Exercise sheet #10

Problem 1. Consider a dispersion of nanoparticles, i.e. particles with a radius $R < 1\mu m$.

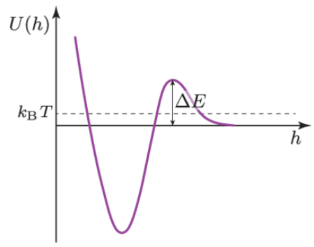
a) Why do nanoparticles tend to aggregate?

b) What can you do to prevent aggregation?

c) You want to intravenously inject iron oxide nanoparticles into humans to enhance the contrast in magnetic resonance images that are used to determine if a patient has cancer. How would you ensure that these nanoparticles do not clog blood vessels?

Problem 2. A suspension of spherical polystyrene particles (density $\rho_p = 1050$ kg m^{-3}) is dispersed in water ($\rho_w = 1000$ kg m^{-3}, viscosity $\eta = 1.0 \times 10^{-3}$ Pa s) at room temperature $T = 298$ K. Each particle has radius $a = 500$ nm. Estimate the time to sediment a distance $h = 1$ cm by advection at velocity v. Comment on whether the particle suspension is well mixed.

Problem 3. Suppose we have a dispersion of glass particles in water at room temperature. If they interact with the potential sketched in the figure below, the energy barrier may prevent particles from crossing into the attraction regime and consequently aggregating. In this problem, we are going to estimate the height of the barrier needed in order to keep the particles dispersed for the duration of a day. Let us consider a 10% dispersion by weight of glass particles with radius of $R = 100$ nm.



a) The relative density of glass is 2.5. Calculate the volume fraction of this suspension and show that the typical distance between colloids is of order 500 nm .

b) Calculate the Stokes-Einstein diffusion coefficient

c) Estimate the mean distance $\ell_1 \simeq \left(\left\langle V^2\tau^2\right\rangle\right)^{1/2}$ a bead moves during the time the velocity is correlated (This distance comes from considering $D \approx \frac{l_1^2}{\tau}$) and show that it is much smaller than the radius R of the beads. What do you conclude from this?

d) Show that the mean time t_{coll} it takes two colloids to 'collide' is of order 0.12 s. Hint: The conclusion you drew in c should convince you that the behavior of the colloids is diffusive also at the scale of microns, and hence that you can estimate the 'collision time' with the help of the results of band a.

e) Requiring the probability of two particles overcoming the energy barrier upon collision to be less than 1/ typical number of collisions, show that the height of the energy barrier should exceed about $13k_\text{B}T$.