Electricity and Magnetism

- Physics 259 – L02
- Lecture 5

Section 21.1

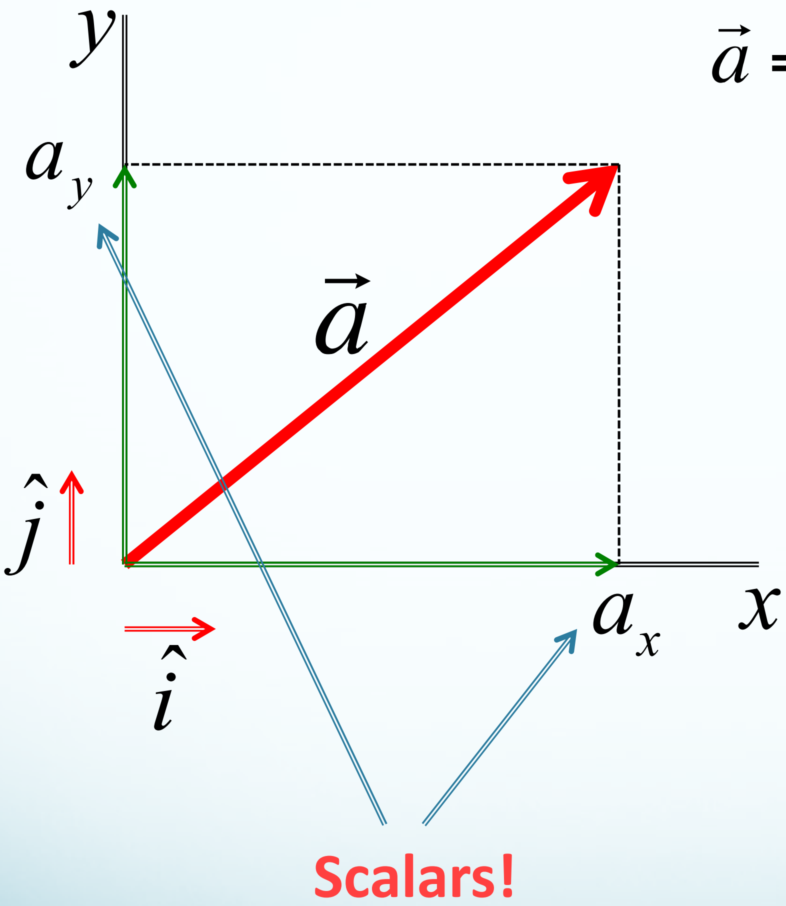
Last time

- Charges and Force Between Charges
- Conductors and Insulators
- Basics of Coulomb's Law
- Van De Graaff Generator Experiment 
- Class Activity

