Van der Waals Attraction Between Colloids [pln42]

Quantum mechanical perturbation theory predicts attractive force between (neutral) atoms due to fluctuating electric dipole moments.

Effective VdW potential:

$$V(r) = -\frac{C}{r^6}, \quad C = \frac{3}{4}\left(\frac{1}{4\pi\epsilon_0}\right)^2 \alpha^2 \hbar\omega,$$

where α is the electric polarizability and $\hbar\omega$ the ionization energy.

Consequence: adhesive force between objects of mesoscopic or macroscopic size with strength depending on size and shape of objects and on distance between them.

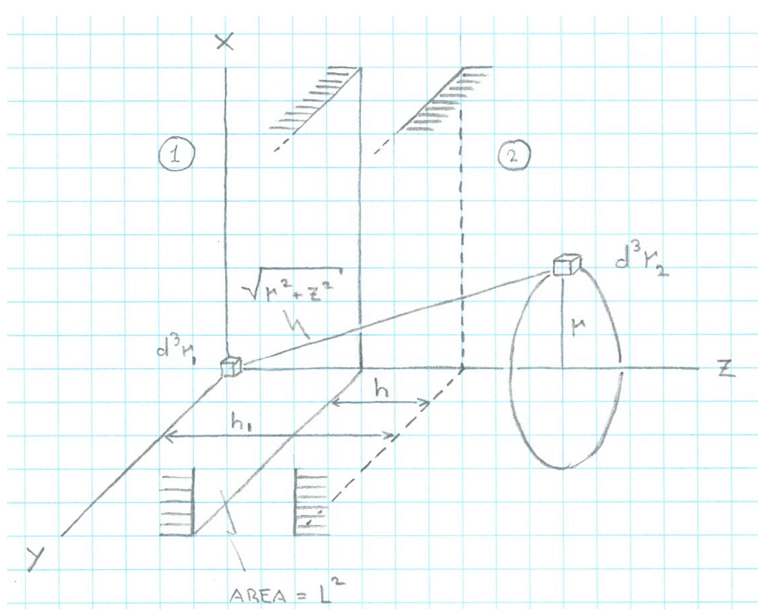
Generic expression for interaction energy:

$$U_{12} = -\int d^3r_1\, \rho(\vec{r}_1) \int d^3r_2\, \rho(\vec{r}_2)\, \frac{C}{|\vec{r}_1 - \vec{r}_2|^6},$$

where $\rho(\vec{r})$ is the atomic number density.

Applications to simple cases:

- two large objects with parallel flat surfaces [pex23],
- two solid objects of spherical shape close to each other [pex24].



Comments:

- Assumption of pairwise additivity neglects many-body effects, i.e. collective nature of fluctuations.
- Assumption of instantaneity neglects retardation effects, i.e. dynamic nature of fluctuations.
- Retardation effects weaken adhesive force at large distances:
  - ▷ $\sim r^{-6} \rightarrow r^{-7}$ (microscopically).
  - ▷ $\sim h^{-2} \rightarrow h^{-3}$ (mesoscopically).
- Assumption of unpolarized space between colloids neglects effects of dispersion medium.
- Casimir effect represents alternative derivation of adhesive force in terms of vacuum fluctuations of elcetromagnetic field in the space between colloids.

[extracted from Jones 2002]