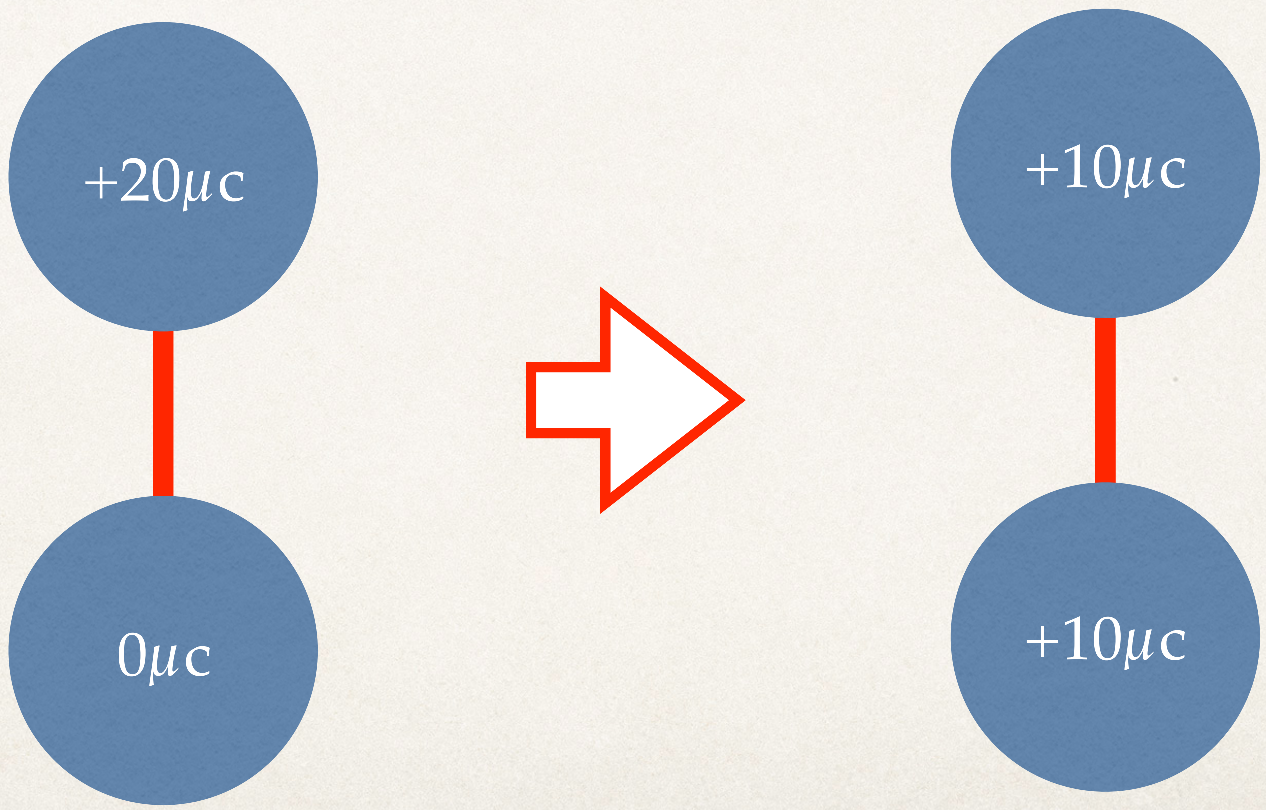
Conduction

- Two Spheres
  - One Positive, One Neutral
  - One Positive, One Neutral + Grounded
  - Two Neutral, charged with a metal rod.

