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ESE- 2018 (Prelims) - Offline Test Series Test-9

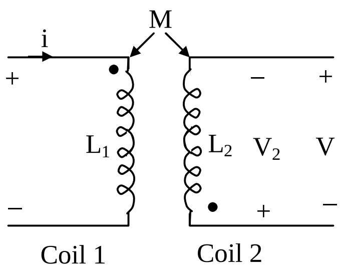
ELECTRICAL ENGINEERING

SUBJECT: ELECTRIC CIRCUITS AND FIELDS + MATERIAL SCIENCE SOLUTIONS

01. Ans: (a)

Sol: The dots indicate that when current entering the dotted terminal of one coil, voltage induced is positive at the dotted terminal of other coil.

Given circuit,



Here current entering the dotted terminal of coil 1.

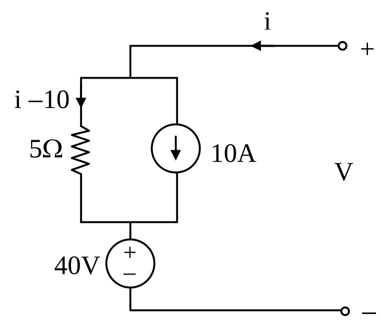
$\Rightarrow$ induced voltage is positive at the dotted terminal of coil2.

$\therefore V_2 = M\frac{di}{dt}$

But, $V = -V_2 = -M\frac{di}{dt}$

02. Ans: (c)

Sol: Given circuit,



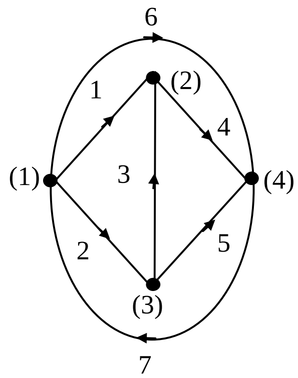
Applying KVL,

$\Rightarrow -V + 5(I - 10) + 40 = 0$

$\Rightarrow V = 5i - 10$

03. Ans: (c)

Sol: Given graph



Number of possible trees = $|[A_r][A_r]^T|$

Where,

$[A_r]$ is the reduced incidence matrix

Incidence matrix, for the given graph is

$$A = \begin{array}{c} \\ (1) \\ (2) \\ (3) \\ (4) \end{array}\begin{array}{c} \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{matrix} \\ \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 & -1 \\ -1 & 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 & -1 & -1 & 1 \end{bmatrix} \end{array}$$

By taking the (4) node as reference,

Reduced incidence matrix,

$$[A_r] = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 & -1 \\ -1 & 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$[A_r][A_r]^T$

$$= \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 & -1 \\ -1 & 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & -1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & 1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \\ -1 & 0 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 4 & -1 & -1 \\ -1 & 3 & -1 \\ -1 & -1 & 3 \end{bmatrix}$$

$$\therefore\ |[A_r][A_r]^T| = \begin{vmatrix} 4 & -1 & -1 \\ -1 & 3 & -1 \\ -1 & -1 & 3 \end{vmatrix}$$

$= 4(9 - 1) + 1(-3-1) - 1(1+3)$

$= 32 - 4 - 4 = 24$

$\therefore$ Number of possible trees = 24

04. Ans: (a)

Sol: Given networks,

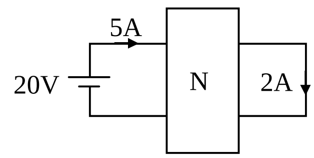


Fig.1

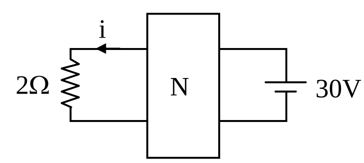
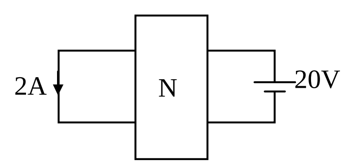


Fig.2

Applying reciprocity theorem to Fig (1)



By using linearity principle,

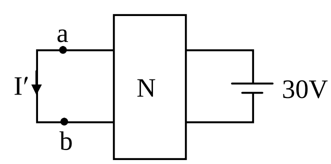


Fig.3

$$I' = \frac{30}{20} \times 2 = 3\text{ A}$$

With respect to the terminals a and b the short circuit current $I_{SC} = I' = 3$ A

Similarly with respect to the terminals a and b the Norton's equivalent resistance R_N is

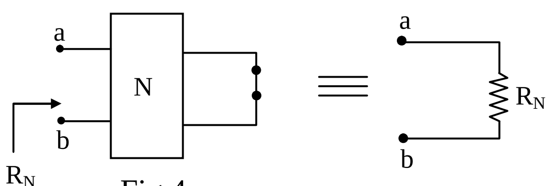
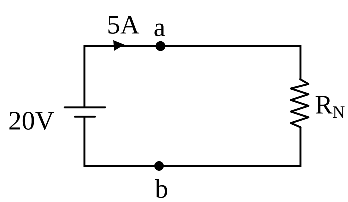


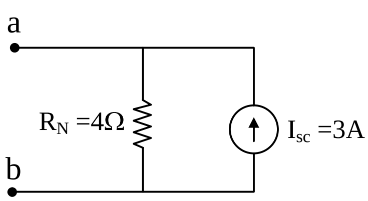
Fig.4

Fig (1) is the energized version of Fig. (4)

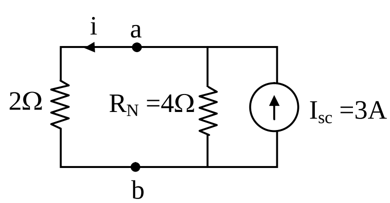


$$\Rightarrow R_N = \frac{20}{5} = 4\ \Omega$$

The Notron's equivalent of Fig. (3) with respect to terminals a and b is



Then the Fig. (2) becomes

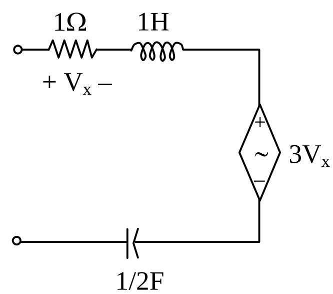


$$\Rightarrow i = I_{SC} \times \frac{4}{2+4}$$

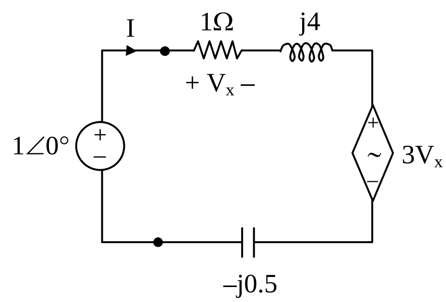
$$\Rightarrow i = 3 \times \frac{4}{6} = 2\text{ A}$$

