Lecture 13:
Static Fluids

- Pressure
- Pascal's Principle
- Buoyancy force

Pressure

An object submerged in a fluid will experience a force acting on the surface.

Pressure p **=** Force magnitude per Area

$$p = \frac{F}{A}$$

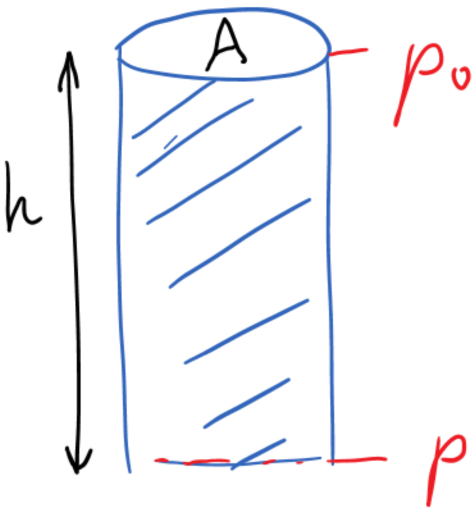
Unit: N/m^2 = Pa

Fluid at rest:

- at given depth, p is same in all directions.
- force due to pressure is perpendicular to all surfaces

Pressure increase with depth

Due to weight of column of fluid above



$$W = Mg = \rho V g = \rho A h g$$

$$\Delta p = \frac{W}{A} = \frac{\rho A h g}{A} = \rho h g$$

$$p_{below} - p_{above} = \rho g h$$

Atmospheric pressure

$$p_{atm} = 100kPa = 10^5 N/m^2$$

On 1cmx1cm: $10\text{N} \approx 1kg * g$
Above head (10cmx10cm): weight of 100kg

Demo: Magdeburg hemispheres

Magdeburg hemispheres

Otto von Guericke, 1654. 30 horses.

Magdeburg Hemispheres: estimate

D=50cm

$$p = \frac{F}{A}$$

$$F = pA = 2x10^4 N$$

Classroom demo: D=10cm

$F = 800N$

(and vacuum not perfect)

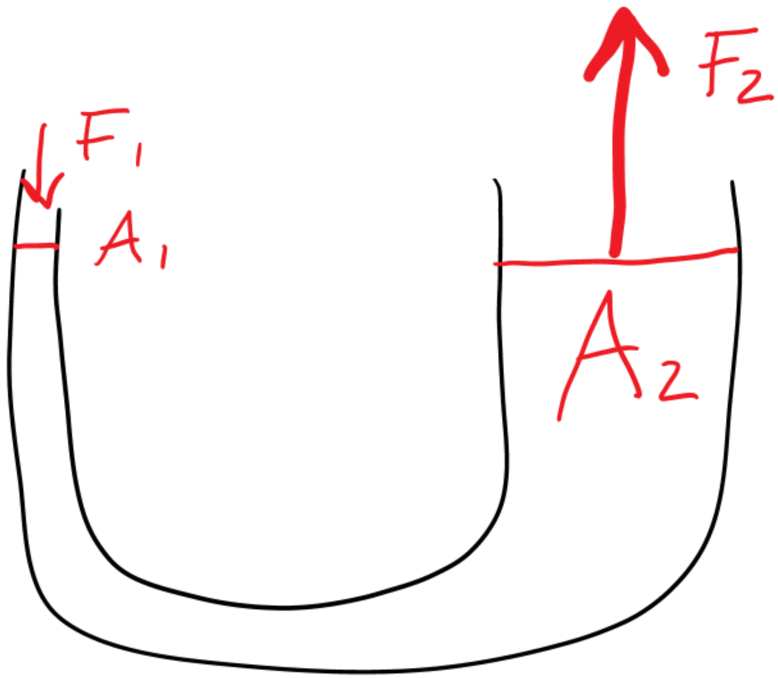
Pascal's Principle

Pressure applied to a confined fluid increases the pressure throughout the fluid by the same amount.

