# Fluid Mechanics

http://www.slideshare.net/guest4f7c558/chapter-11-fluids-vic

# <u>Fluid Mechanics</u>

(C13 - Red (Page 265))
(C11 - CJ (page 300))

<u>Fluid Mechanics</u> - the study of how fluids behave
- fluids are materials that can flow and they include both gases and liquids.

**Fluid Mechanics**

**Hydrostatics**
(study of fluids that do not move)

**Hydrodynamics**
(study of fluids in motion)

# Mass Density

- definition: mass per unit volume
- factor that determines the behavior of a fluid
- represented by the Greek letter rho ($\rho$)

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

$\rho$ - mass density ($kg/m^3$)
m - mass (kg)
V - volume ($m^3$)

* Density does not depend on the amount of material that you have - the density of a teaspoon of tea is the same as the density of the tea filling a swimming pool.

Handout - Densities (Cutnell- Johnson)

**Table 11.1 Mass Densities[a] of Common Substances**

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| Substance | Mass Density $\rho$ ($kg/m^3$) |
|---|---|
| **Solids** | |
| Aluminum | 2700 |
| Brass | 8470 |
| Concrete | 2200 |
| Copper | 8890 |
| Diamond | 3520 |
| Gold | 19 300 |
| Ice | 917 |
| Iron (steel) | 7860 |
| Lead | 11 300 |
| Quartz | 2660 |
| Silver | 10 500 |
| Wood (yellow pine) | 550 |
| **Liquids** | |
| Blood (whole, 37 °C) | 1060 |
| Ethyl alcohol | 806 |
| Mercury | 13 600 |
| Oil (hydraulic) | 800 |
| Water (4 °C) | $1.000 \times 10^3$ |
| **Gases** | |
| Air | 1.29 |
| Carbon dioxide | 1.98 |
| Helium | 0.179 |
| Hydrogen | 0.0899 |
| Nitrogen | 1.25 |
| Oxygen | 1.43 |

[a] Unless otherwise noted, densities are given at 0 °C and 1 atm pressure.

# Weight and Mass Density

Weight can be calculated from mass density, volume and the acceleration due to gravity.

Example - The body of a man whose weight is 690 N contains about $5.2 \times 10^{-3}$ $m^3$ of blood. ($\rho_{blood} = 1060$ kg/$m^3$)

a) Find the blood's weight. (54 N)

b) Express the blood's weight as a percentage of the body's weight. (7.8%)

$W = mg$ | $\rho = \frac{m}{V}$

$m = \rho V$

c) $W_m = 690N$

$V_b = 5.2 \times 10^{-3} m^3$

$\rho_b = 1060 kg/m^3$

$W_b = \rho_b V_b g$

$W_b = (1060)(5.2 \times 10^{-3})(9.80)$

$W_b = 54N.$

b) $\frac{W_b}{W_m} = \frac{54N}{690N} = \boxed{7.8\%}$

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a) $W = mg$

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

$m = \rho V$

$\boxed{W = \rho V g}$

$W = \left(1060 \frac{kg}{m^3}\right)\left(5.2 \times 10^{-3}\, m^3\right)\left(9.80\, m/s^2\right)$

$W = 54N$

b) $\frac{54N}{690N} = 7.8\%$

# Specific Gravity

The specific gravity or relative density of a substance is the ratio of a substance's density to the density of a standard reference material.  Water at 4°C is often used as the reference material.

$$\text{specific gravity} = \frac{\text{density of substance}}{\text{density of water at } 4^{\circ}\text{C}}$$

$$\text{specific gravity} = \frac{\text{density of substance}}{1.000 \times 10^{3}\ \text{kg/m}^{3}}$$

*** Specific gravity has no units.**

# Pressure

The pressure exerted by a fluid is defined as the magnitude of the force acting perpendicular to a surface divided by the area over which the force acts.  Pressure itself is not a vector quantity.  It has no directional characteristic.