05. Ans: (a)

Sol: Given network,



Assume a voltage source of value $1\angle 0^o$ having a frequency of 4 rad/sec is applied across the circuit then



$$\frac{V_x}{1} = I \Rightarrow I = V_x$$

Applying KVL in the loop,

$$\Rightarrow -1\angle 0^o + V_x + j3.5I + 3V_x = 0$$

$$\Rightarrow -1\angle 0^o + I + j3.5I + 3I = 0$$

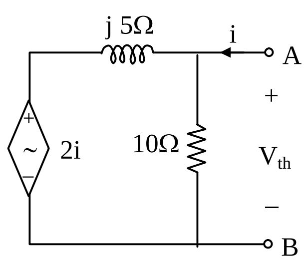
$$\Rightarrow I = \frac{1\angle 0^o}{4 + j3.5} = 0.1881\angle -41.185^o\text{ A}$$

$\therefore$ Circuit power factor = cos(41.185)

= 0.7525 lagging

06. Ans: (a)

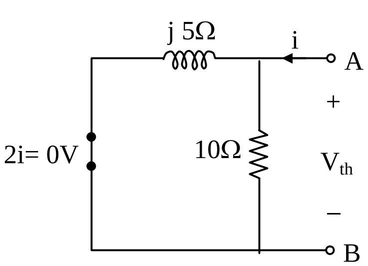
Sol: Given network,



When A and B terminals are open circuited

$\Rightarrow i = 0$

Then the equivalent network becomes

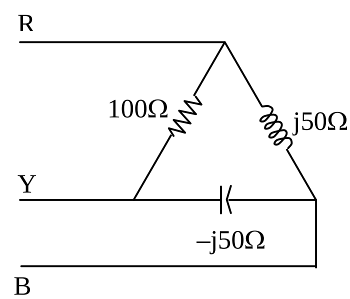


As there is no source to drive the above circuit

$\Rightarrow V_{th} = 0V$

07. Ans: (b)

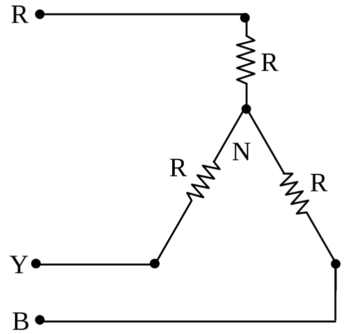
Sol: Given network,



Here the power is consumed only in the 100Ω resistor and its value is

$$P_D = \frac{V_{RY}^2}{100} \text{ …….. (1)}$$

Now connect a balanced star load, each of resistance value R as shown below



Power consumed $P_s = 3\frac{V_{RN}^2}{R}$

$$P_s = \frac{\left(\sqrt{3}V_{RN}\right)^2}{R} = \frac{V_{RY}^2}{R} \text{ .... (2)}$$

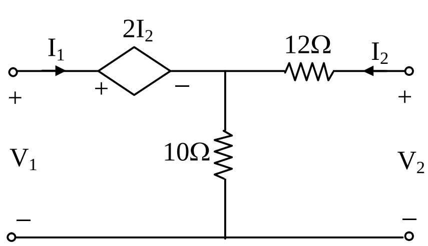
As (1) = (2)

$$\Rightarrow \frac{V_{RY}^2}{100} = \frac{V_{RY}^2}{R}$$

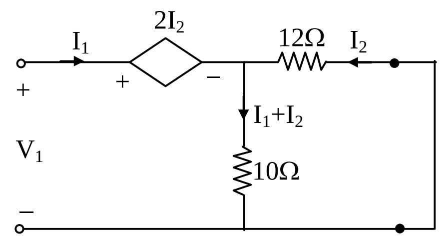
$\Rightarrow R = 100\Omega$

08. Ans: (d)

Sol: Given network,



$$D = \left.\frac{I_1}{-I_2}\right|_{V_2=0}$$



Applying KVL,

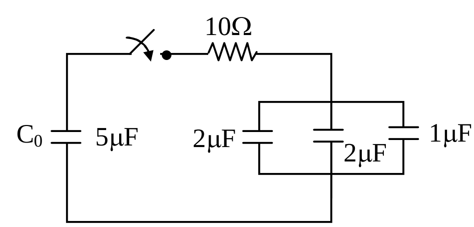
$\Rightarrow -10\,(I_1+I_2) - 12I_2 = 0 \Rightarrow -10\,I_1 = 22I_2$

$$\Rightarrow \frac{I_1}{-I_2} = 2.2$$

$\therefore D = 2.2$

09. Ans: (a)

Sol: Given network,

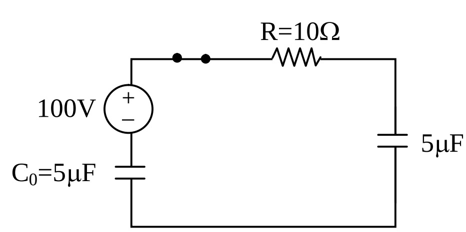


Initial charge in $C_0 = 500\mu C$

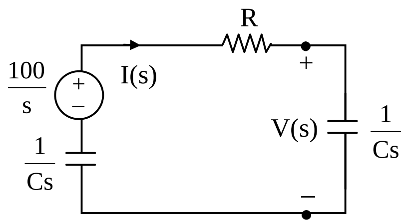
$\Rightarrow$ Initial voltage across capacitor C_0 is

