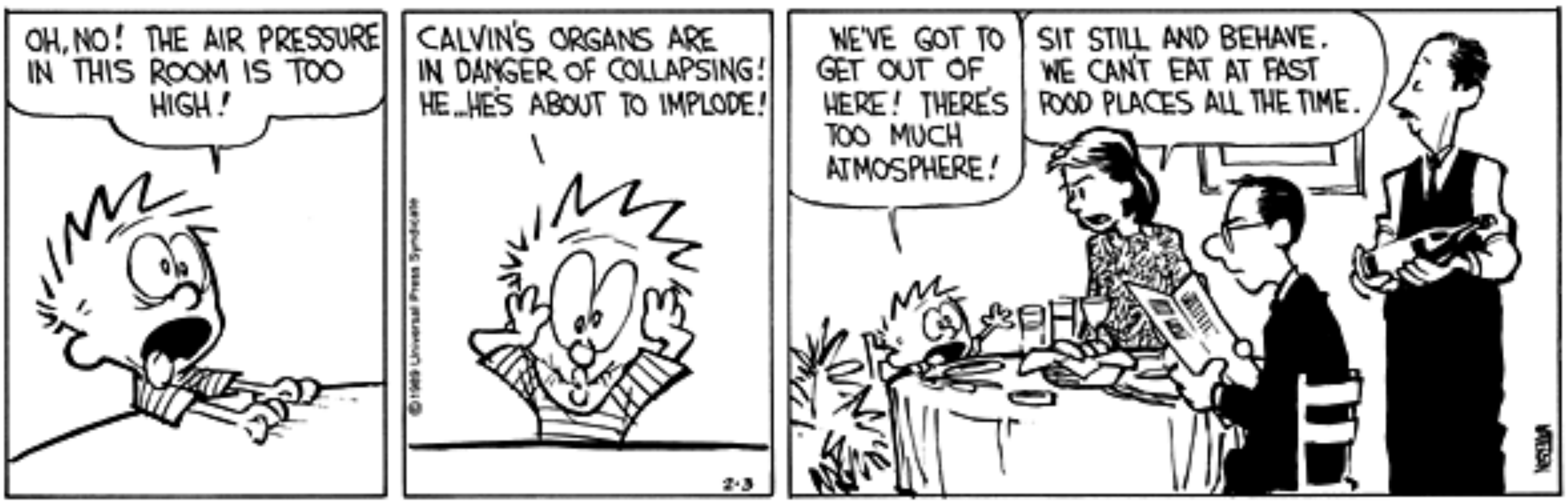
- **Theme Music:** **ZZ Top**

  Got Me Under Pressure

- **Cartoon:** **Bill Watterson**

  Calvin & Hobbes



Outline

- Equations for Rotational KE
- Kinds of Matter
- Properties of Matter
- Fluids: Statics
  - Pressure
  - Archimedes' principle

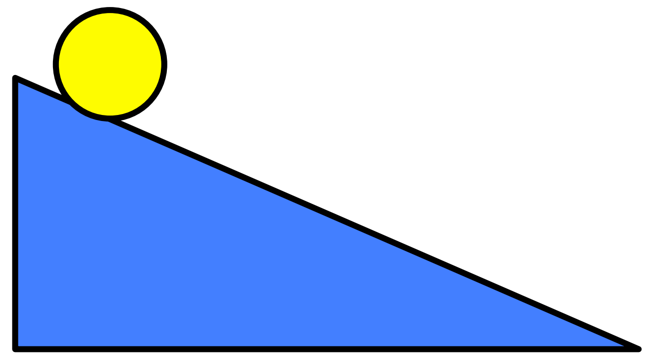
An object rolling down an incline

$$E_i = E_f$$

$$\tfrac{1}{2}mv_i^2 + \tfrac{1}{2}I\omega_i^2 + mgh_i = \tfrac{1}{2}mv_f^2 + \tfrac{1}{2}I\omega_f^2 + mgh_f$$

$$mgh = \tfrac{1}{2}mv_f^2 + \tfrac{1}{2}I\omega_f^2$$

$$\omega = v / R$$



$$mgh = \tfrac{1}{2}mv_f^2 + \tfrac{1}{2}I\left(\frac{v_f}{R}\right)^2$$

$$= \tfrac{1}{2}mv_f^2 + \tfrac{1}{2}\left(\frac{I}{R^2}\right)v_f^2 = \tfrac{1}{2}m\left[1 + \frac{I}{mR^2}\right]v_f^2$$

