國立成功大學 105 學年度碩士班招生考試試題

系　所：電機工程學系

考試科目：電磁學

考試日期：0227，節次：2

※ 考生請注意：本試題可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

※ 試卷後有提供物理常數和可能使用到的公式，請查閱。

簡答題：(30 分，每題 5 分)

1. Answer the following questions.

(a) Explain the concepts of conduction current, diplacement current, polarization current and magnetization current. What are the commonalities among them?

(b) Explaine why the magnetic flux density field and electric density field can be expressed as $\mathbf{B} = \nabla \times \mathbf{A}$ and $\mathbf{E} = -\nabla\Phi - \frac{\partial \mathbf{A}}{\partial t}$, where $\mathbf{A}$ and Φ are the magnetic vector potential and electric scalar potential.

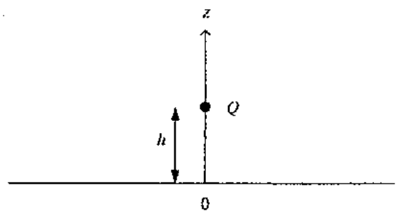
(c) Define the cutoff frequency for a waveguide, the TE, TM modes for a metallic rectangular waveguide and the HE, EH modes for an optical cylindrical waveguide.

(d) State Poynting's theorem for a material medium.

(e) The method of images is commonly used to determine the electric field due to charges in the presence of conductors. For example, the electric field is found as

$$\mathbf{E} = \frac{Q}{4\pi\varepsilon_0}\left[\frac{x\mathbf{a}_x + y\mathbf{a}_y + (z-h)\mathbf{a}_z}{\left[x^2+y^2+(z-h)^2\right]^{3/2}} - \frac{x\mathbf{a}_x + y\mathbf{a}_y + (z+h)\mathbf{a}_z}{\left[x^2+y^2+(z+h)^2\right]^{3/2}}\right], \quad \text{for } z \ge 0$$

for a point charge Q above an infinite grounded perfect conducting plane as shown below. Explain the principle behind the method.



(f) In 1864, Maxwell predicted the existence of electromagnetic wave and proclaimed its wave velocity was exactly the same as the speed of light. What are the reasons for Maxwell to make the prediction?

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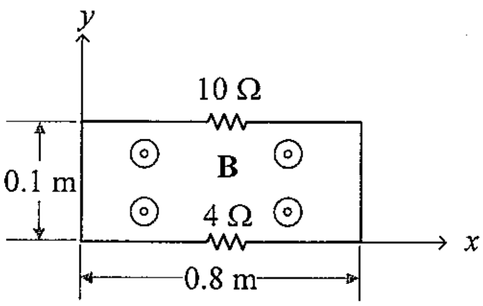
計算題:(共 70 分，每題分數另標註於題號後面)

2. (8 分) The circuit shown below exists in a magnetic field $\mathbf{B} = 40\cos(30\pi t - 3y)\mathbf{a}_z$ mWb/m^2. Assume that the wire connecting the resistors have negligible resistances. Find the current in the circuit.



3. （12 分）(a) Prove that the capacitance for the capacitor made of two conducting spherical shells with radii a and b and filled with the dielectric of permittivity ε as shown in the figure (a) is given by

$$C = \frac{4\pi\varepsilon}{\frac{1}{a} - \frac{1}{b}}.$$

(b) Determine the capacitance of the capacitor made of three conducting spherical shells as shown in the figure (b) if $a = 1$ mm, $b = 3$ mm, $c = 2$ mm, $\varepsilon_{r1} = 2.5$ and $\varepsilon_{r2} = 3.5$.

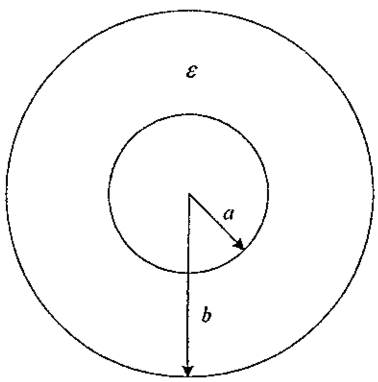


Figure (a)

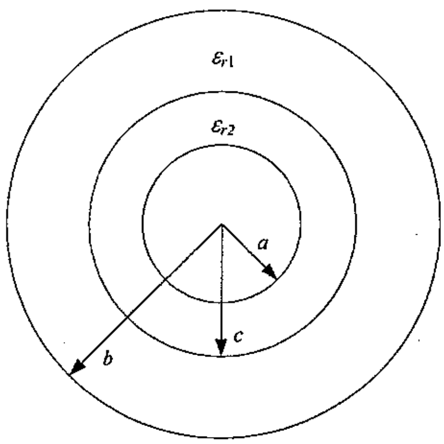


Figure (b)

