Course announcement

- Homework set 4 has been posted on eLearn. It will be due on 12/2 Friday at 5PM.
- Final check of your grade of the first midterm (Posted on eLearn).
- The second midterm will on 12/6 (Tuesday). Range: from chapter 9 to chapter 15 of Wolfson (skip chapter 12). Exam will be started 8:00AM. Please bring student ID and calculator. You can bring one A4 information sheet for the exam.

Midterm Exam 1 Final Score

- Midterm Exam Final Score
- Midterm 1_finale score_final check

11	11/22(Tue.)	**Oscillation and Waves:** propagation of waves
11	11/25(Fri.)	**Fluid Motion:** Density, Pressure, and Hydrostatic Equilibrium (Homework4)
12	11/29(Tue.)	**Fluid Motion:** Fluid Dynamics and Application
12	12/2(Fri.)	**Review II**
13	12/6(Tue.)	Mid Term 2

GENERAL PHYSICS B1
FLUID MOTION

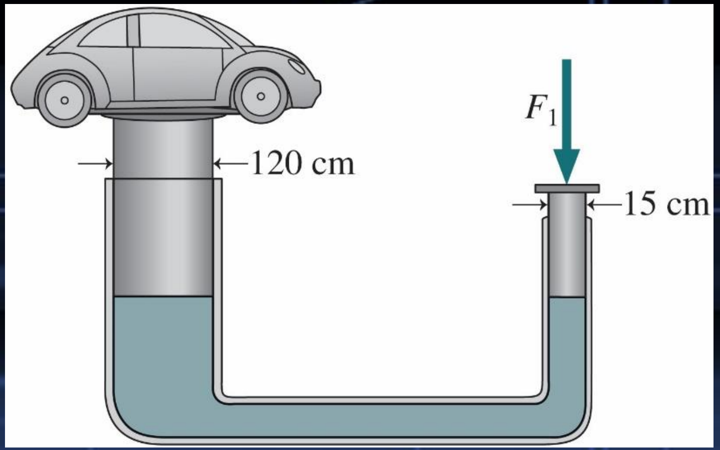
Hydrostatic equilibrium and fluid dynamics
2022/11/29

Pascal's Law

- A pressure increase anywhere is felt through out the fluid: Pascal's law.
- Pascal's law's application: hydraulic press.
- Example: lift a car with hydraulic press as shown

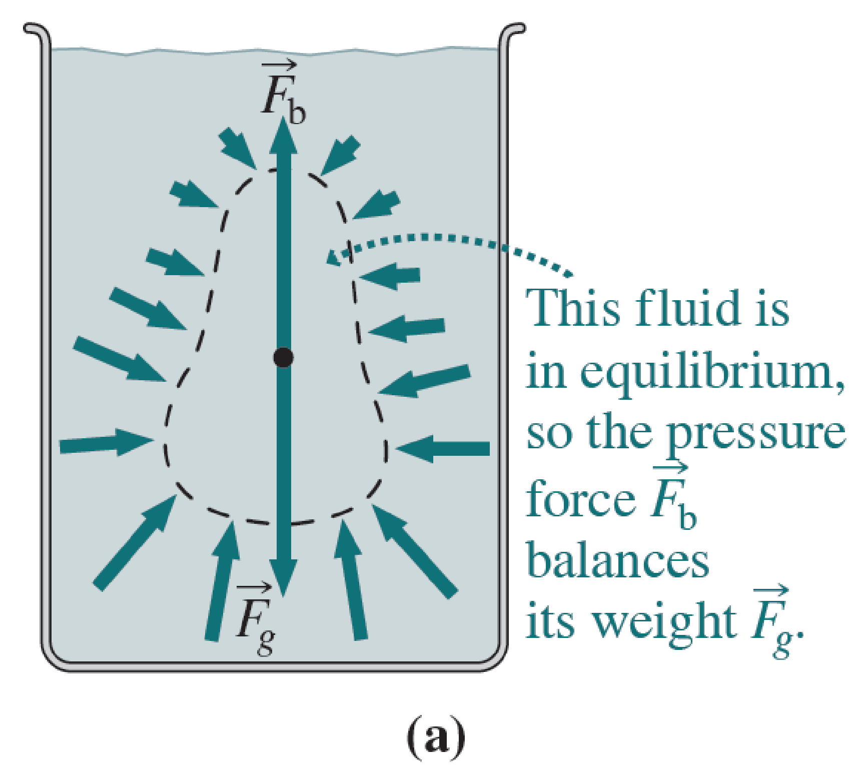
$$m_{car}g = p\pi(60)^2 = \frac{F_1}{\pi(7.5)^2}\pi(60)^2$$

