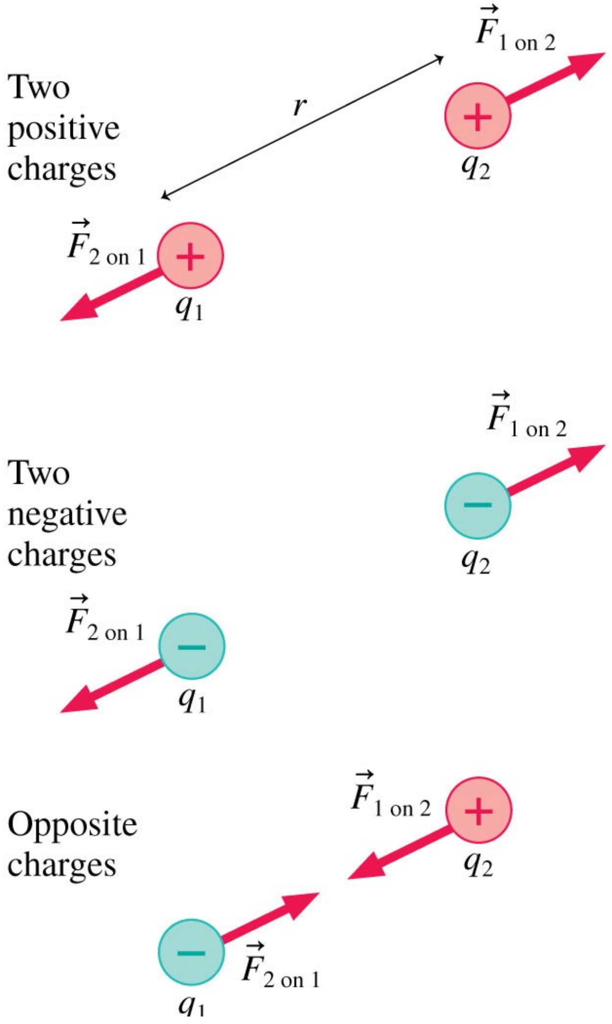
Coulomb's Law

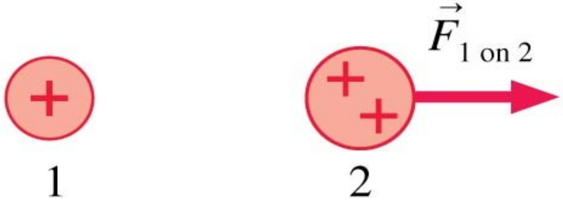
The force exerted by charge 1 on charge 2 is

$$\vec{F}_{1\to 2} = k\frac{q_1 q_2}{r^2}\hat{r}_{1\to 2}$$

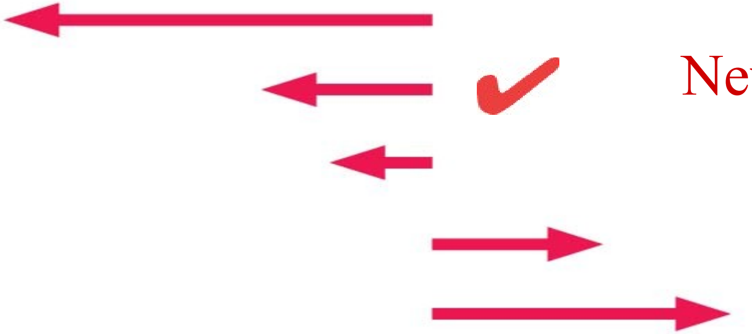


Electrical Force

The charge of sphere 2 is twice that of sphere 1. Which vector below shows the force of 2 on 1?



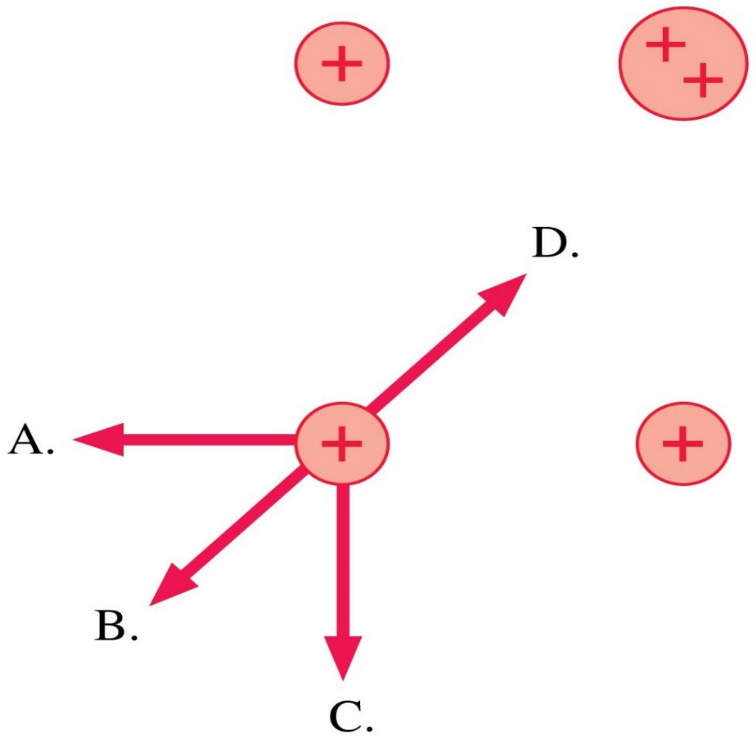
A.
B.
C.
D.
E.



Newton’s third law

Electrical Force

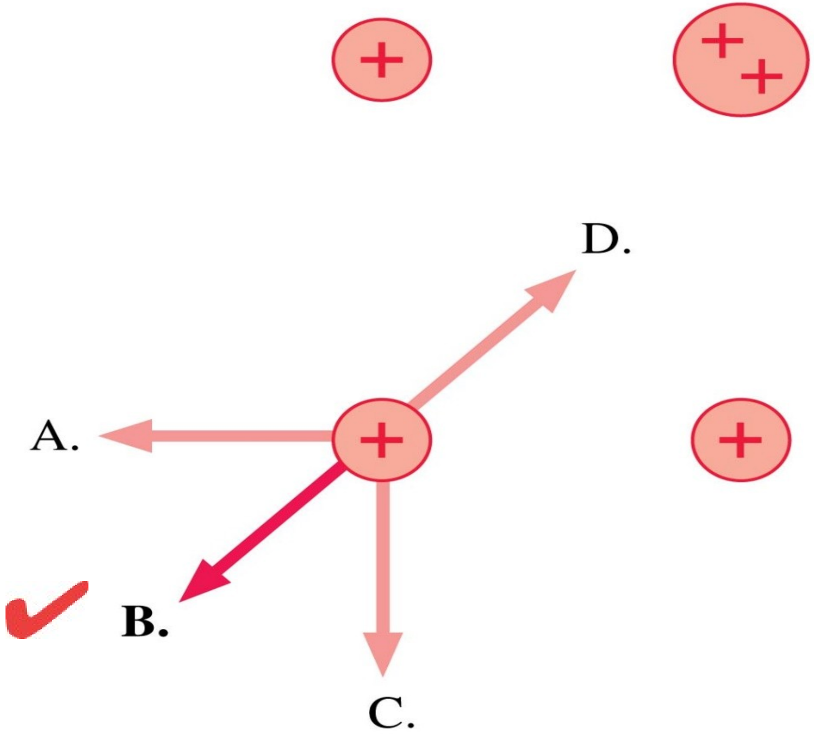
Which is the direction of the net force on the charge at the lower left?



