CS-1

The total momentum of a system is conserved:

(a) only if it is strictly isolated.

(b) if it is isolated, partly isolated, or inertially isolated.

(c) if it is isolated, functionally isolated, or momentarily isolated.

(d) if it is isolated, wholly isolated, and nothing but isolated.

(e) always.

The total momentum of a system is conserved if it is

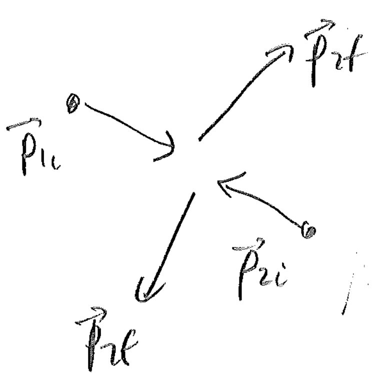
① isolated (no external interactions), eg. in deep space

② functionally isolated (external interactions cancel),

eg, canoe, or air track (push me pull you)

then $\vec{p}^{sys} = M\vec{v}_{cm}$

③ momentarily isolated (external interactions negligible over a short period of time), eg collision



$[d\vec{p}]_{ext} = \vec{F}_{ext} \underbrace{dt}_{small}$

$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$

If know initial momenta and one final momentum, can solve for the other

$\vec{p}_{2f} = \vec{p}_{1i} + \vec{p}_{2i} - \vec{p}_{1f}$

[C5.T4]

[C5-T5]

[vector eqn]

$$\begin{pmatrix} p_{1ix} + p_{2ix} \\ p_{1iy} + p_{2iy} \\ p_{1iz} + p_{2iz} \end{pmatrix} = \begin{pmatrix} p_{1fx} + p_{2fx} \\ p_{1fy} + p_{2fy} \\ p_{1fz} + p_{2fz} \end{pmatrix}$$

In a non isolated system
If external interactions only act in z direction,
then x & y momenta are still conserved.

[Demo: in ~~hallway~~ Phys 103 Lab]

Two students on skateboards. Have one of them pull ⇒ cm
Have other one pull ⇒ cm

Drop book on moving skateboard. It slows down

Q: Is momentum conserved?

A = yes
B = no
C: yes and no; it's complicated

First, momentum of wt? System of book and skateboard.

Is it isolated throughout? No, interacts gravitational and via normal force w/ earth so $[d\vec{p}]$ transferred by external interactions

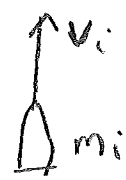
but only in y-direction.

In x-direct, no momentum transfer.

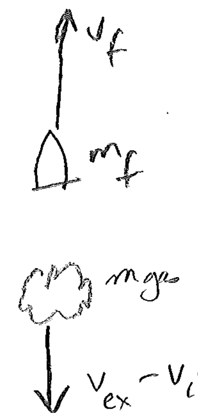
(What if ~~drop~~ book on board from a height, then at momentary contact, ~~@ contact,~~ not isolated, $\vec{F}_N$ spikes up to change p_{vert} of book.)

[How does a rocket accelerate in space?]
Isolated → mom cons → V_{cm} const

Initial



At later



expelled gases →

gases are expelled from rocket w/ relative velocity v_{ex}.

Total momentum is conserved

$$p^{sys}_{zf} = p^{sys}_{zi}$$

$$m_f v_f - m_{gas}(v_{ex} - v_i) = m_i v_i$$

$$m_f v_f - m_{gas} v_{ex} + \underbrace{m_{gas}}_{(m_i - m_f)} v_i - m_i v_i = 0$$

$$m_f (v_f - v_i) = m_{gas} v_{ex}$$

$$\underbrace{m_f \Delta v}_{\text{change in momentum of rocket}} = \underbrace{m_{gas} v_{ex}}_{\text{impulse delivered by gases}}$$

$$\Delta p_{rocket} = [\Delta p]_{thrust}$$

$$F_{thrust} = \frac{[dp]_{thrust}}{\Delta t}$$

$$= \left(\frac{m_{gas}}{\Delta t}\right) v_{ex}$$

$$F_{thrust} = R\, v_{ex}$$

R = rate of expelling gas

[It's not rocket science. Well actually it is.]

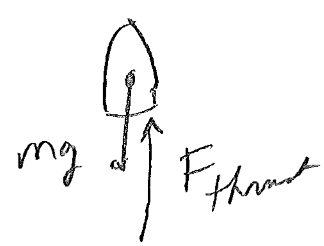
Saturn V:
LOX-kerosene

$$R = \frac{15 \text{ tons fuel}}{\text{sec}} = 14{,}000 \frac{kg}{sec}$$

$$v_{ex} = 2500 \frac{m}{s}$$

$$\Rightarrow F_{thrust} = 3.4 \times 10^7 \, N$$

Rocket launch



initial mass of rocket = 3000 ~~tons~~ = 2.8 E6 kg

$$mg = 2.8 \times 10^7 \, N$$

$\Rightarrow$ initial accel: $2 \frac{m}{s^2}$

First stage burn $\Rightarrow$ 2.5 minutes = 150 sec

gas expelled = 2250 tons so only $\frac{1}{4}$ left.
(mostly fuel)

[videos]

Problem solving

1) draw a picture, w/ info = if cons. law, before + after pictures

2) identify the system
+ internal + external interactions

3) principle? approximations

4) eqns

5) identify knowns + unknowns
→ enough eqns

6) solve algebraically: avoid #s until the end

7) check: units?
sensible?

(went over canoe problem as eg of this)