- Thus: $F_1 = \frac{m_{car}g}{\boxed{64}}$



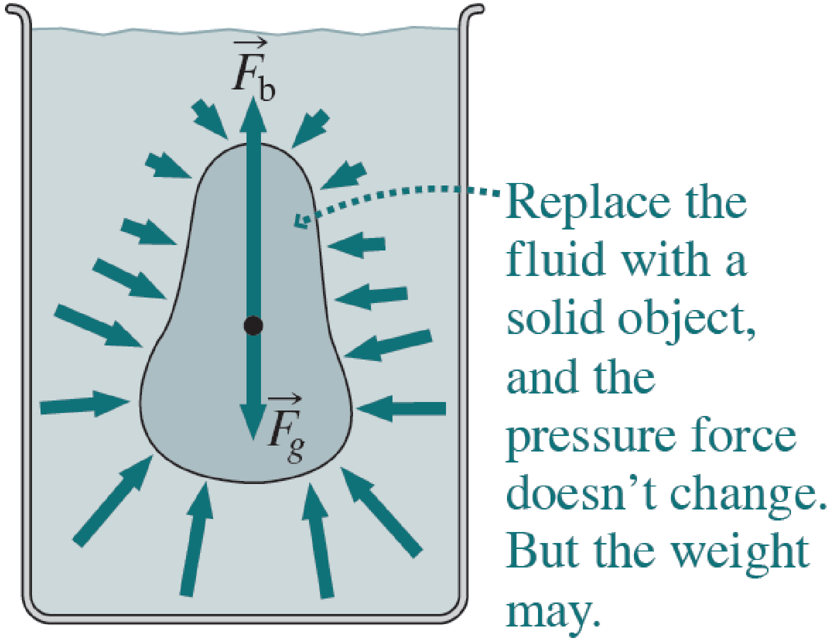
Archimedes' Principle and Buoyancy

- When a fluid is in hydrostatic equilibrium, the force due to pressure differences on an arbitrary volume of fluid exactly balances the weight of the fluid.



Archimedes’ Principle and Buoyancy

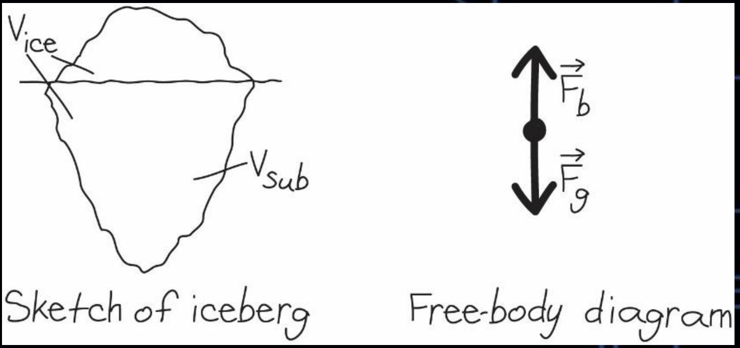
- Replacing the fluid with an object of the same shape doesn’t change the force due to the pressure differences:
  - Therefore, the object experiences an upward force equal to the weight of the original fluid.
  - This is the **buoyancy force**.
  - **Archimedes’ principle** states that the buoyancy force is equal to the weight of the displaced fluid: $F_b = \rho_f g V_f$



(b)

Floating Objects

- If a submerged object is less dense than a fluid, then the buoyancy force is greater than its weight and the object rises.
- In a liquid, the object eventually reaches the surface:
  - Then the object floats at a level such that the buoyancy force equals its weight.
  - That means the submerged portion displaces a weight of liquid equal to the weight of the object.
- In the atmosphere, a buoyant object (like a balloon) rises to a level where its density is equal to that of the atmosphere.
- This is **neutral buoyancy**.



Example

- The average density of a typical arctic iceberg is 0.86 that of sea water. What fraction of an iceberg's volume is submerged?

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The weight of iceberg is equal to buoyancy force:

Weight of iceberg: $m_{ice}g = \rho_{ice}V_{ice}g$

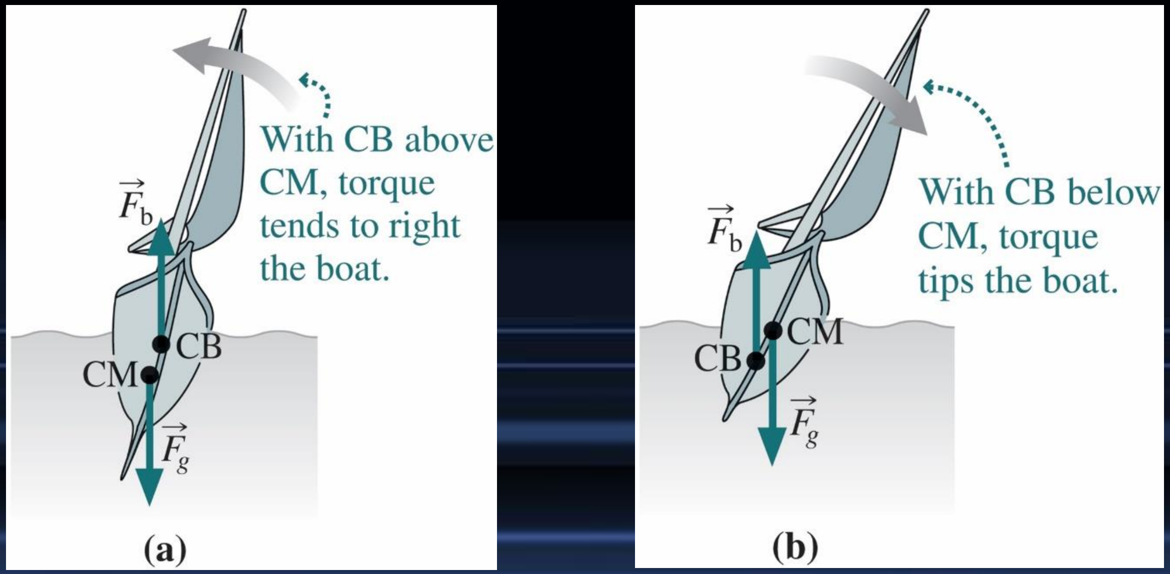
buoyancy force: $W_{water} = \rho_{water}gV_{sub}$

