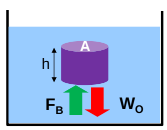
L-14 Fluids - 3

- Fluids at rest → Fluid Statics
  Why things float ➔ *Archimedes' Principle*
- Fluids in Motion → Fluid Dynamics
  –Hydrodynamics
  –Aerodynamics

Example: What does 1 liter (about a quart) of water weigh?

- 1 liter = 1000 cm^3
- Density of water = 1 g/cm^3 = 1000 kg/m^3
- Mass of 1 liter of water
  = 1 g/cm^3 x 1000 cm^3 = 1000 g = 1 kg
- W = mg = 1 kg x 9.8 m/s^2 = 9.8 N (≈ 10 N)
  = 2.2 pounds (1 gallon → 8 pounds)
- Water weighs about 10 N/liter

Archimedes principle

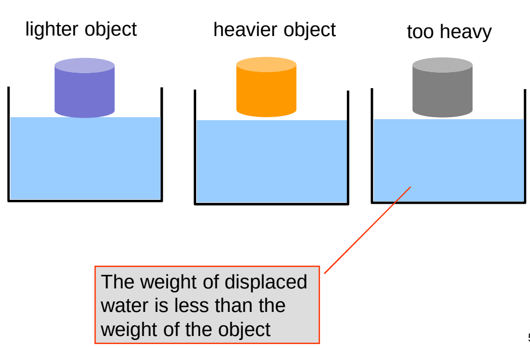


- The buoyant force on an object in a fluid equals the *weight of the fluid (e.g., water) which it displaces*.
- Anything less dense than water will float in water
- water weighs 10N/liter➔ each liter of displaced water provides 10 N of buoyant force

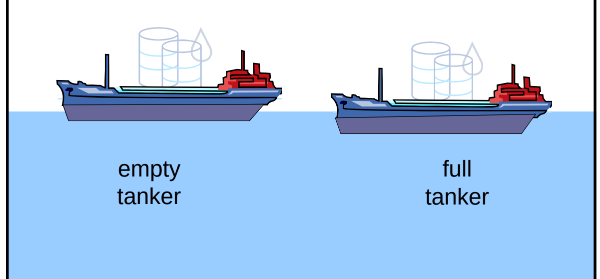
Will it float?

- The buoyant force is always there whether the object floats or not
- The object will float if the buoyant force is big enough to support the object's weight
- The object will displace just enough water so that the buoyant force = its weight
- If the object is completely submerged, and the weight of the displaced water is less than the weight of the object, the object will sink
- *Objects that have a density less than water will float- when fully submerged, they weigh less than the water, so the water supports them*
- An object will float in a liquid that is denser than it;
  ➔ a steel bolt will float in mercury

Floating or sinking objects



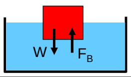
Oil Tankers



example problem

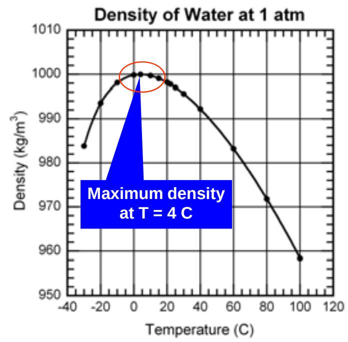
- An object having a volume of 6 liters and weighing W = 30 N is placed in a tank of water. *What will happen? Will it sink? Will it float? What fraction of its volume will be submerged if it floats?*
- If the object were completely submerged, the buoyant force would be

  $F_{B,\,max}$ = 10 N/liter x 6 liters = 60 N
- thus, the object will float with *half* of its volume submerged, so that $F_B = W = 30$ N



7 7

Water is weird stuff!



The pressure of expanding ice can break steel pipes.

VIDEO

8

Why does ice float?

- Water, the most plentiful substance on earth is also one of the most unusual in its behavior in that it *expands when it freezes*.
- Since it expands, the density of ice is slightly less than the density of water (958 kg/ m^3 as compared to 1000 kg/ m^3 for water). So the part of the iceberg above the surface contains less than 10 % of the total volume.

9

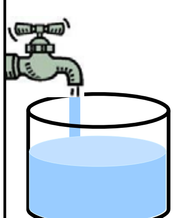
Fluid Flow → fluid dynamics

Daniel Bernoulli

- A Swiss mathematician, born in 1700.
- He applied the laws of mechanics to the problem of fluid flow
- He developed the basic principle that explains, for example, how airplanes work

10

How do we measure fluid flow?