E. None of these.

Electrical Force

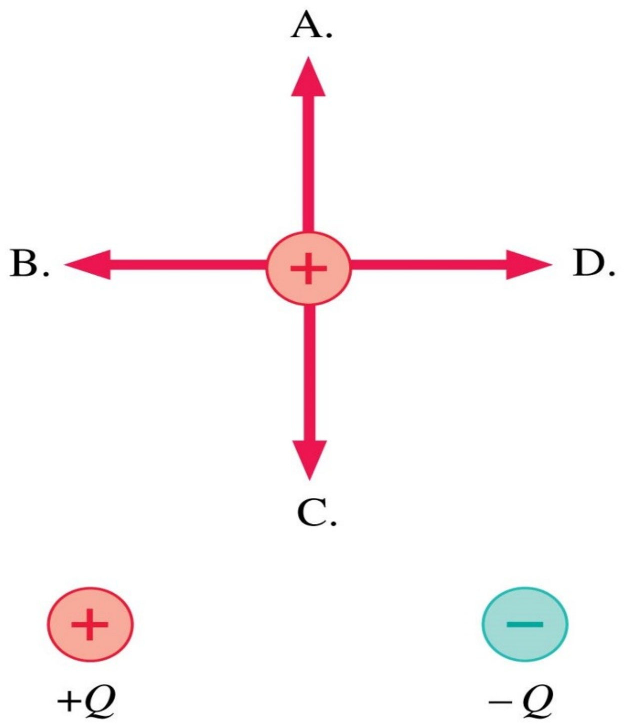
Which is the direction of the net force on the charge at the lower left?



E. None of these.

Electrical Force

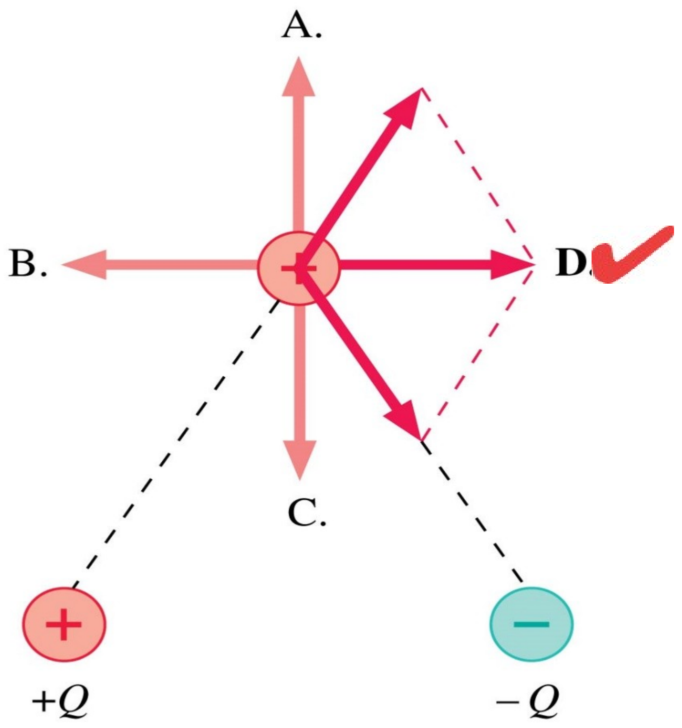
Which is the direction of the net force on the charge at the top?



E. None of these.

Electrical Force

Which is the direction of the net force on the charge at the top?



E. None of these.

Electrical Force

The direction of the force on charge $-q$ is

A. Up.
B. Down.
C. Left.
D. Right.
E. The force on $-q$ is zero.

Electrical Force

The direction of the force on charge $-q$ is

A. Up.

B. Down.

C. Left.

✔ **D. Right.**

E. The force on $-q$ is zero.

$-Q$ is slightly closer than $+Q$.

