國 立 清 華 大 學 命 題 紙

九十二學年度 電子工程 研究所 碩士班研究生入學考試

科目 電磁學 科號 2603 共 3 頁第 1 頁 *請在試卷(答案卷)內作答

1. Solving an electro-static problem, we often encounter the Laplace's equation. In your textbook, you have learned how to solve the electrical potentials within a charged rectangular, metallic object. There, you let the variables to be separable in the Cartesian coordinate system.

   (a) Can you still do this if the object has arbitrary shape? Please CLEARLY discuss it. (4%)
   (b) Are the variables separable in the spherical coordinate system? Please discuss it. (3%)

2. Let us consider an isolated point charge and metallic sphere system.

   (a) First, let us consider the sphere is grounded and the point charge is gradually moving straight toward the center of sphere. Please discuss the movement of induced charged in the latter system. (3%)
   (b) Second, let us consider the sphere, with an amount of charges Q, is isolated but not grounded. The point charge is located at a distance y from the sphere. Please discuss how you can solve this kind of electro-static problems. In your answering sheet, NO calculations are needed. You are ONLY asked to clearly write down the whole method which is enough to numerically solve this problem. (4%)

3. Let us consider signal transmissions in different channels here.

   (a) We can send signals via two-parallel wires and coaxial cables. Please discuss why we often have no choice but to use more expensive coaxial cables instead of cheaper two-parallel wires in sending signals. (4%)
   (b) Today, we use personal computers to send electronic mails while ordinary two-parallel copper wires are the transmission channels. Of course, digitized signals can be directly sent in these channels. However, a modem, inserted between a PC and the telephone wires, is still absolutely needed. Please discuss this. (4%)

4. Without resorting any mathematics, please design a scheme to verify the reflectivity of TE and TM polarized waves are different. Please also CLEARLY explain why these results are different. (4%)

5. You already saw the broadcasting antennas of AM stations before. Actually, antennas can locate an object and there are such antennas of a much smaller size in military fighter jet airplanes.

   (a) Please discuss such military antennas including their design and working principles. (4%)
   (b) The American Air Forces had "invisible" and very expensive B1 bombers. Of course, the bombers were mainly made out of metal. Please discuss why they can be invisible to radars. (2%)
   (c) Please discuss the possibilities of inventing invisible fighter jet airplanes (with first-class pilots) while the cost issue is neglected. (3%)

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科目 電磁學 科號 2603 共 3 頁第 2 頁 ＊請在試卷(答案卷)內作答

6. In terms of the charge density ρ_n and the current density $\mathbf{J}$, the wave equations of the electric scalar potential $\Phi(\mathbf{r},t)$ and the magnetic vector potential $\mathbf{A}(\mathbf{r},t)$ are given by

$$\nabla^2\Phi(\mathbf{r},t)-\frac{1}{c^2}\frac{\partial^2}{\partial t^2}\Phi(\mathbf{r},t)=-\frac{1}{\varepsilon_0}\rho_n(\mathbf{r},t)$$

$$\nabla^2\mathbf{A}(\mathbf{r},t)-\frac{1}{c^2}\frac{\partial^2}{\partial t^2}\mathbf{A}(\mathbf{r},t)=-\mu_0\mathbf{A}(\mathbf{r},t)$$

Please write down the corresponding wave equations of fields $\mathbf{E}(\mathbf{r},t)$ and $\mathbf{B}(\mathbf{r},t)$ in terms of ρ_n and $\mathbf{J}$. (10%)

7. The electric field distribution of the TE_{10} mode in an air-filled rectangular waveguide of size $a \times b$ ($a > b$) is known as

$$E=\hat{y}\sin\left(\frac{\pi}{a}x\right)e^{-j\beta z}$$

This field can be decomposed as

$$E=\hat{y}\frac{j}{2}\left(e^{-j\frac{\pi}{a}x}e^{-j\beta z}-e^{j\frac{\pi}{a}x}e^{-j\beta z}\right)$$

Thus each of the two waves does not propagate along the axial z direction, but along a direction with a tilt angle $\pm\theta$ from the z axis. Determine the angle θ and use it to express λ_g in terms of λ_0, where λ_g is the guided wavelength of TE_{10} mode and λ_0 is the wavelength of a plane wave propagating in free space at the same frequency. (12%)

