Directions: Please read carefully.

1. Simple function calculators only.
2. Read problems carefully and follow all directions in each problem.
3. Please use the charts provided to estimate any values necessary or provide the charts you used if different.
4. If you have a question, come to class time or email me.
5. Exams are individual efforts. No teamwork at all.
6. The exam is open book and note.
7. The exam is not open internet.
8. The exam is not open video, so do not use lecture videos or class videos.
9. Please turn back in as a PDF. Failure to do so will result in a points deduction.
10. You have 24 hours to complete the exam.

Anti-cheating statement:

It is the aim of the faculty of Texas Tech University to foster a spirit of complete honesty and a high standard of integrity. The attempt of students to present as their own any work that they have not honestly performed is regarded by the faculty and administration as a serious offense and renders the offenders liable to serious consequences, possibly suspension. **Specifically, plagiarism (cheating) during the tests is a serious offense and will result in 0 points in the tests, failing the course and possible suspension from the program.**

NAME: ___________________________________

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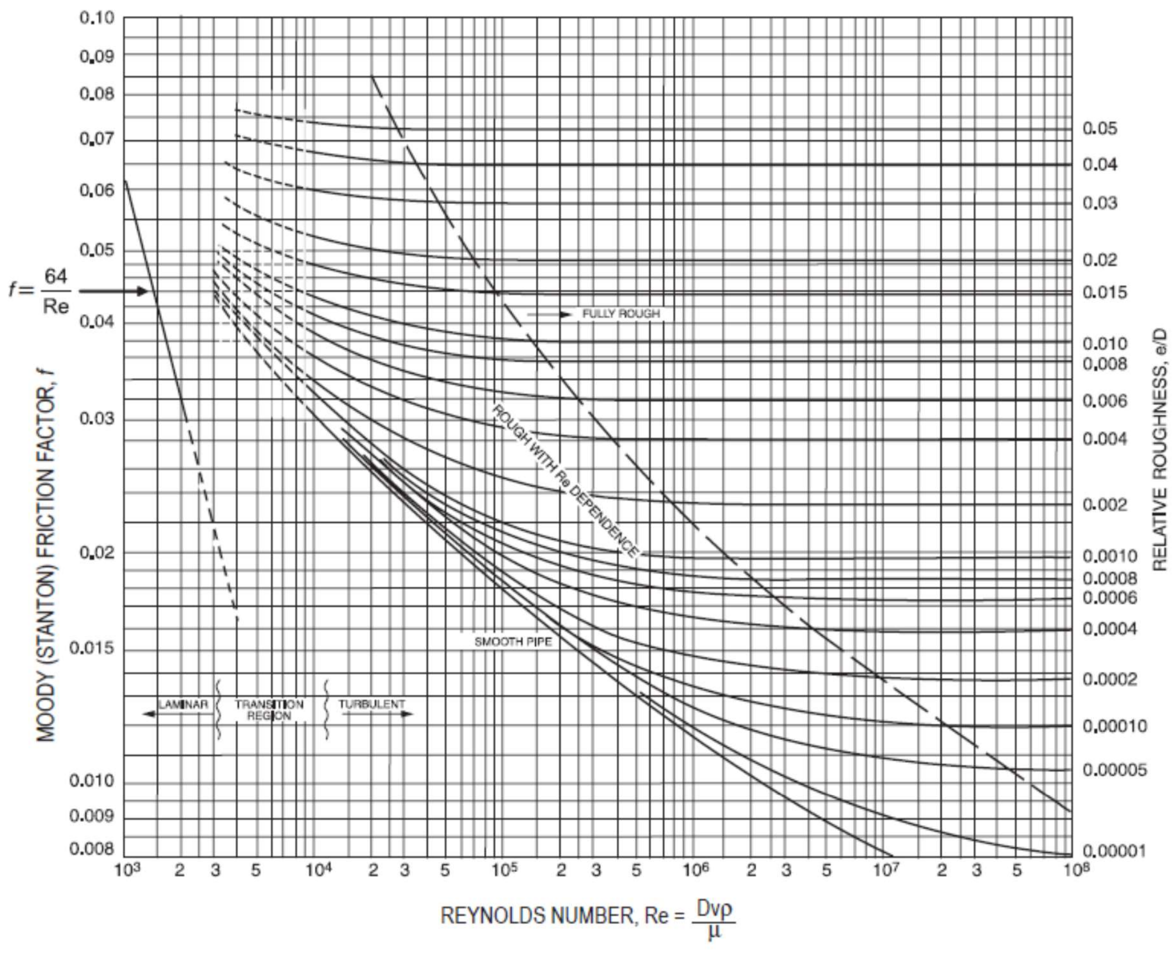
MOODY (STANTON) DIAGRAM

