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

You can get there easily from the courses link on the CEE school home page:

www.cee.cornell.edu

Simply click ‘courses’ and select CEE 3310. The syllabus for the course can be found on the web. 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.

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 (2006). Fluid Mechanics, 6th Edition. The McGraw-Hill Companies. You will be expected to HAVE READ the sections of the text indicated by the lecture indicated on the syllabus.
• Section – lead by the Teaching Assistants, Blair Johnson and Amandeep (Aman) Singh. Note your registered lab section is your recitation section, labs will be signed up for individually based on your schedule in coordinate with your teams (see below) using Google Docs.

• Labs – You will be placed into teams of 3 and perform the labs as a team. There will in general be no lab report due but 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. 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 as a group. 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 carry 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!

• Assignments – There will be 11 assignments with tentative due dates already posted on the syllabus. You will complete these assignments as a team (the same teams you perform the labs in) 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 is 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.

• Preliminary Exams – There will be two evening preliminary exams each 7:30 - 9:00
on Thursday evenings September 30 and November 4 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 – there is a regularly scheduled final for this course on Monday December 13 from 9:00 - 11:30 as shown on the syllabus.

We will form the teams by no later than 8:00 am Monday, August 30 so you can check for your team members before class. I have posted a team formation survey on the web with a link from the syllabus. If you pre-registered for the course you should have received an email from me with a link to the survey. It is imperative that you fill out this survey by Friday evening or we will not be able to place you into an optimal team. The first problem set will be posted, along with the teams, by Monday and will be due the following Tuesday, September 8, by 4 pm. Assignments are to be handed into the assignment box in Hollister 220.

Grades

• Problem sets: 20%
• Laboratory assignments: 10%
• Prelim 1: 19%
• Prelim 2: 19%
• Final: 32%
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.

\[ \rho = \text{density} = \frac{\text{mass}}{\text{volume}} = \frac{M}{V} \]

\[ \rho_A = \frac{4M}{V_A} < \rho_B = \frac{4M}{V_B} \]
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 \([\text{M}]\)
- Length \([\text{L}]\)
- Time \([\text{T}]\)
- Temperature \([\Theta]\)

For example velocity has the dimensions of \(\text{LT}^{-1}\).

#### 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:
\[ [L] = [L] + \left[ \frac{L}{T} \right] \cdot [T] + \left[ \frac{L}{T^2} \right] \cdot [T^2] \]

\[ [L] = [L] + [L] + [L] \]

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 ([L^3/T]), \( h \) is the stage height ([L]), and \( m \) and \( \alpha \) 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

\[ U = \text{is the mean velocity} \]
\[ R = \frac{\text{wetted area}}{\text{wetted perimeter}} \]
\[ S = \text{slope of the river} = \tan \alpha \]
\[ n = \text{Manning’s } n - \text{a dimensionless roughness coefficient} \]

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 Jet Propulsion Lab (JPL) satellite disaster?! In September 1999 we lost a $125,000,000 Mars Orbiter because a subcontractor to NASA was working in English units while NASA had converted to metric units in 1990.

A system of units is a particular method of attaching a number to a dimension. A major source of calculation error is units errors ⇒ 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] ∼ foot
  - Mass [M] ∼ slug; $F = ma$ ⇒ 1 lbs = 1 slug · 1 ft/s²
- Time [T] ∼ second
- Temperature $[\Theta]$ ∼°R (degrees Rankine — absolute temperature scale) = °F + 459.67

International System (SI)

- Length [L] ∼ meter
  - Mass [M] ∼ kilogram; $F = ma$ ⇒ 1 Newton = 1 kg · 1 m/s²
- Time [T] ∼ second
- Temperature $[\Theta]$ K (Kelvin — absolute temperature scale) = °C + 273.15
Manning’s equation units: $C_1 = 1.00 \text{ m}^{\frac{1}{3}}\text{s}^{-1}$, what is it in B.G.?