HW 24-2-1 (4 pts) **Section 24.3**

23. A large, flat, horizontal sheet of charge has a charge per unit area of 9.00 μC/m². Find the electric field just above the middle of the sheet.

\[
\sigma = \frac{9 \times 10^{-6} \text{ C}}{\text{m}^2}
\]

Charge \( \uparrow \)

Extremely small distance \( \downarrow \) to surface moving away from positive charge

Total Flux \( \Phi_E = 2EA \) (since top and bottom surfaces)

\[
\Phi_E = 2EA = \frac{\Phi_{\text{in}}}{\epsilon_0} \quad (\text{by definition})
\]

\[
2EA = \frac{\sigma A}{\epsilon_0}
\]

\[
E = \frac{\sigma}{2\epsilon_0}
\]
27. **Consider a thin, spherical shell of radius 14.0 cm with a total charge of 32.0 \mu C distributed uniformly on its surface. Find the electric field (a) 10.0 cm and (b) 20.0 cm from the center of the charge distribution.**

(a) \( E_{10\text{cm}} = 0 \) since you are inside the shell of charge.

(b) \( E_{20\text{cm}} \)

\[ E = \frac{K \frac{Q}{R^2}}{\varepsilon_0} = \frac{(8.99 \times 10^{-9} \text{ N m}^2/\text{C}^2) (32 \times 10^{-6} \text{ C})}{(0.20 \text{ m})^2} \]

\( = 7.2 \text{ MN/C} \) radially outward.
30. Assume the magnitude of the electric field on each face of the cube is uniform and the directions of the fields on each face are as indicated. Find (a) the net electric flux through the cube and (b) the net charge inside the cube. (c) Could the net charge be a single point charge?

(a) The net electric flux through the cube is zero because it is not symmetric.

(b) The net electric flux is 0, as calculated from the symmetry of the cube.

(c) It is not possible for a single point charge to produce the flux calculated, as distributed charges would be required to achieve the symmetry observed.
A cylindrical shell of radius 7.00 cm and length 2.40 m has its charge uniformly distributed on its curved surface. The magnitude of the electric field at a point 19.0 cm radially outward from its axis (measured from the midpoint of the shell) is $36.0 \text{ kN/C}$. Find (a) the net charge on the shell and (b) the electric field at a point 4.00 cm from the axis, measured radially outward from the midpoint of the shell.

\[ E = \frac{36 \text{ kN/C}}{} \]

\[ r = 0.19 \text{ m} \]

\[ \Phi_E = \oint E \cdot dA \]

\[ E \text{ constant and \ parallel \ to \ surface} \]

Scalar Dot product

\[ E = \oint dA = EA = \frac{Q}{\varepsilon_0} = \frac{Q}{\varepsilon_0} \]

\[ A = 2\pi r L \text{ for curved part of cylinder} \]

\[ E(2\pi r L) = \frac{Q}{\varepsilon_0} \]

\[ E = \frac{1}{2\pi \varepsilon_0 L} = 2k_e \frac{1}{r} = 2k_e \frac{Q}{Lr} \]

\[ Q = \frac{LrE}{2k_e} = \frac{(2.4 \text{ m})(0.19 \text{ m})(36000 \text{ N/C})}{2 \left( \frac{8.99 \times 10^9 \text{ Nm}^2}{\text{C}^2} \right)} \]

\[ Q = 913 \text{ nC} \]

Gauss' Law \[ \overline{E} = 0 \text{ (symmetrical)} \]
34. Review. A particle with a charge of $-60.0 \text{ nC}$ is placed at the center of a nonconducting spherical shell of inner radius 20.0 cm and outer radius 25.0 cm. The spherical shell carries charge with a uniform density of $-1.33 \text{ \mu C/m}^3$. A proton moves in a circular orbit just outside the spherical shell. Calculate the speed of the proton.

Volume of the spherical shell is

$$V = \frac{4}{3} \pi R^3 - \frac{4}{3} \pi r^3 = \frac{4}{3} \pi \left(0.25^3 - 0.20^3\right) \text{m}^3 = 0.0319 \text{m}^3$$

The Q of the shell is

$$Q_{shell} = \frac{Q_{total}}{V} = \frac{-60 \text{ nC} + -42.5 \text{ nC}}{0.0319 \text{m}^3} = -102.5 \text{ nC}$$

So the electric field is directed inward.

$$E = \frac{keQ_{total}}{r^2} = \frac{(8.99 \times 10^9 \text{ Nm}^2/\text{C}^2)(-102.5 \times 10^{-7} \text{ C})}{(0.25 \text{m})^2} = 1.47 \times 10^4 \text{ N/C}$$

So...

$$E = \frac{eq}{r} = \frac{mv^2}{Er} \Rightarrow v = \sqrt{\frac{mv^2}{E}} = \sqrt{\frac{1.67 \times 10^{-27} \text{ kg} \times 594 \text{ km}}{1.47 \times 10^4 \text{ N/C}}} = 5 \text{ m/s}$$

(Not so fast for a proton)