Discipline of Electrical, Electronic and Computer Engineering
ENEL3EM E-M Theory

Main Examination 7 November 2025
Duration: 120 minutes Maximum Marks: 70

Internal Examiner: Dr SS Patel Independent Moderator: Prof. P Kumar

Instructions to Students

- This examination is **Open-Book**
  - Students may use any paper-based physical material (including notes, lecture slides, textbooks, research articles, etc.) as reference material when answering the questions.
  - No digital devices (tablets, smartphones, etc.) are permitted.
- All questions are compulsory.
  Questions may be answered in any order, however, sub-questions should be answered consecutively.
- Answers should be written using a pen with blue or black ink. The use of highlighters and other forms of stationery are permitted if necessary.
  - Answers written in pencil will not be considered with the exception of graphs, sketches or diagrams.
- The use of a non-programmable calculator is permitted.
- Students are advised to plan their time carefully.
- **State any assumptions clearly and justify why they were made.**
- **Answers may be left in surd form.**
- **Questions 5.2 and 5.3 are to be answered using the Smith Chart Provided.**

Including this cover page, the examination question paper has 3 pages.

Students are advised to check that they have all pages of the question paper before commencing with the examination.

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1 An electromagnetic wave travels through a slab of marble (which is a rock) with relative permittivity of $\epsilon_r = 9$. Its magnetic field is given by:

$$\bar{H} = 6\cos(\omega t - 4x)\,\hat{y} - 2\sin(\omega t - 4x)\hat{z}\ \text{A/m}$$

1.1 Why can it be assumed that the relative permeability of the marble slab is $\mu_r \approx 1$? (2)

1.2 Determine the angular velocity of the wave. (2)

1.3 Determine the electric field vector, $\bar{E}$. (5)

1.4 Explain how interpreting the loss tangent of a material provides insight into whether it behaves as a near-perfect conductor, a near-perfect dielectric or a lossy dielectric at a particular frequency. (5)

1.5 Would you expect the slab of marble to be a near-perfect conductor, a near-perfect dielectric or a lossy dielectric? (2)

1.6 Marble is a porous material that soaks in water if it gets exposed to moisture. Explain what you expect to happen to the loss tangent and intrinsic impedance of the marble if it gets wet, assuming that the entire slab is affected uniformly by the moisture. Also state whether you expect the behaviour of wet marble to differ from your answer in Question 5 at any point. (6)

2 Using your knowledge of electromagnetic interference, explain why breadboards are not suitable for prototyping high-frequency circuits. In your explantation, mention (i) the dominant coupling mechanism for high-frequency breadboard circuits, (ii) the source and victims of the EMI and (iii) why it is not possible to mitigate the dominant form of coupling in a breadboard. (5)

3 The power delivered to the load of a lossy transmission line is given by: (5)

$$P_L = \frac{e^{-2\alpha l}\,V_1^2}{2\,Z_0}(1 - |\Gamma_L|^2)\ \text{W}$$

Show how the choice of load impedance impacts the reflection coefficient under open-circuit, short-circuit and matched conditions, and hence what affect the load impedance has on power transfer.

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4 Wi-Fi routers typically transmit at 2.4GHz and are manufactured with linearly-polarized antennas. A particular router transmits an electric field with magnitude 600mV/m oriented in the -x direction and 20mV/m in the +y direction. The wave travels through air and is incident normally on a wall ($\epsilon_r = 3.6$, $\sigma \approx 0$ and $\mu_r = 4$) at z=0. Let the region where z≤0 be the air.

4.1 Determine an equation for the incident electric field vector, including the numerical values of the angular frequency and phase constant. (4)

4.2 Determine the reflection and transmission coefficients of the air-wall boundary. (4)

4.3 Determine equations for the reflected and transmitted electric fields. (4)

5 A 25m long lossless transmission line with $L = 25\ \mathrm{mH/m}$ and $C = 160\mathrm{pF/m}$ operating at 2MHz is terminated with a load $Z_L = 100 - \mathrm{j}250\Omega$.

