$A \Delta P = \Delta F_{Top}$ to bottom

# Fluids I

Monday, March 22, 2010
10:03 AM

incompressible

Fluids are defined as liquids or gases, their effects are based around simple properties such as density and speed of motion.

compressible

Density of a fluid is simply its mass per unit of volume or:

$\rho = \frac{m}{V_{ol}}$ $m \leftarrow kg$, $V \leftarrow m^3$

Fluids Notes:

Density:

The distribution of mass in a volume of any particular substance

Density = mass/volume or

$\rho = m/V$

Units

- (best choice, works with all formulae)
- , , (all equivalent, most commonly used)

$1\,m^3 = 10^6\,cm^3$

$1\,m^3 = 10^3\,l$

$P_1 = P_2$

D - FN $1\,l = 10^3\,cm^3$

## Pressure:

Pressure:

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$P = \frac{F_N}{A\ m^2} = Pa$

$1\ L = 10^3\ cm^3$

The force exerted over a surface area

Pressure = Force / area or

$m = \rho V$

$P = F/A$

Units

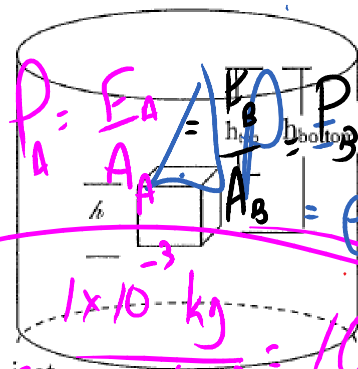
N/m$^2$ or (Pascals) [units are equivalent]

Pressure in fluids is the weight (Fg) of a column of the fluid above an area

Pressure in fluid is perpendicular to surface fluid contacts

$P_{top} = \rho g h_{top}$

$P_{bottom} = \rho g h_{bottom}$



$P_A = \frac{F_A}{A_A} = \frac{F_B}{A_B}$

$P_{bottom} - P_{top} = \rho g \Delta h$

$\rho_{H_2O} = 1 \frac{g}{cm^3} = \frac{1\times10^{-3}\ kg}{1\times10^{-6}\ m^3} = 1000\ \frac{kg}{m^3}$

fully below surface of fluid

Pressure in fluid is equal at same levels (depth below surface)

For the pressure on the cube of length $l$ at the right:

$\rho g V_{ob.} = m_f$ displaced

$P_{on\ top} = Fg_{fluid}/A$

$P = mg/l^2$

$P = (\rho V_{of\ fluid\ above\ cube})g/l^2$

$P = \rho(l^2 h)g/l^2$

1 atm = 101.3 kPa

15 psi

pound square inches

psi

1 atm = 0 gauge

Object A exerts F on B, B exerts −F on A

$$\frac{10N}{\pi\left(\frac{1}{4}\right)^2} = \frac{F_2}{\pi\left(\frac{1}{16}\right)^2}$$

$$\frac{10}{\frac{1}{16}} = \frac{F}{\frac{1}{256}}$$

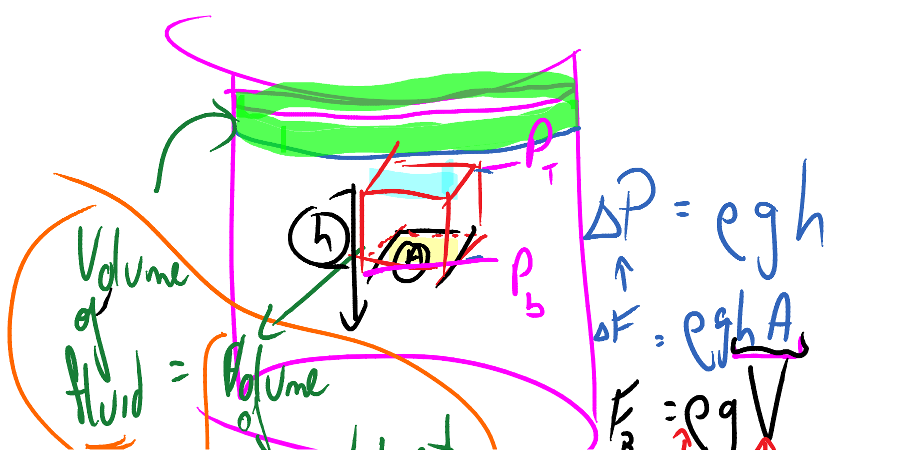
(note
$l^2$
factors leaving:

$$P = \rho g h$$

In the same diagram there is a pressure difference between top and bottom of the cube (
$\Delta P$
)

$$\Delta P = P_{top} - P_{bottom}$$
$$\Delta P = \rho g p - \rho g(h + l)$$
$$\Delta P = \rho g \Delta h$$