Thus:

$$\frac{V_{sub}}{V_{ice}} = \frac{\rho_{ice}}{\rho_{water}} = 0.86$$

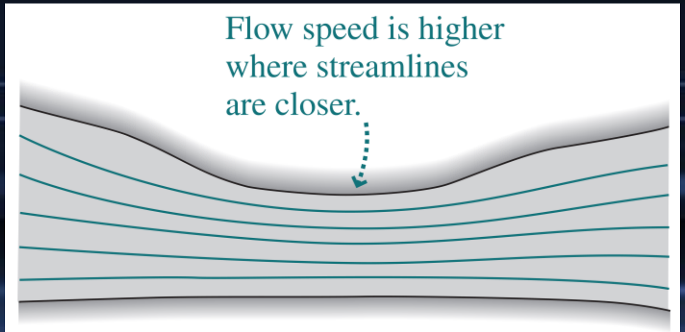
Center of Buoyancy

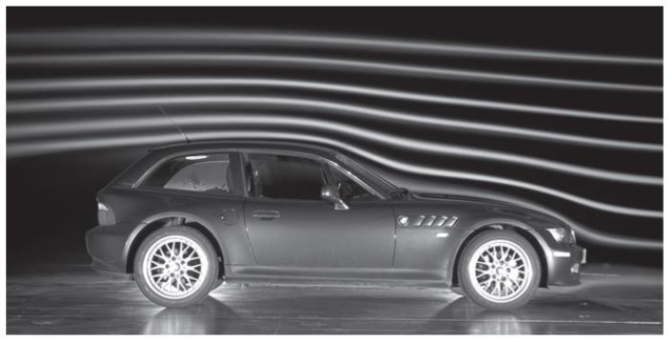
- The buoyancy force acts not at the center of mass of a floating object but at the center of mass of the water that would be there if the object weren't. This point is called the center of buoyancy.
- For stable equilibrium, the center of buoyancy must lie above the center of mass.



Fluid Dynamics

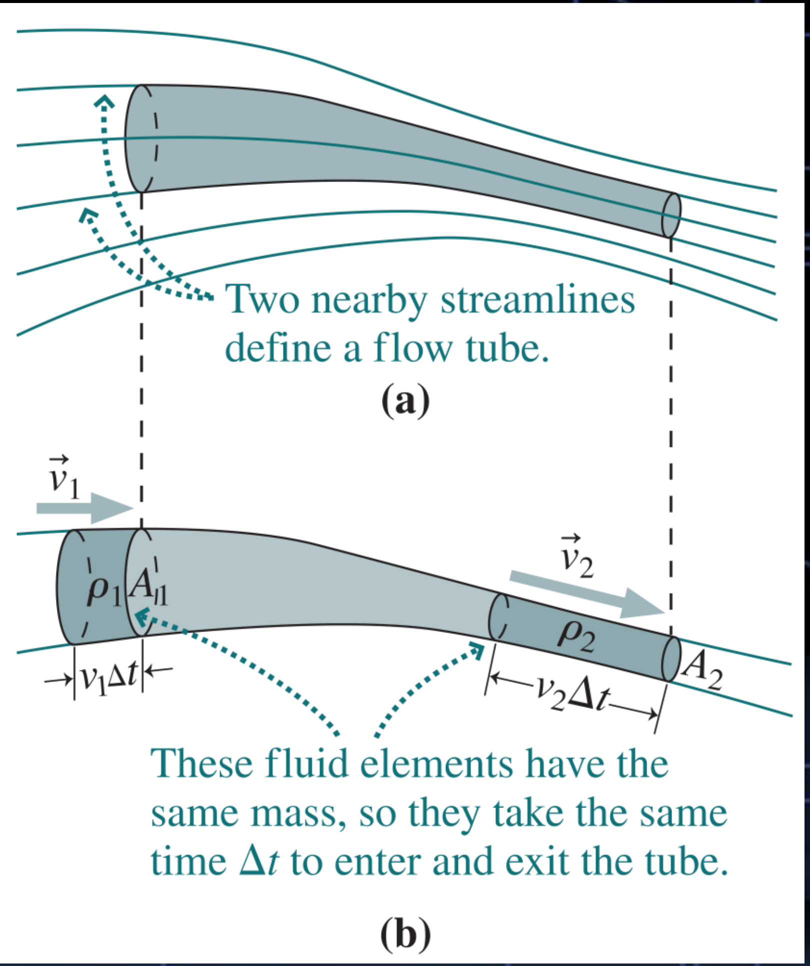
- Moving fluids are characterized by their flow velocity as a function of position and time:
  - In **steady flow**, the velocity at a given point is independent of time:
    - Steady flows can be visualized with **streamlines**, which are everywhere tangent to the local flow direction. The density of streamlines reflects the flow speed.
  - In unsteady flow, the fluid velocity at a given point varies with time. Unsteady flows are more difficult to treat.





Conservation of Mass: The Continuity Equation

- The **continuity equation** expresses conservation of mass in a moving fluid:
  - It follows from considering a **flow tube**, usually an imaginary tube bounded by nearby streamlines:
    - The flow tube may also be an actual physical tube or pipe.



