pg. 42 on Earth: 1 slug = 32.2 lb

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8-14-07

ρ = density (kg/m³) or (slug/ft³)

AERO 315
EQUATIONS

Fluid Mechanics

Manometer: $dP = \Delta P = (P_2 - P_1)$, $dh = \Delta h = (h_2 - h_1)$

$\boxed{dP = -\rho g dh}$ (density of liquid) $\qquad dP = -\rho V dV \qquad \tau_w = \mu\left(\frac{dV}{dy}\right)_{y=0}$

Manometry Equation pg. 45

$\boxed{P_2 - P_1 = -\rho_l g(h_2 - h_1)}$

Viscous Flow

$x =$

$$Re_x = \frac{\rho_\infty V_\infty x}{\mu_\infty} \qquad Re_c = \frac{\rho_\infty V_\infty \bar{c}}{\mu_\infty} \qquad Re_{x_{crit}} = \frac{\rho_\infty V_\infty x_{crit}}{\mu_\infty} \gtrsim 500{,}000$$

Airfoils & Finite Wings

Drag: $\boxed{C_D = \underbrace{c_d}_{C_{D_0}} + \underbrace{C_{D_i}}_{kC_L^2}}$ (parasite, induced) $\qquad \boxed{C_{D_i} = k\, C_L^2} \qquad \boxed{k = \frac{1}{\pi e AR}}$ effic. factor

Lift: $\boxed{C_L = C_{L_\alpha}(\alpha - \alpha_{L=0})}$

≈ 0.11/deg slope

$$\boxed{C_{L_\alpha} = \frac{c_{l_\alpha}}{\left[1 + \left(\frac{57.3^\circ c_{l_\alpha}}{\pi e AR}\right)\right]}} \qquad V = \sqrt{\frac{2W}{\rho S C_L}} \qquad V_{stall} = \sqrt{\frac{2W}{\rho S C_{L_{max}}}}$$

Aspect Ratio $AR = \frac{b^2}{S}$

span efficiency factor

ICE-T

$$V_C = V_i + \Delta V_P \qquad V_e = f \cdot V_C \qquad V_T = V_e\sqrt{\frac{\rho_{SL}}{\rho_{ALT}}} = V_e\sqrt{\frac{P_{SL}\; T_{ALT}}{P_{ALT}\; T_{SL}}} \qquad \vec{V}_G = \vec{V} + \vec{V}_W$$

I C E T G

dynamic pressure $= V_e\, \rho_{SL} = V_T\, \rho_{actual}$

Mach Effects

$$a = \sqrt{\gamma R T} \quad M = \frac{V}{a} \qquad \sin\mu = \frac{1}{M} \qquad M = \frac{1}{\sin\mu}$$

$\gamma = 1.4$ for air

R = perfect gas constant

Stability & Control

Static Margin

$$\bar{x} = \frac{x}{\bar{c}} \qquad SM = \bar{x}_n - \bar{x}_{cg} = -\frac{C_{M_\alpha}}{C_{L_\alpha}}$$

only for best $\frac{L}{D}$: $\boxed{C_L = \sqrt{\frac{C_{D_0}}{k}}}$ pg 196

don't forget (gravity = 9.8 m/s² or 32.2 ft/s²)

Performance

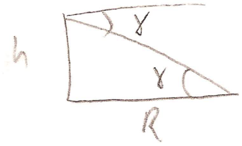
$$n \equiv \frac{L}{W} \qquad \boxed{V = \sqrt{\frac{2\,n\,W}{\rho S C_L}}} \qquad \boxed{V_{stall} = \sqrt{\frac{2\,n\,W}{\rho S\, C_{L_{max}}}}} \qquad V^* = \sqrt{\frac{2\, n_{max}\, W}{\rho S\, C_{L_{max}}}}$$

n = g's

$$c_{t_{ALT}} = c_{t_{SL}}\sqrt{\frac{T_{ALT}}{T_{SL}}} = c_{t_{SL}}\left(\frac{a_{ALT}}{a_{SL}}\right)$$

$$\boxed{T_{A_{ALT}} = T_{A_{SL}}\left(\frac{\rho_{ALT}}{\rho_{SL}}\right) \text{ (dry)}} \qquad T_{A_{ALT}} = T_{A_{SL}}\left(\frac{\rho_{ALT}}{\rho_{SL}}\right)(1 + 0.7M) \text{ (wet)}$$

$$\frac{L}{D} = \frac{W}{D} = \frac{W}{T_R} \qquad D_{min} = 2\,W\sqrt{k\, C_{D_o}} \qquad \boxed{\left(\frac{L}{D}\right)_{max} = \frac{1}{2\sqrt{k\, C_{D_o}}}}$$