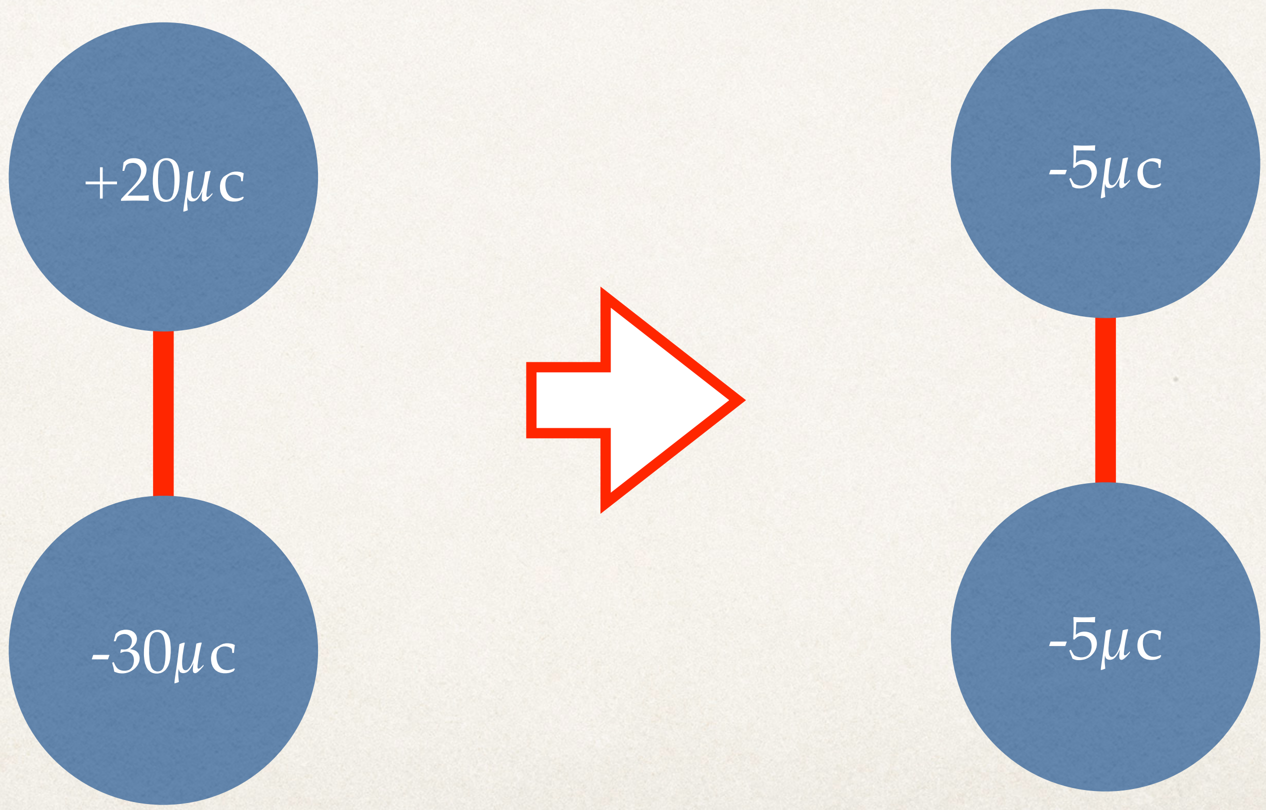
See One

- Two Spheres - One Positive, One Neutral



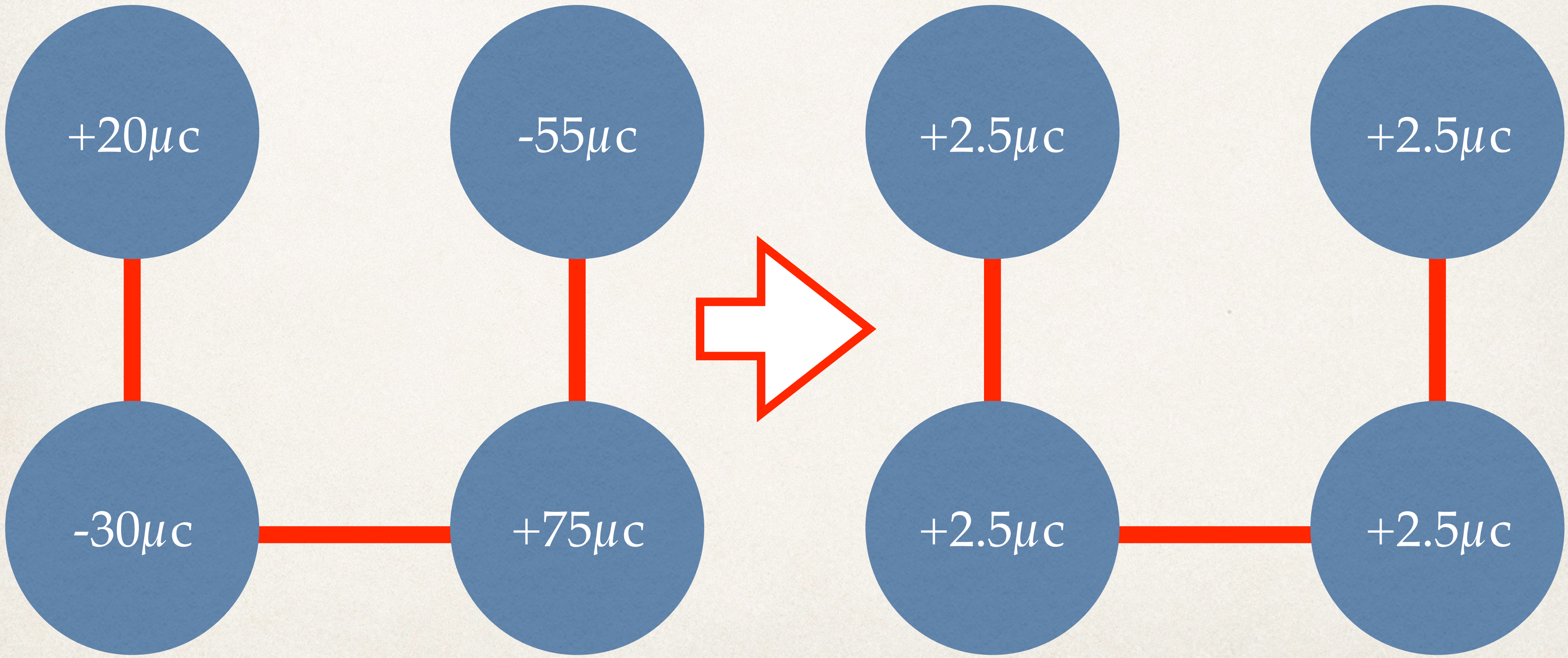
See One

- Two Spheres - One Positive, One Negative



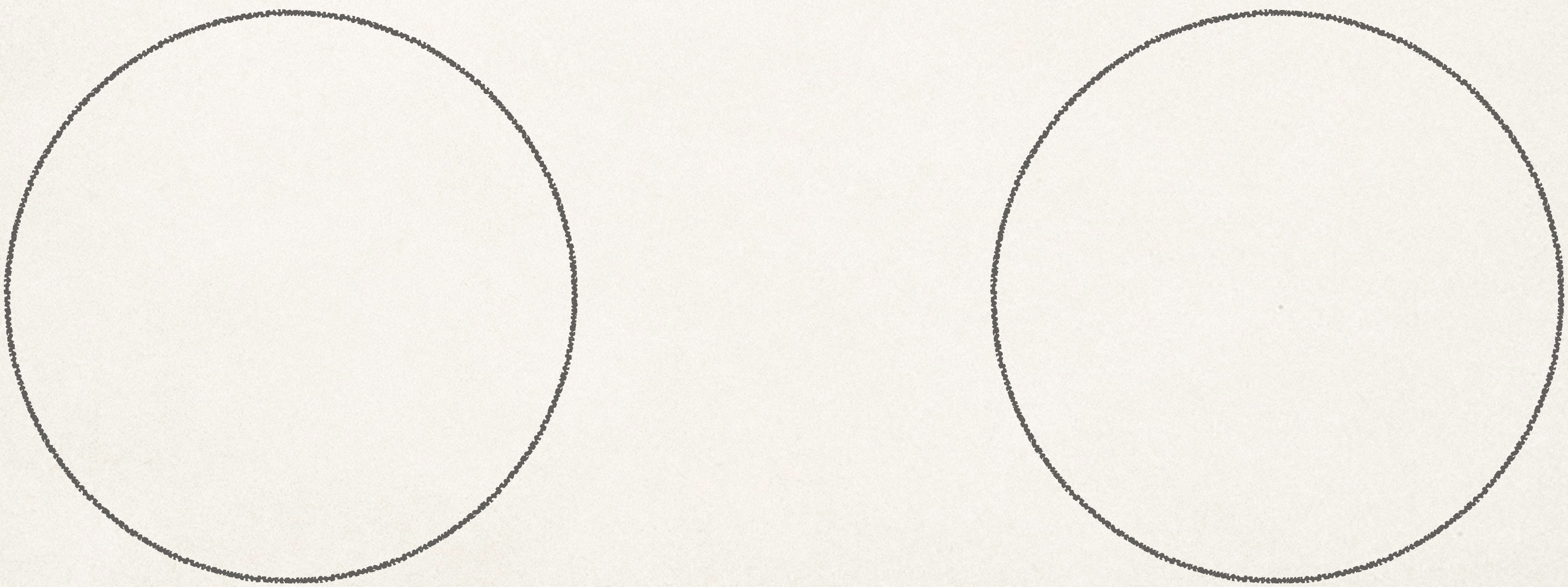
Conduction

- What is the final charge distribution?



