University Physics 226N/231N
Old Dominion University
Fluids (Chapter 14, Credits to Dr. Godunov)

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Wednesday November 28, 2012

Happy Birthday to Jon Stewart, Russell Alan Hulse (1993 Nobel), Claude Levi-Strauss, and Chamillionaire!
Happy Red Planet Day and Make Your Own Head Day!

Apologies: Midterm 3 will be returned Friday (2 min/q=18 hrs)

We have homework due Friday, and a quiz on Friday

NEXT WEEK IS ALL REVIEW

Monday: Material to Midterm 1, Wednesday: Material to Midterm 2

Friday: Material to Midterm 3

Office hours: Whenever you need 'em

Fluids!

Classical fluid – substance that can flow (in contrast to a solid)

- ✓ **Air**
- ✓ **Water**
- ✓ *(Plasmas, kinda)*

Fluids comfort to the boundaries of any container in which we put them, and do not maintain a fixed shape

Density and Pressure

Density – mass per unit volume

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

m – mass of the object

V – its volume

SI units: kg/m^3 .

Example: What is the mass of the air in the class room with dimensions 12 m and 8 m and a height of 4 m . Density of air – 1.29 kg/m^3

$$m = \rho V = (1.29kg/m^3)*(12m*8m*4m) = 495kg$$

Density and Pressure

Pressure – force per unit area

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

F – force

A – area

SI units: N/m^2 = 1 Pascal (Pa)

Other units: 1 atm = $1.01*10^5$ Pa = 760 torr = 14.7 lb/in^2

Example: What is the pressure form a 60-kg person on the ground whose two feet cover an area of 500 cm^2.

$$p = \frac{F}{A} = \frac{mg}{A} = (60kg)*(9.8m/s^2)/(0.050m^2) = 12000N/m^2$$

Checkpoint

The pressure exerted on the ground by a man is greatest when:

A) he stands with both feet flat on the ground

B) he stands flat on one foot

C) he stands on the toes of one foot

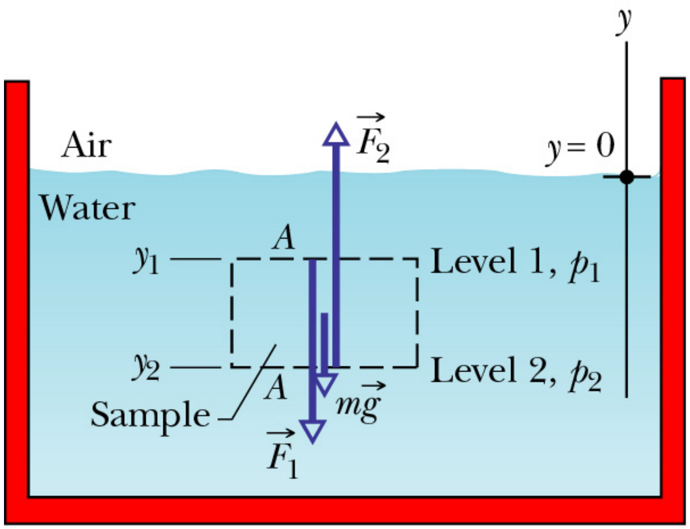
D) he lies down on the ground

E) all of the above yield the same pressure

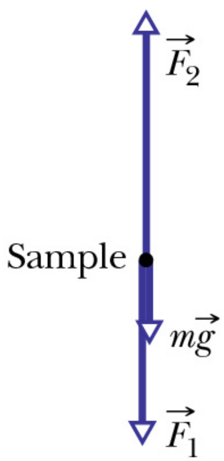
Fluids at rest – experimental facts

- ✓ A fluid exerts a pressure in all directions.
- ✓ At any point at rest the pressure is the same in all directions
- ✓ The pressure increases with depth
- ✓ The force due to fluid pressure always acts *perpendicular* to any surface it is in contact with

Hydrostatic pressure



(a)



(b)

