2006-1331: SIGNIFICANT LEARNING EXPERIENCES IN THE FLUID MECHANICS CLASSROOM

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Significant Learning Experiences in the Fluid Mechanics Classroom

Abstract

This paper will describe recent innovations in the Fluid Mechanics course (CE3300) at the University of Wisconsin-Platteville. The innovations include learning activities and feedback mechanisms. Specifically, the innovations are: "Challenge Problems"; in-class "physical models"; a "Create-A-Lab" exercise; and an effective grading rubric for laboratory reports.

Significant Learning Experiences

In "Creating Significant Learning Experiences" (Jossey-Bass Publishers, 2003) by L. Dee Fink, guidelines are provided to help instructors create significant learning experiences for their students. The basis of Fink's model is the concept of "integrated course design." In an integrated course, the Learning Goals, Teaching and Learning Activities, and Feedback and Assessment are all carefully intertwined. For example, the Teaching and Learning Activities are formulated with the Learning Goals in mind; Feedback and Assessment are used to support the Learning Goals and the Teaching and Learning Activities.

According to Fink, significant learning *experiences* should address significant learning *goals*. Moreover, Fink describes six kinds of learning goals. To be effective, Teaching and Learning Activities should address several of these kinds of learning goals. The kinds of learning goals are:

- **Foundational Knowledge** consists of the key information and ideas of the course.
- **Application** learning pertains to the skills and kinds of thinking students.
- **Integration** refers to the ability of students to make connections among ideas within the course and between the current course and other courses or the students' experiences.
- **Human Dimension** goals increase students' understanding of themselves and their interactions with others.
- **Caring** goals hope to create positive attitudes and feelings within students toward a particular course.
- **Learning how to Learn** goals help students become self-directed learners.

In terms of Fink's taxonomy, the goal of this project was to create new Teaching and Learning Activities and a new Feedback and Assessment tool. The Teaching and Learning Activities have been designed to address as many of the kinds of learning goals as possible.

Fluid Mechanics

CE3300 (Fluid Mechanics) is a 4-credit course with a two-hour lab and three one-hour lectures each week. This course is required of all civil and environmental engineering students, and is typically taken by junior-level students.

CE3300 is a challenging course for me to teach for many reasons. First, unlike Introduction to Transportation Engineering or Introduction to Environmental Engineering, Fluid Mechanics does not "belong" to any specific discipline area, and so there are no students entering the course with a goal of focusing on Fluid Mechanics. Moreover, students find the concepts challenging to grasp, and that they are often overwhelmed with the required workload. Perhaps most importantly, Fluid Mechanics is not my area of expertise, which makes the course even more challenging to teach.

The Need

I revised the Fluid Mechanics course in response to participating in a faculty reading group during Summer 2005, in which Fink's book was read. Reading Fink's book made clear to me that the typical lecture approach to Fluid Mechanics does not provide many significant learning experiences. As a result, I made changes to the Learning Activities and to my Feedback and Assessment techniques and these changes are the basis for this paper.

Challenge Problems

Challenge problems were used during the Fall 2005 semester in CE3300. They were created as a means of supplying significant learning experiences to the students. Challenge problems are a "doing experience," in Fink's terminology and they address the following categories of significant learning: foundational knowledge; application; integration; caring; learning how to learn.

The Challenge Problems used in CE3300 were designed to have five characteristics:

- **Challenging**: Challenge Problems should be "hard" to solve
- **Realistic**: they should help students see the practical side of Fluid Mechanics, and help reinforce the Fluid Mechanics is not just an engineering science class
- **Design-based**: students need to see design other than in Introduction to Engineering courses and in their 400-level courses
- **Open-ended**: Challenge Problems can be solved using more than one approach, the approach will not be found in a textbook, and many different yet feasible solutions exist
- **Reflective**: problems should have a built-in reflection component, to help students examine their own learning process

I used six Challenge Problems during the Fall semester. The problems were solved in class, typically in the lecture period immediately preceding one of the six hourly exams. An entire lecture period was devoted to each problem. Throughout the lecture period, I moved among the various groups, and gave feedback, sometimes to individual teams and other times to the entire class. Moving among the teams provided me with many opportunities to "seize the teachable moment." As students were struggling, I could offer advice and correct their mistakes. Students handed in their calculations and written responses on engineering paper. I broke students up into groups rather than have them select their own groups, so as to break up any cliques and to help students meet other students.

