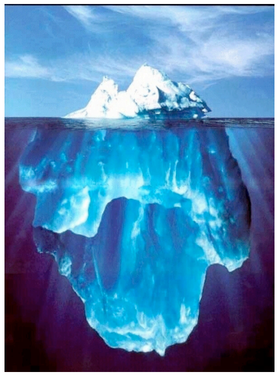
PHY131H1F - Class 23

Today:

- Buoyancy
- Archimedes Principle
- Fluid Dynamics
- Bernoulli's Principle



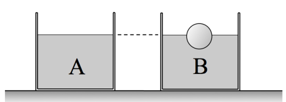
Ch. 15 Reading Quiz
The buoyant force on an object submerged in a liquid depends on:

A. the object's mass.
B. the object's volume.
C. the density of the liquid.
D. both A and B.
E. both B and C.

Last Time I asked:

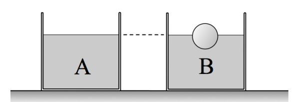
- The two identical beakers shown are filled to the same height with water. Beaker B has a plastic sphere floating in it.

A. Beaker A with all its contents weighs more than Beaker B with all its contents
B. Beaker B with all its contents weighs more than Beaker A with all its contents
C. Beaker A with all its contents weighs the same as Beaker B with all its contents



C. Beaker A with all its contents weighs **the same as** Beaker B with all its contents

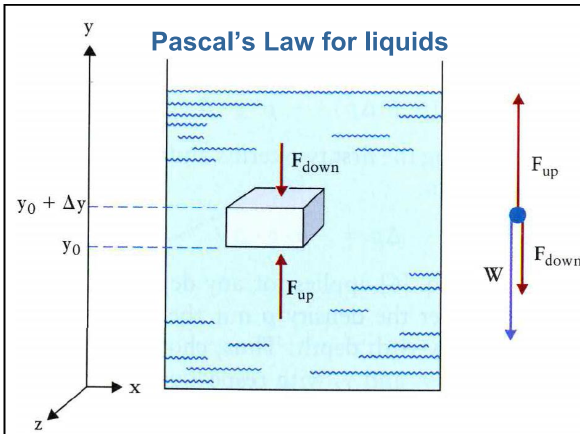
- Beaker B will have V_f less water than beaker A, where V_f is the amount of water displaced by the ball. So the water will weigh $V_f \rho_w g$ less.
- The ball is in equilibrium, so the buoyancy force equals its weight. The buoyancy force is $V_f \rho_w g$.
- The ball weighs exactly the same as the displaced water, so both beakers + contents weigh **the same.**



Fluids Review from Last time

- Fluids include both Liquids and Gases: what's the difference?
- **Gas:** Pressure and Volume are related by the ideal gas law:
- $PV = nRT$
- At constant temperature, if the Pressure of a gas is increased, its Volume decreases (it is compressed)
- **Liquid:** Pressure does not change the Volume much. "Incompressible"

Pascal's Law for liquids

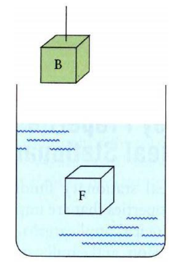


Pascal's Law for liquids

- Consider a small element of fluid in a beaker.
- Pressure acts inward on all surfaces of the small element.
- Gravity pulls it downward.
- To balance the force of gravity, the upward pressure on the bottom surface must be greater than the downward pressure on the top surface: "buoyancy"
- $$p_2 - p_1 = -\rho g\,(y_2 - y_1)$$
- This is the equation for the pressure of an incompressible fluid in hydrodynamic equilibrium in a gravitational field.
- Pressure increases with depth! Scuba divers know this!

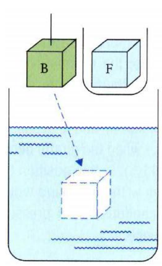
Buoyancy: Archimedes Principle

- Let's do a "thought experiment" (Gedanken).
- Imagine a beaker with a fluid and a block, B, hanging near it.
- There is a fluid element F with the same shape and volume as the block B.
- The fluid element F is in mechanical equilibrium:
  - $F_{\text{up}} - F_{\text{down}} - W_F = 0$
- where F_{up} is the pressure force on the bottom surface, F_{down} is the pressure force on the top surface, and W_F is the weight of fluid F.



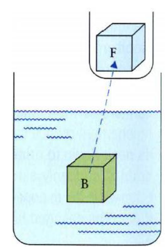
Buoyancy: Archimedes Principle

- **Step 1:** Remove F from the beaker and place it in a small container, leaving an empty bubble of the same size in the beaker.
- The bubble is not in mechanical equilibrium, since its weight is much less than that of the removed fluid, but the pressure forces are the same.:
  - $F_{\text{up}} - F_{\text{down}} = W_F > 0$
- where F_{up} is the pressure force on the bottom surface, F_{down} is the pressure force on the top surface, and W_F is the weight of the removed fluid F.



Buoyancy: Archimedes Principle

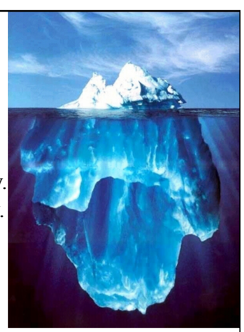
- **Step 2:** Block B, with weight W_B, is placed in the bubble.
- There is a net force on Block B:
  - $F_{\text{net}} = F_{\text{up}} - F_{\text{down}} - W_B = W_F - W_B$
- where W_F is the weight of the removed fluid F, and W_B is the weight of the block B.
- This is equal to the force of gravity, $-W_B$, plus a new force called "Buoyancy",which is due to the pressure gradient in the fluid.



