Why study fluid mechanics?

- It's required for my degree (too literal)
- Fluids are involved in engineering systems
  (engineering systems can be operated and maintained and sometimes designed without detailed mathematical analysis)
Why study fluid mechanics?

• Modern engineering systems are complex and often cannot be operated and maintained without analytical understanding.

• Design of new systems will come from high-tech innovation, which can only come from detailed, analytical understanding of how physics/nature works.
Artificial Heart

Microfluidics – Lab on a Chip

An example of a passive mixer in which fluids are mixed by chaotic advection. (Courtesy of Micronit Microfluidics.)
Centrifugal Pump

How much work it does at a fixed RPM depends on how much work it is asked to do.

\[
H_{2,1} = H_{d,s}
\]

We use macroscopic analysis when we can (simpler); microscopic analysis when details are needed.

Data correlations to match the two.
What kinds of complex phenomena are seen?

Flow around complex obstacles

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Flow around a wing


Effect of flow rate on flow around a cylinder

Source: Young, et al., A Brief Introduction to Fluid Mechanics, Wiley 1997
Effect of angle of attack on flow around an airfoil


Section 1: Quick Start

What do we bring to the study of fluid mechanics?

1. Experience with water, air, household fluids
2. Mechanical energy balance (from CM2120)
3. Mass and energy balance (from CM2110)
4. Math and physics background
   - Algebra – MA1032
   - Calculus – integrals, derivatives – MA1160, MA2160
   - Vectors – MA2160, MA3160
   - Linear algebra – MA2321
   - Differential equations – MA3521
   - Newton's laws of motion (PH1100, PH2100)
Quick Start A): The Mechanical Energy Balance

An energy (not momentum) balance that applies under very narrow (but common) circumstances:

\[
\frac{\Delta p}{\rho} + \frac{\Delta \langle v \rangle^2}{2\alpha} + g\Delta z + F = \frac{W_{s,\text{in}}}{m}
\]

\[
\frac{p_2 - p_1}{\rho} + \frac{(v_2^2 - v_1^2)}{2\alpha} + g(z_2 - z_1) + F_{21} = \frac{W_{s,\text{out},21}}{m}
\]

1. single-input, single output
2. Steady state
3. Constant density (incompressible fluid)
4. Temperature approximately constant
5. No phase change, no chemical rxn
6. Insignificant amounts of heat transferred

EXAMPLE 1.4 Water drains from a tank as shown in Figure 1.15. The level of the water in the tank is maintained at a constant height through control of the flow in the overhead pipe. What is the drain flow rate in terms of the height of the fluid in the tank?
EXAMPLE 1.5 Water is siphoned from a tank as shown in Figure 1.14. What is the flow rate of the water in the siphon tube (inner diameter = 1.5 cm)? What is the limit in the height that the siphon can overcome?

- When the pressure reduces to the vapor pressure of the liquid, boiling occurs.
- When the pressure is less than or equal to the vapor pressure of the liquid, the fluid breaks, the siphon fails.
- When the pressure is equal to the vapor pressure of the liquid, the fluid boils.
- When the pressure is greater than the vapor pressure of the liquid, the siphon functions normally.
Example 1.7: A tropical town is located next to a 40-m waterfall in a river that has a 1,000 m³/s average volumetric flow rate during rainy season and an average flow of 300 m³/s during dry season. What is the maximum amount of hydroelectric power that could be produced by this waterfall? If operating a laptop computer consumes approximately 30 W, estimate the number of computers that the waterfall could run.