TRANSPORT

Keasling and Goren

Goren

You have a tank with a small diameter pipe connected at the bottom. The level in the tank is kept constant (but you don't know what it is.) Given the diameter of the pipe and the Reynolds number of the flow in the pipe, can you figure out if the diameter of the flow of water jetting out of the pipe has a larger/smaller/same size diameter than the diameter in the pipe? (Believe everything that you hear about Goren. He is quite nasty and he'll grill you alive. Initially I said that the diameters would be equal and Goren made me prove it. You have to use the "real" Bernoulli Equation, the one with the alpha correction factors. Alpha for laminar flow is 1, alpha for turbulent flow is 2. It took me forever to pick the correct two points to apply Bernoulli's equation. It turned out that you apply it right inside and right outside the end of the pipe. Friction factors are from Reynold's number. You get the velocity from the Reynold's number (duh!) In conjunction with the continuity equation, you figure out the area of flow outside is different.)

Sketch the velocity profile for laminar flow.

Sketch the velocity profile for turbulent flow (remember your boundary layer!)

Goren showed me a plot of friction factor vs. Reynolds number. He wanted me to explain why the curves flatten out as the Reynold's number got into the turbulent region. That is, why did the friction factors not depend on the Reynold's number? (I didn't know what he was trying to get at and I stumbled for a few minutes before Goren got impatient and moved on.)

No T profile

Jay

Dr. Goren has a computer with a lot of chips in it. These chips heat up so cooling fins are used to keep the temperature down. Write the equations describing a cooling fin. (Don't forget your boundary conditions.)

If this were in space, how would this be different? (heat loss by radiation.)

Jay and Simon

Goren

I was the last prelim person for Goren. He was pretty grumpy at this point. He would ask questions in a sarcastic manner. I thought I had failed this prelim, but I ended up passing it. If you have Goren, study the theoretical transport material.

1. There is a tube coming off the bottom of a tank filled with water. The tank provides the tube with a constant head (some laminar Reynold's number). How does the diameter of the jet compare with the diameter of the tube?

This is just a Bernoulli's equation problem. If you know where to put your points, it simplifies very easily, but I took a few tries to figure out where to put my points.

a. Do you think this is a hard problem? Could undergraduates do this problem?

   Geez, I said it wasn't a hard problem once you set it up. I found these questions rather insulting.

b. What are the alpha terms in the Bernoulli equation? What are the values of alpha for laminar flow and for a jet?

c. How do you find the friction factor for pipes? Why do they become constant at higher Re for even slightly rough pipes?

   I said something, but I'm still not sure what the answer to this question is. Goren didn't make a big effort to lead me to the right answer.

Jay

2. Fins on computer chip problem. Set up the differential equation and boundary conditions. How do you find h?

This was pretty easy, but then Goren comes along again and asks...

Goren

3. Why do correlations for Nu have $Pr^{1/3}$? Where does the 1/3 come from?

I had no idea. I mentioned things about the Chilton-Colburn and Reynold's Analogies, but I said I didn't really know where the 1/3 came from. I said it could be empirical. Again, Goren didn't make an effort to correct me. Now I think the 1/3 comes from the solution to the boundary layer.

4. We have 10 minutes left. Let's ask another question. (I was hoping they would let me leave early). You have two concentric cylinders. Drop one down the other. What is the velocity profile? (This is a Muller question.)

Goren drew the picture of this on the board, but really didn't explain the problem conditions that well. I drew the profile for an infinite outer cylinder, but it turns out the outer cylinder isn't infinite, so I just corrected the profile to make it consistent with conservation of mass.

a. Should the velocity profile have zero slope at the inner cylinder?

b. What causes the fluid to flow back up?

c. Which terms in the Navier-Stokes equation drop out?

(Pressure term does not drop out.)

Chakraborty and Muller

Chakraborty

Arup said that he was interested in solving a problem (and he was dead serious about it)--so I have just finished playing squash. My body is hot, and I would like to know if it's better for me to either: 1. Wait a certain time, t1, to cool off before taking a comfortable shower or 2. Take a cold shower right away.

