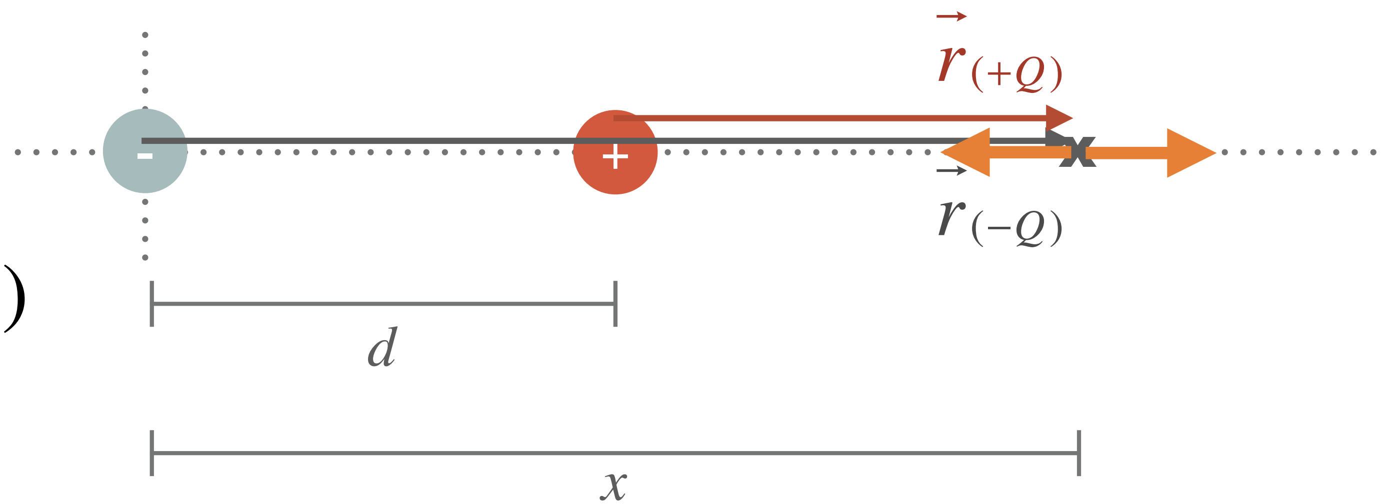
CHAPTER 21 – ELECTRIC FORCES DUE TO MULTIPLE CHARGES

EXAMPLE PROBLEM Principle of Superposition

Taking the location of the negative charge as the origin, which location along the positive x axis is the total electric force on a test charge $+q$ zero? The charges are $-3\mu C$ *and* $+1\mu C$ *separated by 0.3mm.*

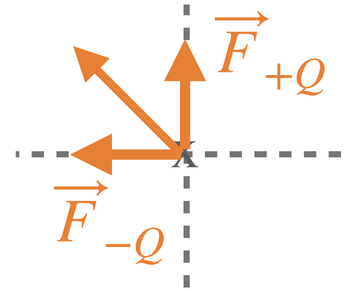


$$\left|\vec{r}_{(+Q)}\right| = (x - d)$$

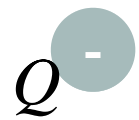
$$\left|\vec{r}_{(-Q)}\right| = x$$

CHAPTER 21 – ELECTRIC FORCES DUE TO MULTIPLE CHARGES

MAGNITUDE OF ELECTRIC FORCE Principle of Superposition

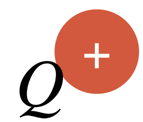


Strategy:



1. *Draw the electric force at the observation location due to each charge*

2. *Determine the vector components of the total electric force, using the diagram as a guide*



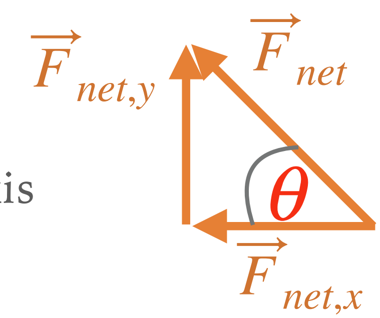
$$\vec{F} = |\vec{F}|\hat{F} \qquad \vec{F}_{net} = \vec{F}_{-Q} + \vec{F}_{+Q} = |\vec{F}_{-Q}|(-\hat{i}) + |\vec{F}_{+Q}|(+\hat{j})$$

$$\vec{F}_{net} = -\frac{kQ_{-}q}{r_{-}^2}\hat{i} + \frac{kQ_{+}q}{r_{+}^2}\hat{j}$$