Field Forces

The Coulomb force: $$\vec{F}_{1\to 2} = k\frac{q_1 q_2}{r^2}\hat{r}_{1\to 2}$$

This interaction can also be modeled with an **electric field**: $\vec{E}$

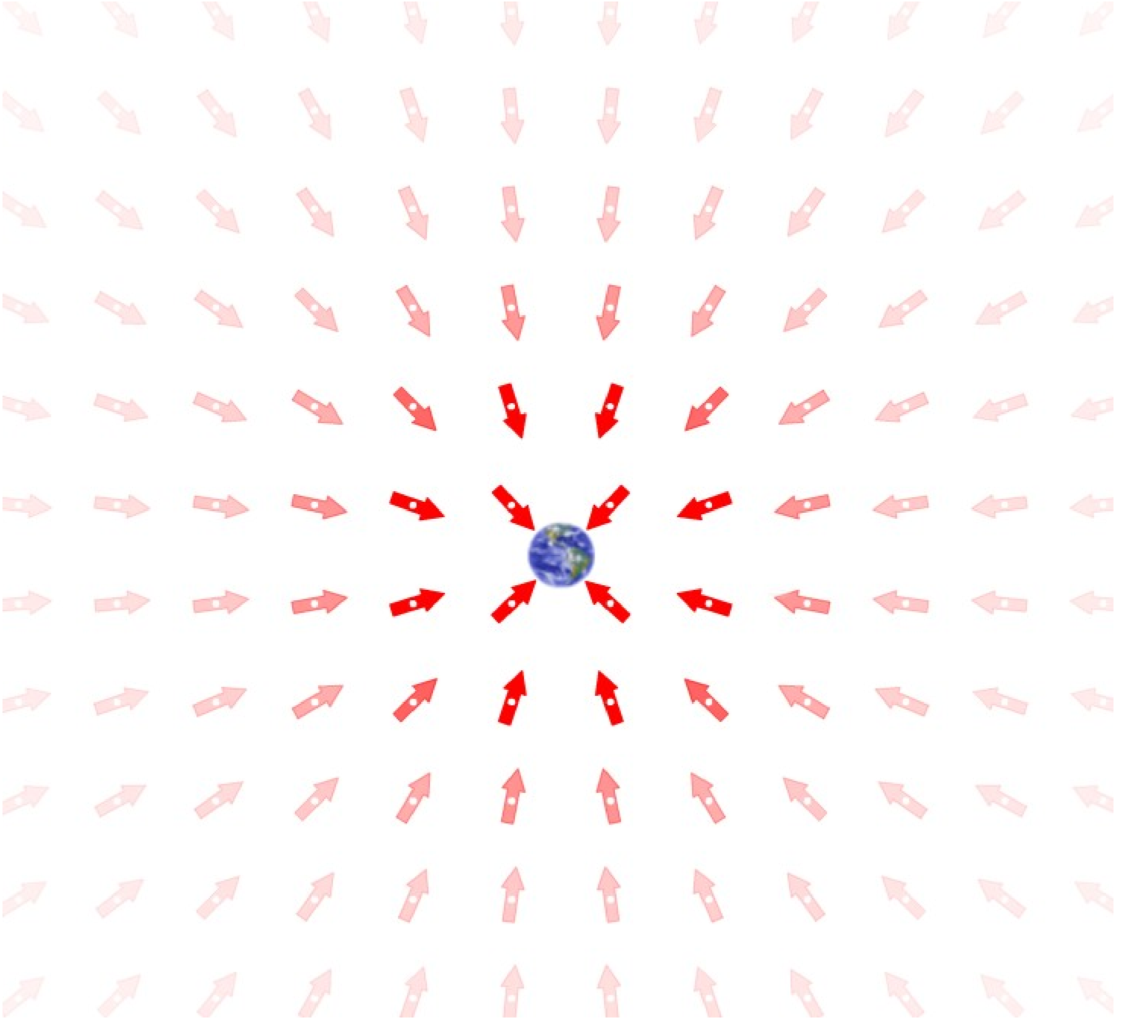
Field Forces

- gravitational, electric and magnetic forces
- do not require contact
- a source (mass or charge or magnetic pole) creates a “field” around it
- bodies respond to the local field; there is no “action at a distance”
- if there are several sources, the net field is the sum of the fields from each

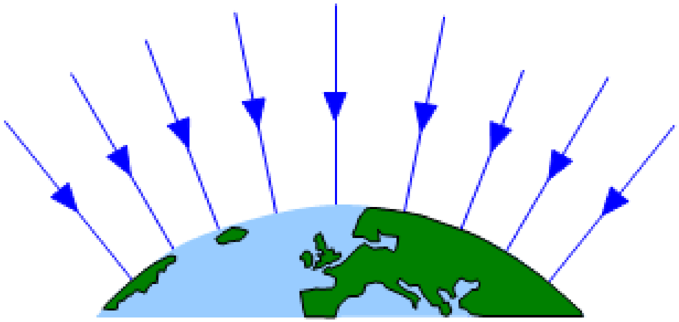
Field Forces

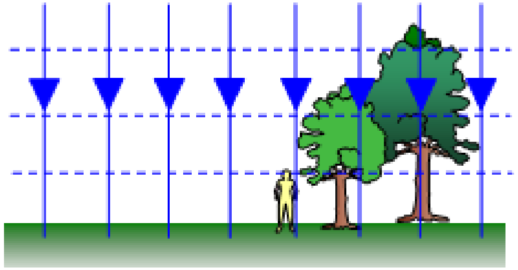
Gravitational Field

$$\vec{g} = -\frac{GM}{r^2}\hat{r}$$



Field Forces





A mass *m* in the gravitational field experiences a force of

$$\vec{F} = m\vec{g}$$

On the surface of the earth, $\vec{g} = 9.8\frac{\mathrm{N}}{\mathrm{kg}}\left(-\hat{\jmath}\right)$

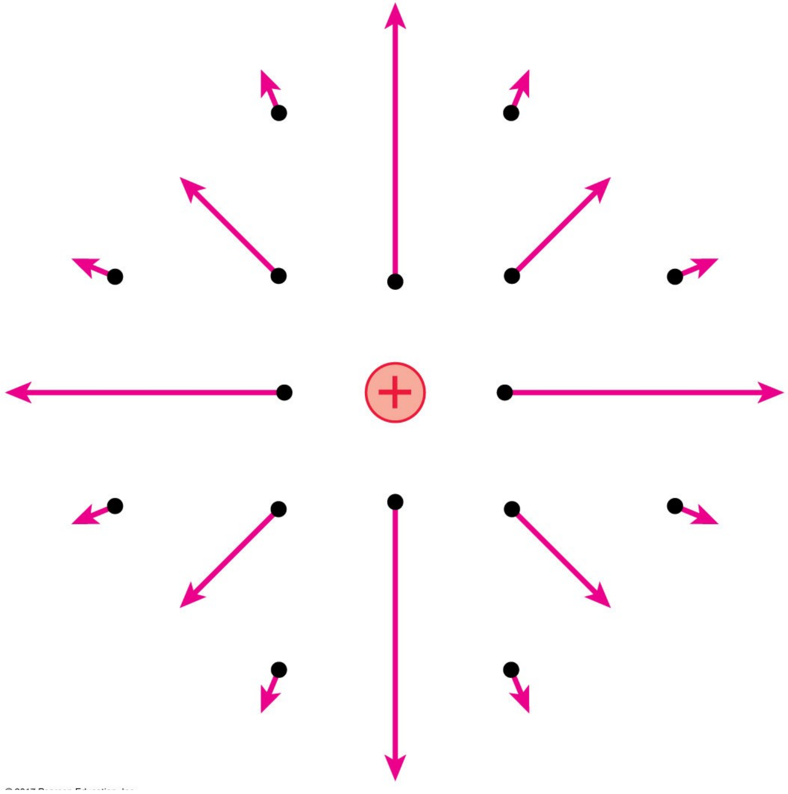
Field Forces

The electric field of a point charge q is

$$\vec{E} = \frac{kq}{r^2}\hat{r}$$

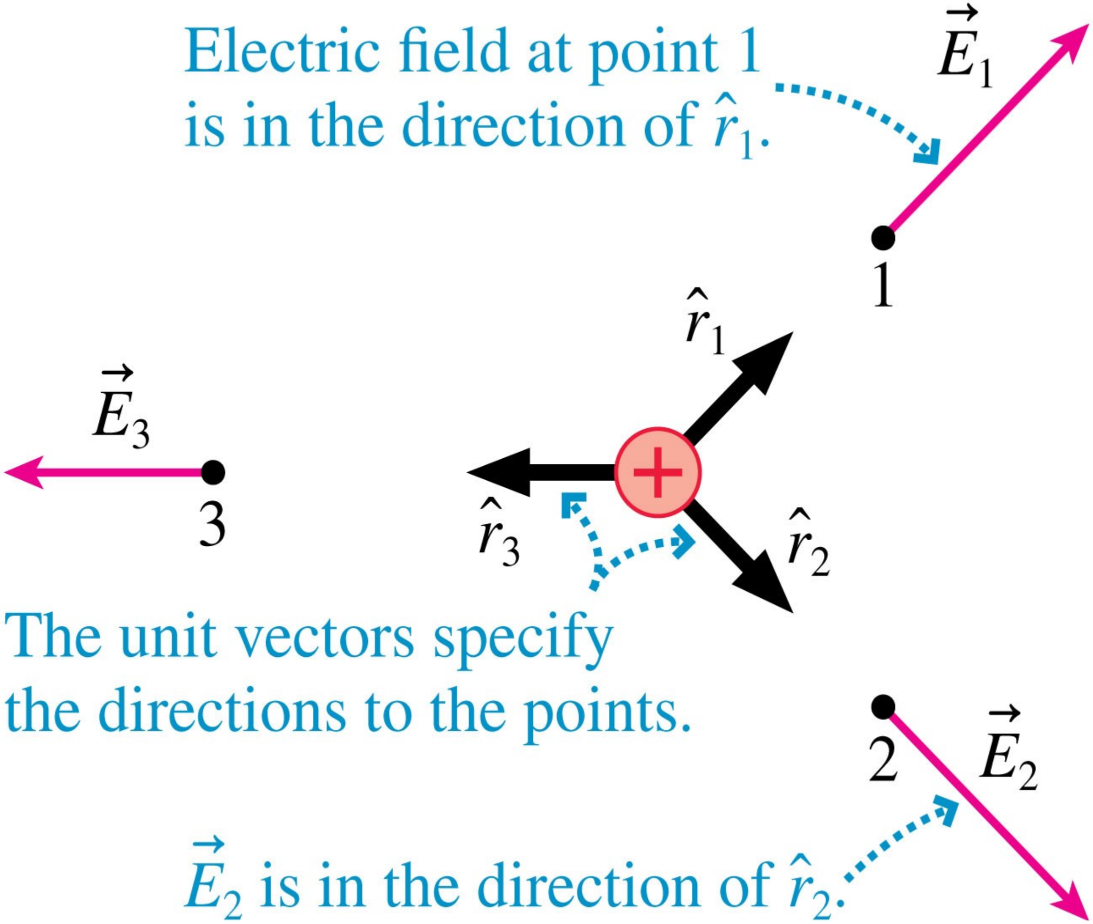
A charge q in an electric field $\vec{E}$ feels a force