$$V_0 = \frac{q}{C_0} = \frac{500\mu}{5\mu} = 100V$$

The equivalent, circuit after the switch is closed is



Convert into Laplace domain



$$\Rightarrow I(s) = \frac{100/s}{R + \frac{2}{Cs}}$$

$$I(s) = \frac{100}{R\left(s + \frac{2}{RC}\right)}$$

And $V(s) = \frac{1}{Cs} I(s)$

$$= \frac{1}{Cs} \cdot \frac{100}{R\left(s + \frac{2}{RC}\right)}$$

Steady state value of v(t) is = $\underset{s\to 0}{\text{Lt}}\ sV(s)$

$$= \underset{s\to 0}{\text{Lt}}\ s.\frac{100}{s(RCs+2)}$$

= 50V

∴ Steady state voltage across 1μF capacitor = 50V

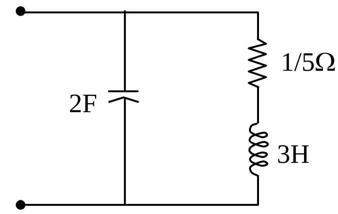
∴ Charge in the 1μF capacitor q = CV

= 1μ×50

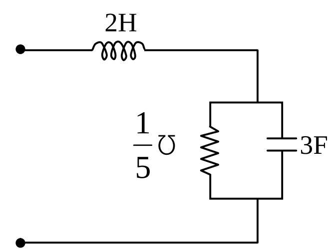
= 50 μC

10. Ans: (c)

Sol: Given network

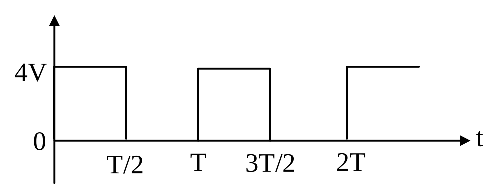


The dual of the above network is



11. Ans: (b)

Sol: The wave form is as shown below



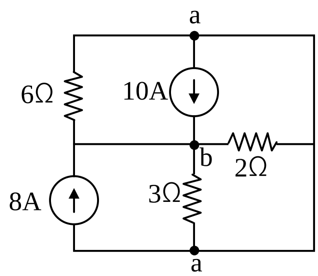
$$V_{rms}^2 = \frac{1}{T}\int_0^{T/2} (4)^2 dt$$

$$\Rightarrow V_{rms}^2 = \frac{1}{T} \times 16 \times T/2 = 8$$

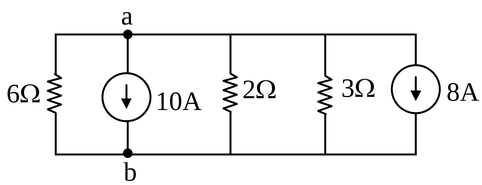
$$\Rightarrow V_{rms} = 2\sqrt{2}V$$

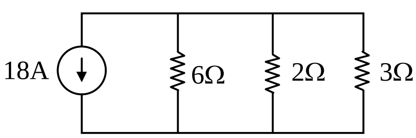
12. Ans: (b)

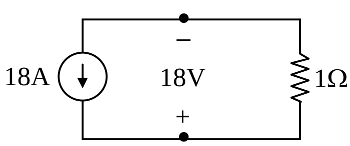
Sol: Given circuit



The above circuit can be redrawn as







$\Rightarrow$ Total power delivered by the sources = $18 \times 18 = 324W$

13. Ans: (d)

Sol: At the cut off frequency $I = \frac{I_m}{\sqrt{2}}$

$$\Rightarrow \frac{V}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{V}{\sqrt{2}R}$$

$$\Rightarrow \left(\omega L - \frac{1}{\omega C}\right)^2 = R^2 \Rightarrow \left(\omega L - \frac{1}{\omega C}\right) = \pm R$$

At the lower cut off frequency ω_1,

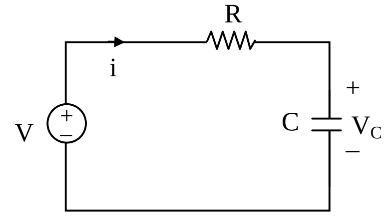
$$\omega_1 L < \frac{1}{\omega_1 C}$$

$$\therefore \omega_1 L - \frac{1}{\omega_1 C} = -R$$

$\Rightarrow$ Net reactance = –R

14. Ans: (a)

Sol:



Under steady state condition $V_c = V = 100V$

And $i(t) = \frac{V}{R} e^{-t/RC}$

Energy dissipated by the resistor

$$E_R = \int_0^\infty i^2 R \ dt$$

$$E_R = \int_0^\infty \frac{V^2}{R^2} e^{-2t/RC} . R \ dt$$

$$= \frac{V^2}{R}\left[\frac{e^{-2t/RC}}{-2/RC}\right]_0^\infty = \frac{-1}{2}CV^2[0-1] = \frac{1}{2}CV^2$$

$$\Rightarrow E_R = \frac{1}{2}CV^2$$

$$= \frac{1}{2} \times 1 \times 10^{-6} \times (100)^2 = 5mJ$$

15. Ans: (a)

Sol: We know, when two, 2-port networks are connected in parallel, their individual Y-parameters gets added.

$\therefore$ First, we need to convert given ABCD parameters to Y-parameters.

For 2-port network

Y-parameters are

$$\left.\begin{aligned} I_1 &= Y_{11}V_1 + Y_{12}V_2 \\ I_2 &= Y_{21}V_1 + Y_{22}V_2 \end{aligned}\right\} (1)$$

ABCD parameters

$$\left.\begin{aligned} V_1 &= AV_2 - BI_2 \\ I_1 &= CV_2 - DI_2 \end{aligned}\right\} (2)$$

Make $V_2 = 0$ to find Y_{11} & Y_{21}

Equation (2) becomes $V_1 = -BI_2$

$$I_1 = -DI_2$$

$$\therefore Y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0} = \frac{D}{B} \qquad Y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2=0} = \frac{-1}{B}$$

Similarly, $V_1 = 0$, to find Y_{12} & Y_{22}

$\therefore$ From equation (2) $AV_2 = BI_2$

$$\Rightarrow V_2 = \frac{B}{A}I_2$$

$$I_1 = CV_2 - DI_2$$

$$I_1 = C\frac{B}{A}I_2 - DI_2 = \frac{CB - DA}{A}I_2$$

$$I_1 = \frac{BC - AD}{A}I_2$$

But $I_2 = \frac{A}{B}V_2$

$$\Rightarrow I_1 = \frac{BC - AD}{A}\frac{A}{B}V_2$$

$$\Rightarrow I_1 = \left(\frac{BC - AD}{B}\right)V_2 \quad \ldots\ldots(3)$$

$$\therefore Y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0} = \frac{BC - AD}{B}$$

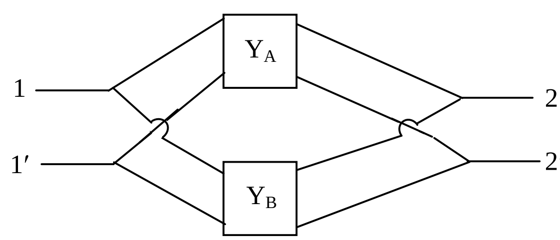
And $I_1 = \frac{BC - AD}{B}I_2$ put this value in equation (3)

$$\frac{BC - AD}{A}I_2 = \frac{BC - AD}{B}V_2$$

$$I_2 = \frac{A}{B}V_2 \Rightarrow Y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1=0} = \frac{A}{B}$$

Y-parameter matrix in terms of ABCD parameter is

$$Y_T = \begin{bmatrix} \frac{D}{B} & \frac{BC - AD}{B} \\ \frac{-1}{B} & \frac{A}{B} \end{bmatrix}$$



