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Detailed Solutions

ISRO

ELECTRICAL ENGINEERING

Written Test of Scientist/Engineer Examination

Date of Test : 12-01-2020

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ISRO (Scientist/Engineer) Examination
Electrical Engineering : Paper Analysis
Exam held on 12.01.2020

Sl.	Subjects	No. of Qs.	Level of Difficulty
1.	Power Systems	6	Easy
2.	Communication Systems	1	Easy
3.	Electrical Machines	7	Easy
4.	Control Systems	4	Easy
5.	Signals & Systems	6	Easy
6.	Digital Electronics	1	Easy
7.	Analog Electronics	7	Easy
8.	Electrical & Electronic Measurements	3	Easy
9.	Engineering Mathematics	7	Easy
10.	Power Electronics	1	Easy
11.	Electromagnetic Theory	27	Easy
12.	Electric Circuits	10	Easy

Q.1 A 50 MHz uniform plane wave is propagating in a material with relative permeability and relative permittivity as 2.25 and 1 respectively. The material is assumed to be loss less. Find the phase constant of the wave propagation.

(a) π rad/m
(b) $\frac{\pi}{4}$ rad/m
(c) $\frac{\pi}{2}$ rad/m
(d) 2π rad/m

Ans. **(c)**

$$f = 50 \times 10^6 \text{ Hz}$$
$$\mu_r = 2.25$$
$$\epsilon_r = 1$$
$$\sigma = 0 \quad \text{(loss less)}$$

Find β

$$v_P = \frac{C}{\sqrt{\mu_r \epsilon_r}} = \frac{\omega}{\beta}$$

$$\frac{3\times10^8}{\sqrt{2.25}} = \frac{2\pi(50\times10^6)}{\beta}$$

$$\beta = \frac{\pi\times10^8\sqrt{2.25}}{3\times10^8} = \frac{\pi}{2} \text{ rad/m}$$

End of Solution

Q.2 A non-magnetic lossy dielectric material with relative permittivity $\varepsilon_r = 2.25$ and conductivity $\sigma = 10^{-4}$ mho/m is applied with electromagnetic wave of 2.5 MHz. What is the loss tangent?

(a) 0.32
(b) 3.13
(c) 11.11
(d) None of the above

Ans. **(a)**

Non-magnetic, $\mu_r = 1$

Lossy dielectric ($\sigma \neq 0$)

$$\sigma = 10^{-4} \text{ (℧/m)}$$
$$\epsilon_r = 2.25$$
$$f = 2.5 \times 10^6 \text{ Hz}$$

$$\text{loss tangent} = \tan\delta = \frac{\sigma}{\omega\varepsilon}$$

$$= \frac{10^{-4}}{2\pi(2.5\times10^6)\left(\frac{1}{36\pi}\times10^{-9}\right)(2.25)}$$

$$= \frac{18(10^{-1})}{(2.5)(2.25)} = 0.32$$

End of Solution

Q.3 A solid conductor with relative permeability $\mu_r = 200$, conductivity $\sigma = 5 \times 10^6$ mho/m having outer dia 8 mm and length 2 mm. If the total current carried by the conductor is $i(t) = 2\cos(\pi 10^4 t)$ A. Find the skin depth.

(a) 2.25 mm
(b) 0.225 mm
(c) 0.16 mm
(d) 1.60 mm

Ans. **(b)**

$$\mu_r = 200$$
$$\sigma = 5 \times 10^6 \ (\mho/\text{m})$$
$$i(t) = 2\cos(\pi 10^4 t)$$
$$\omega = 10^4 \pi$$

$$\Rightarrow \quad f = \frac{1}{2}(10^4)$$

$$\delta = \frac{1}{\sqrt{\pi \frac{1}{2}(10^4)(4\pi \times 10^{-7})(200)(5 \times 10^6)}}$$

$$= \frac{1}{\sqrt{2\pi^2(10^6)}} = \frac{10^{-3}}{\sqrt{2}\pi} = 0.225 \text{ mm}$$

End of Solution

Q.4 A uniform plane wave at the boundary of an overhead transmission line and underground cable has reflection coefficient: γ. The standing wave ratio is

(a) $\frac{(1-\gamma)}{(1+\gamma)}$
(b) $\frac{(1-|\gamma|)}{(1+|\gamma|)}$
(c) $\frac{(1+|\gamma|)}{(1-|\gamma|)}$
(d) $\frac{(1+\gamma^2)}{(1-\gamma)}$

Ans. **(c)**

$$\text{SWR} = \frac{1+|\gamma|}{1-|\gamma|}$$

End of Solution

Q.5 Working principle of thermo-couple is

(a) Seeback effect
(b) Hall effect
(c) Faraday's law
(d) None of the above

Ans. **(a)**

Thermo-couple works on the principle of 'seeback effect".

End of Solution

Q.6 Which of the following represents a stable system?

(a) Impulse response of the system increases exponentially.
(b) Area within the impulse response is infinite.
(c) Roots of the characteristic equation of the system are real and negative.
(d) None of the above

Ans. (c)

Roots of 1 + $G(s)$ $H(s)$ = 0 should be –ve.

End of Solution

Q.7 Of following transfer function of second order linear time-invariant systems, the under damped system is represented by?

(a) $H(s)=\frac{1}{s^2+4s+4}$ (b) $H(s)=\frac{1}{s^2+5s+4}$

(c) $H(s)=\frac{1}{s^2+4.5s+4}$ (d) $H(s)=\frac{1}{s^2+3s+4}$

Ans. (d)

$b^2 - 4ac < 0 \Rightarrow$ underdamped

[9 – 16 = –7]

End of Solution

Q.8 Which of the following measures cannot be effective in reducing the noise?

(a) Reduction in signalling rate (b) Increase in transmitted power
(c) Increase in channel bandwidth (d) None of the above

Ans. (c)

End of Solution

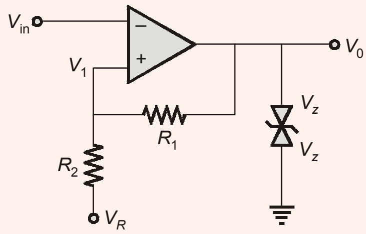
Q.9 Assuming leakage flux to be negligible, when HV side of a single-phase 100 V/50 V, 50 Hz transformer is connected to 50 V, 25 Hz AC source, the core flux of the transformer is

(a) same as that of rated flux (b) half that of the rated flux
(c) twice that of the rated flux (d) four times that of the rated flux

Ans. (a)

End of Solution

Q.10 The Schmitt trigger circuit shown in the figure below uses Zener diode with V_d = 0.7 V. If the threshold voltage V_1 is zero and hysteresis voltage V_H = 0.2 V, then what is R_1/R_2 and V_R?



(a) R_1/R_2 = 67 and V_R = 0.15 V
(b) R_1/R_2 = 67 and V_R = –0.15 V
(c) R_1/R_2 = 66 and V_R = –0.10 V
(d) R_1/R_2 = 66 and V_R = –0.15 V

Ans. (c)

$$V_H = V_{UTP} - V_{LTP}$$

$$= V_R \times \frac{R_1}{R_1+R_2} + V_0 \times \frac{R_2}{R_1+R_2} - \left[V_R \times \frac{R_1}{R_1+R_2} - V_0 \times \frac{R_2}{R_1+R_2}\right]$$

$$= 2V_{sat} \times \frac{R_2}{R_1+R_2} = 0.2$$

$$2V_{sat} \times \frac{1}{1+\frac{R_1}{R_2}} = 0.2$$

Assume, $V_2 = 6$ V

$$2 \times [V_Z + V_D] \times \frac{1}{1+\frac{R_1}{R_2}} = 0.2$$

$$2 \times 6.7 \times \frac{1}{1+\frac{R_1}{R_2}} = 0.2$$

$$67 = 1 + \frac{R_1}{R_2}$$

$$\frac{R_1}{R_2} = 66$$

$$V_1\,(\text{Threshold}) = V_R \times \frac{R_1}{R_1+R_2} + V_D \times \frac{R_2}{R_1+R_2}$$

$$0 = V_R \times \frac{R_1}{R_1+R_2} + V_{sat} \times \frac{R_2}{R_1+R_2}$$

$$\frac{V_R \times R_1}{R_1+R_2} = -V_{sat} \times \frac{R_2}{R_1+R_2}$$

$$V_R = -V_{sat} \times \frac{R_2}{R_1} = -6.7 \times \frac{1}{6} = -0.10 \text{ V}$$

End of Solution

Q.11 For a given relation $\sqrt{1-x^2}+\sqrt{1-y^2}=P(x-y)$, where P is a constant, the value of dy/dx at point (0, 0) is

(a) –1
(b) 0
(c) 1
(d) –2

Ans. (c)

$$\sqrt{1-x^2}+\sqrt{1-y^2} = P(x-y)$$

$$f(x,\ y) = \sqrt{1-x^2}+\sqrt{1-y^2}-P(x-y)=0$$

$$f_x = \frac{1}{\sqrt{1-x^2}}(-x)-P$$

$$f_y = \frac{1}{2\sqrt{1-y^2}}(-2y)+P$$

$$\frac{dy}{dx} = \frac{-f_x}{f_y} = \frac{\dfrac{x}{\sqrt{1-x^2}}+P}{\dfrac{-y}{\sqrt{1-y^2}}+P}$$