$$\vec{F} = q\vec{E}$$



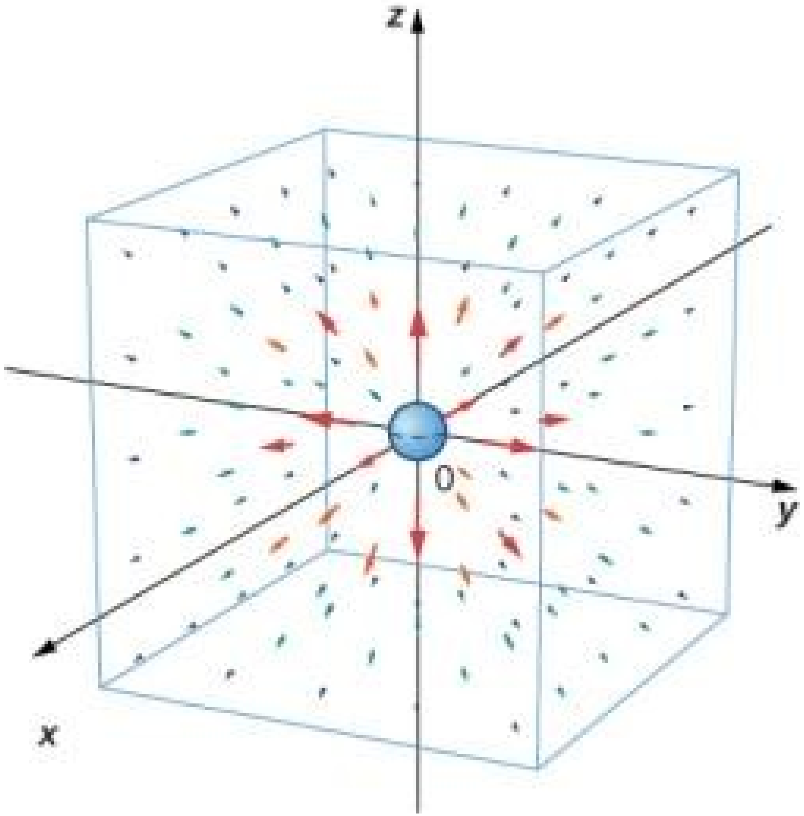
Electric Field

$$\vec{E} = k\frac{q}{r^2}\hat{r}$$



Electric Field

$$\vec{E} = k\frac{q}{r^2}\hat{r}$$



Electric Field

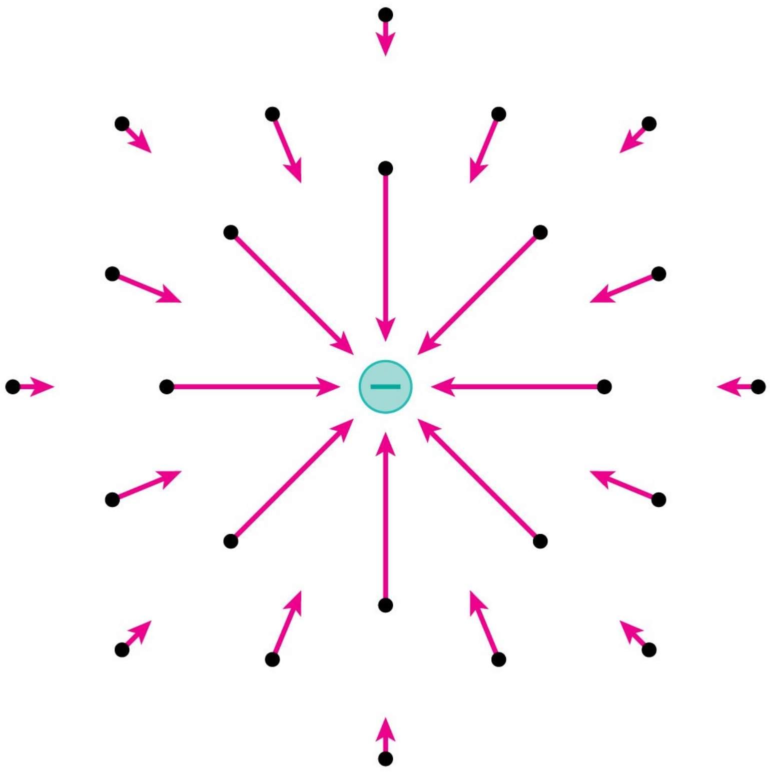
The electric field of a point charge q is

$$\vec{E} = k\frac{q}{r^2}\hat{r}$$

where $\hat{r}$ points away from the source charge.

