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Now total fuel burnt = 27.6 T

fuel in climb + takeoff = 3.5 T ; fuel in descent = 0.35 T

$\therefore$ fuel in cruise = ~~3.85 T~~ 27.6 − 3.85 = 23.75 T

$\therefore$ $M_{fu\ cruise,\ end}$ = 178.5 − 23.75 = 154.75 T

$$R = \frac{+V_a\,(L/D)}{(g_0 \times SFC)} \log_e\left(\frac{M_{ini}}{M_{fin}}\right)$$

Now $M_{final} = M_{cruise,\ end} - M_{fuel,\ descent}$ = 154.4 T.

$V_{a,\ cruise} = 0.78 \times \sqrt{\gamma R T_{cruise}}$

Taking T_{cruise} = ~~218.80 K~~ 216.65 K (at ~37,000 ft)

$\therefore$ $V_{a\ cruise} = 0.78 \times \sqrt{1.4 \times 287.1 \times 216.65}$
$= 230.173$ m/s.

$$\therefore R = \frac{230.173 \times 21.6}{9.81 \times \frac{14.2 \times 10^{-3}}{10^3}} \log_e\left(\frac{182}{154.4}\right)$$

$$= 35.69 \times 10^6 \log\left(\frac{182}{154.4}\right) = 5.869 \times 10^6 \text{ m} = 5869 \text{ km}$$

$\boxed{\text{Range} = 5869 \text{ km}}$

③ Ideal thrust @ cruise $\Rightarrow \frac{L}{D} = 21.6 \Rightarrow \frac{W}{T} = 21.6$

Steady flight assumption

$\therefore$ ~~182~~ $W_{cruise} = \frac{178.5 \times 10^3 \times 9.8}{\text{thrust}} = 21.6$

$\therefore$ Ideal Thrust @ cruise = 80.986×10^3 N.

New thrust = 97.183×10^3 N.

We have thrust climb = thrust cruise + rate of climb (θ) × W

$97.183 \times 10^3 = 80.986 \times 10^3 + \theta \times 178.5 \times 10^3$

$\theta = 0.0907$ rad = 5.196 degrees.

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Q1. $\frac{L}{D}\Big|_{max} = 21.6$ @ $C_L = 0.5$ $SFC = 14.2 \frac{gm}{kN\,s}$

$M_{cruise} = 0.78$ $h_{cruise} = 37000$ ft

$C_L\big|_{takeoff} \leq 1.56$ $C_L\big|_{landing} \leq 1.56$

$V_{a,takeoff} \leq 85$ m/s $V_{a,landing} \leq 70$ m/s

$W_{takeoff} = 175 \times 10^3$ kg $W_{reserve\ fuel} = 7 \times 10^3$ kg

$W_{total\ fuel\ burnt} = 21.6 \times 10^3$ kg $W_{fuel,TO,Climb} = 3.5 \times 10^3$

$W_{fuel,descent} = 0.35 \times 10^3$ kg

Now ① lift at takeoff $L_{TO} = W_{TO}$

$\therefore L_{TO} = \frac{1}{2}\rho V^2 S C_L = W_{TO}$.

$L_{TO} \leq 0.5 \times 1.225 \times (85)^2 \times S \times 1.56 = 6903.48\,S$

$L_{TO} \leq 6903.48 \times S$.

$\therefore$ $182 \times 10^3 \leq 6903.48\,S$

$\therefore$ $S \geq 26.3\ m^2$

The wing area has to be greater than $26.36\ m^2$

② $M_{cruise,beginning} = ?$

$M_{TO} = 182 \times 10^3$ kg $(M_{takeoff} + M_{reserve\ fuel})$

$\therefore M_{cruise,start} = M_{TO} - M_{fuel\ burnt\ takeoff,climb}$

$= M_{TO} ??\ 182\,T - 3.5\,T = 178.5\,T$.

$M_{cruise,end} = M_{cruise,start} - W_{fuel,cruise} = 178.5\,T - W_{fc}$

inclination = 5.196 degrees.

rate of climb = $\tan\theta\ \underline{V_y}$ ⇒

$\tan\theta = \frac{V_y}{V_x}$ $V_y = V_x \tan\theta$ $V_x = 230.173$ m/s

∴ rate of climb = $230.173 \times \tan(5.196)$

$= 20.93$ m/s.

(a) flying @ sea-level $\frac{L}{D} = 21.6$.

$\rho_{SL} = 1.225$ $P_{SL} = 1.013 \times 10^5$ Pa $T_{SL} = 288.15$

$$R = \frac{V_a (L/D)}{g_0 \cdot (SFC)} \log_e \left(\frac{M_{ini}}{M_{fin}} \right)$$

Here as take off & descent is not required we have

$M_{fin} = 182 \times 10^3 - W_{fuel, cruise} = 182\ T - 23.75\ T$

$= 158.25\ T$

and $V_a \le 85$ m/s. $V_a = 0.78 \times \sqrt{1.4 \times 287.1 \times 288.15} = 265.45$

$$\therefore R \le \frac{\overset{265.45}{\cancel{85}} \times 21.6}{9.81 \times 14.2 \frac{\times 10^{-3}}{10^3} \frac{kg}{Ns}} \times \log_e \left(\frac{182\ T}{158.25\ T} \right)$$

$$\le 41.16 \times 10^6 \log \left(\frac{182}{158.25} \right)$$

$R = 5.755 \times 10^6$ m

$R = 5755$ km   if flight @ $M = 0.78$

@ sea level and if

and if flight @ $V = V_{takeoff} = 85$ m/s

$R = 1842.81$ km