At (0, 0),
$$\frac{dy}{dx} = \frac{P}{P}=1$$

End of Solution

Q.12 The integral $\int_0^1\int_0^{x^2}(x^2+y^2)\,dx\,dy$ equals to

(a) $\frac{26}{105}$
(b) $\frac{4}{105}$
(c) $\frac{12}{105}$
(d) $\frac{16}{105}$

Ans. (a)

$$\int_0^1\int_0^{x^2}(x^2+y^2)dx\,dy = \int_0^1\left[x^2y+\frac{y^3}{3}\right]_0^{x^2}dx$$

$$= \int_0^1\left[x^4+\frac{x^6}{3}\right]dx=\left[\frac{x^5}{5}+\frac{x^7}{21}\right]_0^1$$

$$= \frac{1}{5}+\frac{1}{21}=\frac{26}{105}$$

End of Solution

Q.13 An open-loop system represented by the transfer function, $G(s) = \dfrac{(s-1)}{(s+2)(s+3)}$ is

(a) stable and of the minimum phase type
(b) stable and of the non-minimum phase type
(c) unstable and of the minimum phase type
(d) unstable and of the non-minimum phase type

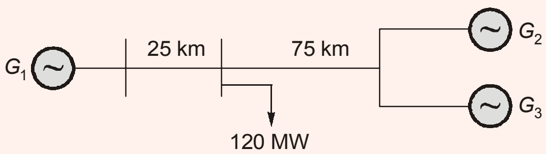
Ans. (b)

$$\text{C.L.T.F.} = \frac{\dfrac{s-1}{(s+2)(s+3)}}{1+\dfrac{s-1}{(s+2)(s+3)}} = \frac{s-1}{s^2+5s+6}$$

(Stable and non-minimum phase)

End of Solution

Q.14 A load center of 120 MW derives power from two power stations connected by 220 kV transmission lines of 25 km and 75 km as shown in figure below. The three generators G_1, G_2 and G_3 are of 100 MW capacity each and have identical fuel cost characteristics. The minimum loss generation schedule for supplying the 120 MW load is



(a) P_1 = 90 MW
P_2 = 15 MW
P_3 = 15 MW

(b) P_1 = 80 MW
P_2 = 20 MW
P_3 = 20 MW

(c) P_1 = 60 MW
P_2 = 30 MW
P_3 = 30 MW

(d) P_1 = 40 MW
P_2 = 40 MW
P_3 = 40 MW

Ans. (a)

For minimum loss, higher power should come from shorter distance accordingly the correct answer is option (a) in which 90 mW comes from 25 km and 30 mW comes from 75 cm.

End of Solution

Q.15 A capacitor is made with a polymeric dielectric having a relative permittivity ε_r of 2.26 and a dielectric breakdown strength of 50 kV/cm. The permittivity of free space is 8.85 pF/m. If the rectangular plates of the capacitor have a width of 20 cm and a length of 40 cm, then the maximum electric charge in the capacitor is

(a) 2 μC
(b) 4 μC
(c) 8 μC
(d) 10 μC

Ans. (c)

Given dielectric has $\epsilon_r = 2.26$

$$E_{BD} = 50 \times 10^5 \text{ (V/m)}$$

$$\text{Area of the plate} = A = (20 \times 10^{-2})(40 \times 10^{-2}) = 8 \times 10^{-2} \text{ m}^2$$

in the capacitor, $E = \frac{\rho_S}{\epsilon} = \frac{Q}{A\epsilon}$

$$E_{BD} = \frac{Q_{BD}}{A\epsilon}$$

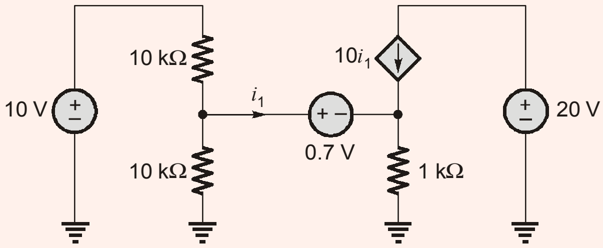
$$\Rightarrow \quad Q_{BD} = E_{BD} A\epsilon$$

$$Q_{BD} = 50 \times 10^5 (8 \times 10^{-2})(8.85 \times 10^{-12})(2.26)$$

$$= 8 \times 10^{-6} \text{ C} = 8 \text{ μC}$$

End of Solution

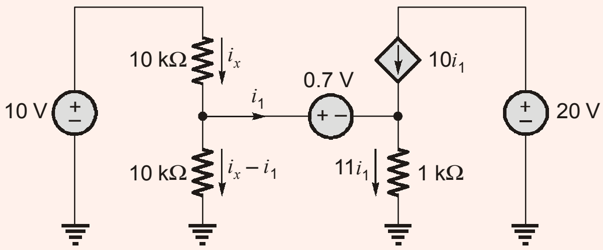
Q.16 For a circuit shown below calculate the value of i_1?



(a) $\frac{43}{160}$ mA (b) $\frac{117}{32}$ mA

(c) $\frac{117}{22}$ mA (d) $\frac{117}{11}$ mA

Ans. (a)



$$10k(i_x - i_1) - 0.7 - 1\ k(11\ i_1) = 0$$

$$10ki_x - 10ki_1 - 11ki_1 = 0.7$$

$$10ki_x - 21i_1 = 0.7 \quad \text{...(i)}$$

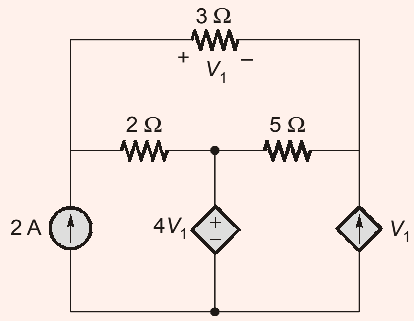
$$10 = (20k)i_x + 10ki_x - 10ki_1$$

$$20ki_x - 10ki_1 = 10 \quad \text{...(ii)}$$

Solve equation (i) and (ii), $i_1 = \frac{43}{160}$ mA

End of Solution

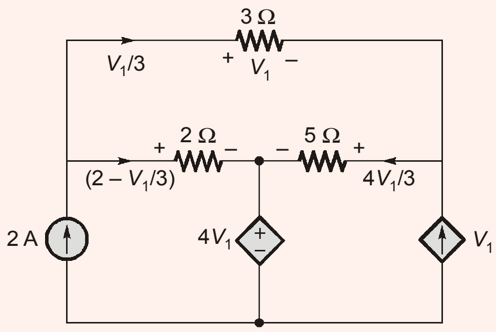
Q.17 Calculate v_1 for the circuit given below?



(a) $\frac{28}{5}$ V (b) $\frac{48}{25}$ V

(c) $\frac{128}{25}$ V (d) $\frac{12}{25}$ V

Ans. (d)



Write KVL equation,

$$V_1 - 2\left(2 - \frac{V_1}{3}\right) + 4\frac{V_1}{3}(5) = 0$$

$$V_1 = \frac{12}{25}\text{ V}$$

End of Solution

Q.18 What is Laplace transform of function $e^{-5t}\cos 4t$?

(a) $\frac{(s+4)}{((s+4)^2+25)}$ (b) $\frac{5}{((s+4)^2+25)}$

(c) $\frac{4}{((s+5)^2+16)}$ (d) $\frac{s+5}{((s+5)^2+16)}$

Ans. (d)

As,
$$\cos 4t \rightleftharpoons \frac{s}{s^2+4^2} = \frac{s}{s^2+16}$$

$$e^{-5t}\cos 4t \rightleftharpoons \frac{s+5}{(s+5)^2+16}$$

End of Solution

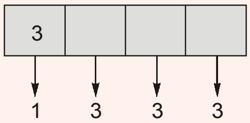
Q.19 Given digits 2, 2, 3, 3, 3, 4, 4, 4, 4. How many distinct 4 digit numbers greater than 3000 can be formed using these digits?

(a) 50 (b) 51
(c) 52 (d) 54

Ans. (b)

Case-1: First digit is 3.

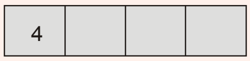
Rest of numbers must come from list: 2, 2, 3, 3, 4, 4, 4, 4



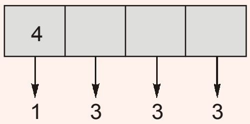
Exceptions are 222, 333

$$\text{Case 1} = 27 - 2 = 25$$

Case-2: First digit is 4.



