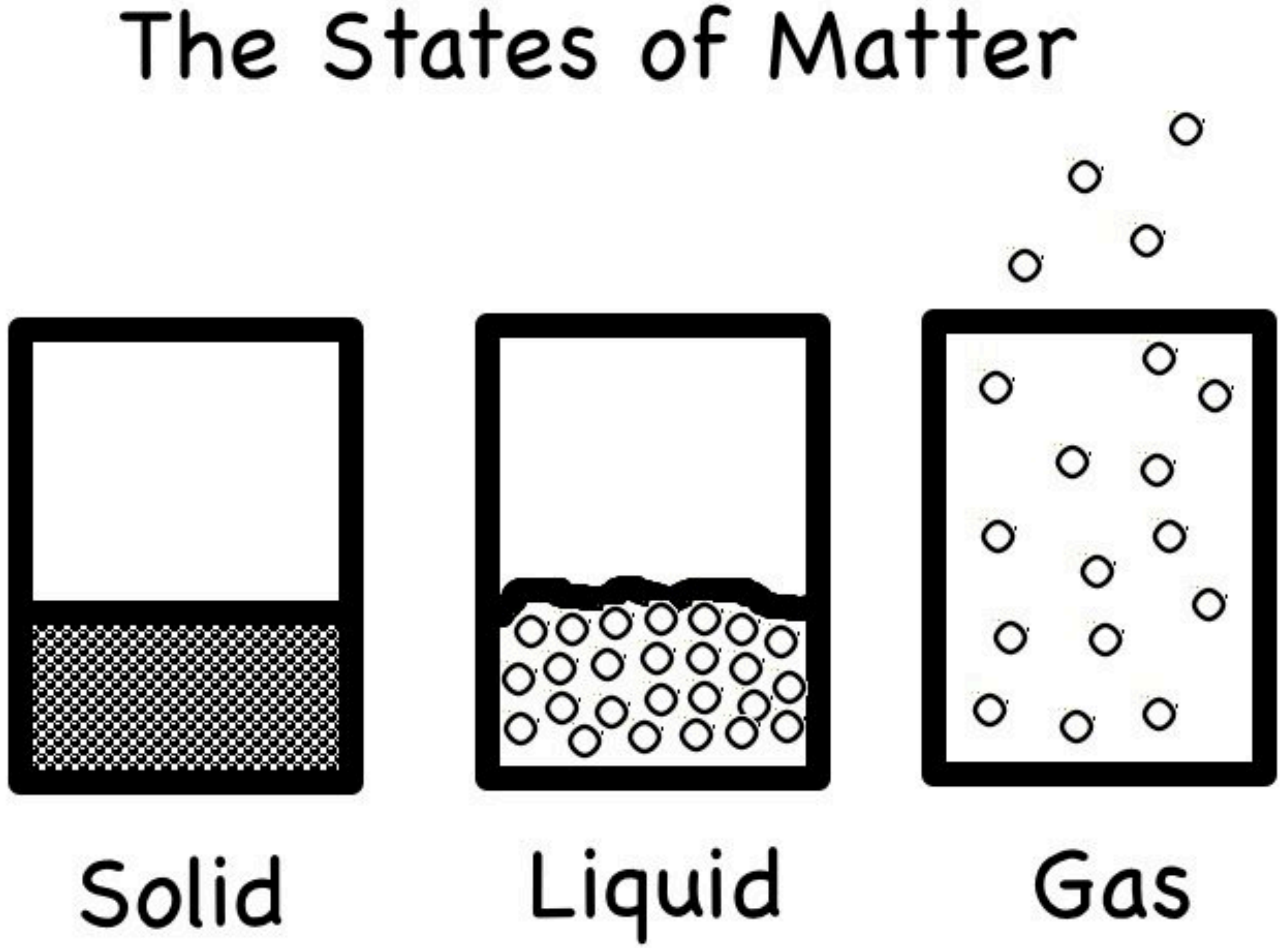
College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

We are Now Finished with Mechanics!



