MAE 158 Lecture 16
Nov. 21 2024

Announcements: Week 8 quiz
landing + turn/pullup/pulldown maneuver

Prof Huynh's OH week 9
tues @ 1pm in EG 4212

TA Reza's OH week 9
Mon @ 9am in EG 2146

Week 8 discussions →
additional time to
Review Midterm
as desired

Today's Objectives: turning (fin)
stability

last time:

determine "theoretical min turn Radius"

$W/S = 76.84\ \text{lb}/\text{ft}^2$

$C_{L\,max} = 1.2$

$K = 0.08$

Sea level conditions

$\rightarrow \rho = 0.00238\ \text{slug}/\text{ft}^3$

$T/W = 0.3795$

$C_{D,P} = 0.015$

$$r_{min} = \frac{V_{r_{min}}^2}{g\sqrt{n_{r_{min}}^2 - 1}} = \frac{4K\left(\frac{W}{S}\right)}{g\rho\left(\frac{T}{W}\right)\sqrt{1 - 4K\frac{C_{D,P}}{(T/W)^2}}}$$

$= 4\ 0.08\ (76.84\ \text{lb}/\text{ft}^2)$

$$(32.2\,\tfrac{ft}{s^2})(0.00238\,\tfrac{slug}{ft^3})(0.3795)\cdot$$

$$\sqrt{1-4(0.08)\frac{0.015}{(0.3795)^2}}$$

$= 861\ ft$ "theoretical min"

Is this feasible? → is it safe?

→ is the load factor Reasonable

→ is this $V_{r_{min}}$ feasible?

→ is it too low or too high?

$$n_{r_{min}} = \sqrt{2-\frac{4KC_{D_0}}{(T/W)^2}} = \sqrt{2-\frac{4(0.08)(0.015)}{(0.3795)^2}} = 1.4$$

$$V_{r_{min}} = \sqrt{\frac{4K(W/S)}{\rho\,(T/W)}} = \sqrt{\frac{4(0.08)\left(76.84\,\frac{lb}{ft^2}\right)}{0.00238\,\frac{slug}{ft^3}\,(0.3795)}}$$

$$= \underline{165\ ft/s}$$

compare load factor to structural load factor

$n_{struct} \sim 2$ thus safe for n_{struct} ✓

because $n_{r_{min}} < n_{struct}$

$$n_{thrust} = \left\{ \frac{\frac{1}{2}\rho \overset{165\,ft/s}{V^2}}{\underset{0.08}{K}\left(\underset{76.84\,\frac{lb}{ft^2}}{W/S}\right)} \left[\overset{0.3795}{\left(\frac{T}{W}\right)} - \frac{1}{2}\rho V^2 \frac{\overset{0.015}{C_{D_P}}}{W/S} \right] \right\}^{1/2}$$

usually want max T/W

$= \underline{1.4}$

using $T/W = 0.3795$
because $T_{A\,max}$ is higher,

then ✓

$n_{C_L max}$

check $C_L = \dfrac{2nW}{\rho V^2 S}$

$= \dfrac{2 \cdot 1.4 \cdot 76.84 \frac{lb}{ft^2}}{0.00238 \frac{slug}{ft^3} \; 165 \frac{ft}{s}}$

$= \underline{\underline{3.32}}$ ✗

given a velocity → what is the min safe turn Radius ?

$$\left.\begin{array}{l} n_{struct} \\ \text{solve } n_{thrust} \\ \text{solve } n_{C_{L}max} \end{array}\right\} \text{whichever is smallest}$$

