Example Problems:
Bar one has a Young’s modulus that is bigger than that of bar Two. This means that bar one:

1. is longer than bar two
2. is shorter than bar two
3. has a greater cross-sectional area than bar two
4. has a smaller cross-sectional area than bar two
5. is made of a different material than bar two
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Density and Pressure

Density = Mass / Volume

\[ \rho = \frac{M}{V} \]

• A material property (such as Young’s Modulus)!

Specific gravity: density / density of water

\[ \frac{\rho}{\rho_{water}} \]

\[ \rho_{water} = 10^3 \frac{\text{kg}}{\text{m}^3} = 1 \frac{\text{kg}}{\text{dm}^3} \quad @ \quad 4^\circ C \]
What has more mass:
1 kg of water or 1 kg of steel?
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What has a higher density:
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What has a higher density:
1kg of water or 1kg of steel?

What has a larger volume:
1kg of water or 1kg of steel?
Density and Pressure

Pressure = Force / Area

Examples:
- Bulk modulus
- Air pressure

More precise:
It is the force component perpendicular (normal) to the area.
- Can, but does not has to come from all sides
Example:

- Tire pressure: The pressure in your tires should be 35psi. Your car has a mass of 1500kg. How large is the area of the tires which make contact to the street?
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Pressure in SI-units:

\[
35 \text{psi} = 35 \frac{\text{lbs}}{\text{in}^2} \left( \frac{4.45 \text{N}}{\text{lbs}} \right) \left( \frac{39.37 \text{in}}{\text{m}} \right)^2 = 241 \text{ kPa}
\]

Has to support the weight of the car:

\[
F = W = 1500 \text{kg} \times g = 14.7 \text{ kN}
\]

\[
A = \frac{F}{P} = \frac{14.7 \text{ kN}}{241 \text{ kPa}} = 0.06 \text{ m}^2 \quad \Rightarrow \quad A_{tire} = \frac{A}{4} = 0.015 \text{ m}^2
\]

Typical Rim width: \( w = 6.5'' = 16.5 \text{ cm} \quad \Rightarrow \quad l \approx 9 \text{ cm} \)
Variations of Pressure with depth

Block of water in water
Variations of Pressure with depth

Fluid at rest:
Pressure/Force must be same on both sides, otherwise would move.

Fluid at rest:
Pressure/Force from bottom must be higher than from top to compensate gravity, otherwise would move.
The pressure increases with depth!

Normally written for pressure \( P \) at a depth \( h \) below the surface of a liquid:

\[
P = P_0 + \rho gh
\]

where \( P_0 \) is the pressure at the surface (often air pressure)
Pascal’s principle:
A change in pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid and to the walls of the container.
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\[ \Delta P = \frac{\Delta F}{A} \]

is the same everywhere

\[ \Delta P = \Delta F \]

\[ F_1 \Rightarrow F_1 + \Delta F \]

\[ P_1 \Rightarrow P_1 + \Delta P \]

\[ P_2 \Rightarrow P_2 + \Delta P \]

\[ P_2 - P_1 = \rho gh \]
Pascal’s principle:
A change in pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid and to the walls of the container.

\[ F_1 \Rightarrow F_1 + \Delta F \]

\[ F_2 \Rightarrow F_2 + \Delta P \cdot A_2 \]

\[ \Delta F_2 = \Delta F \cdot \frac{A_2}{A_1} \]

Hydraulics:
Used to lift heavy stuff

Thursday, November 4, 2010
Pressure Measurements:

\[ P = P_0 + \rho gh \]

A way to measure \( P - P_0 \). Need to know at either \( P \) or \( P_0 \).
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A way to measure \( P - P_0 \). Need to know at either \( P \) or \( P_0 \).

\[ P_0 = \rho gh \]

Pick \( P = 0 \)
Bouyant Force:

Free Body Equation:

\[ Ma = Mg + F_1 - F_2 \]

use:

\[ F_2 - F_1 = A(P_2 - P_1) = A\Delta P \]

\[ A\Delta P = A\rho_{fl}gh = g\rho_{fl}V = gM_{fl} \]

Gives:

\[ Ma = Mg - gM_{fl} \]

The pressure difference in the liquid due to its own weight gives rise to new force on the mass in the water:

Bouyant Force

\[ B = gM_{fl} \]

pushes against gravity.
Bouyant Force:

\[ B = gM_{fl} \]

Equal to the weight of the displaced fluid

\[ Ma = Mg - B = g(M - M_{fl}) \]

Three Situations:

- \( M > M_{fl} \) \( \Rightarrow \) \( M \) sinks
- \( M = M_{fl} \) \( \Rightarrow \) \( M \) stays at constant height
- \( M < M_{fl} \) \( \Rightarrow \) \( M \) rises until it reaches surface, then \( M \) floats
Bouyant Force:

\[ M < M_{fl} \]

\( M \) rises until it reaches surface, then \( M \) floats

\[ Ma = Mg - B = g(M - M_{fl}) \]

In equilibrium: \( a = 0 \)

we have:

\[ M = M_{fl} = \rho_{fl}V_{displ}. \]

For a homogenous mass: \( \rho_{Mass} = \text{constant} \)

Floating:

\( V_{mass} > V_{displ.} \) \( \Rightarrow \) \( \rho_{Mass} < \rho_{fl} \)

“Stuff that is lighter than water floats!”

Thursday, November 4, 2010
Question:
An aircraft carrier appears to be built mainly from iron and steel. It swims on water because:

A. The density of iron and steel is smaller than the density of water

B. Most of the material used to build it is actually light wood and plastic

C. It swims because the speed of the carrier creates a lift similar to the lift that makes an airplane fly

D. Most of the displaced volume is filled with air which is much lighter than water.

E. The Navy sends a team of divers which pushes it up 24h/7d.
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C. It swims because the speed of the carrier creates a lift similar to the lift that makes an airplane fly

D. Most of the displaced volume is filled with air which is much lighter than water. AND if you replace it with water, the ship sinks.

E. The Navy sends a team of divers which pushes it up 24h/7d.
HITT:
How large a force is necessary to stretch a 2.0mm diameter steel wire \((Y = 200 \text{ GPa})\) by 1%?

1. 3.1kN

2. 6.3kN

3. 9.4kN

4. 12.6kN

5. 14.1kN
HITT:
How large a force is necessary to stretch a 2.0mm diameter steel wire ($Y = 200$ GPa) by 1%?

1. 3.1kN
   \[ \frac{F}{A} = Y \frac{\delta L}{L} \]

2. 6.3kN
   \[ \frac{F}{A} = Y \frac{\delta L}{L} = 2 \times 10^{11} \cdot 10^{-2} \frac{N}{m^2} \]

3. 9.4kN
   \[ A = \frac{\pi}{4} d^2 = \pi \times 10^{-6} m^2 \]

4. 12.6kN
   \[ F = \pi \times 10^{-6} 2 \times 10^{11} \cdot 10^{-2} N = 6300N \]

5. 14.1kN
HITT:
How large a force is necessary to stretch a 3.0mm diameter steel wire (Y = 200 GPa) by 1%?

1. 3.1kN
2. 6.3kN
3. 9.4kN
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\]

3. 9.4kN

\[
A = \frac{\pi}{4} d^2 = 7.1 \times 10^{-6} m^2
\]

4. 12.6kN

\[
F = 7.1 \times 10^{-6} \cdot 2 \times 10^9 N = 14.1 kN
\]

5. 14.1kN