KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION TECHNOLOGY)

<u>SPH 314: MICROWAVES AND DEVICES</u>

DATE: Thursday 29th March, 2012 **TIME:** 2.00 p.m. – 4.00 p.m.

INSTRUCTIONS

Answer questions ONE and any other TWO questions.

You may use the following constants:

$\varepsilon_o = 8.85 \times 10^{-12}$ F/m $e = 1.6 \times 10^{-19}$ C. $\mu_o = 4\pi \times 10^{-7}$ H/m

$$\nabla \times \nabla \times \vec{M} = \nabla(\nabla \cdot \vec{M}) - \nabla^2 \vec{M}$$

$$\sqrt{1+x} = 1 + \frac{x}{2} - \frac{x^2}{8} + \ldots \qquad \frac{1}{\sqrt{1+x}} = 1 - \frac{x}{2} + \frac{3x^2}{8} - \ldots$$

$$\int_0^{2\pi} \sin\left[\omega t_b + \alpha\left(1 - \frac{V_b}{2V_o}\sin\omega t_b\right)\right] d(\omega t_b) = 2\pi J_1(x)\sin\alpha$$

$$\int_0^{2\pi} \sin\left[\omega t_b + \alpha'\left(1 - \frac{V_b}{2V_o}\sin\omega t_b\right)\right] d(\omega t_b) = 2\pi x' J_1'(x')\sin\alpha'$$

Q1. (a) (i) What are microwaves? (1 mark)

(ii) State three disadvantages of microwaves. (3 marks)

(b) (i) Sketch a diagram of a flap attenuator. (1 mark)

(ii) How far from the side of a 3 cm x 6 cm rectangular waveguide should he flap be for maximum attenuation in a TE_{40} mode? (3 marks)

(c) (i) What is a directional coupler? (1 mark)

	(ii)	A 20 dB directional coupler has a 3 dB attenuator connected between its auxiliary arm and the input to a power meter. If the reading of the power meter is 17.5 dB, what is the power through the input of the directional coupler? (3 marks)
(d)	(i)	Using a diagram illustrate how a TE_{22} can be induced in a rectangular waveguide? (1 mark)
	(ii)	If the guide and free space wavelengths of a rectangular waveguide are 13.0 cm and 5.5 cm, respectively, calculate the cut-off wavelength. (3 marks)
(e)	(i)	Using a labeled diagram show how magic T-junction can be used as a transmitter and as a receiver simultaneously? (1 mark)
	(ii)	Explain the working of a waveguide with a sliding plunger is used as a variable short. (3 marks)
(f)	(i)	What is Gunn effect? (1 mark)
	(ii)	An IMPATT-operated diode has a depletion width of 3 μm and a doping density of $10^{16}/cm^3$. If the dielectric constant of the material is 2.4, what is the field at breakdown voltage? (3 marks)
(g)	(i)	What is a transfer matrix? (1 mark)
	(ii)	Show that the transfer matrix of two port networks in cascade is the product of the transfer matrix of the individual networks. (3 marks)
(h)		Differentiate between a reciprocal and a non-reciprocal gyrator? (2 mark)

Q2. (a) Consider the two-port network in Fig 1.

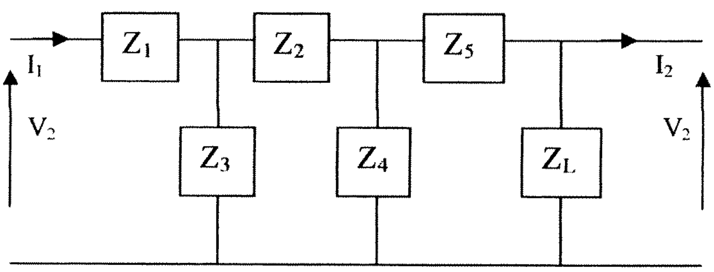

Figure 1

(i) Find the transfer matrix of the network and load in cascade (6 marks)

(ii) Find the input impedance Z_{11}. (2 marks)

(iii) Find the ratio V_1/V_2. (1 mark)

(iv) Find the ratio I_L/I_1 (1 mark)

(b) A two-port device is terminated in a load of reflection coefficient ρ_L and is fed from a generator of reflection coefficient ρ_G as shown in Fig 2 below

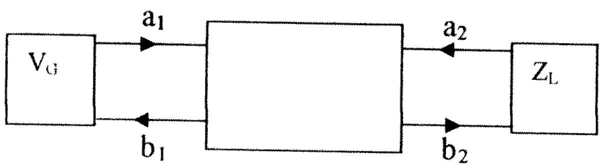

Figure 2

Show that the

(i) reflection coefficient at the input is

$$\rho_i = S_{11} + \frac{S_{12}S_{21}\rho_L}{1 - S_{22}\rho_L}$$ (3 marks)

