How do we go through the beginning of a problem and decide which forces are acting on the system? (i.e. shear, pressure, gravity, gradient)

The problem statement will need to be clear enough to specify what the orientation of the pipe is with gravity, if there is a pressure difference from end to end of a closed pipe or if there are any moving surfaces.

Are the boundary conditions always the same when deriving? The $\frac{\partial V_2}{\partial 2}$ boundary conditions sometimes seem inconsistent or confusing. I understand no-slip, but not on the other ones...why does the deriv=0 at a boundary?

Different problems will have different boundary conditions. However, as I emphasized in lecture, there are only a few possibilities.
(1) Fluids stick to the wall (no slip) and (2) to each other (velocities for each fluid are equal to each other at the interface.)
(3) Shear stress is continuous so that it is the same for each fluid at an interface. For two Newtonian liquids this means $\mu_1\, dv_1/dy = \mu_2\, dv_2/dy$. *(4) If one of the fluids is a gas then its viscosity will be very low so that for the liquid we will have that* $\mu_1\, dv_1/dy = 0$

On the homework there are a lot of questions revolving around min. and max. How do we do this? Do we take the derivative? Sometimes I find that doesn't work.

If a maximum or minimum is asked for, taking a derivative is the most sensible course of action although plotting the answer (i.e. function) first to see what is going on is a good idea. Remember that the extremum points of a function on an interval occur where the derivative is 0 or at the end points. Thus the derivative should work.

Can all three forces act on the fluid?

Yes, problems exist and can be formulated that have moving surfaces, pressure gradients and gravity all in the same problem.

What are the areas and ideas we should focus on most?

I would suggest that you start with the notes from lecture. Most lectures have either a preview with major points or a conclusion with main points – or both. If time was spent on a topic in lecture, then it is important. Next look at the course goals on the web. See what you have worked on that matches closest to the goals. The homework problems are intended to cover as many of the topics as possible.

Will it be lots of memorization or all deriving equations? Just not sure if I have enough experience to actually derive some new thing without guidance of TA.

While it is hard to make a list of things that could be categorized as memorization (as opposed to understanding the subject) but:… You need to remember the boundary conditions, how to do the stress and other components in a momentum balance and how to integrate the first order ODE's and fit the boundary conditions. I will give you the definitions of the dimensionless groups, the Young-LaPlace equation and probably some other stuff (see the first test from last year for examples.) As I mentioned in class several times, you will need to be able to derive the differential equation for the stress and/or velocity. You will have to solve these equations.

What kinds of derivations will we have to know for the test? How much detail in the derivations will we have to know for the test?

As I mentioned in class, you will be asked to derive one stress balance and/or differential equations for the velocity profile. Solving this will also be asked.

I am baffled by difference/relationship of κ&s--what is a good definition for or way to think about each (both mathematically and physically)?

κ is the ratio of the diameters, inside diameter divided by outside diameter. It gives the basic geometry of the flow and does not change during the problem. Thus it is a dimensionless parameter. The term s is the ratio of radial position to outside radius. It is just a dimensionless location and since it varies is a dimensionless variable. There is no particular relationship between κ and s except that $\kappa \leq s \leq 1$.

Will we be asked to derive velocity profiles like this one today, or will the exam questions be limited to fluid flow caused by only one force (of the three we know)? Are fluids tests hard? Will it include combinations of driven flow?

I can't promise that a problem will have only one force. However, I will endeavor to make the algebra as simple as possible. Plus I give partial credit.

Will the test questions be as long and hard as homework questions? What types of questions will be asked on the test? Similar to homework? What is the test format? How much of the test is weighted on derivations? Will it be hard to derive equations on the test? Is it going to be a long test? What is the format going to be like? Will the problems be similar to our homework problems and the examples in the book?

The test format could be very similar to the example on the web. A combination of problems like the homework and questions about important topics that were emphasized in lecture.
The test will be about 3 questions. One part of one question will to derive a stress / velocity equation and the other part will be to solve it.

I am having trouble understanding the lubricating liquid flow problem.

The key points are in the preview and conclusions. If you have some specific questions please come and ask.

How do you derive all those stress equations?

You make sure you have the correct coordinate system for the flow geometry. Draw a differential volume. Include terms for the shear stress and any pressure difference or body force. Divide by the differential volume, shrink it to 0 and get your equation.

Exactly how well does lubricated flow work if the two phases have different density?

If the fluids have different densities, the core will be off-center but in the narrow region, waves will form that push the oil away from the wall. The lubricated flow process will work better if the water wets the steel pipe better than oil. This can be achieved using Sodium Silicate or other silicates in the water. This often does not cost anything as water is always present in oil drilling and silicates are often in the water.

Will we have a review? How should I study for test? How do you recommend studying for test and also what problems at the end of each chapter would be good ones to practice? Can we expect the questions on the test to be similar to those given for homework? How can I study for the test?

