Week 6

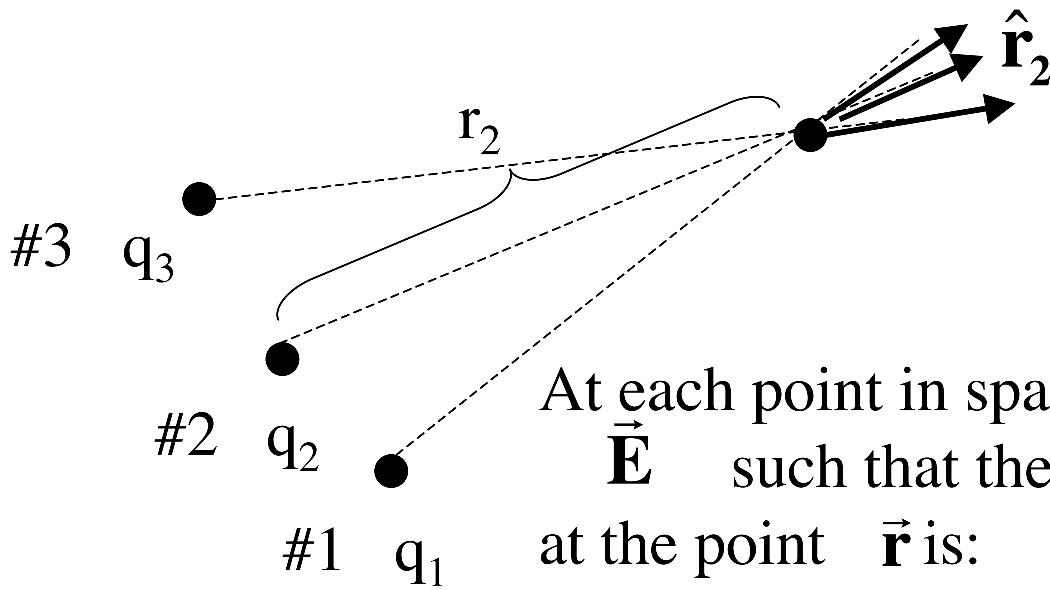
Outline

Electric Fields

Electric Potential

Electric fields

Electric Field
defined at every point in space !



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

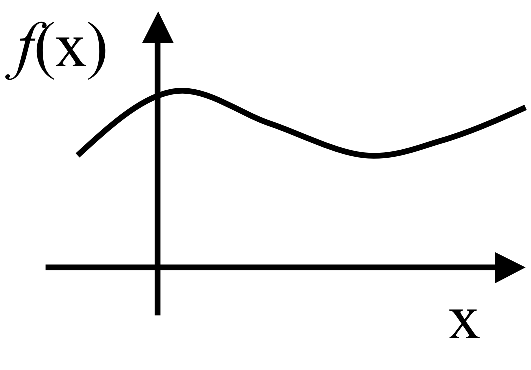
At each point in space we can define a vector, $\vec{\mathbf{E}}$ such that the force on a charge q located at the point $\vec{\mathbf{r}}$ is:

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

Concept of a “field” is important.

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

Fields: Generalizing functions



In Calculus and Analytical Geometry Class you learned about functions.

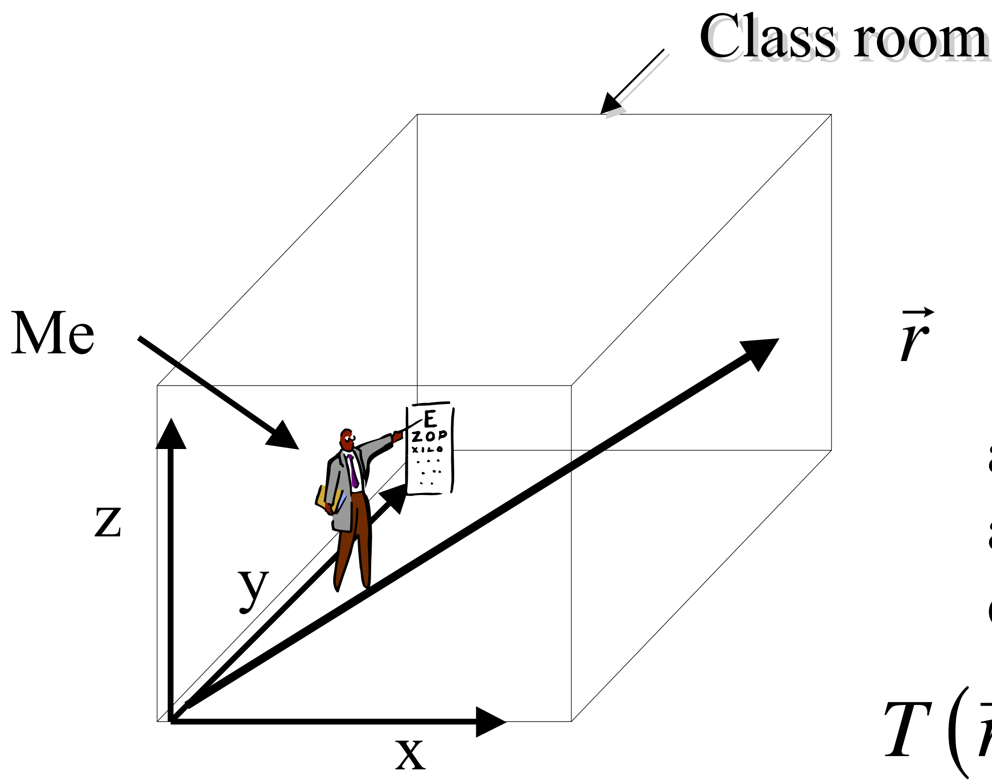
f(x) : for each value of x the function returns a value for f

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.
E (x, y, z) is called a vector field. The electric field

What does $T(\vec{r})$ mean?