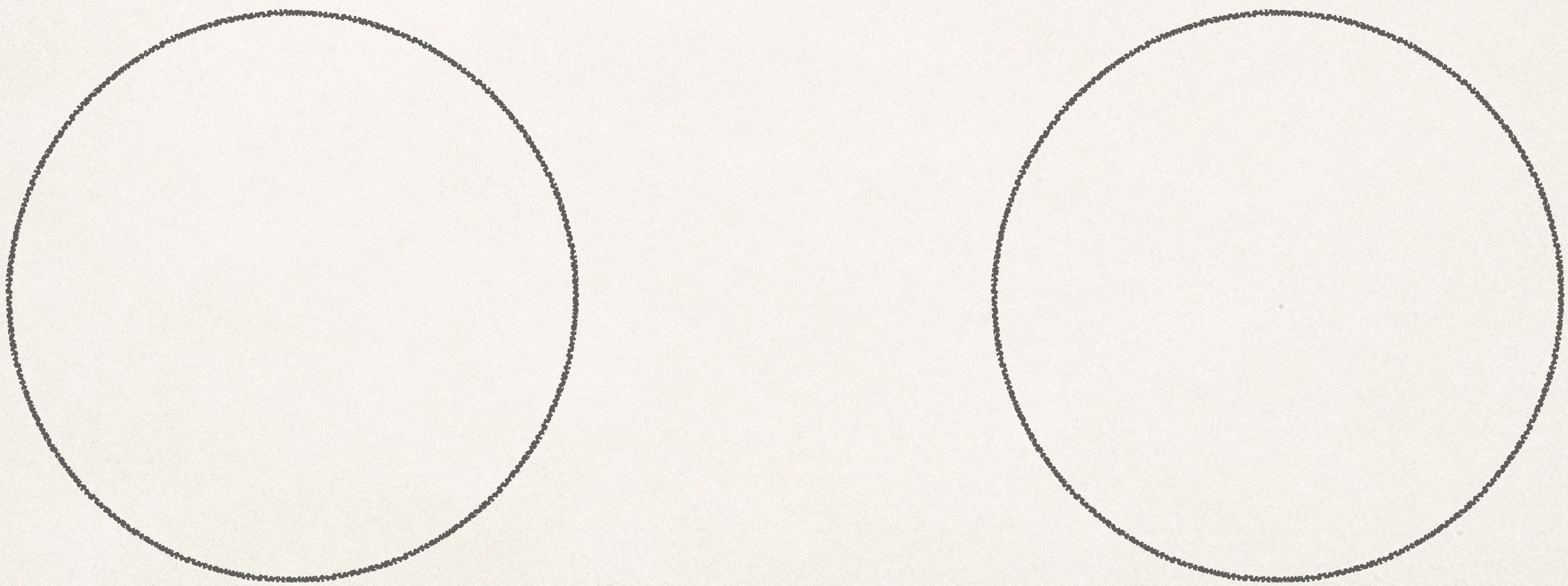
Induction Examples

- Two Spheres - One Positive, One Neutral



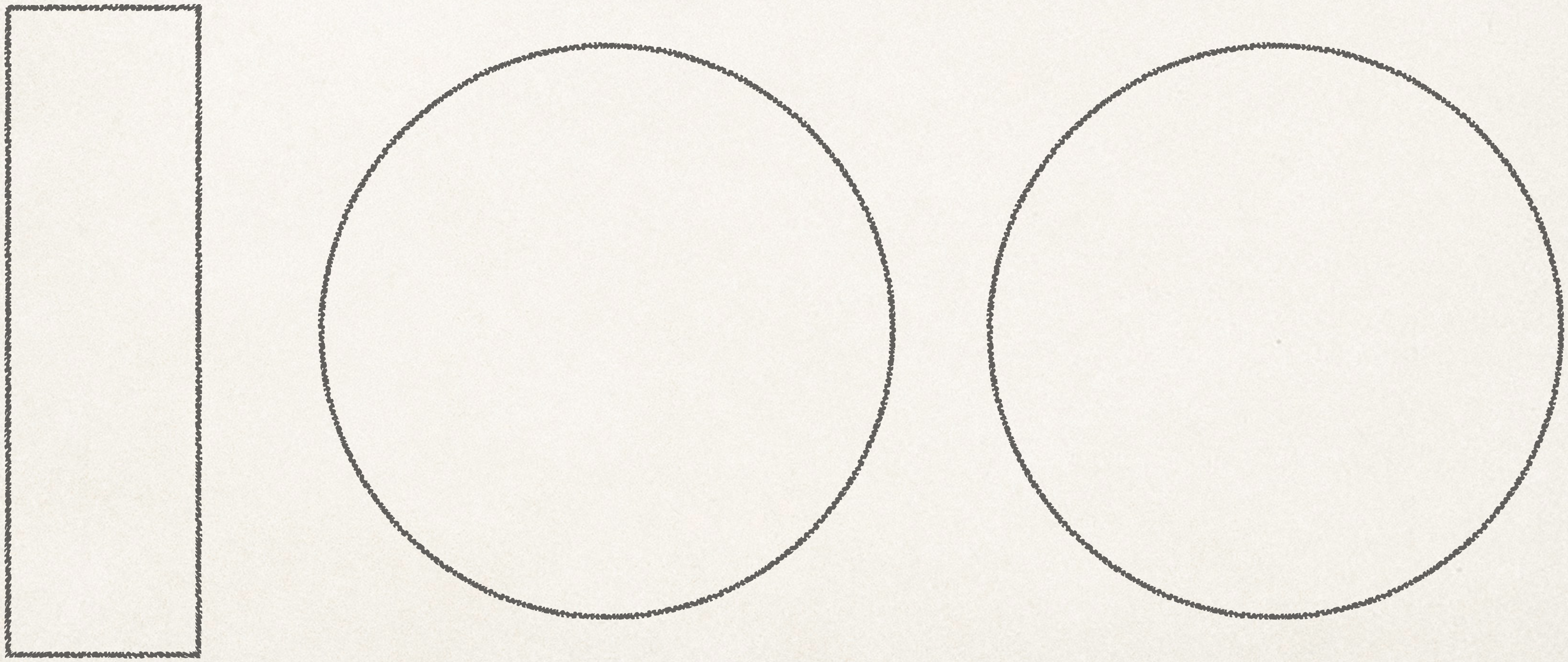
Induction Examples

- Two Spheres - One Positive, One Neutral + Grounded



Induction Examples

- Two Neutral, charged with a metal rod.



Coulomb's Law

- The Magnitude (size) of the force is proportional to the charges and inversely proportional to the distance between the charges.

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

- **NOTE: use the absolute values of the charges and let the geometry of the problem dictate the direction of the forces!**

Coulomb's Law

- $k = \sim 9.0 \times 10^9 \, N \bullet m^2/C^2$
- q = charge in **Coulombs**.
- r = charge separation in **meters**.
- F = force in **Newtons**

adhdheather

to remember how many feet there are in a mile, u just gotta use 5 tomatoes

five to-mate-oes sounds like five, two, eight, 0 and there's 5280 feet in a mile

official-deutschland

To remember how many meters there are in a kilometre you just remember "1000" because the system of measurement in the rest of the world wasn't invented by a drunk mathematician rolling dice.

Charge

- Positive or negative
- Smallest charge is e^- or p^+
  - Charge is quantized
  - $e^- = 1.6 \times 10^{-19}$ Coulombs

See One

- How many electrons make up 1.00 μC of charge?

$$1\,\mu C = 1.00x10^{-6}\,C$$

$$\frac{1.00x10^{-6}\,C}{}\left(\frac{1\,electron}{1.6x10^{-19}\,C}\right) = 6.25x10^{12}!$$

Do One

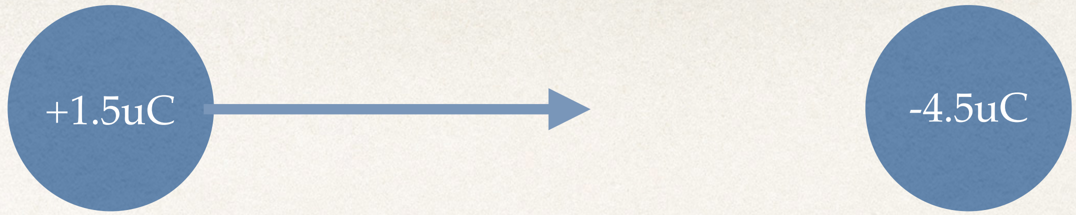
