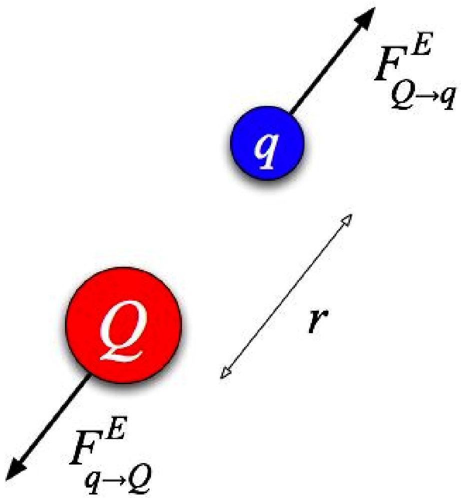
Week 4

Outline

- Review electric Forces
- Review electric Potential

Electric Charge - A property of matter

- Matter is made up of two kinds of electric charges (positive and negative).
- Like charges repel, unlike charges attract.
- Charge is neither created or destroyed, but it can move around.
- Because of the strong attraction between opposite charges, they are often found together.
- Matter with an equal balance is called <u>neutral</u>.
  - Examples: atoms and molecules at room temperature
  - Although atoms and molecules are neutral, their interactions and propensity to form bonds are due to the attraction of their internal charges



Foothold idea: Coulomb's Law

$$\vec{F}_{q\to Q} = \frac{k_C q Q}{r_{qQ}^2}\hat{r}_{q\to Q}$$

$$k_C = 9\times 10^9 \text{ N-m}^2/\text{C}^2$$

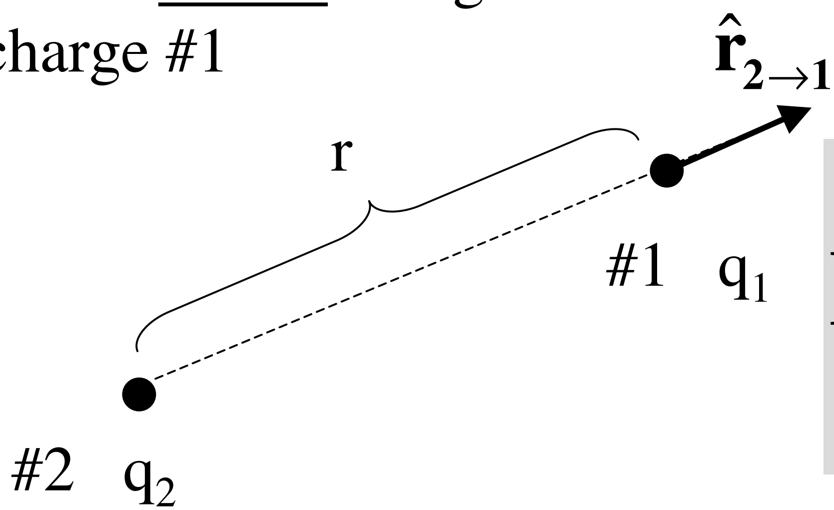
Summary of Coulomb’s Law

- Charges exert forces on each other
  - Opposite signs attract
  - Like signs repel
  - Force decreases with distance squared

- Mathematically expressed as Coulomb’s Law

Coulomb’s Law

The force **<u>due to</u>** charge #2
<u>on</u> charge #1



$$\vec{\mathbf{F}}_{2on1} = \frac{Kq_1q_2}{r^2}\hat{\mathbf{r}}_{\mathbf{2\to1}}$$

$\hat{\mathbf{r}}_{\mathbf{2\to1}}$ is a unit vector pointing away from #2 (the charge making the force) along a line passing through #1 (the charge experiencing the force).

When stated this way all signs and directions are taken care of!

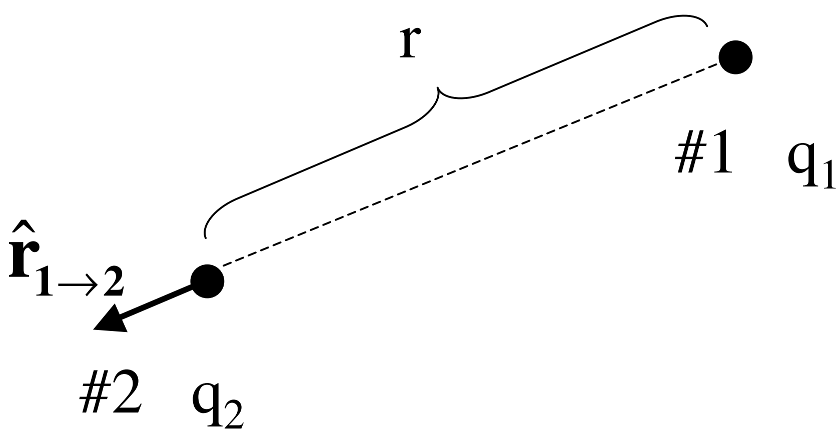
Making Sense of Coulomb's Law

- Changing the test charge
- Changing the source charge
- Changing the distance
- Specifying the direction
- Use Subscripts!

