10/7/98 Kuo starts lecture

reminder : midterm exam # 1 , tonight

Chap 7 momentum

Ex. three football players

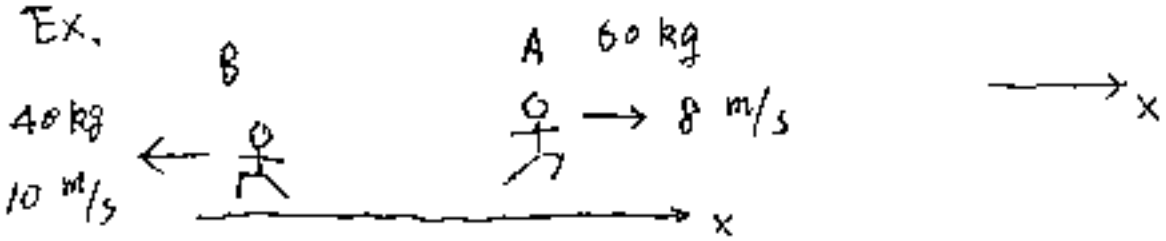
	m mass	v speed		momentum mv
A	150 kg	5 m/s		$150 \times 5 = 750 \frac{kg\,m}{sec}$
B	100 kg	10 m/s		$100 \times 10 = 1000$
C	60 kg	8 m/s		$60 \times 8 = 480$

want the one with biggest mtum } ∴ 1st pick = B
2nd " = A
no-body wants = C

See : momentum $p = mv$ } is important factor for football players

momentum is vector, $\vec{p} = m\vec{v}$

Ex.

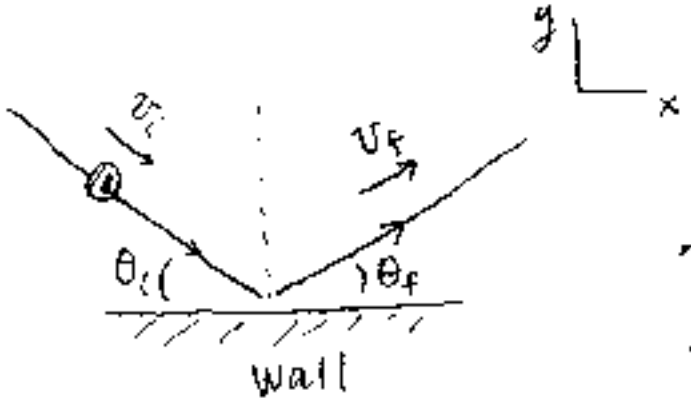


$$\vec{p}_A = 60 \times 8 \, \hat{x} = +480 \, \hat{x} \quad kg\frac{m}{s}$$

$$\vec{p}_B = 40 \times 10(-\hat{x}) = -400 \, \hat{x} \quad kg\frac{m}{s}$$

Change of momentum $\Delta\vec{p}$

Ex. ball bounced by wall



i = initial

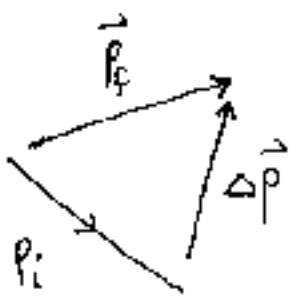
f = final

$m_{ball} = 0.15$ kg

$v_i = 15$ m/s $\quad \theta_i = 45^\circ$

$v_f = 12$ m/s $\quad \theta_f = 30^\circ$

$$\Delta\vec{p} = \vec{p}_f - \vec{p}_i$$



be sure to understand this diagram!

$\vec{a} + \vec{b} = \vec{c}$,

How to calculate $\Delta\vec{p}$?

$$(\Delta p)_x = p_{fx} - p_{ix} = 0.15 \times 12 \times \cos 30^\circ \quad \leftarrow 1.558$$
$$- 0.15 \times 15 \times \cos 45^\circ \quad \leftarrow 1.591$$
$$= -.033 \ \text{kg m/sec}$$

$$(\Delta p)_y = p_{fy} - p_{iy} = 0.15 \times 12 \times \sin 30^\circ \times (+1)$$
$$- 0.15 \times 15 \times \sin 45^\circ \times (-1)$$
$$= +.9 + 1.59 \qquad \uparrow \text{note sign}$$
$$= +2.49 \ \text{kg m/sec}$$

<u>What causes $\vec{p}$ to change</u> ?

