \frac{V^2 A}{\rho(0.9\ell)} = \frac{(1.1)V^2 A}{\rho \ell}$$

20. Ans. (B)

$$\frac{(3v)^2}{r} t = ms\Delta T \qquad ...(1)$$

$$\frac{(Nv)^2}{2R} t = 2ms\Delta T \qquad ...(2)$$

$$\frac{(1)}{(2)} \Rightarrow N = \sqrt{36} = 6$$



21. Ans. (B)

$$\frac{X}{\ell_1} = \frac{R}{100-\ell_1} \Rightarrow \frac{12}{\ell_1} = \frac{18}{100-\ell_1}$$

22. Ans. (C)

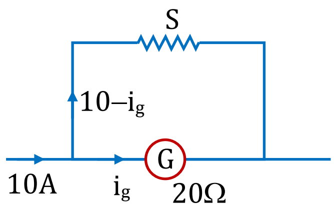
Theoretical

23. Ans. (B)

$S(10 - i_g) = i_g \times 20$

$$S = \frac{\frac{0.2}{20}\times 20}{10 - \frac{0.2}{200}}$$

$$= \frac{0.2}{10-0.01} \simeq 0.02\Omega$$



24. Ans. (C)

F.S.D. of voltmeter = (10×10^{-3}) $(90 + 910) = 10\ V$

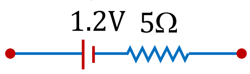
No. of divisions = $\frac{10}{0.1} = 100$

25. Ans. (D)

Opposite direction terminals.

26. Ans. (A)

Initially



$$\varepsilon = \frac{V}{\ell} \times 900 = 1.2V$$

Finally

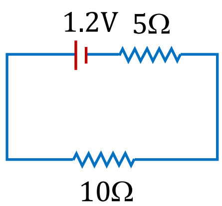
$$1.2 - \frac{1.2}{15} \times 5 = \frac{V}{\ell} \times x$$

$$0.8 = \frac{V}{\ell} \times x$$

$$0.8 = \frac{1.2}{900} x$$

$x = 600\ cm$

$$p.d = 1.2 - \frac{1.2}{15} \times 5 = 0.8V$$



27. Ans. (D)

$C = \frac{A\varepsilon_0}{d}$

28. Ans. (C)

Charge will remain same.

$d \to 2d$

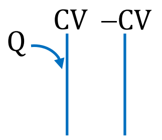
$c \to c' = \frac{A\varepsilon_0}{2d}$

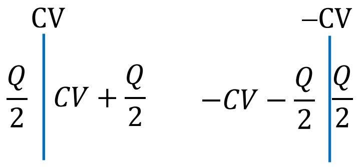
$c' = \frac{c}{2}$

$U' = \frac{1}{2}\frac{Q^2}{C}$

$U' = 2U$

29. Ans. (C)





$V + \frac{Q}{2C}$

30. Ans. (C)

$C_2 = 2C_1$

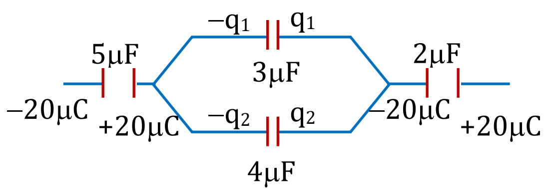
$Q_2 = 2Q_1$

$E_1 = \frac{V}{d}$ $\quad$ $E_2 = \frac{V}{d/2} = 2\left(\frac{v}{d}\right)$

$F_1 = E_1 Q_1$ $\quad$ $F_2 = E_2 Q_2$

$\Rightarrow \quad F_2 = 4F_1$

31. Ans. (A)



$q_1 : q_2 = 3 : 4$

$q_1 = \frac{3}{7} \times 20\mu C$

32. Ans. (D)

$\frac{1}{C_{eq}} = \frac{1}{\frac{\varepsilon_0 A}{2d}} + \frac{1}{\frac{\varepsilon_0 A}{4d}} + \frac{1}{\frac{\varepsilon_0 A}{8d}} + \frac{1}{\frac{\varepsilon_0 A}{16d}}, \; C_{eq} = \frac{\varepsilon_0 A}{30d}$

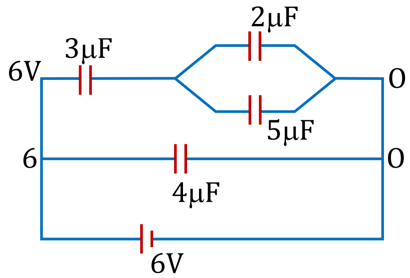
33. Ans. (C)

For charge in 5 μF capacitor

$C_1 : C_2 = 2 : 5$

$$\frac{q_1}{q_2} = \frac{C_1}{C_2}$$

$$q_2 = \frac{63}{5} \times \frac{5}{7}$$

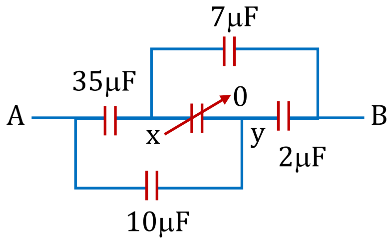


Charge on 5 μF capacitor is 9 μC

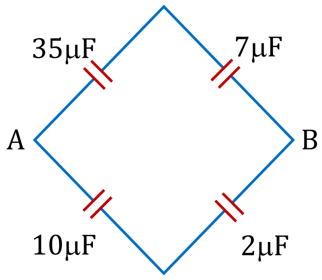
Charge on 4 μF capacitor is 24 μC

Ratio of charges = 9 : 24 = 3 : 8

34. Ans. (B)



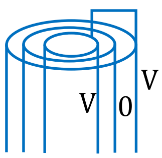
As the resulting circuit is a Wheat stone bridge hence current in 13μF capacitor is zero. Hence the circuit now reduces to



The resultant capacitance is

$$\frac{35}{6} + \frac{10}{6} = \frac{45}{6} = \frac{15}{2}\ \mu F$$

35. Ans. (B)

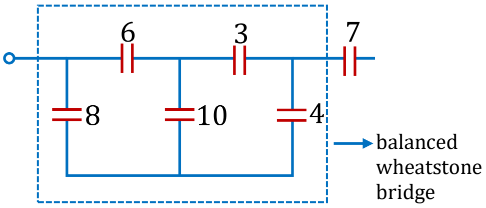


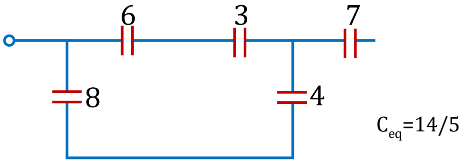
Parallel

$$C = \frac{2\pi\epsilon_0}{\ell n b/a} = \frac{2\pi\epsilon_0}{\ell n\, 2R/R} + \frac{2\pi\epsilon_0}{\ell n \dfrac{2\sqrt{2}}{2R} R}$$

$$= \frac{2\pi\epsilon_0}{\ell n 2}[1+2] = \frac{6\pi\epsilon_0}{\ell n 2}$$

36. **Ans. (A)**





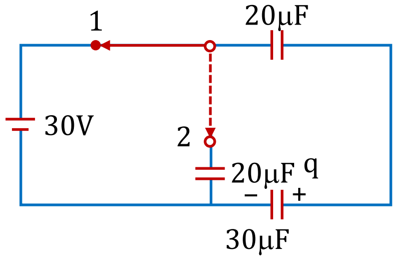
37. **Ans. (A)**

When switch is in position 1,

$$30-\frac{q}{20}-\frac{q}{30}=0\Rightarrow q=360\ \mu C$$

Now, the switch is in position 2,

$$q_1'+q_3=360$$



Loops *ABCD*

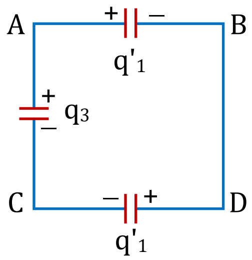
$$-\frac{q_1'}{20}-\frac{q_1'}{30}+\frac{q_3}{20}=0$$

$$-3q_1'-2q'_1+3q_3=0$$

$$5q_1'=3q_3\Rightarrow q_1'=\frac{3}{5}q_3$$

$$\frac{8q_3}{5}=360$$

$$q_3=\frac{360\times 5}{8}=\frac{450}{2}\mu C=225\ \mu C$$



38. **Ans. (B)**

Let q charge flow through the circuit then

Using Kirchoff's law

$$19-\frac{q}{2}-9-\frac{q}{3}+15=0$$

$$25-\frac{5q}{6}=0\Rightarrow q=30\mu C$$

P.D. Across 3μ*F* is $V=\frac{30\mu C}{3\mu F}=10\ V$

39. **Ans. (D)**

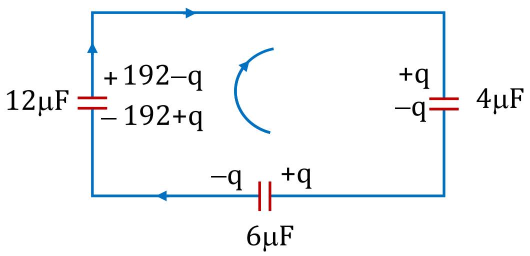
It we close any switch there will be no change in any potential.

40. **Ans. (C)**

$$q_i=192\ \mu C$$

$$\frac{192-q}{12}-\frac{q}{4}-\frac{q}{6}=0$$

$$q=32\mu C$$



41. Ans. (B)

There four capacitors are in parallel and change on each capacitor is $q = CV$.

Change on plate $C = +2\,CV$

$= 2 \times 2 \times 10 = +40\ \mu C$

42. Ans. (B)

$q_i = cv \qquad\qquad q_f = 2cv$

$\Delta q = q_f - q_i = q_f - (-q_i) = 3cv$

$U_i = \frac{1}{2}CV^2$

$U_f = \frac{1}{2} \times \frac{(2CV)^2}{C}$

$W_{\text{battery}} = \Delta H + \Delta U$

$(3CV) \times 2V = 2CV^2 - \frac{CV^2}{2} + H$

Ratio = $\frac{H}{U_f} = 2.25$

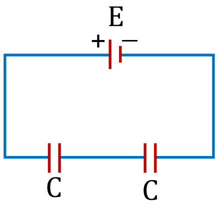
43. Ans. (C)

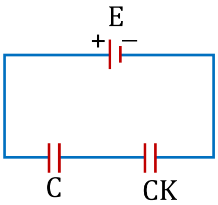
In case-i potential difference remains constant and $U = \frac{1}{2}CV^2$

In case-ii charge remains constant and $U = \frac{Q^2}{2C}$

44. Ans. (D)

Initially | **Finally**





$C_{eq}^{n} = \frac{C}{2}$ | $C_{eq}^{n} = \frac{CK}{K+1}$

$q_i = \frac{CE}{2}$ | $q_f = \frac{CEK}{K+1}$

$q_f - q_i = q_{flown}$ $= \frac{CEK}{K+1} - \frac{CE}{2}$

$= \frac{CE(K-1)}{2(K+1)}$

$\frac{CE}{2} < \frac{CEK}{K+1}$

So charge flows from C to B.

45. Ans. (B)

Charge on 15 μF capacitor $A = 1500\ \mu C$.

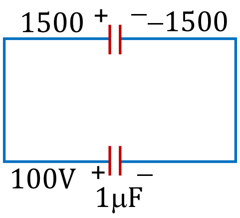
Charge on capacitor $B = 100\ \mu C$.

When they are connected with dielectric removed from A.

Capacitance of A now becomes 1 μF.

$C_{iA} = \frac{\varepsilon_0 A.15}{d} = 15\ C = 15\ \mu F$

$C_{fA} = \frac{\varepsilon_0 A}{d}\ C = 1\mu F$



Q remains constant

$Q_{\text{net}} = C_{\text{eq}} \times V_{\text{common}}$

$1500 + 100 = (1 + 1)V$

$V = 800$ Volt

46. Ans. (B)

Given that $C = \frac{\epsilon_0 A}{d} = 10\ \mu F$

For new arrangement

$C_1 = \frac{K_1 \epsilon_0 (A/2)}{d} = 10\ \mu F$

and $C_2 = \frac{K_2 \epsilon_0 (A/2)}{d} = 20\ \mu F$

C_1 and C_2 are in parallel

$C_{new} = C_1 + C_2 = 30\ \mu F$

47. Ans. (A)

$E = \frac{\sigma}{K\varepsilon_0}$

48. Ans. (A)

As capacity of system increases so the charge supplied by the battery increases.

49. Ans. (D)

$$\frac{V_1}{V_2} = \frac{C_2}{C_1} = \frac{K_2 \frac{A\varepsilon_0}{2d}}{K_1 \frac{A\varepsilon_0}{d}} = \frac{3}{2}$$

50. Ans. (B)

$E_1 = \frac{1}{2} c_1 v^2$

$E_2 = \frac{1}{2} c_2 v^2$

$C_1 = \frac{\varepsilon_0 KA}{d}$

$C_2 = \frac{\varepsilon_0 2KA}{d}$

$E_1 = \frac{1}{2} \frac{\varepsilon_0 KA}{d} v^2$

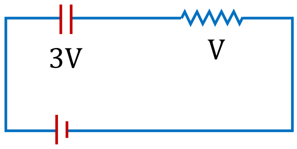
$E_2 = \frac{2}{2} \frac{\varepsilon_0 KA}{d} v^2$

$E_1 = \frac{1}{2} E_2$

51. Ans. (C)

Electric field at P and $P' = \dfrac{V}{D}$

52. Ans. (B)



$4V = 12 \Rightarrow V = 3$ volt

and $3V = 9$ volt

$q = 36\mu C$

$\because \quad q = CV\,(1 - e^{-t/RC})$

$36\ \mu C = 4\mu f \times 12\ (1 - e^{-t/\tau})$

$\tau = 4 \times 2.5 = 10$

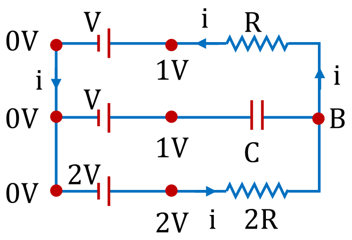
$= (1 - e^{-t/10})$

$e^{-t/10} = 0.25$

$\Rightarrow \quad t = R \times C \times 2\,ln\,2 = 2.5 \times 10^6 \times 4 \times 2 \times 0 \times 0.693$

$t = 13.86$ sec.

53. Ans. (C)



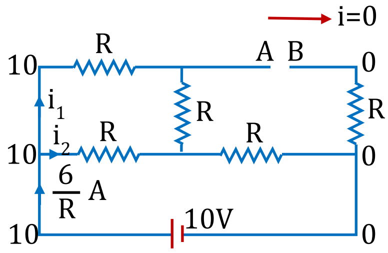
$i = \dfrac{V}{3R}$

$V_B = 2V - \dfrac{V}{3R} \times 2R = \dfrac{4V}{3}$

Potential difference across capacitor $\dfrac{4V}{3} - V = \dfrac{V}{3}$

54. Ans. (D)

In steady state capacitor behaves as open circuit



$\dfrac{i_1}{i_2} = \dfrac{R}{2R} = \dfrac{1}{2}$

$i_1 = \dfrac{6}{R \times 3} \times 1 = \dfrac{2}{R}$

$V_A = I_1R + iR = V_B$

$V_A - V_B = 8V$

55. Ans. (A)

$i = i_0 e^{-t/RC}$

$\dfrac{i_0}{2} = i_0 e^{-t/RC}$

$i_2 = i - i_1 = \dfrac{V}{2R} - \dfrac{V}{6R} e^{-2t/3RC}$

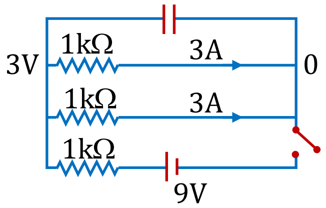
$\dfrac{1}{2} = e^{\frac{-\ell n 2}{(2+r)0.5}}$

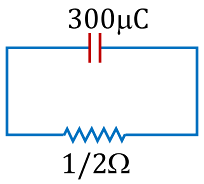
$\dfrac{1}{2} = e^{\frac{-2\ell n 2}{(2+r)}} \Rightarrow 1 = \dfrac{2}{2+r} \Rightarrow (r = 0)$

56. Ans. (D)

To calculate charge on capacitor consider that capacitor acts as open circuit when completely charged and calculate drop across it which comes out to be 3*V*.

