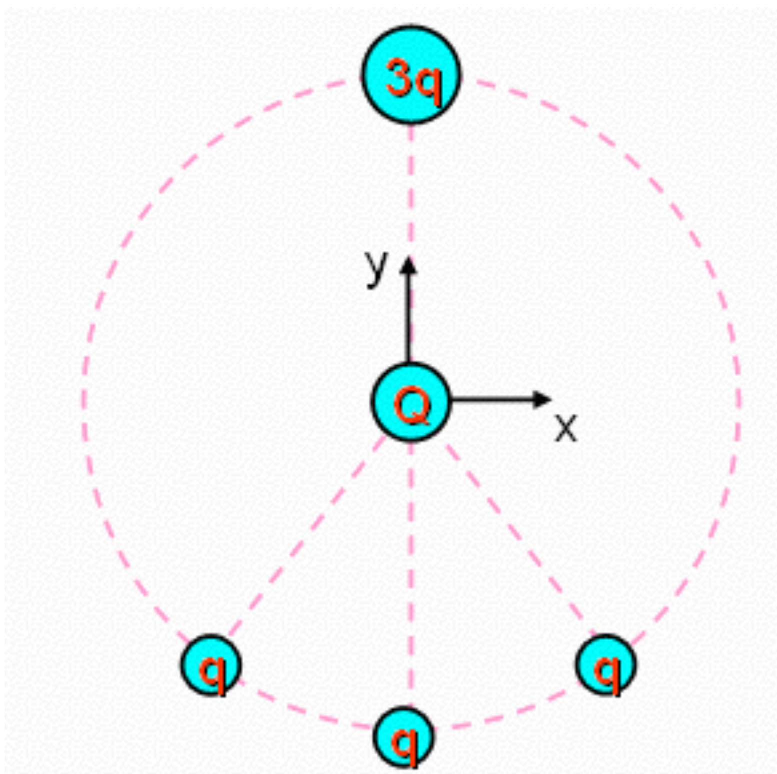
From smartPhysics

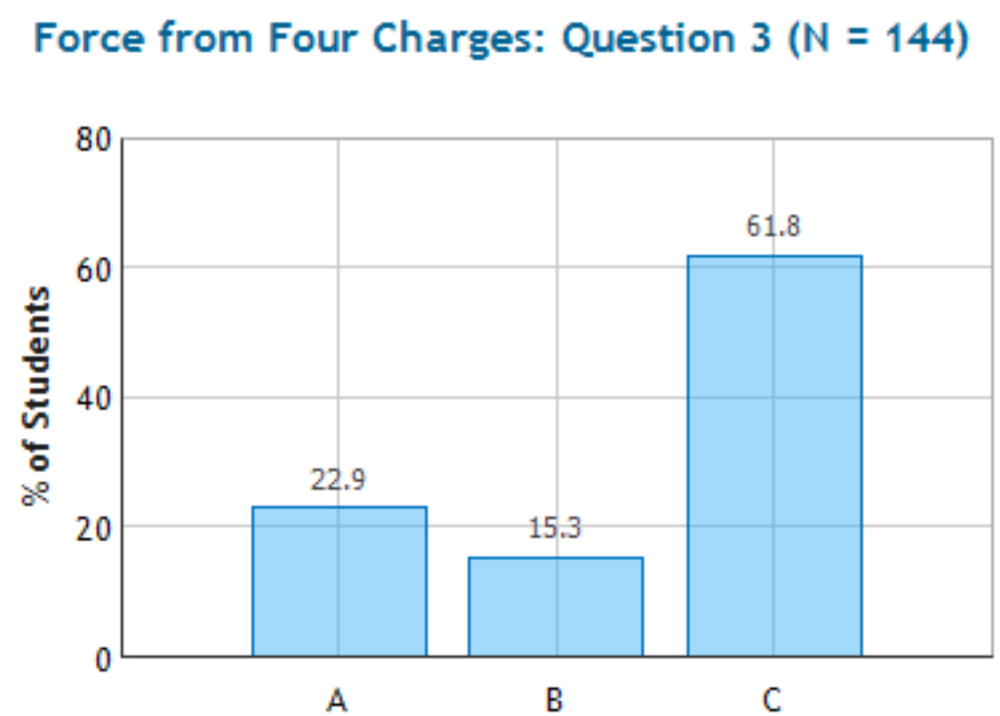


For the collection of charges shown in the above problem, which of the following statements best describes **F**$_Y$, the y component of the net force on the charge at the origin

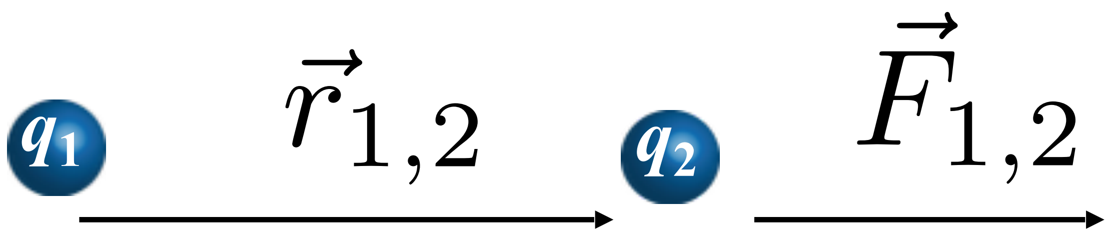
F$_Y > 0$

F$_Y = 0$

F$_Y < 0$



Coulomb Law



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

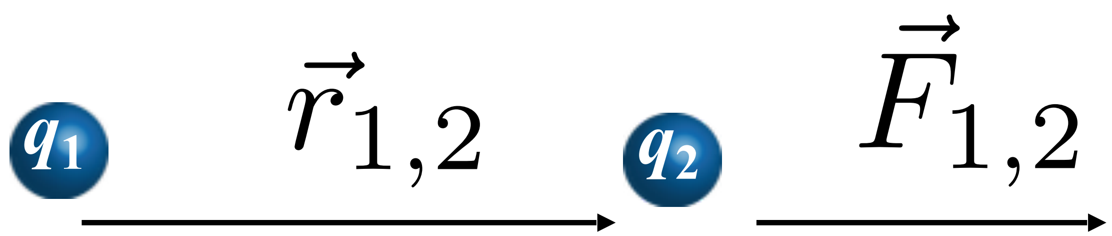
$\vec{F}_{1,2}$: (N) Force applied by charge 1 on charge 2

q_1, q_2 : (C) charges of object 1 and 2

k : A physical constant $k = 8.99 \times 10^9\ \mathrm{N} \cdot \mathrm{m}^2/\mathrm{C}^2$

$\vec{r}_{1,2}$: (m) Displacement vector connecting point 1 to 2

Intuition: Coulomb Law



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

- Direction: Symmetry
- Linear dependence on q_1 and q_2 : Field does not carry charge
- Inverse square law: Conservation of flux ~ A^{-1}

Reading from the book

- Monday: 21-2, 21-3
- Wednesday: 21-4
- Friday: 21-5, 21-6

Demo’s for charge…

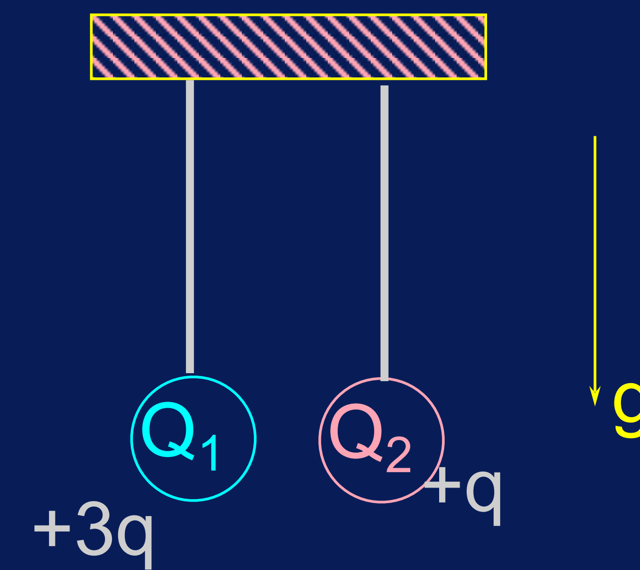
- Like charges repel.

