Assignment VIII, PHYS 308
Fall 2016
Due 11/4/16 at start of class

NOTE: Please leave your answers in terms of actual numbers (with appropriate units) when possible. Please provide full, legible, easy to follow solutions to the following problems. I can't give you credit if I can't follow your reasoning. Extensive exposition on your thought process or strategy is always appreciated.

1. A 0.2 μm particle of density 1 g/cc is being carried by an airstream at 1 atm and 298K in the $+y$ direction with a velocity of 1 m/s. The particle enters a charging device and acquires a charge of two electrons (the charge of a single electron is 1.6×10^{-19} C) and moves into a region containing a constant electric field of 10 V/m in the $+x$ direction.

   a) Calculate the relaxation time τ for the particle.

   b) Find the mean x-component of the velocity for the particle. (Hint – part (a) will be helpful! If you're stuck, talk to me!)

   c) If the region containing the electric field is 15 meters long, how far will the particle be displaced in the x-direction along its original direction upon reaching the end of the electric field region?

   d) Find the answer to part (c) for a 50 nm diameter particle. (This will require you to recalculate parts (a) and (b) for a 50 nm particle). Use a particle with the same density. Note – Kn changes!

2. In class, we developed the following expression for G_{rel}:

$$G_{\text{rel}} = 4\pi r^2\sigma - \frac{4}{3}\pi r^3 nkT\ln\left(\frac{e}{e_s}\right)$$

   a) Find the value of r when G_{rel} reaches a maximum. (We call this value r_c for the critical radius). You may assume all parameters in the problem except for r can be treated as constants. You may also assume $e > e_s$.

   b) Find the value of G_{rel} when $r = r_c$. Please simplify your answer as much as you reasonably can.

   c) For $e > e_s$, $G_{\text{rel}} = 0$ at two values of r. The first is at $r = 0$. Find the other value of r that makes this true. We'll refer to the value of r you find here as $r_{\text{2nd zero}}$ (in the following parts of this problem).

   d) Let's compare $r_{\text{2nd zero}}$ to r_c. You might expect $r_{\text{2nd zero}} = 2r_c$ if the curve is completely symmetric for positive values of G_{rel}. Is $r_{\text{2nd zero}}$ greater than, equal to, or less than $2r_c$?

   e) How many liquid water molecules would be in a sphere of radius $r_{\text{2nd zero}}$? Assume $e/e_s = 1.042$, $\sigma = 0.076$ J/m^2, and $T = 270$K.

   f) Technically, anything with $r > r_{\text{2nd zero}}$ has $G_{\text{rel}} < 0$ and thus is energetically favorable to exist compared to vapor. However, we do not see homogeneous nucleation of water drops that start at $r_{\text{2nd zero}}$ and grow. Explain why we don't see this.

3. The surface tension of Mercury has $\sigma \approx 0.487$ J/m^2. Its saturation vapor pressure at 300K is about 1 Pa, and let's say that the current vapor pressure of Mercury is 3.2 Pa at 300K. Mercury's density at 300K is about 13560 kg/m^3.

   a) Find the value of r_c for Mercury in air under these conditions.

   b) Assuming the typical density of liquid Mercury, how many molecules does a liquid droplet of radius r_c computed in part (a) correspond to?