Rest of numbers must come room list: 2, 2, 3, 3, 3, 4, 4, 4



Exceptions are 222

$$\text{Case 2} = 27 - 1 = 26$$

$$\text{Total} = 25 + 26 = 51$$

End of Solution

Q.20 The characteristic equation of a 3 × 3 matrix P is defined as :

$$|\lambda I - P| = \lambda^3 + \lambda^2 + 2\lambda + 1 = 0$$

"I" denotes identity matrix, then inverse of matrix P will be :

(a) $P^2 + P + 2I$ (b) $P^2 + P + I$
(c) $-(P^2 + P + I)$ (d) $-(P^2 + P + 2I)$

Ans. (d)

Characteristic equation,

$$\lambda^3 + \lambda^2 + 2\lambda + 1 = 0$$

By Caylay Hamilton theorem,

$$P^3 + P^2 + 2P + I = 0$$

Multiplying by P^{-1}

$$P^2 + P + 2I + P^{-1} = 0$$

$$P^{-1} = -P^2 - P - 2I$$

End of Solution

Q.21 A function $y(t)$ satisfies the following differential equation:

$$\frac{dy(t)}{dt} + y(t) = \delta(t)$$

Where $\delta(t)$ is unit impulse function and $u(t)$ is unit step function. Assuming zero initial conditions, what is $y(t)$?

(a) e^{t}
(b) e^{-t}
(c) $e^{t}u(t)$
(d) $e^{-t}u(t)$

Ans. **(d)**

$$\frac{dy(t)}{dt} + y(t) = \delta(t) \rightleftharpoons sY(s) + Y(s) = 1$$

$$\Rightarrow \quad Y(s) = \frac{1}{s+1} \rightleftharpoons y(t)\ e^{-t}\ u(t)$$

Alternate solution:

$$y' + y = \delta(t)$$
$$y(0) = 0$$

Applying L.T.

$$L\{y' + y\} = L\{\delta(t)\}$$
$$sY(s) - y(0) + Y(s) = 1$$
$$L\{y(t)\} = Y(s) = \frac{1}{s+1}$$
$$y(t) = L^{-1}\left\{\frac{1}{s+1}\right\} = e^{-t}u(t)$$

End of Solution

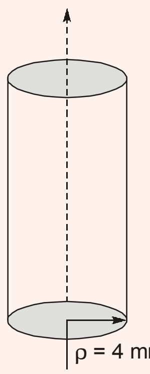
Q.22 A solid non-magnetic conductor of circular cross section has its axis on z-axis and carries a uniformly distributed total current of 60 A in the a_z direction. If the radius of the conductor is 4 mm, find the magnetic flux density at ρ = 5 mm.

(a) 3.1 mT
(b) 2.1 mT
(c) 2.4 mT
(d) 4.0 mT

Ans. **(c)**

$$I = 60 \text{ A}$$

Find $\vec{H}$ at ρ = 5 mm



$$\vec{H} = \frac{I}{2\pi\rho}\hat{a}_\phi = \frac{60}{2\pi(5\times10^{-3})}\hat{a}_\phi$$

$$\vec{H} = \frac{6}{\pi}(10^3)\hat{a}_\phi$$

$$B = \mu_0\vec{H} = 4\pi\times10^{-7}\left(\frac{6}{\pi}\times10^3\right)\hat{a}_\phi$$

$$= 24\times10^{-4}\hat{a}_\phi \quad \text{(Tesla)}$$

$$= 2.4 \text{ mT}\,\hat{a}_\phi$$

End of Solution

Q.23 The magnetic flux density in a magnetic material with susceptibility χ_m = 6 in a given region as $B = 0.005y^2 a_x T$. Find the magnitude of current density J at y = 0.4 m.

(a) $\frac{10^4}{7\pi}$ A/m^2

(b) $\frac{10^4}{5\pi}$ A/m^2

(c) $\frac{10^2}{\pi}$ A/m^2

(d) None of the above

Ans. (a)

$$\chi_m = 6$$

$$B = 0.005y^2\hat{a}_\phi \quad \text{(Tesla)}$$

Find $\vec{J}$ at y = 0.4 m

$$\mu_r = 1 + \chi_m$$

$$\Rightarrow \quad \mu_r = 7$$

$$\vec{\nabla}\times\vec{H} = \vec{J} \qquad \text{...(i)}$$

$$\vec{B} = \mu\vec{H}$$

$$\Rightarrow \quad \vec{H} = \frac{\vec{B}}{\mu} \qquad \text{...(ii)}$$

Equation (ii) in (i),

$$\vec{J} = \vec{\nabla}\times\frac{\vec{B}}{\mu}$$

$$\Rightarrow \quad \vec{J} = \frac{1}{\mu}\vec{\nabla}\times\vec{B}$$

$$\vec{J} = \frac{1}{\mu_0\mu_r}\begin{vmatrix}\hat{a}_x & \hat{a}_y & \hat{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 5\times10^{-3}y^2 & 0 & 0\end{vmatrix}$$

$$= \frac{1}{\mu}\left(\hat{a}_x(0) - \hat{a}_y(0) + \hat{a}_z\left(0 - 10\times10^{-3}y\right)\right)$$

$$= \frac{1}{\mu}\left(10\times10^{-3}y\right)\hat{a}_z$$

$$\vec{J}\Big|_{y=0.4} = \frac{-10\times10^{-3}(0.4)}{4\pi\times10^{-7}(7)}\hat{a}_z = -\frac{10^4}{7\pi}\hat{a}_z = -454.728\hat{a}_z\left(A/x^2\right)$$

End of Solution

Q.24 The internal inductance of a straight wire of circular cross-section with radius r, length l and permeability μ is

(a) $\frac{\mu}{2\pi} ln\left(\frac{r}{l}\right)$ H/m
(b) $\frac{\mu}{4\pi}$ H/m
(c) $\frac{\mu}{8\pi}$ H/m
(d) None of the above

Ans. **(c)**

For L_{internal}

$$B_{\text{internal}} = \mu H_{\text{internal}}$$

$$= \mu \frac{I\rho}{2\pi a^2} = \frac{\mu I \rho}{2\pi r^2}$$

where r is wire radius

ρ is variable internal radius varies from 0 to r

magnetic energy stored in the wire

$$W_M = \iiint \frac{1}{2}\frac{|\vec{B}|^2}{\mu} dv = \iiint \frac{1}{2}\frac{\mu^2 I^2 \rho^2}{\mu(2\pi r^2)} \rho d\rho d\phi dz$$

$$W_M = \frac{\mu^2 I^2}{\mu(2\pi r^2)^2} \int_{\rho=0}^{r} \rho^3 d\rho \int_{\phi=0}^{2\pi} d\phi \int_{z=0}^{l} dz = \frac{1}{2}\frac{\mu I^2}{4\pi^2 r^4}\left(\frac{r^4}{4}\right)(2\pi)l$$

$$W_M = \frac{1}{2}\frac{\mu I^2 l}{2\pi(4)} \text{ Joule}$$

$$L_{\text{internal}} = \frac{2W_M}{I^2} = 2\left(\frac{1}{2}\frac{\mu I^2 l}{8\pi}\right)\left(\frac{1}{I^2}\right) = \frac{\mu l}{8\pi} \text{(Henry)}$$

$$L_{\text{internal}} = \frac{\mu}{8\pi} \text{(Henry/meter)}$$

End of Solution

Q.25 Determine the energy density in free space created by a magnetic field with intensity $H = 10^3$ A/m.

(a) 314 mJ/m^3
(b) 314 μJ/m^3
(c) 628 mJ/m^3
(d) 628 μJ/m^3

Ans. **(c)**

Free space, $H = 10^3$

$$\text{Energy density} = \frac{1}{2}\mu_0 (\vec{H})^2 \text{ (J/m}^3\text{)}$$

$$= \frac{1}{2}(4\pi \times 10^{-7})(10^3)^2$$

$$= 2\pi\ (10^{-1}) = 0.6283 \text{ (J/m}^3\text{)} = 628.3 \text{ (mJ/m}^3\text{)}$$

End of Solution

Q.26 A triangle defined by $A(2, -5, 1)$, $B(0, 2, 4)$ and $C(0, 3, 1)$. What is area of the triangle?

(a) 10.11
(b) 12.41
(c) 16.12
(d) 8.41

Ans. (b)

Area of triangle $A(2, -5, 1)$, $B(0, 2, 4)$, $C(0, 3, 1)$

$$\vec{u} = \overrightarrow{AB} = (0, -2, 2-(-5), 4-1)$$
$$= (-2, 7, 3)$$
$$\vec{v} = \overrightarrow{AC} = (0, 1, -3)$$
$$\vec{u}\times\vec{v} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -2 & 7 & 3 \\ 0 & 1 & -3 \end{vmatrix} = 24i - 6\hat{j} - 2\hat{k}$$
$$\|\vec{u}\times\vec{v}\| = \sqrt{576+36+4} = \sqrt{616}$$
$$\text{Area of } \Delta^k\, ABC = \frac{1}{2}\|\vec{u}\times\vec{v}\| = \frac{1}{2}\sqrt{616} = 12.41$$

End of Solution

Q.27 A 2 mC positive charge is located in vacuum at point $P_1(3, -2, -4)$ and 5 μC negative charge is located at $P_2(1, -4, 2)$. What is the magnitude of force on the charge at P_1?

