PONDICHERRY UNIVERSITY-4623028

B.Tech. DEGREE EXAMINATION, MAY 2015

Third Semester-Electronics and Communication Engineering (ECE)

ENGINEERING ELECTROMAGNETICS AND WAVES (2009-2012 Batches)

Time: Three hours Maximum : 75 marks

PART A — (10 × 2 = 20 marks)

Answer ALL questions. All questions carry equal marks.

1. Define Divergence theorem and Stoke's theorem.
   Ans 1. For answer refer: **Page 30, topic 1.6.3-**Statement with formula.
   For answer refer: **Page 28, topic 1.6.1** greyed box.

2. Calculate the capacitance per Km between a pair of parallel wires each of diameter 1cm at a spacing of 50 cm.
   Ans 2. Capacitance per meter $= \dfrac{\pi\varepsilon}{\ell n\left(\dfrac{d-a}{a}\right)}$

   $d = 50 \text{ cm} = 50\times10^{-2}\text{ m};\ a = \frac{1}{2}\text{ cm} = 0.5\times10^{-2}\text{ m} = 5\times10^{-3}\text{ m}$

   Capacitance per meter $= \dfrac{\pi\varepsilon_0}{\ell n\left(\dfrac{50\times10^{-2} - 5\times10^{-3}}{5\times10^{-3}}\right)}$

   $= 6.05\times10^{-12}\text{ F/m}$

   Capacitance /Km $= \dfrac{6.05\times10^{-12}\text{ F}}{1\times10^{-3}\text{ Km}}$

   Capacitance /Km $= 6.05\times10^{-9}\dfrac{\text{F}}{\text{Km}}$.

3. State Biot-Savart's Law.
   Ans 3. For answer refer: **Page 107, topic 3.4** till fig 3.6 in page 108.

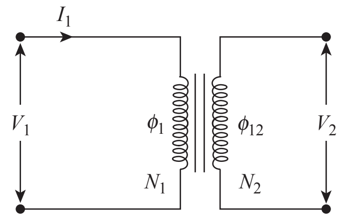
4. Identify the relationship between magnetic field intensity and magnetic flux density.

   Ans 4. $H = \left(\dfrac{B}{\mu}\right)$

   Magnetic flux Intensity, $H = \dfrac{\text{Magnetic flux density, } B}{\text{Permeability of medium, } \mu}$.

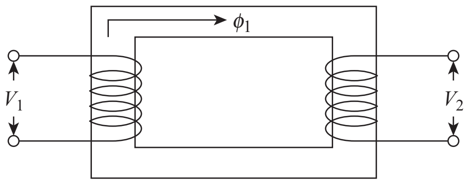
5. Determine the Faraday's Law of electromagnetic induction.
   Ans 5. For answer refer: **Page 154, topic 4.2** –Greyed box with formula.

6. What is meant by mutual inductance? Also give the expression for coefficient of coupling.
Ans 6.



Let a voltage source V_1 set up a flux ϕ_1 per turn in the primary of the transformer taking current I_1.

Then self Inductance is given by $L = \left(\frac{N\phi_1}{I_1}\right)$.



Let the flux linking the secondary be ϕ_{12} per turn, then mutual inductance is given by,

$$M = \left(\frac{N_2\phi_{12}}{I_1}\right)$$

Coefficient of coupling, K $= \frac{M}{\sqrt{L_1 \cdot L_2}}$.

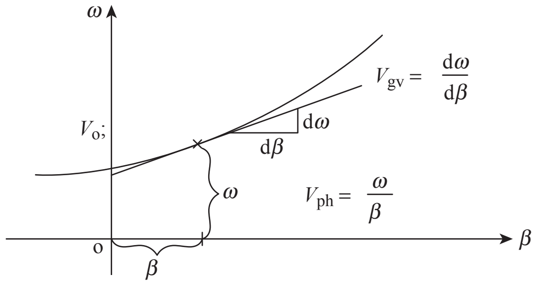
7. Write the Maxwell's equation from electric Gauss's Law in point form?
Ans 7. By Gauss's Law, $\nabla \cdot D = \rho_v$.

