Physics 142: Homework 1 Solutions

Ch. 23, Q: 4, 6, 9, 15, 18, 20
Ch. 23, P: 4, 6, 7, 10, 11, 14, 15, 16, 18, 54

Q4: If hospital personnel wore insulating rubber-soled shoes, charge could build up on the shoes which might lead to a spark, which could start a fire in the oxygen rich environment. If the shoes are conductive, charge would not be able to build up.

Q6: The charge rubber rod (lets say the charge is positive, it is an arbitrary choice), the charge on the rod will induce a polarization within the metal sphere. The negative charges within the sphere will be attracted to the side near the rod, and the positive charges will be pushed to the side away from the rod. Since the negative charge on the metal sphere is closer to the positive rod than the positive charge on the sphere, the attractive force between the positive and negative charges is stronger than the repulsive force so there is a net attraction. But once the metal sphere touches the rod, some of the positive charge rod will be annihilated with some of the negative charge on the surface of the sphere. Now the rod is still positive, but now the metal sphere has a net positive charge, so they will repel.

Q9: The wall does not need to be positively charged since the charge on the balloon could be inducing a polarization within the wall. The balloon eventually falls off because the charge eventually disperses into the wall or the air.

Q15: If the distance from the charge distribution to the point at which you are interested in find the electric force or field is much greater than the distances within the charge distribution.

Q18: Since the magnitude of the charge on an electron and a free proton is the same they will experience a force of the same magnitude only in the opposite direction since the particles have opposite charge. However the acceleration will be 2000x greater for the electron than for the proton, since the proton has the mass of 2000 electrons.

Q20: The charge will accelerate downward, since the charge is negative.

P4: This problem is an application of Coulomb's Law (23.1).

$$F = k_e \frac{q_p q_p}{r^2} = 8.988\times10^9 \frac{N\cdot m^2}{C^2} \frac{\left(1.602\times10^{-19} C\right)^2}{\left(2.00\times10^{-15} m\right)^2} = 57.7N$$

P6: Again, we apply Coulombs Law, only this time we want to solve for the charge (which must be opposite and equal on the two spheres).

$$F = k_e \frac{q_p q_p}{r^2} = 8.988\times10^{9}\frac{N\cdot m^2}{C^2}\frac{\left(1.602\times10^{-19}C\right)^2}{\left(2.00\times10^{-15}m\right)^2} = 57.7N$$

$$1.00\times10^{4}N = 8.988\times10^{9}\frac{N\cdot m^2}{C^2}\frac{q_p^2}{\left(1.00m\right)^2}$$

$$q_p = 1.06mC$$

We want to know how many electrons this is:

$$\frac{q_p}{e} = \frac{1.06\times10^{-3}C}{1.602\times10^{-19}C} = 6.62\times10^{15}$$

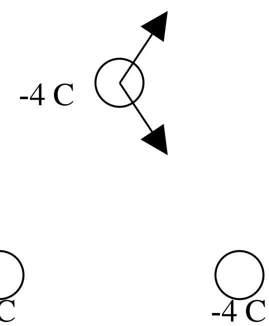
The total number of electrons in a sphere:

$$10g\frac{mol}{107.87g}\frac{6.022\times10^{23}atoms}{mol}\frac{47electrons}{atoms} = 2.62\times10^{24}$$

Therefore the fraction is

$$\frac{6.62\times10^{15}}{2.62\times10^{24}} = 2.53\times10^{-9}$$

P7: This problem requires vector addition. First we find the total force from the2.00 C charge and then the -4.00 C charge.



$$F_{2\mu C} = k_e \frac{q_p q_p}{r^2} = 8.988\times10^{9}\frac{N\cdot m^2}{C^2}\frac{\left(2\mu C\right)\left(7\mu C\right)}{\left(0.5\right)^2} = 0.503N$$

directed 60° above the horizontal. The force from the -4.00 C charge must be twice as strong (2.00 C compared with -4.00 C) and is directed 60° below the horizontal. Now we want to add up the x and y components.

$$F_x = 0.503N\cos 60° + 1.006N\cos 60° = 0.755N$$

$$F_y = 0.503N\sin 60° - 1.006N\sin 60° = -0.436N$$

We subtracted the components for y since one points in the positive y direction and the other in the negative y direction. To get back radial coordinates,

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{\left(0.755N\right)^2 + \left(-0.436N\right)^2} = 0.872N$$

$$angle = \tan^{-1}\left(\frac{-0.436N}{0.755N}\right) = -30.0°$$

P10: We need to find the point on the rod in which the forces from both of the fixed charges cancel each other. Let's say the charge on the middle bead is Q, and the distance from the 3q charge is x and the distance from charge q is (d – x).

$$k_e\frac{\left(3q\right)Q}{x^2} = k_e\frac{\left(q\right)Q}{\left(x-d\right)^2}$$

The charges q and Q as well as k_e, will cancel. What we find is a quadratic equation.

$$\frac{3}{x^2} = \frac{1}{(x-d)^2}$$

$$3(x-d)^2 = x^2$$

$$2x^2 - 6xd + 3d^2 = 0$$

$$x = \frac{-(-6d) \pm \sqrt{(6d)^2 - 4 \cdot 2 \cdot 3d^2}}{2 \cdot 2} = 0.634d, 2.37d$$

The solution 2.37d does not make physical sense, so the charge must be placed at 0.634d. If the charge is negative than the balance of the forces is precarious, any small disturbance and the charge will accelerate to one of the fixed charges, this is unstable. If the charge is positive then after a small disturbance the charge will be repelled back to the old spot, so is stable.

