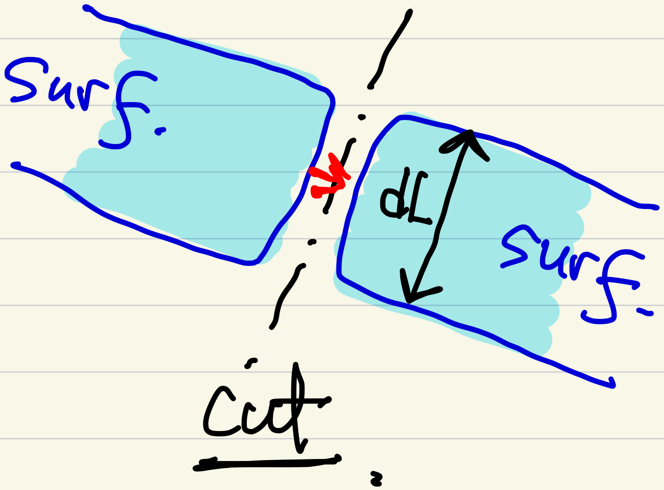
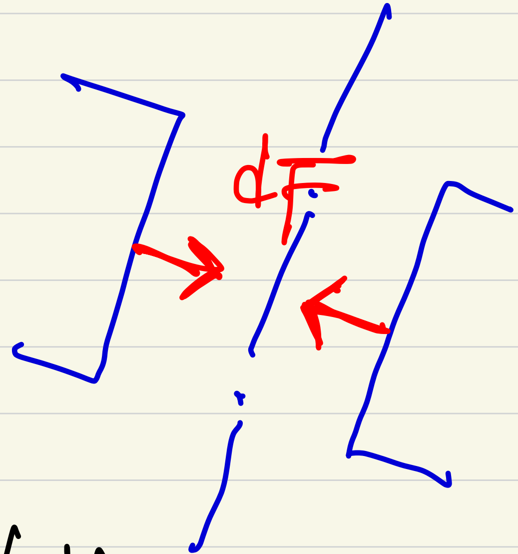
* Surface Tension

- A liquid will form an interface w/ other fluids.
- Molecules deep within the liquid repel each other because of their close packing.
- Molecules at the interface are less dense and attract each other → more cohesive
  → to make it more difficult to move an object through the surface than to move it when it is fully immersed.
- Since half of their neighbors are missing, the mechanical effect is that the surface

is in tension.





$\therefore dF = \gamma \cdot dL$

↳ surface tension coefficient.

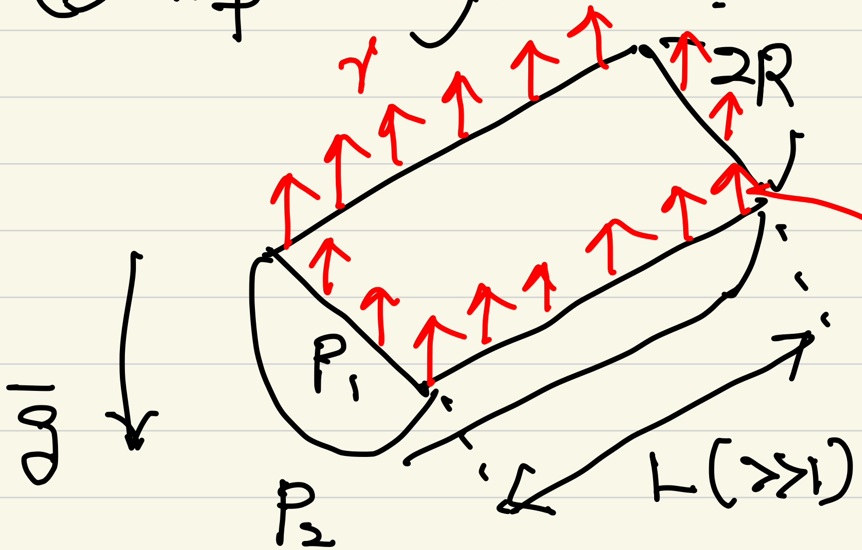
- air-water : 0.073 N/m.
- air-mercury : 0.48 N/m.

- as T ↑, γ ↓.

- If the interface is curved, there is a pressure difference across the interface.

(higher pressure on the concave side)

① liquid cylinder.



