# Electricity

Scott N. Walck

January 18, 2023

# What is Electricity?

A technological or engineering definition:

*Electricity is the flow of electric charge.*

A physics definition:

*Electricity is any phenomenon resulting from electric charge.*

- *Electric charge* is one of the fundamental building blocks of the universe.

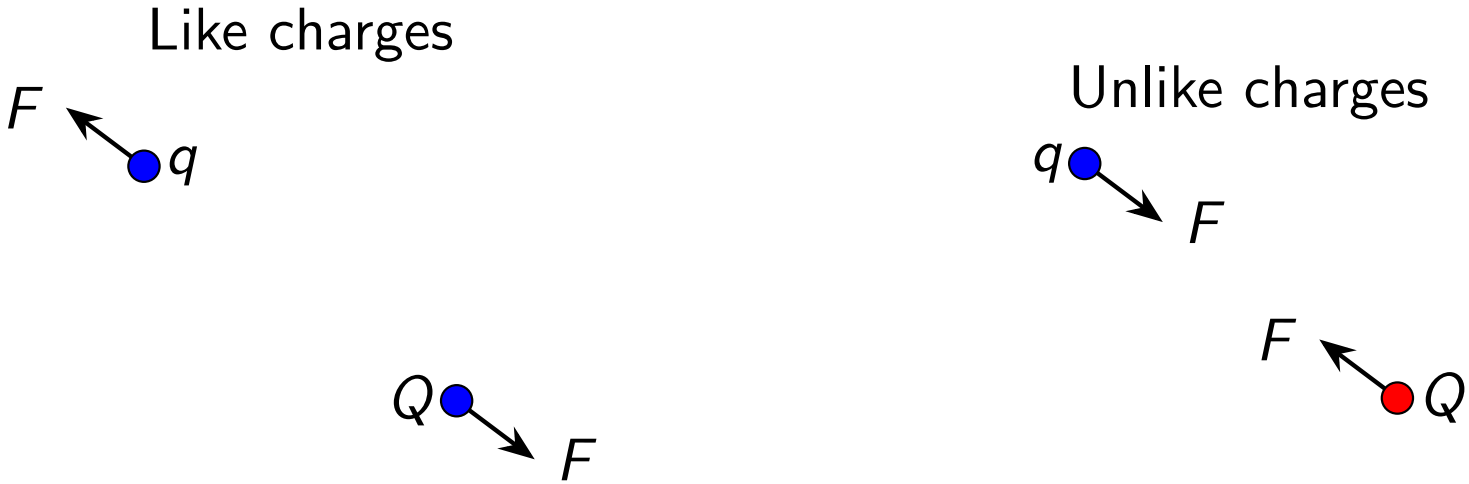
# What is Electric Charge?

- There are two types. We call them *positive* and *negative*.
- Protons are positively charged. Electrons are negatively charged.
- Unlike charges attract. Like charges repel.
- The SI unit of charge is the Coulomb (C).
- We use symbols like $q$ and $Q$ to denote charge.
- Proton charge is $1.602176634 \times 10^{-19}$ C.
- Electron charge is $-1.602176634 \times 10^{-19}$ C.