(a) 2.04 N
(b) 1.96 N
(c) 2.91 N
(d) 3.10 N

Ans. (a)

Q_1 = 2 mc Vacuum Q_2 = 4 mc

• P_1 (3, –2, –4) • P_2 (1, –4, 2)

$$|F| = \frac{|\theta_1\theta_2|}{4\pi\in|\vec{R}_{12}|^2}$$
$$|F| = \frac{(2\times10^{-3})(5\times10^{-6})(9\times10^{9})}{(\sqrt{44})^2}$$
$$= \frac{90}{44} = 2.045 \text{ (Newton)}$$

End of Solution

Q.28 Four infinite uniform sheets of charges with following uniform charge density are placed at different points in space as following :

Sheet-1 : 20 pC/m^2 at $y = 7$
Sheet-2 : –8 pC/m^2 at $y = 3$
Sheet-3 : 6 pC/m^2 at $y = -1$
Sheet-4 : –18 pC/m^2 at $y = -4$

Find the magnitude of Electric field E at point $P(2, 6, -4)$. Consider relative permittivity of the medium as 1.

(a) $\frac{40}{18\pi}$ V/m
(b) 40π V/m
(c) $\frac{18\pi}{25}$ V/m
(d) 18π V/m

Ans. **(c)**

$$\rho_{s1} = 20 \text{ pC/m}^2 \text{ at } y = 7$$
$$\rho_{s2} = -8 \text{ pC/m}^2 \text{ at } y = 3$$
$$\rho_{s3} = 6 \text{ pC/m}^2 \text{ at } y = -1$$
$$\rho_{s4} = -18 \text{ pC/m}^2 \text{ at } y = -4$$

Find (E) at $P(2, 6, -4)$

$\vec{E}$ due to infinite sheet charge is $\vec{E} = \frac{|\rho_s|}{2\epsilon_0}\hat{a}_E$

$$\text{Total } \vec{E} = \frac{20\times10^{-12}}{2\epsilon_0}(-\hat{a}_y) + \frac{8\times10^{-12}}{2\epsilon_0} + \frac{6\times10^{-12}}{2\epsilon_0}\hat{a}_y + \frac{8\times10^{-12}}{2\epsilon_0}\hat{a}_y$$

$$= \frac{10^{-12}}{\epsilon_0}(-20-8+6-18)\hat{a}_y = \frac{10^{-12}}{2\left(\frac{1}{36\pi}\times10^{-9}\right)}(-40)\hat{a}_y$$

$$= -18\pi(40)(10^{-3})\hat{a}_y = -2.261\left(\frac{V}{m}\right)\hat{a}_y$$

$$= \frac{-18\pi}{25}(\text{V/m})\hat{a}_y$$

End of Solution

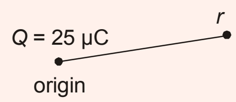
Q.29 A 25 μC point charge is located at origin. Calculate electric flux passing through the portion of sphere defined by $r = 20$ cm, bounded by $\theta = 0$ and π rad, $\phi = 0$ and $\frac{\pi}{2}$ rad.

(a) 5 μC
(b) 25 μC
(c) 6.25 μC
(d) 12.5 μC

Ans. (c)

$$\vec{D} = \frac{\phi}{4\pi r^2}\hat{a}_r \ \text{c/m}^2$$

find ψ crossing, $\gamma = 20$ cm spherical



surface having, $0 \le \theta \le \pi;\ 0 \le \phi \le \frac{\pi}{2}$

$$\psi = \iint \vec{D}\cdot\vec{ds}$$

$$\psi\big|_{r=0.2\text{m}} = \iint \frac{\phi}{4\pi r^2}\hat{a}_r \cdot r^2 \sin\theta d\theta d\phi \hat{a}_r = \frac{\phi}{4\pi}\int_{\theta=0}^{\pi}\sin\theta\, d\theta \int_{\phi=0}^{\pi/2} d\phi$$

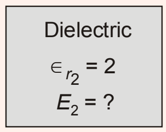
$$= \frac{25\times10^{-6}}{4\pi}(2)\left(\frac{\pi}{2}\right) = 6.25\ \mu\text{C}$$

End of Solution

Q.30 A dielectric material is placed in vacuum in a uniform electric field of E = 4 V/m. What is the electric field inside the material if the relative permittivity of dielectric material is 2?

(a) Zero
(b) 4 V/m
(c) 2 V/m
(d) 8 V/m

Ans. (c)



Vacuum, $\in_{r1} = 1$

$$E_1 = 4 \text{ V/m}$$

$$D_{N1} = D_{N2}$$

$$\in_1 E_{N1} = \in_2 E_{N2}$$

$$E_{N2} = \frac{\in_0 (1)(4)}{\in_0 (2)} = 2 \text{ (V/m)}$$

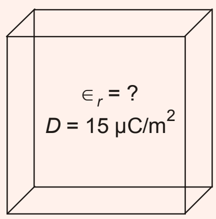
End of Solution

Q.31 Find the relative permittivity of dielectric material used in a parallel plate capacitor if electric flux density $D = 15\ \mu\text{C/m}^2$ and energy density is 20 J/m^3.

(a) 0.6
(b) 0.8
(c) 0.9
(d) 1.1

Ans. (a)

Given, $D = 15\ \mu\text{C/m}^2$



$$\text{Energy density} = \frac{1}{2}\frac{|D|^2}{\in} = 20 \text{ J/m}^3$$

$$= \frac{1}{2}\frac{(15\times10^{-6})^2}{(8.854\times10^{-12})\in_r} = 20$$

$$\in_r = \frac{15\times15}{2(20)(8.854)} = 0.635$$

End of Solution

Q.32 For a homogeneous medium with volume charge density ρ_v, permittivity ε and voltage V. What is the $\nabla^2 V$?

(a) $-\rho_v \varepsilon$
(b) $\frac{\rho_v}{\varepsilon}$
(c) $\rho_v \varepsilon$
(d) $-\frac{\rho_v}{\varepsilon}$

Ans. **(d)**

For homogeneous medium

$$\nabla^2 V = -\frac{\rho_v}{\in}$$

End of Solution

Q.33 Which among the following equation is true for a steady magnetic field? Where B is magnetic flux density, J is current density and H is magnetic field intensity.

(a) $\nabla \cdot B = J$
(b) $\nabla \times H = 0$
(c) $\nabla \times H = J$
(d) None of the above

Ans. **(c)**

For steady magnetic field,

$$\vec{\nabla} \times \vec{H} = \vec{J}$$

End of Solution

Q.34 An electron beam carries a total current of –500 μA in the a_z direction and has a current density J_z in the region $0 \le r \le 10^{-4}$ m and zero in the region $r > 10^{-4}$ m. Electron beam velocity is given by $V_z = (8 \times 10^7 z)$ m/s. Calculate the volume charge density at $z = 2$ cm.

(a) 200 m C/m^3
(b) 10 m C/m^3
(c) –10 m C/m^3
(d) –200 m C/m^3

Ans. **(c)**

Electron beam velocity = 8×10^7 z (msec)

$$J = nq\, v_d$$

$$J = \rho_v\, v_d$$

$$\rho_v = \frac{J}{v_d} = \frac{I}{A v_d} \qquad \text{where } A = r_a^2$$

$$\rho_v = \frac{-500 \times 10^{-6}}{\pi(10^{-4})(8 \times 10^7 z)}$$

$$\rho_v\big|_{z=2\text{cm}} = \frac{-500 \times 10^{-6}}{\pi(10^{-8})(8 \times 10^7)(8 \times 10^{-2})} = \frac{-5 \times 10^{-4}}{\pi(16)(10^{-3})} = \frac{-0.5}{16\pi} \text{C/m}^2$$

$$= -9.9 \times 10^{-3} \text{ C/m}^2$$

$$= -10 \text{ mC/m}^2$$

End of Solution

Q.35 Find the magnitude of the electric field intensity in a sample of silver having conductivity $\sigma = 6.17 \times 10^7$ mho/m, permittivity $\mu_e = 0.006$ m²/Vs and drift velocity 1 mm/s.

(a) $\frac{1}{10}$ V/m
(b) $\frac{1}{3}$ V/m
(c) $\frac{1}{2}$ V/m
(d) $\frac{1}{6}$ V/m

Ans. **(d)**

$$\sigma = 6.17 \times 10^7 \ (\mho/m)$$
$$\mu = \text{mobility} = 0.006 \ m^2/VS$$
$$v_d = 10^{-3} \ (m/sec)$$
$$v_d = \mu E$$
$$E = \frac{v_d}{\mu} = \frac{10^{-3}}{6 \times 10^{-3}} = \frac{1}{6} \ V/m$$

End of Solution

Q.36 Which among the following statement is correct regarding an ideal conductor in a static electric field?

(a) Static electric field intensity inside conductor is non zero
(b) Static field intensity outside conductor is zero
(c) Static field intensity at the surface of conductor is directly normal to the surface
(d) Static field intensity at the surface of the conductor is directly parallel to the surface

Ans. **(c)**

End of Solution

Q.37 Consider electron and hole mobilities of germanium at 300K is 0.36 m²/Vs and 0.17 m²/Vs respectively and hole and electron concentration of 2.7×10^{19} per m³. Find the conductivity of germanium at 300 K.