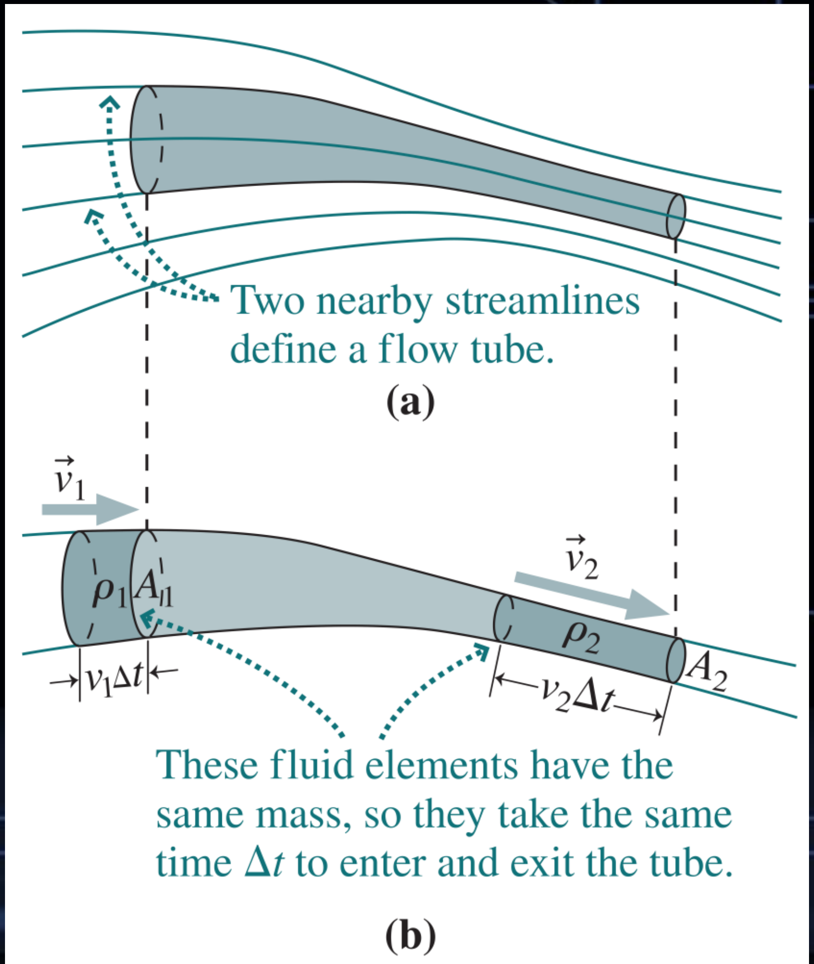
Conservation of Mass: The Continuity Equation

- The continuity equation reads:

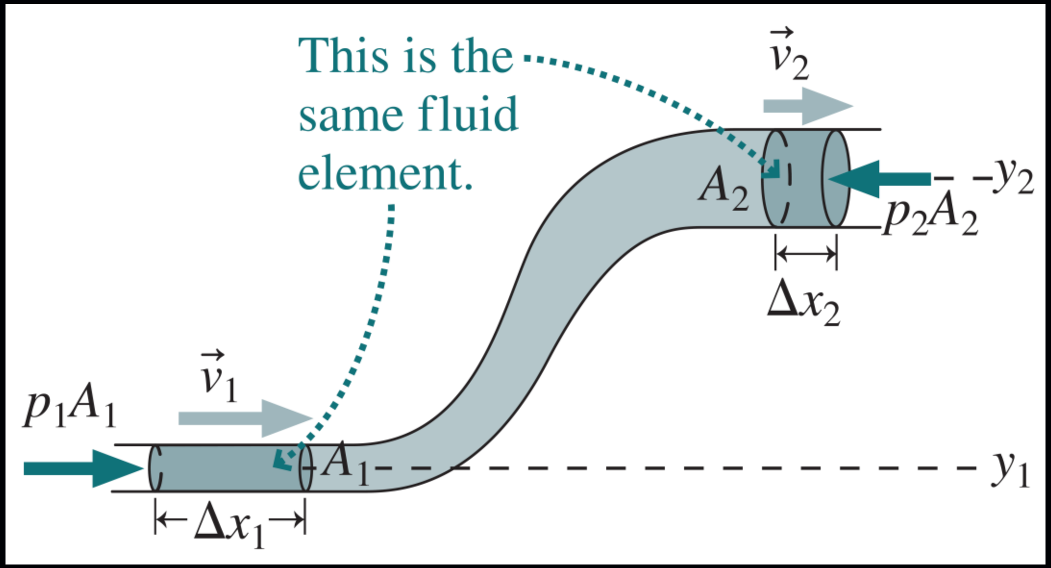
$$\rho v A = \text{constant}$$

where ρ is the density, v is the flow speed, and A is the cross-sectional area; the quantities are evaluated at points along the same flow tube.

  - The quantity ρvA is is the mass flow rate.
  - For incompressible fluids, density is constant and the continuity equation reduces to vA = constant:
    - Here vA is the volume flow rate.