This time

- Solve Class Activity Question
- Coulomb's Law
- Examples

Vector Components



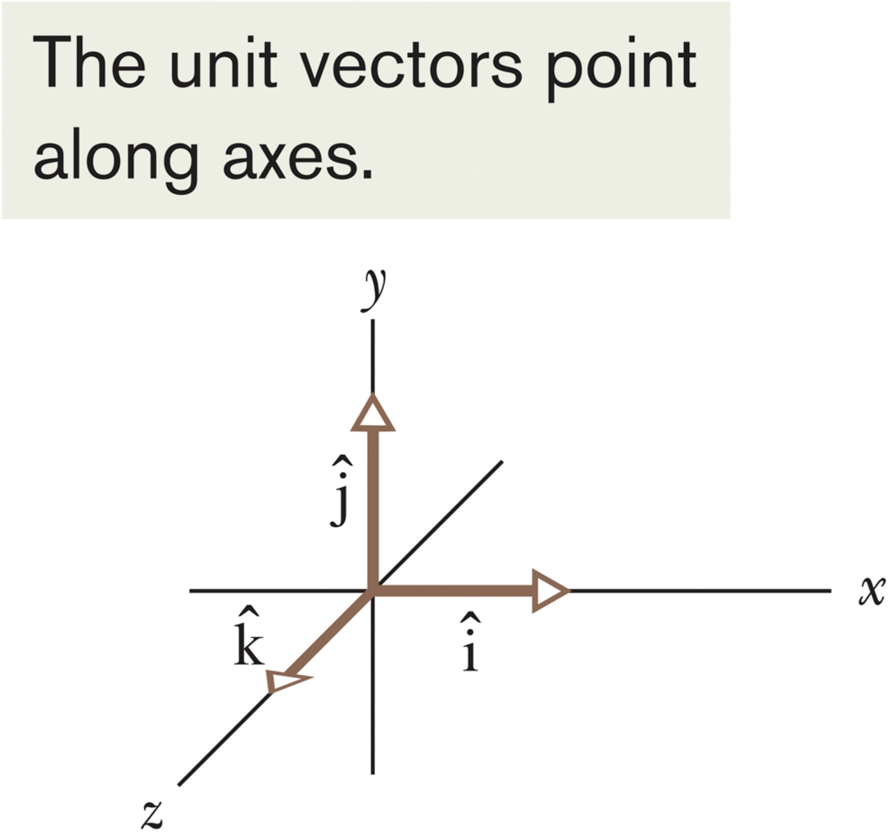
$$\vec{a} = a_x\hat{i} + a_y\hat{j}$$

$$|\vec{a}| = \sqrt{a_x^2 + a_y^2}$$

$$a_y = a\sin\theta$$

$$a_x = a\cos\theta$$

Unit vectors



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Unit→
Size→
Direction→

Class Activity

(10 marks) In a two dimensional Cartesian system $\hat{r}$ is located 30° north of east. What is the mathematical expression for $\hat{r}$ in terms of Cartesian unit vectors?

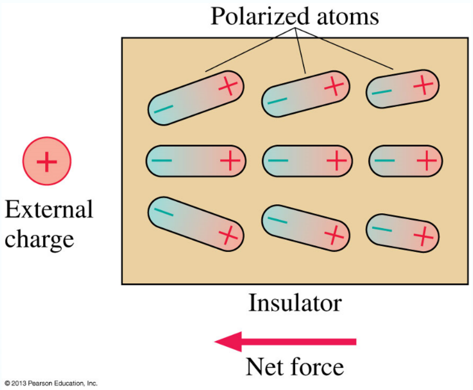
1. **(3 mark)** Draw a two dimensional Cartesian coordinate system (1 mark). Draw $\hat{r}$ and unit vectors which represent the direction in the positive x-axis and y-axis (1 mark each).

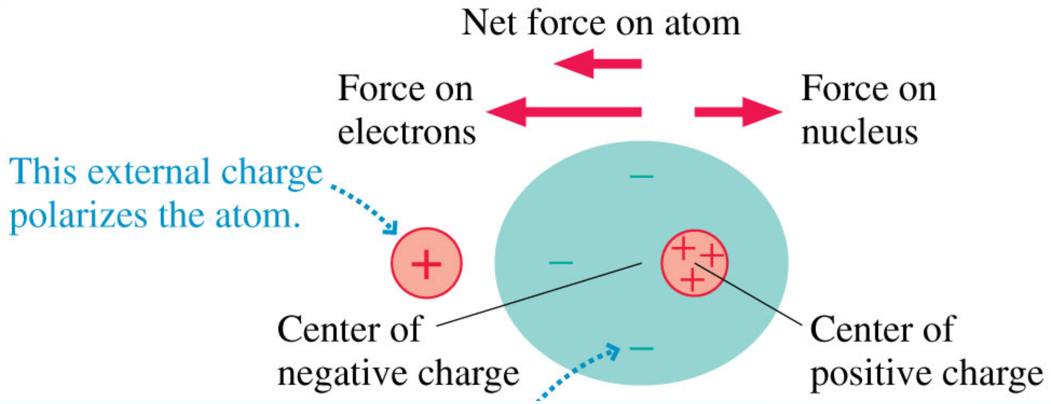
2. **(1 mark)** Do unit vectors have physical units (such as metres)? Explain.

3. **(3 marks)** Write a mathematical expression for $\hat{r}$ in terms of Cartesian unit vectors.