(a) 1.4 mho/m
(b) 2.3 mho/m
(c) 1.3 mho/m
(d) 2.0 mho/m

Ans. **(b)**

$$\sigma = n_i (\mu_N + \mu_p)e$$
$$= 2.7 \times 10^{19} (0.36 + 0.17) \times 1.6 \times 10^{-1}$$
$$= 2.3 \ \mho/m$$

End of Solution

Q.38 The technology 'CMOS' used for fabricating integrated circuit refers to

(a) Compound Metal Oxide Semiconductor
(b) Complementary Metal Oxide Semiconductor
(c) Conditional Metal Oxide Semiconductor
(d) Compound Metal Oxide Superconductor

Ans. **(b)**

End of Solution

Q.39 A 3 phase, 50 Hz synchronous generator is connected to an infinite bus. The maximum power that can be transferred to infinite bus is 1 p.u. The mechanical input to the generator is $\frac{\sqrt{3}}{2}$ p.u. Inertia constant of the generator is 5s. Find the natural frequency of oscillation of the system?

(a) $\sqrt{10\pi}$ rad/sec
(b) $\sqrt{20\pi}$ rad/sec
(c) $\sqrt{15\pi}$ rad/sec
(d) $\sqrt{5\pi}$ rad/sec

Ans. (d)

$$P_{in} = \frac{\sqrt{3}}{2} \text{ pu}$$

$$P_{em} = 1 \text{ pu}$$

$$\delta_0 = \sin^{-1}\left(\frac{P_m}{P_{em}}\right) = \sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

$$\delta_0 = 60°$$

$$S_{P0} = P_{em} \cos \delta_0 = 1 \cos 60°$$

$$S_{P0} = \frac{1}{2}$$

Natural frequency of oscillation

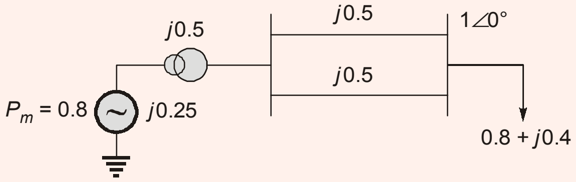
$$\omega_0 = \sqrt{\frac{S_{P0}\omega_s}{2H}} = \sqrt{\frac{\frac{1}{2}\times 2\pi\times 50}{2\times 5}} = \sqrt{5\pi} \text{ rad/sec}$$

End of Solution

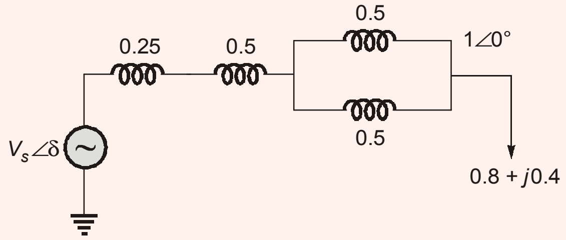
Q.40 A 3 phase, 50 Hz synchronous generator is connected to an infinite bus through a transformer and two parallel transmission lines. The input mechanical power to synchronous generator is 0.8 p.u. Grid is consuming a power of 0.8 + j0.4 p.u., generator impedance is 0.25 p.u., transformer impedance is 0.5 p.u. and each transmission line impedance is 0.5 p.u. If the infinite bus voltage is $1\angle 0$ p.u. then, what is the generator voltage load angle?

(a) 26.56°
(b) 31.30°
(c) 30°
(d) 60°

Ans. (c)



We can redraw system



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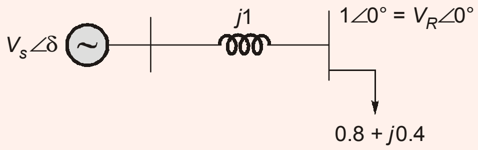


$$Q_R = 0.4 = \frac{V_S V_R}{X_L}\cos\delta - \frac{V_R^2}{X_L} = \frac{V_S \times 1}{1}\cos\delta - \frac{1}{1}$$

Solving, $V_S \cos\delta = 1.4$ ...(i)

$$P_R = 0.8 = \frac{V_S V_R}{X_L}\sin\delta = \frac{V_S \times 1}{1}\sin\delta$$

$0.8 = V_S \sin\delta$ ...(ii)

Solving equations (i) and (ii)

$$\delta = 29.74 \simeq 30° \text{ and } V_S = 1.616 \text{ pu}$$

End of Solution

Q.41 Which is the power semiconductor device having highest switching speed?

(a) SCR (b) IGBT
(c) MOSFET (d) GTO

Ans. (c)

End of Solution

Q.42 For a PN junction diode, width of space charge region increases as?

(a) Forward bias voltage increases
(b) Reverse bias voltage increases
(c) Forward bias voltage reduces
(d) Reverse bias voltage reduces

Ans. (b)

In pn junction diode width of depletion region increases by increasing reverse bias voltage.

Alternate Solution:

$$W \propto \sqrt{V_B}$$
$$V_B = V_R + V_{bi}$$

End of Solution

Q.43 If unit step response of a network is $(1 - e^{-\alpha t})$ then its unit impulse response will be

(a) $\alpha e^{-\alpha t}$
(b) $\alpha e^{-\frac{1}{\alpha t}}$
(c) $\frac{1}{\alpha} e^{-\alpha t}$
(d) $(1 - \alpha)e^{-\alpha t}$

Ans. (a)

$$x(t) = u(t) \xrightarrow{sys} y(t) = (1 - e^{-\alpha t})\, u(t)$$

$$X(s) = \frac{1}{s} \qquad y(s) = \frac{1}{s} - \frac{1}{s+\alpha} = \frac{\alpha}{s(s+\alpha)}$$

Now,
$$H(s) = \frac{Y(s)}{X(s)} = \frac{\alpha}{s+\alpha}$$
$$h(t) = \alpha e^{-\alpha t}$$

End of Solution

Q.44 What is the Laplace transform of function $\delta(t - 2)$?

(a) 2
(b) 0
(c) e^{-2s}
(d) $2s$

Ans. (c)

$$\delta(t) \leftrightarrow 1$$
$$\delta(t-2) \leftrightarrow e^{-2s}$$

End of Solution

Q.45 What is the range of 'K' for which the unity feedback closed loop system with open loop gain $G(s) = \frac{K}{s^2(s+a)}$ will be unstable?

(a) $-a < K < a$
(b) $K > 0$
(c) $K = 0$
(d) $-\infty < K < \infty$

Ans. (d)

End of Solution

Q.46 A power supply having output resistance 1.5 Ω supplies a full load current of 500 mA to a 50 Ω load. Determine the percentage voltage regulation of supply?

(a) 2% (b) 3%

(c) 4% (d) 5%

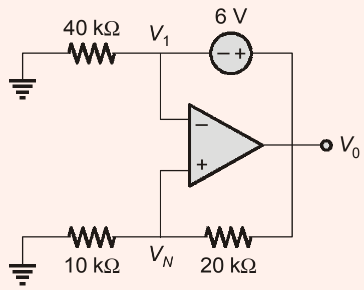
Ans. (b)

$$\% \ V_R = \frac{\text{Output resistance } R_0}{\text{Load resistance } R_L}$$

$$= \frac{1.5\Omega}{50\Omega} = \frac{3}{100} = 3\%$$

End of Solution

Q.47 Find the voltage V_N for the circuit shown below?



(a) 6 V (b) 4 V

(c) 5 V (d) 3 V

Ans. (d)

$$V_0 = 6 + V_1$$

$$V_N = \frac{V_0 \times 10k}{10k + 20k} = \frac{V_0}{3}$$

$$V_1 = V_N \text{ (Virtual short)}$$

$$V_N = \frac{6 + V_N}{3}$$

$$3V_N = 6 + V_N$$

$$3V_N - V_N = 6$$

$$2V_N = 6$$

$$V_N = 3$$

End of Solution

Q.48 The integral $\frac{1}{2\pi}\int_0^{2\pi}\sin(t-\tau)\cos\tau d\tau$ equals to

(a) $\sin t\cos t$
(b) 0
(c) $\frac{1}{2}\cos t$
(d) $\frac{1}{2}\sin t$

Ans. **(d)**

$$\frac{1}{2\pi}\int_0^{2\pi}\sin(t-\tau)\cos\tau d\tau = \frac{1}{2\pi}\int_0^{2\pi}\left[\frac{\sin t+\sin(t-2T)}{2}\right]d\tau$$

$$= \frac{1}{4\pi}\int_0^{2\pi}\left[\sin t(\tau)_0^{2\pi} + \left[\frac{\cos(t-2\tau)}{-2}\right]_0^{2\pi}\right]$$

$$= \frac{1}{4\pi}\left[2\pi\sin t + \frac{\cos t}{2} - \frac{\cos t}{2}\right] = \frac{\sin t}{2}$$

End of Solution

Q.49 If $u(t)$, $r(t)$ denote unit step and unit ramp function respectively and $u(t)*r(t)$ their convolution, then function $u(t+1)*r(t-2)$ is

(a) $\frac{1}{2}(t-1)(t-2)$
(b) $\frac{1}{2}(t-1)^2(t-2)$
(c) $\frac{1}{2}(t-1)^2u(t-1)$
(d) None of the above

Ans. **(c)**

$$u(t)*r(t) = \frac{t^2}{2}u(t) = y(t)$$

$$u(t+1)*r(t-2) = y(t-1) = \frac{(t-1)^2}{2}u(t-1)$$

End of Solution

Q.50 Consider function $f(x) = (x^2-4)^2$, where x is a real number. The function $f(x)$ has

(a) Only one minimum
(b) Only two minima
(c) Only three maxima
(d) None of the above

Ans. **(b)**

$$f(x) = (x^2-4)^2$$
$$f'(x) = 2(x^2-4)(2x) = 4x^3-16x$$
$$f'(x) = 0 \Rightarrow x = 0, \quad +2, -2$$
$$f''(x) = 12x^2-16$$
$$f''(0) = -16 < 0 \quad \text{max}$$
$$f''(2) = 82 > 0 \quad \text{min}$$
$$f''(-2) = 32 > 0 \quad \text{min}$$

Only two minima.