The water is in static equilibrium

Free-body diagram

$$F_2 = F_1 + mg$$

$$F_1 = p_1 A \quad \text{and} \quad F_2 = p_2 A$$

$$p_2 A = p_1 A + \rho A(y_1 - y_2)g$$

$$\boxed{p_2 = p_1 + \rho g(y_1 - y_2)}$$

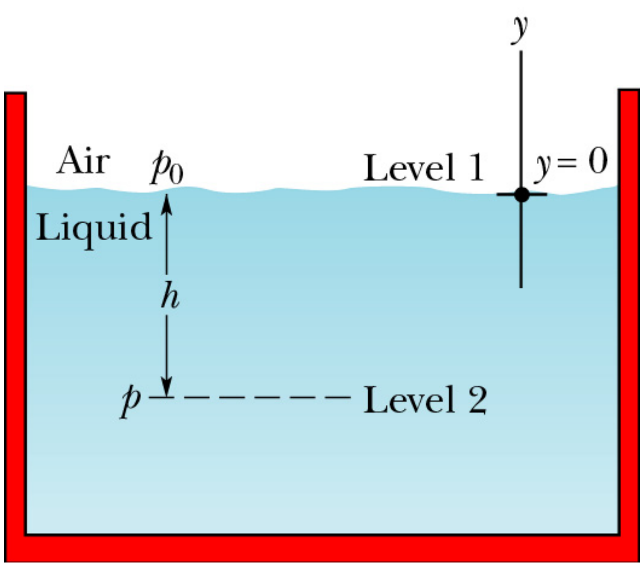
or pressure at depth *h*

$$\boxed{p = p_0 + \rho g h}$$

Hydrostatic pressure – gauge pressure

Pressure at depth *h*

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



p_0 – the pressure due to atmosphere

$\rho g h$ – the pressure due to the liquid above level 2.

The difference between an absolute pressure and an atmospheric pressure and the gauge pressure

Checkpoint

In a stationary homogeneous liquid:

A) pressure is the same at all points
B) pressure depends on the direction
C) pressure is independent of any atmospheric pressure on the upper surface of the liquid
D) pressure is the same at all points at the same level
E) none of the above

Problem: A submarine

Crew members attempt to escape from a damaged submarine 10 m below the surface. What force must be applied to a pop-out hatch, which is 1.2 m by 0.6 m, to push it out at that depth? Assume that the density of the ocean water is 1025 kg/m^3.

$$F = pA$$

$$p = \rho g h$$

$$F = \rho g h A = 7.23 \cdot 10^4 \text{ N} = 16270 \text{ lb}$$

Atmospheric pressure

The pressure of the Earth's atmosphere varies with altitude.

Atmospheric pressure at see level is about 1 atm
or $1.013*10^5$ N/m^2 = 14.7 lb/in^2

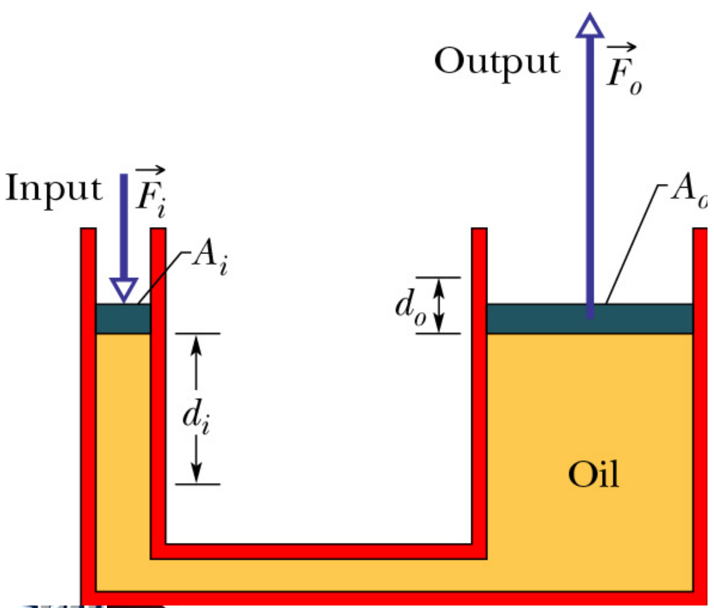
How do windows withstand this pressure?