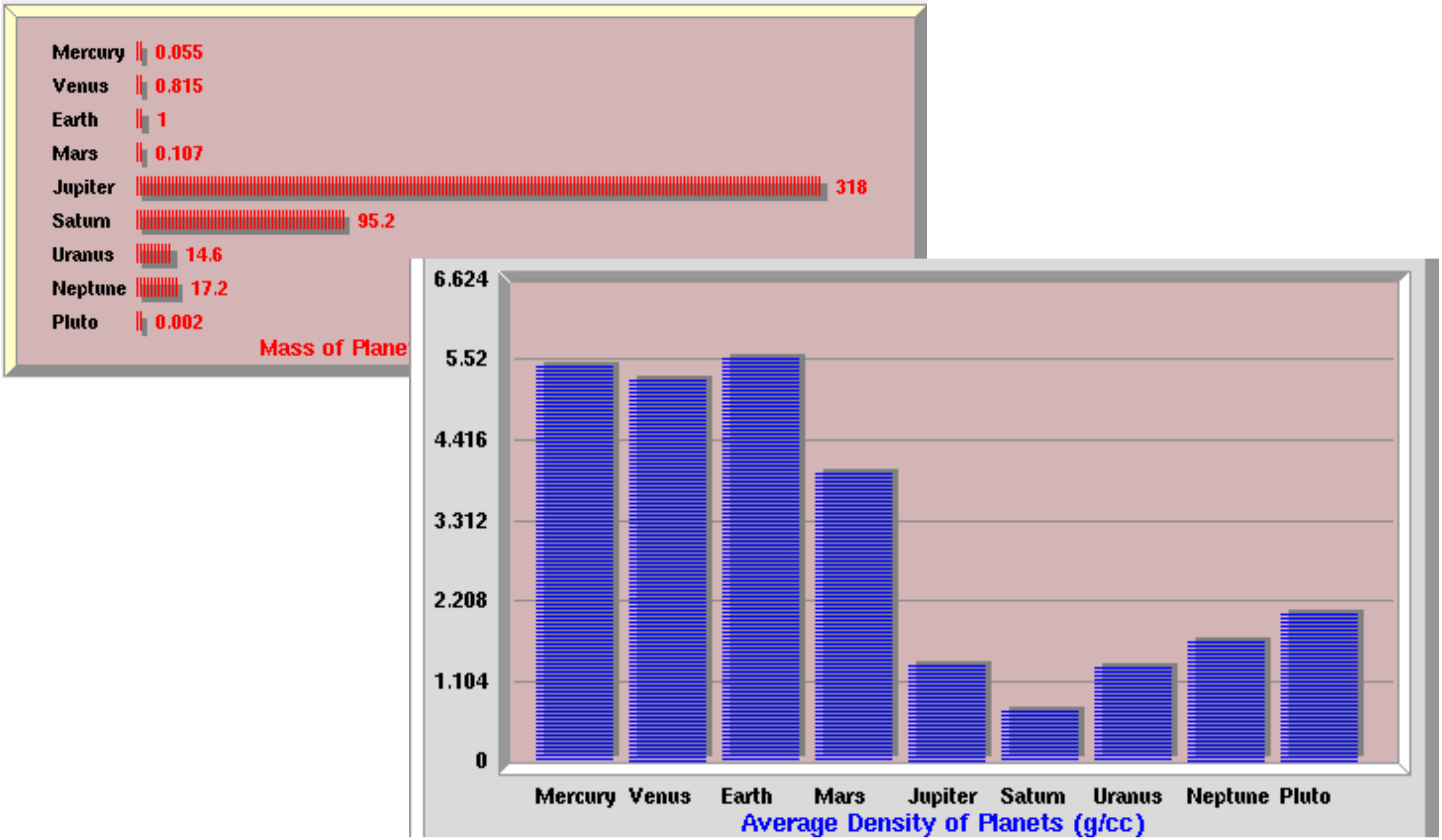
Definition: Mass Density

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

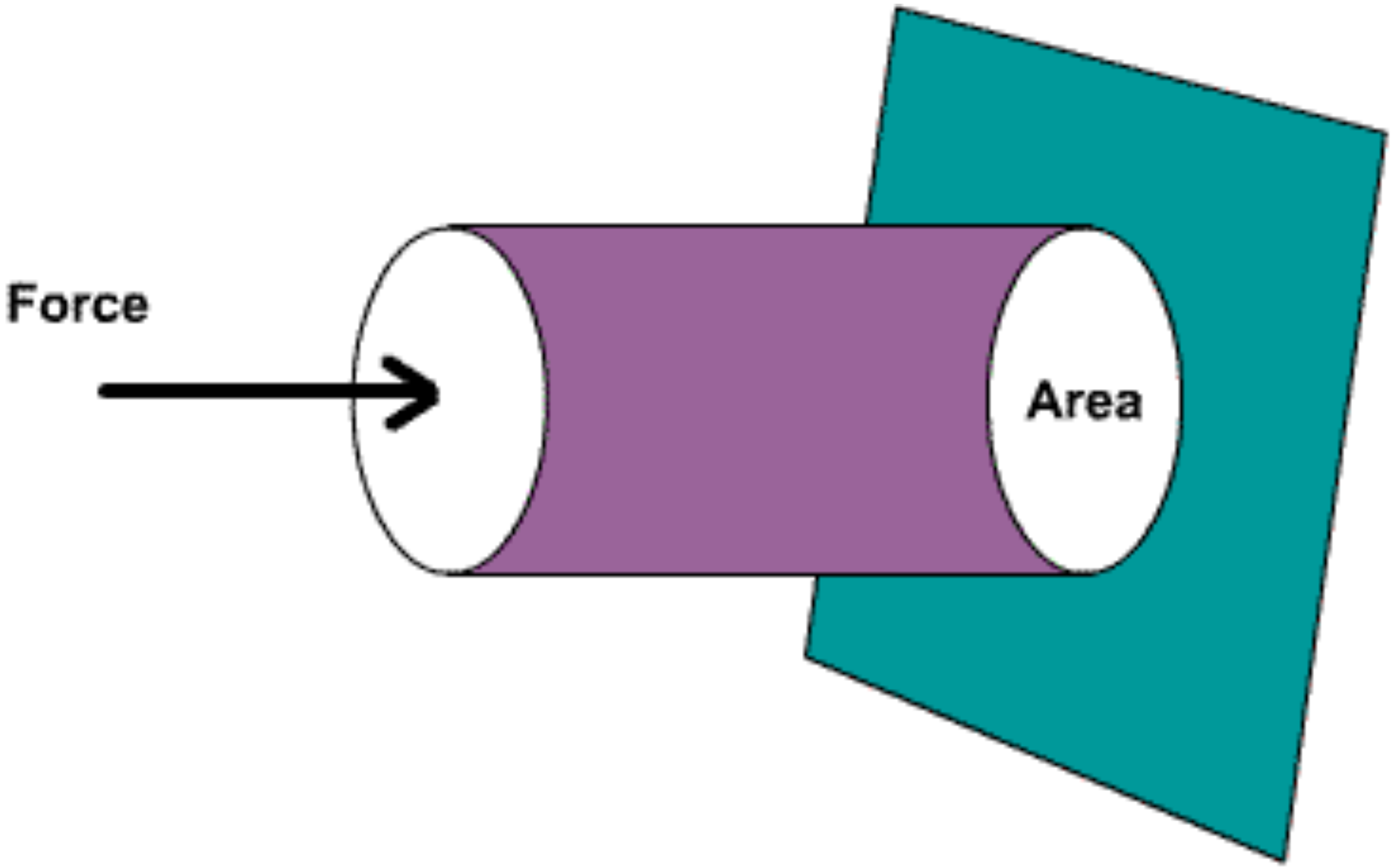
density = mass / volume

SI Unit: kg/m^3

Mass Density Example



Force on Area => Pressure



Definition: Pressure

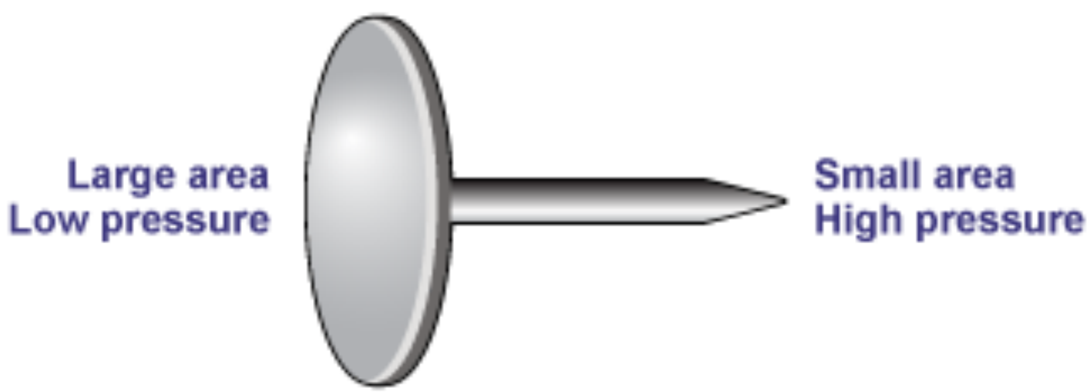
$$P = \frac{Force}{Area} = \frac{F}{A}$$

SI Units: $[N]/[m^2]$ = [Pascals]