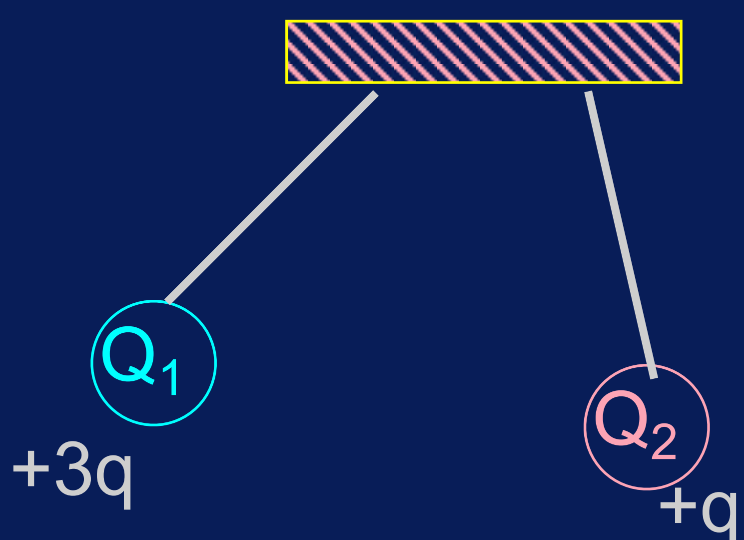
- Opposite charges attract.

Clicker

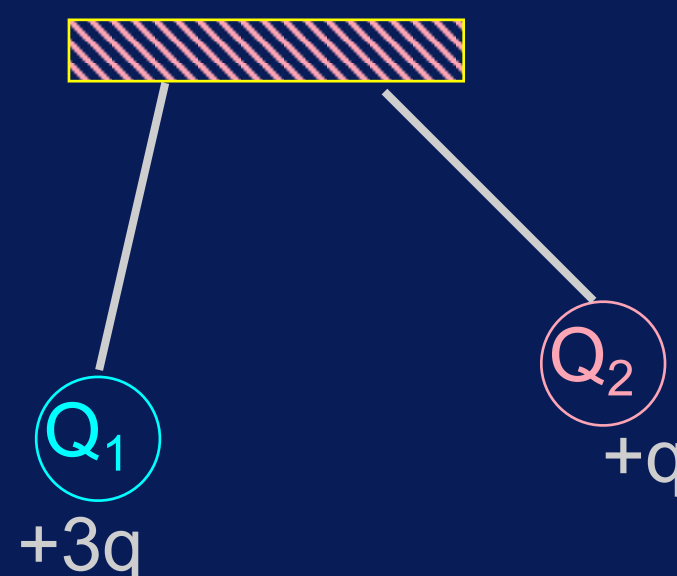
Two equal mass balls are suspended from the ceiling with equal length nonconducting threads as shown. Ball 1 has charge $Q_1 = +3q$ and Ball 2 has charge $Q_2 = +q$.

- Which of the following pictures best represents the equilibrium position?

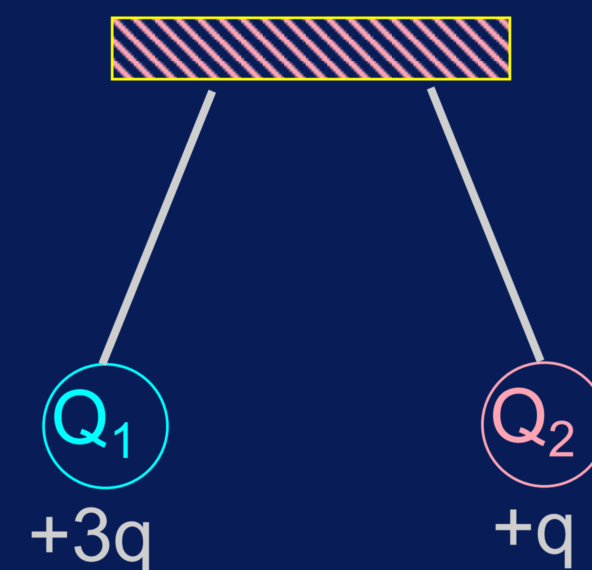




(a)



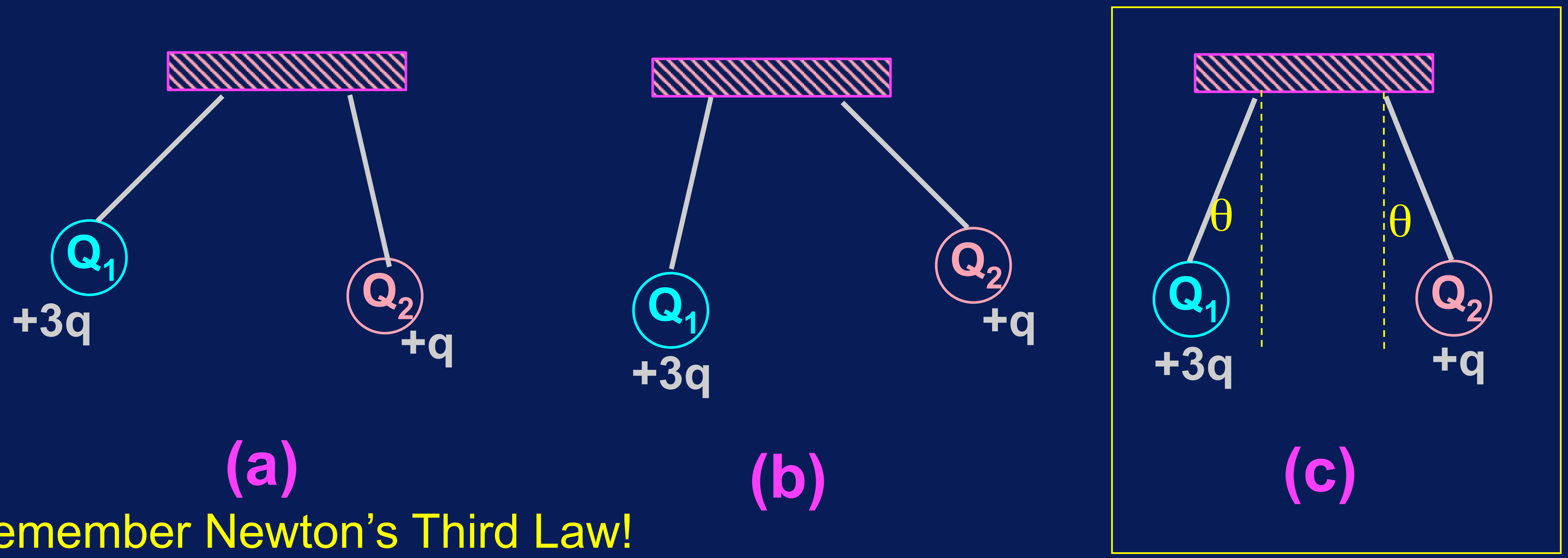
(b)



(c)

Clicker

- Which of the following pictures best represents the equilibrium position?