Clearly, the use of these challenge problems resulted in essentially "losing" six periods of lecture. I made time for the challenge problems by requiring students to read more, thus making the lecturing more efficient. I also freed up lecture time by spending less time on working numerical examples; I felt that students would benefit more from working the in-class challenge problems than following numeric examples used in lecture.

One problem with group work is that students often feel that the work can be accomplished more easily as individuals. In many cases, they are correct, and such cases tend to give group work a bad reputation. In the case of Challenge Problems, the five characteristics mentioned above worked together to make the group work relevant to the students. The open-ended nature of the problems demands creativity, which is often enhanced in groups, and the level of difficulty was such that only the very brightest students could have finished the assignment in the class time as individuals.

The six problems used are shown in the following table. The assignment handouts supply additional details, and are provided in the Appendix.

Table 1: Summary of Challenge Problems

Challenge Problem	Primary Fluid Mechanic Topic Addressed
Draft Requirements of a Mississippi River Barge	Buoyancy
Design of a Plug	Hydrostatics
Thrust Blocks in Water Main Construction	Linear Momentum
Calibrate a Pitot Tube	Energy Equation
Analysis of a Water Distribution System	Energy Equation
Design of an Open Channel	Open Channel Hydraulics

Physical Models

Physical models were used throughout the semester. Two types of physical models were used: simple working demonstrations or artifacts. The “artifacts” are simply a physical example of something that is being lectured on in class (e.g. an impeller). As such, the physical models address three of the six categories Fink suggests: foundational knowledge; application; and caring.

Physical models typically take less than five minutes of class time. They do an excellent job of providing “context” to the students, and provide a necessary pause in lecturing.

Following are a list of the physical models I use.

- To introduce viscosity, I bring in an old falling ball viscometer. This simple device gives students a sense of how viscosity might be quantified.

- Figure 1 shows a glass tube that I use to introduce hydrostatics. The tube is approximately 18 inches tall and contains antifreeze; motor oil rests on top of the antifreeze in the right-hand leg. I use this apparatus to talk about how the pressure is the same at any point in a continuous static liquid.

Figure 1: W-Shaped Glass Tube

- When we introduce barometers, I show the class a coil of clear flexible tubing and a beaker of water, and ask them to use this to design a water barometer. A few easy calculations show that a water barometer measuring standard barometric pressure would need to be more than 33 feet high. Since this is clearly infeasible, the demonstration is followed up in a later lecture where a long test tube is filled with water (dyed blue for ease of viewing in the lecture hall), plugged with a thumb, inverted and submerged. Before my thumb is released, I ask students how large the air gap will be at the top of the tube. Since the test tube length is much less than 33 feet, no air gap is expected, but students often struggle with this "phenomenon."

- When I lecture on pressure measurement, I pass an old Bourdon gage around the class. The back is removed from this gage, so students can see its inner workings.

- I use a beaker of water, a tin can of sand, and spring scale as a physical example of buoyancy. The can is weighed in air, and then students predict the weight in water; alternatively, the weight in air and water can be supplied to students, and they are asked to estimate the depth of submergence. Although this is a simple "textbook-type problem," students are much more engaged by seeing the actual "apparatus."

- To illustrate Pascal's Principle and to introduce hydraulic presses, I break the bottom out of a glass bottle filled with water by hitting the open top of the bottle. The bottle top needs to be hit quite forcefully. I have resorted to using a rubber mallet however as this tends to hurt my hand!

- To show an application of the non-steady-state conservation of mass equation, I bring in a cup with a hole in the bottom and stopwatch. Students measure the time for water to drain from this "apparatus" and compare it to their models derived from the conservation of mass equation. As with many of my physical models, it is imperative to remember to bring a large stack of paper towels to class.

- Figure 2 shows a "wye" with a pressure gage attached.   The components of this simple apparatus are readily obtained from a hardware store. I use it to explain how dynamic and static pressure vary.

- I pass around a pitot-static tube during the discussion of pitot-static tubes and stagnation pressure.

- Using a beaker, water, and clear tubing (and plenty of paper towels…), a simple siphon is created. Results of flowrate vs. head are compared to a student-derived model.

- When discussing frictional losses in pipes, I like to show samples of pipe sections that have been cut out of actual pipe lengths in the building. These samples clearly show the impacts of age on the interior roughness of a pipe.