A charge q in an electric field $\vec{E}$ feels a force

$$\vec{F} = q\vec{E}$$



Electric Field

Field of a point charge q :

$$\vec{E} = k\frac{q}{r^2}\hat{r}$$

$$k = 8.99 \times 10^9 \frac{\mathrm{Nm}^2}{\mathrm{C}^2}$$

Sometimes written as

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

where

$$k = \frac{1}{4\pi\epsilon_0}$$

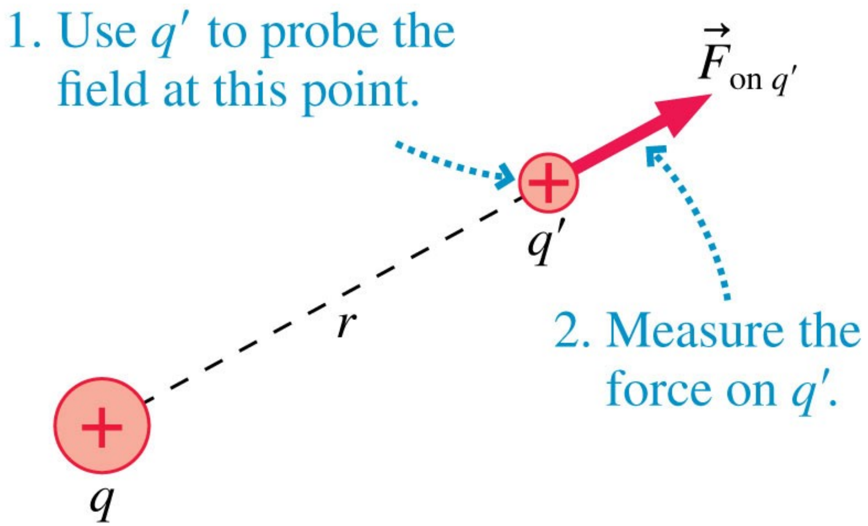
$$\epsilon_0 = 8.85418782 \times 10^{-12} \ \mathrm{m^{-3}\,kg^{-1}\,s^4\,A^2}$$

ϵ_0 is called the **permittivity constant**

Electric Field

$$\vec{F} = q\vec{E}$$

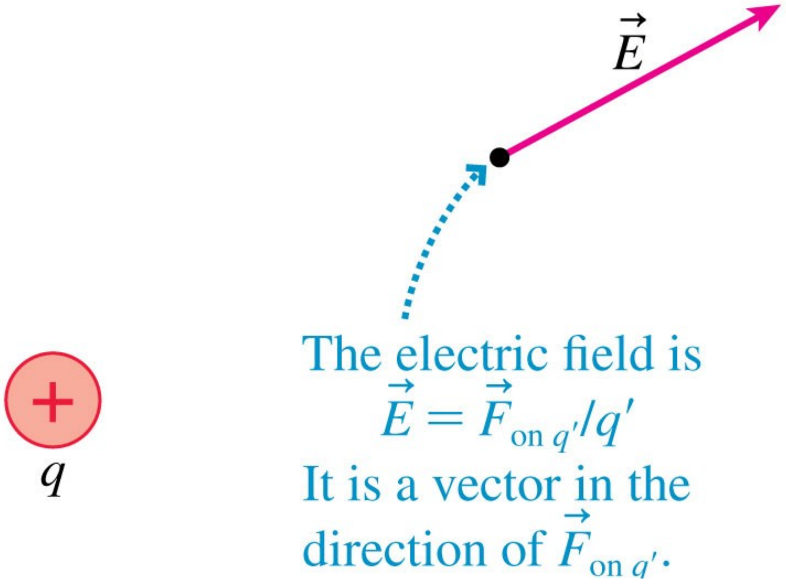
A positive “test charge” can be used to determine the direction of the field.



Electric Field

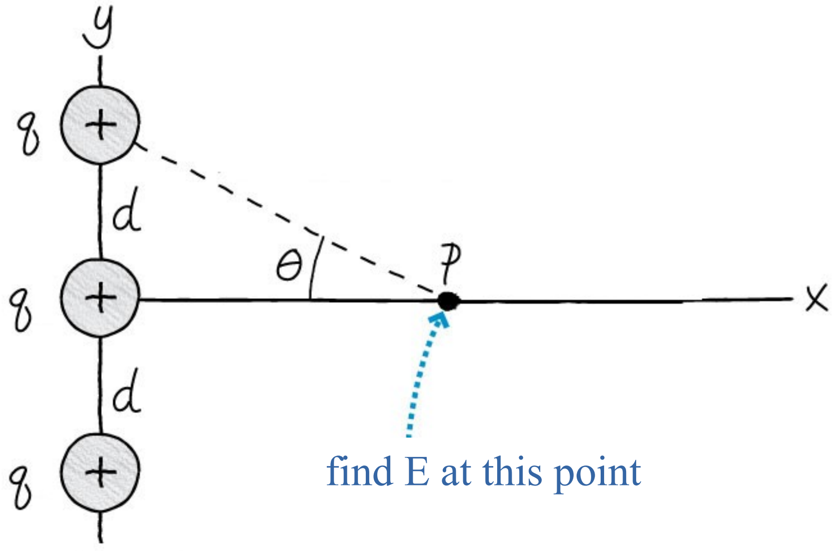
$$\vec{F} = q\vec{E}$$

A positive “test charge” can be used to determine the direction of the field.



Electric Field

$\vec{E}$ is a **vector field**: $\vec{E}(x, y, z, t)$



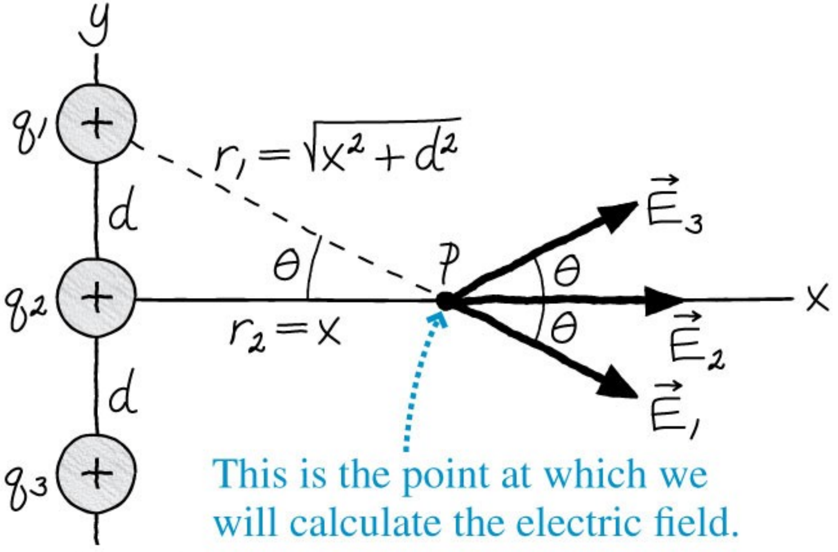
Units are N/C

Superposition: $$\vec{E}_{\text{total}} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \cdots$$

if we know how to compute the electric field from a single charge, then we can compute the electric field from any charge distribution

Electric Field

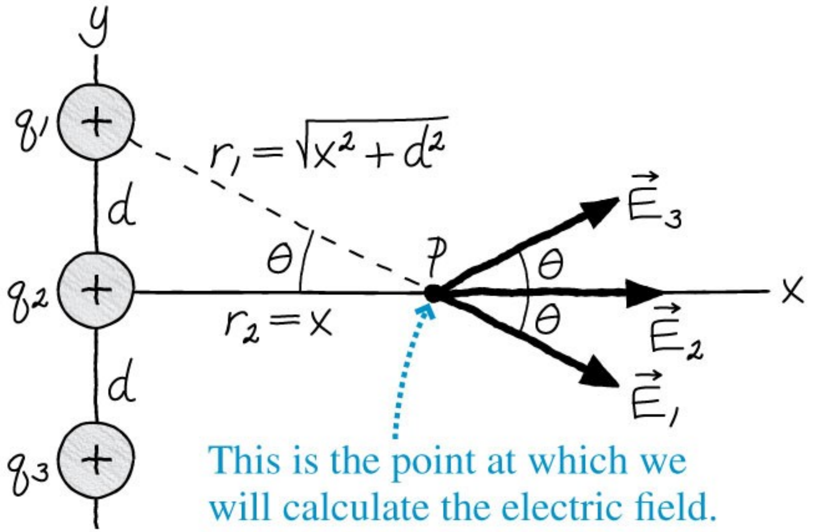
Find the net *E*-field along the x-axis.