- Remember Newton's Third Law!

The electrical force Q_1 exerts on Q_2 must be equal and opposite to the electrical force that Q_2 exerts on Q_1.

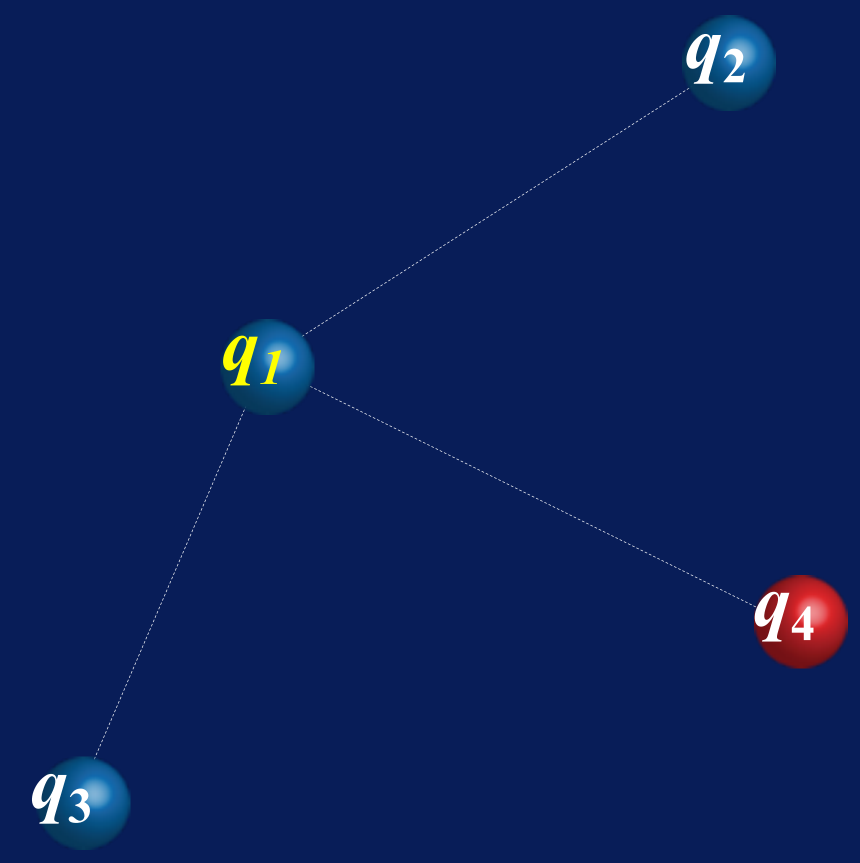
The amount of charge each ball has determines the magnitude of the force, but each each ball experiences the same force.

Therefore, the symmetry demands (c) !!

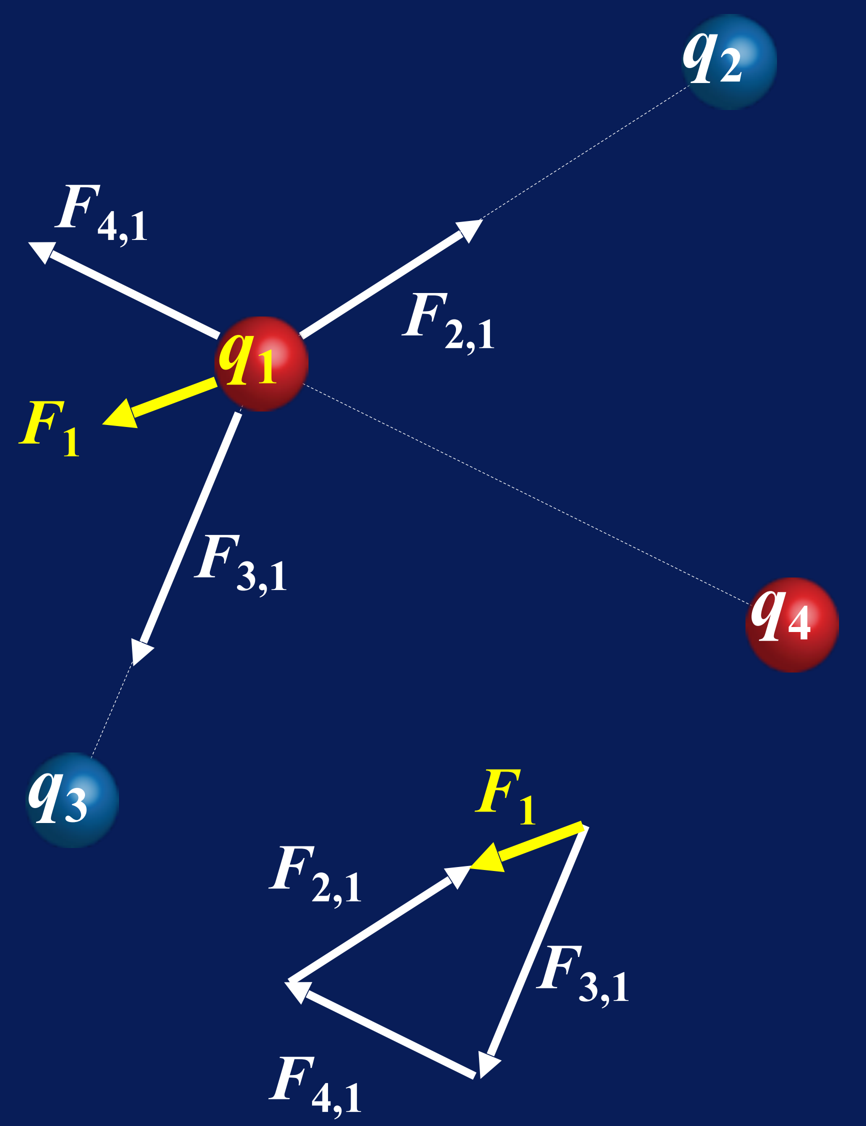
Clicker

What happens to the Force on q_1 if its sign is changed?

