PONDICHERRY UNIVERSITY-3623016

B.Tech. DEGREE EXAMINATION, NOVEMBER 2013

Third Semester-Electronics and Communication Engineering

ENGINEERING ELECTROMAGNETICS

Time: Three hours Maximum : 75 marks

PART A — (10 × 2 = 20 marks)

Answer ALL questions. All questions carry equal marks.

1. Find the gradient of $\phi(X,Y,Z) = XY^2 - 2Z$
   Ans 1. For answer refer: **Page 22, Topic 1.5.1**.

$$\phi(x,y,z) = xy^2 - 2z$$

$$\nabla = \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right).$$

$$\nabla\phi = y^2\hat{i} + 2xy\hat{j} + (-2)\hat{k}$$

$$\nabla\phi = y^2\hat{i} + 2xy\hat{j} - 2\hat{k}$$

2. State and explain coulomb's law.
   Ans 2. For answer refer: **page 32, topic 1.7** with Diagram and formulae.

3. Define Electric dipole and dipole moment.
   Ans 3. For answer refer: **Page 63**, first 2 grey boxes with formula and diagram.

4. State Equation of continuity.
   Ans 4. For answer refer: **Page 87, topic 2.12.2**; Take statement, diagram and final eq (I).

5. State Biot-Savart's law.
   Ans 5. For answer refer: **Page 107, topic 3.4**; Take statement, diagram and formulae.

6. Define:
   (a) Magnetic field and
   (b) Magnetic field intensity, $\overline{H}$
   Ans 6. For answer refer: **Page 105, topic 3.2**; Magnetic field intensity, $H = \left(\frac{B}{\mu}\right)$.

7. What are requirements of a permanent magnetic material?
   Ans 7. It should have (i) high retentivity, and (ii) high magnetic flux density.

8. State the similarities of the electric circuits and magnetic circuits.
   Ans 8. For answer refer: **Page 140, Topic 3.15.1**; take any 2 points from tabular column.

9. Define a Wave.
   Ans 9. For answer refer: **Page 171, topic 5.1**.

10. Define Slepian vector.
Ans 10. Slepian vector "S_1", is used to describe the flow of energy in EM waves. It is sum of two vectors as shown in below equation.

$S_1 = S + \text{curl (VH)} = (E \times H) + \nabla \times (VH)$

S_1 = Slepian vector E = Electric field Intensity

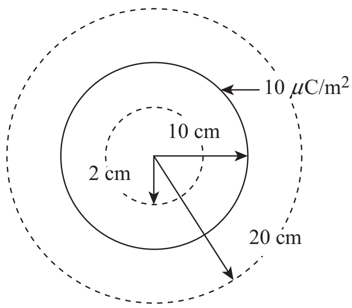
V = Electric potential H = Magnetic field Intensity.

PART B – (5 × 11 = 55 marks)

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

UNIT I

11. A hollow metallic sphere of radius 10 cm has uniform charge density of 10 $\mu C/m^2$ on its surface. Compute electric field intensity at a radial distance of
(a) 2 cm
(b) 10 cm
(c) 20 cm from its centre. Medium is air
Ans 11.



By Gauss's law, we have $Q = \oint D \cdot ds$
(a) for a sphere of 2 cm radius, the charge enclosed is zero. Hence, $D = 0; \Rightarrow E = 0$
(b) At a radius of 10 cms, the charge enclosed is still zero and hence, $E = 0$.
(c) At a radius of 20 cms, the charge enclosed is given by

$$= \text{surface area} \times \text{charge density}$$

$$Q = 4\pi r^2 \cdot \rho_s = 4\pi(10\times10^{-2})^2(10\times10^{-6})$$

By Gauss's law, $$\oint D \cdot ds = D \cdot \oint ds = D \cdot A_s$$

(ie) $$Q = D \cdot 4\pi r^2 = D \cdot 4\pi(20\times10^{-2})^2$$

(ie) $$\cancel{4\pi}(10\times10^{-2})^2(10\times10^{-6}) = D \cdot \cancel{4\pi}(20\times10^{-2})^2$$

$$\frac{(1\cancel{0}\times\cancel{10^{-2}})\,(10\times\cancel{10^{-2}})\,(1\cancel{0}\times10^{-6})}{(2\cancel{0}\times\cancel{10^{-2}})\,(2\cancel{0}\times\cancel{10^{-2}})} = D$$