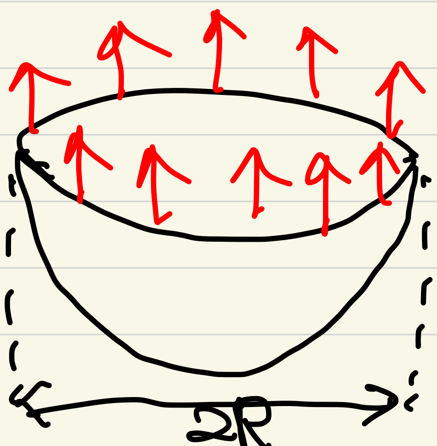
$$\Delta p = P_1 - P_2.$$

- neglect the weight of the liquid itself.

- $$\sum F_{\updownarrow} = \Delta p \cdot (2R \cdot L) - \gamma(2L + 4R) = 0$$

$$\Delta p = \gamma\left(\frac{1}{R} + \frac{2}{L}\right) \simeq \frac{\gamma}{R}$$

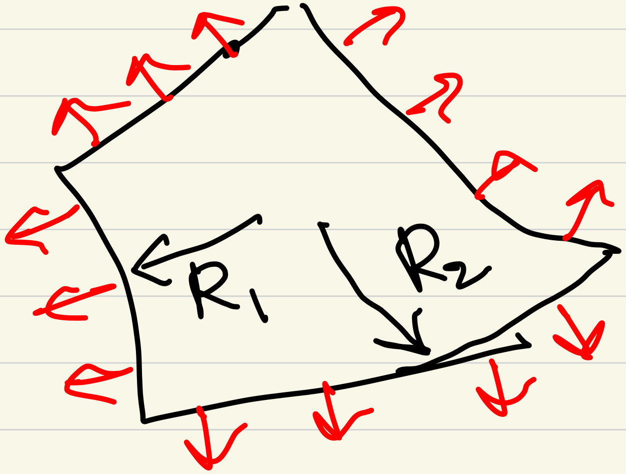
② spherical droplet.



$$\rightarrow \Delta p \cdot \pi R^2 = \gamma \cdot 2\pi R$$

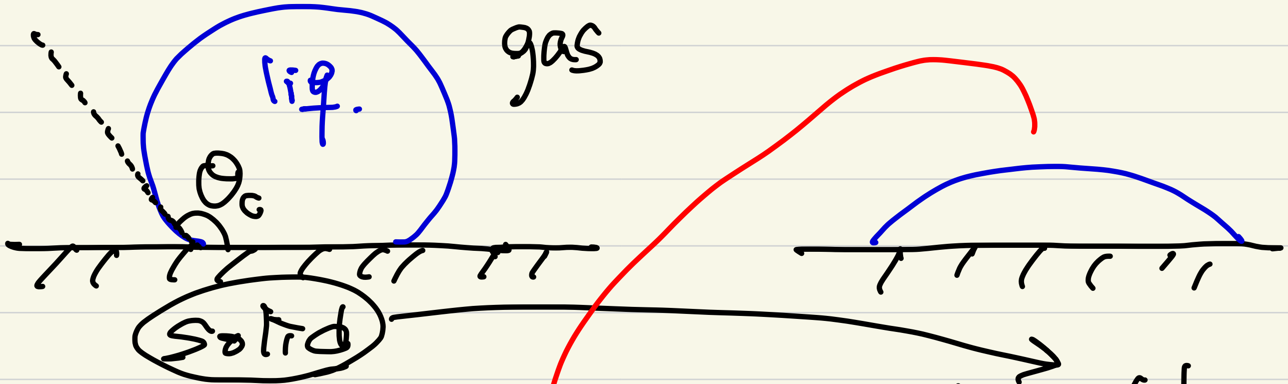
$$\rightarrow \Delta p = 2 \cdot \frac{\gamma}{R} = \gamma\left(\frac{1}{R} + \frac{1}{R}\right)$$

③ general curved interface.



→ $\Delta p = \gamma\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$.

* Contact angle (θ_c)

