Ch 14. Fluid Mechanics

14-1. Density

Density $\rho = m/V$ - kg/m^3

$1 g/cm^3 = 1000\ kg/m^3$

Intrinsic to a material, independent of size & shape

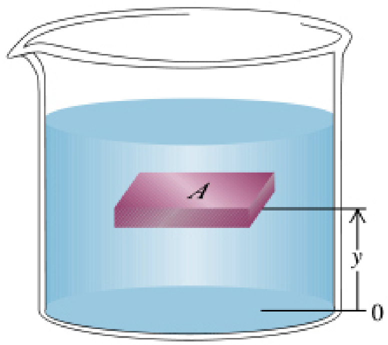
DENSITIES OF SOME COMMON SUBSTANCES

MATERIAL	DENSITY (kg/m^3)*	MATERIAL	DENSITY (kg/m^3)*
Air (1 atm, 20° C)	1.20	Iron, steel	7.8×10^3
Ethanol	0.81×10^3	Brass	8.6×10^3
Benzene	0.90×10^3	Copper	8.9×10^3
Ice	0.92×10^3	Silver	10.5×10^3
Water	1.00×10^3	Lead	11.3×10^3
Seawater	1.03×10^3	Mercury	13.6×10^3
Blood	1.06×10^3	Gold	19.3×10^3
Glycerin	1.26×10^3	Platinum	21.4×10^3
Concrete	2×10^3	White dwarf star	10^{10}
Aluminum	2.7×10^3	Neutron star	10^{18}

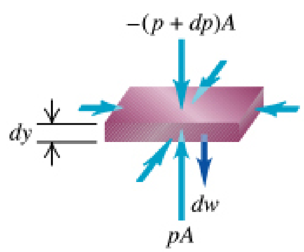
*To obtain the densities in grams per cubic centimeter, simply divide by 10^3.

Specific gravity ρ / ρ_{water}

14-2. Pressure in a Fluid



(a)



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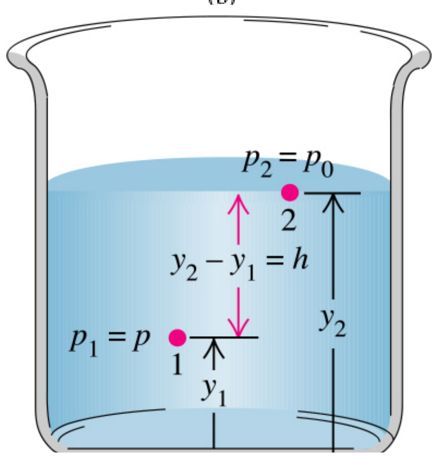


Pressure in a fluid of uniform density (Static Case)

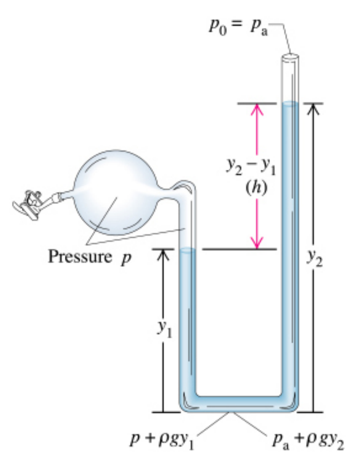
$p_2 - p_1 = -\rho g(y_2 - y_1)$

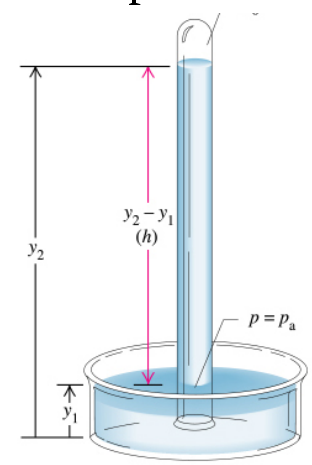
$p = p_o + \rho g h$

Pressure is the same for any 2 points at the same level in the fluid.

