

Your Comments

I'm thinking of changing my major to physics, not because I'm amazing at it, just because it seems interesting and I enjoy it. Should I switch?

I thoroughly looked through the prelecture this time around and things made so much more sense!

I didn't finish my homework for this week. :(WHY AM I BAD AT THIS

In the power points during lecture can the clicker questions be in a larger font? they are extremely difficult to see from the back

There's this really hot guy who sits a few seats away from me. I want to talk to him, but I'm worried that I'm out of his league. I mean, he's totally gorgeous, and I'm just kind of average-looking. What should I do?

Okay, so lots of people ended up asking what epsilon naught was a few lectures ago, but I'm assuming that most of us were aware it was a constant. But what does epsilon naught represent (as unimportant as it might be for this course)

Why does the prelecture sometimes uses K and sometimes uses $1/4\pi\epsilon_0$?

FINALLY SOMETHING THAT MAKES SENSE!!

what frequency are our Iclickers supposed to be on? like 2 or 3 different ones work. and the only one that has a title thing in room 141 is phys 211...

Physics 212

Lecture 5

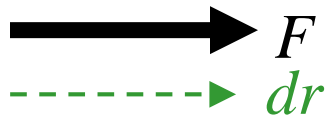
Today's Concept:

Electric Potential Energy

Work (Mechanics Review)

Recall from physics 211:

$$W = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r} \quad W_{TOT} = \Delta K$$

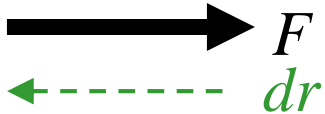


$$W > 0$$

(e.g. W_{gravity} on object dropped)

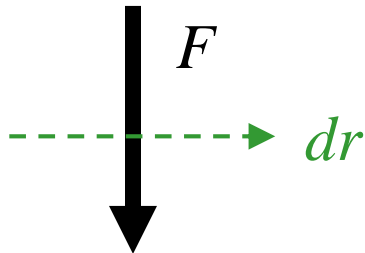


or



$$W < 0$$

(e.g. W_{gravity} on ball going up)



$$W = 0$$

(e.g. W_{gravity} on moving horizontally)

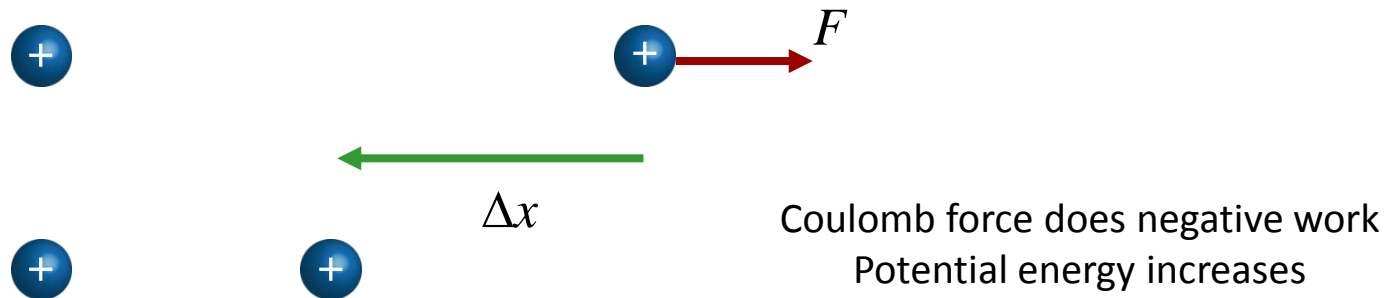
Potential Energy

“This lecture was confusing between the negative and positive work and then the negative and positive work, I really didn't understand it.”

$$\Delta U \equiv -W_{\text{conservative}}$$

If gravity does negative work, potential energy increases!

Same idea for Coulomb force... if Coulomb force does negative work, potential energy increases.