3. *Determine the magnitude and direction of the net electric force*

$$|\vec{F}_{net}| = \sqrt{\left(\frac{kQ_{-}q}{r_{-}^2}\right)^2 + \left(\frac{kQ_{+}q}{r_{+}^2}\right)^2} \qquad \theta = \tan^{-1}\left(\frac{F_{net,y}}{F_{net,x}}\right)$$

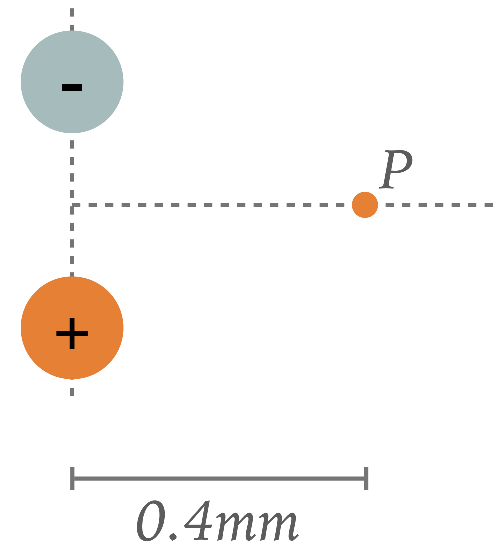
clockwise from **-x** axis



CHAPTER 21 – ELECTRIC FORCES

Superposition Numerical Example Problem

A dipole consisting of two charges, $q1$=-6.2μC and $q2$=+6.2μC are separated by 0.6 mm. A proton is placed at location P. What is the magnitude and direction of the ***net electric force on the proton?***

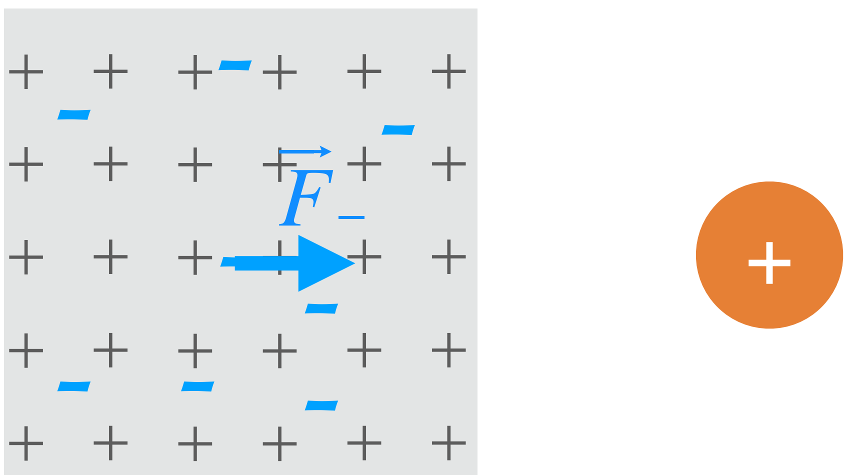


CHAPTER 21 – ELECTRIC FORCES AND NEUTRAL MATTER

Neutral Matter Conductors and Insulators

Conductors - Charge carriers free to move. Excess charge resides on surface.

Insulators - Polarization of atoms induces a temporary dipole. Excess charge is immobile.



