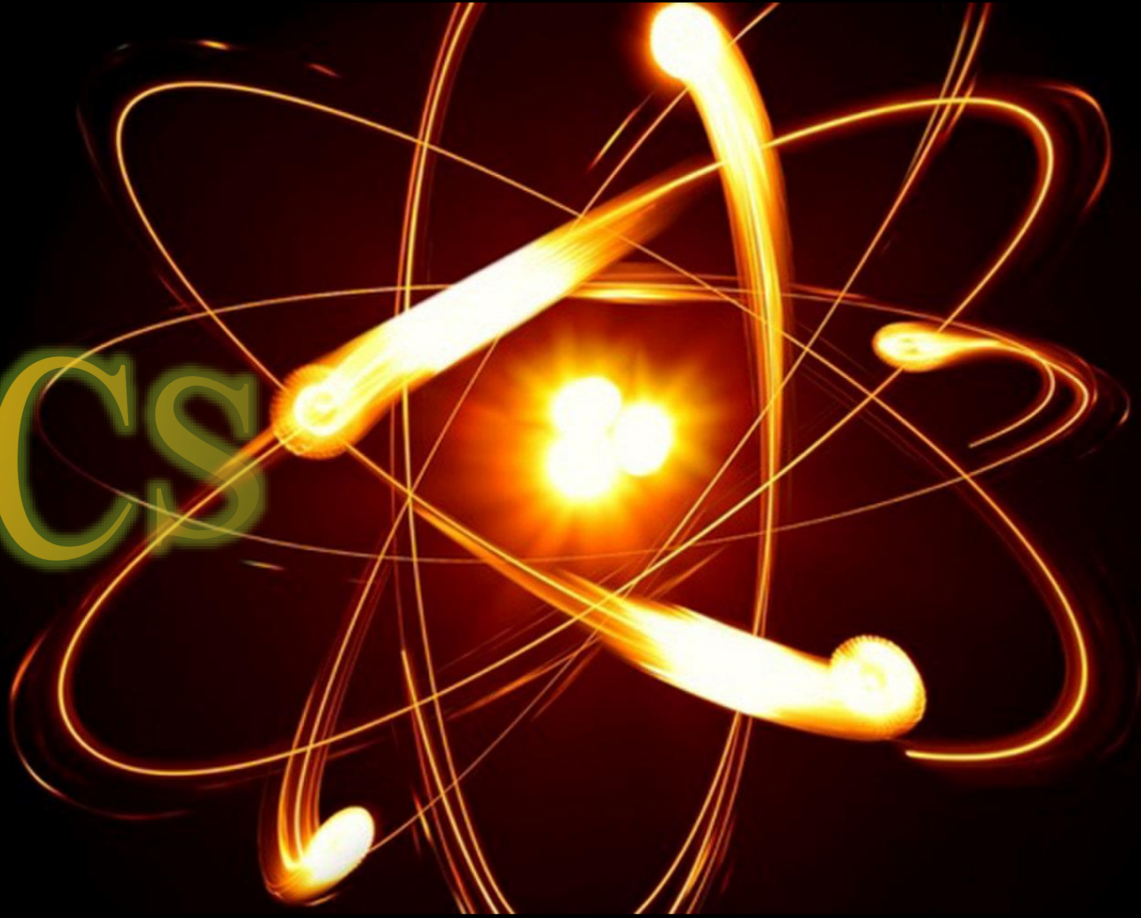
PHYSICS



西南交通大學 Southwest Jiaotong University

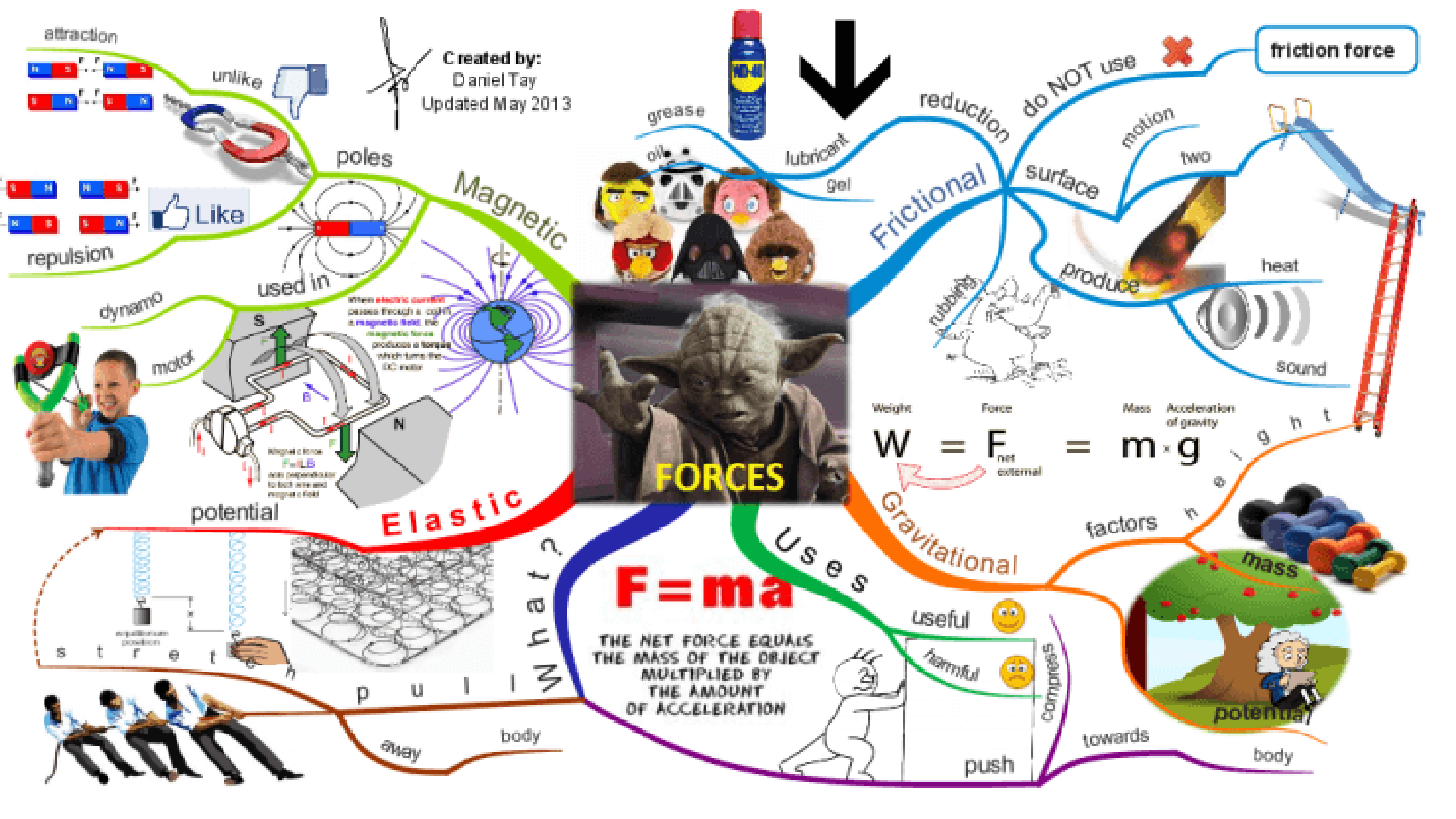
Physics 1: **Mechanics and Waves**

Week 2 – Introduction

2023.2

QQ group: 776916994

cyjing@swjtu.edu.cn



Created by:
Daniel Tay
Updated May 2013
FORCES
Magnetic
poles
attraction
unlike
Like
repulsion
used in
dynamo
motor
S
N
Frictional
reduction
lubricant
grease
oil
gel
WD-40
do NOT use
friction force
surface
motion
two
produce
heat
sound
rubbing
Weight
Force
Mass
Acceleration of gravity
W = F net external = m · g
Gravitational
factors
height
mass
potential
towards
body
Uses
useful
harmful
compress
push
F=ma
THE NET FORCE EQUALS THE MASS OF THE OBJECT MULTIPLIED BY THE AMOUNT OF ACCELERATION
What?
pull
away
body
Elastic
potential
stretch

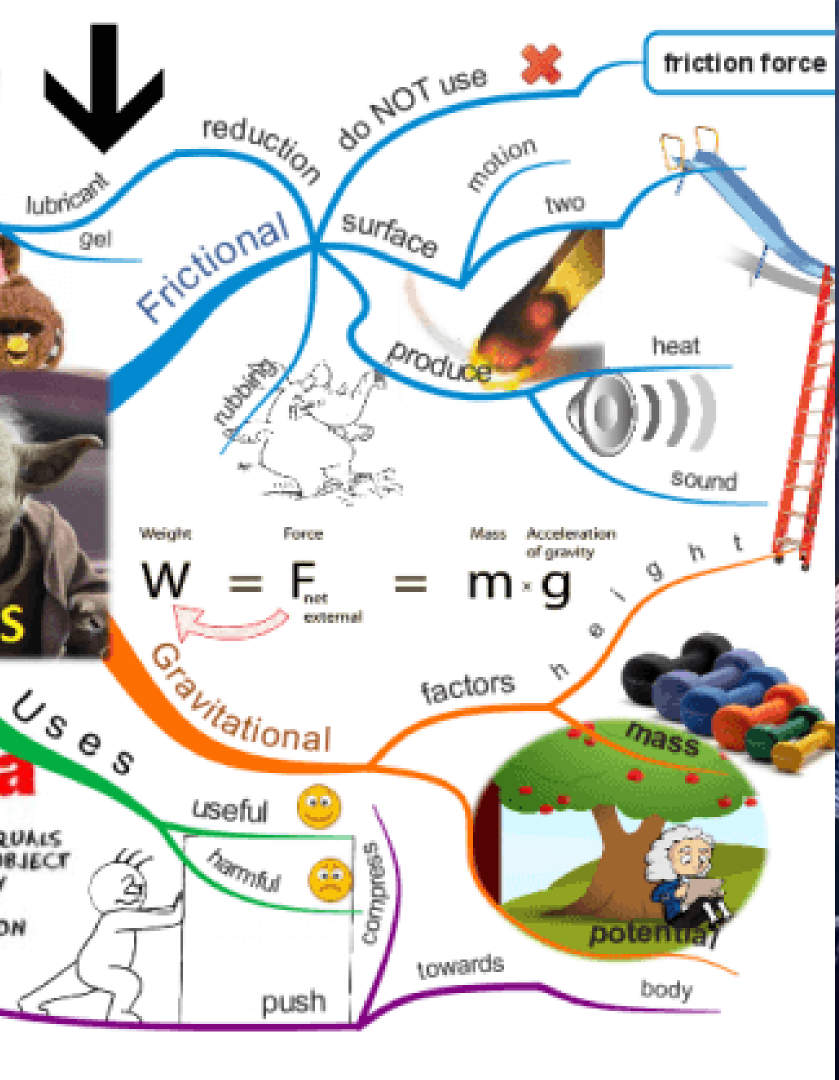
Connections in brains

For Knowledge，

If the brain,

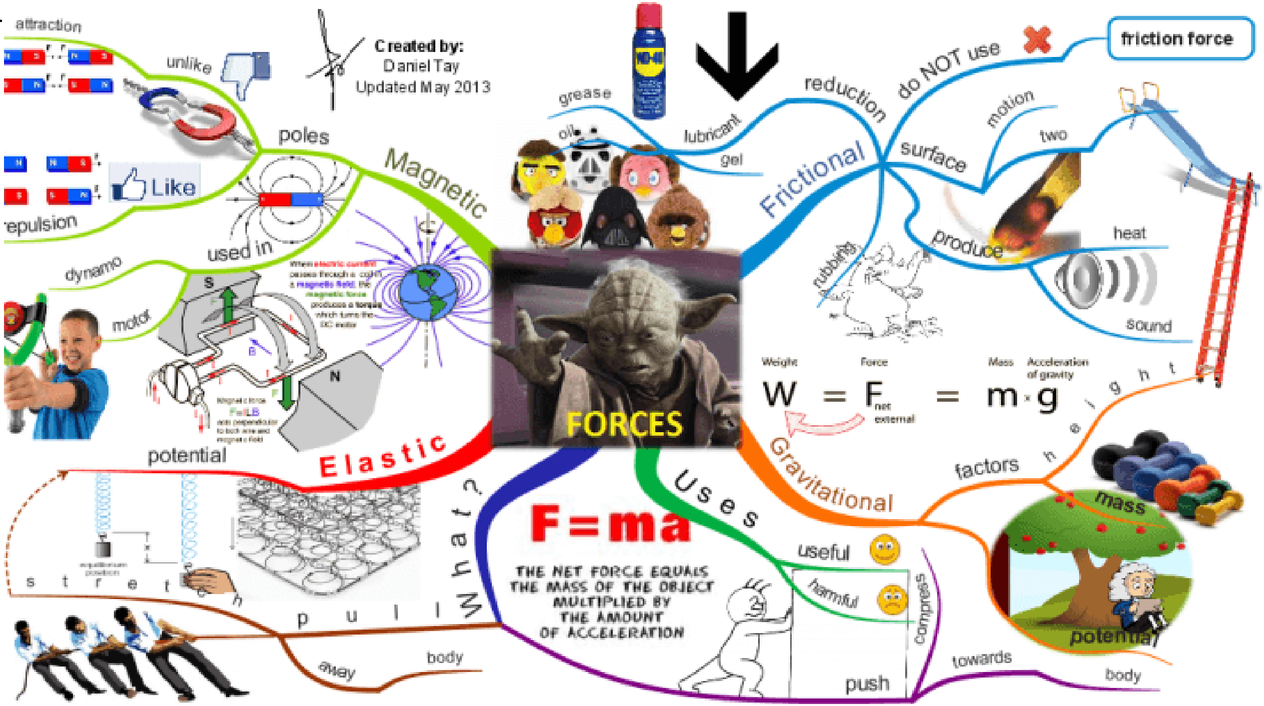
Just See or hear
Can not be stored
permanently