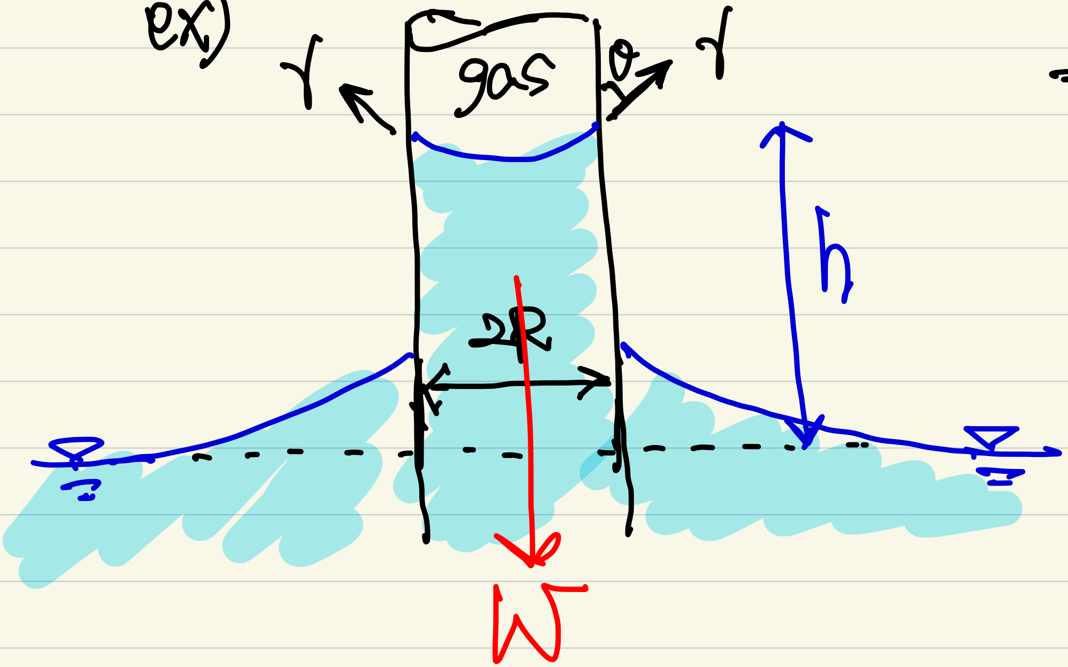


$\theta_c > 90°$: non-wetting (hydrophobic).

($\theta_c \geq 150°$: super ")

$\theta_c < 90°$: wetting (hydrophilic)

ex)



$\rightarrow \gamma \cdot 2\pi R \cdot \cos\theta = W = \pi R^2 h \cdot \rho g$

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

if $\theta < 90°$: $h > 0$

(wetting liquid)

if $\theta > 90°$: $h < 0$

(capillary depression)

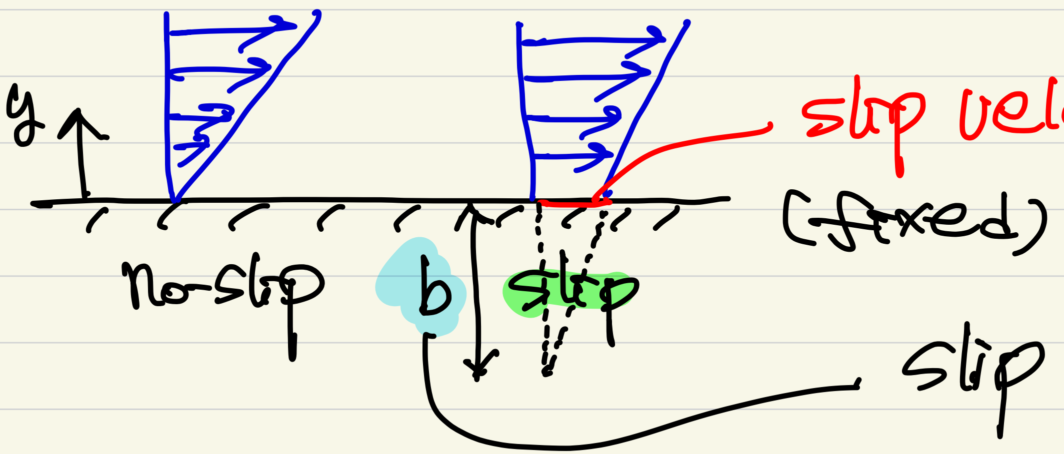
* No-slip & No-jump condition.

(fluid flow over the solid surface)

$V_{fluid} = V_{wall}$ @ the surface.

$T_{fluid} = T_{wall}$

· superhydrophobic surface : No-slip condition is NOT valid.



$$u_s = b \cdot \left|\frac{\partial u}{\partial y}\right|_{wall}$$

(Navier's slip model)

* speed of sound,

$$a^2 \equiv \left.\frac{\partial P}{\partial \rho}\right)_s$$

(isentropic)

$$\text{Mach \#} = \frac{V}{a}.$$

$> 0.2-0.3$

– compressible

$< 0.2-0.3$

– incompressible.