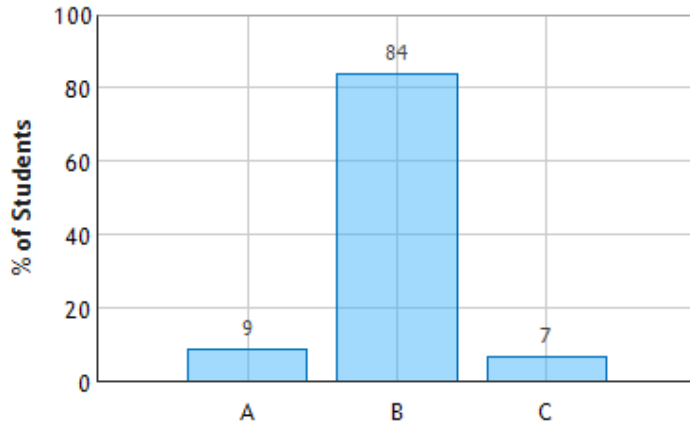
CheckPoint 4

A charge is released from rest in a region of electric field. The charge will start to move

A) In a direction that makes its potential energy increase.

B) In a direction that makes its potential energy decrease

C) Along a path of constant potential energy.

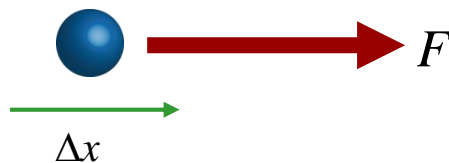


“Similar to gravity. The object always wants to fall

It will move in the same direction as F

Work done by force is positive

$\Delta U = -\text{Work}$ is negative

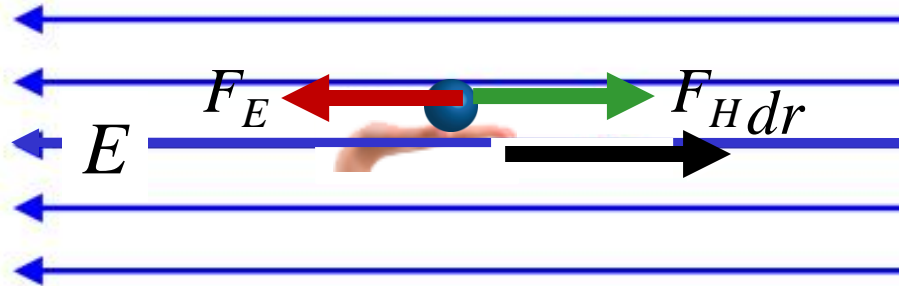


Nature wants things to move in such a way that PE decreases

Clicker Question



You hold a positively charged ball and walk due east in a region that contains an electric field directed due west.



W_H is the work done by the hand on the ball

W_E is the work done by the electric field on the ball

Which of the following statements is true:

A) $W_H > 0$ and $W_E > 0$

B) $W_H > 0$ and $W_E < 0$

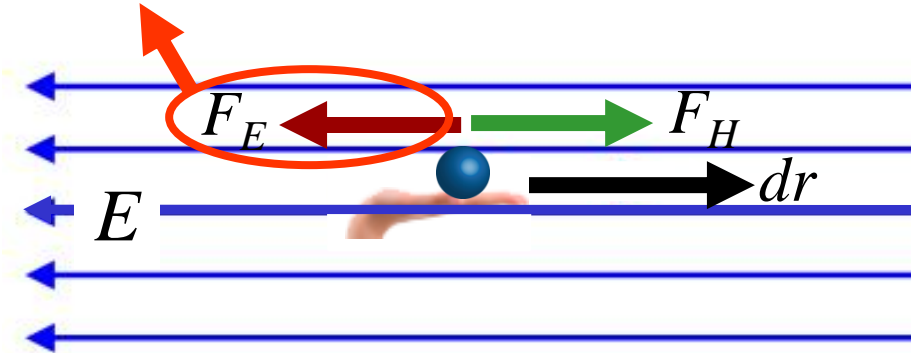
C) $W_H < 0$ and $W_E < 0$

D) $W_H < 0$ and $W_E > 0$

Clicker Question



Conservative force: $\Delta U = -W_E$



B) $W_H > 0$ and $W_E < 0$

Is ΔU positive, negative or zero?

