OPTIONAL FLUIDS APPLICATIONS & EXTRA PRACTICE

Optional Practice: Use this handout only if the class has extra time after the four-day fluids arc, or assign selected problems as enrichment/review.

Warmup: The Curious Straw

When you blow across the top of a straw in a glass of water, the water rises and mists into the air. Why doesn't the water simply stay still? What principle explains this?

THE VENTURI EFFECT

Along one steady, ideal streamline at the same height, faster flow means lower pressure.

From Bernoulli's equation, if kinetic energy increases, pressure energy must decrease. Applications:

- **Atomizers:** Fast air flow → low pressure → liquid drawn up and misted
- **Carburetors:** Air accelerates through a narrow throat, drawing fuel from the reservoir
- **Prairie dog burrows:** Wind across multiple openings creates pressure differences that provide ventilation

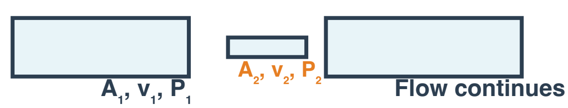
WE DO Narrowing Pipe with Continuity & Bernoulli

A horizontal pipe narrows from A_1 = 0.040 m² to A_2 = 0.010 m². Water enters at v_1 = 2.0 m/s and P_1 = 200,000 Pa. (a) Find v_2 using continuity. (b) Find P_2 using Bernoulli (ρ = 1000 kg/m³). (c) Where is pressure lowest?

(a) v_2 = ?

(b) P_2 = ?

(c) Explanation:



AIRPLANE WINGS & PITOT TUBES

LIFT ON AIRPLANE WINGS

$\Delta P = P_{bottom} - P_{top} = \frac{1}{2}\rho(v_{top}^2 - v_{bottom}^2)$; Lift $\approx \Delta P \times A$

Real wings are not explained by applying Bernoulli across the top and bottom as if they were one streamline. A better picture: streamlines curve over the upper surface, so fluid parcels need centripetal force. That force comes from a pressure gradient, with lower pressure closer to the upper surface.

WE DO Wing Lift: Naive Model vs Mechanism

An airplane wing has area 30 m². Air speeds measured near the surfaces are v_{top} = 60 m/s and v_{bottom} = 50 m/s. ρ_{air} = 1.2 kg/m³.

(a) Naively compute $\Delta P = P_{bottom} - P_{top}$ as if the two measurements were on one streamline.

(b) Find $F_{lift} = \Delta P \times A$, then explain why the calculation is useful but physically suspect.

(c) Use streamline curvature to explain the actual pressure gradient near the top surface.

YOU DO Pitot Tube Airspeed

A pitot tube on an aircraft measures dynamic pressure: $\frac{1}{2}\rho v^2$ = 3600 Pa. If ρ_air = 1.2 kg/m³, find the airspeed v.

Pitot Tubes: Measure airspeed by comparing stagnation pressure (where air stops) to static pressure. The difference is dynamic pressure = $\frac{1}{2}\rho v^2$.

MULTI-CONCEPT SYNTHESIS PROBLEMS

SKILL Problem 1: Submarine at Depth

A submarine has a steel hull (ρ_steel = 7800 kg/m³, but assume only 1 m³ is steel) and an air-filled interior (total volume 2000 m³). It's submerged at depth h = 200 m in seawater (ρ_sea = 1025 kg/m³).

(a) Pressure at the viewport: Find absolute pressure at 200 m depth.

(b) Force on viewport: A viewport has area A = 0.05 m². Find the inward force due to gauge pressure.

(c) Buoyancy check: Find the buoyant force ($F\_b = \rho\_water \times V\_total \times g$). Compare to weight of submarine. Is it sinking or neutrally buoyant? (Assume submarine mass = 1,550,000 kg)

SKILL Problem 2: Uphill Water Flow with Bernoulli

Water flows upward through a pipe from ground level to a height h = 10 m. At ground level: A_1 = 0.02 m², v_1 = 3.0 m/s, P_1 = 300,000 Pa. At the top: A_2 = 0.01 m². Find v_2 and P_2. (ρ = 1000 kg/m³)

(a) v_2 from continuity:

(b) P_2 from Bernoulli ($P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$):

EXIT TICKET

EXIT Garden Hose: Speed & Height

Hose d_1 = 2.0 cm → nozzle d_2 = 0.50 cm, v_1 = 1.5 m/s. (a) Find v_2 (continuity). (b) Max height pointed up?

HOMEWORK PROBLEMS

[1] Blood Flow in Arteries

Plaque narrows an artery from 4.0 mm to 2.0 mm diameter. Blood flows at 30 cm/s in the wide section. Find speed in the narrow section (continuity).

[2] Hot Air Balloon

Balloon volume 2800 m^3, ρ_inside = 0.95 kg/m^3, ρ_outside = 1.2 kg/m^3, mass = 400 kg. Find net lift and max payload.

[3] Torricelli's Law

Water tank 1.6 m tall, hole at bottom. Exit speed $v = \sqrt{(2gh)}$. Find v and max horizontal distance (45°).

Quiz next class covers Days 1–4: density, pressure, buoyancy, continuity, Bernoulli, and Torricelli.