Assignment - 2 Solution
Flight Mechanics AE321A

Question - 1

Solution Given data -

A Jet airplane

$W = 20\,000$ N

$W/S = 1000$ N/m^2

$T_0 = 2000$ N @ sea level

$T = T_0 \sigma^{0.8}$ @ an altitude

$C_{D_0} = 0.015$

$k = 0.024$

$C_{L_{max}} = 1.4$

Absolute and service ceiling problems can be solved graphically.

Steps to plot the absolute and service ceiling propeties

1. Calculate σ @ altitude h
2. Calulate $\rho = \rho_0 \cdot \sigma$
3. Calculate $T = T_0 \sigma^{0.8}$
4. Calulate $V = \sqrt{\dfrac{1}{3\rho S C_{D_0}} \cdot \left[T + \sqrt{T^2 + 12 k C_{D_0} W^2}\right]}$

(5) $C_L = \dfrac{2W}{\rho S V^2}$

(6) $T_R = \frac{1}{2}\rho S V^2 (C_{D_0} + k C_L^2)$

(7) $R/C_{max} = \dfrac{(T - T_R) \cdot V}{W}$

Plot h vs R/C_{max}, V vs R/C_{max} and C_L vs R/C_{max} to find out required quantities.

From the Plots -

(a) Absolute ceiling ≈ 10.95 km

Velocity at abosute ceiling ≈ 83.2592 m/s

Lift coefficient at absolute ceiling ≈ 0.79

(b) Service ceiling ≈ 9.35 km

velocity at service ceiling ≈ 78.63 m/s

Lift coefficient at service ceiling ≈ 0.726

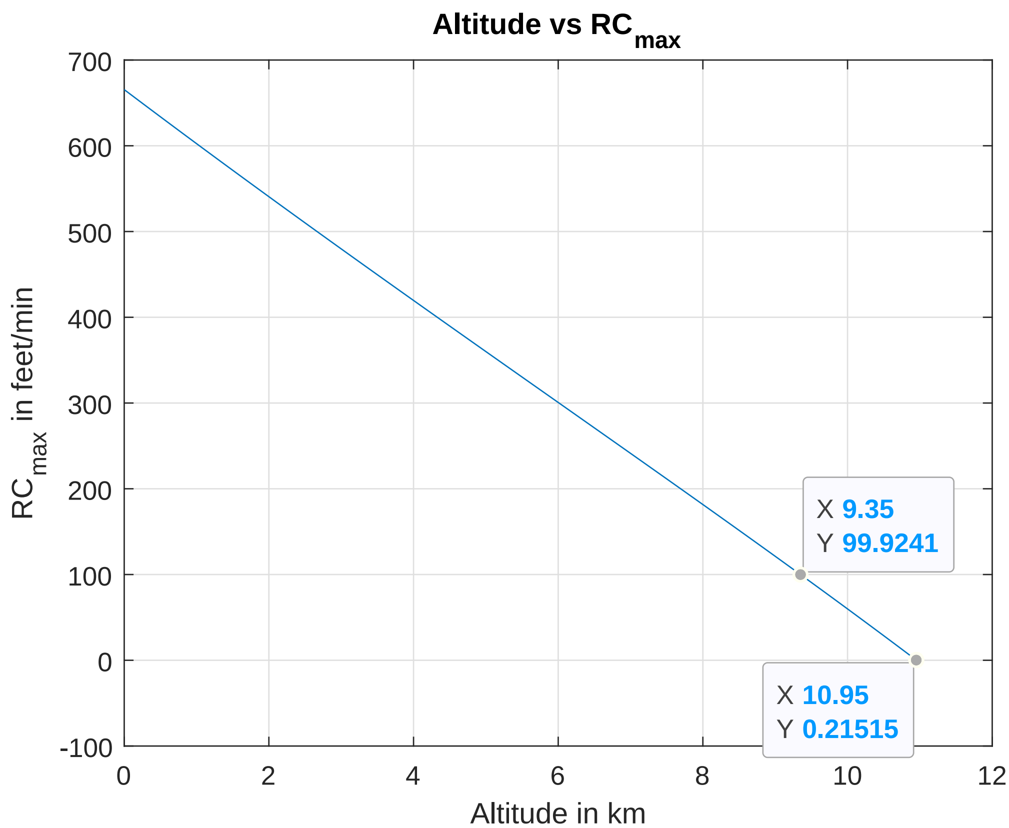
Accepted answers-

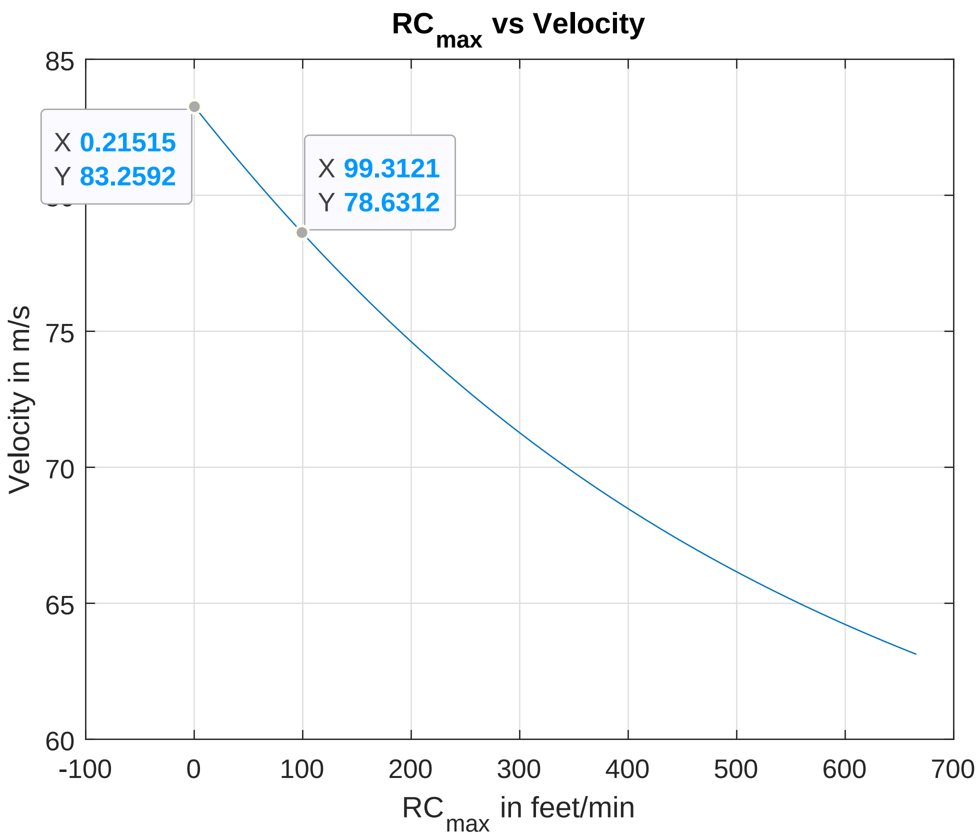
(a) $h_{abs} \in [10.40, 11.5]$ km, $V \in [79.1, 87.4]$ m/s