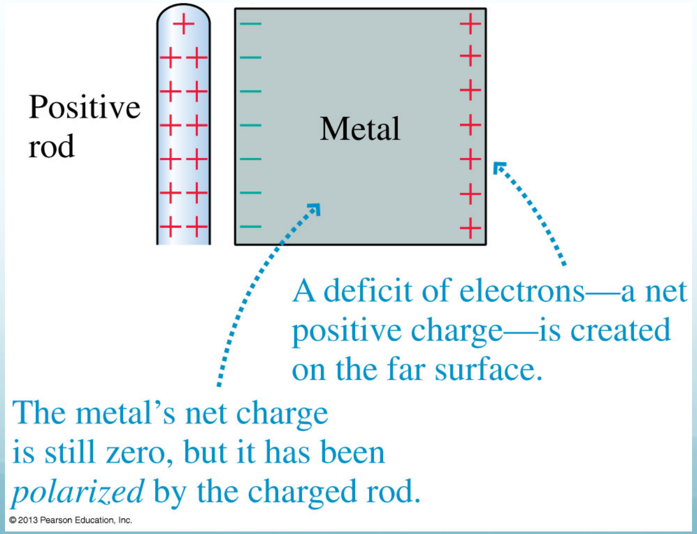
4. **(2 marks)** Show that $\hat{r}$ is indeed a unit vector.

Charge Polarization





Metal



Coulomb's Law

$$\boxed{F_{1\,on\,2} = F_{2\,on\,1} = K\frac{|q_1||q_2|}{r^2}}$$

K = electrostatic constant

$$K = 8.99\times10^{9}\,\frac{N\cdot m^2}{C^2}$$

$$\boxed{F_{1\,on\,2} = F_{2\,on\,1} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}}$$

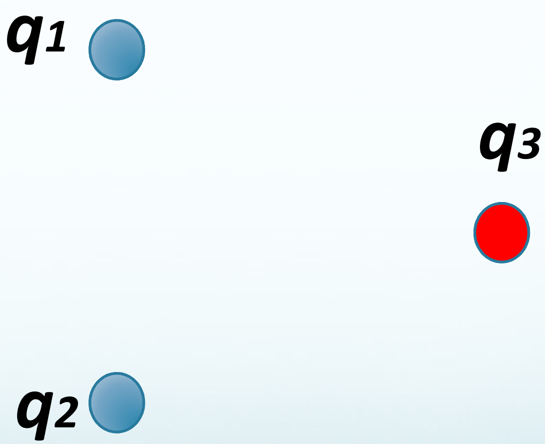
ε_0 = permittivity of free space

$$\varepsilon_0 = \frac{1}{4\pi K} = 8.85\times10^{12}\,\frac{C^2}{N\cdot m^2}$$

Superposition Principle

The total force on q_3 is the vector sum of the individual forces:

$$\vec{F}_{on\,3} = \vec{F}_{1\,on\,3} + \vec{F}_{2\,on\,3}$$

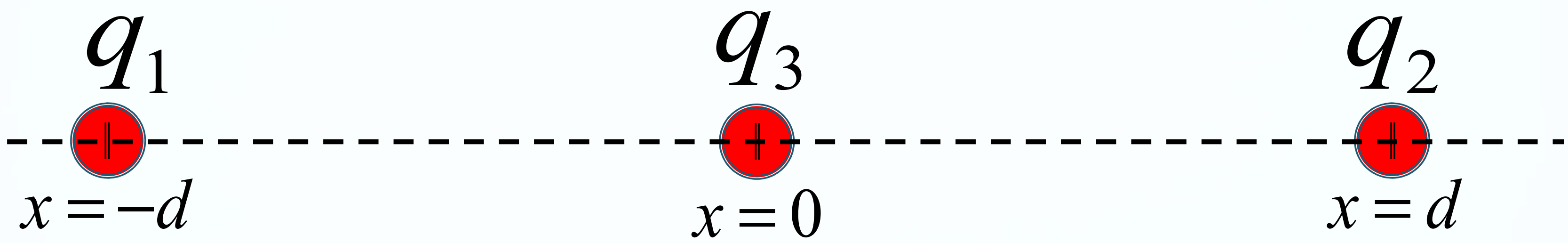


Coulomb's Law

How to compute the magnitude and direction properly.

$$\left|\vec{F}_{21}\right| = K\frac{|q_1||q_2|}{r_{21}^2}$$

Example #1:



If the force of q_1 on q_3 is $\vec{F}_{13} = (+3\text{N})\hat{i}$ (i.e., in the +x direction), and the force of q_3 on q_1 is $\vec{F}_{31} = F_{31}\hat{i}$, what is the component F_{31}?

