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

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: **EEX6441 Electromagnetism and Wave Propagation**
Academic Year	: 2024/2025
Date	: 26th Monday, January 2026
Time	: 13:30 - 16:30 hrs
Duration	: **03 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 **Five (05)** questions in **Three (03)** pages.
4. Answer **All five (05) questions.**
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 a Red color pen.
9. All notations have their usual meanings.
10. Assume any missing parameters with suitable values.

Q1.

(a) State the Gauss law.

[4 Marks]

(b) For a spherical charge distribution,

$$\rho_v = \begin{cases} \rho_0(a^2 - r^2), & r \le a \\ 0, & r > a \end{cases}$$

(i) Determine **E** and V for $r \le a$

(ii) Determine **E** and V for $r > a$

(iii) Determine the total charge

(iv) Show that **E** is maximum when $r = 0.145\,a$

[4 × 4 Marks]

Q2.

(a) Derive Poisson's and Laplace's equations from Gauss' law for a linear homogeneous medium.

[8 Marks]

(b) Semiinfinite conducting planes $\phi = 0$ and $\phi = \pi/4$ are separated by an infinitesimal insulation gap. If $V(\phi = 0) = 0$ and $V(= \pi/4) = 50$ V, calculate V and **E** in the region between the planes.

[12 Marks]

Q3.

(a) A square conducting loop of $2a$ lies in the $z = 0$ plane and carries a current I in the counterclockwise direction. Show that $\mathbf{H} = {}^{\sqrt{2}I}/_{\pi a}\, \boldsymbol{a}_z$ at the centre of the loop.

[10 Marks]

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

[10 Marks]

Q4.

(a) State the Maxwell's equations in differential form.

[4 Marks]

(b) In free space **B** is given as $10e^{j(\omega t+5z)}\boldsymbol{a}_y$. Prove that $\mathbf{E} = -2\omega e^{j(\omega t+5z)}\boldsymbol{a}_x$

[12 Marks]

(c) Calculate the power transmitted.

[4 Marks]

Q5.

(a) In free space **E** is given as $45\sin(\omega t - \beta z)\, \boldsymbol{a}_x$ V/m. What is the average power P_{avg} which crosses a circular disc of radius 2 m in the $z = constant$ plane?

[10 Marks]

(b) An air-filled rectangular waveguide has dimensions of $a = 8\ cm$ and $b = 6\ cm$. The signal frequency is 30 GHz. Determine the following for TE_{10} mode:

i. Cutoff frequency f_c
ii. Guided wavelength λ_g

[5 × 2 Marks]

Note:

1. **Cylindrical Coordinates**

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

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

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

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

2. **Spherical Coordinates**

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

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

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

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

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