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

Newton's third law: action-reaction

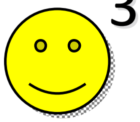
The force **<u>due to</u>** charge #1
<u>on</u> charge #2

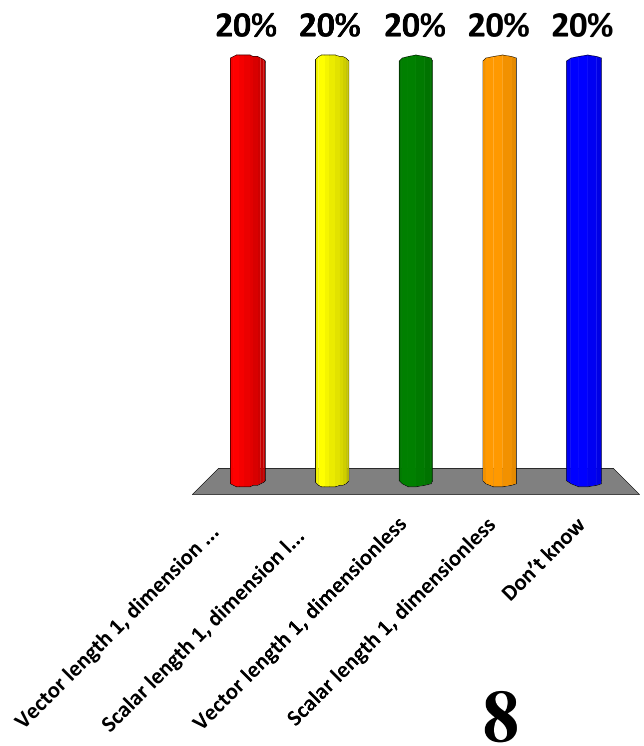


$\hat{\mathbf{r}}$ reverses sign

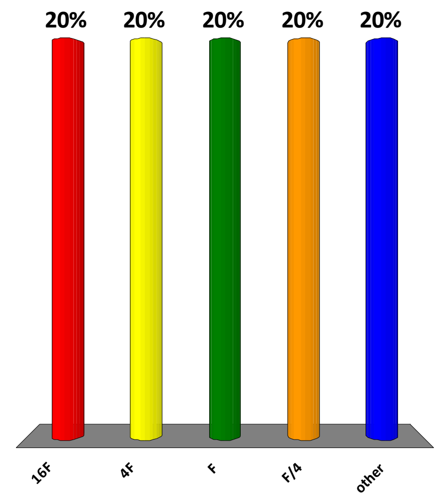
$$\vec{\mathbf{F}}_{1on2} = \frac{Kq_1 q_2}{r^2}\hat{\mathbf{r}}_{\mathbf{1\to 2}} = -\vec{\mathbf{F}}_{2on1}$$

What is $\hat{r}_{1\to 2}$?

1. Vector length 1, dimension length
2. Scalar length 1, dimension length

3. Vector length 1, dimensionless
4. Scalar length 1, dimensionless
5. Don't know



Two small objects each with a net charge of Q (positive) exert a force of magnitude F on each other. We replace one of the objects with another whose net charge is 4Q. The original magnitude of the force on the Q charge was F; what is the magnitude of the force on the Q now?



