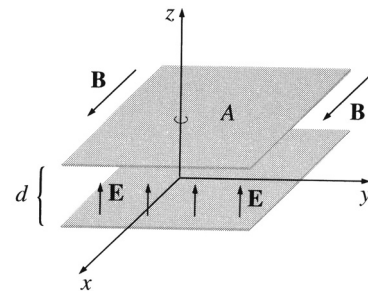


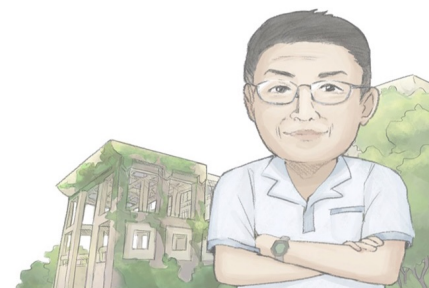
1. (8%, 8%, 9%)
 - (a) Write down Maxwell's equations in matter in terms of free charges ρ_f and current $\mathbf{J}_f$.
 - (b) Write down the boundary conditions for $D^\perp$, $\mathbf{E}^\parallel$, $B^\perp$, and $\mathbf{B}^\parallel$.
 - (c) Write down the equations for conservation of charge, energy, and momentum. Explain the symbols you use as clear as possible.

2. (5%, 5%) Explain the following terms.
 - (a) Group velocity and phase velocity.
 - (b) Brewster's angle.

3. (10%, 10%) A charged parallel-plates capacitor (with uniform electric field $\mathbf{E} = E_0 \hat{\mathbf{z}}$) is placed in a uniform magnetic field $\mathbf{B} = B_0 \hat{\mathbf{x}}$, as shown in the figure.
 - (a) Find the amplitude and direction of the Poynting vector in the space between the plates.
 - (b) Suppose we slowly reduce the magnetic field. This will induce a Faraday electric field, which in turn exerts a force on the plates. Show that the total impulse is equal to the momentum originally stored in the field.

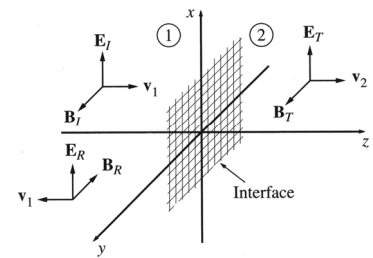


4. (10%, 10%) The skin depth is defined as $d \equiv \frac{1}{\kappa} = \frac{1}{\omega} \sqrt{\frac{2}{\epsilon\mu} \left[\sqrt{1 + \left(\frac{\sigma}{\epsilon\omega}\right)^2} - 1 \right]}^{-1/2}$
 - (a) Show that the skin depth in a poor conductor ($\sigma \ll \omega\epsilon$) is $(2/\sigma)\sqrt{\epsilon/\mu}$ and in a good conductor $\sigma \gg \omega\epsilon$ is $\lambda/2\pi$.
 - (b) Find the skin depth of salt water ($\epsilon = 80\epsilon_0$, $\mu = \mu_0$, $\sigma = 22 (\Omega \cdot \text{m})^{-1}$) at 60 Hz and 60 GHz. Is it a poor conductor or a good conductor?
 [Hint: $\mu_0 = 4\pi \times 10^{-7} \text{ N/A}^2$].



5. (7%, 7%, 6%) A plane wave approaches the interface from the left.

Incident wave:
$$\begin{cases} \mathbf{E}_I(z, t) = E_{0I} \cos(k_1 z - \omega t) \hat{x} \\ \mathbf{B}_I(z, t) = \frac{1}{v_1} E_{0I} \cos(k_1 z - \omega t) \hat{y} \end{cases}$$



- Write down the reflected wave and the transmitted wave in terms of E_{0R} and E_{0T} , respectively.
- Write down the four boundary conditions, if there is no free charge and no free current at the interface.
- Find the reflection coefficient R and the transmission coefficient T .
[Hint: Assume two media are linear.]

6. (6%, 7%, 7%) A square loop of wire (side a) lies on a table, a distance s from a very long straight wire, which carries a current I , as shown in the figure.

- Find the flux of $\mathbf{B}$ through the loop.
- If the loop is pulled away from the wire at speed v , what emf is generated? In what direction does the current flow?
- If the current is slowly varying in time $I(t)$, determine the induced electric field (amplitude and direction), as a function of the distance s from the wire.

