Lecture 3: Electric field
Force between charges: Coulomb’s Law

\[ F = k \frac{|q_1 q_2|}{r^2} \]

Like charges repel
Unlike charges attract

\( k = 9 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2 \)
Charged particles exert forces over a distance. How? Charged particle “sends out” an electric field into space, other charged particles feel the presence of the field by feeling a force.

\[
\vec{E} \text{ at (xyz)} = \frac{\vec{F} \text{ on } q \text{ at (xyz)}}{q}
\]

Electric field or electric field strength. Unit: N/C

Electric field is a vector, exists at every point in space
If $q$ is positive: $\vec{E}$ points in the same direction as $\vec{F}$ on charge

If $q$ is negative: $\vec{E}$ points in the opposite direction as $\vec{F}$ on charge

Field does not depend on the size of the probe charge

If the electric field is given, we can find the force on $q$:

$$\vec{F} = q\vec{E}$$
Electric field of a point charge

\[ \vec{E} = \frac{\vec{F}_{on \ q'}}{q'} \]

\[ F_{on \ q'} = k \frac{|qq'|}{r^2} \]

If \( q \) is negative, force on \( q' \) is towards \( q \), field towards \( q \)

\[ \vec{E} = \frac{k|q|}{r^2}, \quad \text{away from } q \text{ for } q>0 \]

\[ \text{towards } q \quad \text{for } q<0 \]
$\vec{E} = \frac{k|q|}{r^2}$

away from $+$

towards $-$
Example: Field of a dipole

Dipole: pair of charges with equal charge magnitude, opposite signs

Net field at point P?
Uniform electric field

Large parallel plates (size >> separation) of area A

Horizontal components cancel, only vertical components remain
Field inside parallel plate capacitor is constant
A area of plate,
Q charge on one plate
Q/A = σ surface charge density

\[ \vec{E} = \frac{Q}{\varepsilon_0 A}, \text{ from } + \text{ to } - \]

\[ \varepsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12} \frac{C^2}{Nm^2} \]  
Permittivity constant