Physics 1501

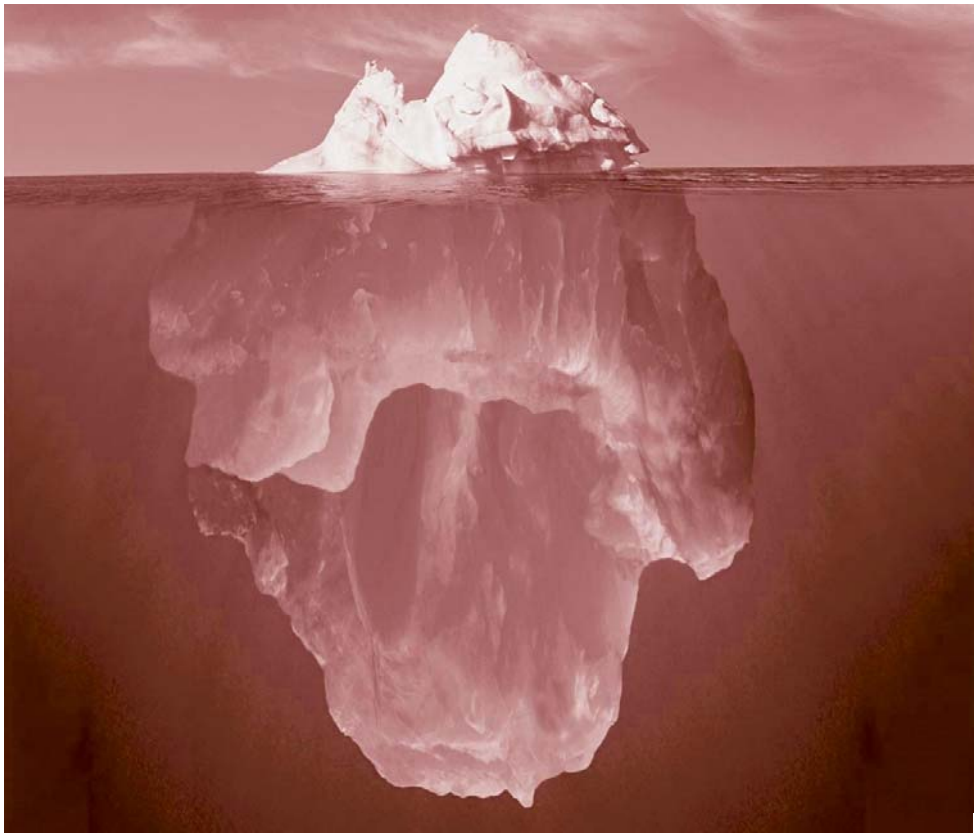
Fall 2008

Mechanics, Thermodynamics, Waves, Fluids

Lecture 26: Fluid motion

In this lecture:

- Quantities used in describing fluid behavior, including pressure and density
- How pressure differences give rise to forces that act on fluids
  - The origin of the buoyancy force and why some objects float while others sink
- How conservation of matter and energy apply to fluids
  - The continuity equation
  - Bernoulli's equation

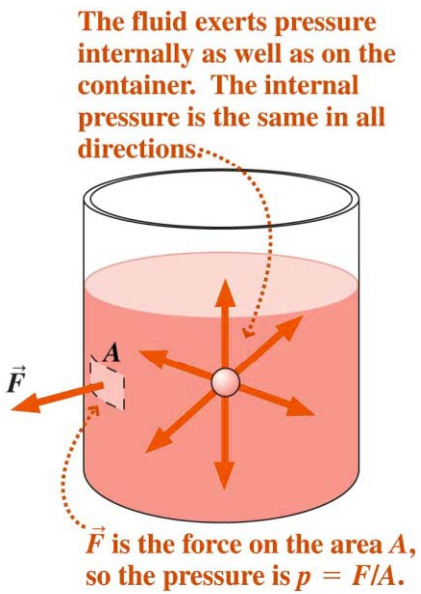


Fluids

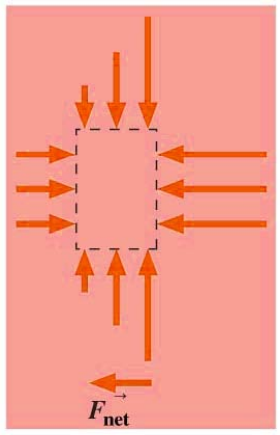
- **Fluid** is matter that flows under the influence of external forces.
  - Fluids include gases and liquids:
    - In gases, molecules are far apart and the density changes readily.
    - In liquids, molecules are close together and density remains essentially constant.
  - Fluids cannot maintain a fixed structure, but flow to assume the configuration of any container they're confined to.

