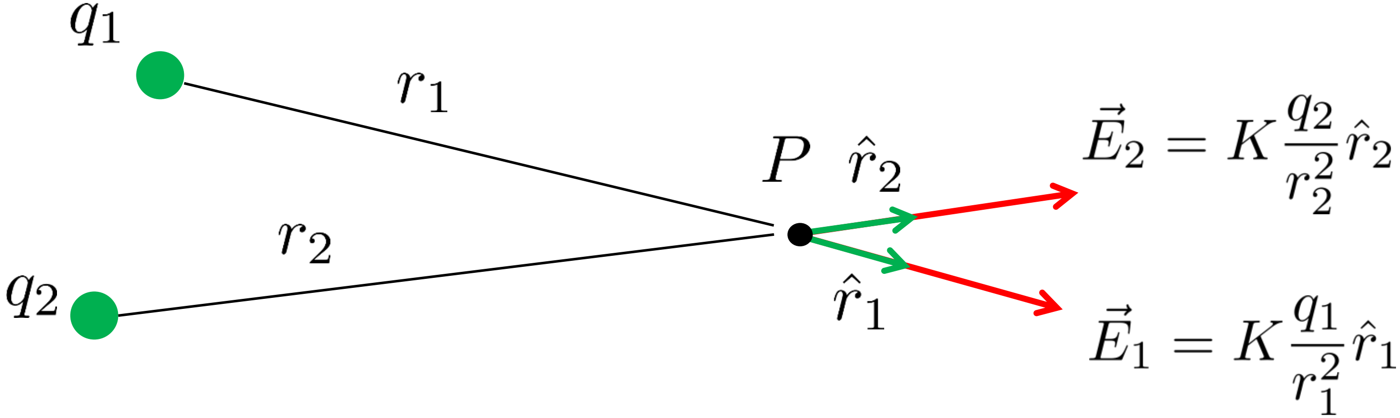
# 23-1: The Electric Field of Multiple Point Charges

Like forces, the net electric field produced at some point in space by multiple charges is the **vector sum** of the fields of the individual charges.

**e.g.**




**Calculate the field at P produced by each charge $q_i$:**
(each $q_i$ has a different $r_i$ and r-hat$_i$)

$$\vec{E}_i = K\frac{q_i}{r_i^2}\hat{r}_i \qquad i = 1, 2, 3, \cdots$$

**Or, Calculate field magnitudes:**

$$|\vec{E}_i| = K\frac{|q_i|}{r_i^2} \qquad i = 1, 2, 3, \cdots$$

Then, write each $\vec{E}_i$ in component form, using what you have from the geometry.

**Find total field by vector addition:**

$$\vec{E}_{\text{total}} = \sum_i \vec{E}_i = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \cdots$$

PROBLEM-SOLVING STRATEGY 23.1

# The electric field of multiple point charges

MP

**MODEL** Model charged objects as point charges.

**VISUALIZE** For the pictorial representation: (Draw it and name the charges!)

(Usually best to put origin at P)

- Establish a coordinate system and show the locations of the charges.
- Identify the point P at which you want to calculate the electric field.
- Draw the electric field of each charge at P. (Most important step! Tails of vectors are on P)
- Use symmetry to determine if any components of $\vec{E}_{net}$ are zero.

**SOLVE** The mathematical representation is $\vec{E}_{net} = \sum \vec{E}_i$.

$$\vec{E}_i = K\frac{q_i}{r_i^2}\hat{r}_i$$

- For each charge, determine its distance from P and the angle of $\vec{E}_i$ from the axes.
- Calculate the field strength of each charge's electric field.
- Write each vector $\vec{E}_i$ in component form. (Using the info on your sketch)
- Sum the vector components to determine $\vec{E}_{net}$.
- If needed, determine the magnitude and direction of $\vec{E}_{net}$.

