Introduction to Granular Matter (JFL302 (3:1:0); January-April 2026)

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Overview of Granular Matter: Granular Matter as Solid, Liquid and Gas. Dense-to-Dilute Regimes and Rapid-to-Slow Flows. Dry-to-Wet Granular Matter. Applications in Industry and Geophysical Phenomena.

Mechanics of Particles and Simulation Techniques: Collision Models for Smooth and Rough Particles. Coefficient of Restitution and Impact Velocity. Coulomb Friction. Electromechanics of Particles. Particle Simulation Techniques: Hard- and Soft-sphere Models.

Kinetic Theory and Constitutive Models: From Liouville Equation to BBGKY-Hierarchy. H-theorem and Irreversibility. Molecular Chaos and Boltzmann Equation. Kinetic Theory of Dense Gases and Enskog Ansatz.

Microscopic Irreversibility and Inelastic Boltzmann Equation. Concept of Granular Temperature, Homogeneous Cooling State (HCS) and the Scaling Solution of Boltzmann Equation. Haff's Law for HCS and its Experimental Verification. Transport Coefficients.

Effects of Particle Roughness and Friction on Inelastic Boltzmann Equation. Binary Mixture and Non-equipartition of Energy.

Rheology and Dynamics: Steady Shear Flows: Rheology, Normal Stress Differences, Dilatancy, Generalized Fourier Law and other Second-order Effects.

Instabilities and Patterns in Shear Flow; Granular Rayleigh-Benard Convection & Faraday Waves; Suspension Taylor-Couette Flow.

Low-dimensional Models for Patterns via Center-manifold Projection.

Dense Slow Flows and Jamming: Dense Granular Matter and Review of Recent Literature. CST, DST (Discontinuous Shear Thickening) and Rigidity Transition. Plasticity-Theory-Based Models for Slow Flows and their 'Regularized' Non-Local Variants.

Reference Books

1. Brilliantov, N. and Pöschel, T. (2004) *Kinetic Theory of Granular Gases*, Oxford Univ. Press.
2. Rao, K.K. and Nott, P.R. (2008) *An Introduction to Granular Flow*, Cambridge University Press.
3. Chapmann, S. and Cowling, T.G. (1939) *Mathematical Theory of Non-Uniform Gases*, Cambridge University Press.
4. *Annual Review of Fluid Mechanics (1990, 2000, 2003, 2007, 2018, 2024)*
5. *Review of Modern Physics (1992, 1996, 1999, 2006)*