Plasma Electrodynamics 2 **Mid-Term Exam 2** Nov. 29, 2009

(20점)

1. If each of the following statements is true, please mark O at the end of each statement. If false or incorrect, mark X and make corrections.

1) Transmission lines are usually long in terms of wavelength and are represented by distributed parameters, while waveguides are normally short and are described by field quantities.

2) A lossless transmission line is distortionless, and has zero α and X_o, constant u_p and R_o.

3) When phase constant is proportional to frequency, transmission lines and single-conductor waveguides are dispersive.

4) Comparing with the phase velocity of unguided plane wave in the dielectric medium, the phase velocity on a lossless or distortionless transmission line is the same, while the phase velocity of both TM and TE modes in a uniform waveguide is greater.

5) Input impedance of a very short open-circuited line is purely inductive.

6) The circuit conditions for an infinite line and for a matched line are the same at the input (sending) end.

7) The distance between neighboring voltage maxima and voltage minima is $\lambda/2$ of a standing wave when a transmission line is not matched.

8) The Smith chart can be used either as an impedance chart or as an admittance chart, and is applicable to transmission lines having any characteristic resistance.

9) The point representing an open-circuit, P_{oc}, is at (1, 0) on a Smith admittance chart.

10) TEM waves cannot exist in a single-conductor dielectric-filled waveguide of any cross section.

11) Since a waveguide lets only waves with higher frequencies than a cutoff frequency propagate through it, it can act as a high-pass filter.

12) For TM modes in rectangular waveguides, neither m nor n can be zero, and the wave impedance is less than the intrinsic impedance of the guide medium.

13) The cutoff frequencies for TM_{nr} and TE_{nr} modes in a circular wave guide are not always the same.

14) The subscripts m and n of TM_{mn} and TE_{mn} modes denote, respectively, the number of wavelengths of field variations in the x- and y-directions in rectangular waveguides.

15) TM_{101} and TE_{110} modes cannot exist in a rectangular cavity resonator referring to the z-axis.

(30점)

2. For uniform two-wire transmission lines with time-harmonic variations,

a) Draw the equivalent circuit of a differential length Δz for distributed circuit analysis.

b) Set up circuit equations for $v(z,t)$ and $i(z,t)$ from Kirchhoff's laws.

c) For cosine-reference time-harmonic variations, $v(z,t) = Re[V(z)e^{j\omega t}]$ and $i(z,t) = Re[I(z)e^{j\omega t}]$, show that the Helmholtz-type wave equation for $V(z)$ is $\frac{d^2V(z)}{dz^2} - \gamma^2 V(z) = 0$, and express $\gamma = \alpha + j\beta$ in terms of $R, L, G, C,$ and ω.

d) Find the general solution for $V(z)$.

e) Define the characteristic impedance Z_o of the transmission line.

f) Determine α, β, Z_o for the distortionless lossy transmission lines.

g) Define the matched line for a finite transmission line connected to a load impedance Z_L.

(15점)

3. Answer the following questions and explain how you've got the answers by using and drawing the Smith Chart.

A given lossless transmission line of 0.1875 (m) long and short-circuited has the characteristic impedance of 5 (Ω).

a) Determine the voltage reflection coefficient in polar form.

b) Find the input impedance at 600 (MHz).

c) Determine the corresponding input admittance for the line in (b).

d) Find the standing-wave ratio.

e) Find all locations of the voltage maximum and the voltage minimum on the line, respectively.

(35점)

4. For an air-filled(ϵ_o, μ_o) $a \times b$ ($a = \sqrt{3}\, b$) rectangular waveguide operating at the frequency $f = 3.6$ GHz for a TM wave traveling along the z-direction,

a) Set up a BVP (boundary-value problem) for finding the phasor $E_z^o(x,y)$.

b) Find a general solution for $E_z^o(x,y)$ by solving this BVP.

c) Determine eigenvalues for $h^2 = \gamma^2 + k^2$ and eigenmodes for $E_z^o(x,y)$.

d) Show that a transverse component field $H_x^o(x,y)$ of this TM wave can be determined by calculating $H_x^o = \frac{j\omega\epsilon_o}{h^2}\frac{\partial E_z^o}{\partial y}$ which is derived from the x-component of Faraday's law and the y-component of Ampere's law.

e) Determine the dispersion relation and find the cutoff frequency for TM_{mn} mode.

f) Find the dominant mode and calculate the cutoff frequency of the dominant mode.

g) Find the cutoff wavelength λ_c of the dominant mode.

h) If the operating frequency $f = 3.6$ GHz is at least 20% higher than the cutoff frequency of the dominant mode, give a typical design for the dimension a.