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Class 11

Physics

Chapter 3

Handwritten Notes

Chapter #03
"Translatory motion"

Motion:- If position of an object changes with time, we say that the object is in motion

Types:- There are three types of motion

Translatory motion

Rotatory motion

Vibratory motion

Translatory motion:- Motion of an object without rotation is called Translatory motion. In such motion. In such motion, each particle / point of moving object follows similar path

There are three types of translatory motion

i). Linear motion/ rectilinear motion

ii) Circular motion

iii) Random motion

~~Linear~~ Random motion:- Translatory motion of an object in an irregular path is path is called random motion

Example: motion of bird in air

Linear motion:- Translatory motion of an object in a straight line is called linear motion.

Examples: Motion of plane on runway
Motion of freely falling object.

Circular motion:- Translatory motion of an object on a circular path is called circular motion.
Examples: Motion of earth around Sun
Motion of stones attached to a string

~~Random~~ Rotatory **motion:-** Motion of an object about a fixed axis is called rotatory motion
Examples: Motion of a fan
Motion of wheel of any vehicle

Vibratory motion:- "To and fro" motion or "Back & forth" motion of an object about a fixed point is called vibratory motion.
Examples: Motion of a pendulum
Motion of object attached to a spring

Equations of motion:-

The equations which relate initial velocity, final velocity, time, acceleration and displacement are called "equation of motion".

- To derive the equations of motion, we make following assumptions

-> Object moves in a straight line

-> Acceleration of object remains uniform/constant

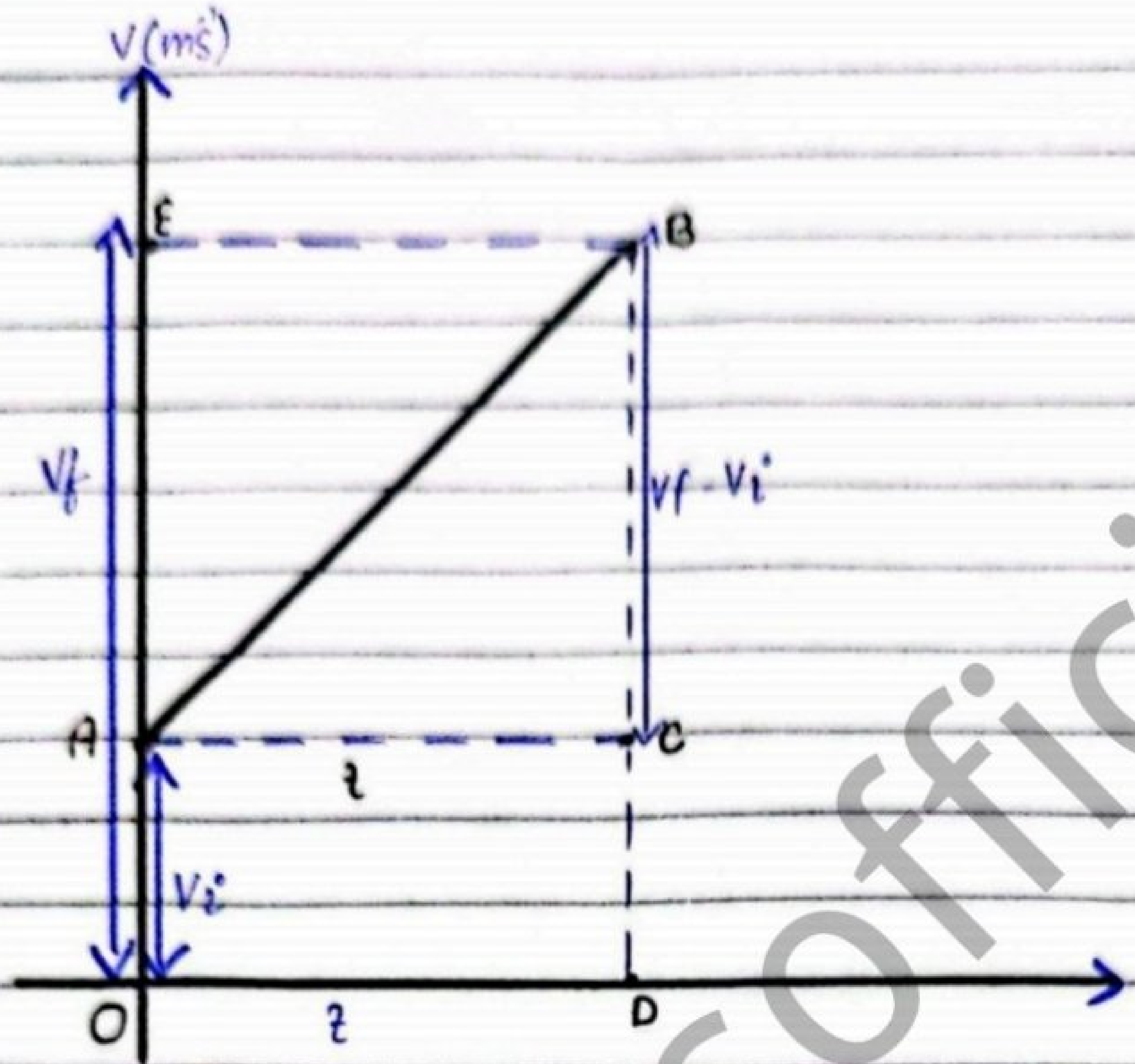
-> We consider only magnitude of vector quantities such as displacement, vector and acceleration.