When *s* is opened i.e. discharging circuit





$$\tau = R_{eq}C$$

$$= \frac{1}{2} \times 100 \times 10^{-6} \times 10^{3} = 50 \times 10^{-3} = 50\ ms.$$

57. Ans. (B)

$V_R = \varepsilon.e^{-t/RC}$

$V_C = \varepsilon[1 - e^{-t/RC}]$

At $t = 100\ ms$

$V_R = V_C$

$\Rightarrow \varepsilon^{-t/RC} = 1/2$

$$RC = \frac{100}{\ell n(2)} \approx 145.45\, ms$$

58. Ans. (C)

When *S* open

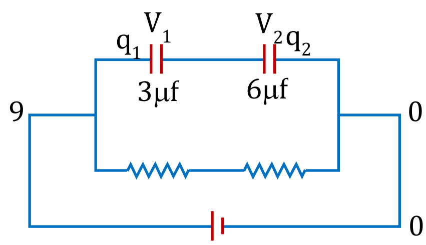
$q_1 = 18\mu f \Rightarrow q_2 = 18\mu f$

$V_1 : V_2 = \frac{1}{3} : \frac{1}{6}$

$V_1 : V_2 = 2 : 1$

$V_1 = \frac{2}{3} \times 9 = 6$ volt

$V_2 = 3$ volt



When S is closed

$I = 1\ A$

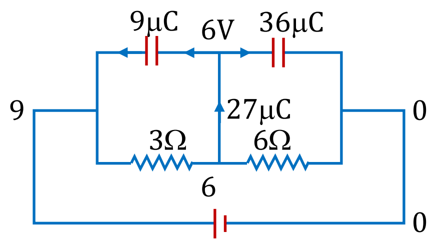
So, potential difference across $3\mu F = 3\times1 = 3V$.

Potential difference across $6\ \mu F = 6V$.

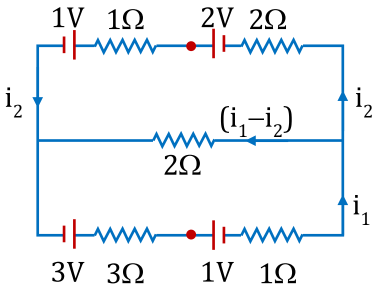
So, charge on $3\mu F = 9\mu C$.

Charge on $6\mu C = 36\mu C$

So, $27\mu C$ will flow through switch.



59. Ans. (ACD)



$+3 - 3i_1 - 1 - 1i_1 - 2\,(i_1 - i_2) = 0$

$+2 - 1i_2 - 1 + 2\,(i_1 - i_2) - 2i_2 = 0$

60. Ans. (ABCD)

$i_P = i_Q \quad ; \quad J_P < J_Q \Rightarrow E_P < E_Q$

$R_P < R_Q \quad ; \quad i^2R_P < i^2R_Q \Rightarrow H_P < H_Q$

$n_P = n_Q$: For metal n is independent of temperature

61. Ans. (BC)

Micrometer $\rightarrow R = 100\ \Omega$

$i = 50\ \mu A$

$V = 100 \times 50 \times 10^{-6} = 5\ mV$

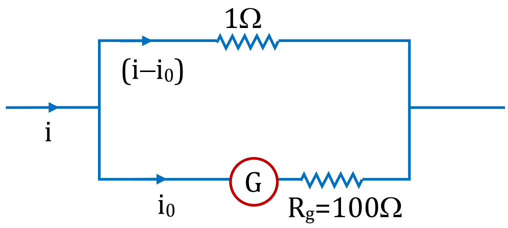
If $\quad R = 10\ k\Omega$

$\quad V = 10 \times 10^3 \times 50 \times 10^{-6} = 0.5\ V$

If $\quad R = 200\ k\Omega$

$\quad V = 200 \times 10^3 \times 50 \times 10^{-6} = 10\ V$

Applying KVL in the circuit



$\quad (i - i_0) \times 1 = i_0 \times 100$

$\quad i_0 = 50\ \mu A$

$\quad i = 101 \times i_0$

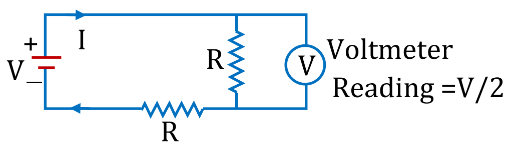
$\quad i = 50 \times 10^{-6} \times 101$

$\quad i = 5mA$

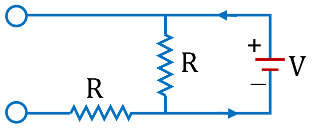
62. Ans. (AD)

(A) Case (1)

Battery is connected at terminal (I)

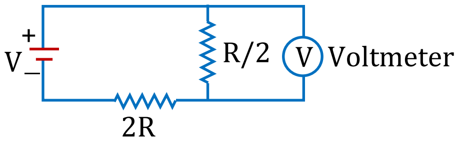


Case:-(2) Battery is connected at terminal (II)



Voltmeter Reading = (V)

All current flow through the resistance (R)



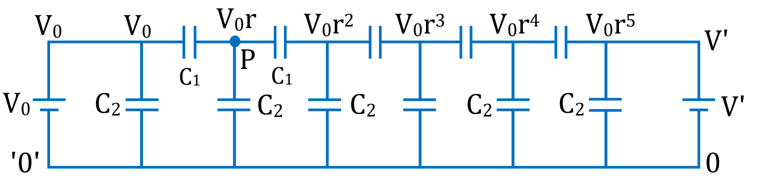
(B)

Reading $\neq V/2$

(C) Reverse case of (A)

(D) Same as (A)

63. Ans. (AB)



Apply nodal at P

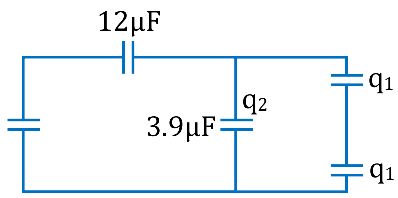
$\Rightarrow \quad C_1(v_0r - v_0r^2) + C_1(v_0r - v_0) + C_2v_0r = 0$

$\Rightarrow \quad 3r^2 - 10r + 3 = 0$

$\Rightarrow \quad r = \frac{1}{3}(or)3$

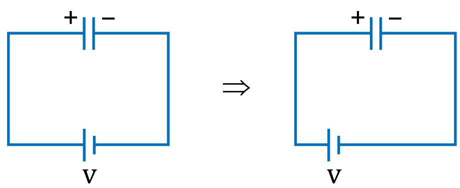
$\Rightarrow \quad v' = \frac{v_0}{3^5}$ or $v_0.3^5$

64. Ans. (BCD)



$$C_{eq} = 3.9 + \left(\frac{1}{3} + \frac{1}{7}\right)^{-1} = 3.9 + 2.1 = 6\mu F$$

$$C_{eq} = 3.9 + \left(\frac{1}{6} + \frac{1}{12}\right)^{-1} = 4\mu F \quad so\ q = 4E\mu C$$



$$q_1 + q_2 = 4E\ and\ \frac{q_1}{2.1} = \frac{q_2}{3.9} \Rightarrow q_1 = \frac{2.1}{6} \times 4E$$

$$= 0.7 \times 2E = 1.4E$$

So ΔV across $7\mu F \Rightarrow \frac{q_1}{7\mu F} = 6$

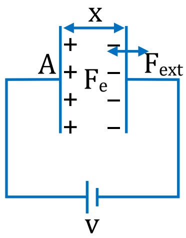
$\Rightarrow \quad E = 30\ V$

$$q_1 = 0.7 \times 2 \times 30 = 42\mu C$$

$$\Delta V\ \text{ acorss } 3\mu F = \frac{q}{3\mu F} = 14V$$

$$\Delta V\ \text{ acorss } 12\mu F = 4 \times \frac{30}{12} = 10V$$

65. Ans. (ACD)



(a) Charge on capacitor is $Q = CV$ $\left[C = \frac{\epsilon_0 A}{d}\right]$

$W_{battery} = Q \cdot V = CV^2$

Energy stored in the capacitor $U = \frac{1}{2}CV^2$

∴ Heat generated = $W_{batt} - U = \frac{1}{2}CV^2$

(b) Let the distance between the plates be x at some intermediate stage.

$C = \frac{\epsilon_0 A}{x}$

$q = CV = \frac{\epsilon_0 AV}{x}$

Field due to charge on one plate is $E = \frac{q}{2A\epsilon_0}$

∴ Force between plates $F = Eq = \frac{q^2}{2A\epsilon_0} = \frac{\epsilon_0 AV^2}{2x^2}$

(c) Assuming that the positive plate is fixed and the negative plate moves slowly towards it, work done by external agent in displacement dx is

$dW_{ext} = -|F_{ext}||dx| = -|F_e||dx| = \frac{\epsilon_0 AV^2}{2}\frac{dx}{x^2}$

∴ Work done in reducing the distance from d to $\frac{d}{2}$ is

$$W_{ext} = +\frac{\epsilon_0 AV^2}{2}\int_d^{d/2}\frac{dx}{x^2} = \frac{\epsilon_0 AV^2}{2d} = -\frac{1}{2}CV^2$$

(d) Energy dissipated must be zero as the plates are moved slowly. Charge flow from battery to the capacitor plates is very slow.

$W_{ext} = \frac{1}{2}CV^2$

Charge in PE stored in the capacitor

$\Delta U = \frac{1}{2}2CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2$

[Capacitance doubled when d was halved]

$W_{batt} = [(2CV) - CV]\ V = CV^2$

∴ $W_{batt} + W_{ext} = \Delta U$ + Heat generated

∴ Heat generated = 0

66. Ans. (BD)

$C = \frac{\varepsilon_0 A}{d_1}, C' = \frac{\varepsilon_0 A}{d_2}$

Extra charge flown $= Q' - Q = (C' - C)V \ = \varepsilon_0 AV\left[\frac{1}{d_2} - \frac{1}{d_1}\right]$

Work done by battery :

$W_b = V \times \text{charge flown} = \varepsilon_0 AV^2\left[\frac{1}{d_2} - \frac{1}{d_1}\right]$

Change in $P.E.$ of capacitor $= \Delta U = \frac{1}{2}(C' - C)V^2 \ = \frac{1}{2}\varepsilon_0 AV^2\left[\frac{1}{d_2} - \frac{1}{d_1}\right]$

67. Ans. (BC)

When switch with position (1) is closed.

Charge flow = $\frac{2CE}{3}$

Now switch shifted to position (2)

Charge flow $4E \cdot \frac{C}{2} = 2CE$

Heat = $\frac{1}{2} \times 2CE \times 4E = 4CE^2$

After switch shifted to position (2)

Total heat from starting $= \frac{CE^2}{3} + 4CE^2 = \frac{13CE^2}{3}$

68. Ans. (AB)

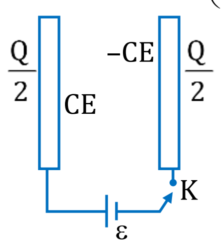
For A : $C = \frac{Q}{V} = \frac{Q}{K\left[\frac{Q}{a} - \frac{Q}{b}\right]} = \frac{4\pi \in_0 ab}{(b-a)}$

For B : $U = \frac{1}{2}\frac{Q^2}{C}$

For C : If inner sphere is earthed, potential of inner sphere becomes zero.

69. Ans. (BD)

Charge flown = $\left(C\varepsilon + \frac{Q}{2}\right) - Q = \left(C\varepsilon - \frac{Q}{2}\right)$

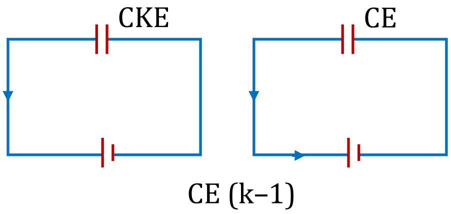


Charge on the inner surface of left plate should be $C\varepsilon$ if $\varepsilon = \frac{2Q}{C}$ then charge flow

$C\varepsilon - \frac{Q}{2} = \frac{3Q}{2}$

Work done = (charge flown) (emf) = $\left(\frac{3q}{2}\right)\left(\frac{2Q}{C}\right) = \frac{3Q^2}{C}$

70. Ans. (ABD)

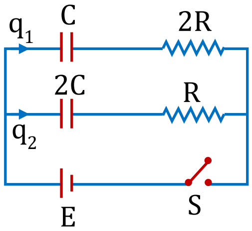


71. Ans. (BCD)

Hence $q_1 = CE\left(1-e^{-\frac{t}{2RC}}\right)$ ...(i)

and $q_2 = 2CE\left(1-e^{-\frac{t}{2RC}}\right)$ ...(ii)

Rate of increases of charge



$= \frac{dq_1}{dt} = CE \times -e^{-t/2RC} \times \frac{-1}{2RC} = \frac{E}{2R}e^{-t/2RC}$

$= \frac{dq_2}{dt} = 2CE \times e^{-t/2RC} \times \frac{-1}{2RC} = \frac{E}{R}e^{-t/2RC}$

$\frac{q_1}{q_2} = \frac{1}{2}$

$\tau_1 = \tau_2$

In steady state $\frac{q_1}{q_2} = \frac{1}{2}$

72. Ans. (B)

73. Ans. (A)

74. Ans. (B)

Solution for Question No. 72 to 74

$i_2 = i_3 = I_b$

$V_1 = (V_2 + V_3) = V$

and $P_2 = P_3 \Rightarrow R_2 = R_3$

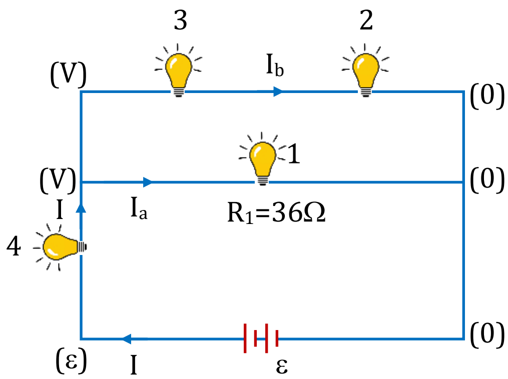
and $V_2 = V_3 = V/2$

$P_1 = P_2 = P_3 = P_4$ (given)

$P_1 = \frac{V^2}{36}$; $P_3 = \frac{(V/2)^2}{R_3}$

As $P_1 = P_3 \Rightarrow R_3 = 9\Omega$

Also $R_3 = R_2 = 9\Omega$ Ans.



$I_a = \frac{I}{3}$ and $I_4 = I$

$P_1 = P_4 = 4W$

$\left(\frac{I}{3}\right)^2 R_1 = (I)^2 R_4 = 4W \Rightarrow \frac{R_1}{9} = R_4 \Rightarrow 4\Omega = R_4$ Ans.

Also $I = 1A$

$R_{eq} = 16\Omega$ and $I = 1A$

$\varepsilon = 16V$ Ans.

75. **Ans. (A)**

These five plates constitute four identical capacitor in parallel, each of capacity $\frac{\in_0 A}{d}$

$\Rightarrow \quad q_1 = \frac{\in_0 AV}{d}$

76. **Ans. (D)**

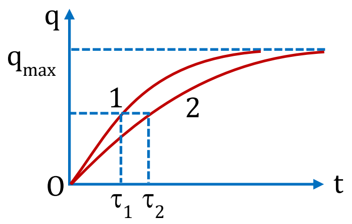
$q_4 = -\frac{2\in_0 AV}{d}$

77. **Ans. (B)**

Total energy stored = $4\times\frac{1}{2}CV^2 = \frac{2A\in_0 V^2}{d}$

78. **Ans. (AC)**

$C_2V_1 = C_2V_2$



As q_{max} for both is same hence A is correct.

As $C_1V_1 = C_2V_2$ Hence EMF's of the cells may be different.

79. **Ans. (D)**

From graph C_2 is taking more time to charge.