- How much charge in an Avogadro's Number worth of protons?

$$\frac{6.022x10^{23}\ electrons}{}\left(\frac{1.6x10^{-19}C}{1\,electron}\right)=96,352\,C$$

See One

- Two charges, +1.5 μC and - 4.5 μC, are separated by a distance of 10 centimeters. What is the magnitude and direction of the force on the 1.5 μC charge?

See One



- Two charges, +1.5 μC and - 4.5 μC, are separated by a distance of 10 centimeters. What is the magnitude and direction of the force on the 1.5 μC charge?

$$F = k\frac{q_1 q_2}{r^2}$$

$$F = \left(9.00x10^9\right)\frac{\left(1.5x10^{-6}\right)\left(4.5x10^{-6}\right)}{\left(0.1m\right)^2}$$

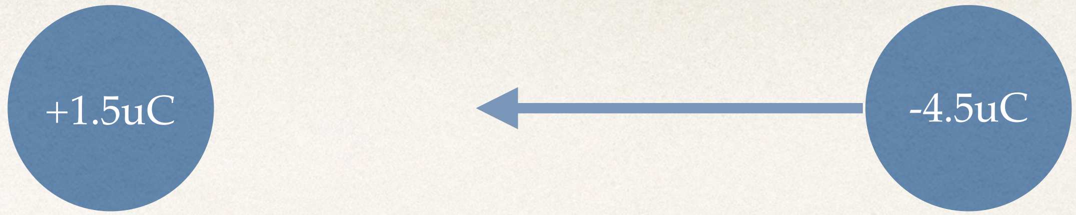
$$\boxed{F = 6.075N}$$

In the +X direction!

See One

- Two charges, +1.5 μC and - 4.5 μC, are separated by a distance of 10 centimeters. What is the magnitude and direction of the force on the 4.5 μC charge?

See One



- Two charges, +1.5 μC and - 4.5 μC, are separated by a distance of 10 centimeters. What is the magnitude and direction of the force on the 4.5 μC charge?

$$F = k\frac{q_1 q_2}{r^2}$$

$$F = \left(9.00x10^9\right)\frac{\left(1.5x10^{-6}\right)\left(4.5x10^{-6}\right)}{\left(0.1m\right)^2}$$

$\boxed{F = 6.075N}$ In the -X direction!

OR…

See One

- Two charges, +1.5 μC and - 4.5 μC, are separated by a distance of 10 centimeters. What is the magnitude and direction of the force on the 4.5 μC charge?

$$F_{-4.5\mu\text{C on }+1.5\mu\text{C}} = -F_{+1.5\mu\text{C on }-4.5\mu\text{C}}$$ 3rd Law!

