※ 請於答案卷上非選擇題作答區標明題號作答。計算題請詳列過程。 $\varepsilon_0 = 10^{-9}/(36\pi)$ F/m, $\mu_0 = 4\pi\times10^{-7}$ H/m

1. (計算題) Consider an electromagnetic *plane wave* which has a wavelength λ_0 and propagates in *free space*. The velocity of propagation of this electromagnetic wave in free space is c. Assume this electromagnetic wave enters a dielectric medium with a relative permeability $\mu_r = 1$, and its velocity of propagation becomes $c/3$. Answer the following questions.
   (1) (4%) What is the relative permittivity (*i.e.*, dielectric constant) ε_r of this dielectric medium?
   (2) (4%) What is the wavelength of this electromagnetic wave when it propagates in this dielectric medium?
   (3) (4%) What is the frequency of this electromagnetic wave when it propagates in this dielectric medium?
2. (計算題)
   (1) (11%) Please see the arrangement in **Figure 1**. (Note: The plates are fixed.) A dielectric slab of permittivity ε sliding between the plates of a parallel-plate capacitor experiences a mechanical force $\mathbf{F}_e$ of electric origin. Assuming width w for the plates normal to the page and neglecting fringing of fields at the edges of the plates, please find $\mathbf{F}_e$. Please remember to indicate the direction of the force.
   (2) (11%) With the arrangement in the **Figure 2** (Note: The plates are fixed.), find the *net* mechanical force of electric origin exerted on the dielectric slab of permittivity ε. Again, assume width w for the plates normal to the page and neglect fringing of fields at the edges of the plates.

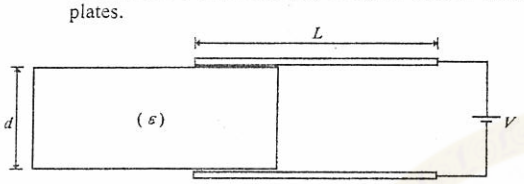


Figure 1

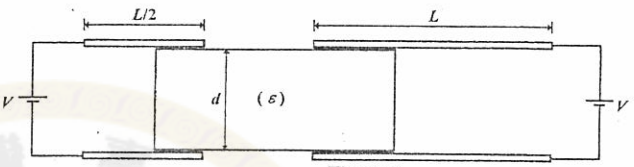


Figure 2

3. (計算題) A quarter-wave transformer (QWT) is used to match the impedance of a load with all the related parameters as shown in **Figure 3**.
   (1) (9%) Please derive d_q for perfect impedance matching. (2) (9%) Please derive Z_q for perfect impedance matching.

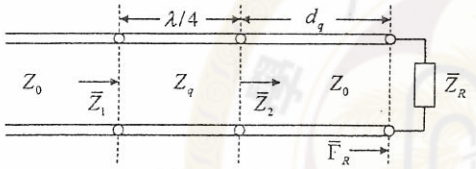


Figure 3

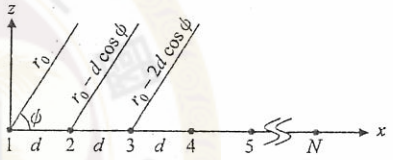
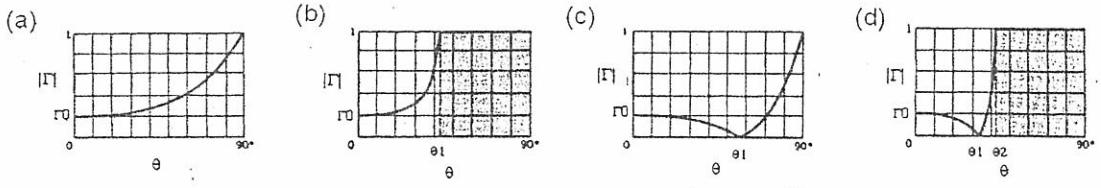


Figure 4

4. (計算題) Consider a uniform linear array of N antennas of spacing d, as shown in **Figure 4** with the electric currents of equal amplitude I_0 and equal phase (phase difference = 0) flowing in the y-direction (normal to the page). The complex electric field at the distant point (r_0, ϕ) (assume $r_0 >> Nd$) due to element 1, 2, 3, … are assumed to be $1\cdot\exp(-j\beta r_0)$, $1\cdot\exp(-j\beta r_0 - d\cos\phi)$, $1\cdot\exp(-j\beta r_0 - 2d\cos\phi)$, …, respectively.
   (1) (5%) Please derive the far field $E(\phi)$ due to the n-element array.
   (2) (5%) Please derive the magnitude of the far field, *i.e.*, $|E(\phi)|$.
   (3) (5%) If $N = 10$ and $d = 0.2\lambda$, please calculate the angular width between the neighboring nulls for the principal maximum of the far field pattern at $\phi = \pi/2$.
5. (計算題) (8%) (1) A uniform plane wave is incident from the air (refractive index $n = 1$) onto a perfect dielectric ($n = 1.5$) plane boundary at an incidence angle θ. Among the following plots (a)–(d), please choose the correct plot of the magnitude of reflection coefficient vs. θ for the perpendicular polarization and calculate the parameters Γ0, θ1 (if it exists), and θ2 (if it exists) on the plot that you choose. (2) If the plane wave is of parallel polarization and incident from a perfect dielectric ($n = 1.5$) onto the air ($n = 1$) plane boundary at an incidence angle θ. Please choose the correct plot of the magnitude of reflection coefficient vs. θ for the parallel polarization and calculate the parameters Γ0, θ1 (if it exists) and θ2 (if it exists) on the plot that you choose.



6. (計算題) (15%) The ω–β curve for a dispersive channel can be approximated by $\frac{1}{\omega^2} = \frac{1}{\omega_0^2} + \frac{k^2}{\beta^2}$ in the vicinity of $\omega = 0.5\omega_0$, where k is a constant. Find the following: (1) the phase velocity for a signal of $\omega = 0.5\omega_0$; (2) the group velocity for a signal composed of two frequencies $\omega = 0.4\omega_0$ and $\omega = 0.6\omega_0$; and (3) the group velocity for a narrowband signal having the center frequency $\omega = 0.5\omega_0$.
7. (計算題) (10%) The radius of an air-dielectric cylindrical waveguide is given by $a = 5$ cm. The propagating modes and their characteristics for a signal of frequency $f = 3$ GHz are listed in the following Table, where the parameters with subscript c are for cutoff and some need calculation.

$\beta_c a$	Mode(s)	f_c (GHz)	λ_c (cm)	λ_g (cm)	v_{pz} (m/s)	η_g (ohms)
1.84	$TE_{1,1}$			12.337	3.701×10^8	465.10
2.40	$TM_{0,1}$			15.500	4.650×10^8	243.24
3.05	$TE_{2,1}$			41.827	12.548×10^8	1576.84
3.83	$TE_{0,1}$, $TM_{1,1}$			—	—	—

A cylindrical cavity resonator is formed by placing two perfectly conducting sheets 5 cm apart in the cross-sectional planes of the cylindrical waveguide described as above, so that $d = 5$ cm. Please find the four lowest frequencies of oscillation and identify the mode(s) of oscillation for each frequency in the cylindrical cavity resonator.

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