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

- Rewiew: state variables, thermodynamic equilibrium and temperature, reversible and irreversible processes.
- Equations of state for perfect gas and seawater.
- The '0^{th}' law: thermodynamic equilibrium, existence of temperture.
- 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 β-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