- I demonstrate laminar flow with a sheaf of papers rolled into a roll. A bright colored piece of paper is inserted in the middle, and represents what an annular "layer" looks like.

Figure 2: Wye with Pressure Gage

Not every topic has a physical demonstration. However, in many instances, the Challenge Problems filled this void (e.g. open channel flow, momentum)

Create-A-Lab

The Create-A-Lab exercise is held near the end of the semester in the weekly laboratory session. Student teams are required to create a laboratory assignment of their own choosing, perform the lab experiment, and present the experiment and results to the class in an oral presentation.

The Create-A-Lab exercise is an example of a significant learning experience. It addresses the following categories of significant learning: foundational knowledge; application; caring. I have used the exercise since I first started teaching Fluid Mechanics in 1998.

Students typically do one of the following in their Create-a-Labs:

- Physically recreate a homework problem;
- Revisit and modify a previous lab;
- Find a piece of equipment in the lab and use it as the basis for an experiment.

This exercise has given students the opportunity to design a variety of creative labs, including using the wind tunnel; calibrating a pitot-static tube with a car's speedometer; conducting various buoyancy experiments; using various pieces of antiquated equipment such as Pelton Wheels, Parshall flume; determining the minor loss coefficient in a valve as a function of fractional opening; etc.

Grading Rubric

Each week, students in Fluid Mechanics hand in a laboratory report. These end up taking a large amount of time to grade. Moreover, grading these labs consistently is a challenge.

Fink describes effective grading with the acronym FIDeLity: effective grading is **F**requent, **I**mmediate, **D**iscriminating, and done **L**ovingly. I would add that the grading must be consistent. In an effort to be a more effective grader as described by FIDeLity, I created a grading rubric for the Fluid Mechanics Laboratory reports.

The grading rubric has evolved over the past few years, and the copy presented in the appendix represents a successful effort used during the Fall 2005 semester. This rubric provides for consistent grading and serves as a guide to students when writing the lab. One significant time-saving technique was to make this grading sheet available on the course web site, and require its use as the laboratory report cover sheet. Thus, I did not have to print out copies of the grading rubric and attach them to each student's report.

I have often resisted using a grading rubric. If the rubrics were very prescriptive and detailed, I felt that the report degenerated into a "fill-in-the-blank" report. It left no room for student creativity, imagination, or even *thinking*. On the other hand, using a very vague and open-ended rubric resulted in the best students scoring well; this of course isn't necessarily a problem, but does not provide the weaker students with a necessary level of guidance. The rubric used in the Fall 2005 semester was a compromise between these two extremes, providing a set of expectations without being overly prescriptive.

The grading rubric is provided in the Appendix. It contains seven categories with a series of rankings in each category. Thus placing a grade in each category is relatively easy. I also used a simple coding system to allow students to understand the basis for the scoring. Whenever I wrote a grading comment in the report, I would place a capital Arabic letter near the comment, and use this letter in the corresponding category on the cover sheet. By working my way through the alphabet, students could clearly see the reason for their lost points.

This rubric was also used by students in performing a laboratory report peer evaluation. By the sixth week of class, they had become comfortable and familiar with the grading rubric. They had an idea of the weight of penalties associated with various infractions, and thus were able to use the rubric to effectively evaluate two classmates' reports. Of course, this decreased my grading load for the week, and had the additional benefit of letting students see the quality of work performed by their peers.

Assessment

The effectiveness of the Challenge Problems was evaluated in several ways.

- I received more unsolicited positive face-to-face feedback on Challenge Problems than any other change I have made to a course.

- The end-of-semester course evaluations, administered by the Dean's office, provided some insight on the effectiveness of the Challenge Problems. Although no feedback on Challenge Problems was specifically targeted on the form, seven students commented favorably and one student commented negatively. The positive comments mentioned that the problems were interesting and provided an excellent review for the exams.

- I wrote down my reflections on the Challenge Problems throughout the semester. I noted that students were active the entire period, and that they asked many good questions. Moreover, I found it exciting to see small groups of students working actively in class, and asking one another high level questions on Fluid Mechanics topics.

- I noted that students are not very good at reflecting. When they were required to reflect on "the most difficult concept" of the day or "what fluid mechanics principles were made clearer to you after completing this exercise," students were unable to respond in a meaningful way.

