※ 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. (填空題) Let us consider the electromagnetic field of a uniform plane wave propagating in seawater (which is non-magnetic material), the instantaneous power flow per unit area is $P_z = 2.251e^{-1.256z}[\cos\pi/4 + \cos(10^5\pi t - 1.256z - \pi/4)]\,W/m^2$. For this electromagnetic wave, please write down the following **parameters with their units** in the answer sheet. (a) The frequency=__①__**(2%)**; (b) The wavelength=__②__**(2%)**; (c) The phase velocity= __③__**(2%)**; (d) The skin depth=__④__**(2%)**.

2. (計算題) For the cross sections of three arrangements (each consisting of two infinitely long, coaxial, perfectly conducting cylinders) in **Figure 1**, the medium between the cylinders is a perfect dielectric for **Fig. 1(a)**, a conductor for **Fig. 1(b)**, and a magnetic material for **Fig. 1(c)**. In **Fig. 1(c)**, current flows in and out along the outer and inner cylinders, respectively. Please ***derive*** **one of the parameters**, i.e., the capacitance C, conductance G, and inductance L per unit length, from electro-static or magneto-static theory **(8%)** and also ***write down*** **the other two (8%)**. (Hint: $\nabla^2\Phi = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\Phi}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2\Phi}{\partial\phi^2} + \frac{\partial^2\Phi}{\partial z^2}$ and the relationships $G/C = \sigma/\varepsilon$ and $LC = \mu\varepsilon$ are valid)

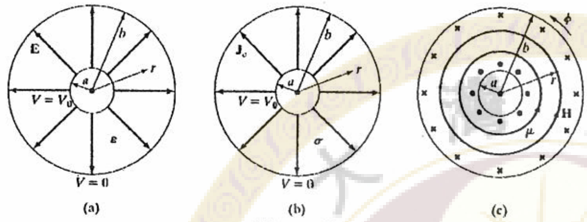


Figure 1

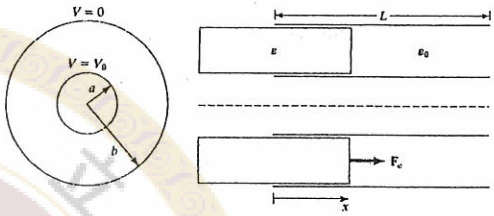


Figure 2

3. (計算題) In **Figure 2** (the top and side view of the setup), a dielectric material of permittivity ε sliding freely in a cylindrical capacitor experiences a mechanical force of electrical origin in the axial direction. **Please show that** $\vec{F}_e = \frac{V_0^2\pi(\varepsilon-\varepsilon_0)}{\ln(b/a)}\vec{a}_x$. **(10%)**

4. (計算題) Time-domain reflectometry (TDR) is a measurement technique for determining the characteristics of a transmission-line circuit. **Figure 3** shows the TDR measurement setup with a perfectly matched load. In this case, there is no reflection and the waveform of the voltage measured at the input side is shown in **Figure 4**.

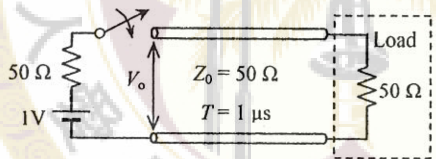


Figure 3

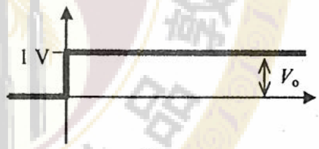


Figure 4

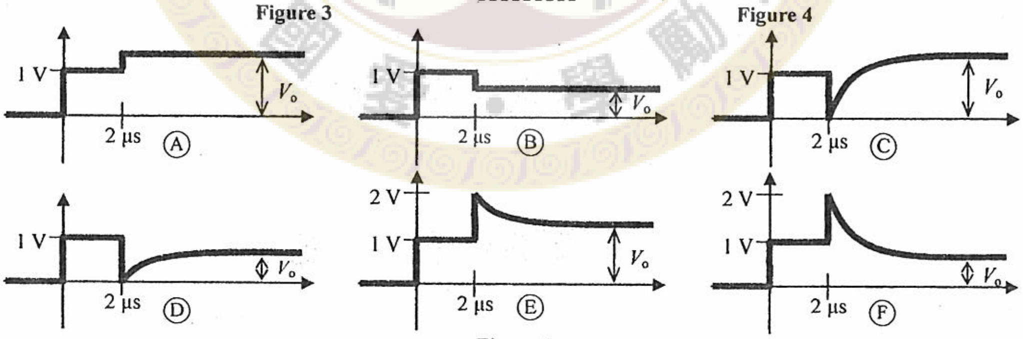
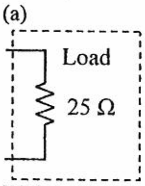


Figure 5

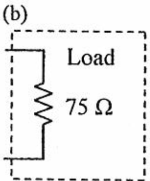
The waveforms Ⓐ – Ⓕ shown in **Figure 5** are measured by using the same TDR setup but with different loads. For the following cases with different loads (a) – (d), please determine their corresponding **TDR waveforms** from Ⓐ – Ⓕ; please also calculate **the steady-state voltage V_o** for each case.

