

Statistical Mechanics of Granular Matter (0540-6430)

Yair Shokef | <http://shokef.tau.ac.il> | shokef@tau.ac.il | Wolfson Mech Eng, Room 231 | 03-640-8393

Syllabus: The course will focus on the particulate-statistical perspective for describing the statics and dynamics of granular materials. Granular systems in nature, in industry and in laboratory experiments will be overviewed, and mechanical phenomena at the system level will be presented. Most of the course will deal with the statistical approach for analyzing many-body systems far from thermodynamic equilibrium, by demonstrating the use of theoretical models for describing granular gases and granular solids.

Course Plan (by week):

- 1) Introduction and overview: applications, experiments, macroscopic phenomena, microscopic / statistical perspective.
- 2) Kinetic theory of gases: elastic and inelastic gases, equipartition principle and its violation in granular gases.
- 3) Boltzmann equation: elastic collisions, molecular chaos hypothesis, H-theorem, Maxwell-Boltzmann distribution.
- 4) Inelastic collisions: velocity distribution in granular gases, clustering, inelastic collapse.
- 5) Statistical mechanics of thermodynamic equilibrium: microstates, phase space, semiclassical approximation.
- 6) Statistical ensembles: microcanonical ensemble, canonical ensemble, Boltzmann distribution, partition function, entropy, free energy.
- 7) Fluctuation-dissipation theorem: stationary and time-dependent.
- 8) Fluctuation-dissipation relations far from thermodynamic equilibrium: approximate results, Maxwell model, experiments.
- 9) Structure of granular solids: geometric considerations in the packing of rigid particles, packing of disks vs. spheres, tetrahedral tiling, geometric frustration, frustration in lattice models.
- 10) Granular packings: volume fraction, crystalline close-packing, random-close-packing, random-loose-packing, parking lot model, tapping experiments.
- 11) Edwards' thermodynamic analogy: volume ensemble, compactivity.
- 12) Mechanics of granular solids: arches, clogging, avalanches, Jensen's law, pressure dip under sand pile.
- 13) Force distributions in granular packings: photoelastic disks, force chains, force distribution, q-model.

Literature:

- | | |
|---------------|---|
| 620.198 MEH | Anita Mehta, "Granular Physics"
Cambridge University Press (2007) |
| 620.198 DUR | Jacques Duran, "Sands, Powders, and Grains - An Introduction to the Physics of Granular Materials"
Springer-Verlag New York (2000) |
| 620.198 GRA | Anita Mehta (Ed.), "Granular Matter: An Interdisciplinary Approach"
Springer-Verlag New York (1994) |
| 620.198 SUN | Qicheng Sun & Guangqian Wang, "Mechanics of Granular Matter"
WIT Press, Southampton, UK (2013) |
| 620.107.2 GRA | Thorsten Pöschel & Stefan Luding (Ed.), "Granular Gases"
Springer-Verlag Berlin (2001) |
| 620.107.2 GRA | Thorsten Pöschel & Nikolai Brilliantov (Ed.), "Granular Gas Dynamics"
Springer-Verlag Berlin (2003) |

- 530.13 KUB Ryogo Kubo, "Statistical mechanics: an advanced course with problems and solutions"
Elsevier Amsterdam (1965)
- 530.13 CHA David Chandler, "Introduction to Modern Statistical Mechanics"
Oxford University Press, New York (1987)
- 530.13 DOR Robert Dorfman, "An Introduction to Chaos in Nonequilibrium Statistical Mechanics"
Cambridge University Press (1999)

Grading:

30% Home assignments, consisting mainly of analytical calculations

30% Project including the construction and investigation of a numerical simulation

30% Oral presentation of a scientific paper

10% Active participation in the presentations of other students