ρgh



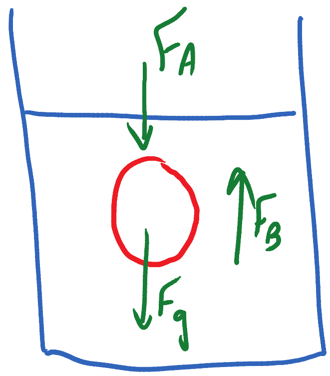
fluid = volume of immersed object

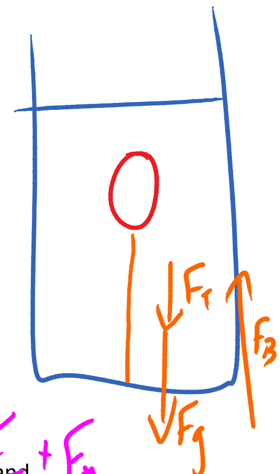
$F_B = \rho g V$ fluid, fluid displaced

$\cancel{\rho_f} V_f \cancel{g} = \cancel{\rho_f} g V_{obj}$

$F_B > F_g$

$\rho_f g V_f > m_o g$




Floating objects (positively buoyant)

Compressibility: able to compress <= gases may be compressed

Incompressibility: not compressable <= liquids are not compressible

Atmospheric Pressure:

This is the weight of a column of air above you at approximately sea level

$F_{net} = 0 = F_A + F_g - F_B$

One atmosphere has approximately constant pressure (it varies with temperature, air mass characteristics, and elevation)

$F_B = F_A + F_g$

$F_B = F_T + F_g$

1 atm = $1.013 \times 10^5$ Pa

or 101.3 kPa (kilopascals)

Gauge Pressure:

Sinking objects

Many meters for pressure measurement (gauges) are set to zero at 1 atm

This means when the gauge is reading a pressure it is really less than the absolute pressure by 1 atm or

objects that neither sink nor float

$P_{absolute} = P_{gauge} + P_{atm}$

negatively buoyant

neutrally buoyant

Pascal's Principle:

A special application of Newton's 3rd Law applied to pressure

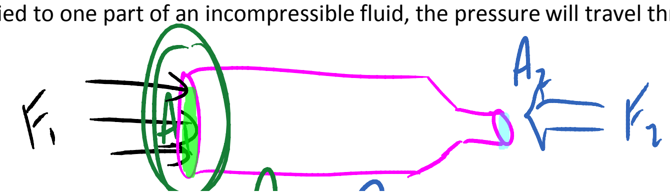
States that when a pressure is applied to one part of an incompressible fluid, the pressure will travel through the fluid so that at the same level

$P_{in} = P_{out}$

This gives an advantage as

$\frac{F_{in}}{A_{in}} = \frac{F_{out}}{A_{out}}$

or



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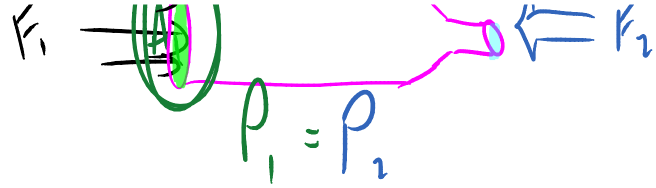


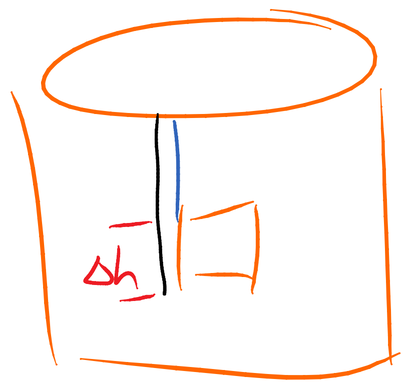

This shows that if the output area is greater than the input then the input force will be much less than the output force. This gives rise to a mechanical advantage in hydraulic systems.

A cylinder of diameter 1/2 inch carries water and tapers down to 1/4 inch, if the force on the 1/2 inch side is 10 N what force is present on the 1/4 inch side (assume pipe is level)

$$\frac{10N}{\pi(2)^2} = \frac{F_2}{\pi(1)^2}$$

$$\frac{10}{2^2} = \frac{F_2}{1^2} \qquad F_2 = 2.5N$$

$$E = hf$$




$$P_B A_B - P_T A_T$$

$$= P_B(l \times w) - P_T(l \times w)$$

$$= \rho g h_B(l \times w) - \rho g h_T(l \times w)$$

$$\rho g A(h)$$

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

Buoyant Force

$F_b$

Any object immersed in a fluid will experience a buoyant force, this is caused by pressure differences between the top and bottom of the object in the fluid.

