PHYS 107 - Week 11 - Wednesday

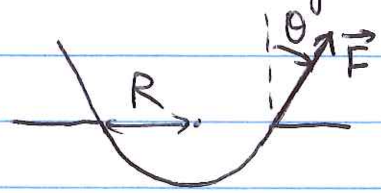
* Surface tension : due to cohesive forces between molecules of the same type in a liquid

surface tension coefficient $\gamma = \frac{F}{\ell}$ in units $\frac{N}{m}$

where ℓ = circumference of the contact area

Water Strider

What is the angle at the contact point with the water?



$F = \gamma \ell = \gamma (2\pi R)$

$\downarrow$

$F_y = F \cos\theta$

$R = 1.5 \times 10^{-4}\,m = 0.15\,mm$

$m = 2 \times 10^{-5}\,kg$

$\gamma = 0.0728\,\frac{N}{m}$

6 legs $\rightarrow$ $6F_y - mg = 0$

$\hookrightarrow 6\,(2\pi R)\gamma \cos\theta = mg$

$\cos\theta = \frac{mg}{12\pi R \gamma} = 0.47$

$\downarrow$

$\theta = 62°$

If $\cos\theta > 1$ $\rightarrow$ force of surface tension is not large enough

* Surfactants: substances in a liquid that change γ {reduces
e.g. detergent in H_2O makes it cling to the grease more

Example: pulmonary alveoli = tiny sacs in lungs coated with mucus (liquid)

1) inhalation: muscles expand the chest cavity → negative pressure of ~−3 mm Hg → air rushes in

surfactant = long lipoproteins in the mucus layer
when alveoli extend → density of surfactant ↘ {concentration
→ surface tension ↗
↓
prevents alveoli from extending too much

2) exhalation: surface tension contracts the alveoli
density of surfactant ↗
→ surface tension ↘
↓
alveoli do not collapse under surface tension

Water in lungs: {concentration density of surfactant ↘ → surface tension ↗
→ can't breathe
↳ drowning, new-born infants, hyaline membrane disease

Emphysma: alveoli walls deteriorate → larger alveoli
→ reduced pressure → can't exhale

↳ water in glass tube with $\theta_{water/glass} = 0$
rises
↳ $\cos\theta = 1$

Question: how high does the water in a tree due to cappillary effect?

$\rho_{sap} = 1080\ kg/m^3$, $\theta = 0°$, $\gamma = 0.0728\ \frac{N}{m}$

~~$R = 1.4 \times 10^{-7}\ m$~~

$$\rightarrow h = \frac{2(0.0728\ \frac{N}{m})\cos 0°}{(1000\ kg/m^3)\, R\, (9.8\ m/s^2)} = 100\ m$$

(Sequoia)

if $R = 1.41 \times 10^{-7}\ m$

but the tubes are $2.5 \times 10^{-5}\ m$ wide

$\rightarrow h = 0.6\ m$

* Fluid dynamics ($\neq$ fluid statics)

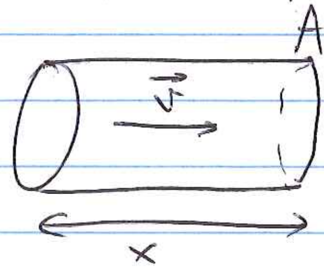
$\hookrightarrow$ $v \neq 0$, fluids are in motion due to forces (pressure differentials, pumps)

assume that the fluids are incompressible (liquids)

$\hookrightarrow$ ρ is constant

- Flow rate $Q = \frac{V}{t} = \frac{\text{volume}}{\text{time}}$ in units $\frac{m^3}{s}$

amount of volume passing a point in a unit of time



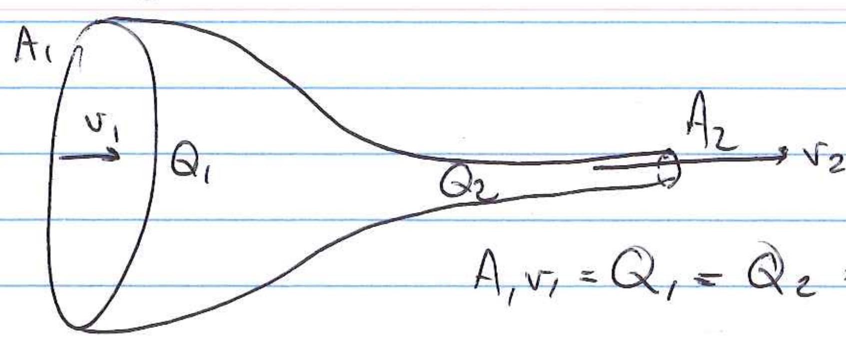
$V = Ax$

$Q = \frac{V}{t} = \frac{Ax}{t} = Av$

v = average velocity

A = area perpendicular to velocity

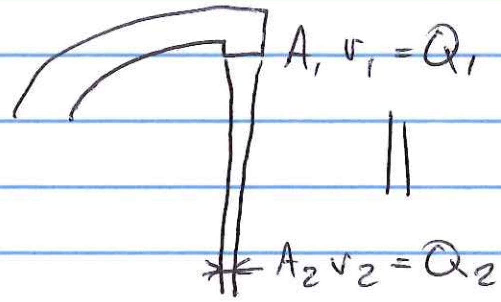
- continuity equation:



$A_1 v_1 = Q_1 = Q_2 = A_2 v_2$

If $A_1 \gg A_2 \rightarrow v_2 \gg v_1$ (spout, river passage)

Example: water faucet : water stream narrows as it falls



$v_2 > v_1 \rightarrow A_2 < A_1$

Example: blockages in arteries : how much faster will the blood flow if half of the radius is obstructed

$$A_2 = \pi R_2^2 = \pi \left(\frac{R_1}{2}\right)^2 = \frac{1}{4} A_1$$

$$A_2 v_2 = A_1 v_1 \rightarrow \quad v_2 = \frac{A_1}{A_2} v_1 = 4 v_1 \rightarrow 4 \text{ times faster}$$

Doppler echo cardiogram : measure local blood velocity to find obstructions