1)

8.6 A 50-MHz plane wave with electric field amplitude of 50 V/m is normally incident in air onto a semi-infinite, perfect dielectric medium with $\varepsilon_r = 36$. Determine the following:

(a) Γ

(b) The average power densities of the incident and reflected waves.

(c) The distance in the air medium from the boundary to the nearest minimum of the electric field intensity, $|\mathbf{E}|$.

$\eta = \sqrt{\frac{\mu}{\varepsilon}} =$

$E_0 = 50$

$$\Gamma_{\perp,\parallel} = \frac{\eta_{\perp,\parallel 2} - \eta_{\perp,\parallel 1}}{\eta_{\perp,\parallel 2} + \eta_{\perp,\parallel 1}}$$

ses

a) $\eta_1 = \eta_0 = 120\pi \qquad \eta_2 = \frac{\eta_0}{\sqrt{\varepsilon_r}} = 20\pi$

$\Gamma = \frac{20\pi - 120\pi}{140\pi} = \boxed{-\frac{5}{7}} \qquad |\Gamma| = 0.71 \quad \theta = 180°$

b)

$$\mathbf{S}^{\mathrm{i}}_{\mathrm{av}} = \hat{\mathbf{z}}\frac{|E^{\mathrm{i}}_0|^2}{2\eta_1} \qquad \mathbf{S}^{\mathrm{r}}_{\mathrm{av}} = -\hat{\mathbf{z}}|\Gamma|^2\frac{|E^{\mathrm{i}}_0|^2}{2\eta_1} = -|\Gamma|^2\mathbf{S}^{\mathrm{i}}_{\mathrm{av}}$$

$S^i_{av} = \frac{50^2}{2 \cdot 120\pi} = 3.316 \text{ W/m}^2 \qquad S^r_{av} = -\left|\frac{5}{7}\right|^2 \cdot \frac{50^2}{2 \cdot 120\pi} = 1.69 \text{ W/m}^2$

c)

$$-z = l_{\max} = \frac{\theta_r + 2n\pi}{2k_1} = \frac{\theta_r \lambda_1}{4\pi} + \frac{n\lambda_1}{2}$$

$$\begin{cases} n = 1, 2, \ldots, & \text{if } \theta_r < 0, \\ n = 0, 1, 2, \ldots, & \text{if } \theta_r \geq 0, \end{cases}$$

$$l_{\min} = \begin{cases} l_{\max} + \lambda_1/4, & \text{if } l_{\max} < \lambda_1/4, \\ l_{\max} - \lambda_1/4, & \text{if } l_{\max} \geq \lambda_1/4. \end{cases}$$

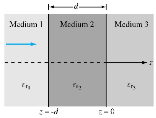
$\lambda_1 = \frac{c}{f} = \frac{3 \cdot 10^8}{50 \cdot 10^6} = 6$

$l_{max} = \frac{\pi \cdot 6}{4\pi} = 1.5$

$l_{min} = 1.5 - \frac{\lambda}{4} = 0$

Q2

2) For the configuration in the figure below use the transmission line equations to calculate the input impedance at $z=-d$ for $\varepsilon_{r1}=1$, $\varepsilon_{r2}=9$, $\varepsilon_{r3}=4$, $d=1.2\,m$, and $f=50MHz$. Also determine the fraction of the incident average power density reflected by the structure. Assume all media are lossless and nonmagnetic. For the same structure parameters, except of d and ε_{r2}, find the thickness of the intermediate slab d that lead to no reflection in the left medium.



$$\eta_3=\frac{\eta_0}{\sqrt{\varepsilon_{r3}}}=\frac{120\pi}{2}=60\pi \qquad \eta_2=\frac{120\pi}{\sqrt{9}}=40\pi$$

$$\beta_2=\frac{2\pi}{\lambda_2}=\pi$$

$$\lambda_2=\frac{\lambda_0}{\sqrt{\varepsilon_r}}=\frac{3\cdot 10^8}{50\cdot 10^6\sqrt{9}}=2$$

$$Z_{in}(-d)=Z_0\left(\frac{Z_L+jZ_0\tan\beta d}{Z_0+jZ_L\tan\beta d}\right)$$

$$=\eta_2\left(\frac{\eta_3+j\eta_2\tan\beta_2\cdot 1.2}{\eta_2+j\eta_3\tan\beta_2 1.2}\right)=40\pi\left(\frac{60\pi+j40\pi\tan\beta_2 1.2\pi}{40\pi+j60\pi\tan\beta_2 1.2\pi}\right)$$

$$=131.64-52.17j$$

$$\eta_1=\frac{\eta_0}{\sqrt{1}}$$

$$\Gamma=\frac{Z_{in}-Z_1}{Z_{in}+Z_1}=\frac{131.64-52.17j-120\pi}{131.64-52.17j+120\pi}\doteq -0.47-0.15j$$

$$P^i_{av}=\frac{|V_0^+|^2}{2Z_0}$$

$$Z_1=Z_L$$

$$120\pi=40\pi\left(\frac{60\pi+j40\pi\tan\beta_2 d\pi}{40\pi+j60\pi\tan\beta_2 d\pi}\right)$$

$$d=0.1458j$$

3)

8.15* A 5-MHz plane wave with electric field amplitude of 10 (V/m) is normally incident in air onto the plane surface of a semi-infinite conducting material with $\varepsilon_r = 4$, $\mu_r = 1$, and $\sigma = 100$ (S/m). Determine the average power dissipated (lost) per unit cross-sectional area in a 2-mm penetration of the conducting medium.