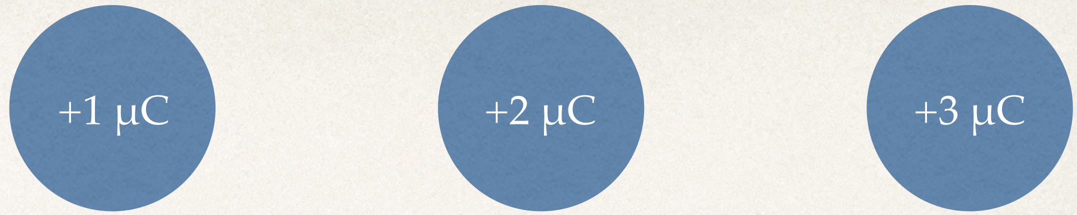
$$F_{-4.5\mu\text{C on }+1.5\mu\text{C}} = 6.075N$$ In the +X direction

$$F_{+1.5\mu\text{C on }-4.5\mu\text{C}} = 6.075N$$ In the -X direction

Extra Credit due Friday

- In solar and lunar eclipses the Sun, Moon, and Earth line up in a straight line. During which eclipse will the **Moon** experience the greatest net force? Calculate the size of the force. Hint: Use the Law of Universal Gravitation!

Extra Practice



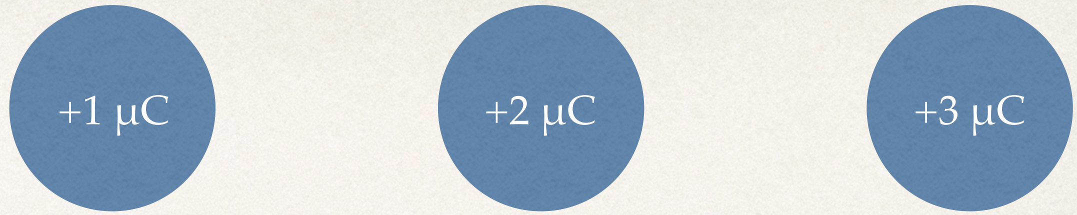
- Three charges: +1 μC, +2 μC, and +3 μC are lined up, in order, along one axis and spaced 15 mm apart. What is the net force on the center charge (2 μC)?

$$F_{1\text{ on }2} = k\frac{q_1 q_2}{r^2}$$

$$F_{1\text{ on }2} = \left(9.00x10^{9}\right)\frac{\left(1x10^{-6}\right)\left(2x10^{-6}\right)}{\left(0.015m\right)^2}$$

$$F_{1\text{ on }2} = 80\ N$$ In the +X direction!

Extra Practice



- Three charges: +1 μC, +2 μC, and +3 μC are lined up, in order, along one axis and spaced 15 mm apart. What is the net force on the center charge (2 μC)?

$$F_{3\text{ on }2} = k\frac{q_1 q_2}{r^2}$$

$$F_{3\text{ on }2} = \left(9.00x10^9\right)\frac{\left(3x10^{-6}\right)\left(2x10^{-6}\right)}{\left(0.015m\right)^2}$$

$$F_{1\text{ on }2} = 240\ N$$ In the -X direction!

Extra Practice

+1 μC   +2 μC   +3 μC

- Three charges: +1 μC, +2 μC, and +3 μC are lined up, in order, along one axis and spaced 15 mm apart. What is the net force on the center charge (2 μC)?

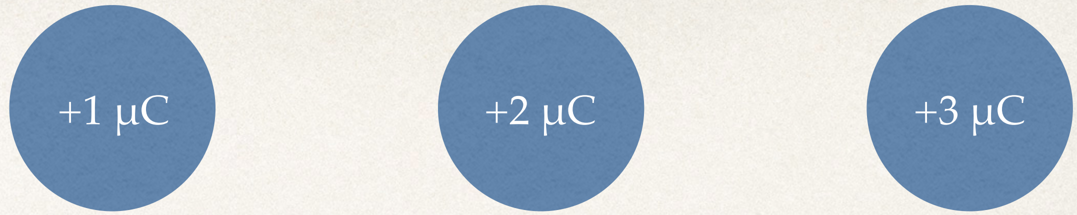
$$F_{net} = F_{1\text{ on }2} + F_{3\text{ on }2}$$

$$F_{net} = 80N(+x) + 240(-x)$$

$$F_{net} = 80N + (-240N) = -160N$$

In the -X direction!

Extra Practice

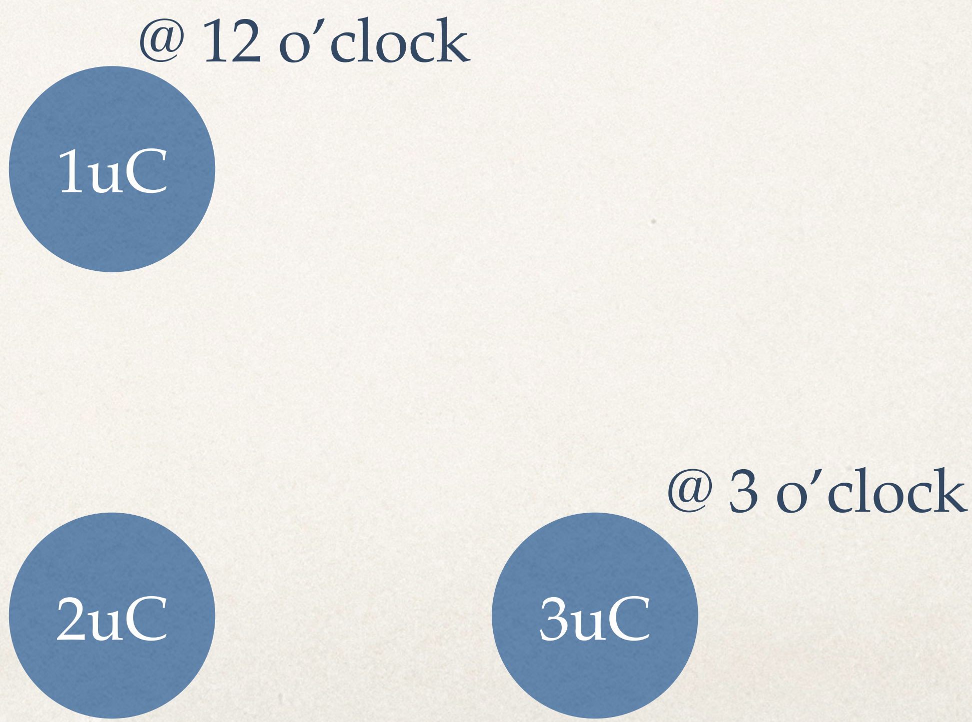


- Three charges: +1 μC, +2 μC, and +3 μC are lined up, in order, along one axis and spaced 15 mm apart. What is the net force on the center charge (2 μC)?