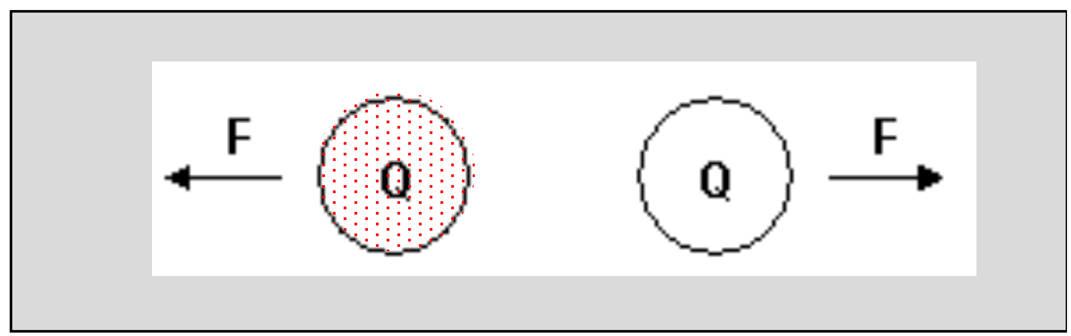
A. 16F

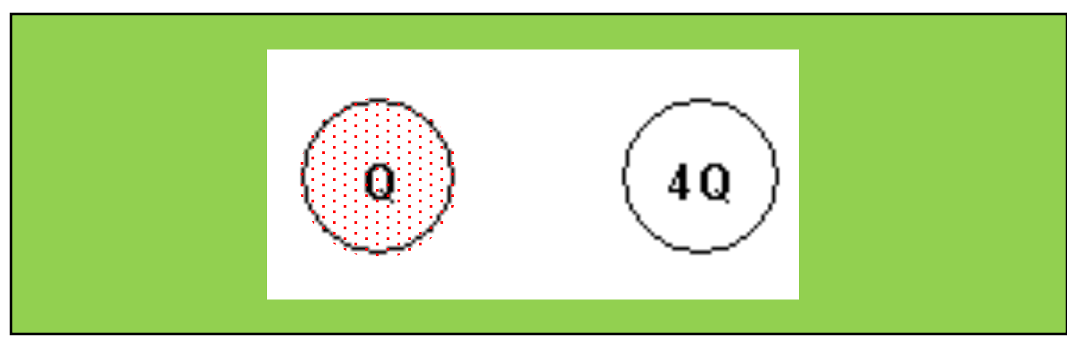
B. 4F

C. F

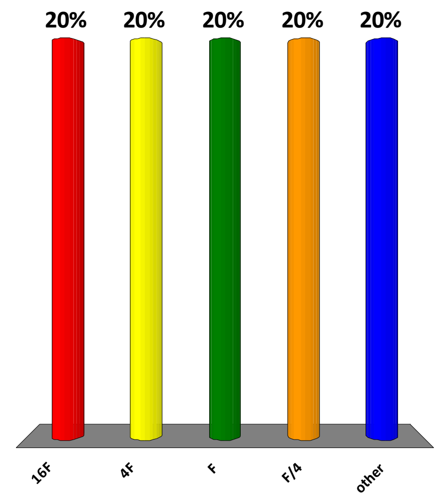
D. F/4

E. other

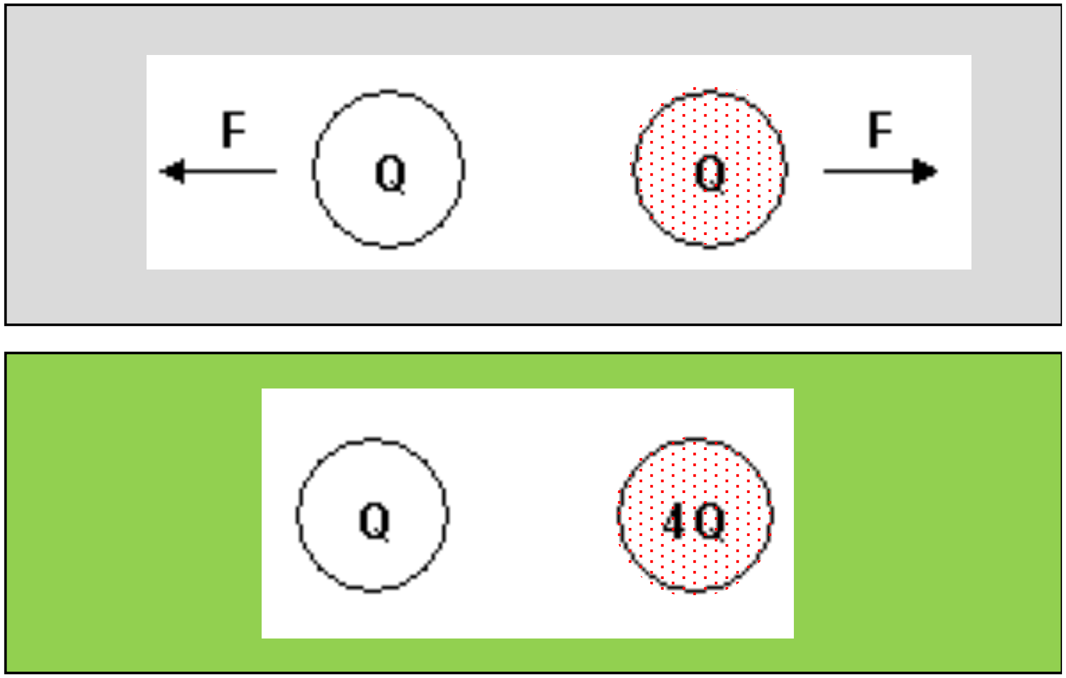




What is the magnitude of the force on the 4Q charge?



A. 16F
B. 4F
C. F
D. F/4
E. other



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Movement of Charges

Can Charges Move?

- Insulators
  - Charges are bound and cannot move around freely.
  - Excess charge tends to just sit there.
- Conductors
  - Charges can move around throughout the object.
  - Excess charge redistributes itself or flows off