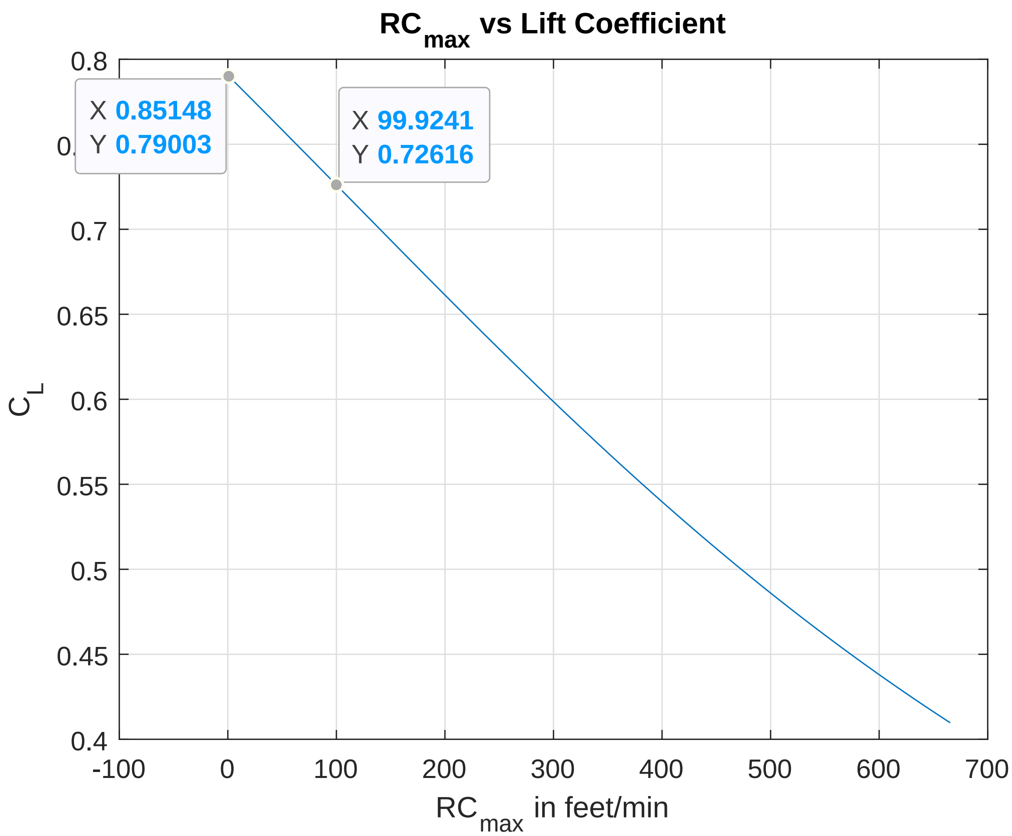
$C_L \in [0.75, 0.83]$

(b) $h_{service} \in [8.9, 9.8]$ km, $V \in [74.7, 82.6]$ m/s

$C_L \in [0.69, 0.76]$


Altitude vs RCmax
RCmax in feet/min
Altitude in km
700
600
500
400
300
200
100
0
-100
0
2
4
6
8
10
12
X 9.35
Y 99.9241
X 10.95
Y 0.21515


RC max vs Velocity
Velocity in m/s
RC max in feet/min
X 0.21515
Y 83.2592
X 99.3121
Y 78.6312
85
75
70
65
60
-100
0
100
200
300
400
500
600
700



RC$_{max}$ vs Lift Coefficient
X 0.85148
Y 0.79003
X 99.9241
Y 0.72616
C_L
0.8
0.7
0.65
0.6
0.55
0.5
0.45
0.4
-100
0
100
200
300
400
500
600
700
RC$_{max}$ in feet/min

Question - 2

Solution Given data -

A piston-prop aircraft.

$W/S = 1400\ N/m^2$

$S = 24\ m^2$

$C_{D_0} = 0.025$

$k = 0.05$

$C_{L_{max}} = 1.5$

$P_0 = 250\ kW$ @ sea level

$P = P_0 \sigma$ @ an altitude

$\eta_p = 0.85$

This problem can be solved graphically.

Steps to plot the characteristics are as follows -

1. σ @ an altitude
2. $\rho = \sigma . \rho_0$
3. $P = P_0 \sigma$
4. $P_a = P . \eta_p$
5. $P_{R_{min}} = 4 . \sqrt{\frac{2 W^3}{\rho S}} . \left(\frac{k^3 C_{D_0}}{27} \right)^{\frac{1}{4}}$
6. $V = \sqrt{\frac{2 W}{\rho S}} . \left(\frac{k}{3 C_{D_0}} \right)^{\frac{1}{4}}$
7. $C_L = \sqrt{\frac{3 C_{D_0}}{k}}$
8. $R/C_{max} = \frac{(P_a - P_{R_{min}})}{W}$

Plot h vs R/C_{max}, V vs R/C_{max} and C_L vs R/C_{max} to get the required quanties.

