**Last time:** • FINAL REPORT DUE FRI. OF EXAM WEEK

Acceleration due to thrust is given by

$$\ddot{a}_T = \frac{I_{sp} \cdot g}{m} \cdot \frac{dm}{dt},$$

where $I_{sp}$ : specific impulse

$g$ : gravitat'l constant

$m$ : mass

$t$ : time.

**Quick Review Questions (2, p. 102)**

Impulse: prod. of thrust & length of time

Specific impulse: impulse per unit weight of burned fuel,

or $\frac{I}{\Delta W}$

QR: (a) Units of measure (or dimensions) for impulse?

Recall: thrust is a force, so

dimensions : $\frac{M \cdot L}{T^2}$.

Therefore, impulse has dimensions $\frac{M \cdot L}{T}$.

L21, ctd.



(a) ~~kg~~, ~~$\frac{kg\cdot m}{s^2}$~~, ~~$\frac{kg}{s^2}$~~, ~~$\frac{m}{s^2}$~~, ~~$\frac{mi}{hr}$~~, ~~N~~, **(N·s)**, ~~lb~~, ~~$\frac{lb}{s^2}$~~, ~~s~~, Meg·s, $\frac{kg\cdot Jord}{s}$, $lb_f \cdot s$, $lb_f \cdot$ years, etc.

(b) Fuel burns 2s, imparts a thrust of 75 N.

$$I = 75\,N \cdot 2\,s = 150\ N\cdot s$$

(c) Specific impulse: impulse per unit weight of burned fuel, or $\frac{I}{\Delta w}$.

Impulse has dimension $[I] = \frac{M\cdot L}{T}$

weight — " — $[w] = [\Delta w] = \left[\frac{M\cdot L}{T^2}\right]$

$$[I_{sp}] = \left[\frac{I}{\Delta w}\right] = \frac{[I]}{[\Delta w]} = \frac{M\cdot L\cdot T^2}{T\cdot M\cdot L} = T$$

~~kg~~, ~~$\frac{kg\, m}{s^2}$~~, ~~$\frac{kg}{s^2}$~~, ~~$\frac{m}{s^2}$~~, ~~$\frac{mi}{hr}$~~, ~~N~~, ~~N s~~, ~~lb~~, ~~$\frac{lb}{s^2}$~~, **(s)**

(d) 0.5 kg fuel burns during 2sec, imparting a force of 75N.

$$I_{sp} = \frac{I}{\Delta w} \approx \frac{150\ N\cdot s}{+5\ N} \approx 30\ \text{sec}.$$

Δ weight due to Δ mass of −0.5 kg

$$\Delta w = -9.8\,\frac{m}{s^2}(-0.5\,kg) \approx +5\ N$$

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Randomly select 8 students: of those 8, how many say yes?

100% − 71.3% = 28.7% say no

yes: 71.3%

## Assumptions for 1st rocket model:

- Only forces acting on rocket are gravitat'n and thrust derived from burning fuel (ignore air resistance) (motion only in one direc'n)
- Acceleratn due to gravity is constant

gravitat'l force : $\frac{G m M}{r^2}$

G: universal grav'l const.
m: mass of obj. 1
M: — " — 2
r: dist. btwn. ctrs. of mass of obj. 1 & obj 2

$$-9.8 \frac{m}{s^2} = \text{"}g\text{"} = \frac{GM}{r^2}$$

r := rad. of earth, G = univ. grav'l const, M := mass of earth

$m \cdot g$

- The earth is flat (many/several interpretat'ns)
- The rocket is vertical (motion in only one direc'n) ("vertical" : "orthogonal to surface") normal
- The rocket has only one stage

Q: How does the weight of the engine itself (which is jettisoned after burning all fuel) compare to the weight of the burned fuel?

(a) Starting w/ skydiving / falling / etc., what add'l variables / qties are necessary for modelling rocket?

$\Delta m$ : change in mass ... over some known $\Delta t$
(this gives an approximate $\frac{dm}{dt}$ )

$I_{sp}$ { thrust : how to compute, ~~so~~ time interval over which it acts, rate of fuel consump'n (calculate from $\frac{dm}{dt}$ ?).

mass of rocket + engine + fuel