Lecture 2

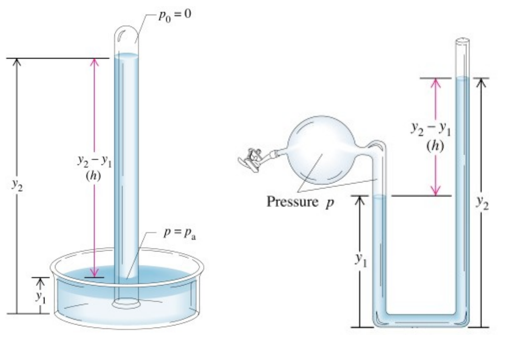
Pascal's Law and Buoyancy

Measuring pressure

Last lecture: we showed the variation of pressure in a fluid:

$$p = p_0 + \rho g h \qquad (\rho \text{ constant})$$

Use this equation to measure an unknown pressure, using a *barometer* or *manometer*.



Barometer Manometer

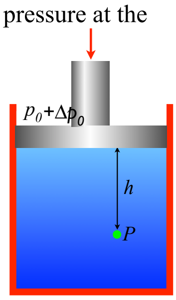
Pascal's principle

What happens if we increase the pressure at the surface?

Increase p_0 by Δp ⇒

$p \rightarrow p + \Delta p$

for *all* points P.

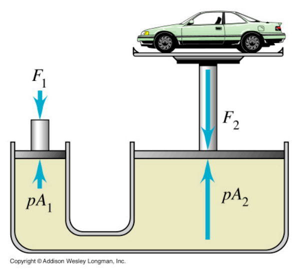


Pascal's principle

Pressure applied to an enclosed fluid is transmitted *undiminished* to every portion of the fluid and the walls of the containing vessel.

Example: Hydraulic lifts

A piston with a small area A_1 exerts a force F_1 on a fluid, which connects a larger piston of area A_2, where $A_2 >> A_1$

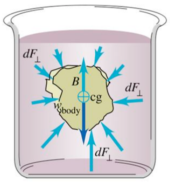


Buoyancy

What happens when you immerse objects in a fluid?

Consider a fluid element with arbitrary shape.

Replace the fluid element with a body of exactly the same shape.



At every point P is the same ⇒

resultant force F_b is the same.

$$\vec{F}_b = -\vec{F}_g$$

the *weight* of fluid displaced, $= m_{\text{fluid}}g$

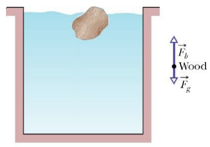
This is *Archimedes' Principle*:

When a body is completely or partially immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

- F_b is called the *buoyancy force*.
- P increases with depth
  ⇒ force is always *upwards*.
- F_b depends only on the *fluid*, not the object.
- An object floats in any liquid with density
  $\rho_{fluid} > \rho_{object}$

An object with $\rho_{object} < \rho_{fluid}$ feels an upward force.

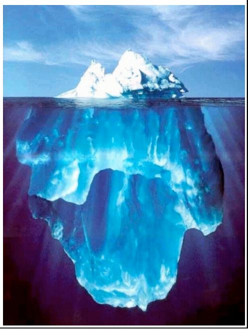
How high will it float?



Example: Icebergs are freshwater ice with density 917 kg m^{-3}

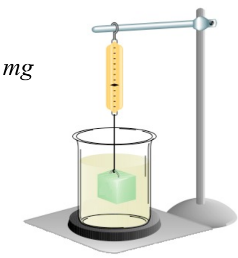
Density of seawater is 1030 kg m^{-3}

What is the fraction submerged?



All bodies weigh less in fluid if $\rho_{\text{fluid}} > \rho_{\text{air}}$

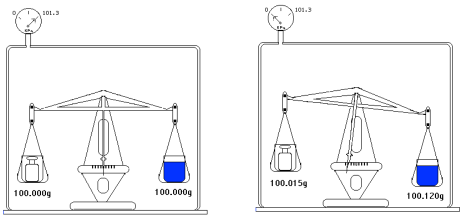
In air:
$T = F_g = mg$



In water:
$T = F_g - F_b$
$= mg - \rho_w gV$

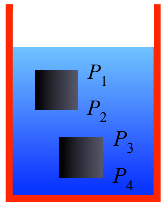
Question

What about buoyancy due to air?



- The buoyancy force arises because the pressure increases with depth
  $P_2 > P_1 \Rightarrow$ force is always *up*.

- Does the buoyancy force increase with depth?

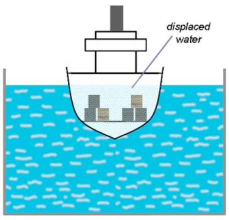


A body floats in any liquid with density

$$\rho_{\text{fluid}} > \rho_{\text{body, av}}$$

The way a body is configured can change how much fluid is displaced and hence the buoyancy force.

e.g. ships can be made of steel and still float if they're hollow.



Next lecture

Surface tension