Physics 208 – Exam I

Answer Key February 13th, 2017

Short Answers:

A) Consider an electric field given by $\vec{E}(x,y,z) = a\hat{i} + b\hat{j} + cz\hat{k}$, where a, b and c are constants. What is the magnitude of the electric flux through a square that is parallel to the xy plane and whose corners are located at the points (x,y,z)=(0,0,1),(1,0,1),(0,1,1),(1,1,1). Answer: $\Phi = c$

B) Two positively charged point particles $4Q$ and Q are placed at the points $x = 0$ and $x = d$, respectively. At what point along the line connecting the two charged particles is the net electric field zero? Answer: $x = \frac{2}{3}d$

C) An alpha particle (charge $+2e$) has an initial kinetic energy E very far from a stationary Xenon nucleus (charge $+54e$). If the alpha particle approaches the Xenon nucleus head-on, how close does it come before reversing its direction of motion? Assume that the Xenon nucleus remains stationary during the process. Answer: $d = \frac{108ke^2}{E}$

D) A charged line segment of length L and uniform linear charge density λ is completely contained inside a sphere of radius R. What is the total electric flux through the surface of the sphere? Answer: $\Phi = \frac{\lambda l}{\epsilon_o}$

Prob 1 Four point charges are located at the corners of a square of side L as shown in the figure.

(a) Draw a free-body force diagram for the $-q$ charge at the bottom right corner of the square. Be sure to indicate both the relative magnitude and direction of these forces.

(b) Find the magnitude of the total force on this $-q$ charge.
Answer: $|\vec{F_{\text{Total}}}| = \frac{kq^2}{L^2}(1/2 + \sqrt{2})$

(c) If the $-q$ charge is moved to the center of the square, does the potential energy of the system increase, decrease or remain the same? Explain your choice.
Answer: The potential energy of the system will decrease since the -q charge is being moved in the direction of the net force acting on it.

Prob 2 An infinite insulating hollow cylinder of radius r_1 and uniform charge per unit length, λ is oriented so that its long central axis is along the z-axis. A fixed point charge, $-Q$, is located at the position $(x,y,z) = (2r_1, 0, 0)$. Answer the following in terms of the constants given:

(a) What is the magnitude of the total electric field at the location $(x,y,z) = (3r_1, 0, 0)$?
Answer: $|\vec{E_{\text{Total}}}| = |\vec{E_{\text{cylinder}}} + \vec{E_{\text{pointcharge}}}| = |(\frac{\lambda}{2\pi\epsilon_o 3r_1} - \frac{Q}{4\pi\epsilon_o r_1^2})|$

(b) Assuming that the reference potential is set to be $V_{\text{ref}} = 0$ on the surface of the cylinder, what electric potential does the $-Q$ charge experience? Answer: $V(2r_1) = -\frac{\lambda}{2\pi\epsilon_o}\ln 2$

(c) How much work must be done by the electric field to bring the point charge from its location at $2r_1$ to the surface of the insulating cylinder at r_1?
Answer: $Work = Q\frac{\lambda}{2\pi\epsilon_o}\ln 2$

Prob 3 A total positive charge Q is distributed uniformly throughout a solid insulating sphere of radius R. A conducting spherical shell with net charge $-2Q$ has an inner radius $a > R$, outer radius b, and is concentric to the insulator.

(a) How much charge is located on the inner and outer surfaces of the **conductor**?
Answer: $q_{\text{inner}} = -Q$, $q_{\text{outer}} = -Q$

(b) What is the electric field in the regions $0 < r < R$, $E(r) = \frac{Qr}{4\pi\epsilon_o R^3}$; $R < r < a$, $E(r) = \frac{Q}{4\pi\epsilon_o r^2}$; and $a < r < b$? , $E(r) = 0$ inside a conductor.

(c) What is the potential difference $\Delta V = V(b) - V(R)$? Answer: $\Delta V = -\frac{Q}{4\pi\epsilon_o}(\frac{1}{R} - \frac{1}{a})$