EM THEORY & TRANSMISSION LINES
(ECEN 2203)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Solution of propagating wave equation
(a) $f(x,y,t) = f(x)f(y)e^{j\omega t}$ (b) $e^{j(\omega t \pm \beta z)}$
(c) $\sin(\omega t)\cos(\beta z)$ (d) only (a) and (b)

(ii) If an electromagnetic wave is incident obliquely at the surface of a dielectric medium 2 (μ_2, ϵ_2) from dielectric medium 1 (μ_1, ϵ_1), the average angle of incidence and the critical angle are θ_i and θ_c respectively. The total internal reflection occurs for
(a) $\epsilon_1 > \epsilon_2, \theta_i < \theta_c$ (b) $\epsilon_1 < \epsilon_2, \theta_i < \theta_c$
(c) $\epsilon_1 < \epsilon_2, \theta_i > \theta_c$ (d) $\epsilon_1 > \epsilon_2, \theta_i > \theta_c$

(iii) Calculate the emf of a material having flux density (5 sin t) in an area of 0.5 units
(a) 2.5 sin t (b) -2.5 cos t
(c) -5sin t (d) 5 cos t

(iv) Effective area of the antenna is
(a) $\frac{\lambda^2}{4\pi} g_d$ (b) $\frac{\lambda^2}{4\pi}$
(c) $\frac{\varepsilon}{4\pi} g_d$ (d) $\frac{\lambda^2}{6\pi} g_d$

(v) Brewster's phenomena is observed in
(a) TE-polarised wave (b) TM-polarised wave
(c) arbitrary polarization (d) both TE and TM polarized waves

(vi) The electric field component of a wave in free space is given by $\mathbf{E}=10\cos(10^7 t+kz)\mathbf{a_y}$ V/m. It can be inferred that
(a) The wave propagation direction along $\mathbf{a_y}$.
(b) Electric field direction along $\mathbf{a_z}$.
(c) Electric field direction along $\mathbf{a_y}$.
(d) The wave propagation direction along $\mathbf{a_x}$.

(vii) For a transmission line terminated by a load, the reflection co-efficient magnitude |Γ | and the Voltage standing wave ratio S is related as

(a) $S = \frac{1}{1+|\Gamma|}$ (b) $S = \frac{1}{1-|\Gamma|}$ (c) $S = \frac{1-|\Gamma|}{1+|\Gamma|}$ (d) $S = \frac{1+|\Gamma|}{1-|\Gamma|}$

(viii) A 50Ω transmission line is terminated at a load$Z_L = 30 + 20j$. The value of standing wave will be

(a) 2.82 (b)2.04 (c) 1.30 (d) 8.01

(ix) In a dielectric medium, electromagnetic wave with different wavelength experiences different velocity due to

(a) diffraction (b) refraction (c) dispersion (d) all of the above

(x) Conditions to be satisfied for a lossless dielectric medium

(a)$\sigma \simeq 0, \varepsilon = \varepsilon_0\varepsilon_r$, $\mu = \mu_0\mu_r$,or $\sigma \ll \omega\varepsilon$ (b) $\sigma = 0, \varepsilon = \varepsilon_0$, $\mu = \mu_0$,or $\sigma \ll \omega\varepsilon$

(c) $\sigma \neq 0, \varepsilon = \varepsilon_0\varepsilon_r$, $\mu = \mu_0\mu_r$,or $\sigma \ll \omega\varepsilon$ (d) $\sigma \simeq 0, \varepsilon = \varepsilon_0\varepsilon_r$, $\mu = \mu_0$,or $\sigma \gg \omega\varepsilon$

Fill in the blanks with the correct word

(xi) The radiation resistance of an isolated half-wave dipole is _____.

(xii) 1 dB_m gain is equivalent to_____ watts of power.

(xiii) The differential form of Faraday's law is_____.

(xiv) Propagation constant of a lossless transmission line _____.

(xv) 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? _____.

Group – B

2. (a) Prove the relation

$$E = -\nabla V - \frac{\partial \boldsymbol{A}}{\partial t}$$

Symbols have their usual meanings. *[(CO2)(Remember/LOCQ)]*

(b) In a certain region for which $\sigma = 0$, $\mu = 2\mu_0$ and $\varepsilon = 10\varepsilon_0$,

$$\boldsymbol{J_D} = 60\sin(10^9 t - \beta z)\,\boldsymbol{a_x} \ \text{mA/m}^2$$

(i) Find **D** and **H** (ii) β. *[(CO2)(Analyse/IOCQ)]*

(c) Define uniform plane wave. *[(CO2)(Remember/LOCQ)]*

4 + 6 + 2 = 12

3. (a) Find induced electromotive force due to a moving loop and static magnetic field. *[(CO1)(Analyse/IOCQ)]*

(b) State Maxwell's Equations for time varying electromagnetic wave. *[(CO1)(Remember/LOCQ)]*

(c) A conducting bar (PQ) can slide freely over two conducting rails as shown in Fig. 1. Calculate the induced voltage in the bar if

(i) the bar is stationary at y=8cm and $\mathbf{B} = 4\cos 10^6 t\ \mathbf{a_z}$ mWb/m^2.