So, $\quad R_2C_2 > R_1C_2$

EXERCISE – S

1. **Ans.** (a) $J_0A/3$; (b) $2J_0A/3$

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

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

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

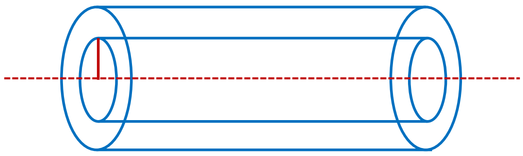
$$= J_0 \cdot 2\pi\left[\frac{R^2}{2} - \frac{R^2}{3}\right] = J_0 \cdot 2\pi \cdot \frac{R^2}{6}$$

(b) $\int_0^R J_0 \frac{r}{R}(2\pi r dr)$

$= \frac{J_0 2\pi}{3} R^2$

$= \frac{2J_0A}{3}$

2. **Ans.** $\frac{1}{R}=\frac{\pi r^2}{3l}\ (2\sigma_2+\sigma_1)$



$\sigma(r)=\sigma_1+\frac{\sigma_2-\sigma_1}{R}\cdot r$

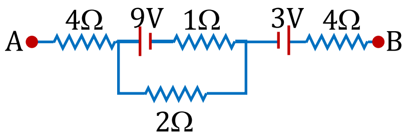
$dR=\frac{\ell}{\sigma\cdot 2\pi r dr}$

$$\frac{1}{R_{eq}}=\int\frac{1}{dR}=\int\frac{\sigma 2\pi r dr}{\ell}=\frac{2\pi}{\ell}.\left(\sigma_1+\frac{\sigma_2-\sigma_1}{r}\right)\cdot rdr$$

$$=\frac{2\pi}{\ell}\left[\int_0^r\sigma_1\, rdr+\frac{\sigma_2-\sigma_1}{r}\cdot\int_0^r r^2\,dr\right]$$

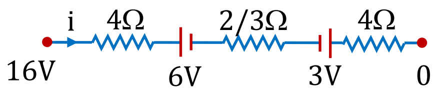
$$=\frac{2\pi}{\ell}\left[\sigma_1\cdot\frac{r^2}{2}+\frac{\sigma_2-\sigma_1}{r}\cdot\frac{r^3}{3}\right]$$

3. **Ans.** 3.5 A



$$E_{eq}=\frac{\frac{9}{1}+\frac{0}{2}}{\frac{1}{1}+\frac{1}{2}}=\frac{9}{\frac{3}{2}}=\frac{18}{3}=6V$$

$$r_{eq}=\frac{1\times 2}{3}=\frac{2}{3}$$



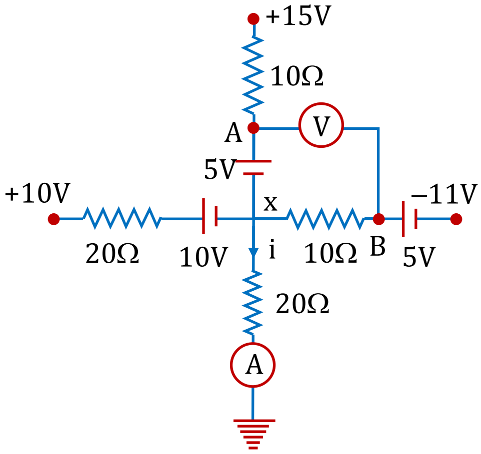
$16-4i-6-\frac{2}{3}\ i+30-4i=0$

$$13=\left(4\frac{2}{3}+4\right)i$$

$$13=\frac{26}{3}i\quad;\quad i=\frac{3}{2}A$$

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

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



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

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

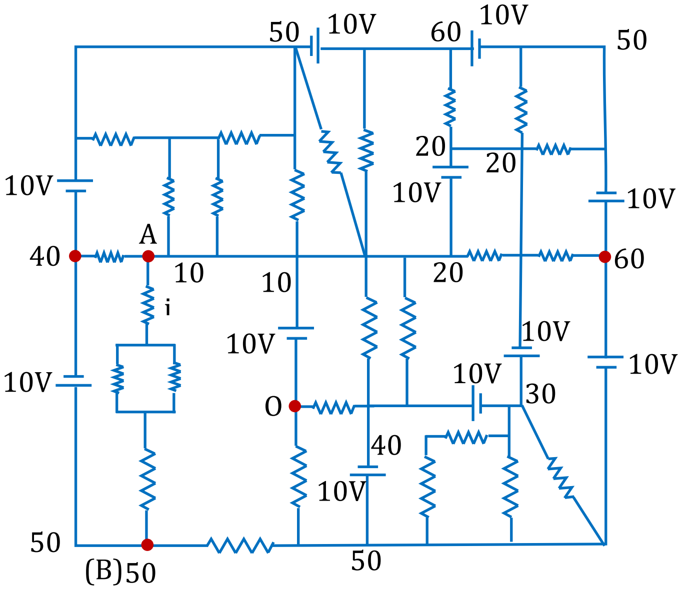
$$V_A=x+5=\frac{4}{3}+5=\frac{19}{3}V$$

$V_B=-11+5=-6$

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

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

5. **Ans.** $4A$



$V_A = 10V$ $\qquad\qquad$ $V_B = 50V$

$\Delta V_{AB} = 40V$

$$R_{AB} = \frac{R}{2} + 2R = \frac{5R}{2} = 10\Omega$$

$$i = \frac{\Delta V}{R} = \frac{40}{10} = 4A \text{ (From } B \text{ to } A)$$

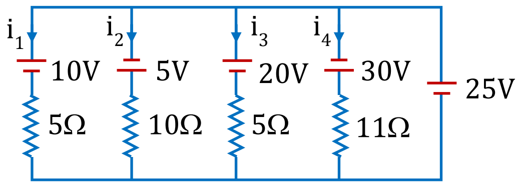
6. **Ans.** 25

Current in 60Ω resistance = $1A$

$\therefore \quad Q = i^2Rt = (1)^2 \times 60 \times 7 \times 60\ J$

$\therefore \quad Q = mS\Delta T \Rightarrow \Delta T = 25°C$

7. **Ans.** $12A$, $-20W$



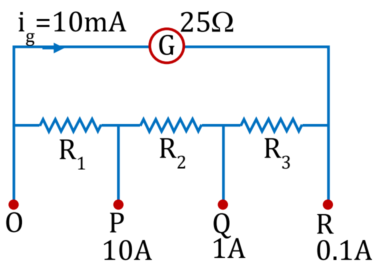
$$i_1 = \frac{15}{5} = 3A \;;\; \frac{7R}{5} \;;\; i_3 = \frac{5}{5} = 1A$$

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

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

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

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



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

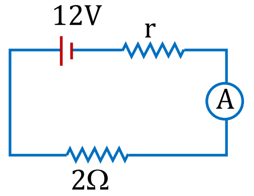
for O-Q $(1 - i_g)(R_1 + R_2) = i_g(25 + R_3)$

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

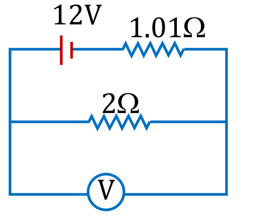
9. **Ans.** (i) 1.01Ω (ii) 0-5 A, 0-10V, (iii) 0.05 A

(i) $r_A = \frac{1\times 99}{100} = 0.99\Omega$

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



⇒ $r + 2.99 = 4$



$r = 1.01\ \Omega$

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

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

$V = 8V$

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

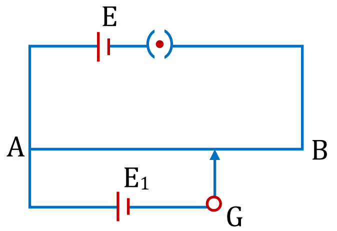
Range of ammeter = 5A

(iii) $1(5 - i_g) = 99\ i_g$

$5 = 100\ i_g$

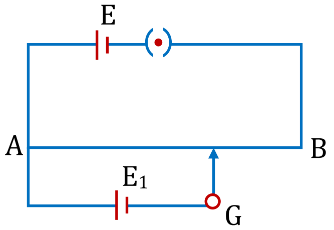
$i_g = 0.05\ A$

10. **Ans.** (a) $+ve$, $E_1 > E$ (b) $-ve$



In this case deflection will decreasing if move from A to B

$E_1 > E$



In this case if we move jockey from A to B deflection will be increased.

11. **Ans.** 4

$V_{AC} = 0.4 \times 10 = 4V$

$5 - i(1) = 4$; $i = 1A$

$i(R) = 4$

$R = 4\Omega$

12. **Ans.** 2

Initial capacitance $C_0 = 4\ \pi\varepsilon_0 R_0$

Now, when they are combined to form a bigger drop of radius R

Total volume of mercury is same.

Final volume = 8 × Initial volume of each drop

$$= \frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi R_0^3$$

$R^3 = 8R_0^3$

$R = 2R_0$

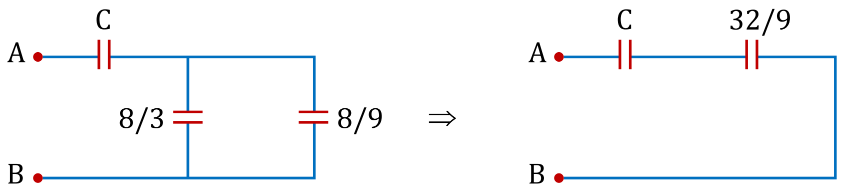
Final capacitance $c = 4\pi\varepsilon_0 R = 2 \times 4\pi\varepsilon_0 R_0$

$C = 2C_0$

13. **Ans.** 5

$$C = \frac{Q}{V} = \frac{Q}{\int_0^1 E.dx} = \frac{1}{5}$$

14. **Ans.** $\frac{32}{23}\mu F$

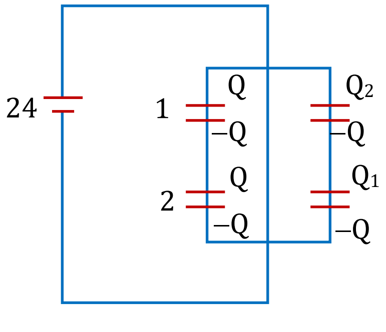


$$\Rightarrow \quad \frac{\frac{32}{9}C}{\frac{32}{9}+C} = 1 \quad \Rightarrow \quad C = \frac{32}{23}\ \mu F$$

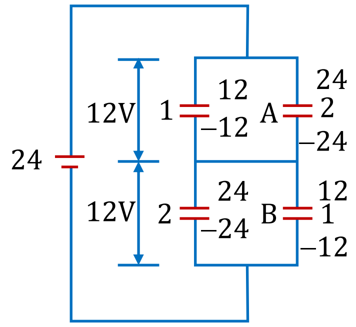
15. **Ans.** 12 μC

Initial circuit

$$Q = \left(\frac{2\times1}{2+1}\right)\times 24 = 16\ C$$



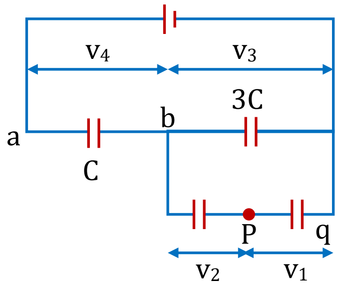
Final circuit



Initially charge on A and B combined is 0 and finally at is –12.

So charge flowing is 12 μC.

16. **Ans.** 30 V



$V_1 : V_2 = \frac{1}{3C} : \frac{1}{C}$

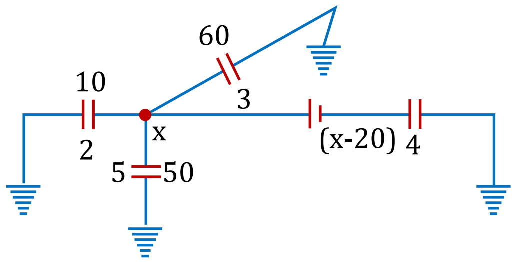
$V_1 : V_2 = 1 : 3$

$V_1 = \frac{1}{4} V_3 \qquad \Rightarrow V_3 = 8V$

$V_3 : V_4 = \frac{4}{15C} : \frac{1}{C} \qquad \Rightarrow \frac{8}{V_4} = \frac{4}{15}$

$V_4 = 30V$

17. **Ans.** (a) $\frac{100}{7}$ volts; (b) 28.56 μC, 42.84 μC, 71.4 μC, 22.88 μC



$2x + 3x + 5x + 4(x - 20) = 120$

$14x = 200$

$x = \frac{100}{7}$ Volt

18. **Ans.** 30

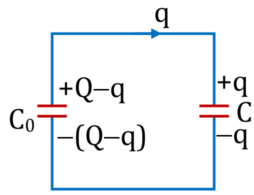
$\frac{q}{C} = \frac{Q-q}{C_0}$

$\Rightarrow \quad q\left(\frac{C+C_0}{CC_0}\right) = \frac{Q}{C_0}$

$\therefore \quad \frac{q}{C} = \frac{Q}{C+C_0} = \frac{C_0V_0}{C+C_0}$

$\Rightarrow \quad \frac{10 \times 12}{C+10} = 3$

$\therefore \quad C = 30$



19. **Ans.** 2.5 kV

$Q_{1max} = 3\ C \times 10^3\ C.$

$Q_{2max} = 4\ C \times 10^3\ C.$

Q_{max} for first branch $3C \times 10^3 C = V_{\max_1} = \frac{3C\times10^3\times5C}{6C^2} = \frac{5}{2}KV$

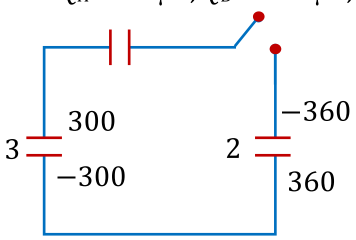
Similarly for second branch

$Q_{1max} = 7C \times 10^3\ C,\ \ Q_{2max} = 6C \times 10^3 C$

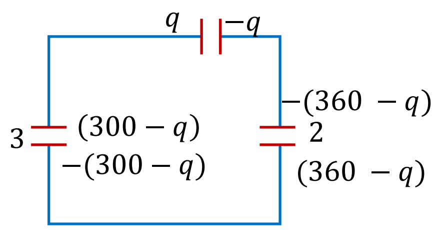
$$V_{\max_1} = \frac{6C\times10^3}{21C^2}\times10C = \frac{20}{7}kV$$

The two branches are in parallel. So in order to find max value of voltage for which no capacitor breaks down should be $V_{\max_1}$.

20. **Ans.** $Q_A = 90\ \mu C$, $Q_B = 150\ \mu C$, $Q_C = 210\ \mu C$, $U_i = 47.4\ mJ$, $U_f = 18 mJ$



Initial circuit



Final circuit

Applying K.V.L. in final circuit

$$\frac{300-q}{3}-\frac{q}{2}+\frac{360-q}{2}=0$$

$Q_C = q = 210\mu C$

$Q_A = 90\ \mu C$

$Q_B = 150\ \mu C$

$$U_i = \frac{1}{2}\times3(10^{-6})(100)^2+\frac{1}{2}(2)(180)^2\times10^{-6}$$

$$U_f = \left(\frac{1}{2}\frac{(210)^2}{2}+\frac{1}{2}\frac{(90)^2}{3}+\frac{1}{2}\frac{(150)^2}{2}\right)\times10^{-6}\,J$$

21. **Ans.** 16

$W_{ext} + W_{battery} = \Delta U$

$W_{ext} = \Delta U - W_{battery}$

$$U_i = \frac{1}{2}kCV^2$$

$$U_f = \frac{1}{2}CV^2$$

$$\Delta U = \frac{1}{2}\times(1-k)CV^2$$

$W_B = \Delta QV$

$Q_i = kCV$

$Q_f = CV$

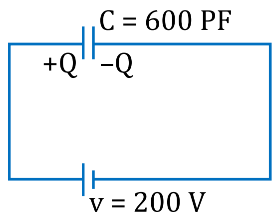
$\Delta Q = (1 - k)CV$

$$\Rightarrow\quad W_{ext} = \frac{1}{2}(k-1)CV^2 = \frac{1}{2}\times\frac{4\times8.85\times10^{-12}\times200\times10^{-4}}{0.885\times10^{-3}}\times4\times10^4$$

$= 16 \times 10^{-6} J = 16\mu J$

22. **Ans.** 6

$Q = CV = 600 \times 10^{-12} \times 200 = 12 \times 10^{-8} C$



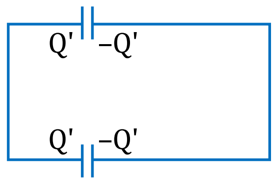
Initial energy = $\frac{1}{2}CV^2$

$= \frac{1}{2} \times 600 \times 10^{-12} \times (200)^2$

$= 12\ \mu J$

When connected to another uncharged capacitor

Charge will be equally distributed on identical capacitor



$Q' = \frac{Q}{2} = 6 \times 10^{-8}$

Final energy = $2 \times \frac{Q'^2}{2C} = \frac{Q'^2}{C}$

$$\frac{\left(6 \times 10^{-8}\right)^2}{600 \times 10^{-12}} = 6\mu J$$

Energy lost = Initial energy – Final energy

$= (12-6)\ \mu J = 6\mu J$

23. **Ans.** 300

$E = 10\% \times 10^7 = 10^6\ V/m$

$E = \frac{v}{d} \Rightarrow 10^6 = \frac{10^3}{d} \Rightarrow d = 10^{-3}\ m$

$C = \frac{kA\varepsilon_0}{d} \Rightarrow 90 \times 10^{-12} = \frac{6\pi A}{10^{-3}} \times \frac{1}{36\pi} \times 10^{-3}$