-> Initial velocity and all vector quantities in direction of initial velocity are taken as opposite and positive, negative.

=>
First Equation of motion:-

Consider a particle of mass "m" moving with initial velocity "V_i". A constant acceleration acts on the particle on its velocity changes from "V_i" to "V_f" in time "t". Displacement travelling during this interval is "S". Speed-time graph of this particle is given as;

Speed time graph



From the graph:-

$OA = DC = V_i$

$OE = DB = V_f$

$OD = AC = t$

$CB = DB - CB$

$CB = V_f \ V_i$

We know that, slope of speed time graph gives acceleration of particle.

According to:

Acceleration = Slope of line AB

$a =$ Slope of line AB

$$a = \frac{\Delta y}{\Delta x} = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{t_2 - t_1}$$

$$a = \frac{V_f - V_i}{t - 0} = \frac{V_f - V_i}{t}$$

$$at = V_f - V_i$$

$$at + V_i = V_f$$

$$V_f = V_i + at$$

Second equation

We know that, area under speed-time graph gives total distance travelled by the particle

Distance = Area of trapezium ODCOAO

$$S = \left(\frac{OA + DB}{2}\right) \times AC$$

$$S = \left(\frac{Vit + Vf}{2}\right) \times t$$

$$S = \left(\frac{Vit + Vi + at}{2}\right) \times t$$

$$S = \frac{2Vi}{2} + \frac{at^2}{2}$$

$$S = Vit + \frac{1}{2}at^2$$

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Third equation of motion

We know that, area under speed-time graph gives total distance travelled by the object. Therefore area under line "AB" is total distance of moving object.

Total object distance = Area of trapezium

$$S = \frac{(\text{Sum of parallel sides})}{2} \times (\text{Separation b/w parallel sides})$$

$$S = \left(\frac{OA + DB}{2}\right) \times AC$$

Multiplying both sides by $\frac{BC}{AC}$

$$S \times \frac{BC}{AC} = \left(\frac{OA + DB}{2}\right) \times \cancel{AC} \times \frac{BC}{\cancel{AC}}$$

$$S \times \frac{BC}{AC} = \left(\frac{OA + DB}{2}\right) \times (BC)$$

$$S\left(\frac{V_f - V_i}{t}\right) = \left(\frac{V_i + V_f}{2}\right)\left(V_f - V_i\right)$$

$$S \times a = \frac{(V_f + V_i)(V_f - V_i)}{2}$$

$$2aS = V_f^2 - V_i^2$$

This is 3rd equation of motion".