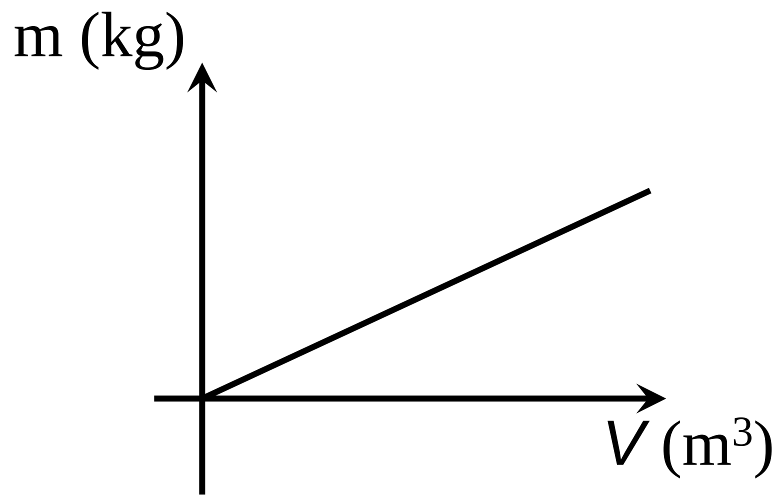
$$v_f^2 = \frac{2gh}{\left[1 + \frac{I}{mR^2}\right]}$$

Expand the Frame

- We have considered the question "Why do objects move (or not move)?" with increasingly complex objects.
  - Small (point) masses
  - Rigid bodies
- Expand our frame now to include bodies that can change their shape.
  - For simplicity, restrict to uniform systems — each part of the system is (in some sense) the same as every other part.

Uniform Systems

- If a system is uniform, every piece of it is like every other piece.
- The mass of the system is proportional to the volume.



$$\rho = \frac{m}{V} = \frac{\Delta m}{\Delta V}$$

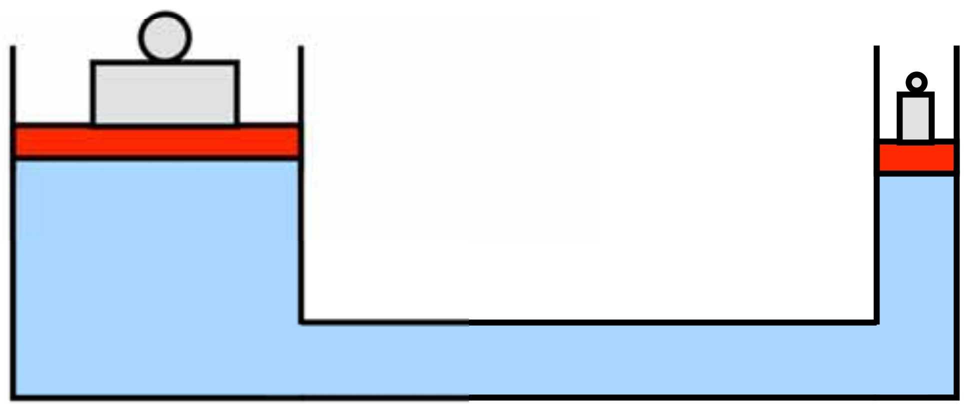
Kinds of Matter

- Classify objects by how they deform.
  - *Solid*: don't change shape if you leave them alone or push on them (not too hard!)
  - *Gel*: look solid if you don't touch them but are "squishy" and change shape easily (jello, butter, clay,…)
  - *Liquid*: Have no shape of their own. Flow to fill a container but have constant volume.
  - *Gas*: Have neither shape nor volume but fill any container.
  - LOTS MORE!