I said that there was a lot of information to think about there at once, so I'd have to analyze each situation one at a time. I started on an energy balance. (Arup said that I could approximate his body as a cylinder--he said that it would have been insulting if I would have used a sphere. He also said I could assume that his body was nonmetabolic [no heat generation]).

The energy balance was pretty easy. He saw that I was getting through it just fine, so without asking me to fully simplify, he wanted me to tell him the general form of the differential equation I would get. Dr. Muller cut in real quick, though, to make sure I was doing the energy balance on the cylinder, and not the air around it. I said that the differential equation would be second order with respect to Temperature and first order with respect to Time (remember in this case, the accumulation term did not drop out of the energy balance expression). I was then asked to give the boundary conditions (plus the initial condition for the time analysis--basically at t=0, T = Tinitial). Think about symmetry and also how the heat flux via conduction through the cylinder will equal the heat flux leaving through conduction to the air).

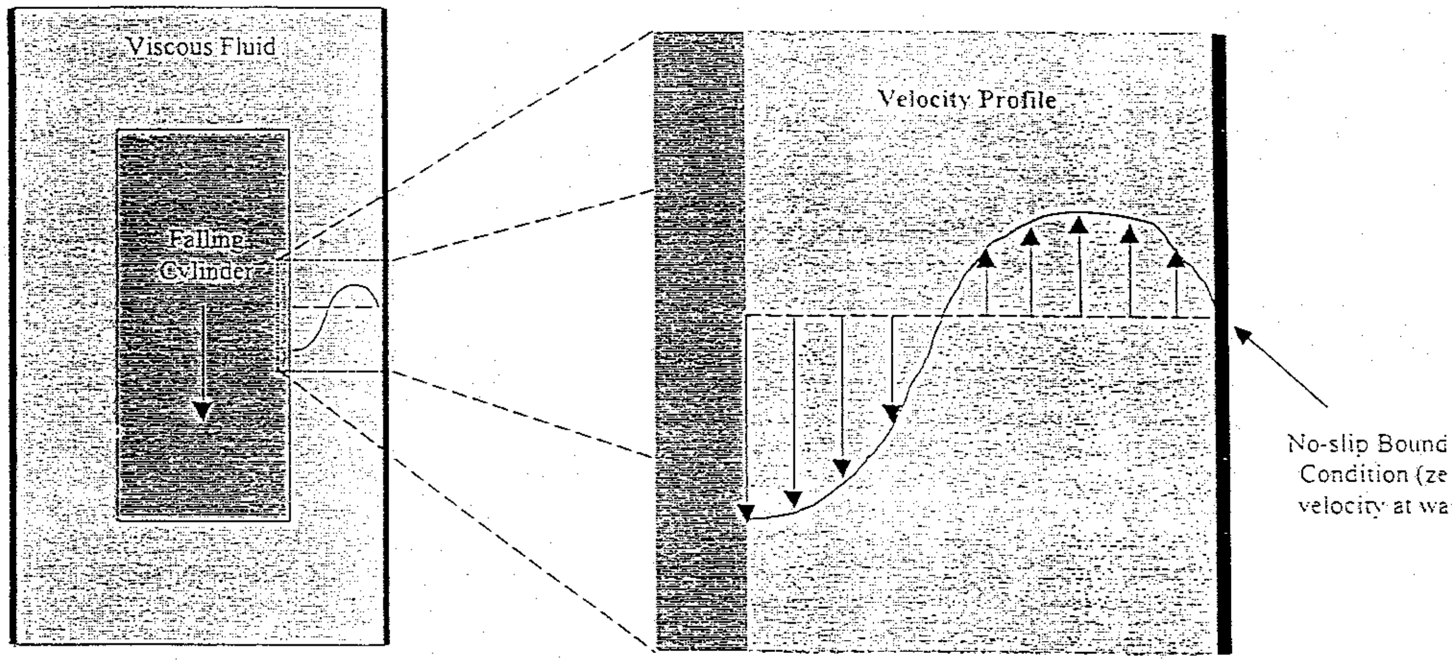
Then there were some questions about the biot number and how I could use it to analytically solve the second order differential equation (low biot number indicates a relatively low internal heat transfer resistance, which means the temperature profile for the cylinder will be relative constant--a high biot number means the conduction resistance is much higher than the convection resistance so there would be a nonconstant T profile in the cylinder as a function of radius, and the temperature difference in the air [convection] is negligible).