8. Express E and B in terms of potential functions V and A.
Ans 8. For answer refer: **Page 59, topic 2.2.2** –Eq (2); **Page 126, topic 3.9.2,** eq (2). $\left(\frac{dV}{dl}\right) = -E$; $(\nabla \times A) = B$.
V = voltage or electric potential; E = Electric field intensity; A = magnetic vector potential.

9. In What ways is group velocity different from phase velocity?

Ans 9. Velocity, $v_0 = \frac{1}{\sqrt{\mu\varepsilon}}$; Group velocity, $V_{Gv} = \left(\frac{d\omega}{d\beta}\right)$; phase velocity $V_{ph} = \left(\frac{\omega}{\beta}\right)$.

Phase velocity V_{ph} is always greater than velocity v_0, whereas group velocity V_{gr} is always less than V_0.



10. What is meant by the wave impedance of the total field? When is this impedance equal to the intrinsic impedance of the medium?

Ans 10. Wave impedance of the material is given by $Z = \sqrt{\frac{\mu}{\varepsilon}}$; Intrinsic impedance of the medium is given by $\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}}$. When the conductivity of the medium $\sigma = 0$, $\eta = \sqrt{\frac{j\omega\mu}{j\omega\varepsilon}} = \sqrt{\left(\frac{\mu}{\varepsilon}\right)}$. When the medium is perfect dielectric, both intrinsic impedance and wave impedance becomes equal to one another.

$$\eta = Z = \sqrt{\frac{\mu}{\varepsilon}} \text{ (iff, } \sigma = 0)$$

PART B – (5 × 11 = 55 marks)

Answer ALL question, One from each Unit. All questions carry equal marks.

UNIT I

11. (a) An infinite sheet of charge is placed in the xy-plane with uniform charge density ρ_s. Derive the expression for electric field at the point (0,0,h). (7)

Ans 11. (a) For answer refer: **Page 40, topic 1.9.4**.

11. (b) Obtain the relationship between electric field 'E' and electric potential 'V'. (4)

Ans 11. (b) For answer refer: **Page 59, topic 2.2.2**.

Or

12 (a) Given that electric potential $V = 10\sin(\theta)\cos(\varnothing)/\text{r}^2$. Find the electric flux density D at $\left(2, \frac{\pi}{2}, 0\right)$. (6)

Ans 12. (a) $V = \frac{10\sin\theta \cdot \cos(\phi)}{r^2}$

$$D = \varepsilon_0 E$$

$$\frac{dV}{d\ell} = -E; \qquad \Rightarrow \nabla V = -E$$

$$\nabla V = \frac{\partial V}{\partial r}\vec{a}_r + \frac{1}{r}\left(\frac{\partial V}{\partial \theta}\right)\vec{a}_\theta + \left(\frac{1}{r\sin\theta}\right)\left(\frac{\partial V}{\partial \phi}\right)\cdot\vec{a}_\phi$$

$$V = 10\sin\theta \cdot \cos\phi \cdot r^{-2}$$

$$\frac{\partial V}{\partial r} = (-2)\cdot 10\sin\theta\cdot\cos\phi\cdot r^{-3}$$

$$\left(\frac{\partial V}{\partial r}\right) = \frac{-20\sin\theta\cdot\cos\phi}{r^3}$$

$$\frac{\partial V}{\partial\theta} = 10\cos\phi\, r^{-2}(\cos\theta) = \frac{10\cos\theta\cdot\cos\phi}{r^2}$$

$$\frac{1}{r}\left(\frac{\partial V}{\partial\theta}\right) = \frac{10\cos\theta\cdot\cos\phi}{r^3}$$

$$\left(\frac{\partial V}{\partial\phi}\right) = 10\sin\theta\, r^{-2}(-\sin\phi) = \frac{-10\sin\theta\cdot\sin\phi}{r^2}$$