$A = 300 \times 10^{-6}\ m^2$

$A = 300\ mm^2$

24. **Ans.** 3

Initial charge on capacitor = CE

Initial potential energy of capacitor = $\frac{CE^2}{2}$

Now, $C = \frac{\varepsilon_0 A}{d}$

And new capacitance : $C' = \frac{\varepsilon_0 A}{d/2}$, in series with $\frac{\varepsilon_0 kA}{d/2}$

$\Rightarrow \quad C' = \frac{2\varepsilon_0 A}{d}$ series $\frac{4\varepsilon_0 A}{d}$

$= \frac{\varepsilon_0 A}{d}\left(\frac{2 \times 4}{2+4}\right) = \frac{4\varepsilon_0 A}{3d} = \frac{4}{3}C \Rightarrow$ New charge = $\frac{4}{3}CE$

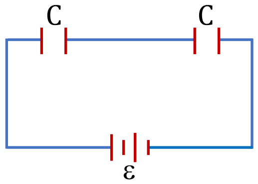
New energy = $\frac{1}{2} \times \frac{4}{3}CE^2 = \frac{2}{3}CE^2$

Now $W_{battery} = \Delta H + \Delta U$

$\Rightarrow \quad E\left(\frac{4}{3}CE - CE\right) = \Delta H + \frac{2}{3}CE^2 - \frac{1}{2}CE^2 \Rightarrow \Delta H = \frac{1}{6}CE^2$

25. **Ans.** $\Delta q = \frac{1}{2} CE \frac{K-1}{K+1}$

$q = \frac{c\varepsilon}{2}$ (with no dielectric)



When dielectric is filed

$$C_{net} = \frac{C \cdot KC}{(1+K)C}$$

$$C_{net} = \frac{KC}{1+K}$$

$q' = \frac{KC}{(1+k)}$ change How = $q' - q = \frac{kc}{1+k} - \frac{c\varepsilon}{2}$

Change how = $\frac{C\varepsilon}{2}\left(\frac{K-1}{K+1}\right)$

26. **Ans.** $dC_{net} = \frac{\varepsilon_0 a k_1 k_2}{(k_1 - k_2)\frac{d}{a}} \log\left(\frac{k_1}{k_2}\right)$

$$\frac{1}{dC_{net}} = \frac{1}{dC_1} + \frac{1}{dC_2}$$

$$= \frac{d_1}{k_1 \varepsilon_0 A_1} + \frac{d_2}{k_2 \varepsilon_0 A_2}$$

$$= \frac{d - x\tan\phi}{k_1 \varepsilon_0 A_1} + \frac{x\tan\phi}{k_2 \varepsilon_0 A_2}$$

$$\int dC_{net} = \int \frac{\varepsilon_0 a dx}{\frac{d - x\tan\phi}{k_1} + \frac{x\tan\phi}{k_2}}$$

$$dC_{net} = \frac{\varepsilon_0 a k_1 k_2}{(k_1 - k_2)\frac{d}{a}} (\log k_1 - \log k_2)$$

$$dC_{net} = \frac{\varepsilon_0 a k_1 k_2}{(k_1 - k_2)\frac{d}{a}} \log\left(\frac{k_1}{k_2}\right)$$

27. **Ans.** $M = \frac{\varepsilon_0 b V^2 (k-1)}{2dg}$

Electric field attracts the dielectric into the capacitor with a force $F = \frac{\varepsilon_0 b V^2 (k-1)}{2d}$

$$\frac{\varepsilon_0 b V^2 (k-1)}{2d} = Mg$$

$$M = \frac{\varepsilon_0 b V^2 (k-1)}{2dg}$$

28. Ans. $\frac{V_1}{V_2}=\frac{\sqrt{k_2-1}}{\sqrt{k_1-1}}$

$C_1=\frac{k_1\varepsilon_0 bx}{d}$ $\qquad C_2=\frac{\varepsilon_0 b(\ell_1-x)}{d}$

$C_{\text{net}} = C_1 + C_2$

$=\frac{\varepsilon_0}{d}[k_1x+\ell_1-x]$

$C_{\text{net}}=\frac{\varepsilon_0 b}{d}[(k_1-1)x+\ell_1]$

$u=\frac{1}{2}CV_1^2=\frac{\varepsilon_0 bV_1^2}{2d}[\ell_1+x(k-1)]$

$F=\frac{\varepsilon_0 bV_1^2}{2d}(k-1)$

$V_1^2=\frac{F\times 2d}{\varepsilon_0 b(k_1-1)}\Rightarrow V_1=\sqrt{\frac{F\times 2d}{\varepsilon_0 b(k_1-1)}},V_2=\sqrt{\frac{F\times 2d}{\varepsilon_0 b(k_2-1)}}$

$\frac{V_1}{V_2}=\frac{\sqrt{k_2-1}}{\sqrt{k_1-1}}$

29. Ans. $8.37W$

$U=\frac{1}{2}\frac{Q^2}{C}=\frac{1}{2}C^2V_0^2(1-e^{-t/RC})^2$

$\frac{du}{dt}=\frac{1}{2}CV_0^2\times 2(1-e^{-t/RC})\times e^{-t/RC}\times\frac{1}{RC}$

$\frac{du}{dt}=\frac{V_0^2}{R}(1-e^{-t/RC})e^{-t/RC}$

$\frac{du}{dt}=\frac{6\times 6}{1}(e^{-1}-e^{-2})$

$\frac{du}{dt}=8.37w$

30. Ans. 18

Vol. across R_2, $V = IR_2$

$V=\frac{E}{R_2+r}R_2=\frac{5}{(4+1)}(4)$

$V = 4$ volt

Vol. across C, $V_C=\frac{V}{2}=2$ volt

Change $q = CV = 3 \times 2 = 6\ \mu C$

31. **Ans.** $E = 1.59 \times 10^{15} J$

$$C = \frac{AK\varepsilon_0}{d} = \frac{20\times10^{-4}\times5\times8.85\times10^{-12}}{1\times10^{-3}}$$

$$C = 88.5\times10^{-12} F$$

$$Q = CV(1 - e^{-t/RC})$$

$$= 88.5\times10^{-12}\times6\left(1 - e^{\frac{-8.9\times10^{-4}}{88.5\times10^{-12}\times10^{4}}}\right)$$

$$= 830.97C$$

$$E = \frac{1}{2}\frac{Q^2}{C} = \frac{530.97\times530.97}{2\times88.5\times10^{-12}} = 1.59\times10^{15} J$$

32. **Ans.** $q_1 = 2\times10^{-6}C$, $q_2 = 8\times10^{-6}C$, $q_3 = 9\times10^{-6}C$, $q_4 = 12\times10^{-6}C$

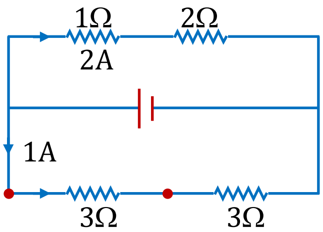
$$q_3 = 3\times10^{-6}\times3 = 9\times10^{-6}C$$

$$q_4 = 4\times10^{-6}\times3 = 12\times10^{-6}C$$

$$q_1 = C_1V_1 \qquad q_2 = 2\times10^{-6}\times4$$

$$= 1\times10^{-6}\times2 \qquad = 8\times10^{-6}C$$

$$= 2\times10^{-6}C$$



Steady

33. **Ans.** 750

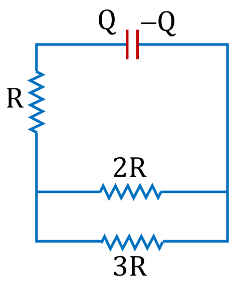
Just after closing switch no current flows through R_2 so $I_1 = 3\ mA$

Long time after closing switch no current flows through C so $I_2 = 2\ mA$

Directly after re-opening the switch no current flows through R_1 and the capacitor will discharge through R_2 so $I_3 = 2\ mA$

34. **Ans.** 225

$$U = \frac{1}{2}\frac{(15)^2\times10^{-12}}{6\times10^{-6}}\times55 = 1031.25\ \mu J$$



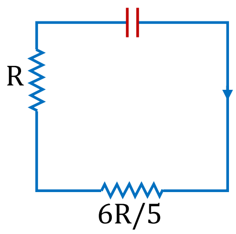
Energy in $\frac{6R}{5}$ is $\frac{U\times\frac{6R}{5}}{\frac{11R}{5}} = \frac{U\times6}{11}$

Energy emitted in $3R$

$$E = \frac{U\times6}{11}\times\frac{\frac{6R}{5}}{3R}$$

$$= \frac{6U}{11}\times\frac{6}{15}$$

$$= 225\times10^{-6} J$$



35. **Ans.** $Q_0 = \dfrac{CVR_2}{R_1+R_2}$ and $\alpha = \dfrac{R_1+R_2}{CR_1R_2}$

$Q_0 = \dfrac{CV}{R_1+R_2} \times R_2$

$\alpha = \dfrac{1}{R_{eq}C} = \dfrac{R_1+R_2}{R_1R_2C}$

$Q_{max} = \dfrac{CV}{R_1+R_2} \times R_2$, $R_{eq} = \dfrac{R_1R_2}{R_1+R_2}$

36. **Ans.** (a) $Q = \dfrac{CV}{2}\left(1-e^{-2t/3RC}\right)$

(b) $i = \dfrac{V}{2R} - \dfrac{V}{6R}e^{-2t/3RC}, \dfrac{V}{2R}$

Let at any time t charge on capacitor C be Q and currents are as shown in figure. Since charge q will increase with time t,

$$i_1 = \frac{dQ}{dt}$$

(a) Applying Kirchoff's second law in the loop $MNABM$, we get

$$V = (i-i_1)R + iR \text{ or } V = 2iR - i_1R$$

Similarly, applying Kirchoff's second law in loop $MNSTM$, we have

$$V = i_1R + \frac{Q}{C} + iR$$

Eliminating i from eqs. (i) and (ii), we get

$$V = 3i_1R + \frac{2Q}{C} \text{ or } 3i_1R = V - \frac{2Q}{C} \text{ or } i_1 = \frac{1}{3R}\left(V - \frac{2Q}{C}\right)$$

or $$\frac{dQ}{dt} = \frac{1}{3R}\left(V - \frac{2Q}{C}\right) \text{ or } \frac{dQ}{V - \frac{2Q}{C}} = \frac{dt}{3R}$$

or $$\int_0^Q \frac{dQ}{V - \frac{2Q}{C}} = \int_0^t \frac{dt}{3R}$$

This equation gives

$$Q = \frac{CV}{2}\left(1-e^{-2t/3RC}\right)$$

(b) $$i_1 = \frac{dQ}{dt} = \frac{V}{3R}e^{-2t/3RC}$$

From eq (i), we get

$$i = \frac{V + i_1R}{2R} = \frac{V + \frac{V}{3}e^{-2t/3RC}}{2R}$$

Current through AB is

$$i_2 = i - i_1 = \frac{V}{2R} - \frac{V}{6R}e^{-2t/3RC}$$

EXERCISE - JEE (Main) PYQ

1. Ans. (3)

Total power $(P) = (15 \times 40) + (5 \times 100) + (5 \times 80) + (1 \times 1000) = 2500W$

$P = VI$

$\Rightarrow \quad I = \frac{2500}{220} A$

$= \frac{125}{11}$

$= 11.3\ A$

Minimum capacity should be $12\ A$.

2. Ans. (1)

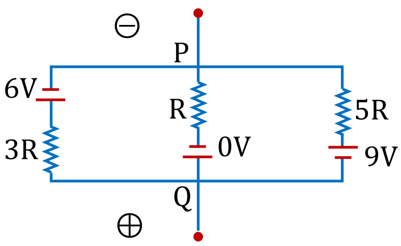
Electric field inside dielectric, $\frac{\sigma}{K\varepsilon_0} = 3 \times 10^4$

$\Rightarrow \quad \sigma = 2.2 \times 8.85 \times 10^{-12} \times 3 \times 10^4$

$= 6 \times 10^{-7}\ C/m^2$

3. Ans. (1)

$$E = \frac{\frac{6}{3}+\frac{0}{1}-\frac{9}{5}}{\frac{1}{3}+\frac{1}{1}+\frac{1}{5}} = \frac{2-\frac{9}{5}}{\frac{5+15+3}{15}} = \frac{3}{23}$$



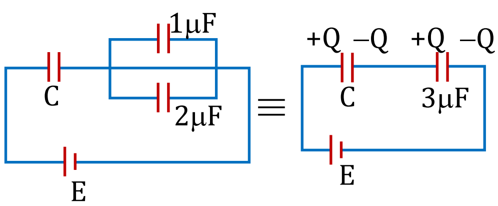
$i = \frac{E}{R} = \frac{3}{23} = 0.13$

From $+ve$ to $-ve$

Q to P.

4. Ans. (4)

$C_{eq} = \frac{3C}{3+C}$



$Q = Ceq{\cdot}E$

$$Q_2 = \frac{2CE}{(C+3)} = \frac{3CE}{(C+3)}$$

$$= 2E\left[1-\frac{3}{C+3}\right]$$

$$Q_{2/\text{when } C = 1\mu F} = 2E\left[\frac{1}{4}\right] = \frac{E}{2}$$

$$Q_{2/\text{when } C = 3\mu F} = 2E\left[\frac{1}{2}\right] = E$$

$$\frac{dQ}{dC} = -\frac{2E\cdot 3}{(C+3)}(-1) = \frac{6E}{(C+3)^2} > 0$$

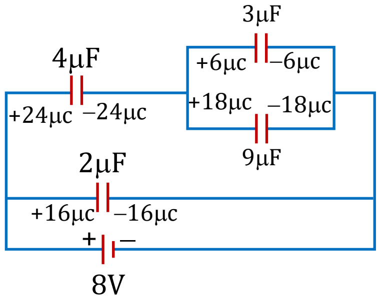
$$\frac{d^2\theta}{dC^2} = \frac{6E(-2)}{(C+3)^3} = -\frac{12E}{(C+3)^2} < 0$$

5. **Ans. (4)**

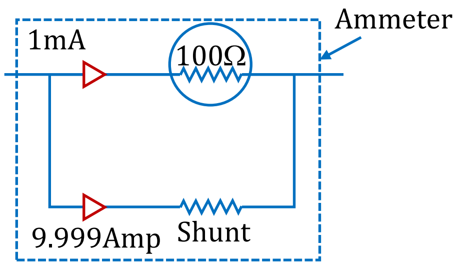
$Q = 24 + 18 = 42\ \mu c$

$E = \dfrac{KQ}{r^2}$

$\Rightarrow \quad E = \dfrac{9\times10^9\times42\times10^{-6}}{(30)^2} = 420\ N/C$



6. **Ans. (2)**



P.D. should remain same

$1\ mA \times 100 = 9.999\ R$

$R = \dfrac{1}{99.99} = 0.01W$

7. **Ans. (3)**

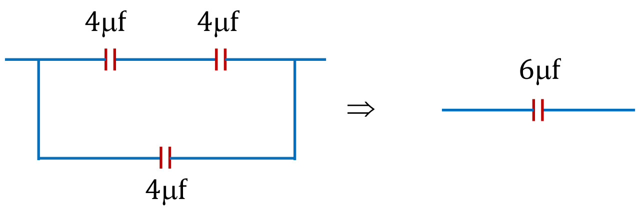
Heat generation in r will be, $H = I_r^2 r$,

$$H = \left(\frac{V}{R+\dfrac{Rr}{R+r}}\times\frac{r}{R+r}\right)^2 r = \left(\frac{V}{R(R+2r)}\right)^2 r$$

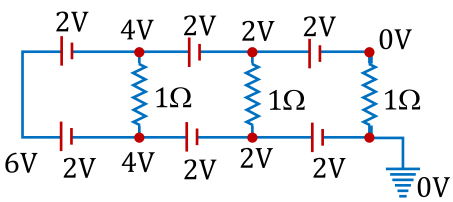
Putting $\dfrac{dH}{dr} = 0$ gives, $r = \dfrac{R}{2}$

Hence, $f = \dfrac{1}{2}$

8. **Ans. (3)**



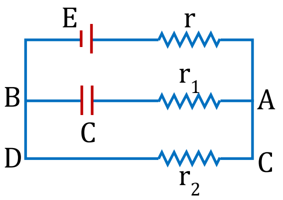
9. **Ans. (1)**



p.d. across each resistance is zero so current is also zero.

10. **Ans. (1)**

It steady state, current through $AB = 0$



$\Rightarrow \quad V_{AB} = V_{CD}$

$$\Rightarrow \quad V_{AB} = \left(\frac{\varepsilon}{r+r_2} \times r_2\right) - V_{CD}$$

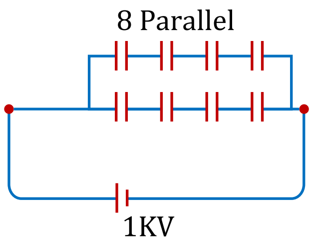
$\Rightarrow \quad Q_C = CV_{AB}$

$$= CE\left(\frac{r_2}{r+r_2}\right)$$

11. **Ans. (2)**

To hold 1 KV potential difference.