How does a human body withstand the enormous pressure on its surface?

Pascal's principle

A change in pressure applied to an enclosed incompressible fluid is transmitted undiminished to every point of the fluid and to the walls of its container

Example – Pascal's principle and the hydraulic lever



$$\frac{F_i}{A_i} = \frac{F_0}{A_0}$$

$$F_0 = F_i \frac{A_0}{A_i}$$

However

$$V = A_i d_i = A_0 d_0 \qquad d_0 = d_i A_i / A_0$$

with a hydraulic lever, a given force applied over a given distance can be transformed to a greater force applied over a smaller distance

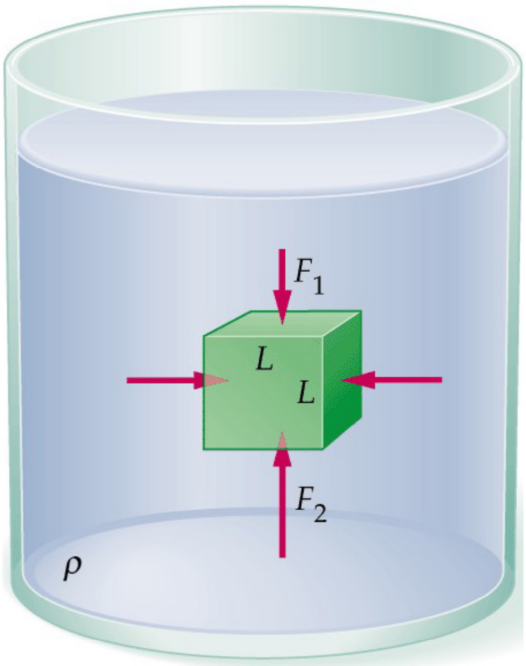
Archimedes' principle of buoyancy

When a body is fully or partially submerged in a fluid, a buoyant force from the surrounding fluid acts on the body. The force is directed upward and has a magnitude equal to the weight of the fluid that has been displaced by the body

$$F_b = m_f g = \rho_f V g$$

m_f – mass of the fluid that is displaced by the body

Archimedes' principle of buoyancy (proof)



$$F_1 = P_1 A$$

$$F_2 = P_2 A$$

$$F_b = F_2 - F_1 = (P_2 - P_1)A =$$

$$= (P_1 + \rho_f gh - P_1)A = \rho_f ghA = \rho_f gV = m_f g$$

$$\boxed{F_b = m_f g = \rho_f Vg}$$

the key – the pressure increases with the depth

Floating (condition)