A) Positive

B) Negative

C) Zero

Example: Two Point Charges

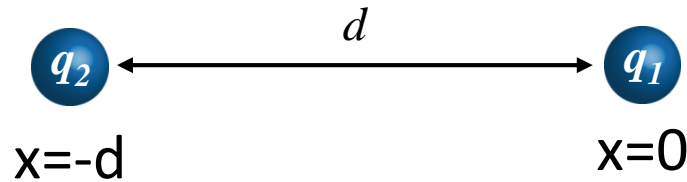
Calculate the change in potential energy for two point charges originally very far apart moved to a separation of “ d ”

$$\Delta U \equiv - \int_{i}^f \vec{F} \cdot d\vec{r}$$

$$= \int_{-\infty}^{-d} F \cdot dx$$

$$= \int_{-\infty}^{-d} k \frac{q_1 q_2}{x_{12}^2} dx$$

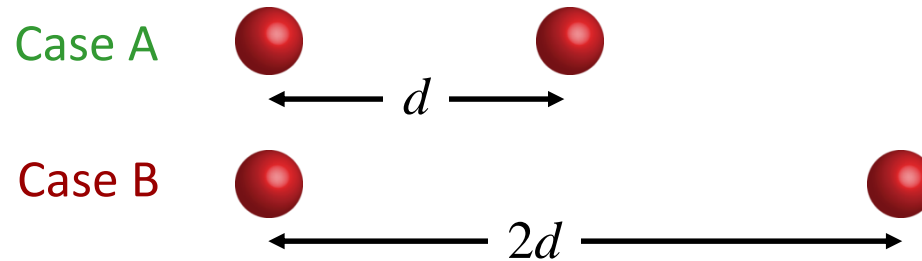
$$= -kq_1 q_2 \left[-\frac{1}{d} - \left(-\frac{1}{\infty} \right) \right] = k \frac{q_1 q_2}{d} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{d}$$



Charged particles with the same sign have an increase in potential energy when brought closer together.

For point charges often choose $r = \text{infinity}$ as “zero” potential energy.

Clicker Question



In **case A** two negative charges which are equal in magnitude are separated by a distance d . In **case B** the same charges are separated by a distance $2d$. Which configuration has the highest potential energy?

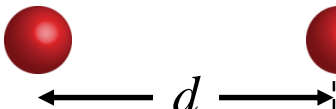
A) Case A

B) Case B

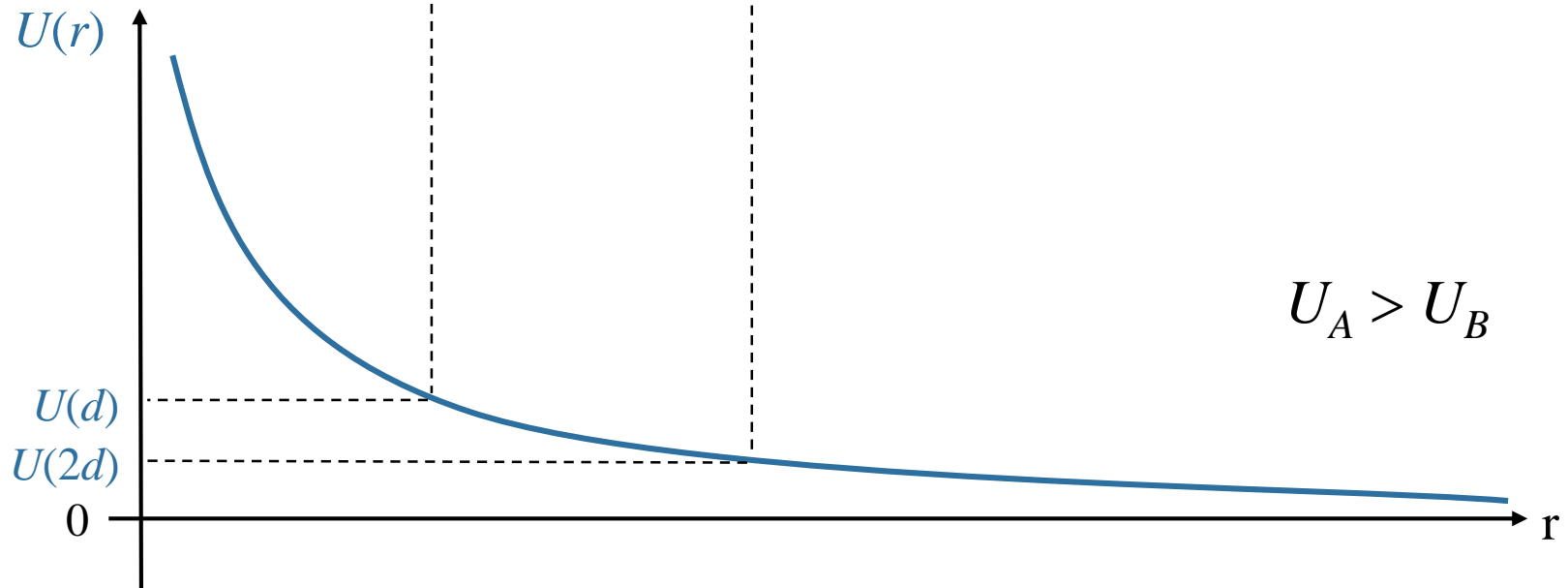
Clicker Question Discussion

As usual, choose $U = 0$ to be at infinity:

$$U(r) = \frac{q_1 q_2}{4\pi\epsilon_0} \frac{1}{r}$$

Case A  $U_A = \frac{q^2}{4\pi\epsilon_0} \frac{1}{d}$

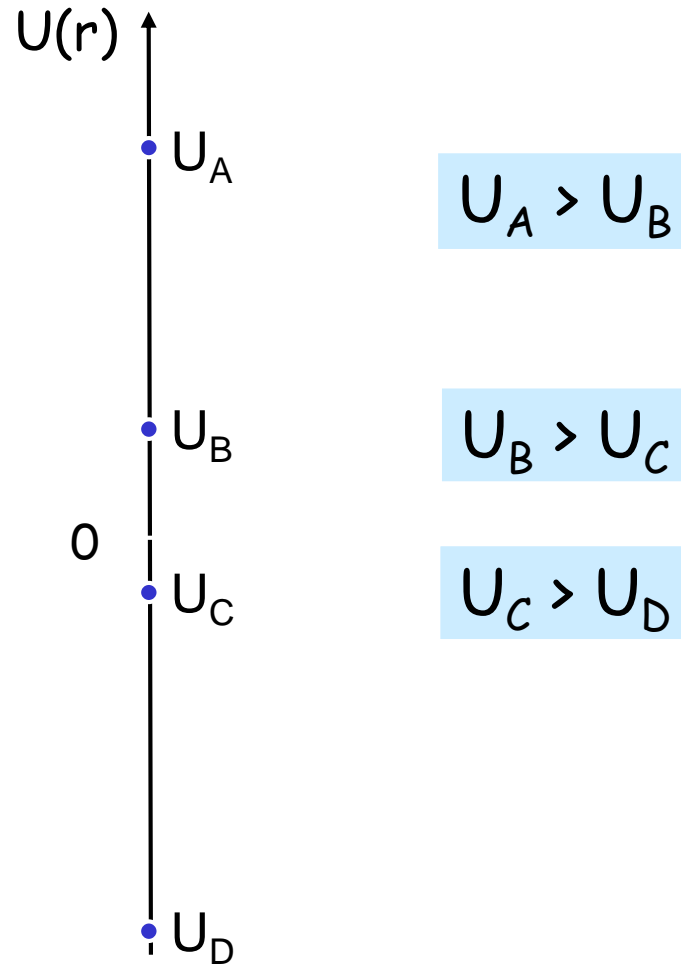
Case B  $U_B = \frac{q^2}{4\pi\epsilon_0} \frac{1}{2d}$



And Remember

U is just a number (not a vector)

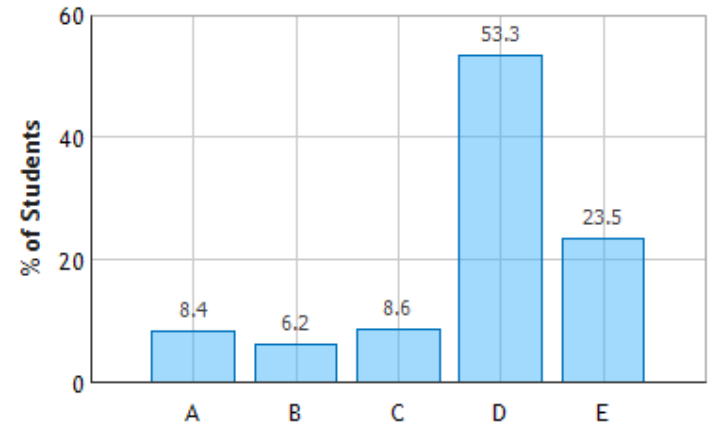
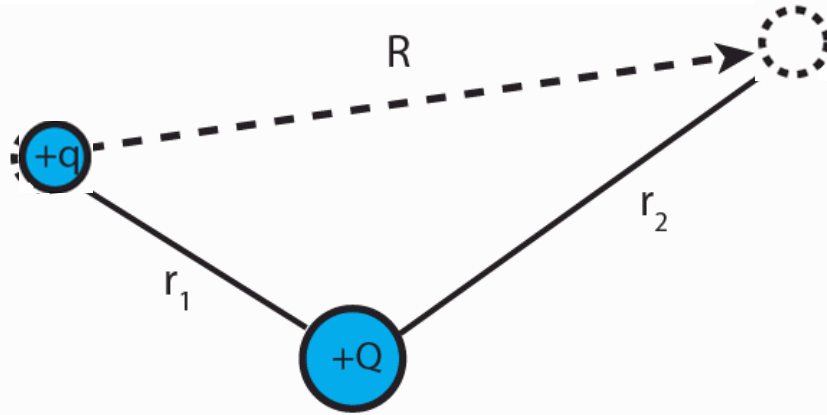
- U DOES have a sign



