PONDICHERRY UNIVERSITY-4643037

B.Tech. DEGREE EXAMINATION, APRIL 2015

Third Semester-Electrical and Electronics Engineering

ELECTROMAGNETIC THEORY (2009–2012 Batches)

Time: Three hours | Maximum : 75 marks

PART A — (10 × 2 = 20 marks)

Answer ALL questions. All questions carry equal marks.

1. Write down the expressions for Laplace's and Poisson's equations?
   Ans 1. For answer refer: **Page 70, Topic 2.7**, "last 6 lines has answer."

   Laplace's eq : $\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$

   Poisson's eq: $\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = \left(\frac{-\rho_v}{\varepsilon}\right)$

2. State Gauss's Law.
   Ans 2. For answer refer: **Page 37, topic 1.9**, greyed box.

3. Write the boundary conditions for dielectric and dielectric interface.

   Ans 3. For answer refer: **Page 80**, $\left.\begin{array}{l} E_{t_1} = E_{t_2} \\ D_{n_1} - D_{n_2} = \rho_s \end{array}\right\}$ Boundary conditions for dielectrics.

4. What is meant by dielectric strength?
   Ans 4. For answer refer: **Page 61**, first grey box.

5. Define Ampere's Law.
   Ans 5. For answer refer: **Page 112**, **Topic 3.6-**grey box.

6. What is meant by magnetic scalar potential?
   Ans 6. Magnetic Scalar Potential.

   1. Magnetic Scalar Potential, V_m is given by

   $$V_m = -\int H \cdot d\ell$$

   2. It satisfies Laplace's Equation.

7. What is called Magnetization?
   Ans 7. For answer refer: **Page 129, Topic 3.10.2**.

8. Define Faraday's Law.
   Ans 8. For answer refer: **Page 154, Topic 4. 2** till $V = N\left(\frac{d\phi}{dt}\right)$.

9. How do you define displacement current?

Ans 9. For answer refer: **Page 68, Topic 2.6.3**; $I_D = \left(\frac{\varepsilon A}{d}\right) \cdot \left(\frac{dV}{dt}\right)$.

10. What is the significance of poynting Vector?

Ans 10. For answer refer: **Page 204** first Greyed box.

PART B – (5 × 11 = 55 marks)

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

UNIT I

11. Point charges 1mC and -2mC are located at (3, 2,-1) and (-1,-1,4) respectively. Calculate the electric force on 10nC charge located at (0, 3, 1) and the electric field intensity at that point. (11)

Ans 11. Similar problem solved in page 44, Q1.11.

To calculate force and electric field intensity on a charge of $Q_1 = 10 \times 10^{-9}$ C at (0, 3, 1), $r_1 = 3\hat{j} + 1\hat{k}$ due to $Q_2 = 1 \times 10^{-3}$ C at (3, 2, –1), $r_2 = 3\hat{i} + 2\hat{j} - 1\hat{k}$. $Q_3 = -2 \times 10^{-3}$ C at (–1, –1, 4), $r_3 = -\hat{i} - \hat{j} + 4\hat{k}$.

$$\vec{F}_{12} = \frac{Q_1}{4\pi\varepsilon_{o1}} \frac{Q_2}{r_{12}^2} \cdot \hat{a}_{12}$$

$$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2 = 3\hat{j} + 1\hat{k} - 3\hat{i} - 2\hat{j} + 1\hat{k}$$

$$\vec{r}_{12} = -3\hat{i} + 1\hat{j} + 2\hat{k}$$

$$|\vec{r}_{12}| = \sqrt{(-3)^2 + (1)^2 + (2)^2} = 3.75$$

$$\vec{a}_{12} = \frac{\vec{r}_{12}}{|\vec{r}_{12}|} = \frac{-3\hat{i} + \hat{j} + 2\hat{k}}{(3.75)}$$

$$F_{12} = \frac{10 \times 10^{-9} \times 1 \times 10^{-3}}{4\pi\varepsilon_0 (3.75)^2} \left[\frac{-3\hat{i} + \hat{j} + 2\hat{k}}{(3.75)}\right]$$

$$\vec{F}_{12} = 1.70 \times 10^{-3}(-3\hat{i} + \hat{j} + 2\hat{k}).$$

$$F_{13} = \frac{Q_1 Q_3}{4\pi\varepsilon_0 r_{13}^2} \hat{a}_{13}$$

$$\vec{F}_{13} = \frac{10 \times 10^{-9} \times (-2 \times 10^{-3})}{4\pi\varepsilon_0 |r_{13}|^2} \cdot a_{13}$$

