Lecture 13a: What causes lift?

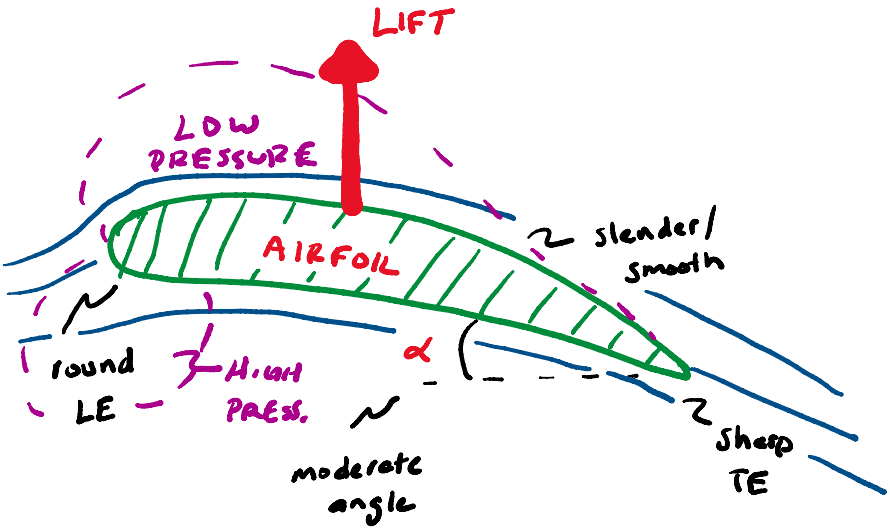
Tuesday, November 2, 2021 9:05 PM

Up to this point:

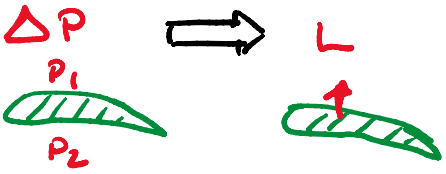
- KUTTA - JOUKOWSKI $L' = \rho U_\infty \Gamma$
- BERNOULLI U↑ P↓

Today: where does LIFT come from?

MASS MOMENTUM ENERGY



Bodies in AERO feel force through P & τ

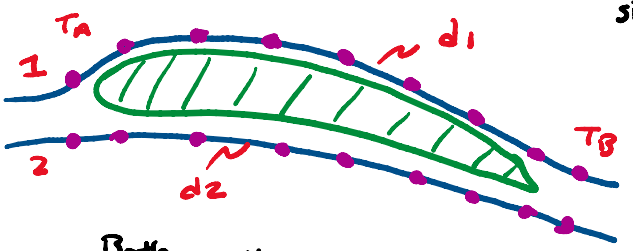


BUT HOW?

Common misconceptions:

1. EQUAL TIME

since $d_1 > d_2$ then $u_1 > u_2$ through Bernoulli:



Both particles meet at TE

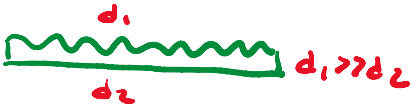
since $d_1 > d_2$ then $u_1 > u_2$ through Bernoulli:

$P_1 < P_2$ then $\Delta P \rightarrow L$

No!

issues: $d_1 > d_2 \neq u_1 > u_2$

1. the particles don't need to meet

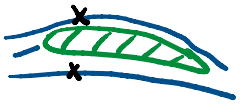


$d_1 \gg d_2$ ← no lift

upside down

2. $u_1 > u_2 \Rightarrow P_1 < P_2$ is Bernoulli:

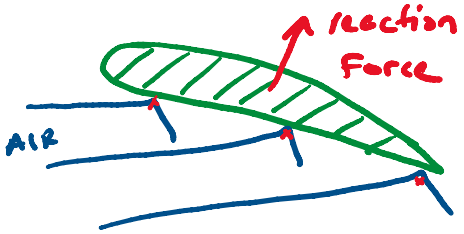
OFF a streamline



special cond. IRRotational

BUT along PATH 1 $u\uparrow \Rightarrow P\downarrow$ ✓ generally $u_1 > u_2$ ✓

2. AIR PUSHES



Air bounces off FOIL creating a REACTION FORCE

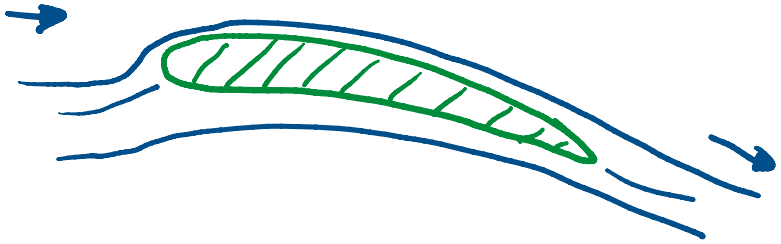
issues: that's not how AIR behaves

(not bouncy balls)

BUT AIR is being turned which requires a FORCE (LIFT)

3. AIR IS TURNED / ROTATED

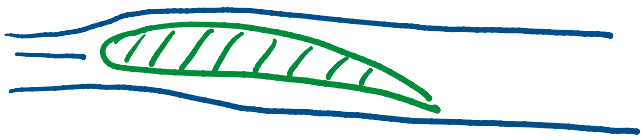
FLOW is redirected DOWN ↓



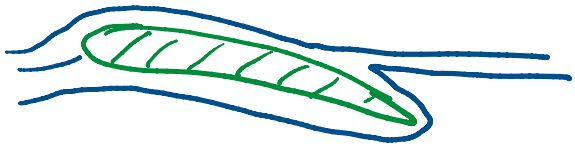
FLOW is redirected DOWN ↓

therefore FORCE UP ↑

Yes! But, this isn't a WHY.... just a FOOTPRINT



or



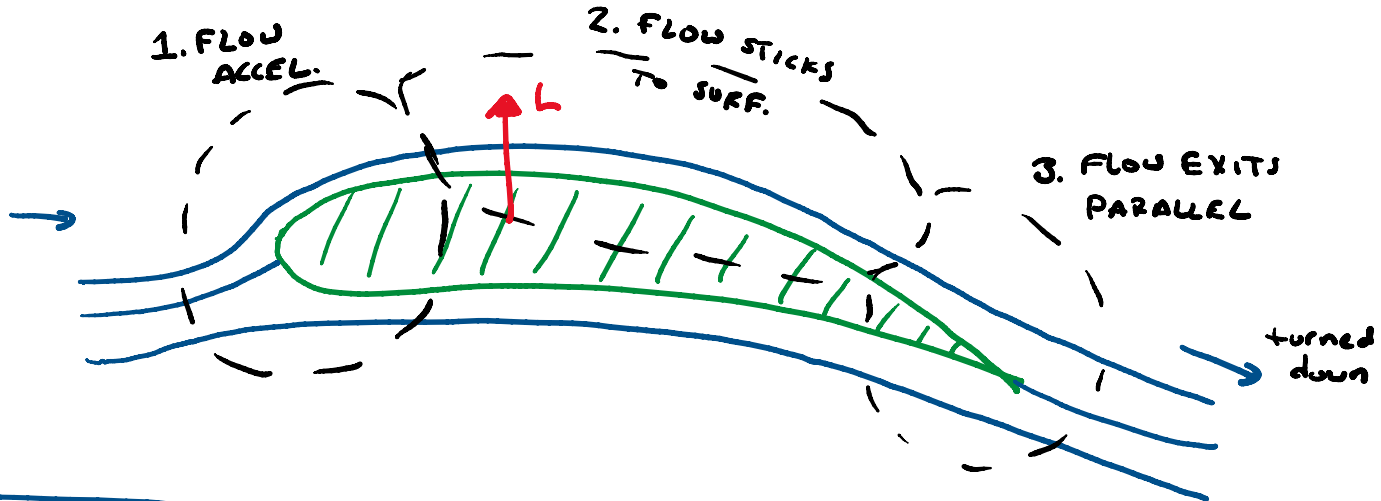
All concepts have something correct, but incomplete ...