(ii) transmission coefficient between the output and input is

$$\tau_{oi} = \frac{S_{21}}{1 - S_{22}\rho_L}$$ (2 marks)

(iii) reflection coefficient at the output port is

$$\rho_o = S_{22} + \frac{S_{12}S_{21}\rho_G}{1 - S_{11}\rho_G}$$ (3 marks)

(iv) transmission coefficient between the input and output ports is

$$\tau_{oi} = \frac{S_{12}}{1 - S_{11}\rho_G}$$ (2 marks)

Q3. (a) Show that for electromagnetic waves propagating in a conducting medium the

(i) propagation constant is given by

$$\gamma = \sqrt{i\omega\mu\,(\sigma + i\omega\varepsilon)}$$

(5 marks)

(ii) attenuation is given by

$$\alpha = \omega\sqrt{\left(\frac{\mu\varepsilon}{2}\right)\left[\sqrt{\left(1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2\right)}-1\right]}$$

(5 marks)

(iii) phase constant is given by

$$\beta = \omega\sqrt{\left(\frac{\mu\varepsilon}{2}\right)\left[\sqrt{\left(1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2\right)}+1\right]}$$

(5 marks)

(b) Show that for electromagnetic waves propagating in a good conducting medium the

(i) attenuation is given by

$$\alpha = \sigma\sqrt{\left(\frac{\mu}{\varepsilon}\right)}$$

(3 marks)

(iii) phase constant is given by

$$\beta = \omega\sqrt{\varepsilon\mu}\left(1+\frac{\sigma^2}{8\omega^2\varepsilon^2}\right)$$

(2 marks)

Q4. (a) (i) Using a labeled diagram, show that the time required to by an electron to travel in the field-free space in a double-resonator klystron is given by

$$T = \frac{s}{v_o\sqrt{1+\frac{V_b}{V_o}\sin\omega t_b}}$$

where s the buncher-to-catcher distance, v_o is the velocity of electron entering the buncher, V_b is the voltage of the rf signal and ωt_b is the phase angle at the buncher. (4 marks)

(ii) Show that the average power per electron transferred to the catcher is given by

$$U_{av} = -q_e V_c J_1(x)\sin\alpha$$

(3 marks)

where $J_1(x)$ is Bessel's function, V_2 is the catcher voltage and α is the transit angle.

(iii) Show that the efficiency of the klystron is given by

$$\eta = -\frac{V_2}{V_o} J_1(x) \sin\alpha$$

where $J_1(x)$ is Bessel's function, V_2 is the catcher voltage and α is the transit angle. (3 marks)

(b) (i) Using a labeled diagram, show that the time required to by an electron to travel in the field-free space in a reflex klystron is given by

$$T = -\frac{2m_e s v_b}{q_e (V_R - V_o)}$$

where s the buncher-to-catcher distance, v_b is the velocity of electron entering the buncher, V_R is the reflector voltage and V_o is the accelerating voltage. (4 marks)

(ii) Show that the average power per electron transferred to the catcher is given by

$$U_{av} = q_e V_c x' J_1{}' (x) \sin\alpha'$$

where $J_1(x)$ is Bessel's function, V_2 is the catcher voltage and α is the transit angle. (3 marks)

(iii) Show that the efficiency of the klystron is given by

$$\eta = \frac{V_b}{V_o} x' J_1{}' (x')$$

where $J_1(x)$ is Bessel's function, V_b is the catcher voltage and α' is the transit angle. (3 marks)

Q5. (a) Use energy conservation law, boundary conditions and Snell's law to show that for oblique incidence with the electric component parallel to plane of incidence the

(i) reflection coefficient is given by

$$\rho_{II} = \frac{\sqrt{\varepsilon_2}\cos\theta_1 - \sqrt{\varepsilon_1}\cos\theta_2}{\sqrt{\varepsilon_2}\cos\theta_1 + \sqrt{\varepsilon_1}\cos\theta_2}$$ (9 marks)

(ii) transmission coefficient is given by

$$\tau_{II} = \frac{2\sqrt{\varepsilon_1}\cos\theta_1\cos\theta_2}{\sqrt{\varepsilon_2}\cos\theta_1\cos\theta_2 + \sqrt{\varepsilon_1}\cos^2\theta_2}$$ (5 marks)

(iii) Brewster angle is given by

$$\tan\theta_B = \sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$$ (3 marks)

(b) Show that for no reflection of a plane wave with parallel polarization incident obliquely on a plane interface between two non-magnetic media the Brewster angle must be $\pi/2 - \theta_t$, where θ_t is the angle of refraction.
(3 marks)

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