



SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING
BEE 3202 TRANSMISSION LINES AND WAVEGUIDES
SPECIAL EXAM

Date: 18th May, 2026

Time: 2 Hours

Instructions:

1. This Examination consists of **FIVE** questions
 2. Answer **Question ONE (COMPULSORY)** and any other **THREE** questions.
-

QUESTION 1 (Compulsory) – 25 marks

1. The Telegrapher's equations form the basis of transmission line analysis. Derive the Telegrapher's equations from the distributed circuit model of a transmission line and explain the physical significance of each parameter involved. (4 marks)
2. A conductor is 5 cm long. Evaluate whether the conductor is electrically very small, borderline electrically small, or electrically large at the following operating frequencies. Justify each classification using appropriate calculations.
 - i) 200 MHz (3 marks)
 - ii) 2 GHz (3 marks)
 - iii) 20 GHz (3 marks)
3. A $50\ \Omega$ coaxial transmission line operating at 2 GHz is terminated with a load impedance $Z_L = 25 + j50\ \Omega$. The dielectric constant of the medium is $\epsilon_r = 2.25$ and the line length is 3 cm.
 - i) Determine the reflection coefficient at the load, clearly indicating both magnitude and phase. (4 marks)
 - ii) Determine the standing wave ratio (SWR) on the line. (2 marks)
 - iii) Determine the input impedance of the transmission line. (4 marks)

4. Air-filled rectangular waveguides WR-75 and WR-62 have dimensions $1.91 \text{ cm} \times 0.95 \text{ cm}$ and $1.58 \text{ cm} \times 0.79 \text{ cm}$ respectively. Determine the dominant-mode cutoff frequency for each waveguide. (2 marks)

QUESTION 2 (Optional) – 15 marks

- a) Transmission line theory becomes essential when circuit dimensions are comparable to the wavelength of operation. Critically evaluate why lumped circuit analysis becomes inadequate at microwave frequencies. (3 marks)
- b) A transmission line operating at 1 GHz has the following parameters: $L = 0.8 \text{ } \mu\text{H/m}$, $C = 250 \text{ pF/m}$, $R = 5 \text{ } \Omega/\text{m}$, $G = 0.02 \text{ S/m}$.
- i) Determine the propagation constant of the line. (4 marks)
 - ii) Determine the characteristic impedance of the line. (4 marks)
- c) For the same transmission line with a length of 25 cm:
- i) Determine the attenuation in dB. (2 marks)
 - ii) Determine the phase shift in radians. (2 marks)

QUESTION 3 (Optional) – 15 marks

- a) An RG213 coaxial cable has the following parameters:
- Inner conductor diameter = 1.0 mm
- Outer conductor diameter = 4.0 mm
- Dielectric: Polyethylene ($\epsilon_r = 2.3$, loss tangent = 0.0003)
- Operating frequency = 2 GHz.
- i) Determine the series resistance per unit length, R . (3 marks)
 - ii) Determine the inductance per unit length, L . (3 marks)
 - iii) Determine the conductance per unit length, G . (3 marks)
 - iv) Determine the capacitance per unit length, C . (3 marks)
- b) Using the calculated parameters, determine the characteristic impedance of the cable. (3 marks)

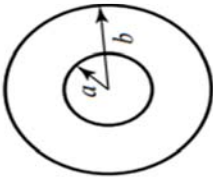
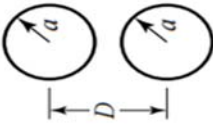
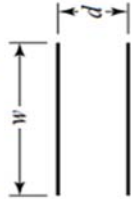
QUESTION 4 (Optional) – 15 marks

- a) A circular waveguide filled with a dielectric material ($\epsilon_r = 2.1$, loss tangent = 0.0003) has an internal radius of 0.6 cm. Determine the cutoff frequencies of the TE₁₁ and TM₀₁ modes. (6 marks)
- b) The operating frequency of the waveguide is 18 GHz.
- i) Determine which modes will propagate at the operating frequency. (2 marks)
 - ii) Determine the wave number within the dielectric medium. (3 marks)
 - iii) Determine the propagation constant of the waveguide. (4 marks)

QUESTION 5 (Optional) – 15 marks

- a) A transmission line operating at 750 MHz has a characteristic impedance of 75Ω and is terminated with a load impedance $Z_L = 150 + j75 \Omega$. Using a Smith Chart:
- i) Determine the normalized load impedance and plot the corresponding load point. (4 marks)
 - ii) Determine the reflection coefficient, indicating both magnitude and phase. (2 marks)
 - iii) Determine the standing wave ratio (SWR) on the line. (3 marks)
 - iv) Design an L-section matching network to achieve impedance matching. (6 marks)