$$\vec{r} \quad - (x,y,z)$$

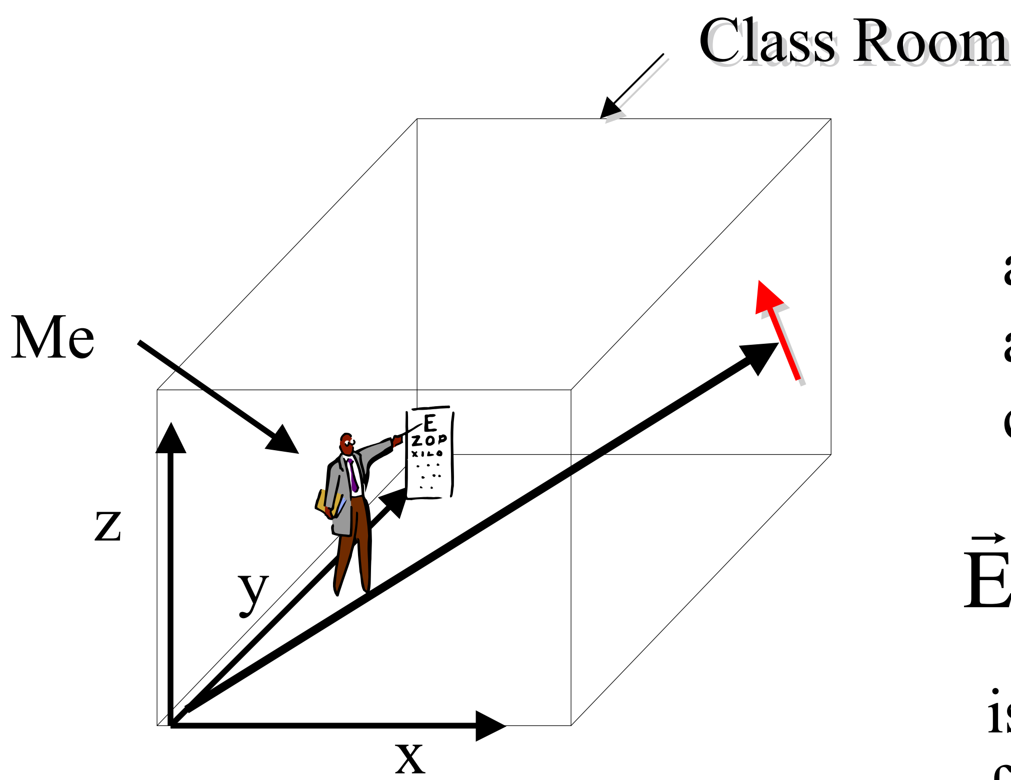
a vector that locates an arbitrary point in the class room

$$T(\vec{r}) = T(x,y,z)$$

is the value of temperature at point

$$\vec{r} \quad - (x,y,z)$$

What does $\vec{\mathrm{E}}(\vec{r})$ mean?



$$\vec{r} \quad - (x,y,z)$$

a vector that locates an arbitrary point in the class room

$$\vec{\mathrm{E}}(\vec{r}) = \vec{\mathrm{E}}(x,y,z)$$

is the value of electric field at point $\vec{r} \quad - (x,y,z)$

A charge q placed at point $\vec{r}$ experiences a force $\vec{\mathrm{F}} = \mathrm{q}\vec{\mathrm{E}}(\vec{r})$

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The force **F** on a charge q at position **r**

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

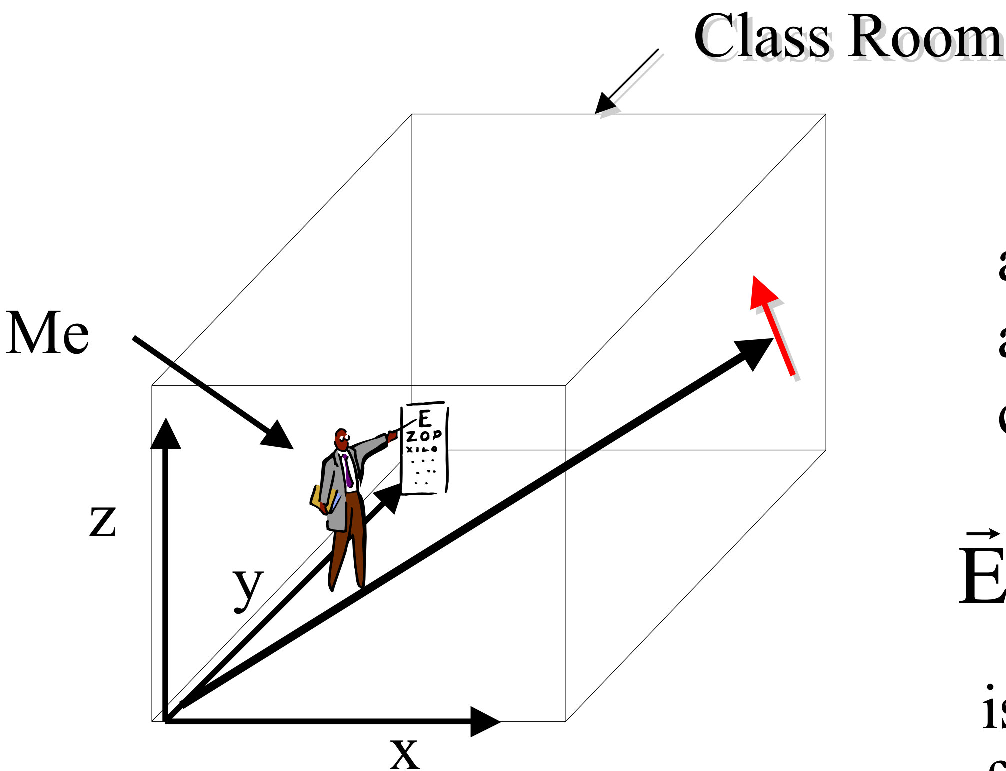
Newtons

Coulombs

Volts/meter
= Newtons/Coulomb

But, where does volts come from?

What does $\vec{\mathrm{E}}(\vec{r})$ mean?