5.1 If the phase velocity $v_p = 2{,}4 \times 10^8 \mathrm{m/s}$ on the line, determine the reflection coefficient and input impedance. (8)

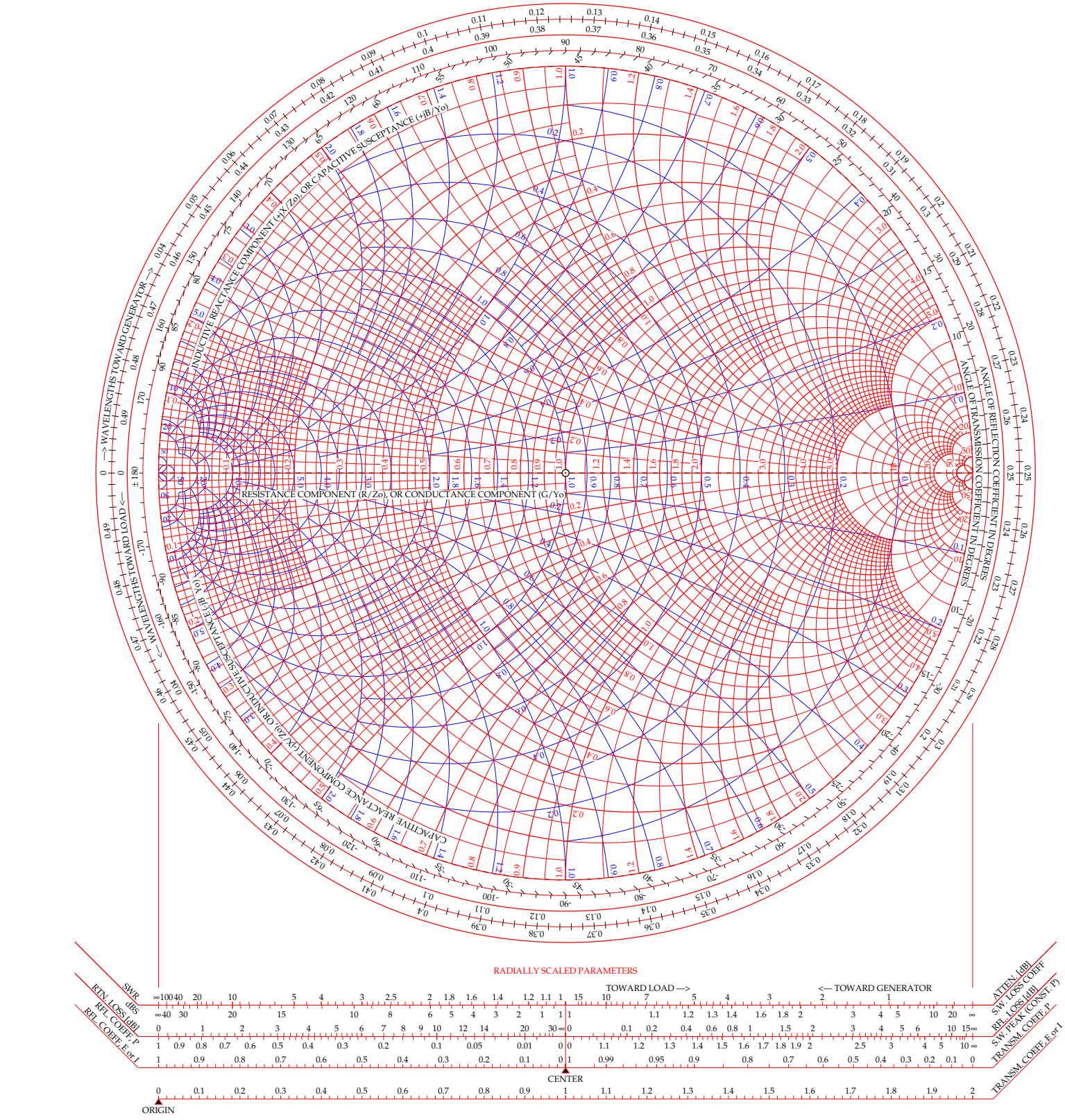
Use the Smith Chart to answer both Q5.2 and Q5.3.
The same transmission line is now used for a load of $Z_L = 1000 - j14000\ \Omega$.

5.2 Use the Smith Chart to determine the approximate Standing Wave Ratio and Reflection Coefficient for a voltage signal transmitted along the line. (5)

5.3 Use the Smith Chart to match the load to the line. Show all working out. (6)

5.4 What is the reflection coefficient of the matched line? (2)

6 Explain what is meant by loss and distortion in the context of transmission lines. How do the concepts of loss and distortion relate to the propagation constant, and what condition is imposed on the phase constant of the line to ensure that it is distortionless? (5)


RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
—> WAVELENGTHS TOWARD GENERATOR —>
<— WAVELENGTHS TOWARD LOAD <—
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD —>
<— TOWARD GENERATOR
SWR
dBS
RTN. LOSS [dB]
RFL. COEFF. P
RFL. COEFF. E or I
ATTEN. [dB]
S.W. LOSS COEFF
RFL. LOSS [dB]
S.W. PEAK CONST. Pj
TRANSM. COEFF. E or I
CENTER
ORIGIN