→ n_{safe}

↳ min safe Radius @ given V

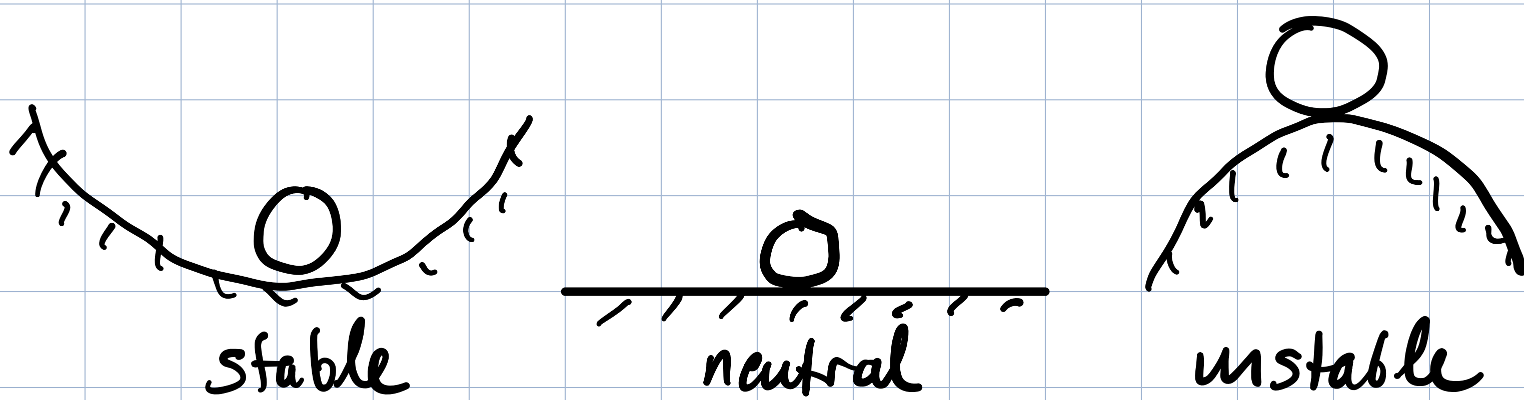
quiz ↑

Stability & control topics shevell Ch. 16

1. stability: ability of Aircraft to Return to equilibrium condition after a disturbance

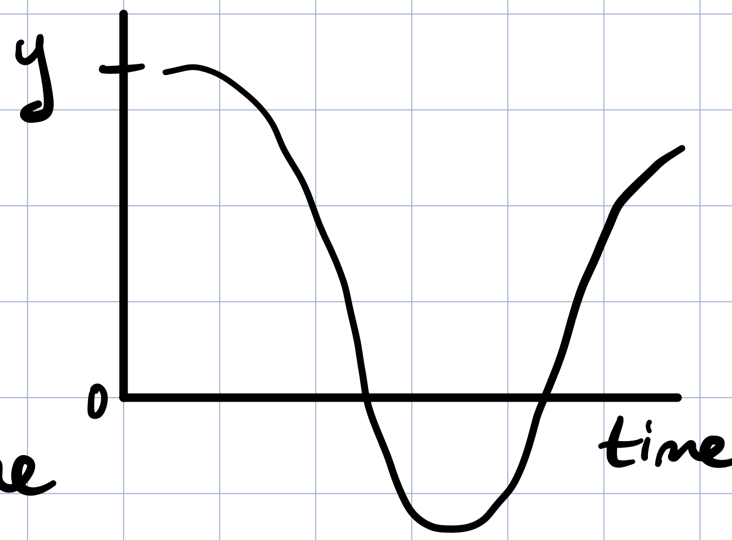
equilibrium : $\Sigma F = 0$
$\Sigma M = 0$
on the body

Static Stability : when forces & moments on a body Return body to equilibrium after a disturbance



Dynamic Stability - after a disturbance the body Returns to equilibrium after some time period

