

Assignment 4. (6 p)

Interactions that are related to the so-called van der Waals interactions are often described by the Lennard-Jones (LJ) potential

$$V(r) = -\frac{A}{r^6} + \frac{B}{r^{12}},$$

where r is distance, and A and B are (positive) constants that depend on the atom types in question.

- Explain the physical origin of the two terms in the above equation.
- Calculate an expression for the force $F(r)$ that results from $V(r)$.
- Make a schematic plot of how $V(r)$ and $F(r)$ vary with r .
- What are the units (dimensions) of the parameters A and B ?
- Determine the minimum of the potential, $V_{\min}(r)$. Even though you do not know the values of A and B , discuss the expected value of $V_{\min}(r)$ (for fluid or soft systems).

Assignment 5. (6 p)

Answer either to part (a) or (b).

- (a) **Ideal gas / Ideal model.** Many of the discoveries of physics have originally been based on "ideal" models such as the ideal gas.

- Explain the underlying assumptions of the ideal model (ideal gas).
- Give a couple of examples where the ideal model has been used.
- The heat capacity at constant temperature is defined as

$$C_V = \left(\frac{\partial U}{\partial T} \right)_V.$$

Compute C_V for the ideal gas.

- Consider a random walker moving along a line in one dimension. It performs jumps of distance L , each jump done with equal probability ($1/2$) either to the left or the right. The period between consecutive jumps is always the same, Δt , and t is time. Even for a system of many random walkers moving at the same time, one can consider the diffusion coefficient D of the random walkers using the ideal gas assumptions. Under these conditions, prove that the diffusion coefficient follows the law $D \sim L^2/t$.

- (b) **Discuss the following themes.**

- Reynolds number.** Define the Reynolds number Re and tell what the two different limits mean: Re is much smaller than one, and Re is much larger than one. If you considered the motion of cells, what value of Re would be realistic?
- Information and function.** Describe how the information in DNA is translated into functions (of, for example, proteins) in cells?
- Energy storage.** Discuss how cells store energy?

These might be useful:

$$\sin 2x = 2 \sin x \cos x$$

$$\sin 3x = 3 \sin x - 4 \sin^3 x$$

$$\cos 2x = 1 - 2 \sin^2 x$$

$$\cos 3x = 4 \cos^3 x - 3 \cos x$$

Taylor expansion $(1+x)^{-1/2} \approx 1 - \frac{1}{2}x + \frac{3}{8}x^2 + \mathcal{O}(x^3)$ for $|x| < 1$.

Boltzmann constant $1.380662 \cdot 10^{-23}$ J / K.

1 amu = 1.66×10^{-27} kg. (atomic mass unit)

Happy Christmas / Happy Holidays to everybody!