Y_T or $Y_{eq} = Y_A + Y_B$

$$= \begin{bmatrix} \frac{D}{B} & \frac{BC - AD}{B} \\ \frac{-1}{B} & \frac{A}{B} \end{bmatrix} + \begin{bmatrix} \frac{D}{B} & \frac{BC - AD}{B} \\ \frac{-1}{B} & \frac{A}{B} \end{bmatrix}$$

$$Y_T \text{ or } Y_{eq} = \begin{bmatrix} 2\frac{D}{B} & 2\frac{(BC-AD)}{B} \\ \frac{-2}{B} & \frac{2A}{B} \end{bmatrix}$$

Now, again connect back to ABCD parameters

$$\left.\begin{aligned} I_1 &= \frac{2D}{B}V_1 + 2\frac{(BC-AD)}{B}V_2 \\ I_2 &= -\frac{2}{B}V_1 + \frac{2A}{B}V_2 \end{aligned}\right\} (4)$$

Make $V_2 = 0$ $\quad I_1 = \frac{2D}{B}V_1$

$$I_2 = -\frac{2}{B}V_1$$

$$B_T = -\left.\frac{V_1}{I_2}\right|_{V_2=0} = \frac{B}{2} = 0.5B$$

$$D_T = -\left.\frac{I_1}{I_2}\right|_{V_2=0} = \frac{2D/B}{2/B} = D$$

Make $I_2 = 0$, equation (4) becomes

$$V_1 = AV_2 \ \& \ I_1 = \frac{2D}{B}V_1 + 2\frac{(BC-AD)}{B}V_2$$

$$= \frac{2D}{B}AV_2 + \frac{(2BC-2AD)}{B}V_2$$

$$= \left(\frac{2AD+2BC-2AD}{B}\right)V_2$$

$I_1 = 2CV_2$

$$\therefore A_T = \frac{V_1}{V_2} = A$$

$$C_T = \frac{I_1}{V_2} = 2C$$

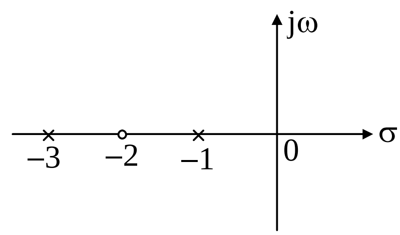
$$[T] = \begin{bmatrix} A_T & B_T \\ C_T & D_T \end{bmatrix} = \begin{bmatrix} A & 0.5B \\ 2C & D \end{bmatrix}$$

16. Ans: (c)

Sol: Given network function

$$F(s) = \frac{(s+2)}{(s+1)(s+3)}$$

The pole zero pattern for the above network function is as shown below



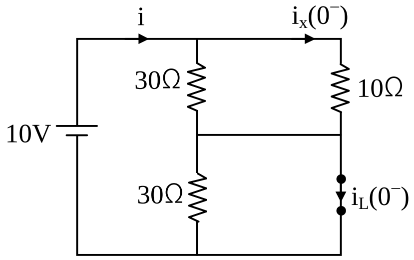
As we can see from above pole zero plot poles and zeros alternate on negative real axis and nearest to the origin is a pole.

$\therefore$ It can be realized as RC impedance function or RL admittance function.

17. Ans: (a)

Sol: Assume the circuit is in steady state before the switch opens.

$\Rightarrow$ The inductor will acts as short circuit. Then the circuit at $t= 0^-$ is



Equivalent resistance seen by the 10V voltage source is = 30 || 10

$$= \frac{30\times10}{40} = 7.5\ \Omega$$

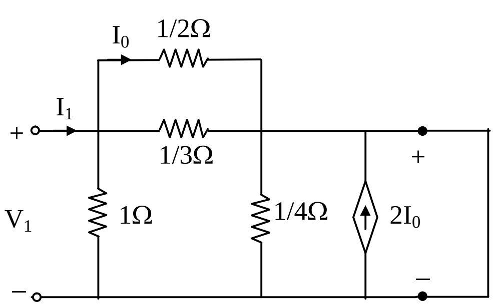
$$\Rightarrow i = \frac{10}{7.5} = \frac{4}{3}\text{ A}$$

$$\therefore i_x(0^-) = i\times\frac{30}{40}$$

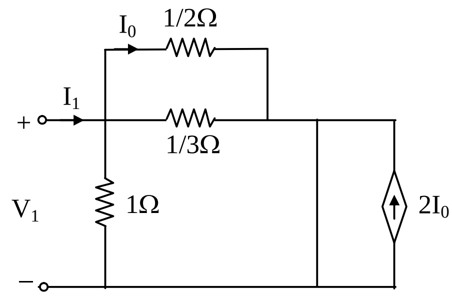
$$= \frac{4}{3}\times\frac{3}{4} = 1\text{ A}$$

18. Ans: (a)

Sol: $Y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0}$



The equivalent network becomes



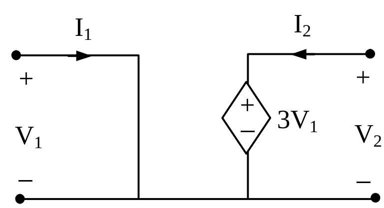
Equivalent resistance seen by the port 1 is =

$$1 \parallel \frac{1}{2} \parallel \frac{1}{3} = \frac{1}{6}\ \Omega$$

$$\Rightarrow V_1 = \frac{1}{6}\ I_1 \Rightarrow \frac{I_1}{V_1} = 6\mho \Rightarrow Y_{11} = 6\mho$$

19. Ans: (d)

Sol: Given network



As we are unable to write I_1 interms of V_1 and V_2 therefore Y parameters doesn't exist.

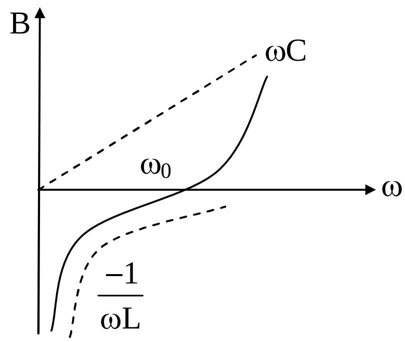
20. Ans: (a)

Sol: For parallel resonant circuit,

Admittance, $Y = \frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right)$

Susceptance B = $\omega C - \frac{1}{\omega L}$

The plot of susceptance is as shown below

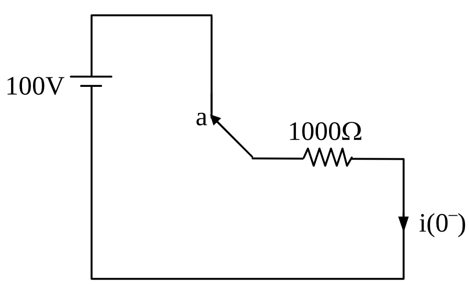


21. Ans: (c)

Sol: Assume the circuit is in steady state before the switch is changed from a to b

$\Rightarrow$ inductor will acts as short circuit.