Gauge pressure:

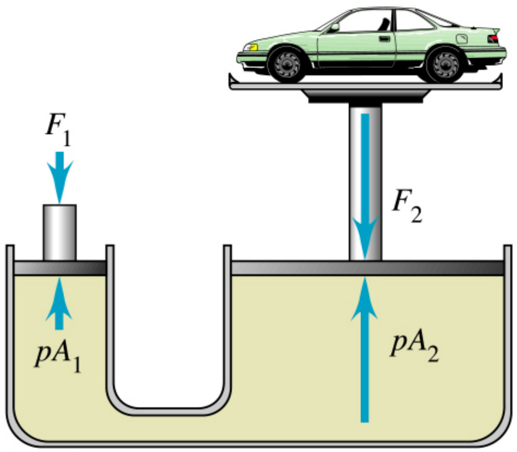
Excess pressure above atmospheric pressure

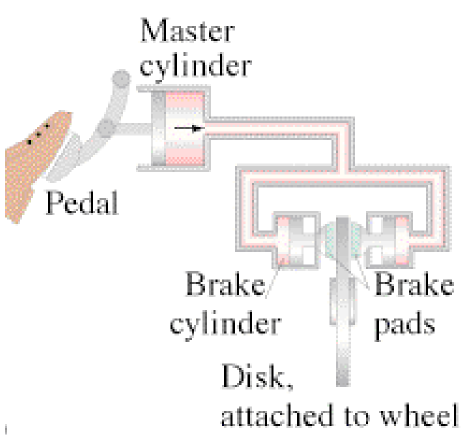




Pascal's Law

Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the container.



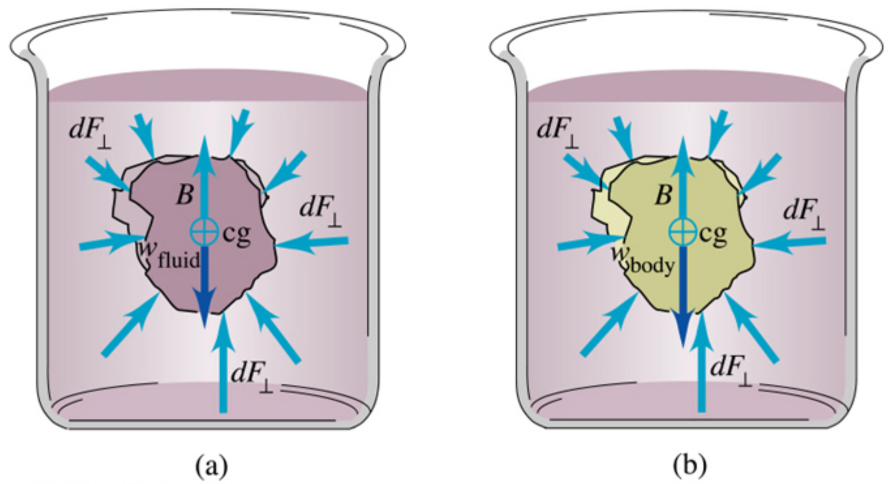


Application in hydraulic lift

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

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

14-3. Buoyancy

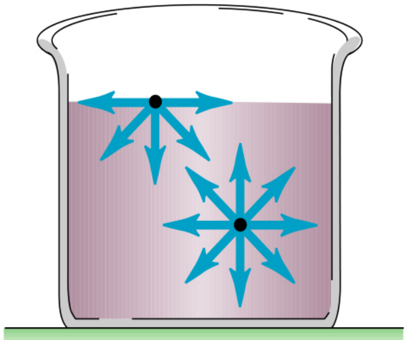


Archimedes' Principle:

When a body is completely or partially immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