$$\vec{r}_{13} = \vec{r}_1 - \vec{r}_3 = 3\hat{j} + 1\hat{k} + \hat{i} + \hat{j} - 4\hat{k}.$$

$$\vec{r}_{13} = \hat{i} + 4\hat{j} - 3\hat{k}$$

$$|r_{13}| = \sqrt{(1)^2 + (4)^2 + (-3)^2} = 5.1$$

$$\vec{a}_{13} = \frac{\hat{i} + 4\hat{j} - 3\hat{k}}{(5.1)}$$

$$\vec{F}_{13} = \frac{10\times10^{-9}\times(-2\times10^{-3})}{4\pi\varepsilon_0(5.1)^2}\left[\frac{\hat{i}+4\hat{j}-3\hat{k}}{(5.1)}\right]$$

$$= -1.36\times10^{-3}(\hat{i}+4\hat{j}-3\hat{k}).$$

Total force, $\vec{F} = \vec{F}_{12} + \vec{F}_{13}$

$$= 10^{-3}\left[1.70\times(-3\hat{i}+\hat{j}+2\hat{k}) - 1.36\times(\hat{i}+4\hat{j}-3\hat{k})\right]$$

$$\vec{F} = 10^{-3}\left[-5.1\hat{i}+1.7\hat{j}+3.4\hat{k}-1.36\hat{i}-5.44\hat{j}+4.08\hat{k}\right]$$

$$\vec{F} = 10^{-3}\times(-6.46\hat{i}-3.74\hat{j}+7.48\hat{k}).$$

Force experienced by 10nC charge is given by $\vec{F} = (-6.46\hat{i}-3.74\hat{j}+7.48\hat{k})\times10^{-3}$ N.

Force experienced by unit positive charge is Electric field intensity E.

(ie) $E = \dfrac{F}{Q} = \dfrac{(-6.46\hat{i}-3.74\hat{j}+7.48\hat{k})\times10^{-3}}{10\times10^{-9}}$

$$\vec{E} = (-6.46\hat{i}-3.74\hat{j}+7.48\hat{k})\times10^{+5}\ \text{V/m}.$$

Or

12. Two point charges $-4\mu C$ and $5\mu C$ are located at (2, –1, 3) and (0, 4, –2) respectively. Find the potential at (1, 0, 1) assuming zero potential at infinity. (11)

$Q_1 = -4\times10^{-6}\,\text{C}$ at $(2,-1,3)$ $\qquad \vec{r}_1 = 2\hat{i} - \hat{j} + 3\hat{k}$

$Q_2 = 5\times10^{-6}\,\text{C}$ at $(0,4,-2)$ $\qquad \vec{r}_2 = 4\hat{j} - 2\hat{k}$. To find potential at (1, 0, 1). $r_0 = \hat{i} + \hat{k}$

$$V_{01} = \left(\frac{Q_1}{4\pi\varepsilon_0\, r_{01}}\right)\overrightarrow{a_{01}}$$

$$V_{02} = \left(\frac{Q_2}{4\pi\varepsilon_0\, r_{02}}\right)\overrightarrow{a_{02}}$$

$$\overrightarrow{r_{01}} = \vec{r}_1 - \vec{r}_0 = \hat{i} - \hat{j} + 2\hat{k} \qquad |r_{01}| = 2.45$$

$$\overrightarrow{r_{02}} = \vec{r}_2 - \vec{r}_0 = -\hat{i} + 4\hat{j} - 3\hat{k} \qquad |r_{02}| = 5.1$$

$$V_{01} = \frac{-4\times10^{-6}}{4\pi\varepsilon_0(2.45)}\left[\frac{\hat{i}-\hat{j}+2\hat{k}}{(2.45)}\right] = -5989.2\left[\hat{i}-\hat{j}+2\hat{k}\right]$$

$$V_{02} = \frac{5\times10^{-6}}{4\pi\varepsilon_0(5.1)}\left[\frac{-\hat{i}+4\hat{j}-3\hat{k}}{(5.1)}\right] = 1728\left[-\hat{i}+4\hat{j}-3\hat{k}\right]$$

$$V_0 = V_{01}+V_{02} = -7717.2\hat{i}+12901\hat{j}-17162\hat{k}$$

$$|V_0| = 22.815 \text{ kV}.$$

Voltage at a point is workdone in moving a unit positive charge from Infinity to the point under consideration.
Since here the force experienced during the movement and at that end of the movement is a vector, we need to use vector addition.

