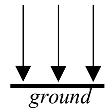
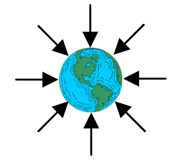
		Constant Field— (Field lines are parallel, like near the earth or near a charged flat plate) 		Point Sources (2 particles) Field lines radiate outward 	
		Gravitational (caused by mass)	Electric (caused by charge)	Gravitational (caused by mass)	Electric (caused by charge)
Vectors	Force (F)	$= mg$ (in N)	$= qE$ (in N)	$F_g = G\dfrac{m_1 m_2}{r^2}$ (in N)	$F_e = k_c\dfrac{q_1 q_2}{r^2}$ (in N)
Vectors	Field (potential for a force)	$= g$ (in N/kg)	$= E = \dfrac{V}{\Delta d}$ (in N/C)	$= G\dfrac{q_1}{r^2}$ (in N/kg)	$E = k_c\dfrac{q_1}{r^2}$ (in N/C)
Scalars	Potential Energy (PE or U)	$= mg\Delta h$ (in J) *h=0 on ground*	$\Delta PE = -qE\Delta d$ (in J)	$PE = G\dfrac{m_1 m_2}{r}$ (in J)	$PE = k_c\dfrac{q_1 q_2}{r}$ (in J)
Scalars	Potential (for energy) or Voltage	$= g\Delta h$ (in J/kg)	$\Delta V = -E\Delta d$ (in J/C)	$= G\dfrac{m_1}{r}$ (in J/kg)	$V = k_c\dfrac{q_1}{r}$ (in J/C)

Please look thru all 4 sections of this help sheet.

Part I—Millikan oil drop experiment

From p. 630 in your Holt Physics Book: In 1909 Robert Millikan used an atomizer (like what women used to use for perfume) to make very small droplets of oil. The droplets of oil were charged as they passed thru the atomizer. These droplets of oil were put between two charged plates. Gravity pulled them down. The charged plate pulled them up. After a lot of very tedious work he realized that the amount of charge on an oil drop was always quantized: multiples of e or −e. This is how we know you can only have amounts of charge that are whole numbers (integrals) times e (you can't have part of an electron or proton).

Part II—Proportionality—if one quantity in an equation is changed, how does another change?

Remembering basic proportionality:

Ex1: If the distance is doubled, by how much does gravity change? ($r_2 = 2r_1$)

Write equation: $F_{1(before)} = G\dfrac{m_1 m_2}{r_1^2}$

Substitute $r_2 = 2r_1$ $F_2 = G\dfrac{m_1 m_2}{(2r_1)^2} = G\dfrac{m_1 m_2}{4r_1^2}$

Pull out F_1 $F_2 = \dfrac{1}{4}\left(G\dfrac{m_1 m_2}{r_1^2}\right) = \dfrac{1}{4}F_1$

You should be easy to see that since r is squared and in the denominator, then putting a 2 in, gives a 4 on the bottom = 1/4.

1. If the distance from a charge is doubled, but how much does the electric field intensity change?

   1. r_2 is on bottom so, $E_2 = \frac{1}{4}E_1$

2. Two charges are separated by a distance of r. If the one of the charges is reduced from 3q to q, by how much did the force between the two charges change?

   2. q_2 was reduced by 1/3, so F reduces by 1/3. or $F_2 = (1/3)F_1$

3. A charge is 4 cm from a point. The charge is then moved 8 cm. By how much does the electric potential change at the point?

   3. r is doubled. r is on bottom so $V_2 = (\frac{1}{2})V_1$

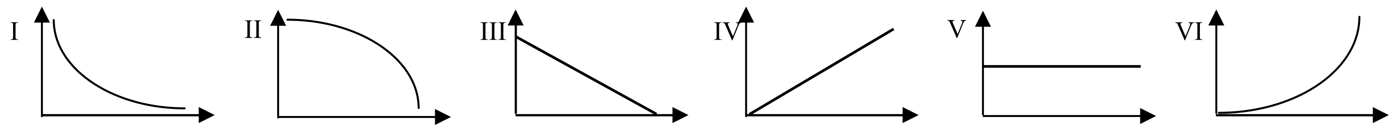
4. Two charges are 2 mm apart. One of the charges is changed from 2q to 4q, while the distance is increased to 6 mm. What is the new potential energy of the system of charges?

   4. $PE = k_c\dfrac{q_1 q_2}{r}$ q Δed (changed) to doubled. r is tripled, so $PE_2 = (2/3)PE_1$

5. Given the above changes, how would the force between them change?

   5. $F_2 = (2/9)F_1$

Part III—Graphs



6. Which of the following graphs shows:
   - A. ____ Voltage versus charge.
   - B. ____ Force versus distance.
   - C. ____ Electric field versus energy.
   - D. ____ Electric Potential Energy vs. distance.
   - E. ____ Electric Potential vs. separation distance.
   - F. ____ Force versus charge.

A. IV
B. I
C. V (no change)
D. I
E. I (voltage)
F. IV

Help on this topic: All of the equations have an r or an r^2 in the denominator. Let's look at V. With r on the bottom, let's start with r = 0 m. You can't divide by 0, so V would be undefined, or would not cross the y axis (an asymptote). When r → ∞ (goes to infinity), V → 0. Is it linear? Put in r = 1, r =2, r = 3, etc, If you graph this (like on that worksheet we did at the beginning of the year), you'd see that this is graph I, above. Why is force vs. distance the same? Doesn't F have an r^2 in its denominator? Yes. That would look very close to graph I, but would be more steep. The difference wouldn't be obvious, so choose the same graph.

