Our Mantra, "Fluid Mechanics is **Fun** (and all around us)!"

Course Mechanics

Information will be disseminated primarily via the website:

http://ceeserver.cee.cornell.edu/eac20/cee331

It is dynamic but it is my best estimate of where we will be when. I will make every effort to link the lecture notes for the upcoming lecture to the syllabus by the evening before the lecture, if not earlier, and you are encouraged to look the notes over in advance of the lecture! All homework and laboratory assignments will be posted to the syllabus well before the due date. Solutions to homework, sample problems, and sample prelims and finals will also be made available through the course website. I will likely use the web site to make data available that you might need for the occasional homework problem as well.

I have set up a twitter page – **@CEE3310** – feel free to follow @CEE3310 and I will notify you every time I update anything on the course website, return graded homework, post a lab sign-up google doc, or other information that is relevant. Don't worry if you are not a twitter user - nothing essential will be sent out via twitter but if you want to know exactly when things become available I will try to remember to update @CEE3310. The twitter feed shows up on the course website so if you are not a twitter user but want to see what is being posted feel free to check in there periodically. Like I said, nothing essential will be posted there.

I also have a simple blog page on tumblr to answer general questions. No promises that this will be used extensively - it depends a bit on you all adopting it by submitting questions or comments on this page:

http://cee3310.tumblr.com

The course will be comprised of the following components:

- Lecture – a hardcopy of my typeset lecture notes will be available for pick-up as you walk into the lecture hall. I will hand out notes for several lectures at a time so bring your current set of notes to class if we have not finished discussing the material contained in them. If you miss a lecture where notes were handed out go to the online syllabus and download the lecture notes. You may want to consult with a classmate about figures and diagrams that are typically given only on the board in class.

- Text – the course textbook is Frank M. White (2011). *Fluid Mechanics, 7th Edition.* The McGraw-Hill Companies. I'm really frustrated at the pricing of this book as its cost has doubled over the past few years. The newest version (8th Edition) is $284.25 at the Cornell Bookstore new and $213.25 used! I do not feel the value proposition for the 8th edition makes sense. This year I will continue to use the 7th edition. There are used copies available online for under $50 at Amazon and elsewhere. I have requested 2 copies be placed on reserve at Uris.

  The textbook is intended to augment my lectures and lecture notes. My typeset lecture notes are the primary source of information and they will be made available in class and as a PDF on the course webpage. The textbook is a valuable way to get a different explanation of the same concept. It will be assumed that you **HAVE READ** the sections of the textbook indicated by the lecture as indicated on the syllabus. You are welcome to use an older edition or even the 8th edition if the price does not scare you off. I will assign problems from the 7th edition and it will be your responsibility to track them down - Uris Library Reserve is always an option.

  Note: You are welcome to work from the electronic version but you can not use any device that can display an electronic edition during the exams. The exams are open book so if you want to have access to a book this will be your responsibility. Older versions would be fine for this. I do bring extra textbooks to exams so an electronic edition is a

viable options.

- Section – led by the Teaching Assistants, Gustavo Rivera-Rosario and Katie Adler. Note your registered lab section is your recitation section, labs will be signed up for individually using Google Docs and optionally in coordination with your teams (see below) or another group of students with which you wish to work.

- Assignments – You will be placed into teams of 3 and perform the problem sets as a team. There will be 11 assignments with tentative due dates already posted on the syllabus. You will complete these assignments as a team handing in one assignment per team. Details on team policies as well as expectations can be found on the web site. It is critical that each team member contribute to the team and understand each problem. It will be obvious if this is not the case come the examinations. Also, I will ask each of you to grade the participation of your team members as part of both prelims and the final and will use this performance grades as a factor in determining final grades near boundaries.

- Labs – There be no lab report due for all but the final lab. You will be required to demonstrate to the TAs that you have performed the lab and at minimum achieved the goals we've set for you via an oral check-out. The final will involve some post-processing of your data and a **brief** lab report. The concept behind the labs is that they are hands-on and give you a chance to see and measure real fluid flows giving you insight into the analytic work we do in class with physical examples. The goal of the check-out with the TAs will simply be to convince us that you have understood the key points. You will be responsible for selecting a time to perform the labs and you may opt to perform the labs with your team or with any other CEE 3310 students you choose. You cannot do the labs alone. An electronic sign-up sheet will be made available in Google Docs for the selection of lab times. The TAs will be available to assist you but it is expected that you will cary out the labs yourselves - the TAs or myself are there to get you across any hurdles you encounter, but it is your hands that should get dirty! You are welcome (and encouraged) to use the labs as a chance to play with fluids beyond the parameters we set for you in the assignment. They are meant to be fun and a chance to explore on your own!

- Preliminary Exams – There will be two evening preliminary exams each 7:30 - 9:00 pm on Thursday evening September 28 and Tuesday evening November 7 as shown on the syllabus. Please contact me as soon as possible if you have a valid conflict with the exam times. We will use the lecture prior to each exam as a review section.
- Final Exam – The final exam for this course is scheduled for Saturday December 9 from 2:00-4:30 pm.

