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); $\sqrt{\mu_0/\varepsilon_0} = 120\pi = 377$ (Ω)

$C = 3 \times 10^8$ m/s

1. **Maxwell's Equations :**

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

2. An antenna system radiates a circular-polarization (CP) far-zone EM wave in the free space. The E_θ field of this far zone CP plane wave is (in spherical coordinates)

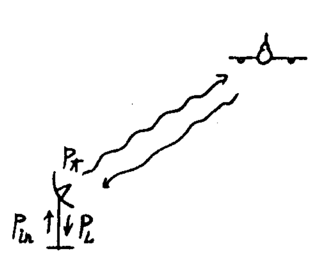
$$E_\theta(r, \theta) = E_0(e^{-j\beta r}/r)\sin\theta$$

(a) Write the E_ϕ field component.
(b) Write the H field components (attention : There are two H field components).
(c) What is the time average power density at the distance r from the antenna ?
(d) If $E_0 = 1$, determine the input average power of the antenna.

Note : $\int_0^\pi [\sin\theta]^3 \, d\theta = 4/3$

3. A radar system operates at 10 GHz. The radar antenna has a directive gain (G_D) of 40 dB and a radiation efficiency (η_r) 0f 90%. The minimum detectable signal power in this radar system is 1 pW. If this radar is designed to be able to detect an airplane (with a backscatter cross section $\sigma_{bs} = 5$ m^2) at a distance 100 km,
(a) determine the minimum input power needed to be fed to the radar antenna.
(b) determine the radiation power density from the radar antenna at the airplane.

* The radar equation is : $\dfrac{P_L}{P_t} = \dfrac{\sigma_{bs}\lambda^2}{(4\pi)^3 r^4} G_D^2$



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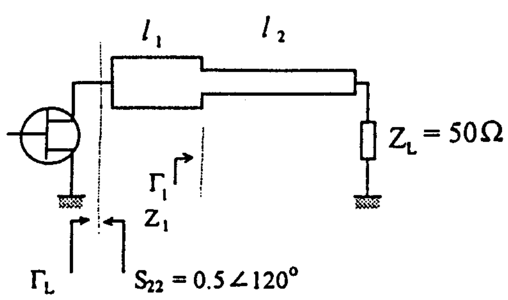
4. The following figure shows a microstrip output-matching network (50-Ω system) for the FET of a 1-GHz high-frequency amplifier. The S_{22} of the FET is $0.5\angle 120^o$. The matching network is to let the reflection coefficient Γ_L equal to $(S_{22})^*$. By using the Smith chart technique, it is found that $l_1 = 0.166\ \lambda$ will let $\Gamma_1 = 0.5$ (the characteristic impedance of the l_1 section is $Z_{1o} = 50\ \Omega$).

(a) Determine the impedance Z_1 seen into the direction as shown in the figure.
(b) What is the simplest way to match Z_1 to the load Z_L? Determine the length (in wavelength) and the characteristic impedance Z_{2o} of the section l_2.
(c) If the dielectric constant of the substrate $\varepsilon_r = 2.5$ and the substrate thickness $h = 1$ mm for the microstrip line, determine the length of l_1 and l_2 (in mm) by using the simple formula of the microstrip line in the textbook (D. K. Cheng).
(d) Determine the width of l_1 and l_2 (in mm).



5. **Waveguide problem** :

(a) Explain the meaning of the TE and TM modes in the waveguide.
(b) Write the E & H fields of TE_{01} mode of an air-filled rectangular waveguide (a x b).
(b) If a = 2 cm & b= 2 cm, determine the cutoff frequency (f_c) of the TE_{01} mode.
(c) Determine the cutoff frequency of the dominant mode in this waveguide.
(d) If this waveguide operates at 8 GHz, will the TE_{01} mode propagate in the waveguide? Why?

* The TE_{mn} modes fields of the waveguide are

$$E_x = (j\omega\mu/h^2)(n\pi/b)H_o\cos(m\pi x/a)\sin(n\pi y/b)$$
$$E_y = -(j\omega\mu/h^2)(m\pi/a)H_o\sin(m\pi x/a)\cos(n\pi y/b)$$
$$H_x = (\gamma/h^2)(m\pi/a)H_o\sin(m\pi x/a)\cos(n\pi y/b)$$
$$H_y = (\gamma/h^2)(n\pi/b)H_o\cos(m\pi x/a)\sin(n\pi y/b)$$

$$h^2 = (m\pi/a)^2 + (n\pi/b)^2$$
$$\gamma = j\beta = j[\omega^2\mu\varepsilon - h^2]^{1/2}$$