$$B = \rho_{fluid} \, g V_{displaced\ fluid}$$

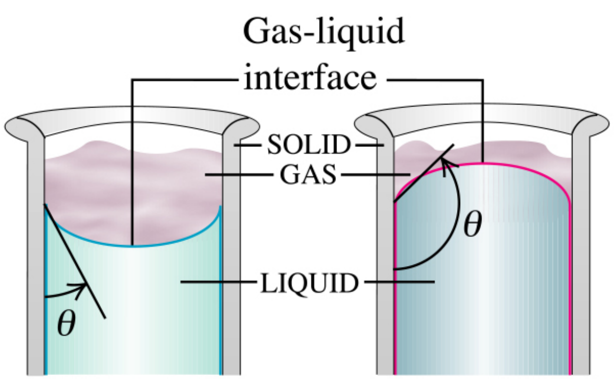
Surface Tension



Liquid alone

tends to minimize its surface area

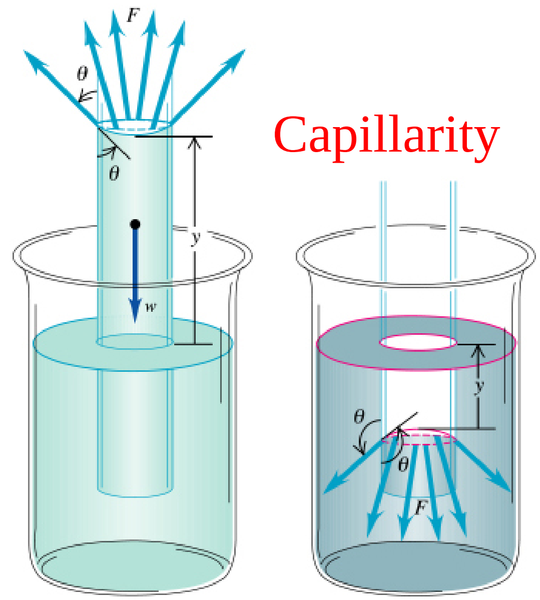
Liquid in contact with solid



Water: $\theta < 90°$ | Mercury: $\theta > 90°$

Wetting | *Non-wetting*

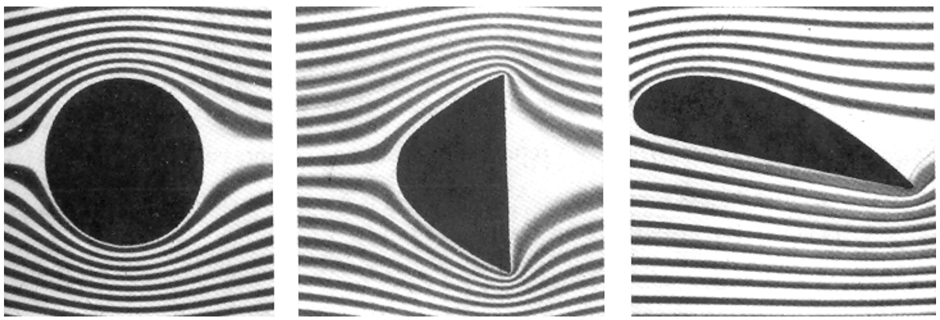
Capillarity



Wetting | *Non-wetting*

14-4. Fluid Flow

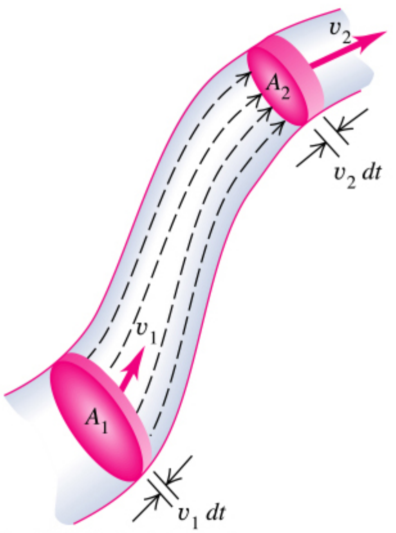
Ideal fluid: incompressible (ρ const.) & no internal friction (viscosity)



Laminar flow:
- adjacent layers of fluid slide smoothly & flow steadily

Turbulent flow:
- irregular & chaotic flow
- no steady-state pattern

Denser streamlines, higher speed



Continuity Equation

Incompressible fluid:

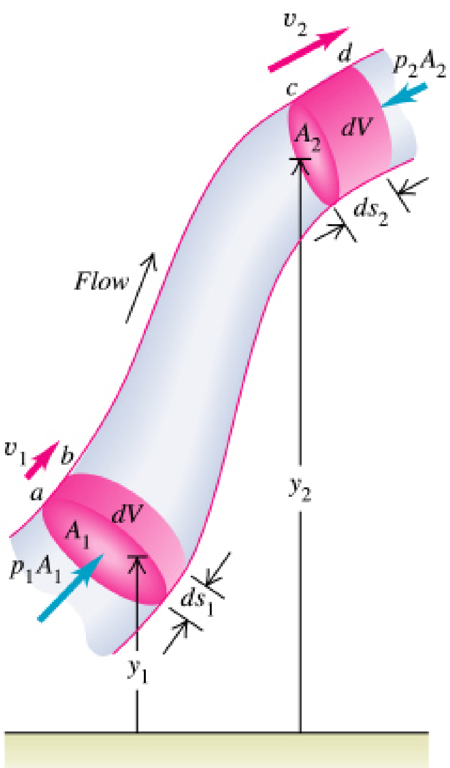
$dm_1 = dm_2$ $\quad (\rho A_1 v_1 dt = \rho A_2 v_2 dt)$

