CHEG 355 Transport Phenomena I
Second Hour Exam

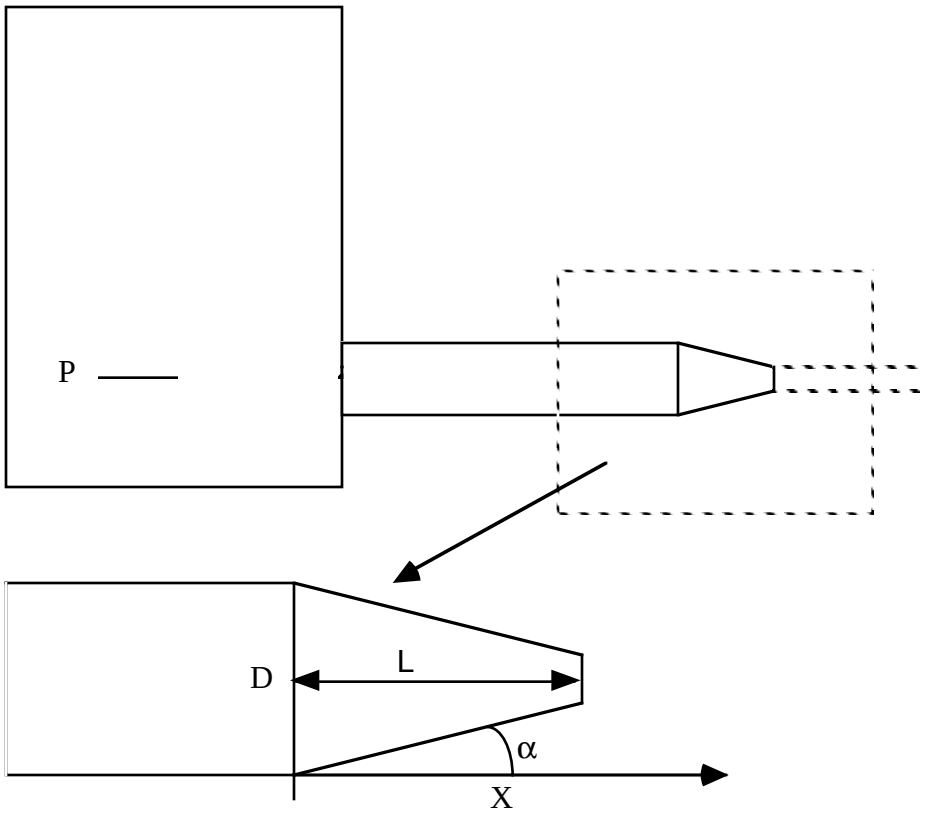
November 20, 2001

Closed Books and Notes

Problem 1). (20 points) Water from a pressurized tank passes through a hose and out a nozzle as is depicted below.

a. If we assume that the flow is inviscid and irrotational (no frictional losses), use the continuity equation to determine the average velocity as a function of position in the nozzle and estimate the pressure distribution as a function of the flow rate Q. You may assume that the flow in the nozzle is uniform, e.g., that it does not vary radially - perfect slip at the walls - but rather only with the distance down the nozzle.

b. What is the pressure in the tank at the level of the hose outlet?



Problem 2. (20 points) Inspectional Analysis of the Equations of Energy: Energy transport is in many ways analogous to momentum transport. Consider flow past a heated sphere. Fluid (density ρ, viscosity μ, thermal conductivity k, and heat capacity per unit volume ρC_p) flows past a sphere of radius **a** whose surface temperature is maintained at T_1. The fluid far from the sphere is moving with velocity U and has temperature T_0. All material properties are assumed to be constant.

The velocity distribution is given by the Navier-Stokes equations (you may neglect gravity) and the temperature distribution by the thermal energy equation:

$$\rho \, \hat{C}_p \left(\frac{\partial T}{\partial t} + \underset{\sim}{u} \cdot \underset{\sim}{\nabla} T \right) = k \, \nabla^2 T$$

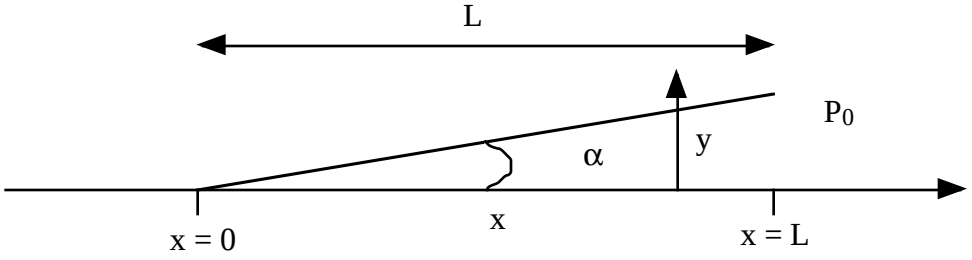
a. Render the equations and boundary conditions which govern the problem dimensionless (remember to render the Navier-Stokes equations dimensionless as well). Use $T^* = (T - T_0)/(T_1 - T_0)$ as the dimensionless temperature.

b. If the heat loss from the sphere is given by:

$$Q = \int_{r = a} - k \, \underset{\sim}{\nabla} T \cdot \underset{\sim}{n} \; dA$$

render this equation dimensionless as well. Upon what dimensionless groups does the dimensionless heat loss depend?

Problem 3. (20 points) Lubrication Flow in a Collapsing Wedge. For homework you solved the 2-D streamfunction flow for a collapsing wedge as depicted below. In this problem, however, we look at the simpler lubrication case where the angle of the wedge is very small (e.g., $\alpha << 1$).



a. Set up the equations and boundary conditions governing this problem (Hint: Use a length scale $H = \alpha L$ and velocity scale $V_C = L \, (d\alpha/dt)$ in the y direction, and recall that from trigonometry $\tan \alpha \approx \sin \alpha \approx \alpha$ for $\alpha << 1$. Remember that the fluid displaced by the closing wedge has to squish out in the x direction).

b. Using dimensional and inspectional analysis, determine the appropriate scaling for the **torque** on the hinge as a function of $d\alpha/dt$ and all the relevant physical parameters. The torque per extension in the third dimension is given by:

$$\frac{T}{W} = \int_0^L (P - P_0) \, x \, dx$$

c. Solve for the pressure distribution and numerical value of this torque.

Problem 4. Additional Readings (10 points):

1. Snapping shrimp produce their snapping sound by closing their snapping claw rapidly. This causes a fast flowing water jet to form, followed by the formation of a bubble, which subsequently collapses. This collapsing bubble creates a shock wave, causing the snapping sound. The formation and collapse of such bubbles is also very important in chemical processing and handling. The formation and collapse of bubbles within a liquid is also known as:

A. Creeping Flow
B. Poiseuille Flow
C. Cavitation
D. Occulation

2. In early atom bomb tests dimensional analysis was used to estimate the yield of an explosion. What fluid dynamicist developed this method?

A. G.I. Taylor
B. R.B Bird
C. J.R. Welty
D. R.L Panton

3. The world's largest venturi meter measures how many inches in diameter?

A. 36
B. 180
C. 590
D. 3375

4. What bridge, located on Puget Sound, collapsed on November 7, 1940 due to vortex shedding matching the structure's vibrational frequency?

A. Clark Bridge
B. Stirling Bridge
C. Golden Gate Bridge
D. Tacoma Narrows Bridge

5. Research in the area of microfluidics is important to developing lab-on-a-chip technologies. These applications occur in what flow regime:

A. High Reynolds number
B. Low Reynolds number
C. High Prandtl number
D. Low Prandtl number