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SOLUTIONS MANUAL TO ACCOMPANY

AERODYNAMICS, AERONAUTICS, AND FLIGHT MECHANICS

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CONTENTS

Solutions Manual

Aerodynamics, Aeronautics & Flight Mechanics

1.1 Given: $V = 70\ m/s$

$T/W = 0.25$

$L/D = 15.0$

Find: R/C in m/s & fpm

Solution:

$$V_c = V\,\frac{(T-D)}{W}$$

$$= V\left(\frac{T}{W} - \frac{D}{W}\right)$$

$$= 70\,(0.25 - 1/15)$$

$$= 12.8\ m/s$$

But $1\ m = 3.28\ ft$

Therefore: $V_c = 12.8\,(3.28)(60)$

$$= 2519\ fpm$$

1.2 Given: $W = 45{,}000$ N (10,117 lb)
$P_R = 597$ kW (800 thp)
$V = 80$ m/s (179 mph)
$P_A = 1193$ kW (1600 bhp)
$\eta = 0.75$

Find: Max R/C in fpm

$$V_c = \frac{TV - DV}{W} = \frac{\eta P_A - P_R}{W}$$

$\boxed{SI}$

$$= \left[\frac{0.75(1193) - 597}{45{,}000}\right] \times 1000$$

$$= 6.617 \text{ m/s} = \underline{\underline{1302}} \text{ fpm}$$

$\boxed{English}$

$$= \left[\frac{0.75(1600) - 800}{10{,}117}\right] 550$$

$$= 21.7 \text{ fps} = \underline{\underline{1305}} \text{ fpm}$$

Difference is from rounding off numbers.

1.3 Given: $I_y = 1300$ slugs-ft^2
$l_t = 4.5$ m
$S_t = 3$ m^2
$a_t = 0.08$/degs.
$h = 6000$ ft
$V = 110$ kt
$\Delta\alpha_t = -5$ degs

Find: $\ddot{\theta}$

<u>In English units</u> $l_t = 14.76'$
$S_t = 32.28$ ft^2

@ 6000', $\rho = 0.001987$
$V = 110(1.69) = 185.9$ fps

$q = \frac{1}{2}\rho V^2 = (.001987)(185.9)^2/2$
$= 34.3$ psf

Increment in tail lift $= \Delta L_t = q S_t a_t \Delta\alpha_t$
$= (34.3)(32.28)(.08)(-5)$
$= -442.9$ lb

Increment in moment $= -l_t \Delta L_t$
$= -(14.76)(-442.9)$
$= 6537$ ft-lb

$\Delta M = I_y \ddot{\theta}$, therefore,

$$\ddot{\theta} = \frac{\Delta M}{I_y} = \frac{6537}{1300} = 5.03 \text{ rad/sec}^2$$

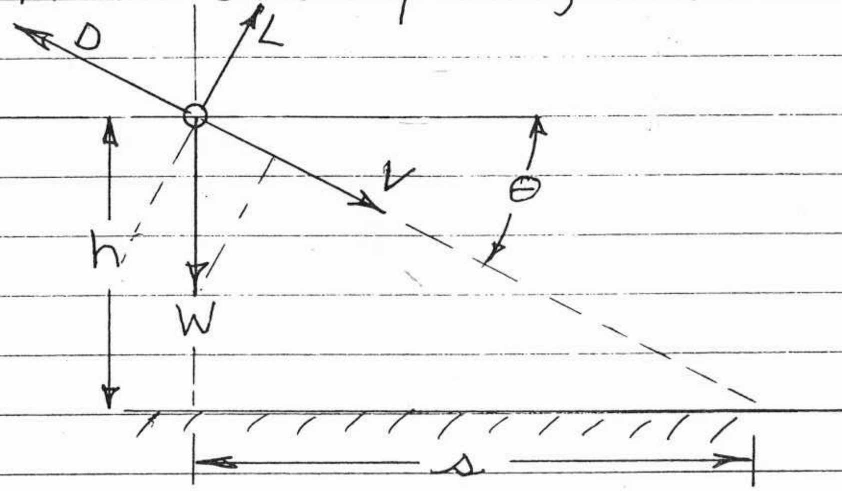
$$= (57.3)(5.03) = 288 \text{ deg/sec}^2$$

1.4 Given: $L/D = 15$

$h = 1500\,m$ (4921 ft)