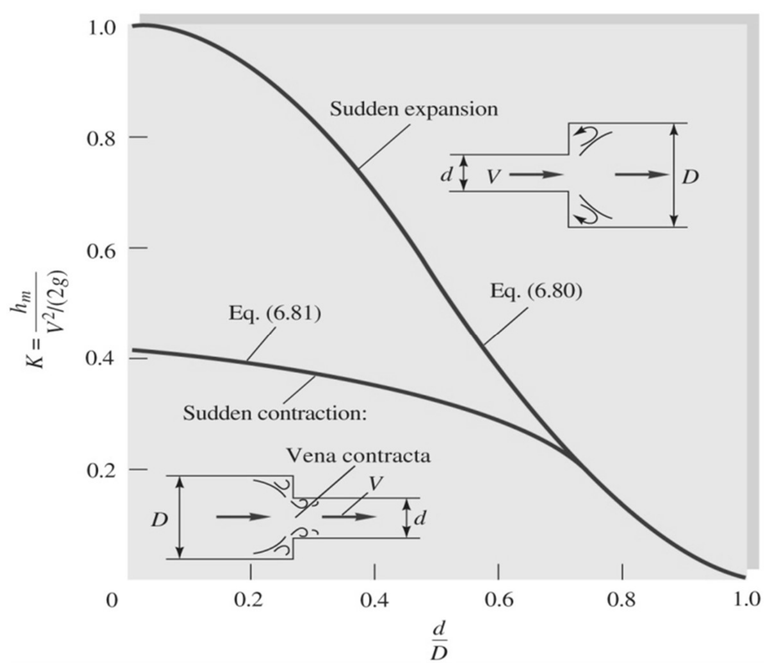
Material	e (ft)	e (mm)
Riveted steel	0.003–0.03	0.9–9.0
Concrete	0.001–0.01	0.3–3.0
Cast iron	0.00085	0.25
Galvanized iron	0.0005	0.15
Commercial steel or wrought iron	0.00015	0.046
Drawn tubing	0.000005	0.0015



From ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.)

Pipe	Equivalent Roughness, ε Feet	Millimeters
Riveted steel	0.003–0.03	0.9–9.0
Concrete	0.001–0.01	0.3–3.0
Wood stave	0.0006–0.003	0.18–0.9
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Commercial steel or wrought iron	0.00015	0.045
Drawn tubing	0.000005	0.0015
Plastic, glass	0.0 (smooth)	0.0 (smooth)

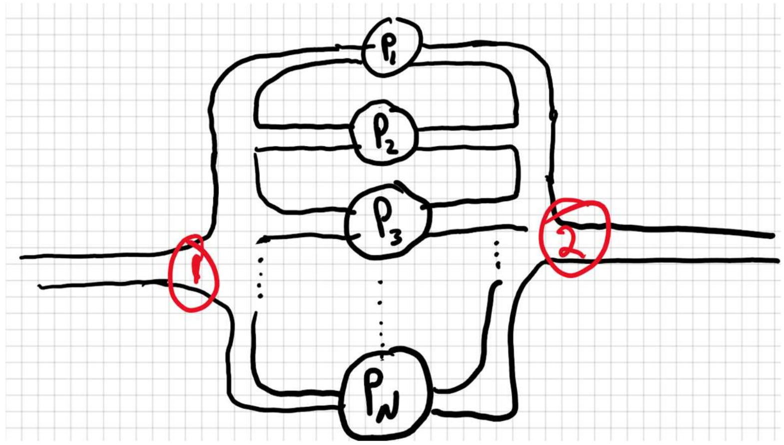
	Nominal diameter, cm								
	Screwed				Flanged				
	$\frac{1}{2}$	1	2	4	1	2	4	8	20
Valves (fully open):									
Globe	14	8.2	6.9	5.7	13	8.5	6.0	5.8	5.5
Gate	0.30	0.24	0.16	0.11	0.80	0.35	0.16	0.07	0.03
Swing check	5.1	2.9	2.1	2.0	2.0	2.0	2.0	2.0	2.0
Angle	9.0	4.7	2.0	1.0	4.5	2.4	2.0	2.0	2.0
Elbows:									
45° regular	0.39	0.32	0.30	0.29					
45° long radius					0.21	0.20	0.19	0.16	0.14
90° regular	2.0	1.5	0.95	0.64	0.50	0.39	0.30	0.26	0.21
90° long radius	1.0	0.72	0.41	0.23	0.40	0.30	0.19	0.15	0.10
180° regular	2.0	1.5	0.95	0.64	0.41	0.35	0.30	0.25	0.20
180° long radius					0.40	0.30	0.21	0.15	0.10
Tees:									
Line flow	0.90	0.90	0.90	0.90	0.24	0.19	0.14	0.10	0.07
Branch flow	2.4	1.8	1.4	1.1	1.0	0.80	0.64	0.58	0.41



