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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

III SEMESTER B. TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
MAKE UP SEMESTER EXAMINATIONS, DECEMBER 2019

ELECTROMAGNETIC THEORY [ELE 2155]

REVISED CREDIT SYSTEM

Time: 3 Hours **Date: December 2019** **Max. Marks: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. Given the following two fields $G_1 = 5(x+y)a_x + 10a_y$ and $G_2 = 5a_x + 2xya_y$. At a point $P(3,2,0)$ in space, determine the following:
a) The unit vector in the direction of G_1
b) The unit vector in the direction of G_2 **(03)**
c) The unit vector in the direction of $G_1 + G_2$

1B. From the fundamentals of co-ordinate systems, determine the following:
a) The volume defined by $4 < \rho < 6, 30^0 < \emptyset < 60^0, 2 < z < 5$.
b) The length of the longest straight line that lies entirely within the above defined volume. **(03)**

1C. State Coulomb's law of electrostatic force of attraction/repulsion. Three equal positive charges of $4 \times 10^{-9}\ C$ each are located at the three corners of a square of side $0.2\ m$. With the help of a neat sketch, determine the magnitude and direction of the electric field at the vacant corner point of the square. **(04)**

2A. Let $D = 6xyz^2a_x + 3x^2z^2a_y + 6x^2yza_z\ C/m^2$. Find the total charge lying within the region bounded by $x = 1\ and\ 3; y = 0\ and\ 1; z = -1\ and\ 1$ by separately evaluating each side of the divergence theorem. **(03)**

2B. The plane $z = 0$ separates air $(z \geq 0, \mu = \mu_0)$ from iron $(z \leq 0, \mu = 200\mu_0)$. Given that: $\bar{\boldsymbol{H}} = 10a_x + 15a_y - 3a_z\ A/m$, in air:
a) Determine the magnetic flux density in iron. **(03)**
b) Calculate the angle between the field vector and the interface in iron.

2C. A thin circular ring of radius $'\boldsymbol{a}'$ has a total charge $' + \boldsymbol{q}'$ distributed uniformly over it.
a) Derive the expression of the electric field intensity at point P which is $'z'$ meters from the centre on the axis of the ring
b) Determine the force on a charge $'Q'$ at the point P which is $'z'$ meters from the centre on the axis of the ring **(04)**
c) Determine the force on the charge $'Q'$ placed at the centre of the ring

3A. A toroidal core has an average radius of 10 cm with a cross sectional radius of 1 cm. If the core was made of steel ($\mu_R = 1000$) and the coil wound on it has 200 turns, calculate the amount of current that should flow so as to produce a magnetic flux of $0.5mWb$ in the core. ***(03)***

3B. In a certain region of space, $\bar{B} = 0.1xa_x + 0.2ya_y - 0.3za_z\ T$. Determine the total force on a rectangular loop as shown in **Fig. Q. 3B**, if it lies in the $z = 0$ plane and is bound by $x = 1; x = 3;\ \ y = 2\ and\ y = 5\ cm$. ***(03)***

3C. A lossy dielectric is characterized by $\varepsilon_R = 2.5, \mu_R = 4\ and\ \sigma = 10^{-3} S/m$ at $10\ MHz$. For a uniform plane wave propagating along the positive z-axis in the dielectric (having propagation constant = γ) at the said frequency, let $\bar{E} = 20e^{-\gamma z}a_x\ V/m$ at $z = 0$. Determine: ***(04)***

a) Attenuation constant b) Phase constant c) Wave velocity
d) wavelength e) Intrinsic impedance f) $\bar{E}(2,3,4, t = 10ns)$

4A. With appropriate explanations, derive Poynting theorem and show that total power leaving a volume is equal to rate of decrease in energy stored in electric and magnetic fields minus the dissipated ohmic power ***(03)***

4B. In a non-magnetic medium, $\bar{E} = 4\ \mathrm{Sin}\ (2\pi \times 10^7 t - 0.8x)a_z\ V/m$.

a) Find ε_r, η
b) The time average power carried by the wave ***(03)***
c) The total power crossing $100cm^2$ of plane $2x + y = 5$

4C. For a uniform plane wave propagating along the positive z-axis as shown in **Fig. Q 4C**, assuming both the mediums to be perfect dielectrics, for a normal incidence, prove with appropriate explanations that:

a) $E_{ro}/E_{io} = \Gamma = [\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}]/[\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}]$
b) $H_{to}/H_{io} = \tau = [2\sqrt{\varepsilon_2}]/[\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}]$ ***(04)***

5A. Applying the concept of plane wave incidence at normal angles to an interface between two media, determine the shielding effectiveness for a sheet of silver whose thickness is $50.8\mu m$ and has a conductivity $\sigma = 6.3 \times 10^7\ \mho/m$ at 10^8 Hz. ***(03)***

5B. With the help of a neat diagram, derive Snell's law for a uniform plane wave incident at oblique angles to the interface between two perfect dielectrics having refractive indices n_1 (for region 1) and n_2 (for region 2). ***(03)***

5C. Using the fundamentals of oblique incidence of a perpendicularly polarized uniform plane wave at an interface z=0 between two perfect dielectrics, prove that:

$$i)\ \frac{E_{ro}}{E_{io}} = \frac{\eta_2 \cos\theta_i - \eta_1 \cos\theta_t}{\eta_2 \cos\theta_i + \eta_1 \cos\theta_t}$$

$$ii)\ \frac{E_{to}}{E_{io}} = \frac{2\eta_2 \cos\theta_i}{\eta_2 \cos\theta_i + \eta_1 \cos\theta_t}$$ ***(04)***

Where $\theta_t =$ angle of refraction; $\theta_i =$ angle of incidence.