Checkpoint 1



A charge $+q$ is moved from position 1 to position 2, What is the change in potential energy?



- A $\frac{kQq}{R}$ B $\frac{kQqR}{r_1^2}$ C $\frac{kQqR}{r_2^2}$
 D $kQq\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$ E $kQq\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$$U_1 = \frac{kQq}{r_1}$$

$$U_2 = \frac{kQq}{r_2}$$



$$\Delta U \equiv U_2 - U_1 = kQq\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

“Find the PE for each position and subtract 2 from 1. k , Q , and q are constant throughout the problem.”

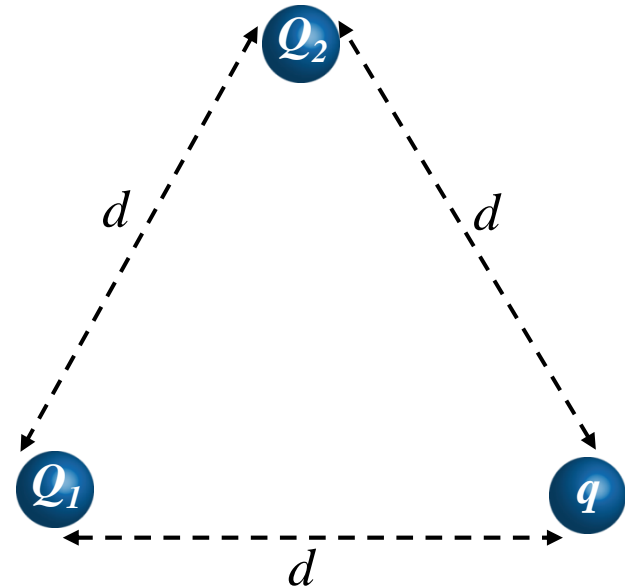
Note: $+q$ moves **AWAY** from $+Q$.
 Its Potential energy **MUST DECREASE**
 $\Delta U < 0$

Potential Energy of Many Charges

Two charges are separated by a distance d . What is the change in potential energy when a third charge q is brought from far away to a distance d from the original two charges?

$$\Delta U = \frac{qQ_1}{4\pi\epsilon_0} \frac{1}{d} + \frac{qQ_2}{4\pi\epsilon_0} \frac{1}{d}$$

(superposition)



Potential Energy of Many Charges



What is the total energy required to bring in three identical charges, from infinitely far away to the points on an equilateral triangle shown.