Transmission on line Parameters for common transmission lines

	COAX	TWO-WIRE	PARALLEL PLATE
			
L	$\frac{\mu}{2\pi} \ln \frac{b}{a}$	$\frac{\mu}{\pi} \cosh^{-1} \left(\frac{D}{2a} \right)$	
C	$\frac{2\pi\epsilon'}{\ln b/a}$	$\frac{\pi\epsilon'}{\cosh^{-1} (D/2a)}$	$\frac{\mu d}{w}$
R	$\frac{R_s}{2\pi} \left(\frac{1}{a} + \frac{1}{b} \right)$	$\frac{R_s}{\pi a}$	$\frac{\epsilon' w}{d}$
G	$\frac{2\pi\omega\epsilon''}{\ln b/a}$	$\frac{\pi\omega\epsilon''}{\cosh^{-1} (D/2a)}$	$\frac{2R_s}{w}$
			$\frac{\omega\epsilon'' w}{d}$

Copper conductivity, $\sigma = 5.813 \times 10^7 \text{ S}$; $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$; $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$

ϵ_0 is the dielectric constant; $R_s = \sqrt{\frac{\omega\mu}{2\sigma}}$

Note:

$$\cosh^{-1} \frac{D}{2a} \cong \ln \frac{D}{a} \text{ if } \left[\frac{D}{2a} \right]^2 \gg 1$$

$$\epsilon = \epsilon' - j\epsilon'' = \epsilon'(1 - j\tan\delta)$$

is the complex permittivity; $\epsilon' = \epsilon_0\epsilon_r$, and $\tan\delta = \epsilon''/\epsilon'$ is the loss tangent of the dielectric material.

Copper conductivity, σ
 $= 5.813 \times 10^7 \text{ S}$;
 $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$;
 $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$

ϵ_0 is the dielectric constant

Values of p'_{nm} for TE Modes of a Circular Waveguide

n	P'_{n1}	P'_{n2}	P'_{n3}
0	3.832	7.016	10.174
1	1.841	5.331	8.536
2	3.054	6.706	9.970

Values of p_{nm} for TM Modes of a Circular Waveguide

n	P_{n1}	P_{n2}	P_{n3}
0	2.405	5.520	8.654
1	3.832	7.016	10.174
2	5.135	8.417	11.620

Summary table for Rectangular waveguides

Quantity	TE _{mn} Mode	TM _{mn} Mode
k	$\omega\sqrt{\mu\epsilon}$	$\omega\sqrt{\mu\epsilon}$
k_c	$\sqrt{(m\pi/a)^2 + (n\pi/b)^2}$	$\sqrt{(m\pi/a)^2 + (n\pi/b)^2}$
β	$\sqrt{k^2 - k_c^2}$	$\sqrt{k^2 - k_c^2}$
λ_c	$\frac{2\pi}{k_c}$	$\frac{2\pi}{k_c}$
λ_g	$\frac{2\pi}{\beta}$	$\frac{2\pi}{\beta}$
v_p	$\frac{\omega}{\beta}$	$\frac{\omega}{\beta}$
Z	$Z_{TE} = \frac{k\eta}{\beta}$	$Z_{TM} = \frac{\beta\eta}{k}$

Summary table for Circular Waveguides

Quantity	TE _{nm} Mode	TM _{nm} Mode
k	$\omega\sqrt{\mu\epsilon}$	$\omega\sqrt{\mu\epsilon}$
k_c	$\frac{p'_{nm}}{a}$	$\frac{p_{nm}}{a}$
β	$\sqrt{k^2 - k_c^2}$	$\sqrt{k^2 - k_c^2}$
λ_c	$\frac{2\pi}{k_c}$	$\frac{2\pi}{k_c}$
λ_g	$\frac{2\pi}{\beta}$	$\frac{2\pi}{\beta}$
v_p	$\frac{\omega}{\beta}$	$\frac{\omega}{\beta}$
α_d	$\frac{k^2 \tan \delta}{2\beta}$	$\frac{k^2 \tan \delta}{2\beta}$
Z	$Z_{TE} = \frac{k\eta}{\beta}$	$Z_{TM} = \frac{\beta\eta}{k}$