UNIT II

13. (a) Deduce an expression for the capacitance of a parallel plate capacitor having two dielectric media. (6)

Ans 13. (a) For answer refer: **Page 72, topic 2.8.3** fully.

13. (b) Obtain an expression for the energy stored in a capacitor. (6)

Ans 13. (b) For answer refer: **Page 78, topic 2.10** fully till fig 2.32.

Or

14. The electric field intensity in polystyrene $(\varepsilon_r = 2.55)$ filling the space between the plates of a parallel plate capacitor is 10 KV/m . The distance between the plates is 1.55 mm. calculate
(a) Electric Flux density
(b) Polarization
(c) Potential difference between the plates. (11)

Ans 14. (a) Electric Flux density $D = \varepsilon E = 2.55\times\varepsilon_0\times10\times10^3$ V/m

$$D = 225.78\times10^{-9}.$$

(b) Polarization, $P = \chi_e\varepsilon_0 E$

$$\varepsilon_r = 1+\chi_e \quad \rightarrow \chi_\ell = \varepsilon_r - 1 = 2.55-1 = 1.55$$

$$P = 1.55\times\varepsilon_0\times10\times10^3$$
$$P = 137.24\times10^{-9}.$$

(c) Potential difference between the plates.

$$V_p = E\cdot d = 10\times \cancel{10^3}\times1.5\times\cancel{10^{-3}} = 15 \text{ Volts}.$$

UNIT III

15. (a) State and explain Biot Savart's Law. (4)

Ans 15. (a) For answer refer: **Page 107,topic 3.4** till fig 3.6 in page 108.

15. (b) Find the expression for magnetic field intensity at the centre of a circular wire carrying current 'I' A in the anticlockwise direction. The radius of the circle is 'a' and the wire is in XY plane. (7)

Ans 15. (b) For answer refer: **Page 119, topic 3.7.2** till page 121, when $h = 0$

$$H = \frac{Ia^2}{2a^3}\hat{k} = \left(\frac{I}{2a}\right)\cdot\hat{k}\,.$$

Or

16. Determine the force per meter length between two long parallel wires A and B separated by 5cm in air and carrying currents of 40A

(a) In the same direction

(b) In the opposite direction. (11)

Ans 16. For answer refer: **Page 146**, Q (1).

UNIT IV

17. A long solenoid with $2\times 2\,\text{cm}^2$ cross section has an iron core $(\mu_r = 1000)$ and 4000 turns/meter. It carries a current of 0.5A. Find

(a) Its self inductance per meter,

(b) Energy stored per meter in its field. (11)

Ans 17. Cross section Area $A = 2\times 2\ \text{cm}^2 = 2\times 2\times 10^{-4}\ \ \text{m}^2$

$$\mu_r = 1000$$
$$N = 4000 \text{ Turns/meter}$$
$$I = 0.5\text{ A}$$

$$L = \left(\frac{\mu_r\ \mu_0\ N^2 A}{\ell}\right) = \frac{1000\times\mu_0\times(4000)^2\times 4\times 10^{-4}}{(1)}$$

Self Inductance/meter, L = 8.04 H

Energy stored per meter, $E = \frac{1}{2}LI^2 = \frac{1}{2}(8.04)\times(0.5)^2$

$E = 1.005$ Watts.

Or

18. Derive the boundary conditions between two different magnetic medias in terms of

(a) Magnetic Flux density and

(b) Magnetic field intensity. (11)

Ans 18. (A) For answer refer: **Page 132, topic 3.12** fully.

UNIT V

19. Derive the Maxwell's equations in point and integral forms from Faraday's Law and Ampere's Law. (11)
Ans 19. For answer refer: **Page 163, topic 4.5.2** Maxwell's Eq I and Maxwell's Eq II fully, till 1^{st} grey box in Page 165.

Or

20. State Poynting's theorem. Derive and illustrate the power balance in electromagnetic fields using Poynting's theorem. (11)
Ans 20. For answer refer: **Page 204** from poynting vector till page 205 before 5.8.1.