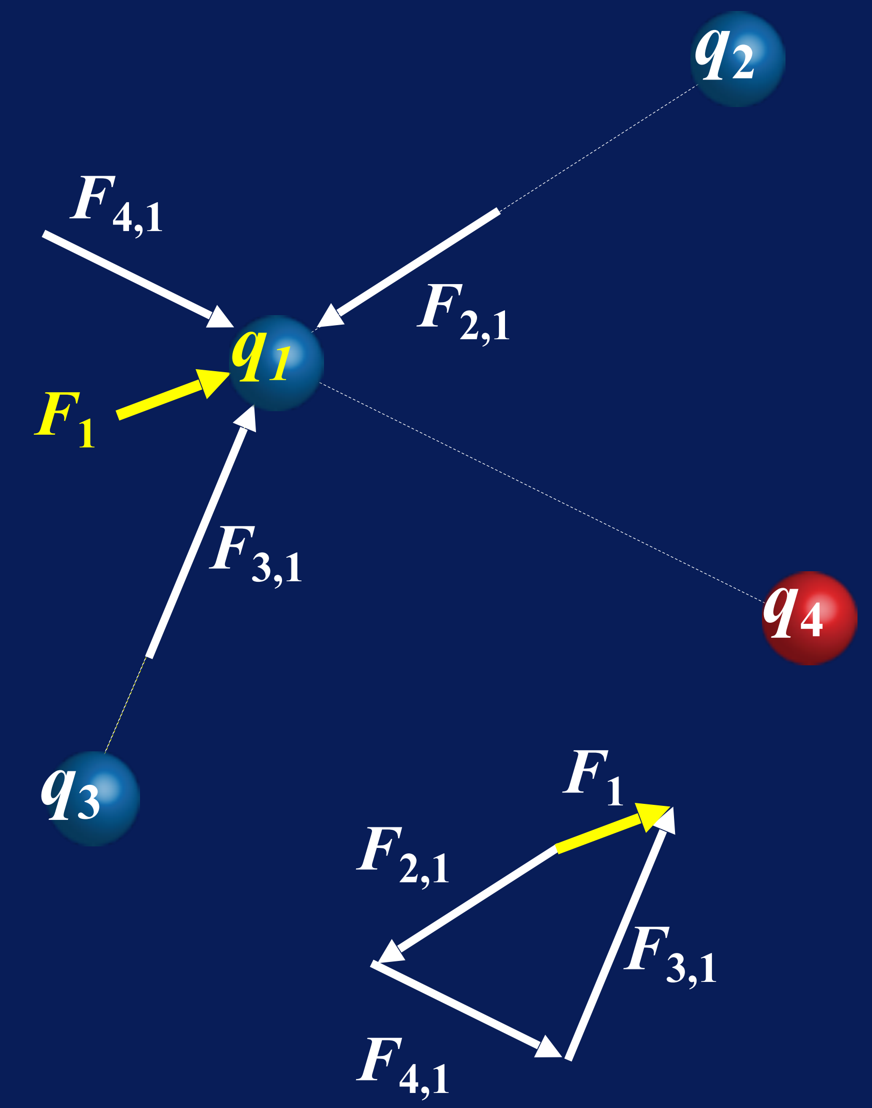
A) $|F_1|$ increases
B) $|F_1|$ remains the same
C) $|F_1|$ decreases
D) Need more information to determine



The **direction** of all forces changes by 180° – the **magnitudes** stay the same:



$$\vec{F}_1 = \vec{F}_{2,1} + \vec{F}_{3,1} + \vec{F}_{4,1} + \ldots$$



$$-\vec{F}_1 = -\vec{F}_{2,1} - \vec{F}_{3,1} - \vec{F}_{4,1} - \ldots$$

Phys122D-Lecture 2
Electric Field

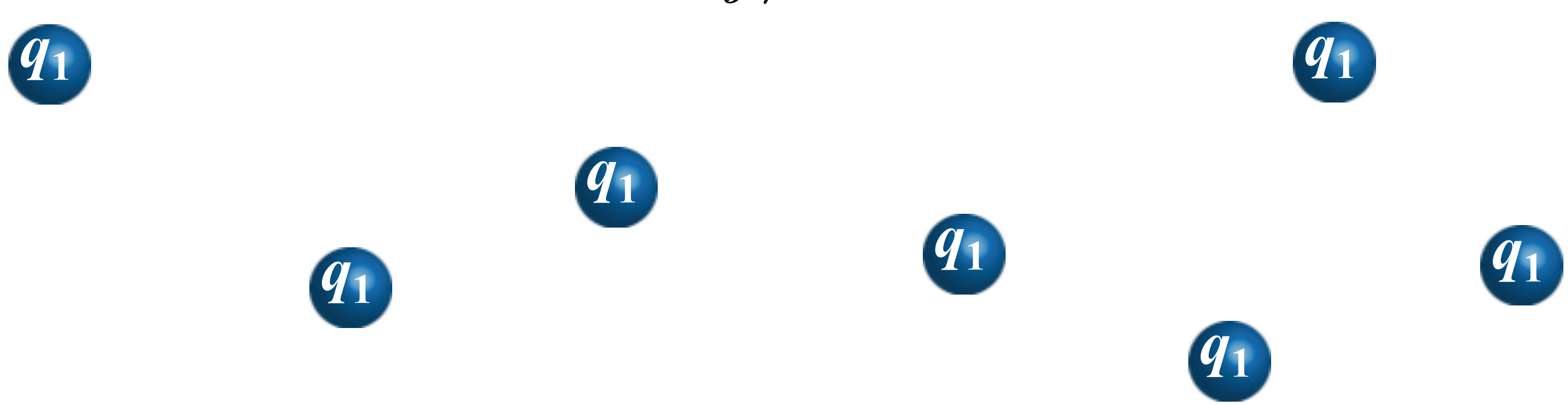
Introduction to the Electric Field…

- Coulomb Law:

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

- Superposition for an collection of *discrete* charges:

$$\vec{F}_{\mathrm{Net},i} = \sum_{j\neq i}\frac{k\ q_i q_j}{r_{j,i}^2}\hat{r}_{j,i}$$



Introduction to the Electric Field…

- Superposition for an collection of *discrete* charges:

$$\vec{F}_{\mathrm{Net},0} = \sum_{j \neq 0} \frac{k\ q_0 q_j}{r_{j,0}^2} \hat{r}_{j,0} = q_0 \sum_{j \neq 0} \frac{k\ q_j}{r_{j,0}^2} \hat{r}_{j,i}$$

- Define the **Electric Field** (q_0 is a test charge):

$$\vec{E} \equiv \frac{\vec{F}_{\mathrm{Net},0}}{q_0}$$

Electric field from a point charge

- **Electric Field** from a point charge (at the origin):