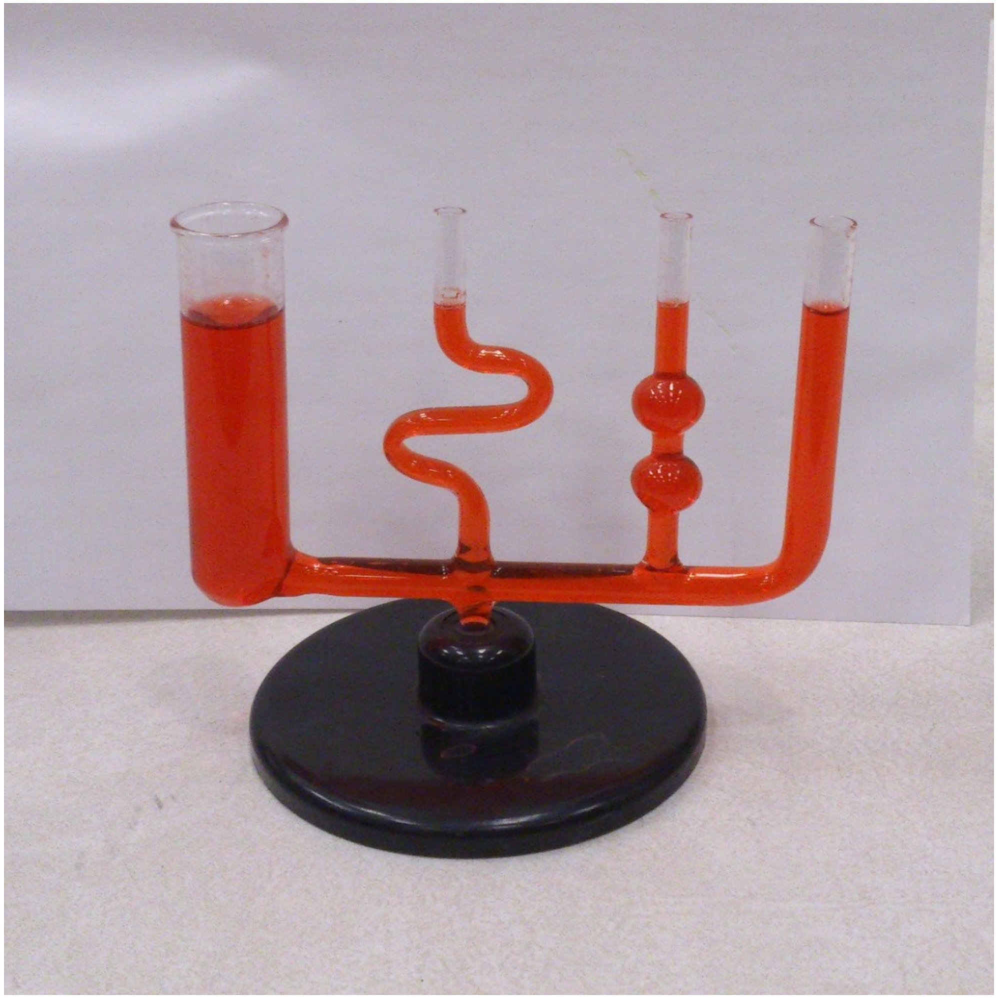
All points at the same level in a **contiguous** fluid have the same pressure.

Application of Pascal's Principle: Hydraulic Lift

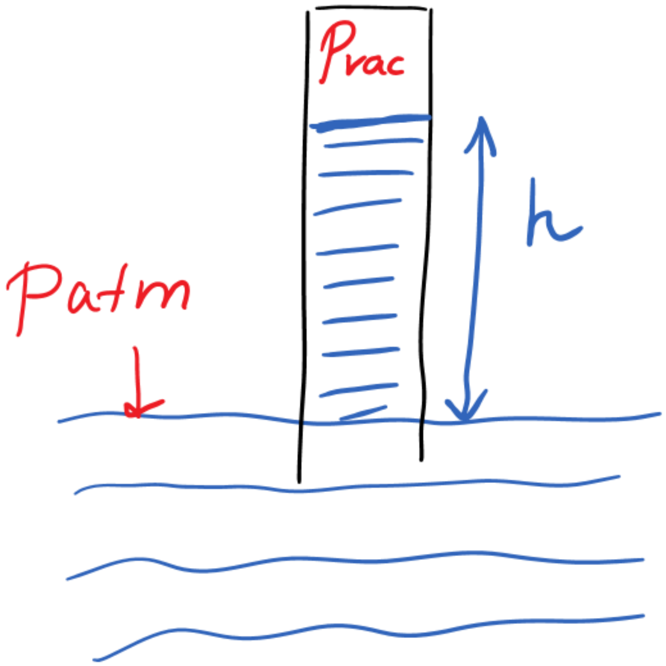
$$\Delta P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$



Demo: same water level in connected tubes of different shapes and cross sections



The longest straw… or: How high can you pump water by suction?