Build connections

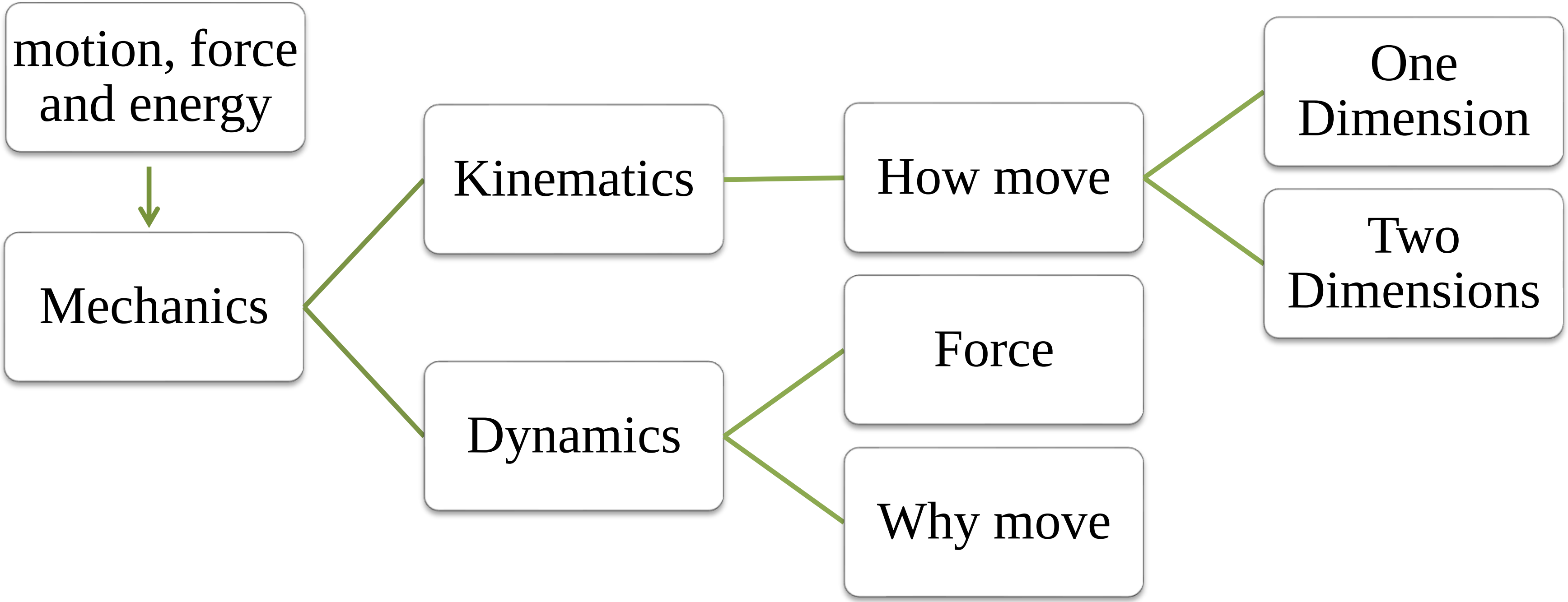

friction force
do NOT use
reduction
lubricant
gel
Frictional
surface
motion
two
rubbing
produce
heat
sound
Weight
Force
Mass
Acceleration of gravity
W = F net external = m · g
height
factors
mass
Gravitational
potential
Uses
useful
harmful
compress
towards
body
push

Mind map

Draw a mind map for what we have learned After our lectur



Review



motion, force and energy
Mechanics
Kinematics
Dynamics
How move
Force
Why move
One Dimension
Two Dimensions

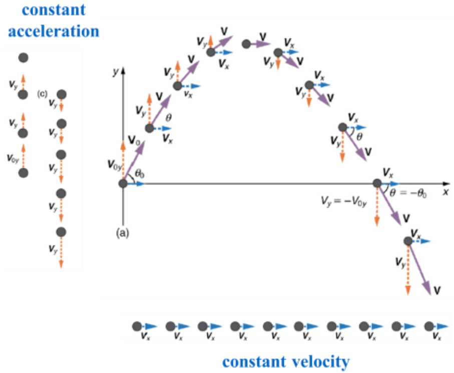
Review

$$\bar{v} = \frac{(v_0 + v_f)}{2}$$

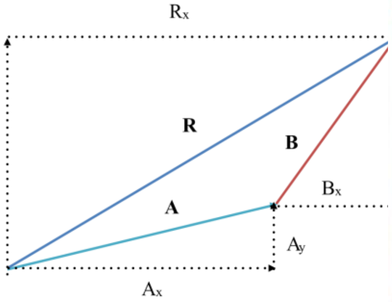
$$v_f = v_0 + at$$

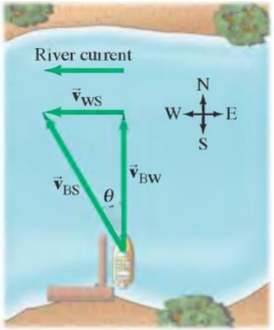
$$x_f = x_0 + v_0 t + \frac{at^2}{2}$$

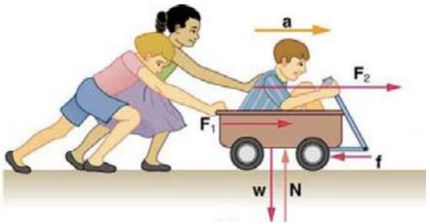
$$v_f^2 = v_0^2 + 2a(x_f - x_0)$$

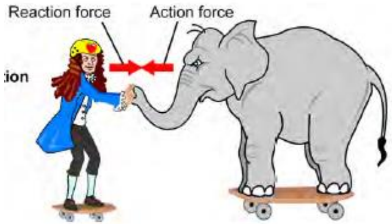


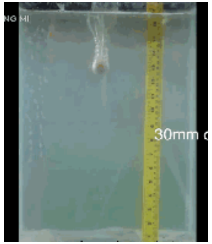
- motion, force and energy
  - Mechanics
    - Kinematics
      - How move
        - One Dimension
        - Two Dimensions
    - Dynamics
      - Force
      - Why move











Physics 1: Mechanics and Waves

Week 8 – Momentum and the conservation of Momentum

崔雅静
Cathy

2023.4

Rocket Propulsion

What is the physics principle to :

- **speed up the rocket?**
- **get the position of the abandoned part of the rocket?**

Feelings

Do you feel the same, when they are moving towards you?

Rhinoceros： 3000 kg
Running at 40 km/h

Dragonfly： 3 g

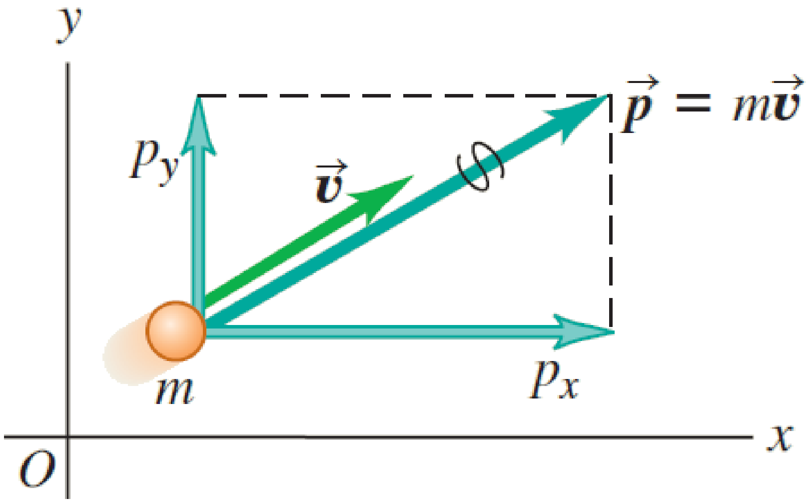
flying at 40 km/h

Pistol bullet： 3 g
flying at 1200 km/h

Momentum

Momentum of a particle: The momentum $\vec{p}$ of a particle is a vector quantity equal to the product of the particle's mass m and velocity $\vec{v}$. Newton's second law says that the net force on a particle is equal to the rate of change of the particle's momentum.

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



$$\begin{cases} p_x = mv_x \\ p_y = mv_y \\ p_z = mv_z \end{cases}$$

Momentum

How is the momentum of an object changed?

By the application of a force F!

The rate of change of momentum

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

Differentiate both sides with respect to time

$$\frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = m\frac{d\vec{v}}{dt} = m\vec{a}$$

Newton's second law?

$$\boxed{\vec{F}_{net} = \frac{d\vec{p}}{dt}} \xrightarrow{v \ll c} \boxed{\vec{F} = m\vec{a}}$$

Momentum

The total force acting on an object = time rate of change of momentum.

$$\boxed{\vec{F}_{net} = \frac{d\vec{p}}{dt}}$$ is more general than $$\boxed{\vec{F} = m\vec{a}}$$

because it allows for the mass m to change with time also!

Example: rocket motion! The Rain drop

Impulse

$$\vec{F}_{net} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t} = \frac{\mathrm{d}(m\vec{v})}{\mathrm{d}t}$$

Differential form

$$\vec{F}_{net}\mathrm{d}t = \mathrm{d}\vec{p} = \mathrm{d}\,(m\vec{v})$$

$$\int_{t_1}^{t_2} \vec{F}_{net}\mathrm{d}t = \vec{p}_2 - \vec{p}_1 = m\vec{v}_2 - m\vec{v}_1$$

Impulse

$$\vec{I} = \int_{t_1}^{t_2} \vec{F} dt \xRightarrow{net\ force} \Delta\vec{p}$$

Integral form

Discussion

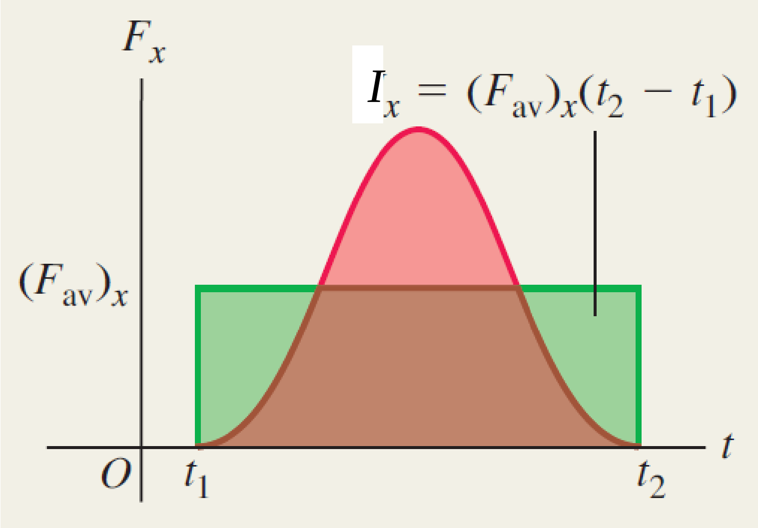
(1) Impulse is a vector, also a process quantity.

the impulse - linear momentum theorem

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

(2) The average force over a time interval

$$\vec{I} = \int_{t_1}^{t_2} \vec{F}\mathrm{d}t \quad = \bar{\vec{F}}(t_2 - t_1) = \bar{\vec{F}}\Delta t$$



Impulse-momentum theorem

Net linear impulse delivered to a particle equals the change in linear momentum of the particle

$$\vec{I} = \Delta\vec{p} = \vec{p}_{\mathrm{f}} - \vec{p}_{\mathrm{i}}$$

Descriptions:

(1) F should be the sum of all external forces. When the force is constant, the direction of I is as same as the force; if F is variable, the direction of I is determined by the integral of $\int \vec{F}\mathrm{d}t$.

(2) Both $\vec{I}$ and $\vec{\boldsymbol{P}}$ are vectors. They have same units and dimensions. This theorem is only hold for IRF.

Impulse-momentum theorem

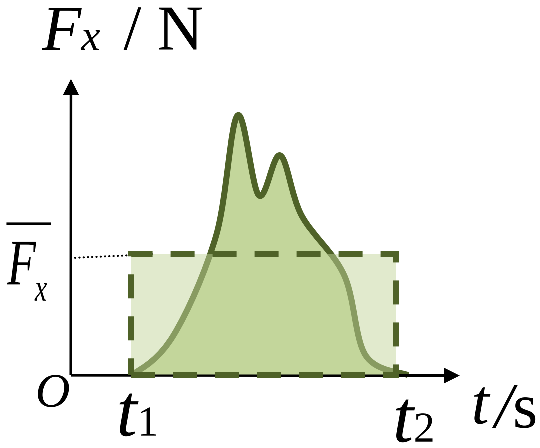
(3) In reality, one often use its component form:

$$\vec{I} = I_x\vec{i} + I_y\vec{j}$$

$$\begin{cases} I_x = \int_{t_i}^{t_f} F_x \mathrm{d}t = mv_{fx} - mv_{ix} \\ I_y = \int_{t_i}^{t_f} F_y \mathrm{d}t = mv_{fy} - mv_{iy} \end{cases}$$

(4) The magnitude of the impulse is equal to the area under the $F(t)$ curve.

$$\overline{F}_x = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} F_x \mathrm{d}t$$



Example

What is the average force on the ball?

Before it stopped, the time the ball is in contact with the racket: **5 ms**

***m* = 0.057 Kg** ***v* = 58 m/s**

Example : Venus Williams' service in 2007: 209 km/h (58 m/s)

Impulse $I = \Delta p = m\Delta v = 0.057\,kg \times 58\,m/s = 3.3\,kg \cdot m/s$

$$F = \frac{I}{\Delta t} = \frac{3.3}{0.005} = 660\ \mathrm{N}$$

What's the weight of a 60-kg person?

