1. The static electric field \((E)\) and magnetic field \((H)\) satisfy the following equations:
\[ \nabla \times E = 0 \quad \nabla \times H = J \]
where \(J\) is the volume density.
Derive the relationships between these two equations and the Kirchhoff's voltage and current laws. (15 points)

2. (a) Find the capacitance per unit length of an air-filled coaxial cable as shown in Fig. 1. (10 points)
(b) Find the capacitance per unit length of a two-wire transmission line as shown in Fig. 2. (15 points)

![Fig. 1](image1)
![Fig. 2](image2)

3. The complex vector representing the electric field of a plane wave in free space is
\[ E = j E_0 (\hat{x} - \hat{y}) e^{-jk(x+y)/\sqrt{2}} \]  
(15 points)
(a) What is the direction of propagation of the wave?
(b) What is the magnetic field in time domain?

4. A plane wave of angular frequency \(\omega\) is incident normally on an infinite dielectric slab of width \(d\). The dielectric material has the permittivity \(\varepsilon\). (15 points)
(a) Find the reflection coefficient.
(b) Find the distance \(d\) in order to achieve total transmission of the wave.
5. (a) On what factors do the characteristic impedance and the input impedance of a transmission line depend? (5 points)

(b) Explain how the value of an arbitrary terminating impedance on a lossless transmission line can be determined by standing-wave measurements on the line. (5 points)

(c) A voltage generator having an internal impedance $Z_g$ is connected at $t = 0$ to the input terminals of a lossless transmission line of length $l$. The line has a characteristic impedance $Z_0$ and is terminated with a load impedance $Z_L$. At what time will a steady state on the line be reached if (1) $Z_L = Z_0$ but $Z_g \neq Z_0$ and (2) $Z_g = Z_0$ but $Z_L \neq Z_0$. (10 points)

(d) For a rectangular waveguide of width $a$ and height $b$, determine the value of $b$ (relative to $a$) such that the single $TE_{10}$ mode bandwidth is maximized without sacrificing the power transmitted by the waveguide. Assume $a > b$. (10 points)