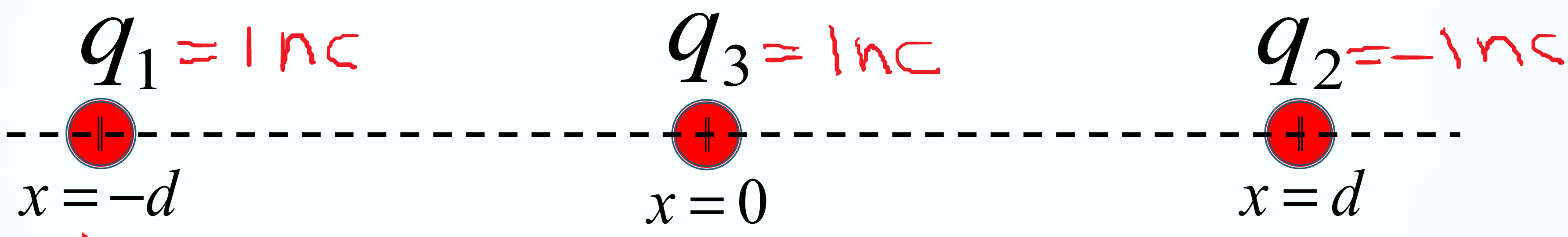
Newton's Third Law→ $\vec{F}_{13} = -\vec{F}_{31}$
Forces are equal and opposite

Coulomb's Law→ $\left|\vec{F}_{13}\right| = \left|\vec{F}_{31}\right|$
Pick direction using charge rules.

$\boxed{F_{31} = -3\text{N}}$

Example #2:

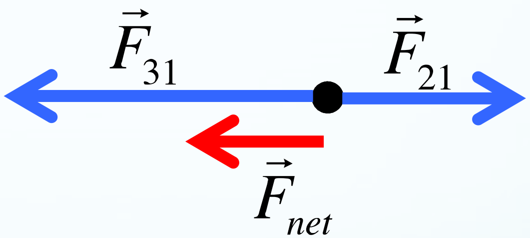
$$K = 8.99\times10^{9}\ \frac{N\cdot m^2}{C^2}$$



d = 1m

What is the total electric force on q_1? Note: nC = 10^{-9} C.

Free Body Diagram:



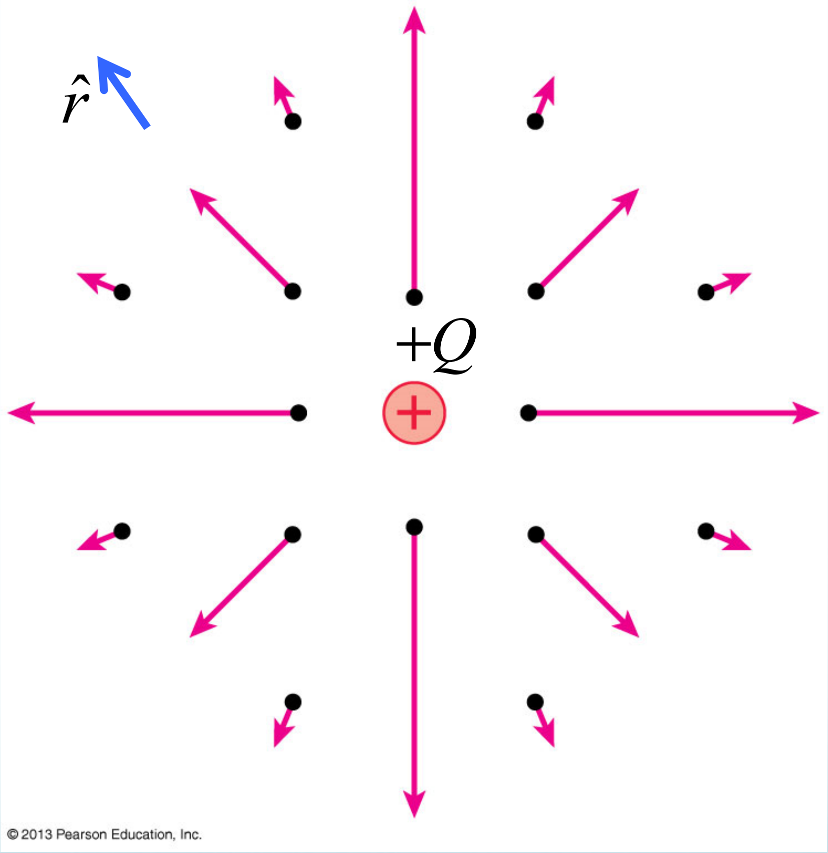
$$\left|\vec{F}_{31}\right| = 8.99\times10^{-9}\ \mathrm{N}$$

