CENG101A: Introductory Fluid Mechanics Fall Quarter 2006
http://maecourses.ucsd.edu/mae210a

Homework I.

Due *Friday September 29, 2006*, in fourth hour.

Read Chapters 1 and 2.

Problems:

1. Discuss how you might test whether a substance is a fluid. Is toothpaste a fluid? Shampoo? I said that glass was not a fluid in class. Find a reference on the Internet discussing this. Do you agree? (Just a few lines.)

2. In two (three) dimensions, which radially (spherically) symmetric fields have vanishing Laplacian?

3. The Stefan–Boltzmann law takes the form $E = \sigma T^4$, where $\sigma = 5.676 \times 10^{-8}$ W m^{-2} K^4. If T is temperature in K, what are the units of E, and so what kind of quantity is E? Calculate σ in Btu hr^{-1} ft^2 $^\circ$R^4.

4. At sea level, take atmospheric pressure to be 100 kPa and the temperature to be 20°C; assume air satisfies the ideal gas law. What is the pressure at the top of Mount Everest ($8,848$ m) if air is assumed to have uniform density? What is the pressure at the top if the air is assumed to have uniform temperature? Which result is more realistic? [You will need the universal gas constant $R = 8.3144$ J mol^{-1} K^{-1} and the molar mass of air $m = 29$ g mol^{-1}.]

5. Calculate the surface integral $\rho \int (0, 0, -g)\, \mathrm{d}S$ over the surface of SSN-21 USS Seawolf. Be clear about the nature of your result (units, type of quantity). [Hint: Gauss and Eureka. The vessel's displacement is 7,800 tons.]

Comments:

Chapter 1 is a short introduction to the study of fluids. *Continuum mechanics* (the study of deformable media such as fluids and elastic solids) requires the definition of properties at a point in the medium. Describing the variation of properties in different locations of a fluid requires using scalar and vector fields, i.e. **vector calculus**. Take the time now to review vector calculus.

An important idea is that the usual conservation laws of physics – conservation of mass, momentum and energy – are the governing equations of fluid mechanics, as will be discussed in Chapters 4–6. The added intricacy of fluid mechanics comes from describing fluid motion, as we shall see in Chapter 3.

In addition, we need a constitutive equation for a fluid and sometimes an equation of state. This will be discussed in Chapter 7. The relevant equation (7-4) is a mathematical description of the definition of a fluid – **a substance that deforms continuously when acted on by a shear stress** – for Newtonian fluids. Shear stress is a force per unit area, like pressure, but it acts parallel to the surface in the direction of fluid motion.

The notion of dimensional consistency is extremely important in continuum mechanics. We shall cover dimensions more thoroughly in Chapter 11.

Chapter 2 deals with static fluids when there are only two forces: gravity and pressure. The fluid is static so there is no velocity and hence no viscous shear forces. The important result (2-2) is Newton's law written 'per unit volume'. You should be clear that the pressure force ∇p is a force/unit volume. For static fluids $\mathbf{a} = 0$, and pressure increases in the direction of the vector gravity $\mathbf{g}$. The buoyancy force is not a new force, but simply the net pressure force of surrounding fluid on a body. Usually, pressure increases downward, so there is a greater pressure on the lower part of a body than on the upper, giving a net force upward.