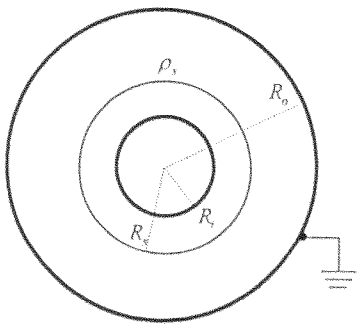
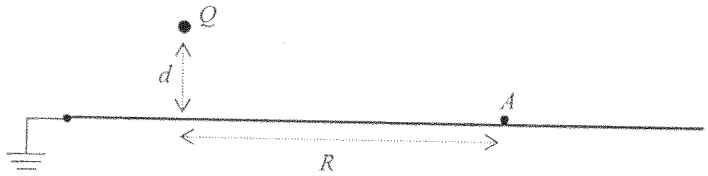
科目：電磁學 B(5008)

校系所組：中大照明與顯示科技研究所(乙組)
中大電機工程學系(固態組)
交大電子研究所(甲組、乙組)
清大光電工程研究所
陽明醫學工程研究所(醫學電子組)
陽明生醫光電研究所(理工組 B)

1. (10%) A group of charges distribute uniformly as a thin spherical shell of radius R_s. The surface charge density is denoted as ρ_s. These charges are inside the region bounded by two conducting spherical shells, as shown in the figure. All the shells share the same center. The outer conducting shell of radius R_o is grounded. Determine the electric field intensity and electric potential at R_1, R_2, R_3, and R_4, where $R_1 > R_o > R_2 > R_s > R_3 > R_4 = R_i$.



2. (10%) A positive point charge Q is located at a distance d above a very large grounded conducting plane, as shown in the figure. Assuming that the conducting plane is on the x-y plane in Cartesian coordinates. Find the electric field intensity at the point A on the plane, where $R >> d$.



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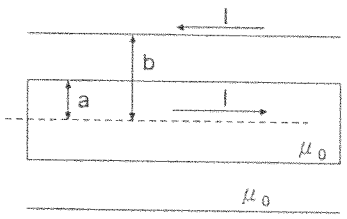
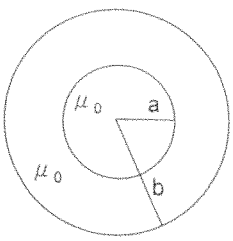
3. (10%) An air coaxial transmission line has a solid inner conductor of radius a with uniform current I and a very thin outer conductor of inner radius b, as shown in following figure.
(a) Determine the magnetic flux density **B** in $r < a$, and $a < r < b$, respectively.
(b) Determine the stored magnetic energy W_m per unit length in $r < a$, and $a < r < b$, respectively.
(c) Use (a) & (b) results, determine the inductance L per unit length.





4. (a) (6%) Start from Maxwell's equations, derive the wave equation. Show all of your works. You need to specify all the assumptions during your derivations in order to earn full credits.
(b) (4%) A simple solution to the wave equation is called time-harmonic plane-wave. Write out the general expressions of plane-waves. Explain the meanings of all parameters.

5. Consider oblique incidence of a TM plane-wave from medium 1 of (ε_1, μ_0) into medium 2 of (ε_2, μ_0) with incident angle θ_i.
(a) (4%) How are the powers of the incident, reflected and transmitted waves related?
(b) (6%) Derive the value of the incident angle so that there is no reflected wave. Show all of your works.

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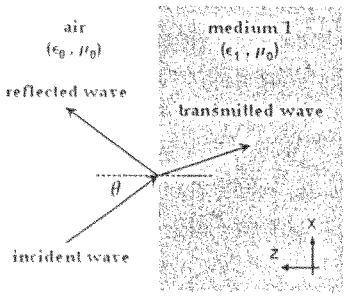
6. There are N time-harmonic plane-waves propagating in vacuum along the z-direction with equal electric field amplitude of $E_0 = \sqrt{P}$, where P is normalized to represent the power of each plane-wave. The frequency difference between any two plane-waves is f_{rep}. Each plane-wave has it's own time-invariant phase.
(a) (2%) Write out the general expression for the total electric field.
(b) (4%) Plot the power at z=0 for random phases. Be specific on all scales.
(c) (4%) Plot the power at z=0 for equal phases. Be specific on all scales.

7. An electromagnetic wave $\vec{E}_i$ is incident on a planar boundary from air to medium 1 (neglecting material loss). The interface is in the xy plane and the plane of incidence is in the xz plane as shown below.



The electric field of the incident wave $\vec{E}_i$ is

$$\vec{E}_i(x,y,z) = E_0(\hat{a}_x \cos\theta + j\hat{a}_y + \hat{a}_z \sin\theta)e^{-j(k\sin\theta)x + j(k\cos\theta)z}$$

where E_0 is the electric field amplitude, k is the wavenumber in air, θ is the incident angle, and $j = \sqrt{-1}$ is the imaginary unit. The permittivities of air and medium 1 are ε_0 and ε_1, respectively, while the permeability of both media is μ_0. Assume both media are homogeneous, linear, and isotropic.

(a) (4%) Decompose the incident wave E_i into perpendicular (TE) $E_i^{\perp}$ and parallel (TM) $E_i^{\parallel}$ components.
(b) (3%) Given $\varepsilon_1=3\varepsilon_0$, please find the incident angle θ (if any) such that the transmission angle is to equal 0.5θ. (Note: $\sin 2\phi = 2\sin\phi\cos\phi$)
(c) (3%) Given $\varepsilon_1=3\varepsilon_0$, please find the incident angle θ (if any) such that the reflected wave is linearly polarized.
(d) (2%) From (c), what is the polarization (parallel or perpendicular or both) of the reflected wave?

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8. Consider that you observe an object through a lens where you see a virtual image reduced in size by a factor of M=3/5. The distance between the lens and the object is 3 cm. Please answer the following questions.
(a) (3%) Find the distance between the lens and the image (in centimeters). Please show your calculations.
(b) (3%) Find the focal length f (in centimeters). Be sure to specify the sign.
(c) (2 %) Which of the following is true?
(1) The lens is converging and the image is erect.
(2) The lens is diverging and the image is inverted.
(3) The lens is diverging and the image is erect.
(4) The lens is converging and the image is inverted.

9. A harmonic plane EM-wave with frequency ν = 1 GHz is propagating in a direction parallel to the vector < 0, 1, 2 >. The speed of the wave is V = 3 x 10^{10} cm/s. The wave impedance of the medium is 377 Ω.
(a) (4%) Find the wave vector **k**.
(b) (4%) If the phase at the position **r** = (0, 0, 0) and t = 0 is $\pi/4$, write the wave in terms of a cosine function.
(c) (4%) According to (b), find the phase at position (0, 0, 3 cm) and time t = 0.1 ns.
(d) (4%) If the wave is linearly polarized with the E-field parallel to the y-z plane, find the direction of the E-field.
(e) (4%) If the irradiance of the wave is 1 W/cm^2, what is the amplitude of the E-field?