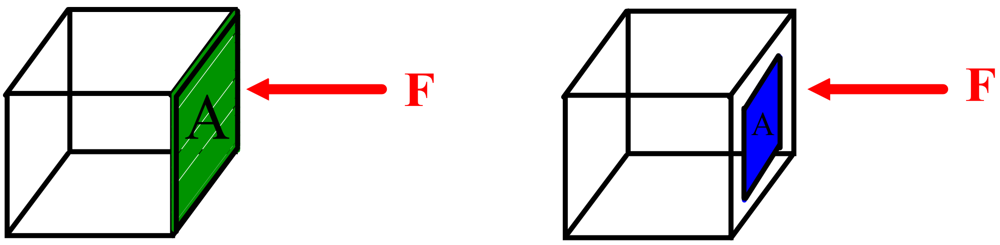
→ Pascal

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

P - pressure (Pa)
F - magnitude of force (N)
A - area ($m^2$)

NOTE

$1\ \text{Pa} = 1\ \frac{\text{N}}{\text{m}^2}$




$$1.013 \times 10^5\ \text{Pa} = 1.0\ \text{atm} = 760\ \text{torr} = 14.70\ \frac{\text{lb}}{\text{in}^2}\ \text{or psi}$$

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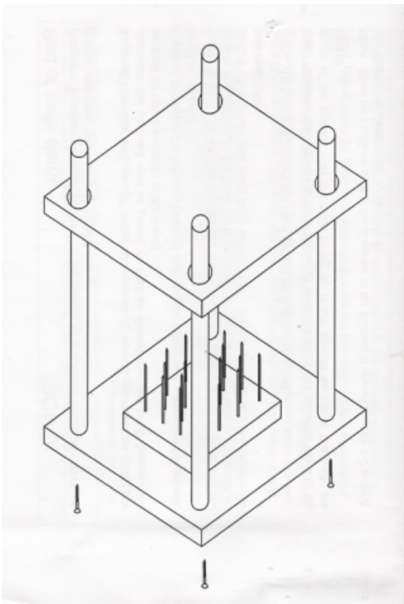
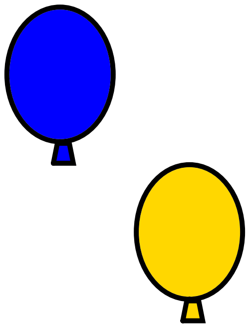
# Pressure - Balloon Demo

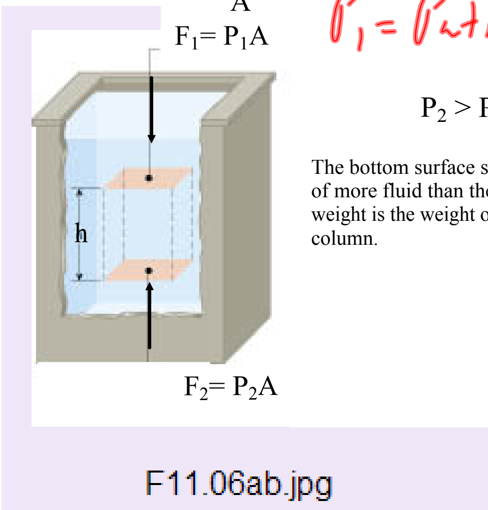




# Pressure and Depth in a Static Fluid

$P_1 = \frac{F_1}{A}$ (P₁ - fluid pressure)

$P_1 = P_{atm}.$




$P_2 > P_1$

The bottom surface supports the weight of more fluid than the top. The excess weight is the weight of the fluid in the column.