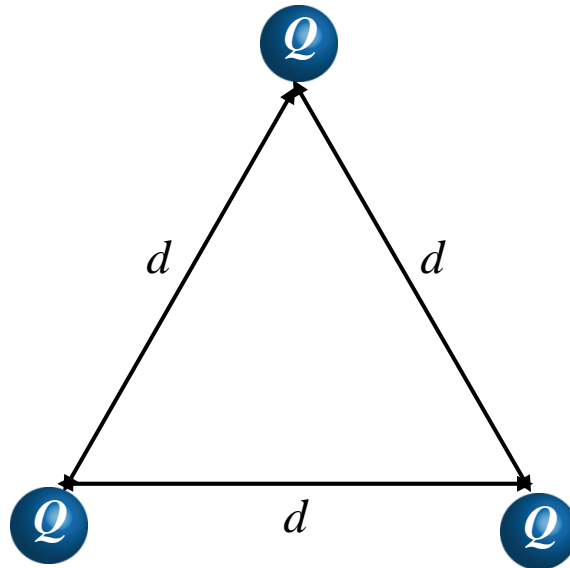
A) 0

B) $\Delta U = \frac{Q^2}{4\pi\epsilon_0} \frac{1}{d}$

C) $\Delta U = 2 \frac{Q^2}{4\pi\epsilon_0} \frac{1}{d}$

D) $\Delta U = 3 \frac{Q^2}{4\pi\epsilon_0} \frac{1}{d}$

E) $\Delta U = 6 \frac{Q^2}{4\pi\epsilon_0} \frac{1}{d}$



$$W = \sum W_i = -\frac{3}{4\pi\epsilon_0} \frac{Q^2}{d}$$

$$\Delta U = +\frac{3}{4\pi\epsilon_0} \frac{Q^2}{d}$$

Work by E to bring in first charge: $W_1 = 0$

Work by E to bring in second charge: $W_2 = -\frac{1}{4\pi\epsilon_0} \frac{Q^2}{d}$

Work by E to bring in third charge: $W_3 = -\frac{1}{4\pi\epsilon_0} \frac{Q^2}{d} - \frac{1}{4\pi\epsilon_0} \frac{Q^2}{d} = -\frac{2}{4\pi\epsilon_0} \frac{Q^2}{d}$

Potential Energy of Many Charges



Suppose one of the charges is negative. Now what is the total energy required to bring the three charges in infinitely far away?

