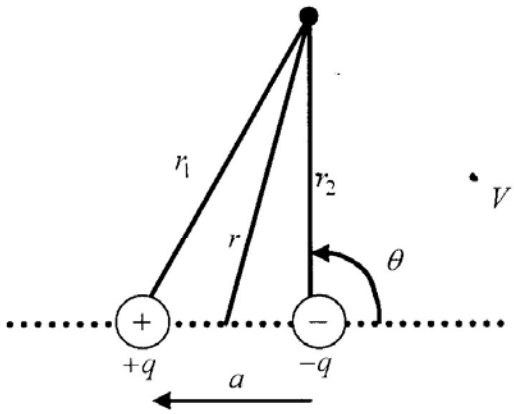
國 立 清 華 大 學 命 題 紙

九十四 學年度第一學期 光電工程研究所 博士班研究生資格考試

科目 電磁理論 科號 共 2 頁第 1 頁 *請在試卷(答案卷)內作答

1. (15%) An electric dipole **p** is suspended freely in a uniform electric field **E** so that **p** can align with **E**. Suppose the dipole is now misaligned by an angle θ_0 and released. For θ_0 is small, show
   (a) The restoring torque on the dipole is proportional to . .
   (b) The dipole undergoes simple harmonic rotational motion with period $2\pi\sqrt{I/pE}$, where I is the moment of inertia of the dipole about an axis through its center of mass. (6%)
   (c) If t = 0 when the dipole is release, what is the equation for . as a function of time? (6%)

2. (10%) Two identical electric dipoles p lie in line on the same line with their centers a distance R apart, which R being very large. Show that the force on one dipole due to the other is $3p^2/2\pi\varepsilon_0 R^4$.
   Hint:

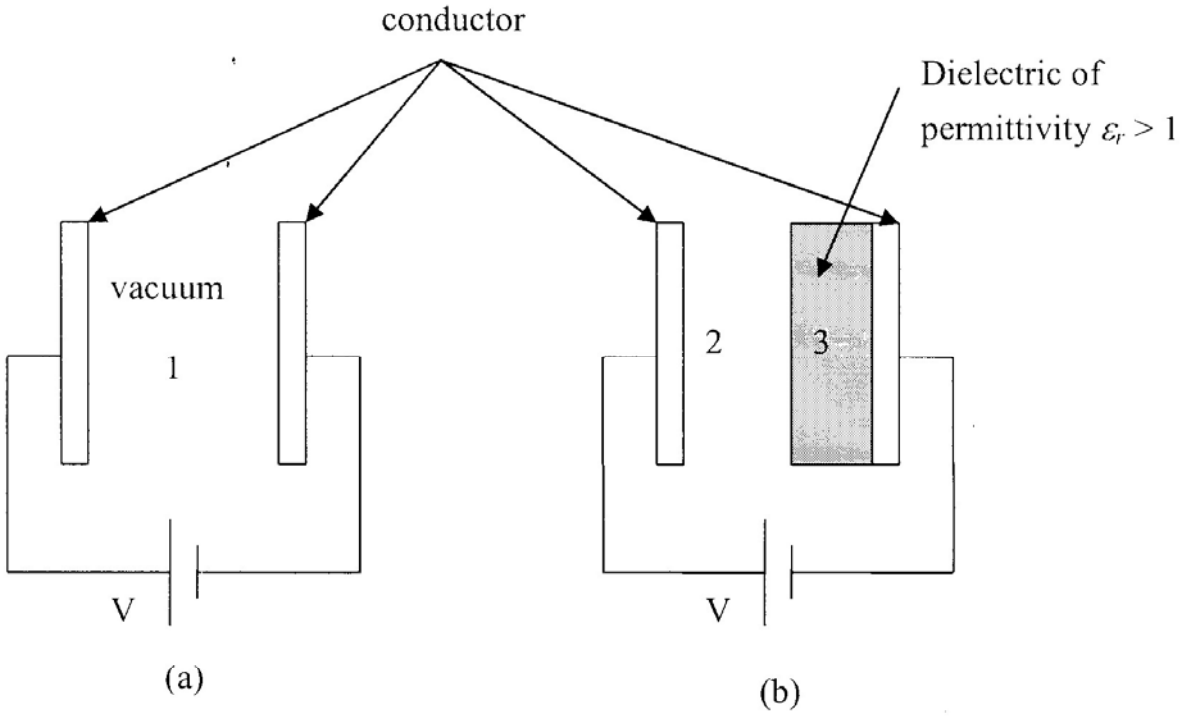


Dipole Moment

$$V \cong \frac{qa\cos\theta}{4\pi\varepsilon_0 r^2} = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$$