- How could I change this problem to make it slightly different and something I would put on a test?

Extra Practice

- Three charges: 1 μC, 2 μC, and 3 μC are placed on the face of a clock as shown below. The radius of the clock is 25cm. What is the net force on the center charge (2 μC)?

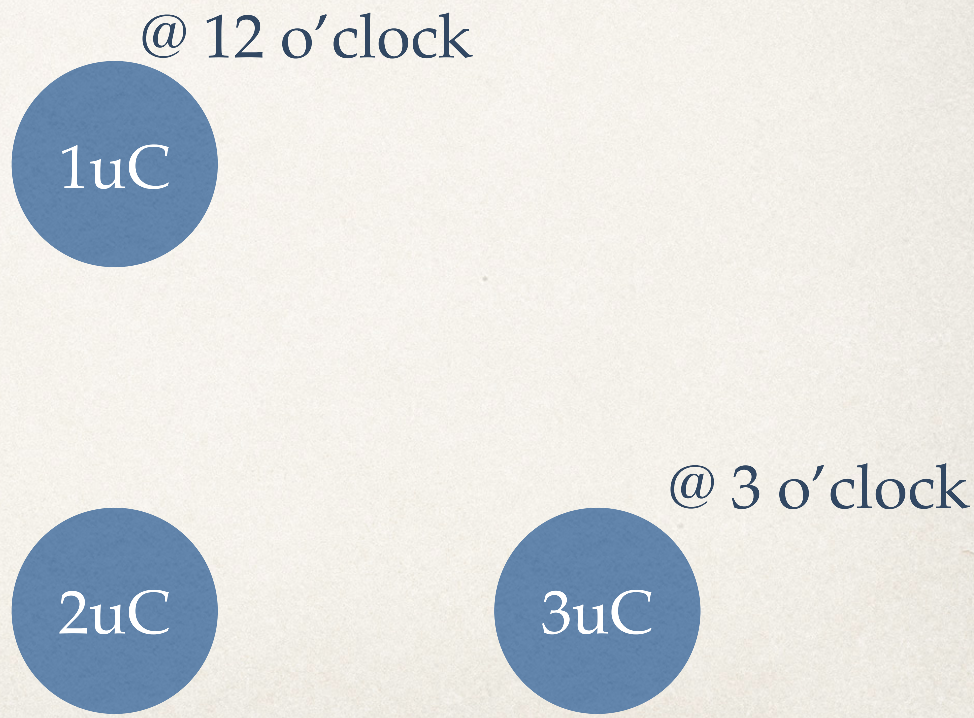


Home Practice (Hints)

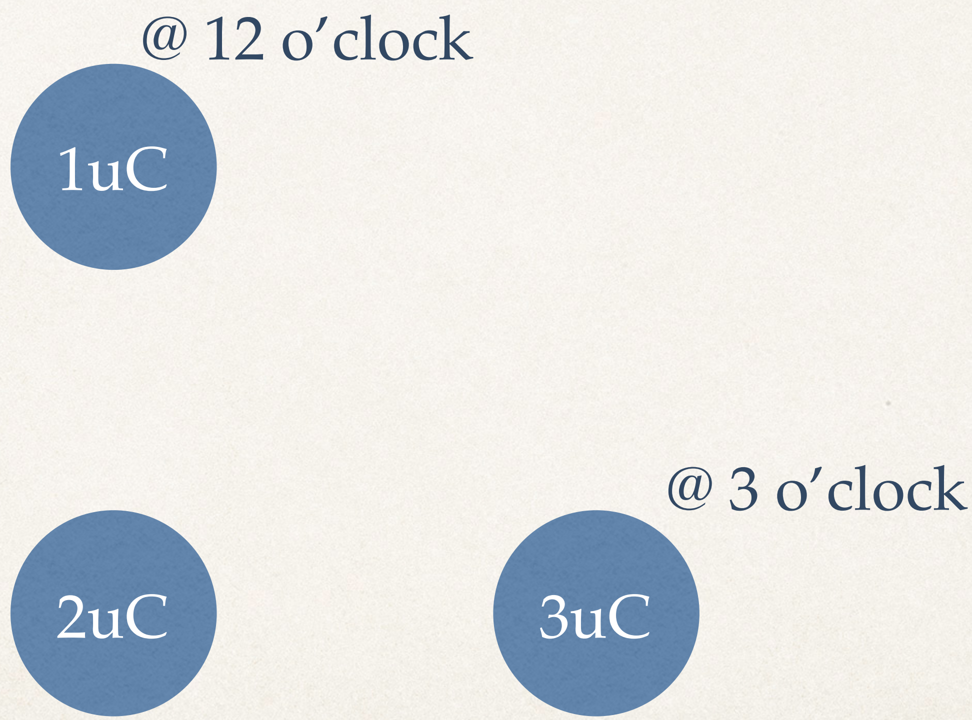
- 1) Determine the sizes of the forces
- 2) Determine the direction of the forces using the geometry (placement) of the charges.
- 3) Break the forces into X and Y components
- 4) Add X forces, Add Y forces,…
- 5) THEN recombine to find the resultant force.

Magnitude of Vectors

- Three charges: 1 μC, 2 μC, and 3 μC are placed on the face of a clock as shown below. The radius of the clock is 25cm. What is the net force on the center charge (2 μC)?