4)

8.21* Figure 8-34 depicts a beaker containing a block of glass on the bottom and water over it. The glass block contains a small air bubble at an unknown depth below the water surface. When viewed from above at an angle of 60°, the air bubble appears at a depth of 6.81 cm. What is the true depth of the air bubble?

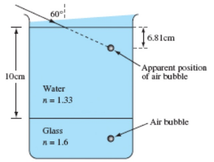


Figure 8-34: Apparent position of the air bubble in Problem 8.21.

5)

5)

8.29* A parallel-polarized plane wave is incident from air onto a dielectric medium with $\varepsilon_r = 9$ at the Brewster angle. What is the refraction angle?

$$\frac{\sin\theta_t}{\sin\theta_i} = \frac{n_1}{n_2} = \frac{u_{p2}}{u_{p1}}$$

6)

$$n_1 = \sqrt{\mu_r \varepsilon_r} = \sqrt{\frac{\mu}{\mu_0} \cdot \frac{\varepsilon}{\varepsilon_0}} = \sqrt{1}$$

$$n_2 = \sqrt{9} = 3$$

$$\sin\theta_t = \sin\theta_i \cdot \frac{1}{3}$$

$$\sin\theta_t = \frac{1}{3}$$

$$\theta_t = \sin^{-1}\left(\frac{1}{3}\right) \qquad \frac{\pi}{180} = \frac{0.34}{x}$$

$$= 0.34$$

$$= \boxed{19.48^\circ}$$

Q6

6)

8.28 Natural light is randomly polarized, which means that, on average, half the light energy is polarized along any given direction (in the plane orthogonal to the direction of propagation) and the other half of the energy is polarized along the direction orthogonal to the first polarization direction. Hence, when treating natural light incident upon a planar boundary, we can consider half of its energy to be in the form of parallel-polarized waves and the other half as perpendicularly polarized waves.

Determine the fraction of the incident power reflected by the planar surface of a piece of glass with $n = 1.5$ when illuminated by natural light at 70°.

$$\frac{n_1}{n_2} = \sqrt{\frac{\varepsilon_{r1}}{\varepsilon_{r2}}} = \frac{\eta_2}{\eta_1}$$

$n=1.5$

$$\Gamma_\perp = \frac{\eta_2 \cos\theta_i - \eta_1 \cos\theta_t}{\eta_2 \cos\theta_i + \eta_1 \cos\theta_t} \qquad \Gamma_\parallel = \frac{\eta_2 \cos\theta_t - \eta_1 \cos\theta_i}{\eta_2 \cos\theta_t + \eta_1 \cos\theta_i}$$

$$\frac{\sin\theta_t}{\sin\theta_i} = \frac{n_1}{n_2}$$

$$= \frac{1}{1.5} \cdot \sin 70° = 1.22$$

$$\theta_t = 0.677$$
$$= 38.79°$$

$$\cos(70°) - \frac{\eta_1}{\eta_2}$$

$$\frac{\eta_1}{\eta_2} = 1.5 \qquad r_\perp = \frac{\cos(70°) - \frac{\eta_1}{\eta_2}\cos(38.79°)}{\cos(70°) - \frac{\eta_1}{\eta_2}\cos(38.79°)}$$

$$= -0.55$$

$$r_\parallel = \frac{\cos(38.79°) - \frac{\eta_1}{\eta_2}\cos(70°)}{\cos(38.79°) - \frac{\eta_1}{\eta_2}\cos(70°)} = 0.213$$

$$\boxed{\begin{aligned} P_\perp &= \frac{1}{2} \cdot P_{total} \cdot (-0.55)^2 = 0.15 \cdot P_{total} \\ P_\parallel &= \frac{1}{2} \cdot P_{total} (0.213)^2 = 0.023 \cdot P_{total} \end{aligned}}$$

Q7

7)

8.30 A perpendicularly polarized wave in air is obliquely incident upon a planar glass–air interface at an incidence angle of 30°. The wave frequency is 600 THz ($1\,\text{THz} = 10^{12}$ Hz), which corresponds to green light, and the index of refraction of the glass is 1.6. If the electric field amplitude of the incident wave is 50 V/m, determine the following:

(a) The reflection and transmission coefficients.

(b) The instantaneous expressions for **E** and **H** in the glass medium.

$$\frac{\sin\theta_t}{\sin\theta_i} = \frac{n_1}{n_2} = \frac{\eta_2}{\eta_1} = \frac{1}{1.6}$$

$$\theta_t = \sin^{-1}\left(\sin\theta_t \cdot \frac{1}{1.6}\right) = 0.32$$

$$\Gamma_\perp = \frac{\eta_2\cos\theta_i - \eta_1\cos\theta_t}{\eta_2\cos\theta_i + \eta_1\cos\theta_t} \qquad \Gamma_\parallel = \frac{\eta_2\cos\theta_t - \eta_1\cos\theta_i}{\eta_2\cos\theta_t + \eta_1\cos\theta_i}$$

$$\tau_\perp = \frac{2\eta_2\cos\theta_i}{\eta_2\cos\theta_i + \eta_1\cos\theta_t}$$

$$\tau_\perp = \frac{2\cos\theta_i}{\cos\theta_i + \frac{\eta_1}{\eta_2}\cos\theta_t}$$

a)

$$\Gamma_\perp = \frac{\cos(0.523) - 1.6\cos(0.32)}{\cos(0.523) - 1.6\cos(0.32)} = -0.27$$

$$\tau_\perp = \frac{2\cdot\cos(0.523)}{\cos(0.523) + 1.6\cos(0.32)} = 0.73$$