Electromagnetics II

Final Exam (10:10am–12:00m) 6/24/02

1. (20%) A transmission line of characteristic impedance 50 $\Omega$ is terminated by a load impedance $\overline{Z_R} = (15 - j20)\ \Omega$. Use the provided Smith chart to find the following quantities:
(a) reflection coefficient at the load, (3%)
(b) SWR on the line, (2%)
(c) distance of the first voltage minimum of the standing-wave pattern from the load, (3%)
(d) line impedance at $d = 0.05\ \lambda$ ($d$ is the distance from the load), (3%)
(e) line admittance at $d = 0.05\ \lambda$. (3%)
(f) If the same transmission line is short-circuited and at a distance $L$ ($L < 0.5\ \lambda$) from the short the input susceptance is found to be $-0.0232$ S, please determine the possible values of $L$. (6%)

2. (10%) Consider a lossy transmission line with characteristic impedance $\sqrt{(R + j\omega L)/(G + j\omega C)}$, where $R$, $G$, $L$, and $C$ are per unit length quantities. (a) What are the conditions for the so-called "low-loss line"? (4%) (b) Derive an approximate expression for the attenuation constant for propagation along the low-loss line. (6%)

3. (8%) Consider a magnetic core surrounded by air in a magnetic circuit. Please give a proof with simple derivation to show why one can assume the magnetic flux is confined to the magnetic core.

4. (10%) Consider a TE (perpendicular polarization) uniform plane wave obliquely incident on a dielectric interface from medium 1, as shown in Fig. P4, where medium 2 is free space with permittivity $\epsilon_0$ and permeability $\mu_0$, and medium 1 is with permittivity $2\epsilon_0$ and permeability $\mu_0$. The free-space wavelength of the wave is 1 $\mu$m = $10^{-6}$ m and the angle of incidence $\theta_1$ is 60°. (a) What is the magnitude and direction of the phase velocity of the wave fields in medium 2 (free space)? (5%) (b) Give an expression for the electric field variation along the $x$ direction in medium 2. (5%)

5. (8%) Consider a dielectric slab waveguide, as shown in Fig. P5(a). (a) For the $TE_0$ mode (the fundamental mode), please plot the variation of $E_y$ with $x$ for two situations, one is very far from cutoff, and the other is not very far from cutoff. Please make your plots using the axes as shown in Fig. P5(b). (4%) (b) Repeat part (a) but for the $TE_1$ mode. (4%)

6. (12%) A dielectric slab of thickness 4 cm and permittivity $2.25\epsilon_0$ exists in an air-dielectric rectangular waveguide of dimensions $a = 3$ cm and $b = 1.5$ cm, as shown in Fig. P6. Find the lowest frequency for which the dielectric slab is transparent (i.e., allows complete transmission) for $TE_{1,0}$ mode propagating in the waveguide.

7. (12%) For a rectangular cavity resonator having the dimensions $a = 2.5$ cm, $b = 2$ cm, and $d = 5$ cm, and filled with a dielectric of permittivity $2.25\epsilon_0$ and permeability $\mu_0$, find the five lowest frequencies of oscillation. Identify the mode(s) for each frequency.

8. (5%) For the same cavity resonator in Problem 7, please explain the difference between the $\mathrm{TM}_{m,m,0}$ mode and the $\mathrm{TM}_{m,m,1}$ mode in terms of field variation along the $z$ direction.

9. (10%) Consider an ideal air-filled parallel-plate waveguide, as shown in Fig. P9. Under the assumption that the two plates are perfect conductors, the magnetic field intensity of the $\mathrm{TM}_{m,0}$ mode at the angular frequency $\omega$ is found to be $\overline{H_y} = H_0 \cos(m\pi x/a)\exp(-j\beta_z z)$.
(a) What are the cutoff wavelength and the waveguide wavelength of the mode? (4%)
(b) If the plate conductors are replaced with practical good conductors with conductivity $\sigma$, permittivity $\epsilon$, and permeability $\mu_0$, there will be an electric field component in the $z$ direction. Please give an expression for $\overline{E_z}$ at the $x = 0$ interface. (6%)

10. (5%) What is the definition of the "directivity" of an antenna?

$4\pi \frac{f(\theta,\phi)}{}$

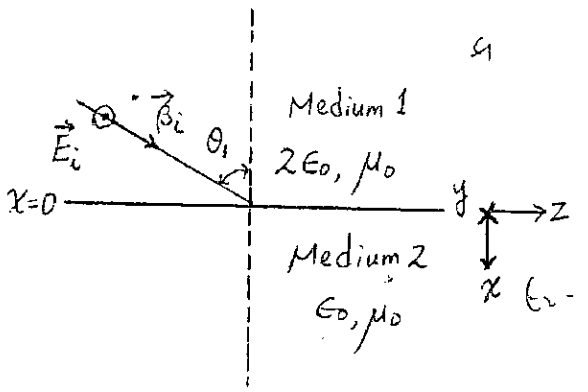


Fig. P4

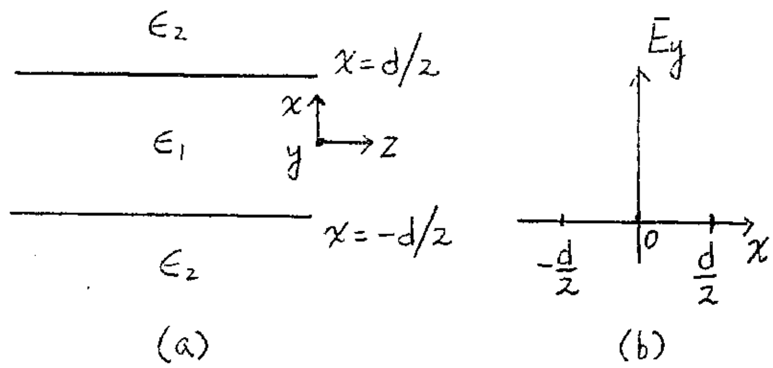


Fig. P5

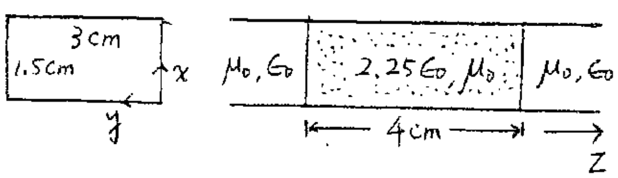


Fig. P6

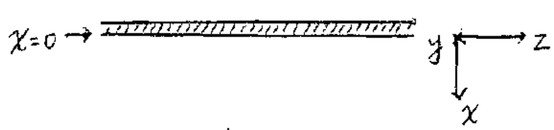


Fig. P9