Less injury

Impulse-momentum theorem

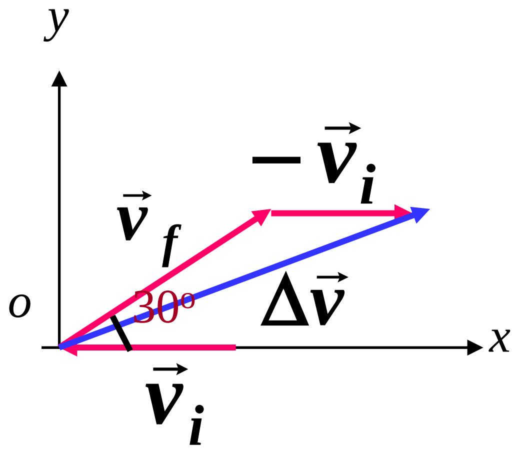
Example

A pitched 140g baseball, in horizontal flight with a speed of 39m/s, is struck by a bat and the ball leaves the bat with a speed of 45m/s, at an upward angle of 30° (a) what impulse act on the ball? (b) If the impact time is 1.2ms, what average force act on the baseball.

(a) $$\vec{I} = \vec{p}_f - \vec{p}_i = m(\vec{v}_f - \vec{v}_i)$$

$$\vec{I} = 10.92\vec{i} + 3.15\vec{j} \ (\text{kg}\cdot\text{m/s})$$

$$\begin{cases} I = \sqrt{I_x^2 + I_y^2} = 11.4 \ (\text{kg}\cdot\text{m/s}) \\ \theta = \tan^{-1}(I_y / I_x) = 16^\circ \end{cases}$$



Example

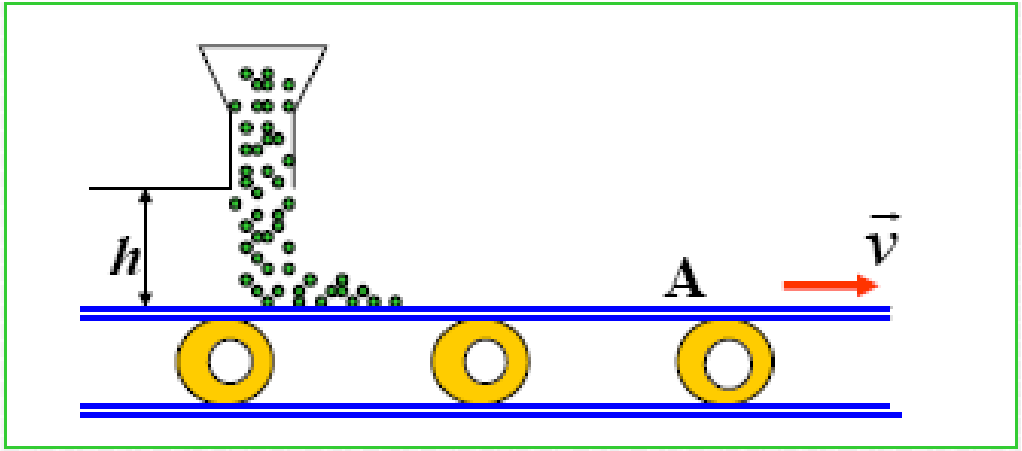
A pitched 140g baseball, in horizontal flight with a speed of 39m/s, is struck by a bat and the ball leaves the bat with a speed of 45m/s, at an upward angle of 30^o (a) what impulse act on the ball? (b) If the impact time is 1.2ms, what average force act on the baseball.

(b) $\because\ F_{avg} \cdot \Delta t = I \qquad \therefore\ F_{avg} = \frac{I}{\Delta t} = \frac{11.4}{0.0012} = 9500\ (\mathrm{N})$

Discussion: Comparing the F_{avg} with the F_{ext}.

Example 2

Coal drops from a stationary hopper of height 2.0 m at rate of 40 kg/s on to conveyer belt moving with a speed of 2.0 m/s, find the average force exerted on the belt by the coal in the process of the transportation. (Ignore the gravity)



Example 2

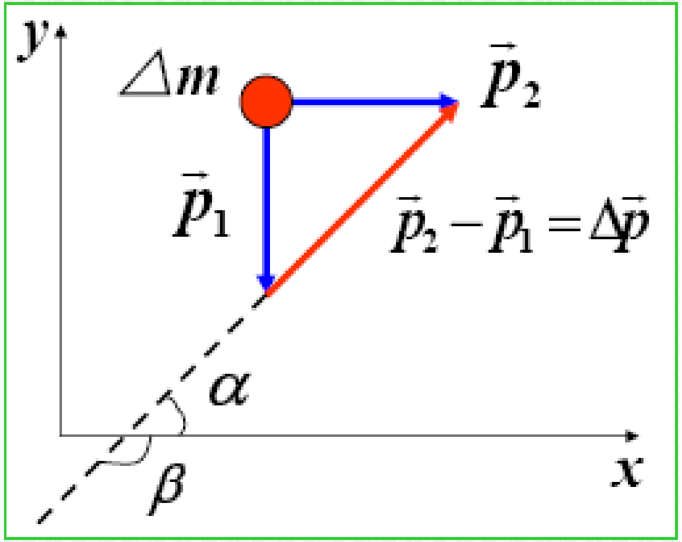
Choose the mass element of the coal as the particle

$$\Delta p_x = p_{2x} - p_{1x} = p_2 = \Delta m v$$

$$\Delta p_y = p_{2y} - p_{1y} = p_1 = \Delta m v'$$

$$= \Delta m \sqrt{2gh}$$

$$v = 2.0\, m/s$$



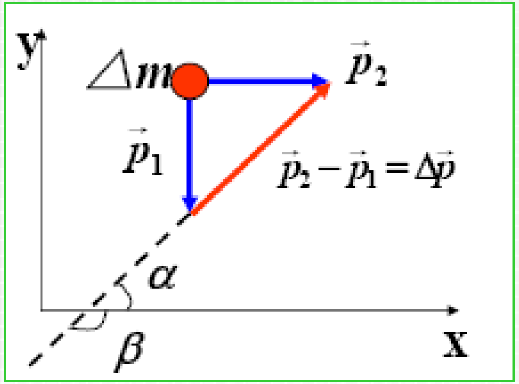
According to the impulse-momentum theorem $\vec{I} = \int_{t_i}^{t_f} \vec{F} dt = \vec{F}_{av} \Delta t = \Delta \vec{p}$

Example 2

$$F_{xav} = \frac{\Delta p_x}{\Delta t} = \frac{p_2}{\Delta t} = \frac{\Delta m v}{\Delta t} = qv = 80\ (N)$$

$$F_{yav} = \frac{\Delta p_y}{\Delta t} = \frac{p_1}{\Delta t} = \frac{\Delta m}{\Delta t} = q\sqrt{2gh} = 125.2\ (N)$$

$$F_{av} = \sqrt{F_{xav} + F_{yav}} = 149\ (N)$$



The angle with respect to the x axis

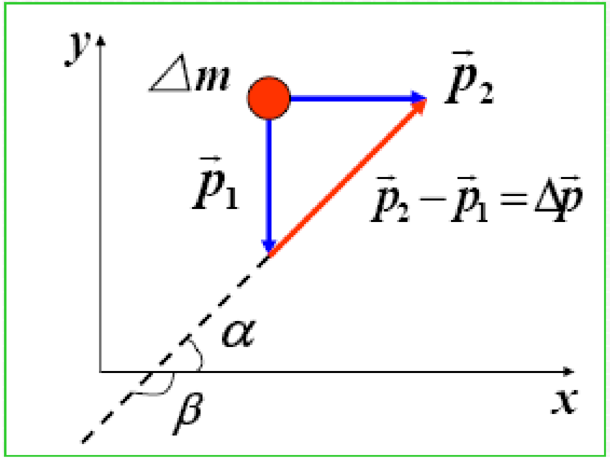
$$\alpha = \tan^{-1}\frac{F_{yav}}{F_{xav}} = \tan^{-1}\frac{125.2}{80} = 57.4^\circ$$

Example 2

the average force exerted on the belt by the coal

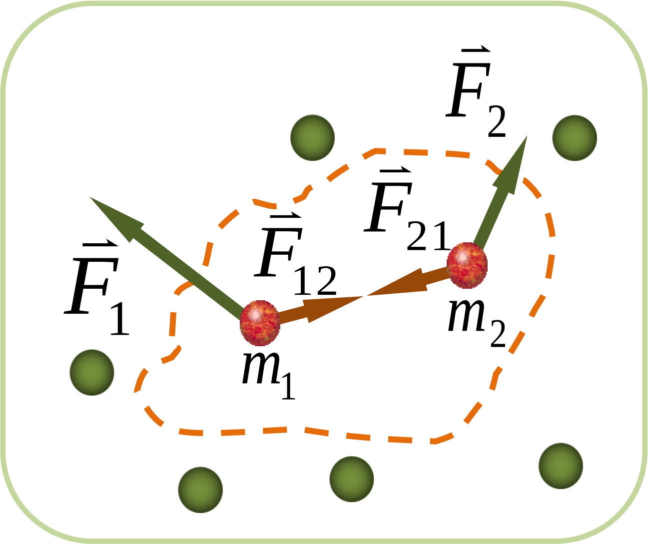
$$F' = 149(N)$$

$$\beta = 180° - 57.4° = 122.6°$$



Internal and External Force

Internal force	Objects within the system exert on other objects in the system.
External force	Forces on objects of the system are exerted by objects outside the system.



$$\vec{F}_{ext} = \sum_i \vec{F}^i_{ext}$$

$$\vec{F}_{int} = \sum_i \vec{F}^i_{int} \equiv 0$$

$$\vec{F}_{ext} = \sum_{i=1}^{N} \vec{F}^i_{ext} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t}$$

Conservation of Momentum

For a system of particles, the total momentum changes …

$$\Delta\vec{\boldsymbol{p}} = \vec{\boldsymbol{J}}_{\boldsymbol{ext}} = \int_{t_1}^{t_2} \vec{\boldsymbol{F}}_{\boldsymbol{ext}} \boldsymbol{dt}$$

Has nothing to do with internal forces

$$\boldsymbol{if}\ \ \vec{F}_{ext} = 0,\ \boldsymbol{then}\ \vec{P} = \sum_{i} \vec{P}_i = \text{constant}$$

When the net external force on a system is zero, the total momentum remains constant

---- ***the law of conservation of momentum***

Conservation of Momentum

For a system of particles, the total momentum changes …

$$\Delta\vec{\boldsymbol{p}} = \vec{\boldsymbol{J}}_{\boldsymbol{ext}} = \int_{t_1}^{t_2} \vec{\boldsymbol{F}}_{\boldsymbol{ext}} \boldsymbol{dt}$$

Has nothing to do with internal forces

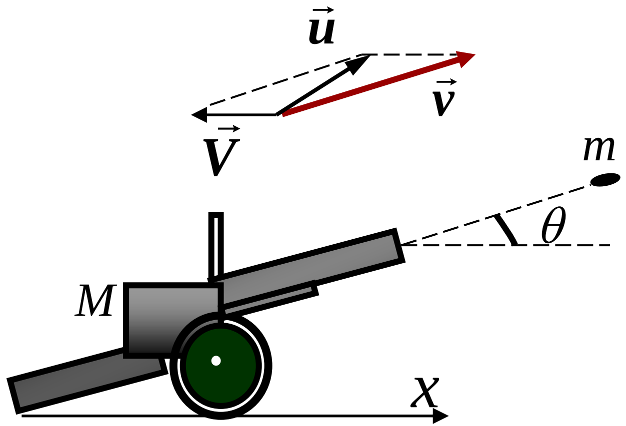
$$\boldsymbol{if}\ \ \vec{F}_{ext} = 0,\ \boldsymbol{then}\ \vec{P} = \sum_{\mathrm{i}} \vec{P}_i = \text{constant}$$

No exceptions to this law have been discovered. So it is considered to be more fundamental than Newton's second law in both macroscopic and microscopic physical worlds.

Example 1

A gun mounted on wheels of mass M shoots a projectile of mass m with muzzle (出口) velocity of v (对炮车) at an angle θ above the horizontal. Find the horizontal recoil (反冲) speed V of the gun (求：炮车反冲速度 V). (neglect friction)

$$\because \quad \vec{u} = \vec{v} + \vec{V} \qquad\qquad u_x = v\cos\theta - V$$



$$-MV + m(v\cos\theta - V) = 0$$

The recoil speed: $$V = \frac{m}{m+M} v\cos\theta$$

Explanations

(1) Conditions of validity: $\boxed{\sum \vec{F}_{\text{ext}} = 0, \ \text{or} \quad \vec{F}_{\text{ext}} << \vec{F}_{\text{int}}}$

Net forces can be neglected in the case of collision, strike, explosion, … ,and so on.

(2) Conclusion: Only external force can change the state of motion of a system.

(3) If component of net external force on a system along an axis is zero, the component of *momentum of the system along that axis does not change.*

(4) It is only suitable for inertial reference frame.

