Rate of Climb:

Imagine that we are flying an airplane and we suddenly encounter a major obstacle ahead, - like large building, a hill or even a mountain. The ability of our airplane to fly up and over such obstacles depends critically on its climbing characteristics.

∴ The previous class we have dealt with steady, level flight of an airplane. In this section we change our focus to an airplane in steady, unaccelerated climbing flight.

∴ Climb angle θ, is defined as the angle between the instantaneous flight path direction and the horizontal.

'θ' is different from 'α'.

In this section we consider steady (unaccelerated) climb, equation of motion.

$$\frac{dV_\infty}{dt} = 0, \quad \frac{V_\infty^2}{r_1} = 0, \quad \frac{(V_\infty \cos\theta)^2}{r_2} = 0.$$

The latter two statement imply $r_1 \to \infty$ and $r_2 \to \infty$, that is flight along a straight path. This also implies that the bank angle ϕ is zero.

So the equation of motion for this case,

$$T\cos\epsilon - D - W\sin\theta = 0. \longrightarrow (1)$$

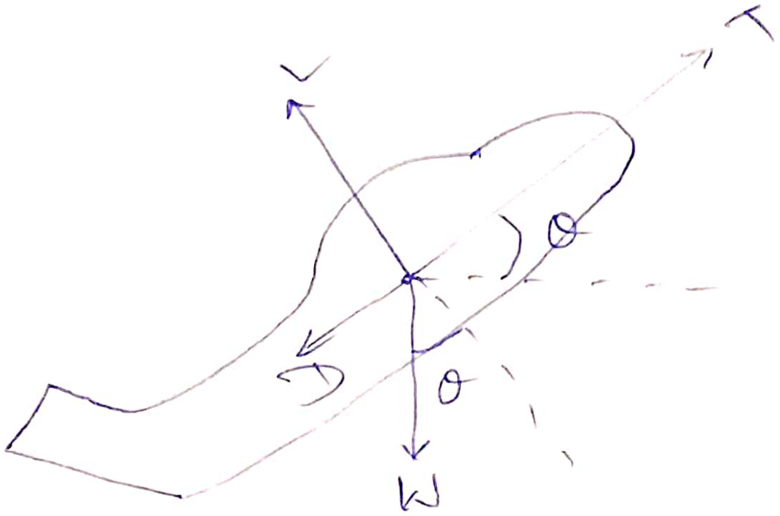
$L + T\sin\epsilon - W\cos\theta = 0 \longrightarrow (2)$

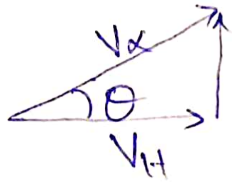
∴ we assume the thrust line and flight path are in same ∴

$\epsilon = 0$

$$T - D - W\sin\theta = 0 \longrightarrow (3)$$

$$L - W\cos\theta = 0 \longrightarrow (4)$$





$V_V = R/C$

$= V_\alpha \sin\theta$

rate of climb by R/C.

$$R/C = V_\alpha \sin\theta \longrightarrow (5)$$

multiplying the (3) & (4) equ with V_α / W

$$V_\alpha \sin\theta = R/C \Rightarrow \left[T - D - W\sin\theta = 0\right] \times \frac{V_\alpha}{W}$$

$$\frac{TV_\alpha}{W} - \frac{DV_\alpha}{W} = \cancel{W}\sin\theta \times \frac{V_\alpha}{\cancel{W}} = 0$$

$$\therefore \boxed{V_\alpha \sin\theta = \frac{TV_\alpha - DV_\alpha}{W}} \longrightarrow (6)$$

∴ in equ (6) $TV_\alpha \rightarrow$ Power available

$DV_\alpha \rightarrow$ Power required to over Come the drag.

∴ $TV_\alpha - DV_\alpha$ = excess power.

∴
$$\boxed{R/C = \frac{\text{excess power}}{W}} \rightarrow (7)$$

∴ now clearly rate of Climb (c) depends on raw power in Combination with the weight of the airplane.