* Vapor pressure (Cavitation)

"when the liquid pressure is dropped below the vapor pressure due to a flow phenomenon, vapor bubbles begin to appear in the liquid."

pressure at which a liquid boils (P_v)

e.g.) water 20°C, 2340 Pa.

$$Ca = \frac{P_a - P_v}{\frac{1}{2}\rho V^2}$$

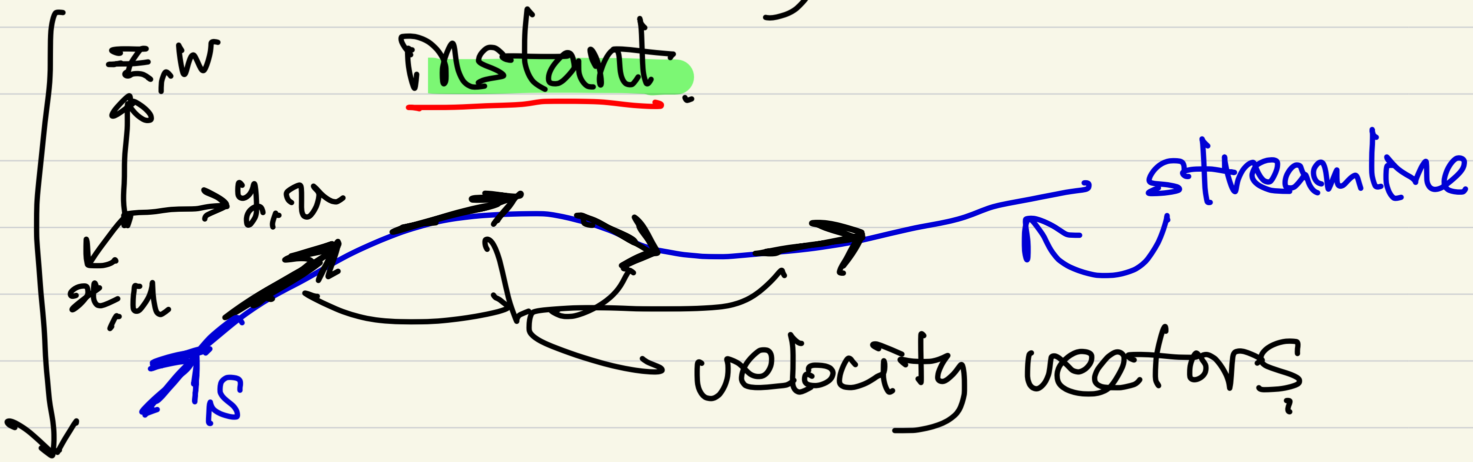
Ca: Cavitation Number

P_a: ambient pressure.

→ if $Ca < Ca_{crit}$, flow begins to cavitate.

1.8 Flow Patterns (Visualization)

- streamline (유선) : a line everywhere tangent to the velocity vector at a given instant.



mathematically achievable

$$\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w} = ds.$$

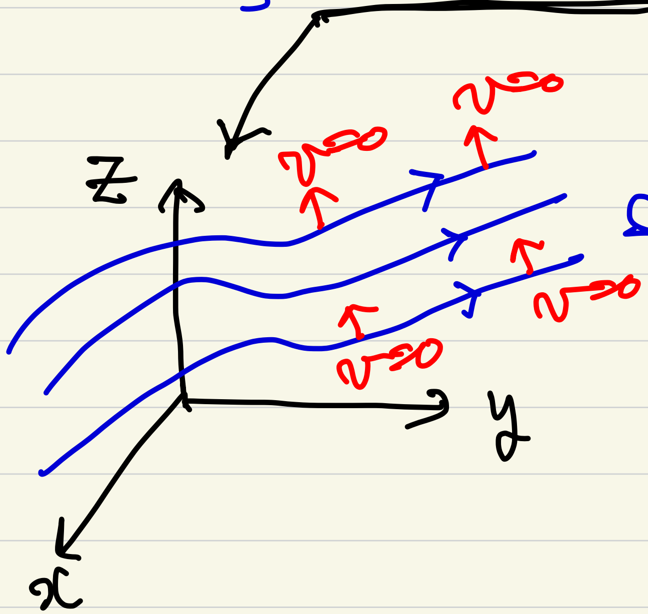
- pathline : actual path travelled by a given fluid particle.
- streakline : locus of particles which have

earlier passed through a prescribed point.