Electric Field

Find the net *E*-field along the x-axis.

$$\vec{E}_{\text{net}} = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{x^2} + \frac{2x}{\left(x^2+d^2\right)^{3/2}}\right]\hat{\imath}$$



Check solution:

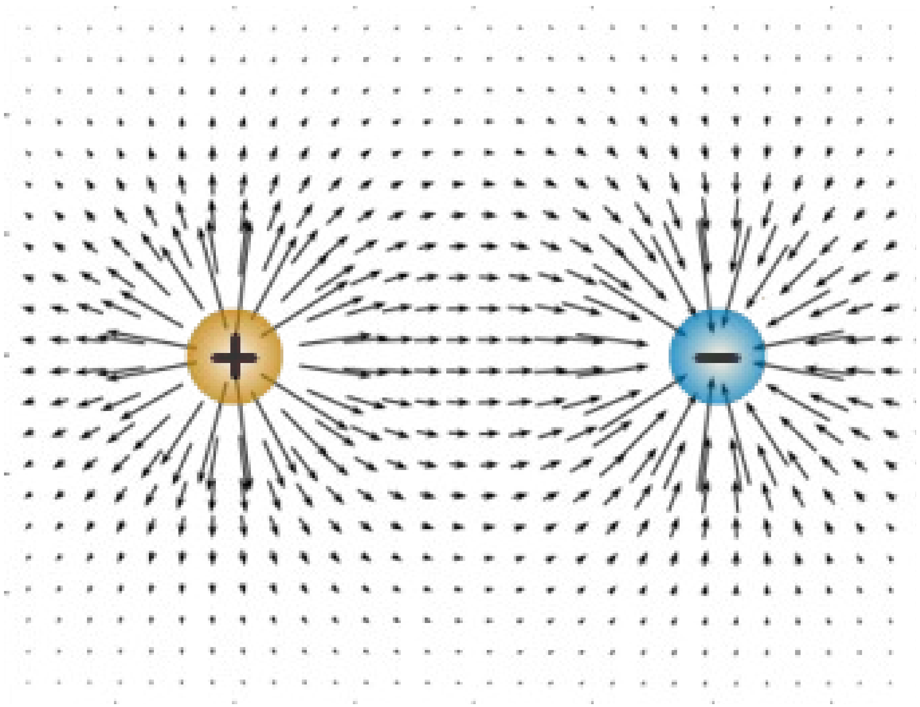
Dimensional analysis (units)

Check limits of x : $x \ll d$ $x \gg d$

Electric Field

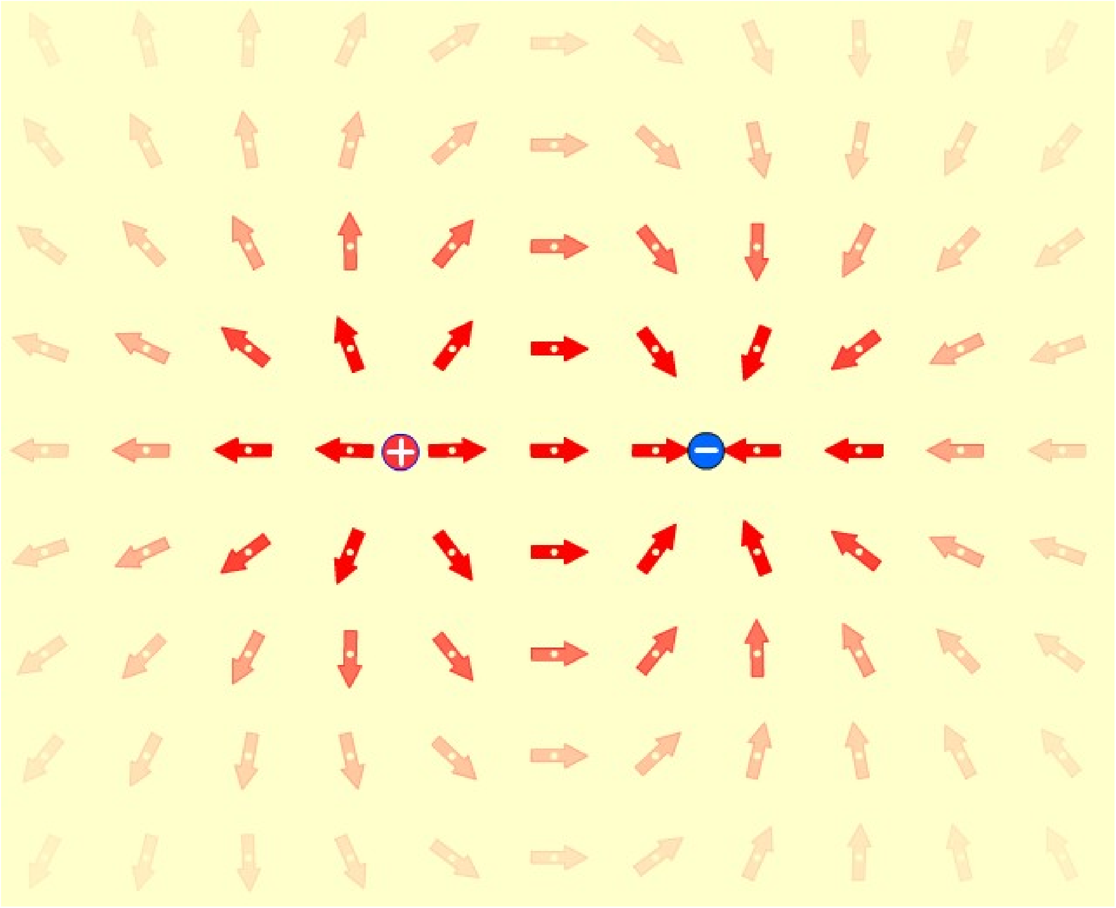
An equal-and-opposite point charge pair is called a **dipole**.

Sketch some of the electric field vectors around the dipole.