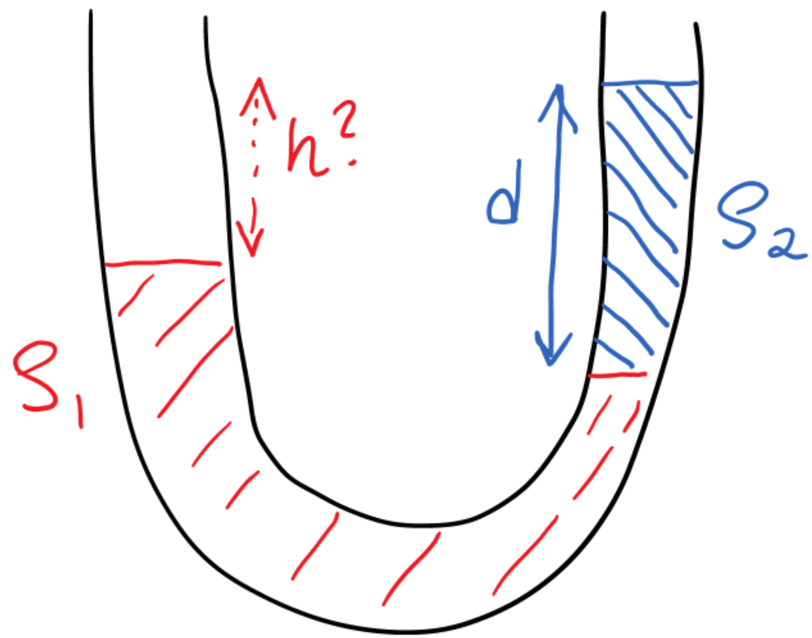


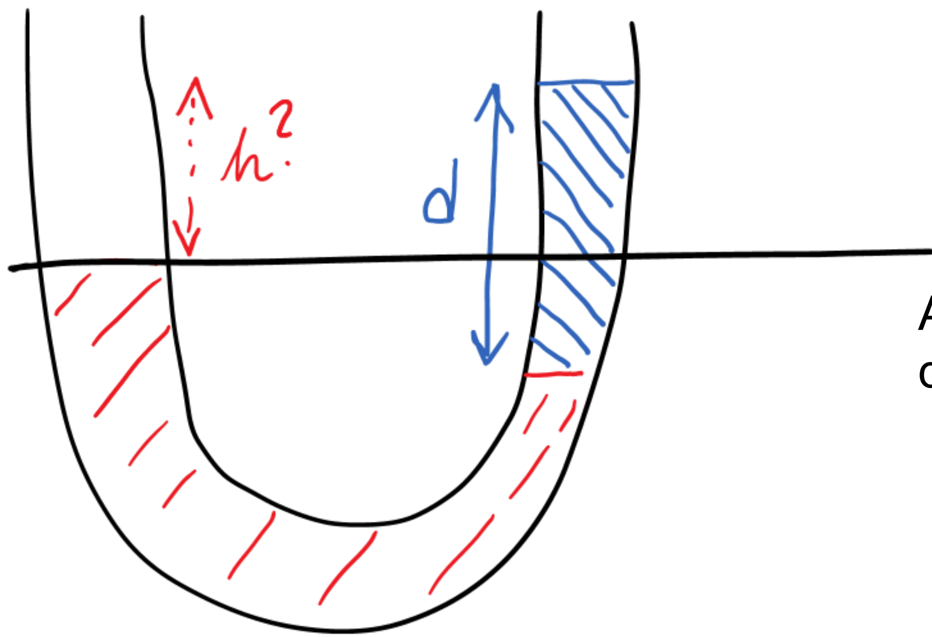
$$p_{below} - p_{above} = \rho g h$$

$$p_{atm} - p_{vac} = \rho g h$$

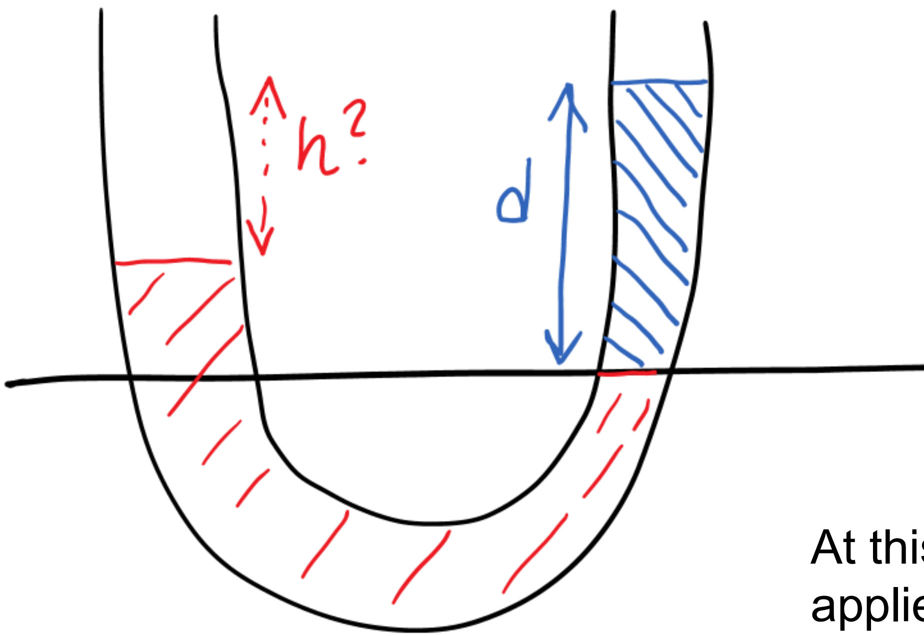
$$h_{max} = \frac{p_{atm}}{\rho_{water} g} = 10\ m$$

Example 1





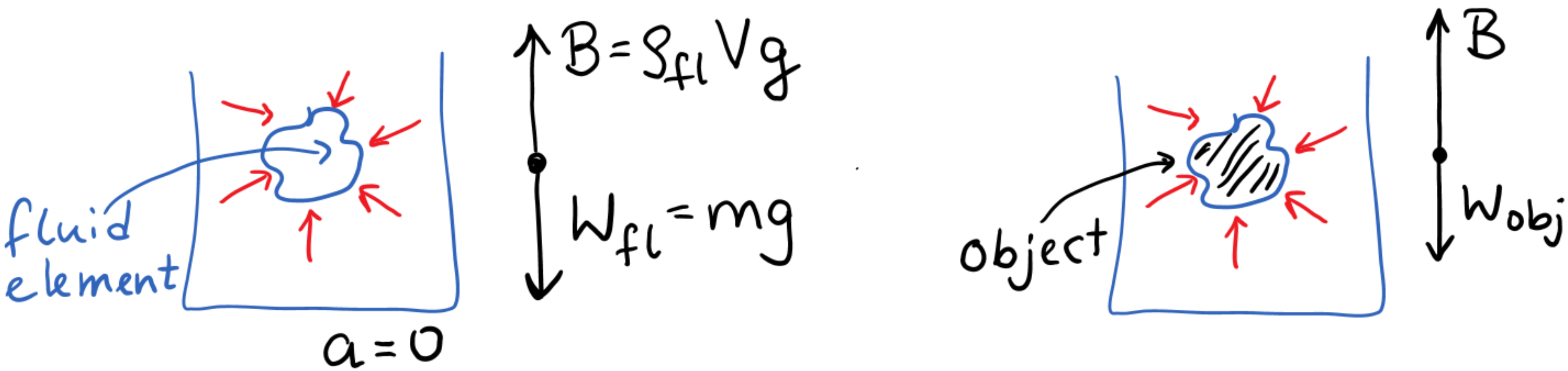
At this level, Pascal’s Principle does not apply



At this level, Pascal's Principle applies (continuous fluid)

Buoyancy and Archimedes' Principle

An object fully or partially submerged in a fluid experiences an upward buoyancy force equal to the weight magnitude of the fluid displaced by the object.



