SISSA ISAS

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October 2003 – Entrance Examination: Statistical and Biological Physics

Solve **one** of the following problems (no extra credit is given for attempts to solve more than one problem). Write out solutions clearly and concisely. State each approximation used. Diagrams welcome. Number page, problem, and question clearly. Do not write your name on the problem sheet, but use extra envelope.

Problem 1

Consider a one-dimensional chain consisting of $n >> 1$ segments as illustrated schematically in the figure.

Let the length of each segment be a when the long dimension of the segment is parallel to the chain and zero when the segment is vertical (i.e. long dimension normal to the chain direction). Each segment has just two states, a horizontal orientation and a vertical orientation, and each of these states is not degenerate, The distance between the chain ends is nx.

1. Find the entropy of the chain as a function of x.
2. Obtain a relation between the temperature T of the chain and the tension F which is necessary to apply to mantain the distance nx, assuming the joints turn freely.
3. Under which conditions does your answer lead to Hook's law?

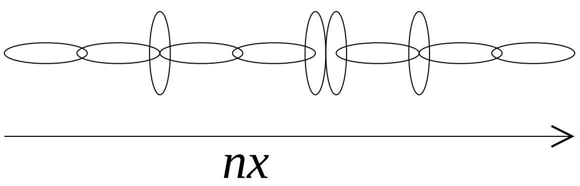

Figure 1: Schematic drawing of a possible chain configuration

Problem 2

Consider a non-relativistic gas of identical (classical) particles in a box. Let $f(\vec{v})\,d^3v$ be the mean number of particles per unit volume with velocity whose components are in the range $(v_\alpha, v_\alpha + dv_\alpha)$ with $\alpha = x, y, z$.

1. determine the number of particles with velocity in the range $(v_\alpha, v_\alpha + dv_\alpha)$ with $\alpha = x, y, z$, striking a unit area in the box wall per unit time;
   assume equilibrium conditions.
2. explain why $f(\vec{v}) = \hat{f}(v)$ (where $v = \mid \vec{v} \mid$). Calculate the total number of particles striking the unit area in the box walls, J_T (= flow). Express your result in terms of the mean number of particle per unit volume, n, and mean particle velocity, $< v >$;
3. express the pressure, P, in terms of n, the mass of the particles, m, and $< v^2 >$;
4. if f is the Maxwellian distribution calculate P (point 3) in terms of n and the temperature, T, and J_T (point 2) in terms of P, m and T.

Problem 3

Address the following issues:

- What is the hydrophobic effect in proteins?
- Describe the structural and energetical properties of α helices
- Electrostatics interactions in proteins.

Problem 4

Consider the nitrate anion.

- Describe its symmetry properties
- Use the Huckel approximation to the determine the delocalization of the π electrons. Assume that the Coulomb integrals are α_0, α_N, and that the resonance integral is β.