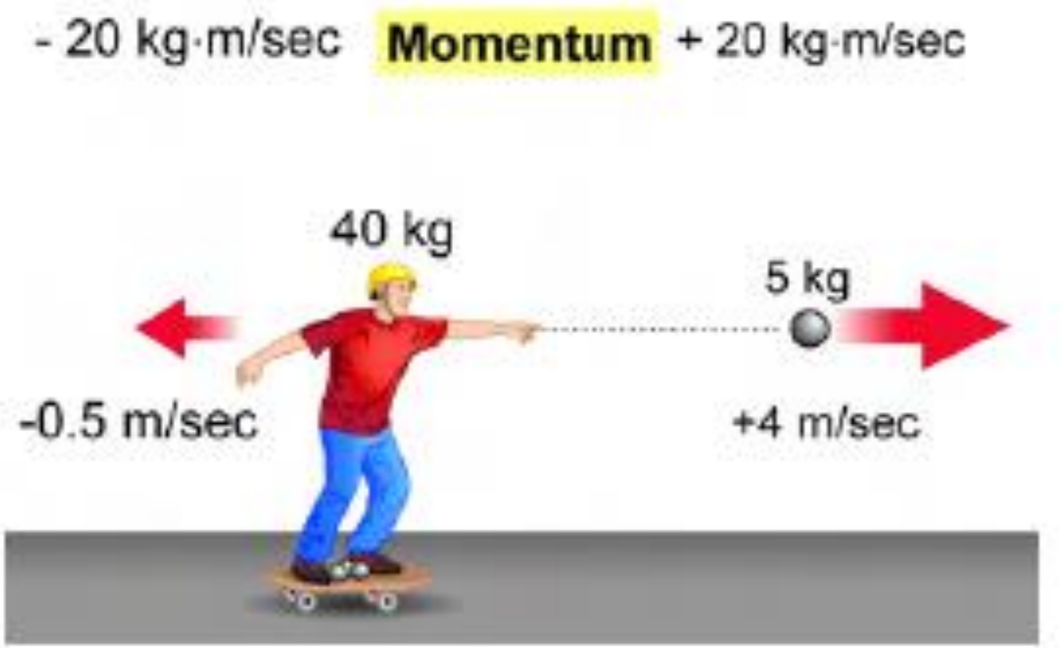
Conservation of Momentum

No external force

Momentum conserved

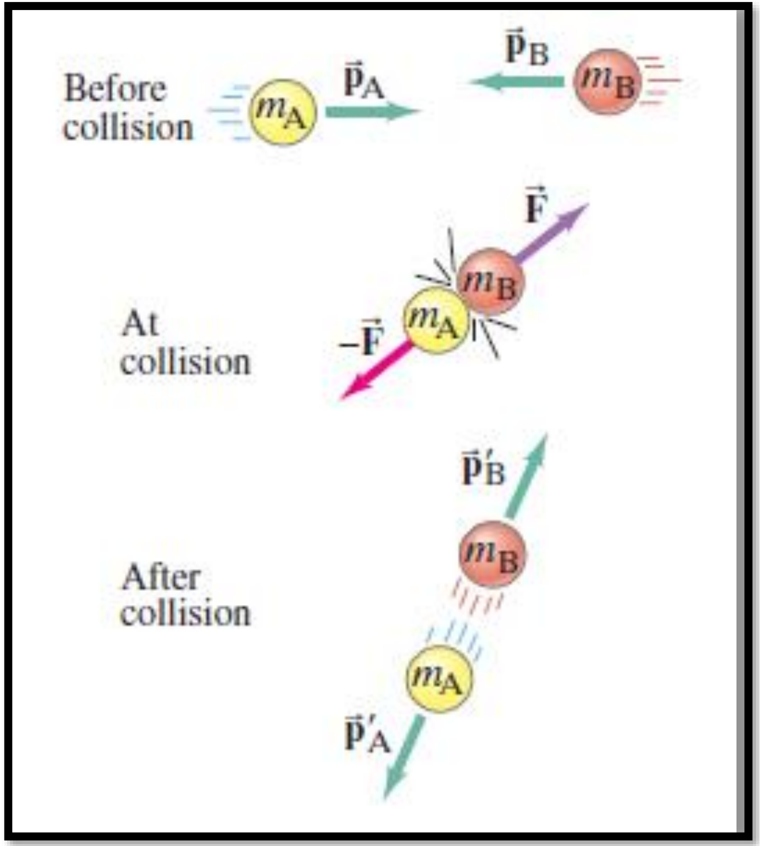
Discovered Experimentally

Can be derived

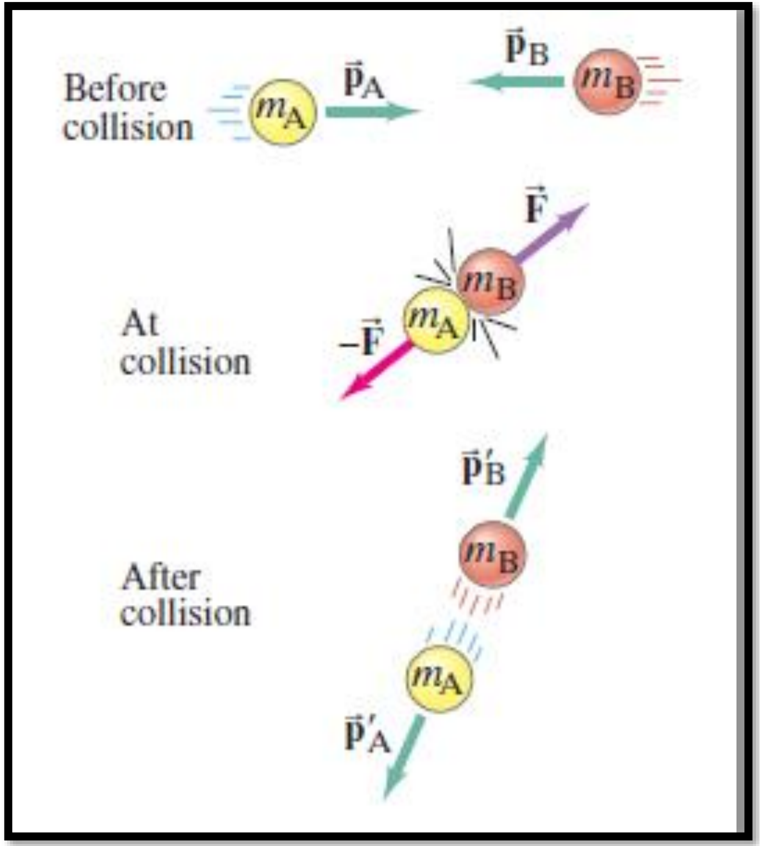


BUT ONLY IN 'ISOLATED' SYSTEMS!

Conservation of Momentum



Conservation of Momentum



$$\vec{F} = \frac{\Delta \vec{p}_B}{\Delta t} = \frac{\vec{p}'_B - \vec{p}_B}{\Delta t}$$

$$-\vec{F} = \frac{\Delta \vec{p}_A}{\Delta t} = \frac{\vec{p}'_A - \vec{p}_A}{\Delta t}.$$

$$0 = \frac{\Delta \vec{p}_B + \Delta \vec{p}_A}{\Delta t} = \frac{(\vec{p}'_B - \vec{p}_B) + (\vec{p}'_A - \vec{p}_A)}{\Delta t}$$

$$\vec{p}'_B - \vec{p}_B + \vec{p}'_A - \vec{p}_A = 0,$$

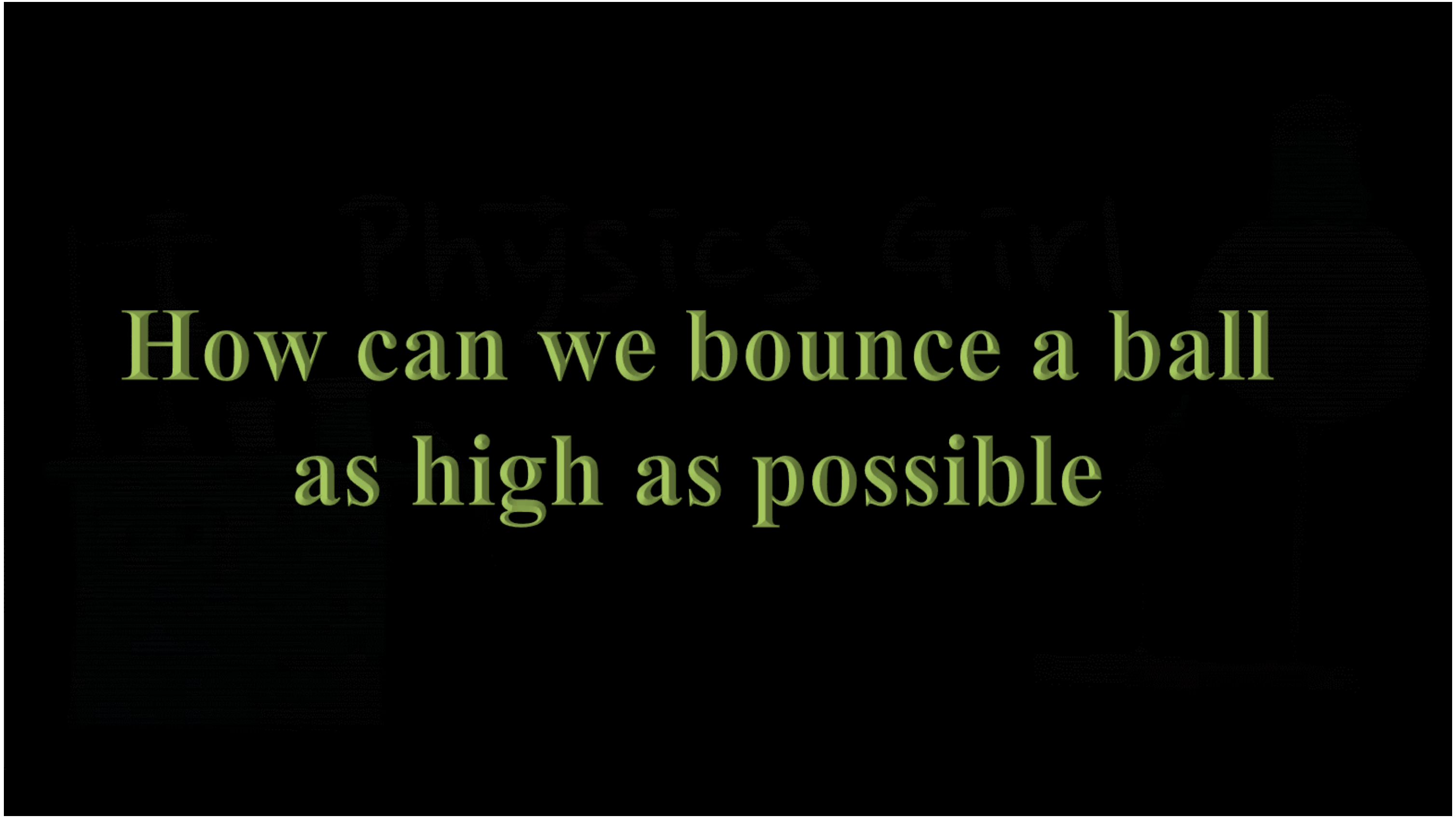
$$\vec{p}'_A + \vec{p}'_B = \vec{p}_A + \vec{p}_B.$$

Tell yourself you can

Try to derive
on the lecture

I can

Bouncing ball



Problem-Solving Strategy: Conservation of Momentum

IDENTIFY *the relevant concepts:* Confirm that the vector sum of the external forces acting on the system of particles is zero. If it isn't zero, you can't use conservation of momentum.

Problem-Solving Strategy: Conservation of Momentum

SET UP *the problem* using the following steps:

1. Treat each body as a particle. Draw "before" and "after" sketches, including velocity vectors. Assign algebraic symbols to each magnitude, angle, and component. Use letters to label each particle and subscripts 1 and 2 for "before" and "after" quantities. Include any given values such as magnitudes, angles, or components.
2. Define a coordinate system and show it in your sketches; define the positive direction for each axis.
3. Identify the target variables.

Problem-Solving Strategy: Conservation of Momentum

EXECUTE *the solution:*

1. Write an equation in symbols equating the total initial and final x-components of momentum, using $p_x = mv_x$ for each particle. Write a corresponding equation for the y-components. Velocity components can be positive or negative, so be careful with signs!
2. Solve your equations to find the target variables.

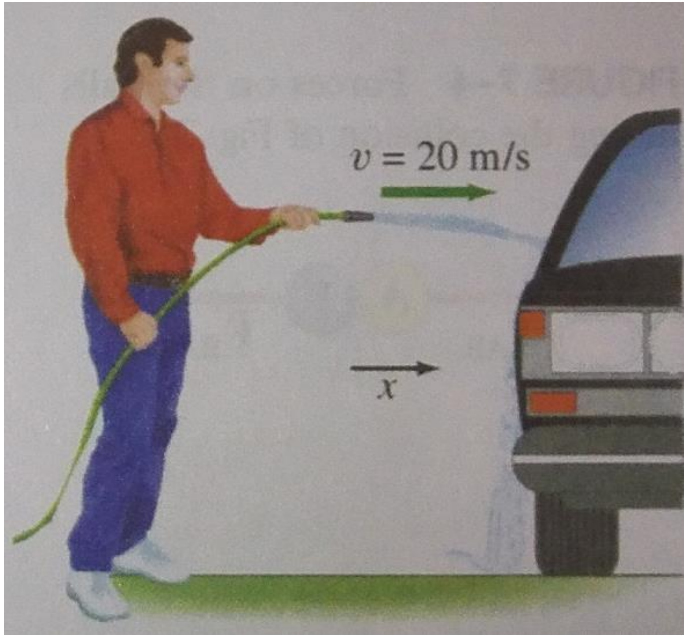
Problem-Solving Strategy: Conservation of Momentum

EVALUATE *your answer:* Does your answer make physical sense? If your target variable is a certain body's momentum, check that the direction of the momentum is reasonable.

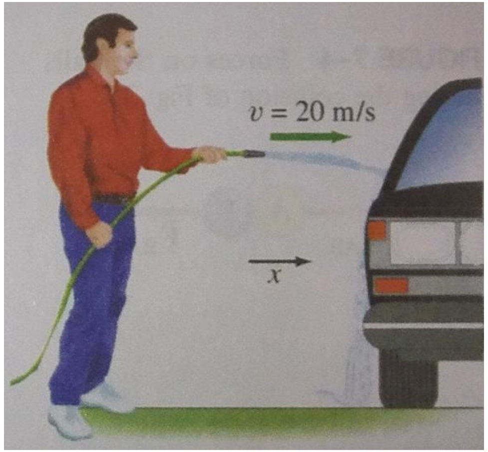
Example – washing a car

Water leaves a hose at a rate of 1.5 kg/s with a speed of 20 m/s and is aimed at the side of a car, which stops it. (We ignore any splashing back.)

What is the force exerted by the water on the car?



Example – washing a car



Water leaves a hose at a rate of 1.5 kg/s with a speed of 20 m/s and is aimed at the side of a car, which stops it. (We ignore any splashing back.) What is the force exerted by the water on the car?