Minimum four capacitors are required in series.



$\Rightarrow \quad C_1 = \frac{1}{4}$ for one series.

So, for Ceq to be 2μF, 8 parallel combinations are required.

$\Rightarrow \quad$ Minimum no. of capacitors = 8 × 4 = 32.

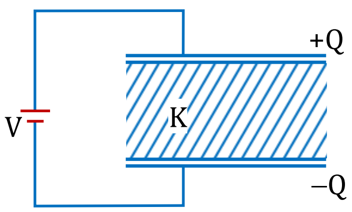
12. **Ans. (4)**

Using formula $r = R\left(\frac{\ell_1}{\ell_2} - 1\right)$

$$= 5\left(\frac{52}{40} - 1\right) = 5 \times \frac{12}{40} = 1.5\Omega$$

13. **Ans. (4)**

$Q = (kC)\,V$



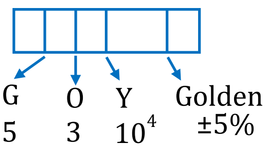
$$= \left(\frac{5}{3} \times 90pF\right)(20V)$$

$= 3000\ pC = 3nC$

Induced charges on dielectric

$$Q_{ind} = Q\left(1 - \frac{1}{K}\right) = 3nC\left(1 - \frac{3}{5}\right) = 1.2nC$$

14. **Ans. (2)**



$R = 53 \times 10^4 \pm 5\% = 530\ k\Omega \pm 5\%$

15. **Ans. (4)**

$$i = \frac{\varepsilon}{13r}$$

$$i\left(\frac{x}{L}12r\right) = \frac{\varepsilon}{2}$$

$$\frac{\varepsilon}{13r}\left[\frac{x}{L}.12r\right] = \frac{\varepsilon}{2} \Rightarrow \boxed{x = \frac{13L}{24}}$$

16. Ans. (4)

Case I $\quad i_g = \dfrac{E}{220+R_g} = C\theta_0 \qquad$ ...(i)

Case II $\quad i_g = \left(\dfrac{E}{220+\dfrac{5R_g}{5+R_g}}\right)\times\dfrac{5}{(R_g+5)} = \dfrac{C\theta_0}{5} \qquad$ ...(ii)

$\Rightarrow \quad \dfrac{5E}{225R_g+1100} = \dfrac{C\theta_0}{5} \qquad$ ...(ii)

$\dfrac{E}{220+R_g} = C\theta \qquad$ ...(i)

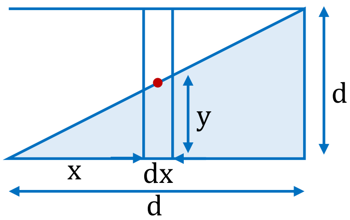
$\Rightarrow \quad \dfrac{225R_g+1100}{1100+5R_g} = 5$

$\Rightarrow \quad 5500 + 25R_g = 225R_g + 1100$

$200R_g = 4400$

$R_g = 22\Omega$

17. Ans. (3)



$\dfrac{y}{x} = \dfrac{d}{a}$

$y = \dfrac{d}{a}x$

$dy = \dfrac{d}{a}(dx)$

$\dfrac{1}{dc} = \dfrac{y}{KE\cdot adx} + \dfrac{(d-y)}{\epsilon_0\, adx}$

$\dfrac{1}{dc} = \dfrac{1}{\epsilon_0\, adx}\left(\dfrac{y}{k}+d-y\right)$

$\int dc = \int \dfrac{\epsilon_0\, adx}{\dfrac{y}{k}+d-y}$

$c = \epsilon_0\, a\cdot\dfrac{a}{d}\displaystyle\int_0^d \dfrac{dy}{d+y\left(\dfrac{1}{k}-1\right)}$

$= \dfrac{\epsilon_0\, a^2}{\left(\dfrac{1}{k}-1\right)d}\left[\ell n\left(d+y\left(\dfrac{1}{k}-1\right)\right)\right]_0^d$

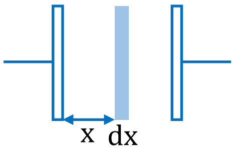
$= \dfrac{k\epsilon_0\, a^2}{(1-k)d}\ell n\left(\dfrac{d+d\left(\dfrac{1}{k}-1\right)}{d}\right) = \dfrac{k\epsilon_0\, a^2}{(1-k)d}\ell n\left(\dfrac{1}{k}\right) = \dfrac{k\epsilon_0\, a^2\ell nk}{(k-1)d}$

18. Ans. (1)

Figure of Merit = $C = \frac{i}{\theta}$ = $C = \frac{6\times10^{-3}}{2} = 3\times10^{-3}\,Am^2$

19. Ans. (1)

As K is variable we take a plate element of Area A and thickness dx at distance x Capacitance of element



$$dC = \frac{(A)K(1+\alpha x)\varepsilon_0}{dx}$$

Now all such elements are is series so equivalent capacitance

$$\frac{1}{C} = \int\frac{1}{dC} = \int_0^d \frac{dx}{AK\varepsilon_0(1+\alpha x)}$$

$$\frac{1}{C} = \frac{1}{\alpha AK\varepsilon_0}\ln\left(\frac{1+\alpha d}{1}\right)$$

$$= \frac{1}{C} = \frac{1}{\alpha AK\varepsilon_0}\left(\alpha d - \frac{(\alpha d)^2}{2} + \frac{(\alpha d)^3}{3} + ...\right)$$

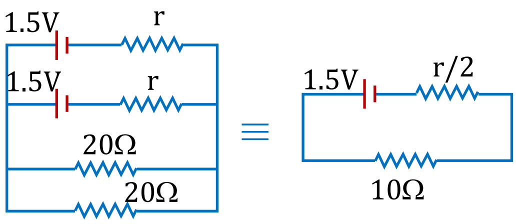
$$\Rightarrow \quad \frac{1}{C} = \frac{\alpha d}{\alpha AK\varepsilon_0}\left(1 - \frac{\alpha d}{2} + \frac{(\alpha d)^2}{3} + ...\right)$$

$$\frac{1}{C} = \frac{d}{AK\varepsilon_0}\left(1 - \frac{\alpha d}{2}\right)$$

$$C = \frac{AK\varepsilon_0}{d}\left(1 + \frac{\alpha d}{2}\right)$$

20. Ans. (3)

$V = E - ir/2$



$$1.2 = 1.5 - i\left(\frac{r}{2}\right)$$

$$i\frac{r}{2} = 0.3$$

$$i = \frac{1.5}{10+\frac{r}{2}} \Rightarrow 10i + \frac{ir}{2} = 1.5$$

$10i = 1.5 - 0.3$

$i = 0.12\ A$

$$\Rightarrow \quad r = \frac{0.6}{0.12} = 5\Omega$$

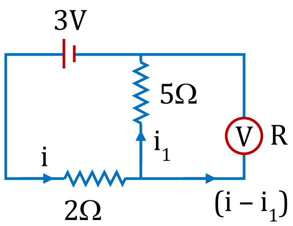
21. Ans. (4)

$$K = \frac{q}{A\epsilon_0 E} = \frac{7\times10^{-6}}{30\pi\times10^{-4}\times\frac{1}{4\pi\times9\times10^9}\times3.6\times10^7}$$

$$K = \frac{36\times7}{30\times3.6} = 2.33$$

22. Ans. (20)

$$i_1 = \frac{2V}{5\Omega} = \frac{2}{5}A$$



$$i = \frac{1V}{2\Omega} = \frac{1}{2}A$$

$\therefore$ Current through voltmeter = $i - i_1$

$$= \frac{1}{2} - \frac{2}{5} = \frac{5-4}{10} = \frac{1}{10}A$$

$\therefore$ For voltmeter

$$2 = \left(\frac{1}{10}\right)R \Rightarrow R = 20\Omega$$

23. Ans. (25)

$R = \rho\frac{\ell}{A}$ be the initial resistance new resistance $R' = \rho\frac{1.2\ell}{0.96A} = 1.25\rho\frac{\ell}{A} = 1.25R$

Percentage change $= \frac{1.25R - R}{R} \times 100 = 25\%$

24. Ans. (5)

$$c = \frac{\varepsilon_0 A}{(d-c)}$$

$$= \frac{\varepsilon_0 \times 200 \times 10^{-4}}{4 \times 10^{-3}}$$

$\therefore \quad x = 5$

The situation is equivalent to a conducting slab placed between the plates

25. Ans. (3)

For $x = \frac{d}{3}$

$$C_1 = \frac{\epsilon_0 A}{\left(\frac{d/3}{k} + \frac{2d}{3}\right)} = \frac{\epsilon_0 A}{\frac{d}{12} + \frac{2d}{3}} = \frac{\epsilon_0 A}{d} \times \left(\frac{12}{9}\right)$$

$$C_1 = \frac{4}{3}\frac{\epsilon_0 A}{d} = 2\mu F$$

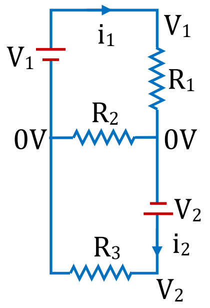
For $\quad x = \frac{2d}{3}$

$$C_2 = \frac{\epsilon_0 A}{\left(\frac{2d/3}{k} + \frac{d}{3}\right)} = \frac{\epsilon_0 A}{d} \times 2$$

$$\Rightarrow \quad \frac{6}{4} \times 2 = 3\mu F$$

EXERCISE - JEE (Advanced) PYQ

1. **Ans. (ABD)**



$i_1 = i_2$

$\frac{V_1}{R_1} = \frac{V_2}{R_3}$

2. **Ans. (5)**

$\frac{6}{1000}(G + 4990) = 30$

$\Rightarrow \quad G + 4990 = \frac{30,000}{6} = 5000$

$\Rightarrow \quad G = 10$

$\frac{6}{1000} \times 10 = \left(1.5 - \frac{6}{1000}\right) S$

$\Rightarrow \quad S = \frac{60}{1494} = \frac{2n}{249}$

$\Rightarrow \quad n = \frac{249 \times 30}{1494} = \frac{2490}{498} = 5$

3. **Ans. (AD)**

$C = \frac{K\varepsilon_0 A}{3d} + \frac{2\varepsilon_0 A}{3d}$

$C_1 = \frac{K\varepsilon_0 A}{3d}$

$\frac{C}{C_1} = \frac{2+K}{K}$ **Ans. (D)**

$E_1 = E_2 = \frac{V}{d}$

$\Rightarrow \quad \frac{E_1}{E_2} = 1$ **Ans. (A)**

$Q_1 = C_1 V = \frac{K\varepsilon_0 A}{3d} V$

$Q_2 = C_2 V = \frac{2\varepsilon_0 A}{3d} V$

$\Rightarrow \quad \frac{Q_1}{Q_2} = \frac{K}{2}$

4. **Ans. (B)**

$R_{A\ell}$ and R_{Fe} are Parallel to each other

$$\frac{1}{R_{eq}} = \frac{1}{R_{Al}} + \frac{1}{R_{Fe}}$$

$$R_{Al} = \frac{2.7\times10^{-8}\times(.05)}{(.007)^2-(.002)^2}$$

$$R_{Al} = \frac{2.7\times10^{-8}\times5}{10^{-6}\times45\times100} = 3\times10^{-5}$$

$$R_{Fe} = \frac{1.0\times10^{-7}\times(.05)}{(.002)^2}$$

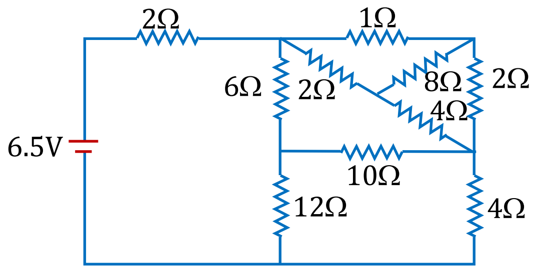
$$R_{Fe} = \frac{10^{-7}}{4\times10^{-6}}5\times10^{-2} = \frac{5}{4}\times10^{-3}$$

$$\frac{1}{R_{eq}} = \frac{1}{3\times10^{-5}} + \frac{4}{5\times10^{-3}} = \frac{10^5}{3} + \frac{4\times10^3}{5}$$

$$\frac{1}{R_{eq}} = \frac{15}{5\times10^5+12\times10^3} = \frac{15}{5.12\times10^5}$$

$$\frac{1}{R_{eq}} = \frac{150}{5.12}\mu\Omega = \frac{1875}{64}\mu\Omega$$

5. **Ans. (1)**



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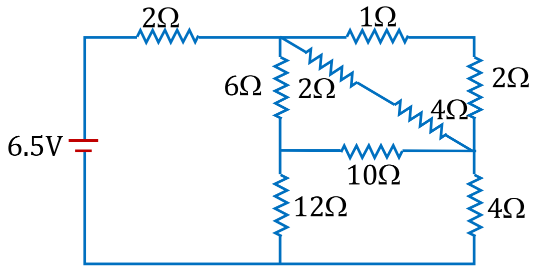

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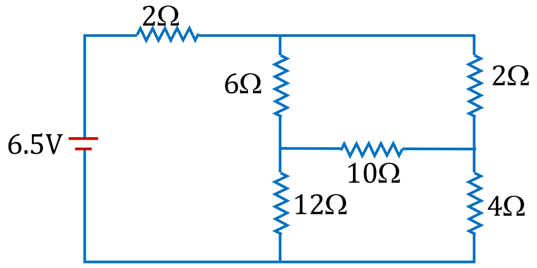

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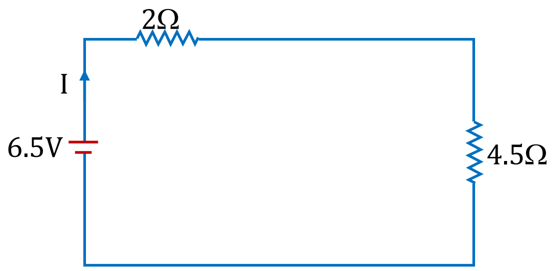
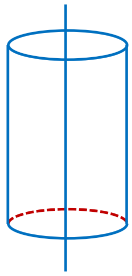


$$I = \frac{6.5}{6.5} = 1amp$$

6. **Ans. (C)**

Suppose charge per unit length at any instant is λ and initially it is λ_0

Electric field at a distance *r* any instant is



$$E = \frac{\lambda}{2\pi\epsilon r}$$

$$J = \sigma\frac{\lambda}{2\pi\epsilon r}$$

$$\frac{dq}{dt} = J(1) = -J \times 2\pi r\ell$$

$$\frac{d\lambda\ell}{dt} = -\frac{\lambda}{2\pi\epsilon r} \times \sigma 2\pi r\ell$$

$$\lambda = \lambda_0 e^{-\frac{\sigma}{\epsilon}t}$$

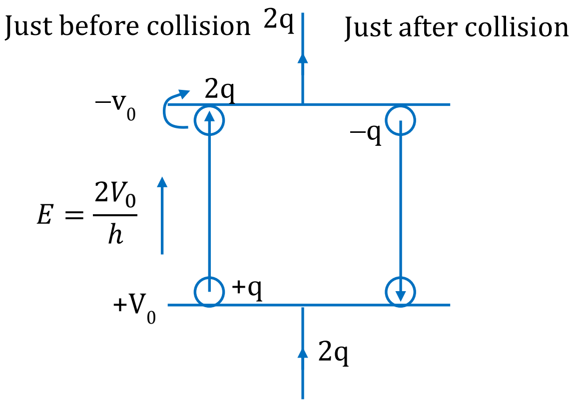
$$J = J_0 e^{-\frac{\sigma}{\epsilon}t}$$

7. **Ans. (B)**

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.

8. **Ans. (A)**



$$\frac{Kq}{r} = Vo = q = \frac{V_o r}{K}$$

$$\frac{1}{2}\left(\frac{qE}{m}\right)t^2 = h; \frac{1}{2}\frac{V_0 r}{K}\frac{2V_0}{hm}t2 = h; t2 = \frac{h^2}{V_0^2}\frac{mk}{r}$$

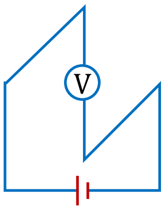
$$t = \frac{h}{V_0}\sqrt{\frac{mk}{r}}$$

During every collision 2*q* charge will flow from circuit.