The higher the thrust, the lower the drag and the lower the weight. the better the climb performance.

It is important to note that for steady climbing flight, lift is less than weight.

$L = W \cos\theta$ because for climbing flight part of weight of the airplane is supported by the thrust and hence less lift is needed than for level flight.

$$\therefore C_L = \frac{L}{q_\infty} = \frac{W\cos\theta}{q_\infty S}$$

From the drag polar

$$D = q_\infty S C_D = q_\infty S \left[C_{D,0} + K C_L^2 \right]$$

$$D = q_\infty S \left[C_{D,0} + K \left(\frac{W \cos\theta}{q_\infty S} \right)^2 \right]$$

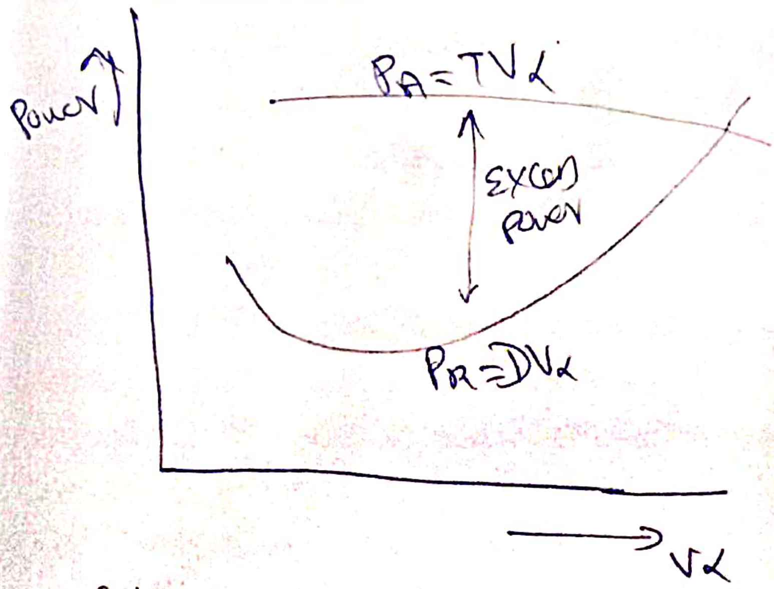
$$D = q_\infty S C_{D,0} + \frac{K W^2 \cos^2\theta}{q_\infty S} \longrightarrow (8)$$

Sub (8) in (6)

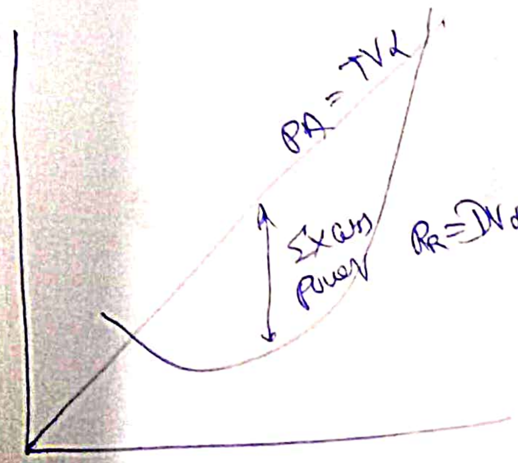
$$V_\infty \sin\theta = (R/C) = V_\infty \left[\frac{T}{W} - \frac{1}{2} \rho_\infty V_\infty^2 \left(\frac{W}{S} \right)^{-1} C_{D,0} - \frac{W}{S} \frac{2K \cos^2\theta}{\rho_\infty V_\infty^2} \right] \longrightarrow (9)$$

Thus in equ (9) the weight does not appear separately, but rather in the form of Thrust to weight ratio (T/W) & wing loading (W/S) $\Rightarrow$ Two design parameters.

∴ Now for case,



(a) propeller driven airplane



(b) Jet-propelled airplane

∴ Variation of R/C with velocity at the a given altitude.