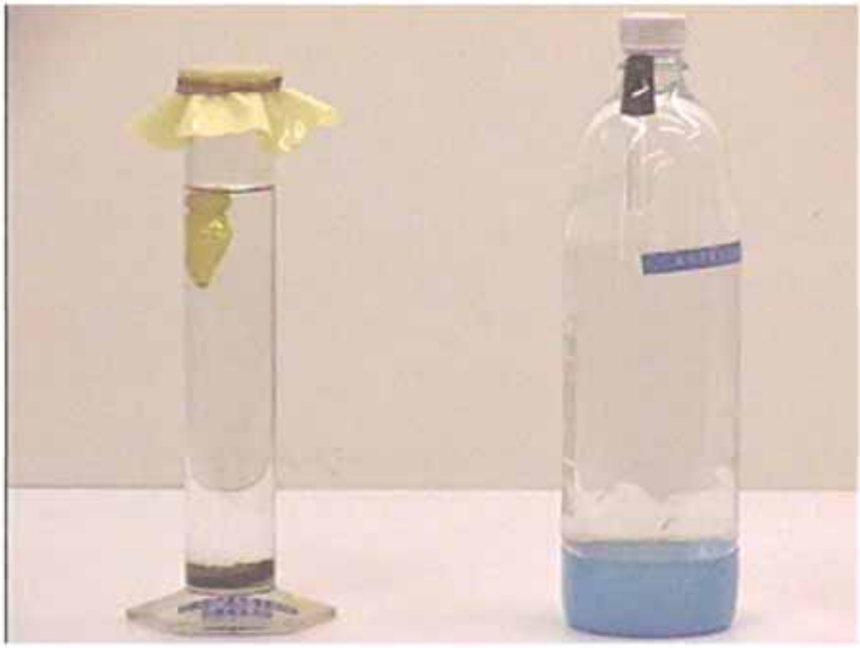
Pascal's Principle

A force exerted
on a part of a fluid
is transmitted through
the fluid and expressed
in all directions.

$$\frac{W_1}{A_1} = \frac{W_2}{A_2}$$

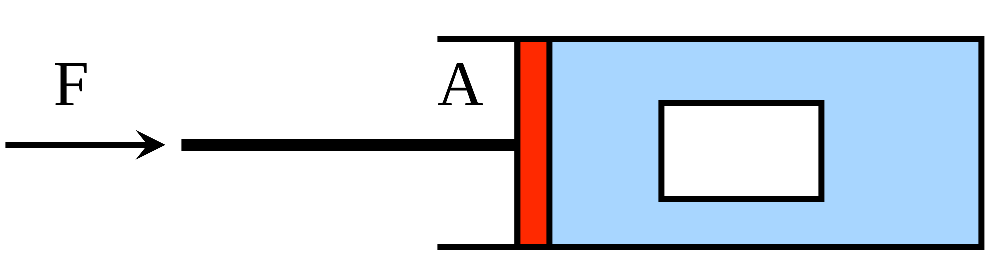


The Cartesian Diver

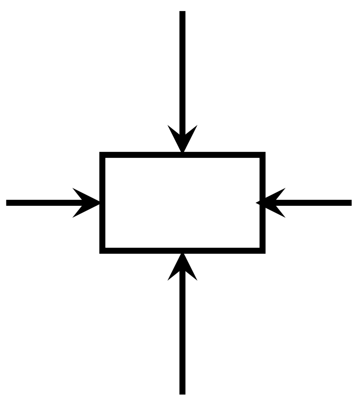


Pressure

- What forces are exerted
  on the box imbedded in the fluid?



Pressure has
no direction!
It acts in all
directions at once!



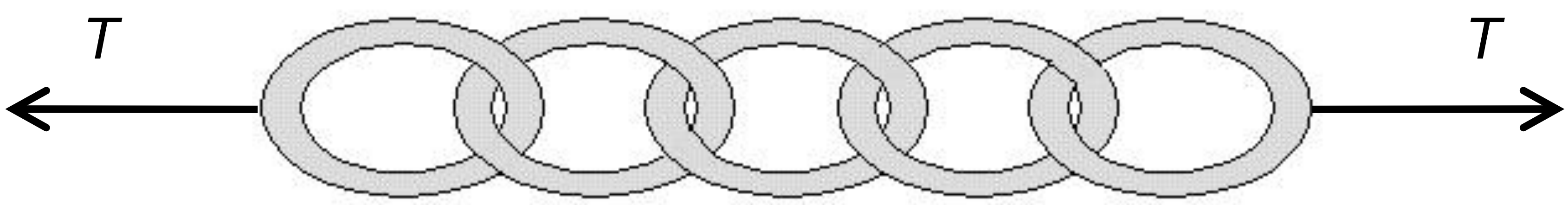
$$p = \frac{F}{A}$$

$$\vec{F} = p\vec{A}$$

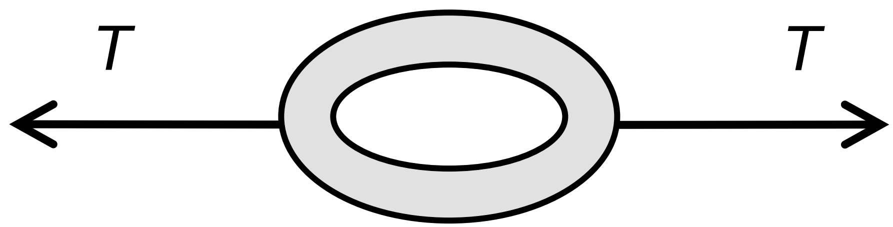
The force takes its direction from A.