From the plots -

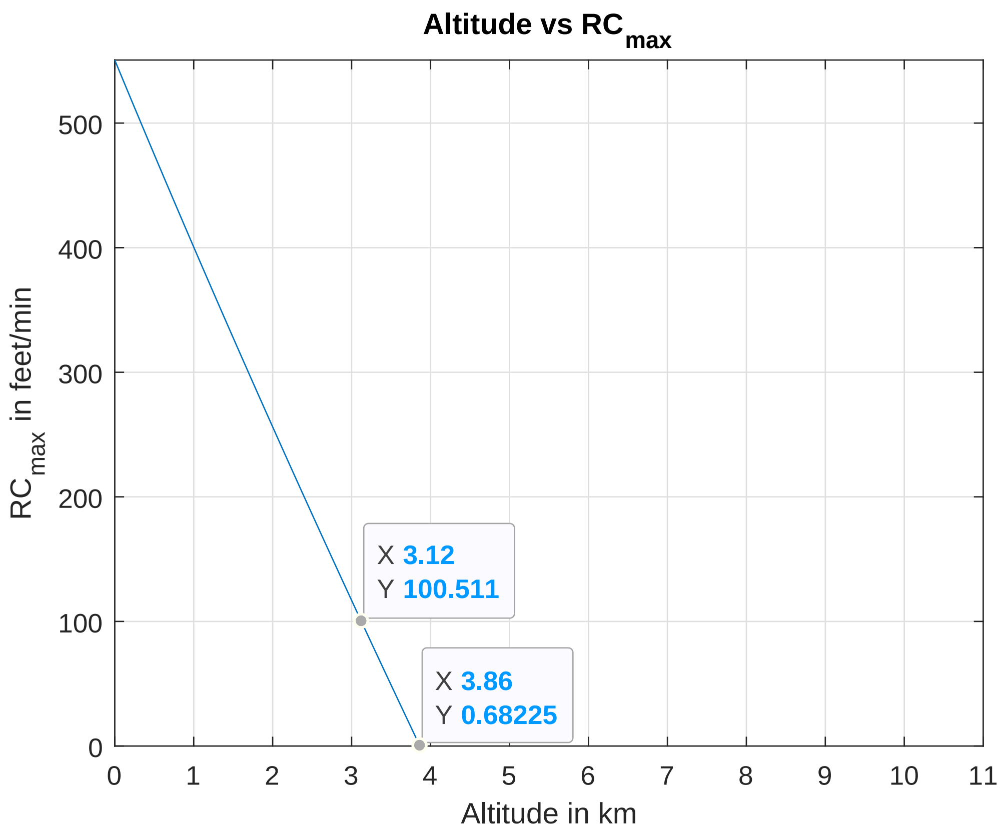
(a) Absolute ceiling ≈ 3.86 Km
Velocity at absolute ceiling ≈ 52.47 m/s
Lift coefficient at absolute ceiling ≈ 1.225

(b) Service ceiling ≈ 3.12 km
Velocity at ~~at~~ service ceiling ≈ 50.5 m/s
Lift coefficient at service ceiling ≈ 1.225