Grades

- Problem sets: 20% (We will drop the lowest grade so problem sets each count 2% of your total grade)
- Laboratory assignments: 10%
- Prelim 1: 20%
- Prelim 2: 20%
- Final: 30%

Chapter 1

An Introduction to Fluids

1.1 What is a Fluid?

A solid resists shear stress by deforming statically.

A fluid is a substance that ____

1.2 What distinguishes a liquid from a gas?

1.2.1 The Continuum Hypothesis

Fluids are composed of molecules. At the molecular scale the particles are colliding. Hence we have trillions and trillions of particle-particle interactions, this is too cumbersome to deal with tractably.

$$\rho = \text{density} = \frac{\text{mass}}{\text{volume}} = \frac{M}{\forall}$$

$$\rho_A = \frac{4M}{\forall_A} < \rho_B = \frac{4M}{\forall_B}$$

Therefore, we must let the volume be large enough that $\rho \neq f(\text{volume})$

1.3 Dimensions

Dimensions represent classes of units we use to describe a physical quantity. Most fluid problems involve four primary dimensions

- Mass [M]
- Length [L]
- Time [T]
- Temperature [Θ]

For example velocity has the dimensions of LT^{-1}.

1.3.1 Dimensional Consistency

An equation is said to be *homogeneous* or *dimensionally consistent* if every term in the equation has the same dimensions. An example from physics:

$$z = z_o + w_o t + \frac{g}{2} t^2$$

where z is the vertical position, z_o is the initial position, w_o is the initial vertical velocity, g is the acceleration of gravity, and t is time. Let's check the dimensions:

$$
\begin{aligned}
[\mathrm{L}] &= [\mathrm{L}] + \left[\frac{\mathrm{L}}{\mathrm{T}}\right] \cdot [\mathrm{T}] + \left[\frac{\mathrm{L}}{\mathrm{T}^2}\right] \cdot \left[\mathrm{T}^2\right] \\
[\mathrm{L}] &= [\mathrm{L}] + [\mathrm{L}] + [\mathrm{L}]
\end{aligned}
$$

It checks out!

Any equation derived from first principles (e.g., based on physics) will be dimensionally consistent. While this is a necessary condition for an equation to be descriptive of fundamental physics it is not sufficient! Equations that are inhomogeneous are often the results of observed trends in data records. For example, the U.S. Geological Survey infers stream flow by measuring the depth of the flow at a point (known as the stage height). They then fit the data to

$$Q = \alpha h^m$$

where Q is the flow rate ($[\mathrm{L}^3/\mathrm{T}]$), h is the stage height ($[\mathrm{L}]$), and m and α are constants. Clearly this is a dimensionally inconsistent equation.

An Example for you to try:

Manning's Equation

$$U = \frac{C_1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

where

$$
\begin{aligned}
U &= \text{is the mean velocity} \\
R &= \frac{\text{wetted area}}{\text{wetted perimeter}} \\
S &= \text{slope of the river} = \tan\alpha \\
n &= \text{Manning's } n \text{ - a dimensionless roughness coefficient}
\end{aligned}
$$

What are the units of the constant, C_1?

Can Manning's equation capture a fundamental physical process?

1.3.2 System of Units

Units are the bane of the United States! Remember the NASA Mars Climate Orbiter?! In September 1999 we lost a $330,000,000 investment because a subcontractor to NASA was working in English units while NASA had converted to metric units in 1990. Corrections to the flight trajectory were input in British Gravitational units (lbf) while the thrusters were designed to accept commands in SI unites (N). The spacecraft encountered Mars at too low an altitude ending up in the upper atmosphere where it experienced too much drag (fluid mechanics!) and it burnt up! The good news is that just a few weeks ago (August 5, 2012) the rover Curiosity landed successfully!

A system of units is a particular method of attaching a number to a dimension. A major source of calculation error is units errors $\Rightarrow$ **check your units!** Use your engineering common sense, you should always have a rough estimate of the answer you expect, at least to an order of magnitude. If the answer is outside this range there is a good chance you have made a units error.

British Gravitational (BG)

- Length [L] $\sim$ foot
- Mass [M] $\sim$ slug; $F = ma \quad \Rightarrow \quad 1 \text{ lbs} = 1 \text{ slug} \cdot 1 \text{ ft/s}^2$
- Time [T] $\sim$ second
- Temperature [Θ] $\sim$°R (degrees Rankine — absolute temperature scale)=°F+459.67

International System (SI)

- Length [L] $\sim$ meter
- Mass [M] $\sim$ kilogram; $F = ma \quad \Rightarrow \quad 1 \text{ Newton} = 1 \text{ kg} \cdot 1 \text{ m/s}^2$
- Time [T] $\sim$ second

- Temperature [Θ] K (Kelvin — absolute temperature scale)=°C+273.15

Manning's equation units: $C_1 = 1.00\ \mathrm{m}^{\frac{1}{3}} s^{-1}$, what is it in B.G.?