Ex.

car at rest, $p_i = 0$

give car a push

F = pushing force

Δt = duration of push

suppose $F = 1000$ N, $\Delta t = 10$ s, $p_f = 2500 \ \frac{\text{kg m}}{\text{sec}}$

then if F = bigger, Δt = same, p_f = bigger

F = same, Δt = longer, p_f = bigger, too

Hence expect $\Delta p_f \propto F \Delta t$

This is indeed so !

Impulse of a force is defined as the product

$\vec{F}\,\Delta t$ — $\vec{F}$: external force, average; Δt: duration of the force

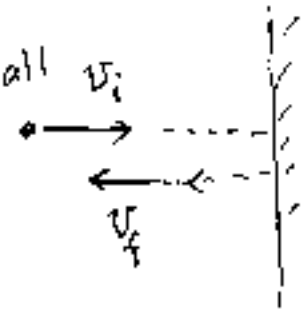
unit = N sec

$\frac{kg\,m}{sec^2}\,sec = \frac{kg\,m}{sec}$ ← unit of momentum

$\vec{F}_{av}\,\Delta t = \Delta \vec{p}$

or $\vec{F}\,dt = d\vec{p}$, in the limit of $\Delta t \to 0$

Ex.



$m_{ball} = .2$ kg

$v_i = 20$ m/sec

$v_f = -18$ m/sec

Find F = average force wall to ball = ? time of contact given as $\Delta t = 10^{-2}$ sec

impulse on ball $= p_f - p_i = 0.2 \times (-18) - 0.2 \times 20 = -7.6 \ \frac{kg\,m}{sec}$

$$F = \frac{p_f - p_i}{\Delta t} = \frac{-7.6}{10^{-2}} = -760 \text{ N}$$

7-4-4

CAPA-6 (mainly momentum) due 10/16

A131

my office hours: tues. 2-4 pm, I in HELP room

my office = C137: open door
welcome to come any time
call 632 8125

lecture notes:

will put on web

put some xerox copies in HELP room A131

some copies at Bookstore

exam-2 11/12 Thur.

10/9/98 brief review

object with mass m moving with $\vec{v}$

has momentum $\vec{p} = m\vec{v}$ kg-m/s

how to change it ?

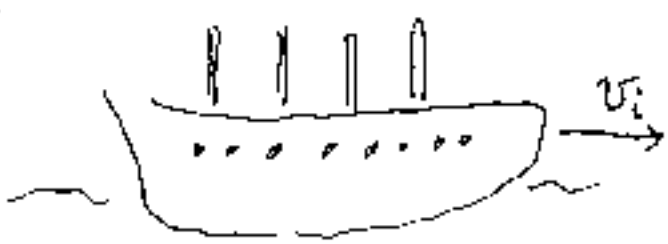
$$\vec{p}_f - \vec{p}_i = \Delta\vec{p} = \vec{F}\,\Delta t$$

($\vec{F}$: N, Δt: sec)

$\vec{F}$: external force applied to the obj

Δt: duration of the force

Ex. titanic



iceberg

$m \approx 50000$ ton $= 5 \times 10^7$ kg

$v_i \approx 50$ km/hr $= \frac{50 \times 1000}{3600} \approx 13.7$ m/s

$p_i = 5 \times 10^7 \times 13.7 \approx 6.83 \times 10^8$ kg m/s

suppose want to stop it in 5 min, $F_{av} = ?$

$\Delta p = p_f - p_i = 0 - 6.83 \times 10^8 = F_{av} \times 5 \times 60$, $F_{av} \approx -2.2 \times 10^6$ N

$F_{\text{ball to wall}} = ? = -F_{\text{wall to ball}}$

$= +760\ N$

Ex.

