SCHOOL OF COMPUTING AND ENGINEERING SCIENCES

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

BEE2204: ELECTROMAGNETISM

END OF SEMESTER EXAMINATIONS

Date: 19th March 2025 **Time:** 13:30-16:00 Hours

Instructions:

1. This Examination consists of **FOUR** questions
2. Answer **Question ONE (COMPULSORY)** and any other **TWO** questions.

QUESTION ONE

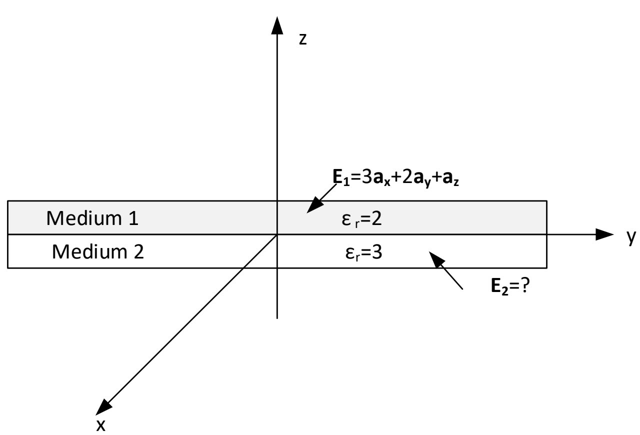
a) State Coulomb's law of electrostatics **(2 marks)**

b) Determine the force on a charge Q_1, $20\mu C$ at point $(0,1,2)$ due to charge Q_2 at point $(2,0,0)$. All distances are in meters. **(3 marks)**

c) State the electrostatic boundary conditions for dielectric media **(2 marks)**

d) Figure 1 shows two dielectric with electrical properties as illustrated in the Figure. Determine the electric field strength E_2 in material 2

(4 marks)



e) State the Maxwell's equations in **integral** form **(4 marks)**

f) Dielectric material between capacitors does not conduct current but current flows through the capacitor. Explain. **(2 marks)**

g) Moist soil has a conductivity of $10^{-3}\ S/m$ and $\varepsilon_r = 2.5$. Determine each of the following where $\vec{E} = 6.0 \times 10^{-6} \sin 9.0 \times 10^9 t \quad V/m$

i. Conduction current density

ii. Displacement current density **(5 marks)**

h) Given that $E = E_m \sin(\omega t - \beta z)\boldsymbol{a_y}$ in free space. Determine each of the following

i. Electric flux density $\boldsymbol{D}$

ii. magnetic field strength $\boldsymbol{B}$

iii. Magnetic field strength $\boldsymbol{H}$

(6 marks)

i) Electric flux I a region is given by $D = x^2\boldsymbol{a_x} + y^3\boldsymbol{a_y}$ determine the volume charge density ρ in the region.

(2 marks)

QUESTION TWO

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a) Define each of the following as used in dielectric materials

i. Polarization

ii. Electric susceptibility

(2 marks)

b) Figure 1 shows a coaxial cable of inner radius a and outer radius b. The space between the conductors is filled with a homogenous dielectric with permittivityε. Determine the expression of each of the following:

i. Electric field strength at any point in the radial direction

(3 marks)

ii. The potential function between the conductors

(3 marks)

iii. The capacitance of the coaxial cylinder

(3 marks)

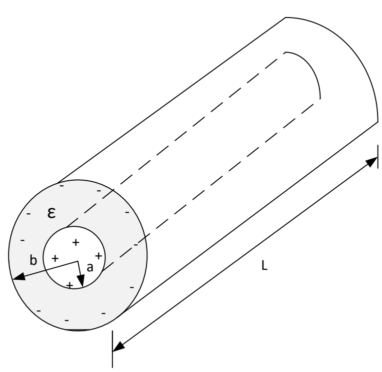

Figure 1: Coaxial Cylinder

c) The inner radius of a coaxial cable is $1mm$ and the outer radius is $3mm$. The dielectric material between the conductors has a relative permittivity of $\varepsilon_r = 4.5$. Determine the capacitance per unit length of the cable.

(4 marks)

QUESTION 3

a) Define potential following as used in electrostatics **(1 marks)**

b) An electrohydrodynamic (EHD) pumps is a type of non-mechanical pumps, which induce dielectric fluid under a high voltage electric field by injection of ions in the vicinity of electrode. Figure 2 shows the model of the pump. The region between the electrodes A and B contain a uniform charge $\rho_0 = 25\, mC/m^3$ and $V_0 = 25kV$. Determine each of the following:

i. The potential function between the plates **(4 marks)**

ii. The electric field strength between the plates **(3 marks)**

iii. The force per unit area between the plates **(3 marks)**

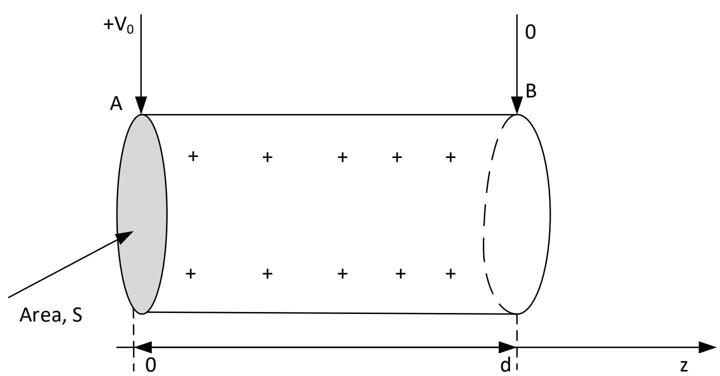

Figure 2

c) Explain the law of conservation of

i.The electric field intensity

ii.The magnetic flux

(4 marks)