Average current $I_{avg} = \frac{2q}{t} = \frac{2V_0^2}{h}\frac{r\sqrt{r}}{mk\sqrt{k}} I_{avg} \alpha V_0^2$

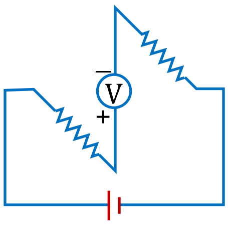
9. Ans. (ABCD)

(A) At $t = 0$, capacitor acts as short-circuit

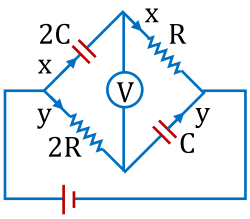


At $t \to \infty$, capacitor acts as open circuit and no current flows through voltmeter.

$\therefore$



(B)



$$q_x = 2CV\left(1 - e^{-t/2CR}\right) \quad x = \frac{V}{R}e^{-t/2CR}$$

$$q_y = CV\left(1 - e^{-t/2CR}\right) \quad y = \frac{V}{2R}e^{-t/2CR}$$

$$\Delta V = -y2R + \frac{q_x}{2C}$$

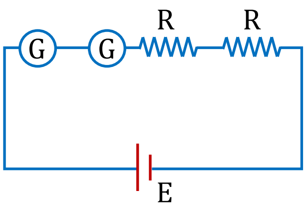
$$= V\left[1 - 2e^{-t/2CR}\right] = 0$$

(C) $\tau = 1$ sec.

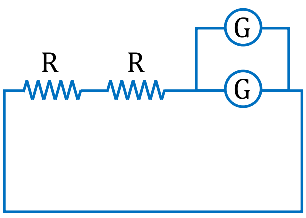
So, by $i = i_0 e^{-t/\tau}$ current at $t = 1$ sec. is $= i_0/e$

(D) After long time no current flows since both capacitor and voltmeter does not allow.

10. Ans. (BC)



Range = $i_g(2R_C + 2R)$



Range = $2i_g \times R_{eq}$

$= 2i_g\left(2R+\frac{R_C}{2}\right)$

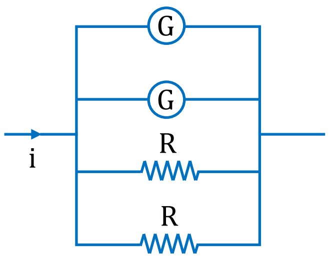
$= i_g\,(4R + R_C)$

$R_C < \frac{R}{2}$

$2R_C < R \Rightarrow$ Range in $1 < 3i_gR$

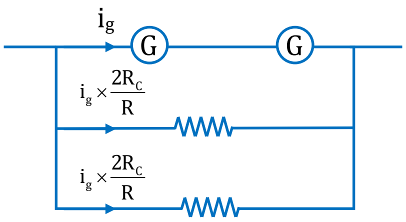
Range in $2 > 4i_gR$

So (B)



Range = $2i_g + 2i_g$

$= 2i_g\left(1+\frac{R_C}{R}\right)$



Range = $i_g + 4i_g\frac{R_C}{R}$

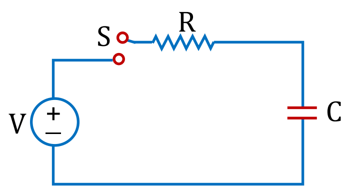
$= 2i_g\left[\frac{1}{2}+\frac{2R_C}{R}\right]$

$= 2i_g\left(\frac{1}{2}+\frac{R_C}{R}+\frac{R_C}{R}\right)$

So (C)

11. Ans. (A)

When switch is closed for *A* very long-time capacitor will get fully charged and charge on capacitor will be $q = CV$.



Energy stored in capacitor,

$$\in_C = \frac{1}{2}CV^2 \qquad ...(i)$$

Work done by battery (ω) = $Vq = VCV = CV^2$

Dissipated across resistance $\in_D$ = (work done by battery) – (energy store)

$$\in_D = CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2 \qquad ...(ii)$$

From (i) and (ii)

$$\in_D = \in_C$$

12. **Ans. (A)**

For process (1)

Charge on capacitor = $\frac{CV_0}{3}$

Energy stored in capacitor = $\frac{1}{2}C\frac{V_0^2}{9}=\frac{CV_0^2}{18}$

Work done by battery = $\frac{CV_0}{3}\times\frac{V}{3}=\frac{CV_0^2}{9}$

Heat loss = $\frac{2CV_0}{3}$

For process (2)

Charge on capacitor = $\frac{CV_0}{3}$

Extra charge flow through battery $\frac{CV_0}{3}$

Work done by battery : $\frac{CV_0}{3}.\frac{2V_0}{3}$ = $\frac{2CV_0^2}{9}$

Final energy store in capacitor : $\frac{1}{2}C\left(\frac{2V_0}{3}\right)^2=\frac{4CV_0^2}{18}$

Energy store in process 2 : $\frac{4CV_0^2}{18}-\frac{CV_0^2}{18}=\frac{3CV_0^2}{18}$

Heat loss in process (2) = work done by battery in process (2) – energy store in capacitor process (2)

$$= \frac{2CV_0^2}{9}-\frac{3CV_0^2}{18}=\frac{CV_0^2}{18}$$

For process (3)

Charge on capacitor = CV_0

Extra charge flow through battery : $CV_0 - \frac{2CV_0}{3}=\frac{CV_0}{3}$

Work done by battery in this process : $\left(\frac{CV_0}{3}\right)(V_0)=\frac{CV_0^2}{3}$

Find energy store in capacitor : $\frac{1}{2}CV_0^2$

Energy stored in this process : $\frac{1}{2}CV_0^2-\frac{4CV_0^2}{18}=\frac{5CV_0^2}{18}$

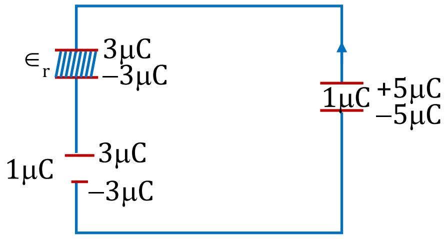
Heat loss in process (3) : $\frac{CV_0^2}{3}-\frac{5CV_0^2}{18}=\frac{CV_0^2}{18}$

Now total heat loss (E_D) : $\frac{CV_0^2}{18}+\frac{CV_0^2}{18}+\frac{CV_0^2}{18}=\frac{CV_0^2}{6}$

Final energy store in capacitor : $\frac{1}{2}CV_0^2$

So we can say that $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$

13. Ans. (1.50)

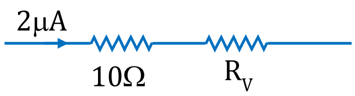


Applying loop rule

$$\frac{5}{1}-\frac{3}{\in_r}-\frac{3}{1}=0\,,\ \frac{3}{\in_r}=2$$

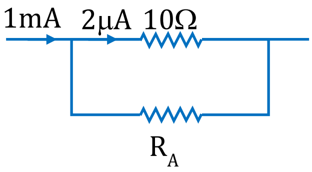
$\in_r = 1.50$

14. Ans. (AC)



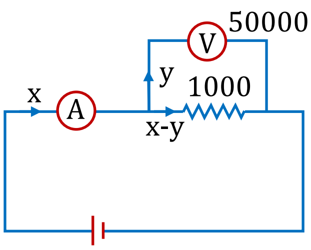
$0.1 = 2 \times 10^{-6}\,(10 + R_V)$

$\therefore \quad R_V = 49990\ \Omega$



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

$\therefore \quad R_A = 0.02\ \Omega$

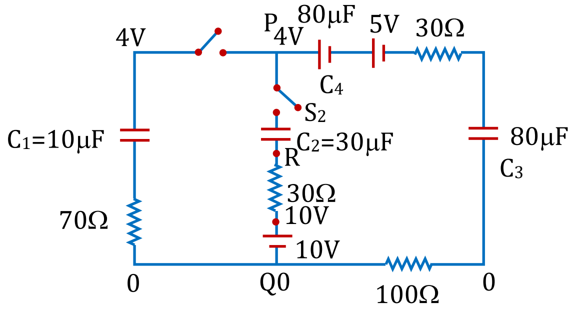


$y\,50000 = (x - y)\,1000$

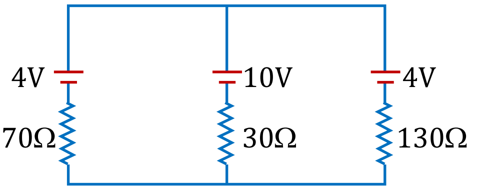
$\therefore \quad 51y = x$

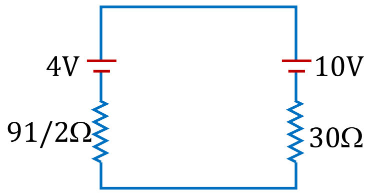
$$\text{Reading} = \frac{y50000}{x} \approx 980$$

15. Ans. (CD)



(1) At $t = 0$, capacitor C_1 acts as A battery of $4V$, C_4 *and* C_3 of each, C_2 is shorted circuit is



$\Rightarrow$ 

$$\Rightarrow i = \frac{6}{30+\frac{91}{2}} = 0.079A$$

(2) and (4)

At steady state, When capacitor is fully charged it behave as open circuit and current through it zero.

Hence, Charge on each capacitor is same.

$Q = C_{eq}\, V = (8\ \mu F) \times 5$

$Q = 40\ \mu C$

Now, $V_P - \frac{40}{10} = V_Q$

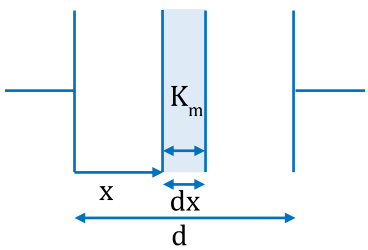
$\boxed{V_P - V_Q = 4V}$

(3) At $t = 0$, S_1 is closed, capacitor act as short circuit.

$$i = \frac{V}{R_{eq}} = \frac{5}{200} = 25mA$$

16. Ans. (0.99 to 1.01)

$\delta = dx = \frac{d}{N}$ and $\frac{m}{N} = \frac{x}{d}$



$K_m = K\left(1+\frac{m}{N}\right)$

$\Rightarrow \quad K_m = K\left(1+\frac{x}{d}\right)$

$C' = \frac{K_m A \in_0}{dx}$

$$\frac{1}{C_{eq}} = \int_0^d \frac{dx}{K_m A \in_0} = \frac{1}{KA \in_0} \int_0^d \frac{dx}{\left(1+\frac{x}{d}\right)}$$

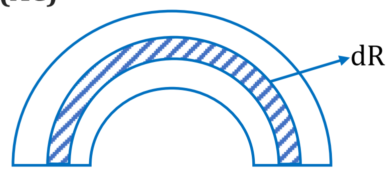
$$\Rightarrow \quad \frac{1}{C_{eq}} = \frac{d}{KA \in_0}\left[\ell n\left(1+\frac{x}{d}\right)\right]_0^d$$

$$\Rightarrow \quad \frac{1}{C_{eq}} = \frac{d}{KA \in_0}\left[\ell n 2 - \ell n(1)\right]$$

$$\Rightarrow \quad C_{eq} = \frac{KA \in_0}{d \ell n 2}$$

$\Rightarrow \quad \alpha = 1$

17. Ans. (AC)

(1) 

$$dR = \frac{\rho(\pi r)}{tdr}$$

$$\int \frac{1}{dR} = \int_{r_1}^{r_2} \frac{tdr}{\rho \pi r} = \frac{t}{\rho \pi} ln \frac{r_2}{r_1}$$

$$Correct\ v_0 = \frac{v_0}{Res} = v_0 \frac{t}{\rho \pi} ln \frac{r_2}{r_1}$$

(2) $$E = \frac{mv^2}{er} = \frac{-dv}{dr}$$

$$dv = -\left[\frac{mv^2}{er}\right] dr$$

$$Av = \frac{mv^2}{e} ln \frac{r_2}{r_1}$$

$$di = \frac{v_0}{\frac{\rho \pi r}{tdr}} = ne(tdr)\ (v_d)$$

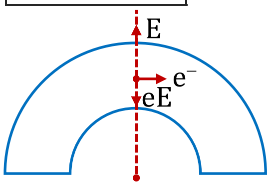
$$\frac{v_0(tdr)}{\rho \pi r} = ne(tdr)(v)$$

$$\boxed{vel = v = \frac{v_0}{ne\rho\pi r}}$$

$\Delta v = p.d. \propto v^2$

And $v \propto v_0$

$$\boxed{v = p.d \propto v_0^2}$$

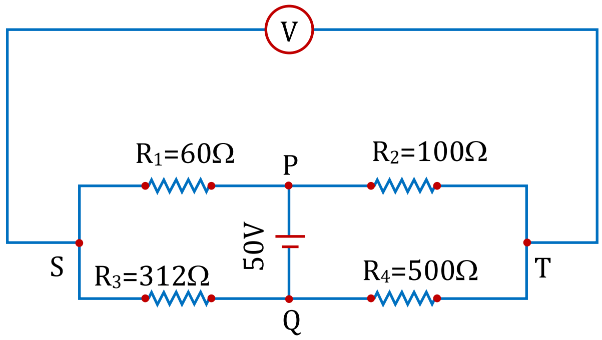
(4) 

Electrons are moving in circle so required centripetal force = $\frac{mv^2}{r} = eE$ so direction of electric filed is radially outward so inner layer is at higher potential.

18. Ans. (0.27)

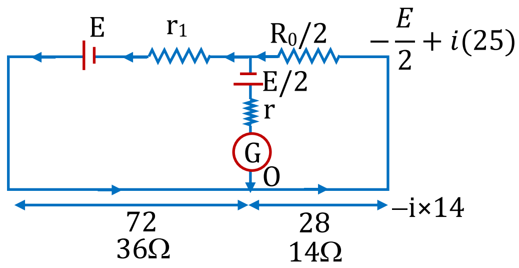
When temperature of R_3 is increased

$$R_3 = 300\,[1 + 0.004 \times 100]$$
$$= 312\ \Omega$$



$$I_1 = \frac{50}{312+60} = \frac{50}{372} A$$
$$I_2 = \frac{50}{600} = \frac{5}{60} A$$
$$V_S - V_Q = I_1 \times 312 = \frac{50}{372} \times 312$$
$$V_T - V_Q = I_2 \times 500 = \frac{5}{60} \times 500$$
$$V_S - V_T = \frac{50}{372} \times 312 - \frac{5}{60} \times 500 = 0.2688$$
$$V_S - V_T = 0.27$$

19. Ans. (3)



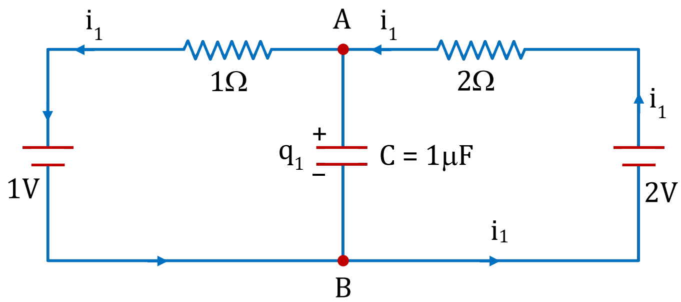
$$-\frac{E}{2} + i(25) = -i(14)$$
$$i(25 + 14) = \frac{E}{2}$$
$$\frac{39E}{r_1+75} = \frac{E}{2}$$
$$r_1 = 3\ \Omega$$

20. Ans. (1.33)

21. Ans. (0.67)

Solution for Question No. 20 and 21

Switch connected to position '*P*'

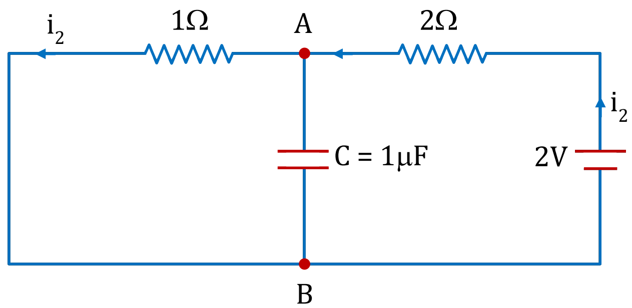


$$V_A - 1 \cdot i_1 - 1 + 2 - 2i_1 = V_A$$
$$3i_1 = 1$$
$$i_1 = \frac{1}{3} A$$
$$V_A - 1 \cdot i_1 - 1 = V_B$$
$$V_A - V_B = 1 + i_1 = \frac{4}{3} \text{ volt}$$