Example:-

Given Datas- $V_i = 4ms^{-1}$, $a = 2ms^{-2}$

$t = 5s$

To find

$V_f = ?$

Solution:

$V_f = ?$

$V_f = V_i + at$

$V_f = (10) + (2)(5)$

$V_f = 10 + 10$

$V_f = 20ms^{-1}$

Ex 3.2

Given:

$V_i = 4ms^{-1}$

$a = 1ms^{-2}$

$t = 10s$

To find:

$S = ?$

Solution:

$S = V_i t + \frac{1}{2} at^2$

$S = (4)(10) + \frac{1}{2}(1)(10)^2$

$S = 40 + 50$

$S = 90m$

OR

$2as = V_f^2 - V_i^2$

$V_f = 4 + 1(10)$

$V_f = 4 + 10$

$V_f = \cancel{40}\ 14ms^{-1}$

$2as = V_f^2 - V_i^2$

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$$2(1)s = (14)^2 - (4)^2$$

$$2s = 196 - 16$$

$$2s = 180$$

$$s = 180/2$$

$$s = 90m$$

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Motion under gravity

Free fall motion

Motion of an object under the action of gravity is called free fall motion. It has been observed that during free fall, the acceleration of object remains uniform, with magnitude of $9.8 ms^{-2}$ and is directed towards towards the centre of earth. This acceleration is called gravitational acceleration, and is denoted by "g". Since, acceleration is uniform equations of motions are applicable with same symbolic changes

$V_f = V_i + at$	$V_f = V_i + gt$
$S = V_i t + \frac{1}{2} at^2$	$V_f = V_i t + \frac{1}{2} gt^2$
$2aS = V_f^2 - V_i^2$	$2gH = V_f^2 - V_i^2$

Example 3.3

Given Data:-

$H = 2.50 m, V_f = 0$

$g = -9.8 ms^{-2}$

To find:-

$V_i = ?$

$t = ?$

Sol

We know that

$2gH = V_f^2 - V_i^2$

$2(-9.8)(2.5) = (0)^2 - (V_i)^2$

$\cancel{-}49 = \cancel{-}V_i^2$

$\sqrt{(7)^2} = \sqrt{V_i^2}$

$V_i = 7 m/s^{-1}$

Assignment 3.2

Given Data:-

$m = 5kg$, $V_i = 0$

$t = 3.34s$, $g = 9.8 m/s$

To find:-

$H = ?$

$V_f = ?$

Solution:-

We know that

$H = V_i t + \frac{1}{2} g t^2$

$H = (0)(3.34) + \frac{1}{2}(9.8)(3.34)^2$

$H = 0 + \frac{1}{2}(9.8)(3.34)^2$

$H = 54.6m$

Now;

$V_f = V_i + gt$

$V_f = 0 + (9.8)(3.34)$

$V_f = (9.8)(3.34)$

$V_f = 32.73 ms^{-1}$

Assignments: 3.1

Q#01).

Given Data:

$V_i = 80\ kmh^{-1} = 22.2\ ms^{-1}$

$V_f = 20\ kmh^{-1} = 5.6\ ms^{-1}$

To find:

$t = ?$

Solution:

We know that

$V_f = V_i + at$

$at = V_f - V_i$

$t = \frac{V_f - V_i}{a}$

$t = \frac{5.6 - 22.2}{-2}$

$\boxed{t = 8.3\ s}$ Answer

Q#02).

Given Data

$V_i = 5ms^{-1}$, $V_f = 15ms^{-1}$

$S = 50m$

To find:

$a = ?$

$t = ?$

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Solution:-

We know that

$$2as = V_f^2 - V_i^2$$

$$a = \frac{V_f^2 - V_i^2}{2S}$$

$$a = \frac{(15)^2 - (5)^2}{2(50)}$$

$$a = \frac{225 - 25}{100}$$

$$a = \frac{200}{100}$$

$$\boxed{a = 2ms^{-2}}$$

Now

$$V_f = V_i + at$$

$$at = V_f - V_i$$

$$t = \frac{V_f \quad V_i}{a}$$

$$t = \frac{15 - 5}{2}$$

$$t = \frac{10}{2}$$

$$\boxed{t = 5s}$$ - Ans

Projectile motion

Two dimensional motion of an object thrown into air under action of gravity only is called projection motion. Object in motion is called projectile and path followed by projectile is called trajectory of projectile.

Example :-

→ Motion of a cricket ball thrown into the air.

