JF 306: Advanced Topics in Fluid Mechanics, 3 CREDITS

1. Nearly unidirectional flows at low Reynolds numbers

Low-Reynolds number lubrication flows:the sliding block problem, Analysis of the normal approach of rigid cylinders, spheresand drops, The Reynolds Lubrication equation,Gravity and surface tension-driven spreading of thin film on a flat substrate, Centrifugal spreading (Spin-coating).

2. Fully three-dimensional (Stokes) flows at low Reynolds numbers

Introduction to spherical-harmonics-based solution of the Stokes equations, Solution for a translating particle/drop in Stokes flow, Drag for anisotropic bodies, the Boussinesq-Scriven Interfacial boundary condition, Thermo-capillary migration, Principle of dynamic reversibility for Stokes flows.
Motion of particles in rotating fluids, Wave-drag on floating particles.

3. Non-Newtonian Fluid Rheology

Maxwell model for linear viscoelasticity, Contrasting Newtonian and viscoelastic flow phenomena, non-linear constitutive models: the upper convected Maxwell and Oldroyd-B models for dilute polymer solutions, Microstructural responses in weak and strong flows, the retarded motion expansion.
Viscoplastic fluids – The squeeze-flow paradox.

4. Large-Reynolds-numberflows

Potential flow theory for slender bodies of revolution.
Singular perturbation concepts at small Re and the Laminar wake, Scaling arguments for Turbulent wakes.
The Origin of Lift (2D aerofoil theory), Effect of finite span on tip vortices, Wake behind a Lifting body.
Axisymmetric and Planar jets, Scaling arguments for Turbulent jets.
Large-Reynolds-number gravity currents.
The Laminar boundary layer and related topics: Boundary layer hypothesis and singular perturbation at large Reynolds number, the Blasius boundary layer, Drag coefficient v/s Re curve for streamlined bodies, Scaling arguments for the turbulent boundary layer.
The Falkner-Skan solutions: effect of ambient pressure-gradient.
Flow past bluff bodies: Boundary layer separation.
Drag coefficientv/s Re for bluff bodies; Laminar-Turbulent transition and thedrag crisis.
Jeffery-Hamel flow: Breakdown of Boundary-layer hypothesis and solution multiplicity as function of Re.

5. Natural and Forced convection

Relevant dimensionless parameters (the Grashof and Raleigh numbers), the inertial and viscous convection regimes, the Rayleigh Benard and double diffusive problems.
The self-similar Laminar (buoyant) plume, scaling arguments for the turbulent plume.
Forced convection: Heat and Mass transfer from drops at small and large Peclet numbers, the Nusselt vs Peclet scalings for the exterior and interior problems.
Acoustic streaming.

6. The Bernoulli theorem

Open Channel flows (Subcritical vs Supercritical flows), Convergent-Divergent Nozzle: 1D compressible flows, Volumetricoscillations of a bubble (the Rayleigh-Plesset equation), Shape oscillations of a bubble, Bjerknes forces, Sound propagation through two-phase bubbly flows.

7. Hydrodynamic stability