Neutral ***Conductor***

CHAPTER 21 - ELECTRIC FORCES AND NEUTRAL MATTER

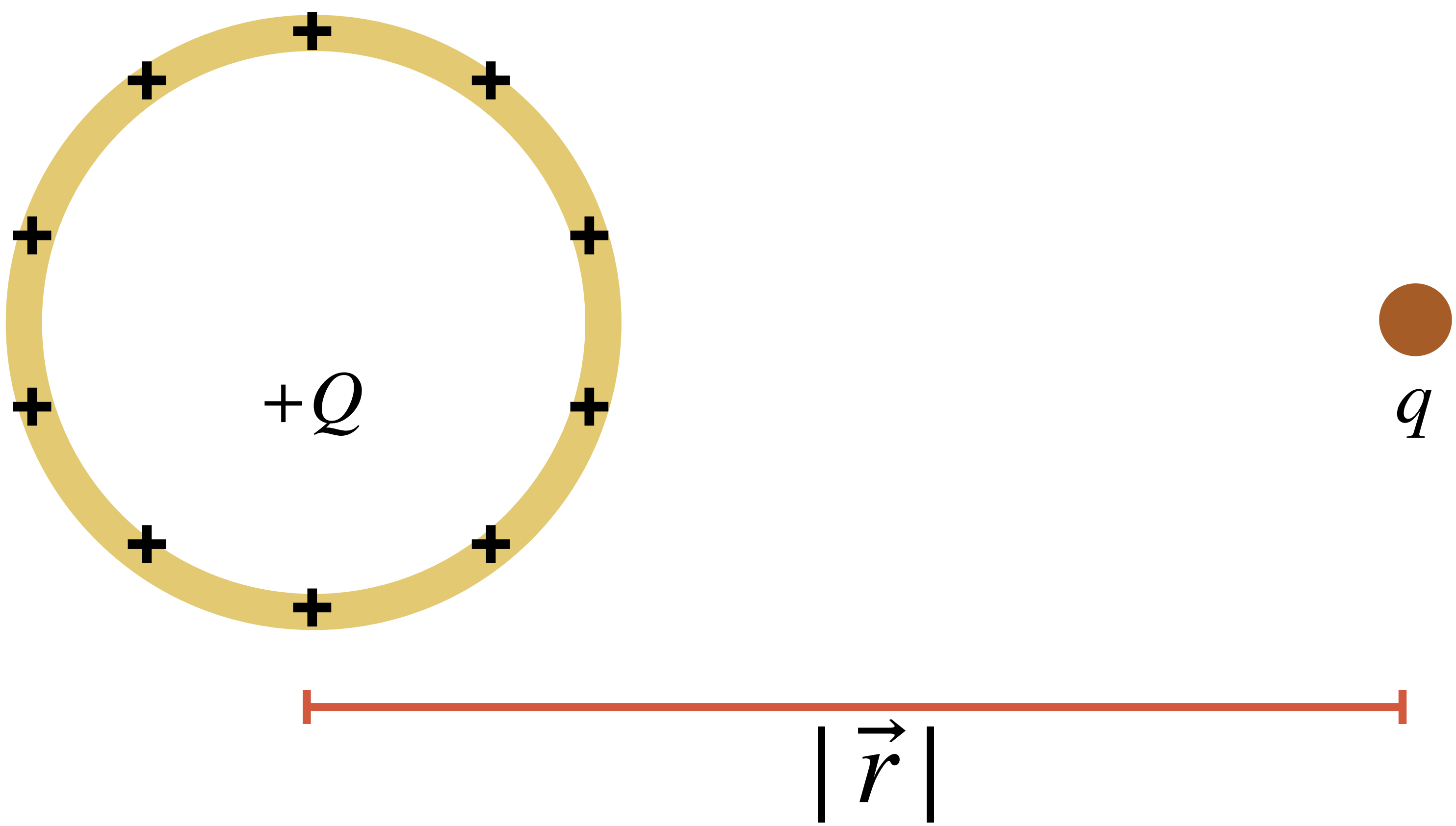
Conductors - Charge carriers free to move. Excess charge resides on surface.

Insulators - Polarization of atoms induces a temporary dipole. Excess charge is immobile.

Neutral ***Insulator***

Shell Theory

Theorem 1. *Charged particles* ***outside*** *of a shell, with a uniform charge distribution on its surface, is attracted or repelled* ***as if the shell's charge were concentrated at its center.***

