# EXAM #2

[ * Newtons Laws (Ch. 4, Ch. 5)
 * Work-Energy (Ch. 6, Ch. 7)
 Impulse-Momentum (Ch. 8) *

Newton $\Rightarrow$ Work done by all Forces $=$ $\Delta K.E.$

1666 ~1800's

## "Faces" of the 2nd Law

- Applied to a single mass
  "Choose a mass to which..."

Impulse-Momentum: Applied to a single mass in collision.

Conservation of Momentum: Applied to a system of colliding masses.

## Impulse-Momentum

$$\underbrace{\sum \vec{F}}_{\vec{F}_{NET}} = \frac{d}{dt}(\vec{p})$$

$$\vec{F} = \frac{d\vec{p}}{dt}$$

$\vec{p}$ is Momentum

$\vec{p} = m\vec{v}$

$$\int_{t_{initial}}^{t_{final}} \vec{F}\,dt = \int_{\vec{p}_{initial}}^{\vec{p}_{final}} d\vec{p}$$

$\Delta t = t_{final} - t_{initial}$

$$\frac{\Delta t}{\Delta t}\int_{t_i}^{t_f} \vec{F}\,dt = \vec{p}\,\Big|_{\vec{p}_{initial}}^{\vec{p}_{final}} = \underbrace{\vec{p}_{final} - \vec{p}_{initial}}_{\Delta\vec{p}}$$

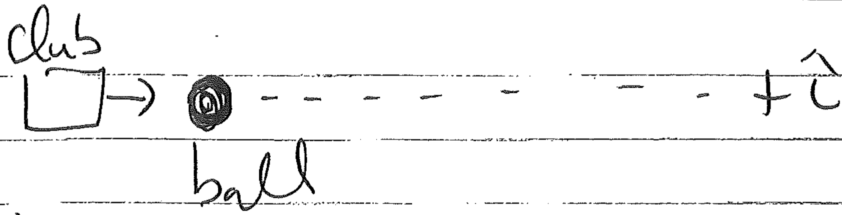
Change in momentum

$$\Delta t\underbrace{\left[\frac{\int_{t_i}^{t_f} \vec{F}(t)\,dt}{\Delta t}\right]}_{\vec{F}_{AVERAGE}}$$

$$\star \quad \underbrace{\vec{F}_{AVERAGE}\,\Delta t}_{\text{Impulse delevered to an object}} = \underbrace{\Delta\vec{p}}_{\text{change in the objects momentum}} \quad \star$$

Ex | A 20 g golf ball is struck by a club head moving 80 mph. If high speed photography shows the ball in contact w/ the club for 15 ms, what is the ball's speed when it leaves the club face? Sensors on the club record an average force of 600 N.

1-d




For ball:

$V_{initial} = 0$ $\quad P_{initial} = 0$

$V_{final} = ?$ $\quad P_{final} = mV_f$

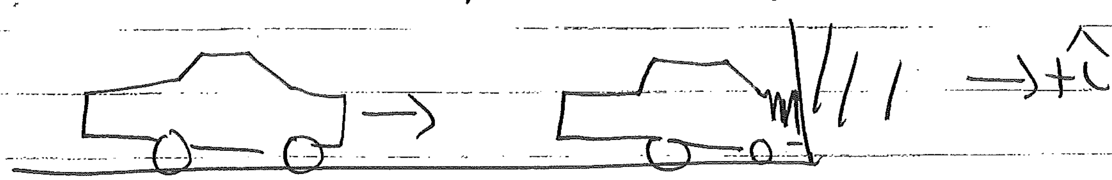
$\boxed{\hat{i}}$ $\quad F_{AVG}\,\Delta t = P_{final} - P_{initial}$

$600(15\times10^{-3}) = 0.020\,V_f$

$450\ m/s = V_f$

EX] A car moving @ 5 m/s crashes into a brick wall which does not move. The front of the car "crumples" 0.3 meters as the car comes to rest.

Find the average force exerted on the car. ($M_{car} = 3000$ kg)



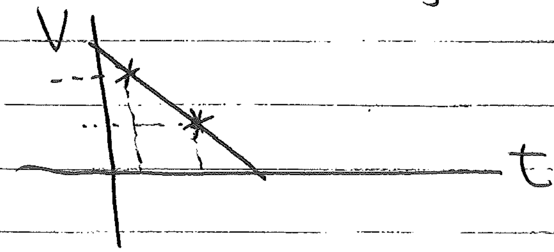

$\vec{P}_{initial} = m\vec{V}_{initial} = 3000(5)\,\hat{i}$

$\vec{P}_{final} = m\vec{V}_{final} = 0$

For CAR: $\quad \vec{F}_{AVG}\,\Delta t = \Delta\vec{P}$

$\Delta t = ??$ "trick" ☺

As an approximation, will assume acceleration is constant during collision




$\Delta X \approx V_{Average} * \Delta t$

Stopping Distance

collision time

$\left(\frac{5\,m/s + 0\,m/s}{2}\right)$

$0.3 \approx 2.5 * \Delta t$

$\Delta t = 0.12$ seconds

$\therefore \quad \vec{F}_{AVG} = \frac{\Delta \vec{P}}{\Delta t} = \frac{-15000\,\hat{i}}{0.12} = -125000\,\hat{i}$ newtons

!!