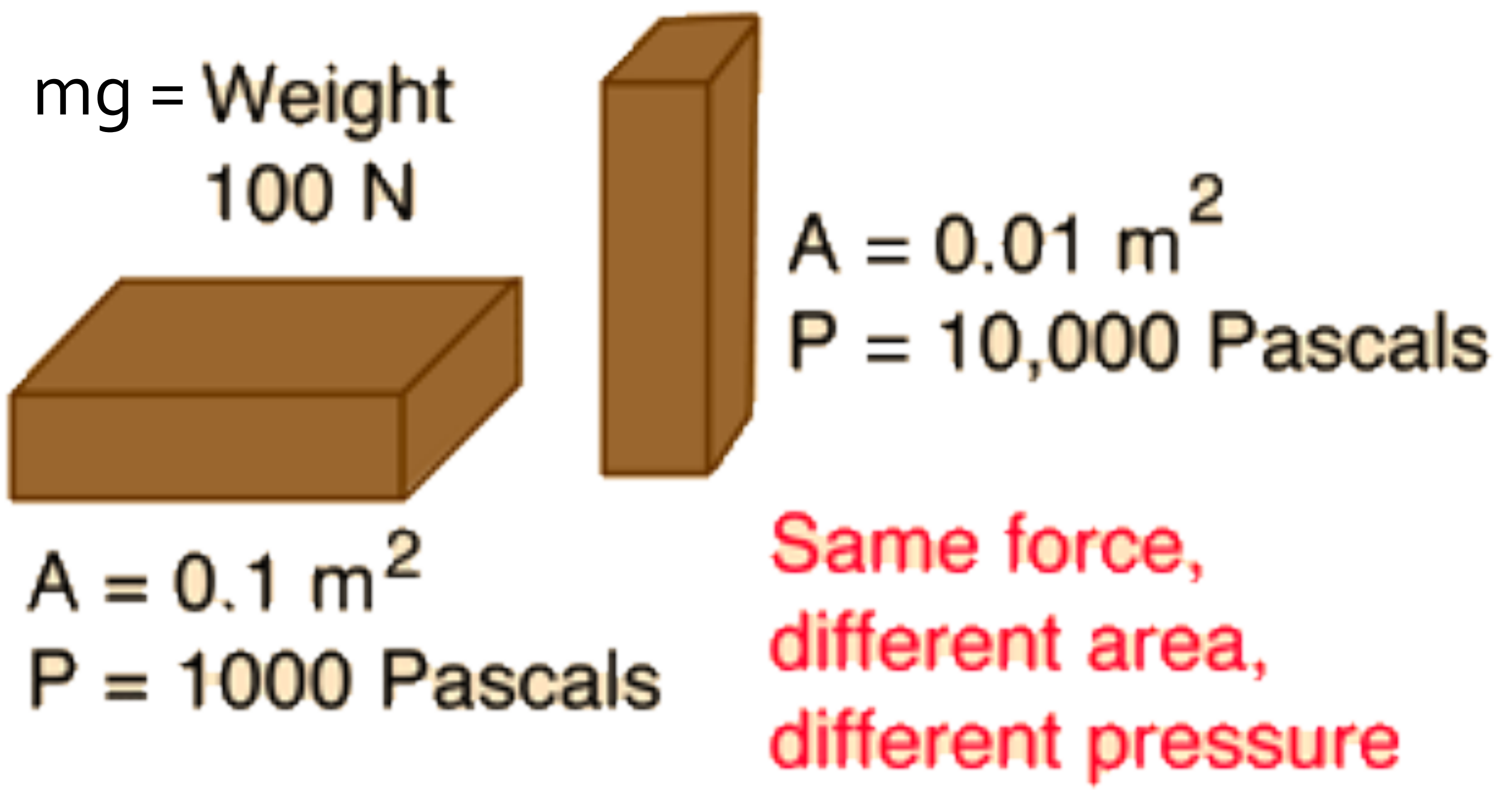
1 atmosphere = 1.013×10^5 Pa
1 pound per square inch (PSI) = 6895 Pa
1 Torr = 133.3 Pa

Why Pressure Instead of Force?

$$\text{PRESSURE} = \frac{\text{FORCE}}{\text{AREA}}$$



Pressure Due to Weight



Concept Check

- **You are walking out on a frozen lake and you begin to hear the ice cracking beneath you. What is your best strategy for getting off the ice safely?**

    a) stand absolutely still and don’t move a muscle

    b) jump up and down to lessen your contact time with the ice

    c) try to leap in one bound to the bank of the lake

    d) shuffle your feet (without lifting them) to move toward shore

    e) lie down flat on the ice and crawl toward shore

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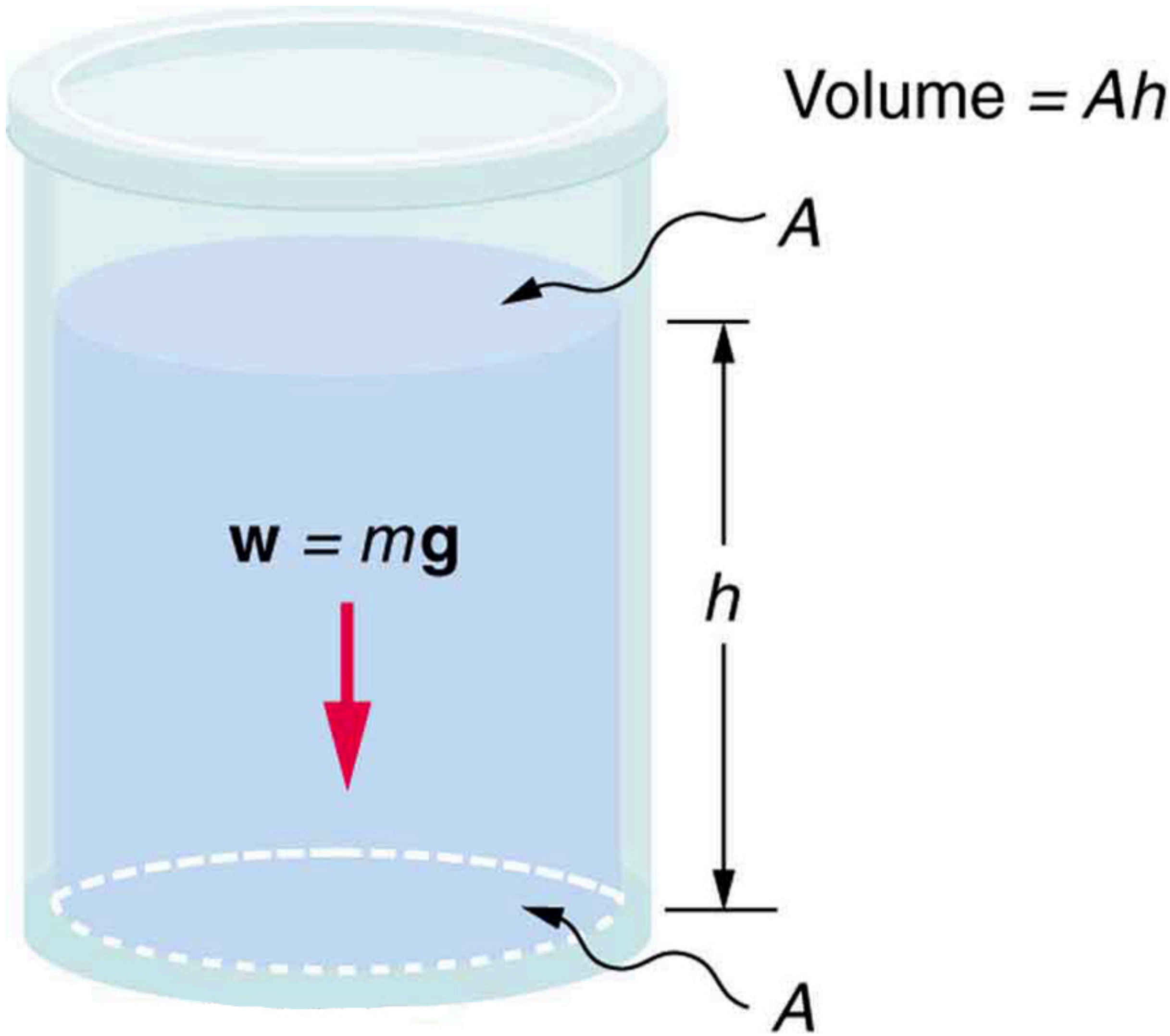
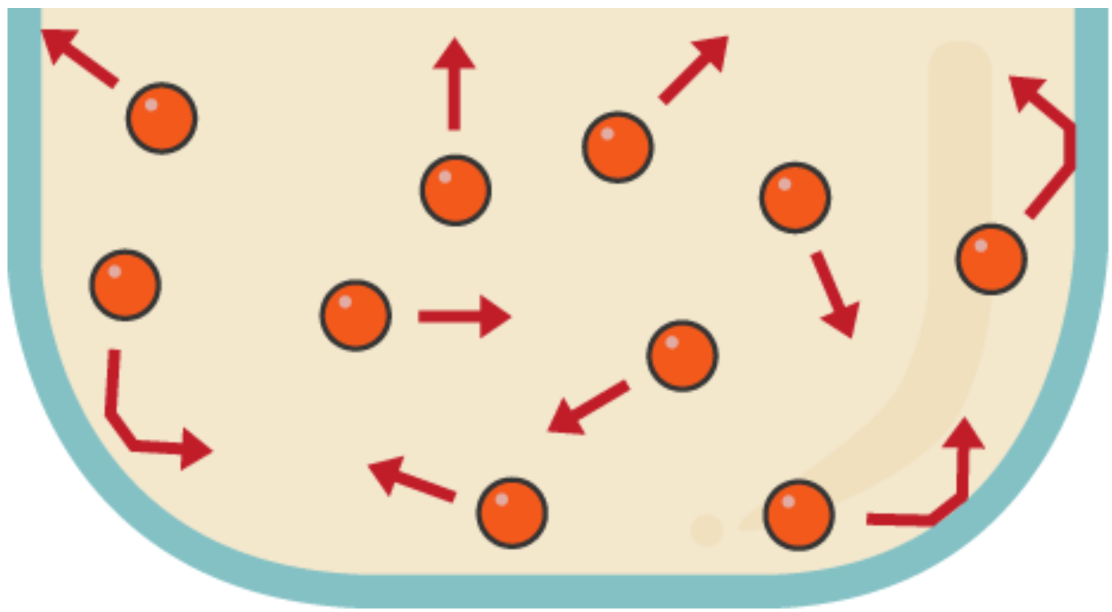
Pressure Due to Weight