→ Motion of a missile

Assumptions :-

While studying the projectile motion in our syllabus, we make following assumptions

→ Only gravitational force is acting on the projectile

→ No frictional / air drag force is acting on the object / projectile

→ No force due to rotation of earth is acting on projectile

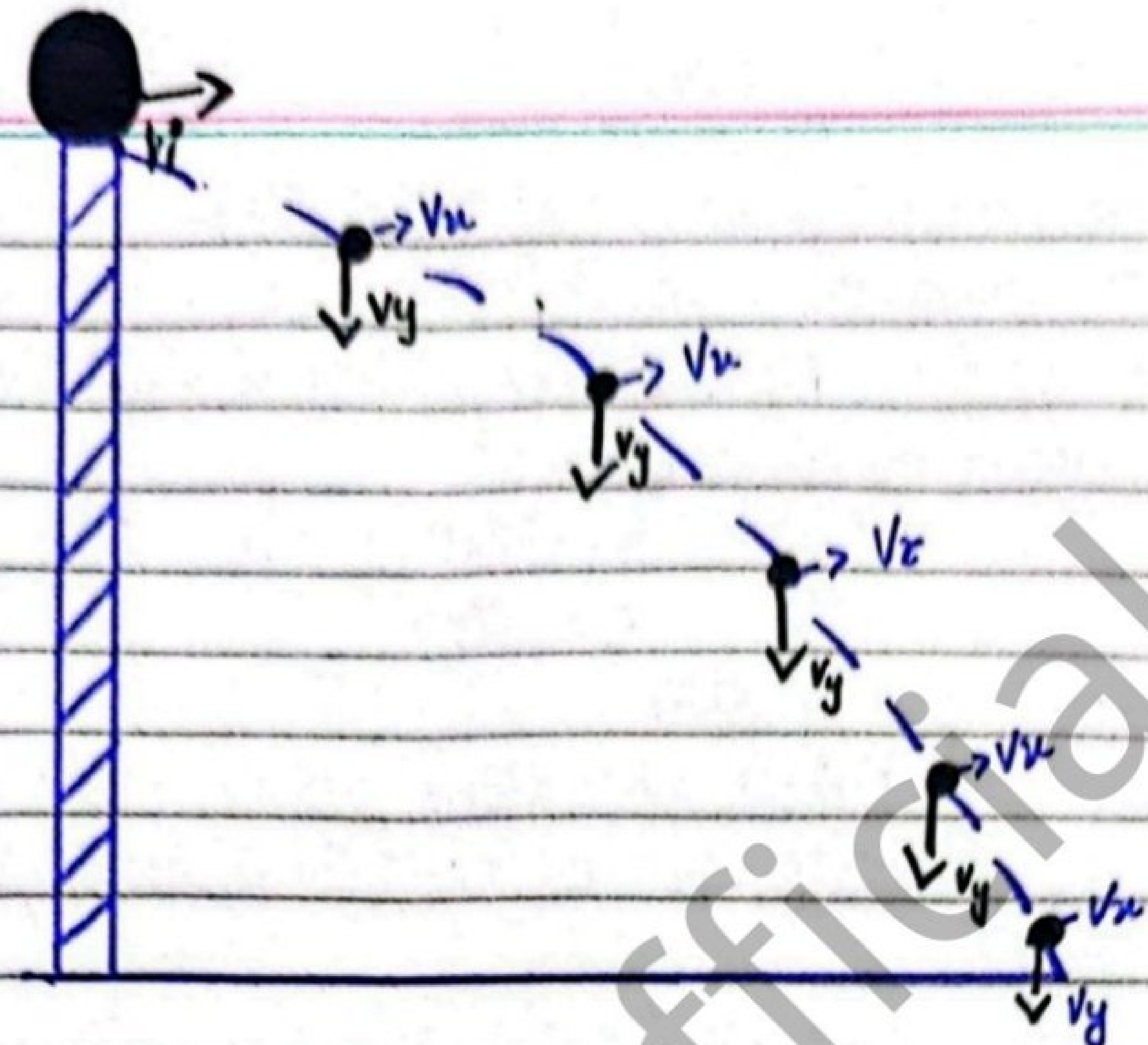
Types :-

There are two types :-

1). Projectile from the height in horizontal

2). Projectile from the surface of earth at same angle with horizontal.

Projectile from height in horizontal :-



Consider a projectile of mass "m" thrown at from the top of a height "h" with initial velocity "Vi" along horizontal direction only. The projectile follow a parabolic "2-D," trajectory during its motion. We analyze the motion along x-axis and y-axis independently.