In reality:

CONSERVATION OF...

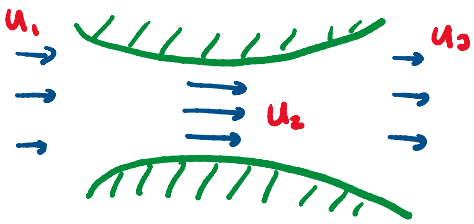
MASS → **ENERGY** → **MOMENTUM**

- MASS: └ flow accel
- ENERGY: └ accel becomes force
- MOMENTUM: └ expleins force from flow rotation



AT THE NOSE flow acceleration

$u_1 = u_3$ CONSERVATION of MASS



$u_1 = u_3$

$u_2 > u_1, u_3$

CONSERVATION OF MASS

$\dot{m} = \text{const.} \Rightarrow \rho u_1 A_1 = \rho u_2 A_2$

$A \downarrow \Rightarrow u \uparrow$

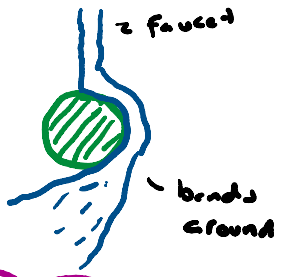
same happens on a foil

Rapid changes in curvature cause ACCELERATION

BERNOULLI: $p + \frac{1}{2}\rho u^2 = \text{const.} \Rightarrow p_2 < p_1$

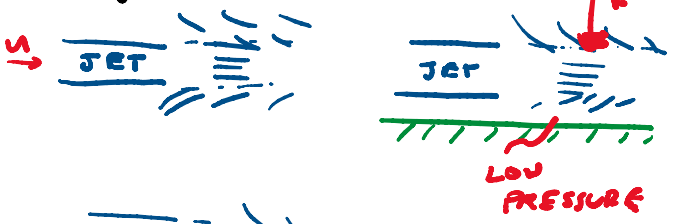
ON THE SURFACE flow sticks

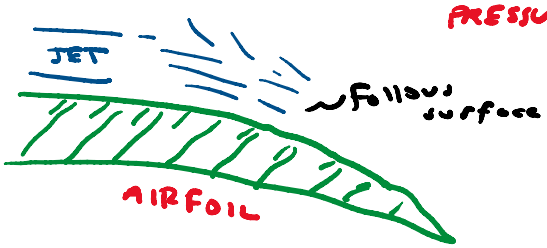
COANDĂ EFFECT



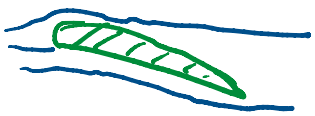
Flow tends to prefer to stay on surface

Why? ~ entrainment





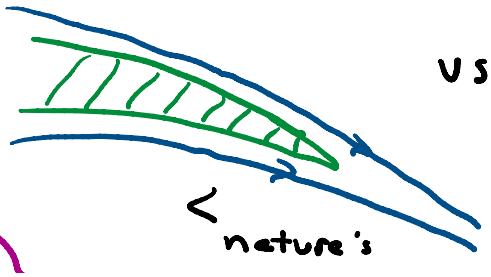
So flow doesn't do this:



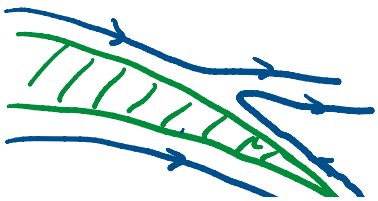
AT THE TIP easy flow exit

KUTTA-CONDITION

Flow smoothly leaves



VS.