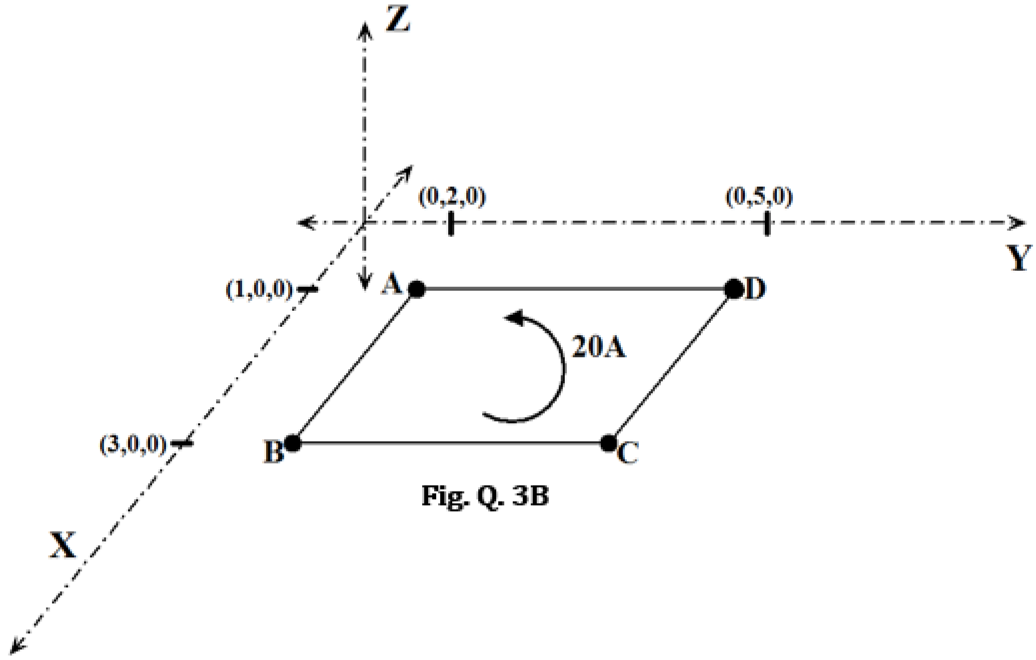

Fig. Q. 3B

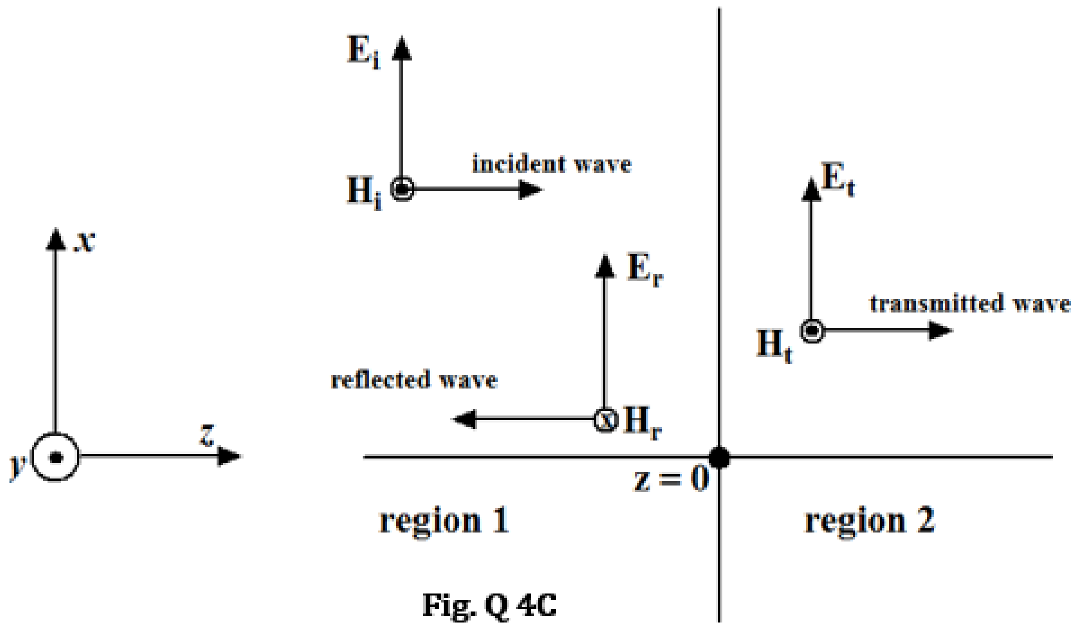

Fig. Q 4C