A. Velocity of projectile:-

Along x-axis

There is no along x-axis

Therefore

$F_x = 0$

$a_x = 0$

$V_{ix} = V_i$

$V_{fx} = V_f$

Along y-axis

Gravi-tational force acts on the projectile along y-axis

Therefore,

$F_y = mg$

$a_y = g$

$V_{iy} = 0$

$V_{fy} = gt$

b). Displacement of Projectile:-

i). Along x-axis:-

Projectile moves along x-axis with uniform velocity, therefore:-

$$S_x = V_x t$$

$$x = V_i t$$

ii). Along y-axis:-

Projectile moves along y-axis with uniformly varying velocity due to gravitational acceleration. Therefore,

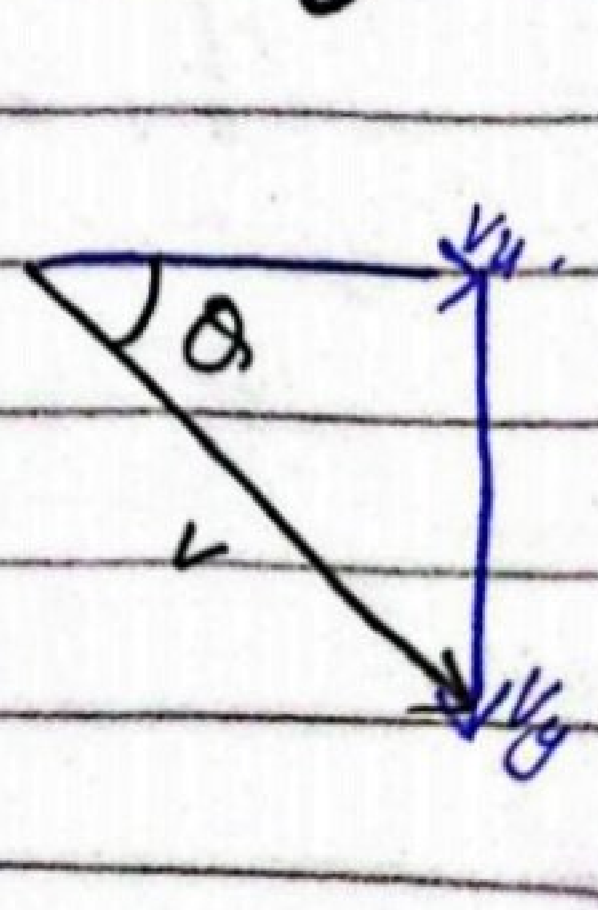
$$S_y = V_{iy} t + \frac{1}{2} a_y t^2$$