    - Solid: Electrons move
    - Fluid: Charged atoms move
- Unbalanced charges attract neutral matter (polarization)

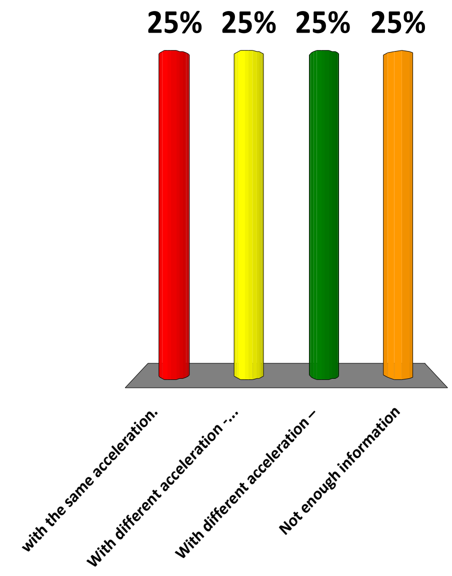
When two objects with the same sign of charge but different magnitudes are put near each other, they accelerate

A. with the same acceleration.

B. With different acceleration -   Larger charge has higher acceleration.

C. With different acceleration –
Smaller charge has higher acceleration.

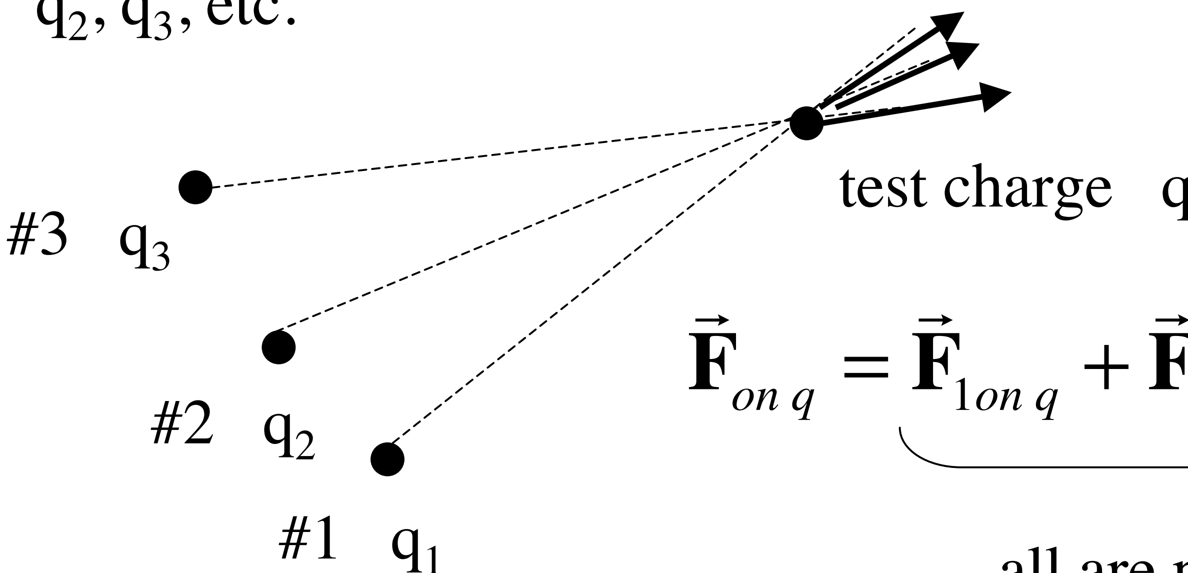
D. Not enough information



Addition of forces

Superposition - Forces add

Charges making force: q_1, q_2, q_3, etc.



