1.

(a) (10%) Consider a source-free and lossless medium; derive the wave equation for **E** from Maxwell's equations

$$\begin{aligned}\nabla\times\mathbf{E} &= -\frac{\partial\mathbf{B}}{\partial t}\\ \nabla\cdot\mathbf{D} &= 0\\ \nabla\times\mathbf{H} &= \frac{\partial\mathbf{D}}{\partial t}\\ \nabla\cdot\mathbf{B} &= 0\end{aligned}$$

(b) (5%) Now, for the special case that **E** is independent of x and y, write the one-dimensional wave equation for E_x.

(c) (5%) The solution of the wave equation in (b) should represent waves propagating in the $+z$ and $-z$ directions. What is E_x?

(d) (5%) What is the velocity of the propagating wave?

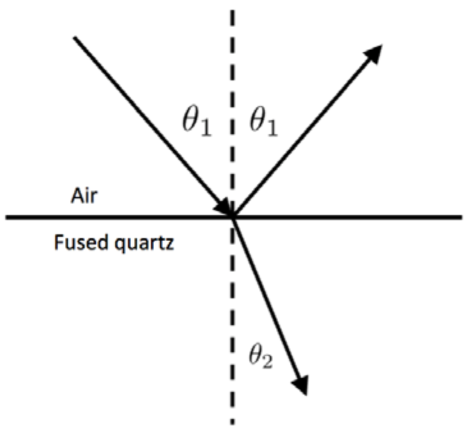
2.

Consider a circularly polarized wave, incident at an angle θ_1=60° from air onto fused quartz with ε_r=3.78.

(a) (5%) Find θ_2

(b) (15%) If the time-average power of the incident wave is 1 W/m^2, what are the time-average powers of the transmitted and reflected waves?

(C) (5%) What are the polarization states of the transmitted and reflected waves? (linear, circular, or elliptic)



1. (20 %) The electric field inside a certain dielectric-slab waveguide (where $\varepsilon_d = 9\,\varepsilon_0$, $\mu_d = \mu_0$) is given by

$$\vec{E} = \vec{y}10\cos(5000\,x)e^{-j\,5000\,z} \quad mV \cdot m^{-1}$$

The thickness of the slab is d = 2 mm. What is the waveguide wavelength $\bar{\lambda}$ in meters? What is the wave frequency f ? Identify the propagating mode (i.e. specific whether it is TE or TM, odd or even, and find the value of the mode index number m). Specify all other possible propagating modes at frequency f .

2. (15 %) A circular cavity resonator is designed to resonate in the TE_{011} mode over a frequency range of 8 GHz to 12 GHz. The tuning is accomplished by moving one end plate, which effectively changes the length of the resonator. If the radius of the circular resonator is 3 cm, calculate the range displacement of the movable end that is required to meet the design specifications.

TABLE 5.3. lth roots (s_{nl}) of $J_n'(\cdot) = 0$.

	n							
l	0	1	2	3	4	5	6	7
1	3.832	1.841	3.054	4.201	5.317	6.416	7.501	8.578
2	7.016	5.331	6.706	8.015	9.282	10.520	11.735	12.932
3	10.173	8.536	9.969	11.346	12.682	13.987	15.268	16.529
4	13.324	11.706	13.170	14.586	15.964	17.313	18.637	19.942

3. (15 %) An air-filled coaxial line has thick walls made of copper. Its attenuation constant is $\alpha_c = 0.003\ \text{np}\cdot\text{m}^{-1}$ at 300 MHz. (a) What is its attenuation constant at 600 MHz? (b) If all of its cross-sectional linear dimensions (i.e., inner and outer radii a, b, and thickness d of the outer conductor) are doubled, what is the new value of α_c at 300 MHz? (c) Suppose the original line is filled with a dielectric for which $\varepsilon' = 2\,\varepsilon_0$ and the loss tangent $\tan\delta_c = (15/\pi)\times 10^{-4}$ at 300 MHz. Find the total attenuation constant constant $(\alpha_c + \alpha_d)$ at 300 MHz.

1. (20pts) A point charge q is constrained to the vicinity of the origin of a coordinate system by a driving force $\boldsymbol{F}=-k\boldsymbol{x}$, where k is a constant and $\boldsymbol{x}$ is the displacement from the origin to the point where q is located. The charge q acts as a damped oscillator with a damped coefficient κ. (a) If an external electric field $\boldsymbol{E} = E_0\hat{x}$ is applied, please write down the force equation of a driven damped oscillator. [4pts] (b) Let $E = E_0 e^{i\omega t}$ and $x = x_0 e^{i\omega t}$, where E_0 and x_0 are real quantities. Substitute into the above equation and solve the displacement x. [3pts] (c) A polarization is defined as $\mathrm{P} = \hat{\boldsymbol{x}} Nqx = \epsilon_0 \chi_e \boldsymbol{E}$, where N is the volume density of charge and permittivity $\epsilon_r = 1 + \chi_e$. Substitute x into polarization to respectively solve the real and imaginary parts of ϵ_r. [5pts] (d) Plot the real and imaginary parts of $\epsilon_r(\omega)$, and explain the significances of them. [8pts]

2. (14pts) A silicon sample with unknown doping is tested in a Hall effect experiment with B_0=1T, as shown in Fig.1. The sample dimensions are L=3mm, w=0.5mm, and d=0.1mm. A dc voltage of V_0=100mV is applied, which results in a current flow of I_0~5mA. If a Hall voltage of V_H~3mV is measured with its plus terminal being at the top terminal, find (a) the type of the semiconductor (n-type or p-type); (b) the approximate impurity concentration (~N_e or ~N_p); and (c) the mobility of the impurity carriers (μ_e or μ_p).

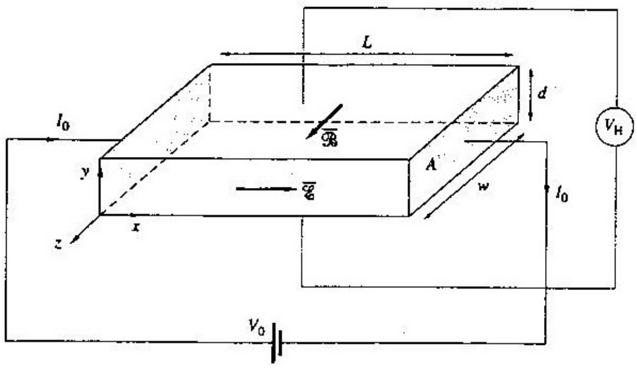


Fig.1

3. (16pts) Define the following antenna parameters: (a) directive gain, (b) power gain, (c) effective area (or effective aperture), and (d) radiation resistance.