Menoufia University
Faculty of Electronic Engineering
Electronics and Electrical Commun. Eng. Dept.
Third Year – Second Semester
Microwave Engineering

Course Code: ECE 323

Final Examination 2016-2017
Time : 3 Hours
Date : Sunday, May 21, 2017
Total Marks: 90 Marks
Instructor : Dr. Ahmed Farghal

ISA, you can ACE this exam!! **Think!!**

Instructions:

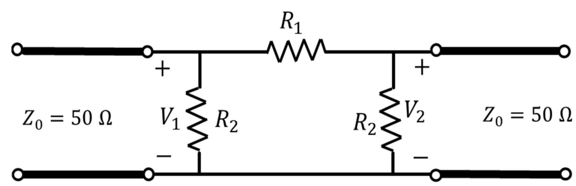
1. Answer **ALL** questions. Provide the solutions in this exam booklet.
2. There should be **16 numbered pages** (including Smith chart) in this exam.
3. Work **efficiently**. Some questions are easier, some more difficult. Be sure to give yourself time to answer all of the easy ones, and avoid getting bogged down in the more difficult ones before you have answered the easier ones.

$$\varepsilon_o = 8.854 \times 10^{-12} \text{ F/m}, \qquad \mu_o = 4\pi \times 10^{-7} \text{ H/m}, \qquad \eta_o = 377\ \Omega$$

<u>QUESTION 1</u>: [20 pts. total]

A] For the Π network shown below, $R_1 = 18\ \Omega$ and $R_2 = 291\ \Omega$. Find

(a) The scattering matrix. [**4 points**]



(b) The reflected-to-incident power ratio. [**1 point**]

(c) The transmitted-to-incident power ratio. [**1 point**]

(d) The loss-to-incident power ratio. [**1 point**]

(e) What is the function of this device? [**1 point**]

B] The S-parameters of a 2-port network are given by

$$[S] = \begin{bmatrix} 0.5 + j0.5 & 0.15 - j0.05 \\ 0.95 + j0.25 & 0.5 - j0.5 \end{bmatrix}$$

The system impedance is $Z_0 = 50\ \Omega$.

(a) Is this network loss-free? Justify your answer. [**2 points**]

(b) Is this network reciprocal? Justify your answer. [**2 points**]

(c) If port 2 is matched, find the reflection coefficient Γ_1 at port 1 as well as the input impedance $Z_{\mathrm{in}1}$ at port 1. [**2 points**]

(d) Assuming that the network is fed at port 1 and the load at port 2 is Z_0, what is the internal impedance of the generator at port 1 such that maximum power is delivered to the network? [**2 points**]

(e) If port 2 is short-circuited, find the reflection coefficient Γ_1^{sc} at port 1 as well as the input impedance $Z_{\mathrm{in}1}^{sc}$ at port 1. [**4 points**]

<u>QUESTION 2</u>: [25 pts. total]

A] For a rectangular waveguide supporting TE waves, we have the following electric fields:

$$\tilde{E}_x = \frac{j3w\mu\pi}{k_c^2 b}\cos\left(\frac{2\pi x}{a}\right)\sin\left(\frac{3\pi y}{b}\right)\ e^{-j\beta z}$$

$$\tilde{E}_y = -\frac{j2w\mu\pi}{k_c^2 a}\sin\left(\frac{2\pi x}{a}\right)\cos\left(\frac{3\pi y}{b}\right)\ e^{-j\beta z}$$

(a) What is the mode of operation? [**1 point**]

(b) What is the direction of propagation? [**1 point**]

(c) Using **Maxwell's equations** ($\nabla \times E = -jw\mu H,\ \nabla \times H = jw\varepsilon E$), find the corresponding magnetic fields in the x, y and z directions (Hint: $\nabla \times A = \left(-\frac{\partial A_y}{\partial z}\right)\hat{x} + \left(\frac{\partial A_x}{\partial z}\right)\hat{y} + \left(\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y}\right)\hat{z}$). [**6 points**]

(d) Prove that the power transmitted by TE_{10} mode is given by $P = \frac{E_0^2 ab}{4Z_{\mathrm{TE}}}$, where E_0 is the peak electric field value (Hint: $\int_0^a \cos^2\left(\frac{\pi x}{a}\right) dx = \int_0^a \sin^2\left(\frac{\pi x}{a}\right) dx = \frac{a}{2}$). [**4 points**]

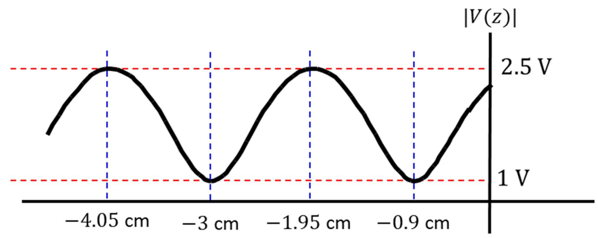
(e) The waveguide has dimensions $a = 4$ cm and $b = 2$ cm and filled with air and $E_0 = 63.77$ V/m. Find the average power propagated inside the guide at $f = 3$ GHz. [**2 points**]