Problem 1 (20 points)

Part 1 (10 Points)

Assume you have N pumps in parallel as shown in the figure below. If the path from point 1 to 2 is symmetric for all of these pumps (i.e. each path has length L_n and diameter D_n) and all minor losses are ignored, show that the total flow rate Q_t from 1 to 2 is proportional to N. Assume that the head provided by a pump can be represented with the following equation: $h_p = h_0 - CQ^2$, where h_0 and c are known constants. Hint: Equate the system head from points 1 to 2 to the head provided by a pump.

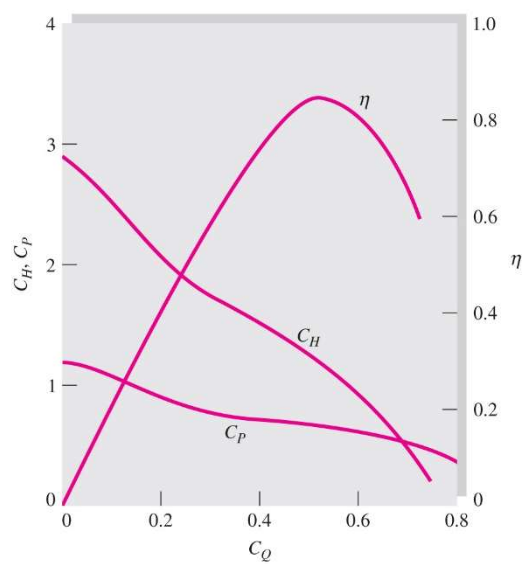


Part 2 (5 Points)

You have a pump from a particular family being used to move water (1000 kg/s and 0.001 Pa s) from a lower reservoir to an upper reservoir, such that the total system head the pump needs to provide is 20m . The pump has a diameter of 0.25m, runs at a speed of 30 r/s, provides a flow rate of 0.002 m^3/s and a BHP of 40 kW. Find the efficiency.

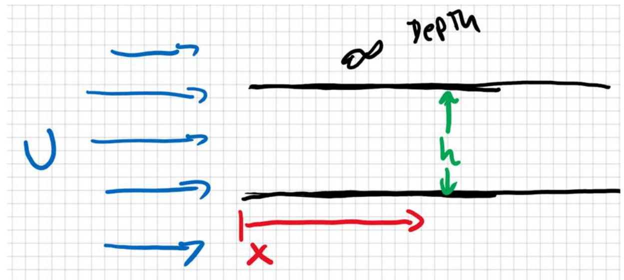
Part 3 (5 Points)

The particular pump you have used in Part 2 has the family curve pictured to the right. Assuming you need to provide the same Head and flow rate for the same fluid. Find the most efficient designed pump for the job and provide its brake horse power, diameter, and speed.



Problem 2 (20 points)

Part 1 (8 Points)



We have discussed the concept of being fully developed and entry length for pipe flows and how it is related to boundary layer growth. Assume you have 2 infinitely wide flat plates separated by a distance *H,* which are used to create a pipe (Figure to the right. The incoming velocity is known, *U*. Find an equation for the entry length of this pipe using the results from the Von-Karman Plate Analysis.

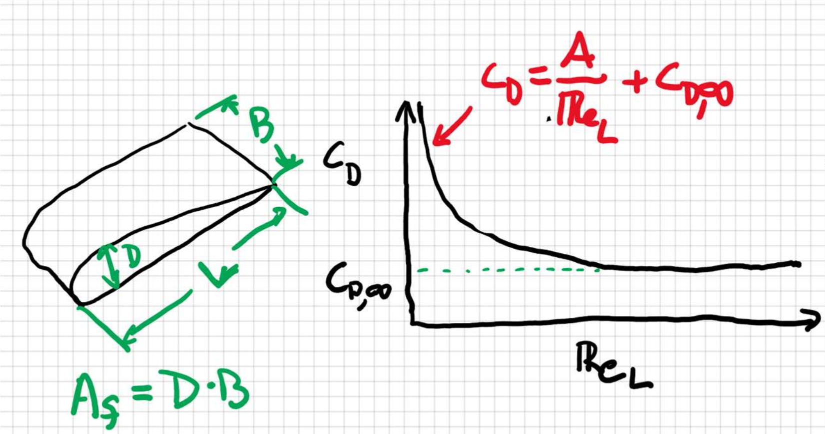
Part 2 (4 Points)

Explain the differences between the Bernoulli equation and the energy equation.

