Coulomb's Law Worksheet Solutions

1. Two charged spheres 10 cm apart attract each other with a force of 3.0 x 10^{-6} N. What force results from each of the following changes, considered separately?

   a) Both charges are doubled and the distance remains the same.
   b) An uncharged, identical sphere is touched to one of the spheres, and then taken far away.
   c) The separation is increased to 30 cm.

$$F \propto q_1 q_2 \quad \rightarrow \quad 4F \propto 2q_1 2q_2 \quad \rightarrow \quad 4F = 4(3E-6N) = 1.2E-5N$$

$$one\ of\ the\ spheres\ loses\ half\ its\ charge \quad \rightarrow \quad F \propto q_1 q_2 \quad \rightarrow \quad \tfrac{1}{2}F \propto \tfrac{1}{2}q_1 q_2$$

$$\rightarrow \quad \tfrac{1}{2}F = \tfrac{1}{2}(3E-6N) = 1.5E-6N$$

$$F \propto \tfrac{1}{d^2} \quad \rightarrow \quad \tfrac{1}{9}F \propto \tfrac{1}{(3d)^2} \quad \rightarrow \quad \tfrac{1}{9}F = \tfrac{1}{9}(3E-6N) = 3.3E-7N$$

2. The force of electrostatic repulsion between two small positively charged objects, A and B, is 3.6 x 10^{-5} N when AB = 0.12m. What is the force of repulsion if AB is increased to

   a) 0.24 m   b) 0.36 m

Since $F \propto \tfrac{1}{d^2}$,

a) Double the distance, quarter the force. $\rightarrow$ $\dfrac{1}{4}(3.6E-5N) = 9E-6N$

b) Triple the distance, reduce the force to 1/9th its original value. $\rightarrow$ $\dfrac{1}{9}(3.6E-5N) = 4E-6N$

3. Calculate the force between charges of 5.0 x 10^{-8} C and 1.0 x 10^{-7} C if they are 5.0 cm apart.

$$F = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9\ \frac{N \cdot m^2}{C^2})(5E\text{-}8C)(1E\text{-}7C)}{(.05m)^2} = 0.0180N = 1.8E-2N$$

4. What is the magnitude of the force a 1.5 x 10^{-6} C charge exerts on a 3.2 x 10^{-4} C charge located 1.5 m away?

$$F = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9\ \frac{N \cdot m^2}{C^2})(1.5E\text{-}6C)(3.2E\text{-}4C)}{(1.5m)^2} = 1.92N$$

5. Two spheres; 4.0 cm apart, attract each other with a force of 1.2×10^{-9} N. Determine the magnitude of the charge on each, if one has twice the charge (of the opposite sign) as the other.

$$F = \frac{kq_1q_2}{d^2}$$

$$F = \frac{(k)(q)(2q)}{(d)^2} \quad \rightarrow \quad 1.2E-9N = \frac{(8.99E9\ \frac{N\cdot m^2}{C^2})(q)(2q)}{(.04m)^2} \quad \rightarrow \quad q = 1.03E-11C$$

$$2q = 2.06E-11C$$

6. Two equal charges of magnitude 1.1×10^{-7} C experience an electrostatic force of 4.2×10^{-4} N. How far apart are the centers of the two charges?

$$F = \frac{kq_1q_2}{d^2}$$

$$d = \sqrt{\frac{(k)(q)(2q)}{F}} = \sqrt{\frac{(8.99E9\ \frac{N\cdot m^2}{C^2})(1.1E\text{-}7C)(1.1E\text{-}7C)}{4.2E\text{-}4N}} = .51m$$

7. How many electrons must be removed from a neutral, isolated conducting sphere to give it a positive charge of 8.0×10^{-8} C?

$$q = ne \quad \rightarrow \quad n = \frac{q}{e} = \frac{8E-8C}{1.6E-19C} = 5E11\ electrons$$

8. What will be the force of electric repulsion between two small spheres placed 1.0 m apart, if each has a deficit of 10^8 electrons?

$$q = ne = (1E8\ electrons)(1.6E-19C\ per\ electron) = 1.6E-11C$$

$$F = \frac{kq_1q_2}{d^2} = \frac{(8.99E9\ \frac{N\cdot m^2}{C^2})(1.6E\text{-}11C)(1.6E\text{-}11C)}{(1m)^2} = 2.30E-12N$$