The review will be Tuesday. You should study the notes, redo the homework and read the pertinent sections in the book. Finally look on the web at the course goals and find the topics we have covered. I would not go looking for other problems to do at the ends of the chapter. Many of these are lengthy and cover the same principles as the ones you worked so hard to solve already.

How much of the test deals with derivations vs. calculations? Are the problems going to require numbers or just derivations? How much deriving do we have to do?

There will some numbers and some problems that are just algebra.

How to approach a derivation. When to use which τ equation and especially for annular flow how would we be able to get that final answer? Obviously we won't have a computer at the test, so even if we memorize final answer, many steps are missing.

I am looking forward to the day where a "computer" will be as standard as a calculator in class. Until then (and even after) you need to be able to write down the forces acting on your control volume and then shrink it to 0 to get a differential equation. Once you have this you solve the ODE and match the boundary conditions. On a test or even for homework I could not expect you to work thorough all of the algebra necessary to solve the lubricated flow problem. I could expect you to understand it however.

What are the shear stress equations and how to draw velocity profiles. What are the different equations for shear stress? i.e. under what conditions does each equation hold true? What are the three equations for shear stress that we can derive so far? Can you derive the differential equation for stress in a tube for any geometry using the three equations you were talking about? What are those three equations?

There are really only 2 differential equations for the shear stress that you can derive:

(1) If the geometry is planar the differential equation for the shear stress will be something like

$-\frac{\partial \tau_{zx}}{\partial x} - \frac{\partial p}{\partial z} + \rho g \cos(\beta) = 0$. *If there is no pressure gradient the dp/dz term will be absent and if $\beta = \pi/2$, then there is no gravity term. (If this is the case then one of the walls has to be moving or there is no flow.)*

(2) If the geometry is cylindrical the corresponding equation is

$-\frac{1}{r}\frac{\partial (r\tau_{zr})}{\partial r} - \frac{\partial p}{\partial z} + \rho g \cos(\beta) = 0$. *As above, there may not be pressure gradient or gravity term for a specific problem.*

To get the stress profile, integrate these equations use one boundary condition. The solution is then the stress profile.

To get the velocity profile, Substitute the constitutive relation for the shear stress-- velocity gradient relation into the stress equation and integrate to get the velocity profile.

How come $s=\kappa$, but when we do the ratio of $\ln s/\ln\kappa$ it is not one, more generally, how does eq. 3.3.26 work if $s=\kappa$?

s can only equal κ on the inside cylinder. If $s = \kappa$, then the ratio of $\ln s/ \ln\kappa = 1$, so there is no problem. At this point, the velocity is just the velocity of the inside cylinder -- which is what we have required. There is no problem.

Will we need to remember dimensionless groups such as the Reynolds and Weber #'s?

I will give the definitions of Reynolds and other numbers if they are needed.

Could you do an example of another derivation of one of the equations using a specific geometry?

Yes, this was done on Thursday.

How do you solve/derive the equations for a system with two types of flow forces?

When you are including the terms in the stress balance, you just include the ones that are present in the problem. There are 2 that you need to worry about. For an enclosed flow there is likely to be a pressure gradient. If the flow is not exactly perpendicular to gravity, then gravity will need to be included.

However if there is a moving surface, it will come in through a boundary condition and since the shear stress will always be present, there is no effect on the differential equation of a moving surface.

How do you know when you can find pressure differences and when you can't for flow of a liquid through a tube?

You can figure this out from the information given in the problem. If there is imposed forcing, I either have to give you this or ask you to find it from other information. If the flow is open at the ends and all the way through the pipe, there is no pressure effect. If there is a closed region and no information, then you need to figure it out from other information. This is either a "no net flow" constraint, or a given amount of net flow restriction.

In the surface tension example with water rising in a capillary tube, why is only the surface tension between the water and air taken into account through ΔP while the surface tension between the water and capillary glass is neglected.

Surface or interfacial tension exists only between two fluids. If we call it surface tension, we are thinking of interfacial tension between the fluid and air. For the capillary rise problem we have implicitly assumed that the liquid wets the glass very well. This, along with a capillary radius of big enough, but not too big, sets use up to have a macroscopic interface between the fluid and air that will have a defined curvature and a corresponding pressure difference. If the fluid did not wet, such as Mercury on glass, there would be capillary depression. If the glass had a lot of "crud" on it, the experiment would not work very well. If the tube were different kinds of plastics you would get a mix of answers and the experiment would not tell you a true surface tension.

What sections do we need to study? Can you explain the reasoning behind the homework problem dealing with the thickness of the liquid mercury telescope lens, spinning vs. stationary?

I put up a list of the most important sections on the web. The rotating mercury mirror is not part of this and is a section that I thought you might find interesting and could get a little understanding of without lecturing about it.