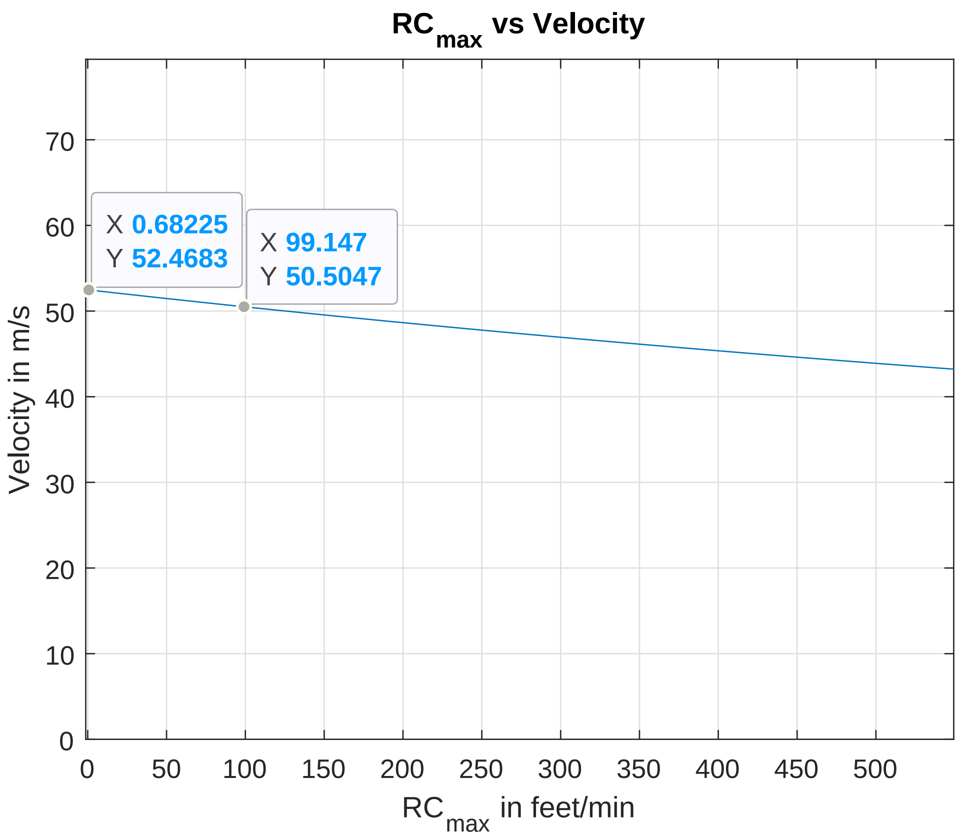
Accepted Answers

(a) $h_{abs} \in [3.7, 4.1]$ Km, $V \in [49.8, 55.1]$ m/s
$C_L \in [1.225]$

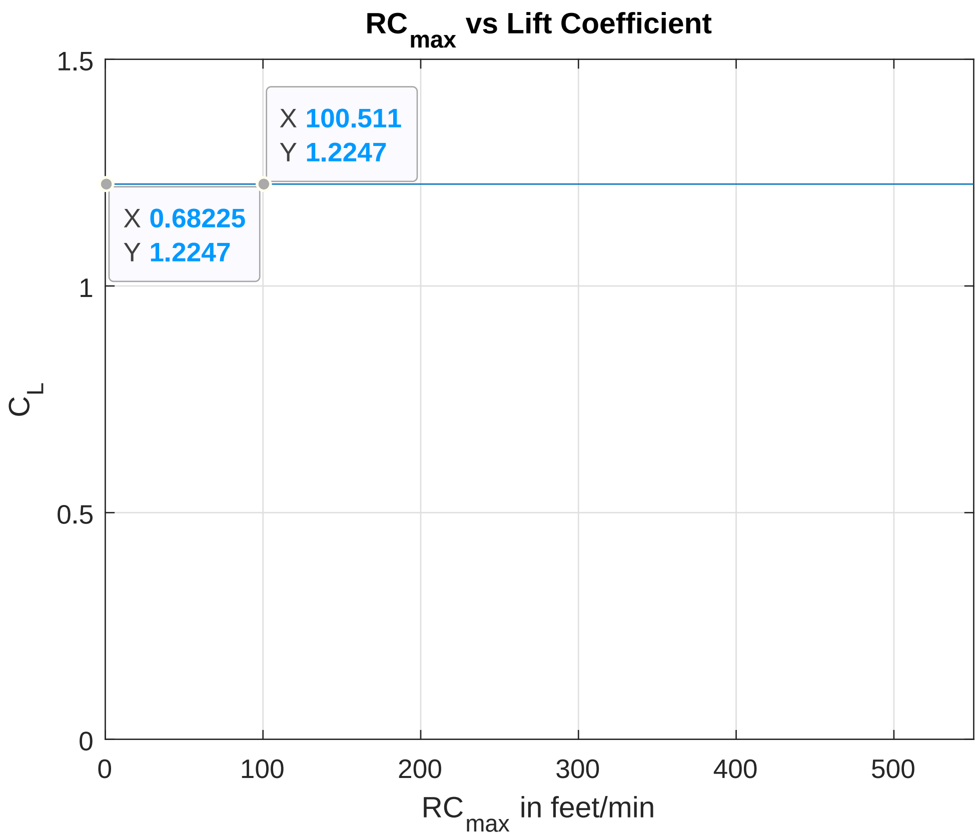
(b) $h_{service} \in [2.96, 3.28]$ Km, $V \in [47.98, 53.03]$ m/s
$C_L \in [1.225]$



Altitude vs RC max
RC max in feet/min
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
Altitude in km
X 3.12
Y 100.511
X 3.86
Y 0.68225



RCmax vs Velocity
70
60
50
40
30
20
10
0
X 0.68225
Y 52.4683
X 99.147
Y 50.5047
Velocity in m/s
0
50
100
150
200
250
300
350
400
450
500
RCmax in feet/min


RCmax vs Lift Coefficient
X 100.511
Y 1.2247
X 0.68225
Y 1.2247
1.5
1
0.5
0
CL
0
100
200
300
400
500
RCmax in feet/min

Question - 3

Solution

A propeller air craft

$W = 35000 \ N$

$S = 21.8 \ m^2$

$C_{D_0} = 0.021$

$k = 0.045$

$C_{L max} = 1.5$

$P_s = 700 \ kW$

$\eta_p = 0.85$

$n_{Lim} = 3.0$

(a) fastest sustained turn rate - (MSTR)

It can be solve graphically.

The deciding parameters of fastest sustained turn rate are

$n \leq n_{Lim}$

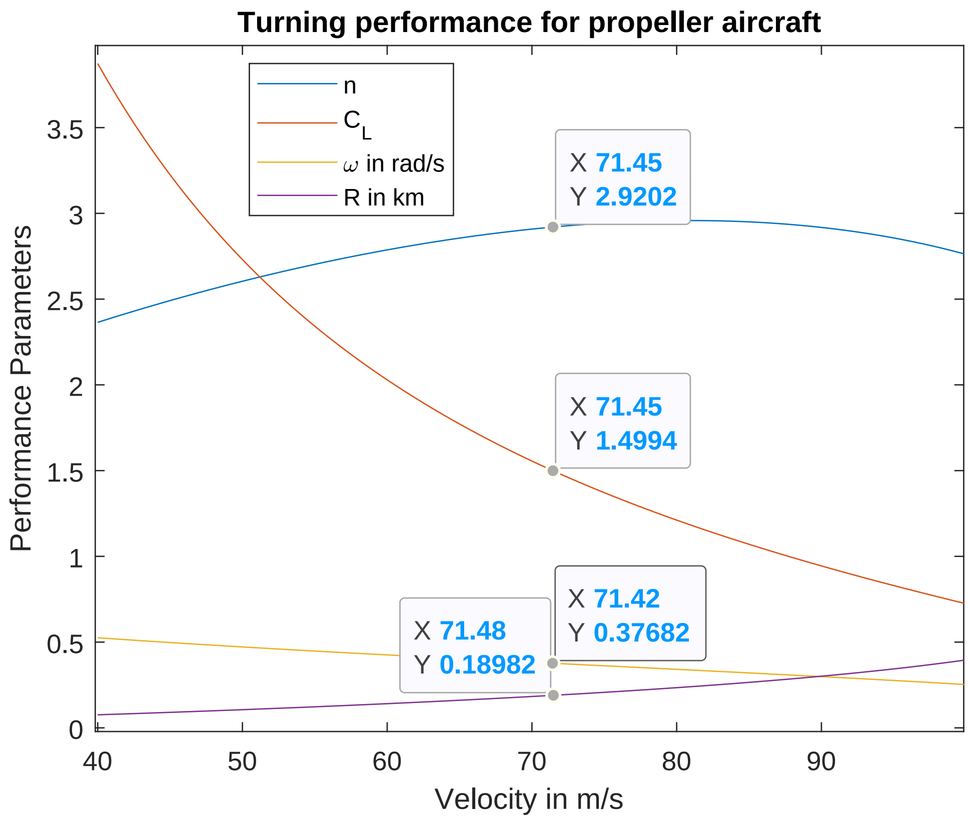
and $C_L \leq C_{L,max}$

From the figure, we can see that n always remains Less than the limitting laad factor. Hence, C_L will be the deciding parameter for this case.

@ $C_{L_{MSTR}} = C_{L max}$, $V_{MSTR} \approx 71.45 \ m/s$

$\omega_{MSTR} \approx 0.377 \ rad/sec$, $R_{MSTR} \approx 189.82 \ m$

$n_{MSTR} \approx 2.92$


Turning performance for propeller aircraft
n
C_L
ω in rad/s
R in km
X 71.45
Y 2.9202
X 71.45
Y 1.4994
X 71.42
Y 0.37682
X 71.48
Y 0.18982
Performance Parameters
Velocity in m/s
0
0.5
1
1.5
2
2.5
3
3.5
40
50
60
70
80
90

Accepted Answers -

$n_{MSTR} \in [2.8, 3.0]$, $V_{MSTR} \in [67.8, 75.0]$ m/s

$W_{MSTR} \in [0.358, 0.396]$ rad/sec $R_{MSTR} \in [180.33, 199.31]$ m

(b) Sharpest sustained turn (SST) -

It can be solve graphically.