4. （8 分）The electric-field intensity of a uniform plane wave propagating in free space is given by

$$\mathbf{E} = 37.7\cos(9\pi \times 10^7 t + 0.3\pi y)\mathbf{a}_x \text{ V/m}$$

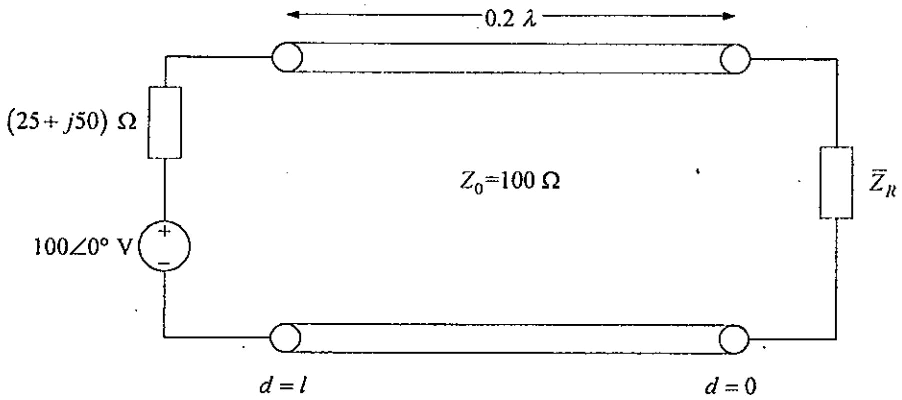
Find: (a) the frequency; (b) the wavelength; (c) the direction of propagation of the wave; and (d) the associated magnetic-field intensity vector $\mathbf{H}$.

5. (12 分) A current distribution is given in cylindrical coordinates by

$$\mathbf{J} = \begin{cases} J_0\mathbf{a}_z & \text{for } r < 3a \\ -J_0\mathbf{a}_z & \text{for } 4a < r < 5a \end{cases}$$

Find the energy stored in the magnetic field of the current distribution per unit length in the z-direction.

6. (10 分) In the system shown below, find: **(a)** the value of the load impedance $\bar{Z}_R$ that enables maximum power transfer from the generator to the load and **(b)** the power transferred to the load for the value found in (a).



7. (10 分) For a rectangular cavity resonator having the dimensions $a = 2.5$ cm, $b = 2$ cm and $d = 5$ cm, and filled with a dielectric of $\varepsilon = 2.25\varepsilon_0$ and $\mu = \mu_0$, find the five lowest frequencies of oscillation. Identify the mode(s) for each frequency.

8. (10 分) The electric field of a uniform plane wave propagating in the +z-direction in a nonmagnetic material medium is given by

$$\mathbf{E} = 8.4e^{-0.0432z}\cos(4\pi \times 10^6 t - 0.1829z)\boldsymbol{a}_x \text{ V/m}$$

Find the magnetic field of the wave. Further, find the values of conductivity σ and permittivity ε of the medium.

Some formula and constants for your reference:

$\varepsilon_0 = 10^{-9}/36\pi$ F/m, $\eta_0 = 120\pi = 377\ \Omega$, $\mu_0 = 4\pi \times 10^{-7}$ henrys/m

In a general medium: $\bar{\gamma} = \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$, $\bar{\eta} = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}}$

Cartesian coordinate:

$$\nabla \bullet \mathbf{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}, \quad \nabla \times \mathbf{A} = \begin{vmatrix} \mathbf{a}_x & \mathbf{a}_y & \mathbf{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix}, \quad \nabla \Phi = \frac{\partial \Phi}{\partial x}\mathbf{a}_x + \frac{\partial \Phi}{\partial y}\mathbf{a}_y + \frac{\partial \Phi}{\partial z}\mathbf{a}_z,$$

$$\nabla^2 \Phi = \frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial y^2} + \frac{\partial^2 \Phi}{\partial z^2}$$

Cylindrical coordinate:

$$\nabla \bullet \mathbf{A} = \frac{1}{r}\frac{\partial}{\partial r}(rA_r) + \frac{1}{r}\frac{\partial A_\phi}{\partial \phi} + \frac{\partial A_z}{\partial z}, \quad \nabla \times \mathbf{A} = \begin{vmatrix} \frac{\mathbf{a}_r}{r} & \mathbf{a}_\phi & \frac{\mathbf{a}_z}{r} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_r & rA_\phi & A_z \end{vmatrix}, \quad \nabla \Phi = \frac{\partial \Phi}{\partial r}\mathbf{a}_r + \frac{1}{r}\frac{\partial \Phi}{\partial \phi}\mathbf{a}_\phi + \frac{\partial \Phi}{\partial z}\mathbf{a}_z,$$

$$\nabla^2 \Phi = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial \Phi}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 \Phi}{\partial \phi^2} + \frac{\partial^2 \Phi}{\partial z^2}$$

Spherical coordinate:

$$\nabla \bullet \mathbf{A} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 A_r\right) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}\left(A_\theta \sin\theta\right) + \frac{1}{r\sin\theta}\frac{\partial A_\phi}{\partial \phi}, \quad \nabla \times \mathbf{A} = \begin{vmatrix} \frac{\mathbf{a}_r}{r^2\sin\theta} & \frac{\mathbf{a}_\theta}{r\sin\theta} & \frac{\mathbf{a}_\phi}{r} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\ A_r & rA_\theta & r\sin\theta A_\phi \end{vmatrix},$$

$$\nabla \Phi = \frac{\partial \Phi}{\partial r}\mathbf{a}_r + \frac{1}{r}\frac{\partial \Phi}{\partial \theta}\mathbf{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial \Phi}{\partial \phi}\mathbf{a}_\phi, \quad \nabla^2 \Phi = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial \Phi}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial \Phi}{\partial \theta}\right) + \frac{1}{r^2\sin\theta}\frac{\partial^2 \Phi}{\partial \phi^2}$$