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A charge q placed at point $\vec{r}$ experiences a force $\vec{\mathrm{F}} = \mathrm{q}\vec{\mathrm{E}}(\vec{r})$

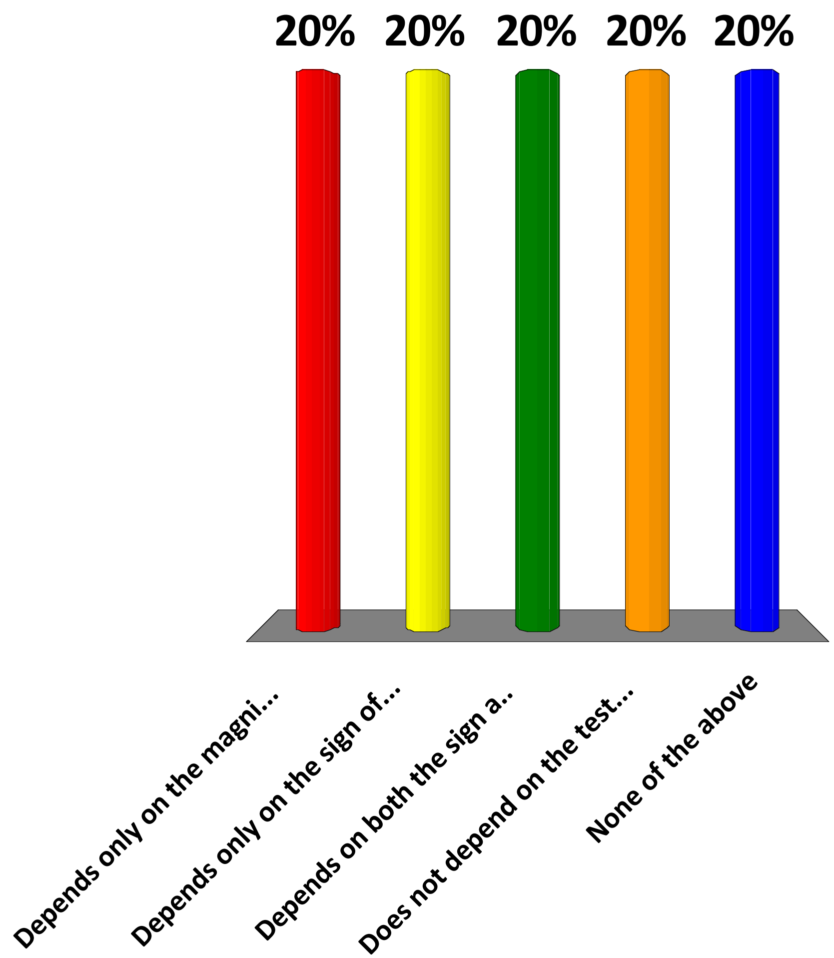
Foothold ideas: Fields

- 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 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 predict the force that a test object would experience. The field does not depend on what test object is used.

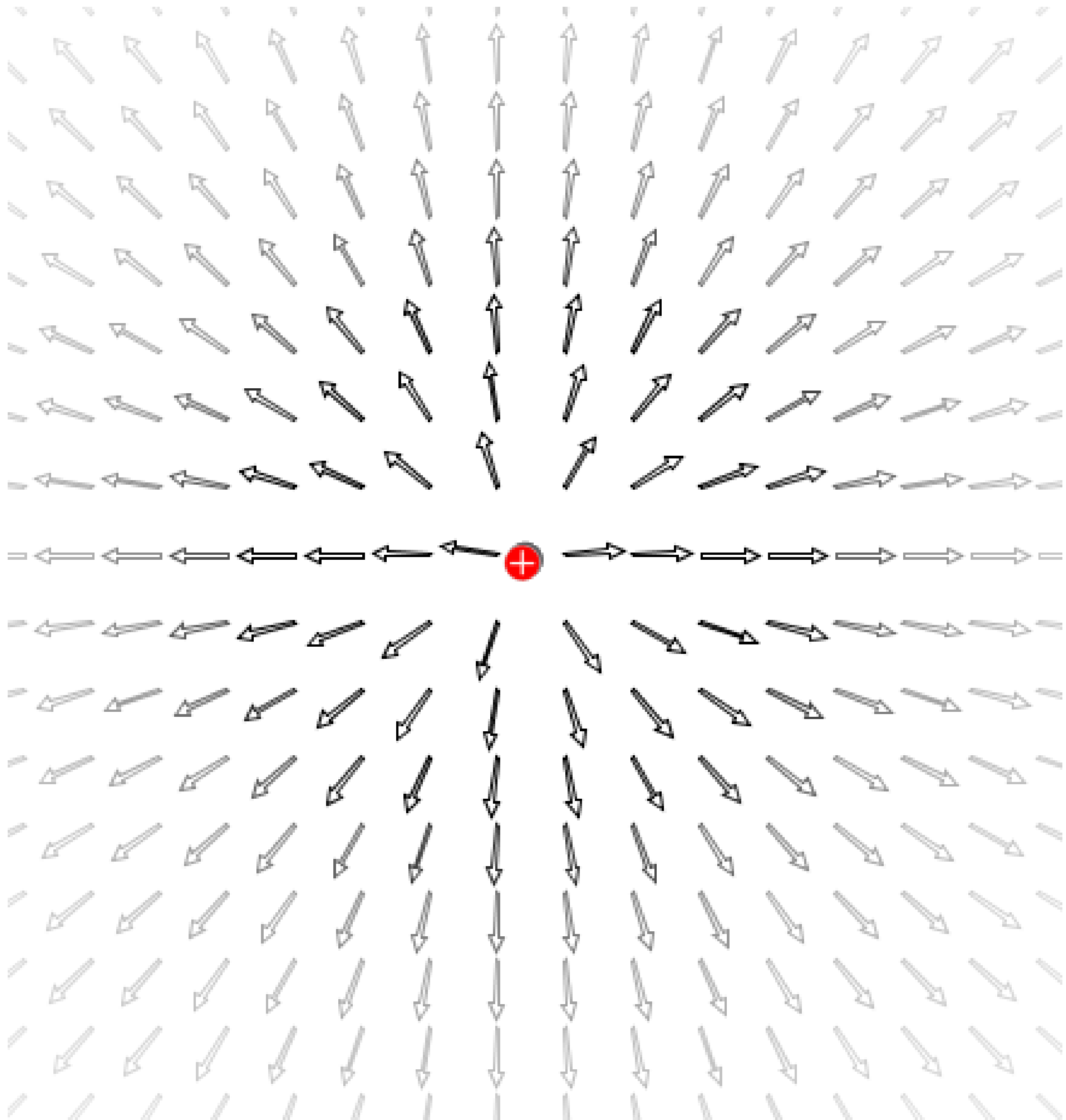
A Field has a value at a position in space " *r* "