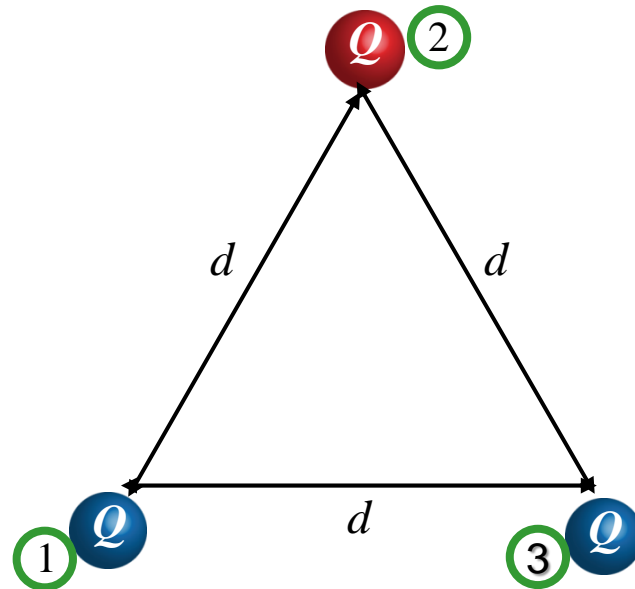
A) 0

B) $\Delta U = +1 \frac{Q^2}{4\pi\epsilon_0 d}$

C) $\Delta U = -1 \frac{Q^2}{4\pi\epsilon_0 d}$

D) $\Delta U = +2 \frac{Q^2}{4\pi\epsilon_0 d}$

E) $\Delta U = -2 \frac{Q^2}{4\pi\epsilon_0 d}$



$$W = \sum W_i = + \frac{1}{4\pi\epsilon_0} \frac{Q^2}{d}$$

$$\Delta U = - \frac{1}{4\pi\epsilon_0} \frac{Q^2}{d}$$

Work by E to bring in first charge: $W_1 = 0$

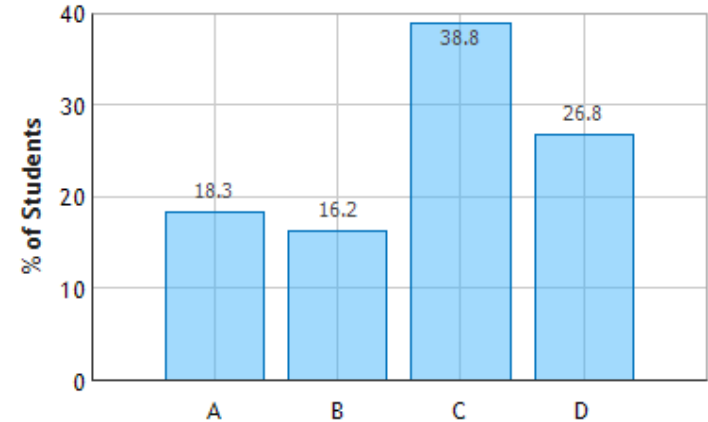
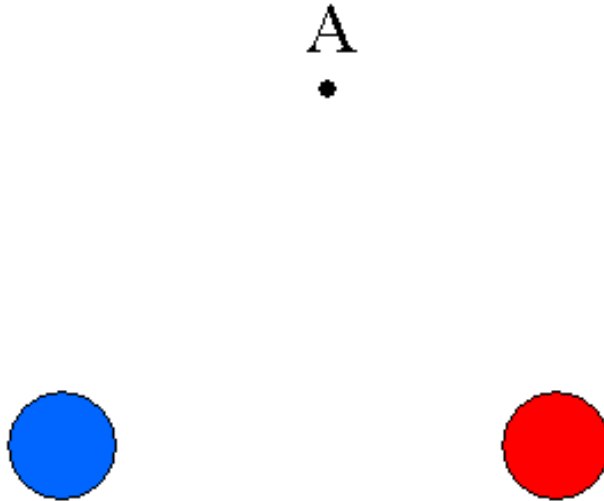
Work by E to bring in second charge: $W_2 = + \frac{1}{4\pi\epsilon_0} \frac{Q^2}{d}$

Work by E to bring in third charge: $W_3 = + \frac{1}{4\pi\epsilon_0} \frac{Q^2}{d} - \frac{1}{4\pi\epsilon_0} \frac{Q^2}{d} = 0$

Checkpoint 2



Two charges with equal magnitude but opposite sign are located at equal distances from the point labeled A



If a third charge is brought in from far away to point A, how does the potential energy of the collection of charges change?

Increases Decreases **Same** Depends on sign of charge
A B C D

C) "The added part of potential energy from a third charge cancels out, regardless of the sign.."

D) "The sign of the third charge would determine the sign of the overall potential energy when the forces on all 3 charges are added."

Checkpoint 3



A positive charge is placed on the right side of a negative charge. The magnitude of the negative charge is twice that of the positive charge.



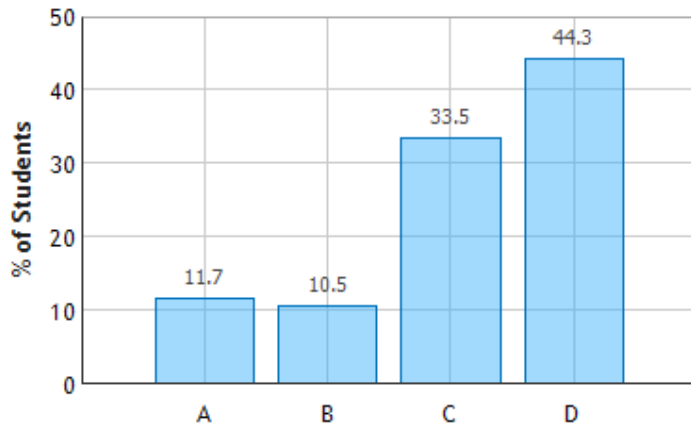
Is there any (finite) location that a third charge can be placed such that the total potential energy of the system does not change?

- YES, as long as the third charge is positive
- YES, as long as the third charge is negative
- YES, no matter what the third charge is
- NO

C) "If the charge is placed twice as far from the greater negative charge as from the smaller positive charge, then it should work."

D) "A charge will always create a force to the other charges no matter how far away the charge is. Furthermore, after looking at the potential energy graph, the graph never reaches 0 only approaches it"

Electric Potential Energy of a System of Point Charges, II: Question 1 (N = 838)

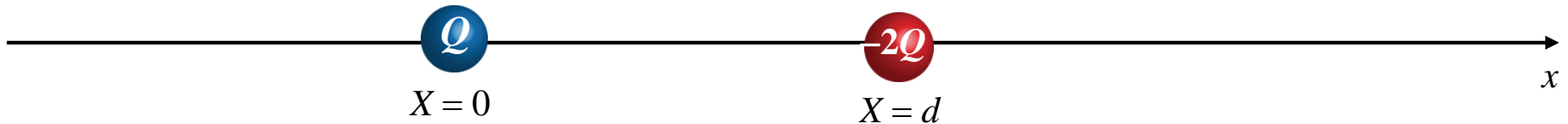


LET'S DO THE CALCULATION!