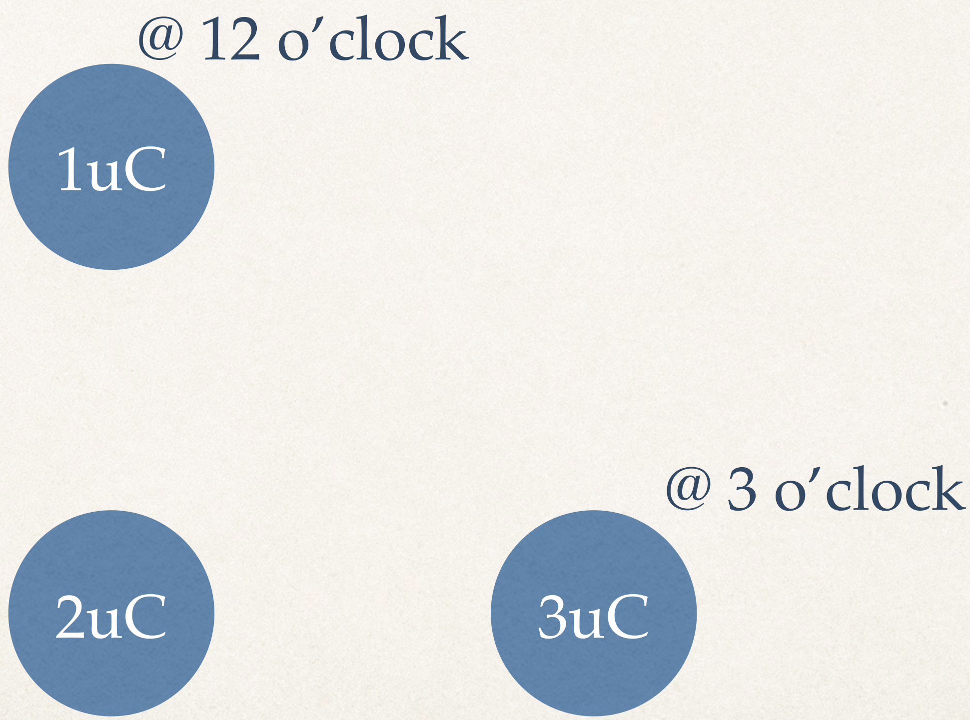


Direction of Vectors

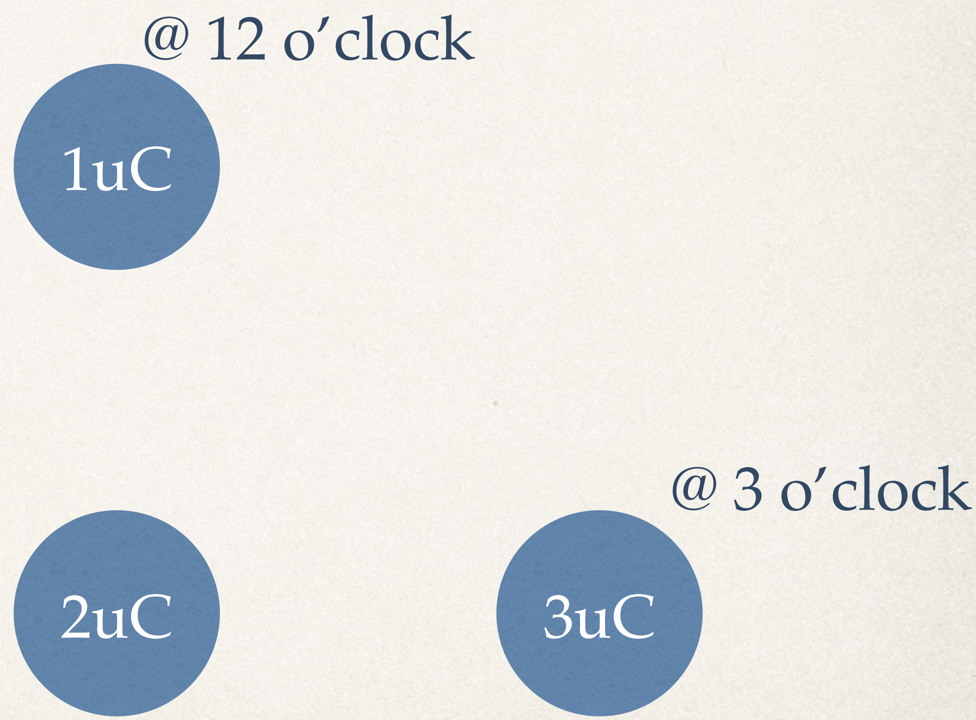


Vector Decomposition

- … if needed

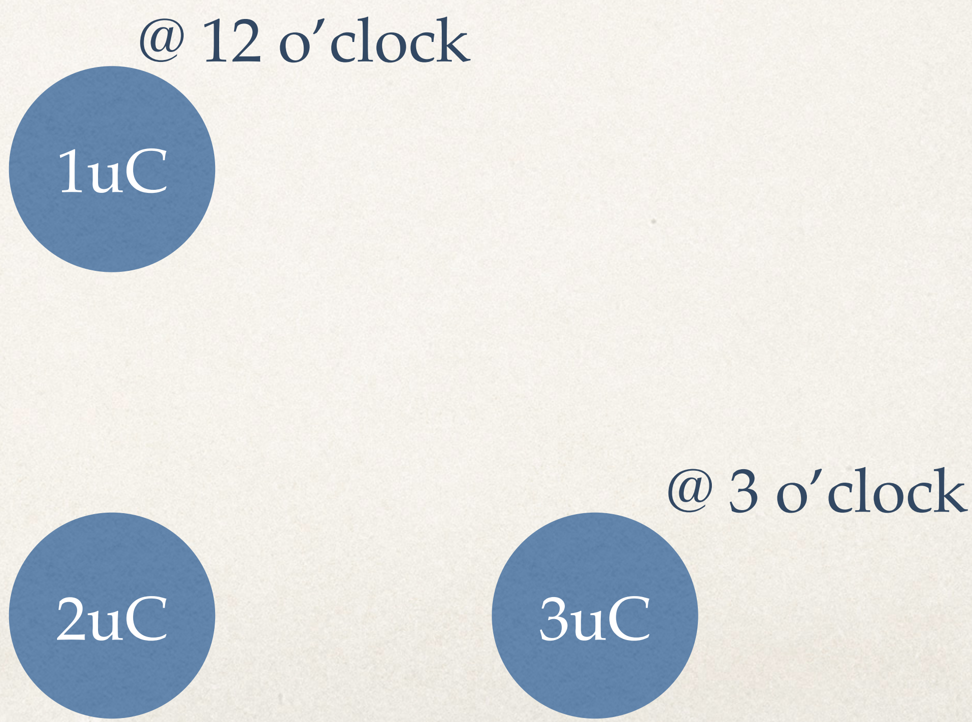


Sum of Component Vectors



Resultant Vector

- Three charges: 1 μC, 2 μC, and 3 μC are placed on the face of a clock as shown below. The radius of the clock is 25cm. What is the net force on the center charge (2 μC)?



