Study Guide for the First Quiz AOS 610 GFD I

1. Dynamical similarity and the Reynolds number
What is implied by dynamical similarity?
What is laminar flow?
What mathematical condition ensures that the flow is steady?
What are the units of molecular kinematic viscosity and dynamic viscosity?
What are typical values of molecular kinematic viscosity in air and in water?
Why are these ignored for many GFD problems?
What is eddy viscosity?
Derive the Reynolds number a) by using dynamical similarity and
b) as a ratio of two terms in the 1-D momentum equation.
Provide a physical explanation for why each factor appears in the numerator or denominator.
In flow through a pipe, what sequence of flow types occurs with increasing Reynolds number?
What is entry length turbulence?
What is a turbulent slug?
What is the approximate balance of forces in the momentum equation for laminar flow?
What is the approximate balance of forces for turbulent flow?

2. Forces and flow through a pipe
Provide a mathematical formula for the pressure gradient force.
What is the formula for viscous stress, and what are its units?
Provide a mathematical formula for the net viscous force.
What are the units of the pressure gradient force and net viscous force?
Give a physical description of how the net viscous force works.
Why must the flow be curved to have a non-zero viscous force?
In channel and pipe flow, where is the viscous stress and net viscous force the largest?
What is the no-slip condition?
What mathematical condition occurs at the flow maximum?
What strategy is used to obtain an analytic solution for a steady, laminar flow profile?
How is mass flux defined?
Why does the flow accelerate in the center of a pipe in the entry length region?
What happens to the flow speed in the pipe when the flow becomes turbulent? Why?

3. Flow around a cylinder and drag
Contrast form drag and molecular viscous drag.
What are the units of drag over a 2D surface?
Define the drag coefficient.
What is the dependence of drag coefficient (and drag) on flow speed for creeping flow?
What is the dependence of drag coefficient (and drag) on flow speed for tubulent flow?
What are the changes in flow regimes as Re is increased for flow past a cylinder?
What fundamental instabilities are associated with flow around a cylinder?
How is vorticity introduced into the flow?
How essential is viscosity?
What is eddy shedding?
What are von Karman vortex streets?

What are some properties of a wake?
What is turbulent reattachment?
How do pressure and velocity vary from the front to the back of a cylinder?
Compare how drag changes upon transition to turbulence for flow through a pipe and flow around a cylinder.
What common formula is often used in numerical models to express vertical exchange of momentum, or drag, in a planetary boundary layer? Why does it depend on u^2?

4. Rayleigh number and convection
Contrast the two physical situations expressed by the Reynolds number and Rayleigh number.
Derive the Rayleigh number by using dynamical similarity.
Express the Rayleigh number in terms of a ratio of two terms in the vertical momenum equation.
Provide a physical explanation for why each factor appears in the numerator or denominator.
What happens at Ra = 1700?
Describe the succession of forms seen when Ra is increased systematically (Benard convection).
What is the coefficient of expansion?
What is "reduced gravity"?
What is the Prandtl number?
What is Marangoni convection?
Give a qualitative description of the energy pathway for the general circulation.
How does convective instability relate to chaos theory?

5. Flow Kinematics
What is a streamline?
How are streamfunction and velocity related?
Show that 2D flow is non-divergent.
How are streamfunction and vorticity related?
What does the Laplacian do to the sign of a term?
What is the "invertibility principle"?
How do vorticity maxima relate to flow maxima?
Be able to identify the cyclonic and anticyclonic sides of a jet stream.
How does velocity potential relate to the divergent part of the flow?
Define and compare "solid body rotation" and "irrotational vortex".
What is a Rankine vortex?
What does an irrotational vortex do to fluid elements?
Where is the vorticity in an irrotational vortex?
Contrast trajectories and streak lines.
What is the definition of circulation?

6. Navier-Stokes Equations
What is the continuum hypothesis?
What are typical sizes of molecules, collision cross-sections, mean spacing, and mean free paths?
What is Loschmidt's number?
Define rate of linear strain, 2D divergence, rate of volumetric strain, rate of shear strain, vorticity
What is the stress-strain, or "constitutive" relationship?
What fundamental assumption makes a fluid Newtonian?

Do pressure and stress have the same units?
Write down the Navier-Stokes equations and describe each term in words.
What are four underlying assumptions in deriving these equations?
How would these equations simplify for high and for low Re?

The following material (*) will not be on the first quiz.

* 7. Tensors
Provide an example of a zeroth, first, second, third, and fourth order tensor.
What is the Einstein summation convention?
Define the Kronecker delta and the alternating tensor.
Write divergence and vorticity in tensor notation.

* 8. Boundary layers
At high Re, what is the primary mode of momentum coupling?
What is the Blasius profile?
How does boundary layer thickness depend on distance, viscosity, and speed?
What is Kelvin's circulation theorem?
How can Euler's equation be used to evaluate separation and attachment?
What is a good signature of being within a specific boundary layer?
What is the approximate pressure distribution on the surface of a cylinder in high Re flow?
How can an airfoil reduce drag? How does an airfoil cause lift?
What kind of downstream pressure gradient will favor separation of a boundary layer?
What pressure gradient will favor attachment of the boundary layer?
How does the Coanda effect work?
How do sports balls curve in flight?

* 9. Continuity Equation
Write down and compare the Eulerian and Lagrangian versions of the continuity equation.
Be able to derive one form from the other.
What does incompressible mean?
When is this a reasonable approximation?
What does a low Mach number say about the relative amounts of kinetic versus internal energy?
What is the Boussinesq approximation?
At typical flow speeds the atmosphere and ocean are essentially incompressible. Why can't we assume that density is a constant everywhere in the Navier-Stokes equations?