Fluid Pressure Due to Weight



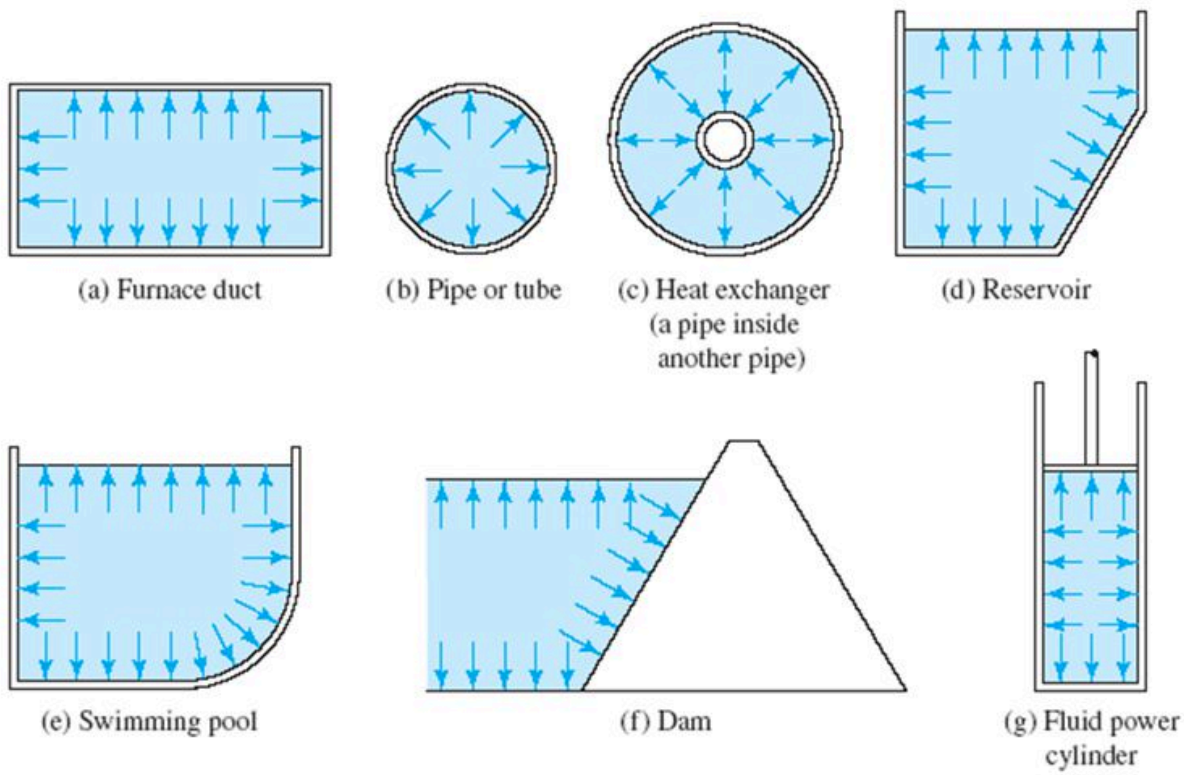
Pressure of Fluid Vs. Pressure from Solid

Pressure in Many Directions



Fluid Pressure and Direction of Force

- The pressure in a static fluid at a given point is the same in all directions
  - Otherwise the fluid would flow!
  - This means force is exerted on all surrounding surfaces



Incompressibility of Fluids

- Many fluids are to a good approximation incompressible
  - This means that no matter how hard you push on them, they do not change their volume
  - This means that if you push on a fluid, it doesn't squeeze together, but instead transmits the pressure throughout
- Air is more compressible than water, but at a given temperature and altitude can still often be treated as incompressible

Concept Check

- Imagine you stretch a balloon over the mouth of a bottle, with the balloon inside
- What happens if you try to blow it up?

