EM THEORY & TRANSMISSION LINES
(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) The unit of relative permeability is
(a) henry/metre (b) henry
(c) henry/sq. m (d) it is dimensionless.

(ii) The induced voltage across a coil with 250 turns that is located in a magnetic field which is changing at a rate of 8 Wb/s is
(a) 31.25 (b) 2000 (c) 1000 (d) 3125.

(iii) What happens when a steady potential difference is applied across the ends of a conducting wire?
(a) All electrons move with a constant velocity.
(b) All electrons move with constant acceleration.
(c) The random electronic motion will, on the average, be equivalent to a constant velocity.
(d) The random electronic motion will, on the average, be equivalent to a non zero constant acceleration of each electron.

(iv) A transmission line transfers maximum power to the load if
(a) $\Gamma = 0$ (b) $\Gamma = 1$ (c) $\Gamma = -1$ (d) $\Gamma = 0.5$.

(v) Which of the following is not Maxwell's equation for a static electromagnetic field in a linear homogeneous medium?
(a) $\nabla \cdot \mathbf{B} = 0$ (b) $\oint_s \mathbf{D}.d\mathbf{S} = Q$ (c) $\nabla \times \mathbf{D} = 0$ (d) $\nabla^2 \mathbf{A} = \mu_0 \mathbf{J}$.

(vi) Which of the following statements is not true for a phasor?
(a) It may be scalar or a vector
(b) It is a time dependent quantity.
(c) A phasor V_s may be represented as $V_0 \angle\theta$ or $V_0 e^{j\theta}$ where $V_0 = |V_s|$.
(d) It is a complex quantity.

(vii) An electromagnetic wave has $\boldsymbol{E} = 10\, e^{-z} \sin\,(2 \times 10^8 t - 2.5z)\, a_x$. The attenuation and phase constant are
(a) 1.5, 2.5 (b) 2.5, 2.5
(c) 1, 2.5 (d) none of them.

(viii) An electromagnetic wave being incident at a partial reflector reflects and transmits partially with amplitude reflection and amplitude transmission coefficients as R and T, respectively. T and R follow the equation
(a) T + R = 1 (b) R + 1 = T
(c) T + 1 = R (d) none of the above.

(ix) A receiving antenna in an airport is located 100m away from the transmitting antenna. If the effective area of the receiving antenna is 500 cm^2 and the power density at the receiving location is 2 mW/m^2, the total power received is
(a) 100 μW (b) 10 nW
(c) 10 μW (d) 100 nW.

(x) The antenna most commonly used for TV broadcasting in UHF band is a
(a) parabolic dish antenna (b) dipole antenna
(c) Yagi Uda antenna (d) patch antenna.

Group – B

2. (a) State the Coulomb's law and present it using vector notations. Derive an expression for electric force experienced by a point charge due to presence of N number of other discrete charges around it.

(b) Point charges 1 mC and -2 mC are located at (3, 2, -1) and (-1, -1, 4), respectively. Calculate the electric force on a 10 nC charge located at (0, 3, 1) and the electric field intensity at that point.

(2 + 4) + 6 = 12

3. (a) For the vector field $A = r^2 \sin\theta\, a_r + r^2 \sin\theta \cos\varphi\, a_\theta$, find the surface integral $\nabla \times \boldsymbol{A}$ over a sphere of radius r_0.

(b) Electric field lines are perpendicular to equipotential surfaces. Justify.

(c) Does the potential field in cylindrical coordinates $V = \dfrac{10\sin(2\varphi)}{\rho^2}$ satisfy Laplace's equation? Find the potential at $\rho = 5$, $\varphi = \pi/6$. What is the electric field at this point?

3 + 3 + 6 = 12

Group – C

4. (a) What do you mean by Magnetic vector Potential? Explain its significance.

   (b) What is skin depth? Explain how inverse frequency dependence of skin depth helps to reduce material costs of high performance transmission lines with silver/gold plating.

   (c) The xy plane serves as the interface between two different media. Medium 1 ($z < 0$) is filled with a material whose $\mu_r = 4$ and Medium 2 ($z > 0$) is filled with a material whose $\mu_r = 6$. If the interface carries a current $(1/\mu_0)\, a_y$ mA/m and $B_1 = 5a_x + 8a_z$ mWb/m^2, find H_2 and B_2.

3 + 4 + 5 = 12

5. (a) Derive the relevant expressions of electric and magnetic field expressions for wave propagation in lossy dielectrics.

   (b) If the electric field expression for a plane wave is given as $E_x = E_0 \cos(1.5 \times 10^{10}\, t) + 60z$, then determine (i) its wavelength (ii) phase velocity and (iii) direction of travel. Also find the magnetic field H associated with this electric field.

6 + 6 = 12

Group – D

6. (a) For a lossless coaxial transmission line, show that

   (i) The phase velocity = $\frac{1}{\sqrt{LC}}$

   (ii) The characteristic impedance $Z_0 = 60 \ln(b/a)\ \Omega$.

   (b) A distortionless transmission line satisfies RC = LG. If the line has R = 10 mΩ/m, C = 82 pF/m and L = 0.6 μH/m, calculate its characteristics impedance and propagation constant. Assume that the line operates at 80 MHz.

   (c) Establish relation between standing wave ratio (SWR) and reflection coefficient for a loaded transmission line.

3 + 4 + 5 = 12

7. (a) Derive the generalized expression for the input impedance of a transmission line at any point z on it, in terms of load impedance and characteristics impedance.

   (b) Starting from the generalized expression of the propagation constant, derive the exact expression for (i) attenuation constant and (ii) phase constant.

6 + 6 = 12

Group – E

8. (a) Derive expressions of α, β and Z_0 for lossless and distortion less transmission line.

   (b) An air line ($\sigma = 0, \sigma_c = \infty$) has a characteristic impedance of 70Ω and a phase constant of 3 rad/m at 100 MHz. Calculate the inductance per meter and the capacitance per meter of the line.

   (c) Show that a transmission line can transfer maximum power to a load only if the load is matched with the characteristic impedance of the transmission line.

4 + 4 + 4 = 12

9. (a) Explain radiation intensity, directive gain and directivity.

   (b) Determine the electric field intensity at a distance of 10 km from an antenna having a directive gain of 5 dB and radiating a total power of 20 kW.

(2 + 2 + 2) + 6 = 12