PHY 690 Y: Thermal Physics at Nano-scale

Instructor-in-charge: Prof. Debashish Chowdhury

1. Brief overview of Thermal Physics at Macro-scale:
   Laws of thermodynamics; fundamental relations and equations of state; Energy transduction by heat engines.
   Rules of calculation of equilibrium Statistical Physics; Fluctuations and relation with response functions.
   (4 Lectures).
2. Kinetics of chemical reactions:
   rates of reactions in bulk; concept of dwell times in single-molecule reactions.
   (2 Lectures).
3. Wandering on energy landscapes:
   Langevin equation and Fokker-Planck equation; Applications to simple systems and activated barrier crossing.
   (6 Lectures)
4. Hopping on a network of discrete states:
   Master equation; Applications to simple systems.
   (6 Lectures)
5. Light emitted by single molecule and reverse modeling:
   smFRET , Maximum Likelihood and Bayesian analysis;
   (2 Lectures)
6. Single-molecule mechanics:
   Elasticity of single molecules, entropic springs; Thermodynamics and kinetics of mechanical rupture of bonds, Slip- versus catch-bonds. (6 Lectures)

7. Single-molecule thermal physics:
   Fluctuation theorems, Jarzynski and Crooks identities; Dissipation, entropy production in irreversible processes; From ensemble thermodynamics to trajectory thermodynamics; Enzymes and chremo-chemical nano-machines; Energy transduction by nano-motors
   (15 Lectures)

Text:

1. D.E. Makarov, “Single Molecule Science: Physical Principles and Models, (CRC Press, 2015).
2. D.J. Evans, D.J. Searles and S.R. Williams, “Fundamentals of Classical Statistical Thermodynamics: Dissipation, Relaxation and Fluctuation Theorems” (Wiley-VCH, 2016).
3. L.A. Blumenfeld and A.N. Tikhonov, “Biophysical Thermodynamics of Intracellular Processes: Molecular Machines of the Living Cell” (Springer, 1994).