12.800 Syllabus  
(L. Pratt and C. Cenedese)

1. **Introduction:**
   - Class aims.
   - Class administration (problem sets, exams, grades, etc.).
   - Scheduling issues.
   - Introduction to fluid dynamics.
   - Cartesian Tensors.

   Reading: KC08: Chapter 1.1-1.7, Chapter 2. CR94: Chapter 1.

2. **Kinematics of fluid flow**
   - Eulerian and Lagrangian representations of flow.
   - The material derivative.
   - Trajectories, streaklines, and streamlines.
   - Cauchy-Stokes theorem.
   - The velocity gradient tensor.

   Reading: Handout. KC08: Chapter 3.

3. **Conservation equations**
   - Reynolds transport theorem.
   - Momentum equations (Navier-Stokes, Boussinesq form of Navier-Stokes, Euler).
   - Momentum equations in a rotating frame.
   - Centripetal acceleration, Coriolis acceleration.
   - Mechanical energy equation.

   Reading: KC08: Chapter 4.1- 4.13. Chapter 10.1-10.5

4. **Thermodynamics**
   - Review: state variables, thermodynamic equilibrium and temperature, reversible and irreversible processes.
   - Equations of state for perfect gas and seawater.
   - The ‘0th’ law: thermodynamic equilibrium, existence of temperature.
   - The first law: internal energy, work, heating.
• The second law: entropy.
• Specific heats and enthalpy.
• Static stability, potential temperature, adiabatic and isentropic processes, adiabatic lapse rate, the Brunt Väisälä frequency.
• Energy equations for a perfect gas and temperature-dependent liquid.

Reading: KC08 1.7 thru 1.10. Pratt’s thermodynamics notes. Pedlosky notes, Ch. 6.

4. **Viscous boundary layers.**
   • Viscous flow along a flat plate.
   • Prandtl boundary layer
   • Ekman Layer *(LAB EXPERIMENT)*

5. **Vorticity and Potential Vorticity.**
   • Geostrophic flow, Rossby number. *(LAB EXPERIMENT)*
   • Vortex lines, tubes, non-divergence. Vortex tube strength.
   • Circulation and relation to vorticity.
   • Kelvin’s theorem, interpretation. Friction, baroclinicity. effect of rotation, induction of relative vorticity on the sphere. Rossby waves as an example.
   • Ertel’s theorem of potential vorticity. Relation to Kelvin’s theorem. PV in a homogeneous layer of fluid.

Reading: KC Chapter 5.

6. **Approximations**
   • Boussinesq.
   • $f$-plane and $\beta$-plane.
   • Shallow water approx.

Reading: handouts

7. **Geostrophic flow**
   • Thermal wind. Taylor-Proudman theorem. *(LAB EXPERIMENT)*
   • Simple scaling arguments and heuristic derivation of quasi-geostrophic PV equation.
   • The Sverdrup relation.

Reading: KC08: Chapter 5, Chapter 14.6-14.7. CR94: Chapter 5.

6. **Bernoulli theorems**
   • Energy equation for time dependent dissipative motion.
• Bernoulli theorem for steady inviscid flow. The Bernoulli function.
• Bernoulli’s theorem for a barotropic fluid.
• Shallow water theory and the Bernoulli equation, Crocco’s theorem.
Reading: KC08: Chapter 4.16-4.17.

7. Turbulence

• phenomenology, scaling
• Reynolds decomposition
• Instability, transition to turbulence.

Reading: Handouts