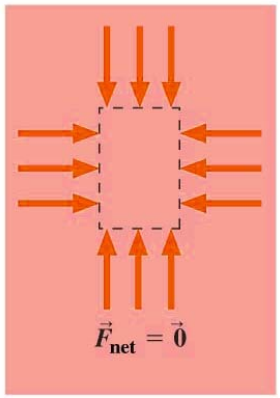
Pressure

- **Pressure** is the force per unit area exerted by a fluid.
  - Pressure is exerted on the fluid's container as well as on adjacent fluid.
  - Pressure is exerted equally in all directions.



  - There is a net force due to pressure only when pressure varies with position.



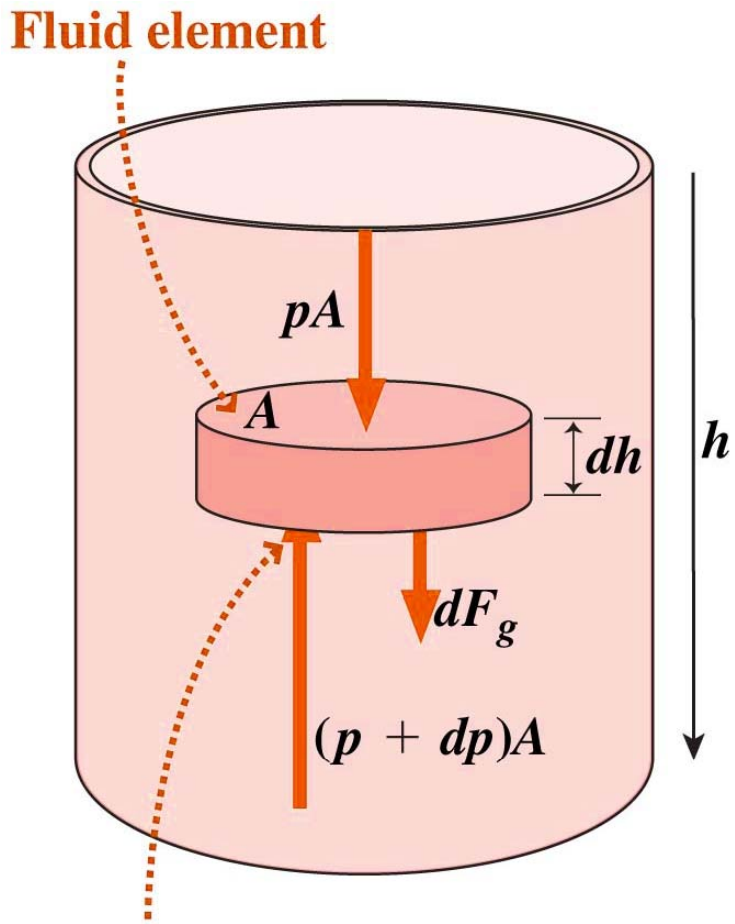


Hydrostatic equilibrium

- In the presence of gravity, pressure in a static fluid increases with depth.
  - This allows an upward pressure force to balance the downward gravitational force.
  - This condition is **hydrostatic equilibrium.**
  - Details depend on the nature of the fluid.
    - **Incompressible fluids** like liquids have constant density; for them, pressure as a function of depth h is