Conservation of Energy: Bernoulli's Equation

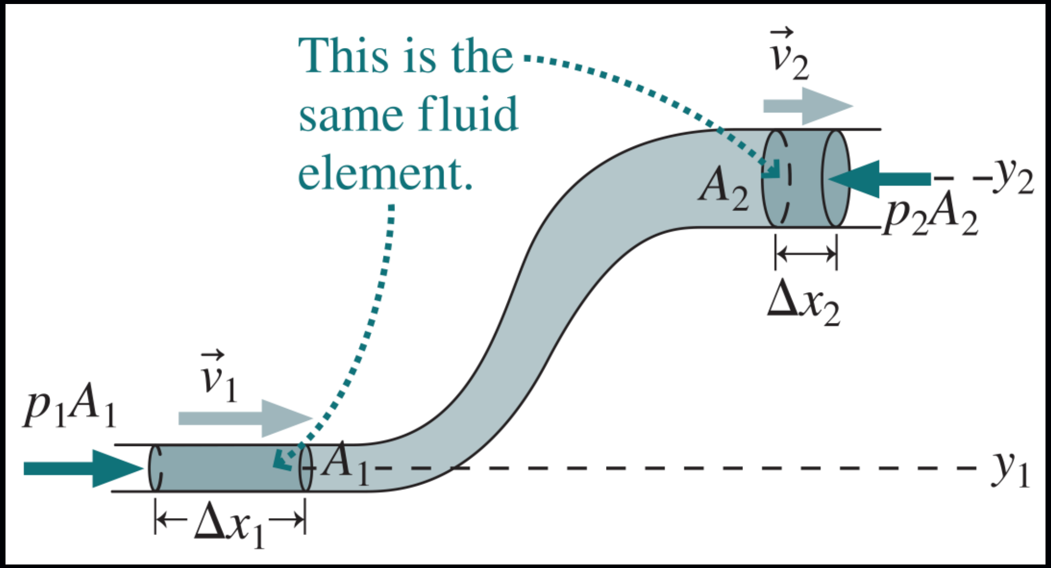


- Consider the conservation of energy in fluid motion: the same fluid element flow from one side to the other side:

The work done by pressure when enter: $W_1=p_1A_1\Delta x_1$.

The work done by pressure when leaving: $W_2=-p_2A_2\Delta x_2$.

Conservation of Energy: Bernoulli's Equation

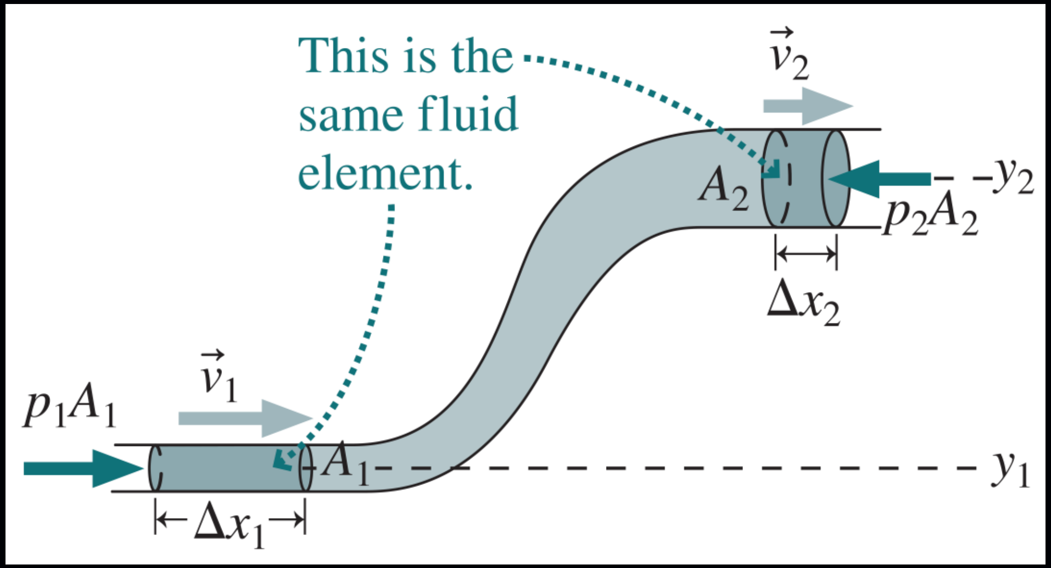


- The change of gravitation energy: $W_g=mg(y_2-y_1)$.
- The change of kinetic energy: $\Delta K = \frac{1}{2}m(v_2^2 - v_1^2)$

With work energy theorem: $W1+W2+W_g=\Delta K$

We have $p_1A_1\Delta x_1-p_2A_2\Delta x_2+mg(y_2-y_1)= \frac{1}{2}m(v_2^2 - v_1^2)$

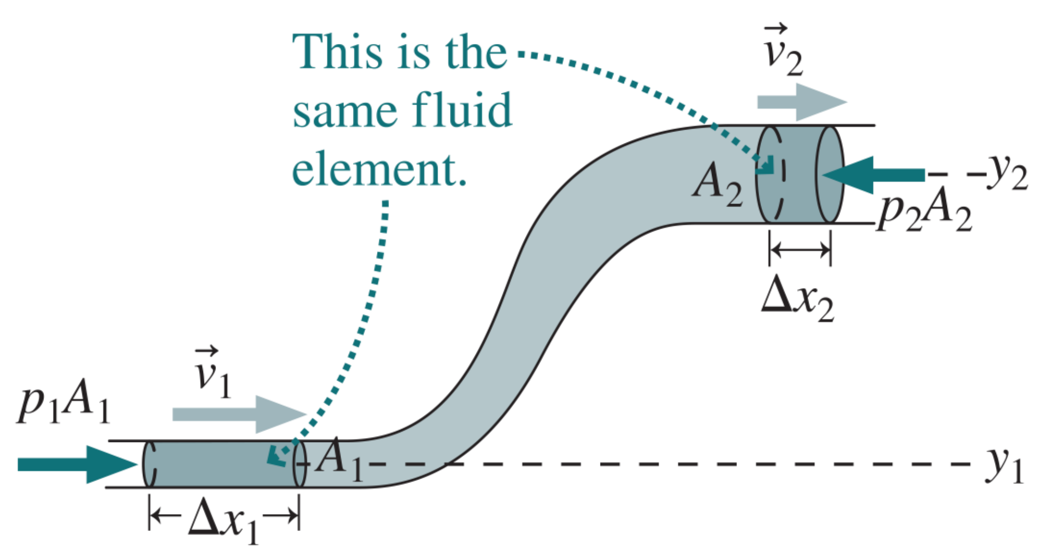
Conservation of Energy: Bernoulli's Equation



