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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical and Computer Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX6541 Field Theory**
Academic Year	: 2020/2021
Date	: 19th Saturday February 2022
Time	: 0930 - 1230 hrs
Duration	**: 3 hours**

General Instructions

1. Read all the instructions carefully before answering the questions.
2. This is a Closed Book Test (CBT).
3. This question paper consists of **Six (06)** questions in **Three (03)** pages.
4. Answer **only five (05) questions** by answering **ALL in Section A** and selecting only **two (02) from Section B**.
5. All questions carry equal marks.
6. The answer for each question should commence from a new page.
7. Answers should be in clear handwriting.
8. Do not use Red color pen.
9. All the notations have their usual meaning.
10. Assume any missing parameters with suitable values.

Section A

Answer all questions in this section.

Q1.

(a) Discuss the Poisson's and Laplace's equations.

[2 Marks]

(b) Three charges $+q, -q$ and $+q$ are situated at the vertices of an equilateral triangle of side a. Determine the field at the centroid of the triangle.

[6 Marks]

(c) Conducting spherical shells with radii $a = 10\ cm$ and $b = 20\ cm$ are maintained at a potential difference of $100\ V$ such that $V(r = b) = 0$ and $V(r = a) = 100\ V$. Given that $\varepsilon_r = 2.5$ in the region, determine

(i) V and $\boldsymbol{E}$ in the region between the shells,

(ii) the total charge induced on the shells and

(iii) the capacitance of the capacitor.

[12 Marks]

Q2.

(a) What is Biot-Savart law?

[2 Marks]

(b) A circular loop a of wire carries a current $\boldsymbol{I}$ in positive θ direction has a radius a and lies on the xy-plane. The center of the loop is at the origin. Determine $\boldsymbol{H}(0,0,z)$ using the Biot-Savart law.

[6 Marks]

(c) Two coaxial circular wires of radii a and b $(b > a)$ are separated by a distance h $(h \gg a, b)$. Find the mutual inductance between the wires.

[12 Marks]

Q3.

(a) State Maxwell's equations in Integral and Differential forms.

[4 Marks]

(b) In free space it is given that $\boldsymbol{B} = B_m e^{j(\omega t - \beta z)} \boldsymbol{a}_y$. Determine $\boldsymbol{E}$.

[6 Marks]

(c) In a medium characterized by $\sigma = 0$, $\mu = \mu_0$, ε_0 and $\boldsymbol{E} = 20 \sin(10^8 t - \beta z) \boldsymbol{a}_y\ V/m$, calculate β and $\boldsymbol{H}$.

[10 Marks]

Section B

Select only two questions from this section.

Q4.

(a) Explain plane wave propagation in free space.

[4 Marks]

(b) State Poynting theorem and explain its physical meaning.

[4 Marks]

(c) A uniform plane wave propagating in a medium has

$$\boldsymbol{E} = 2e^{-\alpha z} \sin(10^8 t - \beta z)\, \boldsymbol{a}_y \; V/m$$

If the medium characterized by $\varepsilon_r = 1, \mu_r = 20$ and $\sigma = 3\; S/m$. Determine α, β and $\boldsymbol{H}$.

[12 Marks]

Q5.

(a) Explain the term "Monopole antenna".

[4 Marks]

(b) What do you mean by radiation pattern of an antenna.

[4 Marks]

(c) Derive an equation for effective aperture of an antenna.

[6 Marks]

(d) An antenna is having a directivity of 200 and a wavelength of 10 m. Calculate its maximum effective aperture.

[6 Marks]

Q6. Discuss the topic "Microwaves can be used in several applications" with reference to the following applications.

(a) Telecommunication

(b) Radar systems and

(c) Heating.

[20 Marks]

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Note:
Cylindrical Coordinates

$$\nabla f = \frac{\partial f}{\partial \rho}\hat{\boldsymbol{\rho}} + \frac{1}{\rho}\frac{\partial f}{\partial \varphi}\hat{\boldsymbol{\varphi}} + \frac{\partial f}{\partial z}\hat{\mathbf{z}}$$

$$\nabla \cdot \boldsymbol{A} = \frac{1}{\rho}\frac{\partial}{\partial \rho}(\rho A_\rho) + \frac{1}{\rho}\frac{\partial A_\varphi}{\partial \varphi} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \boldsymbol{A} = \left(\frac{1}{\rho}\frac{\partial A_z}{\partial \varphi} - \frac{\partial A_\varphi}{\partial z}\right)\hat{\boldsymbol{\rho}} + \left(\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial \rho}\right)\hat{\boldsymbol{\varphi}} + \frac{1}{\rho}\left(\frac{\partial}{\partial \rho}(\rho A_\varphi) - \frac{\partial A_\rho}{\partial \varphi}\right)\hat{\mathbf{z}}$$

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

Spherical Coordinates

$$\nabla f = \frac{\partial f}{\partial r}\hat{\mathbf{r}} + \frac{1}{r}\frac{\partial f}{\partial \theta}\hat{\boldsymbol{\theta}} + \frac{1}{r\sin\theta}\frac{\partial f}{\partial \varphi}\hat{\boldsymbol{\varphi}},$$

$$\nabla \cdot \mathbf{A} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 A_r\right) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta A_\theta\right) + \frac{1}{r\sin\theta}\frac{\partial A_\varphi}{\partial \varphi},$$

$$\nabla \times \mathbf{A} = \frac{1}{r\sin\theta}\left(\frac{\partial}{\partial \theta}\left(A_\varphi \sin\theta\right) - \frac{\partial A_\theta}{\partial \varphi}\right)\hat{\mathbf{r}}$$
$$+ \frac{1}{r}\left(\frac{1}{\sin\theta}\frac{\partial A_r}{\partial \varphi} - \frac{\partial}{\partial r}\left(rA_\varphi\right)\right)\hat{\boldsymbol{\theta}}$$
$$+ \frac{1}{r}\left(\frac{\partial}{\partial r}\left(rA_\theta\right) - \frac{\partial A_r}{\partial \theta}\right)\hat{\boldsymbol{\varphi}},$$

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