Dynamics

Force is that which changes or tries to change a body's state of rest or uniform motion in a straight line, the force causes a body to accelerate.

Newton's 1st law of motion

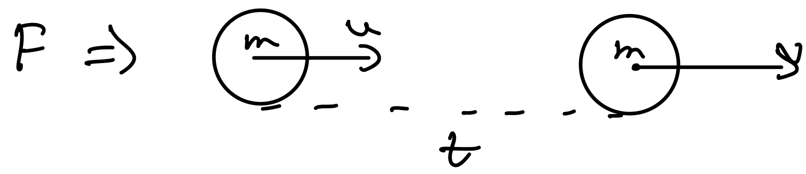
Every object continues in its state of rest or of uniform motion in a straight line, unless compelled to change that state by a net force.

Mathematically if $\Sigma \vec{f} = 0$ then $\vec{v} =$ constant

Newton's 2nd law

The rate of change of momentum is proportional to the net force, acting on the object and the change of momentum occurs in the direction of the force acts.

lets consider a mass 'm' with initial velocity 'u'. when a force 'F' acts in the direction of motion for time 't', the objects speed becomes 'v'.



mu = initial momentum
mv = final momentum
$mv - mu$ = change in momentum
$\frac{mv - mu}{t}$ = Rate of change of momentum.

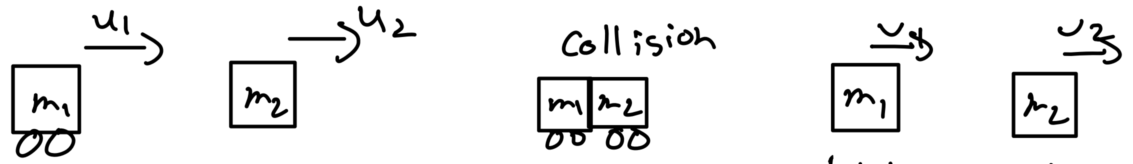
Newton's 3rd law

If an object A exerts a force on another object B, object B exerts equal and opposite force on object A.

law of conservation of momentum

In a closed system, total momentum before collision is equal to total momentum after collision.
ie. the total momentum of a system remains constant or conserved.

Case 1



$u_1 > u_2$

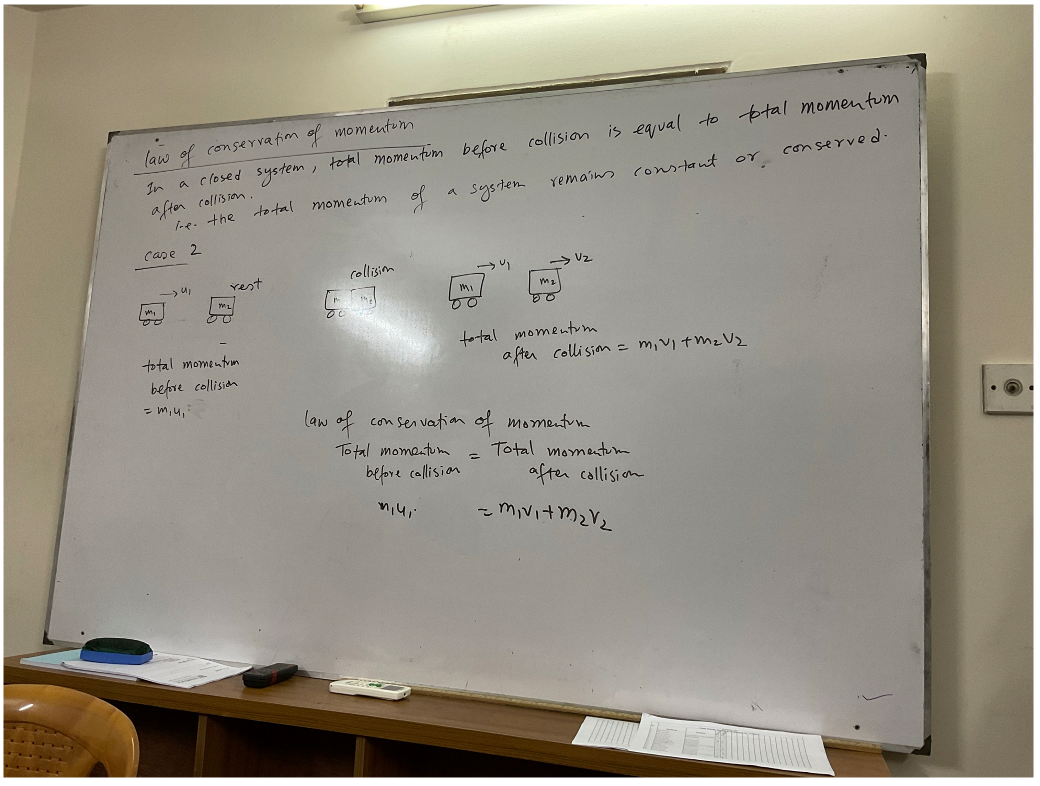
total momentum before collision = $m_1u_1 + m_2u_2$

