1. (10%) Please write down Maxwell equations in the form of differential equations, and explain the physical meaning of each equation.

2. (15%) Consider the region enclosed on three sides by grounded conducting planes shown in Fig. 2. The end plate on the left is insulated from the grounded sides and has a constant potential $V_0$. All planes are assumed to be infinite in extent in the $z$-direction. Used separation of variable method, determine the potential distribution within the region.

![Cross section of potential box](image)

**Figure 1: Cross section of potential box**

3. Consider a straight, thin conductor in air parallel to and at a distance $d$ above the plane interface of a magnetic material of relative permeability $\mu_r$. A current $I$ flows in the conductor.

   a) (15%) Show that all boundary conditions are satisfied if

      i) the magnetic field in the air is calculated from $I$ and an image current $I_i$,

      $$ I_i = \frac{\mu_r - 1}{\mu_r + 1} I $$

      and these currents are equidistant from the interface and situated in air;

      ii) the magnetic field below the boundary plane is calculated from $I$ and $-I_i$ both at the same location. These currents are situated in an infinite magnetic material of relative permeability $\mu_r$.

   b) (10%) For a long conductor carrying a current $I$ and for $\mu_r \gg 1$, determine the magnetic flux density $B$ at the point $P$ in the figure.

   ![Current-carrying conductor near a ferromagnetic medium](image)
4. Please answer the following questions

(a) The velocity of light propagation at free space \((c = 3 \times 10^8 \text{ m/s})\) depends on two physical constants, please state these two constants and the equation relating these two constants and \(c\). (5%)

(b) Please define transverse electromagnetic (TEM) wave. (5%)

(c) The electric field intensity of a linearly polarized uniform plane wave propagating in the \(+z\) direction is \(E = 10 \cos(10^7\pi t)\) (V/m). Find the angular frequency (rad/s) and the frequency (Hz) of the wave. (5%)

(d) Phase velocity \([u_p = \frac{\omega}{\beta}\text{ (m/s)}]\) describes the motion of a point, line or surface of constant phase for waves in one, two and three dimensions respectively, as shown in the figure below, where \(\omega\) is the angular frequency and \(\beta\) is the phase constant or propagation constant. Given the \(\beta = 8.89\text{ rad/m}\), please find the phase velocity and the wavelength of the wave. (5%)

(e) Given that a wave packet consists of two traveling waves having equal amplitude and slightly different angular frequency \(\omega_0 + \Delta \omega\) and \(\omega_0 - \Delta \omega\) where \(\Delta \omega \ll \omega_0\) as shown in the figure below. The phase constants, being functions of frequency, will also be slightly different. Assume the phase constants corresponding to the frequencies be \(\beta_0 + \Delta \beta\) and \(\beta_0 - \Delta \beta\). Derive the group velocity equation. (5%)
5. An air-filled lossless rectangular waveguide with brass walls - \( \varepsilon_0, \mu_0, \sigma = 1.57 \times 10^7 \text{S/m} \) has the following dimensions: \( a = 2 \text{cm}, b = 1.5 \text{cm} \).

(a) Determine the dominate mode, and what is the allowable operation frequency range with 10% above the dominate cut-off frequency and no higher than 95% of the next higher cut-off frequency? (10%)

(b) If the waveguide was cut and made as a cavity resonator which has \( d = 2.5 \text{cm} \), and filled with a lossless dielectric material having \( \varepsilon = 2.5 \); Please determine the dominated mode and its resonant frequency for the cavity. (5%)

(a) Waveguide

(b) Cavity

6. For the YUGI-UDA ANTENNAS (八木-宇田 天線), please answer the following questions:

(a) What is the most usual application the YUGI-UDA ANTENNAS. (3%)

(b) Please explain the functions of the three components, reflector, active element, and director. (7%)