Fields

- Created to help understand “action at a distance”
- Electric, Magnetic, Gravitational Fields are all similar, but each have important differences.
- The field tells us how a “test object” would move if brought near the “base object”, but <u>base</u> charge is <u>MOST</u> important.

Gravitational Field

- Field is always towards the mass.
- "Test mass" always moves in the direction of the field.
- KEY: there is only one type of mass so Gravitational Fields are easy.

Electric Field

- The field tells us how a “test charge” would move if brought near the “base” charge, but “base” charge is MOST important.
- Measured in N/C

Electric Fields

- Any **Positive** "Base" Charge will be a <u>SOURCE</u> of an E-Field.
- Any **Negative** "Base" Charge will be a <u>SINK</u> of an E-Field.
  - E and F are <u>parallel</u> for a positive (+) test-charge,
  - E and F are <u>anti-parallel</u> for a negative (-) test-charge

Coulomb's Law (Revisited)

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

assume

$$q_1 = Q \text{ (Base)}$$

$$q_2 = q \text{ (test)}$$

$$\boxed{F = k\frac{|Q||q|}{r^2}}$$

Electric Field

- Assumes the test charge is really small. (limit q→0)

$$\vec{E} = \frac{\vec{F}}{q}$$

assume

$$\boxed{E = k\frac{|Q|}{r^2}}$$

- Be prepared to use BOTH equations!

Electric Field

- Assumes the test charge is really small. (limit $q \to 0$)

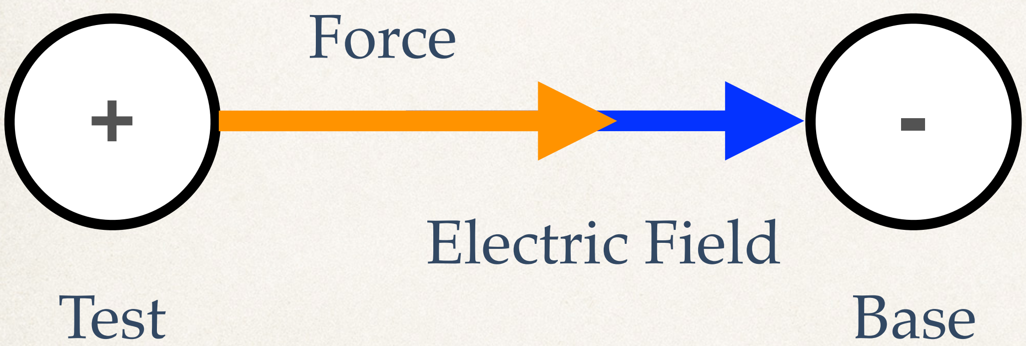
$$\vec{E} = \frac{\vec{F}}{q}$$

(or)

$$\vec{F} = q\vec{E}$$

See One (The Hard Way)

- Find the magnitude and direction of the E-Field and the force on a proton at 1.0 meters from an electron.

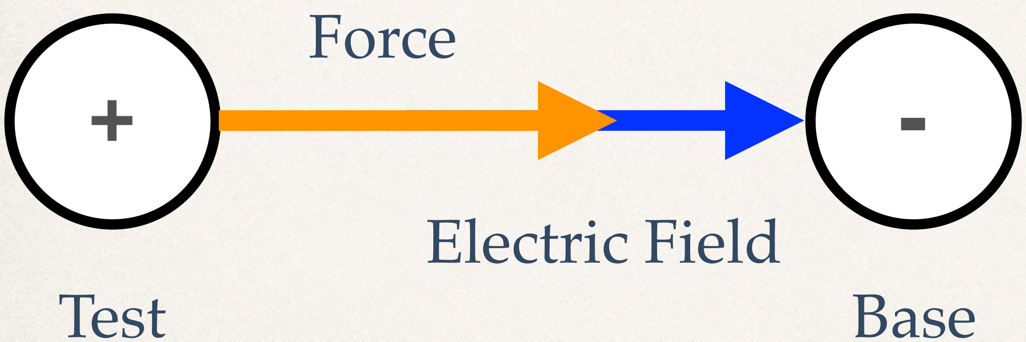


$$F = k\frac{|Q||q|}{r^2}$$

$$F = \left(9x10^9 \ \frac{N \bullet m^2}{C^2}\right)\frac{\left(1.6x10^{-19}\ \mathrm{C}\right)\left(1.6x10^{-19}\ \mathrm{C}\right)}{\left(1\ \mathrm{m}\right)^2} = \boxed{2.3x10^{-28}\ \mathrm{N}}$$

See One (The Hard Way)

- Find the magnitude and direction of the E-Field and the force on a proton at 1.0 meters from an electron.



$$E = k\frac{|Q|}{r^2}$$

$$E = \left(9x10^{9}\ \frac{N \bullet m^2}{C^2}\right)\frac{\left(1.6x10^{-19}\ \mathrm{C}\right)}{\left(1\ \mathrm{m}\right)^2} = \boxed{1.44x10^{-9}\ \mathrm{N}/C}$$

See One (The Easy Way)

$$F = 2.3x10^{-28}\ \text{N}$$

$$E = 1.44x10^{-9}\ {}^{N}\!/\!_{C}$$

- Find the magnitude and direction of the E-Field and the force on a proton at 1.0 meters from an electron. (assume test charge is positive)

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E} = \frac{2.3x10^{-28}\ \text{N}}{1.6x10^{-19}\ \text{C}}$$

$$\boxed{E = 1.44x10^{-9}\ {}^{N}\!/\!_{C}}$$

$$\vec{F} = q\vec{E}$$

$$\vec{F} = \left(1.6x10^{-19}\ C\right)\left(1.44x10^{-9}\ {}^{N}\!/\!_{C}\right)$$

$$\boxed{F = 2.3x10^{-28}\ \text{N}}$$

Group Work

- Find the magnitude and direction of the E-Field at point in the middle between two +10 μC charges?

- Find the magnitude and direction of the E-Field at point in the middle between two charges, +10 μC and -10 μC?