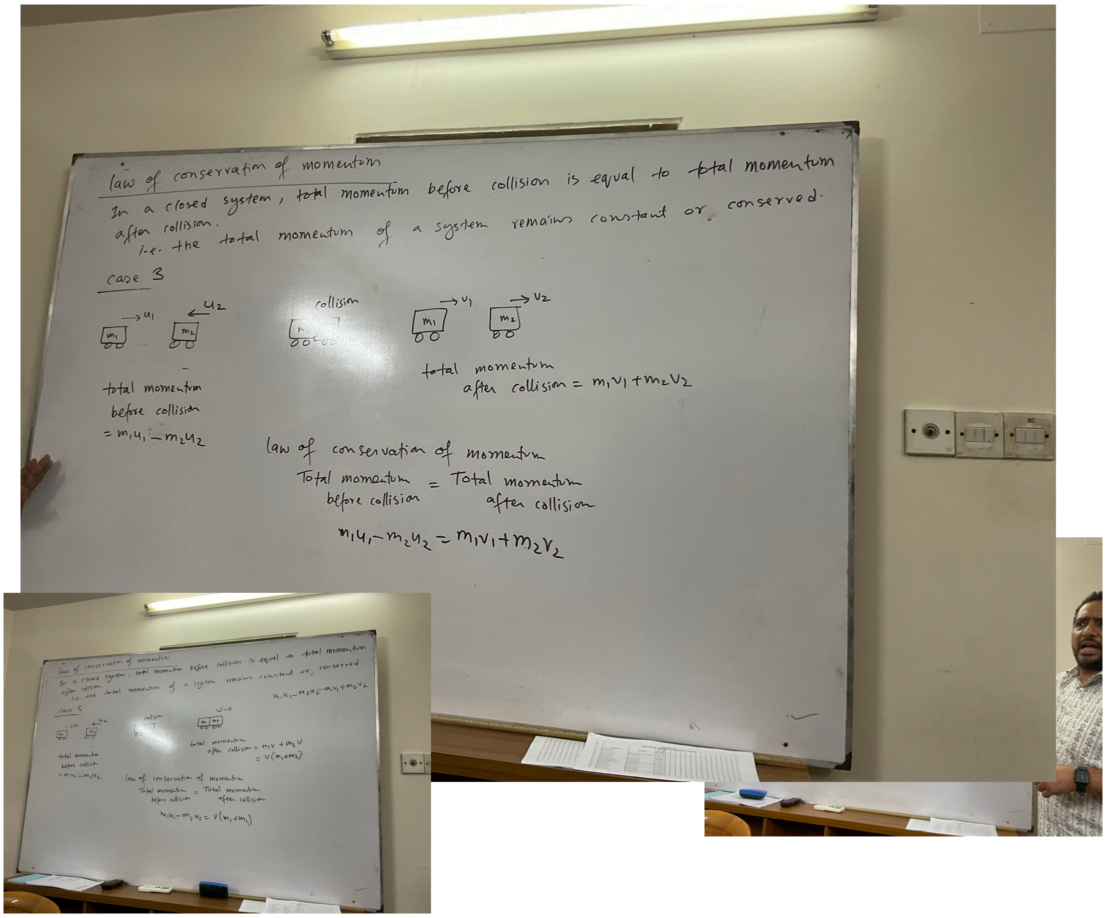
total momentum after collision = $m_1v_1 + m_2v_2$

law of conservation of momentum

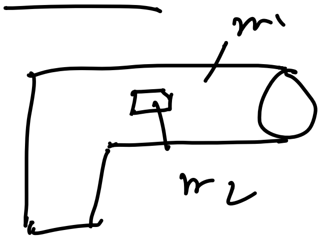
total momentum before collision = total momentum after collision.

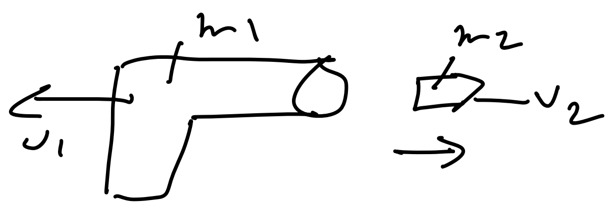
$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$





Recoil





total momentum before $= 0$

total momentum after

$m_2 v_2 \quad - m_1 v_1$

$m_2 v_2$

Q1. Trolley A of mass 5 kg is moving right wards over a smooth runway with a velocity of $3 ms^{-1}$. Trolley B of mass 4 kg is also moving right wards following A with a velocity of $5 ms^{-1}$. After some time they collide, time of coll ision is 0.2 s

Calculate:

1) total momentum before and after collision.
2) Find out the velocity of B just after collision, velocity of A is $5 ms^{-1}$.
3) Calculate the charge in momentum of trolley A
4) Determine the force exerted by trolley A on trolley B.