$$\left|\vec{F}_{21}\right| = 2.25\times10^{-9}\ \mathrm{N}$$

$$\boxed{\vec{F}_{net} = \left(-6.74\times10^{-9}\ \mathrm{N}\right)\hat{i}}$$

Building blocks of electric force

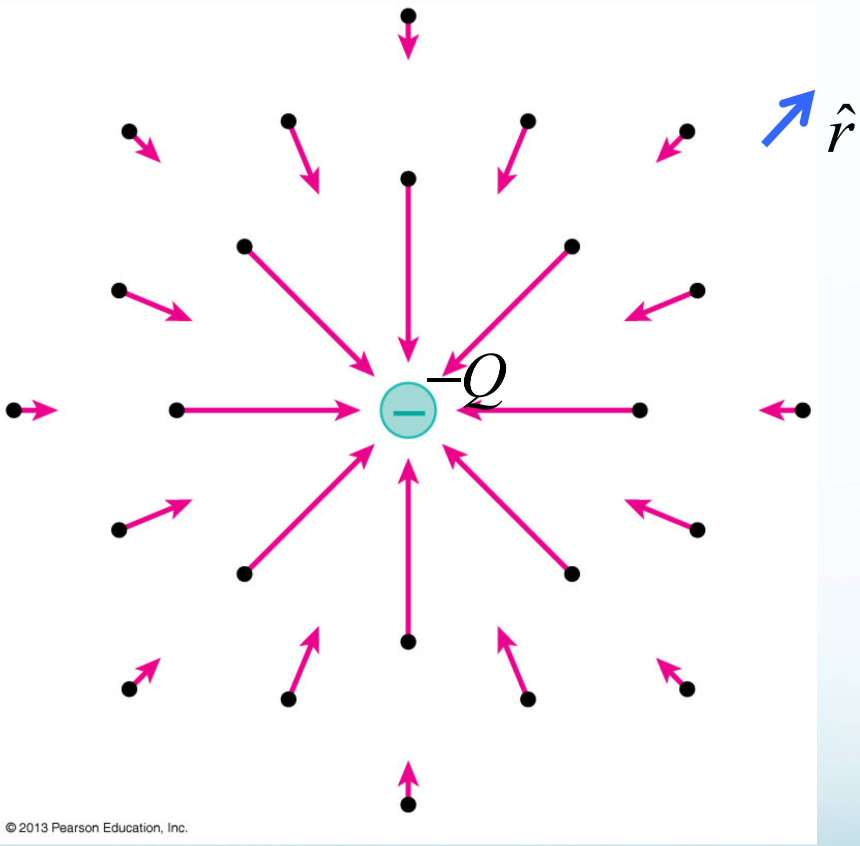
$$\vec{F} = \frac{KQq}{r^2}\hat{r}$$



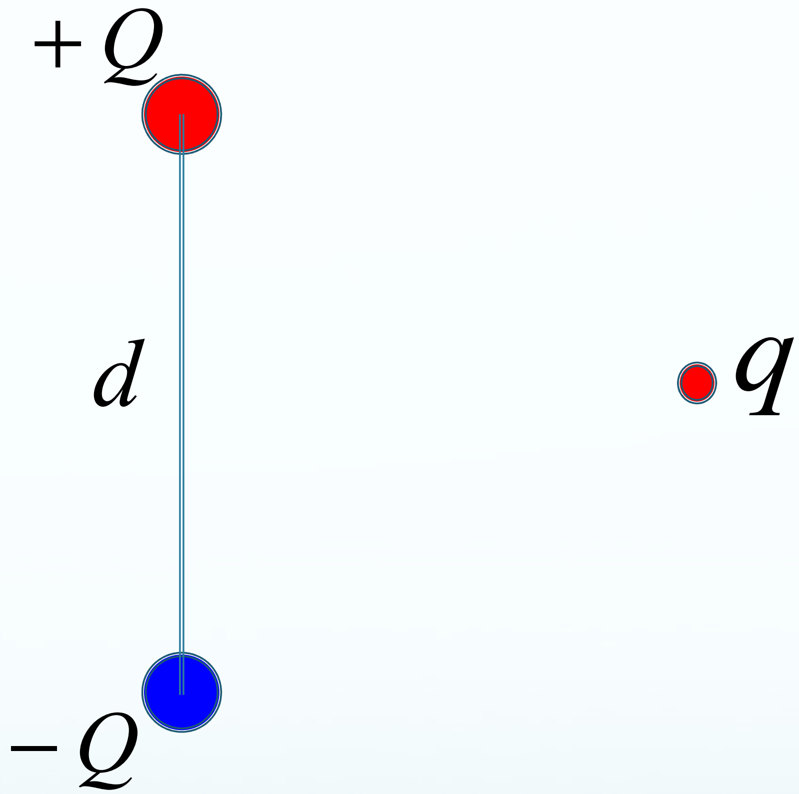
● = positive charge *q* at the position indicated