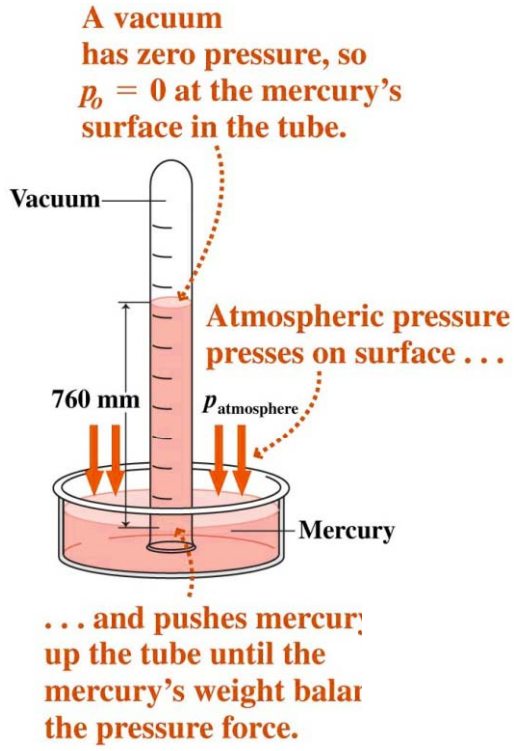
      $$p = p_0 + \rho g h$$

      where p_0 is the pressure at the surface.

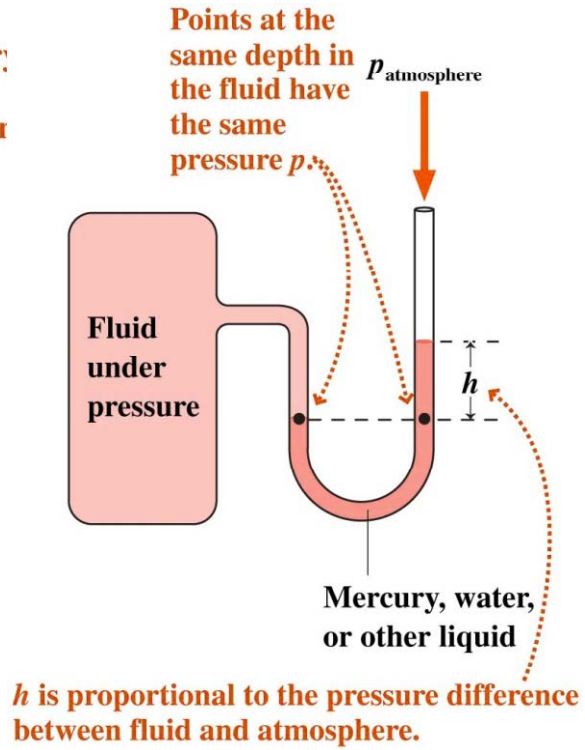


Measuring pressure

- A **barometer** measures the absolute pressure of a fluid, typically air.
  - Although modern barometers often have electronic sensors, the principle of fluid pressure measurement is best illustrated by the traditional mercury barometer.