$$\frac{1}{r\sin\theta}\left(\frac{\partial V}{\partial\phi}\right) = \frac{-10\sin\phi}{r^3}$$

$$\nabla V = \frac{-20\sin\theta\cdot\cos\phi}{r^3}\ \vec{a}_r + \frac{10\cos\theta\cdot\cos\phi}{r^3}\vec{a}_\theta - \frac{10\sin\phi}{r^3}\vec{a}_\phi$$

$$-E = -\left[\left(\frac{10}{r^3}\right)\left(2\sin\theta\cos\phi\cdot\vec{a}_r - \cos\theta\cdot\cos\phi\,\vec{a}_\theta + \sin\phi\vec{a}_\phi\right)\right]$$

$$E = \left(\frac{10}{r^3}\right)\left[2\sin\theta\ \ \cos\phi\cdot\vec{a}_r - \cos\theta\cdot\cos\phi\vec{a}_\theta + \sin\phi\,\vec{a}_\phi\right]$$

$$D = \varepsilon_0 E = \frac{10\varepsilon_0}{r^3}\left[2\sin\theta\cos\phi\cdot\vec{a}_r - \cos\theta\cdot\cos\phi\vec{a}_\theta + \sin\phi\vec{a}_\phi\right]$$

$$\left(2,\frac{\pi}{2},0\right):\qquad r = 2;\qquad \theta = \frac{\pi}{2};\qquad \phi = 0.$$

$$D = \frac{10\varepsilon_0}{2^3}\left[2\sin\left(\frac{\pi}{2}\right)\cdot\cos(0)\cdot\vec{a}_r\right] = \frac{10\varepsilon_0}{2^2}$$

$$D = 2.5\,\varepsilon_0 = 22.135\times 10^{-12}.$$

12. (b) Derive Poisson's and Laplace's equations. (5)
Ans 12. (b) For answer refer: **Page 70, topic 2.7 fully**.

UNIT II

13. Derive an expression for force between two current carrying conductors. (11)
Ans 13. For answer refer: **Page 118, topic 3.7.1.1 fully**.

Or

14. Write detailed notes on the following:
(a) Ampere's Law. (6)
Ans 14. (a) For answer refer: **Page 112, topic 3.6 fully** and **Page 112, topic 3.6.1.1 fully**.

14. (b) Helmholtz's Theorem. (5)
Ans 14. (b) Helmholtz's theorem is stated as : A vector function is determined uniquely, if the values of its curl and divergence are known at all points.

UNIT III

15. Obtain the boundary conditions for the normal and tangential components of electric fields at an interface separating (a) dielectric and dielectric (b) conductor and dielectric. (11)
Ans 15. For answer refer: **Page 80, topic 2.11**.

Or

16. Explain briefly about energy density in magnetic field. (11)
Ans 16. For answer refer: **Page 138, topic 3.14** and **topic 3.14.1 in page 139**.

UNIT IV

17. With necessary explanation, derive the Maxwell's equation in differential and integral forms. (11)
Ans 17. For answer refer: **Page 163, topic 4.5.2** fully till $\nabla . B = 0$ in page 166.

Or

18. From the Maxwell's equation, derive the electromagnetic wave equation in conducting medium for E and H fields. (11)
Ans 18. For answer refer: **Page 176, topic 5.3** and **topic 5.3.1** till eq II in page 178.

For answer refer: **Page 179, topic 5.3.3** till eq (3) only.

UNIT IV

19. Explain different types of polarization of uniform waves. (11)
Ans 19. For answer refer: **Page 176, topic 5.2.2**.

Or

20. Discuss in detail about wave propagation in good dielectric and good conductor. (11)

Ans 20. For answer refer: **Page 177, eq (I) only, topic 5.4 in page 181** till "$E = C_1 e^{-j\beta x} + C_2 e^{j\beta x}$"

For answer refer: **Page 183, topic 5.4.1** till "$\nabla^2 E - \gamma^2 E = 0$" at page end.