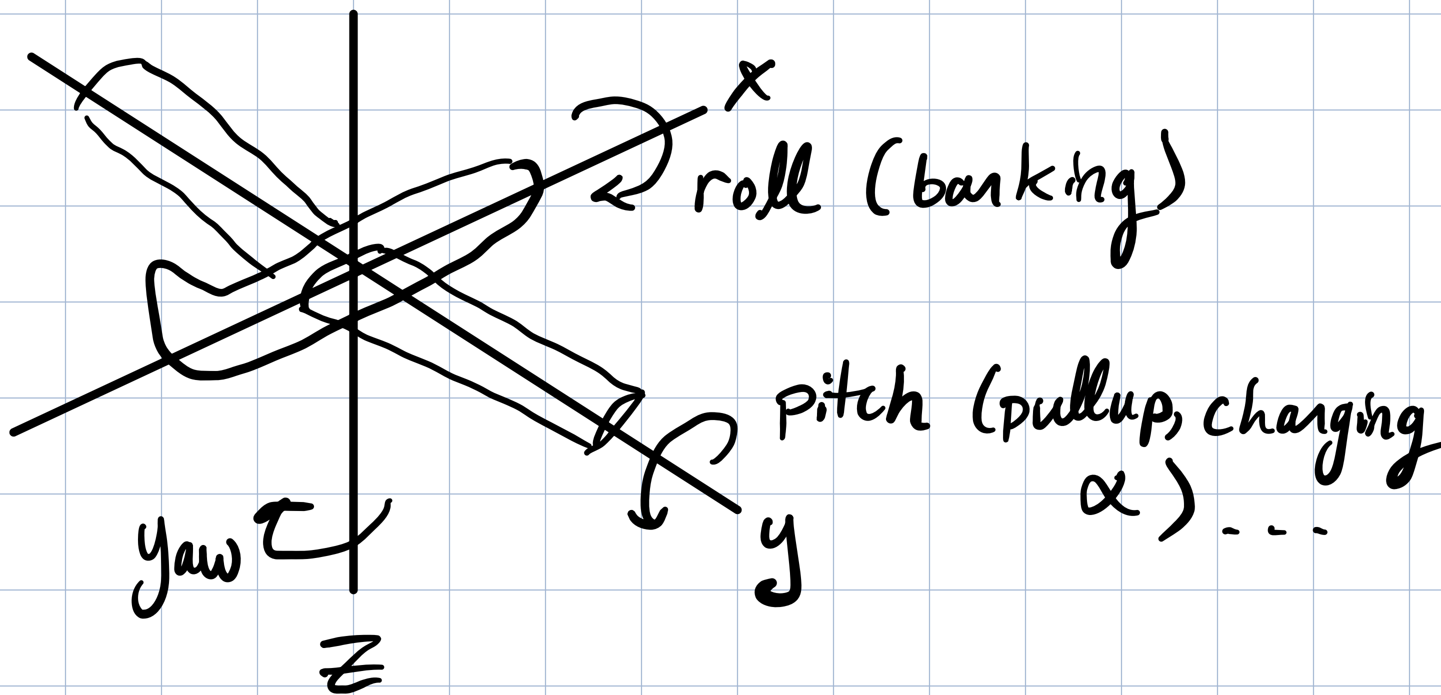
stable



unstable

2. Control: ability of pilots to produce forces & moments on A/C using ailerons, elevators, rudder, differential thrust etc... to change A/C direction

We will assume A/C is a Rigid body



6 degrees of freedom

- motion along x, y, z axis
- Rotate around:

x axis (Roll)
y axis (pitch)

z axis (yaw)

· + moment defined as:

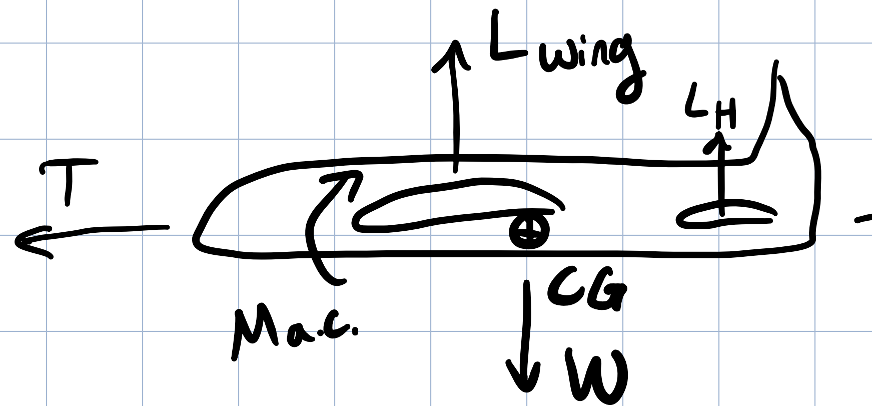
- Rolling Right
- Pitching up
- yawing nose goes to Right

longitudinal Static Stability

Recall $C_M = \dfrac{M}{\frac{1}{2}\rho V^2 S \bar{c}}$

aerodynamic m.a.c. when dealing with stability & control

↳ $C_{R_0} \rightarrow$ m.a.c.



L_H = lift horiz. tail

weight will center @ CG (center of Gravity)

Conditions for equilibrium ($C_{M_{CG}} = 0$)

→ <u>trim point</u>

Few other points:

@ aerodynamic center:

C_M const w/ α
const w/ C_L

if C_L is 0 → condition where no force vectors from wing / tails contributing to moment

