Hints for Problem 2

LEVEL I

The most important point is that for the propagation of the electromagnetic wave in the conducting medium, the Ampère–Maxwell law in Maxwell Equations become

$$\mathbf{\nabla} \times \vec{\mathbf{H}} = \vec{\mathbf{J_f}} + \frac{\partial \vec{\mathbf{D}}}{\partial t},$$

where $\vec{\mathbf{J_f}} \neq 0$.
Then, how to find $\vec{\mathbf{J_f}}$?
In general, the Ohm's law can give us the relation

$$\vec{\mathbf{J_f}} = \sigma \vec{\mathbf{E}}$$

However, sometimes you need to think further, i.e., by its definition

$$\vec{\mathbf{J_f}} = \frac{I_f \vec{\mathbf{e_I}}}{S} = \frac{-\rho_e e \vec{\mathbf{v_e}} S}{S} = -\rho_e e \vec{\mathbf{v_e}}$$

LEVEL II

For the electromagnetic wave, which is a wave of course, you should always pay attention to the wave equation. What's the key here? For the wave equation

$$\nabla^2 \vec{\xi} - \frac{1}{v^2}\frac{\partial^2 \vec{\xi}}{\partial t^2} = 0 \quad \text{or} \quad \nabla^2 \vec{\xi} + k^2 \vec{\xi} = 0,$$

the values of v and k are the key.

LEVEL III

Pay attention that we usually use complex notations for the wave expression. Then, we will have

$$\nabla \rightarrow ik \quad \text{and} \quad \partial_t \rightarrow -i\omega.$$

Due to the complex notations, the equivalent expression of $\varepsilon, k, ...$ can become a complex one instead of a real one. From Maxwell's Equations, you can find out the complex expression of these parameters.

LEVEL IV

For the reflection and refraction of the electromagnetic waves on the surface of the medium, you need to consider the boundary condition for the electrical field and magnetic field and then get the relations.

For Part B Q3, "the optical properties of metals" refers to whether electromagnetic waves can propagate in metals in the specific band.