(a)



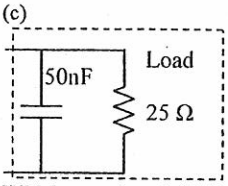
Which waveform? (2%)
V_o = ? (3%)

(b)



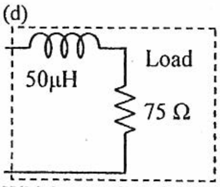
Which waveform? (2%)
V_o = ? (3%)

(c)



Which waveform? (2%)
V_o = ? (3%)

(d)



Which waveform? (2%)
V_o = ? (3%)

見背面

※ 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

5. (計算題) A dielectric layer on a substrate is employed as a quarter-wave transformer to completely eliminate reflections of uniform plane waves of 500 THz incident normally from the free space side as shown in **Figure 6**.

(a) What is the **optimal dielectric constant** ε_1 of the dielectric layer? **(2%)**

(b) What is the **minimum required thickness** t_1 of the dielectric layer? **(2%)**

(c) Please **analytically find the bandwidth** between frequencies on either side of 500 THz at which the SWR in free space is 2.0. **(5%)**

(d) What is the **maximum SWR** in free space as the frequency is varied on either side of 500 THz? **(4%)**

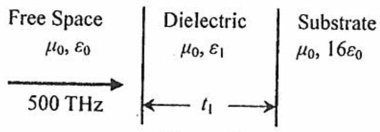


Figure 6

6. (計算題) A rectangular metallic waveguide made by *perfectly* conducting sheets for transmitting electromagnetic wave in z-direction is shown in **Figure 7**. Assume the environment is free space. Please answer the following questions.

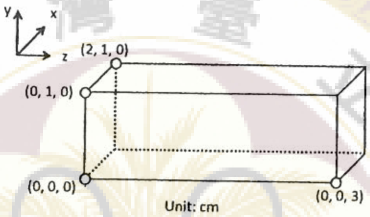


Figure 7

(a) Write down the **dominant mode** and the corresponding **cutoff frequency**. **(3%)**

(b) **How many** propagating modes for $f=16$ GHz in this waveguide? **(3%)**

(c) List the ***non-zero*** **term(s)** of $\vec{E}_x, \vec{E}_y, \vec{E}_z, \vec{H}_x, \vec{H}_y, \vec{H}_z$ for the dominant mode at the points: (a) (0, 0.5, 1); (b) (1, 1, 2). **(6%)**

(d) Suppose now we terminate the waveguide with two *imperfectly* conducting sheets at z = 0 and z = 3 cm and make it a rectangular cavity resonator with the Q-factor of Q_1. If there is another *similar* cavity resonator with double the volume by increasing z-distance from 3 cm to 6 cm with the Q-factor of Q_2. **How does Q_1 compare with Q_2**? Justify your answers. **(5%)**

7. (填空題) We want to couple light from air into a single-mode fiber as shown by the cross-section in **Figure 8**. Assume the refractive indices are n_1 =1.45 and n_2 = 1.455. Please write down the following parameters in the answer sheet.

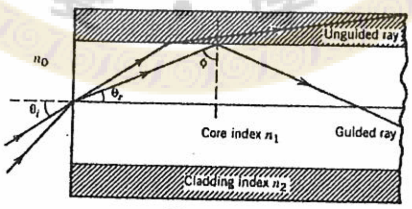


Figure 8

(a) The maximal allowable incident angle θ_i for guiding the light in the core by total internal reflection is ___⑤___ degree. **(3%)** (b) In the fiber communication systems, the operating wavelength ranges from 1.2 to 1.6 μm. So the required core radius should be smaller than ___⑥___ μm in order to maintain single-mode operation. **(3%)**

8. (計算題) Consider a circular loop antenna of radius a such that the circumference is small compared to the wavelength. Assume the loop antenna to be in the xy-plane with its center at the origin and the loop current to be $I = I_0 \cos\omega t$ in the sense of increasing ϕ. For the radiation fields, the magnetic vector potential due to the loop antenna is given by

$$\vec{A} = \frac{\mu_0 I_0 \pi a^2 \beta \sin\theta}{4\pi r}\sin(\omega t - \beta r)\vec{a}_\phi \text{ , where } \beta = \frac{\omega}{v_p}.$$

(a) Write down **the field direction** $(\vec{a}_r, \vec{a}_\theta, \vec{a}_\phi)$ of the radiation fields $\vec{E}, \vec{H}$, and $\vec{P}$. **(6%)**

(b) What is the **directivity** of the circular loop antenna? **(4%)**

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