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

III SEMESTER B.TECH. (ELECTRICAL & ELECTRONICS ENGINEERING)
MAKE UP EXAMINATIONS, APRIL 2022
SUBJECT: ELECTROMAGNETIC THEORY [ELE 2155]

1A. State Coulomb's law of electrostatic force of attraction/repulsion.

A $5nC$ point charge is located at $A(2,-1,-3)$ in free space in Cartesian coordinate system.

a) Determine the electric field intensity at the origin.
b) Plot $|E(x,0,0)|$ $versus$ $'x'$ $for;$ $-10 \le x \le 10m$
c) Determine the maximum value of $|E(x,0,0)|$ ***(04)***

1B. Two parallel $10\ cm \times 10\ cm$ conducting plates are separated by a distance of $2\ mm$. The region between the plates is filled with a perfect dielectric where $\varepsilon_R = (1+500x)^2$, where $'\ \boldsymbol{x}\ '$ is the distance from one plate. Assuming a uniform surface charge density of $10nC/m^2$ on the positive plate, determine the following:

a) Total charge Q_{total}
b) The potential developed between the plates V_0
c) The total capacitance ***(03)***

1C. 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 $'x'$ meters from the centre and along the axis of the ring
b) Determine the force on a charge $'q'$ at the point P which is $'x'$ meters from the centre and along the axis of the ring
c) Determine the force on the charge $'q'$ placed at the centre of the ring ***(03)***

2A. Let $D = 6xyz^2 a_x + 3x^2z^2 a_y + 6x^2yz a_z\ \ C/m^2$. 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. ***(04)***

2B. With neat diagram and appropriate explanation, prove that, for a uniformly charged disc having radius $'\boldsymbol{a}'$ meters and charge density $'\boldsymbol{\sigma}\ \boldsymbol{C/m^2}'$, the potential at any point situated $'\boldsymbol{h}'$ meters above its center and along its axis is $\boldsymbol{V} = \frac{\sigma}{2\varepsilon_0}\left[\sqrt{(\boldsymbol{h^2}+\boldsymbol{a^2})} - \boldsymbol{h}\right]\ volts$ ***(03)***

2C. The plane $z = 0$ separates air $(z \ge 0, \mu = \mu_0)$ from iron $(z \le 0, \mu = 200\mu_0)$. Given that: $\overline{\boldsymbol{H}} = 10a_x + 15a_y - 3a_z\ A/m$, in air:

a) Determine the magnetic flux density in iron.
b) Calculate the angle between the field vector and the interface in iron. ***(03)***

3A. Given $\overline{H} = y^2 z a_x + 2(x+1)yz a_y - (x+1)z^2 a_z A/m$ in free space: ***(04)***

a) Determine $\oint H.dL$ around a square path defined **Fig. Q 3A** and further calculate its value for $b = 0.1$

b) Determine the curl of the magnetic field intensity and calculate its x- component value at P(0,2,0)

c) Prove that $(\nabla \times H)_x|_P = {[\oint H.dL]}/{\Delta S}$

3B. A solenoid of length '$\boldsymbol{l}$' and radius '$\boldsymbol{a}$' consists of '$\boldsymbol{N}$' turns of wire through which current '$\boldsymbol{I}$' flows. With a neat diagram and suitable explanation, prove that at point '$\boldsymbol{P}$' along its axis, $\boldsymbol{H} = {[nI(cos\theta_2 - cos\theta_1)]}/{2}\, a_z$

Where: $n = N/l$; θ_1 and θ_2 are the angles subtended at P by the end turns. ***(03)***

3C. The core of a toroid has a cross sectional area of 12 cm^2 and is made of a material having relative permeability of 200. If the mean radius of the toroid is 50 cm, calculate the number of turns needed to obtain an inductance of 2.5 H. ***(03)***

4A. A perfectly conducting filament containing a 500 Ω resistor is formed into a square as shown in **Fig. Q 4A**. determine the flowing current $I(t)$ in the loop if:

a) $\bar{B} = 0.2\ \cos 120\pi t\ a_z\ T$

b) $\bar{B} = 2\ \cos[3\pi \times 10^8(t - {x}/{c})]a_z\ \mu T$ where $c = 3 \times 10^8 m/s$ ***(04)***

4B. 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 ohmic power dissipated. ***(03)***