Potential drop across capacitor, $\Delta V = \frac{4}{3} volt$

$\therefore$ Charge on capacitor $q_1 = C\Delta V$

$$= 1 \times \frac{4}{3} \mu C$$
$$q_1 = 1.33\ \mu C$$



Switch at Position '*Q*'

$$V_A - 1 \cdot i_2 + 2 - 2i_2 = V_A$$
$$3i_2 = 2$$

$$i_2 = \frac{2}{3} A$$

$$V_A - i_2 \times 1 = V_B$$

$$V_A - V_B = i_2 \times 1 = \frac{2}{3} \text{ volt}$$

Potential difference across capacitor

$$\Delta V = \frac{2}{3} \text{ volt}$$

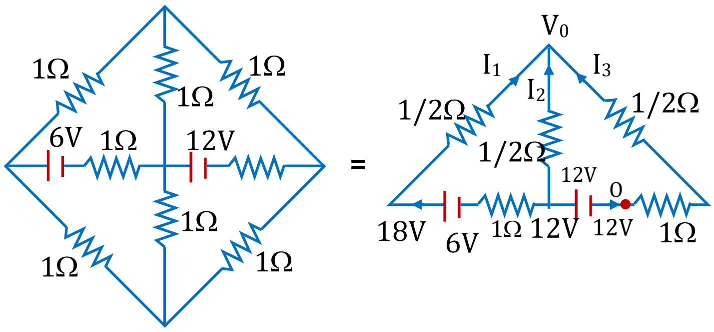
$\therefore$ Charge on capacitor $q_2 = C\Delta V$

$$= 1 \times \frac{2}{3} = 0.67 \mu C$$

22. Ans. (ABCD)

From *KCL*

$i_1 + i_2 + i_3 = 0$



$\Rightarrow \quad \frac{18 - V_0}{3/2} + \frac{12 - V_0}{1/2} + \frac{0 - V_0}{3/2} = 0$

$\Rightarrow \quad 18 - V_0 + 36 - 3V_0 - V_0 = 0$

$\Rightarrow \quad 54 = 5V_0$

$$I_{R_1} = \frac{36}{5} = 7.2A$$

$$I_{R_2} = \frac{6}{5} = 1.2A$$

$$I_{R_3} = \frac{24}{5} = 4.8A$$

$$I_{R_5} = \frac{12}{5} = 2.4A$$

23. Ans. (5)

For the balanced Wheatstone bridge

$$\frac{R_1}{R_2} = \frac{\int_0^{0.5} \frac{\rho dx}{\pi r_x^2}}{\int_{0.5}^{1} \frac{\rho dx}{\pi r_x^2}}$$

$$\frac{R_1}{R_2} = \frac{+\left[\frac{1}{r_x}\right]_0^{0.5}}{+\left[\frac{1}{r_x}\right]_{0.5}^{1}}$$

$\therefore \quad R_1 = 5R_2 = 5\Omega$

24. **Ans. (ABC)**

Case (I)

When both switches are open equivalent resistance in circuit 1

$$R_{C_1} = \frac{16}{11}\Omega$$

Equivalent resistance in circuit 2

$$R_{C_2} = \frac{6}{11}\Omega$$

For voltage source

$$P = \frac{V^2}{R}$$

$$P \propto \frac{1}{R}$$

$$R_{C_1} > R_{C_2}$$

$\Rightarrow$ $P_2 > P_1$ (Option (A) correct)

For constant current source

$P = i^2R$

$P \propto R$

$\Rightarrow$ $P_1 > P_2$ (Option (B) correct)

Case-II

When switch is closed

$$R'_{C_1} = \frac{5}{11}\Omega$$

$$R'_{C_2} = \frac{1}{2}\Omega$$

$$R'_{C_1} < R_{C_1}$$

For voltage source

$$P \propto \frac{1}{R} \Rightarrow Q_1 > P_1 \text{ (Option (C) correct)}$$

and $R'_{C_1} > R'_{C_2}$

For current source $P \propto R$

$Q_1 > Q_2$ (Option (D) also correct)

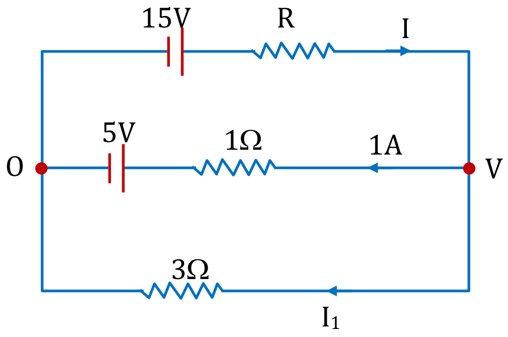
25. **Ans. (8)**

Potential difference across the terminals of C_3 is $2V$.

$\therefore$ $Q_3 = CV = (4\mu)(2) = 8\mu C$

26. Ans. (ABCD)

By writing voltage drop across 1Ω



⇒ $0 + 5 + 1 \times 1 = V$

$V = 6$

⇒ Similarly across R

$0 + 15 - I \times R = 6$

$IR = 9$

⇒ Across 3Ω

$6 - 3\,I_1 = 0$

$I_1 = 2A$

Hence option (B) is correct

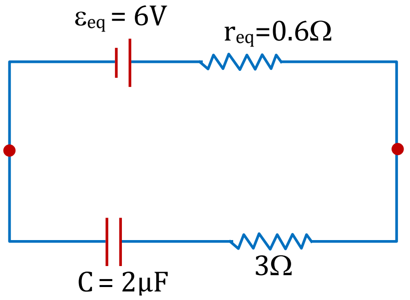
⇒ $I = 1 + 2$ (by KCL)

$I = 3$

$IR = 9$

$R = 3\Omega$

Option (A) is correct



$$\varepsilon = \frac{\frac{15}{3}+\frac{5}{1}+\frac{0}{3}}{\frac{1}{3}+\frac{1}{1}+\frac{1}{3}} = 10\times\frac{3}{5} = 6V$$

$q_{max} = 2 \times 6 = 12\mu C$

$$i = \frac{6}{3.6}e^{-\frac{t}{\tau}}$$

$$= \frac{5}{3}e^{-\frac{7.2}{7.2}} = \frac{5}{3}e^{-1} \approx 0.6A$$

27. Ans. (B)

In $t = 10$ sec volume of liquid is

$V = 2500\ cc$

$$h = \frac{2500}{50\times 5} = 10cm$$

$$C_d = \frac{A_d\varepsilon_0 k}{d}$$

$$= \frac{50\times10^{-2}\times10\times10^{-2}\varepsilon_0\times3}{5\times10^{-2}} = 3\varepsilon_0$$

$$C_a = \frac{A_a\varepsilon_0}{d} = \frac{50\times10^{-2}\times40\times10^{-2}\varepsilon_0}{5\times10^{-2}} = 4\varepsilon_0$$

$C = C_a + C_d = 7\varepsilon_0$

$= 7 \times 9 \times 10^{-12} = 63\ Pf$

JEE (Main) Practice Paper

SECTION–A

1. **Ans. (1)**

Equivalent resistance

$R_1 = \frac{r}{3}$

$R_2 = 3r$

$R_3 = r + \frac{r}{2} = \frac{3r}{2}$

$R_4 = \frac{(r)(2r)}{r+2r} = \frac{2r}{3}$

$\Rightarrow \quad R_2 > R_3 > R_4 > R_1$

We know,

$P = I^2R$

$P \propto R \quad (I \text{ same})$

$\Rightarrow P_2 > P_3 > P_4 > P_1$

2. **Ans. (1)**

Increase in cross-section area will not affect then ratio of $\left(\frac{R_1}{R_2}\right)$

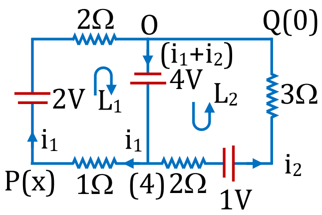
3. **Ans. (2)**

Loop 1 $\longrightarrow 4 - i_1 + 2 - 2i_1 = 0$

$i_1 = 2A$

$V_P + 2 - 2(2) = V_Q$

$V_P - V_Q = 2A$



4. **Ans. (2)**

$V \propto I^2$

$P \propto VI \propto I^3$

5. **Ans. (3)**

For balanced wheatstone bridge

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

(1) The above condition is independent of emf of cell, so if battery emf is increased the bridge will remain balanced.

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

(2) $\frac{R_1+10}{R_2+10} = \frac{R_3+10}{R_4+10}$

$\Rightarrow (R_1+10)(R_4+10) = (R_3+10)(R_2+10)$

$\Rightarrow R_1R_4 + 10(R_1+R_4) + 100 = R_2R_3 + 10(R_2+R_3) + 100$

This condition will not yield the balanced wheat stone bridge.

(3) $\frac{5R_1}{5R_2} = \frac{5R_3}{5R_4} \Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4}$

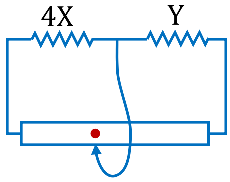
hence, condition remains same.

(4) If galvanometer and cell are interchanged.

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

Condition remains same.

6. Ans. (1)



$\left(\frac{X}{20}\right) = \left(\frac{Y}{80}\right) \Rightarrow \frac{X}{Y} = \frac{1}{4}$ ...(1)

$\frac{4X}{l} = \frac{Y}{100-l} \Rightarrow \frac{X}{Y} = \frac{l}{4(100-l)}$ ...(2)

From equation (1) and (2) $\Rightarrow \frac{1}{4} = \frac{l}{4(100-l)}$

$100 - l = l \Rightarrow l = 50cm$

Null point = 50 *cm* (Mid point)

7. Ans. (3)

For balanced meter bridge –

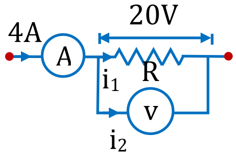
$$\frac{\ell_1}{100-\ell_1} = \frac{R}{S}$$

$$\Rightarrow \frac{2.9}{100-2.9} = \frac{R}{100} \Rightarrow R = 3\Omega$$

On improving accuracy the null point should be found near the middle of the meter bridge wire, i.e. both the known and unknown resistance should be nearly equal.

$$\frac{R}{S} = \frac{1}{1} \Rightarrow R = S = 3\Omega$$

8. Ans. (3)

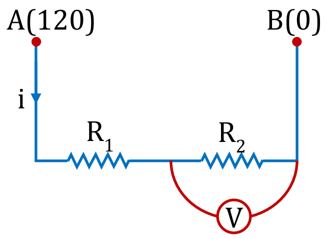


$R = \frac{V}{i_1} = \frac{20}{i_1}$

Since, voltmeter is non-ideal, so same current will also pass through it.

$$i_1 < 4A \Rightarrow \frac{20}{R} < 4 \Rightarrow R > 5\Omega$$

9. Ans. (1)



$R_{eq} = R_1 + R_2 \,||\, R_V$

$= 60 + 60 \,||\, 120 = 60 + \frac{60 \times 120}{60+120}$

$= 100\ \Omega$

$i = 1.2\ A$

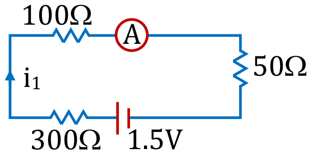
Voltmeter reading = $i\,(R_2 \,||\, R_V)$

$= 1.2\ (60 \,||\, 120)$

$= 1.2 \times 40 = 48\ V$

10. Ans. (3)

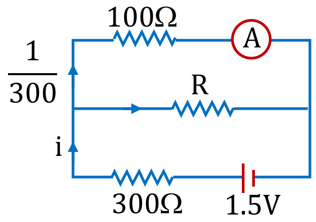
When both switch open



$$i_1 = \frac{1.5}{50+300+100} \Rightarrow i_1 = \frac{1}{300} Amp$$

When both switch closed

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



$$\Rightarrow \quad i = \frac{7}{6\times 300}$$

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

$$R\left(\frac{7}{6\times 300} - \frac{1}{300}\right) = \frac{1}{3}$$

$$R = 600\ \Omega$$

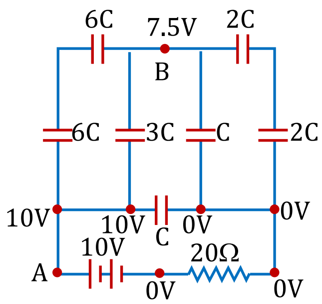
11. Ans. (1)

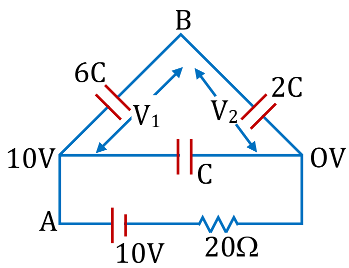
$$V = \frac{Q}{C}$$

$$V \propto \frac{1}{C}$$

$$\frac{V_1}{V_2} = \frac{C_2}{C_1} \Rightarrow \frac{V_1}{V_2} = \frac{2}{6} = \frac{1}{3}$$

$$\Rightarrow \quad V_1 = \frac{1}{4} \times 100 = 2.5V$$

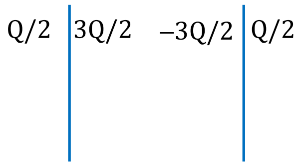




12. Ans. (2)

$$F = \frac{Q^2}{2A\varepsilon_0} = \frac{\left(5\times 10^{-6}\right)^2}{2\times 0.3\times 8.85\times 10^{-12}} \simeq 5N$$

13. Ans. (4)

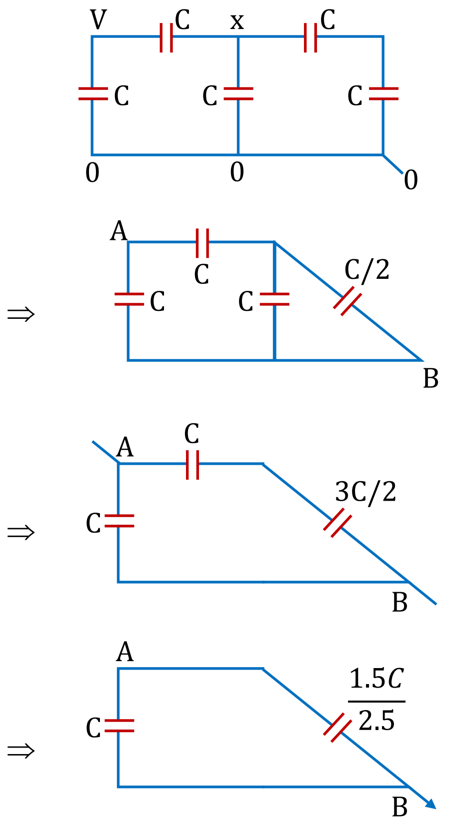


$$\Delta V = \frac{3Q}{2C}$$

$$U = \frac{\frac{1}{2}\left(\frac{3Q}{2}\right)^2}{C}$$

14. Ans. (2)

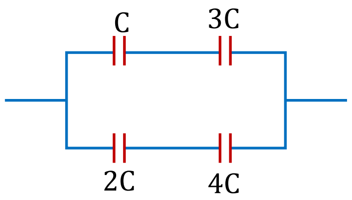
Solving the circuit using following steps



Resultant capacitance of the circuit = 1.6*C.*

15. Ans. (2)

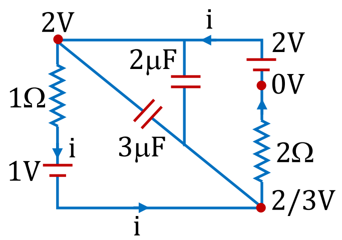
Let $\frac{\varepsilon_0 A}{2d} = C$ $\quad$ {Area = $A/2$}



$$C_{eq} = \frac{3C^2}{C+3C} + \frac{(2C)(4C)}{2C+4C}$$

$$= \frac{3}{4}C + \frac{4}{3}C = \frac{25}{24}\frac{\varepsilon_0 A}{d}$$

16. Ans. (2)

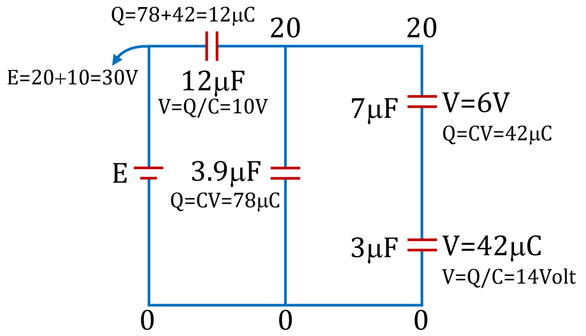


$$i = \frac{2-1}{3} = \frac{1}{3}$$

$$Q = \left(2 - \frac{2}{3}\right) \times 3$$

17. Ans. (3)

From the diagram



18. Ans. (4)

When capacitors are connected in series, charges is same but potential drop is different across the capacitors –

$$E = \frac{Q^2}{2C} \quad \Rightarrow \quad E \propto \frac{1}{C} \text{ (Q same)}$$

$\Rightarrow \quad Q > P$

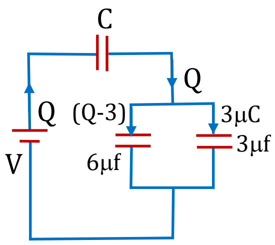
Now, capacitors charged separately using same battery

$$E = \frac{1}{2}CV^2$$

$\Rightarrow \quad E \propto C$ (v is same)

$\Rightarrow \quad R > S$

19. Ans. (3)



$$\Rightarrow \quad \frac{3}{3} = \frac{Q-3}{6} \Rightarrow Q-3=6 \Rightarrow Q = 9\mu c$$

20. Ans. (2)

Capacitance are

$$C_{AB} = \frac{\varepsilon_0 A}{\ell_1}, \; C_{BC} = \frac{\varepsilon_0 A}{\ell_2}$$

$$\ell_1 > \ell_2$$

$\Rightarrow \quad C_{BC} > C_{AB}$

Also,

$$C_{AB} = \frac{q_1}{V_{AB}}, \; C_{BC} = \frac{q_2}{V_{BC}}$$

But $\quad V_{AB} = V_{BC} \quad \Rightarrow \quad \frac{q_1}{V_{AB}} < \frac{q_2}{V_{BC}} \Rightarrow q_2 > q_1$

Hence, charge on C increases and on A decreases. Thus, attraction of B and C increases and that of A and B decreases.