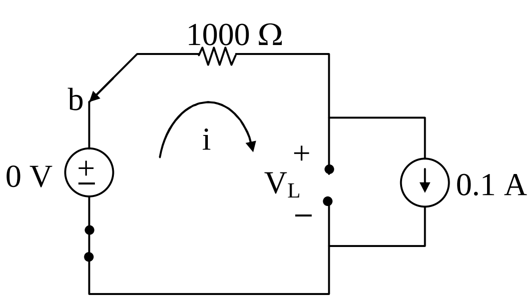
Then the circuit is



$\Rightarrow i(0^-) = \frac{100}{1000} = 0.1\,A$

And initial voltage across the capacitor is $V_C(0^-) = 0$ V

At t= 0^+ the equivalent circuit is



$\Rightarrow V_L$ at t = 0^+ is = –100

$\Rightarrow L\frac{di}{dt} = -100 \Rightarrow \frac{di}{dt} = -100$

$\therefore \frac{di}{dt}$ at t = 0^+ is = –100 A/sec.

22. Ans: (b)

Sol: For

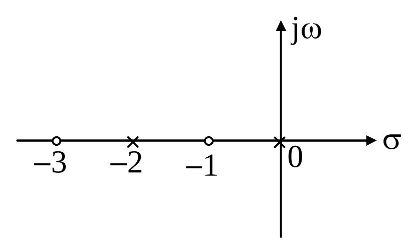
RC driving point impedance function
RC driving point admittance function
RL driving point impedance function
RL driving point admittance function

→ Poles and zeros should alternate only on negative real axis

23. Ans: (b)

Sol: Given $Z(S) = \frac{(s+1)(s+3)}{s(s+2)}$

The pole zero pattern is as shown below

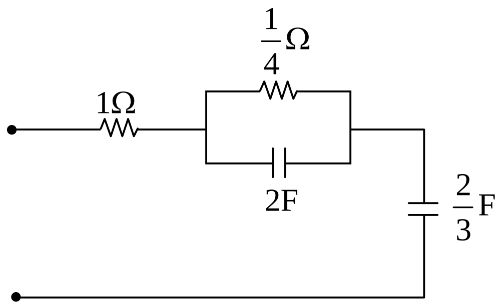


As we can see the poles and zeros alternate on negative real axis and nearest to the origin is a pole.

$\therefore$ It can be realized as RC driving point impedance

$$Z(S) = 1 + \frac{2s+3}{s(s+2)} = 1 + \frac{3/2}{s} + \frac{1/2}{s+2}$$

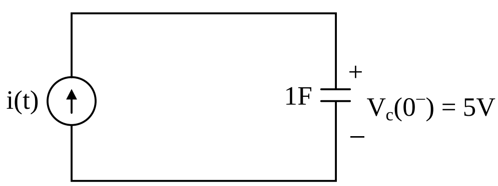
The network for the above impedance function is as shown below



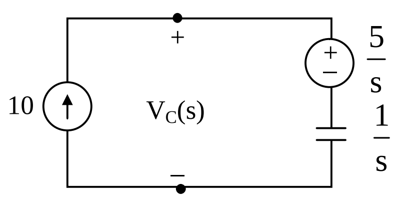
∴ Two energy storage elements are present.

24. Ans: (d)

Sol: At t= 0^+ the circuit is



Convert into Laplace domain



$$\Rightarrow V_C(s) = \frac{5}{s} + \frac{1}{s} \times 10 = \frac{15}{s}$$

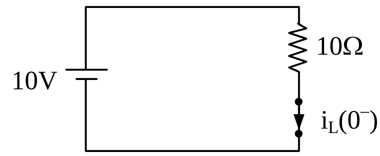
$\Rightarrow v_C(t) = 15\, u(t)$

At t= 0^+ $\Rightarrow u(t=0^+) = 1$

$\Rightarrow v_C(0^+) = 15$ V

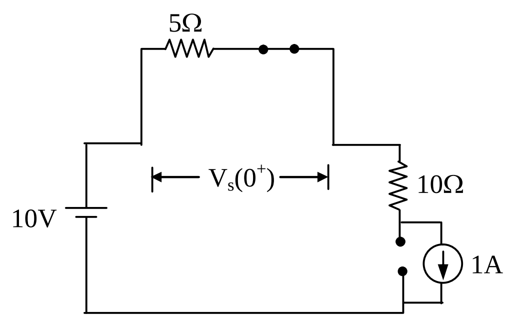
25. Ans: (b)

Sol: The equivalent network at t=0^- is



$$\Rightarrow i_L(0^-) = \frac{10}{10} = 1\text{A}$$

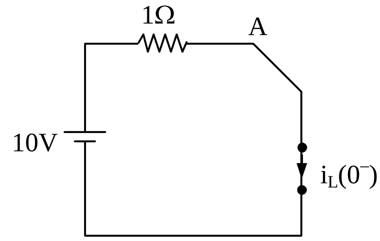
At t= 0^+ the network is



$\Rightarrow V_S(t = 0^+) = 5 \times 1 = 5$V

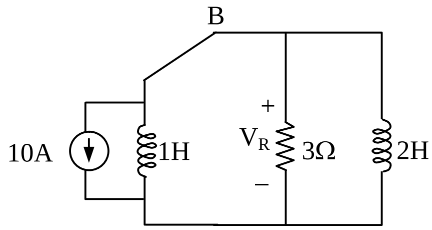
26. Ans: (d)

Sol: At t = 0^- the network is

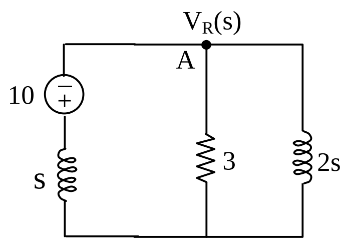


$$\Rightarrow i_L(0^-) = \frac{10}{1} = 10\text{A}$$

At t= 0^+ the network is



Convert the above circuit into Laplace domain



Applying KCL at node 'A'

$$\Rightarrow \frac{V_R(s)+10}{s}+\frac{V_R(s)}{3}+\frac{V_R(s)}{2s}=0$$

$$\Rightarrow V_R(s)\left[\frac{3}{2s}+\frac{1}{3}\right]=-\frac{10}{s}$$

$$\Rightarrow V_R(s) = \frac{-30}{s+\frac{9}{2}} \Rightarrow v_R(t) = -30\,e^{-4.5\,t}$$

As $t \to \infty \Rightarrow V_R(t) = 0V$

27. Ans: (a)

Sol: Statement-1 is correct because in case of charged bodies of arbitrary shape, it is difficult to find the actual distance between them.