4C. Let $E_0 = (1000a_x + 400a_z)e^{-j10y}\ V/m$ for a 250 MHz uniform plane wave propagating in a perfect dielectric. If the maximum amplitude of the magnetic field intensity is 3 A/m, determine the following:

a) Relative permittivity of the dielectric

b) Relative permeability of the dielectric

c) $\bar{E}(x, y, z, t)$ ***(03)***

5A. A lossy dielectric is characterized by $\varepsilon_R = 2.5, \mu_R = 4\ and\ \sigma = 10^{-3} S/m$ at $10^8\ Hz$. For a propagating uniform plane wave at the said frequency, let $E_0 = 20e^{-\gamma z}a_x\ V/m$ at $z = 0$. Determine:

a) Attenuation constant b) Phase constant c) Wave velocity

d) wavelength e) Intrinsic impedance f) $\bar{E}(2,3,4, t = 10ns)$ ***(04)***

5B. For a uniform plane wave propagating along the positive z-axis as shown in **Fig. Q 5B**, 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) ${H_{to}}/{H_{io}} = \tau = {[2\sqrt{\varepsilon_2}]}/{[\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}]}$ ***(03)***

5C. A uniform plane wave $\bar{E} = 50\sin(\omega t - 5x)a_y V/m$ in a lossless medium $(\mu = 4\mu_0,\ \varepsilon = \varepsilon_0)$ encounters a lossy medium $(\mu = \mu_0,\ \varepsilon = 4\varepsilon_0, \sigma = 0.1 S/m)$ normal to the x-axis. Determine:

a) The reflection and transmission coefficients

b) The reflected wave $(E_r\ and\ H_r)$

c) The transmitted wave $(E_t\ and\ H_t)$ ***(03)***

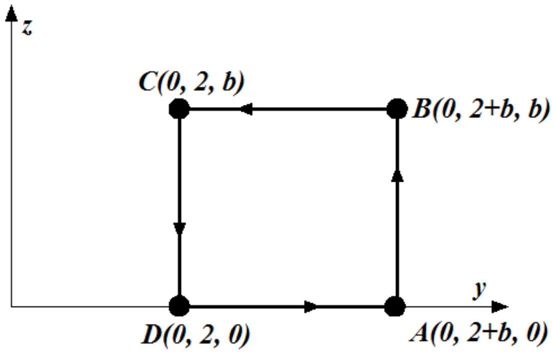

Fig. Q 3A

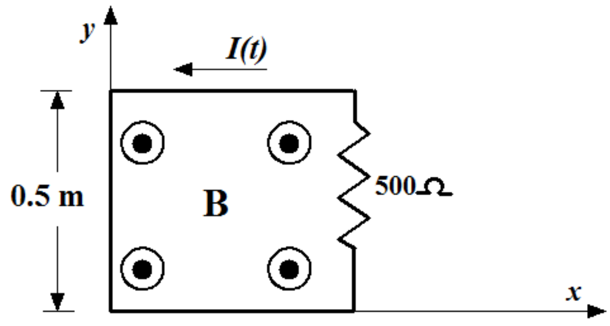

Fig. Q 4A

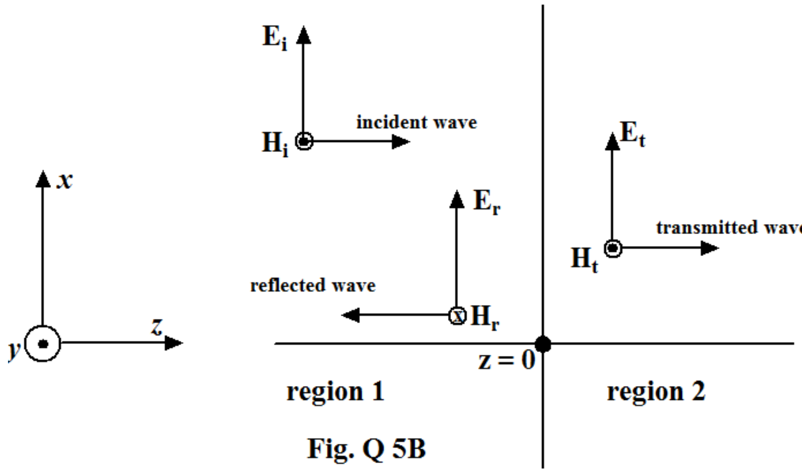

Fig. Q 5B