Strathmore
UNIVERSITY

SCHOOL OF COMPUTER AND ENGINEERING SCIENCES
BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING
END OF SEMESTER EXAMINATIONS
BEE2204: ELECTROMAGNETISM

DATE: **7th March 2024** Time: **13:00-16:00 Hrs.**

Instructions

1. This examination consists of **FIVE** questions.
2. Answer **Question ONE (COMPULSORY)** and any other **TWO** questions.
3. You are provided with Coordinate Systems and Vector derivative formula sheet
4. Take:
   - Permittivity of free space: $\varepsilon_0 = \frac{10^{-9}}{36\pi} \quad F/m$
   - Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}\, H/m$
   - Speed of light in free space $c = 3 \times 10^8\, m/s$

Please Turn Over

QUESTION ONE (30 MARKS)

a) Vectors A and B are given in cylindrical coordinates by:

$\boldsymbol{A} = 2\hat{a}_r + 3\hat{a}_\phi - \hat{a}_z$

$\boldsymbol{B} = \hat{a}_r - \hat{a}_z$

Determine the:

i. projection of $\boldsymbol{B}$ in the direction of $\boldsymbol{A}$

ii. vector component of $\boldsymbol{B}$ in the direction of $\boldsymbol{A}$

(4 marks)

b) Point $P = \left(2\sqrt{3},\ \pi/3\ , -2\right)$ is given in cylindrical coordinates. Express P in spherical coordinates.

(4 marks)

c) State the Maxwell's equations in **point form**

(4 marks)

d) Determine the directional derivative of $T = x^2 + y^2\text{z}$ along the direction $2\hat{a}_x + 3\hat{a}_y - 2\hat{a}_z$ and evaluate it at $(1, -1,2)$.

(3 marks)

e) State **THREE** factors affecting the magnitude of Coulomb's force **(3 marks)**

f) Given the electric flux density $\boldsymbol{D} = 2(x + y)\boldsymbol{a_x} + (3x + 2y)\boldsymbol{a_y}$**.** Determine the volume charge density ρ **(3 marks)**

g) In a certain region, $D = 420\ nc/m^2$and $\varepsilon = 5.2\varepsilon_0$Determine the values of each of the following:

i. Electric susceptibility, χ_e

ii. Electric field strength E

iii. Polarization P

(3 marks)

h) State the Lorenz force equation, writing down the meaning of each term

(2 marks)

i) Two charges of $10\mu C$ each are located in free space at points with Cartesian Coordinates $(-3,0,0)$ and $(3,0,0)$. Determine the force on a $20\mu C$ charge located at $(0,0,4)$. All distances are in metres.

(4 marks)

QUESTION TWO (15 MARKS)

a) From Gauss law in point form, derive the expression of the Poisson's equation

(3 marks)

b) State the electrostatic boundary conditions between **two dielectric** materials

(2 marks)

c) Figure 1 shows the interface between air (Region 1, $\varepsilon_{r1} = 1$) and human body, (Region 2 $\varepsilon_{r2} = 2.4$).At communication frequency, human body behaves as a dielectric. The electric flux in air, D_1 is given by: $D_1 = 3a_x - 4a_y + 6a_z$. Obtain the:

i. Magnitude of D_2

(5 marks)

ii. The angles θ_1 and θ_2

(5 marks)

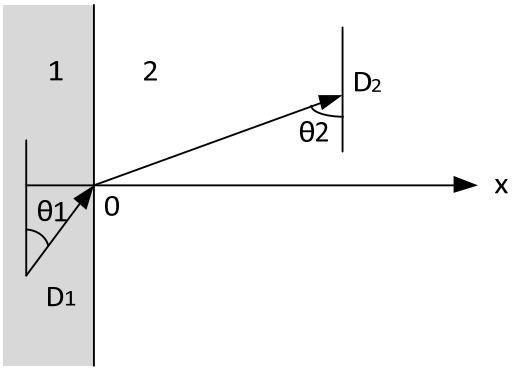

Figure 1

QUESTION THREE (15 MARKS)

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 in each of the following regions.

I. $r < a$
II. $a < r < b$
III. $r > b$

(7 marks)

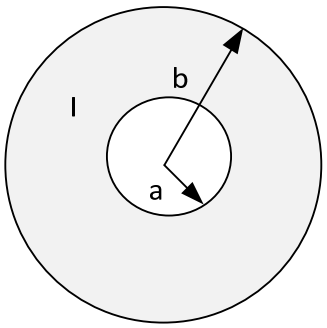

Figure 2

b) (i)State the Faraday's law in words

(ii) A conducting bar can slide freely over two conducting rails as show in Fig.3. Determine the induced voltage in the bar if it is stationed at $y = 8\ cm$ and $B = 4cos10^6 t\boldsymbol{a_z}$mWB/$\boldsymbol{m^2}$.

