MAE 222
Mechanics of Fluids
Spring 1996

Sample 2nd Mid-Term

There are more questions here than could be done in 50 minutes.

Closed book;

1. When you place a circular cylinder of diameter D in a uniform, steady flow of velocity U, it is found that the flow in the wake of the cylinder is unsteady. The unsteadiness in the wake can be characterized by a frequency f (the dimension of f is $second^{-1}$).

   It is believed that f depends on the density ρ, the pressure p, and the viscosity μ of the fluid, in addition to the cylinder diameter D and the flow velocity D.

   Using dimensional analysis, determine how many independent dimensionless parameters are expected, and propose your choices for them. Remember, the answers to the last question are non-unique. **(20 points)**

2. What is *substantial derivative* in English?**(5 points)**

3. Let the Cartesian velocity components of a flow field be given by:

   u=4 m/sec, v=5 m/sec, w=6 m/sec.

   Let the temperature field of this flow be given by:

   T(x,y,z,t)= 20 Sin(x-2y+3z+7t).

   Find the substantial derivative of T at x=y=z=t=0. **(5 points)**

4. What is the momentum equation for fluid mechanics in English. State it for steady flow only. Draw a diagram, show your control volume, unit normal, etc. The English sentence must make sense to you, and must include the word "flux". **(5 points)**

5. Write the momentum equation in mathematical form, making sure that your vectors have a bar (either on top or on bottom). You need to include pressure as the only surface force, and gravity as the only body force. Dimension of all terms must agree. **(5 points)**

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Sample 2nd Mid-Term, continued

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Open book;

6. Water is supplied to your house via a horizontal pipe system which consists of "smooth" round straight high quality pipes totaling 1000 meters. The diameter of all the pipes is 10 cm . You may assume the water density to be 1000 kg/m^3, and the absolute viscosity to be 1×10^{-3} $N\text{-}sec/m^3$.

Assume you are the only user of this water system.

The water gage pressure at the water company is two atmosphere (2×10^5 N/m^2).

You have a well designed nozzle (no loss in Bernoulli's constant) attached to this water system to water your lawn. You may set the kinetic energy coefficient α of the flow in the pipe to be unity everywhere (for the sake of simplicity).

(i) Find the gage pressure at the junction of the pipe system with the nozzle when the Reynolds number of the flow in the pipe is (b) 10,000. **(40 points)**

(ii) Find the velocity of the water as it comes out of your nozze. **(10 points)**

(iii) You know the water company has a water tower. Approximately how tall (in meters) should the tower be to provide a one atmosphere gage water pressure at the inlet of this pipe system? **(10 points)**

7. In a standard open-channel flow problem where x measures along the channel, b(x) is the channel width, and h(x) is the elevation of the channel bottom, the volume flow rate Q is given by

$$Q=\sqrt{g}\left(b(x)(y_o - h(x))^{3/2}\right)D(F_r)$$

where y_o is a constant defined by:

$$gy_o = \frac{1}{2}V^2 + g(y+h) \quad \text{(This is the Bernoulli's equation of the surface streamline)}$$

and $D(F_r)$ is given by:

$$D(F_r) \equiv \frac{F_r}{\left(1+\frac{1}{2}F_r^2\right)^{3/2}} .$$

(a) You are give $F_{r\,1} = \sqrt{2}$ at $x=x_1$ in a open-channel with b(x)=constant, but has a “bump” on the bottom surface. The peak of the bump is at $x=x_2$. Find the value of $h(x_2)-h(x_1)$ so that the Froude number at station 2 is just critical. **(20 points)**

(b) Tell me in words what happens if the peak of the bump is higher than the number you just calculated. **(10 points)**

(c) Consider the channel with constant b and h, but with the same Froude number at station one. Find the height of the free surface at station 2 if there is a hydraulic jump between the two stations. **(10 points)**