國　立　清　華　大　學　命　題　紙

九十三學年度 電子工程研究所 系（所） 組碩士班入學考試

科目 電磁學 科號 2903 共 2 頁第 1 頁 *請在試卷【答案卷】內作答

1. An infinitely long dielectric cylinder with $\varepsilon_1 = 4\varepsilon_0$ for $r \le 10$ (cm) is surrounded by a material with $\varepsilon_2 = 8\varepsilon_0$. If $\mathbf{E_1} = \mathbf{a}_r\, r^2 - \mathbf{a}_\phi r\cos\phi + \mathbf{a}_z\, 3$ (V/m) in the cylinder region, find $\mathbf{E_2}$ and $\mathbf{D_2}$ in the surrounding $r \ge 10$ (cm) region . Assume that no free charges exist along the cylinder's boundary. (10%)

2. Consider a shorted pair of parallel plate electrodes of area A sandwiched a lossy dielectric slab of thickness d with dielectric permittivity ε and conductivity σ. Assume that the lossy dielectric has a uniformly distributed free volume charge density ρ_0 at $t = 0$ and that the fringing field can be neglected.

   (a) What is the volume charge density between these two electrodes as a function of time and position? (5%)

   (b) What is the electric field between these two electrodes as a function of time and position? (5%)

   (c) What is the surface charge density at the plates as a function of time? (5%)

   (d) What is the current flow through the short circuit as a function of time? (5%)

3. The interpretation of Poynting vector $\mathbf{S} = \mathbf{E} \times \mathbf{H}$ as power flow per unit area at a point in space is a very useful and experimentally verified concept in electromagnetic wave theory. Consider a charged particle placed next to a permanent magnet. Is there power flow due to the electric field $\mathbf{E}$ generated by the charged particle and the magnetic field $\mathbf{H}$ generated by the magnet? Show that the net power flow is zero for static electric and magnetic fields in the absence of currents. (10%)

4. Green's function relates sources to the potentials and hence plays an important role in electromagnetics. It is known that Green's function G is given by

$$G(R) = \frac{e^{-jk_0 R}}{4\pi R}$$

   where k_0 is the propagation constant in free space. Let the source be placed at the origin of spherical coordinates, such that R is the radial distance r in spherical coordinates. Find $\nabla^2 G(R)$ at $R \neq 0$. (10%)

Hint: In spherical coordinates, $\nabla^2 f = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial f}{\partial r}\right) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 f}{\partial \varphi^2} + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta \frac{\partial f}{\partial \theta}\right)$

5. The nonhomogeneous wave equations for the electric scalar potential $\Phi(\mathbf{r}, t)$ and the magnetic vector potential $\mathbf{A}(\mathbf{r}, t)$ relate the potentials with the associated sources. In some respects these two equations can be regarded as the fundamental postulation of electromagnetics. Write down these two important equations. (10%)

6. In electromagnetism, we heard of a term "perfectly grounded" which is always needed in consumer electronic products. Please clearly discuss what a perfectly grounded means. (4%)

7. When you take a train from Hsinchu to Taipei, you will find on the top of the train only one (not two) power line connected to the electrically powered train. Is that anything wrong? (3%)

8. In the presence of electric fields, the randomly oriented molecules of a (electrically neutral) medium will be polarized. Accordingly, the distributions of these polarized molecules will affect the resultant fields to be measured.

(a) Based on the definition of polarization vector **P** associated with the medium, please verify the relationship between the polarization surface charge density and **P**. (5%)

(b) In addition, we have polarization volume charge density due to the "excess charges" (or not neutralized locally) of the polarized molecules within the medium. Based on simple physics instead of any equation, please explain why originally neutral molecules will contribute a volume charge and it vanishes if **P** is fixed (or is a constant vector). (5%)

(c) Based on the above results, please verify the relationship between **P** and polarization volume charge density. (7%)

(REMINDER: you should answer these questions as asked. You will get partial credits if you use other formulas to answer these questions.)

9. If we send a signal through the two-parallel transmission lines, i.e., the ordinary telephone lines. The shape of the sent signal will be distorted. Please discuss the physics behind it and your possible solution to "alleviate" the problem. (5%)

10. Consider the case where we transmit a signal below the cut-off frequency of a hollow metallic waveguide. Please discuss the dynamic behavior of the sent signal along its propagation direction. (5%)

11. Please prove the TEM waves is not allowed in a hollow metallic waveguide of any shape. (6%)