Force on the car (exerted by the water) = Force on the water (exerted by the car)

$$F = \frac{\Delta p}{\Delta t} = \frac{p_f - p_i}{\Delta t}$$

$$\frac{p_f}{\Delta t} = \frac{\Delta m}{\Delta t} \times v_f = 0$$

$$\frac{p_i}{\Delta t} = \frac{\Delta m}{\Delta t} \times v_i = 1.5\, kg/s \times 20 m/s$$

$$F_{car} = 30\ N$$

Reading

The law of conservation of momentum is particularly useful when we are dealing with fairly simple systems such as colliding objects and certain types of "explosions." For example, *rocket propulsion*, which we saw in Chapter 4 can be understood on the basis of action and reaction, can also be explained on the basis of the conservation of momentum. We can consider the rocket plus its fuel as an isolated system if it is far out in space (no external forces). In the reference frame of the rocket before any fuel is ejected, the total momentum of rocket plus fuel is zero. When the fuel burns, the total momentum remains unchanged: the backward momentum of the expelled gases is just balanced by the forward momentum gained by the rocket itself (see Fig. 7–6). Thus, a rocket can accelerate in empty space. There is no need for the expelled gases to push against the Earth or the air (as is sometimes erroneously thought). Similar examples of (nearly) isolated systems where momentum is conserved are the recoil of a gun when a bullet is fired (Example 7–5), and the movement of a rowboat just after a package is thrown from it.

Example – rocket propulsion problem

Mass of rocket: 1000 *kg*

Ejecting gas at a rate of 10 *kg/s*

The velocity of gas is 3000 *m/s*

Relative to the rocket

What is the propulsion force on the rocket?

What is its acceleration?

$\boldsymbol{F} = ?$

$\boldsymbol{a} = ?$

Rate - 10 kg /s

v = 3000 m/s relative to the rocket

Example – rocket propulsion problem

Force on gas = Force on rocket

$$F = \frac{\Delta p}{\Delta t} = \frac{p_f - p_i}{\Delta t}$$

$$p_i = \Delta m \times v_i$$

$$p_f = \Delta m \times v_f$$

$$\Delta p = \Delta m \times (0 - 3000 m/s)$$

$$F = \frac{\Delta m \times (-3000 m/s)}{\Delta t} = -3 \times 10^4 \, kgm/s^2$$

$$F_{propulsion} = 3 \times 10^4 N$$

$$a = \frac{F - Mg}{M} = \frac{3 \times 10^4 - 1000 \times 10}{1000} = 20 m/s^2$$

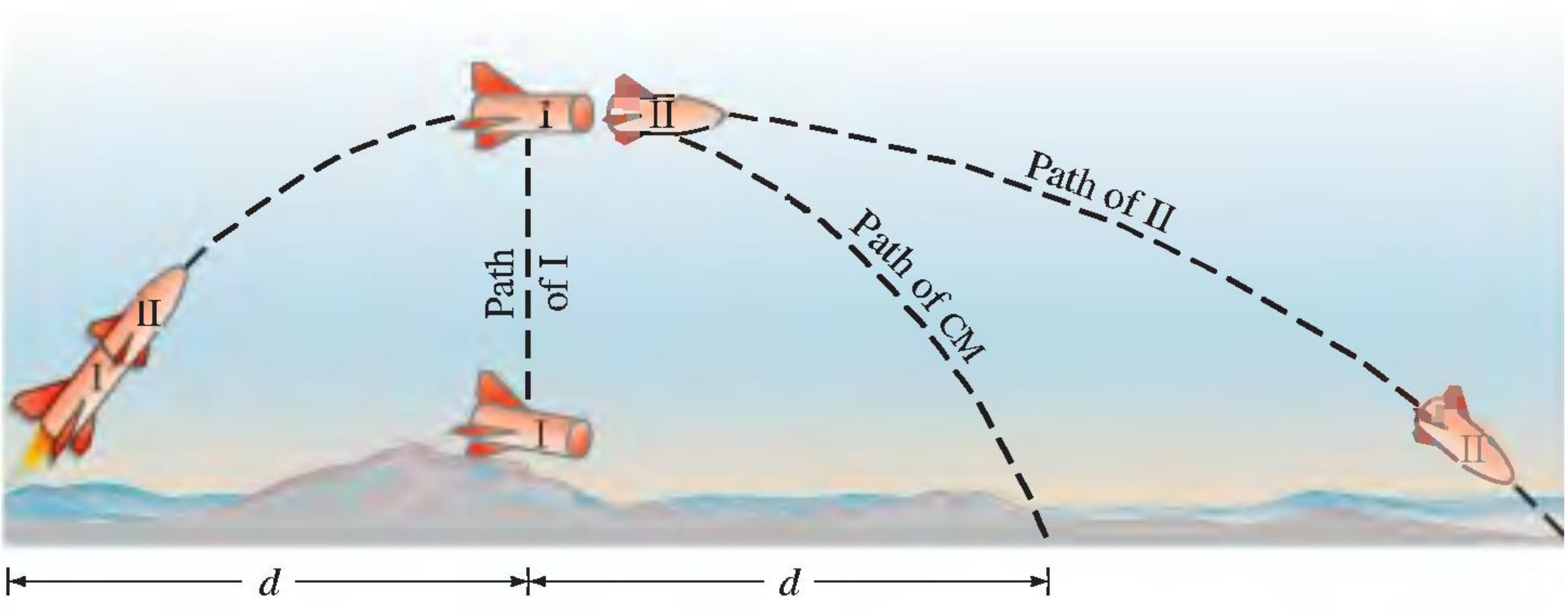
F = ?

a = ?

Rate - 10 kg /s

v = 3000 m/s relative to the rocket

CM and Translational Motion



Physics 1: **Mechanics and Waves**

Center of mass

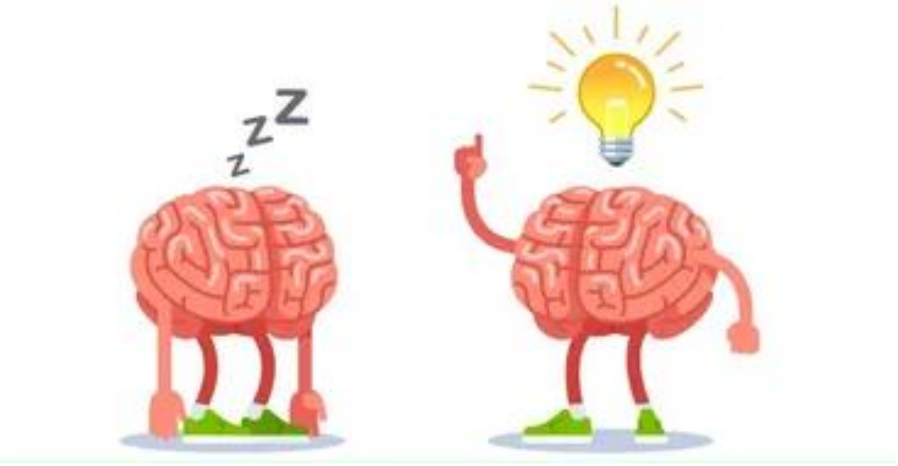
Just have a concept of it

崔雅静

Cathy

2023.4

Balance a Can?



Fixed mindset Growth mindset

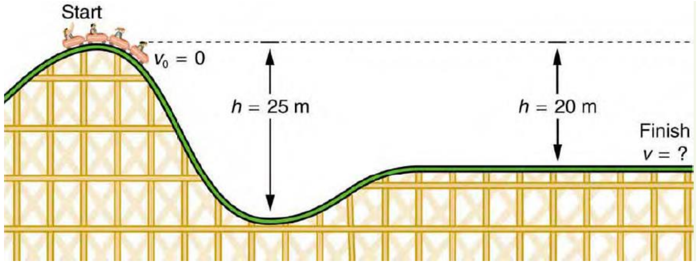
OUTLINE

WHAT IS?

WHY USE?

HOW TO USE?

How are objects simplified ?



Motion of the object

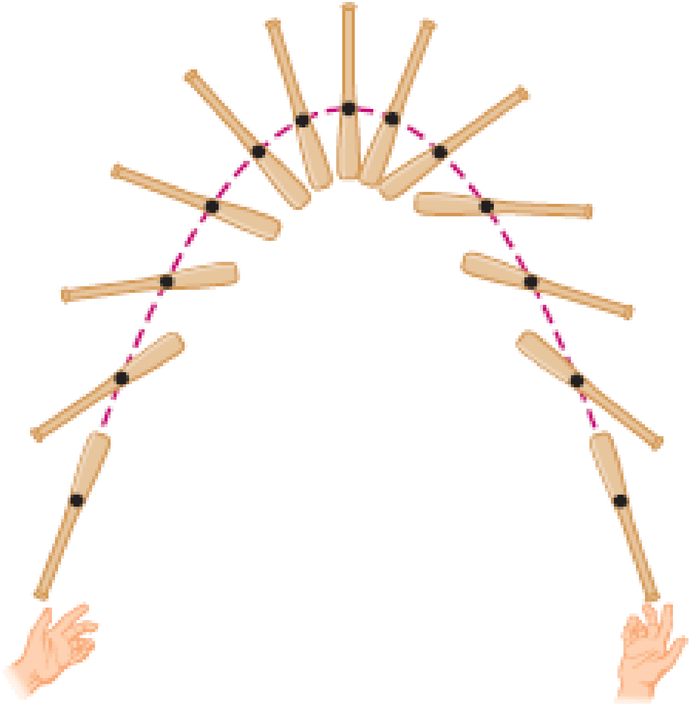
Work and Energy

Newton's laws

What?

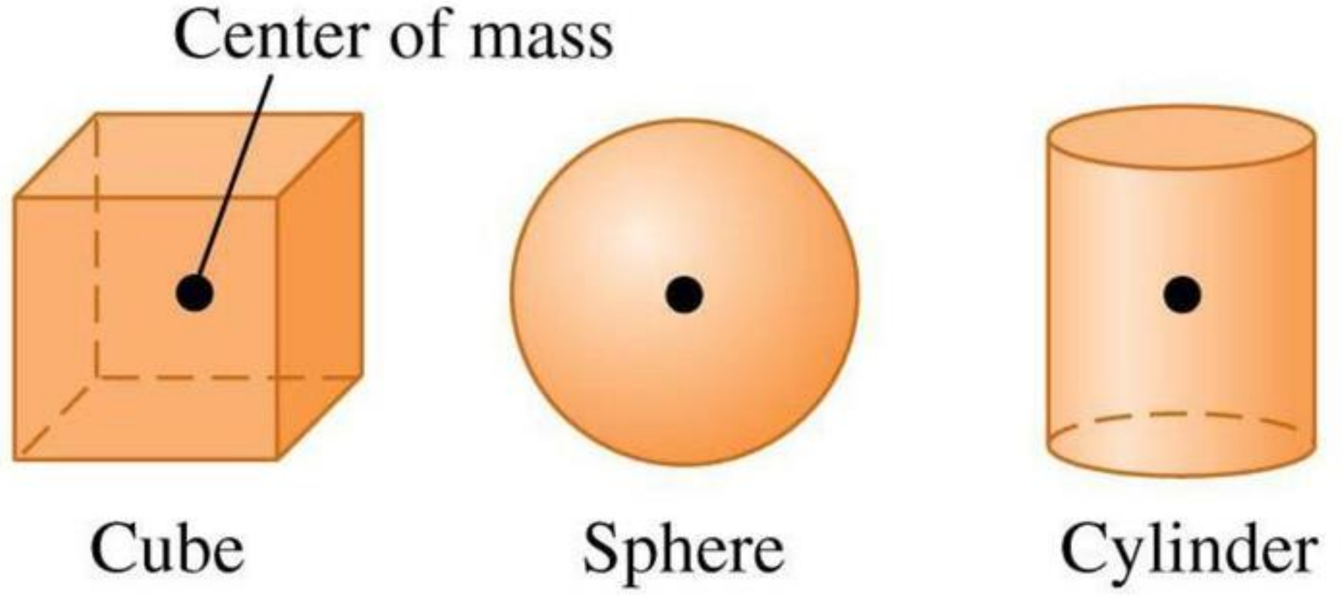
Center of mass

one point that moves in the same path that a **particle** would move



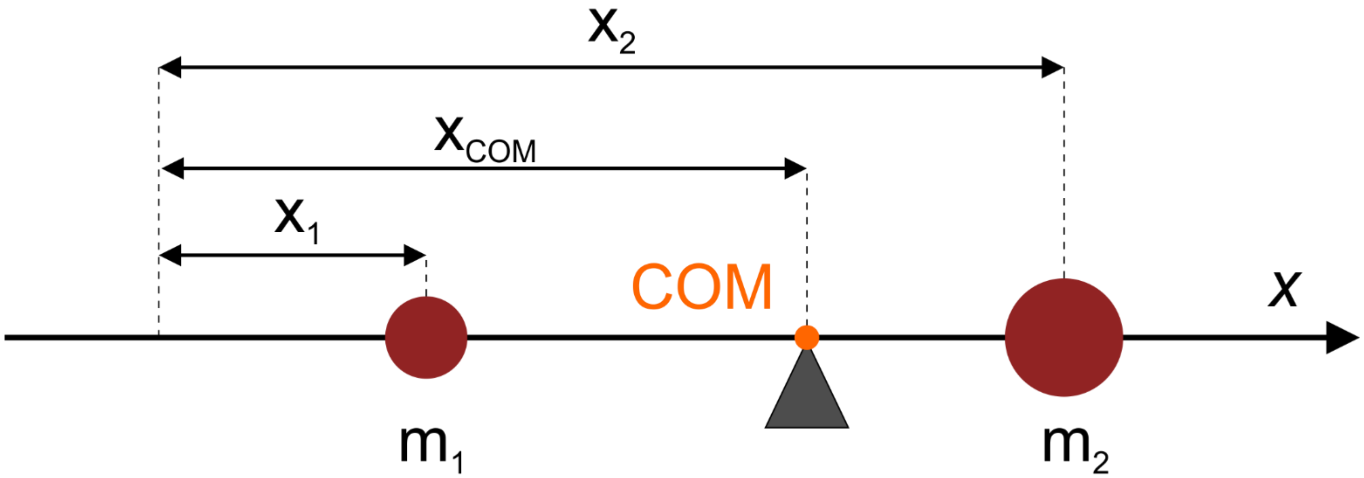
Center of Mass

Center of mass of symmetrical objects (uniform)