**ASSESS** Check that your result has the correct units, is reasonable, and agrees with any known limiting cases.

Exercise 16

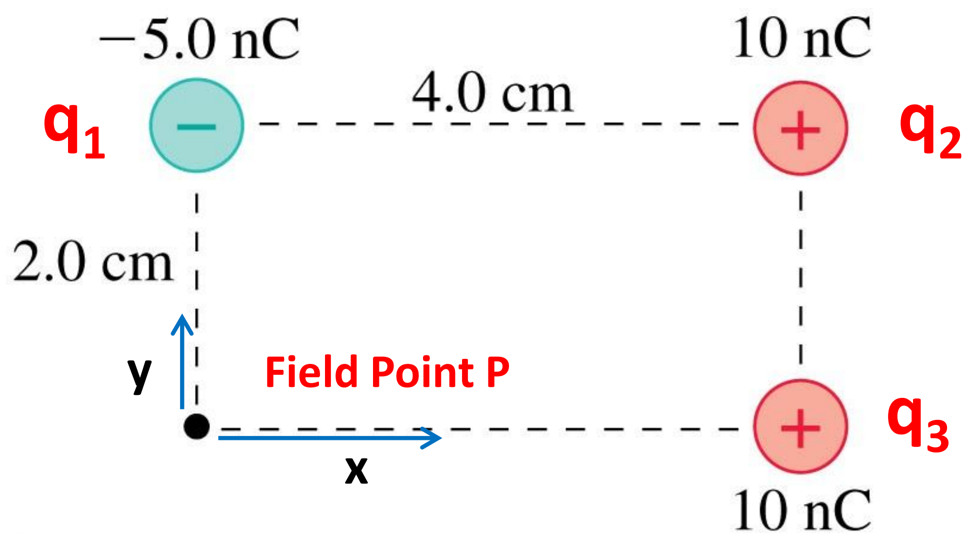
# Whiteboard Problem 23-1

For the configuration of charges shown below, we want to find the total electric field vector at the point P.

a) **Sketch and label the three field vectors at P for each charge.** **(LC)**

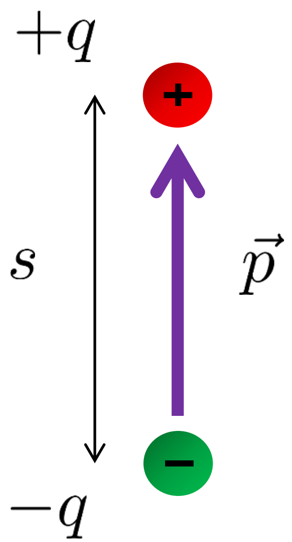
Now, follow the proper steps to find the total field in **component form** at the point P: *(note charges are already named and coordinate system chosen)*

b) **Enter your answer for the total electric field vector as we did in previous WB problems.** **(LC, a two-point shot!)**



# The Electric Dipole Moment

An electric dipole moment is **defined** to be **two equal but opposite charges, +q and –q, separated by a fixed distance s**.




**Define: The Electric Dipole Moment:**

$$\vec{p} \equiv \{qs, \text{from } -\text{q to } +\text{q}\}$$

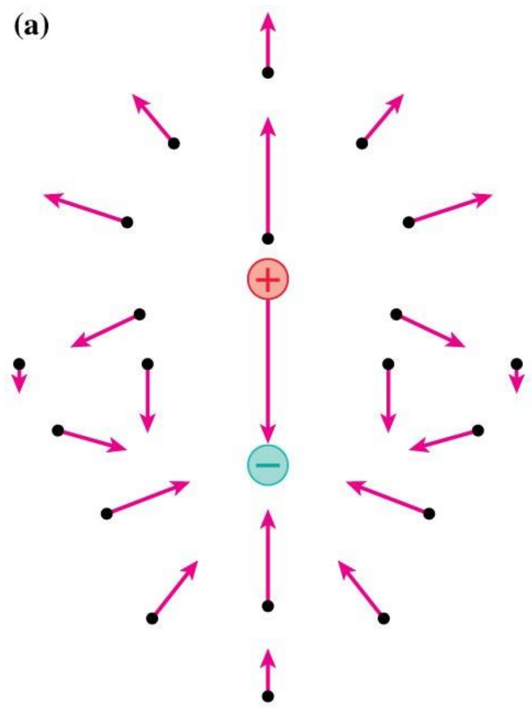
[Units: Cm]