From figure we can see that as velocity increases radius of turn increasing.

In this case, C_{Lmax} will also be the deciding parameter. Hence, all the performance parameters will be the same.

(c) Maximum load factor turn -

$$E_m = \frac{1}{\sqrt{4 k_2 C_{D0}}} = \frac{1}{\sqrt{4 \times 0.045 \times 0.021}} = 16.265$$

$$n_{max} = \frac{0.687 \times S}{W} \cdot \left(\frac{P_a^2 \rho E_m}{k S^2} \right)^{\frac{1}{3}}$$

$$\boxed{\begin{aligned} P_a &= P_s \eta_p \\ &= 595 \text{ kW} \end{aligned}}$$

$$= \frac{0.687 \times 21.8}{35000} \left(\frac{(595 \times 10^3)^2 \times 1.225 \times 16.265}{0.045 \times 21.8^2} \right)^{\frac{1}{3}}$$

$$= 2.96$$

$$V_{n_{max}} = \left(\frac{P_a}{2 \rho S C_{D_0}}\right)^{\frac{1}{3}}$$

$$= \left(\frac{595000}{2 \times 1.225 \times 21.8 \times 0.021}\right)^{\frac{1}{3}}$$

$$= 80.95 \ m/s$$

$$\omega_{n_{max}} = \frac{g\sqrt{n_{max}^2 - 1}}{V_{n_{max}}}$$

$$= \frac{9.81 \times \sqrt{2.96^2 - 1}}{80.95}$$

$$= 0.3372 \ rad/sec$$

$$R_{n_{max}} = \frac{V_{n,max}^2}{g\sqrt{n_{max}^2 - 1}}$$

$$= \frac{80.95^2}{9.81\sqrt{2.96^2 - 1}}$$

$$= 240.1 \ m$$

Accepted Answers —

$n_{max} \in [2.8, 3.0]$, $V_{n,max} \in [76.9, 84.9]$ m/s

$\omega_{n_{max}} \in [0.32, 0.354]$ rad/sec , $R_{n_{max}} \in [228.1, 252.1]$ m

Question - 4

Solution A jet aircraft

$W = 60000\,N$

$T = 22500$

$C_{L\alpha} = 5$ per radian

$\alpha_{C_L=0} = -2^\circ$

$C_{L\max} = 1.5$

$S = 18.75\ m^2$

$C_{D_0} = 0.018$

$k = 0.08$

$n_{lim} = 6.0$

$h = 1.5$ km

$\rho = 1.058\ kg/m^3$

$$E_m = \frac{1}{\sqrt{4 k C_{D_0}}} = \frac{1}{\sqrt{4\times 0.08\times 0.018}} = 13.1762$$

$$Z = \frac{T E_m}{W} = \frac{22500\times 13.1762}{60\,000} = 4.9411$$

$$C_L^* = \sqrt{\frac{C_{D_0}}{k}} = \sqrt{\frac{0.018}{0.8}} = 0.4743$$

$$V_R = \sqrt{\frac{2W}{\rho S C_L^*}} = \sqrt{\frac{2\times 60\,000}{1.225\times 18.75\times 0.4743}} = 112.928\ m/s$$

(a) Fasted sustained turn rate (MSTR) —

$$n_{MSTR} = \sqrt{2Z-1} = \sqrt{2\times 4.9411 - 1} = 2.98$$

$$V_{MSTR} = V_R = 112.928\ m/s$$

$$\omega_{MSTR} = \frac{g\sqrt{2Z-2}}{V_R} = 9.81\frac{\sqrt{2\times 4.9411 - 2}}{112.928} = 0.2438\ rad/sec$$

$$R_{MSTR} = \frac{V_{MSTR}^2}{g\sqrt{n_{MSTR}^2 - 1}} = \frac{112.928^2}{9.81\sqrt{2.98^2 - 1}}$$

$= 463.03$ m

Accepted answers

$n_{MSTR} \in [2.83, 3.13]$, $V_{MSTR} \in [107.28, 118.57]$ m/s

$W_{MSTR} \in [0.23, 0.256]$ rad/sec , $R_{MSTR} \in [439.88, 486.18]$ m

(b) Sharpest sustained turn (SST) –

$$n_{SST} = \frac{\sqrt{2Z^2-1}}{Z} = \frac{\sqrt{2\times 4.9411^2-1}}{4.9411} = 1.399$$

$$V_{SST} = \frac{V_R}{\sqrt{Z}} = \frac{112.928}{\sqrt{4.9411}} = 50.8 \text{ m/s}$$

$$W_{SST} = \frac{g}{V_R}\cdot\sqrt{\frac{Z^2-1}{Z}}$$

$$= \frac{9.81}{112.928}\cdot\sqrt{\frac{4.9411^2-1}{4.9411}} = 0.189 \text{ rad/s}$$

$$R_{SST} = \frac{V_{SST}^2}{g\sqrt{n_{SST}^2-1}} = \frac{50.8^2}{9.81\sqrt{1.399^2-1}} = 268.66 \text{ m}$$

Accepted answers –

$n_{SST} \in [1.32, 1.47]$, $V_{SST} \in [48.26, 53.34]$ m/s

$W_{SST} \in [0.179, 0.198]$ rad/sec , $R_{SST} \in [255.2, 282.1]$ m

(c) Turn with maximum load factor -

$$n_{max} = Z = 4.94$$

$$V_{n_{max}} = \sqrt{Z}\, V_R = \sqrt{4.94} \cdot \cancel{\theta} \times 112.928$$

$$= 251.02 \text{ m/s}$$

$$\omega_{n_{max}} = \frac{g\sqrt{n_{max}^2 - 1}}{V_{n_{max}}} = \frac{9.81 \times \sqrt{4.94^2 - 1}}{251.02}$$

$$= 0.189 \text{ rad/sec}$$

$$R_{n_{max}} = \frac{V_{n_{max}}^2}{g\sqrt{n_{max}^2 - 1}} = \frac{251.02^2}{9.81\sqrt{4.94^2 - 1}}$$

$$= 1327.44 \text{ m}$$

Accepted answers -

$n_{max} \in [4.69, 5.19]$, $V_{n_{max}} \in [238.4, 263.6]$ m/s

$\omega_{n_{max}} \in [0.179, 0.198]$ rad/sec , $R_{n_{max}} \in [1261.06, 1393.8]$ m

Question - 5

Solution

A light turbojet

$W = 20000\ N$

$W/S = 1000\ N/m^2$

$T_0 = 2000\ N$ @ sea level

$T = T_0 \sigma^{0.8}$ @ an altitude

$C_{D_0} = 0.015$

$k = 0.024$

$C_{L_{max}} = 1.4$

$C_{L_{min}} = -0.5$

$n_p = 6.0$ [Positive limiting load factor]

$n_2 = 3.0$ [Negative limiting load factor]

V-n diagram is shown in figure.