End of Solution

Q.51 A is an $(m \times n)$ matrix with $m > n$ and 'I' is identity matrix. Let $A_1 = (A^TA)^{-1} A^T$, then which of the following statement is false?

(a) $AA_1A = A$
(b) $(AA_1)^2 = AA_1$
(c) $AA_1 = I$
(d) $AA_1A = A_1$

Ans. (d)

$A_{m \times n}$

$$A_1 = (A^TA)^{-1} A^T$$
$$= A^{-1}(A^T)^{-1} A^T = A^{-1} \cdot I$$
$$A_1 = A^{-1}$$

(a) $AA_1A = AA^{-1}A = A$

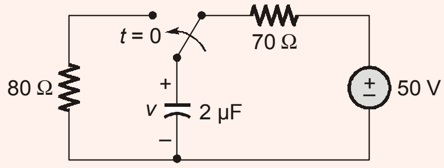
(b) $(AA^1)^2 = (AA^{-1}) = I^2 = I = AA_1$

(c) $AA_1 = I$

(d) $AA_1A = AA^{-1}A$
$$= IA = A \neq A^{-1}$$

End of Solution

Q.52 For the circuit diagram shown below, calculate the voltage across capacitor $V(t)$ at t = 160 μs?



(a) 16.5 V
(b) 18.4 V
(c) 20.2 V
(d) None of the above

Ans. (b)

$t = 0^-$

$$V_c(0^-) = 50 \text{ V}; \quad V_c(0^+) = 50 \text{ V}$$

$t \to \infty$

$$V_c(\infty) = 0 \text{ V}$$
$$\tau = 80 \times 2\mu = 160\ \mu$$
$$V_c(t) = V_c(\infty) + (V_c(0^+) - V_c(\infty))\ e^{-t/\tau}$$
$$V_c(t) = 50e^{-t \times 10^6/160}$$
$$V_c(160\mu) = 50e^{-\frac{160 \times 10^{-6} \times 10^6}{160}}$$
$$V_c = 18.4 \text{ V}$$

End of Solution

Q.53 Consider a parallel RLC circuit having inductance of 10 mH, capacitance of 100 μF. Determine the value of resistance that would lead to a critically damped response?

(a) 5 Ω (b) 10 Ω
(c) 20 Ω (d) 15 Ω

Ans. **(a)**

For parallel RLC:

$$\zeta = \frac{1}{2R}\sqrt{\frac{L}{C}}$$

$$1 = \frac{1}{2R}\sqrt{\frac{10\times10^{-3}}{100\times10^{-6}}}$$

$$R = 5\ \Omega$$

End of Solution

Q.54 A power BJT has collector current I_C = 20 A at I_B = 2.5 A and reverse saturation current I_{CS} = 15 mA. Find out current gain β?

(a) 8 (b) 7.95
(c) 7 (d) 8.95

Ans. **(b)**

$$I_C = \beta I_B + (1+\beta)I_{CO}$$
$$= \beta(I_B + I_{CO}) + I_{CO}$$

$$\beta = \frac{I_C - I_{CO}}{I_B - I_{CO}} = \frac{2.0 - 0.015}{2.5 + 0.015} = 7.95$$

End of Solution

Q.55 One cycle of square wave signal observed on an oscilloscope is found to occupy 6 cm at a scale setting of 30 μs/cm. What is the signal frequency?

(a) 1.8 kHz (b) 5.55 kHz
(c) 18 kHz (d) 55.5 kHz

Ans. **(b)**

End of Solution

Q.56 Two equal voltages of same frequency applied to *X* and *Y* plates of CRO produce a circle on the screen. The phase difference between the two voltages will be?

(a) 30° (b) 60°
(c) 90° (d) 150°

Ans. **(c)**

End of Solution

Q.57 The magnetic field intensity of uniform plane wave in air is 20 A/m in the direction a_y. The wave is propagating in the a_z direction at a frequency of 2×10^9 rad/s. What is the wave length of the plane wave.

(a) $\frac{3}{20}$ m
(b) $\frac{3}{10}$ m
(c) $\frac{3\pi}{20}$ m
(d) $\frac{3\pi}{10}$ m

Ans. (d)

$$\vec{H} = 20\,(\text{A/m})\hat{a}_u \text{ in air medium}$$

wave propagation is $\hat{a}_z$

$$\omega = 2 \times 10^9 \text{ (rad/sec) find } \lambda$$

$$\lambda = \frac{C}{f} = \frac{3\times10^8}{\left(\frac{2\times10^9}{2\pi}\right)} = 3\pi \times 10^{-1} = 0.942 \text{ meter}$$

$$= \frac{3\pi}{10} \text{meter}$$

End of Solution

Q.58 A loss less transmission line segment has characteristic impedance Z_0 = 100 Ω electromagnetic wave propagation velocity in the transmission line v = 0.8 times velocity of light in vacuum. The frequency of the electromagnetic wave transmitted is 100 MHz. The phase constant is β and $\beta l = \pi$ rad, then what is the length of the transmission line segment l ?

(a) 24 m
(b) $\frac{12\pi}{10}$ m
(c) $\frac{10\pi}{12}$ m
(d) 1.2 m

Ans. (d)

Given loss less transmission line has Z_0 = 100 Ω

$$v_p = 0.8\text{ C}$$
$$f = 100 \text{ MHz}$$
$$Bl = \pi \quad \text{find } \lambda$$
$$Bl = \pi$$
$$\omega\sqrt{LC}\,l = \pi$$

$$\Rightarrow \quad l = \frac{\pi}{\omega\sqrt{LC}} \quad ...(i)$$

$$v_p = \frac{1}{\sqrt{LC}} \quad ...(ii)$$

Equation (ii) in (i),

$$\Rightarrow \quad l = \frac{\pi v_p}{\omega}$$

$$l = \frac{\pi(0.8\times3\times10^8)}{2\pi(10^8)} = 1.2 \text{ m}$$

End of Solution

Q.59 A 100 pF capacitor has a maximum charging current of 150 μA. What is the slew rate of capacitor?

(a) 1.50 V/s
(b) 0.67 V/μs
(c) 0.67 V/s
(d) 1.50 V/μs

Ans. (d)

End of Solution

Q.60 An operational amplifier has a time rate of change of voltage of 2 V/μs. If the peak output voltage is 12 V, what is the bandwidth of the amplifier?

(a) $\frac{1}{12\pi}$ MHz
(b) $\frac{1}{24\pi}$ kHz
(c) $\frac{1}{24\pi}$ MHz
(d) None of the above

Ans. (a)

$$\frac{A_{CL}V_m\omega_0}{10^6} \le SR$$

Take, $A_{CL} = 1$

$$f_0 = \frac{SR\times10^6}{2\pi V_m} = \frac{2\times10^6}{2\pi\times12} = \frac{1}{12\pi} \text{ MHz}$$

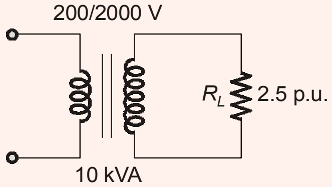
End of Solution

Q.61 A 10 kVA, 200 V/2000 V transformer is feeding a load resistance of 2.5 p.u. based on ratings of HV side. The actual value of load resistance referred to LV side?

(a) 10 Ω
(b) 100 Ω
(c) 1000 Ω
(d) 10000 Ω

Ans. (a)

H.V. side,



$$I_{rating} = \frac{10000}{2000} = 5 \text{ A}$$

$$V_{rating} = 2000 \text{ V}$$

$$Z_{base} = \frac{V_{rated}}{I_{rated}} = \frac{2000}{5} = 400 \ \Omega$$

$$\text{p.u.} = \frac{\text{Actual}}{\text{Base}}$$

$$\Rightarrow \quad \text{Actual} = \text{Base} \times \text{p.u.}$$

$$= 400 \times 2.5 = 1000\ \Omega$$

R_L actual value on H.V. side = 1000 Ω

R_L referred to L.V. side = $1000 \times K^2$

$$K = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{200}{2000} = \frac{1}{10}$$

$$R_L \text{ ref to L.V. side} = 1000 \times \left(\frac{1}{10}\right)^2 = 10\ \Omega$$

End of Solution

Q.62 While performing short circuit test on a single-phase 110/220 V, 50 Hz transformer with LV side shorted, wattmeter reading is found to be 20 W. If the same test is performed on the transformer with HV side shorted, the wattmeter reading will be?