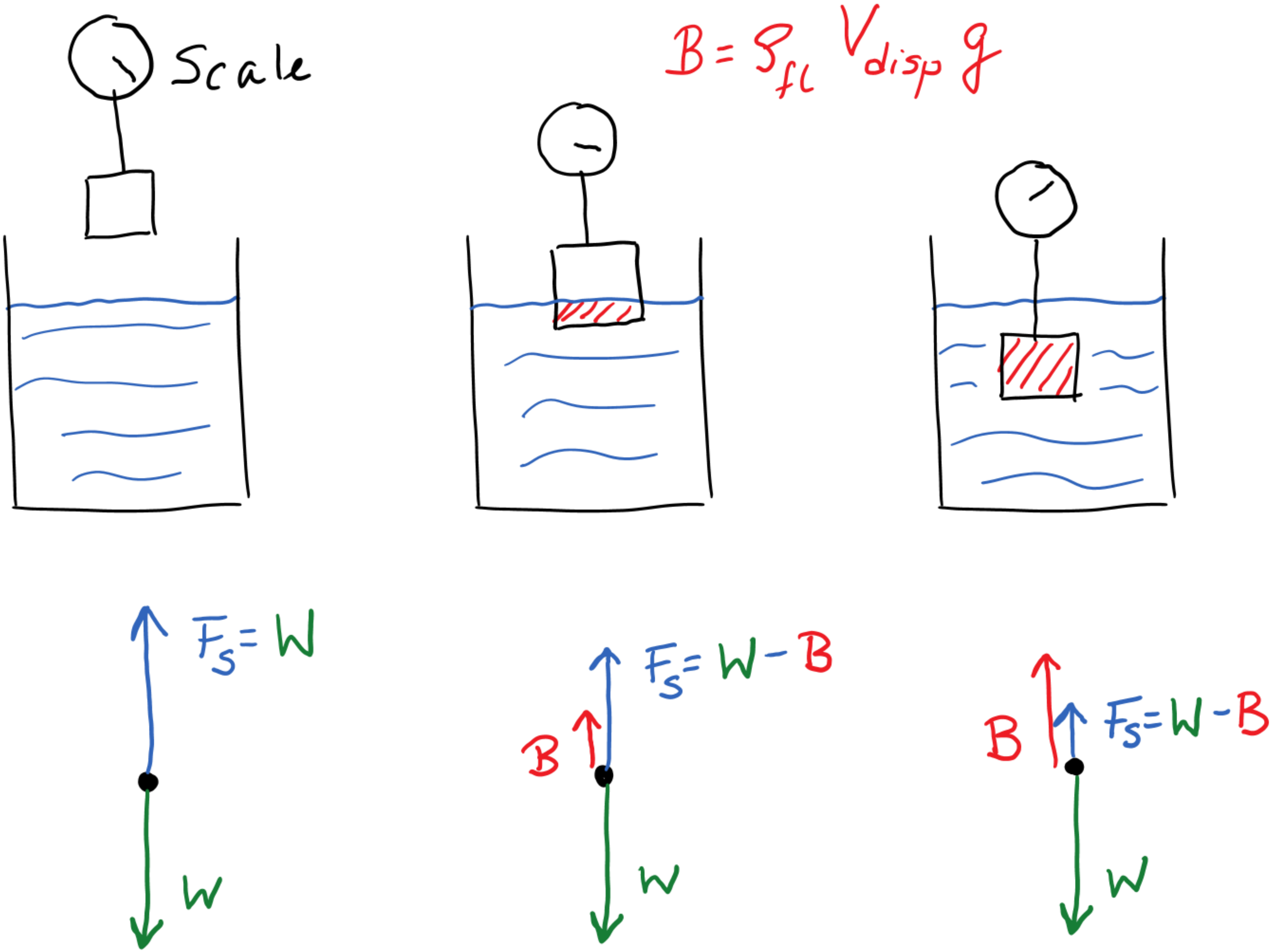
$$B = \rho_{fluid} V_{disp} g$$

Consequences of Archimedes' Principle

Density of object less than density of fluid:
Object floats

Density of object larger than density of fluid:
Object sinks

Demo: Buoyancy force



Scale
B = ρfl Vdisp g
Fs = W
W
B
Fs = W - B
W
B
Fs = W - B
W

Example 2

A ball has a uniform mass density of ⅓ the density of water. What fraction of the ball's volume is below the water line?

Example 3

A cube of side length *L* is placed in water and an object with twice the cube's weight is placed on top of it. Because the density of water is ρ and the cube has a uniform density of ¼ρ, a portion of the cube remains above the waterline. If the cube stays in a level orientation, what is the difference between the pressure at the cube's lower (submerged) surface and atmospheric pressure, i.e., what is the gauge pressure at the lower surface?