Fluid Statics
7.1

Fluids
Density and Pressure
Hydrostatic equilibrium

Fluids

Fluids – materials that flow when acted upon by external forces.

- Liquids – occupy specific volume, incompressible.
- Gases - take the volume of the container, compressible

Density

Density is the mass per unit volume.

$$\rho = \frac{m}{V}$$ SI units of kg/m^3

Density of materials

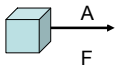
	ρ (kg/m^3)
water	1000
air (20° C)	1.2
olive oil	920
ice	917

Pressure

Pressure is the Force per unit Area

$$P = \frac{F}{A}$$ Units N/m^2
Pascal (Pa)

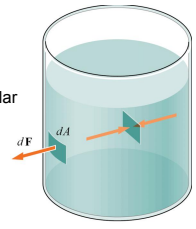
Pressure is a scalar quantity



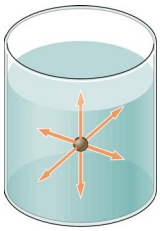
Atmospheric pressure (1 atm) =1.01×10^5 Pa
= 14.7 (pounds/in^2)

Pressure exerted by a fluid

The force is exerted perpendicular to the area



Pressure is exerted by the fluid on the container walls or on adjacent volume of fluid.



The pressure is the same in all directions.

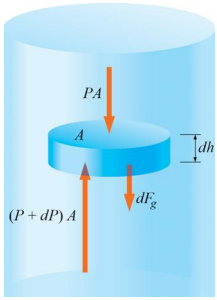
Hydrostatic equilibrium

- The net forces on each part of the fluid is zero.
- The fluid is at rest.

Gravitational equilibrium

The force of gravity acting on the segment equals the difference in force due to pressure at top and bottom.

$$dF_g = gdm = g\rho Adh$$



Pressure increases with depth

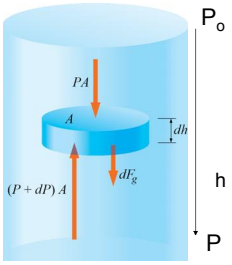
$$F_{up} = F_{down}$$

$$(P + dP)A = PA + g\rho Adh$$

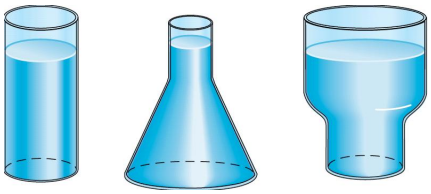
$$dP = g\rho dh$$

$$\frac{dp}{dh} = g\rho$$

$$P = P_o + \rho gh$$



Which container has the highest pressure at the bottom

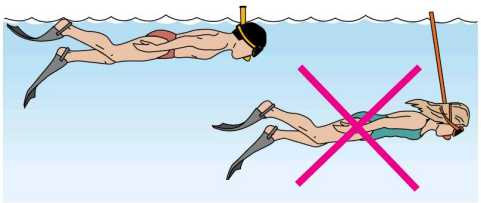


a) a
b) b
c) c
d) all have the same pressure √

Question

A submarine with a door 1.5 m^2 is trapped at a depth of 100 m below the surface of the water. How much force must be exerted to open the door. The pressure inside is 1atm

Why can't you breath with a long snorkel tube.

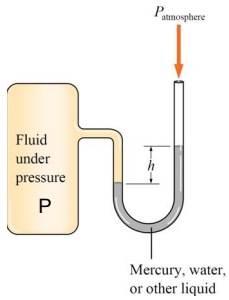


The pressure difference inside and outside of the lung is too great
The lung will collapse.

Scuba equipment delivers air at the ambient pressure

Pressure regulator

Gauge pressure is the pressure difference from atmospheric



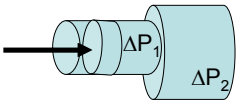
Gauge pressure

$P-P_{atmospheric} = g\rho h$

Tire pressure is a gauge pressure. (not absolute pressure)

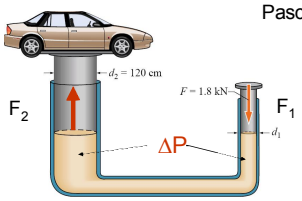
Pascal's Law

The change in pressure in a fluid is the same everywhere in the fluid.



$\Delta P_1 = \Delta P_2$

Hydraulic press



Pascal's Law

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

A small force on a small area can generate a large force from a large area

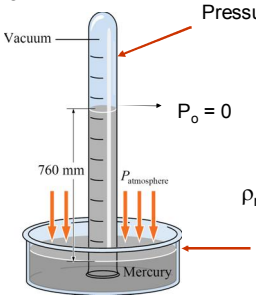
(However, the distance moved must be larger.)

Question

In a hydraulic lift, a120 cm diameter piston supports a car. If the total mass of the piston and car is 3200 kg what should the diameter of the smaller piston be if a force of 450 N is to maintain the system in equilibrium.

Atmospheric pressure

Atmospheric pressure is due to the weight of the atmospheric gas above the earth' surface



Pressure in the vacuum is zero

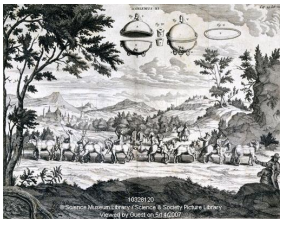
$P_o = 0$

$\rho_{mercury} = 1.353 \times 10^4$ kg/m^3

$P=g\rho h$

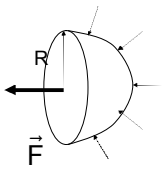
$P=9.8(1.353 \times 10^4)(0.760)$
$= 1.01 \times 10^5$ Pa

Magdeburg sphere



Otto von Guericke in Magdeburg Germany, 1672. Showed the pressure of the atmosphere could hold together two evacuated hemispheres.

Force on a hemisphere due to the atmospheric pressure



$\overrightarrow{dF} = P d\vec{A}$

(normal force)

$\vec{F} = \int_{\text{hemisphere}} P d\vec{A}$

$F = P(\pi R^2)$

Area of the circle

Question

Two hemispheres with diameter of 35 cm are evacuated. What force is required to pull them apart?

Question

A U-shaped tube open at both ends contains water and a quantity of oil occupying a 2.0 cm length of the tube. If the oil's density is 0.82 times that of water, what is the height difference h?