The electric field at a particular point in space

A. Depends only on the magnitude of the test charge used to measure it.
B. Depends only on the sign of the test charge used to measure it.
C. Depends on both the sign and magnitude of the test charge used to measure it.
D. Does not depend on the test charge used to measure it.
E. None of the above



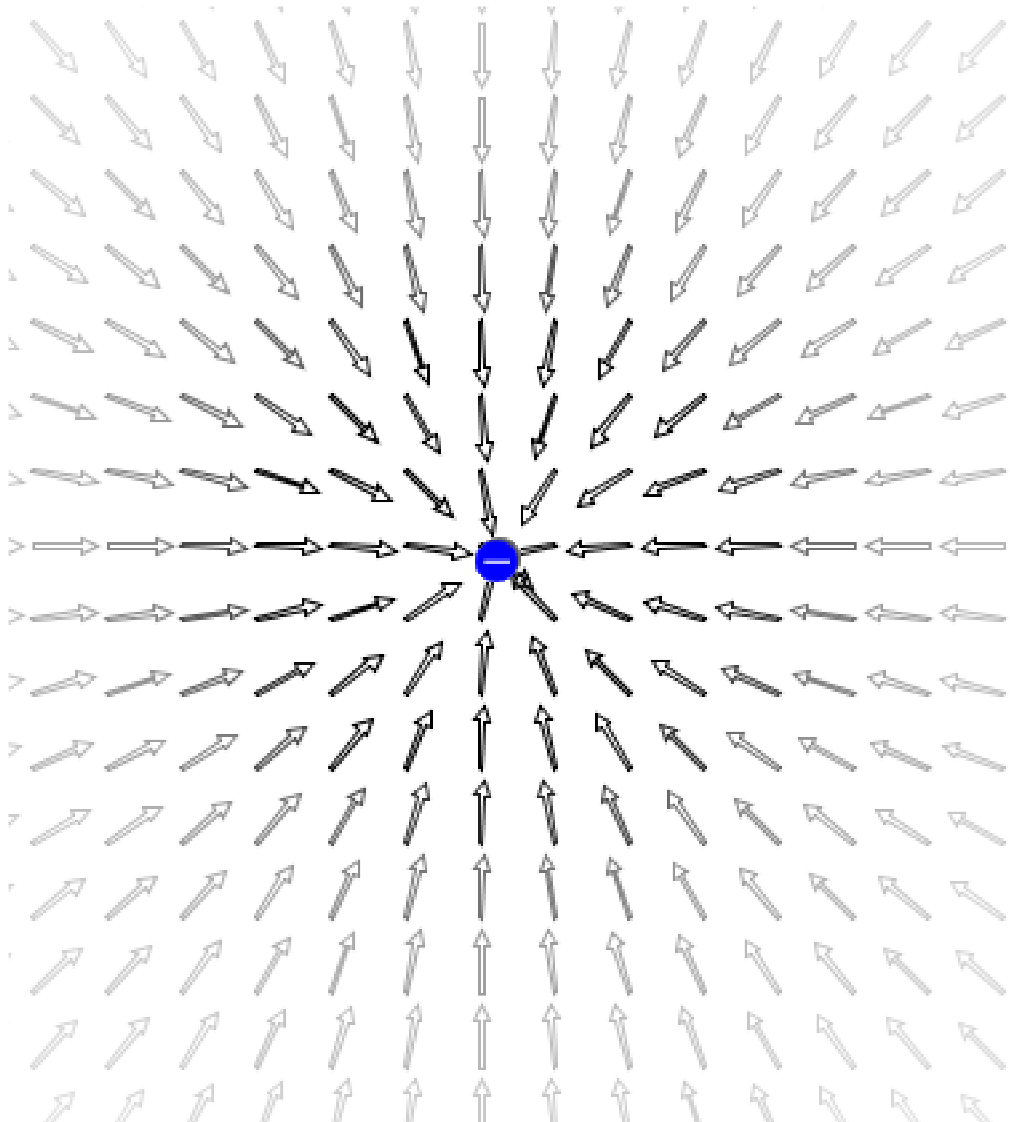
Electric field vectors surrounding a positive charge



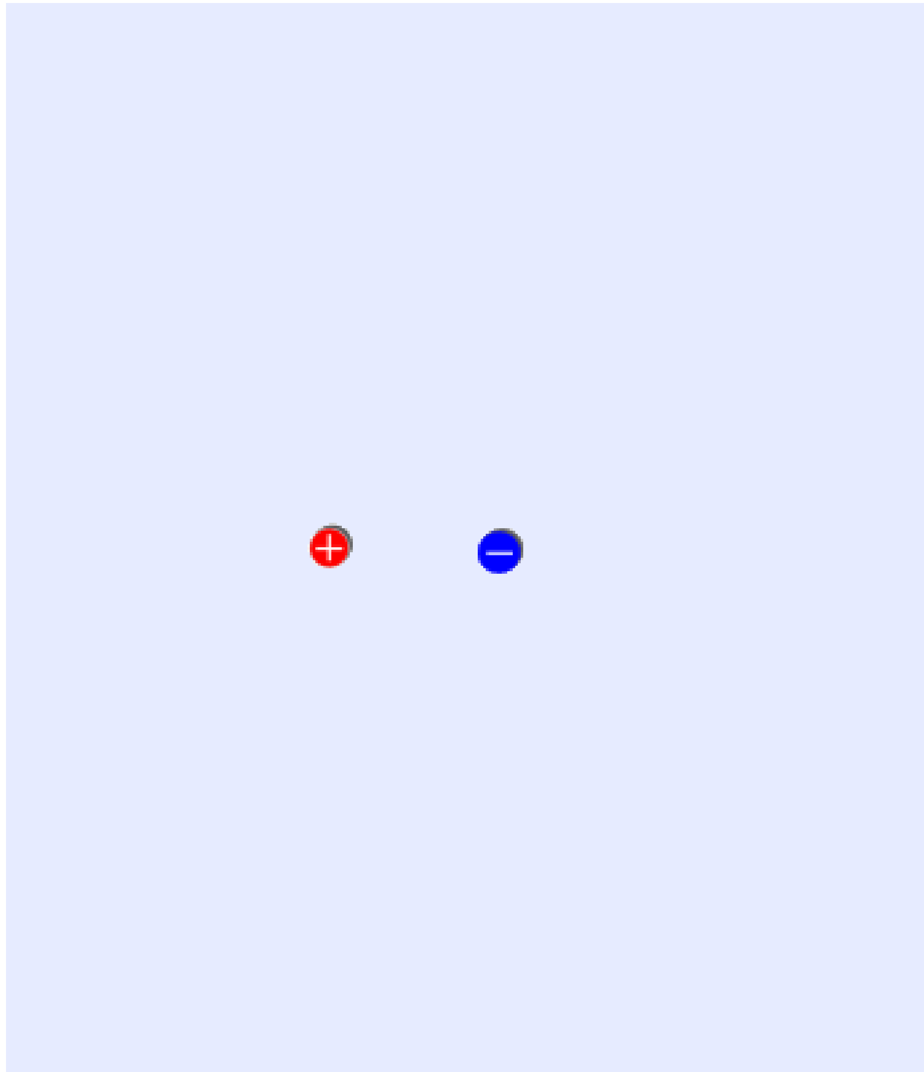
Arrow gives direction of E field.