The fluid in the column is in equilibrium.

$$F_{nety} = 0$$

$$F_2 - F_1 - W = 0$$

$$P_2A - P_1A - mg = 0$$

$$P_2A = P_1A + mg$$

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

$$P_2A = P_1A + \rho Vg$$

$V = Ah.$

$$P_2A = P_1A + \rho(Ah)g$$

$$\boxed{P_2 = P_1 + \rho gh}$$

absolute pressure — gauge pressure

**hydrostatic pressure equation**

$P_2 - P_1 = \rho gh$

$\Delta P = \rho gh$

$P_2$ - pressure at lowest level (Pa)
$P_1$ - pressure at highest level (Pa)
$\rho$ - density of fluid (kg/m$^3$) -> Assuming an incompressible fluid
$g = 9.80$ m/s$^2$
h - vertical distance between levels (m)

$$\boxed{\Delta P = \rho gh}$$

gauge.

The pressure at a surface exposed to air is called atmospheric pressure. It is sometimes represented by $P_{atm}$.

$$\boxed{P_{atm} = 1.01 \times 10^5 \text{ Pa}}$$

Δ

The pressure increment $\rho gh$ is affected by the vertical distance, h, but not by any horizontal distance within the fluid.

Example:

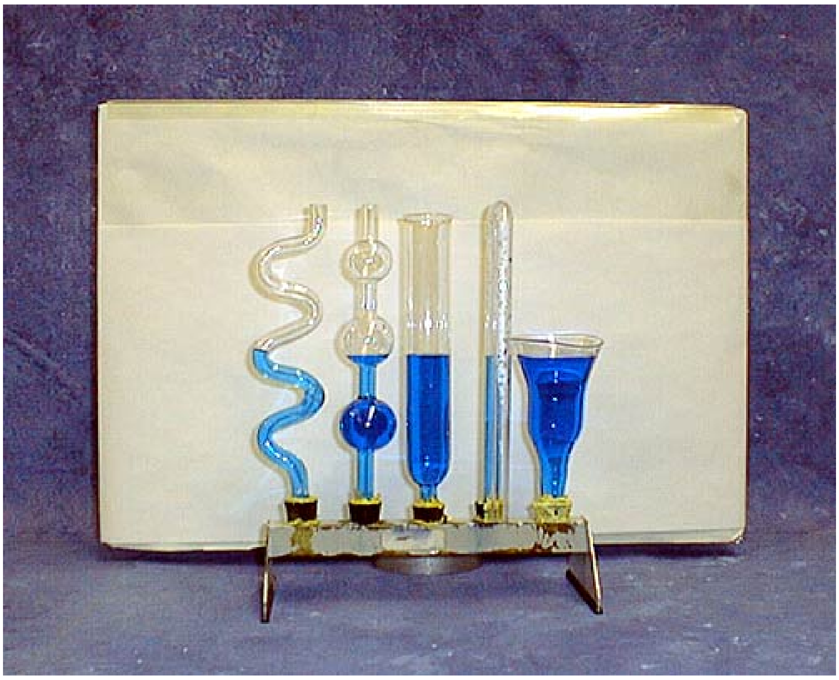
The pressure 100 m below the surface of the ocean is the same as the pressure at the bottom of a hypothetical soda straw that is 100 m long and filled with water.

Example:

**Pascal's Vases** **http://www.youtube.com/watch?v=e6_DDx07JJM**

**Description:**

Several differently shaped vases are all connected at the bottom, and fluid is put into all of them. Since atmospheric pressure is the same in each vase, the fluids will seek their own level, no matter what the shape of the container. The pressure at the bottom of each container is the same.