9. Two identical, small spheres of mass 2.0 g are fastened to the ends of a 0.60m long light, flexible, insulating fishline. The fishline is suspended by a hook in the ceiling at its exact centre. The spheres are each given an identical electric charge. They are in static equilibrium, with an angle of 30° between the string halves, as shown. Calculate the magnitude of the charge on each sphere. *(Hint: start off by drawing a FULL, DETAILED FBD of one of the charged spheres).*

.30 m

30°

2.0 g   2.0 g
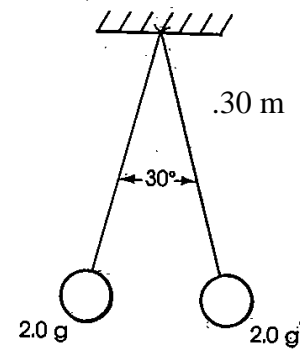
$T_y = mg = (.002\text{kg})(9.8\frac{m}{s^2}) = .0196N$

$\tan 15^o = T_x / T_y \quad \rightarrow \quad T_x = T_y \tan 15^o$

$\qquad\qquad = (.0196N)\tan 15^o = .0052518N$

$F_e = T_x = .0052518N$

Seperation distance $= 2 \cdot (.30\text{m})(\sin 15^o) = .15529\text{m}$

$F_e = \dfrac{kq_1q_2}{d^2} = \dfrac{kq^2}{d^2}$

$.00525N = \dfrac{(8.99E9\,\frac{N\cdot m^2}{C^2})q^2}{(.15529\text{m})^2} \qquad q = 1.2E-7N$

T_x

T

T_y ¦15°

F_e

mg

.3m

15°

$(.3)\sin(15^o)$
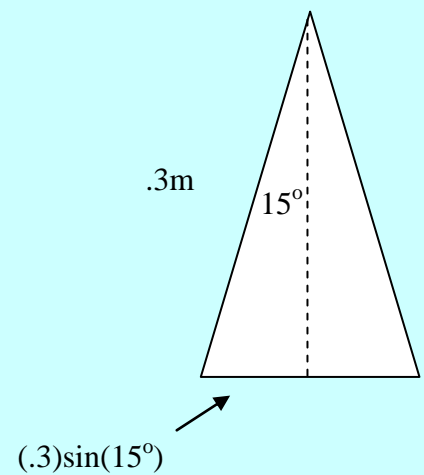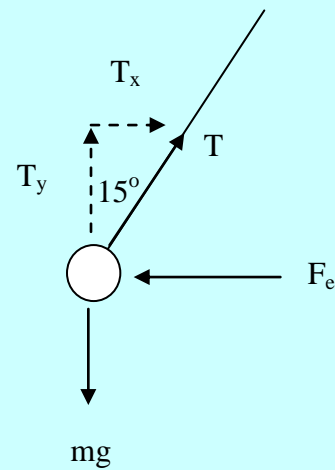
10. Three negatively charged spheres, each with a charge of 4.0×10^{-6} C, are fixed at the vertices of an equilateral triangle whose sides are 20 cm long. Calculate the magnitude and direction of the net electric force on each sphere.

4μC

.2m   .2m

60°

4μC   .2m   4μC

$$F_e = \frac{kq_1q_2}{d^2} = \frac{(8.99\text{E}9 \frac{\text{N·m}^2}{C^2})(4\text{E-}6\text{C})(4\text{E-}6\text{C})}{(.2\text{m})^2} = 3.596N$$