Darker arrow indicate magnitude of E field

Electric field vectors surrounding a negative charge.

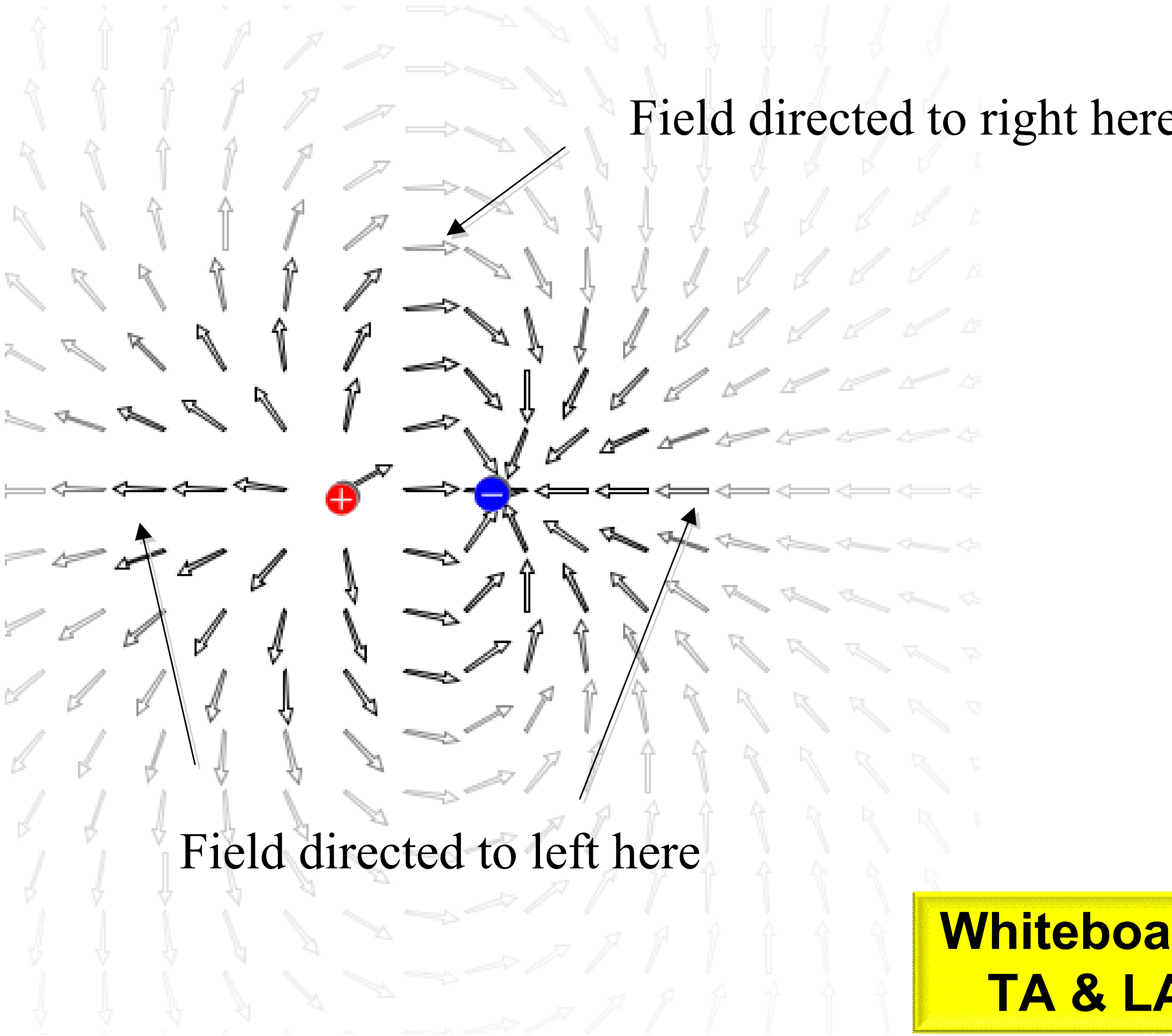


Draw the electric field vectors around a dipole.