Statement-2 is incorrect as Coulomb's law is valid only when the point charges are at rest.

28. Ans: (b)

Sol:

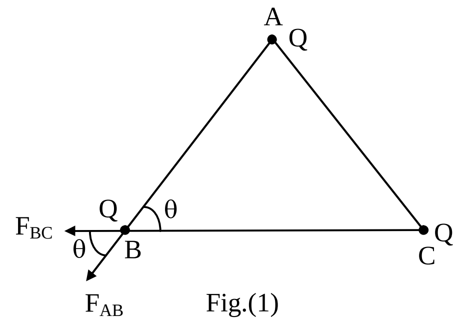


Fig.(1)

Consider string AB, the net force on string AB is given as,

$$F = F_{AB} + F_{BC}\cos\theta$$

Where,

$$F_{AB} = F_{BC} = \frac{Q^2}{4\pi\varepsilon_0 a^2} \text{ and } \theta = 60°$$

$$\Rightarrow F = \frac{Q^2}{4\pi\varepsilon_0 a^2}(1+\cos 60°)$$

$$= \frac{Q^2}{4\pi\varepsilon_0 a^2}\left(1+\frac{1}{2}\right)$$

$$= \frac{3Q^2}{8\pi\varepsilon_0 a^2} \text{ …….. (1)}$$

For string AB to break due to electrostatic force,

$F \geq 3$

From equation -1,

$$\frac{3Q^2}{8\pi\varepsilon_0 a^2} \geq 3 \Rightarrow Q^2 \geq 8\pi\varepsilon_0 a^2$$

or, $Q_{min} = \sqrt{8\pi\varepsilon_0}\ a$,

29. Ans: (d)

Sol: Given data, H_1 = 2A/m

Let, I be the current in the loop and a be the radius of the loop, then H at the centre of the loop is given as,

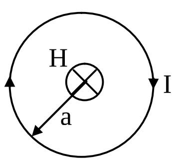


Fig.(1)

$$H = \frac{I}{2a}\,A/m \Rightarrow H\alpha\frac{I}{a}$$

$$\Rightarrow \frac{H_2}{H_1} = \left(\frac{I_2}{I_1}\right)\left(\frac{a_1}{a_2}\right)$$

$$\because I_2 = 2I_1 \;\&\; a_2 = \frac{a_1}{2} \Rightarrow H_2 = 2\times 2\times H_1 = 4H_1$$

$$\Rightarrow H_2 = 4\times 2 = 8A/m$$

30. Ans: (a)

Sol: Given data,

$$\vec{J} = kx\;\hat{a}_x - 5y\,\hat{a}_y$$

Then for a steady current i.e, charge entering and leaving a cross-section of the conductor to be equal at any time,

$$\nabla.\vec{J} = 0$$

{Continuity equation, $\nabla.\vec{J} = -\frac{\partial \rho_v}{\partial t}$

but ρ_v = constant}

$$\Rightarrow \left(\frac{\partial}{\partial x}\hat{a}_x + \frac{\partial}{\partial y}\hat{a}_y + \frac{\partial}{\partial z}\hat{a}_y\right).\left(kx\,\hat{a}_x - 5y\,\hat{a}_y\right) = 0$$

k–5 =0⇒ k = 5

31. Ans: (c)

Sol: 1. $\nabla.(\nabla \times \vec{A}) \equiv 0$ (correct)

i.e, divergence of curl of a vector is always zero.

2. $\nabla \times (\nabla.V) \equiv 0$ (correct) i.e; curl of gradient of a scalar is always zero.

3. $\int_S (\nabla \times \vec{A})\overrightarrow{ds} = \oint_L \vec{A}.\overrightarrow{d\ell}$ (correct)

The above expression is the Stoke's theorem which says that closed line integral of a vector is equal to the surface integral of the curl of that vector.

4. $\int_V (\nabla \times \vec{A})dv = \oiint_S \vec{A}.\overrightarrow{ds}$ (incorrect)

Gauss's diversion theorems is given as,

$\int_V (\nabla.\vec{A})dv = \oiint_S \vec{A}.\overrightarrow{ds}$

Which says that closed surface integral of a vector is equal to the volume integral of the diversion of that vector.

32. Ans: (b)

Sol: Electric flux:

According to Gauss's law, the surface integral of the electric field intensity gives the amount of electric flux.

$$\oint \vec{E}.\overrightarrow{ds} = \frac{q}{\varepsilon_0} = \phi_{electrical}$$

$$\Rightarrow \text{unit of } \phi_e = \frac{\text{Coulombs}}{\text{Coulombs}^2 / \text{Newton} - \text{meter}^2}$$

= Newton-meter^2/Coulombs.

33. Ans: (c)

Sol: Statement-1 is correct

For a linear dielectric

Polarization (P) $\propto$ E (Electric field)

$\Rightarrow P = \chi_e E$

χ_e is susceptablity (constant for a linear dielectric)

A capacitor with a linear dielectric has capacitance independent of the charge on the plates and their potential difference, rather the capacitance is equal to the ratio of the charge on the plate to that of the potential difference between them. $C = \frac{Q}{V}$

Statement-2 is correct

As the capacitor is connected to battery, hence voltage 'V' is fixed.

Let Q_d and Q_a be the charge on the plates for dielectric and air case, then,

$$\frac{Q_d}{Q_a} = \frac{C_d V}{C_a V} = \frac{C_d}{C_a} = \frac{\varepsilon_0 \varepsilon_r A}{d} \times \frac{d}{\varepsilon_0 A}$$

$$= \varepsilon_r$$

$\because Q_d = 2Q_a$

$\Rightarrow \varepsilon_r = 2$

But, $\varepsilon_r = 1 + \chi_e = 2$

$\Rightarrow \chi_e = 1$

34. Ans: (b)

Sol:

