INDIAN INSTITUTE OF TECHNOLOGY DELHI

DEPARTMENT OF PHYSICS

MID-TERM EXAM (PYL101)

Date: 10 April, 2021 Time: 9.30 – 11.30 AM Max. Marks: 50

All questions are compulsory. Use new page for each question.

Q1. Assume that the electric field of a point charge is given by

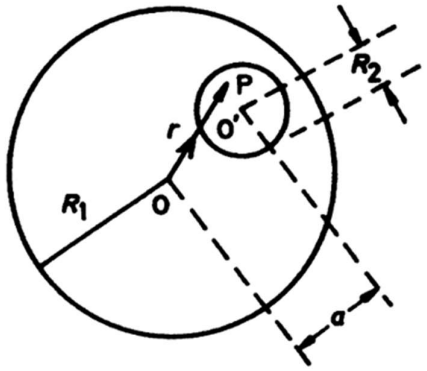
$$\mathbf{E}(r) = \frac{q}{4\pi\epsilon_0}\frac{1}{r^2}\left(1-\sqrt{r}\right)\hat{\mathbf{r}}.$$

Consider two concentric spherical shells S_1 and S_2 of radii 'r_0' and '$r_0+\delta$', respectively, surrounding the point charge 'q' located at their center. Find out the divergence of the electric field at $r = r_0$. **[5 marks]**

Q2. Consider a sphere of radius R_1 with uniform charge density ρ. Now if we remove a sphere of radius R_2 out of it such that the centers of the two spheres are at a distance 'a'. Find the following at the center of the spherical cavity:

(a) the electric field **[3 marks]**

(b) the electric potential **[3 marks]**

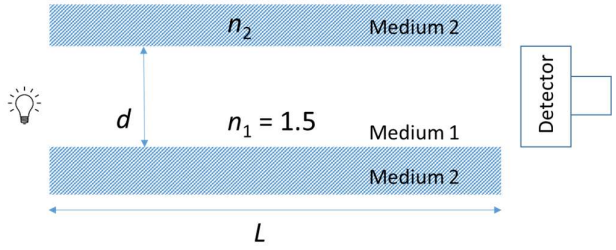


Q3. Consider a sphere of radius R made up of linear dielectric material with dielectric constant ε_r. Now if a free charge density $\rho(r) = Ar^2$ is embedded in this sphere, find

(a) the electric field inside and outside the sphere **[3 marks]**

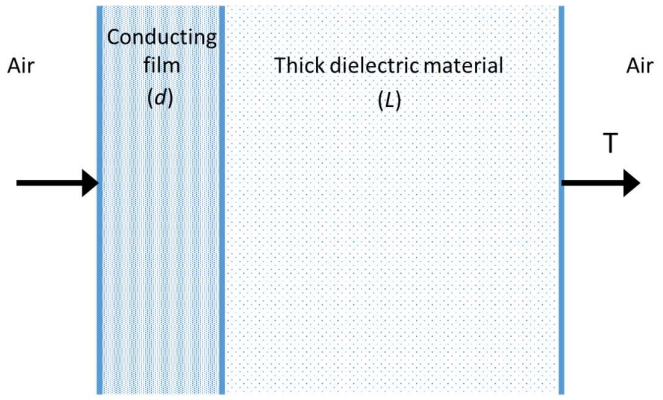
(b) the potential at the center of the sphere **[3 marks]**

Q4. In the figure below, a dielectric strip of height d and length L is surrounded by another material. The dielectric strip has material refractive index, $n_1 = 1.5$. The surrounding medium is either (i) air, OR (ii) another dielectric material of index $n_2 = 1.45$, OR (iii) a metal coating of thickness, 1 micron. A point like light source is placed at the centre of the input, while at the exit point, a large photo detector is placed. Compare the transmitted light intensity in each case? Explain. **[5 marks]**

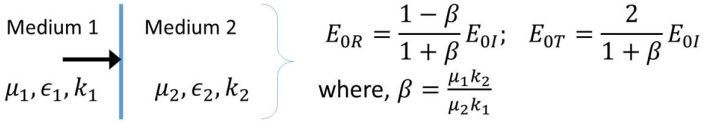


Q5. Express mathematically in Cartesian coordinates, a monochromatic EM wave that is propagating along a direction (1,-2,1) in air and its polarization in the xy-plane. At any arbitrary time, *t* and phase angle, 0, what is the wave phase front of the above wave? Express mathematically and draw a sketch in the same xyz-axis system. **[5 marks]**

Q6. Consider a conducting (not a perfect conductor) thin film (thickness *d*) on a dielectric substrate (thickness *L*) as shown in the figure below. A monochromatic plane wave, $\boldsymbol{E} = E_0\, cos(kz - \omega t)\, \hat{\boldsymbol{x}}$ is incident from left at normal incidence. All symbols have their usual meaning. Calculate the transmission coefficient, T. You can assume, μ(air) = μ(conducting film) = μ(thick dielectric material) = μ_0. **[6 marks]**



Hint: The reflected and transmitted fields for an interface between two media are given by

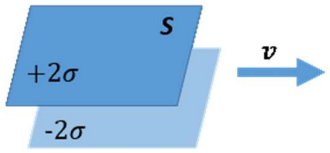


Q7. Consider a long rod (of radius a) made-up of a magnetic material whose magnetization varies as $\vec{M} = \frac{\alpha^2}{2r}\hat{\phi}$, where α is a constant and r is the distance from the axis of the rod. This rod is now connected to a battery and a uniformly distributed current, I flows across it. By calculating bound currents, find the following and clearly mention the directions.

a) Magnetic field, $\vec{B}$ inside the rod **[3 marks]**

b) Magnetic field, $\vec{B}$ outside the rod **[3marks]**

Q8. As shown in the figure below, consider a large parallel plate capacitor with uniform surface charges 2σ and -2σ on the upper and the lower plates, respectively. These charges are moving with a constant speed v. The area of each plate is given as S. Find the following and clearly mention the directions.



a) Magnetic field in between the plates **[3 marks]**

b) The value of v for which magnetic force on upper plate balances the electric force?

[3 marks]

Q9. Consider an infinitely long solenoid of radius R and N turns per unit length. A current $I = 4I_0 \sin \omega t$ flows in the circumferential direction of the solenoid. Find the electric fields at a distance r from the axis and clearly state the directions.

a) Inside the solenoid **[3 marks]**

b) Outside the solenoid **[2 marks]**