Whiteboard, TA & LA

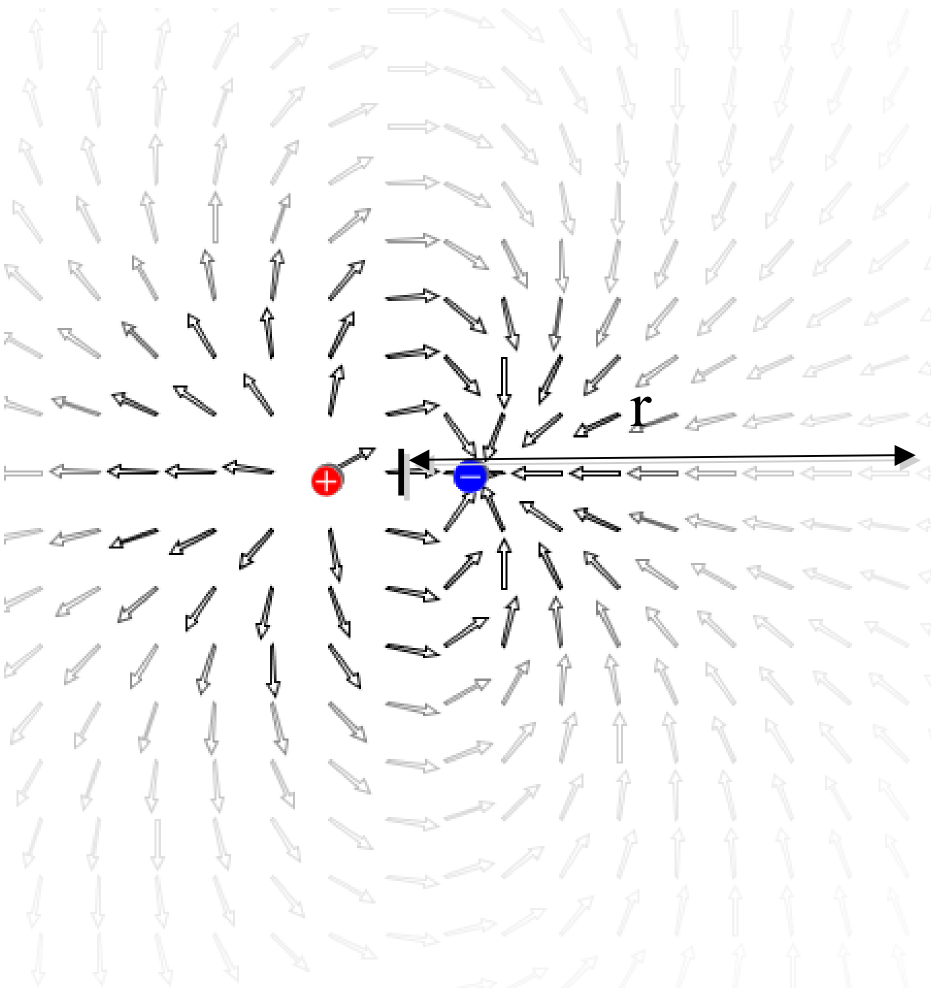
Draw the electric field vectors around a dipole.



Whiteboard, TA & LA

Everyone knows the magnitude of the electric field decreases as r^{-2} where r is the distance from the observation point to the source charge.

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



$$\vec{\mathbf{E}}(\vec{\mathbf{r}}) \propto r^{-?}$$

A. ?= 1
B. ? = 2
C. ? = 3
D. ? = 3.14159….

Whiteboard, TA & LA

Potential energy

Remember our relation between force and work?

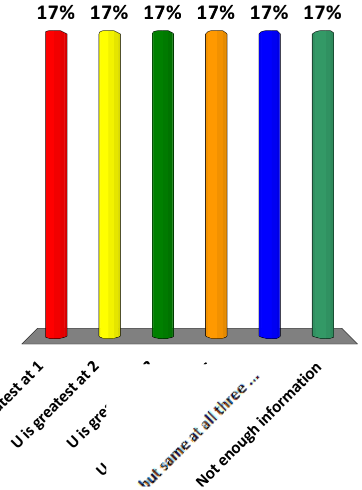
What is the work done by a force in moving an object a distance Δx?

$$W = \mathbf{F} \cdot \Delta \mathbf{x} = q\mathbf{E} \cdot \Delta \mathbf{x}$$

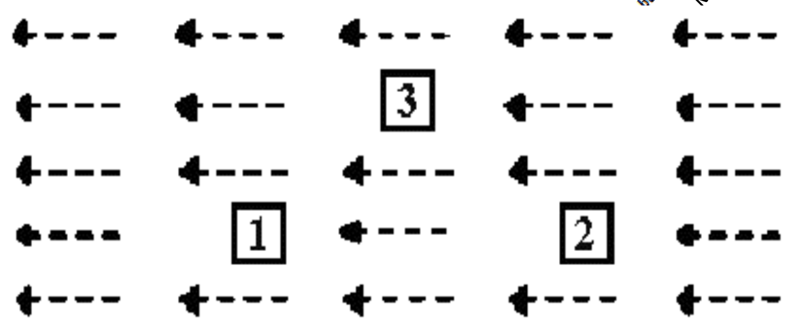
Potenial energy difference

$$\Delta U = -q\mathbf{E} \cdot \Delta \mathbf{x}$$

A positive charge might be placed at one of three spots in a region. It feels the same force (pointing to the left) in each of the spots. How does the electric potential energy, U_{elec}, on the charge at positions 1, 2, and 3 compare?

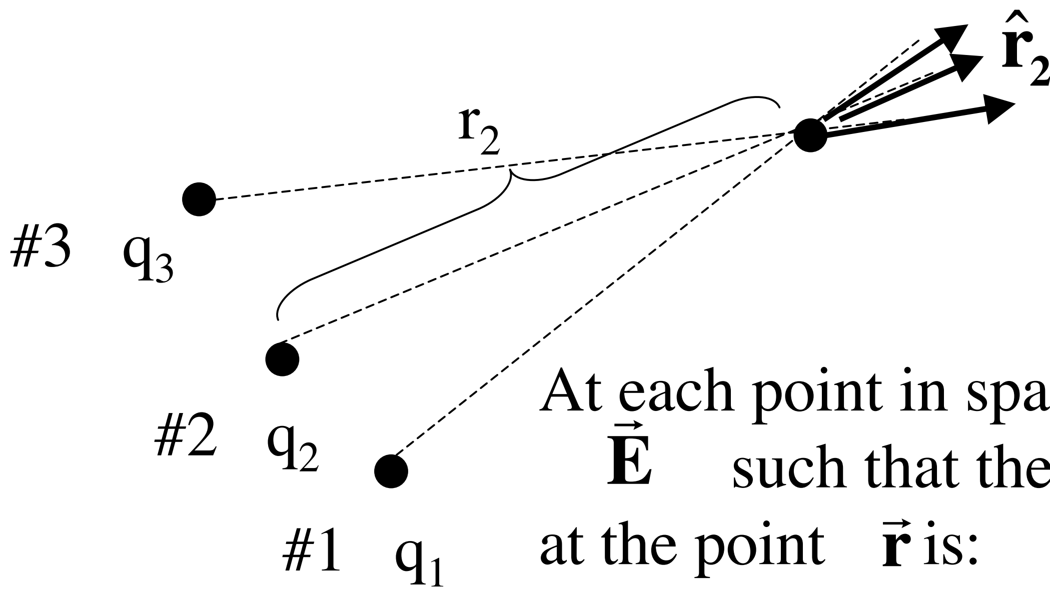


A. U is greatest at 1
B. U is greatest at 2
C. U is greatest at 3
D. U = 0 at all three spots
E. $U \neq 0$ but same at all three spots
F. Not enough information



Electrostatic Potential

Electric Field and Electric Potential defined at every point in space !