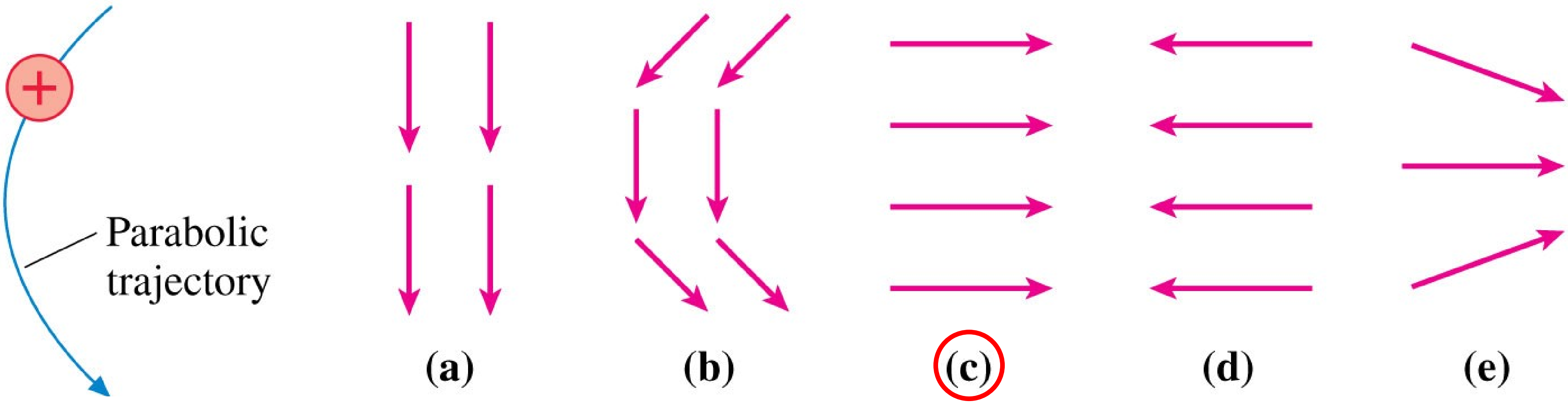
Electric Field

See Charges and Fields sim.



Electric Field

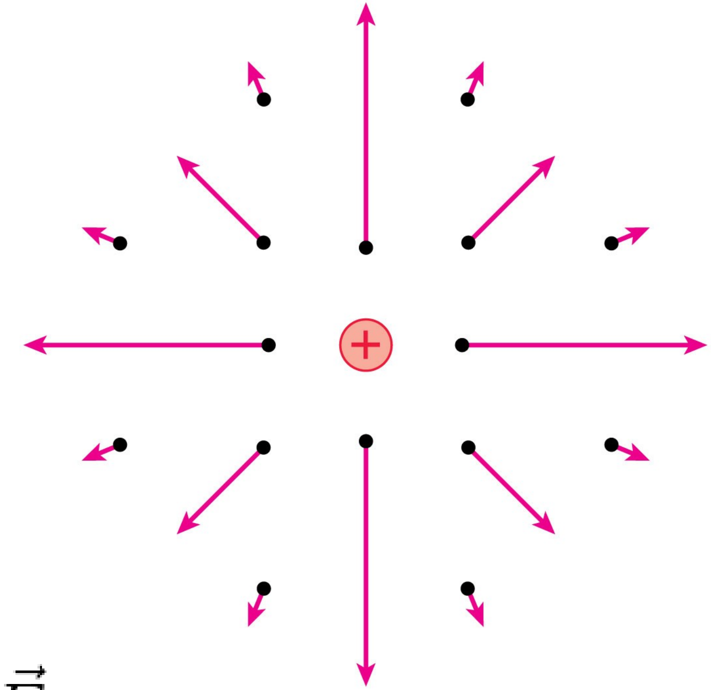
Which electric field is responsible for the proton's trajectory?

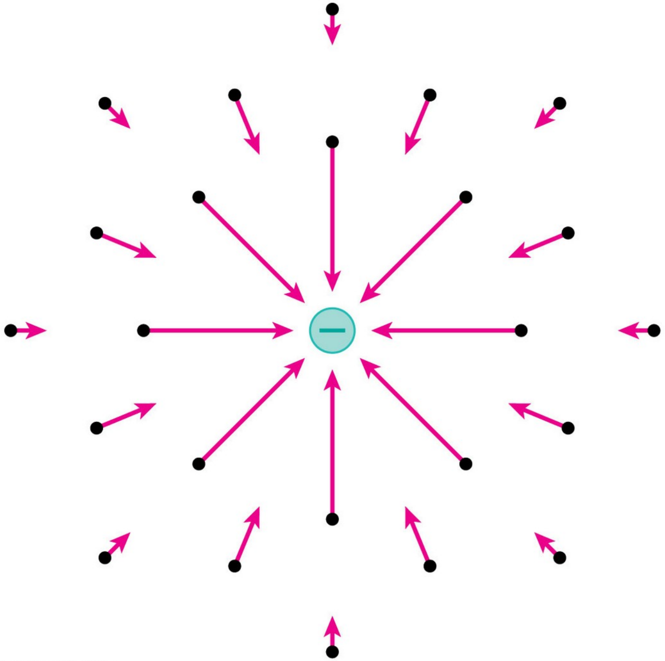


Electric Field

The electric field of a point charge q is

$$\vec{E} = k\frac{q}{r^2}\hat{r}$$





A charge q in an electric field $\vec{E}$ feels a force

$$\vec{F} = q\vec{E}$$

Electric Field

When $r >> d$, the electric field strength at the dot is

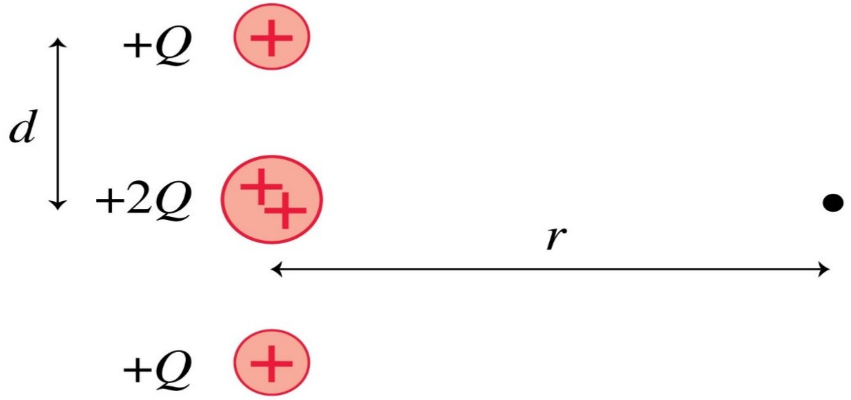
A. $\dfrac{Q}{4\pi\epsilon_0 r^2}$

B. $\dfrac{2Q}{4\pi\epsilon_0 r^2}$

C. $\dfrac{4Q}{4\pi\epsilon_0 r^2}$

D. $\dfrac{4Q}{4\pi\epsilon_0 (r^2 + d^2)}$

E. $\dfrac{4Q}{4\pi\epsilon_0 r}$



Electric Field

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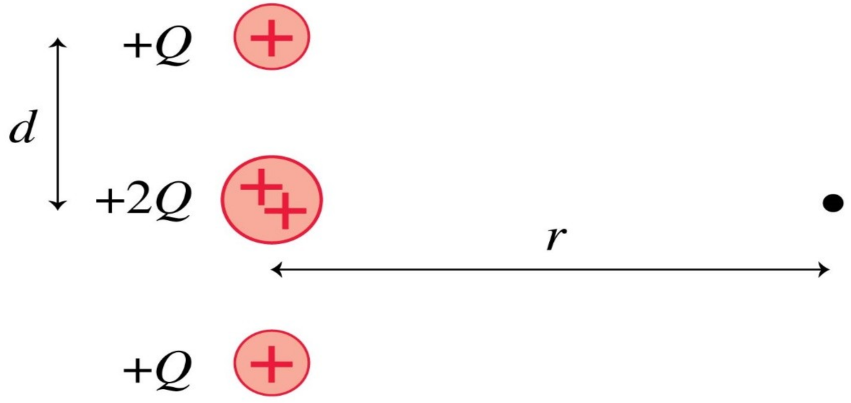
✔ C. $\dfrac{4Q}{4\pi\epsilon_0 r^2}$