**Note the dipole moment is the whole thing; so the net charge of the dipole is zero.**

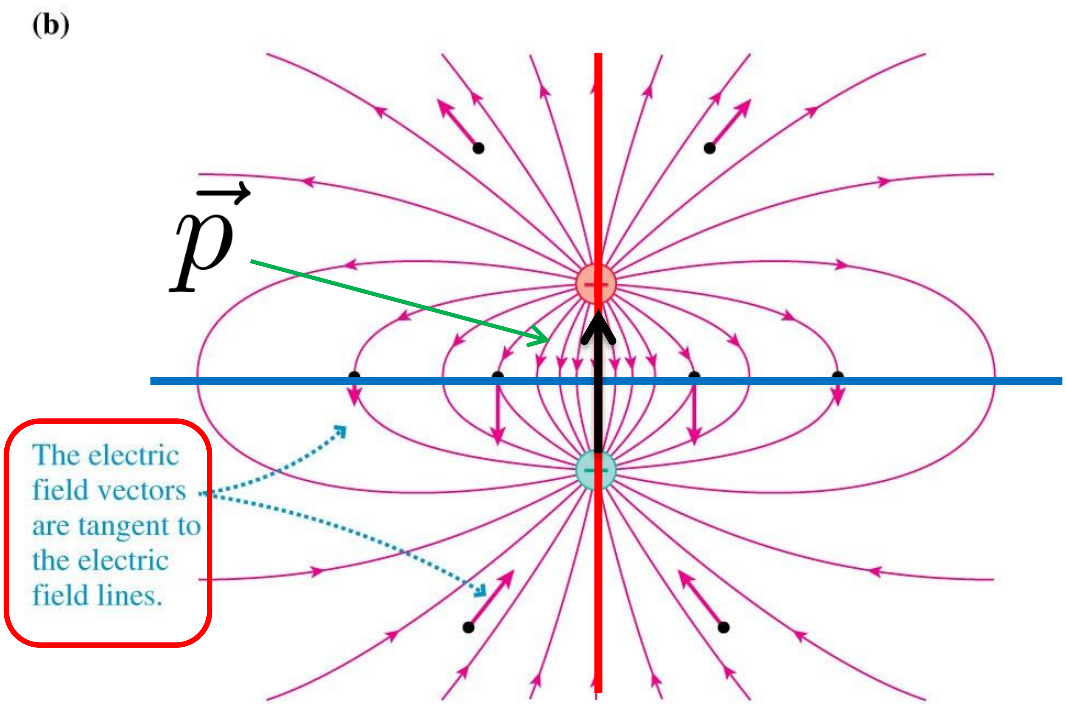
Many objects (*in particular molecules*) have zero net charge, but can have a non-zero dipole moment due to the location of the charges inside. Dipoles do all kinds of interesting things – as we will see.

# The Electric Dipole Moment Field

**Field Vectors**




**Field Lines**




Your author derives some useful equations that give approximate expressions for the **field at a distance r >> s from the center of the dipole**:

$$\text{Note: for both of these: } E \propto \frac{1}{r^3}$$

$$\vec{E} \approx \frac{2K\vec{p}}{r^3}$$ **(on dipole Axis)**

**(only on these axes!)**

$$\vec{E} \approx -\frac{K\vec{p}}{r^3}$$ **(on bisecting Axis)**

# Whiteboard Problem: 23-2

An electric dipole moment is formed by a + 1.0 nC charge and a -1.0 nC charge where the charges are 2.0 mm apart. The dipole is centered at the origin, and the dipole moment points along the +x axis.

a) **What is the electric field strength at (x,y) = (10 cm, 0 cm)? (LC)**
b) **What is the electric field strength at (x,y) = (0 cm, 10 cm)? (LC)**

$$\vec{E} \approx \frac{2K\vec{p}}{r^3}$$ **(on dipole Axis)**

$$\vec{E} \approx -\frac{K\vec{p}}{r^3}$$ **(on bisecting Axis)**