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

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

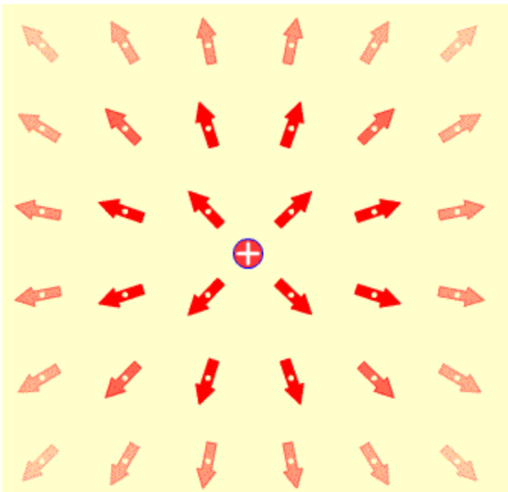
Potential energy of charge q

$$U(\vec{\mathbf{r}}) = q\sum_{q_j} \frac{Kq_j}{r_j}$$

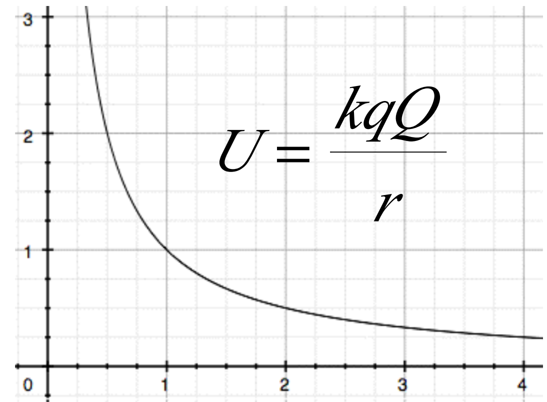
Electric potential at point **r**

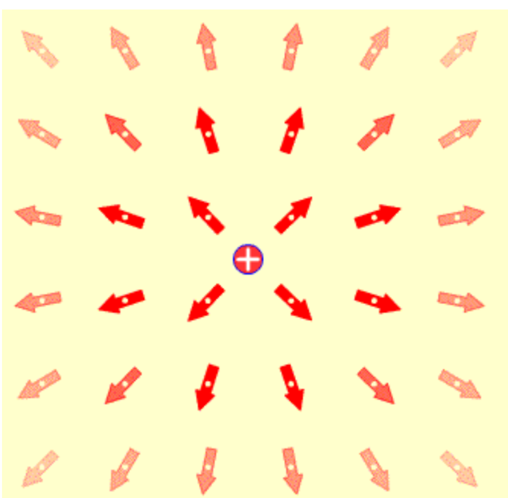
$$V(\vec{\mathbf{r}}) = U(\vec{\mathbf{r}})/q = \sum_{q_j} \frac{Kq_j}{r_j}$$

Positive test charge with positive source

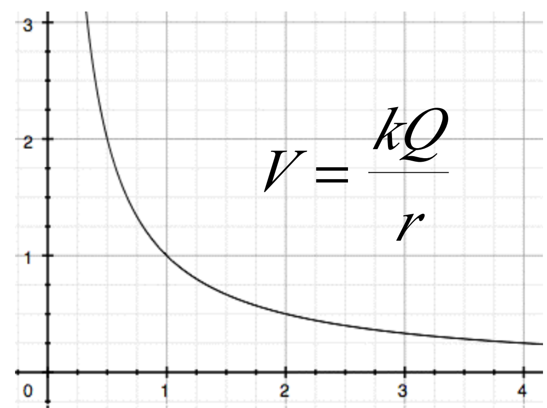


Potential energy
of a positive test charge
near a positive source.



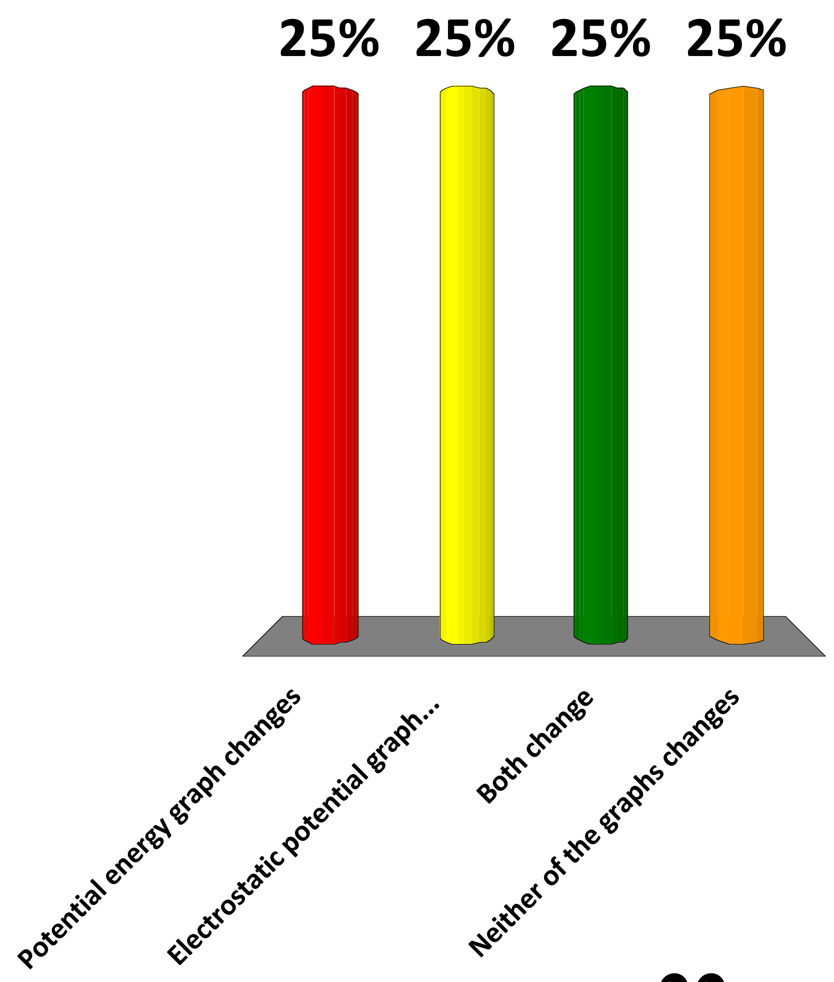


Electric Potential
of a positive test charge
near a positive source.