- I administered a mid-term evaluation. One question asked students to "describe the in-class "Challenge Problems" with a single word or phrase. Only four students described the challenge problems in a negative way, and they elaborated that the time could be used more effectively by working homework problems. The remaining 23 students had positive comments. The most common word was "challenging," which in retrospect was not surprising given the wording of the question. Other adjectives ranged from "awesome" to "the bee's knees."

The rubric was a success from all viewpoints. Grading laboratory reports was much less of an annoyance for me. I feel that I spent less time grading the reports, although I have no data to verify this claim. Also, I had a *very* small number of discussions with students about how points were awarded; there were no issues concerning consistency of the grade among students. I believe that the rubrics served as a guide to help students write their reports. Because of the large penalty for grammar errors, and the focus on "professionalism," I found the reports to be easier to read than in previous years. Additionally, I used the midterm evaluation to assess how the students were using the feedback. Figure 3 shows the results. The response "I use feedback" is abbreviated on the chart; the actual response was "I analyze the feedback in the hopes that it will make me a better writer." These results were very encouraging in terms of motivating me in my grading and showed that another very important impact of the rubrics is the ability for interested students to use the rubrics to improve their writing.

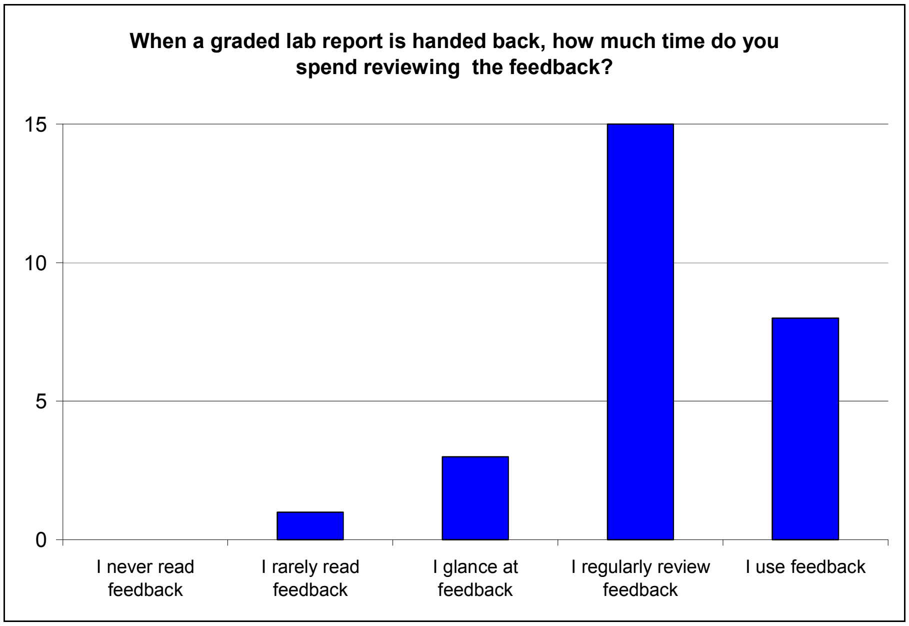


Figure 3: Student Use of Rubric Feedback

The Create-a-Lab and physical models are more difficult to assess, as these have both been in use for several years, and have continually evolved. In terms of the Create-a-Lab, the most difficult aspect for many students is one of creativity; i.e., coming up with an idea in the first place. Most students enjoy the freedom and open-endedness of the process, and I enjoy the change from the weekly routine. Indeed, Create-A-Lab is my favorite laboratory, and the students put a lot of effort into this task.

Summary

The innovations shared in this paper include learning activities and feedback mechanisms. Specifically, the innovations are: “Challenge Problems”; in-class “physical models”; a “Create-A-Lab” exercise; and an effective grading rubric for laboratory reports. The innovations were successful in engaging the students and in providing a varied and enjoyable learning atmosphere.

Appendix

The following is a copy of the Grading Rubric used for Fluid Mechanics laboratory reports.