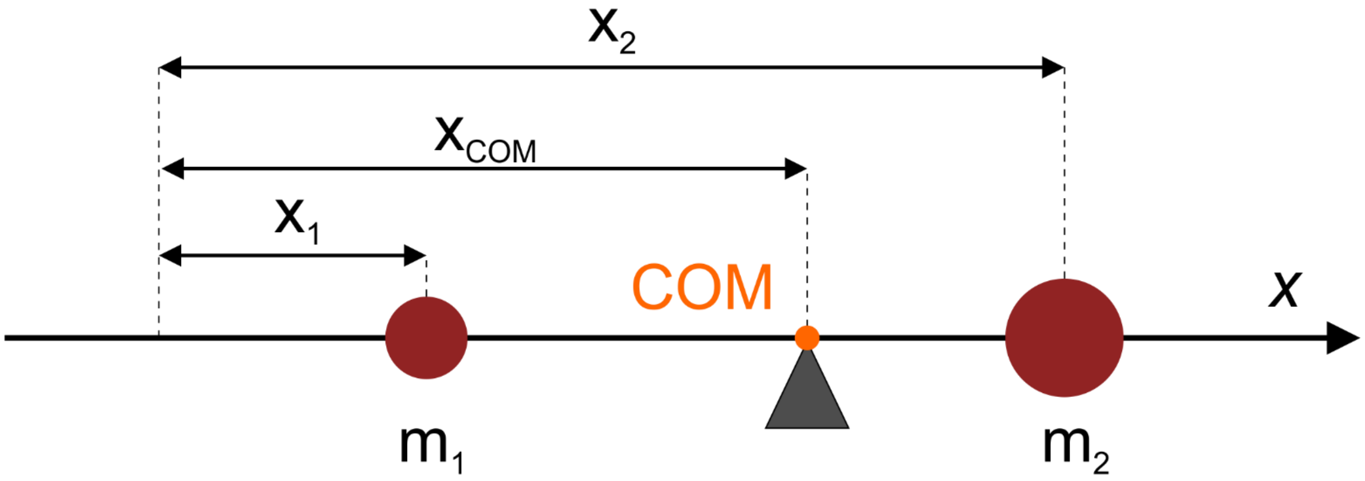
Not symmetrical

Center of mass



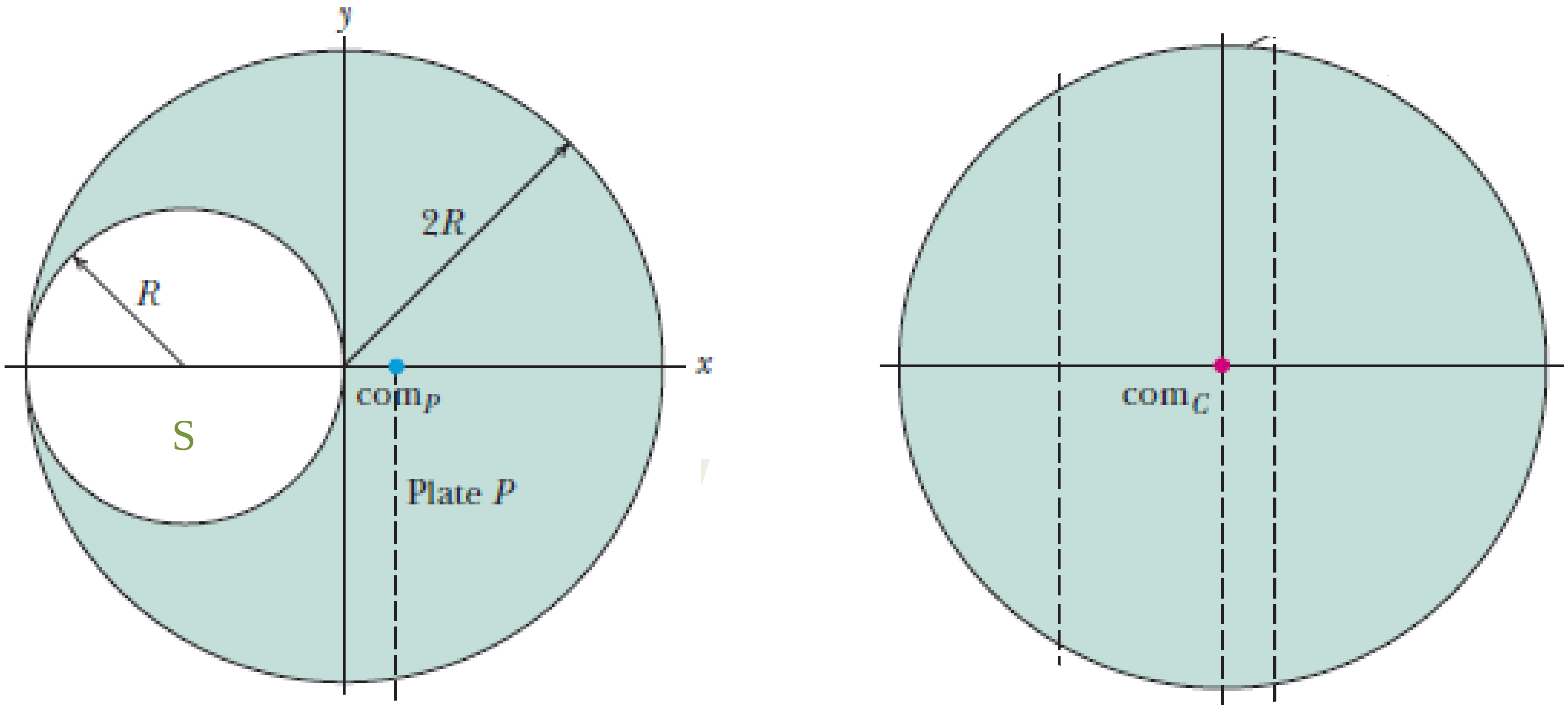
$$x_{CM} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

Center of mass

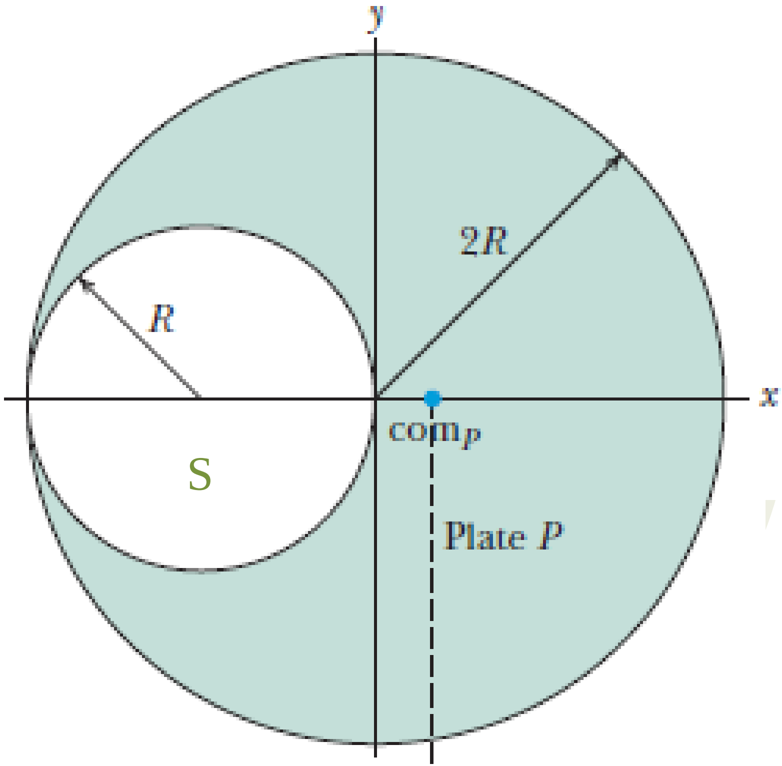


$$x_{CM} = \frac{1}{M}\sum_{i=1}^{n} m_i x_i$$

Example of Center of mass



Example of Center of mass



$$x_{S+P} = \frac{m_S x_S + m_P x_P}{m_S + m_P}$$

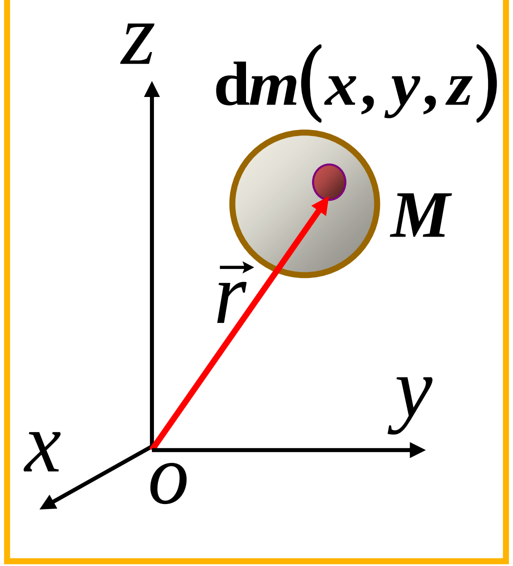
$$x_{S+P} = x_C = 0$$

$$x_P = -x_S \frac{m_S}{m_P}$$

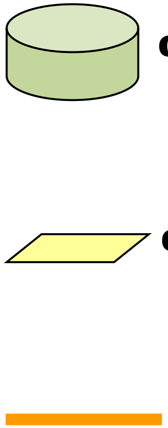
$$x_P = \frac{1}{3} R$$

The center of mass

For the common objects as essentially continuous distribution of matter



$$\vec{r}_c = \frac{\int \vec{r}\,dm}{M} \quad \begin{cases} x_c = \dfrac{\int x\,dm}{M} \\ y_c = \dfrac{\int y\,dm}{M} \\ z_c = \dfrac{\int z\,dm}{M} \end{cases}$$



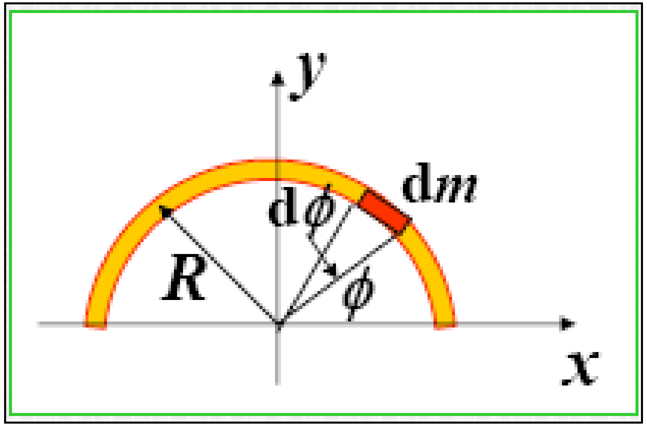
$$dm = \rho dV$$

$$dm = \sigma dS$$

$$dm = \lambda dl$$

Example

A thin strip of material is bent into the shape of a semicircle of radius *R*. Find its center of mass.



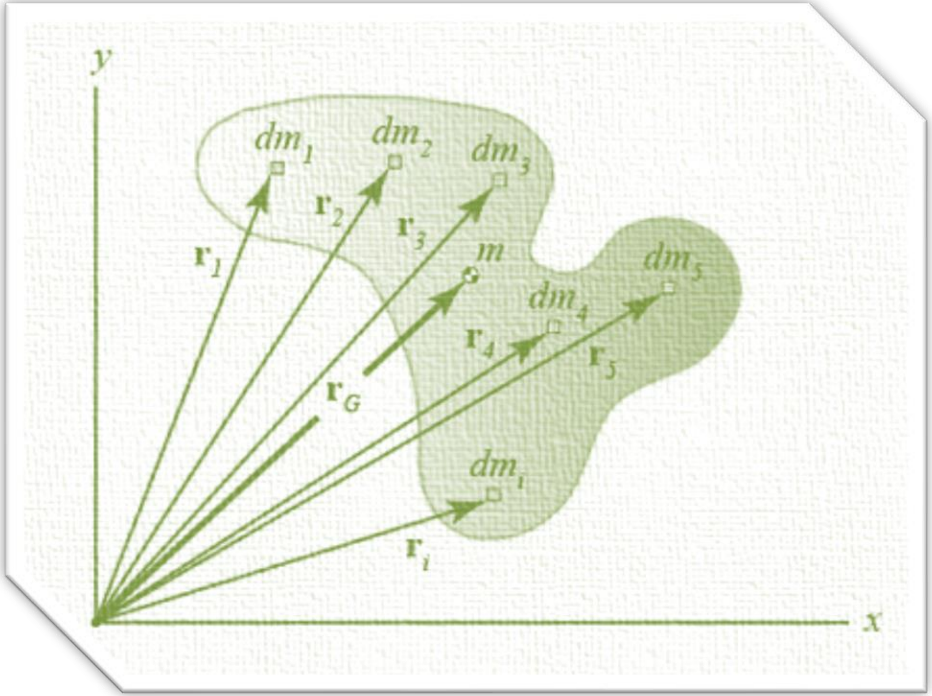
Solution:

since the symmetry, we obtained $x_{CM} = 0$

$$y_{CM} = \frac{1}{M}\int y dm = \frac{1}{M}\int_0^{\pi} (R\sin\phi)\frac{M}{\pi} d\phi$$