1.798N

3.596N

3.114N

60°

3.596N

$=$

5.394 N

30°

3.114N

6.228N
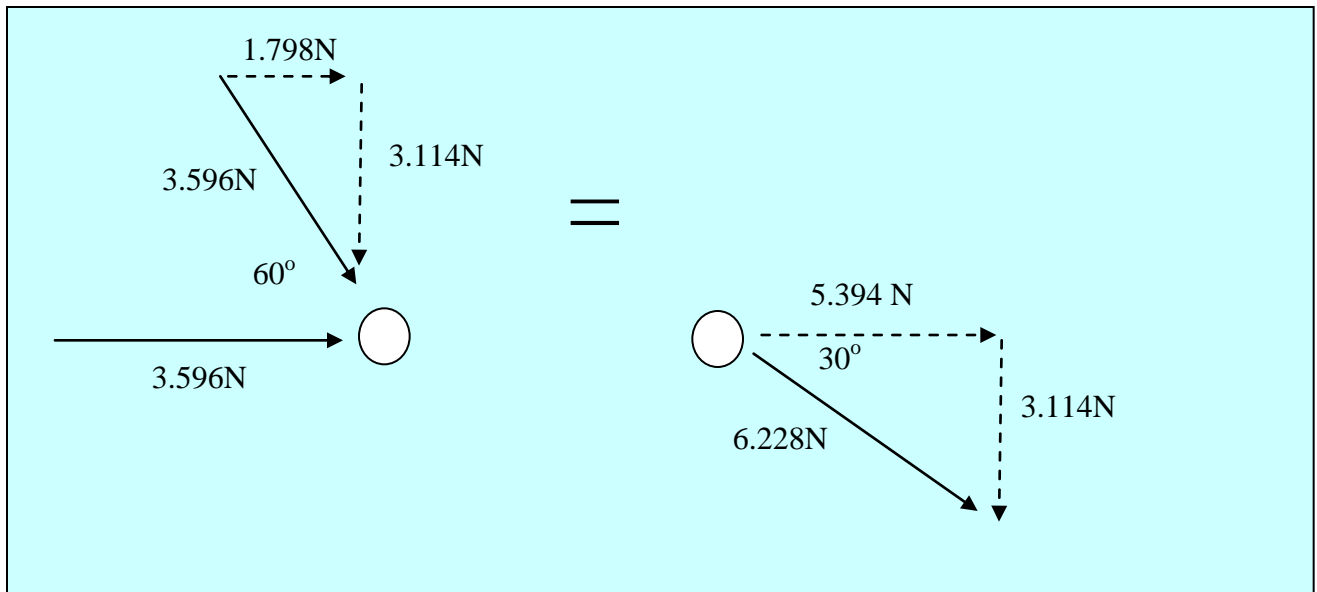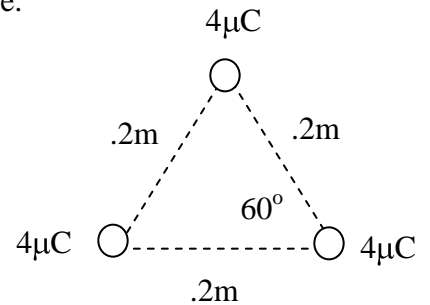
Instead of giving three different directions, we can give one direction that applies to all 3 forces.

outward, 150° away from each side

150°   4μC

150°

60°

4μC   4μC

150°
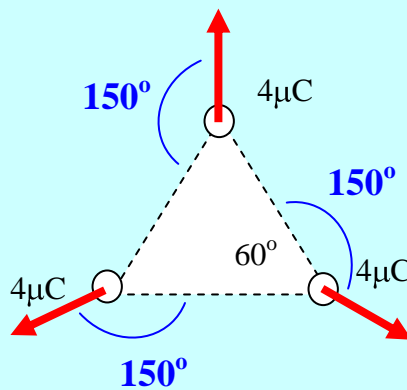
11. Three objects, carrying charges of -4.0×10^{-6} C, -6.0×10^{-6} C, and $+9.0 \times 10^{-6}$ C, respectively, are placed in a line, equally spaced from left to right by a distance of 0.50 m. Calculate the magnitude and direction of the net force acting on each charge that results from the presence of the other two.
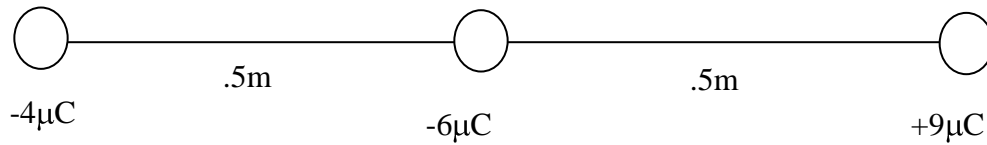
on $-4\mu C$ charge

$$F_e = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9 \frac{N \cdot m^2}{C^2})(-4E\text{-}6C)(-6E\text{-}6C)}{(.5m)^2} = .86304N, \quad .86304N[\leftarrow]$$

$$F_e = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9 \frac{N \cdot m^2}{C^2})(-4E\text{-}6C)(9E\text{-}6C)}{(1m)^2} = -.32364N, \quad .32364N[\rightarrow]$$