CE3300 Fluid Mechanics Lab #

Author:

Lab Partners:

Lab Title:

Date:

/10	**Grammar, Spelling, and Punctuation**	
	10 points:	No errors
	3 points:	1 error
	0 points:	2 - 4 errors
	-5 points:	5 errors
	-10 points:	6 errors[1]
/10	**Sensible writing**	
	10 points:	All sentences make sense
	0 points:	One or more sentences do not make sense
/10	**Word Choice**	
	10 points:	Care has been taken to use the BEST word possible
	0 - 8 points:	One or more word choices could be improved upon.
/10	**Professional Tone**[2]	
	10 points:	Sounds like a Professional Engineer
	8 points:	Sounds like a very good student
	6 points:	Sounds like a good student
	0 points:	Sounds like a first draft
/20	**Completeness and Correctness of Analysis**	
	20 points:	Questions are answered completely and supported with appropriate and effective evidence
	1 – 19 points:	Questions are not answered completely and/or are not properly supported with appropriate evidence.
	0 points:	Questions are not answered.
/10	**Format**	
	10 points:	0 or 1 formatting mistakes
	8 points:	2 formatting mistakes
	5 points:	3 formatting mistakes
	0 points:	more than 3 formatting mistakes
/30	**Technical Merit**	
	30 points:	All calculations are correct and sample calculations are clear and legally defensible
	1 - 29 points:	Some calculations are incorrect and/or sample calculations are not clear or legally defensible
	Deductions[3]	
/100	**Total Score**	

[1] You will receive a grade of zero if more than 6 grammar, spelling, and punctuation errors are noted.
[2] See attached "Professional Writing Checklist" for guidance.
[3] Improper significant figures *anywhere* in document (25 points).

Challenge Problem #1 – Page 1

1. Read the following article from the Dubuque Telegraph-Herald (August 11, 2005).

AP

Barges sit idle along the Mississippi River just south of downtown St. Louis on Wednesday. Barge traffic along the river has been restricted due to the low level of the river caused by the drought in the Midwest.

Barges lighten loads as drought drops river levels

The Army Corps of Engineers says any further reduction could be troublesome

ST. LOUIS (AP) — As the Midwest's worst drought in 17 years continues to lower inland rivers, Larry Daily and other barge operators shake their heads at sunny skies and hope for rain — lots of it — to buoy their cargos, spirits and bottom lines.

"We were supposed to have scattered thunderstorms here today, but I'm looking at nothing but blue skies right now," Daily, president of Alter Barge Line Inc., said from his business in Bettendorf, Iowa.

The summerlong drought has squeezed Alter's fleet of 300 barges and six towboats. Because of lower water levels in the Mississippi River, Alter has had to trim payloads by about six inches per barge — or about tons apiece — to shed enough weight to clear shallow spots in the last two weeks.

He figures the lighter loads stand to cost his company about $300,000 per month.

"But we're moving," he said optimistically as his crew continue to transport everything from corn and soybeans to cement, steel products, coal and fertilizer up and down the Mississippi, largely between St. Louis and St. Paul, Minn.

Near where the Ohio River hooks up with the Mississippi near Cairo on Illinois' southern tip, several barges ran aground beginning on Sunday. Those vessels since have been cleared and that stretch has reopened on a case-by-case basis with barges allowed to pass if they sit high enough, said Coast Guard Lt. Anthony Baird in Paducah, Ky.

"That's not necessarily a typical trouble area there," Baird said. "The last time we saw low water this severe or extreme was in 1997, then previously in 1988."

Commercial traffic on the Mississippi ekes on, though any further drop in the water level may make shipping troublesome, according to the Army Corps of Engineers. The Corps is charged with maintaining a navigational channel at least nine feet deep and 300 feet wide on the river.

Around St. Louis, the National Weather Service forecasted Wednesday that the Mississippi's level would continue to decline over the next month. Some potentially strong rainfall was expected in coming days in northwest Missouri, but whether that matters — feeding into the Missouri River then into the Mississippi River — depends on the rain's intensity, said Scott Dummer, a weather service hydrologist.

"When it first hits the ground, a lot of it is going to soak into the ground," he said. "What's needed is a sustained rainfall over a couple of days, a good several-inch rainfall."

A Coast Guard advisory Tuesday recommended that deep-draft barges — those with the heaviest loads — be moved out of the Upper Mississippi River as soon as possible. Mariners also are urged to be vigilant about repositioned channel-marking buoys.

The Corps has been scrambling to keep the Mississippi open, hustling its 247-foot-long dredger up the river to lower the bottom of St. Louis' harbor. The work is expected to be completed today.

