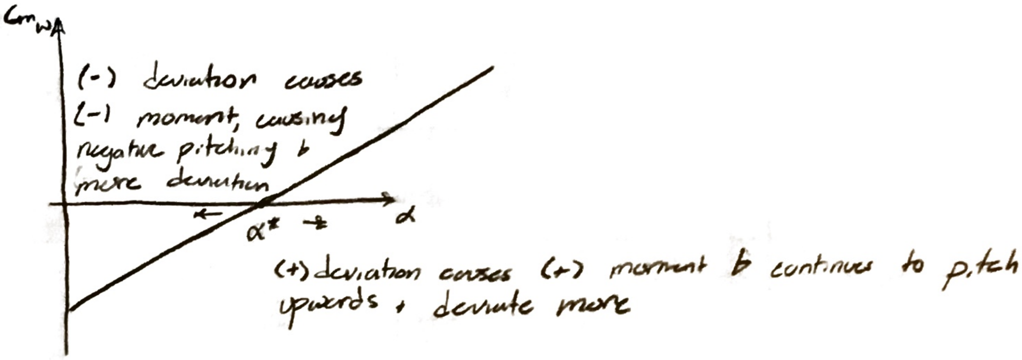
Assignment # 5 | ASEN 3128 | Connor Ott

Problem 1

for a cambered airfoil,

$$C_{m_w} = \underset{<0}{C_{m_{ac_w}}} + C_{L_w}\underset{>0}{(h - h_n)}$$

is required for level, steady flight, however, any deviation from the trim angle of attack will induce a moment that drives the wing away from trim, making this system unstable for any c.g. location



Problem 2

$C_{L_{\alpha=0}} = 0$

$C_{m_{ac_w}} = 0.2$; $C_{L_\alpha} = 0.1/\text{deg}$; symmetric; $b = 10m$; $c = 1.0m$

a) ~~$0 = 0.2 + C_{L_w}(h - h_n)$~~ $\qquad h_n = 0.25$

~~-0.2~~

$$h_n - h = 0.05$$

$$h - 0.25 = 0.05$$

$$\boxed{h = 0.2 \Rightarrow 0.2\ m \text{ from leading edge}}$$

b) $a_w \cdot k_n = 0.1\left(\frac{180}{\pi}\right) \cdot 0.05 = \boxed{\begin{array}{l} 0.286\ /\text{rad} \\ = 0.005\ /\text{deg} \end{array} = \text{pitch stiffness}}$

Problem 2 cont.

c) Trimmed AoA

$$0 = 0.02 + 0.1(\alpha_w)(-0.05)$$

$$\boxed{4° = \alpha_w}$$

d) $W = 100kg \cdot 9.81 = 981\,N$

$L = 0.1(4)\frac{1}{2}\rho V^2 S = 981\,N$

ρ = 1.225, S = $10m^2$

$$\boxed{20.01\ m/s = V_\infty}$$

in Boulder, $\rho = 1.00\ kg/m^2$

$$\boxed{22.15\ m/s = V_\infty}$$

e) $R = \frac{\rho V x}{\mu}$

$\rho = 1.225\ kg/m^3$
$\mu = 1.81 \times 10^{-5}$
$V = 20.01\ m/s$
$x = 1\ m$

$$\boxed{Re = 1.35 \times 10^6}$$

in Boulder $\rho = 1.225\ kg/m^3$, $V = 22.15\ m/s$

$$\boxed{Re = 1.22 \times 10^6}$$

f) $L/D = 10 \Rightarrow D = \frac{L}{10} \Rightarrow D = 98.1\ N = T$

$\boxed{T\ \text{required} = 98.1N} \Rightarrow P = TV = \boxed{1962.98\ W = P_{req}}$

g) Pitch stiffness $= -C_{m_\alpha}$

in $N \cdot m/deg$:

Pitch Stiffness $= -\underbrace{C_{m_\alpha}}_{-0.05} \cdot (\frac{1}{2}\rho V^2 S c) = \boxed{12.26\ Nm/deg}$

Problem 2 cont

h) $0 = 0.02 + a_w \alpha (h - h_n)$

$\cancel{-\frac{0.02}{a_w \alpha} + h_n = h}$

c.g.

$\cancel{\frac{0.2}{\alpha} + 0.25 = h}$

$$-\frac{0.02}{a_w (h - 0.25)} = \alpha$$

$$\boxed{\frac{0.2}{0.25 - h} = \alpha(h) \Rightarrow PS = a_w (h_n - h)}$$

PS & AoA are inversely related

changing location of c.g. (either w/ loss of fuel or whatever) will change the Angle of attack required for trim

i) $C_m = C_{m_{ac_w}} + C_{L_w}(h - h_n) - V_H C_{L_t}$ $\quad V_H = \frac{S_t l_t}{S_w \bar{c}_w}$

$= 0$ for trim

$$h_n = \frac{V_H a_t}{a_w} + h_{n_w}$$

$$k_n = h_n - h \quad 0.25$$

$$0.05 = h_n - h = \frac{V_H a_t}{a_w} + h_{n_w} - h$$

$$0.05 = V_H + 0.25 - 0.25$$

$$0.05 = V_H = \frac{S_t l_t}{10}$$

$$\boxed{0.5\,m^3 = S_t l_t}$$

tail must meet this criteria

Problem 2 cont

j) $PS = a_w k_n = 0.1\left(V_H + \cancel{0.25} - \cancel{0.25}\right)$

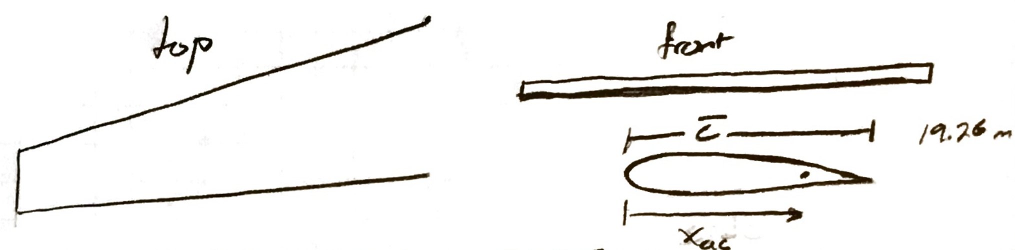
$$PS = 0.1\left(\frac{S_t l_t}{10}\right)$$

$$\boxed{PS = \frac{S_t l_t}{100}}$$ ← easy, just triple $S_t l_t$

Problem 3

2.1

a)



b) Wing Area $= \frac{1}{2}(c_r + c_t)\,b = 2775$

$$\boxed{S = 2775\ ft^2}$$

Aspect ratio:

$$AR = \frac{b^2}{S} = \boxed{8.108 = AR}$$

Taper Ratio:

$$\lambda = \frac{c_t}{c_r} = \boxed{0.48 = \lambda}$$

$$\bar{c} = \frac{2c_r}{3}\,\frac{1+\lambda+\lambda^2}{1+\lambda} = \boxed{19.26\ ft = \bar{c}}$$

c) Mean aerodynamic center

$$X_{ac} = \frac{b}{2}\cdot\frac{1}{3}\,\frac{1+2\lambda}{1+\lambda}\tan\Lambda_0$$ ← 28°

$$\boxed{X_{ac} = 16.15\ ft}$$

⇒

Problem 3 cont

c) $\alpha = 16.15\ ft$

$$\bar{x} = \frac{2}{C_L S}\int_0^{b/2} C_{l_a}' \, c x \, dy$$

$c =$

$$\bar{x} = \frac{2}{S}\int_0^{b/2} c x \, dy$$