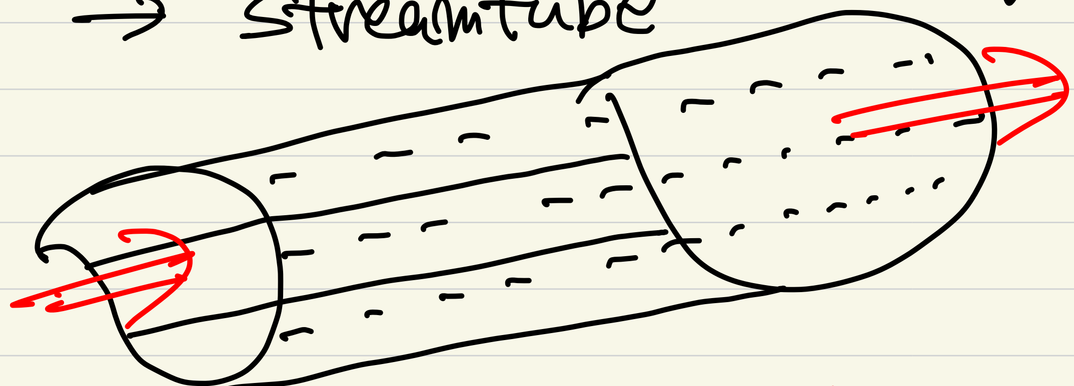
· timeline : a set of fluid particles that form a line at a given instant.

in a steady flow. ($\partial/\partial t \simeq 0$)

; streamline = pathline = streakline.



streamlines → streamtube (imaginary)

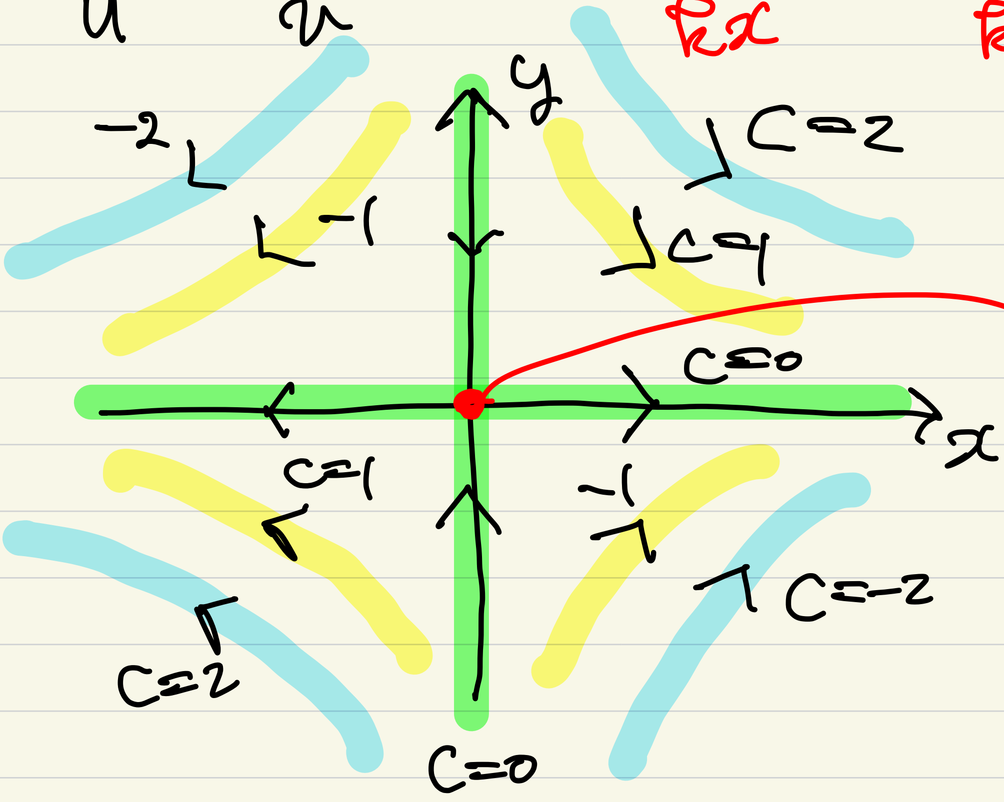


no flow across the streamtube surface!

ex) 2D velocity field, $u = kx,\ v = -ky,\ w = 0$.
(steady), streamlines?

$$\frac{dx}{u} = \frac{dy}{v} \rightarrow \frac{dx}{kx} = -\frac{dy}{ky} \Rightarrow \ln x = -\ln y + C$$

$$\boxed{xy = C.}$$



$x=0,\ y=0$
↓
$u=0,\ v=0.$
→ stagnation pt.
(정체점)

1.9. Basic flow analysis techniques.

① Control volume (or integral) method. – Ch. 3

② Infinitesimal system. (or differential) analysis – Ch. 4.

③ Experimental study (or dimensional analysis) – Ch. 5.

↓

Basic conservation laws.

① mass — continuity eq.

② momentum – Newton's 2ND Law.

③ energy – thermodynamics 1st Law.

\+ state eq. (e.g. $\rho = \rho(P, T)$)

+ boundary conditions.

Ch.2 PRESSURE DISTRIBUTION IN A FLUID.

⇒ Hydrostatic condition (zero velocity)

; pressure variation is due only to weight of the fluid.