2023 Spring PHYS2320 電磁學（Electromagnetism) Midterm (double sides)

[Griffiths Chs. 7-9.4] 2023/04/18, 10:10am – 12:00am, 教師：張存續

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 $D^{\perp}$, $\mathbf{E}^{/\!/}$, $B^{\perp}$, and $\mathbf{B}^{/\!/}$.

(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.

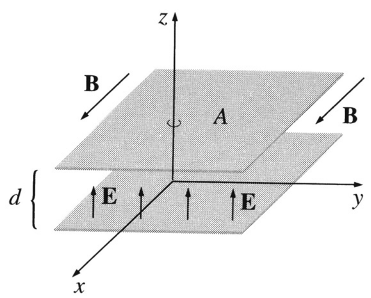
(a) Group velocity and phase velocity.

(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.

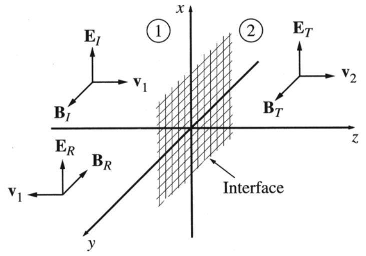


4. (10%, 10%) The skin depth is defined as $d \equiv \dfrac{1}{\kappa} = \dfrac{1}{\omega}\sqrt{\dfrac{2}{\varepsilon\mu}}\left[\sqrt{1+(\dfrac{\sigma}{\varepsilon\omega})^2}-1\right]^{-1/2}$

(a) Show that the skin depth in a poor conductor ($\sigma \ll \omega\varepsilon$) is $(2/\sigma)\sqrt{\varepsilon/\mu}$ and in a good conductor $\sigma \gg \omega\varepsilon$ is $\lambda/2\pi$.

(b) Find the skin depth of salt water ($\varepsilon = 80\varepsilon_0,\ \mu = \mu_0,\ \sigma = 22\ (\Omega\cdot \mathrm{m})^{-1}$) at 60 Hz and 60 GHz. Is it a poor conductor or a good conductor?
[Hint: $\mu_0 = 4\pi\times 10^{-7}$ N/A^2].

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



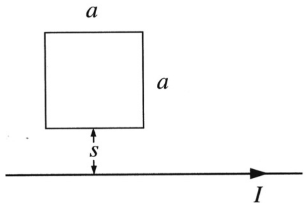
Incident wave: $\begin{cases} \mathbf{E}_I(z,t) = E_{0I}\cos(k_1 z - \omega t)\hat{\mathbf{x}} \\ \mathbf{B}_I(z,t) = \dfrac{1}{v_1} E_{0I}\cos(k_1 z - \omega t)\hat{\mathbf{y}} \end{cases}$

(a) Write down the reflected wave and the transmitted wave in terms of E_{0R} and E_{0T}, respectively.

(b) Write down the four boundary conditions, if there is no free charge and no free current at the interface.

(c) 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.



(a) Find the flux of **B** through the loop.

(b) If the loop is pulled away from the wire at speed *v*, what emf is generated? In what direction does the current flow?

(c) 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.