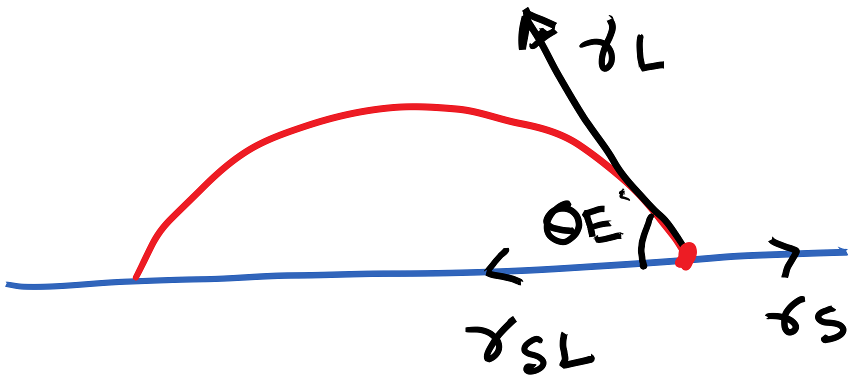
Young's Equation

Date: 19.01.2022

Force Balance in the Horizontal Direction:



Equilibrium Contact Angle.

Contact Angle Does not change → As contact Line is stationary →.

The outward force = Inward force | at the Contact Line

$$\rightarrow \boxed{\gamma_S = \gamma_{SL} + \gamma_L \cos\theta_E}$$

Young's Eqn:

$$\Rightarrow \cos\theta_E = \frac{\gamma_S - \gamma_{SL}}{\gamma_L}$$

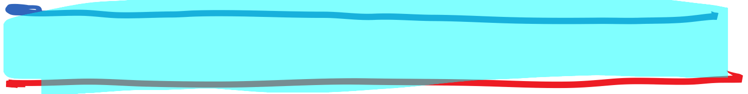
[Physically measurable Entities →]

What are the Limiting values of θ_E

(Partial Wetting)

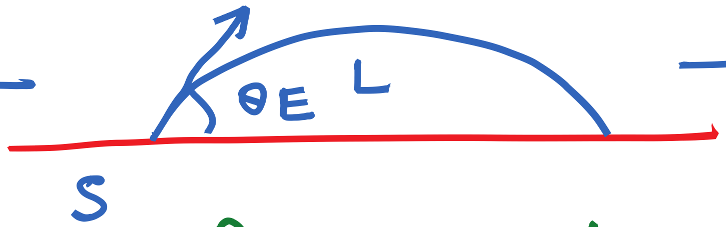
FILM

(Complete Wetting)



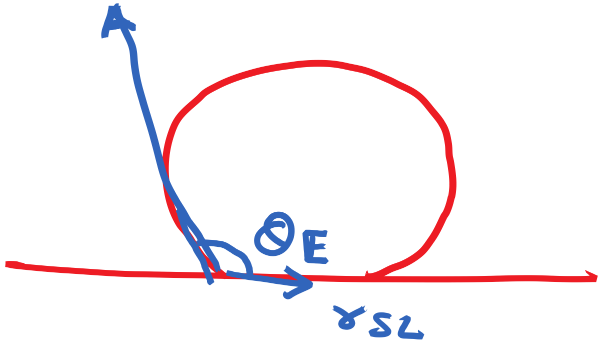
$\theta_E \to 0$

Lower Limit $\to 0$



θ_E is acute

($< 90°$)



Higher Limit

$\theta_E \to 180°$

Not Possible

$\theta_E = 0$ would mean Liquid Surface and the Solid Surface are parallel.

Liquid is Spreading Completely on the Surface

Complete Wetting

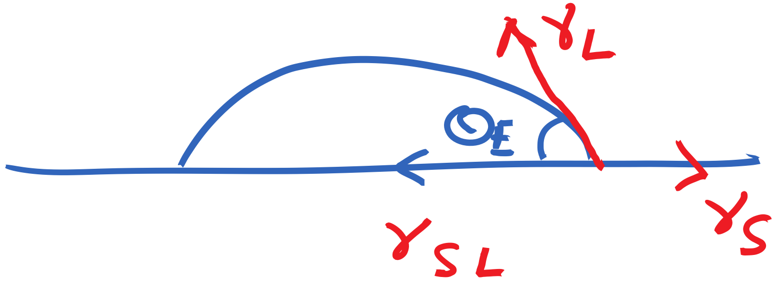
Liquid Spreads partially on the Solid Surface →

→ Extent of Spreading Reduces as θ_E increases ✓

← Partial Wetting →

A liquid partially wets a solid surface $\rightarrow$ $\underline{0 < \theta_E < 180^\circ}$

$$\gamma_S = \gamma_{SL} + \gamma_L \cos\theta_E$$



$$\Rightarrow \quad \cos\theta_E = \frac{\gamma_S - \gamma_{SL}}{\gamma_L}$$

We are dispensing the same liquid on surfaces with different γ_S.