# Coulomb's law gives the force that one charged particle exerts on another.

$$F = k\frac{|qQ|}{r^2}$$

$$k = 9 \times 10^9 \text{ N m}^2/\text{C}^2$$



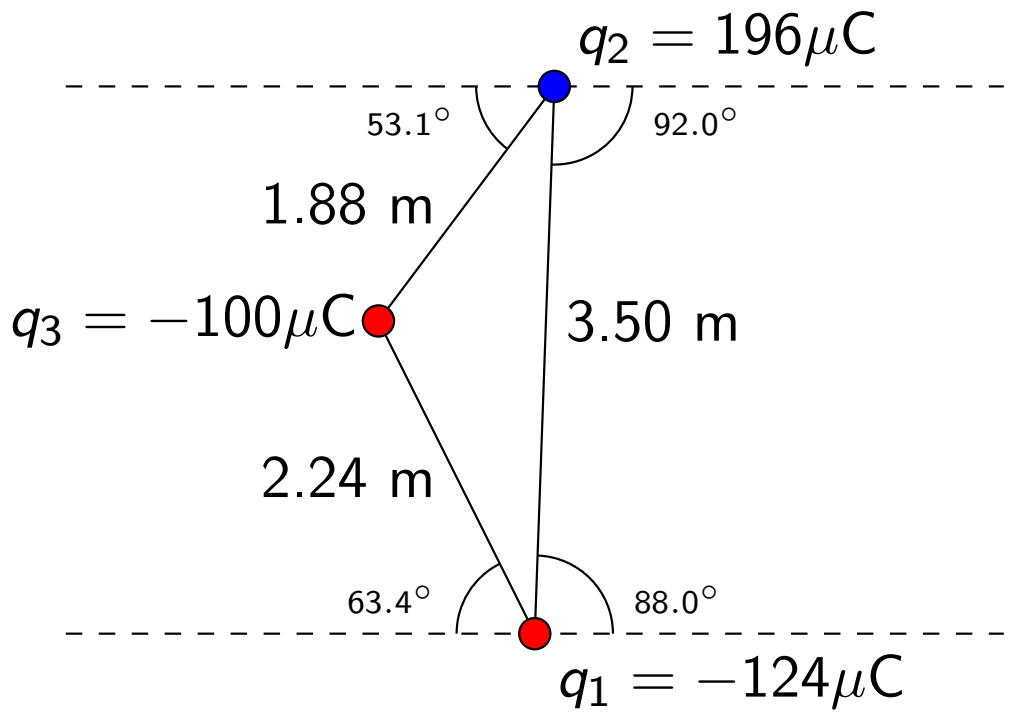
# Force is measured is Newtons.

| Correct | Incorrect |
| --- | --- |
| $F = 2.56\ \mathrm{N}$ | $F = 2.56$ |
| $F = k\frac{\lvert qQ\rvert}{r^2}$ | $F = k\frac{\lvert qQ\rvert}{r^2}\ \mathrm{N}$ |
| $F = (9 \times 10^9\ \mathrm{N\ m^2/C^2})\frac{\lvert qQ\rvert}{r^2}$ | $F = (9 \times 10^9)\frac{\lvert qQ\rvert}{r^2}$ |
| $k = 9 \times 10^9\ \mathrm{N\ m^2/C^2}$ | $k = 9 \times 10^9$ |

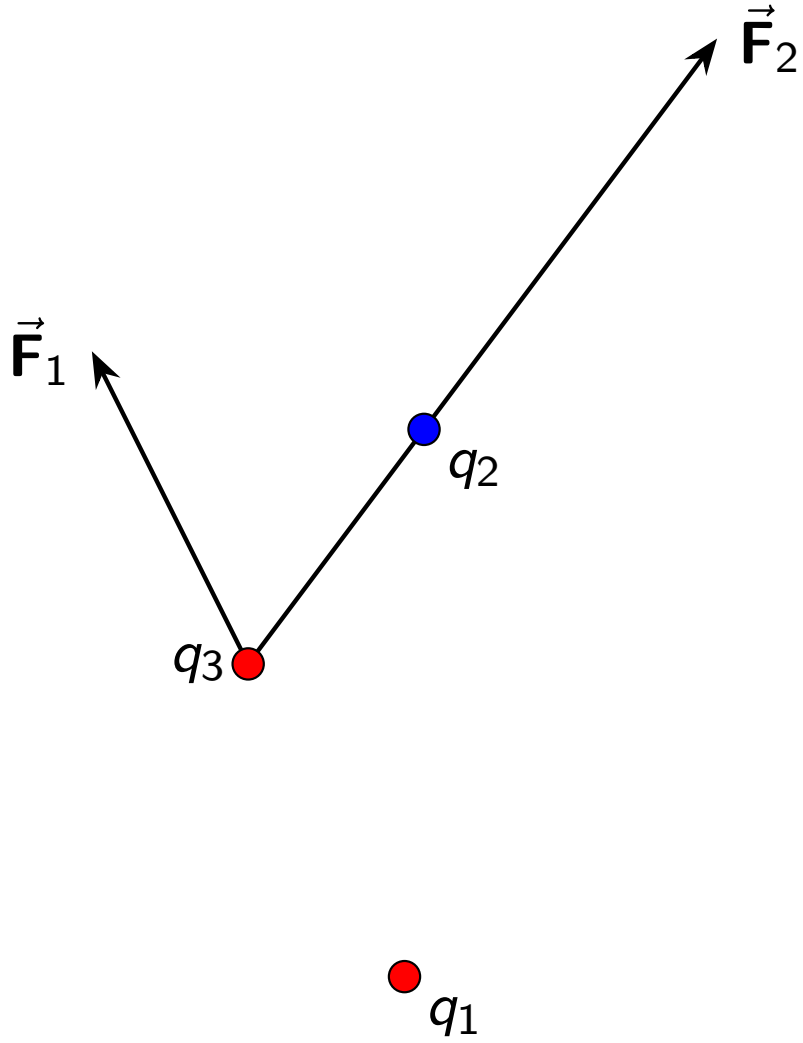
- Why don't we write $F = k\frac{\lvert qQ\rvert}{r^2}\ \mathrm{N}$? Because the units are included in $k$, $q$, $Q$, and $r$.
- $k$, $q$, $Q$, and $r$ are not just numbers. They are quantities with a number and a unit.