$$\vec{\mathbf{F}}_{on\;q} = \underbrace{\vec{\mathbf{F}}_{1 on\;q} + \vec{\mathbf{F}}_{2 on\;q} + \vec{\mathbf{F}}_{3 on\;q} + \ldots}_{\text{all are proportional to q}}$$

$$\vec{\mathbf{F}}_{on\;q} = q\vec{\mathbf{E}}$$

Definition of Electric Field

In the figure are shown four arrangements of charge. Each charge has the same magnitude, but some are + and some are -. All distances are to the same scale. In which arrangement would the magnitude of the force felt by a positive test charge placed at P be the largest?

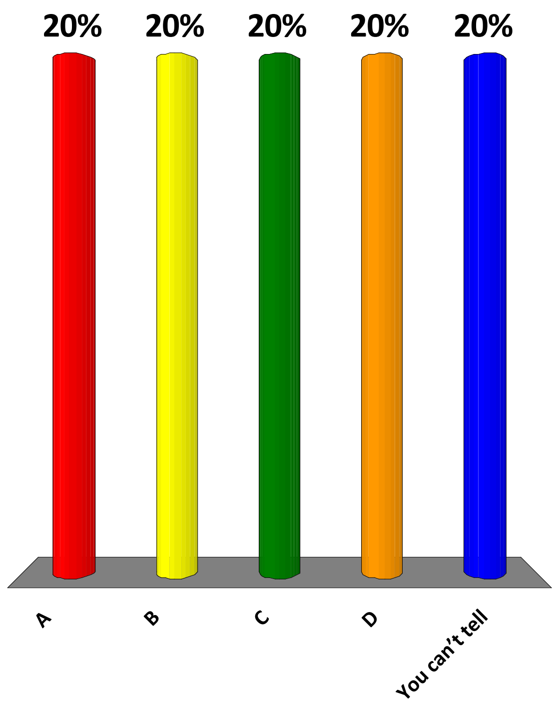
A. A

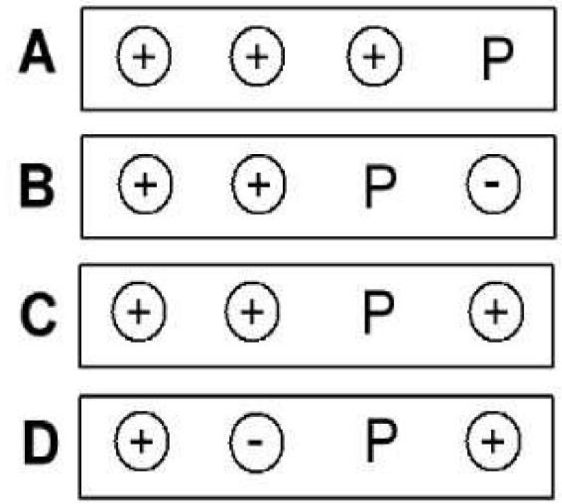
B. B

C. C

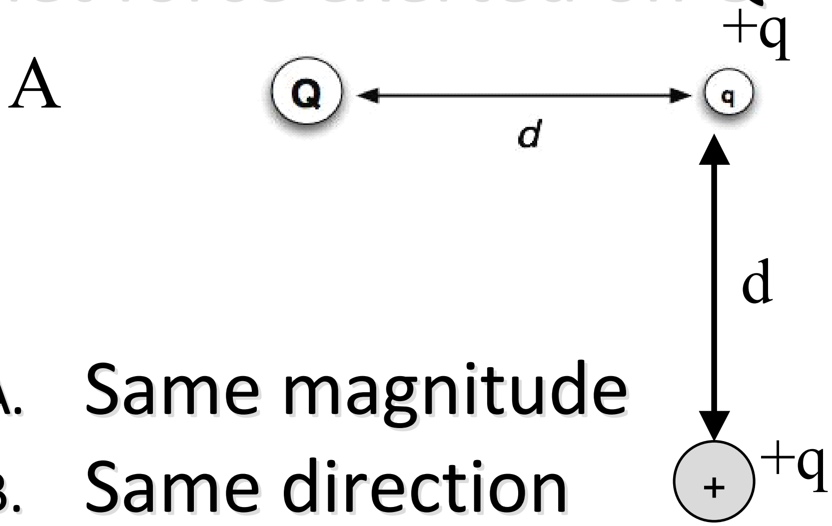
D. D

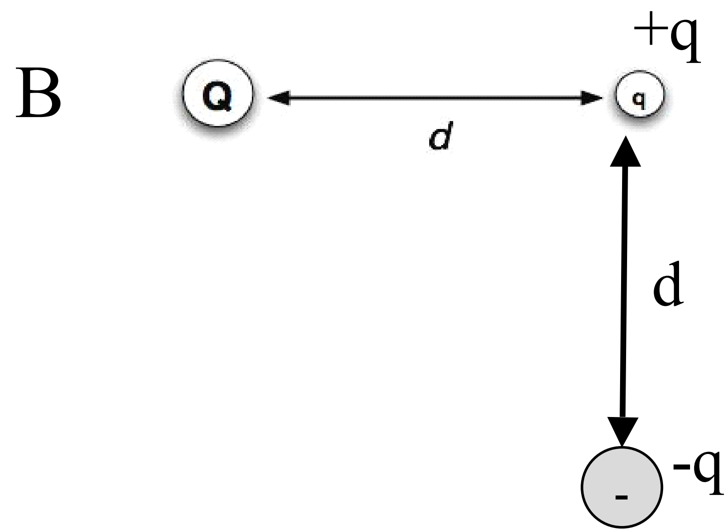