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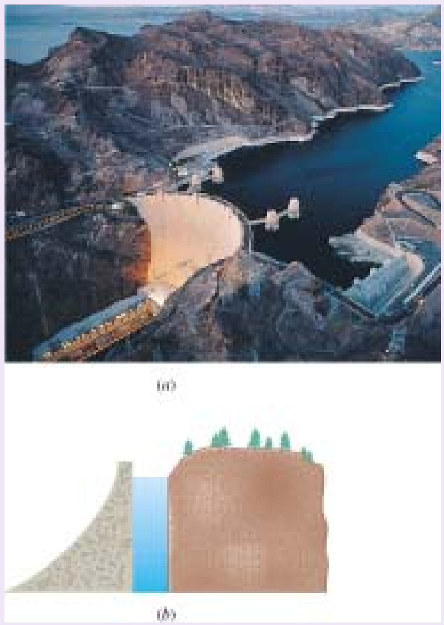
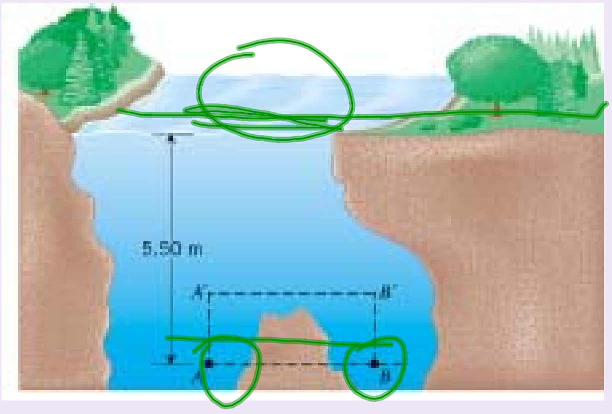
Example:



F11.07.jpg

Example → The cross-section of a swimming hole is shown. Points A and B are both located at a distance $h = 5.50\text{ m}$ below the surface of the water. Find the pressure at A and B. hydrostatic.




F11.08.jpg

$W = mg$

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

$P_2 = P_1 + \rho g h.$

$P_1 = (P_{atm}) = 1.01 \times 10^5 \text{ Pa}$

$P_2 = ? = P_A = P_B$

$\rho = 1000 \text{ kg/m}^3$

$g = 9.80 \text{ m/s}^2$

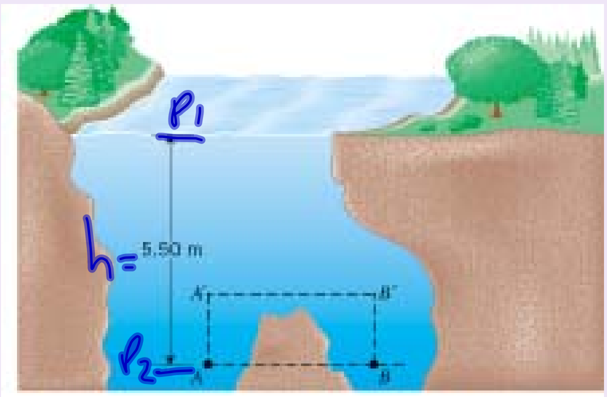
$h = 5.50 \text{ m.}$

$P_2 = P_1 + \rho g h$

$P_2 = 1.01 \times 10^5 + (1000)(9.80)(5.50)$

$P_2 = \_\_\_\_\_\_ \text{ Pa}$

Example → The cross-section of a swimming hole is shown. Points A and B are both located at a distance $h = 5.50$ m below the surface of the water. Find the pressure at A and B.

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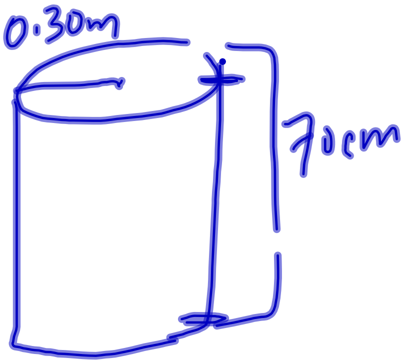
$$P_2 = P_1 + \rho g h$$

$$P_2 = P_{atm} + \underbrace{\rho}_{1000\ \frac{kg}{m^3}} g h$$

$$P_2 = P_A = P_B = 1.55 \times 10^5 \text{ Pa}$$

Example → The varsity football team's water cooler is a plastic cylinder 70cm high with a 30cm radius. A 2.0cm diameter hole is cut near the bottom for the water to flow out. What is the force on the plug in the hole due to the water in the cooler when the cooler is full? Assume the container is open to the atmosphere.

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Attachments

Science 122 - Fluids - Problems (Pressure and Depth).doc