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$5 \times 3 + 4 \times 5 = 35 \text{ kg } ms^{-1}$$

2) $35 - 25 = \frac{10}{4} = 2.5 \ ms^{-1}$

3) $5 \times 3 - 5 \times 5 = -10$

Ans: 10 kg ms^{-1}

4) $\frac{10}{0.2} = 50N$

Impulse: The product of Force and time of action of force is called impulse.

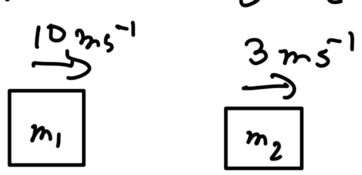
$$F = \frac{mv - mu}{t}$$

$$Ft = mv - mu$$

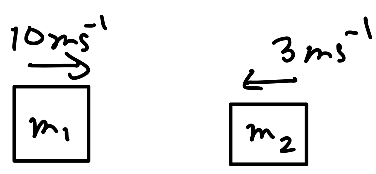
* A small gravitational force from the sun acting over a long time gives a comet enourmous momentum ie. huge speed.

Velocity of approach (voa)

Before the collision, the relative velocity by which they come close is v.o.a.

① 

voa = 7 ms^{-1}

② 

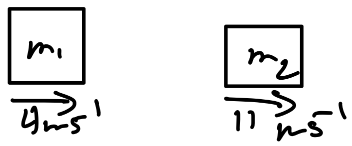
voa = 13 ms^{-1}

→ 10 ms^{-1} rest

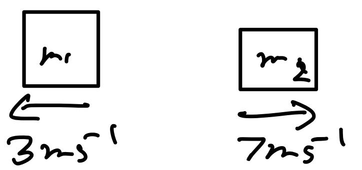
(3) 

voa = 10

Velocity of seperation

(1) 

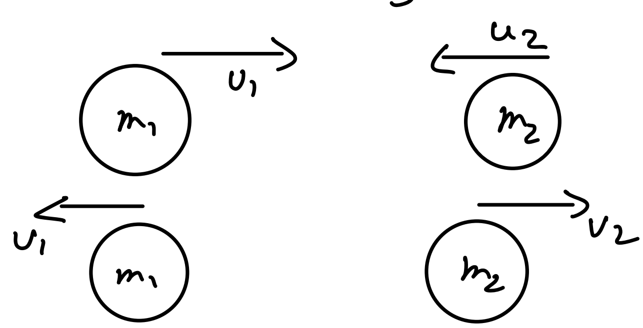
vos = $7ms^{-1}$



vos = $10 ms^{-1}$

Elastic Collision

1) Kinetic energy is conserved ie. no loss in energy during collision



Kinetic energy before collision = Kinetic energy after collision

$$\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m v_1^2 + \frac{1}{2} m_2 v_2^2$$

(2) Momentum is conserved in every collision (whether elastic or inelastic).

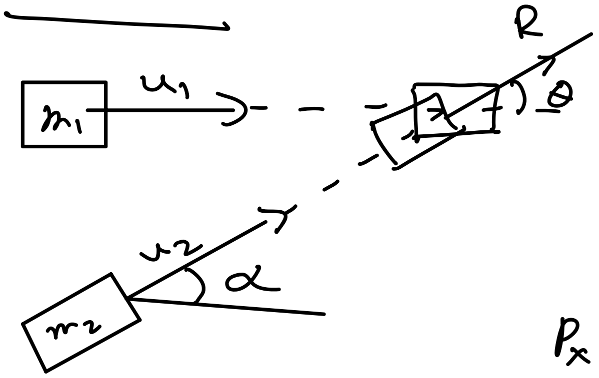
(3) relative velocity and after collision remains

same. voa = vos.

Two dimensional collision

In two dimensional collision, component of momentum is conserved in any direction. Usually we resolve all components in two perpendicular direction and then we combired momentum.