Pressure has no direction!

- It's like a 3D generalization of tension in a chain!



- By alternating N2 and N3, each link has a FBD:

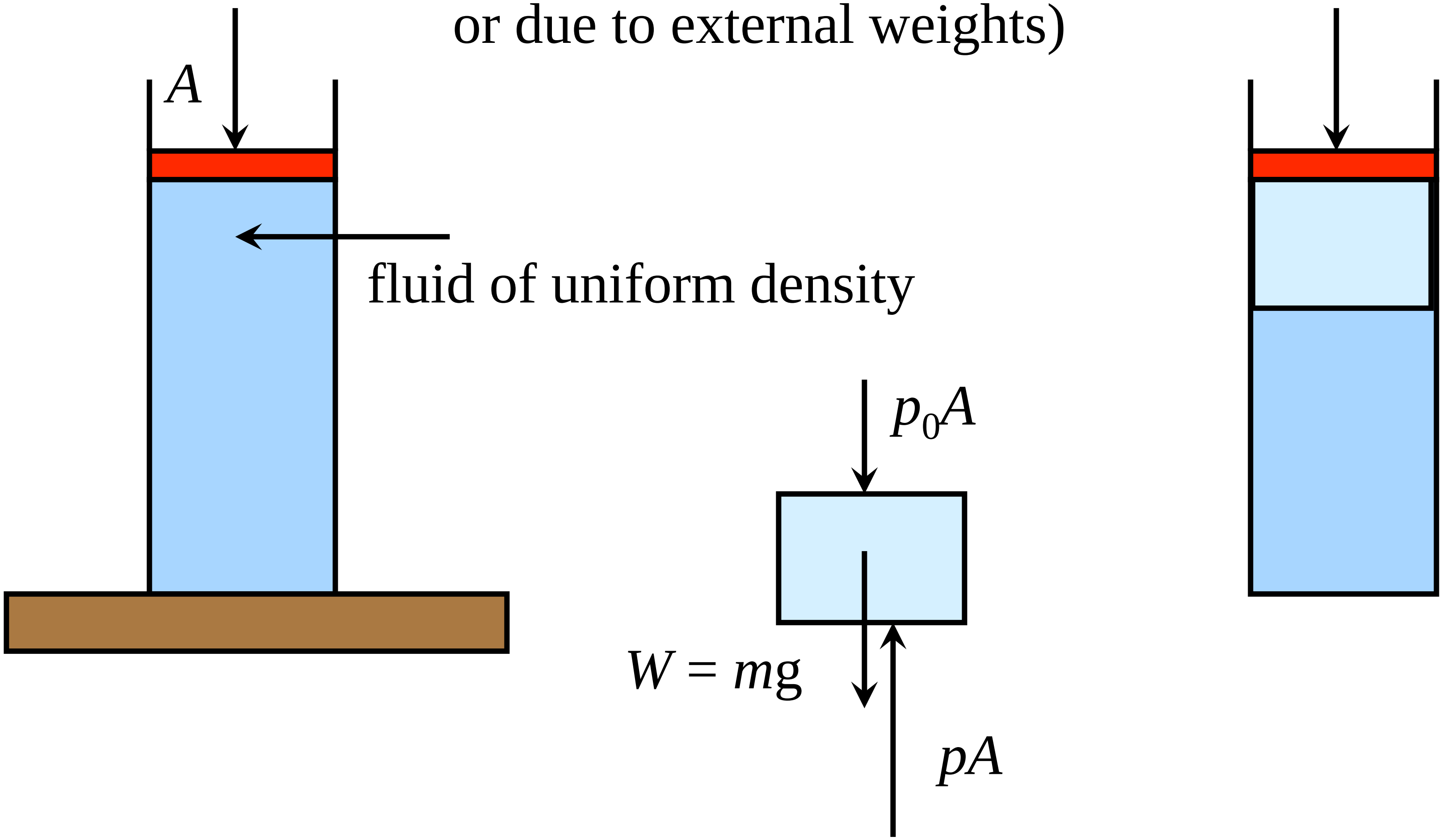


Drawing on experience

- What happens when an object is immersed in a fluid?
- Examples?

