MAE 222

Mechanics of Fluids

Princeton University

Assignment # 1

February 2, 1998

Due on Wednesday, 2PM, February 11, 1998

- Assignments will be posted on the web, usually by noon each monday. The URL is:
  http://lam95.princeton.edu/mae222.html
  You can download the assignments directly each week right after class.
- The assignments are posted in .pdf file formal. You will need *Acrobat Reader*, available free from Adobe's web page, to decipher the .pdf files. Most university computers should already have Acrobat reader available. If not, click on *Acrobat* on the course web page and follow the instructions.
- I have also set up a MAE 222 newsgroup, called "pu.mae.222". If you are using Netscape, go to the Netscape icon on the menu bar, and select "Collabra Discussion Groups." Go inside "nntpserver.princeton.edu" to subscribe to "pu.mae.222." You are encouraged to ask me questions and give me feedbacks using this newsgroup. I will also use this newsgroup to provide brief clarifications of lectures.
- Additional detailed information about the course can be found on the course web page.

In doing homeworks, do not substitute numbers in your formula until the very last step (whenever that is possible). Formula in symbolic form is much less prone to errors and is much easier to check for correctness.

For the first week, we will cover Chapters 1 and 2 of **Young, Munson and Okiishi** (YMI).

Chapter 1 :

§1.1 We all instinctively know what a fluid is. Air and water immediately come to mind. How about milk? Yes! How about honey? Well, yes. How about tooth paste? Now I am not too sure. For the moment, we will let the pompous definition given by YMI on the bottom of page 1 stand. At the end of the course, we will see whether we can come up with a better definition of what we had been studying.

§1.2 We will use both SI and the British units in this course. It should be obvious to all that if an equation is correct, then each term in the equation must have the same units (you can't add appled and oranges). However, some equations as presented to you can be used in any system of units you may choose, and some equations (as presented to you) are valid only when a specific unit is used. The former is obviously theoretically preferred, but the latter is frequently pragmatically preferred. The latter occurs when some variables in the former formula have been substituted by their numerical values in one specific unit.

§1.3-1.6 These are the major properties of fluids we shall be concerned with: density (mass per unit volume), pressure (normal force per unit area), and viscosity (the Newtonian description of fluid friction). You should know by heart the "order of magnitude" of these properties for air and water. See Table 1.4-1.7 of the inside front cover of YMI. Do you know the relation between the Gas Constant R and the "Universal Gas Constant" and the molecular weight of the gas? If not, ask me in class.

§1.7 Focus your attention only on §1.7.3 where you are told the formula for the speed of sound eq.(1.15). Please note that the speed of sound for a perfect gas is solely a function of the (absolute) temperature of the gas.

§1.8-1.9 Just scan these sections. This course does not emphasize these topics.

- Problem 1.5,
- Problem 1.7,

- Problem 1.15 (an estimate is a good estimate when you are "in the ball park."),
- Problem 1.29, (you know the definition of viscosity eq.(1.8), and you can compute du/dy and evaluate it at $y = 0$).
- Problem 1.42, (if you inhale helium (don't do it) then try to talk, you will sound funny).

Chapter 2 : Fluid Statics. This is a course in *fluid dynamics*, but we will get started by first consider the simple case when the fluid is not moving at all. Fluid statics is also called *hydrostatics*.

§2.1 This is to convince you that *pressure is a scalar*. It is represented by a number, and *not* a vector. This is called *Pascal's Law*.

§2.2-2.3 Eq.(2.2) gives us Newton's law for fluid dynamics. What is $\mathbf{a}$? It is the "acceleration" of a glob of fluid. When the glob of fluid is at rest, we have $\mathbf{a} = 0$, and eq.(2.4) is the governing equation for pressure in hydrostatics ($\gamma \equiv \rho g$). If density is constant, we have eq.(2.8) where h is vertical distance from a reference "altitude," its positive direction is downward.

§2.4 Appendix C has the standard atmosphere. Note that the pressure at about 20,000 ft is about half an atmosphere. So, if you are dealing with problems which vertical extent is a few tens of feet, we can say "the air pressure is a constant" with good justification for this approximation.

§2.5-2.6 When the specific weight γ is a constant as is the case of a manometer, Eq.(2.8) is all you need.

§2.7 Just scan this section.

§2.8-2.9 If you have a plane surface under water, how much (normal) force is being exerted by the water on the surface? This is just an excercise in multi-variable integration. §2.9 just shows you what you are integrating to obtain is just the volume of the "pressure prism."

§2.10 What happens if the surface in contact with water is curved? The force (vector) experienced by the curved surface must be computed one component at a time, that is all! You just need to be careful with your trigonometry and geometry. (The unit normal **n** of a surface element, and the "dot" product of two vectors, are useful tools which you must master) In general, the calculation is usually messy but straightforward (examples in homework use only simple geometries to reduce the messiness). Remember, whenever you see a frictionless hinge, the *moment* about the hinge is zero.

§2.11 Archemedes Principle comes to the rescue! We will see in class that Archemedes Principle (and an elegant trick to be given in class) can greatly simplified the calculation of the total vertical force vector on some curved surfaces (It does not provide help in problems involving frictionless hinges). Watch for this is the lecture. Scan the interesting stability section.

§2.12 If the fluid is in rigid-body rotation, then **a** is known. The static pressure distribution is then easily calculated.

- 2.13 (you may assume that the static pressure distribution in the space filled with air is constant. However, the static pressure distribution in the water is *not* a constant),
- Problem 2.30 (the force exerted by the water is resisted by P *and* by the hinge. Since the hinge is frictionless, the moment about the hinge must be zero. This determines P),
- 2.44 No hinge here. (Archemedes is at your service! So is my elegant trick),
- Problem 2.46 (this one you have to do the moment integration in details. Note the force exerted by the water on the curved surface is always "radial." Use polar coordinates, and integrate over θ to get the moment exerted by the water about the hinge).

I believe the homework load is reasonable. Let me know if I erred.