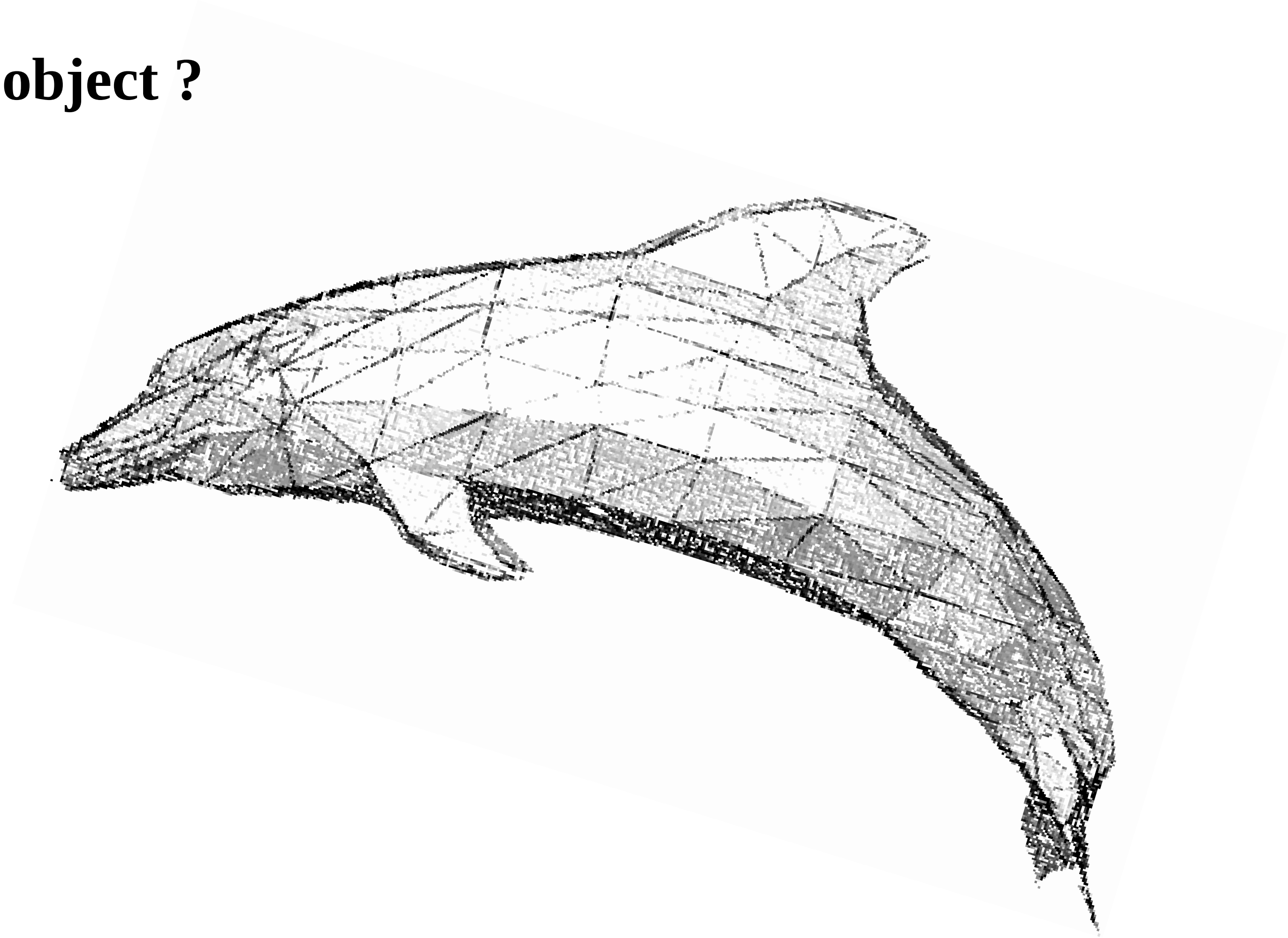
$$= \frac{R}{\pi}\int_0^{\pi} \sin\phi d\phi = \frac{2R}{\pi} = 0.637R$$

Determine Center of Mass

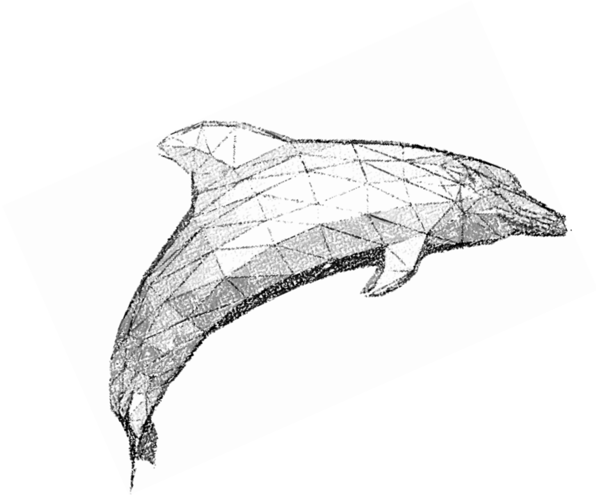


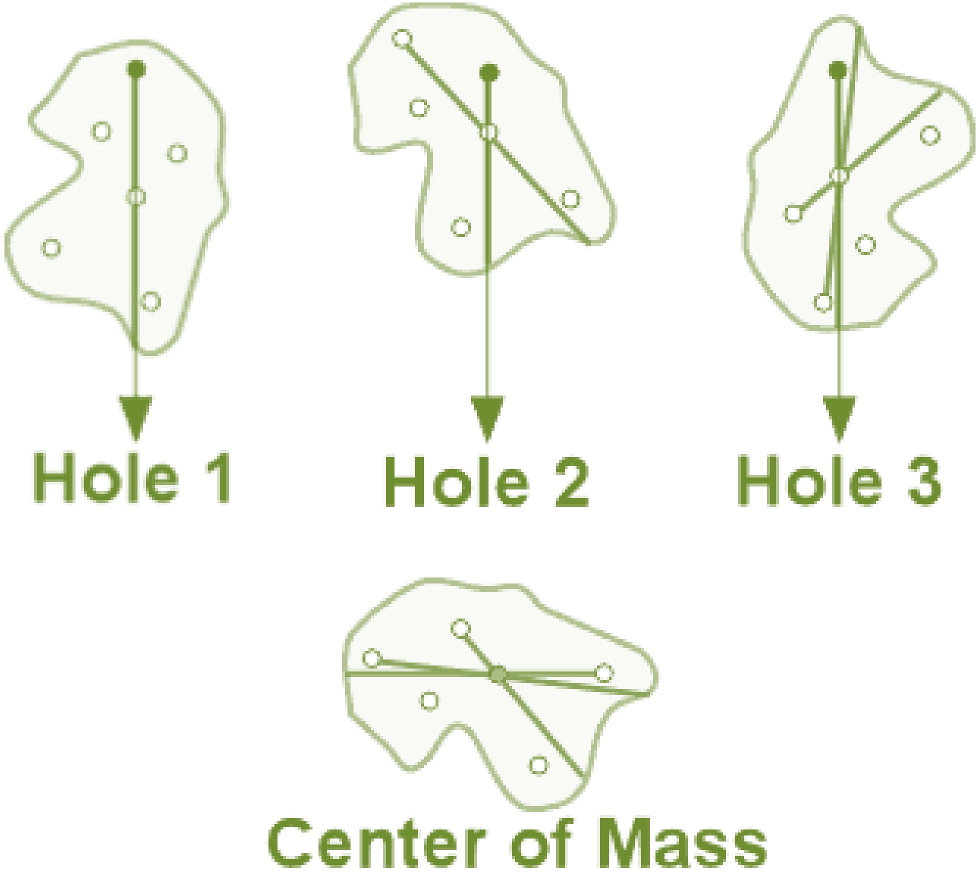
Have to Calculate?

Extended object ?



Determine Center of Mass





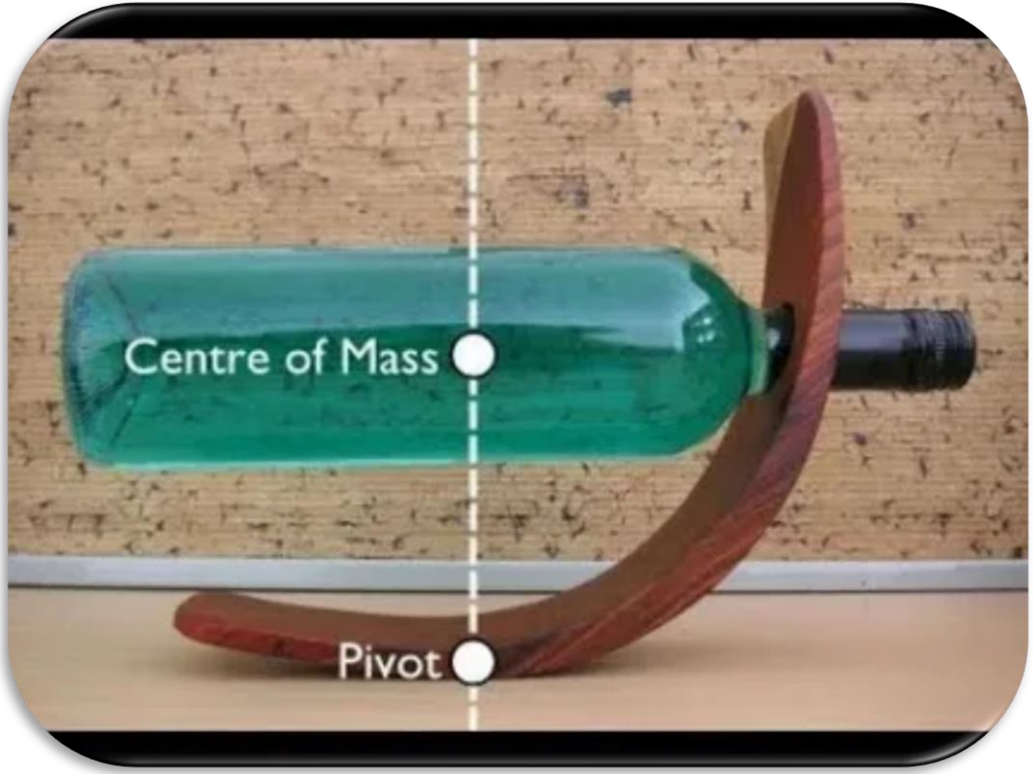
Center of our body

15 cm above the public symphysis

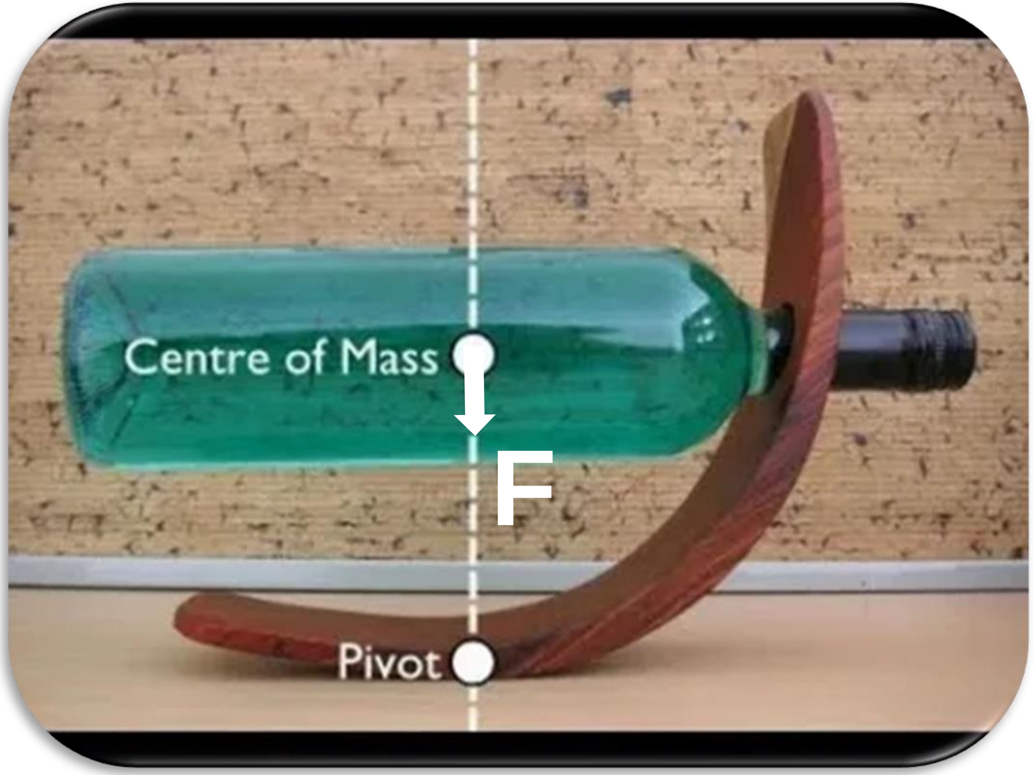
55% of standing height in **female**

57% of standing height in **male**

Balance



Balance



Balance

More

Experiments of center of mass

https://video.tudou.com/v/XMjc4OTgyODgyNA==.html?f=50513641

Homework:

Any problem of the demonstration about the CM of the Cola Can?

N-II Law for the motion of the center of mass

$$\vec{v}_{CM} = \frac{d\vec{r}_{CM}}{dt} = \frac{\sum_{i=1}^{N} m_i \frac{d\vec{r}_i}{dt}}{\sum_{i=1}^{N} m_i} = \frac{\sum_{i=1}^{N} m_i \vec{v}_i}{m}$$

$$m\,\vec{v}_{CM} = \sum_i m_i \vec{v}_i = \sum_i \vec{p}_i = \vec{p}$$

$$\vec{F} = \frac{d\vec{P}}{dt} \quad \Rightarrow \quad \vec{F} = m\vec{a}_C$$

The sum of all forces acting on a system = total mass of the system times $\vec{a}$ of its center of mass.

