USN | | | | | | | | | | 18EC55

Fifth Semester B.E. Degree Examination, July/August 2021
Electromagnetic Waves

Time: 3 hrs. Max. Marks:100

Note: ***Answer any FIVE full questions.***

1 a. Point charges of 50nc each are located at A(1, 0, 0), B(–1, 0, 0), C(0, 1, 0) and D(0, –1, 0). Determine the total force on the charge at A. Also, find $\vec{E}$ at 'A'. **(07 Marks)**

b. Two point charges, 5μC and –3μC are placed along a straight line 10m apart. Determine the location of third charge, 4μC such that it is subjected to no force. **(07 Marks)**

c. Derive an expression for electric field intensity at a point due to an infinite sheet charge, ρ_S c/m^2. Compare the nature of this field with that of infinite line charge. **(06 Marks)**

2 a. Given the two points C(–3, 2, 1) and D(5, 20°, –70°), find the spherical coordinates of 'C' and Cartesian coordinates of 'D'. Also find the distance from 'C' to 'D'. **(07 Marks)**

b. A uniform line charge, infinite in extent, with the density 34nc/m is located at x = –3m and z = 5m in free space. Find $\vec{E}$ at P(1, 12, 4)m. **(07 Marks)**

c. Find the total charge within each of the indicated volume :

i) $0 \le \rho \le 0.1$, $0 \le \phi \le \pi$, $2 \le z \le 4$ and $\rho_v = \rho^2 z^2 \sin(0.6\phi)$

ii) Universe : $\rho_v = \frac{e^{-2r}}{r^2}$. **(06 Marks)**

3 a. A cube of side 2m is centred at the origin with edges parallel to the coordinate axes of the rectangular coordinate system. If $\vec{D} = 10\frac{x^3}{3}\hat{a}_x, c/m^2$, find the volume charge density. Also, find the total charge enclosed by the cube. **(06 Marks)**

b. A vector field is given by $\vec{A} = 30e^{-r}\hat{a}_r - 2z\hat{a}_z$, verify the divergence theorem for the volume enclosed by r = 2, z = 0 and z = 5. **(08 Marks)**

c. Determine the electric field intensity everywhere due to a spherical volume charge of density, ρ_v c/m^3 using Gauss's law. Also, sketch E as a function of distance. **(06 Marks)**

4 a. Calculate the work done in moving a 4C charge from B(1, 0, 0) to A(0, 2, 0) along the path y = 2 – 2x, z = 0 in the field $\vec{E} = 5x\hat{a}_x + 5y\hat{a}_y, V/m$. **(07 Marks)**

b. State and explain the continuity equation of current. Also, mention its physical significance. **(08 Marks)**

c. Given the potential field, $V = 2x^2y - 5z$ and a point P(–4, 3, 6), find the numerical values of the following quantities at point, P : i) Electric potential ii) Electric field intensity $\vec{E}$ iii) the direction of $\vec{E}$ iv) electric flux density, $\vec{D}$ v) volume charge density ρ_v. **(05 Marks)**

5 a. Using the Laplace's equation, derive an expression for capacitance per unit length of a coaxial cable using the following boundary conditions :
$V = V_0$ at r = a, and V = 0 at r = b, b > a. **(08 Marks)**

b. Determine $\vec{H}$ at (0.4, 0.3, 0) in the field of 8A filamentary current directed inward from infinity to the origin on the positive x–axis and then outward to infinity along the y-axis. **(08 Marks)**

c. State and explain the Stoke's theorem. **(04 Marks)**

6 a. Given the potential field $V = (Ar^4 + Br^{-4}) \sin(4\phi)$, show that $\nabla^2 V = 0$. Also find A and B such that V = 100 volts and $|\vec{E}| = 500 V/m$ at $p(1, 22.5°, 2)$. **(07 Marks)**

b. Evaluate both sides of the Stoke's theorem for the field, $\vec{H} = 6xy\hat{a}_x - 3y^2\hat{a}_y, A/m$ and the rectangular path around the region $2 \le x \le 5$, $-1 \le y \le 1$, $z = 0$. Let the positive direction of $d\vec{S}$ be $\hat{a}_z$. **(07 Marks)**

c. State the following and write the corresponding equations :
Biot Savart law, Ampere's law and Curl $\vec{F}$. **(06 Marks)**

7 a. Derive an expression for the force acting between two differential current elements. **(04 Marks)**

b. Find the magnetization in a wire where i) $\mu = 1.8 \times 10^{-5}$H/m, and H = 120A/m ii) $\mu_r = 22$, there are 8.3×10^{28} atoms/m^3 and each atom has a dipole moment of 4.5×10^{-27}A-m^2 iii) $\beta = 300\mu T$ and $\Psi_m = 15$. **(08 Marks)**

c. A conducting filamentary triangle joins points A(3, 1, 1), B(5, 4, 2) and C(1, 2, 4). The segment AB carries a current of 0.2A in $\hat{a}_{AB}$ direction. The magnetic field is $\vec{B} = 0.2\hat{a}_x - 0.1\hat{a}_y + 0.3\hat{a}_z$ T.
i) Find the force on segment BC
ii) The torque on the loop about an origin at 'A'
iii) The torque on the loop about an origin at 'C'. **(08 Marks)**

8 a. Obtain the torque on a square loop having the corners (–2, –2, 0), (2, –2, 0), (2, 2, 0) and (–2, 2, 0) :
i) About the origin by $\vec{B} = 0.4\hat{a}_x$ T;
ii) About the origin by $\vec{B} = 0.6\hat{a}_x - 0.4\hat{a}_y$ T and
iii) About (4, 6, 8) by $\vec{B} = 0.4\hat{a}_x + 0.6\hat{a}_y - 0.7\hat{a}_z$ T. Take I = 0.8A. **(08 Marks)**

b. Determine the boundary conditions for the magnetic field at the interface between two different magnetic materials. **(06 Marks)**

c. Derive the Maxwell's equation from Faraday's law of electromagnetic induction. **(06 Marks)**

9 a. Let $\mu = 10^{-5}$H/m, $\epsilon = 4 \times 10^{-9}$F/m, $\sigma = 0$ and $\rho_v = 0$. Determine 'K' so that each of the following pair of fields satisfies Maxwell's equation :
i) $\vec{D} = 2x\hat{a}_x - 3y\hat{a}_y + 4z\hat{a}_z$ nC/m^2, $\vec{H} = Kx\hat{a}_x + 10y\hat{a}_y - 25z\hat{a}_z$ A/m
ii) $\vec{E} = (20y - kt)\hat{a}_x$ V/m, $\vec{H} = (y + 2\times10^6 t)\hat{a}_z$ A/m. **(08 Marks)**

b. Explain the wave propagation in good conductors using the skin depth. **(06 Marks)**

c. For a perfect dielectric medium, $\mu_r = 1$ and $\epsilon_r = 81$ at f = 1MHz. Determine attenuation constant, phase constant, propagation constant, wave length, phase velocity and intrinsic impedance for the medium. **(06 Marks)**

10 a. In a certain dielectric medium, $\epsilon_r = 5$, $\sigma = 0$ and displacement current density. $\vec{J}_d = 20\cos(1.5\times10^8 t - \beta x)\hat{a}_y \mu A/m^2$. Determine the electric flux density and electric field intensity. **(06 Marks)**

b. Explain the propagation of electromagnetic waves in free space. **(08 Marks)**

c. State and prove Poynting theorem. **(06 Marks)**

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