Building blocks of electric force

$$\vec{F} = \frac{-KQq}{r^2}\hat{r}$$

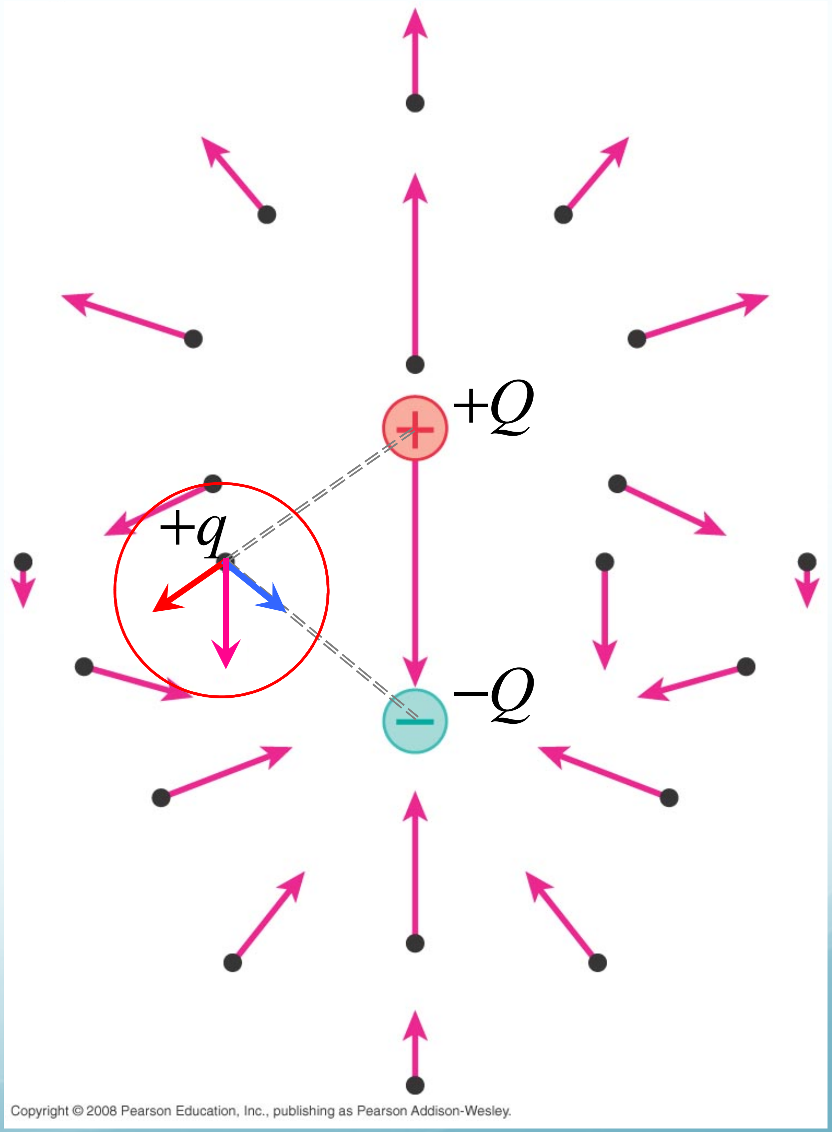


● = positive charge q at the position indicated


$+Q$
d
q
$-Q$

Superposition with Building Blocks

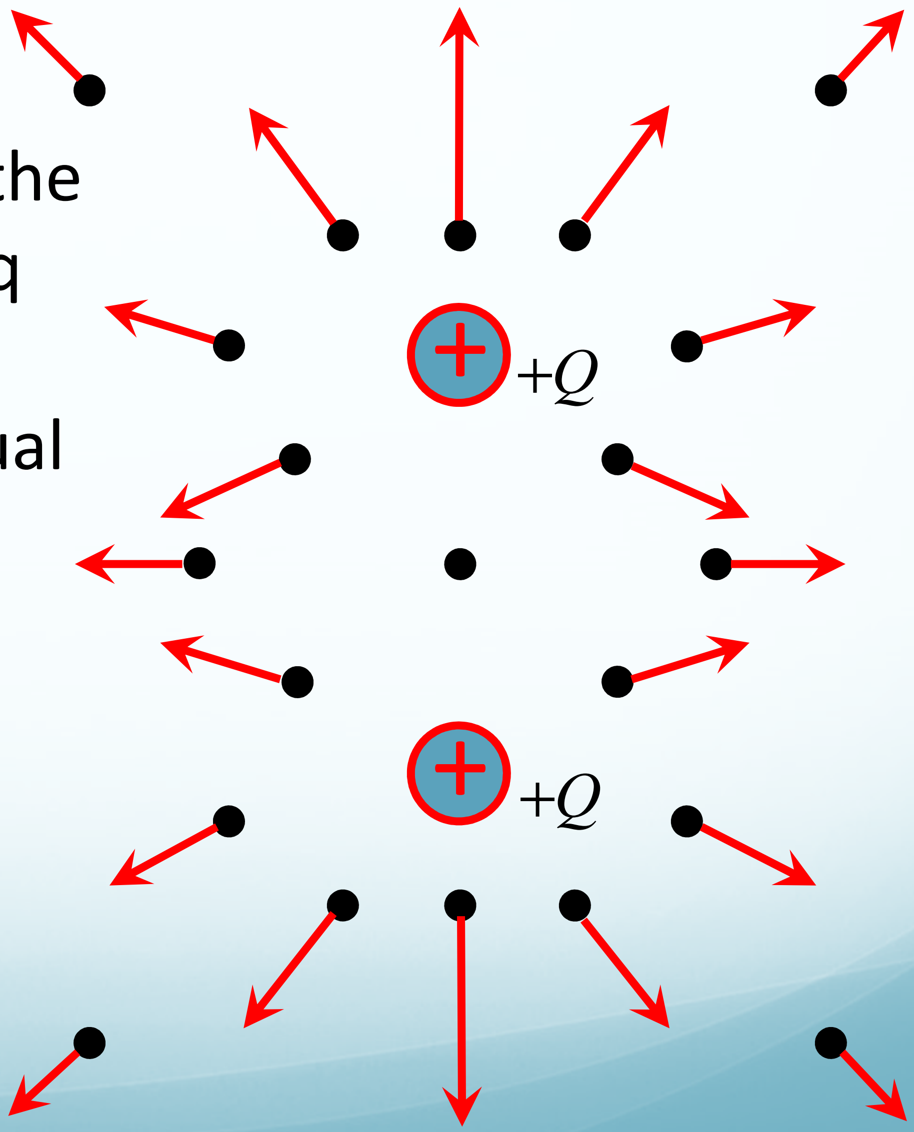
The vector represents the magnitude and direction of the electric force on the charge q **at that point**. It comes from superposition of the individual forces from +Q and –Q.



Superposition with Building Blocks

The vector represents the magnitude and direction of the electric force on the charge q **at that point**. It comes from superposition of the individual forces from +Q and +Q.

Direction again comes from superposition! Same steps as previous apply here too.



This section we talked about:

Chapter 21.1

See you on Wednesday