Glides

$$\gamma = \tan^{-1}\left(\frac{1}{\frac{L}{D}}\right) = \sin^{-1}\left(\frac{D}{W}\right) = \cos^{-1}\left(\frac{L}{W}\right) \qquad R = h\left(\frac{L}{D}\right) \qquad \boxed{ROD = \frac{P_R}{W} = V\sin\gamma}$$

$$\gamma = \tan^{-1}\left(\frac{D}{L}\right) = \tan^{-1}\left(\frac{C_D\, q S}{C_L\, q S}\right) = \boxed{\tan^{-1}\left(\frac{C_D}{C_L}\right)}$$

Climbs

$$\sin\gamma = \frac{T_x}{W} \qquad ROC = \frac{P_x}{W}$$

$c_t = TSFC$?

Cruise

Avg. Value Method

$$\boxed{R = \frac{\Delta W_{fuel}}{c_t\left(\frac{D}{V}\right)_{ave}}}$$

Breguet

$$\boxed{R = \frac{1}{c_t}\sqrt{\frac{8}{\rho S}}\left(\frac{\sqrt{C_L}}{C_D}\right)\left(\sqrt{W_1} - \sqrt{W_2}\right)}$$

Avg. Value Method (use w/charts)

$$\boxed{E = \frac{\Delta W_f}{c_t\, D_{ave}}}$$

Breguet (when you have drag polar: $C_D = C_{D_0} + kC_L^2$)

$$\boxed{E = \left(\frac{1}{c_t}\right)\left(\frac{C_L}{C_D}\right)\ln\left(\frac{W_1}{W_2}\right)}$$

W_1: takeoff wt
W_2: landing wt

Take Off / Landing

(i.e. the value of these parameters at $0.7\,V_{TO}$)

dist. of takeoff (takeoff roll) →

$$\boxed{s_{TO} = \frac{1.44\,W_{TO}^2}{\rho S C_{L_{max}}\, g\left[T - D - \mu(W_{TO} - L)\right]_{0.7V_{TO}}}} \qquad \boxed{V_{TO} = 1.2V_{stall}}$$

μ: rolling coeff.

T: (contains another ρ term)

$$\boxed{T_{A_{ALT}} = T_{A_{SL}}\left(\frac{\rho_{ALT}}{\rho_{SL}}\right)}$$

For very high-thrust aircraft:

$$\boxed{s_{TO} = \frac{1.44\,W_{TO}^2}{\rho S C_{L_{max}}\, gT}} \quad \text{(thrust >> retarding forces)}$$

Landing roll →

$$\boxed{s_L = \frac{1.69\,W_L^2}{\rho S C_{L_{max}}\, g\left[D + \mu(W_L - L)\right]_{0.7V_L}}} \qquad \boxed{V_L = 1.3V_{stall}}$$

μ: rolling (braking) coeff.

Steady Level Turn

load factor (g's) →

$$\boxed{n = \frac{1}{\cos\phi}} \qquad \underset{\text{turn radius}}{r} = \frac{V^2}{g\sqrt{n^2 - 1}} \qquad \underset{\text{turn rate (rad/sec)}}{\omega} = \frac{g\sqrt{n^2 - 1}}{V}$$

g: gravitational constant?

Pull-up (instantaneous, bottom of loop)

$$r = \frac{V^2}{g(n-1)} \qquad \omega = \frac{g(n-1)}{V}$$

Pull-down (instantaneous, top of loop)

$$r = \frac{V^2}{g(n+1)} \qquad \omega = \frac{g(n+1)}{V}$$

p. 245

Energy Height & Specific Excess Energy

E height →

$$\boxed{H_e = E_s = h + \frac{V^2}{2g}}$$

Specific Excess Energy (power) →

$$P_s = \dot{E}_s = \boxed{\frac{dh}{dt} + \frac{V}{g}\frac{dV}{dt}} = \boxed{V\left(\frac{T_A - D}{W}\right)} = \frac{P_x}{W}$$

$$E = mgh + \tfrac{1}{2}mV^2$$

$$\frac{E}{mg} = h + \frac{V^2}{2g}$$