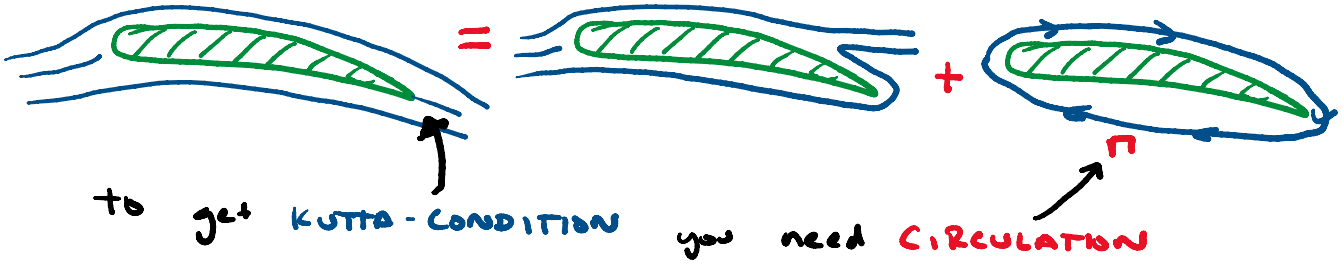


Flow smoothly leaves Top/Bottom at the TE

< nature's preference

too much energy!

recall ELEMENTARY FLOWS



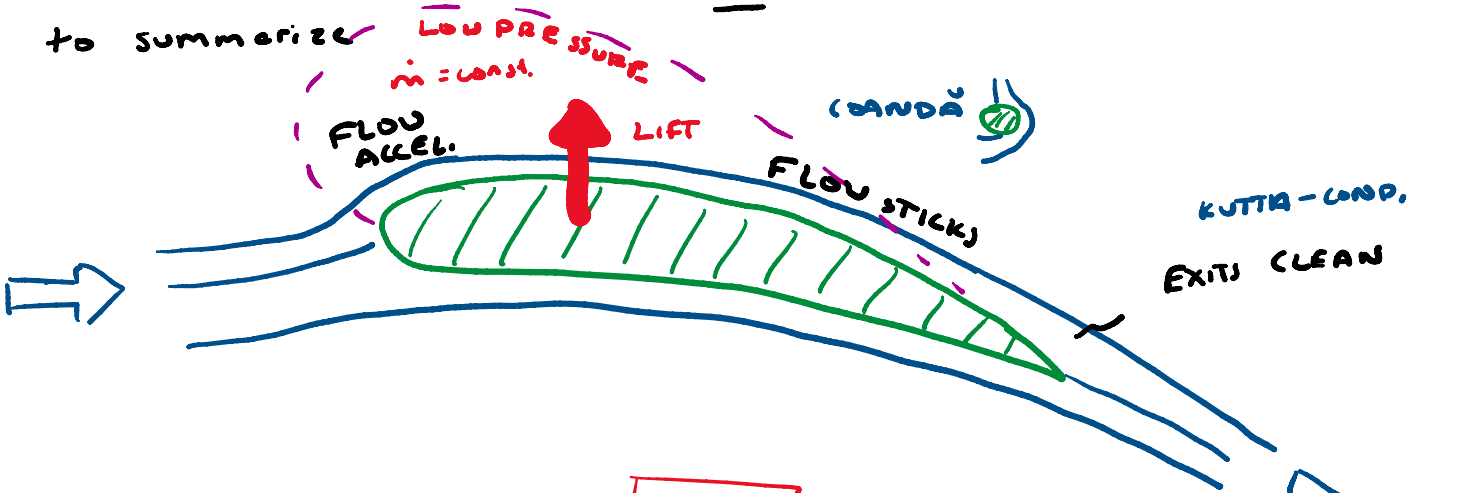
to get KUTTA-CONDITION you need CIRCULATION

$L' = \rho U_\infty \Gamma$ ← circ.

leads to LIFT

KUTTA-JOUKOWSKI THEOREM

to summarize



LIFT comes from