(a) 5 W
(b) 10 W
(c) 20 W
(d) 40 W

Ans. (c)

End of Solution

Q.63 For a 3-phase slip-ring induction motor, the electrical rotor losses are proportional to

(a) Synchronous speed
(b) Air gap power
(c) Slip
(d) None of the above

Ans. (c)

End of Solution

Q.64 The blocked-rotor test of squirrel-cage induction motor determines?

(a) Its equivalent series resistance and reactance as seen from the stator
(b) Its equivalent shunt resistance and reactance as seen from the stator
(c) Its equivalent series resistance and reactance as seen from the rotor
(d) Its equivalent shunt resistance and reactance as seen from the rotor

Ans. (a)

End of Solution

Q.65 Which among the following statement is true for a power system with lagging power factor?

(a) Active power will flow from lagging voltage bus to leading voltage bus
(b) Active power will flow from leading voltage bus to lagging voltage bus
(c) Reactive power will flow from lagging voltage bus to leading voltage bus
(d) Reactive power will flow from leading voltage bus to lagging voltage bus

Ans. (b)

Active power always flows from leading voltage towards lagging voltage.

End of Solution

Q.66 What is the volume charge density at point $P(1, 2, 1)$ associated with electric flux field $D = xy^2a_x + yx^2a_y + za_z$ C/m^2.

(a) 6 C/m^3
(b) 4 C/m^3
(c) 1 C/m^3
(d) 10 C/m^3

Ans. (a)

$$\vec{D} = xy^2\hat{a}_x + yx^2\hat{a}_y + z\hat{a}_z \text{ c/m}^2$$

find ρ_v at $P(1, 2, 1)$

$$\rho_v = \vec{\nabla}\cdot\vec{D}$$

$$\rho_v = \frac{\partial D_x}{\partial x} + \frac{\partial D_y}{\partial y} + \frac{\partial D_z}{\partial z}$$

$$= y^2 + x^2 + 1$$

$$\rho_v\big|_{p(1,2,1)} = 2^2 + 1^2 + 1 = 6 \text{ c/m}^3$$

End of Solution

Q.67 An electric Field is given by $E = zy^2a_x + 2xyz\,a_y + xy^2a_z$ V/m, an incremental path is represented by $\Delta L = -3a_x + 5a_y - 2az$ μm. Find the work done in moving 4 μC charge along the incremental path if the location of the path is at point $P(1, 1, 1)$.

(a) 20 pJ
(b) 40 pJ
(c) –40 pJ
(d) –20 pJ

Ans. (d)

$$\vec{E} = zy^2\hat{a}_x + 2xyz\,\hat{a}_y + xy^2\hat{a}_z$$

$$\Delta L = \left(-3\hat{a}_x + 5\hat{a}_y - 2\hat{a}_z\right)10^{-6}\text{m}$$

$$Q = 4\ \mu\text{C}$$

$$P(1, 1, 1)$$

$$E(1, 1, 1) = 1\hat{a}_x + 2\hat{a}_y + \hat{a}_z \text{ (V/m)}$$

Differential work done by an external source in moving Q charge for $\overrightarrow{\Delta l}$ distance is

$$dW = -Q\vec{E}\cdot\Delta\vec{l}$$

$$= -(4\times 10^{-6})\left(1\hat{a}_x + 2\hat{a}_y + \hat{a}_z\right)\cdot\left(-3\hat{a}_x + 5\hat{a}_y - 2\hat{a}_z\right)$$

$$= -4(10^{-12})\,[-3 + 10 - 2]$$

$$= -20\ (10^{-12}\text{ J}) = -20 \text{ pJ}$$

End of Solution

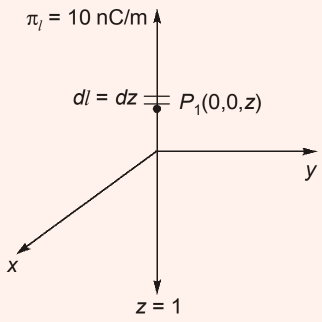
Q.68 Assuming zero voltage at infinity, find the potential at $P(0, 0, 10)$ that is caused by a charge distribution of 10 nC/m along the line $x = 0$, $y = 0$, $-1 < z > 1$ in free space.

(a) 18 V (b) 8 V
(c) 5 V (d) 20 V

Ans. (a)

$$dV = \frac{d\phi}{4\pi \epsilon_0 |\vec{R}_{12}|} = \frac{\rho_l \, dl}{4\pi \epsilon_0 |\vec{R}_{12}|}$$

$$\text{Total } V = \int \frac{\rho_l \, dl}{4\pi \epsilon_0 |\vec{R}_{12}|}$$



$$\vec{R}_{12} = P_2(0,0,10) - P_1(0,0,z)$$

$$\vec{R}_{12} = (10 - z)\hat{a}_z$$

$$V = \int_{z=-1}^{1} \frac{p_l \, dz}{4\pi \epsilon_0 (10 - z)} = (10 \times 10^{-9})(9 \times 10^9) \int_{z=-1}^{1} \frac{dz}{10 - z}$$

$$V = 90(-\ln(10 - z))_{z=1}^{1} = -90 \, (\ln (9) - \ln 11)$$

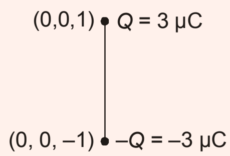
$$V = 90 \ln\left(\frac{11}{9}\right) = 18.043 \text{ Volt}$$

End of Solution

Q.69 A point charge of $+3$ µC and -3 µC are located at (0, 0, 1) and (0, 0, –1) respectively, in free space. Find the magnitude of dipole moment. Consider distances in meters.

(a) 12 µCm (b) 6 µCm
(c) 18 µCm (d) 3 µCm

Ans. (b)

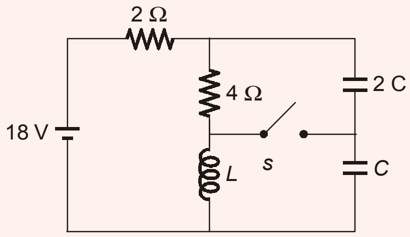


Electric dipole moment $= \vec{p} = Q\vec{d}$

$= (3 \times 10^{-6})\ (2)\ (\text{Cm}) = 6\ \mu\text{Cm}$

End of Solution

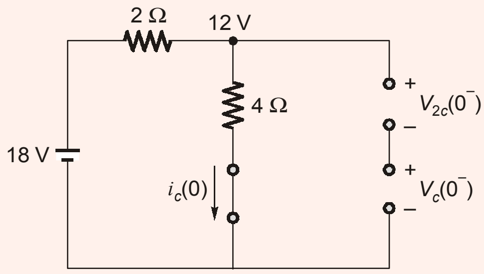
Q.70 In the circuit shown below, steady state was reached when the switch 's' was open. The switch was closed at t = 0. The initial value of the current through the capacitor 2 C is



(a) 0 A
(b) 1 A
(c) 2 A
(d) 3 A

Ans. (c)

$t = 0^-$

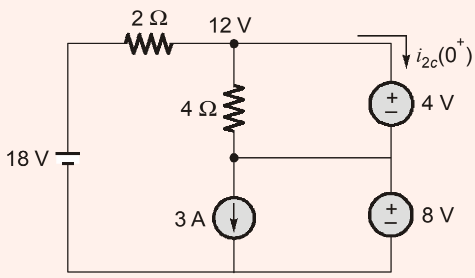


$$i_c(0^-) = \frac{18}{2\times 4} \Rightarrow 3\text{ A}$$

$$V_{2c}(0^-) = 12\times\frac{C}{2C\times C} = 4\text{ V}$$

$$V_c(0^-) = 12\times\frac{2C}{2C+C} = 8\text{ V}$$

$t = 0^+$



$$\frac{18-12}{2} = \frac{4}{4}+i_{2c}(0^+)$$

$$i_{2c}(0^+) = 2\text{ A}$$

End of Solution

Q.71 The Laplace transform of $(t^2 - 2t)u(t-1)$ is?

(a) $\frac{2}{s^3}e^{-s} - \frac{2}{s^2}e^{-s}$
(b) $\frac{2}{s^3}e^{-s} + \frac{2}{s^2}e^{-s}$
(c) $\frac{2}{s^3}e^{-2s} - \frac{2}{s^2}e^{-s}$
(d) None of the above

Ans. (d)

$$x(t) = (t^2 - 2t)\, u(t-1)$$
$$= [(t-1)^2 - 1]\, u(t-1)$$
$$= (t-1)^2\, u(t-1) - u(t-1)$$

$$\Rightarrow \quad X(s) = \frac{2}{s^3}e^{-s} - \frac{1}{s}e^{-s}$$

End of Solution

Q.72 A source $V_s = 200 \cos \omega t$ delivers power to a load at power factor 0.8 lag. The reactive power is 300 VAR. The Active Power is given by?

