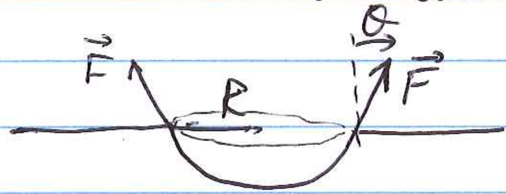
* Surface tension = force due to the cohesive forces between similar molecules in the liquid

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

l is circumference of the disturbance in surface



$l = 2\pi R$

$R = 1.5\times10^{-4} m = 0.15 mm$

$m = 2\times10^{-5} kg$

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

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

$F_y = F\cos\theta = \gamma(2\pi R)\cos\theta$

$F_{net} = 6F_y - mg = 0 \rightarrow 6\gamma(2\pi R)\cos\theta - mg = 0$

θ ?

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

$\downarrow$

$\theta = 62°$

$\cos\theta > 1$? bug sink , surface tension not large enough

Surfactants : substance that is added to the liquid
to reduces surface tension γ
↓
e.g. detergent to cling better to grease

Example : pulmonary alveoli : liquid/mucus covered
tiny sacs of air

1) inhalation : muscles expand chest cavity, results in
under pressure ~3 mm Hg → air rushes in

surfactant : long lipoproteins
when alveoli extend → concentration goes down
→ surface tension increase
↓
prevents you from inhaling too much
prevent alveoli from bursting

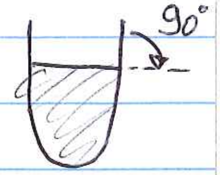
2) exhalation : let surface on the alveoli contract and
push out air
↓
concentration increases, surface tension
decreases
prevents alveoli from collapsing

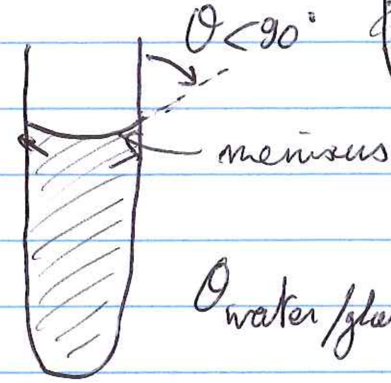
Water in lungs → concentration is lower → surface tension
is higher
↳ drowning, new born infants, hyaline membrane dis.

Emphysma : concentration increases due to combining alveoli
→ difficulty exhaling

* Cohesive forces ⟷ Adhesive forces

between identical types of molecules — between different molecules

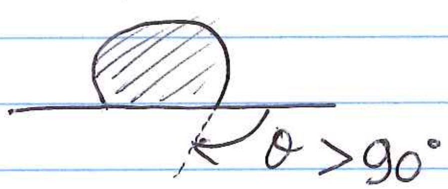


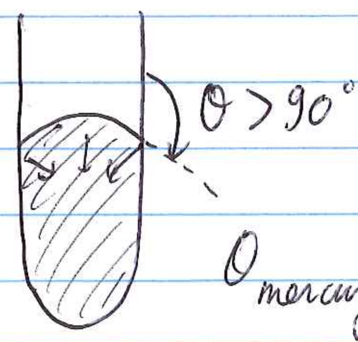


* adhesive > cohesive
  - "wetting" of surface
  - concave meniscus upwards
  - θ<90°

$\theta_{water/glass} = \underline{0^\circ}$

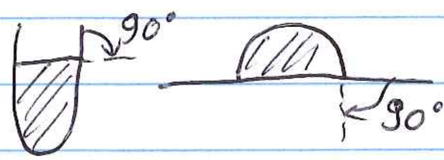
* adhesive < <u>cohesive</u>
  - θ>90°
  - concave meniscus downwards





$\theta_{mercury/glass} = 140^\circ$

$\theta_{water/silver} = 90^\circ$



* ~~[illegible]~~

* Adhesive vs. cohesive forces

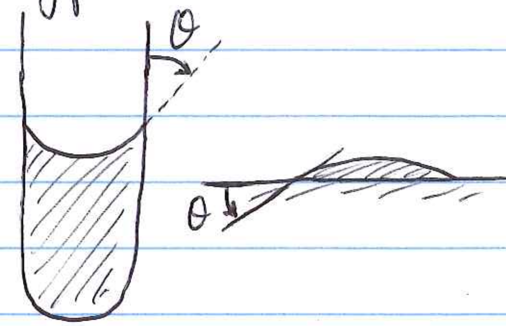
↓ forces between molecules of a different type