3. (15%) Refer to the following figures (a) and (b) for two parallel-plate capacitors each connected to a DC voltage V. The two capacitors have the same physical dimension, but the one in (b) has a perfect dielectric spacer of relative permittivity $\varepsilon_r > 1$ occupying a finite thickness of the capacitor. Ignore the fringe fields.
   (d) Give a **physical** explanation to the relationship $E_2 > E_3$. Think about microscopically what happens to the inside of the dielectric. No credit will be given, if you only provide formulas or describe it from the electrostatic boundary conditions. (5%)
   (e) Compare the magnitude of the electric field intensity E_1, E_2, E_3 in regions 1, 2, and 3. (5%)
   (f) **Discuss** which capacitor stores more electrostatic energy? Physical reasoning is

necessary for your answer. (5 %)



4. (10%) A plane wave propagates in z with a propagation constant β and an angular frequency ω.

   (1) (5%) Suppose this plane wave hits a dielectric surface at $z = 0$ and is partially reflected to form a standing wave in the region $z < 0$. (a) What is the *phase velocity* of this standing wave in the region $z < 0$? (b) What is the *group velocity* of this standing wave in the region $z < 0$?

   (2) (5%) Suppose this plane wave hits a conducting surface at $z = 0$ and is completely reflected in $-z$ to form a standing wave in the region $z < 0$. (a) What is the *phase velocity* of this standing wave in the region $z < 0$? (b) What is the *group velocity* of this standing wave in the region $z < 0$?

   Note: Credits will be given to your ability in approaching and reasoning this problem, but not to any answer without explanations.

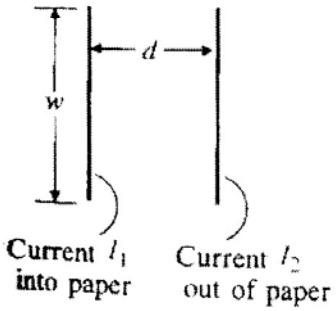
5. (10 %) Consider two coupled circuits, having self-inductances L_1 and L_2, that carry currents I_1 and I_2, respectively. The mutual inductance between the circuit is M.

   (a) Find the ratio I_1/I_2 that makes the stored magnetic energy W_2 a minimum. (5 %)

   (b) Show that $M \le \sqrt{L_1 L_2}$. (5 %)

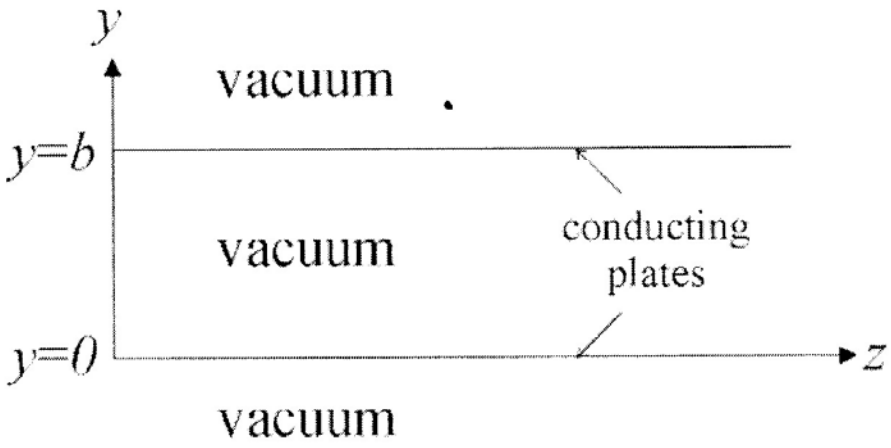
6. (15 %) Determine the force per unit length between two parallel, long, thin conducting

strips of equal width w. The strips are at a distance d apart and carry currents I_1 and I_2 in opposite directions as shown. (15 %)



7. (8%) We normally use the models of lumped circuit, transmission line, and waveguide to describe electromagnetic wave propagation at different frequencies. Can you discuss the criterion of each model?

8. (17%) Consider a pair of perfectly conducting parallel plates located at y=0 and y=b, respectively. (see Figure). The space other than the plates is vacuum, and only harmonic wave at angular frequency ω is of interest.



(a) Deduce vector fields $\vec{E}$ and $\vec{H}$ for TEM wave. (4%)

(b) Deduce $\vec{E}$ and $\vec{H}$ for the n-th TM mode. What does n = 0 mean? (5%)

(c) If the conducting plates are removed, while a dielectric slab with refractive index n_d(>1) is inserted between y=0 and y=b. Can TEM and TM modes exist, respectively? If yes, please deduce the corresponding $\vec{E}$ and $\vec{H}$. (8%)