$$y = (0)t + \frac{1}{2} g t^2$$

$$y = \frac{1}{2} g t^2$$

c). Angle made by velocity with horizontal at any instant of time (t):-

From the graph:-

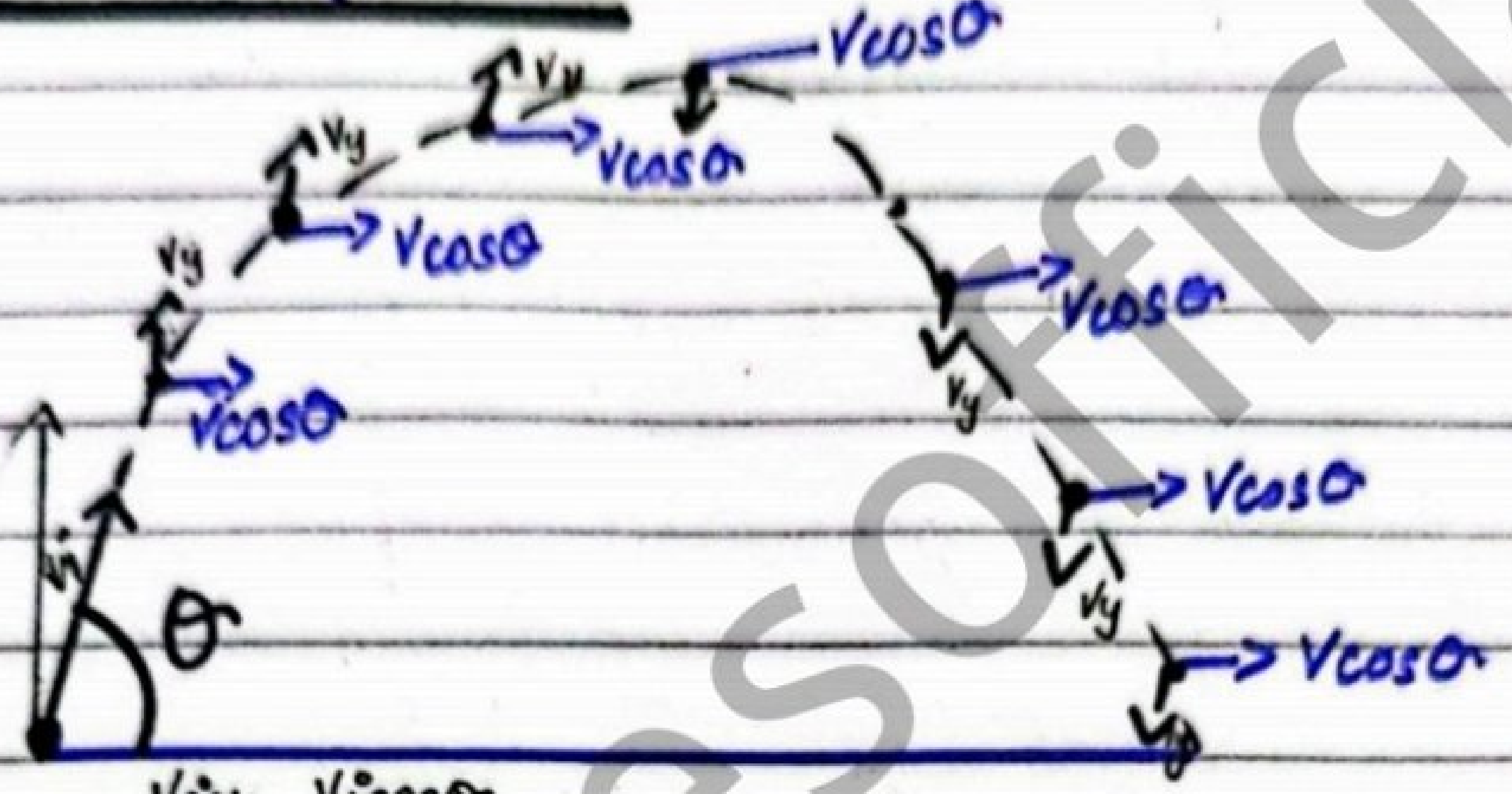


$$\tan\theta = \frac{V_y}{V_x}$$

$$\tan\theta = \frac{gt}{V_i}$$

$$\theta = \tan^{-1}\left(\frac{gt}{V_i}\right)$$

Projectile thrown at same angle with horizontal:



Explanation:- Consider a projectile of mass "m" thrown with initial velocity "V_i" at some angle "θ" with the horizontal. The projectile follows a "2-D" parabolic trajectory during its motion to analyze the motion of projectile, we consider the horizontal and vertical motion of projectile independently.

(A). Analysis of Velocity of projectile:-

- Along x-axis:-

There is no net force acting on projectile along horizontal direction, Therefore, There is no acceleration along horizontal direction.