mass $= .25$ kg

$v_i = -20$ m/sec

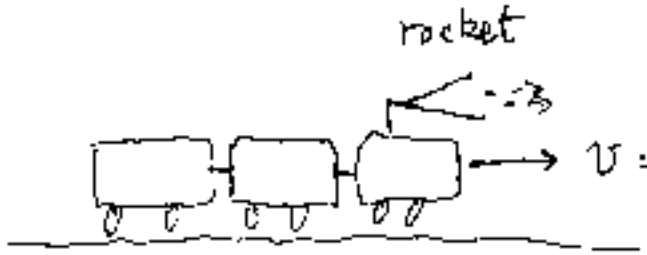
$v_f = 0$ (after hit)

$\Delta t = \frac{1}{500}$ sec

$$F_{\substack{\text{hammer}\\\text{to nail}}} = ? = -F_{\substack{\text{nail}\\\text{to hammer}}} = -\frac{(P_f - P_i)}{\Delta t}$$

$$= -\frac{[0 - (-.25 \times 20)]}{1/500} = -2500\ N$$

Ex.



$m_{train} = 20000$ kg

$$P_{train} = mv = 20000 \times \frac{75 \times 1000}{3600} = 4.166 \times 10^5 \ \frac{kg\text{-}m}{sec}$$

rocket turned on (braking purpose),

passengers feel $a = -\frac{g}{2} = -4.9\ m/s^2$

Δt = time duration for rocket to stop the train = ?

$$p_f - p_i = F\,\Delta t$$

p_f: 0 ; p_i: $4.166 \times 10^{+5}$; F: ma

$= 20000 \times (-4.9)$

$\therefore \Delta t = 4.25$ sec

different way: $v_{train} = 75 \frac{km}{hr}$ stop

$$= \frac{75 \times 1000}{3600} = 20.83 \frac{m}{sec}$$

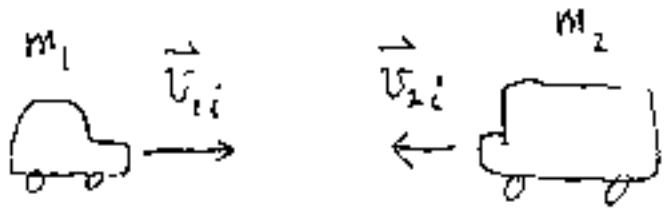
$v_f = v_i + at$

$0 = 20.83 + (-4.9)\,t$; $t = 4.25$ sec, checks ✓

Conservation of momentum and collision

Say 2 cars,

before collision



initial momenta $\vec{p}_{1i} = m\vec{v}_{1i}$ $\vec{p}_{2i} = m\vec{v}_{2i}$

collision, bang ...

after collision

$\vec{p}_{1f} = m_1 \vec{v}_{1f}$

To policemen: collision is complicated, insurance, ...

To 121: collision is "simple", i.e.

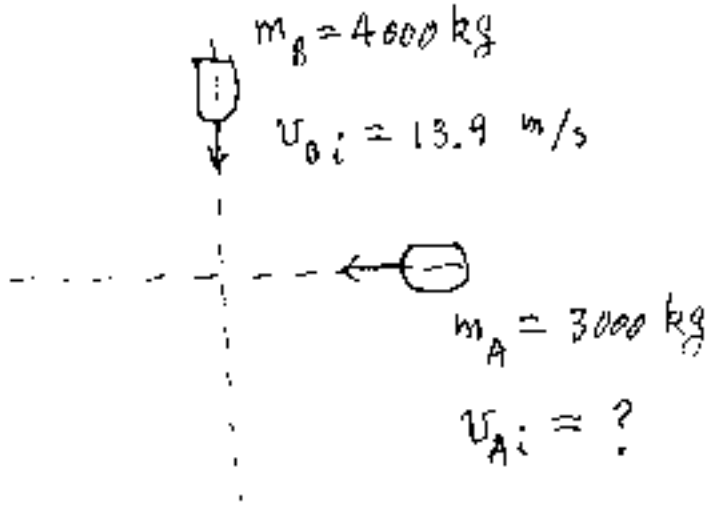
(sum of mtum before collision) $=$ (always) (sum of mtum after collision)

