Lecture 3

Fluid Dynamics

4/25/25
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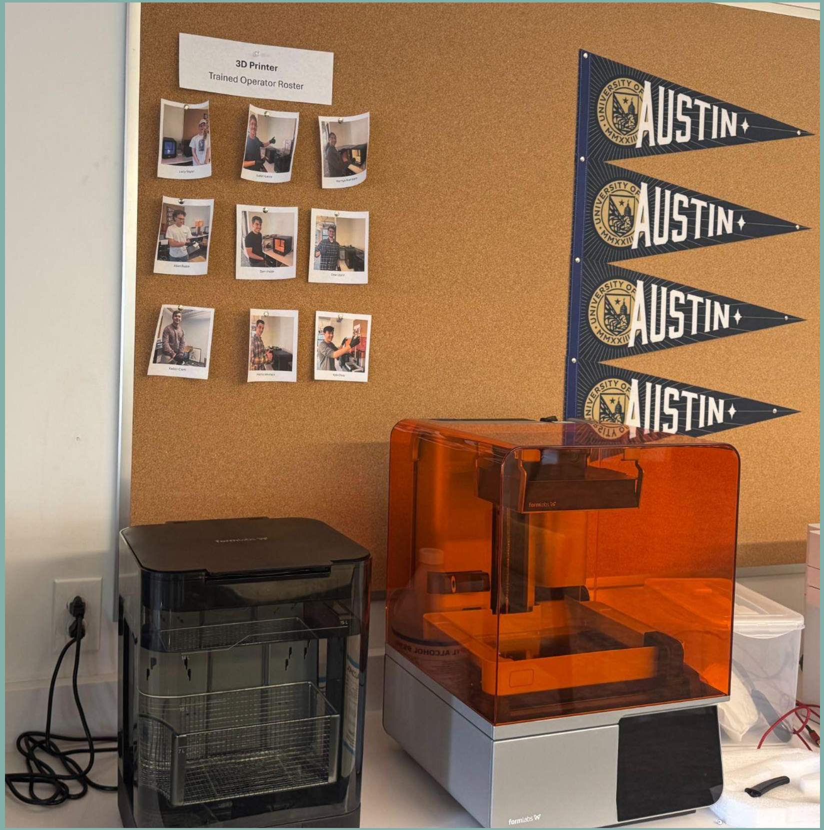
University of Austin (UATX)

Form 4 printer training



Updates

1. There is a black pad that can be used as a build platform cleaning station
2. IPA squirt bottle is available
3. Let me know if we are running low on any materials over email
4. Google calendar for printer booking
5. Weekends?
6. Emergency contact info

Agenda

1. Concepts in Fluid Dynamics
2. Fluids on the ISS
3. Redesigned Fluid Systems
4. CAD Sandbox

Hydrostatic Pressure

Hydrostatic pressure is the pressure exerted by a fluid at rest that arises solely from the fluid's own weight acting along the local gravity vector.

For a uniform-density fluid on Earth, the magnitude at a depth h measured downward from a free surface is:

$$p = p_{\text{surface}} + \rho g h$$

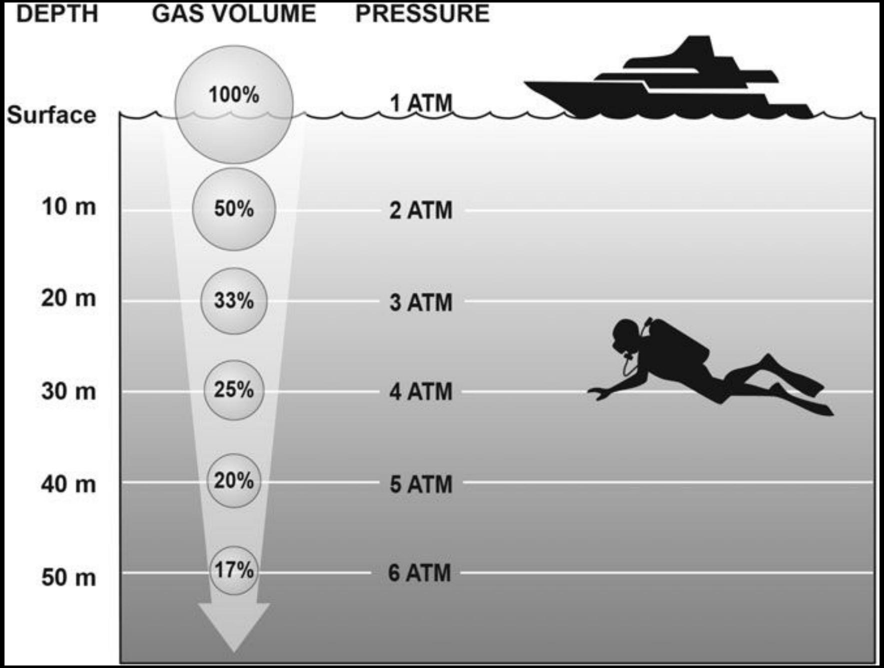
- p_{surface} is the pressure at the reference surface (often atmospheric pressure)
- ρ is the fluid's density, and
- g is the local gravitational acceleration.