If γ_S decreases $\rightarrow$ How θ_E would change as γ_S changes

$\rightarrow$ Increase in θ_E.

(Assumption: $\gamma_{SL} \approx$ Constant)

Reduction in $\gamma_S \rightarrow$ Reduction in $\cos\theta_E \rightarrow$ Increase in θ_E

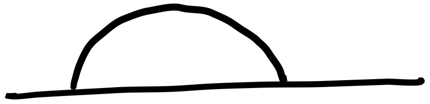
$\cos 0^\circ = 1$

$\cos 90^\circ = 0$

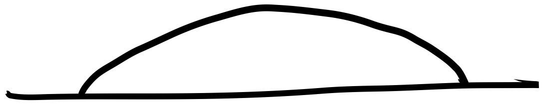
$\cos 180^\circ = -1$

$\cos(\theta) = -ve$

$90 < \theta < 180^\circ$



γ_{S_1}



γ_{S_2}

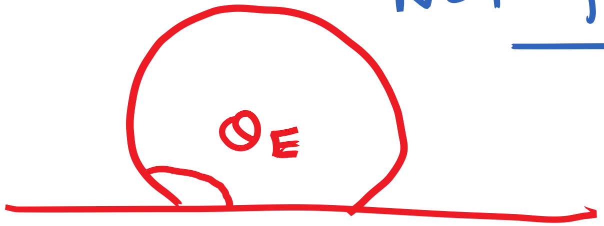
If γ_S reduces, θ_E increases

Favored

Spreading is Favored

$\theta_E \rightarrow$ Acute

Not favored.



$\theta_E \rightarrow$ obtuse

As if Surface does not want to get covered.

<Both Examples of Partial Wetting>

In case the Liquid is Water

$\theta_E < 90^\circ \longrightarrow$ Term the Surface as Hydrophilic

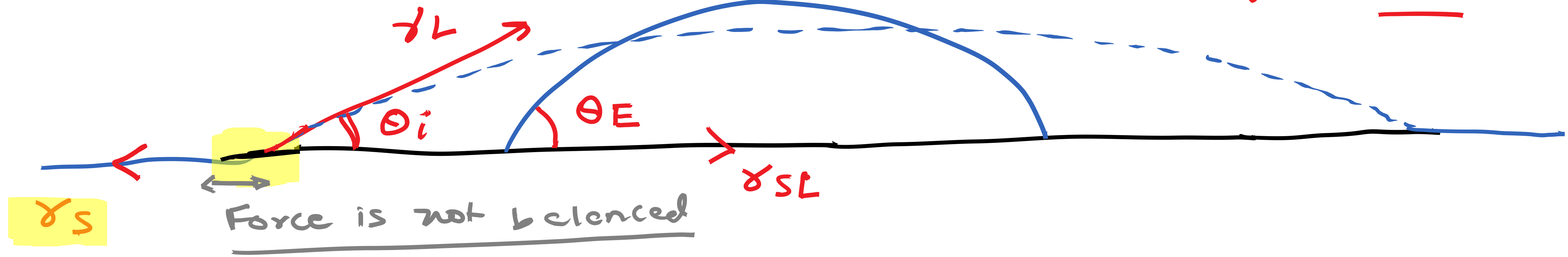
$90^\circ < \theta_E < 180^\circ \longrightarrow$ The surface is Hydrophobic.

Spreed the drop with finger (Forced Spreeding),

What will happen next !

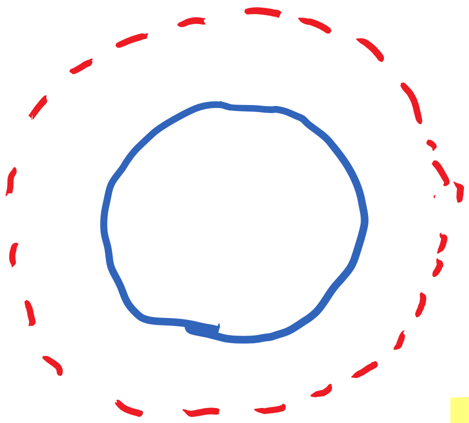
$\theta_i \rightarrow$ Intrinsic Contact Angle

(lower the θ_E)



The Contact Line will retract back.

$$\gamma_L = \gamma_{SL} + \gamma_L \cos \theta_E$$



Under spreaded condition, forces at the point of contact

$\cos \theta_i > \cos \theta_E$

Outward $\rightarrow \gamma_S$

Inward $= \gamma_{SL} + \gamma_L \cos \theta_i$

(Net inward force higher)