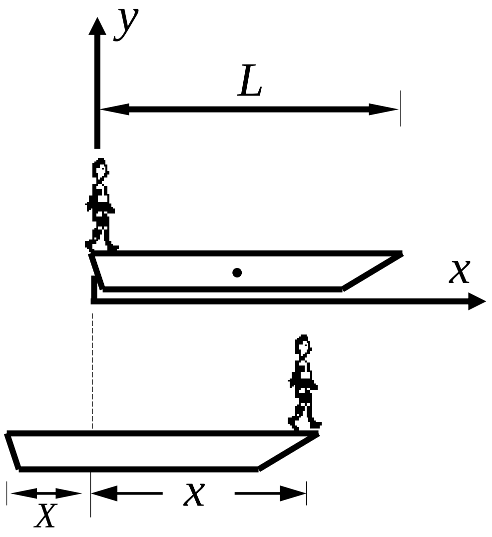
If a particle system exerted by zero force, the velocity of mass center keep constant.

Example

As figure shown, a boat L=4m, M=150kg. It is initially rest on the water. When a men, m = 50kg, walks from the head to the tail of the boat, what are the distances of the men and boat relative to the beach, respectively. neglect the friction from water.

Solution 1:

$$\sum F_{ix} = 0 \quad a_{cx} = 0 \rightarrow v_{cx} = 0 \quad \rightarrow x_c = \text{constant}$$



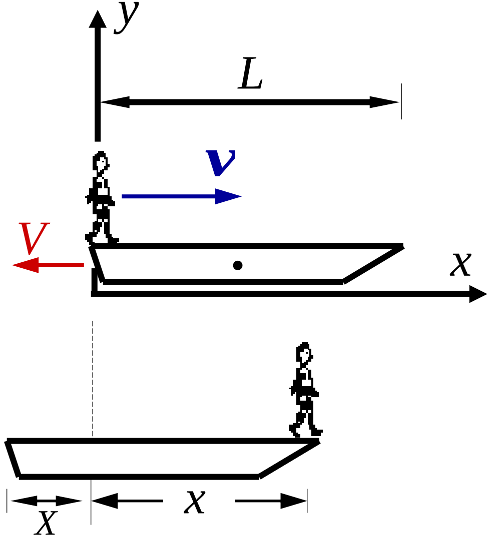
Initial: $$x_c = \frac{m \cdot 0 + M\frac{L}{2}}{m+M}$$ Final: $$x'_c = \frac{m \cdot x + M(x - \frac{L}{2})}{m+M}$$

$$x = \frac{ML}{m+M} = 3\text{m} \quad ; \quad X = L - x = 1\text{m}$$

Example

Solution 2:

Let $\vec{V}$ and $\vec{v}$ denote the velocity of boat and men relative to the beach at any instant, then



$$mv - MV = 0$$

$$m\int_0^t v\mathrm{d}t - M\int_0^t V\mathrm{d}t = 0$$

$$mx = MX \quad , \quad x + X = L$$

$$X = \frac{m}{M+m}L = 1\mathrm{m} \quad ;$$

$$x = L - X = 3\mathrm{m}$$

CM and Translational Motion

$$v = \frac{dx}{dt}$$

$$a = \frac{dv}{dt}$$

$$\boxed{Mx_{CM} = m_1x_1 + \ m_2x_2 + m_3x_3}$$

$$\boxed{Mv_{CM} = m_1v_1 + \ m_2v_2 + m_3v_3}$$

$$\boxed{Ma_{CM} = m_1a_1 + \ m_2a_2 + m_3a_3}$$

$$\boxed{Ma_{CM} = F_{net}}$$

Rocket Propulsion

Rocket Propulsion

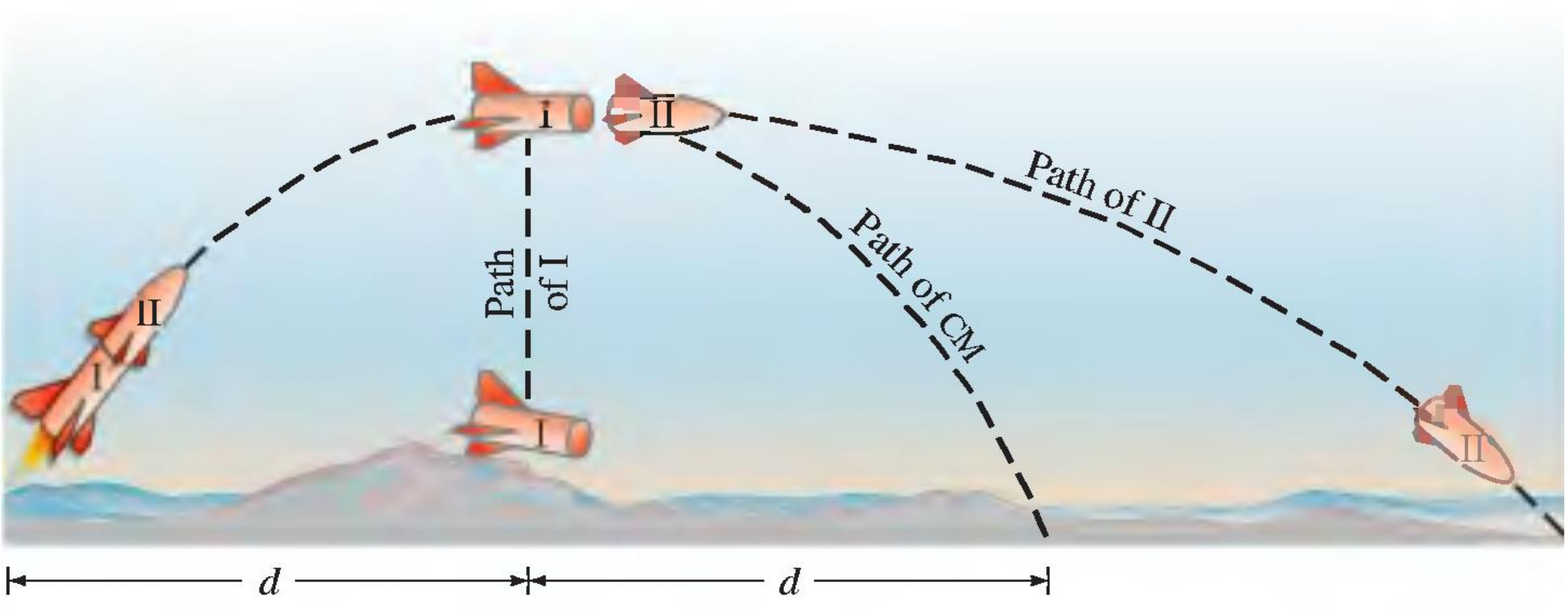
Basic principles

What is the physics principle to :

Speed up the rocket?

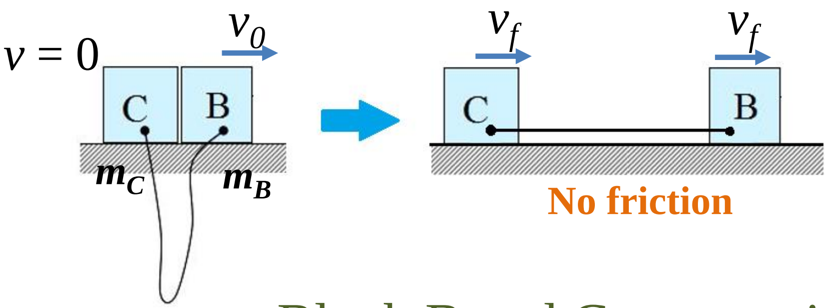
Get the position of the abandoned part of the rocket?

CM and Translational Motion



Example – Two blocks connected by a rope

Initially, Block C is **at rest**, Block B is moving to the right at the velocity of v_0, and the rope between them is **loose**.



After the rope becomes tense , Block B and C are moving at the same velocity. What is this velocity v_f ?

Is the momentum conserved?

yes

What are the initial and final momenta?

$$v_f = \frac{m_B v_0}{m_B + m_C}$$

Example – Two blocks connected by a rope

rope becoming tense = effective collision

During collision

$$\left.\begin{array}{l}\Delta t \rightarrow 0 \\ F_{int} \gg F_{ext}\end{array}\right\} J_{ext} = F_{ext}\Delta t \rightarrow 0$$

external forces can be neglected! -- total momentum is conserved

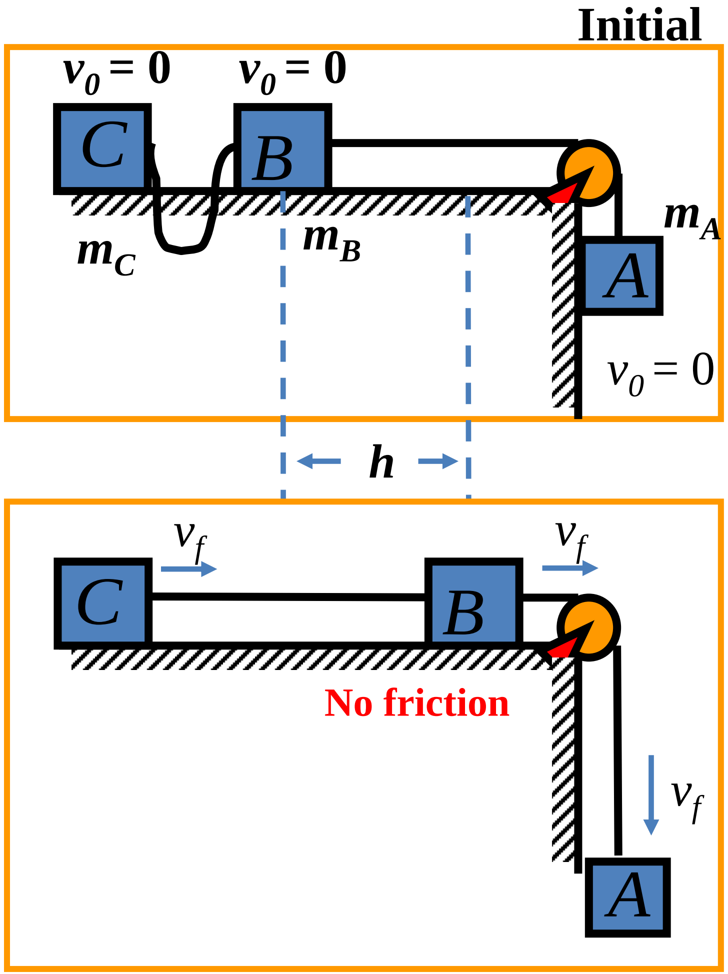
What about if an external force is also very strong, comparable with that large internal force?

Example – Three-blocks problem

Initially, all three blocks are **at rest**. The rope between Block B and C is **loose**. The rope between Block A and B is **tense**.

Block A start to move down due to the weight.

At the moment the rope between Block B and C becomes tense , all blocks are moving at the same speed. What is this speed v_f?



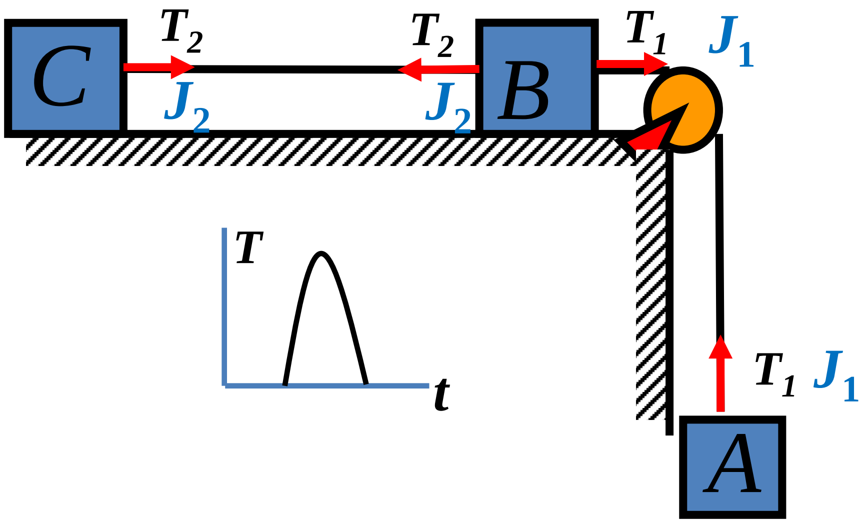
Example – Three-blocks problem

$$\Delta p_A = m_A(v_f - v_i) = -J_1$$

$$\Delta p_B = m_B(v_f - v_i) = J_1 - J_2$$

$$\Delta p_C = m_C(v_f - 0) = J_2$$

$$\Delta p_A + \Delta p_B + \Delta p_C = 0$$



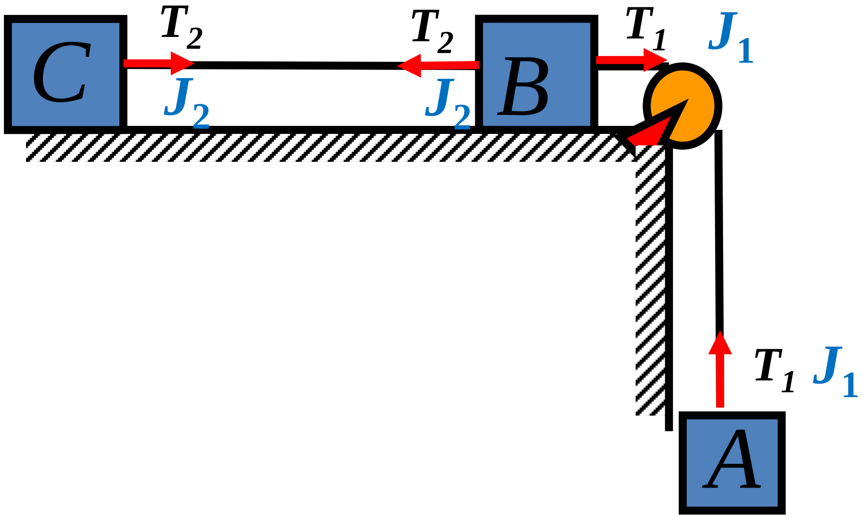
It looks like "conservation of momentum".

But these are only magnitudes, not the momenta themselves!

Example – Three-blocks problem

Final result (dynamic method):

$$v_i = \sqrt{\frac{2m_A g h}{(m_A + m_B)}}$$



Summary

Mindmap