$s = 16\,km$ (9.94 mi) to airport

Find: Gliding horizontal distance



$$\tan\theta = \frac{h}{s} \qquad L = W\cos\theta$$
$$D = W\sin\theta$$

Thus, $$s = \frac{h}{\tan\theta} = \frac{h}{D/L} = \frac{1500}{1/15}$$
$$= 22500\,m = 22.5\,km$$

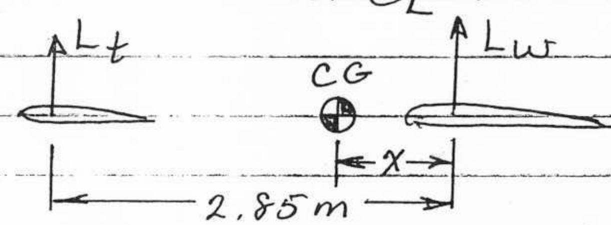
Pilot will make the airport since gliding distance is longer than actual distance to airport.

1.5 Given: $C_{L_\alpha} = 0.1 \frac{A}{A+2}$

$ac = 0.25\ c$
Wright Brothers' Flyer
no interaction of lifting surfaces
Use Figure 1.2 for geometry

Find: (a) CG beyond which airplane is statically unstable.
(b) Orville Wright $W = 145$ lb
Gasoline $W = 5$ lb
$W_E = 450$ lb.
Flew 260 m in 59 secs
Find C_L for one wing.

(a)



planform area of one canard $\simeq 2.26\ m^2$
" " " " wing $\simeq 22.9\ m^2$

wing $A = b^2/S = 12.3^2/22.9 = 6.61$
canard $A = 3.74^2/2.26 = 6.19$

$a_w = 0.1(6.61)/(6.61+2) = 0.0768/deg$
$a_t = 0.1(6.19)/(6.19+2) = 0.0756/deg.$

Nose-up (+) moment about CG = M_{CG}

$$M_{CG} = q S_t a_t \alpha (2.85 - x) - q S_w a_w \alpha x$$

1.5 - cont'd.

For static stability, $\frac{\partial M_{CG}}{\partial \alpha} < 0$

$$\frac{\partial M_{CG}}{\partial \alpha} = 0 = 2(2.26)(.0756)(2.85 - x)$$
$$- 2(22.9)(.0768)x$$

Solving: $X = 0.252$ m

If the CG is behind this point the airplane is statically unstable. Since pilot & engine are on the wing, this is certainly the case.

(b) Assume CG is on wing a.c. Then $L_w = W$

$W = PL + W_E = 145 + 5 + 450 = 600$ lb.

Average $V = s/t = 260/59 = 4.41$ m/s

Assume SSL conditions.

$$\rho = 1.225 \text{ kg/m}^3$$

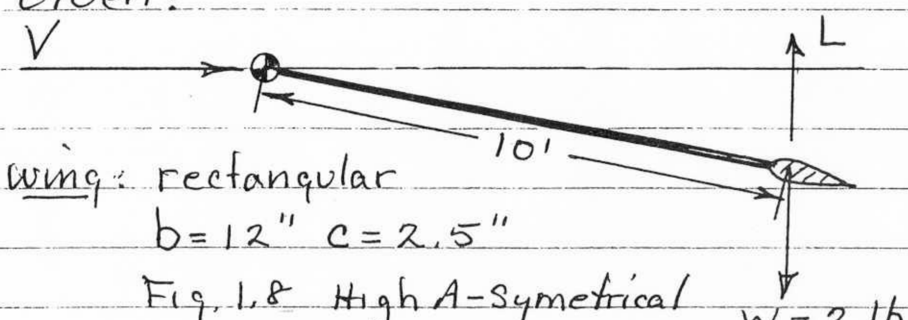
Therefore $q = \frac{1}{2}\rho V^2 = 1.225(4.41)^2/2$
$= 11.91$ Pa $= 0.249$ psf

$$C_L = \frac{W/S}{q} = \frac{(600)(4.48)/2/22.9}{11.91}$$

$$= 4.928$$

This result is obviously too high. Why? Re-read the writing of Orville Wright on pg. 1. The wind was blowing at 27 mph (corrected). Adding this to the previous V results in $C_L = 0.353$.

1.6 Given:



wing: rectangular
b = 12" c = 2.5"
Fig. 1.8 High A-Symetrical
In wind tunnel @ Denver

Find: V for wing to operate at $C_{L_{max}}$.

