MAE 101B
Fluid Mechanics, Spring 2009
Regarding Midterm 1

Closed book. Closed notes. No calculator. You will have to solve 2 problems. Equation sheet given in this document will be provided to you.

Summary of Material

The relevant sections of the book are also given below. Please consult notes and book.

- **Chap. 6. Viscous Flow in ducts**

  Reynolds number; laminar, transitional and turbulent regimes; entrance length; fully-developed flow (sections 6.1 and 6.2).

  Conservation of energy; simplfication for steady, low-speed flow; frictional head loss, h_f. Definition of (Darcy-Weisbach) friction factor, f (section 6.3, also review 3.6)

  Solution of the incompressible N.S. equations to obtain laminar flow profile in ducts, channels and other simple flows. Use of laminar flow profile to obtain wall shear stress, average velocity, flow rate, power, etc. (section 6.4, also review 4.10)

  Turbulent pipe flow. Reynolds averaging; turbulent stresses. The mean velocity profile in turbulent wall-bounded flows: viscous (plus units) scaling, multiple regions (inner, logarithmic overlap, outer region). The friction law for smooth pipes. Effect of roughness. Colebrook formula for friction factor. Moody chart. (sections 6.5 & 6.6)

  Pipe flow problems: obtain head loss; obtain flow rate; pipe sizing; pipe length. The need for iteration in some problems when using the Moody chart or the Colebrook formula.

  Non circular ducts: procedure for laminar flow; turbulent flow and the use of hydraulic diameter.

Equation sheet (will be given to you with midterm)

Navier Stokes equations in vector form as given below. You should know simplification to get components in Cartesian coordinates.

$$\boldsymbol{\nabla} \cdot \mathbf{v} = 0 \tag{1}$$

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \boldsymbol{\nabla})\, \mathbf{v} = -\frac{1}{\rho} \boldsymbol{\nabla} p + \nu \nabla^2 \mathbf{v} \tag{2}$$

Conservation of energy for incompressible flow:

$$\left(\frac{p}{\rho g} + \frac{V^2}{2g} + z \right)_{in} = \left(\frac{p}{\rho g} + \frac{V^2}{2g} + z \right)_{out} + h_f - h_{pump} + h_{turbine} \tag{3}$$

The friction factor is defined by

$$f = \frac{h_f}{V^2/2g} \frac{d}{L} \tag{4}$$

Logarithmic overlap law:

$$\frac{u}{u^*} = \frac{1}{\kappa} \ln \frac{y u^*}{\nu} + B\,, \tag{5}$$

where $\kappa = 0.41$ and $B = 5.2$.

Colebrook formula for turbulent duct flow:

$$\frac{1}{\sqrt{f}} = -2.0 \log \left(\frac{\epsilon/d}{3.7} + \frac{2.51}{Re_d \sqrt{f}} \right) \tag{6}$$

The Moody chart will be given to you.