Part 3 (8 Points)

Find the pressure drop in the entry region. You will have to use your knowledge of both fully developed, pressure driven flows and analysis of inviscid flows.

Problem 3 (20 Points)



D/L	$C_{D,\infty}$
0.1	0.5
0.33	1
0.66	2
1	3

B/D	A
1	1
5	2
10	3

Use the above figure to answer the following questions.

Part 1 (5 points)

A miniature airfoil was tested in a wind tunnel and the figure above are the results from testing. Find a formula for the velocity of the wing for a given constant thrust force. Explain how you would solve this equation. **Hint:** You can either use the formula in red for the drag coefficient, or you can leave drag coefficient in the equation and explain a method we have previously discussed.

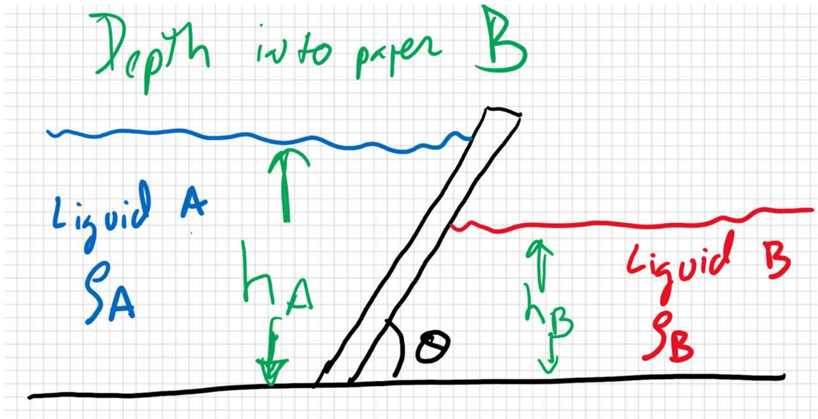
Part 2 (10 Points)

Assume that for a real life application, this wing is intended to work in air (density 1kg/m^3, viscosity 1x10^{-6} Pa s), for a wing that has L=10m, D=1m, and B=5m. This wing is meant to operate at velocities ranging from 1 – 10 m/s. Your wind tunnel has a maximum width of 1 M. How big would your model airfoil be and how fast would the wind tunnel flow need to be in order to model your real foil. What would the drag force on your real foil be for the range of velocities.

Part 3 (5 Points)

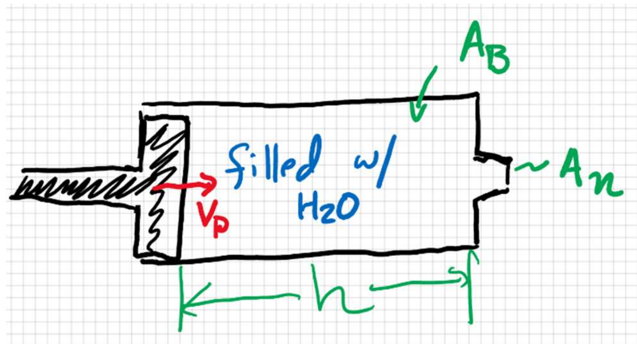
What physical phenomenon causes the drag coefficient to plateau?

Problem 4 (20 Points)



Above is a picture of a wall firmly connected to the ground with 2 liquids on either side with different heights and densities. The wall has a depth into the paper of B. Assuming you know all the fluid properties and geometry, find the reaction forces at the walls base.

Problem 5 (20 Points)



Above is pictured a simple pool toy squirt gun that creates a jet of water by moving a solid piston into a water filled chamber. The barrel has an area A_B and the nozzle A_n. The piston moves with a constant velocity of V_p. Answer the following questions.

Part 1 (7 points)

Assuming the velocity of the piston, geometry, and fluid properties are known. Find the velocity exiting the nozzle as a function of known variables.

Part 2 (12 Points)

Find the force needed to make the piston move at a constant velocity in terms of known variables. You may assume that the outlet velocity at the nozzle is now known due to **Part 1.**