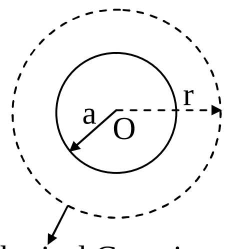


Fig. 1

Applying Gauss's law,

$$\oint \vec{D}.\vec{ds} = Q_{enclosed}$$

$$D(4\pi r^2) = \rho\frac{4}{3}\pi a^3$$

$$\Rightarrow D = \frac{\rho a^3}{3r^2}$$

At the surface of the sphere, r = a

$$\Rightarrow D = \frac{\rho a}{3}$$

35. Ans: (d)

Sol: Statement -1 is correct as angle between $\vec{r}$ and $\nabla\times\vec{r}$ is 90^o, therefore,

$$\vec{r}.(\nabla\times\vec{r}) = 0$$

Statement -2 is correct as

$$\nabla.\vec{r} = \left(\frac{\partial}{\partial x}\hat{a}_x + \frac{\partial}{\partial x}\hat{a}_y + \frac{\partial}{\partial x}\hat{a}_z\right).\left(x\hat{a}_x + y\hat{a}_y + z\hat{a}_z\right)$$

$$\Rightarrow \nabla.\vec{r} = 3$$

Statement – 3 is correct as,

$$\nabla.(\vec{r}.\vec{r}) = \left(\frac{\partial}{\partial x}\hat{a}_x + \frac{\partial}{\partial x}\hat{a}_y + \frac{\partial}{\partial x}\hat{a}_z\right).\left(x^2 + y^2 + z^2\right)$$

$$= 2x\hat{a}_x + 2y\hat{a}_y + 2z\hat{a}_z$$

$$= 2(x\hat{a}_x + y\hat{a}_y + z\hat{a}_z)$$

$$= 2\vec{r}$$

Statement-4 is correct as, angle between ∇ and $\nabla\times\vec{r}$ is 90^o

Therefore,

$$\nabla.(\nabla\times\vec{r}) = 0$$

36. Ans: (d)

Sol: As the sphere is conducting and has potential 0 on its surface (grounded)

Hence, $V_A = V_B = 0$

Where, V_A and V_B are the potential at points A and B due to q and q′, hence

For $V_A = 0$

$$\Rightarrow \frac{q}{4\pi\varepsilon_0(d-a)} + \frac{q'}{4\pi\varepsilon_0(a-b)} = 0 \quad \text{......... (1)}$$

For $V_B = 0$,

$$\Rightarrow \frac{q}{4\pi\varepsilon_0(d+a)} + \frac{q'}{4\pi\varepsilon_0(a+b)} = 0 \quad \text{........ (2)}$$

$$\text{Eqn (1)} \Rightarrow q' = -q\frac{(a-b)}{(d-a)}$$

$$\text{Eqn (2)} \Rightarrow q' = -q\frac{(a+b)}{(d+a)}$$

$$\Rightarrow \frac{a-b}{d-a} = \frac{a+b}{d+a}$$

$ad + a^2 - bd - ab = ad - a^2 + bd - ab$

$\Rightarrow 2a^2 = 2bd \Rightarrow a^2 = bd$

$$\Rightarrow b = \frac{a^2}{d} \quad \text{......... (3)}$$

Then, $q' = \dfrac{-q\left(a - \dfrac{a^2}{d}\right)}{(d-a)} = \dfrac{-qa\left(\dfrac{d-a}{d}\right)}{(d-a)}$

$\Rightarrow q' = -\dfrac{qa}{d}$ ………… (4)

37. Ans: (a)

Sol: Ionic polarization takes place by displacement of cations and anions. It is independent of temperature

$\alpha_i = \dfrac{e^2}{\omega^2 m}$

Ionic Polarizability is inversely proportional to the square of natural frequency (ω)

38. Ans: (b)

Sol: Polarization (P) = $\varepsilon_0(\varepsilon_r - 1)E$

$= 8.854 \times 10^{-12} \times (8-1) \times 10 \times 10^3$

$= 6.2 \times 10^{-7}$

39. Ans: (b)

Sol: If the radius X = 0.155, a more stable configuration is possible with three anions bonding with cation. This form a stable structure only upto an X value of 0.225 for 0.155 < X < 0.225 the anions do not touch each other.

40. Ans: (c)

41. Ans: (a)

42. Ans: (b)

Sol: $\rho = \dfrac{1}{ne\mu} \Rightarrow \mu = \dfrac{1}{ne\rho}$

$= \dfrac{1}{6\times10^{28}\times1.6\times10^{-19}\times1.54\times10^{-8}}$

$= 6.76 \times 10^{-3}$ m^2/V-s

43. Ans: (c)

Sol: $H_C = H_0\left[1-\left(\dfrac{T}{T_C}\right)^2\right]$

$\mathbf{1} \times 10^5 = 2 \times 10^5\left[1-\left(\dfrac{8}{T_C}\right)^2\right]$

$\dfrac{1\times10^5}{2\times10^5} = 1-\left(\dfrac{8}{T_c}\right)^2$

$\dfrac{1\times10^5}{2\times10^5} + \left(\dfrac{8}{T_c}\right)^2 = 1$

$\dfrac{64}{T_c^2} + 0.5 = 1 \Rightarrow T_c^2 = \dfrac{64}{0.5}$

$T_C = 11.31$ K

44. Ans: (b)

Sol: $J_c = \dfrac{i_C}{A} = \dfrac{H_C \times 2\pi R}{\pi R^2} = \dfrac{2H_C}{R}$

45. Ans: (a)

Sol: Based on F.London and H.London research, magnetic flux density is allowed by super conductor up to some layers from the surface.

London penetration depth: It is the depth from the surface of super conductor upto which flux density is decreased by 63%.

$$B = B_0 e^{\frac{-X}{\lambda_L}}$$

B = Flux density at a depth 'X'

B_0 = flux density at surface of super conductor

λ_L = London penetration depth

46. Ans: (d)

Sol: Hall angle $\tan\theta_H = \mu B = 0.041\times0.1 = 0.0041$

$\theta_H = \tan^{-1}(0.0041)$

$\theta_H = 0.2349$

47. Ans: (a)

48. Ans: (c)

Sol: Total magnetic moment $= N \times i \times A$

$= 500 \times 20 \times 10^{-3} \times \pi\,(2 \times 10^{-2})^2$

$= 500 \times 20 \times 10^{-3} \times 4\pi \times 10^{-4}$

$= 4\pi \times 10^{-3}$ A-m^2

49. Ans: (a)

Sol: Magnetic flux density (b) = 88×10^{-4} Wb/m^2

Field strength (H) = 100 A/m

$$\mu_R = \frac{\mu}{\mu_0} = \frac{B}{H\mu_0}$$

$$= \frac{88\times10^{-4}}{100\times4\pi\times10^{-7}} = 70$$

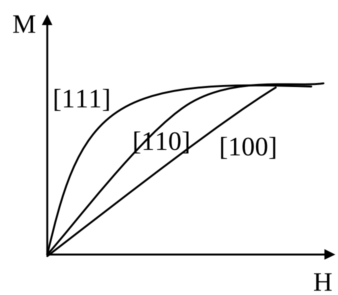
50. Ans: (a)

Sol: The hysteresis loop of ferromagnetic material depends on

1. Temperature
2. Crystallographic imperfection
3. Cold working

51. Ans: (a)

Sol:



52. Ans: (b)

Sol: Magneto rheological materials has the ability to increase viscosity drastically with applied field.

