a) Write Maxwell's *macroscopic* equations in their most complete form, including contributions from free-charge and free-current densities, as well as those from polarization and magnetization source terms. Explain the meaning of each symbol that appears in these equations.

b) Derive the charge-current continuity equation directly from Maxwell's equations, and explain the meaning of this equation. Be brief but precise.

c) Define the bound-electric-charge and bound-electric-current densities. Use these entities to eliminate the $\boldsymbol{D}$ and $\boldsymbol{H}$ fields from Maxwell's equations. (In other words, rewrite Maxwell's equations with the help of bound-charge and bound-current densities in such a way that only the $\boldsymbol{E}$ and $\boldsymbol{B}$ fields would appear in the equations.)

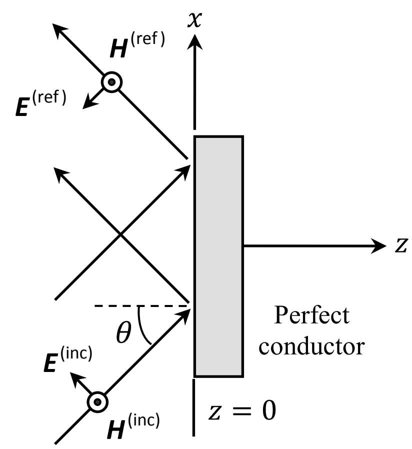
d) Show that the bound-charge and bound-current densities of part (c) satisfy their own charge-current continuity equation.

A monochromatic plane-wave of frequency ω traveling in free space is reflected from a perfectly-conducting, flat mirror surface at an oblique incidence angle θ, as shown in the figure. In the half-space $z \le 0$, the electric and magnetic fields of the incident and reflected waves are

$$\begin{cases} \boldsymbol{E}^{(\text{inc})}(\boldsymbol{r},t) = E_{\text{o}}(\cos\theta\hat{\boldsymbol{x}} - \sin\theta\hat{\boldsymbol{z}}) \exp\{\mathrm{i}(\omega/c)[(\sin\theta)x + (\cos\theta)z - ct]\}, \\ \boldsymbol{H}^{(\text{inc})}(\boldsymbol{r},t) = (E_{\text{o}}/Z_{\text{o}})\hat{\boldsymbol{y}} \exp\{\mathrm{i}(\omega/c)[(\sin\theta)x + (\cos\theta)z - ct]\}. \end{cases}$$

$$\begin{cases} \boldsymbol{E}^{(\text{ref})}(\boldsymbol{r},t) = -E_{\text{o}}(\cos\theta\hat{\boldsymbol{x}} + \sin\theta\hat{\boldsymbol{z}}) \exp\{\mathrm{i}(\omega/c)[(\sin\theta)x - (\cos\theta)z - ct]\}, \\ \boldsymbol{H}^{(\text{ref})}(\boldsymbol{r},t) = (E_{\text{o}}/Z_{\text{o}})\hat{\boldsymbol{y}} \exp\{\mathrm{i}(\omega/c)[(\sin\theta)x - (\cos\theta)z - ct]\}. \end{cases}$$

a) Find the tangential component of the E-field at the mirror surface, and verify that it satisfies the relevant boundary condition.



b) Find the tangential component of the H-field at the mirror surface, and determine the current density $\boldsymbol{J}_s(x, y, z = 0, t)$ that must exist on the surface in order to satisfy the relevant boundary condition.

c) Find the perpendicular component of the E-field at the mirror surface, and determine the charge density $\sigma_s(x, y, z = 0, t)$ that must exist on the surface in order to satisfy the relevant boundary condition.

d) Show that the surface charge and current densities obtained in parts (b) and (c) satisfy the continuity equation $\boldsymbol{\nabla} \cdot \boldsymbol{J}_s + \partial\sigma_s/\partial t = 0$.