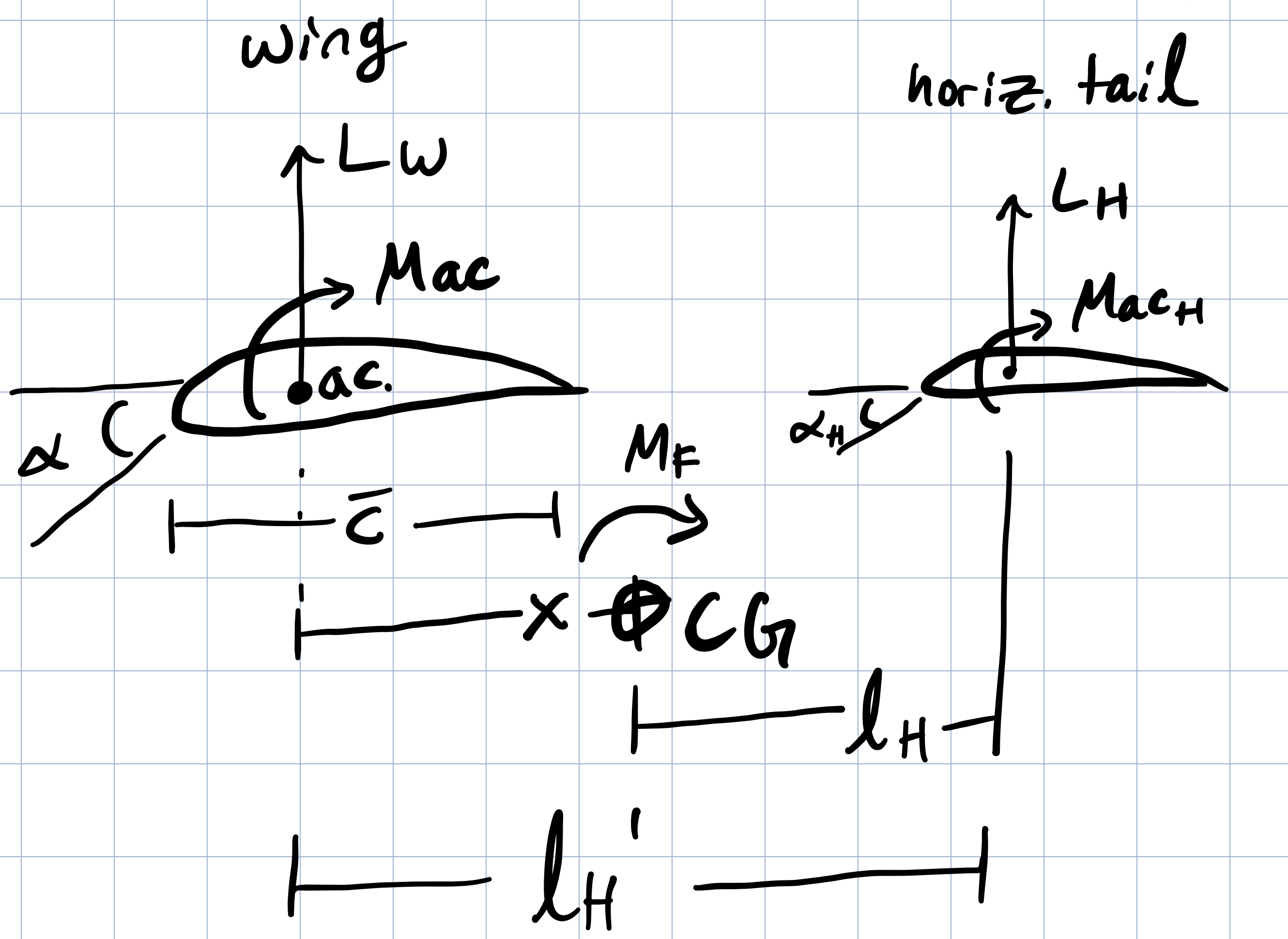
assume T, D contributions to moment are negligible

conditions for longitudinal static stability?

Stable if C_m becomes more negative w/ α or C_L increases → restores the pitching moment → prevent stalling

- $\frac{dC_M}{dC_L} < 0$ ←

Solve location of CG that leads to Stability



$\bar{c}$ = M.A.C aerodynamic

x = distace between a.c. of wing & CG

l_H = distace between a.c. of

tail & CG

l_H' = distance between a.c. of wing & a.c. tail

M_F = moment contribution due to fuselage

M_{ac_H} ~ small, negligible

$$\Sigma M_{CG} = M_w + M_H + M_F$$

$$= M_{ac_w} + L_w \cdot X - L_H \cdot l_H + M_F$$

$$C_{M_{CG}} = \frac{M}{qS\bar{c}} = C_{m_{ac}} + \frac{C_{L_w} \cdot X}{\bar{c}} - C_{L_H}\left[\frac{S_H \cdot l_H}{S_w \cdot \bar{c}}\right] \cdot \eta_H$$

$$+ C_{m_F}$$

$\eta_H \equiv$ tail efficiency factor due to wing wake influence