$V_{lim} = 1.5\ V_{max}$

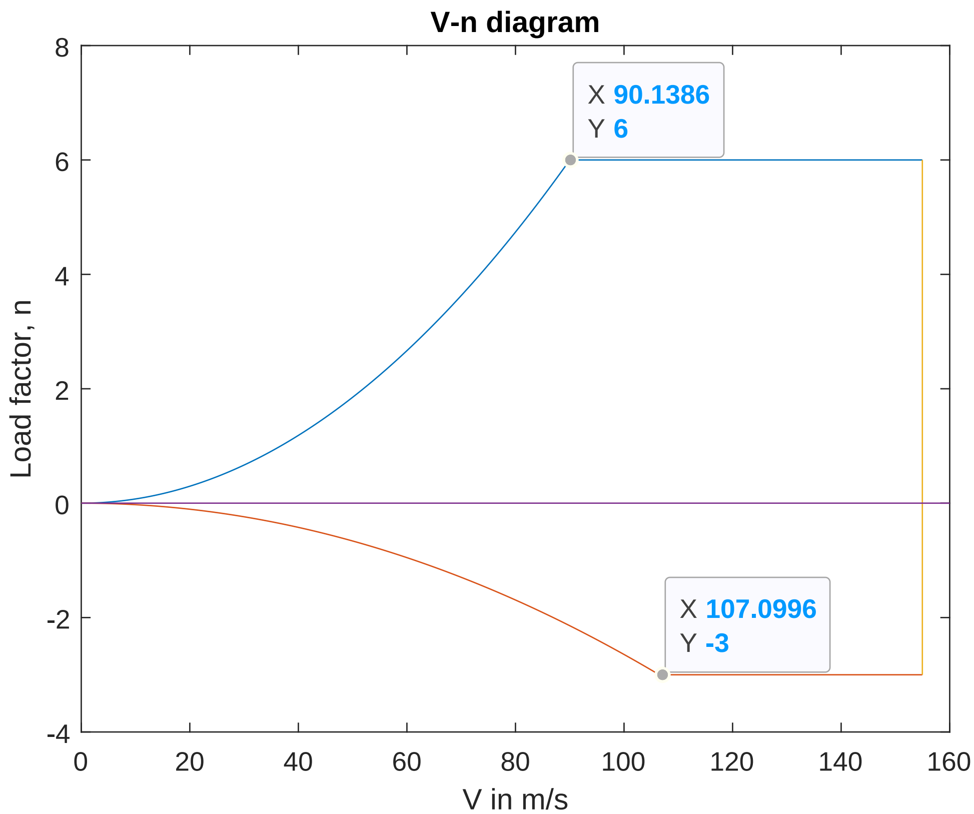
$$V_{max} = V_R \sqrt{z + \sqrt{z^2 - 1}}$$

where $$V_R = \sqrt{\frac{2W}{\rho S}} \cdot \left(\frac{k}{C_{D_0}}\right)^{\frac{1}{4}}$$

$$z = \frac{T E_m}{W}$$

(a) Corner velocity $$V_c = \sqrt{\frac{2 n_1 (W/S)}{\rho\, C_{L_{max}}}} = \sqrt{\frac{2 \times 6 \times 1000}{1.058 \times 1.4}}$$

$$= 90.0\ m/s$$


V-n diagram
X 90.1386
Y 6
X 107.0996
Y -3
8
6
4
2
0
-2
-4
Load factor, n
0
20
40
60
80
100
120
140
160
V in m/s

(b) Corner radius of turn

$$C_D = C_{D_0} + k C_{L_{max}}^2$$

$$= 0.015 + 0.024 \times 1.4^2$$

$$= 0.062$$

$$D = \frac{1}{2} \rho S C_D V_c^2$$

$$= \frac{1}{2} \times 1.058 \times 20 \times 0.062 \times 90^2$$

$$= 5317.7 \text{ N}$$

$$T_a = T_0 \sigma^{0.8}$$

$$= 2000 \left(\frac{1.058}{1.225} \right)^{0.8} = 1778.7 \text{ N}$$

$$\gamma_c = \sin^{-1}\left(\frac{T_a - D}{W} \right)$$

$$= \sin^{-1}\left(\frac{1778.7 - 5317.7}{20000} \right)$$

$$= -0.1779 \text{ rad} = -10.19^\circ$$

$$R_c = \frac{(V_c \cdot \cos \gamma_c)^2}{g \sqrt{n_1^2 - (\cos \gamma_c)^2}}$$

$$= \frac{(90 \times \cos(-10.19^\circ))^2}{9.81 \sqrt{6^2 - (\cos(-10.19^\circ))^2}}$$

$$= 135.16 \text{ m}$$

$$\omega_c = \frac{V_c \cos(\gamma_c)}{R_c} = \frac{90 \times \cos(-10.19^\circ)}{135.16}$$

$$= 0.655 \text{ rad/sec}$$

$$t_\pi = \frac{\pi}{\omega_c}$$

$$= \frac{\pi}{0.655} = 4.79 \text{ sec}$$

Accepted answers–

$V_c \in [85.5,\ 94.5]$ m/s , $R_c = [128.4,\ 141.9]$ m

$\omega_c \in [0.622,\ 0.687]$ rad/s , $t \in [4.5,\ 5.03]$ sec

Question – 6

Solution

given data –

$W = 10000$ N

$S = 3.4$ m^2

$T = 2500$ N

$C_{D0} = 0.021$

$k = 0.045$

$C_{Lmax} = 1.8$

$\mu = 0.05$

ⓐ minimum ground run will occur when

$$C_L^* = \frac{\mu}{2k} = \frac{0.05}{2 \times 0.045} = 0.556$$

$$V_{stall} = \sqrt{\frac{2W}{\rho S C_{Lmax}}} = \sqrt{\frac{2 \times 10000}{1.225 \times 3.4 \times 1.8}}$$