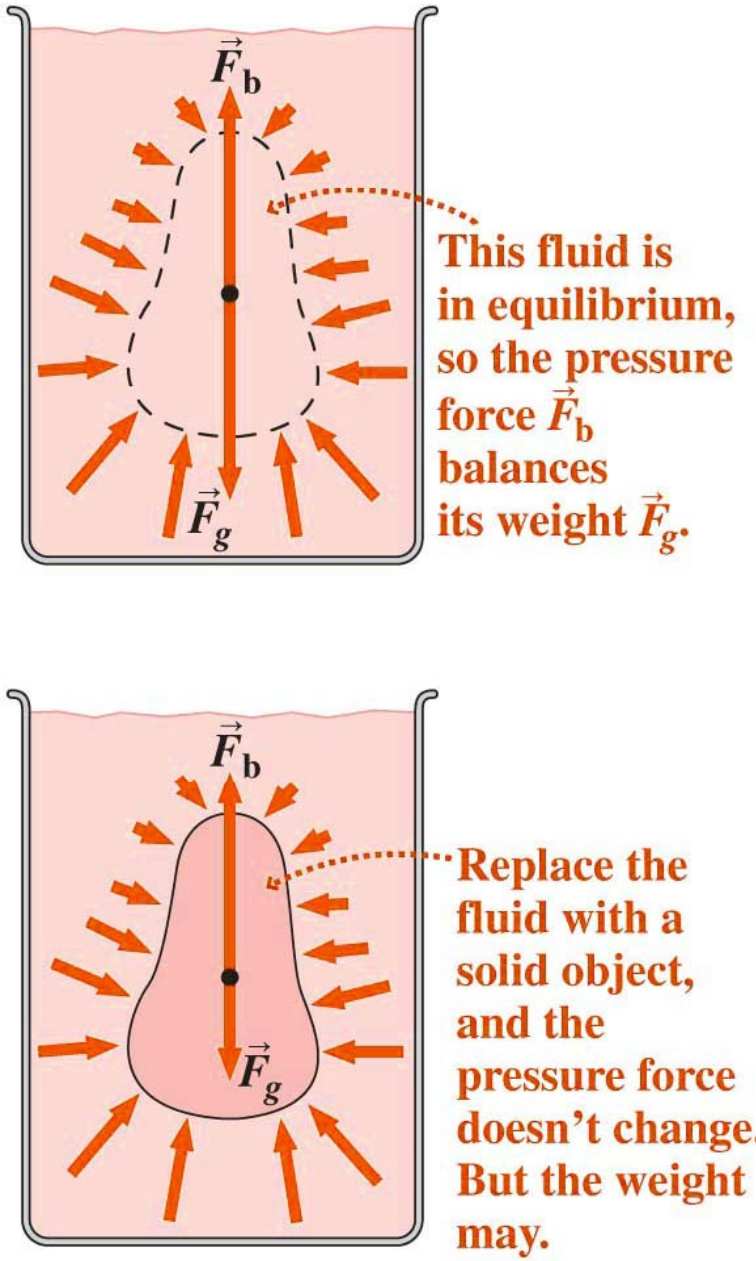


- A **manometer** measures pressure differences.
  - **Gauge pressure** is a measure of pressure relative to the ambient atmosphere.
  - Tire pressure, for example, is actually gauge pressure—the tire's excess pressure over atmospheric pressure.



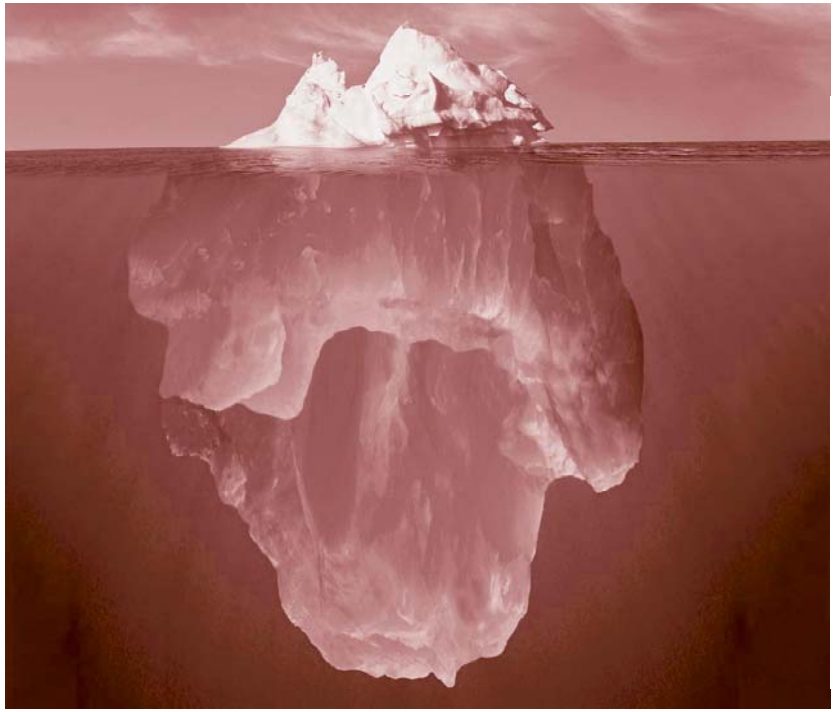
Buoyancy

- 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.
- 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.



Floating and sinking

- 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, it 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**.



question

Which one of the following does not contribute to a rise in sea level?

A. Melting of pack ice in the Arctic Ocean

B. Melting of ice supported by land in Greenland