請勿著急想做完全部試題，儘量做即可。 *Good Luck.*

* Useful constants :

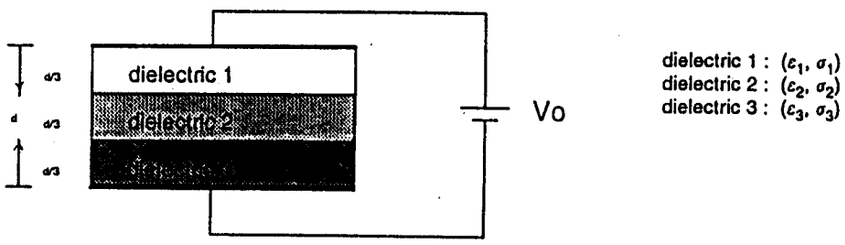
$\varepsilon_0 = 10^{-9}/(36\pi)$ (F/m); $\mu_0 = 4\pi \times 10^{-7}$ (H/m); $\sqrt{\mu_0/\varepsilon_0} = 120\pi$ (Ω)

1. Maxwell's equations and plane wave problems :

   (a) Write the differential form of the Maxwell's equations.
   (b) Which term in the Maxwell's equations is the ***displacement current density*** term?
   (c) Explain the physical meaning of the ***displacement current***.
   (d) Write the mathematical form of homogeneous (source-free) Helmholtz's equation.
   (e) Explain what is the TEM wave.
   (f) Write the mathematical form of a z-direction propagating TEM wave.
   (g) Show that the TEM wave (f) satisfies the Helmholtz's equation (d).

2. A parallel-plate capacitor of area S is filled with three different lossy dielectrics.

   (a) Determine the current density J between the plates.
   (b) Determine the electric field E in each layer.
   (c) Determine the surface charge densities ρ_S on the upper and lower plates.
   (d) Use (c) (with S) and voltage V_0 to determine the capacitance of this capacitor.

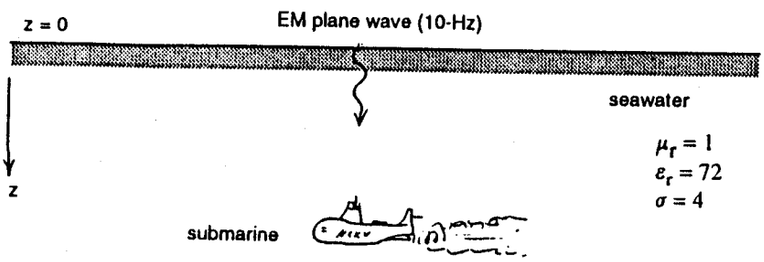


3. A 10-Hz ELF (extremely low frequency) linearly polarized plane wave propagates into the seawater at z-direction. The propagation constant γ of the TEM wave in a lossy medium (μ, ε, σ) is

$$\gamma = \alpha + j\beta = j\omega[\mu(\varepsilon + \sigma/j\omega)]^{1/2} = j\omega[\mu\varepsilon(1 + \sigma/j\omega\varepsilon)]^{1/2}$$

   (a) Determine the attenuation constant (α), phase constant (β) and skin depth (δ).
   (b) Determine the phase velocity (u_p) and group velocity (u_g) of this plane wave in the seawater.
   (c) Explain the dispersion of the EM wave in the lossy medium.
   (d) Is this ELF wave dispersive in the seawater? Why?
   (e) If the submarine is located 100 m below the seawater surface, determine how many dB decay of the EM wave power received by the submarine (compared with the EM wave power just below the surface).
   (power-ratio (dB) = 10 log(power-ratio))

   Hint : Calculate the value of ($\sigma/\omega\varepsilon$) first to make a good approximation of γ.



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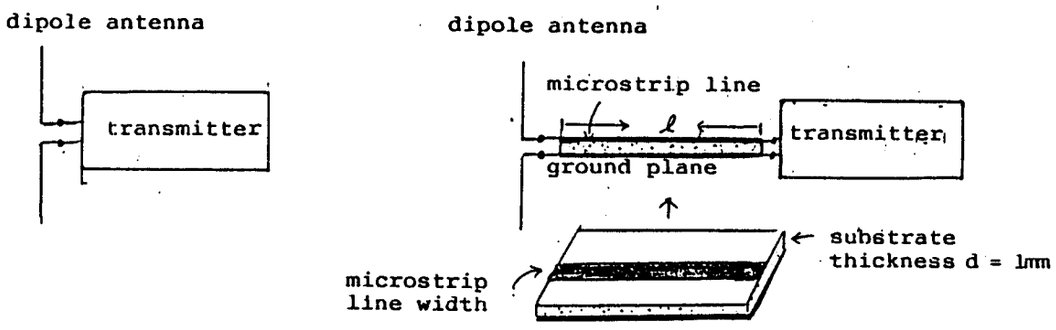
4. A dipole antenna having a terminal input-impedance 72 Ω at 1-GHz is connected to a transmitter having a 300 Ω output impedance.

(a) Determine the reflection coefficient Γ and the VSWR.
We want to use a quarter-wave section of the microstrip line with a substrate dielectric ($\varepsilon_r = 4$, $\mu_r = 1$) to match the 72 Ω load to the 300 Ω transmitter output-impedance. If the substrate thickness d is 1 mm, determine
(b) the required length l of this quarter-wave section microstrip line,
(c) the required characteristic impedance Z_0 of this microstrip line,
(c) the required width W of this microstrip line.

Hint : Use the approximated microstrip-line Z_0 formula : $Z_0 = (d/W)\sqrt{\mu/\varepsilon}$



5.. A uniform plane wave from the air is incident normally on the boundary of the dielectric ($\mu_r = 1$, $\varepsilon_r = 4$) and air. We write the E-field of the incident wave, reflected wave, and transmitted wave as

$$E^i = E_{ix}e^{-j\beta z},\quad E^r = E_{rx}e^{-j\beta z},\quad E^t = E_{tx}e^{-j\beta z}$$

(a) Determine the H-field of the incident wave, reflected wave, and transmitted wave,
(b) If E_{ix} is known, use the boundary conditions (tangential E & H fields continuous) to determine E_{rx} and E_{tx}.
(c) If the average power density P_i of the incident plane wave is 1 W/m^2, find the average power densities P_r & P_t of the reflected wave and transmitted wave.