53. Ans: (a)

54. Ans: (c)

55. Ans: (d)

56. Ans: (a)

Sol: Wiess-Domain Theory: Based on Wiess Domain theory in a domain all the dipoles are aligned in a particular direction. If the magnetic field is applied Domain growth takes place in the field direction and at higher field, inside domain dipole relation takes place.

57. Ans: (a)

Sol: Output voltage $= t \times g \times p$

$= 2\times10^{-3}\times0.055\times1.25\times10^{6}$

$= 137.5$ V

58. Ans: (d)

Sol: Ga-As compound is a zinc blende structure

59. Ans: (b)

Sol: $\sqrt{2}\,a = 4R$

$$a = \frac{4R}{\sqrt{2}}$$

$$d_{111} = \frac{a}{\sqrt{h^2+k^2+\ell^2}}$$

$$= \frac{4\left(0.128\times10^{-9}\right)}{\sqrt{2}\times\sqrt{1^2+1^2+1^2}} = 2\ \text{A}^{o}$$

60. Ans: (d)

Sol: $X \to 1 \qquad (-1, 2, \infty)$

$Y \to 2 \qquad \left(\frac{-1}{1}, \frac{1}{2}, \frac{1}{\infty}\right) = \left(\bar{2}10\right)$

$Z \to \infty$

61. Ans: (d)

Sol: The bullet proof jocket is made up of aramid fiber reinforced polymer (AFRB) with reinforcement phase is Aramid and matrix phase is polymer.

62. Ans: (d)

Sol: The bonding in ceramics is predominantly ionic, it consists of anions and cations. The crystal structure of ceramics is influenced by the radius ratios of the ions. The coordination number depends on the radius of the bonding ions. Ceramics are classified according to their crystal structure as AX, AX_2, ABX_3 and AB_2X_4 types.

Examples under each type are given below:

AX : NaCl, CsCl, Zns

AX_2: SiO_2, CaF_2, PuO_2, ThO_2

ABX_3: $BaTiO_3$, $SrZrO_3$, $SrSnO_3$

AB_2X_4: $MgAl_2O_4$, $FeAl_2O_4$

63. Ans: (c)

Sol: If the temperature of metal increases, the lattice vibration in the crystal structure increases. Hence collision frequency increases and relaxation time decreases. Due to that resistivity of metal increases.

64. Ans: (c)

Sol: Ceramics have high melting point and can with stand high temperature.

65. Ans: (b)

Sol: Laplacian equation

$\nabla^2 V = 0 \rightarrow$ (1)

But we know, $\nabla^2 V = -\frac{\rho_V}{\varepsilon}$ from Poisson's equation

Therefore Laplacian equation is true for charge free region where $\rho_V = 0$

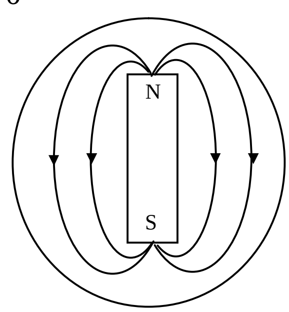
Every physical problem must contain atleast one conducting boundary but may contain more than one.

Solution of Laplace's equation with two different methods (valid methods) lead to same solution. Since E field is harmonic (conservative).

66. Ans: (d)

Sol: **Statement I** is incorrect as

$\int_S \overline{B} \,.\, ds \neq 0$



Maxwell equation: $\oint B.ds = 0$

i.e., net flux leaving closed surface is zero.

When surface is open

$\int B.ds = \psi_m \rightarrow$ weber

Statement II is correct as

Tubes of magnetic flux have no source (or) sink i.e. monopoles do not exist in case of magnetic field.

67. Ans: (a)

Sol: õ When AC field is applied to a dielectric material, then dielectric constant of material is no longer real

It is having both real part as well as imaginary part

$\varepsilon_r = \varepsilon_r' - j\,\varepsilon_r''$

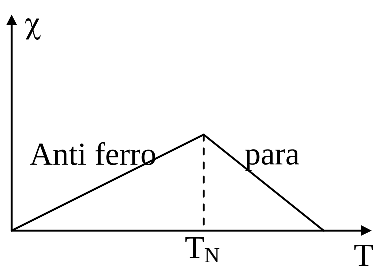
$j\varepsilon_{r''}$ part (Imaginary part) of ε_r is due to power loss in material.

- When AC field is applied to dielectric material, ε_r becomes complex quantity as a result power loss in dielectric material.

68. Ans: (b)

Sol: The antiferro magnetic material depends on Neel's law

$$\chi = \frac{C}{T - T_N}$$



69. Ans: (d)

Sol: Impressed voltage V = (100 – j90) V

Current I = (3 – j4) A

Complex power, $S = V I^*$

= (100 – j90) (3 + j4) = (660 + j130) VA

∴ Real power = 660 W ∴ Statement (I) is false.

70. Ans: (b)

71. Ans: (d)

Sol: Equivalent network obtained from Δ - Y transformation relation is valid for any frequency.

So statement (I) is false.

72. Ans: (b)

73. Ans: (b)

Sol: Poly crystal materials are stronger than single crystal material because they require more stresses to initiate slip and yielding. Poly crystalline materials there are many preferred planes and direction for different grains due to their random orientation.

74. Ans: (a)

Sol: $BaTiO_3$ crystal is Ferroelectric material upto 120°C, due to non-centro symmetric (asymmetric) structure. But above 120°C it become centro-symmetric and hence it looses its ferroelectric character.

75. Ans: (d)

Sol: **Statement I** is incorrect

because when there is no charge inside the conductor the electric field inside a conductor is zero not infinity.

Statement II is correct as

Gauss law: Electric flux leaving any closed surface is equal to the charge enclosed.

In case of a conductor as the charge enclosed by any closed surface inside a conductor is zero hence there should not be any electric field inside the conductor.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3 EE
4 EE HARSHIT KUMAR SINGH
5 EE NIKHIL KUMAR
6 EE DUSHYANT SINGH
8 EE APOORVA GUPTA
9 EE KIRAN BABU KONERU
7 IN TOP 10 RANKS
ME
3 ME SAURABH
4 ME AMIT KUMAR RAI
6 ME ANKAN GUPTA
7 ME DHRUW JHA
9 ME ACHARAJ GUPTA
5 IN TOP 10 RANKS
7 All India 1st Rank in ESE.
and many more...
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