

# Blast Off!

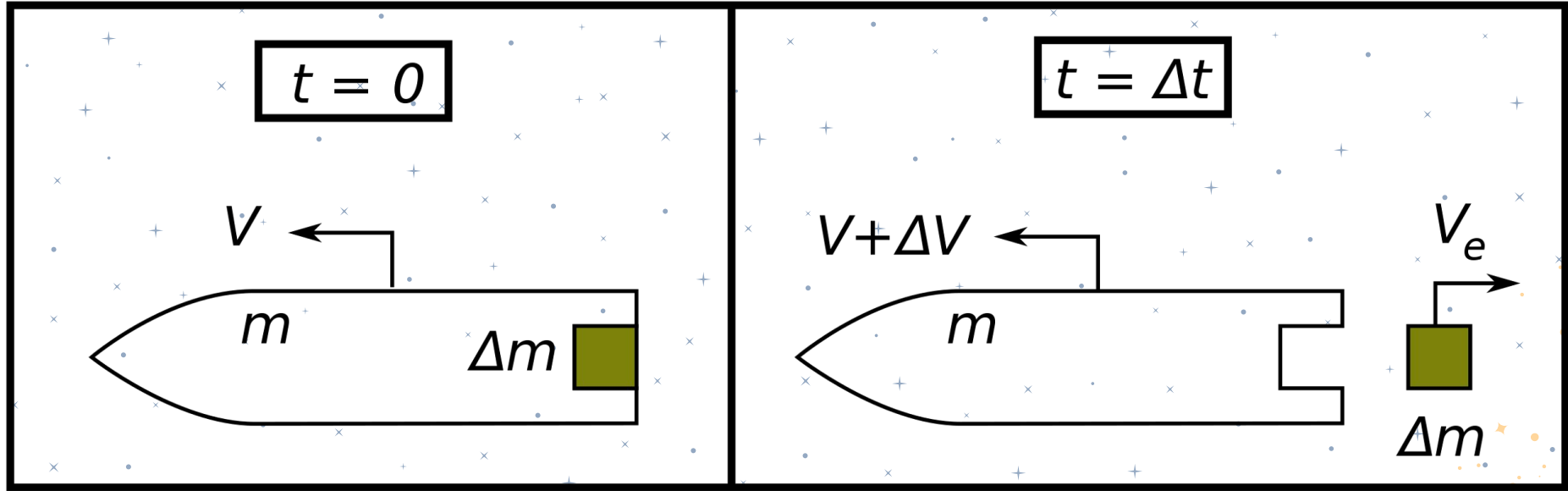
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## Lecture 3



# The Rocket Equations





Using basic momentum conservation can you find an equation which describes a rocket?

At  $T=t$ ,

$$\text{Momentum} = M.[v] \quad \dots(1)$$

At  $T=t+dt$ ,

$$\text{Momentum} = (M-dM).[v+dv] - dM.[V_e] \quad \dots(2)$$

So, By Momentum Conservation, equating (1) and(2)

$$\mathbf{M.v = (M-dM).(v+dv) - dM.(V_e)}$$

Let's try to simplify the Momentum Conservation equation a little :

$$\Rightarrow M.v = M.v + M.dv + dM.v + dM.dv - dM.V_e$$

$$\Rightarrow M.dv + dM.v - dM.V_e = 0$$

$$\Rightarrow M.dv + dM.v - dM.(v - v_{ex}) = 0$$

[Note:  $V_e = v - v_{ex}$  at  $t+dt$ ]

$$\Rightarrow M.dv + dM.v_{ex} = 0$$

$$M.(dv/dt) = -(dM/dt).v_{ex}$$

We can SOLVE Further, Let's do that :

$V_{\text{ex}}$  is somewhat constant at the steady state arrival hence

$$\Rightarrow \int(dV) = -v_{\text{ex}} \int((1/M) \cdot dM)$$

Limits from  $v$  to  $v+\Delta v$  (L.H.S.) and  $M_o$  to  $M_f$  (R.H.S.) where

$v_{\text{ex}}$  = velocity of exhaust and we get ;

$$\Delta v = -v_{\text{ex}} \cdot \ln (M_f / M_o)$$

Solving further,

$$\Rightarrow M_f = M_o \exp(\Delta v/v_{ex})$$

$$\text{P.S. : } M_o = M \text{ and } M_f = M - \Delta M$$

$$\text{so : } (M - \Delta M)/M = \exp(\Delta v/v_{ex})$$

$$\Delta M/M = 1 - \exp(\Delta v/v_{ex})$$

What does  $\Delta M$  represent here?

# Specific Impulse

Specific Impulse is a measure of how efficiently a reaction mass engine creates thrust. It represents the efficiency of an engine.

$$I_{sp} = \lim (\Delta t \rightarrow 0) \{ (F_{thrust} \cdot \Delta t) / (m_{prop} \cdot g_o) \}$$

Check By Definition of Impulse..

$$I_{sp} = F_{thrust} / [(dm/dt) \cdot g_o]$$

$$\Delta v = I_{sp} \cdot g_o \cdot \ln(M_o/M_f)$$

[Change in velocity in terms of specific impulse].

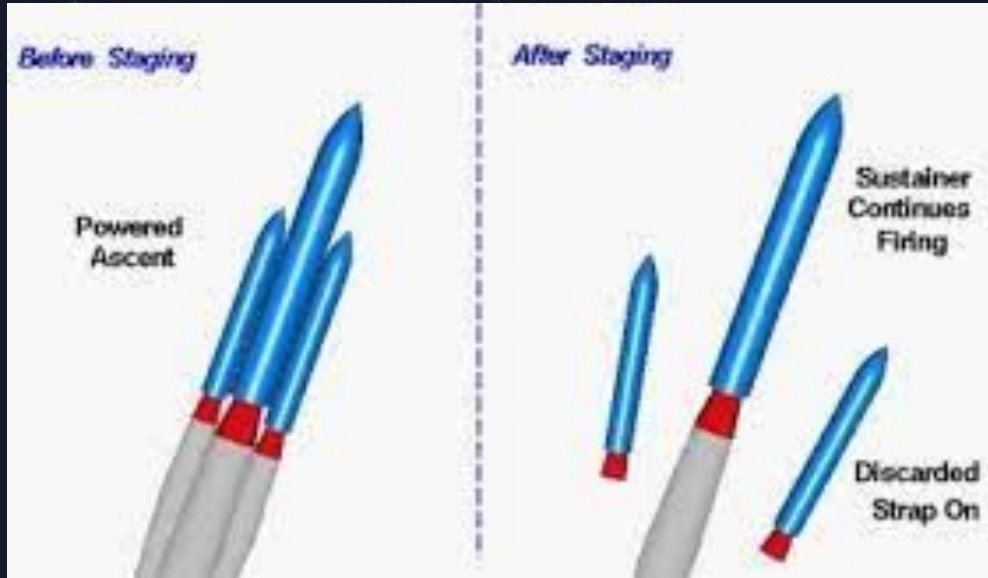
Note : [  $\int (F_{thrust}) dt = I$  and to make it specific just divide by mp ]



# Staging

The background is a dark blue space-themed image. It is filled with numerous small, light blue plus signs and 'x' marks scattered across the entire area. In the top right corner, there is a cluster of bright yellow and orange dots of varying sizes, with a stylized yellow and orange spiral galaxy icon integrated into the cluster. In the bottom left corner, there is another cluster of yellow and orange dots, with a stylized yellow and orange spiral galaxy icon integrated into the cluster.

# Parallel Staging



# Serial Staging