(6 marks)

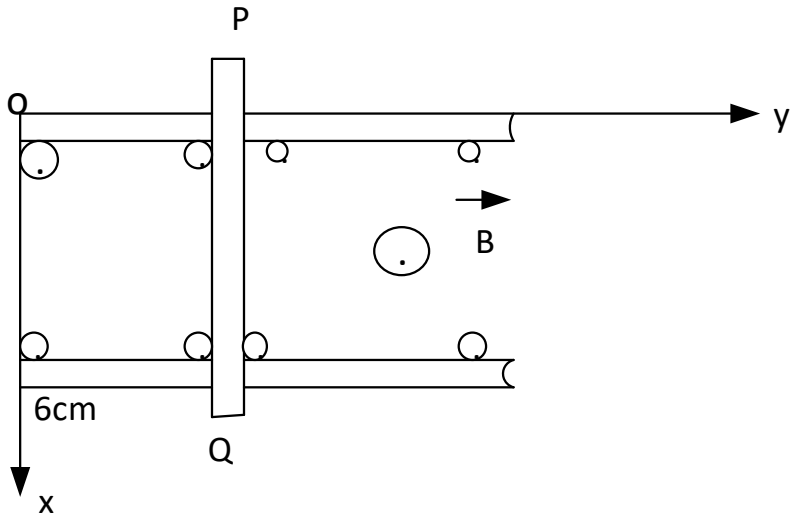

Figure 3

QUESTION FOUR (15 marks)

a) (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)

b) Figure 4 shows an infinitely long conducting cylinder of radius a situated a distance d from a parallel conducting plane and having a line charge density of ρ_l

i. Draw the cylinder and its image at distance

(2 marks)

ii. Write down the expression of the electric field strength $\boldsymbol{E_1}$ at any point along the line joining the centre from the centre of the cylinder, in terms of distances z and d

(1 marks)

iii. Write down the expression of the electric field strength $\boldsymbol{E_2}$ at any point along the line joining the centre from the centre of the image of the cylinder, in terms of distances z and d

(1 marks)

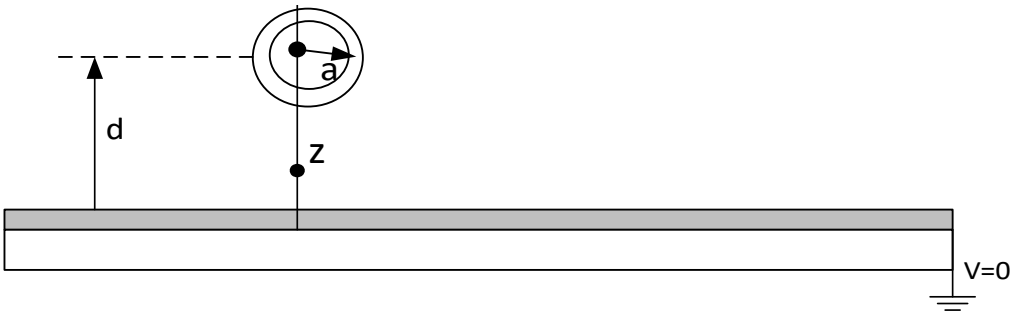

Figure 4

c) Figure 5 shows parallel conductors where $V = 0$ at $= 0$ and $V = 100V$ at $z = d$. The region between the plates is charge free. Use Laplace equation to obtain the expression for:

i. Voltage between the plates
ii. Electric field intensity between the plates

(5 marks)

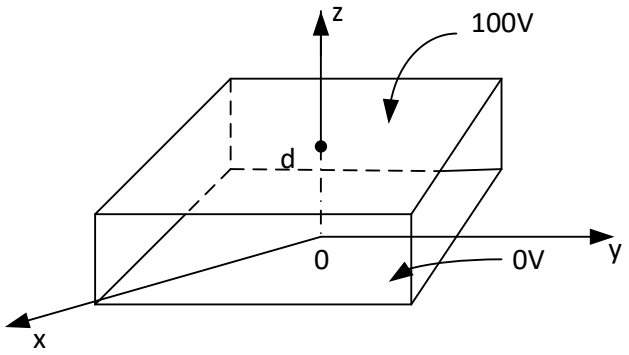

Figure 5

QUESTION FIVE (15 marks)

a) State **Biot-Savart law** and explain all the symbols used

(2 marks)

b) (i)Derive the expression for the magnetic field intensity at the centre of a current carrying loop with a radius R and current I

(7 marks)

(ii)A current loop of radius $1m$ carries a certain current to produce magnetic field $H = 5\ mA/m$ at the centre. Determine the current.

(2 marks)

c) In a medium characterized by $\sigma = 0$, $\mu = \mu_0$ $\varepsilon = \varepsilon_0$ and $E = 20\sin(10^8 t - \beta z)\boldsymbol{a_y}$, obtain the expression of H.

(4 marks)