Before we continue: Where Did Coulomb’s Law Go?

Now, that we’re beginning to learn the language of fields, some students get nostalgic for Coulomb’s Law. After all, it is familiar and easy to work with. **Where did it go?**

Here’s how we think using Coulomb’s Law:

\[ \begin{align*}
Q &> 0 \\
\vec{F}_{on\ q} &\quad q > 0
\end{align*} \]

Now, we think in terms of Fields:

\[ \begin{align*}
\vec{E} &\quad (of\ Q) = K \frac{Q}{r^2} \hat{r} \\
\vec{F}_{on\ q} &= q \vec{E} = K \frac{Q q}{r^2} \hat{r}
\end{align*} \]

Coulomb’s Law is contained in the equation of a point charge field.
Calculate the field at $P$ produced by each charge $q_i$:
(each $q_i$ has a different $r_i$ and $\hat{r}_i$)

Or, calculate field magnitudes:

Then, write each $\vec{E}_i$ in component form.

Find total field by vector addition:
The electric field of multiple point charges

MODEL  Model charged objects as point charges.

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

- 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!)*
- Use symmetry to determine if any components of $\vec{E}_{\text{net}}$ are zero.

SOLVE  The mathematical representation is $\vec{E}_{\text{net}} = \sum \vec{E}_i$, $\vec{E}_i = K \frac{q_i}{r_i^2} \hat{r}_i$

- 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.
- Sum the vector components to determine $\vec{E}_{\text{net}}$.
- If needed, determine the magnitude and direction of $\vec{E}_{\text{net}}$.

ASSESS  Check that your result has the correct units, is reasonable, and agrees with any known limiting cases.
Whiteboard Problem 26-1

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

a) On LC, sketch 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: \((note \ charges \ named \ and \ coordinate \ system \ chosen)\)

b) Enter your answer for the electric field vector this way:

Use only 2 significant figures and e-notation. \((LC)\)

For example: \(5.743 \times 10^5 \hat{i} - 3.789 \times 10^4 \hat{j} = (5.7e5, -3.8e4)\)

\[ \begin{align*}
q_1 & = -5.0 \text{ nC} \\
q_2 & = 10 \text{ nC} \\
q_3 & = 10 \text{ nC} \\
\end{align*} \]

No spaces!
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 Dipole Moment:

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

[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.
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 $r \gg s$ from the center of the dipole:

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

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

Note: for both of these: $E \propto \frac{1}{r^3}$
Whiteboard Problem: 26-2

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 
   \[(x,y) = (10 \text{ cm}, 0 \text{ cm})? \text{ (LC)}\]

b) What is the electric field strength at 
   \[(x,y) = (0 \text{ cm}, 10 \text{ cm})? \text{ (LC)}\]

\[
\vec{E} \approx \frac{2K\vec{p}}{r^3} \quad \text{(on dipole Axis)}
\]

\[
\vec{E} \approx -\frac{K\vec{p}}{r^3} \quad \text{(on bisecting Axis)}
\]
Computer Activity: Charges and Electric Fields

Using the group’s computer, one of you log onto masteringphysics and begin the exercise: Charge and Electric Field Computer Activity

Use the computer to complete the exercise, but record your answers on the sheet to hand in – that’s what will be graded.

Make sure for part K that you show all of your work.

When you’re done with the exercise, make sure your Group’s name and all of your names are on it, and turn it in. Feel free to play with the simulation if you have time.
Geometry for Part K on the Computer Activity

$q_1 = +5 \text{ nC}$

$q_2 = -3 \text{ nC}$

$q_3 = -2 \text{ nC}$

$q_4 = +4 \text{ nC}$