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

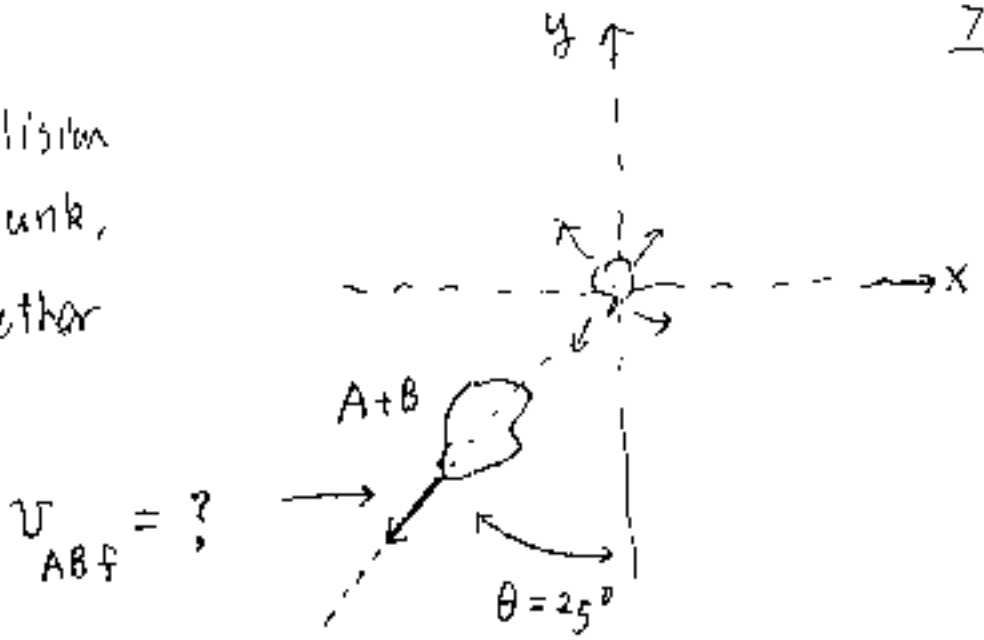
$i \equiv$ initial
$f \equiv$ final

This is important!

Ex. 2 cars before collision at intersection



after collision
A + B = junk,
stuck together



Note, we have two unknowns to find: v_{Ai} and v_{ABf}:

mtum conservation $\vec{p}_{Ai} + \vec{p}_{Bi} = \vec{p}_{ABf}$ ①

y components of ①: ← be sure to understand this

$$p_{Aiy} + p_{Biy} = p_{ABfy}$$

$$0 \quad -4000 \times 13.9 = (4000 + 3000)\, v_{ABf} \underbrace{\cos 25^\circ}_{.906}$$

$$\rightarrow v_{ABf} = -8.77 \text{ m/s}$$

x components of ①: $p_{Aix} + p_{Bix} = p_{ABfx}$

$$3000\, v_{Ai} + 0 = 7000 \times (-8.77) \times \underbrace{\sin 25^\circ}_{.423}$$

$$\rightarrow v_{Ai} = -8.66 \text{ m/s}$$

Let us look at KE (kinetic energy):

$$KE_{\substack{before\\collision}} = KE_{Ai} + KE_{Bi}$$

$$= \frac{1}{2}\, 3000 \times \underset{\substack{\uparrow\\ 8.66^2}}{v_{Ai}^2} + \frac{1}{2}\, 4000 \times \underset{\substack{\uparrow\\ 13.9^2}}{v_{Bi}^2} = 4.809 \times 10^5 \text{ J}$$

$$KE_{\substack{after\\collision}} = KE_{ABf}$$

$$= \frac{1}{2}(3000 + 4000) \times 8.77^2 = 2.307 \times 10^5 \text{ J}$$

important observation : $KE_{before} \gg KE_{after}$

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2 types of collisions

elastic collisions $\longrightarrow$ those with

$$KE^{total}_{before} = KE^{total}_{after}$$

inelastic collisions $\longrightarrow$ those with

$$KE^{total}_{before} \neq KE^{total}_{after}$$

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above car collision is <u>inelastic</u> .

F am