B] Draw the field patterns inside a rectangular waveguide for TE_{20}, TE_{01}, TM_{20}, and TM_{01} modes in xy and xz planes. [**8 points**]

C] Explain impossibility of TEM wave propagation through hollow waveguide. [**3 points**]

<u>QUESTION 3</u>: [20 pts. total]

A] The results of a slotted-line experiment are plotted in the following figure. The length of the line is $\ell = 8.4$ cm; its characteristic impedance is $Z_0 = 50\ \Omega$. Find



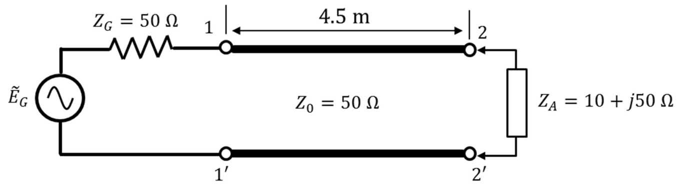
(a) The reflection coefficient at the load. [**2 points**]

(b) The load impedance. [**1 point**]

(c) The input impedance. [**2 points**]

(d) The reflection coefficient at the generator terminals. [**1 points**]

B] A radio transmitter operated at 400 MHz has an internal impedance of 50 Ω and it delivers power of 1 W to a matched load. It is connected to an antenna of impedance $Z_A = 10 + j50\ \ \Omega$ via a loss-free 50 Ω coaxial cable with L =0.625 [μH/m], C = 40 [pF/m] (Hint: $\mu = 10^{-6}, \mathrm{p} = 10^{-12}$). Find



(a) The Thevenin equivalent of the transmitter together with the transmission line, i.e., with respect to terminals $2 - 2'$. [**7 points**]

(b) The power delivered to the antenna. [**3 points**]

(c) The power reflected back to the generator. [**2 points**]

<u>QUESTION 4</u>: [15 pts. total]

A] Explain briefly with diagrams the differences between Isolator and Circulator. [**3 points**]

B] Draw schematic of four port circulator constructed using magic tees and explain its operation. [**3 points**]

C] Circle or underline the correct answer. [**9 points**]

1. A directional coupler has a directivity =25 dB and an isolation =40 dB. The coupling value will be
   a. 65 dB
   b. 40 dB
   c. 15 dB
   d. None of these.

2. The scattering parameters are used to express relations between
   a. Impedances and admittances of the ports.
   b. Total voltages on the ports and total currents on the ports.
   c. Voltage waves incident on the ports and those travelling away from the ports.
   d. None of these.

3. The Isolator is used to
   a. Attenuate the power level to the wanted value.
   b. Pass microwave signal at low attenuation in one direction, and not the other.
   c. Pass microwave signal in both directions at low loss.
   d. Produce phase shift for the transmitted signal in one direction, and not the other.

4. When it is required to split a microwave signal into two parts that are equal in magnitude and opposite in phase, the following matched device is used
   a. H-plane T-junction waveguide.
   b. 3-dB directional coupler.
   c. 3-port circulator.
   d. E-plane T-junction waveguide.

5. A waveguide section in a microwave circuit acts as
   a. Low pass filter
   b. Band pass filter
   c. High pass filter
   d. Band stop filter

6. A magic-Tee is nothing but
   a. A modification of E-plane tee.
   b. A modification of H-plane tee.
   c. A combination of E-Plane and H-Plane.
   d. Two E-plane tees connected in parallel.

7. An ideal directional coupler has________ directivity, and_________insertion loss.
   a. infinity, zero
   b. zero, zero
   c. zero, infinity
   d. infinity, infinity

8. A transmission line is:
   a. A pair of wire.
   b. A special type of cable.
   c. A copper trace on a printed circuit board with ground plane.
   d. Any metallic structure with at least 2 conductors that is long compared to the wavelength of the wave guided by the structure.

9. An-air transmission line with length l connects a load to a sinusoidal voltage source operating at a frequency f. Transmission line effects can be ignored for the case
   a. l = 20 cm, f = 10 KHz
   b. l = 400 km, f = 50 Hz
   c. l = 20 cm, f = 300 MHz
   d. l = 1 mm, f = 100 GHz

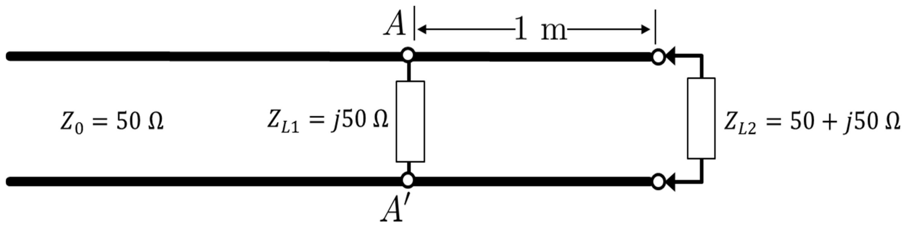
QUESTION 5: [10 pts. total]

A transmission line is loaded with an impedance $Z_{L1} = j50\ \Omega$ at a distance 1 m from the load $Z_{L2} = 50 + j50\ \Omega$ as shown below. If the wavelength on the line equals 5 m. Use a short-circuited parallel stub placed **to the left** of points $A - A'$ to match the load to the line. Using Smith chart,

(a) Find the distance d where the stub should be placed (in terms of λ)

(b) What is the length of the stub L^{stub} (in terms of λ)?

