Reg. No.									

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

III SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
END SEMESTER EXAMINATIONS, DECEMBER 2023

ELECTROMAGNETIC FIELD THEORY [ELE 2124]
REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 07th DECEMBER 2023** **Max. Marks: 50**

Instructions to Candidates:
- ❖ Answer **ALL** the questions.
- ❖ Missing data may be suitably assumed.

1A. For a given vector $\bar{F} = F_x\boldsymbol{a_x} + F_y\boldsymbol{a_y} + F_z\boldsymbol{a_z}$, through the application of the fundamentals of vector algebra, prove that: $\nabla \times \nabla \times \bar{F} = \nabla(\nabla.\bar{F}) - \nabla^2\bar{F}$ ***(03)***

1B. A circular disc of radius 'a' is uniformly charged with $\rho_s\ {}^{C}/_{m^2}$. If the disc lies on the $z = 0$ plane with its axis along the $z - axis$, prove that at point $(0,0,h)$: ***(03)***

$$\bar{E} = \frac{\rho_s}{2\varepsilon_0}\left\{1 - \frac{h}{(h^2 + a^2)^{1/2}}\right\}\boldsymbol{a_z} V/m$$

1C. Given the following two fields $\bar{G}_1 = 5(x + y)\boldsymbol{a_x} + 10\boldsymbol{a_y}$ and $\bar{G}_2 = 5\boldsymbol{a_x} + 2xy\boldsymbol{a_y}$. At a point $P(3, 2, 0)$ in space, determine the following: ***(04)***

a) The unit vector in the direction of $\bar{G}_1$
b) The unit vector in the direction of $\bar{G}_2$
c) The unit vector in the direction of $\bar{G}_1 + \bar{G}_2$

2A. A parallel plate capacitor has a plate separation distance of 't'. The capacitance with air only between the plates is 'C'. When a slab of thickness 't_1' and relative permittivity 'ϵ_R' is placed on the lower plate (as shown **Fig. Q2A**), the new capacitance is 'C_1'. Through detailed steps, show that – ***(03)***

$$\frac{C_1}{C} = \frac{\epsilon_R t}{t_1 + \epsilon_R(t - t_1)}$$

2B. A homogeneous dielectric ($\varepsilon_r = 2.5$) fills the region 2 ($x < 0$) while region 1 ($x > 0$) is free space. For an electric field vector travelling from region 2 to region 1, determine the following: ***(03)***

- If $\bar{D}_1 = 12\boldsymbol{a_x} - 10\boldsymbol{a_y} + 4\,\boldsymbol{a_z}\ nC/m^2$, find $\bar{D}_2\ and\ \theta_2$.
- If $|\bar{E}_2| = 12\ V/m$ and $\theta_2 = 60^0$, find $\bar{E}_1\ and\ \theta_1$.

Let the vector $\bar{E}_2$ make an angle of $\theta_2 < 90^0$ with the normal to the surface while $\theta_1 < 90^0$ is the angle $\bar{E}_1$ makes with the normal to the surface.

2C. With a neat schematic derive an expression for the magnetic field intensity, both - inside and outside a solid cylindrical conductor having radius **'a'** and carrying a current **'I'** with uniform density. Also sketch its variation with respect to the distance from the conductor axis. ***(04)***

3A. A perfectly conducting filament containing a 500Ω resistor is formed into a square as shown in **Fig. Q 3A** below. Determine the flowing current in the loop if the existing magnetic field is given by: ***(03)***

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

3B. A conducting bar PQ can slide freely over two conducting rails as shown in **Fig. Q 3B**. Calculate the induced voltage in the bar ***(03)***

- If the bar is stationed at $y = 8cm$ and $\bar{B} = 4\cos(10^6 t)\,\boldsymbol{a_z}\,mWb/m^2$.
- If the bar slides at a velocity $\bar{u} = 20\boldsymbol{a_y}\,m/s$ and $\bar{B} = 4\boldsymbol{a_z}\,mWb/m^2$.
- If the bar slides at a velocity $\bar{u} = 20\boldsymbol{a_y}\,m/s$ and $\bar{B} = 4\cos(10^6 t - y)\,\boldsymbol{a_z}\,mWb/m^2$.