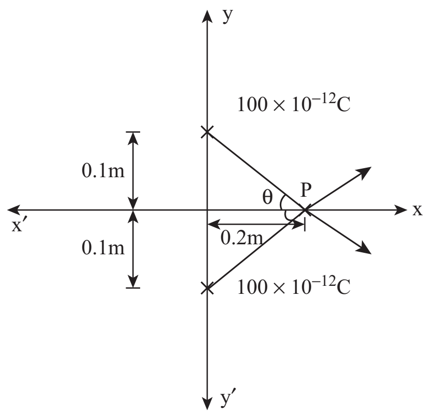
$$2.5\times10^{-6} = \varepsilon_0 E.$$

$$\Rightarrow\ E = \frac{2.5\times10^{-6}}{\varepsilon_0} = 282.35\times10^3 \text{ V/m}$$

$$E = 282.35\times10^3 \text{ V/m}$$

Or

12. A positive charge of 100 pico coulombs is located in air at $x = 0$, $y = 0.1$ m. Another charge which is identical with the above mentioned charge is located at $x = 0$, $y = -0.1$ m. what are the magnitude and direction of the electric field intensity E and what is the absolute potential V at $x = 0.2$m, $y = 0$? The charges are in $x - y$ Plane. Medium is air.



$$\text{Hypotenus} = \sqrt{(0.1)^2 + (0.2)^2}$$

$$= 0.2241 = 22.4\times10^{-2}$$

$$\tan\theta = \left(\frac{0.1}{0.2}\right) = 26.6°$$

Electric field intensity at point P is given by

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} = \frac{100\times10^{-12}}{4\pi\varepsilon_0(22.4\times10^{-2})^2}$$

$$E = \frac{100\times10^{-12}}{4\pi\varepsilon_0(22.4\times10^{-2})^2} = 17.91 \text{ V/m}$$

Horizontal component of one vector $E_x = 17.91\cos(26.6) = 16.0$
For Both the vector $E_x = 32$ V/m and it is directed along x-axis.
The vertical component cancel each other as it is equal and opposite. Hence, $E_y = 0$.
Absolute potential at "P" is given by

$$V_p = \frac{Q}{4\pi\varepsilon_0 r_a} = \frac{100\times10^{-12}}{4\pi\varepsilon_0(22.4\times10^{-2})}$$

$V_p = 4$ Volts

Potential at P due to another point charge = 4V. Hence total potential, $V_p = 8$ volts.

UNIT II

13. (a) Distinguish between absolute electric potential and relative electric potential.

Ans 13. (a) For answer refer: **Page 55, Topic 2.1** Electric potential, 2nd grey box is for Absolute potential, 1st grey box is for relative potential.

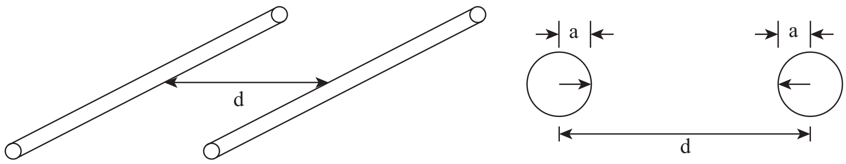
13. (b) Derive an expression for potential capacitance of two cylindrical parallel conductors (two conductor transmission line.)

Ans 13. (b) For answer refer: **Page 75, Topic 2.8.7** Transmission line fully.

Or

14. Evaluate the capacitance per Km length of identical parallel Lines of diameter 1.5cm spaced 0.75 m apart. Also find the potential difference between them which will make maximum electric field intensity at the conductor surface just 3×10^6 V/m.