Fluids in Gravity

$F = p_0 A$ (could be outside air pressure or due to external weights)



Variation of Pressure with Depth*

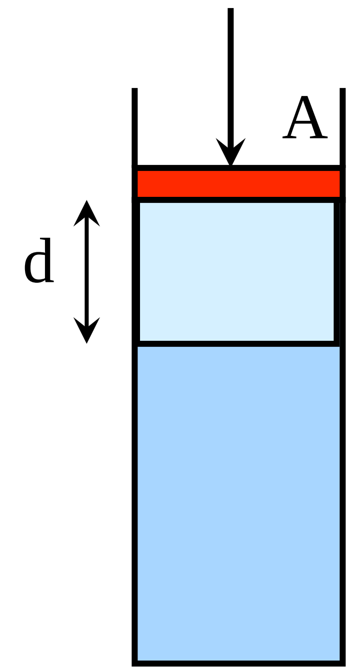
$$F^{down} = F^{up}$$

$$mg + p_0 A = pA$$

$$\rho V g + p_0 A = pA$$

$$\rho A d g + p_0 A = pA$$

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



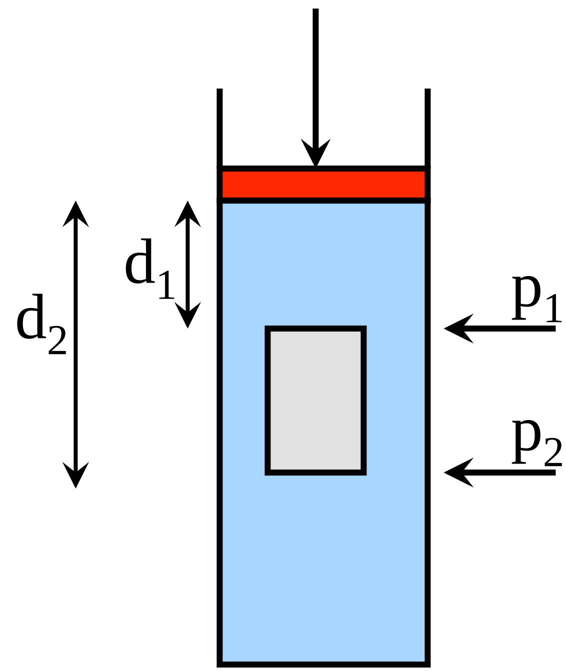
* We assumed uniform density. Is this OK?

For water (ρ ~ 1000 kg/m^3) yes.

For air (ρ ~ 1 kg/m^3) OK for meters — not km.

Archimedes' Principle: 1

- What happens when an object is immersed in a fluid?
- The pressure at the bottom is greater than the pressure at the top so overall the fluid pushes up.



Archimedes' Principle: 2

$$F^{net} = p_2 A - p_1 A$$

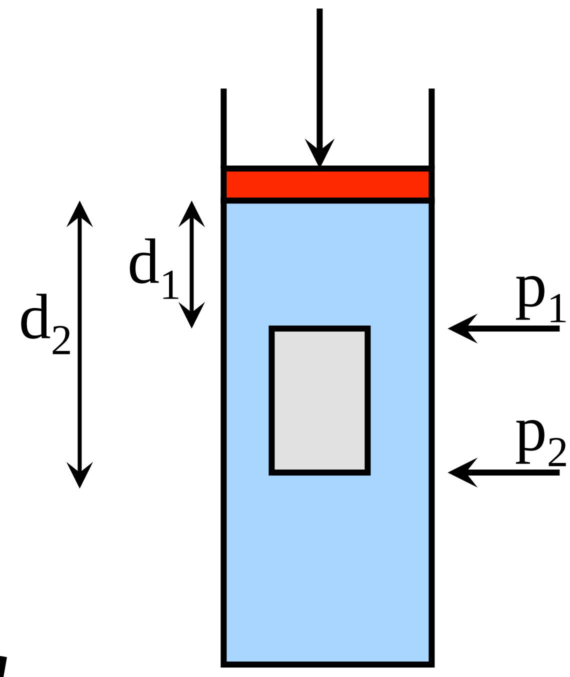
$$p_1 = p_0 + \rho g d_1$$

$$p_2 = p_0 + \rho g d_2$$

$$F^{net} = (p_2 - p_1) A$$

$$F^{net} = (p_0 + \rho g d_2 - p_0 - \rho g d_1) A$$

$$F^{net} = \rho g (d_2 - d_1) A = \rho V g = mg$$



The buoyant (upward) force = the weight of the fluid displaced.