Where did the "key parameter" $\Phi = \dfrac{\Delta p R^2}{4 L \mu V}$ come from? Is that the forcing ratio?

The key parameter arises naturally in the problem when the equations are made dimensionless. In the example from class, this is the ratio of the pressure increase caused by the flow to the shear forces necessary to cause it. In other types of problems where there is an imposed pressure and a moving surface it would be the ratio of the two different kinds of forcing.

When can you assume a fluid is Newtonian?

You really can't assume a fluid is Newtonian or not. This needs to be specified in a problem and for a real situation with a different fluid, this needs to be verified.

How can I relate the different coordinate systems to each different equation and derivation referring to flow?

If the flow is planar, then Cartesian is the correct coordinate system. If the flow is in a circular pipe (or outside of a circular pipe) then the problem should be solved in the cylindrical coordinates.

It appears that knowing when certain initial conditions (ex. when velocity=0) are true is one of the most important parts of solving a problem. Is this true and what are some assumptions that we can make?

Yes it is true. You asked this question before I again made a big point about the boundary conditions. You must remember the possible boundary conditions and the equations that describe them. Please be sure to study this. See above for another recap of boundary conditions.

Didn't understand the last thing we discussed concerning the graph of the velocity profile to position. What does the concept of the circle having less arc length radially inward mean?

The differential area element on a circle is the radial distance, dr times the distance around the circle at whatever radius you are at, which is r dθ. So that

$dA = r\, d\theta\, dr$*, where you get an "extra" r.*

For a rectangular area you would just get

$dA = dx\, dy$.

This is what I meant.

If gravity acts downward in a horizontal pipe, is the velocity profile still parabolic?

Yes it is. For a perfectly horizontal pipe the pressure is higher at the bottom of the pipe than at the top, but this does not contribute to any momentum change in the flow direction.

The homeworks have been mostly "find equations in the book and solve them" kinds of questions. How many and which of these questions should we be familiar with for the test?

You should make sure you understand all of the homework questions and all of the derived results (equations in the book) in the sections that I marked as of high importance.

Is the test going to be mostly conceptual or calculation based? Who's a better football coach, Bob Davie or Lou Holtz?

You will have to think in either case but there will be both algebraic/calculus manipulations and some calculations involving numbers.

There are many criteria that can be used to judge football coaches and so you will have to make your own judgements based on perhaps soundness of fundamental football philosophy and ability to implement it. However a much more fun way to judge coaches and other people you see in public is their ability come up with one liners that make a lasting point. Holtz is great at this. When his Arkansas team beat the more mighty than any team is supposed to be today) Oklahoma team in (about) the 1978 (Orange?) Bowl he was asked how did he get his team so fired up before the game. He said he told them that the "last 11 guys out of the locker room had to start!" A year or so after he came here there were some complaints about why we did this or didn't do that and he said, he wasn't going to change his coaching philosophy based on comments by someone who couldn't find his car in the parking lot after a game!

What are the differences between laminar and annular flow, and what assumptions can you make in each case? What is the difference between annular flow and laminar flow?

We have solved only laminar flow problems so far. Laminar means straight or smoothly varying flow paths that do not have any randomness in time or with changes in spatial position. The "annular flows" are just laminar flows in annular geometry.

Amongst all of the significant theoretical work, how can one avoid making silly arithmetic mistakes?

The better you understand what we have been doing and the more time you have practiced it, the better you will probably do on the test. (Note I cannot say this for you compared to *someone else). This is because you will have a greater level of comfort and familiarity. Exclusive of a test where there is a time constraint, another answer to this question is for you to always think about the basic* <u>*sensibility*</u> *of any answer (Can it possibly be correct?), Also for any equation or calculation, are the dimensions correct?*

So far, I consider these to be the types of problems I now know how to solve in this class:

--drop problems/capillaries

--flow through a pipe

and I know the equations used to solve these problems (i.e. stuff from the homework). Am I prepared for one of your tests? What else should I be sure to understand?

While I will not ask you to go through a dimensional analysis calculation, I may ask questions that use the results of these.

Dumb math question:

Why does $-\frac{1}{r}\frac{\partial\left[-r\,\mu\frac{\partial/v_z}{\partial r}\right]}{\partial r}=\frac{\Delta P}{L}$

become

$$\mu\left(\frac{\partial^2 V_z}{\partial r^2}+\frac{1}{r}\frac{\partial V_z}{\partial r}\right)=\frac{\Delta P}{L}$$

Is it because you can simplify the top equation two different ways and you sum the two?

No. This is just the chain rule for derivatives.

$$\frac{d\left[u(x)v(x)\right]}{dx}=u(x)\frac{d\,v(x)}{dx}+v(x)\frac{d\,u(x)}{dx}$$