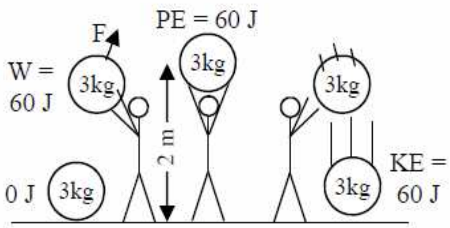
Name: ____________________

Period: ____________________

Electric Potential Energy

9.4

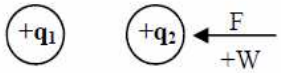
Remember that potential energy (PE) is energy of position. ***PE equals the work that moved the object and also equals the kinetic energy it will have after it is released.***



Electric Potential Energy for Two Charges

Electric Potential Energy (*in J*) $\longrightarrow PE = k_c \dfrac{q_1 q_2}{r}$

When q_2 is brought from infinity to a point a distance of "r" meters from q_1.

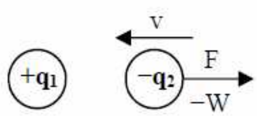


q_2 has PE due to its position near q_1. When like charges are brought together from infinity, +W is necessary, increasing q_2's PE, like compressing a spring.

Ex: A −2μC charge is 3 mm from a 6μC charge. Calculate the electric potential energy.

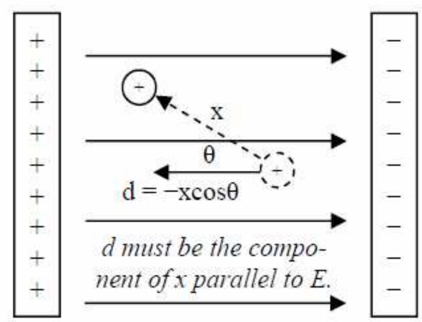
Variables:	
$k_c = 9\times10^9$ $q_1 = -2\times10^{-6}$C $q_2 = 6\times10^{-6}$C $r = 3\times10^{-3}$m	$PE = k_c \dfrac{q_1 q_2}{r}$ $= 9\times10^9 \dfrac{(-2\times10^{-6})(6\times10^{-6})}{(3\times10^{-3})}$ $= 9\times10^9 \dfrac{-1.2\times10^{-11}}{3\times10^{-3}} = -36\ \text{J}$ *And for unlike charges PE is −.*

If opposite charges are brought together, a force (and −W) is necessary to hold them back. PE is negative because the force is reducing the PE it had at infinity. At infinity it could have accelerated all the way to the positive charge, but now it can only accelerate a short distance. ***Anytime a charge moves the direction it wants to move, it loses PE.***



Only ΔPE Matters With gravitational potential energy we usually assume that the zero point (the reference point) is at the ground. **For two charges our reference point is infinity—where the electric force is zero.** In a uniform electric field, there is no zero point, so only the change of PE is important.

The electric field is uniform within charged parallel plates. E always points from + to −. As always, up or right are +.



ΔPE in a Uniform Electric Field

Change of Electric Potential Energy (*in J*) $\longrightarrow \Delta PE = -Eqd$

Electric Field (*in N/C*); Electric Charge (*in C*); Distance Moved Parallel to E (*in m*)

Ex: A 5.6μC charge is moved 1.2mm to the left in a constant 2.3 N/C electric field. If the positive plate is on the left, what is the change of potential energy of the charge?

Variables:	
$q = 5.6\times10^{-6}$C $d = -1.2\times10^{-3}$m *(left is negative)* $E = 2.3$ N/C *(+ on left means E points right)*	$\Delta PE = -Eqd$ $= -2.3(5.6\times10^{-6})(-1.2\times10^{-3})$ $= 1.55\times10^{-8}$ J *And we know that the positive sign is correct because when a + charge moves closer to the + plate, it gains energy.*

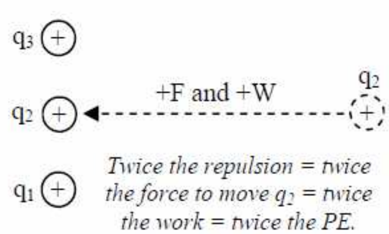
$PE = F_e r$ OR $\Delta PE = F_e d_{\parallel}$

F_W (weight) = mg and PE = mgh, so PE = (F_W)h. Likewise: if you know F_e, then $PE_{electric} = (F_e)d$. Simply multiply F_e by the distance moved or the distance between the charges:

If $F_e = k_c \dfrac{q_1 q_2}{r^2}$ then, $PE = \left(k_c \dfrac{q_1 q_2}{r^2}\right) r = k_c \dfrac{q_1 q_2}{r}$

PE is a scalar If there are multiple charges, just add the potential energies together. Vector addition is unnecessary.

