Announcements Jan 11

• Yes the University is open all day (?)

• Webassign Online forum schedule:
  – Fri, Sat, Sun, Mon. evenings 7-10pm before a homework is due on a Tuesday morning
  – See web site

• Help labs have started
  – See course web page for details
Example  A Model of the Hydrogen Atom

In the Bohr model of the hydrogen atom, the electron is in orbit about the nuclear proton at a radius of $5.29 \times 10^{-11}$ m. Determine the speed of the electron, assuming the orbit to be circular.
### Example: A Model of the Hydrogen Atom

In the Bohr model of the hydrogen atom, the electron is in orbit about the nuclear proton at a radius of $5.29 \times 10^{-11}$ m. **Determine the speed of the electron**, assuming the orbit to be circular.

The force on the electron is exerted by the proton, as given by Coulomb’s Law

$$F = k \frac{|q_1||q_2|}{r^2} = \left(\frac{8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2}{5.29 \times 10^{-11} \text{ m}}\right)^2(1.60 \times 10^{-19} \text{ C})^2 = 8.22 \times 10^{-8} \text{ N}$$

But the SAME force is responsible for the centripetal motion

$$F = ma_c = \frac{mv^2}{r}$$

Solving for $v$ gives

$$v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{(8.22 \times 10^{-8} \text{ N})(5.29 \times 10^{-11} \text{ m})}{9.11 \times 10^{-31} \text{ kg}}} = 2.18 \times 10^6 \text{ m/s}$$
18.5 Coulomb’s Law

**Example Three Charges on a Line**

Determine the magnitude and direction of the net force on $q_1$. 

(a) Charges on a line

(b) Free-body diagram for $q_1$
18.5 Coulomb's Law

**Example Three Charges on a Line**

Determine the magnitude and direction of the net force on \( q_1 \).

\[
F_{ij} = \left| \vec{F}_{ij} \right| = k \frac{|q_i| |q_j|}{r_{ij}^2}
\]

where \( r_{ij} \) represents the distance between \( q_i \) and \( q_j \).

\[
F_{12} = k \frac{|q_1| |q_2|}{r_{12}^2} = \left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right) \left(3.0 \times 10^{-6} \text{ C}\right) \left(4.0 \times 10^{-6} \text{ C}\right) \left(0.20 \text{ m}\right)^2 = 2.7 \text{ N}
\]

\[
F_{13} = k \frac{|q_1| |q_3|}{r_{13}^2} = \left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right) \left(3.0 \times 10^{-6} \text{ C}\right) \left(7.0 \times 10^{-6} \text{ C}\right) \left(0.15 \text{ m}\right)^2 = 8.4 \text{ N}
\]

\[
\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} = -2.7\hat{i} + 8.4\hat{i} = +5.7\hat{i}
\]

Here \( \hat{i} \) denotes the unit vector in the + x direction.
Example Three Charges not in line
Assuming the horizontal to be the x-direction, and vertical the y-direction, determine the magnitude and direction of the net force on $q_1$. 

![Diagram of three charges not in line with distances and angles labeled.](image)
Example Three Charges not in line
Assuming the horizontal to be the x-direction, and vertical the y-direction, determine the magnitude and direction of the net force on $q_1$. 

\[
\begin{align*}
q_1 & \quad 4.0 \ \mu C \\
q_2 & \quad -6.0 \ \mu C \\
q_3 & \quad -5.0 \ \mu C
\end{align*}
\]
Example Three Charges not in line

Assuming the horizontal to be the x-direction, and vertical the y-direction, determine the magnitude and direction of the net force on \( q_1 \)

Solution: First we apply the Inverse Square (Coulomb’s) Law to find the magnitudes of the two forces on \( q_1 \):

\[
F_{ij} = \lvert \vec{F}_{ij} \rvert = k \left| \frac{q_i}{r_{ij}^2} \right| q_j
\]

where \( r_{ij} \) represents the distance between \( q_i \) and \( q_j \)

\[
F_{12} = k \frac{q_1}{r_{12}^2} \frac{q_2}{2} = \frac{8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \cdot 4.0 \times 10^{-6} \text{ C} \cdot 6.0 \times 10^{-6} \text{ C}}{(0.15 \text{ m})^2} = 9.59 \text{ N}
\]

\[
F_{13} = k \frac{q_1}{r_{13}^2} \frac{q_3}{2} = \frac{8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \cdot 4.0 \times 10^{-6} \text{ C} \cdot 5.0 \times 10^{-6} \text{ C}}{(0.10 \text{ m})^2} = 17.98 \text{ N}
\]
18.5 Coulomb’s Law

The resulting force $F$ on $q_1$ is the vector sum of the forces exerted by charges $q_2$ and $q_3$. We make this sum component by component:

Both forces are attractive here, with directions indicated in the figure to the left

$$F_x = +F_{12} \cos \theta_2 + F_{13} \cos \theta_3$$

$$= (9.59 \text{ N}) \cos(73^\circ) + (17.95 \text{ N}) \cos(0^\circ)$$

$$= 2.80 \text{ N} + 17.95 \text{ N} = 20.75 \text{ N}$$

$$F_y = +F_{12} \sin \theta_2 + F_{13} \sin \theta_3$$

$$= (9.59 \text{ N}) \sin(73^\circ) + (17.95 \text{ N}) \sin(0^\circ)$$

$$= 9.17 \text{ N} + 0 = 9.17 \text{ N}$$

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(20.75 \text{ N})^2 + (9.17 \text{ N})^2} = 23 \text{ N}$$

Angle of $\vec{F}$ counter-clock-wise from the $+x$-axis:

$$\theta = \tan^{-1} \left| \frac{F_y}{F_x} \right| = \tan^{-1} (0.442) = 24^\circ$$
18.6 The Electric Field

**DEFINITION OF ELECTRIC FIELD**

The electric field that exists at a point is the electrostatic force experienced by a (small) test charge \( q_0 \) placed at that point divided by the charge \( q_0 \) itself:

\[
\vec{E} = \frac{\vec{F}}{q_0}
\]

**SI Units of Electric Field:** newton per coulomb (N/C)

**NOTE:** It is the surrounding charges that create the electric field at a given point. The effect of the test charge itself is NEVER included in this definition.

![Diagram of electric field](image-url)