$$\vec{E} \equiv \frac{\vec{F}_{1,0}}{q_0} = \frac{k\, q_1}{r^2}\hat{r}$$

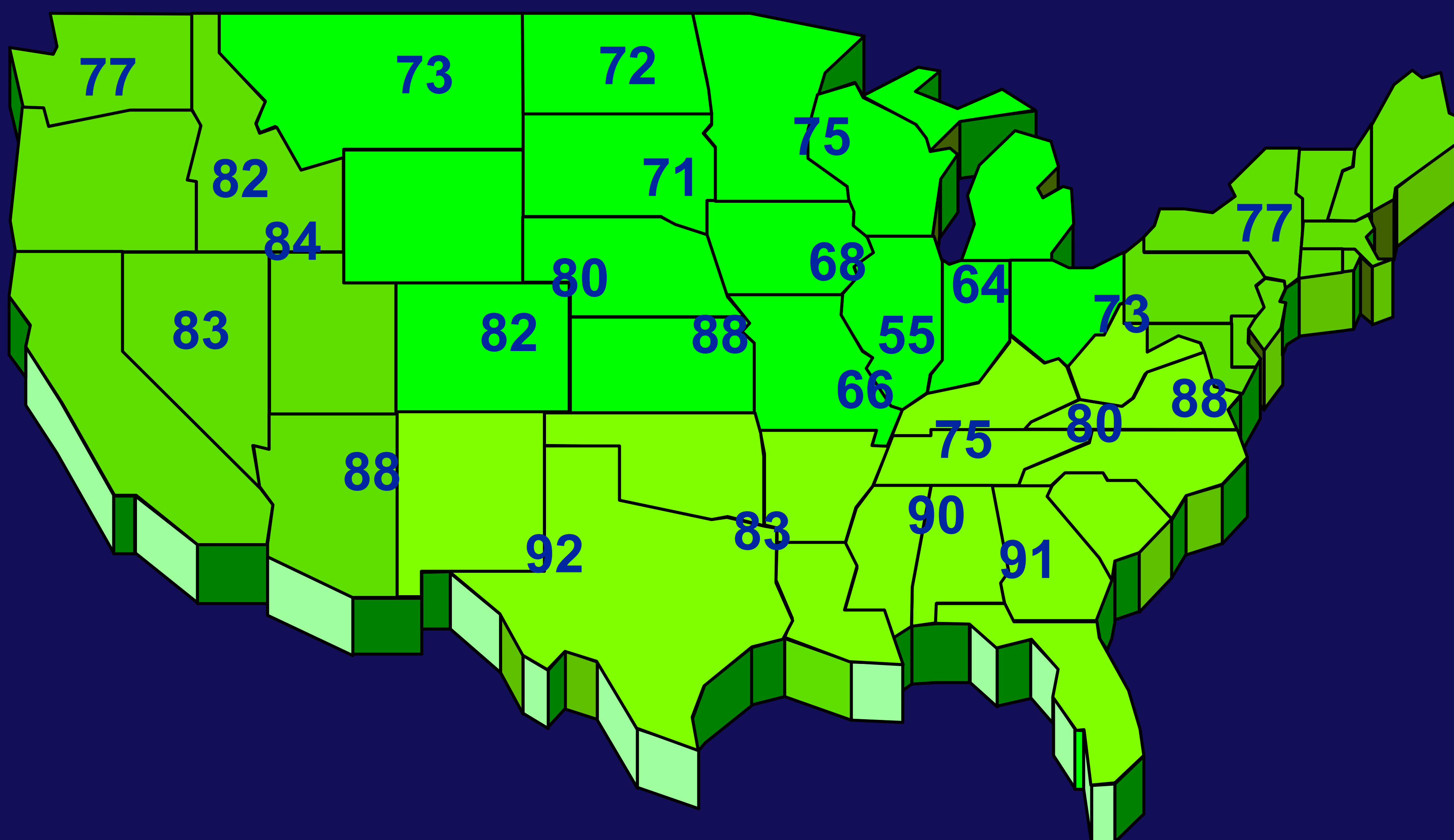
- **Electric Field** from a collection of charges:

$$\vec{E}(\vec{r}_0) = \sum_{j\neq 0} \frac{k\ q_j}{r_{j,0}^2}\hat{r}_{j,0}$$

What is a field?

- Scalar, vector (or tensor…) valued function of space (and time).
  - Electric Field (vector) $\vec{E}(\vec{r}, t)$
  - Magnetic Field (vector) $\vec{B}(\vec{r}, t)$
  - Electric Potential (scalar) $\Phi(\vec{r}, t)$

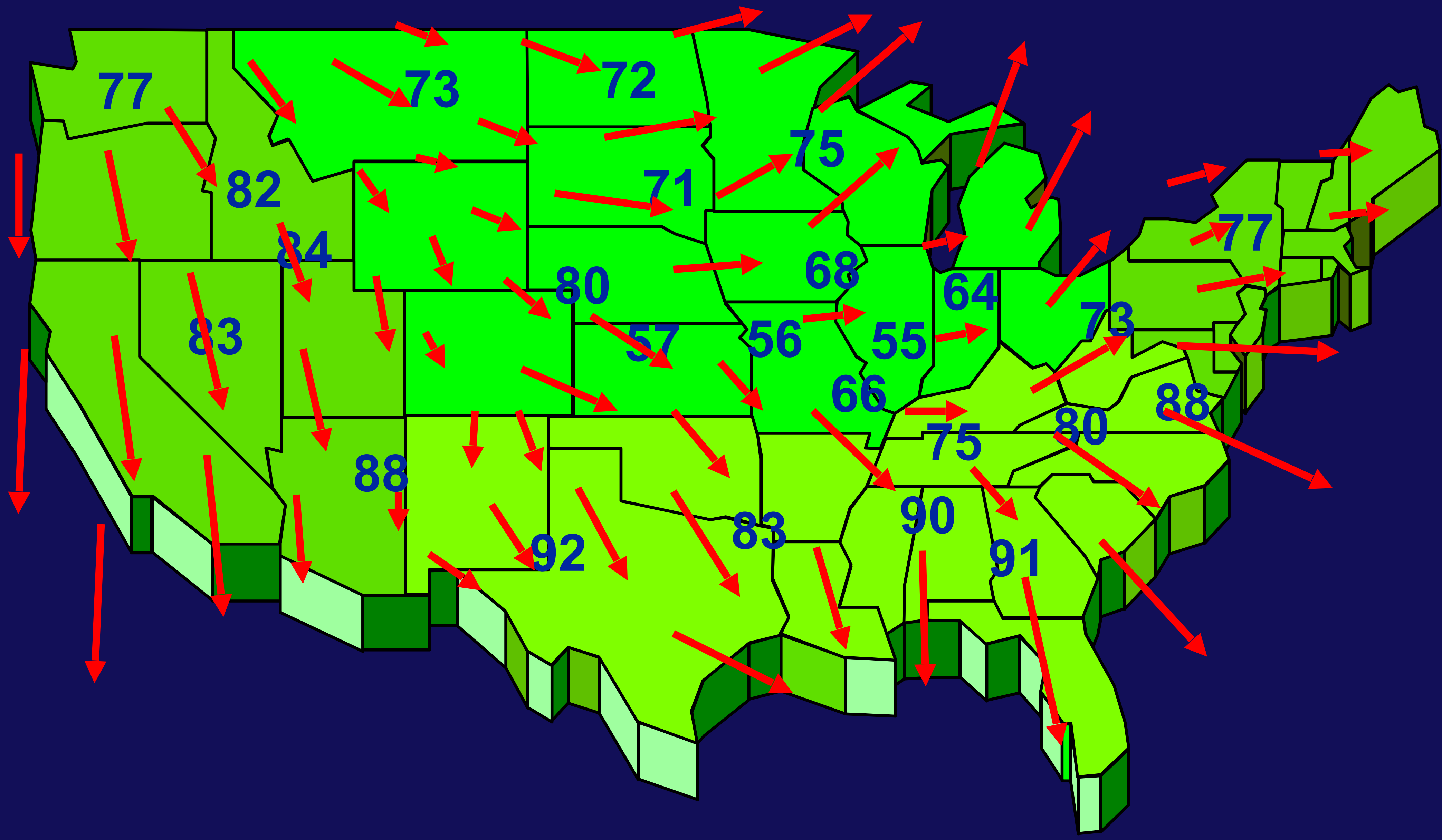
Fields of all kinds...



These isolated Temperatures make up a Scalar Field
(you learn only the temperature at a place you choose)

Fields of all kinds...

It may be more interesting to know which way the wind is blowing …



That would require a VECTOR field.

(you learn how fast the wind is blowing, AND in what direction)

Does the E field really exist?

