Electric field causes Force

\[ \vec{F}_E = q_0 \vec{E} \]

\( \Theta \) is pushed with \( \vec{E} \) ; \( \Theta \) pulled against \( \vec{E} \)

Source charges (not \( q_0 \)) cause \( \vec{E} \).

- Point Charge \( \vec{E} = \frac{kQ}{r^2} \) (away from \( \Theta \))

- Charge Distribution \( \vec{E} = \int \frac{k \, dQ}{r^2} \)

- Gauss's Law
  - Electric Flux is like "total \( \vec{E} \) piercing a surface."

\[ \Phi_E = \oint \vec{E} \cdot d\vec{A} = E_{\text{avg}} \cdot A \]

- Each charge generates flux proportional to \( Q \).

\[ \Phi_E = \frac{Q}{\varepsilon_0} = \frac{Q}{4\pi k Q} \]
To apply Gauss's Law, we must create an imaginary surface to "catch" the flux generated by our charges. \[
\left( \frac{N m^2}{C^2} \right) \cdot (C) = \left( \frac{N}{C} \right) m
\]

**Ex.: Point Charge**

Flux generated:

\[
\Phi = 4\pi k Q
\]

\[
q = 1.6 \times 10^{-19} C
\]

\[
\Phi = 4\pi (9 \times 10^9)(1.6 \times 10^{-19})
\]

\[
= 6.8 \times 10^{-8} \left( \frac{N \cdot m^2}{C} \right)
\]

"Catch" with sphere of radius \( r \).

\[
\Phi = E \cdot A
\]

\[
E = \frac{\Phi}{A} = \frac{4\pi k Q}{4\pi r^2} = \frac{kQ}{r^2}
\]

- Any charges inside our "net" contribute to the flux caught.
- Any charges outside it don't contribute.
- Flux is E-Field Lines.

\[\text{This line goes in & out of the net,}
\]
\[\text{This charge doesn't contribute to caught } \Phi.\]
Solid Ball of Charge

\[ Q = +5 \ \text{nC} \]
\[ R = 0.25 \ \text{m} \]

For points outside, \( r > 0.25 \ \text{m} \)

Our "net" surrounds the whole ball.

\[ \Phi = 4\pi k Q_{\text{enc}} \]
\[ E = \frac{\Phi}{A} = \frac{4\pi k Q_{\text{enc}}}{4\pi r^2} = \frac{kQ}{r^2} = \frac{k(5\ \text{nC})}{r^2} \]

For points inside, \( r < 0.25 \ \text{m} \)

\[ Q_{\text{enc}} \] isn't the entire ball.

\[ \rho = \frac{Q}{\frac{4}{3}\pi R^3} = \frac{Q_{\text{enc}}}{\frac{4}{3}\pi r^3} \Rightarrow \frac{Q_{\text{enc}}}{R^3} = \frac{r^3 Q}{R^3} \]

\[ E = \frac{kQ_{\text{enc}}}{r^2} = \frac{k}{r^2} \frac{r^3 Q}{R^3} = \frac{kQ}{R^3} \]
Long Line Charge

\[ \lambda = \frac{Q}{L} = \frac{Q_{enc}}{L} \]

This is cylindrical symmetry.

Total Flux caught
- Generated by \( Q_{enc} \)

\[ \Phi_E = 4\pi k Q_{enc} = 4\pi k \lambda L \]

* Caught by "net":

Round Part: \[ \Phi_E = E_A = E \frac{2\pi r}{L} \]

Flat Caps: \[ \Phi_E = E_A = 0 \]

\[ E_{2\pi r L} = \frac{2kL}{r^2} \]

\[ E = \frac{2kL}{r^2} \]

Electric Field of infinite line charge.
Conductor in an $E$-Field

Solid Conductor: $\Theta$ fixed
most $\Theta$ fixed
valence $\Theta$ mobile ($\approx 1$ or $2$
per atom)

How much $\Theta$ or $\Theta$ on the metal surface?

Flux generated

$E = 0$

$\Phi = 4\pi k Q_{ens} < 4\pi k \sigma A$

$E = 4\pi k \sigma$

$\Phi = \frac{Q}{A}$

Flux Caught

$= \sigma / \varepsilon_0$

Left: $\Phi = EA$

$E$ outside metal

Right: $\Phi = 0$

$E$ surface
Conductive Shell

1

+5 nC

-8 nC on shell

\( E = \frac{k(5 \text{ nC})}{r^2} \)

2 Inside

\( E = \frac{k(5 \text{ nC} - 8 \text{ nC})}{r^2} \)

3 Outside

\( \text{In metal: } E = 0 = \frac{k(5 \text{ nC} + 5 \text{ nC})}{r^2} \)

Where is the \(-5 \text{ nC}\)?

On inner surface of shell.

Where is the other \(-3 \text{ nC}\)?

On the outer surface of the shell.