Lecture 34

Thurs: Discussion / quiz

Ex 311, 312, 315, 316, 317, 318, 319

Fluids

Fluids are materials which

* have a continuous distribution of mass
* fill a container

Fluids are important is:

1) flow of liquids and gasses through pipes
2) hydraulics
3) liquids and gases in biological systems.

We will briefly survey

1) pressure in fluids.
2) buoyancy in fluids.

Density

We will consider fluids where the mass is uniformly distributed. Here an important parameter for the fluid is the density

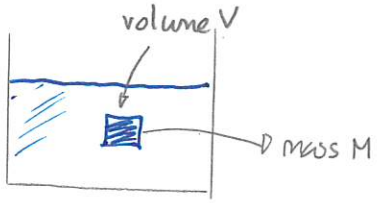
Consider a portion of a fluid. The density of this portion is

$$\rho = M/V$$

(ρ = rho)

where M = mass of portion

V = volume of portion



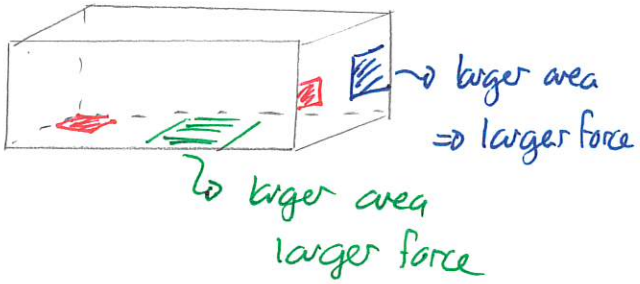
Units: kg/m^3

See Table 13.1

Pressure

Consider any surface within or at the edge of a fluid. The fluid will exert a force on this surface. The force will generally depend on the area of the surface. This can be accounted for by defining

Pressure ~ force per unit area



Specifically

> The pressure of a fluid is
>
> $$P = F/A$$
>
> where F is the force exerted on a surface with area A.

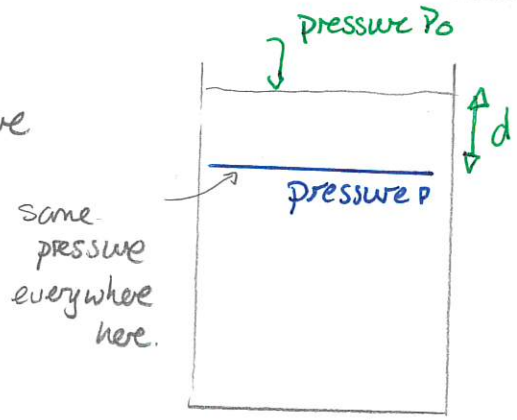
units: Pascal $Pa = N/m^2$

Sometimes $1 atm = 1.01 \times 10^5 Pa$

Pressure in a fluid

Our usual experience with fluids is that the fluid pressure will vary with the depth in the fluid. We can use Newton's Laws to show

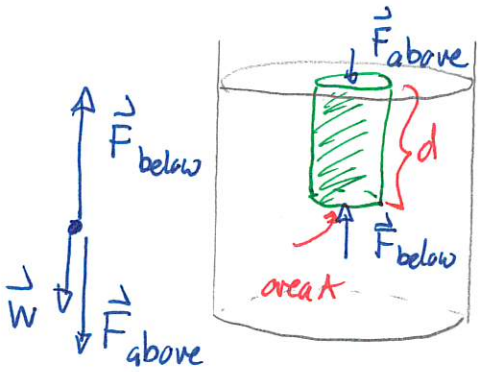
> If a fluid is not accelerating then
>
> 1) the pressure is the same everywhere along one horizontal level.
>
> 2) the pressure at depth d below the surface is
>
> $$P = P_0 + \rho g d$$
>
> where P_0 is the pressure at the surface