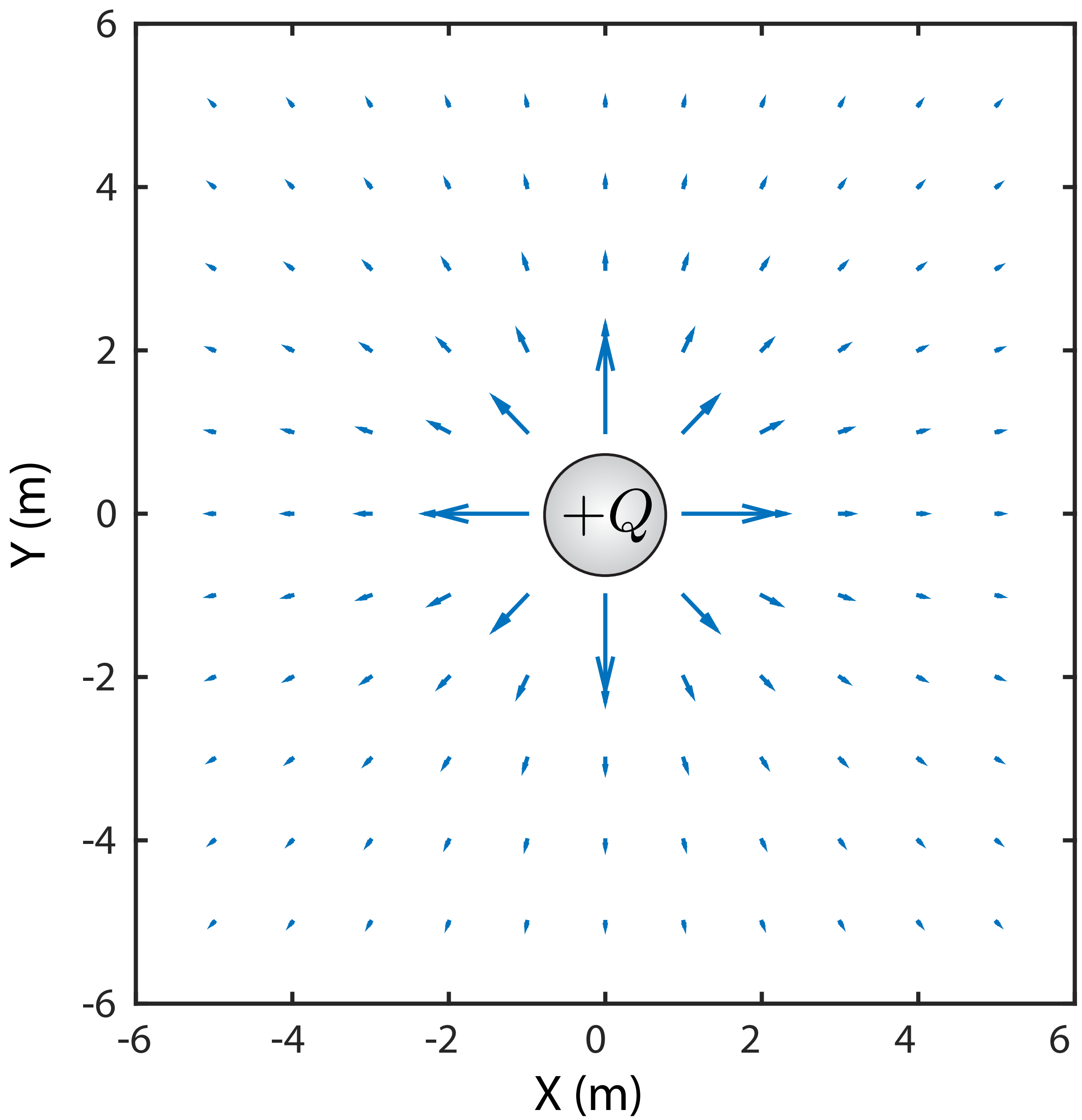
- Computation tool or physical entity?
- Two unattractive alternatives:
    - Assume E field exists at all locations in space ✔
    - *Assume action at a distance* ✘
- Useful heuristic for understanding physics:
  There is no instantaneous ***action at a distance.***

Visualizing the E field

$$\vec{E}(\vec{r}) = \frac{k\ q_1}{r^2}\hat{r}$$

- **Direction:**
  - Radial
  - Direction of the force on a positive charge
- **Amplitude:**
  - Decreases with distance

Visualizing the E field



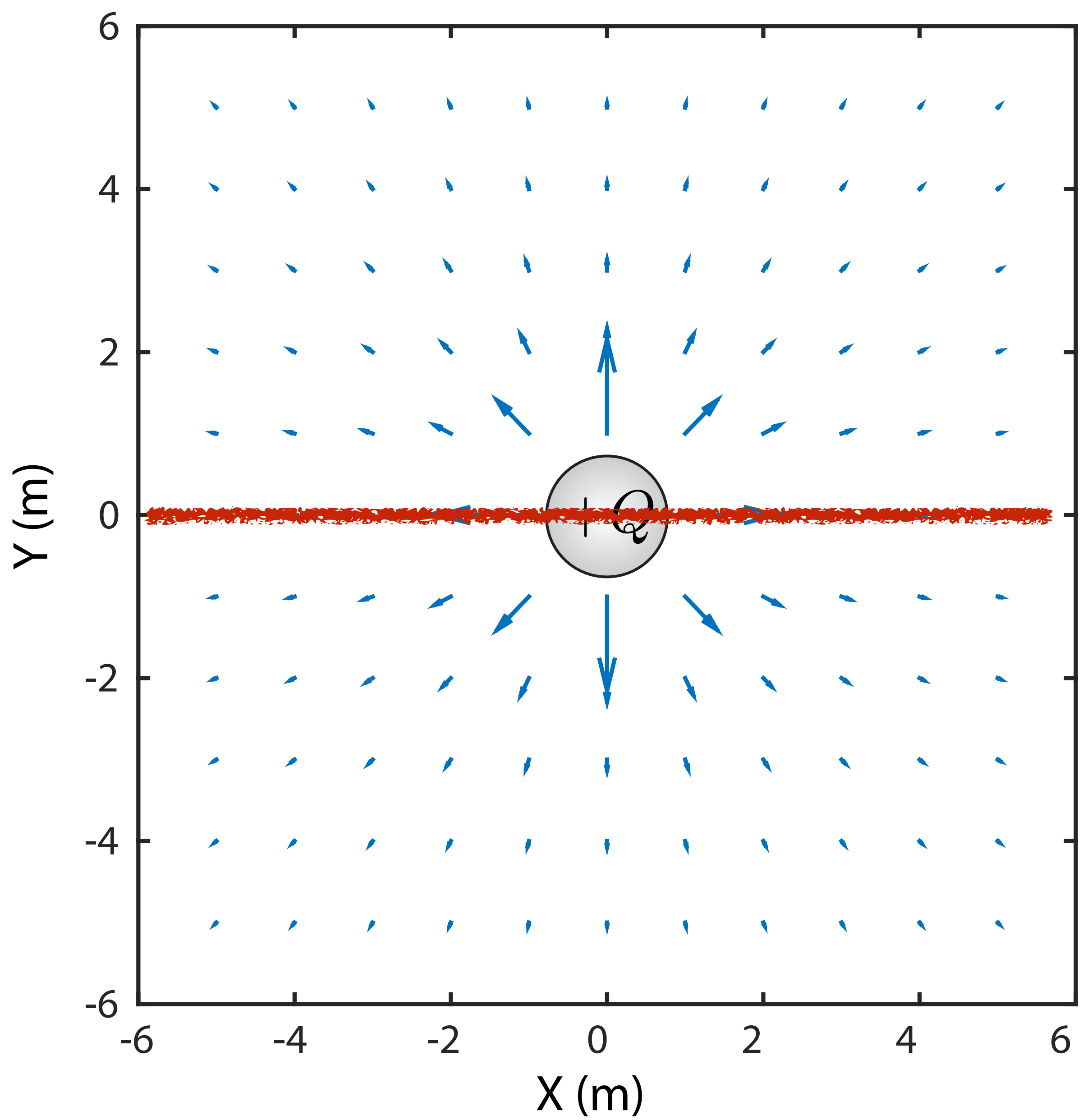
$$\vec{E}(\vec{r}) = \frac{k\ q_1}{r^2}\hat{r}$$

- “quiver” or Velocity Plot
- You almost never see the E field drawn this way!
- General tool for visualizing a vector field.