- Since volume V=AΔx and m/V=ρ, plug in to the previous equation we get:

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

Conservation of Energy: Bernoulli's Equation

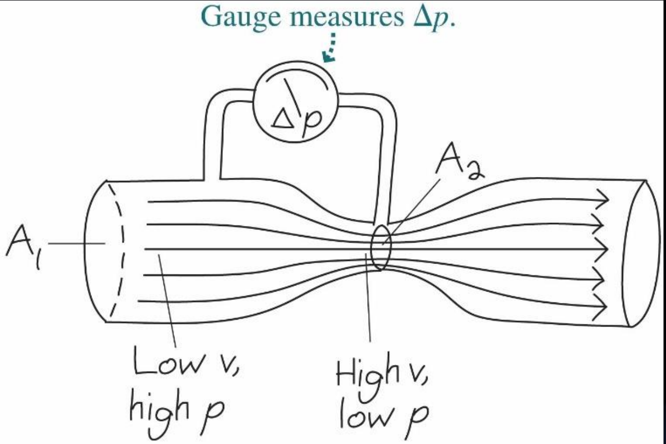


Neglecting fluid friction (viscosity) and in the absence of mechanical pumps and turbines that add or remove energy from the incompressible fluid, Bernoulli's equation reads

$$p + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

Venturi Flows and the Bernoulli Effect

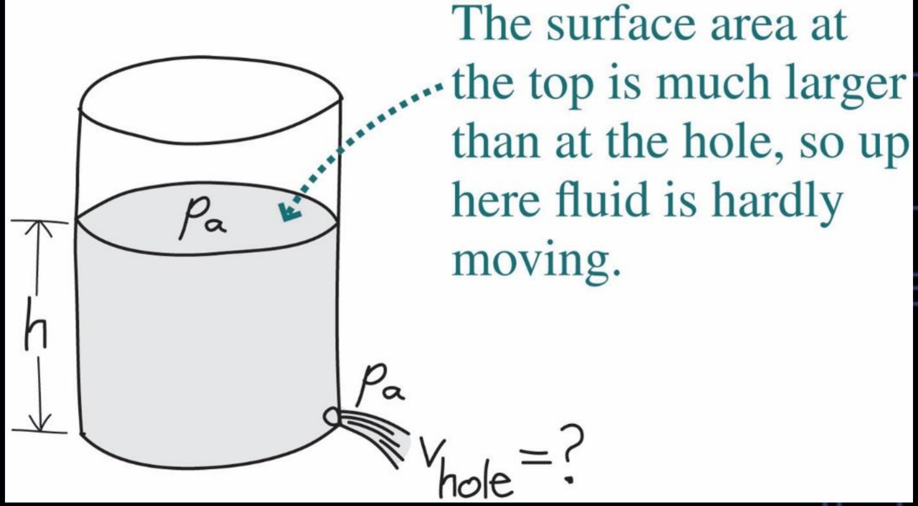
- For flows that don’t involve height differences, Bernoulli’s equation shows that higher flow speeds are accompanied by lower pressures: This is the **Bernoulli effect**.



- The venturi flow : Measuring the pressure difference between the constricted and the unconstricted pipe gives a measure of the flow speed.

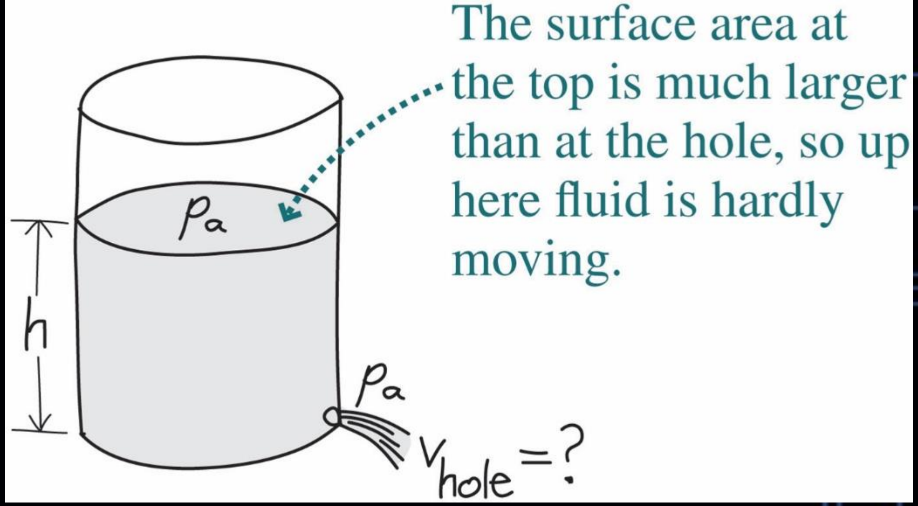
Example: Draining a Tank

- A large, open tank is filled to a height *h* with liquid of density *ρ*. Find the speed of the liquid emerging from a small hole at the base of the tank?