3C. Let $\bar{E} = \left[(1000\boldsymbol{a_x} + 400\boldsymbol{a_z})e^{-j10y}\right]{}^{V}/_{m}$ 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: ***(04)***

a) Relative permittivity of the dielectric
b) Relative permeability of the dielectric
c) $\bar{E}(x, y, z, t)$

4A. 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 $= \gamma$) at the said frequency, let $\bar{E} = 20e^{-\gamma z}\boldsymbol{a_x}\,V/m$ at $z = 0$. Determine: ***(03)***

a) Attenuation constant
b) Phase constant
c) Intrinsic impedance

4B. In a non-magnetic medium, an electromagnetic wave propagating along the X – axis is characterized by its electric field as: ***(03)***

$$\bar{E} = 4\sin(2\pi \times 10^7 t - 0.8x)\boldsymbol{a_z}\,V/m$$

Determine the following parameters:

a) The relative permittivity of the medium
b) The intrinsic impedance of the medium
c) The time average power carried by the wave

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: ***(04)***

a) ${}^{E_{ro}}/_{E_{io}} = \Gamma = {}^{[\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}]}/_{[\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}]}$

b) ${}^{H_{to}}/_{H_{io}} = \tau = {}^{[2\sqrt{\varepsilon_2}]}/_{[\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}]}$

5A. The plane $z = 0$ separates air $(z \geq 0, \mu = \mu_0)$ from iron $(z \leq 0, \mu = 200\mu_0)$. Given that: $\overline{\boldsymbol{H}} = 10\boldsymbol{a_x} + 15\boldsymbol{a_y} - 3\boldsymbol{a_z}\ A/m$, in air: ***(03)***

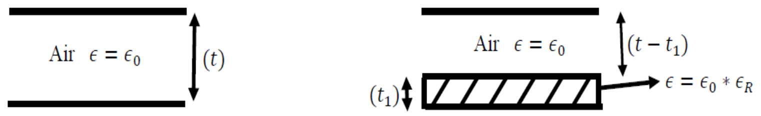
a) Determine the magnetic flux density in iron.
b) Calculate the angle between the field vector and the interface in iron.

5B. A wave propagating in a lossless dielectric has the components $\overline{\boldsymbol{E}} = 500\cos(10^7 t - \beta z)\ \boldsymbol{a_x}\ V/m$ and $\overline{\boldsymbol{H}} = 1.1\cos(10^7 t - \beta z)\ \boldsymbol{a_y}\ A/m$ If the wave is travelling at a velocity of $1.5 \times 10^8\ m/s$, determine: ***(03)***

a) The relative permittivity and relative permeability of the dielectric medium.
b) The phase constant of the wave.
c) The wavelength of the propagating wave.
d) The intrinsic impedance of the dielectric medium.

5C. Applying the related fundamentals of electromagnetic wave propagation, determine the shielding effectiveness in dB for a 0.508mm thick sheet of copper ($\sigma = 5.8 \times 10^7$S/m) at 1MHz given: ***(04)***

a) An electric source at a distance 1 m from the shield
b) A magnetic source at a distance 1 m from the shield



Capacitor plates with only air as dielectric

Plates with a slab on one of them

Fig. Q 2A

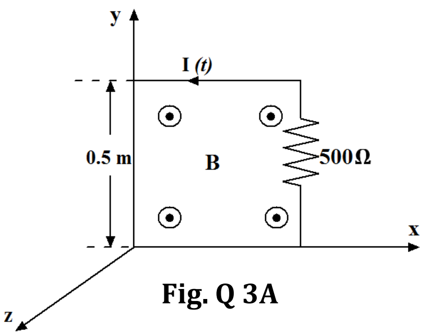


Fig. Q 3A

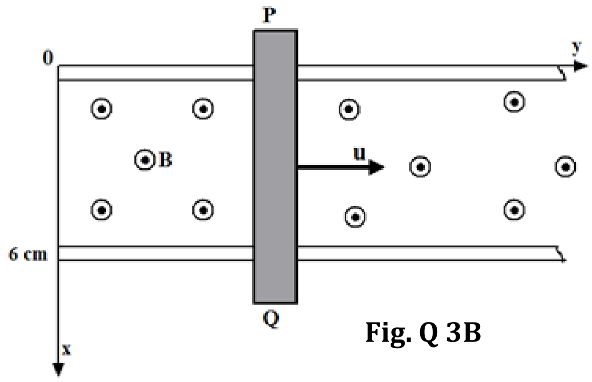


Fig. Q 3B

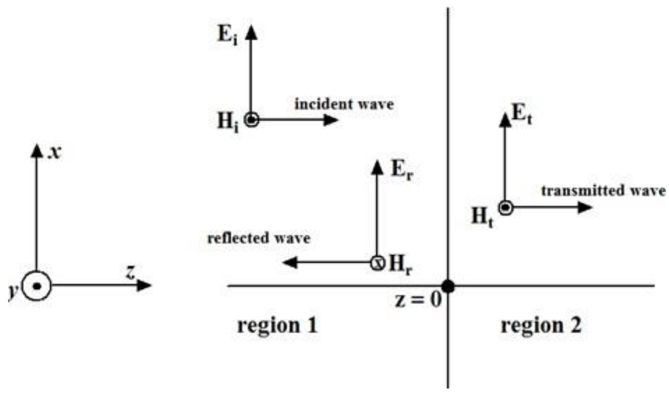


Fig. Q 4C