(a) 200 Watts
(b) 225 Watts
(c) 400 Watts
(d) 300 Watts

Ans. (c)

$$\cos\phi = 0.8$$
$$\phi = 36.86°$$
$$Q = V_{rms} I_{rms} \sin\theta$$
$$300 = \frac{200}{\sqrt{2}} \cdot I_{rms} \sin 36.86°$$
$$I_{rms} = 3.5355 \text{ A}$$
$$P = V_{rms} I_{rms} \cos\phi$$
$$P = \frac{200}{\sqrt{2}} \times 3.5355 \times 0.8 = 400 \text{ W}$$

Alternative solution:

$$Q = VI \sin\theta$$
$$300 = \frac{200}{\sqrt{2}} I \times 0.6$$
$$\Rightarrow \quad I = \frac{300 \times \sqrt{2}}{200 \times 0.6}$$
$$P = VI \cos\phi$$
$$= \frac{200}{\sqrt{2}} \times \frac{300\sqrt{2}}{200 \times 0.6} \times 0.8 = 400 \text{ Watt}$$

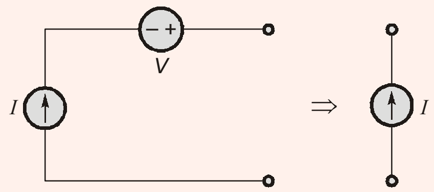
End of Solution

Q.73 An ideal constant current source is connected in series with an ideal constant voltage source. Considering both together the combination will be *a*?

(a) Constant voltage source (b) Constant current source

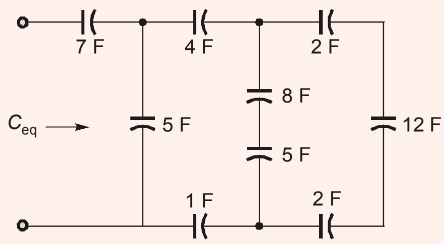
(c) Constant power source (d) None of the above

Ans. (b)



End of Solution

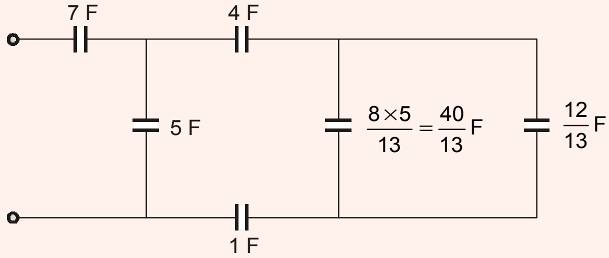
Q.74 Calculate C_{eq} of the circuit given below?



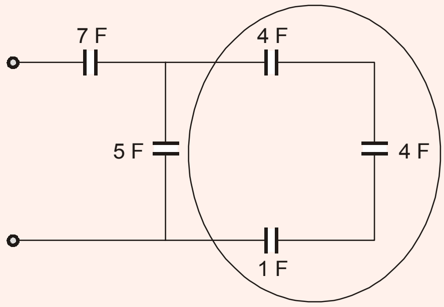
(a) $\frac{17}{3}$ F (b) $\frac{119}{38}$ F

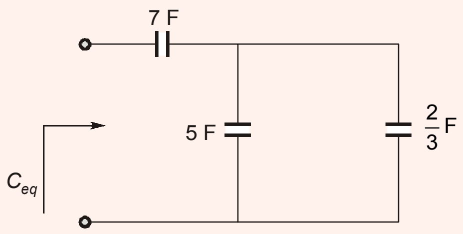
(c) 5 F (d) 4 F

Ans. (b)



$$\frac{12}{13}+\frac{40}{13} = 4\text{ F}$$





$$C_{eq} = \frac{\left(\frac{2}{3}+5\right)\times 7}{\frac{2}{3}+5+7} = \frac{119}{38}\text{ F}$$

End of Solution

Q.75 The voltage across 2H inductor is 6 cos (5t) V. Determine the resulting inductor current at $t = \pi$, if the inductor current at $t = -\pi/2$ is 1 A?

(a) 1.6 A
(b) +1 A
(c) –1.6 A
(d) Zero

Ans. (a)

$$i_L(t) = \frac{1}{L}\int V_L dt + i_L(0)$$

$$i_L(t) = \frac{1}{2}\int 6\cos 5t = \frac{1}{2}\frac{(6\sin 5t)}{5} + k$$

$$i_L(t) = 0.6\sin 5t + k$$

$$\left(t = -\frac{\pi}{2}\right)$$

$$i_L\left(-\frac{\pi}{2}\right) = 0.6\sin\left(-\frac{\pi}{2}\right) + k$$

$$k = 1.6$$

$$i_L(t) = 1.6 + 0.6\sin 5t$$

Inductor current,

$$i_L(t)\big|_{t=\pi} = 1.6\text{ A}$$

End of Solution

Q.76 Given the points $A(x = 2, y = 3, z = -1)$ and $B(r = 4, \theta = 30°, \phi = 120°)$. Find distance between A and B.

(a) 7.26 (b) 4.10
(c) 6.12 (d) 5.53

Ans. (d)

$$x = r\cos\phi\sin\theta$$
$$= 4\times -\frac{1}{2}\times\frac{1}{2} = -1$$
$$y = r\sin\phi\sin\theta$$
$$= 4\times\frac{\sqrt{3}}{2}\times\frac{1}{2} = \sqrt{3}$$
$$z = r\cos\theta = 4\times\frac{\sqrt{3}}{2} = 2\sqrt{3}$$

$A(2, 3, -1)$; $B(-1, \sqrt{3}, 2\sqrt{3})$

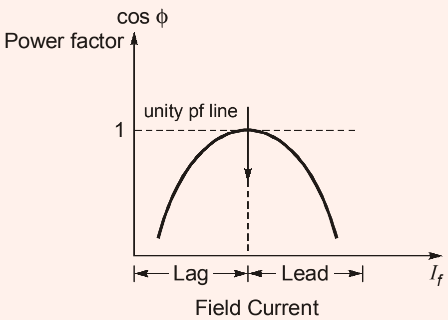
$$= \sqrt{9+(3-\sqrt{3})^2+(-1-2\sqrt{3})^2} = \sqrt{34-2\sqrt{3}} = 5.53$$

End of Solution

Q.77 A synchronous motor is operating at constant load, while its excitation is adjusted to get unity power factor. If the excitation is now increased, the power factor will be?

(a) Leading (b) Remains at unity
(c) Lagging (d) Becomes zero

Ans. (a)



Excitation (I_f) ↑ pf becomes leading.

End of Solution

Q.78 If the positive, negative and zero-sequence reactances of an element of a power system are 0.3, 0.3 and 0.8 p.u. respectively, then the element would be a?

(a) Synchronous generator (b) Synchronous motor
(c) Static load (d) Transmission line

Ans. (d)

For transmission line,

$$X_1 = X_2 < X_0$$

End of Solution

Q.79 A 100 MW power station delivers 100 MW for 2 hours, 50 MW for 6 hours in a day and is shut down for maintenance for 45 days each year. Calculate its annual load factor?

(a) 20%
(b) 21%
(c) 22.5%
(d) 18.3%

Ans. **(d)**

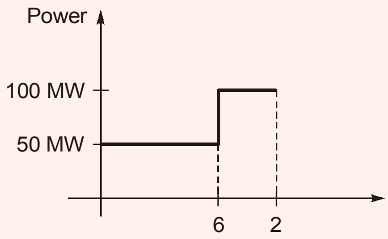
$$P_{avg} = \frac{100\times 2 + 50\times 6 + 0\times(24-8)}{24} = 20.833\text{ MW}$$

$$P_{LF} = \frac{P_{avg}\times \text{Number of days of plant operation}}{P_{max}\times 365}$$

Number of days of plant operation

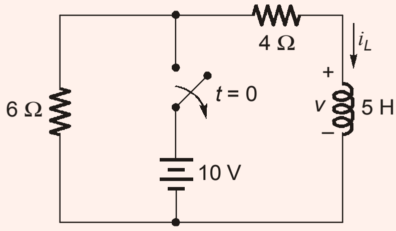
$= 365 - 45 = 320$ days

$$= \frac{20.833\times 320}{100\times 365} = 0.1826 \text{ or } 18.26\% \simeq 18.3\%$$



End of Solution

Q.80 Determine the inductor voltage 'V' in the circuit shown below for $t > 0$?



(a) $25e^{-2t}$
(b) $2.5e^{-0.5t}$
(c) $-2.5e^{-0.5t}$
(d) $-25e^{-2t}$

Ans. **(d)**

$t = 0^-$

$$i_L(0^-) = \frac{10}{4} = 2.5\text{ A}$$

$t = \infty$

$i_L(\infty) = 0$

$R_{eq} = 10\ \Omega$

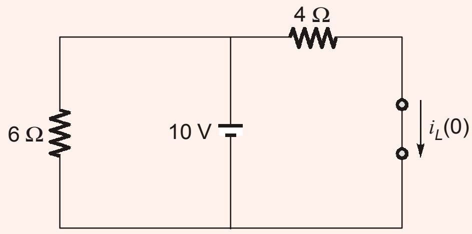
$L = 5$ H

$$\tau = \frac{5}{10} = 0.5\text{ sec}$$

$i_L(t) = 2.5e^{-t/0.5}$

$i_L(t) = 2.5e^{-2t}; \quad t \geq 0$

$$V_L(t) = \frac{Ldi}{dt} = -25e^{-2t}; \quad t \geq 0$$



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