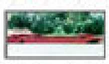
Challenge Problem #1 – Page 2

2. Initial analysis (on scrap paper):
   a. calculate how many tons correspond to decreasing the draft by six inches
      i. brainstorm some simplifying assumptions;
      ii. draw a schematic;
3. Advanced analysis
   a. Estimate a range of values for each of the variables that you have used.
   b. Estimate a range in your answer to part '2-c. Fill in the blank: "I am ______% confident that the true answer lies within this range."
   c. Show how the depth of water impacts the barge's draft.
4. High-level analysis
   a. What did this exercise teach you about engineering?
   b. What did this exercise teach you about fluid mechanics?
   c. What did this exercise teach you about working in teams?
   d. What did this exercise teach you about making assumptions?
5. Arrange your analysis into an organized and professional report on engineering paper.

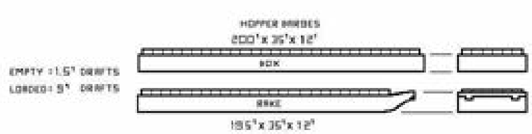
6. Homework: How might the barge company determine how much weight they must remove to meet a certain draft requirement? They could perform the calculations that you just did or they could physically load a barge and note the draft. Or, even better, they could hire you to create a graph that would simply show them how much weight their barge should hold given various draft requirements. Create such a graph for the two barge cross sections shown below.

"The Standard - Jumbo Hopper

Tap To Enlarge



New Jumbo Hoppers ..... *"They won't look - like this, Long!* Pushed, bumped & banged around in lots of hard use and treatment, quickly will have these new units, looking like any other barge, after a couple years of service. Lasting often over 50 years - in constant service, if properly maintained and repaired, barges are then sent to the scrap-yard.



Capacity = 1500 Tons .... Materials Commonly Hauled = Coal, Grain, Salt, Fire Clay, Rock, Sand, Steel = Sheets or Coils & Scrap Metals, Logs & Pulp Wood and Saw Dust, Machinery and Construction Supplies of all types. NOTE ... Hopper's can also be built as Tankers, and haul most any type chemical. But commonly haul - Alcohol, Benzene, Diesel Fuels or Used Oil, Gasoline, Soybean Oil, and Other products - for a few examples!

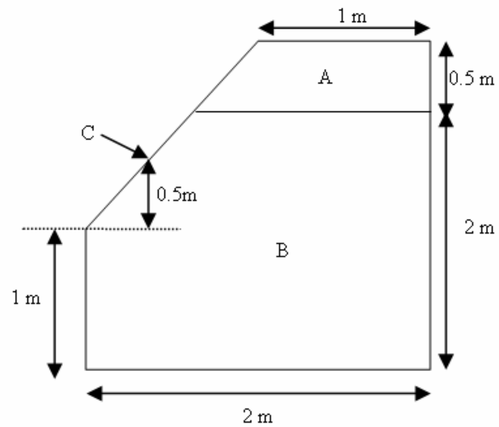
Box - Barge *(See Above - Top Drawing)*, meaning the barge is square shaped - at both ends. This is not a barge that's used normally - as a lead barge, in a tow. Because its more difficult to push and better suited for use, further back - in the tow.

Rake Barge *(See Above - Bottom Drawing)*, used at the head of barge tows, as lead the barges, because of its - sloped rake shapes in the bow, which pushes more easily. But can also be used anywhere in a tow, which these barges are also designed as Double Raked - End Barges too. Meaning their carry a rake, at both ends. The raked shape, passes through water more freely than and reduces the force that must be applied to push them.

Standardized Hopper Barge - Sizes *(Used On All Rivers)*, built as Single or Double Raked - end designs, or Box Ended versions ..... Length = 195' to 200' ... Width = 35' ... Drafts = 12' Overall ... *Maximum Loaded Drafts = 9' Empty Waterline - Draft = Approx. ... 1.5' Drafts*

Challenge Problem #2

The tank shown in the following diagram holds air at 190 kPa (abs) in area A and water in area B. The tank is made of 10 mm-thick steel. The tank is 5 m wide (into the paper). Arrow C points to a 50 mm diameter hole.