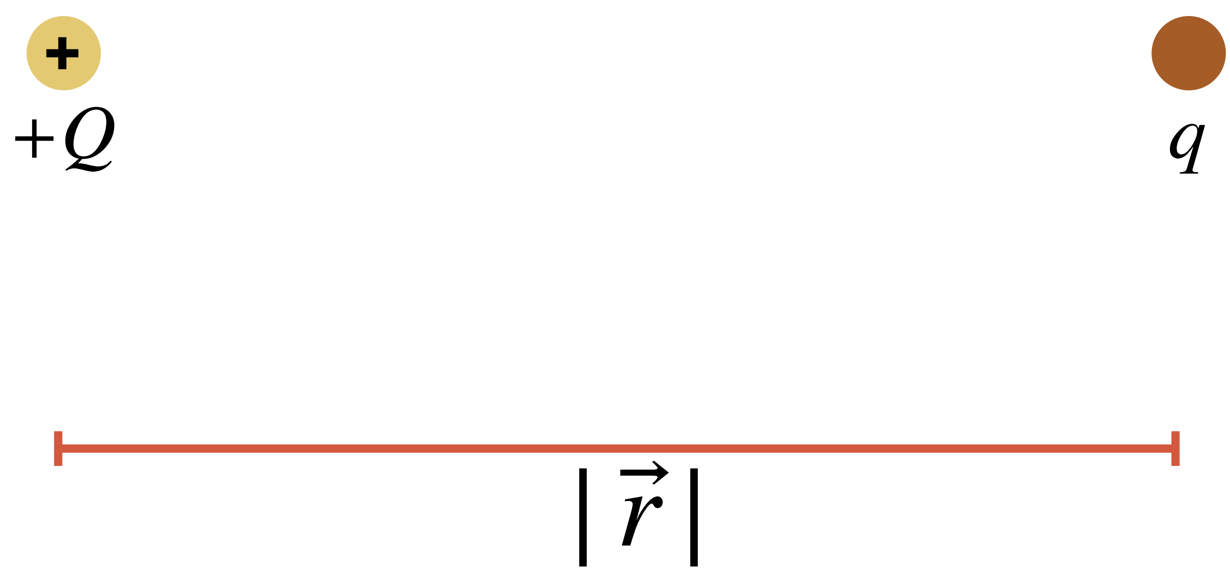


CHAPTER 21 – ELECTRIC FORCES

Shell Theory

Theorem 1. *Charged particles* ***outside*** *of a shell, with a uniform charge distribution on its surface, is attracted or repelled* ***as if the shell's charge were concentrated at its center.***

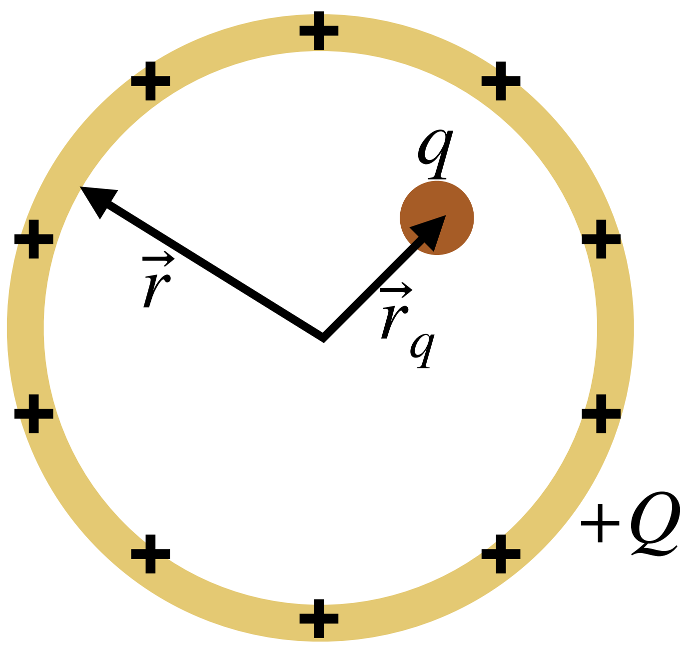
$$\overrightarrow{F}_{el} = \frac{1}{4\pi\epsilon_0}\frac{Qq}{|\vec{r}|^2}\hat{r}$$



Shell Theory

Theorem 1. *Charged particles* ***outside*** *of a shell, with a uniform charge distribution on its surface, is attracted or repelled* ***as if the shell's charge were concentrated at its center.***

Theorem 2. *A charged particle inside a shell with a charge uniformly distributed over its surface as no net force acting on it due to the shell.*



$$\overrightarrow{F}_{el} = \overrightarrow{0}$$

Example Problem

Two small positively charged spheres have a combined charge of 25.0E-5 C. If each sphere is repelled from the other by an electrostatic force of 1.0 N when the spheres are 1.6 m apart, what is the charge on the sphere with the smaller charge?

CHAPTER 21 – ELECTRIC FORCES

Example Problem

In a spherical metal shell of radius R, an electron is shot from the center directly towards a tiny hole in the shell, through which it escapes. The shell is negatively charged with a surface charge density of 6.9E-13 C/m^2. What is the electron's acceleration after traveling a distance of $r = 0.5R$, and $r = 2.0R$?