EM THEORY & TRANSMISSION LINE
(ECEN 2201)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Convert the point (3,4,5) from Cartesian to Spherical coordinates
(a) $(7.07,45^0,53^0)$ (b) $(0.707,45^0,53^0)$
(c) $(7.07,54^0,63^0)$ (d) $(0.707,54^0,63^0)$

(ii) Energy stored in a magnetic field is
(a) $W = \frac{1}{2}\sqrt{\frac{\mu H}{4}}$ (b) $W = \mu\sqrt{\frac{H}{2}}$
(c) $W = \frac{\mu H^2}{2}$ (d) $W = \frac{\epsilon H^2}{2}$

(iii) A field line and an equipotential surface are
(a) always parallel (b) always at 90°
(c) inclined at any angle (d) none of the above.

(iv) Depth of penetration δ is given by
(a) $\delta = \sqrt{\frac{1}{2\omega\mu r}}$ (b) $\delta = \sqrt{2\omega\mu\sigma}$
(c) $\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$ (d) $\delta = \sqrt{\frac{2\omega\mu}{\sigma}}$.

(v) "The total electric flux through any closed surface surrounding charges is equal to the amount of charge enclosed". The statement is associated with
(a) Coulomb's square law (b) Gauss's law
(c) Maxwell's first law (d) Maxwell's second law.

(vi) The characteristics impedance of a lossless transmission line is given by
(a) $Z_0 = \sqrt{L/C}$ (b) $Z_0 = \sqrt{C/L}$
(c) $Z_0 = \sqrt{CG/L}$ (d) $Z_0 = LC$.

(vii) The radiation pattern of Yagi-Uda antenna is
(a) Omni directional (b) Bidirectional
(c) Isotropic (d) Multidirectional.

(viii) Which of these functions does not satisfy the wave equation?
(a) $50e^{j\omega(t-3z)}$ (b) $\cos^2(y+5t)$
(c) $(x+2t)^2$ (d) $\sin x \cos t$

(ix) In a certain medium, $E = 10\cos(10^8 t - 3y)a_x$ V/m. What type of medium is it?
(a) Free space (b) Lossless dielectric
(c) Lossy dielectric (d) Perfect conductor.

(x) An antenna located in a city is a source of radio wave. How much time does the transmitted wave take to reach a town 12,000 km away?
(a) 36 s (b) $40\mu s$ (c) 20 ms (c) None of the above.

Group – B

2. (a) Suppose, a scalar field $f(x,y,z)$ varies rapidly. In order to find how fast the field varies along the direction of maximum variation, what combination of Gradient, Divergence and Curl is to be applied? Justify your answer.

(b) Find gradient of the following fields:
(i) $U = \rho^2 z\cos 2\phi$ (ii) $W = 10\, r\sin^2\theta\cos\phi$.

(c) Show that, electric field at any point on the z axis for an infinite sheet on the xy plane with uniform surface charge density, ρ_s C/m² is $E = \frac{\rho_s}{2\epsilon_0}\, a_z$, where, ϵ_0 is free space permittivity.

(d) A circular ring of radius, a carries a uniform charge ρ_LC/m and is placed on the xy-plane with axis as the z-axis. Show that $E(0,0,h) = \frac{\rho a}{2\epsilon_0[h^2+a^2]^{\frac{3}{2}}}\, a_z$.
3 + 2 + 4 + 3 = 12

3. (a) Establish relation between static electric field and potential.

(b) Differentiate between convection current and conduction current. Derive point form of Ohm's law for a conductor.

(c) A solid cylindrical conductor of radius R has a uniform current density. Derive expression for H both inside and outside of the conductor. Plot the variation of H as a function of radial distance from the centre of wire.
3 + 3 + 6 = 12

Group – C

4. (a) A uniform plane wave propagating in a medium has $E = 2e^{-\alpha z}\sin(10^8 t - \beta z)$ a_y V/M. If the medium is characterized by $\epsilon_r = 1,\ \mu_r = 20, \sigma = 3$ S/m, find α, β and H.

   (b) A 60 MHz plane wave travels in a lossless medium with $\epsilon = 3\epsilon_0$ and $\mu = 4\mu_0$. Find the wave velocity, wavelength and intrinsic impedance of the medium.

6 + 6 = 12

5. (a) Explain Poynting theorem. For a time harmonic electromagnetic field, write the expression in terms of electric and magnetic field intensity vectors for (i) instantaneous poynting vector (ii) time average poynting vector.

   (b) The electric field intensity of an electromagnetic wave in free space is given by E_x=0, E_z=0, $E_y = E_0 \cos\omega(t\text{-}z/v)$. Determine the expression for the components of magnetic field intensity $\vec{H}$, using Maxwell's equation for free space.

6 + 6 = 12

Group – D

6. (a) A transmission line is characterised by distributed parameters such as R (Ω/m), L (H/m), G (S/m) and C (F/m). Show that, the characteristics impedance Z_0 of such a transmission line is expressed as $Z_0 = \sqrt{\frac{(R+j\omega L)}{G+j\omega C}}$.

   (b) A distortion-less line has $Z_0 = 60\Omega$, $\alpha = 20$ mNp/m, $u = 0.6c$, where c is the speed of light in a vacuum. Find R, L, G, C and λ at 100 MHz.

8 + 4 = 12

7. (a) What do you understand by distortionless transmission through a transmission line? Show that the line parameters should satisfy the condition RC = LG for distortion less transmission.

   (b) A transmission line has the following constants, R = 10.4Ω, L = 3.666 mH, C = 0.00835 μF and G = 0.08 μ mhos. Calculate Z_0, α, β and v_p at ω = 5000 radian/ sec.

5 + 7 = 12

Group – E

8. (a) What is antenna array factor? Find expression of the array factor for N elements arranged uniformly and symmetrically on either side of the z axis.

   (b) Let, the electric and magnetic fields of an antenna at the far field are obtained as $E_\theta = \frac{\eta I_0 dl}{4\pi}\sin\theta\frac{j\beta}{r}e^{-j\beta}$ and $H_\phi = \frac{jI_0\beta dl}{4\pi r}\sin\theta\, e^{-j\beta}$. Find the expression of the time-averaged radiated power.

6 + 6 = 12

9. (a) Illustrate the radiation characteristics of half wave dipole antenna in two planes. Comment on the characteristics of the antenna.

   (b) Explain the significance of radiation resistance of an antenna. Find the radiation resistance of an antenna whose loss resistance is of 10 Ω, power gain is of 20 and directivity 22.

   (c) Find the gain, beam width and capture area for a parabolic antenna with a 6 metres diameter dish and dipole feed at a frequency of 10 GHz.

3 + 4 + 5 = 12