D. $\dfrac{4Q}{4\pi\epsilon_0 (r^2 + d^2)}$

E. $\dfrac{4Q}{4\pi\epsilon_0 r}$



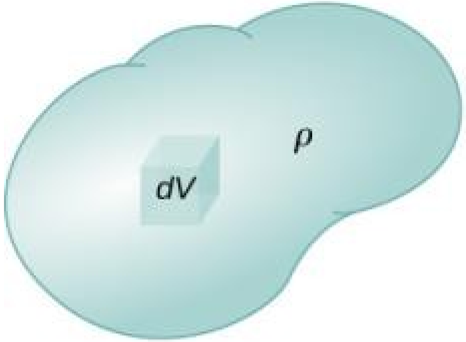
Looks like a point charge $4Q$ at the origin.

Electric Field of a Charge Distribution

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r} \qquad \text{(electric field of a point charge)}$$

(a)

(b)



(c)

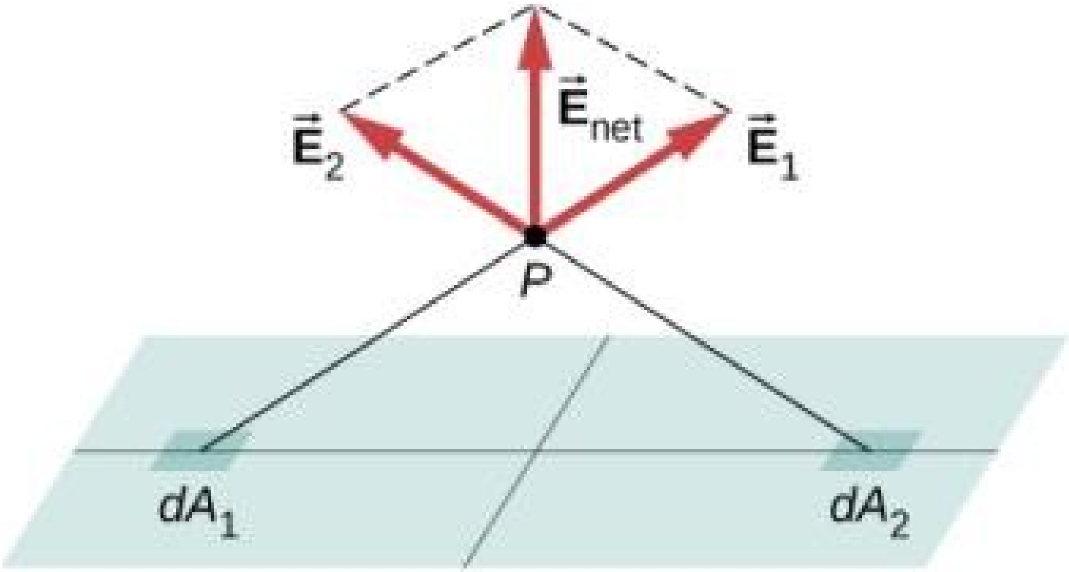
- break up the charge into little parts, each with charge dq
- each dq contributes a field of $d\vec{E}$ at the point *P*
- add up all the contributions to find the total field

$$\vec{E} = \int d\vec{E} \quad = \int \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{r}$$

Electric Field of a Charge Distribution

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r} \qquad \text{(electric field of a point charge)}$$

Look for symmetry to simplify the problem.

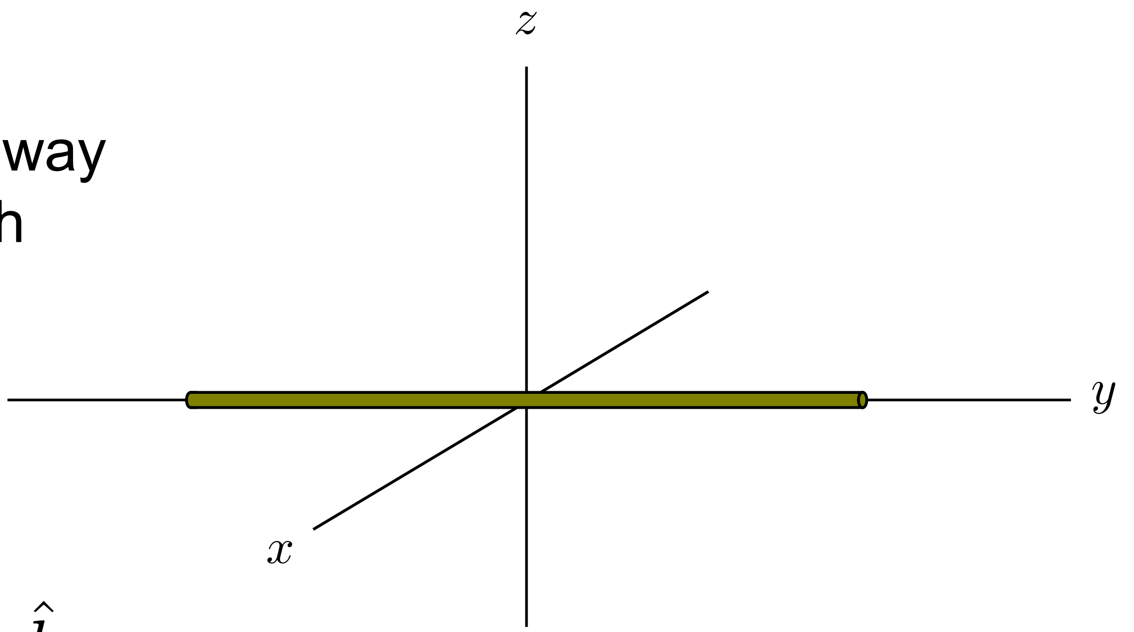


Electric Field of a Charge Distribution

$$\vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \hat{r}$$

Find the electric field a distance z away from the center of a line charge (with charge density λ C/m).

(you may consult a table of integrals)



$$\vec{E}(P) = \frac{1}{4\pi\epsilon_0} \frac{Q}{z\sqrt{z^2 + (L/2)^2}} \hat{k}$$

Check limits:

$z \ll L \qquad z \gg L$