A. It blows up
B. It won't blow up
C. The bottle will break
D. The balloon will pop

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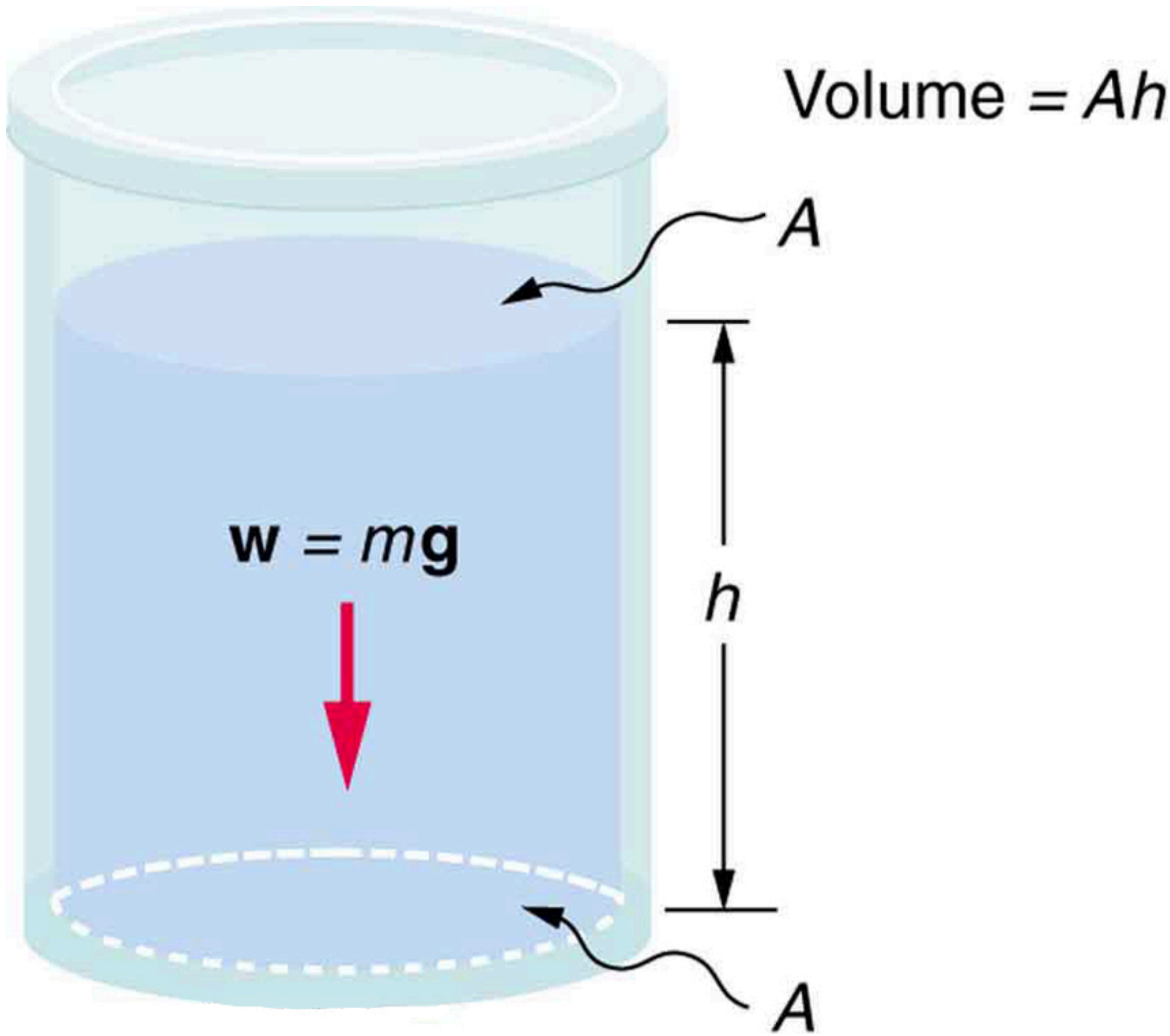
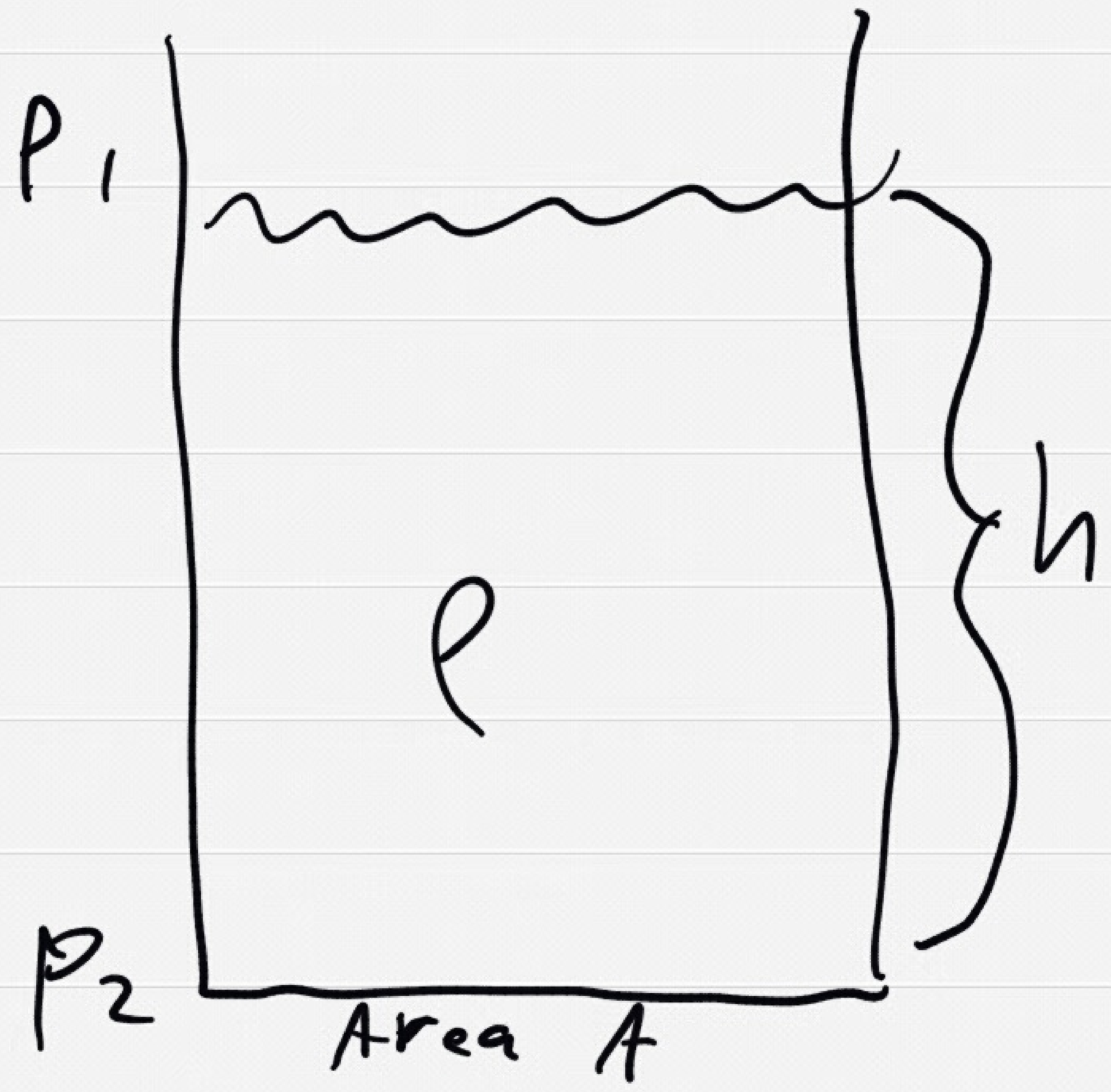
Fluid Pressure Due to Weight