Example: Draining a Tank

- The fluid at the top of the tank and just outside the exit hole are both at atmospheric pressure, p_a.
- Because the tank is large, the fluid velocity at the top is nearly zero.
- Assuming $y = 0$ at the hole and $y = h$ at the top of the fluid, we can find the exit speed using Bernoulli's equation:

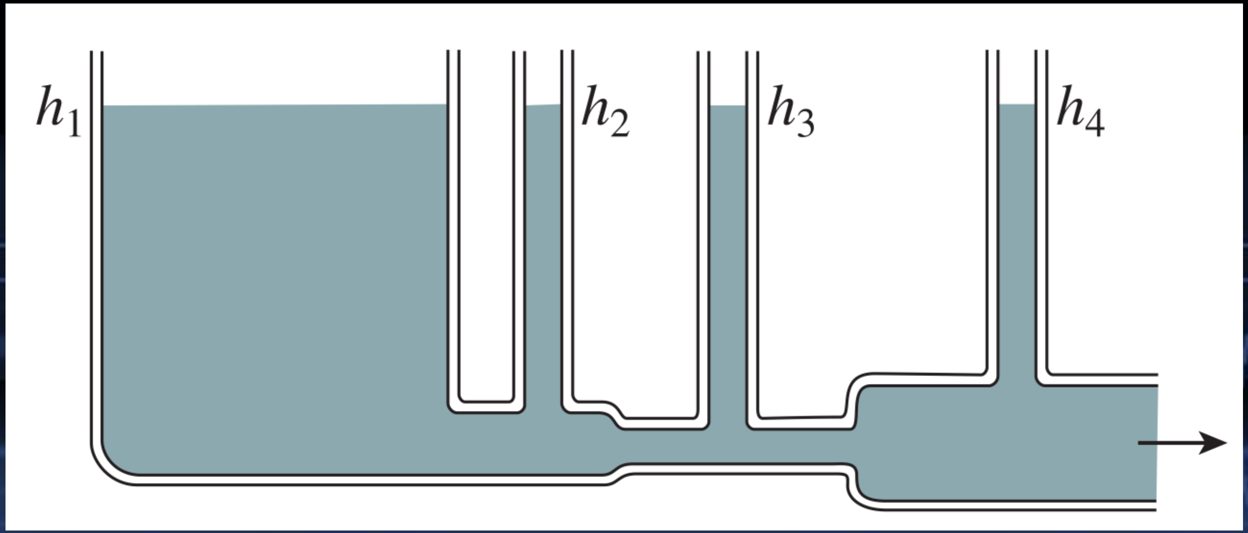


$$p_a + \rho g h = p_a + \frac{1}{2}\rho v_{hole}^2$$

- Solving for v_{hole}, we obtain: $v_{hole} = \sqrt{2gh}$

Think about it…

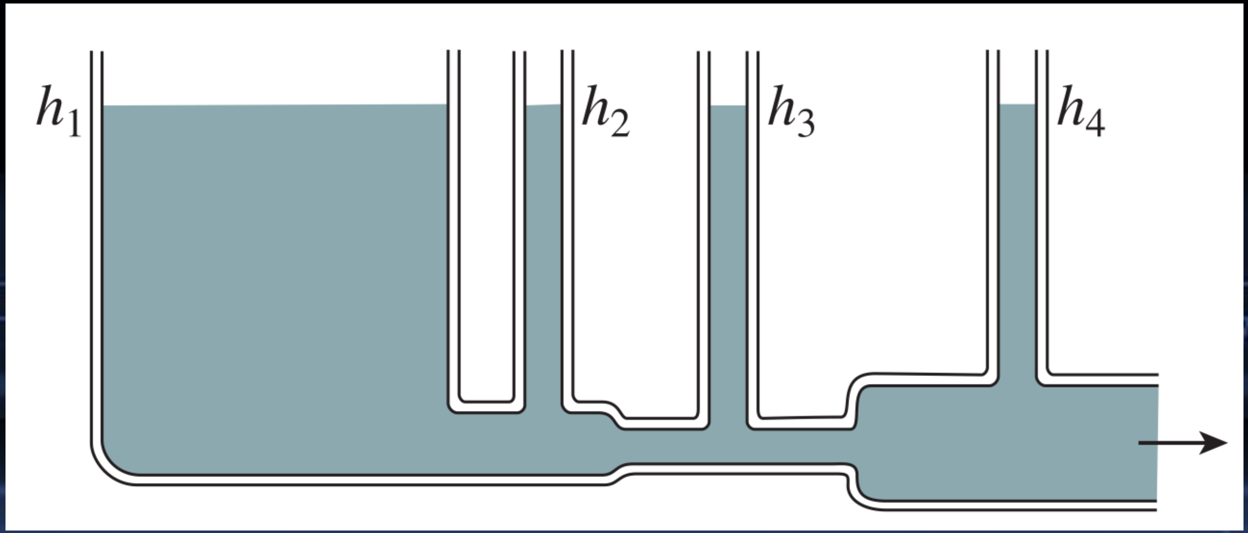
- A large tank is filled with liquid to the level h_1 shown in the figure. It drains through a small pipe whose diameter varies; emerging from each section of pipe are vertical tubes open to the atmosphere. Although the picture shows the same liquid level in each pipe, they really won't be the same.
- Rank levels h_1 through h_4 in order from highest to lowest.