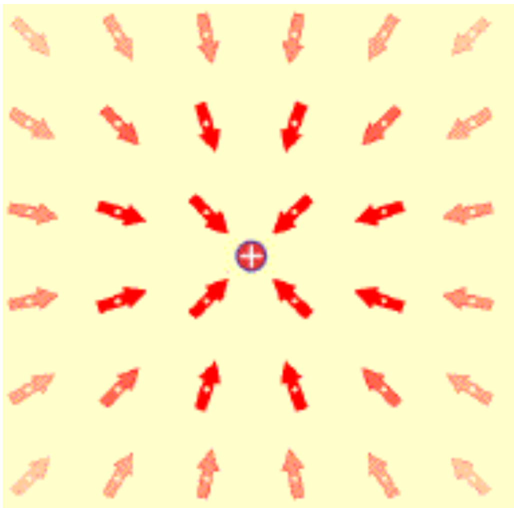


What happens when I change the sign of the test charge?

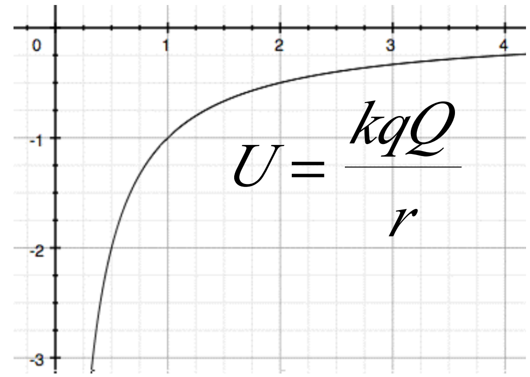
A. Potential energy graph changes
B. Electrostatic potential graph changes
C. Both change
D. Neither of the graphs changes

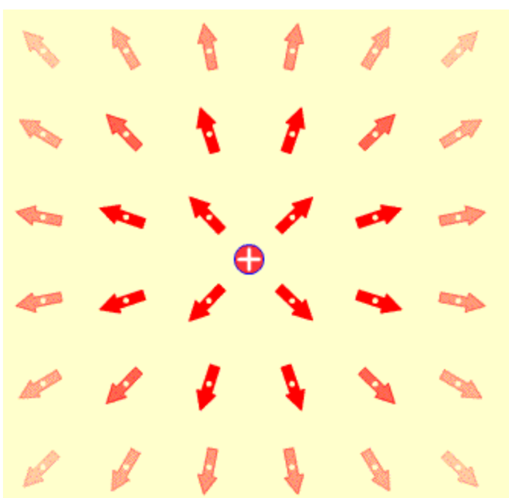


Negative test charge

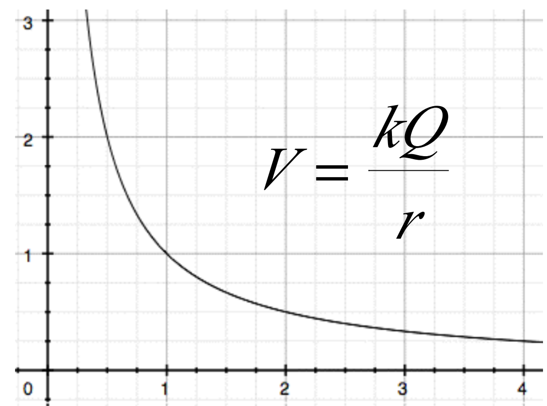


Potential energy
of a negative test charge
near a positive source.





Electric Potential
of a negative test charge
near a positive source.



Foothold ideas: Energies between charges

- The potential energy between two charges is

$$U_{12}^{elec} = \frac{Kq_1q_2}{r_{12}}$$

No vectors!

- The potential energy between many charges is

$$U_{12\ldots N}^{elec} = \sum_{i<j=1}^{N} \frac{k_C q_i q_j}{r_{ij}}$$

Just add up all pairs!

Foothold ideas: Electrostatic potential energy and potential

- The potential energy between two charges is
- The potential energy of many charges is
- The potential energy added by adding a test charge *q* is

$$U_{12}^{elec} = \frac{k_C Q_1 Q_2}{r_{12}}$$

$$U_{12\ldots N}^{elec} = \sum_{i<j=1}^{N} \frac{k_C Q_i Q_j}{r_{ij}}$$

$$\boxed{\Delta U_q^{elec} = \sum_{i=1}^{N} \frac{k_C q Q_i}{r_{iq}} = qV}$$

Potentials

Foothold ideas: Electrostatic Potential energy and Electrostatic Potential

- Again we focus our attention on a test charge!
- Usual definition of “electrostatic potential energy”: How much does the energy of our system change if we add the test charge

It’s really a change in potential energy!

$$U_{q_0}^{elec}(\vec{r}_0) = \frac{k_C q_0 q_1}{r_{01}} + \frac{k_C q_0 q_2}{r_{02}} + \ldots + \frac{k_C q_0 q_N}{r_{0N}} = \sum_{i=1}^{N} \frac{k_C q_0 q_i}{r_{0i}}$$

- We ignore the electrostatic potential energies of all other pairs (since we assume the other charges do not move)
- We can pull the test charge magnitude out of the equation and obtain en **electrostatic potential**

$$V(\vec{r}_0) = \frac{U_{q_0}^{elec}(\vec{r}_0)}{q_0} = \frac{k_C q_1}{r_{01}} + \frac{k_C q_2}{r_{02}} + \ldots + \frac{k_C q_N}{r_{0N}} = \sum_{i=1}^{N} \frac{k_C q_i}{r_{0i}}$$

Two charges are brought separately into the vicinity of a charge +Q. First, charge +q is brought to point A a distance r from +Q. Next, +q is removed and a charge +2q is brought to point B a distance 2r from +Q. Compared with the electrostatic potential of the charge at A, that of the charge at B is

A. greater
B. smaller
C. the same
D. You can't tell from the information given