gravitational force = buoyancy force

$$F_g = F_b$$

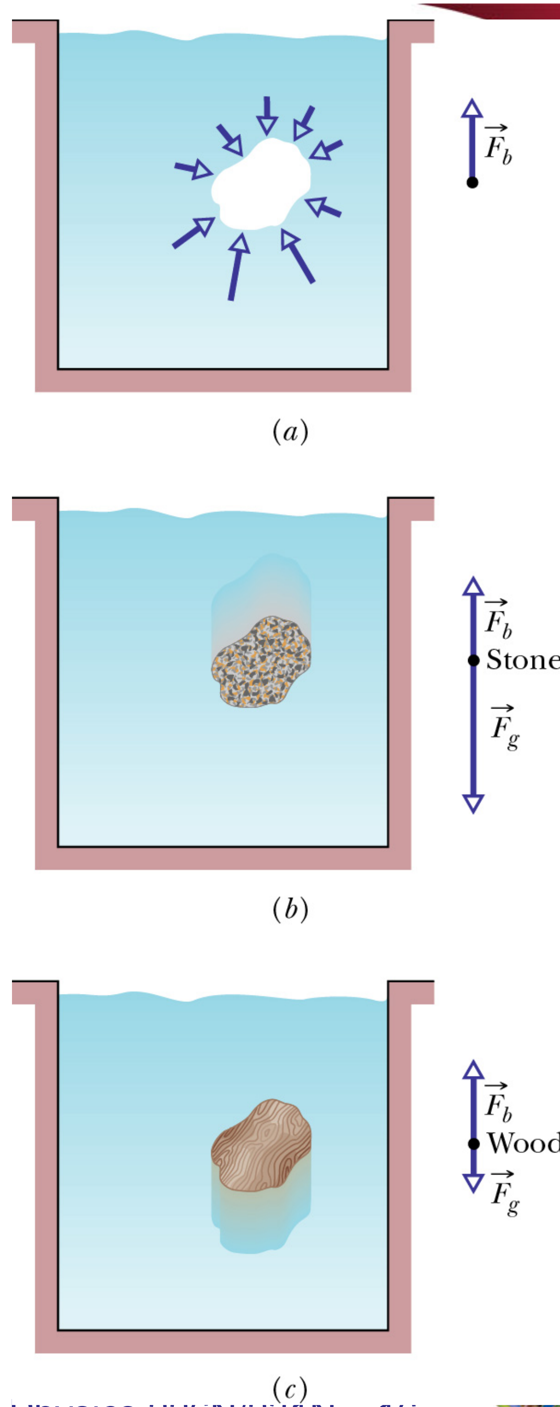
for an object with a uniform density

$$\rho V g = \rho_f V_{submerged}\, g$$

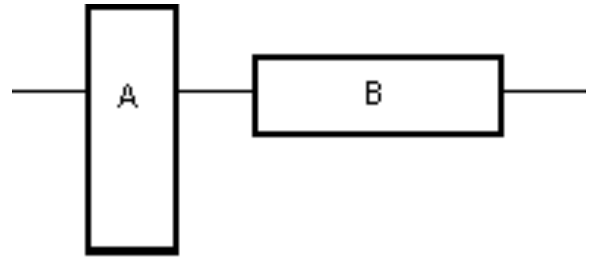
$$\rho V = \rho_f V_{submerged}$$

$$\rho \le \rho_f$$

How do steel battleships float?



Checkpoint



Two identical blocks of ice float in water as shown. Then:

A) block A displaces a greater volume of water since the pressure acts on a smaller bottom area

B) block B displaces a greater volume of water since the pressure is less on its bottom

C) the two blocks displace equal volumes of water since they have the same weight

D) block A displaces a greater volume of water since its submerged end is lower in the water

E) Block B displaces a greater volume of water since its submerged end has a greater area

Problem: Helium balloon

What volume of helium is needed if a balloon is to lift a load of 180 kg (including the weight of the empty balloon (air density: 1.29 kg/m^3, helium density 0.179 kg/m^3)

$$F_g = (m_{He} + 180kg)g$$

$$F_b = \rho_{air} V g$$

$$(\rho_{He} V + 180kg)g = \rho_{air} V g$$

$$V = \frac{180kg}{\rho_{air} - \rho_{He}} = 160m^3$$

Which weights more, a pound of wood, or pound of lead?

Apparent weight in a fluid

$$weight_{app} = weight - F_b = mg - \rho_{fluid} V g$$

Archimedes: Is the crown gold?

Real story?