↳ of a same type

if adhesive > cohesive
- surface is "wetted"
- concave meniscus upward

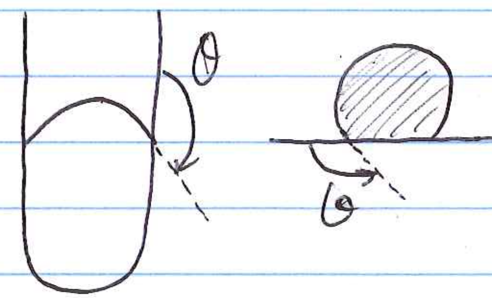
$\theta < 90°$

$\theta_{water/glass} = 0°$

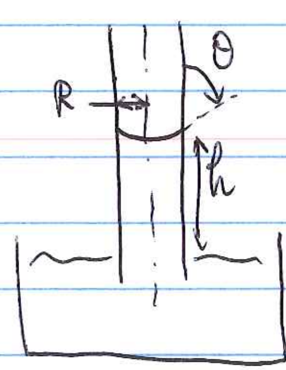


if cohesive > adhesive
- concave meniscus downward
- $\theta > 90°$

$\theta_{mercury/glass} = 140°$
$\theta_{water/silver} = 90°$



* Capillary effect : surface tension causes force F in narrow tubes



$$\gamma = \frac{F}{\ell} \rightarrow F = \gamma \ell = \gamma (2\pi R)$$

vertical component upwards

$$F_y = \gamma (2\pi R) \cos\theta$$

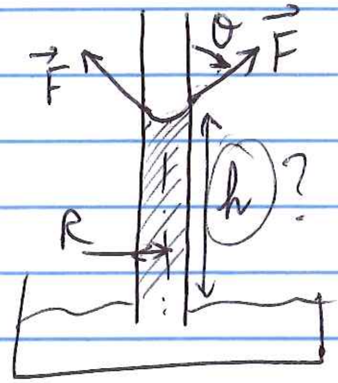
weight causes downward force

$$W = mg = \rho V g = \rho(\pi R^2 h) g$$

equilibrium when $W = F_y$ or $\gamma(2\pi R)\cos\theta = \rho(\pi R^2 h) g$

or $$h = \frac{2\gamma \cos\theta}{\rho R g}$$

* Capillary effect:



FBD:

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

$$F_y = F\cos\theta = \gamma(2\pi R)\cos\theta$$

upwards force of surface tension

W = downwards force of weight

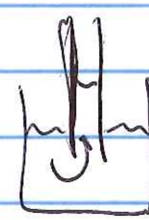
$$W = mg = \rho V g = \rho(\pi R^2 h) g$$

$$F_{net} = 0 = F_y - W = \gamma(2\pi R)\cos\theta - \rho(\pi R^2 h) g$$

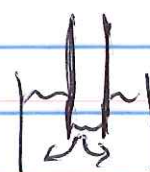
$$h = \frac{2\gamma\cos\theta}{\rho R g}$$

R small $\rightarrow$ h high

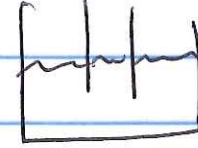
$\cos\theta$: $\theta_{water/glass} = 0 \rightarrow \cos\theta = 1$



$\theta_{mercury/glass} = 140^\circ \rightarrow \cos\theta < 0$



$\theta_{water/silver} = 90^\circ \rightarrow \cos\theta = 0$



How does the water from the soil get to top of a redwood tree? Can capillary effect explain this?

What is R required to get $h = 100 m$?

$$h = \frac{2\gamma\cos\theta}{\rho R g} = 100 \text{ m}$$

$\rho = \rho_{H_2O} = 1000 \, kg/m^3$

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

$\theta = 0° \rightarrow \cos\theta = 1$

$$R = \frac{2\gamma\cos\theta}{\rho h g} = \frac{2(0.0728 \frac{N}{m})(1)}{(1000 \, kg/m^3)(100 m)(9.8 \, m/s^2)}$$

$$R = 1.41 \times 10^{-7} \text{ m} = 0.141 \, \mu m$$

$\hookrightarrow$ not found, $R = 2.5 \times 10^{-5} \text{ m} = \underline{25 \, \mu m}$

$$h = \frac{2(0.0728 \frac{N}{m})(1)}{(1000 \, kg/m^3)(2.5 \times 10^{-5} m)(9.8 \, m/s^2)} = 0.6 m$$

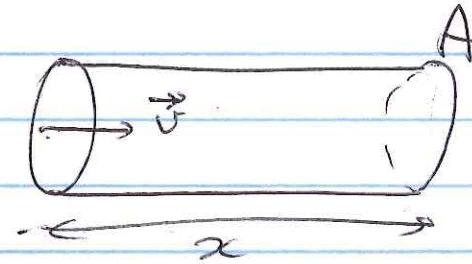
* Fluid dynamics ($\leftrightarrow$ fluid statics)

↳ $v \neq 0$, fluids in motion, forces that cause motion (pressure differential, pumps)

Assumption: ρ is constant, incompressible fluids = liquid

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

↳ amount of volume passing through cross section in a unit time



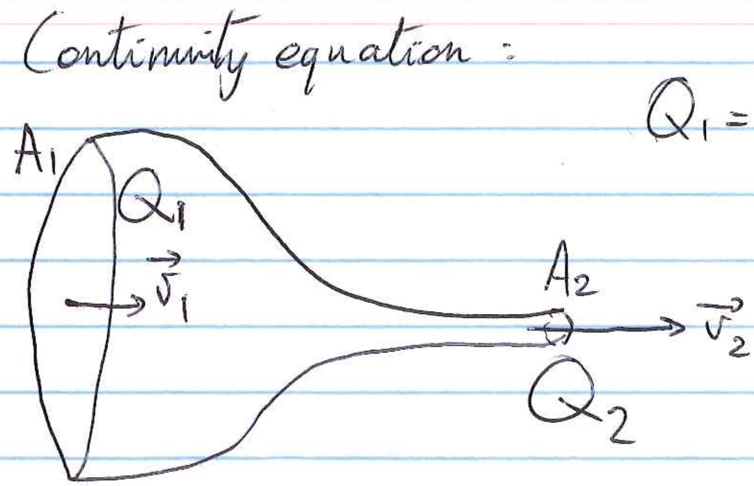
$$Q = \frac{V}{t} = \frac{Ax}{t} = Av$$

$$Q = \underset{A}{(0.1\,m^2)}\underset{v}{(10\,m/s)} = 1\,\frac{m^3}{s}$$

$$= \frac{(1\,m^3)}{(1\,s)}$$

- Continuity equation:

$$Q_1 = A_1 v_1 = Q_2 = A_2 v_2$$



$$\boxed{A_1 v_1 = A_2 v_2}$$

$$v_2 = \frac{A_1}{A_2} v_1$$