E. You can't tell



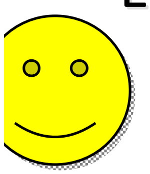


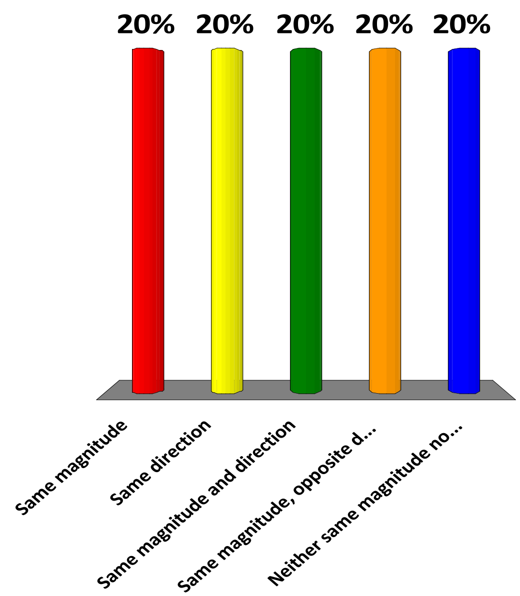
Compare the magnitude and direction of the net force exerted on Q



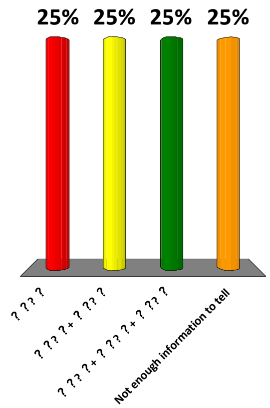


A. Same magnitude
B. Same direction
C. Same magnitude and direction
D. Same magnitude, opposite direction
E. Neither same magnitude nor same direction

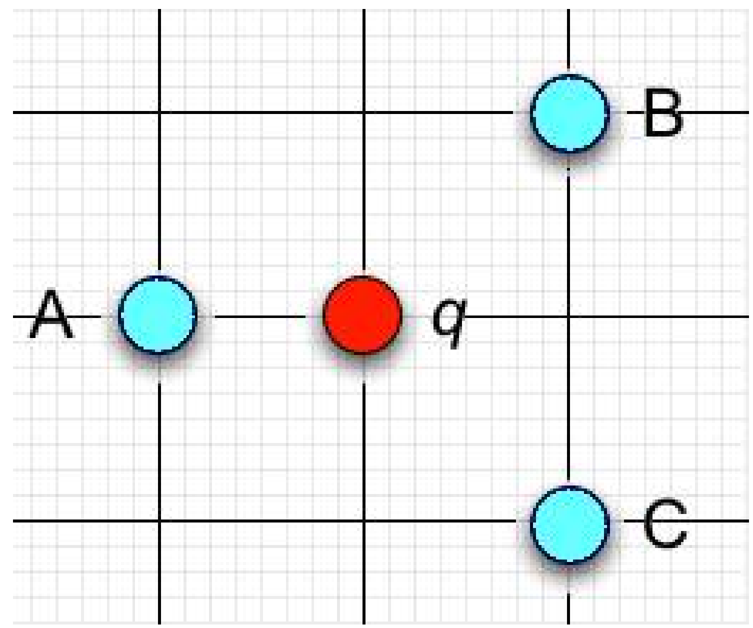




A test charge (labeled *q*) is placed in a situation in which it feels the electrical force from three other charges (of opposite sign to it) labeled A, B, and C. (The charges are on a uniform grid as shown and the positions are to scale.) Which of the following combinations of forces has the greatest magnitude?