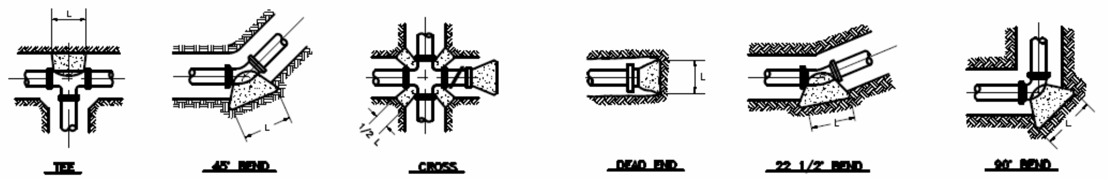
1. Design a plug to seal up this hole. The plug is to be held in place by hydrostatic pressure only and should be sturdy and able to withstand occasional bumping.
    a. Brainstorm all of the variables that might impact this plug design.
    b. Design a plug, keeping in mind that the plug should be *as small as possible*, by volume. Make sure to at least consider a plug with a curved surface.
    c. State the volume of your plug.
2. Will your plug work if the liquid in area 'B' is ammonia? Mercury?
3. What factors had the greatest impact on your team's success (or lack thereof)?
4. What was the most difficult part to solving this problem?
5. How might you improve your team's performance in the future?

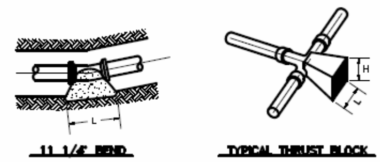
Challenge Problem #3 – Page 1

Thrust blocks are used in the construction of water mains to hold the pipe in place during operation. They are typically poured blocks of concrete. As you know, changes in velocity or direction can cause a change in momentum, and may result in significant forces.

1. For an 8-inch water main carrying 5 cfs of water at a pressure of 70 psi, design a thrust block for a:
    a. 90° elbow
    b. tee
    c. 45° bend.

Challenge Problem #3 – Page 2





GENERAL NOTES

1. PRESSURE TEST SHALL BE PERFORMED IN ACCORD WITH CONCRETE CURING REQUIREMENTS. CONCRETE SHALL BE 560-C-3250.
2. THRUST BLOCKS SHALL BEAR AGAINST UNDISTURBED SOIL, BACKFILL COMPACTED TO 100% RELATIVE COMPACTION, OR CLASS 100 E100 SLURRY.
3. BEARING AREAS L X H ARE COMPUTED FOR TEST PRESSURES OF 225 PSI IN MAINS LAID IN A COHESIONLESS SOIL (C=0) WITH INTERNAL ANGLE OF FRICTION OF 37°, A UNIT WEIGHT OF 110 PCF, AND AT LEAST 36" OF COVER.
4. BEARING AREAS L X H SHALL BE APPROVED BY THE DISTRICT WHERE MAINS: (A) BEAR AGAINST WEAKER SOIL THAN DESCRIBED ABOVE, (B) HAVE LESS THAN 36" OF COVER, OR (C) ARE NOT REPRESENTED BY A FITTING OR SIZE SHOWN HEREON.
5. L IS APPROXIMATELY EQUAL TO H FOR SMALLER THRUST BLOCKS. L IS GREATER THAN H FOR LARGER THRUST BLOCKS. H SHALL NOT EXCEED TRENCH HEIGHT.

THRUST BLOCK SIZES

Bearing Area (sq–ft) and Thrust Block Dimensions (in)

PIPE SIZE (inches)	DEAD END			TEE OR CROSS			90° BEND			45° BEND			22.5° BEND			11.25° BEND		
	Area (sq–ft)	L (in)	H (in)	Area (sq–ft)	L (in)	H (in)	Area (sq–ft)	L (in)	H (in)	Area (sq–ft)	L (in)	H (in)	Area (sq–ft)	L (in)	H (in)	Area (sq–ft)	L (in)	H (in)
4	2.0	17	17	2.0	17	17	2.9	21	21	1.9	17	17	1.0	12	12	0.4	8	8
6	4.3	25	25	4.3	25	25	6.0	30	30	4.3	25	25	2.2	18	18	1.0	12	12
8	7.4	36	30	7.4	36	30	10.5	42	36	7.6	37	30	3.9	24	24	1.9	17	17
10	12.1	42	42	12.1	42	42	17.1	59	42	10.3	42	36	5.5	30	27	3.1	22	22
12	17.2	52	48	17.2	52	48	24.3	73	48	17.2	52	48	8.7	42	30	4.3	26	24
16	26.7	72	54	26.7	72	54	37.8	101	54	30.6	82	54	15.6	54	42	7.8	38	30