Ans 14. Two parallel transmission line



$$C = \frac{\pi \varepsilon_0}{\ell n\left(\frac{d-a}{a}\right)}$$

$$d = 0.75 = 75\times10^{-2} \text{ m}$$

$$a = \frac{1.5}{2}\text{cm} = 0.75 \text{ cm} = 75\times10^{-2}\text{cm}$$

$$a = 75\times10^{-4} \text{ m}$$

$$C = \frac{\pi\varepsilon_0}{\ell n\left(\frac{75\times10^{-2} - 75\times10^{-4}}{75\times10^{-4}}\right)}$$

$$\frac{C}{m} = \frac{\pi\varepsilon_0}{4.59511} = 6.05\times10^{-12} F(= 6.05 \text{ pico } F)$$

$$\frac{C}{K_m} = 6.05\times10^{-12}\ F\times1000 = 6.05\times10^{-9} \text{F/km}$$

$$E = \left(\frac{\rho_\ell}{2\pi\varepsilon_0}\right)\left[\frac{1}{r} + \frac{1}{d-r}\right] = \left(\frac{\rho_\ell}{2\pi\varepsilon_0}\right)\left[\frac{1}{a} + \frac{1}{d-a}\right]$$

$$E = \frac{\rho_\ell}{2\pi\varepsilon_0}\left[\frac{1}{75\times10^{-4}} + \frac{1}{75\times10^{-2} - 75\times10^{-4}}\right]$$

$$3\times10^6 = \rho_\ell \cdot (2.42\times10^{12})$$

$$\Rightarrow \rho_\ell = 1.24\times10^{-6} \text{ C/m}$$

$$V_{ab} = \left(\frac{\rho_\ell}{\pi\varepsilon_0}\right)\cdot\left[\ell n\left(\frac{d-a}{a}\right)\right]$$

$$= \frac{1.24\times10^{-6}}{\pi\varepsilon_0}\left[\ell n\left(\frac{75\times10^{-2}-75\times10^{-4}}{75\times10^{-4}}\right)\right]$$

$$V_{ab} = 204.84\text{ kV}$$

UNIT III

15. Derive the formula for H due to a current carrying solenoid.
Ans 15. For answer refer: **Page 122, topic 3.7.3** fully.

Or

16. State and Prove Ampere's circuital Law.
Ans 16. For answer refer: **Page 112, topic 3.6, 3.6.1.1 and 3.6.1.2**.

UNIT IV

17. An electromagnetic wave is propagating through free space. The rms value of E is 106V/m. Find H_{rms}, velocity of propagation and average energy density in the wave.

$E_{rms} = 106$ V/m (similar problem solved in page 189, Q – 1)

$$E_{\max} = \sqrt{2}\times106 = 150\text{ V/m}$$

$$H_{\max} = \frac{E_{\max}}{\eta}$$

Since wave is propagating through free space, we have, $\eta = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.73$

$$H_{\max} = \frac{150}{376.7} = 398.2\times10^{-3}\text{ Tesla}$$

$$H_{\text{rms}} = 281.57\times10^{-3}\text{ Tesla}$$

Velocity of propagation, $v = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3\times10^8$ m/sec

Average energy density in the wave [page 190, Q 2]

$$P = \frac{E_m^2}{120\pi} = \frac{(150)^2}{120\pi} = 59.68\text{ Watts / m}^2$$

Or

18. Derive an expression for the inductance of toroid.
Ans 18. For answer refer: **Page 123, topic 3.7.4 & topic 3.13.2**.

UNIT V

19. Derive Maxwell's wave equation for $\overline{H}$ and $\overline{E}$ in general form and for a non-dissipative medium like free space $\sigma = 0$.
Ans 19. For answer refer: **page 176, topic 5.3, topic 5.3.1 and topic 5.3.2**.

Or

20. State and prove Poynting's theorem.
Ans 20. For answer refer: **Page 204**, Poynting's theorem till Page 205, "Total power leaving the volume = ……."