Total mass of fluid

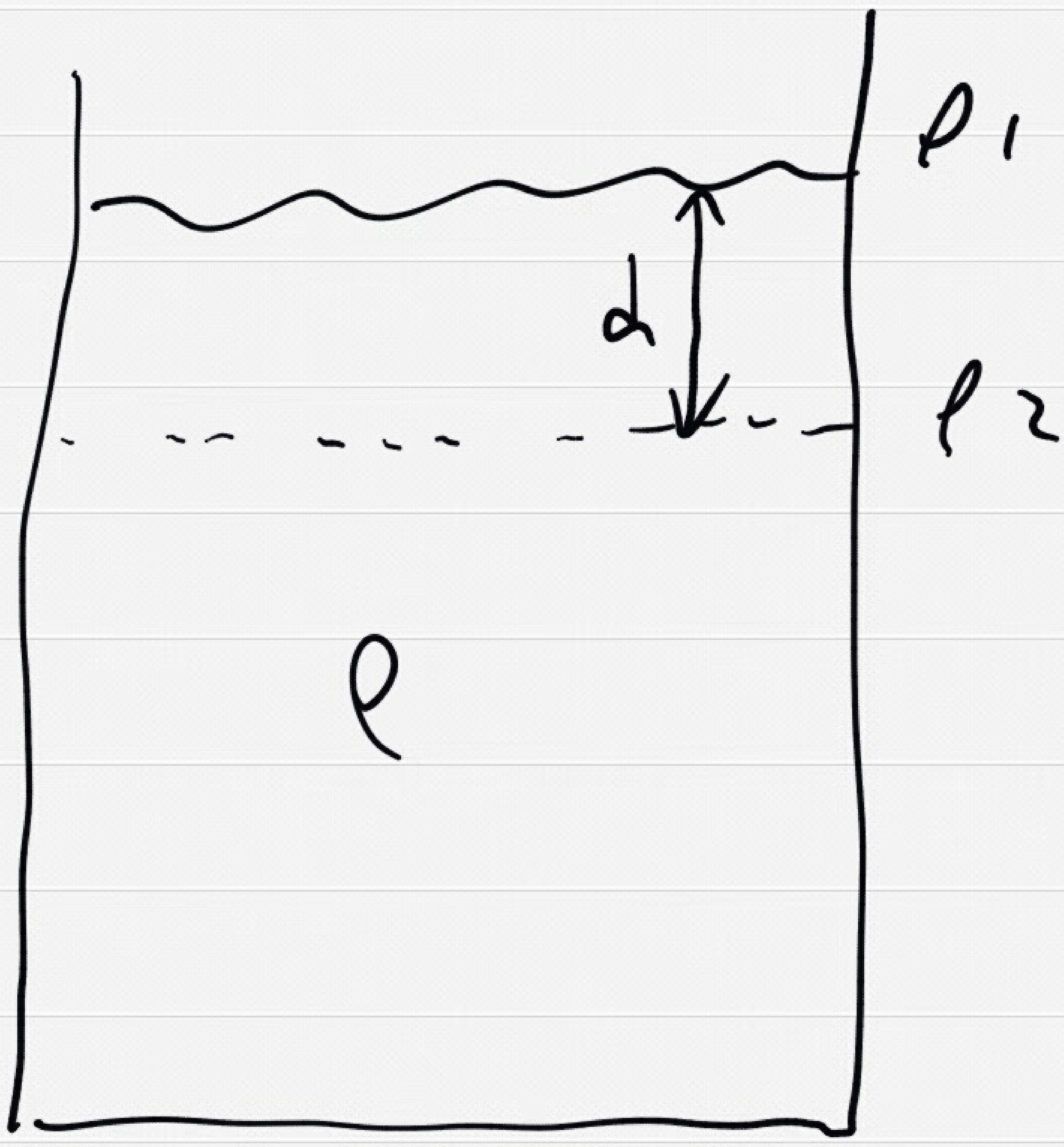
$$m = \rho A h$$

$$F = mg$$
$$= \rho A h g$$

$$P_2 = P_1 + F/A$$
$$= P_1 + \rho g h$$

Notice A cancels out!!

Works at any depth:



$$P_2 = P_1 + F/A$$

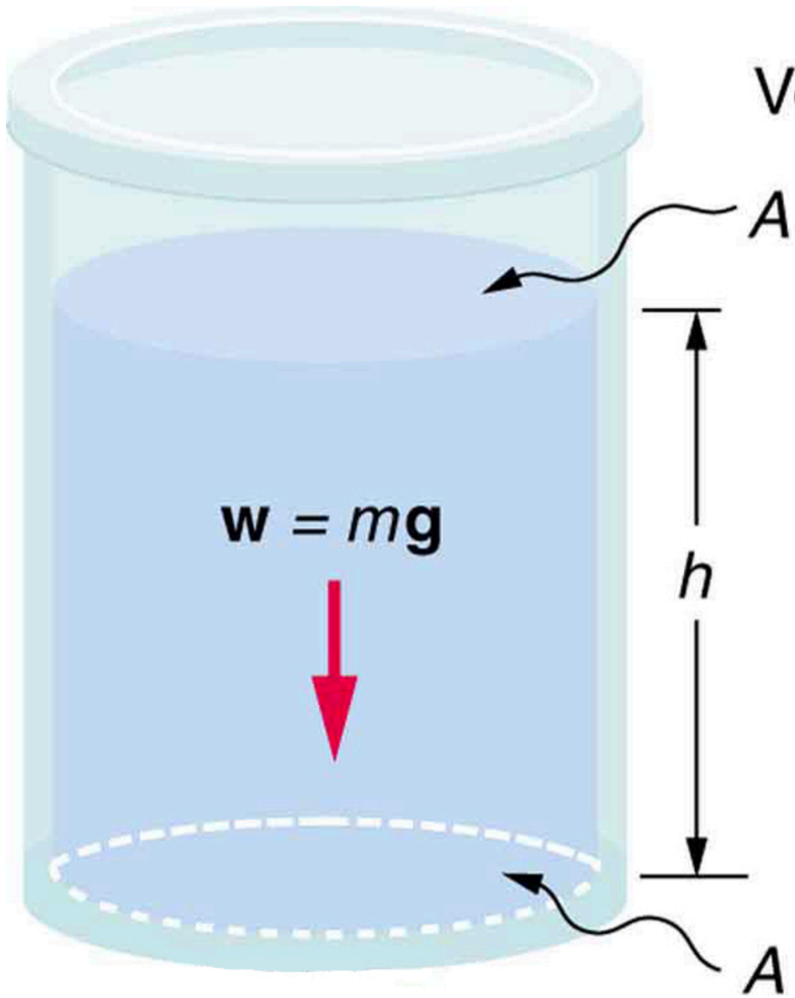
$$= P_1 + m_{above}\, g/A$$

$$= P_1 + \rho A d\, g/A$$

$$= P_1 + \rho g d$$

— Pressure goes up linearly with depth for incompressible fluid.

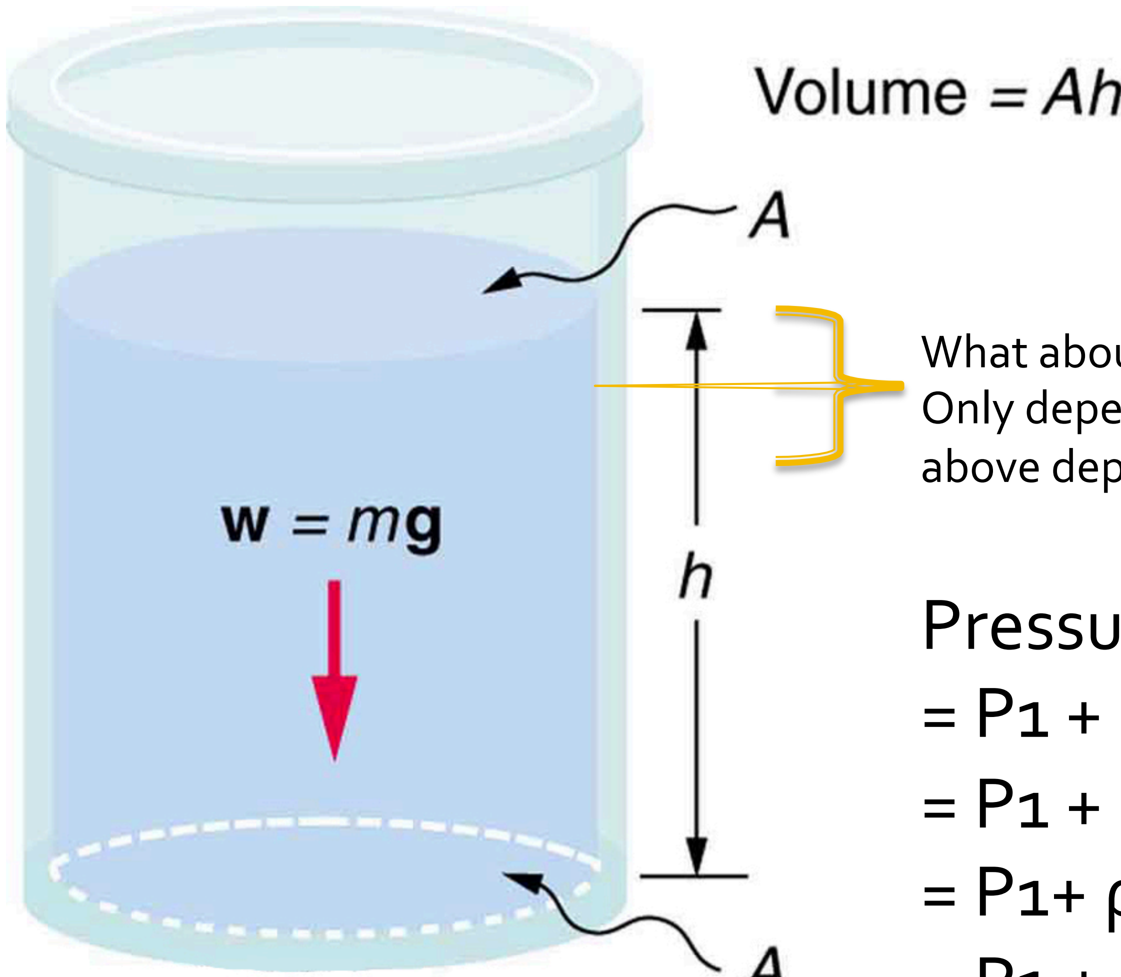
Pressure Vs. Depth



Given Pressure P1 at top:

Pressure P2 at bottom =
$P_1 + mg/A$
$= P_1 + \rho * volume * g/A$
$= P_1 + \rho * A * h * g/A$
$= P_1 + \rho g h$

Pressure Vs. Depth



What about pressure at intermediate depth d? Only depends on mass m_d and volume V_d above depth d

Pressure P2 at depth d

$= P1 + m_d g/A$

$= P1 + \rho * Vd * g/A$

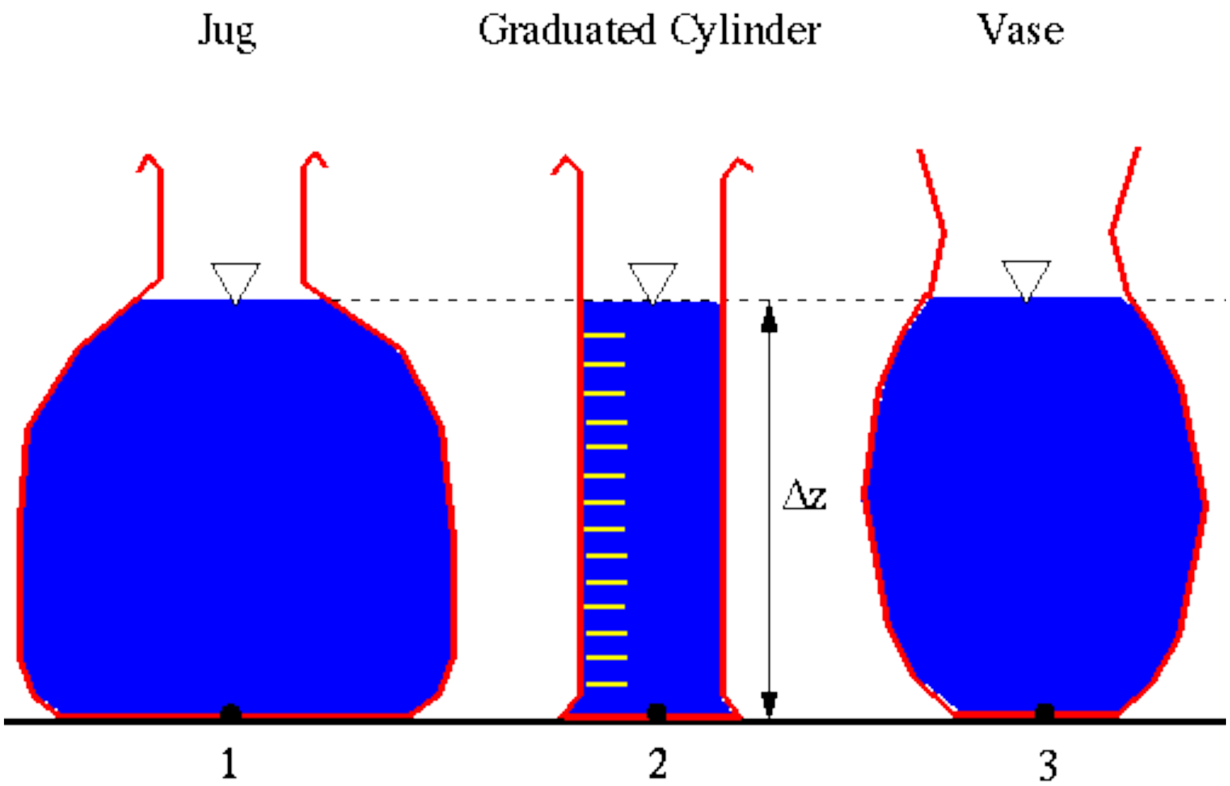
$= P1 + \rho * A * d * g/A$

$= P1 + \rho g d$

Concept Check

- Which one of these containers has a higher pressure at the bottom?