- We can time how long it takes to fill a bucket, say 30 seconds
- the flow rate is then 1 bucket say per 30 seconds
- in other words, the flow rate is **volume of fluid per unit time**
- gallons per min (gpm), liters/s, cubic feet per min (cfm), or m^3/s

→ Q_V = **volume flow rate**

11

Volume flow rate → Q_V

- If the water comes out of a tube of cross sectional area A with a flow speed u the volume flow rate = $Q_V = u \times A$ (m/s $\times m^2$)

m^3/s

- To measure u just see how long it takes to fill a gallon jug from a hose and measure the diameter of the hose.

12

Mass flow rate → Q_m

- We could also measure how much mass comes out per unit time – kg/s for example
- if you are using a fluid of density ρ coming out of a hose of cross sectional area A with speed v the mass flow rate is
- mass flow rate = $\mathbf{Q_m = \rho \times u \times A = \rho\, Q_V}$

13

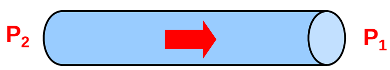
What makes water flow?

- gravity
- by placing the water up high, the pressure at the bottom is high enough to supply water to all parts of town that are lower than the tower

Stanton, IA
Montgomery Co. Pop. 680

14

Pressure differences

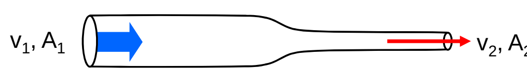


- Water experiences a *resistance* to flow
- a *pressure difference* must be maintained across the ends of the pipe to push the water along → P_2 must be greater than P_1
- this pressure difference can maintained by a water pump

15

Water does not disappear!

- If water goes in one end of a pipe it must come out the other end (if there are no leaks). Sounds obvious, but it has a number of interesting consequences!
- This applies to pipes that have constrictions



16

Principle of the continuity of flow

- since whatever goes in must come out, we have that the incoming flow rate – outgoing flow rate or, $Q_{V1} = Q_{V2}$
  - ➔ $v_1 A_1 = v_2 A_2$ (continuity principle)
- thus the fluid in the narrow part of the tube must flow FASTER that the fluid on the left.
- Cardiologists use this to determine if arteries might be clogged.

17

Other examples - the nozzle effect

- you use this principle whenever you hold your finger over the end of the hose to make the water spray farther.

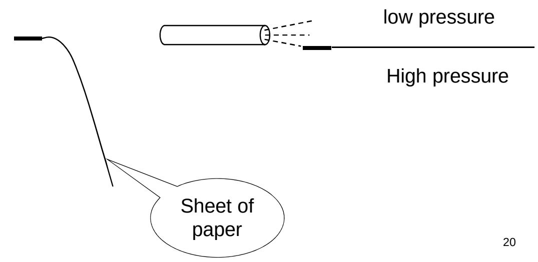
18

An amazing thing about moving fluids

- **The pressure in a moving fluid is less than the pressure in a fluid at rest → this is Bernoulli's Principle**
- Where a fluid moves faster its pressure is lower, where it moves slower, its pressure is higher
- As we will see, this is the principle that allows airplanes to fly

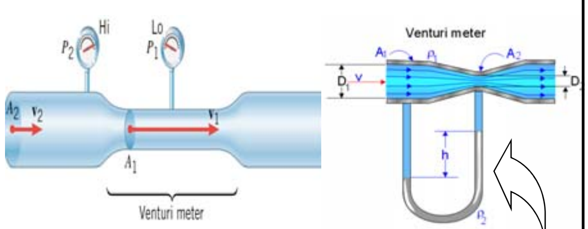
19

You can demonstrate Bernoulli's principle with a sheet of paper!



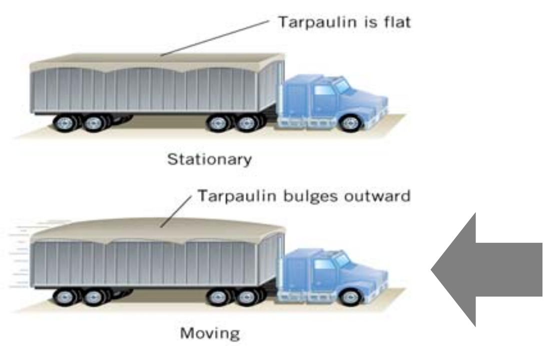
20

The Venturi Meter



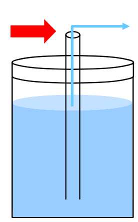
Pressure is lower in the right lube because the air moves faster there, so the liquid rises

21



22

Atomizers (perfume spritzers)



Using the Bernoulli effect, fine droplets of liquid are formed with this device

23