Archimedes' principle: When an object is immersed in a fluid, the fluid exerts an upward force on the object equal to the weight of the fluid displaced by the object.

If a very large floating iceberg were to melt, what, in principle, would happen to the overall sea-level?

A. sea-level would rise very slightly.
B. sea-level would fall very slightly.
C. sea-level would stay the same.



Iceberg Reasoning:

- When an object is immersed in a fluid, the fluid exerts an upward force on the object equal to the weight of the fluid displaced by the object.
- Iceberg not melted has weight *W* and volume V_1. It displaces a weight of water *W* with volume V_w which is less than V_1. So it floats: some of the iceberg sticks up above the water.
- Iceberg melted has the same weight *W* and less volume. But it still displaces the same amount of water. It displaces a weight of water *W*.
- So melting an iceberg which is floating does not change sea level.
- If the iceberg were not floating, but sitting on a land-mass, and it melted and added water to the ocean, this would increase the sea-level.

The Ideal Fluid Model

- The fluid is *incompressible*. It does not change its volume with pressure.
- The fluid is *nonviscous*. It slips along the walls of the container with zero friction.
- The flow is *steady*. The flow follows smooth lines which do not cross or twist.

Fluid Dynamics

Comparing two points in a flow tube of cross section A_1 and A_2, we may use the **equation of continuity:**

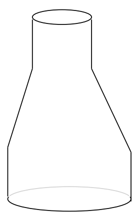
$$v_1A_1 = v_2A_2$$

where v_1 and v_2 are the fluid speeds at the two points.
The flow is faster in narrower parts of a flow tube, slower in wider parts.
This is because the volume flow rate Q, in m^3/s, is constant.

$$Q = \frac{\Delta V}{\Delta t} = A \cdot |v|$$

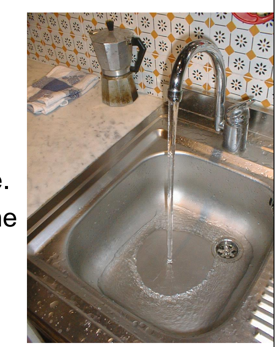
- A tube widens from a cross-sectional area A_1 to a cross sectional area $A_2 = 4\,A_1$. As a result the speed of an ideal dynamic fluid in the tube changes from v_1 to

A. $v_2 = v_1/16$
B. $v_2 = v_1/4$
C. $v_2 = v_1$
D. $v_2 = 4v_1$
E. $v_2 = 16v_1$



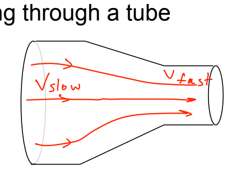
- We study the steady flow of water from a water tap, e.g., in your kitchen sink. The jet of water

A. broadens as it falls.
B. narrows as it falls.
C. does not change its cross-sectional shape.
D. slows before hitting the bottom of the sink.



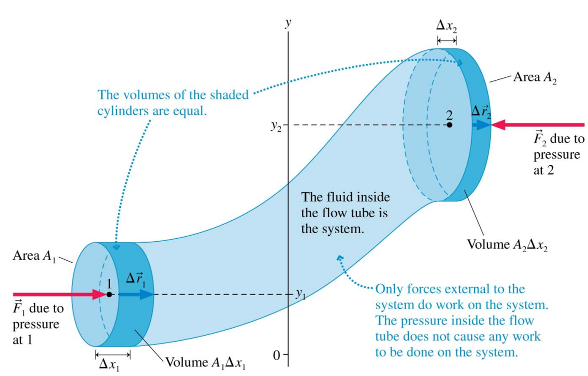
Bernoulli's Law

- Consider an ideal fluid, flowing through a tube which narrows.



- It increases its velocity. This means the kinetic energy per volume of the fluid will increase.
- How can this be? There must be a force which does work on the fluid to speed it up.
- The force must come from a **pressure difference**.
- Pressure must be **lower** in the region of increased fluid velocity.

Bernoulli's law



Bernoulli's Law

• Bernoulli's law is an expression of the conservation of energy for a closed system.
• It states that an increase in the speed of an ideal dynamic fluid is accompanied by a drop in its pressure.
• When combined with Pascal's law for pressure drop with height in a fluid, it is written:

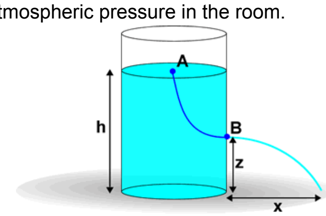
$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

or:

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

Bernoulli's Example

- A cylinder with water of height **h** has a small hole cut in the side at height **z**. The water strikes the ground at **x**. The figure shows the streamline from the top of the water at **A** to just outside the hole **B**.
- If the hole is small, it is reasonable to approximate that the speed of the water at **A** is zero. Since point A and B are in contact with the outside air, it is reasonable to approximate that the pressure is the same at point A and B, that of atmospheric pressure in the room.
- Find **x**.



that's all the new material for PHY131…

- Final Exam is Thursday, Dec. 15, 2:00 PM in EX building
- The 2 hour final exam will cover the entire course, including all of the assigned reading, error analysis assignment, plus Practicals materials and what was discussed in class
- Approximately even spread over Knight Chs. 1-15 minus the exclusions
- I recommend you are familiar with all Masteringphysics homework and Practicals work you did.
- Please email me (jharlow @ physics.utoronto.ca) with any questions or review suggestions for Wednesday.