So, net force will act towards right.

SECTION-B

1. Ans. (5)

$$\frac{3R}{4}\left(1+\alpha_{eff}\Delta T\right)=\frac{3R(1+2\alpha\Delta T)(1+\alpha\Delta T)}{3(1+2\alpha\Delta T)+(1+\alpha\Delta T)}$$

$$\frac{1}{4}\left(1+\alpha_{eff}\Delta T\right)=\frac{(1+3\alpha\Delta T)}{(4+7\alpha\Delta T)}$$

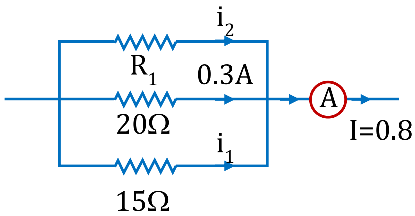
$$(1+\alpha_{\text{eff}}\Delta T)=\left(1+3\alpha\Delta T-\frac{7}{4}\alpha\Delta T\right)$$

$$\left(1+\alpha_{eff}\Delta T\right)=\left(1+\frac{5}{4}\alpha\Delta T\right)$$

2. Ans. (60)

$20\times 0.3 = 15\, i_1$

$$i_1=\frac{20\times 0.3}{15}=0.4A$$



$$I=i_1+0.3+i_2$$

$\Rightarrow \quad 0.8=0.4+0.3+i_2$

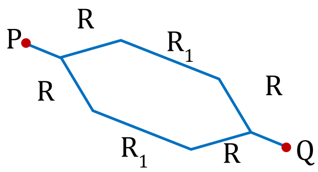
$\Rightarrow \quad i_2=0.1A$

$20\times 0.3=i_2\times R_1$

$\Rightarrow \quad R_1=\dfrac{6}{0.1}=60\Omega$

3. Ans. (1)

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



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

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

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

4. Ans. (12)

If an ideal voltmeter with very high resistance is connected in series, then whole potential will drop across it.

5. **Ans. (3)**

As the potential difference is constant hence we can say that

$Q_1 = 60\ \mu C = V \times C$ ...(1)

Now there is already 60 μC on the capacitor.

More 120 μC charge flows from battery.

Hence net charge on capacitor is

$Q_2 = 180\ \mu C = V \times KC$ ...(2)

(2) / (1) $\Rightarrow 3 = K$

6. **Ans. (7)**

Req = $\dfrac{3R \times R}{3R+R} + R = \dfrac{7R}{4}$

time constant (τ) = $\dfrac{7RC}{4}$

7. **Ans. (9)**

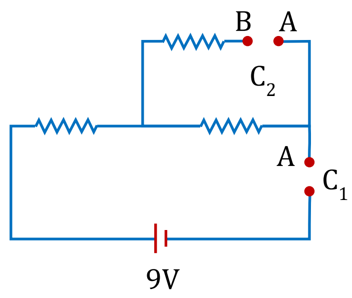
In steady state there will be no current in the circuit

P.d across $C_2 = 0$

So charge = 0

P.d across $C_1 = 9V$

$Q = 9\ \mu C$



8. **Ans. (2650)**

Using energy conservation –

$\frac{1}{2}mv^2 = eV$

$v = \sqrt{\dfrac{2eV}{m}} = \sqrt{\dfrac{2 \times 1.6 \times 10^{-19} \times 20}{9.11 \times 10^{-31}}}$ = $2.65 \times 10^6\ m/s$

9. **Ans. (27)**

When S open

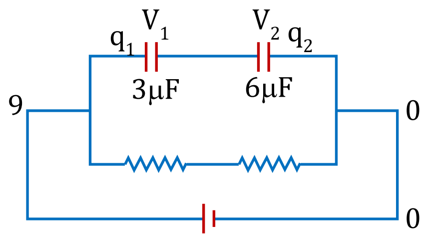
$q_1 = 18\mu f \Rightarrow q_2 = 18\mu f$

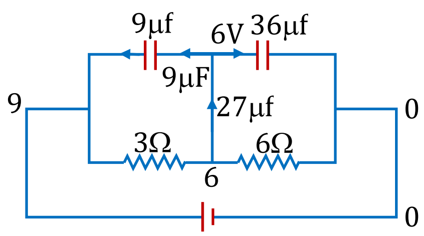
$V_1 : V_2 = \dfrac{1}{3} : \dfrac{1}{6}$

$V_1 : V_2 = 2 : 1$

$V_1 = \dfrac{2}{3} \times 9 = 6$ volt

$V_2 = 3$ volt





When S closed.

10. **Ans. (12)**

For loop ABEFGA

$15 = 3i_1 + 3\,(i_1 + i_2)$

$2i_1 + i_2 = 5$ ...(i)

for loop ABCDEFGA

$15 = Ri_2 + Ri_2 + R(i_1 + i_2)$

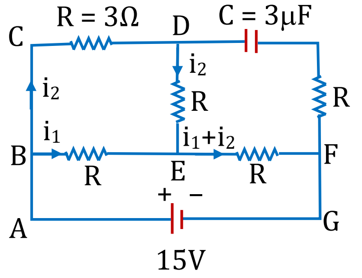
$\Rightarrow \quad i_1 + 3i_2 = 5$ ...(ii)

from (i) & (ii)

$i_1 = 2A\,,\ i_2 = 1A$

Potential stress 'C' = $V_{DF} = V_{DE} + V_{EF}$

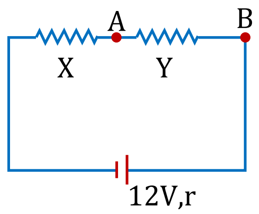
$V_C = Ri_2 + R\,(i_1+i_2) = 3(1) + 3(3) = 12\ V$



JEE (Advanced) Practice Paper

1. **Ans. (C)**

$i = \dfrac{12}{(r+X+Y)} = 1\ Amp.$



$(r + X + Y) = 12$

$V_X = 1V = iX = 1 \times X$

$X = 1\Omega$

$r + Y = 11$

Now, A and B are shorted

$V_X = iX$

$10 = \dfrac{12}{(X+r)}X$

$1 + r = \dfrac{6}{5}$

$r = \dfrac{1}{5}$

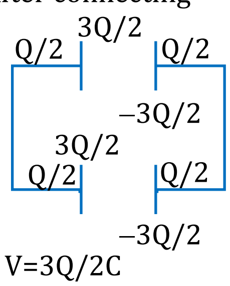
$r = 0.2\ \Omega$

2. **Ans. (C)**

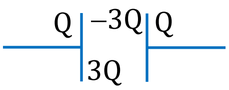
$$C = \frac{Q}{V} = \frac{Q}{\int_0^1 E.dx} = = \frac{Q}{\int_0^1 3Q(x^2+\frac{4}{3})} = \frac{1}{3\left[\frac{x^3}{3}+\frac{4}{3}\times\right]_0^1} = \frac{1}{5}$$

3. **Ans. (A)**

After connecting



Before connecting



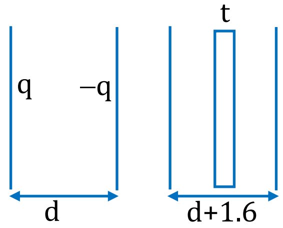
4. **Ans. (B)**

Charge will remain same & find potential is also same

From $q = cv \rightarrow c_1 = c_2$ ...(1)

$C_1 = \dfrac{\varepsilon_0 A}{d}$ (initial capacitance) ...(2)

$C_2 = \dfrac{\varepsilon_0 A}{(d+1.6) - t + \dfrac{t}{K}}$ ...(3)



$\dfrac{\varepsilon_0 A}{d} = \dfrac{\varepsilon_0 A}{d + 1.6 - 2 + \dfrac{2}{K}} \times \; t = 2mm$

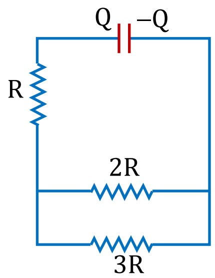
Companing both side

$1.6 - 2 + \dfrac{2}{K} = 0$

$K = 5$

5. **Ans. (C)**

$U = \dfrac{1}{2}\dfrac{(15)^2 \times 10^{-12}}{6 \times 10^{-6}} \times 55$ = 1031.25 μJ



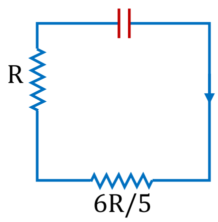
Energy in $\dfrac{6R}{5}$ is $\dfrac{U \times \dfrac{6R}{5}}{\dfrac{11R}{5}} = \dfrac{U \times 6}{11}$

Energy emitted in $3R$

$E = \dfrac{U \times 6}{11} \times \dfrac{\dfrac{6R}{5}}{3R}$

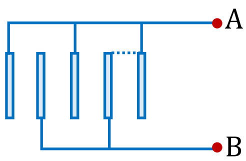
$= \dfrac{6U}{11} \times \dfrac{6}{15}$

$= 225 \times 10^{-6}\, J$



6. **Ans. (A)**

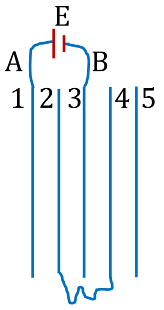
Each plate is taking part in the formation of two capacitors except the plates at the ends.

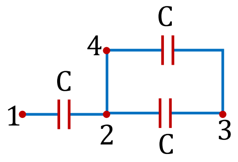


These capacitors are in parallel and n plates form $(n - 1)$ capacitors.

Thus, equivalent capacitance between A and B = $(n - 1)\, C$.

7. Ans. (B)

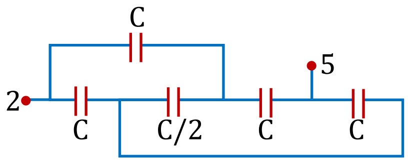




$$C_{eq} = \frac{2C \times C}{3C} = \frac{2\in_0 A}{3d}$$

$$Q = \frac{2}{3} \times \frac{\in_0 A}{d} \times E$$

8. Ans. (B)



Redraw the circuit $C_{eq} = C = \dfrac{\in_0 A}{d}$

9. Ans. (D)

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

10. Ans. (D)

$$P = \frac{dW}{dt} = i^2 R$$

$dW = i^2 Rdt$

Insulated wall ($\Delta Q = 0$)

$dW = -dU$

$dU = i^2 \times 100 \times 5 \times 60 = 30 \times 10^3$ Joule $= 30\ kJ$

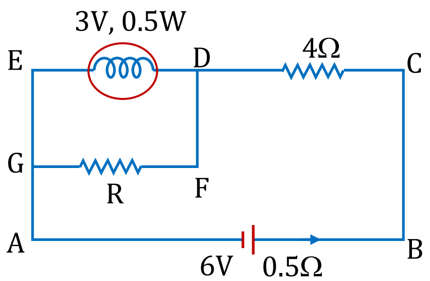
11. Ans. (B)

$$R_{Bulb} = \frac{V^2}{P} = \frac{(3)^2}{0.5} = 18\Omega$$

$V_{Bulb} = 3V$

$(i_{bulb}) \times 18 = 3$

$$i_{bulb} = \frac{1}{6}\text{Ampere}$$



Apply KVL in ABCDEGA

$+6 - 0.5\,i - 4i - V_{DE} = 0$

$V_{DE} = 3V$

$4.5\, i = 3$

$i = 2/3$ Ampere

$i = i_{bulb} + i_R$

$i_R = \frac{2}{3} - \frac{1}{6} = \frac{1}{2}$ Ampere

$V_R = i_R R$

$3 = \frac{1}{2} \times R$

$R = 6\Omega$

12. Ans. (BD)

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

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

Across 8Ω $E_{N.C} = 0$

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

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

Since, $\int_{loop} \vec{E}_C.\vec{d\ell} = 0$

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

$\therefore$ (B), (D)

13. Ans. (AC)

$R_{eq} = \left(\frac{8R}{8+R} + 2\right)$; $i = \frac{12}{R_{eq}}$

$P = i^2 R = \frac{12^2}{R_{eq}^2} \times 2 = \frac{12^2 \times 2}{R_{eq}^2}$

P_{max} when $R_{eq} \to$ min

14. Ans. (ABD)

Power is maximum when $r = R$

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

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

15. Ans. (5)

$\frac{R_1}{R_2} = \frac{0.4}{0.6} = \frac{2}{3} \Rightarrow R_1 = \frac{2R_2}{3}$

$R_1 = \frac{R_2 \times 10}{R_2 + 10} = \frac{2R_2}{3}$

16. Ans. (1)

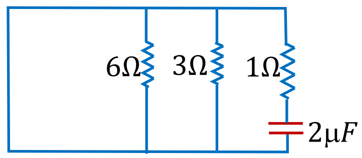
$P_1 = P_2$

$$\frac{V^2}{(R_1+r)^2}\cdot R_1 = \frac{V^2}{(R_2+r)^2}\cdot R_2$$

$R_1(R_2 + r)^2 = R_2(R_1 + r)^2$

17. Ans. (C)

(P)

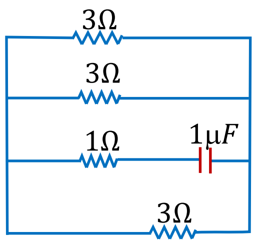


$R_{eq} = \frac{6\times 3}{6+3} + 1 = 3\Omega$

Time constant $(\tau) = R_{eq} \times C$

$= 3 \times 2 = 6\ \mu$ sec

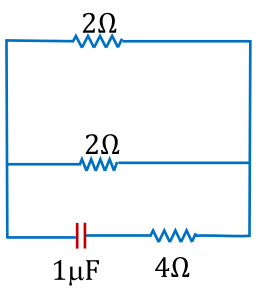
(Q)



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

Time constant $(\tau) = 2\times 1 = 2\ \mu s$

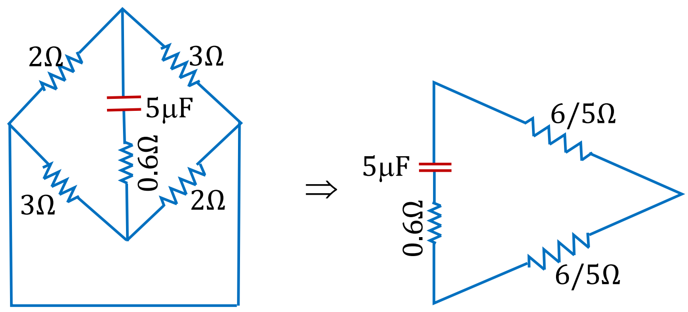
(R)



$R_{eq} = 1+4 = 5\ \Omega$

Time constant $(\tau) = 5\times 1 = 5\ \mu s$

(S)



$$R_{eq} = \frac{6}{5}+\frac{6}{5}+0.6=\frac{15}{5}=3\Omega$$

Time constant (τ) = $R_{eq} \times C$ = 3×5 = 15 μs

18. **Ans. (B)**

Potential gradient $X=\frac{V}{L}$

$E_2 = (X)\ell$

$$X=\left(\frac{V}{\ell}\right)=\frac{(E_1-iR)}{\ell}$$

(A) If $E_1\uparrow, X, \ell\downarrow$

(B) If $R\uparrow, X\downarrow, \ell\downarrow$

(C) If $E_2\uparrow, \ell\uparrow$

Important Notes

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