Visualizing the E field

Field lines … next time.

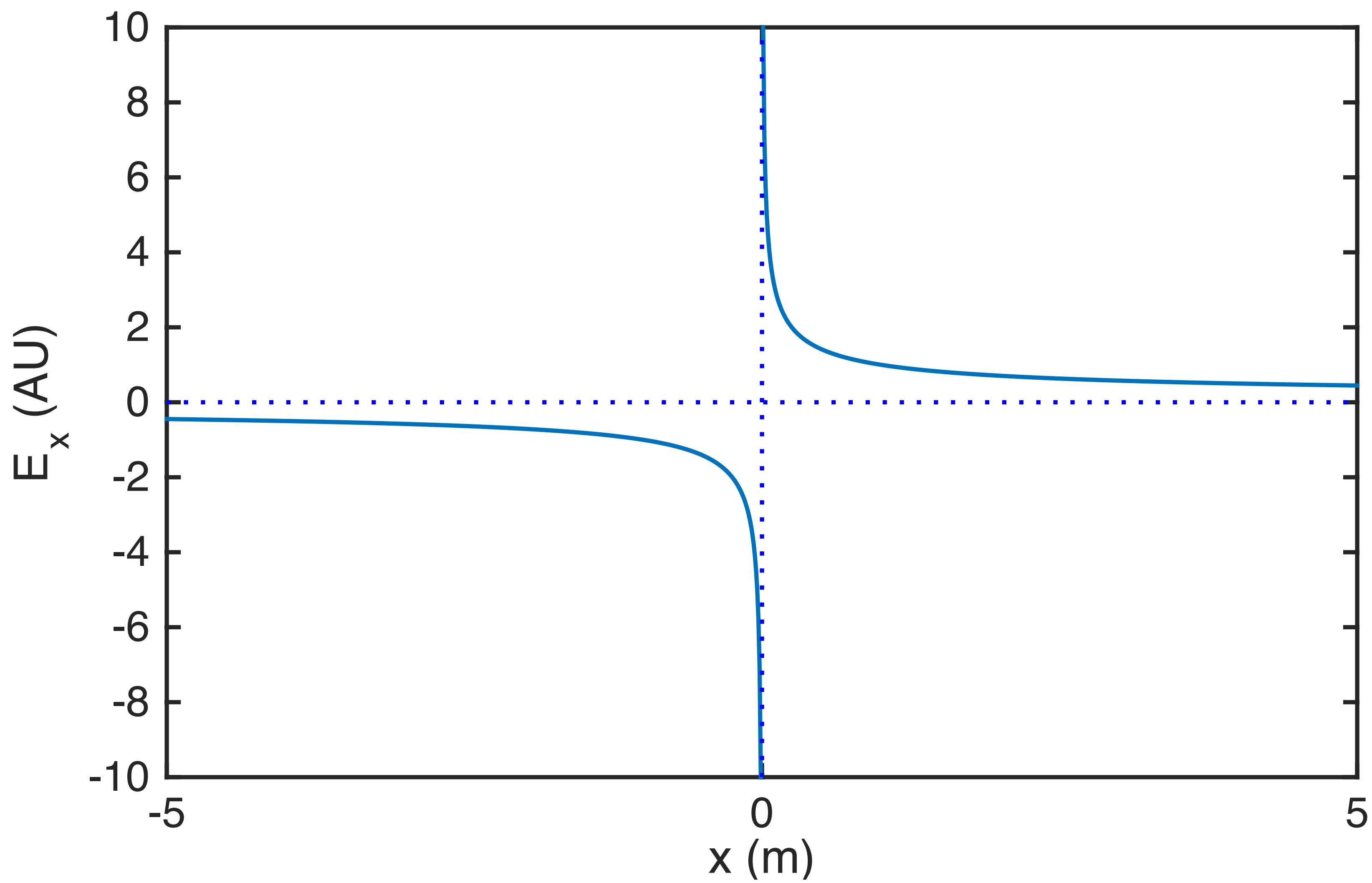
Visualizing the E field



- “quiver” or Velocity Plot
- You almost never see the E field drawn this way!
- General tool for visualizing a vector field.

Visualizing the E field

$$\vec{E}(x,y)\Big|_{y=0} = k\ q_1 \frac{x\hat{i}}{|x|^3}$$



Electric field from a point charge

- **Electric Field** from a point charge (at the origin):

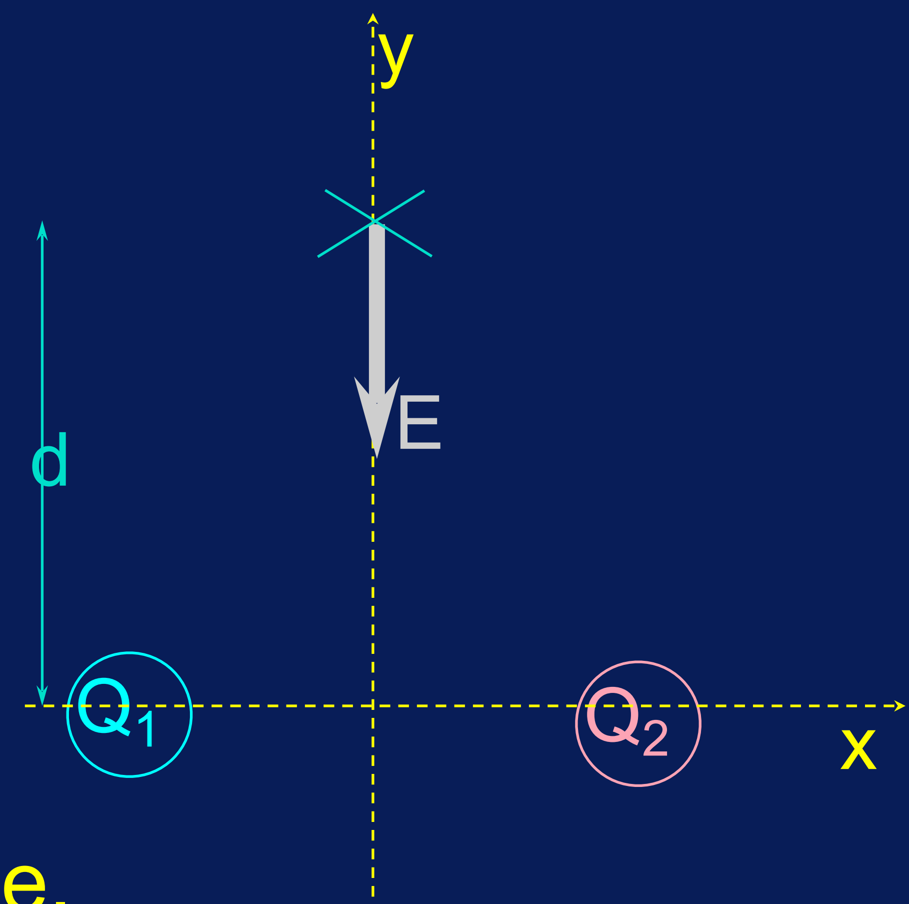
$$\vec{E} \equiv \frac{\vec{F}_{1,0}}{q_0} = \frac{k\,q_1}{r^2}\hat{r}$$