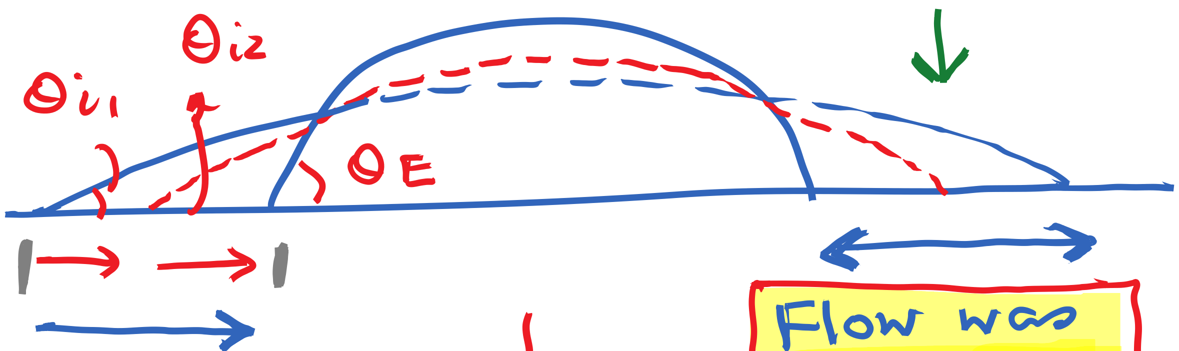
Inward retraction of the Contact Line.

Surface Tension Mediated Flow

→ How long will this retraction continue

→ Dynamics will stop.

$$|\theta_E - \theta_i| < \epsilon = 0$$
$$\approx 0$$



Contact line will Retract

Flow was observed

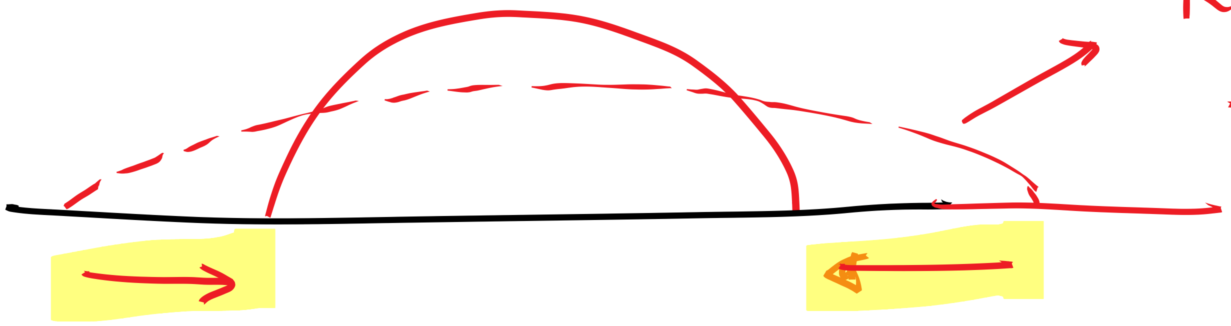
Retraction of Contact line is associated with Flow :-

What is the driving Force for this flow? →

Exposing a bare surface which was earlier under liquid → Dewetting.

Retracts back to its original configuration

NO SLIP – VALID or NOT ?



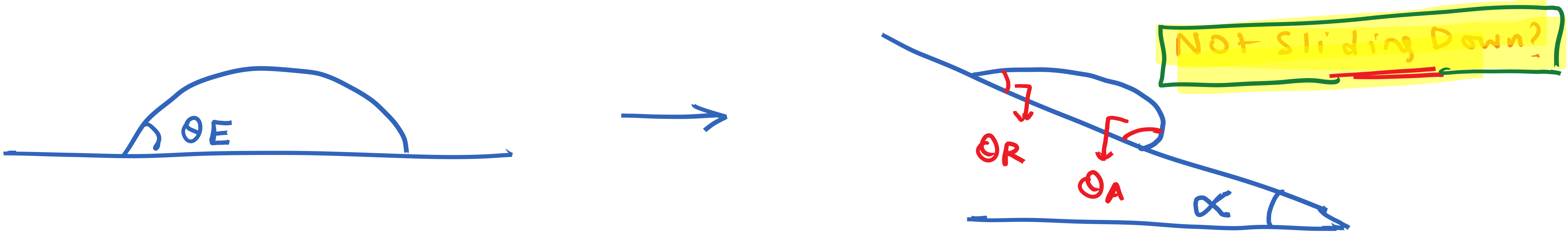
Retraction of the Contact line
→ Surface Tension mediated flow.

Retraction violates one fundamental assumption in classical Fluid Dynamics → NO SLIP CONDITION.

Had NO SLIP Condition been effective, what would have happened after you had spread the drop ?

↳ Contact Line would have remained Stuck.

Have you seen a drop sliding Down an inclined Plain?



What will happen?

The moment you tilt the Surface → There will be $-g \sin\alpha$ body force acting on the drop!

* A drop on an inclined or a vertical Surface that's not moving → ?