Hydrostatic Pressure on Earth

It depends only on **depth** (distance along g), not on the container's shape or cross-section.

It produces the vertical pressure gradient **$\nabla p = \rho g$** that supports buoyancy and drives phenomena like convection.

Example: Scuba Diving. Limitations/restrictions on depth humans can dive due to how hydrostatic pressure changes gas dynamics in the body.



Mallen *et al.* (2019)

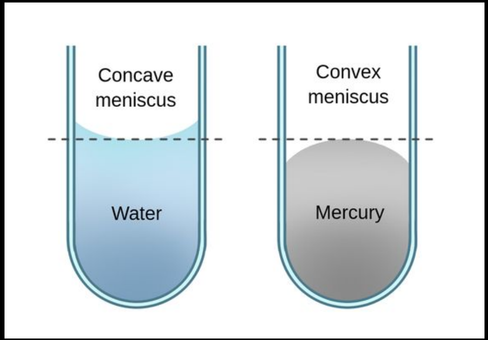
Turning the Gravity Knob Down

Environment	Effective g	Resulting pressure gradient	Consequence
Earth	$9.81\ m\ s^{-2}$	$\rho\ g\ h$	Strong buoyancy, convection.
Moon	$1.62\ m\ s^{-2}$	~1/6 Earth's gradient	Buoyancy weak; fluids still "fall," but sluggishly
ISS orbit	$\ll 10^{-3}\ m\ s^{-2}$ ("micro-g")	Negligible	No buoyancy, no "up," liquids cling to walls

In microgravity, $g \approx 0g \Rightarrow$ the hydrostatic pressure gradient effectively vanishes

Surface Tension and Capillary Action

Earth-gravity	Microgravity
Surface tension shapes menisci only in small-scale systems; on larger scales gravity flattens the interface.	**Surface tension becomes the dominant shaping force.** Capillary action can draw fluids meters through tubes and across corners; interfaces seek minimum-energy shapes (spheres, catenoids).



Bond Number

A dimensionless quantity that compares the body force due to gravity to the surface-tension force acting on a fluid interface:

$$\boxed{Bo = \frac{\rho\, g\, L^2}{\sigma}}$$

Symbol	Meaning
ρ	Density difference between the two adjoining fluids (e.g., liquid–gas)
g	Magnitude of the gravitational acceleration vector
L	Characteristic length scale of the system (drop radius, capillary diameter, etc.)
σ	Interfacial (surface) tension between the fluids

Bo ≪ 1 → Surface-tension forces dominate; the interface seeks minimum-energy shapes (spheres, capillary menisci).

Bo ≫ 1 → Gravity dominates; the interface is flattened or distorted by hydrostatic pressure differences.

Fluid Behavior in Space

Surface Tension

Containment of Fluid Experiments

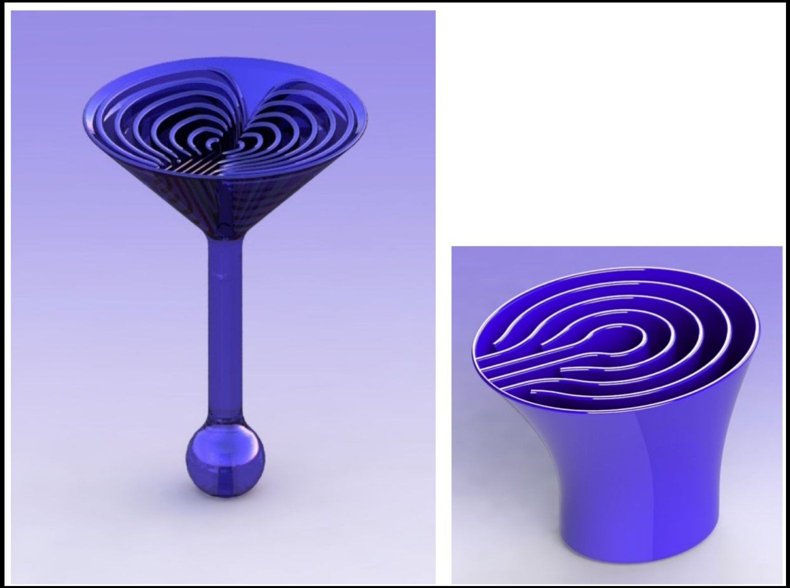
Cola Wars: Soda in Space

Cola Wars: Soda in Space

Fluid Container: Coffee Cups

Fluid Container: Coffee Cups

Fluid Container: Martini Glass



Cosmic Lifestyle Corp

Fluid Manipulation: Serving Champagne

Unpublished Images/Videos

CAD Software Sandbox

Recommended Software: OnShape
https://www.onshape.com/en/

Instructions

1) Open the test tube file.
2) Experiment with different ways to modify the shape of the tube.
   a) Ex: Can you make the tube rectangular?
   b) Ex: Can you add ridges to the inside?