# Superposition

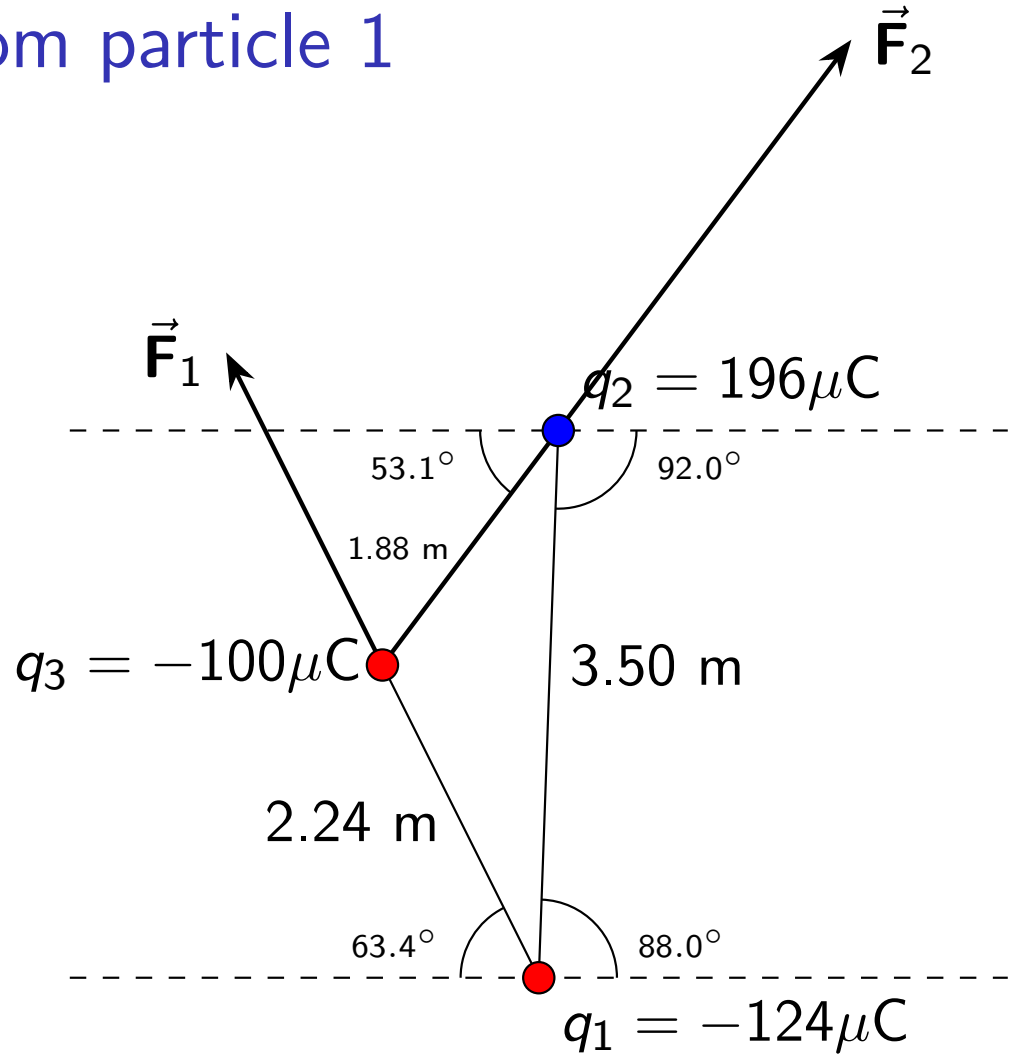
- To find the force on a charged particle produced by two or more other particles, add the forces (as vectors) produced by each other particle alone.
- Find the force on $q_3$ produced by $q_1$ and $q_2$:



# Forces on particle 3: conceptual picture



# Force from from particle 1

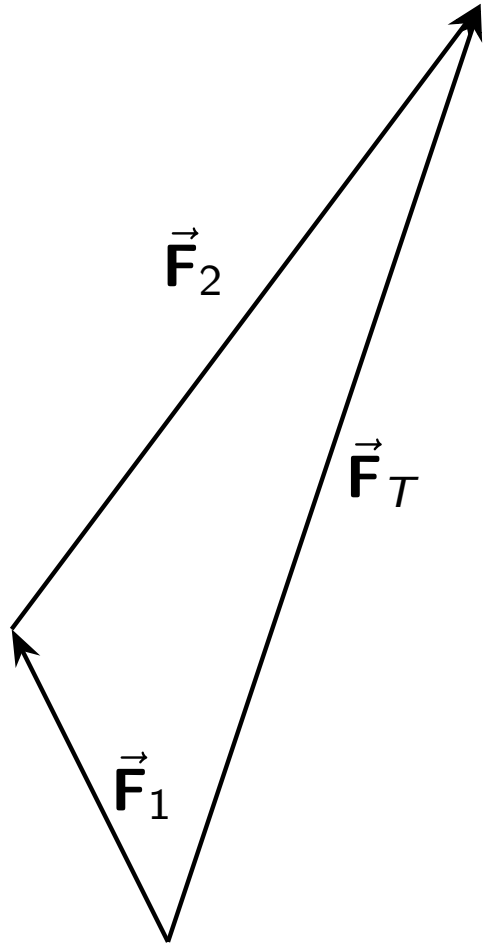



$$F_1 = k\frac{|q_1 q_3|}{r^2} = (9 \times 10^9 \text{ N m}^2/\text{C}^2)\frac{(124 \times 10^{-6} \text{ C})(100 \times 10^{-6} \text{ C})}{(2.24 \text{ m})^2}$$

$$= 22.36 \text{ N}$$

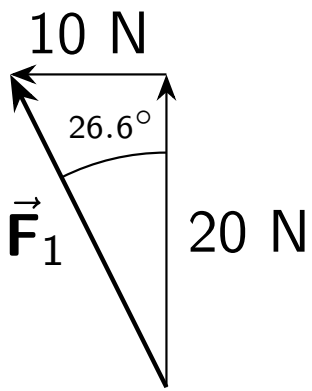
# Add these two vectors

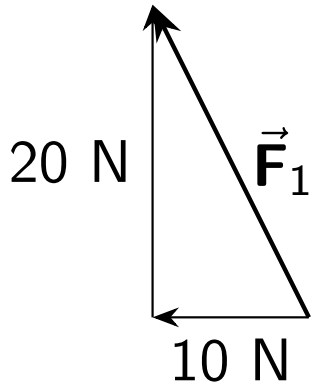
| Force | Magnitude | Angle |
|---|---|---|
| $\vec{\mathbf{F}}_1$ | 22.36 N | 26.6° W of N |
| $\vec{\mathbf{F}}_2$ | 50.00 N | 53.1° N of E |
| $\vec{\mathbf{F}}_T$ | ? | ? |



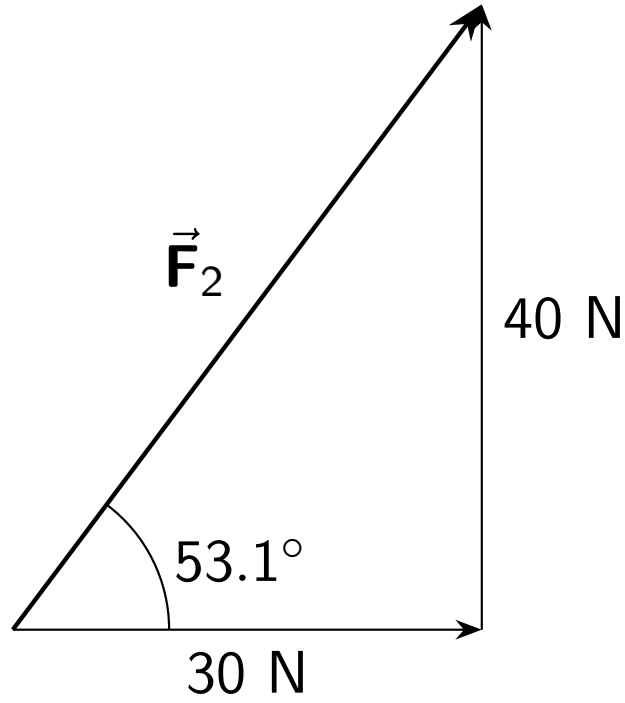

- To add vectors, you can add the components.