8. In everyday life we connect a load of unknown impedance Z_L to the electric power line through a two-wire line of unknown characteristic impedance Z_0 and length ℓ. Ordinarily, it can be expected that the voltage V_L at the load is just the supplied voltage V_g. However, as predicted from the transmission-line theory, the general relation between V_g and V_L is rather complicated as

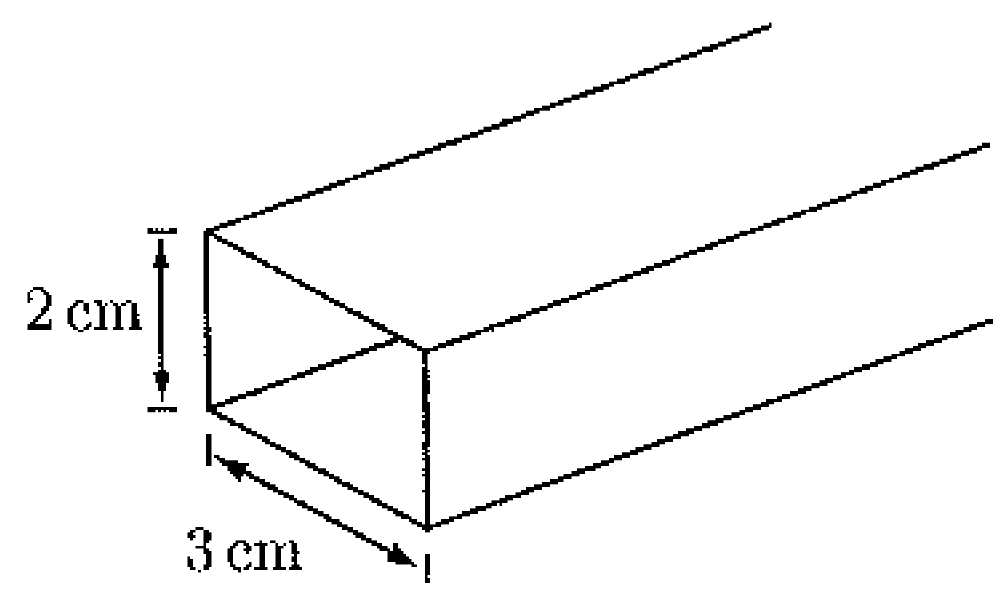
$$V_L=V_g\frac{Z_0}{Z_0+Z_g}\frac{1}{1-\Gamma_g\Gamma e^{-j2k\ell}}e^{-jk\ell}(1+\Gamma)$$

where $\Gamma=\dfrac{Z_L-Z_0}{Z_L+Z_0}$, $\Gamma_g=\dfrac{Z_g-Z_0}{Z_g+Z_0}$, Z_L is the load impedance, and Z_g is the generator internal impedance. State with explanations the conditions under which the simple relation $V_L=V_g$ holds. (12%)

9. You are given a ellipsoid object containing a total charge of Q.

(a) Can you calculate the electric field distribution by Gauss's Law? Explain. (4%)
(b) Can you calculate the electric field distribution by Coulomb's Law? Explain. (4%)

10. Consider an air-filled rectangular metallic waveguide shown in the figure below.



(a) What is the fundamental mode of this waveguide? (4%)
(b) Find the allowed frequency band for single mode operation. (4%)
(c) If a single wire is allowed to connect between two opposite wall, what is the most effective wave to pickup the TE_{02} mode? (3%)

11. For a uniform plane wave propagating in free space, the electric field of the wave is described by

$$E = (\hat{x} - \hat{y} + \hat{z})e^{-j(ax+by+cz)}$$

where a, b, c are constants.

(a) Give one possible combination of a, b, and c. (4%)
(b) What is the polarization of plane wave? (4%)
(c) For your choice of a, b, and c, find the frequency of this plane wave. (4%)

Some Physical Constant: $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m, $\mu_0 = 4\pi \times 10^{-7}$ H/m, and $c = 3 \times 10^8$ m/s.