$$= 51.65 \text{ m/s}$$

$$V_1 = 1.2\, V_{stall}$$
$$= 1.2 \times 51.65$$
$$= 61.98 \text{ m/s}$$

$$F_0 = T - \mu W$$
$$= 2500 - 0.05 \times 10000$$
$$= 2000 \text{ N}$$

$$F_1^* = T - \frac{1}{2} \rho S V_1^2 \left(C_{D0} + k C_L^{*2} \right)$$

$$= 2500 - \frac{1}{2} \times 1.225 \times 3.4 \times 61.98^2 \left(0.021 + 0.045 \times 0.556^2 \right)$$

$$= 2220.9 \text{ N}$$

a

$$S_1 = \frac{W}{2g} \times \frac{V_1^2}{F_0 - F_1^*} \ln\left(\frac{F_0}{F_1^*}\right)$$

$$= \frac{10000}{2 \times 9.81} \times \frac{61.98^2}{2000 - 2220.9} \ln\left(\frac{2000}{2220.9}\right)$$

$$= 928.6 \text{ m}$$

(b) time to ground run

$$A = F_0 = 2000$$

$$B = \frac{F_1^* - F_0}{V_1^2} = \frac{2220.9 - 2000}{61.98^2}$$

$$= 0.0575$$

Since $A > 0$ & $B > 0$

$$t_1 = \frac{W}{g\sqrt{AB}} \cdot \tan^{-1}\left(\sqrt{B/A}\, V_1\right)$$

$$= \frac{10000}{9.81\sqrt{2000 \times 0.0575}} \cdot \tan^{-1}\left(\sqrt{\frac{0.0575}{2000}} \times 61.98\right)$$

$$= 30.49 \text{ sec}$$

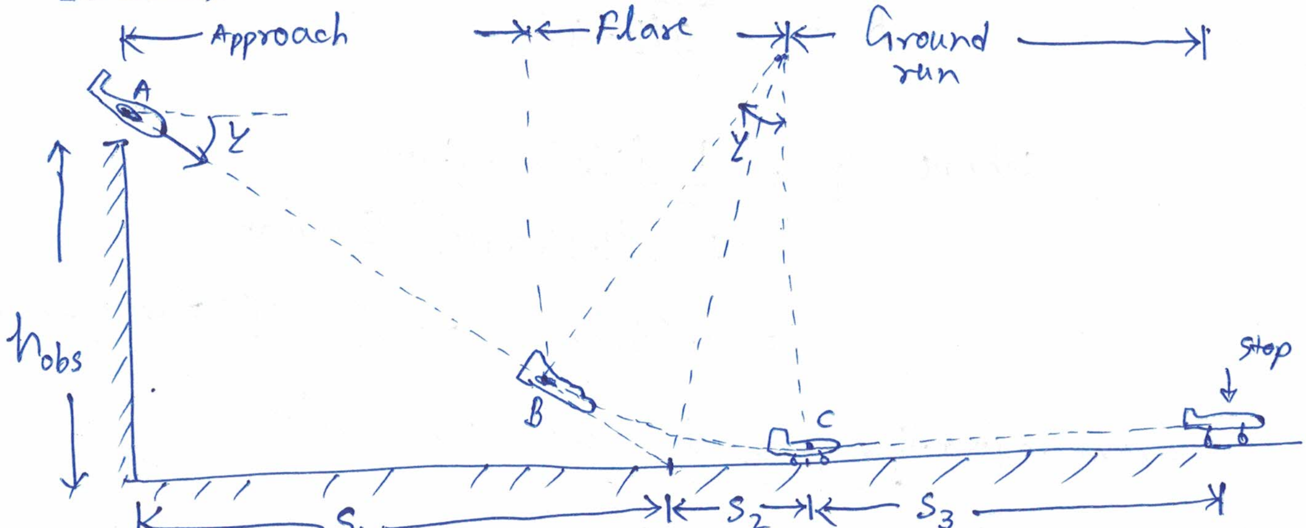
Accepted answers -

$S_1 \in [882.17,\ 975.0]$ m

$t_1 \in [28.97,\ 32.0]$ sec

Question - 7

Solution



from figure -

$$\frac{h_{obs}}{S_1} = \tan\gamma$$

$$\boxed{S_1 = \frac{h_{obs}}{\tan\gamma}}$$

$$\boxed{t_1 = \frac{S_1}{V_A \cos\gamma}}$$

V_A = Approach velocity
$= 1.3\, V_{stall}$
$= V_1$

from equations of motion -

$$L - W\cos\gamma = \frac{W V_A^2}{Rg} \quad \text{—} \quad (1)$$

$$T - D - W\sin\gamma = 0 \quad \text{—} \quad (2)$$

$$\sin\gamma = \frac{T-D}{W} \quad \text{—} \quad (3)$$

Assuming γ is small, from equation (1), we can write -

$$R = \frac{W V_A^2}{g(L-W)} \quad \text{—} \quad (4)$$

where $L = \frac{1}{2}\rho V_A^2 S C_{Lmax}$

$= \frac{1}{2}\rho (1.3 V_{stall})^2 S C_{Lmax}$

$= 1.69\, W$ — (5) $\because [L = W = \frac{1}{2}\rho S C_{Lmax} V_{stall}^2]$

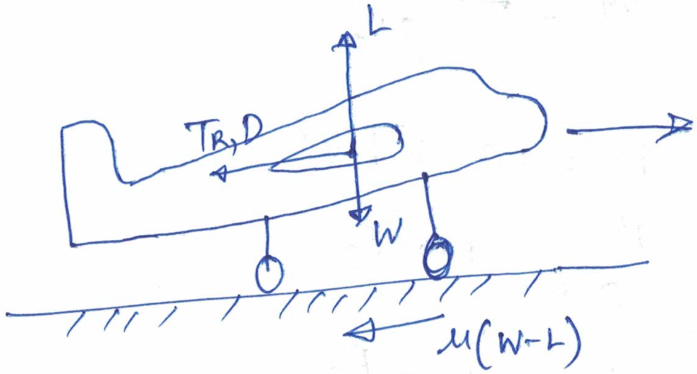
from equation (4) & (5), we can write -

$$\boxed{R = \frac{V_A^2}{0.699\, g}}$$

$$\boxed{S_2 \approx \frac{1}{2} R \gamma}$$

$$\boxed{t_2 = \frac{S_2}{V_A \gamma}}$$

ground run -



net deaccelerating force -

$$F_a = T_R + D + \mu(W-L) \quad —— (6)$$

where T_R is the thrust reversal.