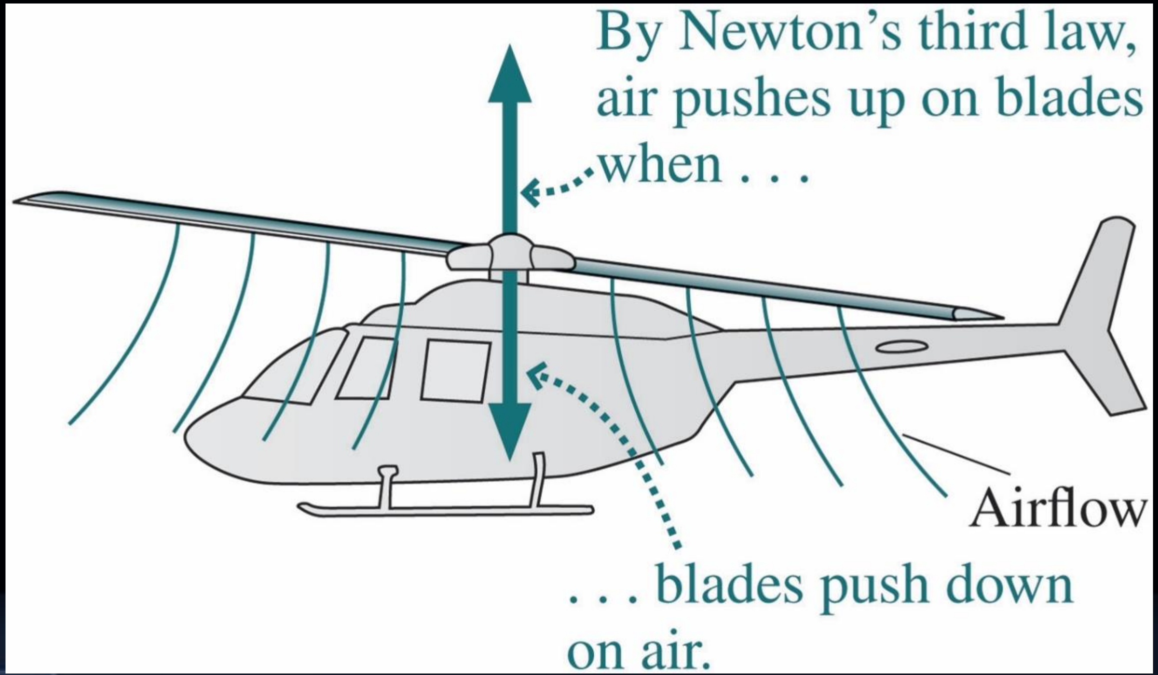
Think about it…

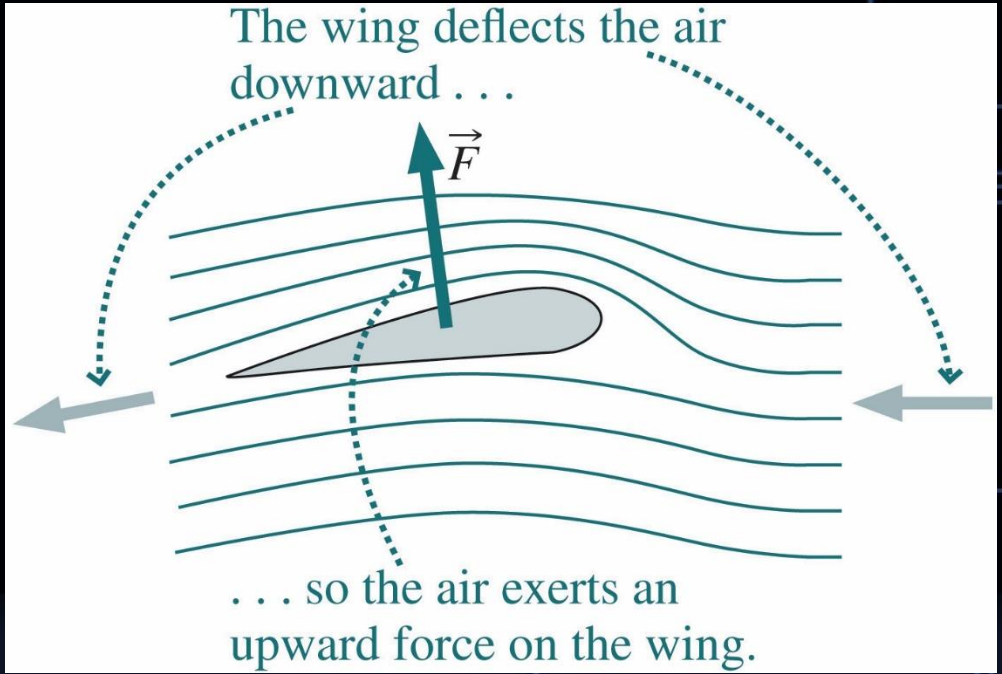
$$p + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

- v large, then h is small. For pipe area is small, v is large: $h_4 > h_1 = h_2 > h_3$



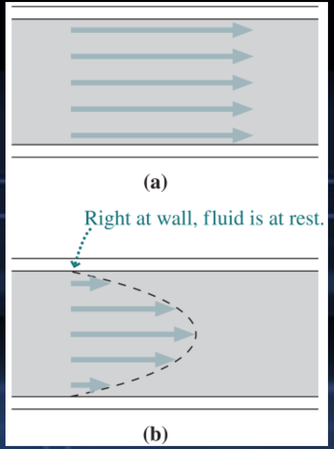
Flight and Lift





Viscosity and Turbulence

- **Viscosity** is fluid friction:
  - It's associated with the transfer of momentum among adjacent layers within a fluid.
  - It also occurs where a fluid contacts pipe walls, river banks, and other material containers.
  - Viscosity dissipates flow energy.
- **Turbulence** is complex, chaotic, time-dependent fluid motion.



Without viscosity, flow in a pipe would be uniform. Viscous drag at the pipe walls introduces a parabolic flow profile.

Smooth flow becomes turbulent in a column of rising smoke.