Case 1



Resolving horizontally

Total momentum before

$$P_x = m_1 u_1 + m_2 u_2 \cos\alpha$$

Resolving vertically

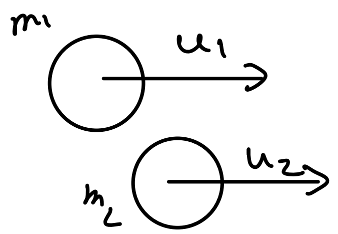
Total momentum before

$$P_y = 0 + m_2 u_2 \sin\alpha$$

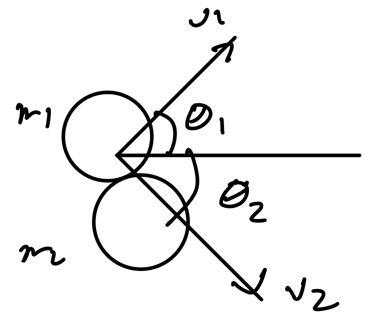
$$R = \sqrt{P_x^2 + P_y^2}$$

$$\theta = \tan^{-1} \frac{P_y}{P_x}$$

Case 2



$u_1 > u_2$



Horizontally

Total momentum before collision

Horizontally

Total momentum after collision.

$$m_1 v_1 + m_2 u_2 = m_1 v_1 \cos\theta_1 + m_2 v_2 \cos\theta_2$$

Vertically

Total momentum before collision

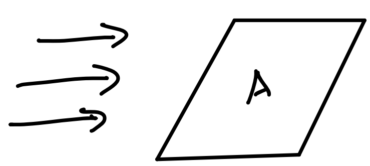
$= 0$

Vertically

Total momentum after collision

$$= m_1 v_1 \sin\theta_1 - m_2 v_2 \sin\theta_2$$

Force exerted by wind on a surface area.



Wind hits the surface Area 'A' with speed 'v'.

Density of air $= \rho$

Volume of wind hitting per second = Av

Mass of air hitting per second = $\rho A v$

Momentum of air hitting per second = $\rho A v \cdot v$

$\rho A v^2$

If air completely stops after hitting the wall, then momentum change every second $= 0 - A\rho v^2$

$\therefore$ Rate of change momentum $= -A\rho v^2$

$\therefore$ Force $= A\rho v^2$

Avg. power = Force x avg. velocity

$\Rightarrow A\rho v^2 \times \left(\frac{0+v}{2}\right)$

$$\boxed{\text{Power} = \frac{A\rho v^3}{2}}$$

Newton's 3rd law

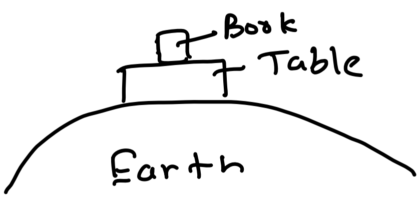
When a body A applies a force on another body B. Body B applies equal force on body A in the opposite direction for the same length of time and the two forces are of the same type.

The pair of forces involved is called Newton's 3rd law pair.

Properties

1) They are equal and opposite.
2) They are of same type.
3) They act for the same length of time.
4) They have the same line of action
5) They act in opposite directions.
6) They act on different bodies.

Free body Force diagram



For Book

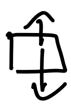
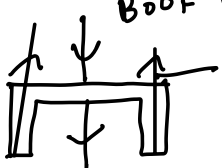


table pushing up with normal contact force (B)

Earth pulling down with gravitational force (A)

For Table

Book pushing down with contact force (E)



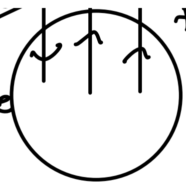
Earth pushing up with contact force (D)

Earth pulling down with gravitational force (C)

For Earth

Book pulling up with gravitational force (F)

pushing ... up with



Newton's 3rd law pair

B E   A F   D H   C G

Rocket Propulsion

When the exhaust gas rushes downwards, according to Newton's 2nd law motion. The rate of change momentum of exhaust gas is equal to the force applied on gas by the rocket downwards.

According to Newton's 3rd law, the exhaust gas applies equal force on the rocket upwards. If the magnitude of this force is larger than weight then the rocket will accelerate upwards.

If the velocity of the exhaust gas is 'v' and mass of gas leaving the rocket per second is m/t, the change in momentum of exhaust gas = $\frac{m(v-u)}{t} \mid u=0$

thrust $= \frac{mv}{t}$ $\therefore$ Resultant force = thrust - weight.

2 **(a)** systematic: the reading is larger or smaller than (or varying from) the true reading by a constant amount

random: scatter in readings about the true reading

(b) precision: the size of the smallest division (on the measuring instrument)
or
0.01 mm for the micrometer

accuracy: how close (diameter) value is to the true (diameter) value

3 **(a)** (gravitational potential energy is) the energy/ability to do work of a <u>mass</u> that it has or is stored due to its position/height in a gravitational field

kinetic energy is energy/ability to do work a object/body/mass has due to its speed/velocity/motion/movement