# Find components of each vector.



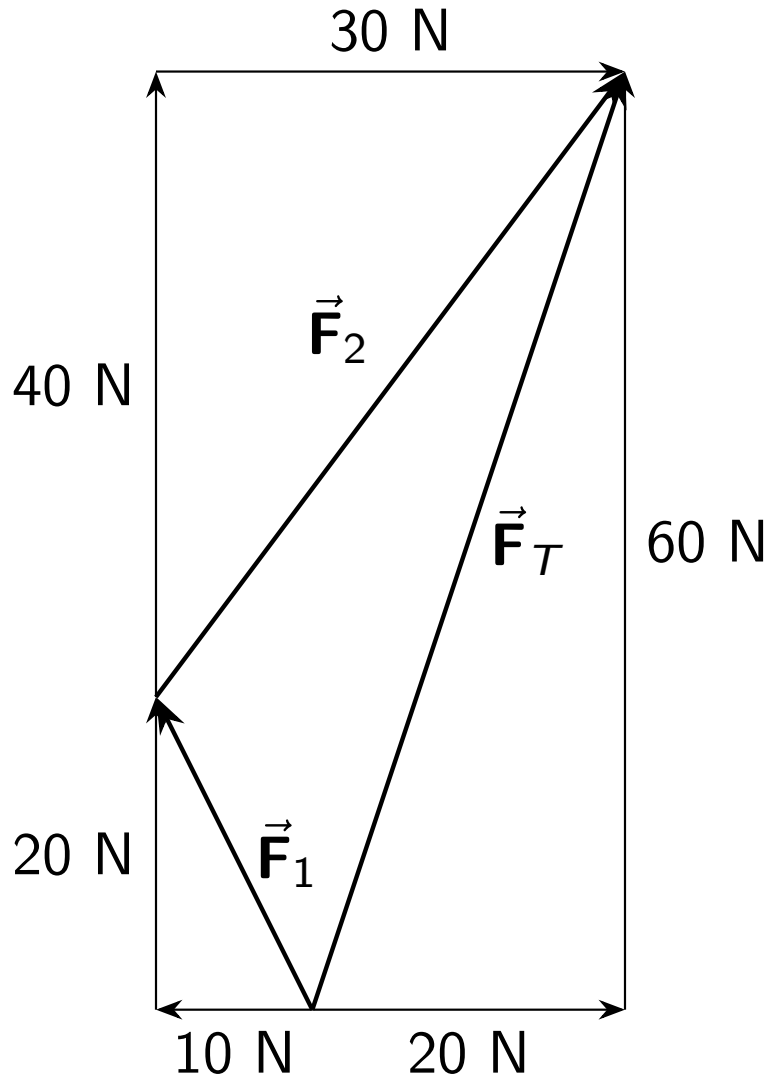




$$F_{1x} = -(22.36\ \text{N}) \sin 26.6^\circ$$
$$= -10\ \text{N}$$
$$F_{1y} = (22.36\ \text{N}) \cos 26.6^\circ$$
$$= 20\ \text{N}$$




$$F_{2x} = (50.00\ \text{N}) \cos 53.1^\circ$$
$$= 30\ \text{N}$$
$$F_{2y} = (50.00\ \text{N}) \sin 53.1^\circ$$
$$= 40\ \text{N}$$

# Why does adding the components work?



# To add vectors, you can add the components.

- Add the $x$ components to get the total $x$ component.
- Add the $y$ components to get the total $y$ component.
- Never add an $x$ to a $y$.
- Convert back to magnitude/angle form if you need/want to.

| Force | Magnitude | Angle | $F_x$ (N) | $F_y$ (N) |
|---|---|---|---|---|
| $\vec{\mathbf{F}}_1$ | 22.36 N | 26.6° W of N | −10 | 20 |
| $\vec{\mathbf{F}}_2$ | 50.00 N | 53.1° N of E | 30 | 40 |
| $\vec{\mathbf{F}}_T$ | 63.25 N | 71.6° N of E | 20 | 60 |