PreAP Electrostatics 4 **(Understanding Electric PE and Electric Potential)**

In the last homework we learned that the electric field (in N/C) stayed the same as we changed charges. So the electric field is a constant for a particular position. Also, we learned that F = qE (the units make this clear.)

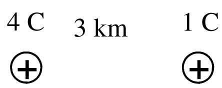
Let's again start with some background information: k = 9×10^9 ; μ = $\times10^{-6}$; "m" (in mm) = $\times10^{-3}$.

1. k_c/3km = k/(3×10^3m) =

    We already know that PE = mgh and F_{weight} = mg, so PE = Fh or Fd, or Newtons times meters.

2. What variable in the electric force equation has the units of meters?
3. Write the electric force equation, multiply by r, and give the new equation for PE.

    And now we have an equation for the potential energy between two charges.



4. A 1 C charge is 3km from a 4C charge.
    A. Calculate the potential energy between them.

    B. Divide this PE by the 1 C charge.

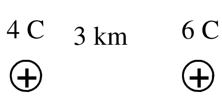
5. The 1 C charge is replaced with a 2 C charge.
    A. Calculate the potential energy between them.

    B. Now divide the energy by the 2 C charge.

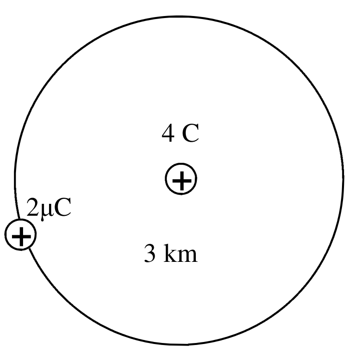
6. Then the 2C charge is replaced with a 3C charge.
    A. Calculate the potential energy between them.

    B. Divide the energy by the 3 C charge.

Once again we see that there is something special about this position in space. 3km away from a 4C charge will have 12×10^6 J/C of.....?. So what is this thing that has the units of J/C. You should recognize this as voltage, which we call <u>electric potential</u>. It is the same as what's made by a battery. So, what is J/C? It tells you, at this position, how many joules of energy is possible for every coulomb of charge placed at that position: it is the potential for energy, but not energy. If you know volts and coulombs, you know energy.



7. A 6 C charge is placed 3km to the right of a 4C charge.
    A. What is the electric potential at the 6C charge's position?
    B. What is the PE of the 6C charge at this position?



8. A. What is the electric potential everywhere on the 3km radius circle shown on the diagram (*no direction—it is a scalar*)?

    B. Calculate the potential energy of the 2μC charge.

    Now, using units, you should see that you can just multiply the electric potential (J/C) by the charge (C) to calculate the PE.

9. A point in space has an electric potential of 9V (J/C). How much energy does a 0.5 C charge have at that position?

10. A 12μC charge is placed where the electric potential is 0.25 V. What is the energy of the charge?

11. A 3μC charge has 9J of potential energy. What is the electric potential at that point?

$$F_e = k_c \frac{|q_1 q_2|}{r^2}$$

1: 9/3 = 3
and $10^9/10^3 = 10^6$
$= 3\times10^6$

2: r is in meters.

3:
$$F_e r = k_c \frac{|q_1 q_2|}{r^2} r$$
$$PE = k_c \frac{q_1 q_2}{r}$$

4A. PE = 9E9(4)1/3E3 =
Since 9E9/3E3 = 3E6,
PE = (3E6)4(1)
PE = 12×10^6 Joules

4B: 12E6/1 = 12×10^6 J/C

5A: = 3E6(2)(4) = 24E6 J
(PE doubles if q doubles)

5B: 24E6/2C = 12×10^6 J/C
hmmmm

6A: 3 times the charge =
3 times the energy =
36×10^6 J

6B: 36E6J/3C = 12×10^6 J/C

7A: 12×10^6 J/C (still)

7B: (12E6J/C)(6C) =
72×10^6 J

8A: 12×10^6 J/C (Same q and same r) but no direction.

8B: (12E6J/C)(2E−6C) =
$2(12)(10^6)(10^{-6})$ =
$24(10^0)$ = 24(1) =
24 J

9. $$\frac{9\,J}{1\,C}\left(\frac{0.5\,C}{1}\right) = 4.5\,J$$

10. (0.25J/C)12E−6C
= 3E−6J

11. 3×10^6 J/C

cstephenmurray.com

$$k_c = 9\times10^9 \qquad F_e = k_c\frac{|q_1q_2|}{r^2} \qquad E = k_c\frac{q_1}{r^2} \qquad PE = k_c\frac{q_1q_2}{r}$$

Let's derive the equation for voltage (electric potential). We will use what we did on the front, where to find V we did PE/q.

12. A. Write the equation for electric potential energy over (divided by) q_2.

B. q_2 is really $q_2/1$. Remembering to multiply by the reciprocal, divide the potential energy equation by q_2 and give the new equation for electric potential (voltage).

12A $$\frac{PE_e}{q_2} = \frac{\left(k_c\frac{|q_1q_2|}{r}\right)}{q_2}$$

12B $$\frac{PE_e}{q_2} = \left(k_c\frac{|q_1q_2|}{r}\right)\left(\frac{1}{q_2}\right)$$

$$V = k_c\frac{q_1}{r}$$

---

13. A 3μC charge is 2 mm away from an 8μC charge.

8μC ⊕ 2 mm 3μC ⊕

A. With our new equation, calculate the electric potential at the 3μC's position due to the 8μC. (*Again, you don't need a calculator.*)

$$V = k_c\frac{q_1}{r}$$
$$V = \frac{9E9(8E-6)}{(2E-3)}$$
$$V = 9E9(4E-3)$$
$$V = 36\times10^6 V$$

B. Using the electric potential, calculate the potential energy of the 3μC charge. (*No calculator.)*

$$PE = (36\times10^6 J/C)(3E-6C)$$
$$PE = [36(3)](10^6)(10^{-6})$$
$$PE = [(30+6)3](10^0)$$
$$PE = (90+18)(1)$$
$$PE = 108J$$