$A_1 v_1 = A_2 v_2$

Volume flow rate: $dV/dt = Av$

14-5. Bernoulli's Equation

For incompressible, steady flow of a fluid with no viscosity

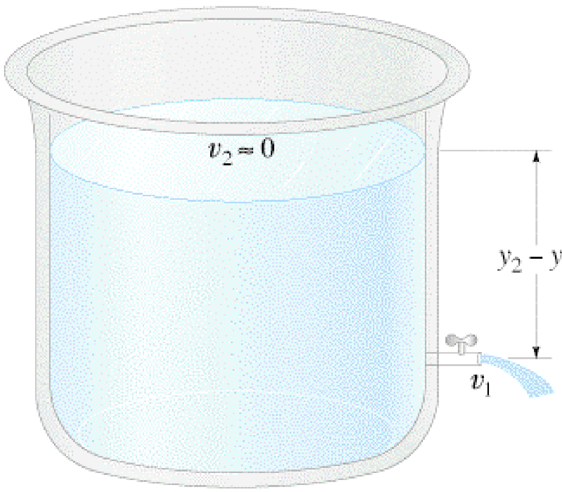


$$p_1 + \rho g y_1 + \frac{1}{2}\rho {v_1}^2 = p_2 + \rho g y_2 + \frac{1}{2}\rho {v_2}^2$$

Links pressure *p*, height *y*, flow speed *v*

Special Cases of Bernoulli's Equation

Special case #1:



$p_1 = p_2$

$$\rho g y_1 + \frac{1}{2}\rho {v_1}^2 = \rho g y_2$$

Torricelli's theorem:

$$v_1 = \sqrt{2g(y_2 - y_1)}$$

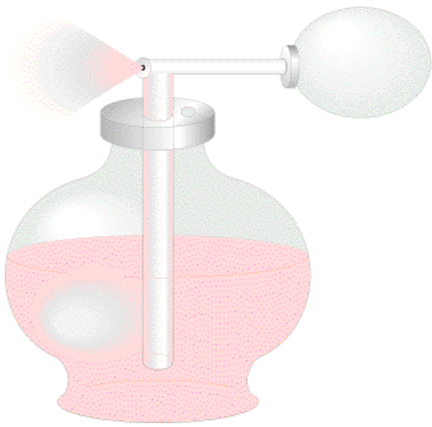
Special case #2:

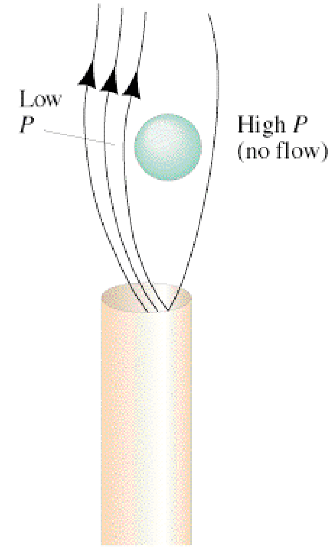
Same height:

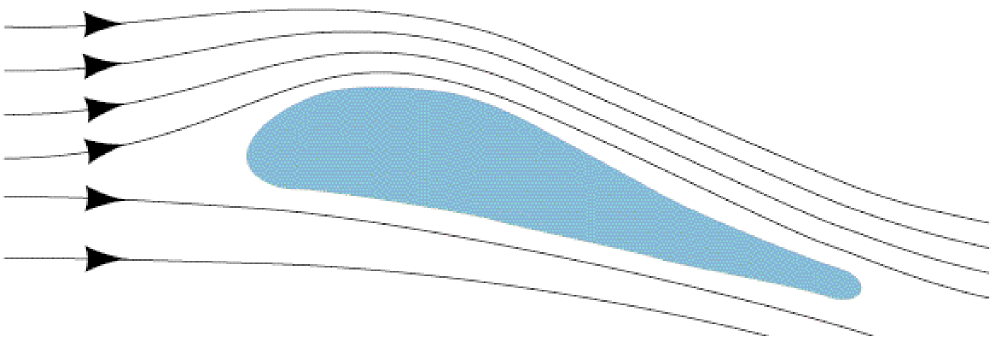
$$p_1 + \frac{1}{2}\rho {v_1}^2 = p_2 + \frac{1}{2}\rho {v_2}^2$$

Where the speed is high, the pressure is low.

Applications of Bernoulli's Principle







Dec. 17, 1903: First flights by Wright brothers.