Consider a 70 kg Passenger

for Passenger: $\quad F_{AVG}\,\Delta t = \Delta P \quad [\hat{i}]$

$F_{AVG} = \frac{0 - 70(5)}{\left(\frac{\Delta X}{2.5}\right)} = \frac{-350}{\left(\frac{\Delta X}{2.5}\right)}\,\hat{i}$

If stopped by steering wheel, $\Delta X \approx 0.01$ meters

$F_{Avg} = -87500\,\hat{i}$ newtons

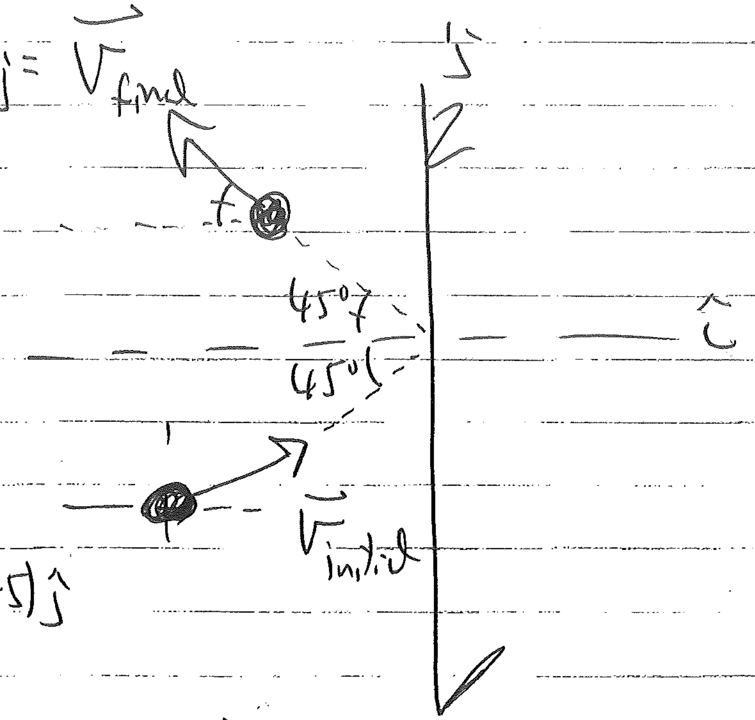
If stopped by an airbag, $\Delta x \approx 0.35$ m

$F_{Avg} = -2500\,\hat{i}$

EX] A 1 kg steel ball has a speed of 10 m/s and collides as shown below.

What impulse was delivered to the ball?

$-10\cos(45)\hat{i} + 10\sin(45)\hat{j} = \vec{V}_{final}$




$\vec{V}_{initial} = 10\cos(45)\hat{i} + 10\sin(45)\hat{j}$

$$\Delta\vec{p} = m\vec{V}_{final} - m\vec{V}_{initial} = m[-10\cos(45) - 10\cos(45)]\hat{i} + m[10\sin(45) - 10\sin(45)]\hat{j}$$

$$\Delta\vec{p} = m(-20\cos(45))\hat{i} + 0\hat{j}$$

$$\vec{F}_{AVG}\Delta t = -20\cos(45)(1)\hat{i}$$

$$\underbrace{\vec{F}_{AVG}\Delta t}_{\text{Impulse } (\vec{I})} = -14.14\,\hat{i}$$

Answer

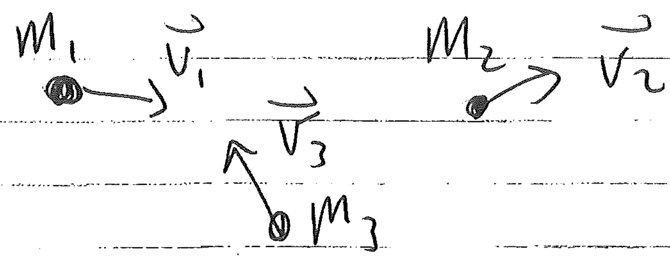
$\frac{Kg\,m}{s}$ || Ns

"Impulse Approximation" → Short collision times

Collision force >> others

Third form of 2nd law

- System of colliding masses.




For each mass:

$$\vec{F}_{NET_1} = \frac{d\vec{p}_1}{dt}$$

$$+$$

$$\vec{F}_{NET_2} = \frac{d\vec{p}_2}{dt}$$

$$+$$

$$\vec{F}_{NET_3} = \frac{d\vec{p}_3}{dt}$$

$$\vdots \qquad +$$

$$\underbrace{\vec{F}_{net_1} + \vec{F}_{net_2} + \vec{F}_{net_3} + \cdots}_{} = \frac{d}{dt}\left(\vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \cdots\right)$$

IF no external forces, 3rd law has these "pairing off"

So that the VECTOR SUM IS ZERO!

$$\therefore \quad 0 = \frac{d}{dt}\left(\vec{P}_{TOTAL}\right)$$

"Conservation of Momentum" $\vec{P}_{TOTAL} =$ CONSTANT

Process: - Define "System" (Things whose $\vec{p}$ you will track)

- Write $\vec{P}_{TOTAL}$ before the "event" (collision) (explosion)
- Write $\vec{P}_{TOTAL}$ after the "event"
- Apply conservation of momentum

$\boxed{L}$ $\boxed{J}$ $\boxed{C}$

$$\vec{P}_{\substack{TOTAL \\ BEFORE}} = \vec{P}_{\substack{TOTAL \\ AFTER}}$$