Due Mon., Jan 30

Understanding Electric Fields (2011-12 PreAP Electrostatics 3)

I need you to follow along with this discussion, so I am going to put the answers on the right side of the page. Please cover it up and move your paper down as you go. If you choose to cheat, you will learn nothing.

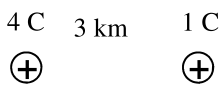
$$F_e = k_c \frac{|q_1 q_2|}{r^2}$$

To help our discussion and make calculations much easier, let's begin reviewing some math and prefixes.

1. A. 3μC = B. 4km =
2. In the $F = kq_1q_2/r^2$ equation k =
3. A. $10^3/10^4$ = B. $(10^9)/(10^6)$ =
4. A. $(3\times10^3)^2$ = B. $9\times10^9/(3\times10^3)^2$ =
5. So, $k/(3\text{km})^2$ =

1A: 3×10^{-6}C; 1B: 4×10^3m
2: k = 9×10^9
3A: 10^{-1} 3B: 10^3
4A: 9×10^6 4B: 1×10^3
5: 1000 (units are not important here)

OK—the answer for #5 is going to be used a lot as we discuss what the electric field really is. I know that a 1 C charge is huge and so is 1 km, but they make the math easy.



6. A 1C charge is 3 km from a 4C charge.
   A. Calculate the force between them.

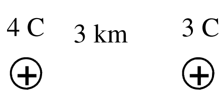
   B. Now divide this force by the 1 C charge.

6A: $9E9(4)(1)/(3E3)^2$ = (9E9/9E6)4 = 1000(4) = 4000 N
6B: 4000/1 = 4000 N/C

7. The 1 C charge is replaced with a 2 C charge.
   A. Calculate the force between them.

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

7A: Again $k/(3\text{km})^2 = 1000$
So, $k(4)(2)/(3\text{km})^2$ = 1000(4)2 = 8000 N
B. 8000/2 = 4000 N/C

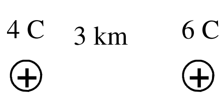


8. Then a 3C charge is placed 3km to the right of the 4C charge.
   A. Calculate the force between them.

   B. Divide the force by the 3 C charge.

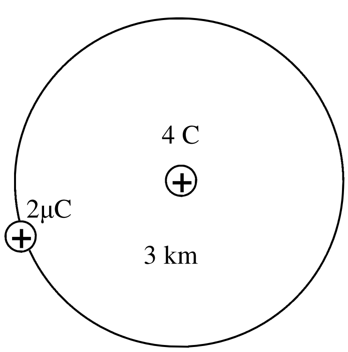
8A: 1000(4)(3) = 12,000N
8B: 12,000/4 = 4000N/C

You should see that in each case the force was different, but the second number was the same! Obviously there is something the same about each of these situations. This common number (in N/C) is the electric field 3km away from a 4C charge. It tells you that AT THIS POSITION there will be 4000N of force for every 1C of charge placed there. This is powerful information. By knowing the electric field, we can easily calculate forces. So, the following questions should be easy.



9. A 6 C charge is placed 3km to the right of a 4C charge.
   A. What is the electric field at the 6C charge's position?
   B. What is the force on the 6C charge?

9A: 4000N/C (still)
9B: (4000N/C)(6C) = 24,000 N



10. A. What is the electric field strength everywhere on the 3km radius sphere shown on the diagram (include direction and notice μC)?

    B. Calculate the force on the 2μC charge.

10: 4000N/C (Same q and same r) and direction is away (repel)

Now, using units, you should see that you can just multiply the electric field (N/C) by the charge (C) to calculate the force.

11. A point in space has an electric field strength of 12 N/C. How much force does a 0.5 C charge feel?

11. $\frac{12\,N}{1C}\left(\frac{0.5\,C}{1}\right) = 6\,N$

12. A 4μC charge is placed in an electric field of 1.5N/C. What is the force on the charge?

12. $(1.5\text{N/C})4\times10^{-6}\text{ C} = 6\times10^{-6}\text{ N}$

13. A 2μC charge feels 4N of force. What is the electric field strength?

13. 2×10^6 N/C

$$F_e = k_c \frac{|q_1 q_2|}{r^2} \text{ and } k_c = 9\times10^9$$

Let's return to the 4C charge example. Let's call the 4C charge q_1, since it is the one that stays constant. Let's call the 2C charge q_2. To find the electric field we divided the force by q_2.

4 C 3 km 2 C

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14. A. Write the equation for electric force over (divided by) q_2.

$$\frac{F_e}{q_2} = \frac{\left(k_c \frac{|q_1 q_2|}{r^2}\right)}{q_2}$$

B. q_2 is really $q_2/1$. Now remembering to multiply by the reciprocal, divide the force equation by q_2 and give the new equation for electric field.

$$\frac{F_e}{q_2} = \left(k_c \frac{|q_1 q_2|}{r^2}\right)\frac{1}{q_2}$$

$$E = \left(k_c \frac{|q_1|}{r^2}\right)$$

Where q_1 is the charge setting up the field and q_2 is interacting with it to create a force.

8μC 2 mm 3μC

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

$$E = \left(k_c \frac{|q_1|}{r^2}\right)$$

$$E = \frac{9E9(8E-6)}{(2E-3)^2}$$

$$E = 18E9\ N/C$$

B. Using the electric field strength, calculate the force on the 3μC charge. (*Again, no calculator.)*

$$E = (18E9\ N/C)(3E-6C)$$

$$E = [18(3)](10^9)(10^{-6})$$

$$E = [(10+8)3](10^3)$$

$$E = (30+24)(10^3)$$

$$E = 54E3$$

$$E = 5.4E4N$$