At q_2's position the electric field (E) and electric force (F) are both zero. As vectors the E and F from q_1 and q_3 balance each other. Yet, as a scalar, PE is not zero. There is twice as much PE as with only one charge.



PE is not zero because it would take work to bring q_2 to this point. With two positive charges repelling, it takes twice as much force (and work) to push q_2 here, storing twice as much energy. Though it requires no force to keep it at the midpoint, the slightest bump would cause q_2 to fly off, until all of its PE becomes kinetic energy at infinity.

1. A 2μC charge and a 6μC charge are 3 mm apart.
   A. Calculate the electric potential energy between them.

   B. How much work was done to bring them together?

2. Where is the reference point for potential energy for point charges?
   Why?

3. Two charges are 3 m apart and have 15 J of PE. Calculate the force between them.

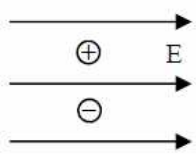
4. A 1.2μC charge and a −3μC charge have −4 joules of PE.
   A. What is the distance between the charges?

   B. Why is the PE negative?

5. A proton and an electron are near each other. To increase the potential energy of the system, should you move them closer together or farther apart?

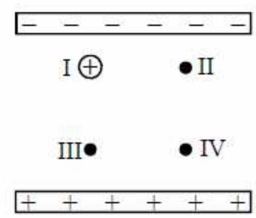
6. Two positive charges are near each other. If the distance between them is decreased, how does the potential energy between them change?

7. A + and − charge are at rest in an electric field, as shown.



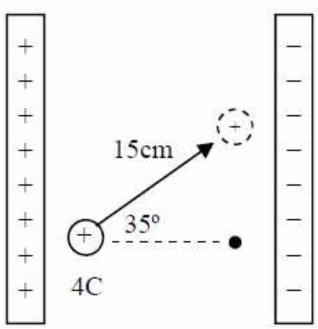
   A. Which way will the + move?
   B. When the + moves due to the field will it gain or lose PE?
   C. Which way would you move the − to increase its PE?
   D. If + work is done on the − charge, which way did it move?

8. A + charge is between the charged plates of a capacitor.



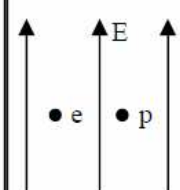
   A. Draw the direction of the electric field between the plates.
   B. Will the charge have more PE at point III or point IV?
   C. If moved to point III is its ΔPE + or −?
   D. How much work is required to move the charge to II?

9. The electric field strength is 2.5 N/C between the plates.



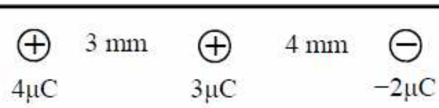
   A. Draw E between the plates.
   B. Is E + or −?
   C. Is the charge gaining or losing PE?
   D. Calculate d.
   E. Calculate ΔPE.

10. A proton and electron are placed into an electric field.



   A. Which has more charge?
   B. Which has more mass?
   C. Draw the direction each will move due to the field.
   D. Will the proton gain or lose PE?
   E. Will the electron gain or lose PE?
   F. What does the PE become?
   G. After a long time which will be moving faster?
   H. Why?

11. Three charges are placed as shown.



PE = 　　　　　　PE =

   A. Calculate PE between the 4μC and 3μC charges.
   B. Calculate PE between the −2μC and 3μC charges.
   C. Is energy a scalar or vector?
   D. Calculate the net PE of the middle charge.

12. The −2μC charge is then moved. Calculate the net potential energy of the 3μC charge in this configuration.