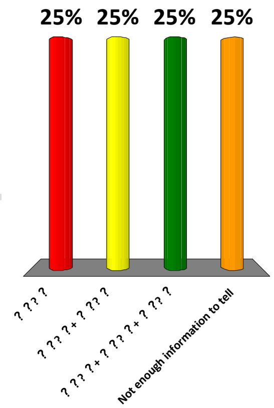


1. $\boldsymbol{F}_{\text{A on q}}$
2. $\boldsymbol{F}_{\text{B on q}} + \boldsymbol{F}_{\text{C on q}}$
3. $\boldsymbol{F}_{\text{A on q}} + \boldsymbol{F}_{\text{B on q}} + \boldsymbol{F}_{\text{C on q}}$
4. **Not enough information**



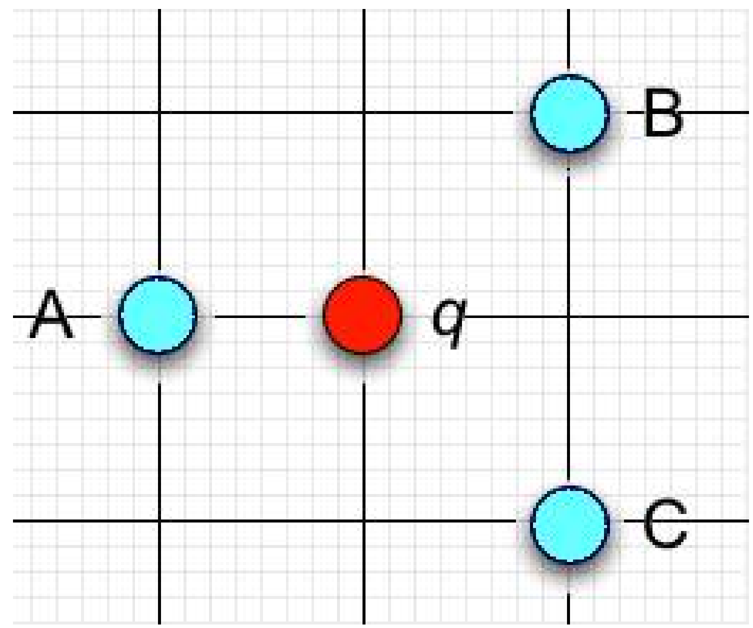
Whiteboard, TA & LA

A test charge (labeled *q*) is placed in a situation in which it feels the electrical force from three other charges (of opposite sign to it) labeled A, B, and C. (The charges are on a uniform grid as shown and the positions are to scale.) What is the following?



magnitude of $(\boldsymbol{F}_{\text{B on q}} + \boldsymbol{F}_{\text{C on q}})$

/ magnitude of $(\boldsymbol{F}_{\text{A on q}})$



Whiteboard, TA & LA

Electric fields

Foothold idea: Electric Forces and Fields

When we focus our attention on the electric force on a particular object with charge q_0 (a "test charge") we see the force it feels depends on q_0.

Define quantity that does not depend on charge of test object "test" charge -> **Electric Field E**