Solution: @ Denver, h = 5280 ft.
Interpolating from Appendix B
$\rho = 0.00203$ slugs/ft^3
From Fig. 1.8, $C_{L_{max}} = 1.35$

Since wing is free to pivot,

$$W = L = \frac{1}{2}\rho V^2 S\, C_{L_{max}}$$

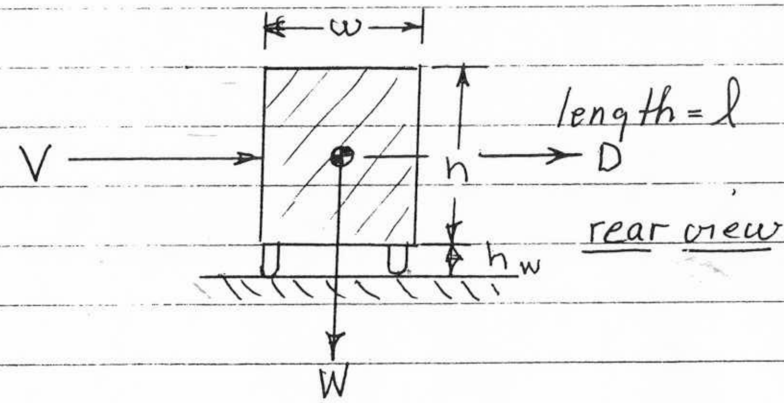
where $S = \frac{(12)(2.5)}{144} = 0.208 \text{ ft}^2$

Therefore, $V = \sqrt{\frac{W/S}{\frac{1}{2}\rho\, C_{L_{max}}}} = \sqrt{\frac{2/.208}{\frac{1}{2}(.00203)(1.35)}}$

$= \underline{83.76}$ fps

1.7 Given: $C_D = 1.0$

Derive: Conditions to overturn mobile home.



Home would lift off of left wheels when moment from drag exceeds weight moment at right wheels

$$D\left(\frac{h}{2} + h_w\right) > W\frac{w}{2}$$

But $D = \frac{1}{2}\rho V^2 (h\ell)\, C_D$

$$= \frac{.002378}{2}(\text{mph} \times 1.467)^2 h\ell(1)$$

$$= .00256\,(\text{mph})^2 h\ell$$

$$\therefore \; \text{mph} > \sqrt{\frac{W w}{2\left(\frac{h}{2} + h_w\right)(.00256)\, h\ell}}$$

1.8 Given: Symmetrical wing

$L = 10{,}000$ N

$h = 10$ km

$\alpha = 10^\circ$

Find: L for similar wing with half the area and $\alpha = 5^\circ$ at SSL conditions ($h=0$) at twice the speed.

Solution: Denote "given" by sub 1 and "to find" by sub 2

$$L \propto \rho V^2 S \alpha$$

$$\frac{L_2}{L_1} = \frac{\rho_2}{\rho_1}\left(\frac{V_2}{V_1}\right)^2 \frac{S_2}{S_1}\frac{\alpha_2}{\alpha_1}$$

$$= \frac{1.225}{.4136}\left(\frac{2}{1}\right)^2 \frac{1}{2}\frac{5}{10}$$

$$= 2.962$$

$\therefore \quad L_2 = 29{,}620$ N

1.9 Given: $\Lambda_{LE} = 35^\circ$

$C_o = 10'$

$\lambda = 0.5$

$A = 8$

Find: b

Solution: $A = \frac{b^2}{S}$

$$S = b\left(\frac{C_o + C_T}{2}\right) = \frac{b}{2} C_o (1+\lambda)$$

$$\therefore A = 8 = \frac{b^2}{\frac{b}{2} C_o (1+\lambda)} = \frac{2b}{10(1.5)}$$

or, $b = 60$ ft.

1.10 Given: $W = 10{,}000$ lb
$R/C = 1500$ fpm
$V = 200$ Kts
$h = 10{,}000$ ft.

Find: Power to climb

Solution:

$$P = (W)(R/C)$$
$$= (10{,}000)\left(\frac{1500}{60}\right)$$
$$= \underline{250{,}000 \text{ ft-lb/sec}}$$
$$= \underline{454.5 \text{ hp}}$$

Of course this is the thrust power. The power required of the engine will equal the above divided by propeller efficiency for a prop-driven airplane.