The net upward force

$F_b =$

the force on the bottom – the force on the top area

$F_b = F_{bottom} - F_{top}$

$F_b = P_{bottom}A_{bottom} - P_{top}A_{top}$

$F_b = \rho g A(h_{bottom} - h_{top})$

$F_b = \rho g A h_{object}$

$F_b = \rho g V$

(where volume is $Ah$

)

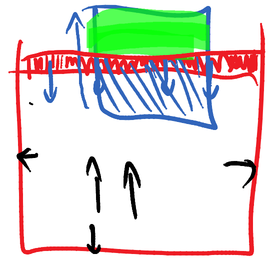
Archimedes' Principle:

The buoyant force on any object immersed in a fluid is equal to the weight of the fluid displaced by that object.

$F_{B\ object} = F_{g\ fluid}$ ← displaced

$\rho_{fluid}\, g V_{obj} = m_{fluid}\, g$

in the fluid



$F_{g\,fluid} = F_{b\,obj}$

For any object which floats,

$F_b > F_g$

but the volume of fluid displaced will be less than the object's volume

$F_b < F_g$ sinking

Relative Density

$\dfrac{\rho_{obj}}{\rho_{fluid}}$

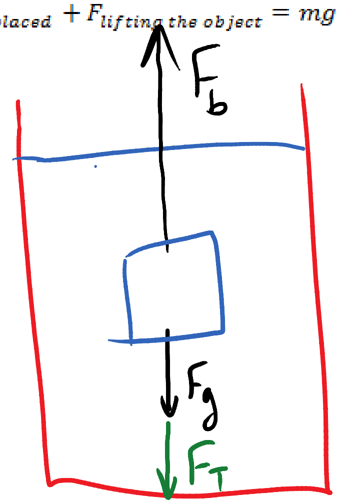

$\rho g V_{displaced} = mg$

For any object which sinks,

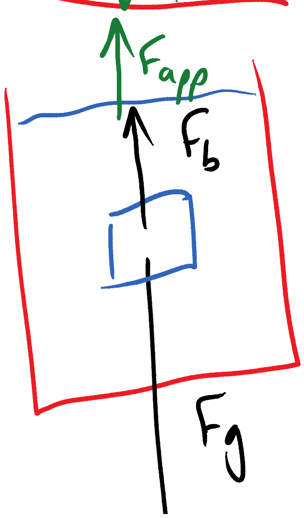
$F_b < F_g$

$\rho g V_{object} < mg$

$\rho g V_{displaced} + F_{lifting\ the\ object} = mg$




$F_T + F_g = F_b$ if $F_b > F_g$




The object is held in equilibrium

$F_b + F_T = F_g$

$F_g$ on displaced fluid

$\rho_f V_f = m_f$

$m_f g + F_T = m_o g$

$F_g$

$\rho_f V_f = m_f$

fluid

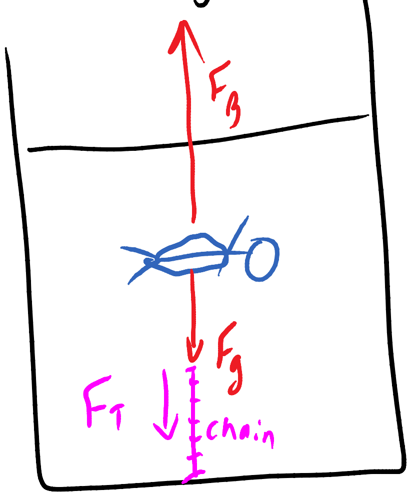
$m_f g + F_T = m_o g$

$\rho_f V_f g + F_T = \rho_o V_o g$

$F_T = \rho_o V_o g - \rho_f V_f g$

$F_T = (\rho_o - \rho_f)(V_o g)$

# Hiding the Body Principle




$$\boxed{F_B = F_g + F_T}$$

A bloated body has density $850 \frac{kg}{m^3}$ and Volume $2.10 \times 10^{-4}\ m^3$ calculate min. the force of tension required to keep the body chained to the bottom of a lake.

$\rho_f V_{displaced}\, g = M_{obj}\, g + F_T$

$\rho_f V_{disp}\, g - \rho_{obj} V_{obj}\, g = F_T$

$(\rho_f - \rho_{obj}) V g = F_T$

$(1000 - 850)(2.1 \times 10^{-4})\, 10 = F_T = .315\,N$

F:1

$\rho 1$

$\rho 2$

den in $\rho 3$