Charge - Amount of electric "Stuff"
Can be + or -

Coulomb Force - Long-range, "central force", attractive or repulsive

Alternative to Coulomb Force: Electric Field

\[ F \propto \frac{E_1}{q_1} \]

Old Process: \[ F = \frac{k q_1 q_2}{R^2} \]

New Process:
- \( q_1 \) makes \( E_1 \) \[ E_1 = \frac{k q_1}{R^2} \]
- \( q_2 \) "Feels" \( E_1 \) \[ F = q_2 E_1 \]

Compare to \[ F_g = m g \]

Here, \( q_1 \) is the "source" and \( q_2 \) is the "test charge".
The force is exerted on \( q_2 \).
Electric Field is force per charge (i.e. per test charge)
\[ \vec{F}_E = q_0 \vec{E} \quad \Rightarrow \quad \vec{E} = \frac{\vec{F}_E}{q_0} \]

\( \vec{E} \) is a vector.
- Points in same direction as \( \vec{F}_E \) on a positive \( q_0 \).
- If \( q_0 \) is negative, \( \vec{E} \) is opposite to \( \vec{F}_E \).

\( \vec{E} \) is caused by source charges.
- For + source, a + \( q_0 \) is pushed away.
  - \( \vec{E} \) points away from + source.
- For - source, a - \( q_0 \) is attracted.
  But \( \vec{E} \) is opposite to \( \vec{F} \) for - \( q_0 \), so \( \vec{E} \) points away from - source.

Effect on materials: \( \vec{E} \) distorts atom/molecule shapes.

In a thunderstorm:
- Cloud
- Air molecule
- E points "up"
  - \( \vec{E} > 10^6 \text{ N/C} \), Bang!

Ground
Electric field of charge distributions

\[ \mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 + \ldots \]

\( \mathbf{E} \) of each source.

\[ E_0: \quad I \quad \text{II} \quad \text{III} \]

\[ q_1 = -5 \, \text{nC} \quad q_2 = +8 \, \text{nC} \]

Is \( \mathbf{E} \) even zero? At each point, \( \mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 \)

For \( \mathbf{E} = 0 \), \( \mathbf{E}_1 \) & \( \mathbf{E}_2 \) are equal & opposite.

* Our point must be along the connecting line.

* In region II: \( \mathbf{E}_1 \) is (left) toward \( q_1 \)
  \( \mathbf{E}_2 \) is (left) away \( q_2 \)

Plausible: In region I: \( \mathbf{E}_1 \) is toward \( q_1 \) = (right)
  \( \mathbf{E}_2 \) is away \( q_2 \) = (left)

Plausible: In region III: ...

Want \[ \mathbf{E}_1 = \mathbf{E}_2 \]

\[ \frac{kq_1}{r_1^2} = \frac{kq_2}{r_2^2} \]
Need one variable to solve for.

Our Point $q_1$ $q_2$

$r_1 = x$ $r_2 = x + 0.25$

$$\frac{5}{x^2} = \frac{8}{(x+0.25)^2}$$

$E$ of charge distributions

$$Q = \int dq$$

$$E = \int dE$$

For a point charge: $E = k \frac{q}{r^2}$ $\hat{r}$ points away from source

$\hat{r}$ is a unit vector

- magnitude is 1 w/ no units
- direction is specific to that unit vector

Easy to calculate as $\hat{r} = \frac{\vec{r}}{r}$

$$dE = k dq \frac{\hat{r}}{r^2}$$
E of a line charge

\( \vec{r} = \text{From } (dx) \text{ to } P \)

\( \vec{r} = \left( -x \hat{i} + y \hat{j} \right) \)

\( r^2 = x^2 + y^2 \)

\( \hat{r} = \frac{-x \hat{i} + y \hat{j}}{\sqrt{x^2 + y^2}} \)

\( E = \int k \frac{d\vec{r}}{r} \frac{-x \hat{i} + y \hat{j}}{\left(x^2 + y^2\right)^{3/2}} \)

\( = \frac{2k}{\left| y \right|} \hat{u} \)