MOULTON NIGUEL WATER DISTRICT

TYPICAL THRUST BLOCK

W-12

Challenge Problem #4

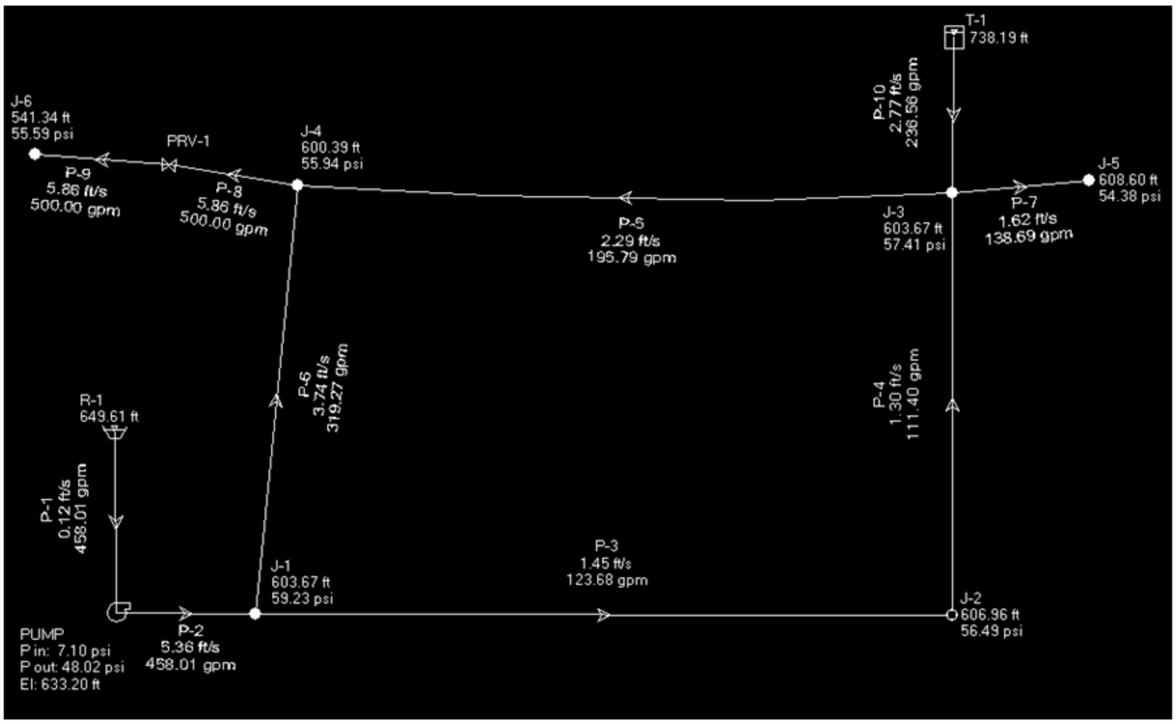
Create a velocity meter using a flexible straw, ruler, tape, marker, etc.

1. Determine the range of velocity values that the velocity meter can measure.
2. Create a scale on the meter such that it can be used to measure water flow velocity in an open channel.
3. Determine the accuracy of the meter.
4. Keep note of the time spent on various tasks in this exercise.
5. Use your time log from step 4 to make some recommendations on how your group could have improved its performance.
6. Which fluid mechanics principles did this exercise clarify in your mind?

Adapted from **Fluid Mechanics: Fundamentals and Applications** by Y. Cengel and J Cimbala (McGraw Hill).

Challenge Problem #5

1. A quick rule of thumb is that 1 psi is equivalent to 2.307 feet of water. Show where this conversion comes from. It is a very useful conversion for analyzing water systems.
2. Analyze the provided schematic.
3. Create an HGL and EGL between Tank T-1 and junction J-6. Be sure to show the ground elevation.
4. Estimate the pressure at junction J-6 if there were no pressure reducing valve (PRV-1) installed.
5. Does the headloss around the loop sum to zero? Should it?
6. Do the flows at each node sum to zero? Should they?



Challenge Problem #6

You are to design a prismatic channel to convey water from Design Point A to Design Point B. The flow to be conveyed consists of stormwater runoff from a small watershed (5.4 cfs).

Consider the following:

- You need to minimize cost, while conveying the necessary flow.
- The channel should be positioned within valleys whenever possible to minimize excavation.
- You cannot build the channel through or within 100 feet of the house.
- You have two choices of materials to work with, corrugated steel or concrete. The concrete can only be formed into a rectangular cross section while the corrugated steel can only be formed into a semi-circle. The concrete costs $15.00/ft^2 while the corrugated steel costs $18.50/ft^2.

The first student that submits the lowest cost alternative (that is clearly justified) will be awarded up to 5 homework bonus points.