$.86304N[\leftarrow] + .32364N[\rightarrow] = .5394N \; [left]$

on $-6\mu C$ charge

$$F_e = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9 \frac{N \cdot m^2}{C^2})(-4E\text{-}6C)(-6E\text{-}6C)}{(.5m)^2} = .86304N, \quad .86304N[\rightarrow]$$

$$F_e = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9 \frac{N \cdot m^2}{C^2})(-6E\text{-}6C)(9E\text{-}6C)}{(.5m)^2} = -1.94184N, \quad 1.94184N[\rightarrow]$$

$.86304N[\rightarrow] + 1.94184N[\rightarrow] = 2.8N \; [right]$

on $+9\mu C$ charge

$$F_e = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9 \frac{N \cdot m^2}{C^2})(-9E\text{-}6C)(+9E\text{-}6C)}{(.5m)^2} = -1.94184N, \quad 1.94184N[\leftarrow]$$

$$F_e = \frac{kq_1 q_2}{d^2} = \frac{(8.99E9 \frac{N \cdot m^2}{C^2})(-4E\text{-}6C)(9E\text{-}6C)}{(1m)^2} = -.32364N, \quad .32364N[\leftarrow]$$

$1.94184N[\leftarrow] + .32364N[\leftarrow] = 2.26N \; [left]$

12. Delicate measurements indicate that the Earth has an electric field surrounding it, similar to that around a positively charged sphere. Its magnitude at the surface of the Earth is about 100 N/C. What charge would an oil drop of mass 2.0×10^{-15} kg have to have, in order to remain suspended by the Earth's electric field? Give your answer in coulombs ?

$$E = \frac{F}{q} = 100\,\frac{N}{C}$$

To remain suspended above the earth, the Electric Force must perfectly balance the weight.

$$\frac{mg}{q} = 100\,\frac{N}{C} \quad \rightarrow \quad mg = q \cdot 100\,\frac{N}{C} \quad \rightarrow \quad q = \frac{mg}{100} = \frac{(2E-15kg)(9.8\,\frac{m}{s^2})}{100} = 1.96E-16C$$

13. Compute the gravitational force and the electric force between the electron and the proton in the hydrogen atom if they are 5.3×10^{-11} meters apart. Then calculate the ratio of F_e to F_g.

$$F_e = \frac{kq_1q_2}{d^2} = \frac{(8.99E9\,\frac{N \cdot m^2}{C^2})(-1.602E-19C)(+1.602E-19C)}{(5.3E-11m)^2} = 8.21E-8N$$

$$F_g = \frac{Gm_1m_2}{d^2} = \frac{(6.67E-11\,\frac{N \cdot m^2}{kg^2})(9.11E-31kg)(1.67E-27kg)}{(5.3E-11m)^2} = 3.61E-47N$$

$$F_e / F_g = 2.3E39$$

14. The earth is used to "ground" objects. That is because its neutral. If the earth is neutral, then we will be neutral as well (since we are touching it). Neutral doesn't attract neutral.

17. Two point charges of +2.0μC and +4.0μC are fixed at opposite ends of a meter stick. Where on the meter stick (if anywhere!) could (a) a free electron and (b) a free proton be placed so that they are in electrostatic equilibrium (and won't move).

$$F_{e1} = F_{e2} \quad \rightarrow \quad \frac{kQ_1q}{d^2} = \frac{kQ_2q}{d^2} \quad \rightarrow \quad \frac{Q_1}{x^2} = \frac{Q_2}{(1-x)^2} \quad \rightarrow \quad \frac{\sqrt{Q_1}}{x} = \frac{\sqrt{Q_2}}{(1-x)}$$

$$\sqrt{Q_1}(1-x) = x\sqrt{Q_2} \quad \rightarrow \quad \sqrt{(2E\text{-}6)}(1-x) = x\sqrt{(4E\text{-}6)} \quad \rightarrow \quad x = .414m = 41.4cm$$

Place the electron or proton at 41.4 cm, where the $+2\mu C$ charge is placed at 0cm.

18. Using the same orbital distance from problem #13 above, find the orbital speed and the centripetal acceleration (in g's) of an electron orbiting the nucleus of a hydrogen atom (assuming the orbit to be circular).

$$F_e = F_c = \frac{mv^2}{R} \quad \rightarrow \quad 8.21E-8N_c = \frac{(9.11E-31kg)v^2}{(5.3E-11m)} \quad \rightarrow \quad v = 2.2E6\frac{m}{s}$$

$$a_c = \frac{v^2}{R} = 9.03E22\frac{m}{s^2} = 9.21E12 \ g's$$