- **Electric Field** from a collection of charges:

$$\vec{E}(\vec{r}_0) = \sum_{j\neq 0} \frac{k\ q_j}{r_{j,0}^2}\hat{r}_{j,0}$$

Clicker

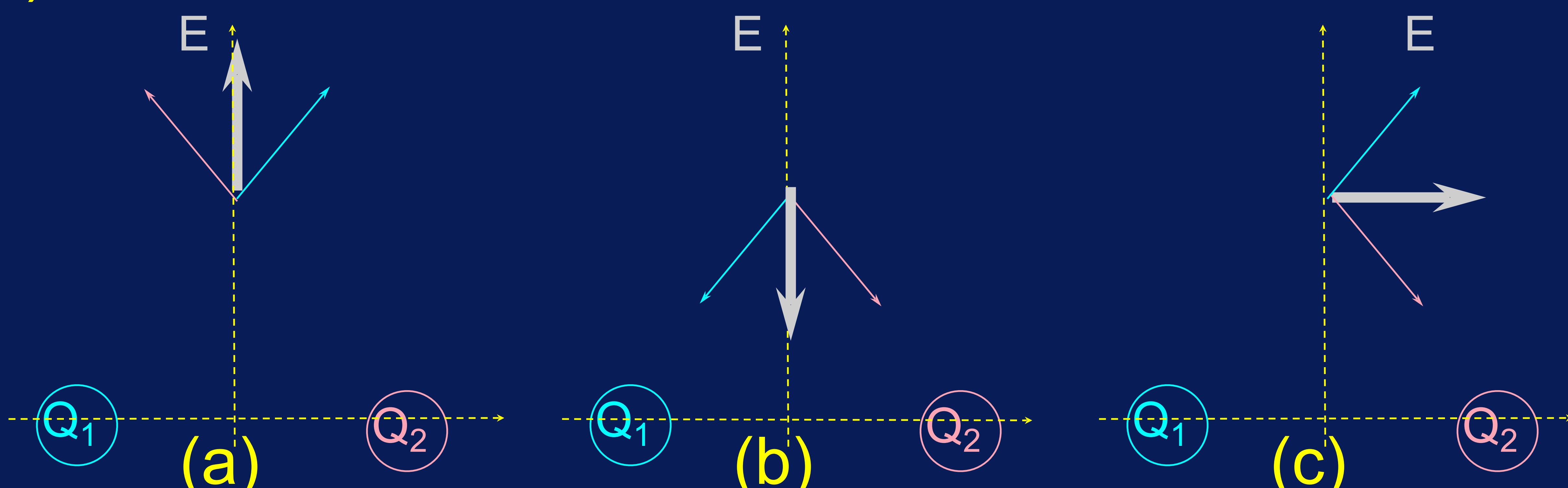
- Two charges, Q_1 and Q_2 , fixed along the x-axis as shown, produce an electric field E at a point (x,y) = (0,d) which is directed along the negative y-axis.
  - Which of the following statements is true?



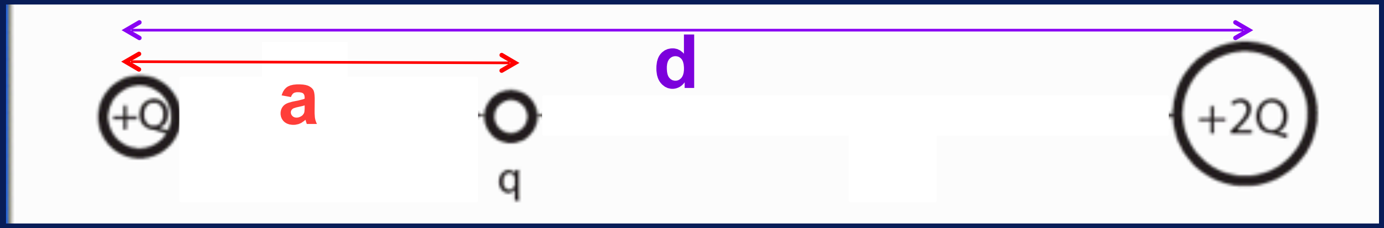
(a) Both charges Q_1 and Q_2 must be positive.

$\boxed{\text{(b) Both charges } Q_1 \text{ and } Q_2 \text{ must be negative.}}$

(c) The charges Q_1 and Q_2 must have opposite signs.



Clicker followup



Same setup:

- Q_1 has charge +Q
- Q_2 has charge +2Q
- They are separated by d.
- Charge q is a distance a away from Q_1

Is there a place – the value for a -- between Q_1 and Q_2 where the force on ANY charge (positive or negative) is zero?

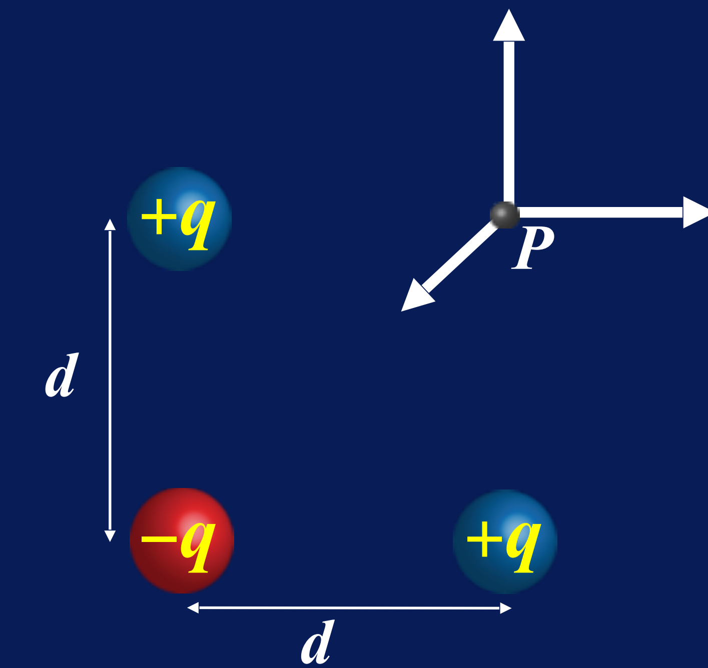
(a) NO

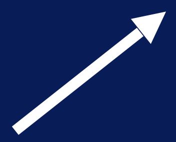
(b) Yes, but I can't find it with all this time pressure.

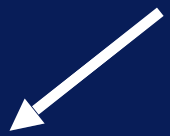
(c) Yes and my answer is ________ from Q_1. I will volunteer to specify if you ask me

Clicker

What is the direction of the electric field at point P, the unoccupied corner of the square?



A) 

B) 

C) $E = 0$

D) Need to know d

E) Need to know d & q

Calculate E at point P.

$$\vec{E} = \sum_i k \frac{Q_i}{r_i^2} \hat{r}_i$$

$$E_x = \frac{1}{4\pi\varepsilon_o}\left(\frac{q}{d^2} - \frac{q}{\left(\sqrt{2}d\right)^2}\cos\frac{\pi}{4}\right)$$

> 0

$$E_y = \frac{1}{4\pi\varepsilon_o}\left(\frac{q}{d^2} - \frac{q}{\left(\sqrt{2}d\right)^2}\sin\frac{\pi}{4}\right)$$

> 0

E field from a line charge

- **Electric Field** from a collection of charges:

$$\vec{E}(\vec{r}_0) = \sum_{j\neq 0} \frac{k\ q_j}{r_{j,0}^2}\hat{r}_{j,0}$$

- **Electric Field** from a continuous charge distribution:

$$\vec{E}(\vec{r}) = k \int dq_{\vec{r}\,'}\ \frac{\vec{r}-\vec{r}\,'}{|\vec{r}-\vec{r}\,'|^3}$$