Other questions about how to find heat transfer coefficients (Nusselt number/correlations). Also, the difference between situations (taking a shower and cooling off in air)--basically, one is forced convection so Nu is a function of Reynold's # and Prandtl #, and the other is natural convection so Nu would be a function of the Grashof # and the Prandtl #.

So the difference between the two options is in the heat transfer coefficient and also the driving force (the ambient T is used for cooling off in air, while the shower situation uses T of the cold water to calculate delta T in our heat transfer equation).

Muller
This problem is a cylinder falling in a viscous fluid which is contained in an enclosed cylinder. I had to do a momentum shell balance and also a force balance on the system (gravity, drag, pressure, and buoyancy). Similar to the falling sphere viscometer, but the drag force can't be calculated from the drag coefficient correlations (which are given for a sphere)--so we had to think of the problem by thinking about the shear stresses (force per area).

I whipped up a quick second order differential equation, then. I had to give boundary conditions and then come up with a profile for the fluid velocity. Remember that it's an enclosed cylinder so liquid will flow down with the cylinder due to shearing/momentum transfer, but it eventually has to come back up. Also of importance is to remember the no-slip boundary condition. So the final profile looks like this:



Graves and Chakraborty
Graves
Given a cylindrical wire with an electrical current passing through it, derive the energy balance equation. (Solve using a shell energy balance with constant volumetric heating.) The wire is cooled by forced convective heat transfer to the air. How would you measure the heat transfer rate or what is the form of the heat transfer correlation that applies to this situation? (He was looking for the appropriate dimensionless numbers: Nu, Re, Pr). What are the definitions of these numbers?

Chakraborty
You have a planar membrane in which diffusion is taking place. At a certain point in the membrane, the diffusivity changes abruptly. Write and solve the governing equations to find the molar flux through the membrane. (Solved by analogy with heat transfer through a wall with two different thermal conductivities). Sketch the concentration profile through the wall, given the diffusivity through the left side is much lower than the right.

Goren and Muller

When I found out that I had Goren for Transport, I just about died. He wasn't that bad, though. I think the problem with him is that even though he gives hints, he just can't give the hints in a way that you understand them. That was where Dr. Muller was useful. I also think that exuding confidence is a big plus with Goren.

The first question was posed by Dr. Goren. He asked me to show if the diameter of water flowing out of a pipe at the end of a large, tall tank would increase or decrease. So it was a Bernoulli's eq'n problem (don't forget the alpha terms in front of the velocity and know why it's there!) with losses. I was nervous and flubbed things up a bit, but helped me through it to discover my mistakes.

Dr. Muller asked me to find the temperature profile in a rear window defroster if the defroster were modeled as a solid block with uniform heat generation. You needed to know the boundary conditions at both ends (q from conduction through solid equals q convected away at surface). They also asked me about natural convection - indirectly they asked me about the Grashof number. And they asked where I would get the values for h and got me into a discussion about boundary layer thickness and of course, the Prandtl number!

The last question they asked was about a small cylinder falling through a large cylinder with fluid between the two. They wanted the velocity profile. Both cylinders were really long, but remember that there is a back pressure that forces fluid up from the bottom of the cylinder, so the next flow of fluid is zero. I superposed the solutions for pressure driven flow and Couette flow to solve this. Basically lid driven cavity flow cast in a different light.