$$\frac{W}{g} V \frac{dV}{ds} = -F_a$$

$$ds = -\frac{W \, dV^2}{2g F_a}$$

$$F_a = F_0 + \frac{F_1 - F_0}{V_1^2} V^2$$

$$\int_0^{S_3} ds = -\frac{W}{2g} \int_{V_1}^{0} \frac{dV^2}{F_0 + \frac{F_1 - F_0}{V_1^2}}$$

$$\boxed{S_3 = \frac{W}{2g} \left(\frac{V_1^2}{F_1 - F_0}\right) \ln\left(\frac{F_1}{F_0}\right)}$$

where, $F_1 = T_R + D$

$$F_0 = T_R + \mu W$$

★ For minimum ground run $\quad C_L^* = \frac{\mu}{2k}$

$$\frac{W}{g}\frac{dV}{dt} = -F_a$$

$$dt = -\frac{W\,dV}{g F_a}$$

$$F_a = a + bV^2$$

$$a = F_0$$

$$b = \frac{F_1 - F_0}{V_1^2}$$

$$\int_0^{t_3} dt = -\int_{V_1}^{0} \frac{W}{g} \cdot \frac{dV}{a + bV^2}$$

$$t_3 = \frac{W}{g\sqrt{ab}} \tan^{-1}\left(\sqrt{\frac{b}{a}}\, V_1\right) \quad [a>0,\ b>0]$$

$$t_3 = \frac{W}{2g\sqrt{a b_1}} \ln\left(\frac{\sqrt{a} + \sqrt{b_1}\,V_1}{\sqrt{a} + \sqrt{b_1}\,V_1}\right) \quad [a>0,\ b<0]$$

where, $b_1 = |b|$

Question - 8

Solution Given data -

$W = 62784 \text{ N}$

$S = 20 \text{ m}^2$

$C_{D0} = 0.0254$

$k = 0.178$

$C_{L max} = 0.95$

$\sigma = 0.9074$

$\mu = 0.02$

$\gamma = 3.5^\circ = 3.5 \times \pi/180 = 0.0611 \text{ rad}$

$h_{obs} = 15 \text{ m}$

(a) Airborne distance (including flare) = $S_1 + S_2$

$$S_1 = \frac{h_{obs}}{\tan(\gamma)}$$

$$= \frac{15}{\tan(3.5^\circ)} = 245.25 \text{ m}$$

$$S_2 = \frac{1}{2} R \gamma$$

$$V_1 = 1.3 V_{stall} = 1.3 \times \sqrt{\frac{2W}{\rho S C_{L max}}}$$

$$= 1.3 \times \sqrt{\frac{2 \times 62784}{1.1116 \times 20 \times 0.95}} = 100.24 \text{ m/s}$$

$$L = \frac{1}{2} \rho S V_1^2 C_{L max} = \frac{1}{2} \times 1.1116 \times 20 \times 100.24^2 \times 0.95$$

$$= 1.061 \times 10^5 \text{ N}$$

$$R = \frac{W V_1^2}{g(L - W\cos\gamma)}$$

$$= \frac{62784 \times 100.24^2}{9.81\left(1.061\times10^5 - 62784\cos(3.5^\circ)\right)}$$

$$= 1.4804\times10^3 \text{ m}$$

$$= 1480.4 \text{ m}$$

or $$R = \frac{V_1^2}{0.669\,g} = \frac{100.24^2}{0.669\times9.81}$$

$$= 1531.04 \text{ m}$$

$$S_2 = \frac{1}{2} R \gamma$$

$$\approx \frac{1}{2}\times1480.4\times0.0611 = 45.22 \text{ m}$$

or $$\approx \frac{1}{2}\times1531.04\times0.0611 = 46.77 \text{ m}$$

Airborne distance $= S_1 + S_2$

$= 245.25 + 45.22$

$= 290.46$ m

Accepted answer -

Airborne distance $\in [275.9, 304.9]$ m

(b) ground run (S_3)

(1) Case -

$$C_L^* = \frac{\mu}{2k} = \frac{0.02}{2 \times 0.178}$$

$$= 0.95$$

$$F_0 = \mu W$$

$[T_R = 0]$ no thrust reversal.

$$= 0.02 \times 62784$$

$$= 1255.7 \text{ N}$$

$$F_1^* = \frac{1}{2} \rho S V_1^2 (C_{D0} + k C_L^{*2})$$

$$= \frac{1}{2} \times 1.1116 \times 20 \times 100.24^2 (0.0254 + 0.178 \times 0.95^2)$$

$$= 2899.7 \text{ N}$$

$$S_3 = \frac{W}{2g} \cdot \frac{V_1^2}{F_0 - F_1^*} \ln\left(\frac{F_0}{F_1^*}\right)$$

$$= \frac{62784}{2 \times 9.81} \times \frac{100.24^2}{1255.7 - 2899.7} \ln\left(\frac{1255.7}{2899.7}\right)$$

$$= 16369.0 \text{m}$$

~~Accepted Answers~~ -

S_3 ~~6~~

Second Case

when $C_L^* = C_{L max}$

$$F_0 = \mu W = 1255.7 \text{ N}$$

$$F_1 = 20779 \text{ N}$$

$$S_3 = 4621.66 \text{ m}$$

$C_L = C_{L\,max}$ will give the minimum ground run.

$$\boxed{(S_3)_{min} = 4621.66 \text{ m}}$$

★ It requires very large ground run because there is no thrust reversal system.

Accepted answers

① Case $S_3 \in [15550, 17187]$ m

② Case $S_3 \in [4390.5, 4852.7]$ m