Warm Up 1

Proof: Consider a stationary fluid.
For the shaded column

$$\sum \vec{F} = 0$$



$$\Rightarrow F_{below} - F_{above} - W = 0$$

$$\Rightarrow F_{below} = W + F_{above}$$

$$\Rightarrow P_{below} A = mg + P_{above} A$$

Then $m = \rho V = \rho A d$ gives

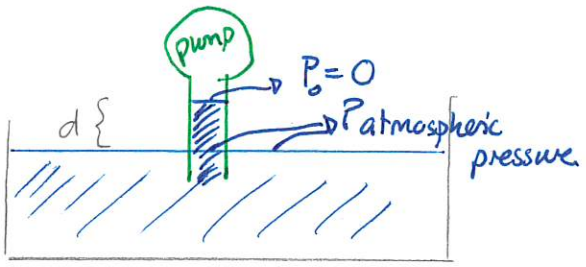
$$P_{below} \cancel{A} = \rho \cancel{A} d g + P_{above} \cancel{A}$$

$$\Rightarrow P_{below} = P_{above} + \rho d g. \quad \blacksquare$$

Quiz1 60% → 30%

310 Vacuum pump

A vacuum pump creates creates a vacuum region that is connected by a pipe to a pool of water. Assuming that the pool of water is at sea-level, determine the maximum height which the pump can lift water.



Answer: $P = P_o + \rho g d$

$1.01 \times 10^5 Pa = 0\,Pa + 1000 \frac{kg}{m^3} \times 9.8 m/s^2 \times d$

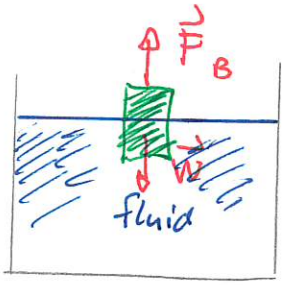
↑ sea-level atmospheric pressure

$\Rightarrow \quad 1.01 \times 10^5 P = 9.8 \times 10^3 N/m^3 \, d$

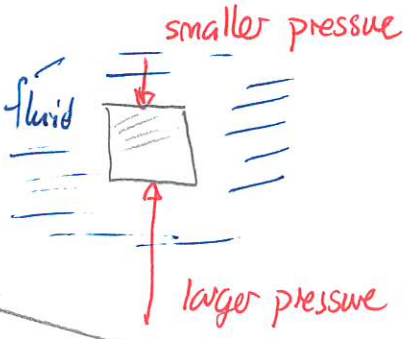
$\Rightarrow \quad d = \frac{1.01 \times 10^5 Pa}{9.8 \times 10^3 N/m^3} \quad \Rightarrow \quad d = 10.3 m$ ∎

Warm up2

Buoyancy



Certain objects float in fluids. Thus the fluid must exert an upward buoyant force to counteract the downward weight force. This force exists even when the object is immersed in the fluid and results from a pressure gradient. Newton's laws give:



Any fluid exerts a buoyant force that

1) points upward
2) has magnitude $F_B = \rho_{fluid} g V_{disp}$

where V_{disp} is the volume of the fluid displaced (moved aside to accommodate) by the object.

314 Wooden block in water

A piece of wood has volume $8.00 \times 10^{-3}\,\mathrm{m}^3$ and density $910\,\mathrm{kg/m}^3$. It is submerged in water (density $1000\,\mathrm{kg/m}^3$) and held at rest by a hand.

a) Determine the buoyant force exerted by the wood.

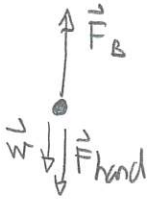
b) Determine the downward force exerted by the hand on the block.

Answer: a) $F_B = \rho_{water}\, g\, V_{disp}$

$\rightarrow$ object immersed $\Rightarrow$ volume of object

$F_B = 1000\,kg/m^3 \times 9.8\,m/s^2 \times 8.00\times10^{-3}\,m^3$

$F_B = 78.4\,N$

b) 

$\sum F_y = 0 \Rightarrow F_B - F_{hand} - w = 0$

$\Rightarrow F_B - w = F_{hand}$

$\Rightarrow F_B - mg = F_{hand}$

Now the mass of the block is $m = \rho_{wood} V_{block}$

$= 910\,kg/m^3 \times 8.00\times10^{-3}\,m^3$

$= 7.28\,kg$

$F_B - mg = F_{hand} \Rightarrow 78.4\,N - 7.28\,kg \times 9.8\,m/s^2 = F_{hand}$

$\Rightarrow F_{hand} = 7.06\,N$

Quiz 2

Temperature:

We often consider the temperature of an object or a system. This is measured with a thermometer in various scales.

		Water freezes	Water boils
Celsius	°C	0°C	100°C
Fahrenheit	°F	32°F	212°F
Kelvin	K	273K	373K

Conversion is done via:

In Fahrenheit

$$T_F = \frac{9}{5} T_C + 32°F$$

In Celsius

$$T_C = \frac{5}{9}\left[T_F - 32°F\right]$$

$$T_K = T_C + 273\,K$$

In Kelvin