Example



A positive charge q is placed at $x = 0$ and a negative charge $-2q$ is placed at $x = d$. At how many different places along the x axis could another positive charge be placed without changing the total potential energy of the system?



A) 0

B) 1

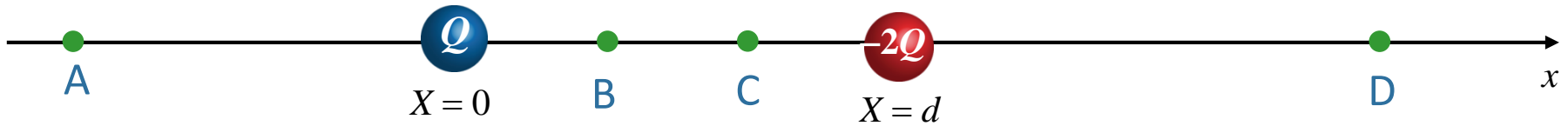
C) 2

D) 3

Example



At which two places can a positive charge be placed without changing the total potential energy of the system?



A) A & B

B) A & C

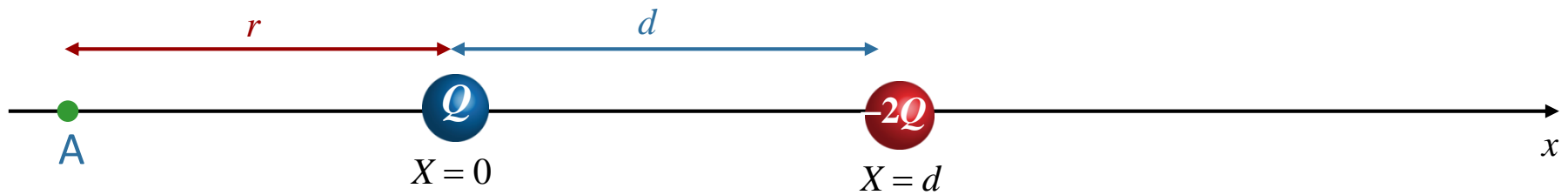
C) B & C

D) B & D

E) A & D

Let's calculate the positions of A and B

Lets work out where A is



$$\Delta U = +\frac{1}{4\pi\epsilon_0} \frac{Qq}{r} - \frac{1}{4\pi\epsilon_0} \frac{2Qq}{r+d}$$

Set $\Delta U = 0$

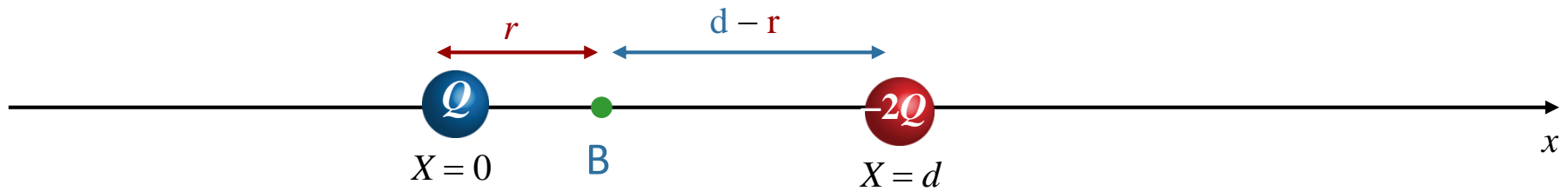
$$\frac{1}{r} = \frac{2}{r+d}$$

$$r = d$$

Makes Sense!

Q is twice as far from $-2q$ as it is from $+q$

Lets work out where B is



Setting $\Delta U = 0$



$$\frac{1}{r} = \frac{2}{d - r}$$



$$2r = d - r$$



$$r = \frac{d}{3}$$

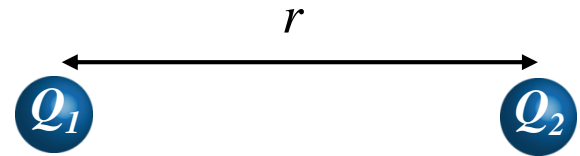
Makes Sense!

Q is twice as far from $-2q$ as it is from $+q$

Summary

For a pair of charges:

Just evaluate $U = k \frac{q_1 q_2}{r}$



(We usually choose $U = 0$ to be where the charges are far apart)

For a collection of charges:

Sum up $U = k \frac{q_1 q_2}{r}$ for all pairs