P11: $F = k_e \frac{q_p q_p}{r^2} = 8.988 \times 10^9 \frac{N \cdot m^2}{C^2} \frac{(1.602 \times 10^{-19} C)^2}{(0.529 \times 10^{-10} m)^2} = 8.22 \times 10^{-8} N$

Recall that the formula for centripetal force is

$$F = m\frac{v^2}{r}$$

$$v^2 = \frac{Fr}{m} = \frac{8.22 \times 10^{-8} N \cdot 0.529 \times 10^{-10} m}{9.109 \times 10^{-31} kg}$$

$$v = 2.20 \times 10^6 m/s$$

We have assumed that the proton is stationary and that the electron is orbiting it like the moon orbits the earth, this is valid since although the proton experiences the same force as the electron its much greater mass means it has a much smaller acceleration.

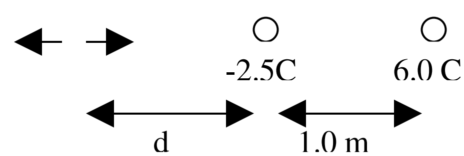
P14: In order for the object to float the electric force must equal the gravitational force.

$$qE = mg$$

$$(24.0 \times 10^{-6} C) \cdot 610 \frac{N}{C} = m \cdot 9.80 \frac{m}{s^2}$$

$$m = 1.5g$$

This is about the mass of large paperclip.



P15: In order for the electric field to be zero, the field from each of the charges must be equal in magnitude and opposite in direction. The field radiates away from the positive charge and towards the negative charge. So we know where to expect our point of interest to be.

$$k_e \frac{q}{d^2} = k_e \frac{q}{(d+1.0m)^2}$$

$$\frac{2.5\mu C}{d^2} = \frac{6.0\mu C}{(d+1.0m)^2}$$

$$(d+1.0m)^2 = \frac{6.0}{2.5} d^2$$

$$(d+1.0m) = \sqrt{\frac{6.0}{2.5}} d$$

$$1.0m + d = \pm 1.55d$$

$$d = 1.82m, -0.392m$$

By the way we defined d we know it must be positive, so the spot is 1.82 m to the left of the -2.5 C charge.

P16: First we find the charge from the +40.0 C charge above the plane.

$$E = k_e \frac{q}{r^2} = 8.988\times 10^9 \frac{N\cdot m^2}{C^2} \frac{(40.0C)}{(1000m)^2} = 3.60\times 10^5 N$$, directed downward.

The field form the – 40.0 charge is also directed downward, and since the charge is also 1000 m from the plane, so the magnitude must be the same so the total field must be

$$E = 2\cdot 3.60\times 10^5 N = 7.20\times 10^5 N$$ directed downward

P18: Taking a similar approach as we did in problem 7:

$$E_{7\mu C} = k_e \frac{q}{r^2} = 8.988\times 10^9 \frac{N\cdot m^2}{C^2} \frac{(7\mu C)}{(0.50m)^2} = 252\times 10^3 \frac{N}{C}$$, directed 120° below the x-axis.

$$E_{-4\mu C} = k_e \frac{q}{r^2} = 8.988\times 10^9 \frac{N\cdot m^2}{C^2} \frac{(-4\mu C)}{(0.50m)^2} = -144\times 10^3 \frac{N}{C}$$, directed along the x-axis.

$$E_x = 0.252\times 10^6 \frac{N}{C}\cos(-120°) + 0.144\times 10^6 \frac{N}{C} = 18\times 10^3 \frac{N}{C}$$

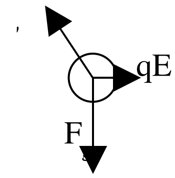
$$E_y = 0.252\times 10^6 \frac{N}{C}\sin(-120°) = -218\times 10^3 \frac{N}{C}$$

b) We only need to multiply by the charge to find the force on the 2 C.

$$F_x = qE_x = 2\mu C\cdot 18\times 10^3 \frac{N}{C} = 36\times 10^{-3} N$$

$$F_y = qE_y = 2\mu C\cdot -218\times 10^3 \frac{N}{C} = 436\times 10^{-3} N$$

P54: We first want to find the tension in the string, using trigonometry we can relate the tension in the string to the force of gravity on the ball. The force of gravity on the ball is



$$F_g = 2.00g \cdot 9.80\frac{m}{s^2} = 0.0196N = T\cos(15.0°)$$

$$T = 0.0203N$$

Here T is the tension in the string. We can also relate the tension in the string to the electric force on the ball.

$$F = qE = T\sin 15°$$

$$q \cdot 1.00\times10^3 \frac{N}{C} = 0.0203N \cdot \sin 15°$$

$$q = 5.25\mu C$$