Supplemental Homework Set on Diffusion and Flux Forces

1. Particles of equal size and density are released simultaneously and allowed to settle in still air for five minutes. Because of Brownian motion, some particles will settle farther than others. If the particles are 0.6 μm unity-density spheres, what are the mean and standard deviation of their displacements from the origin after five minutes?

ans. 0.42 cm; 0.0140 cm

2. How long would you have to wait for 32% of some 0.1 μm diameter aerosol particles to be more than 1.0 m from their position at time t = 0? Assume ambient conditions and that the only motion is Brownian motion.

ans. 39 years

3. In 1914, Fletcher (Phys. Rev. 4: 440) published a paper describing his experimental verification of diffusion coefficients. His measurements are based on the distribution of settling times for a particle settling over a fixed vertical distance. Fletcher was able to make 6000 replications on a single particle by raising the particle back up to the starting point with an electric field. If his particle was 0.36 μm diameter and the settling distance was 0.74 mm, what are the theoretical mean and standard deviation of the settling times? Assume no experimental error and that the density of the particle was 1 g/cm^3. Approximately how long did it take to conduct this experiment? Assume 25 seconds were required to reposition the particle each time it was dropped.

Ans. 129 s, 22 s, 10.7 days nonstop.

4. A clean surface is placed into an aerosol whose concentration of 0.01 μm particles is $10^3/cm^3$.

a. Consider a spot that is 1 mm away from the surface. What will the concentration of 0.01 μm particles be at that spot after 1 second? After 1 minute? After 1 hour?

b. What is the instantaneous flux of particles to the surface, in particles/(cm^2 s), after one second? After one minute? After 1 hour?

c. How many particles 0.01 μm in diameter will have deposited on the surface per cm^2 after 1 second? After 1 minute? After 1 hour?

5. Consider a droplet of evaporating carbon tetracholoride in air.

a. Will the diffusiophoretic force on a particle near the droplet be toward or away from the droplet?

b. Will the Stephan flow drag force on the particle near the droplet be toward or away from the droplet?

c. As the droplet evaporates it cools. What will be the direction of the thermophoretic force that acts on a particle near the droplet?