Self-similar flows (unsteady or steady boundary layers

~~HW9~~ HW10. ✗ ✗ ✗
HW11. ✗
HW12
HW13 5? 6?

Stokes ~~type~~ hw9#1, hw10#1 $u_{plate} = U_1 t$

Boundary layer type hw13#7 (sink)

Dimensional analysis $f(y/\sqrt{\nu t})$, linear hw13#7 (sink)
hw10#1 (plate)

Potential flows

"Corners" → HW12, #4 Ellipses → HW13, #2 Cylinders Plates

Superposition of vortices (sources (sinks), uniform flow, cylinder flow ~~HW11~~ hw11#3 motion of vortices
hw11#2 (trailing vortices above ground) hw13#3 (Rankine) HW13#5,6 (airfoil) (sources + uniform)

Bernoulli law using W, $\frac{\partial \phi}{\partial t}$, φ, ψ
hw13#1 HW12, #2 (cylinder acceleration) HW12, #3 (trail. vortices) HW12, #4 (corner) HW12#4 (corners)
HW11.2 trailing vortices

Find streamlines using ψ = constant HW12, #3 (trailing vortices) HW12, #4 (corner)
hw13#1, hw13#4 (Magnus) hw13#5 (airfoil) ~~HW10#5 (rotating flow around balloon)~~

Integral pressure forces ~~HW12~~ HW12#1 (cylinder) HW12#2 (acc. cylinder)
Rankine

(Find solution to $\nabla^2 \varphi = 0$ or $\nabla^2 \psi = 0$ using real analysis)
(Find stagnation points hw12#4 (corners) hw13#1 (Rankine) using W
HW11#4 → Find stagnation points
Find velocity using chain rule hw13#2

Boundary layers

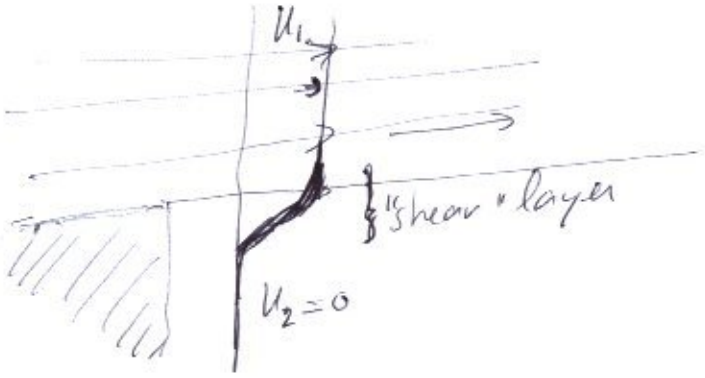
formulate boundary layer problem (what are x_p, y_p, U_1, V_2, what are B.C., I.C.),
~~integrate~~ Solve p hw13#6

find (form) of stress, displacement thickness (??) hw13# 9,10 (duct enhance)
hw13#8? (airfoil L and D)

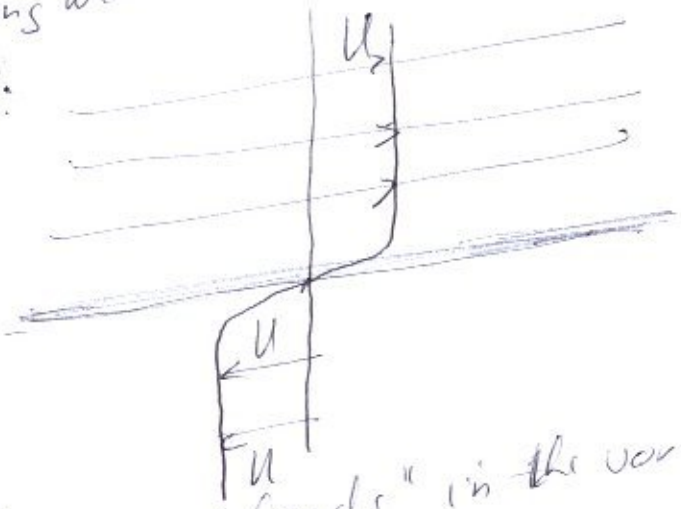
integrate stress to find force ~~hw10#5~~ hw10#5 (rotating flow around balloon)
hw13#8 (airfoil forces)

use displacement effect to find inviscid flow effects
hw13#9,10 (duct enhance)

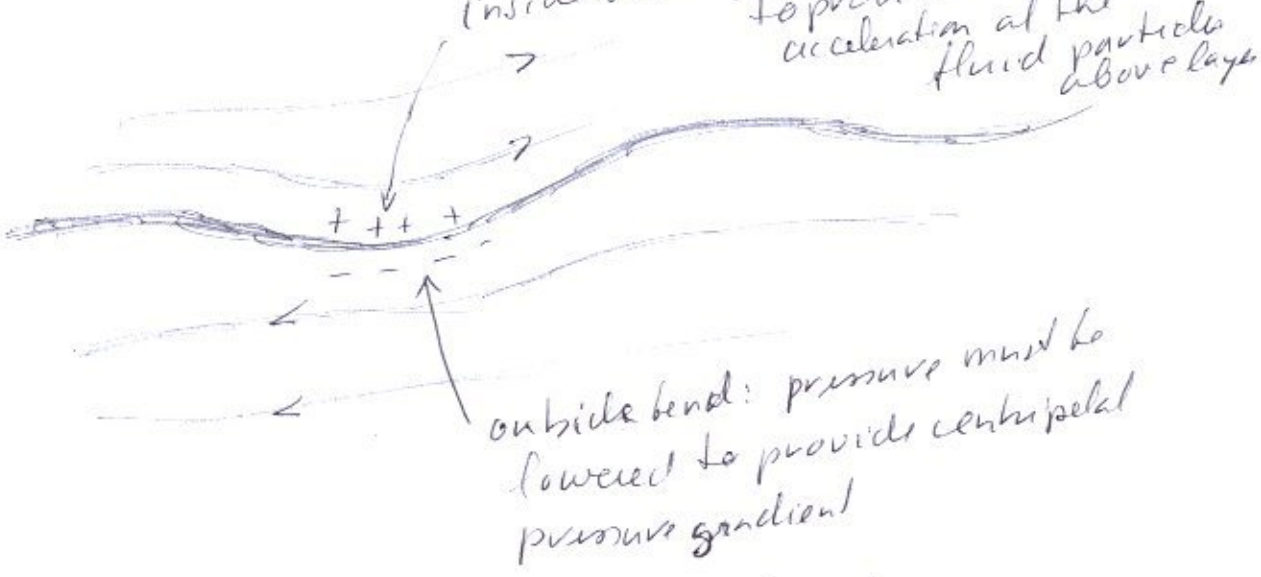
Kelvin-Helmholtz instability qualitatively



Moving along with the average velocity, the picture looks like:



Assume there are "bends" in the vortex sheet



Net pressure force pushes sheet down:
Bend becomes deeper!

(Note: particle paths are not really same as streamlines.)

In general, disturbances in high Reynolds number flows want to grow in amplitude → development of turbulence