Forces in a Climb

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m = aircraft mass
a = acceleration

Equations:

Vertical $F \sin(\gamma) - D \sin(\gamma) - L \cos(\gamma) - W = m\,a_v$

Horizontal $F \cos(\gamma) - D \cos(\gamma) - L \sin(\gamma) = m\,a_h$

Definition of Excess Thrust: $F - D = F_{ex}$

Vertical $F_{ex} \sin(\gamma) - L \cos(\gamma) - W = m\,a_v$

Horizontal $F_{ex} \cos(\gamma) - L \sin(\gamma) = m\,a_h$

Cruise – Balanced Forces

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Lift = Weight
Thrust = Drag

Airplane moves in a straight line at constant airspeed.

Ramjet Propulsion

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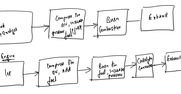
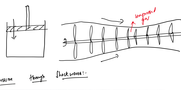
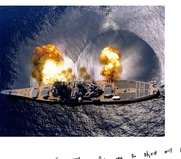
X – 15 with ramjet engine

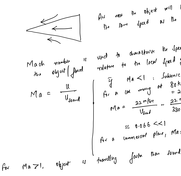
Ramjet test

Working fluid is the surrounding air.







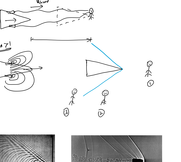
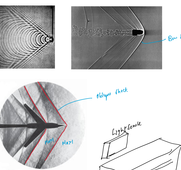
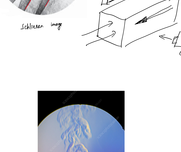
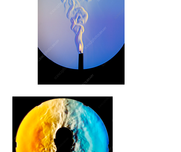
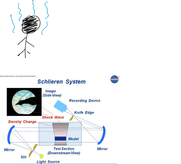
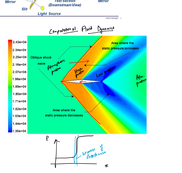
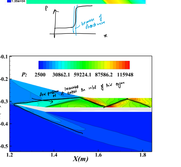
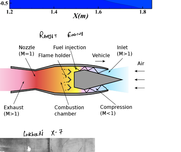
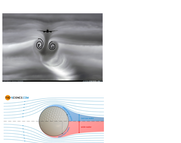


Mach number = ratio of object speed / speed of sound

$$M = \frac{u}{u_{sound}}$$

Mach wave: wave in which the object will have to move faster than speed of the object.

Speed of sound: speed at which a disturbance in the medium travels.

For $M < 1$: Subsonic
For a gas moving at $\frac{1}{3}$ the speed of sound, $M = \frac{\frac{1}{3}u_{sound}}{u_{sound}} = \frac{1}{3}$
$\Rightarrow 0.8 \le M \le 1$
For a compressible flow, $M \approx 0.85$

For $M > 1$, object is travelling faster than sound.