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

Part IV—Calculations (*answers on next page*)

7. A 6 C charge is at a point that has an electric potential of 3 V. How much Potential Energy does the charge have?

8. A 0.5 F capacitor is connected to a 12 V battery. How much charge is held on one plate?

9. A point in space has an electric field intensity of 1.5 N/C. A charge put at that point feels 3 N of force. What is the magnitude of the charge?

10. A 2 F capacitor holds 5 coulombs.
    - A. What is the voltage across the capacitor?
    - B. How much energy is held by the capacitor?

11. 20 Joules of work is done to move a charge thru 40 volts. How big was the charge?

12. A 4.0 coulomb charge gains 12 joules of kinetic energy after it is released from rest from a point in space. What was the electric potential at the point from which it was released?

13. A proton and an electron are separated by 1.2 mm.
    - A. What is the electrostatic force between them?
    - B. How much work was done to bring them together?
    - C. What is the electric field intensity felt by the electron?

14. A 2μC charge is 5 mm away from a −4μC charge. Calculate the force, electric field, potential energy, and potential at the 2μC charge's position.

Part IV—Calculations (*answers on next page*)

7. A 6 C charge is at a point that has an electric potential of 3 V. How much Potential Energy does the charge have?
   3V = 3J/C(3J/C)(6C) = 18 J

8. A 0.5 F capacitor is connected to a 12 V battery. How much charge is held on one plate?
   0.5F = 0.5 C/V, so (0.5C/V)12V = 6C

9. A point in space has an electric field intensity of 1.5 N/C. A charge put at that point feels 3 N of force. What is the magnitude of the charge?
   E = N/C So, Coulombs = E/newtons So, q = F/E = 3N/(1.5N/C)q = 2 coulombs

10. A 2 F capacitor holds 5 coulombs.
    A. What is the voltage across the capacitor? *2 F = 2 C/volt So, V = Coulombs/ farads V = 5C/2F = 2.5 volts*

    B. How much energy is held by the capacitor? *PE = ½QV PE= ½(5C)(2.5V) =6.25joules*

11. 20 Joules of work is done to move a charge thru 40 volts. How big was the charge?
    40 V = 40 J/C J/C = V, so C = J/V C = 20 J/40V = 0.5 coulombs

12. A 4.0 coulomb charge gains 12 joules of kinetic energy after it is released from rest from a point in space. What was the electric potential at the point from which it was released?
    V = J/C V = 12 J/ 4.0 C = 3 volts

since $F = \frac{kqq}{r^2}$, $PE = \frac{kqq}{r}$, $PE = F(r)$

13. A proton and an electron are separated by 1.2 mm.
    A. What is the electrostatic force between them? $F = \frac{kqq}{r^2} = \frac{(9\times10^9)(1.6\times10^{-19})(1.6\times10^{-19})}{(1.2\times10^{-3})^2} = 1.6\times10^{-22}\,N$ attractive

    B. How much work was done to bring them together? $PE = F(r) = (1.6\times10^{-22})(1.2\times10^{-3}) = 1.92\times10^{-25}\,J$ see left

    C. What is the electric field intensity felt by the electron? $E = \frac{N}{C}$, div by q electron $\frac{F}{q} = \frac{1.6\times10^{-22}\,N}{1.6\times10^{-19}\,C} = 1\times10^{-3}\,\frac{N}{C}$
    E is always F/q or div by q at that point.

14. A 2μC charge is 5 mm away from a −4μC charge. Calculate the force, electric field, potential energy, and potential at the 2μC charge's position.

$$F_e = k_c\frac{q_1q_2}{r^2} = \frac{(9\times10^9)(4\times10^{-6})(2\times10^{-6})}{(5\times10^{-3})^2} = 2.88\times10^3\,\text{N}$$

This is the force on both charges (Newton's 3rd Law).

$$E = k_c\frac{q}{r^2} = \frac{(9\times10^9)(4\times10^{-6})}{(5\times10^{-3})^2} = 1.44\times10^9\,\text{N/C} \text{ OR } E = \frac{F_e}{q_2} = \frac{2.88\times10^3\,\text{N}}{2\times10^{-6}} = 1.44\times10^9\,\text{N/C}$$

The electric field at the 2μC's position is due to external charges, not itself. So you look at the 2μC's position and calculate E due to what is around it.

$$PE = k_c\frac{q_1q_2}{r} = \frac{(9\times10^9)(-4\times10^{-6})(2\times10^{-6})}{(5\times10^{-3})} = -14.4\text{J} \text{ OR } PE = F_e(r) = 2.88\times10^3(5\times10^{-3}) = -14.4\text{J}$$

PE is same for both. It is negative because you had to hold them back when bringing them together. OR the closer they get, the possible KE gets smaller (more negative).

$$V = k_c\frac{q}{r} = = \frac{(9\times10^9)(-4\times10^{-6})}{(5\times10^{-3})} = -7.2\times10^6\text{V} \text{ OR } V = \frac{PE}{q_2} = \frac{-14.4\text{J}}{2\times10^{-6}C} = -7.2\times10^6\text{V}$$

Electric potential is like Electric Field: it is about the position, not what's there. So, look at the 2μC's position and calculate V due to what is around it.