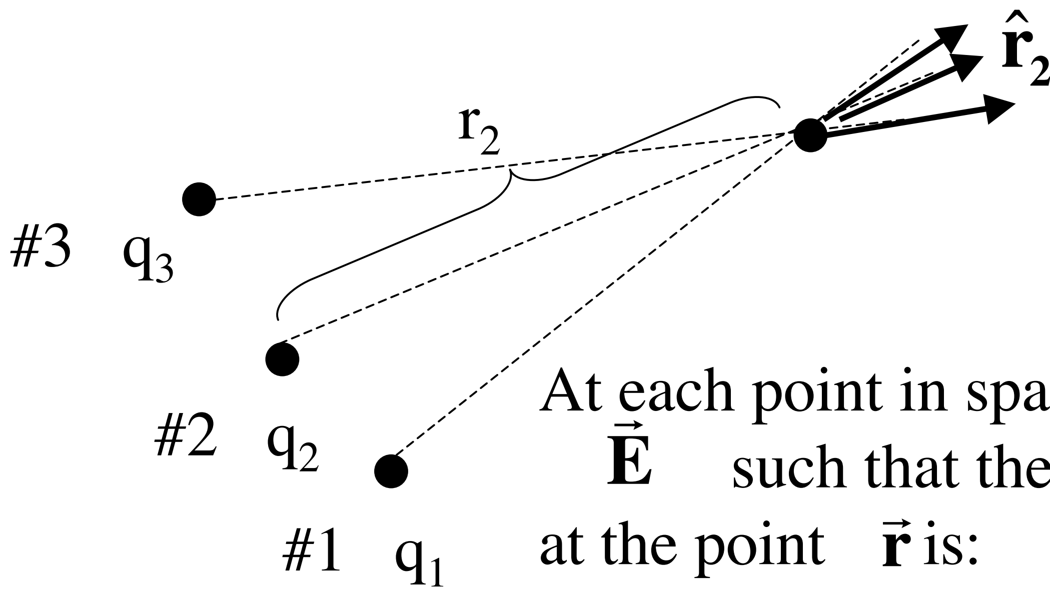
$$\vec{F}_{q_0}^{E\,net} = \frac{k_C q_0 q_1}{r_{01}^2}\hat{r}_{1\to 0} + \frac{k_C q_0 q_2}{r_{02}^2}\hat{r}_{2\to 0} + \frac{k_C q_0 q_3}{r_{03}^2}\hat{r}_{3\to 0} + \ldots \frac{k_C q_0 q_N}{r_{0N}^2}\hat{r}_{N\to 0}$$

$$\vec{F}_{q_0}^{E\,net} = q_0 \vec{E}(\vec{r}_0)$$

$$\vec{E}(\vec{r}_0) = \frac{k_C q_1}{r_{01}^2}\hat{r}_{1\to 0} + \frac{k_C q_2}{r_{02}^2}\hat{r}_{2\to 0} + \frac{k_C q_3}{r_{03}^2}\hat{r}_{3\to 0} + \ldots \frac{k_C q_N}{r_{0N}^2}\hat{r}_{N\to 0}$$

E is defined everywhere in space not just in places where charges are present

Electric Field
defined at every point in space !



$$\vec{\mathbf{E}}(\vec{\mathbf{r}}) = \sum_{q_j} \frac{Kq_j}{r_j^2}\hat{\mathbf{r}}_{\mathbf{j}}$$

At each point in space we can define a vector, $\vec{\mathbf{E}}$ such that the force on a charge q located at the point $\vec{\mathbf{r}}$ is:

$$\vec{\mathbf{F}} = q\vec{\mathbf{E}}(\vec{\mathbf{r}})$$

Concept of a “field” is important.

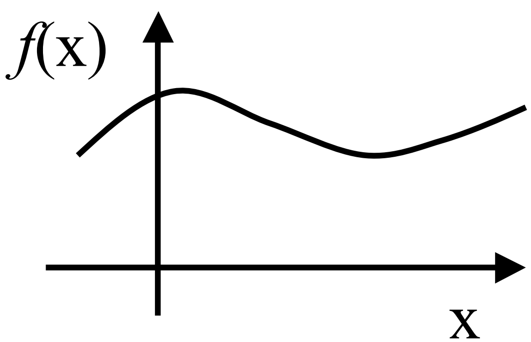
Think about the temperature in this room
Temperature is a scalar field. $T(\vec{\mathbf{r}})$

Foothold ideas: Fields

- A *field* is a concept we use to describe anything that exists at all points in space, even if no object is present.
- A *field* can have a different in magnitude at different points in space. (and if it's a vector field, direction). Examples: temperature, wind speed, wind direction
- A *gravitational, electric, or magnetic field* is a force field. Fields allow us to predicts the force that a test object would experience. The field does not depend on what test object is used.

A Field has a value at a position in space " *r* "

Generalizing a function



In Calculus and Analytical Geometry Class you learned about functions.

$f(x)$: for each value of x the function returns a value for f

What if the function depends on more than one variable x?

Example: $T(x, y, z)$ Temperature at different points in this room.

$T(x, y, z)$ is called a scalar field