QUESTION FOUR

a) (i)State the Amperes circuital law

(2 marks)

(ii)A hollow conductor cylinder has inner radius a and outer radius b and carries current I along positive z direction. The cross sectional view of the conductor is shown in Fig.2 Find H all regions.

(7 marks)

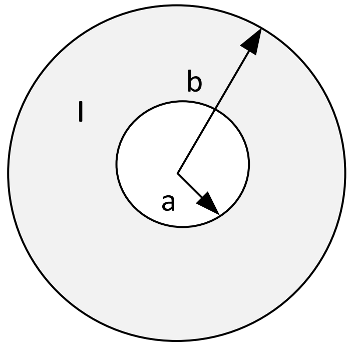

Figure 3

(b) (i)State the continuity equation in point form **(2 marks)**

(ii)The current density in a conducting medium is given by $J(x,y,z;t) = z\boldsymbol{a_x} - 4y^2\boldsymbol{a_y} + 2x\boldsymbol{a_z}$. Determine the corresponding charge distribution.

(4 marks)

Coordinate Systems and Vector Derivatives Formula Sheet

Rectangular (Cartesian) Coordinates (*x,y,z*)

Gradient:

$$\vec{\nabla} f = \frac{\partial f}{\partial x}\hat{x} + \frac{\partial f}{\partial y}\hat{y} + \frac{\partial f}{\partial z}\hat{z}$$

Divergence:

$$\vec{\nabla} \cdot \vec{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$$

Curl:

$$\vec{\nabla} \times \vec{v} = \left(\frac{\partial v_z}{\partial y} - \frac{\partial v_y}{\partial z}\right)\hat{x} + \left(\frac{\partial v_x}{\partial z} - \frac{\partial v_z}{\partial x}\right)\hat{y} + \left(\frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y}\right)\hat{z}$$

Laplacian:

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} + \frac{\partial^2 f}{\partial z^2}$$

Spherical Coordinates (*r,θ,φ*)

Gradient:

$$\vec{\nabla} f = \frac{\partial f}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial f}{\partial \theta}\hat{\theta} + \frac{1}{r\,\sin\theta}\frac{\partial f}{\partial \phi}\hat{\phi}$$

Divergence:

$$\vec{\nabla} \cdot \vec{v} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 v_r) + \frac{1}{r\,\sin\theta}\frac{\partial}{\partial \theta}(\sin\theta\, v_\theta) + \frac{1}{r\,\sin\theta}\frac{\partial v_\phi}{\partial \phi}$$

Curl:

$$\vec{\nabla} \times \vec{v} = \frac{1}{r\,\sin\theta}\left[\frac{\partial}{\partial \theta}(\sin\theta\, v_\phi) - \frac{\partial v_\theta}{\partial \phi}\right]\hat{r} + \frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial v_r}{\partial \phi} - \frac{\partial}{\partial r}(r\, v_\phi)\right]\hat{\theta}$$
$$+\frac{1}{r}\left[\frac{\partial}{\partial r}(r\, v_\theta) - \frac{\partial v_r}{\partial \theta}\right]\hat{\phi}$$

Laplacian:

$$\nabla^2 f = \frac{1}{r}\frac{\partial^2}{\partial r^2}(rf) + \frac{1}{r^2\,\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial f}{\partial \theta}\right) + \frac{1}{r^2\,\sin^2\theta}\frac{\partial^2 f}{\partial \phi^2}$$

CylindricalCoordinates (*r,φ,z*)

Gradient:

$$\vec{\nabla} f = \frac{\partial f}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial f}{\partial \phi}\hat{\phi} + \frac{\partial f}{\partial z}\hat{z}$$

Divergence:

$$\vec{\nabla} \cdot \vec{v} = \frac{1}{r}\frac{\partial}{\partial r}(r v_r) + \frac{1}{r}\frac{\partial v_\phi}{\partial \phi} + \frac{\partial v_z}{\partial z}$$

Curl:

$$\vec{\nabla} \times \vec{v} = \left[\frac{1}{r}\frac{\partial v_z}{\partial \phi} - \frac{\partial v_\phi}{\partial z}\right]\hat{r} + \left[\frac{\partial v_r}{\partial z} - \frac{\partial v_z}{\partial r}\right]\hat{\phi} + \frac{1}{r}\left[\frac{\partial}{\partial r}(r v_\phi) - \frac{\partial v_r}{\partial \phi}\right]\hat{z}$$

Laplacian:

$$\nabla^2 f = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial f}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 f}{\partial \phi^2} + \frac{\partial^2 f}{\partial z^2}$$