A. Jug
B. Cylinder
C. Vase
D. All the same



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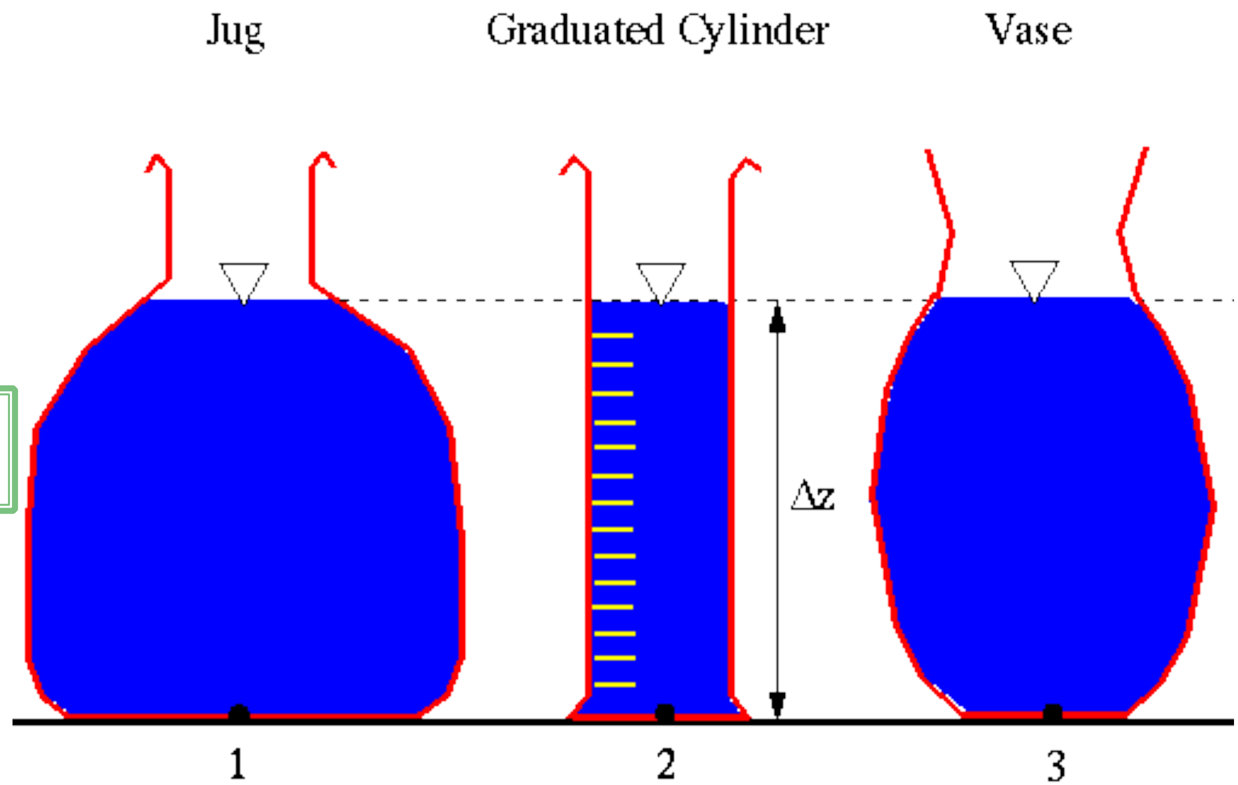
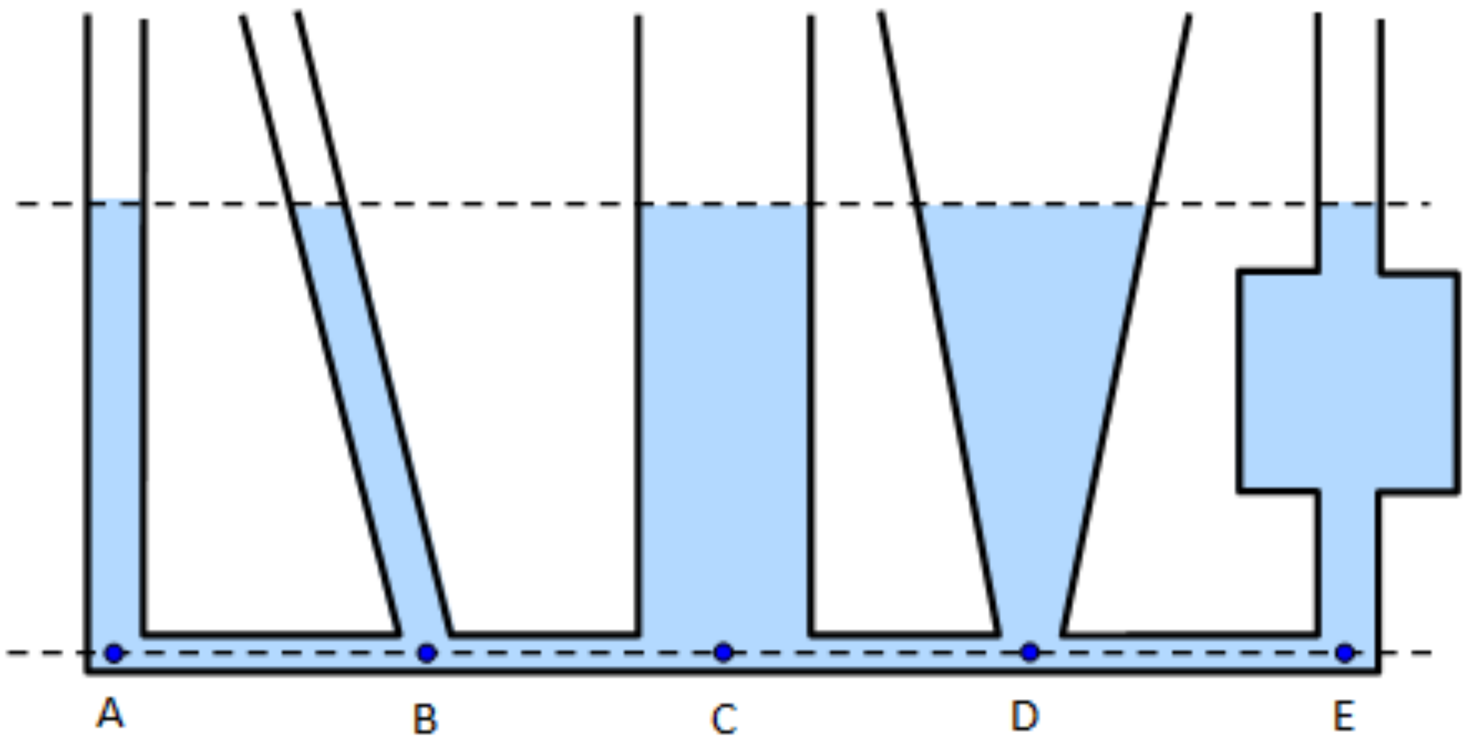
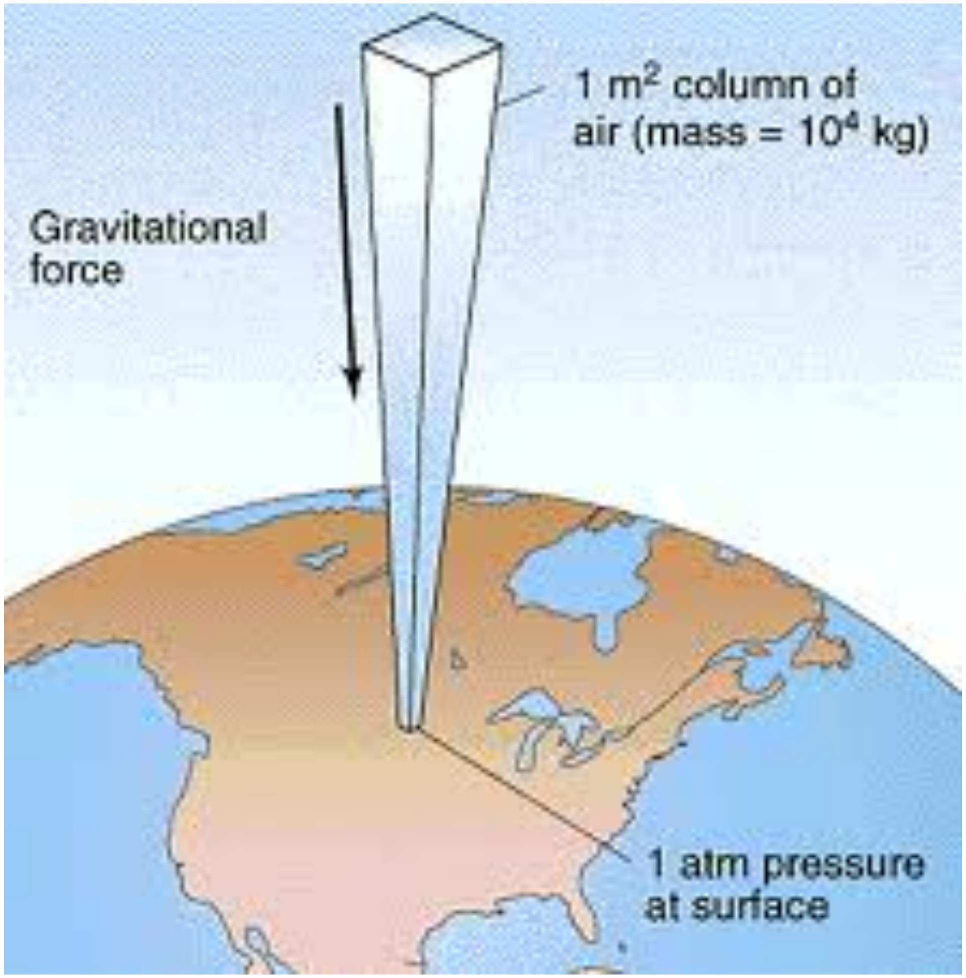


Pressure Vs. Depth

- Static fluid pressure does not depend on the shape, total mass, or surface area of the liquid, but only on the mass density and the depth



Atmospheric Pressure



Atmospheric pressure from the weight of the atmosphere above us is constantly exerted upon us

This pressure is very large:
$\sim 10^5$ Pa = 14.7 psi

Since atmosphere is a gas, we feel this pressure from all directions and we typically don't notice it

Force and Pressure Differential

Pressure P_1

Force on Area A

$F_1 = P_1*A$ to right

Pressure P_2

Force on Area A

$F_2 = P_2*A$ to left

Total Force on Wall $F = F_1 - F_2 = P_1A - P_2A = (P_1 - P_2)A$

Concept Check

- Where would a suction cup be hardest to remove after it is pushed on to a surface?

A. On the surface of the Earth
B. On top of a tall mountain
C. In space
D. At the bottom of your swimming pool

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Force and Pressure Differential

- We don't usually feel the force from the atmosphere or from a liquid, since it's balanced on all sides
- But, if you have atmosphere or liquid only on one side, it can exert a very large force
- Even the difference in pressure over a small change in depth can result in a force on an object…