(ii) the bar slides at velocity $\mathbf{u} = 20\mathbf{a_y}$ m/s and $\mathbf{B} = 4\mathbf{a_z}$ mWb/m^2. *[(CO1)(Analyse/IOCQ)]*

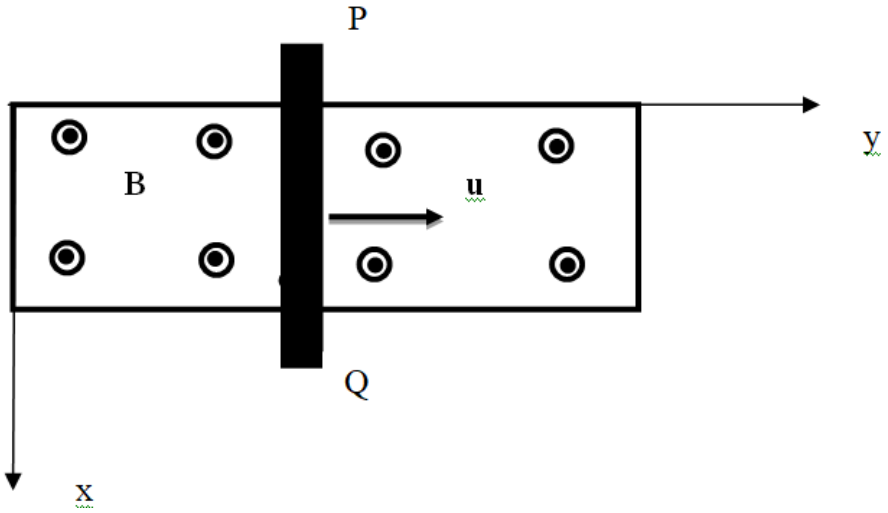

Fig. 1

4 + 2 + 6= 12

Group - C

4. (a) Find attenuation constant, phase constant and intrinsic impedance for electromagnetic plane waves in good conductors. *[(CO3)(Analyse/HOCQ)]*

   (b) Express incident reflected and transmitted components of the electric field and magnetic field due to reflection and transmission of a plane wave at oblique incidence. *[(CO3)(Remember/LOCQ)]*

5 + 7 = 12

5. (a) Prove that the tangential wave vectors must be continuous to satisfy electric and magnetic boundary conditions at an interface between two mediums. *[(CO3)(Analyse/HOCQ)]*

   (b) Electric field corresponding to an EM wave is given as $\vec{E} = 0.5e^{-z/3}\cos(2\pi 10^6 t - 0.021\,z)\;\hat{\boldsymbol{a}}_x + 0.8e^{-z/3}\sin(2\pi 10^6 t - 0.021\,z)\;\hat{\boldsymbol{a}}_y$. Identify the type of polarisation. What is the phase difference between two components of the electric field? *[(CO4)(Remember/LOCQ)]*

   (c) Using suitable diagrams explain the differences between TM-polarized and TE-polarized wave. What is Brewster's angle and which polarization exhibits Brewster's phenomena? *[(CO2)(Apply/IOCQ)]*

5 + 4 + 3 = 12

Group - D

6. (a) For a transmission line placed along the z direction show that $\frac{d^2V_s}{dz^2} - \gamma^2 V_s = 0$, where the total voltage $V(z,t) = \mathrm{Re}[V_s(z)e^{j\omega t}]$ and γ is complex propagation constant. Hence show that the characteristics impedance $Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$. *[(CO3)(Analyse/HOCQ)]*

   (b) A lossless transmission line has a characteristics 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. *[(CO4)(Remember/LOCQ)]*

8 + 4 = 12

7. (a) Prove that the condition for a distortion less transmission line should be $\frac{R}{L} = \frac{G}{C}$.
[(CO4)(Analyse/IOCQ)]

(b) A 60Ω transmission line operating at 20MHz is 10m long. If the input impedance is 90+j150 Ω. Calculate Z_L, Γ, s. Symbols have their usual meanings.
[(CO4)(Analyse/IOCQ)]

(c) Explain the statement – 'A lossless transmission line is also a distortion less transmission line but a distortion less transmission line is not a lossless line'.
[(CO4)(Understand/LOCQ)]

3 + 6 + 3 = 12

Group – E

8. (a) Show that the directive gain of the Hertzian dipole is
$$G_d(\theta, \phi) = 1.5sin^2\theta$$
[(CO5)(Analyse/HOCQ)]

(b) Define HPBW and FNBW. *[(CO5)(Remember/LOCQ)]*

(c) Find the radiation resistance of a Hertzian dipole of length λ/40 and λ/80.
[(CO5)(Analyse/IOCQ)]

6 + 3 + 3 = 12

9. (a) The magnetic field of certain antenna at very large distance r is given as $\mathbf{H} = j\frac{I_0 dl\beta}{4\pi r} \sin\theta\, e^{j\beta r}\, \hat{\boldsymbol{a}}_\phi$. Find the corresponding electric field. Also find the time-averaged radiated power in free space. *[(CO3)(Analyse/HOCQ)]*

(b) The radiation intensity of a certain antenna is
$$U(\theta, \phi) = \begin{cases} 2sin\theta \sin^3\phi\,, 0 \le \theta \le \pi, 0 \le \phi \le \pi \\ 0, \text{elsewhere} \end{cases}$$
Determine the directivity of the antenna. *[(CO4)(Remember/LOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	41.67	32.29	26.04

Course Outcome (CO):

After the completion of the course students will be able to
1. Apply their pre-requisite knowledge of Electrostatics and Magneto statics.
2. Comprehend Electromagnetic wave propagation in different mediums.
3. Understand different electromagnetic phenomena associated with Transmission Lines.
4. Design of Impedance Matching Networks for two wire Transmission Lines.
5. Develop the ability to analyze the radiation characteristics of antenna configurations and identify respective areas of application.
6. Understand pattern synthesis and analysis in linear antenna array.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*