Apparent weight in a fluid

$$weight_{app} = weight - F_b$$

Mass of the crown: 14.7 kg
when submerged in water: 13.4 kg

$$w' = w - \rho_f V g$$

$$w = \rho_c V g$$

$$\Rightarrow \quad \frac{w - w'}{w} = \frac{\rho_f V g}{\rho_c V g} = \frac{\rho_f}{\rho_c}$$

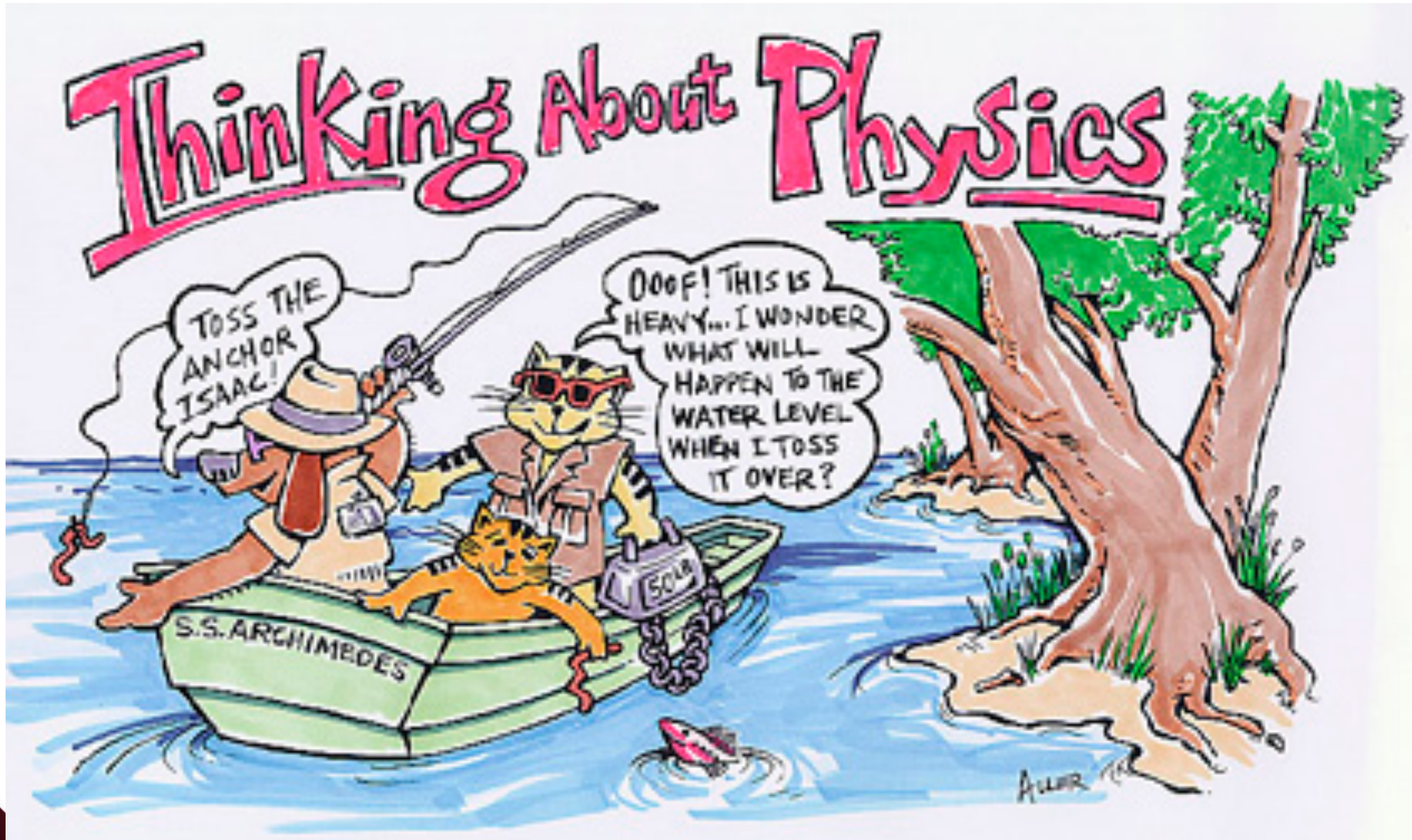
then the density of the crown 11,300 kg/m^3

density of gold 19,300 kg/m^3

density of lead 11,300 kg/m^3

Thinking about physics

from http://www.amherst.edu/%7ephysicsqanda/



A simple question?