STATISTICAL PHYSICS AND BIOPHYSICS

By A. Pelizzola

Subject fundamentals

Mandatory course for the Master in Physics of Complex Systems, 1st year, 2nd term. In this course the knowledge of statistical physics, started in Introduction to quantum mechanics, quantum statistics and field theory, is deepened, with a particular attention to its applications to the physics of biological systems. To this end, a few basic elements of fluid dynamics and molecular biology are also introduced.

Expected learning outcomes

The student must acquire a deep knowledge of statistical physics, of its methodologies and its relationships with information theory. The student must also acquire some basic elements of fluid dynamics and molecular biology and must learn to apply the techniques of statistical physics to some problems from the physics of biological systems, mainly in the field of biopolymers.

Prerequisites / Assumed knowledge

Basic elements of statistical physics, in particular the canonical ensemble.

Contents

Partition function, free energy, entropy.
Ideal systems. Interacting systems: Ising model and phase transition. Approximate methods for interacting systems: mean field and generalizations: Bethe-Peierls and belief propagation.
Low and high temperature expansions, duality. Free energy of the two-dimensional Ising model.
The XY model in 2 dimensions.
An introduction to the position space renormalization group.

Kinematics of a continuum body (Lagrangian and Eulerian descriptions, rigid motion, Reynolds' transport theorem), dynamics of a continuum body (principle of mass conservation, principle of conservation of linear and angular momentum, Cauchy's stress theorem and stress tensors), fluid mechanics (constitutive assumptions of ideal and viscous fluids, Reynolds' number, solutions of Navier-Stokes equations in simple situations).

Introduction to molecular biology: the cell, small molecules, proteins and nucleic acids.
Stretching a single DNA molecule: experiments, the Freely Jointed Chain, the one-dimensional cooperative chain, the worm-like chain.
DNA melting: experiments, zipper model, Poland-Scheraga model.
The helix-coil transition. Polymer collapse: Flory's theory. Collapse of semiflexible polymers: lattice models and the tube model.
The self-avoiding walk and the O(n) model.
An introduction to protein folding and design. RNA folding and secondary structure.
Protein and RNA mechanical unfolding.
Molecular motors.

Texts, readings, handouts and other learning resources
M. Plischke and B. Bergersen, *Equilibrium statistical physics*, World Scientific
R.K. Pathria and P.D. Beale, *Statistical mechanics*, Academic Press
L. Peliti, *Statistical mechanics in a nutshell*, Bollati Boringhieri
J.P. Sethna, *Entropy, order parameters and complexity*, Clarendon
K. Sneppen and G. Zocchi, *Physics in molecular biology*, Cambridge
P. Nelson, Biological Physics, Freeman
B. Alberts et al, *Molecular biology of the cell*, Garland
Lecture notes and slides will be provided

Assessment and grading criteria
The exam is based on two oral tests, one for Statistical Physics and one for Biophysics. Both tests typically involve questions on 2-3 topics, the first one being chosen by the student.