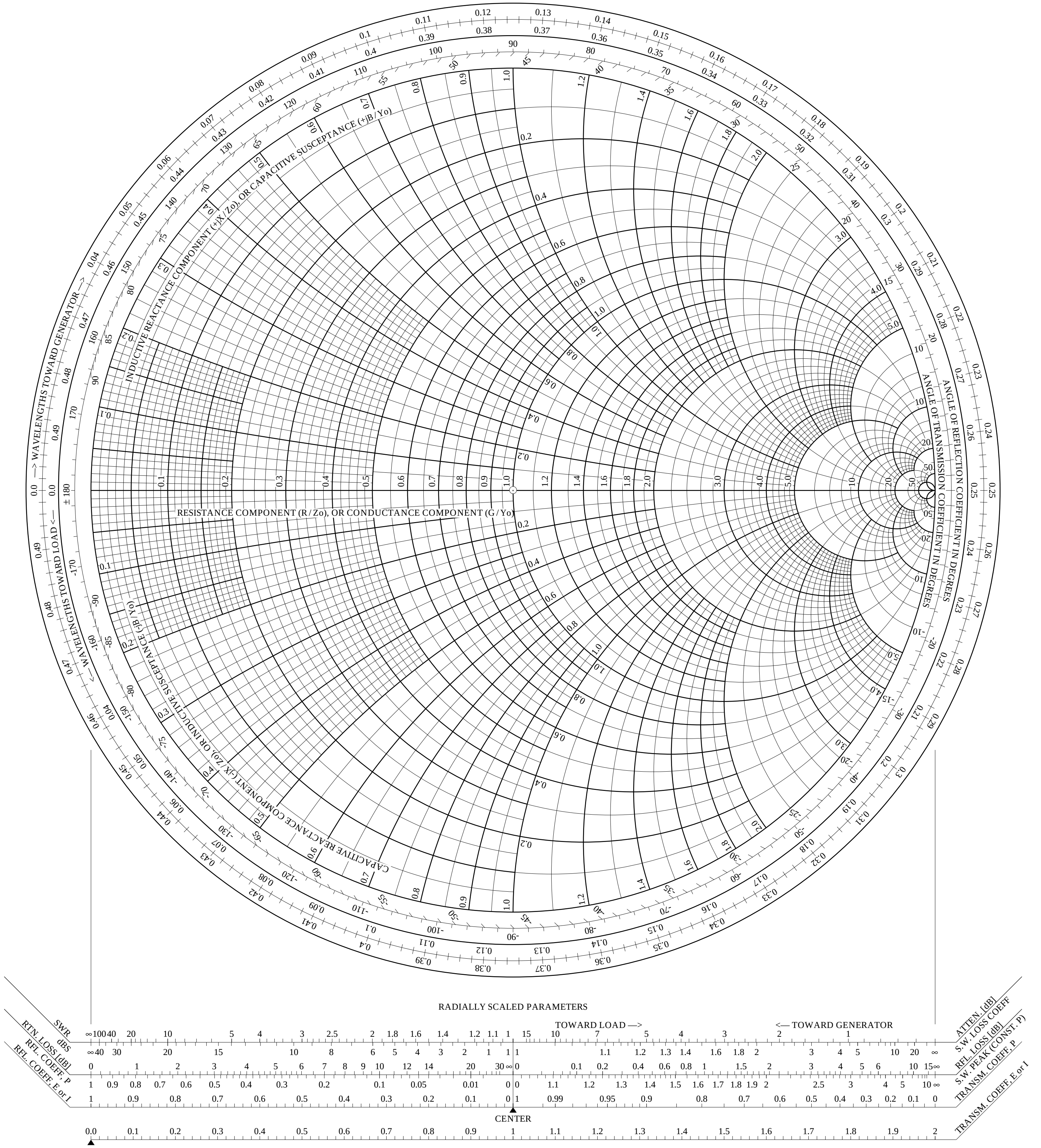
(c) Plot the resulting circuits.



d_1	L_1^{stub}	d_2	L_2^{stub}

The Complete Smith Chart

Black Magic Design



If you need to continue the solution to a problem here, mark clearly on the page where the problem is stated that the "***solution is continued on page 16***", and on this page mark clearly which problem you are continuing.

END OF EXAMINATION