$$F_x = 0$$

$$a_x = 0$$

$$V_{ix} = V_i\cos\theta$$

$V_x = V_{ix} = V_{fx} = V_i\cos\theta$

Along y axis:-

$F_y = mg$

$a_y = -g$

$V_{iy} = V_i\sin\theta$

$V_{fy} = ?$

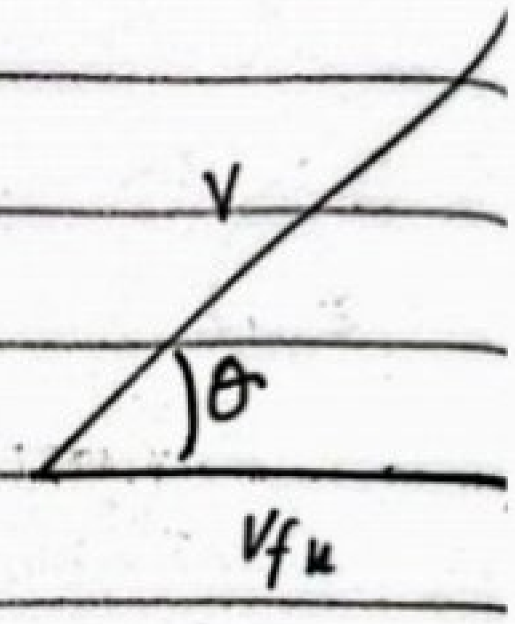
$V_{fy} = V_{iy} + a_y t$

$V_{fy} = V_i\sin\theta - gt$

Angle made by velocity of projectile with horizontal:-

$$\tan\theta = \frac{V_{fy}}{V_{fx}}$$

$$\tan\theta = \frac{V_i\sin\theta - gt}{V_i\cos\theta}$$



Analysis of displacement of projectile:-

Along x axis:-

Projectile moves with uniform velocity along horizontal direction

Therefore

$V_x = V_i\cos\theta$

$a_x = 0$

$S_x = V_x \times t$

$S_x = V_i\cos\theta\, t$

Along y-axis:

Along vertical direction, reciprocle moves under gravitational acceleration.

$$V_y = V_i \sin\theta$$

$$a_y = -g$$

$$S_y = y$$

Use 2nd equation of motion

$$S_y = V_{iy} t + \frac{1}{2} a_y t^2$$

$$y = V_i \sin\theta + \frac{1}{2} gt^2$$

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Time of flight :- Time of flight is spent by projectile in air during its motion is called Time of flight. It is represented by T. It's SI unit is second.

Derivation: To derive the formula for Time of flight, we consider vertical motion of projectile

$$V_{iy} = V_i \sin\theta$$
$$a_y = -g$$
$$S_y = 0$$
$$t = T$$

Use 2nd equation of motion:

$$S_y = V_{iy}t + \frac{1}{2} a_y t^2$$
$$0 = (V_i \sin\theta)T + \frac{1}{2}(-g)T^2$$
$$0 = V_i \sin\theta \, T - \left(\frac{gT^2}{2}\right)$$
$$\frac{gT^2}{2} = V_i \sin\theta \, T$$
$$\frac{gT}{2} = V_i \sin\theta$$
$$T = \frac{2V_f \sin\theta}{g}$$

This is time of flight of projectile.

Height of projectile (H) :- The maximum vertical distance of projectile from horizontal is called height of projectile.

It is represented by H. It's SI unit is meter.

Derivations- To derive formula for height of projectile, we consider vertical motion of projectile

$$V_{iy} = V_i \sin\theta$$
$$a_y = -g$$
$$V_{fy} = 0$$
$$S_y = H$$

Use 3rd equation

$$2aS = V_f^2 - V_i^2$$
$$2(-g)H = (0)^2 - (V_i \sin\theta)^2$$
$$-2gH = -V_i^2 \sin^2\theta$$
$$2gH = V_i^2 \sin^2\theta$$
$$H = \frac{V_i^2 \sin^2\theta}{2g}$$
$$H = \frac{V_i^2 \sin^2\theta}{2g}$$

This is height of projectile.

Range of Projectile

The horizontal displacement of projectile from point of projection to landing point is called range of projectile. It is respresented by "R". It's unit is meter (m).

Derivation: To calculate range of projectile we consider horizontal motion of projectile

$$V_x = V_i \cos\theta$$
$$t = T$$
$$S_x = R$$

We know that

$$S_x = V_x \times t$$

$R = V_i \cos\theta \times T$

$R = V_i\cos\theta \times \frac{2V_i\sin\theta}{g}$

$R = \frac{2V_i^2 \sin\theta \cos\theta}{g}$

$R = \frac{V_i \sin 2\theta}{g}$

For maximum range:-

Range of projectile is given by relation

$R = \frac{V_i^2 \sin 2\theta}{g} \rightarrow eq(1)$

It will be maximum range only if;

$\sin 2\theta = 1$

$2\theta = \sin^{-1}(+1)$

$2\theta = 90$

$\theta = 90/2$

$\theta = 45^\circ$

This is condition for maximum range of projectile corresponding maximum range is;

$R_{max} = \frac{V_i^2}{g}(1)$

$R_{max} = \frac{V_i^2}{g}$

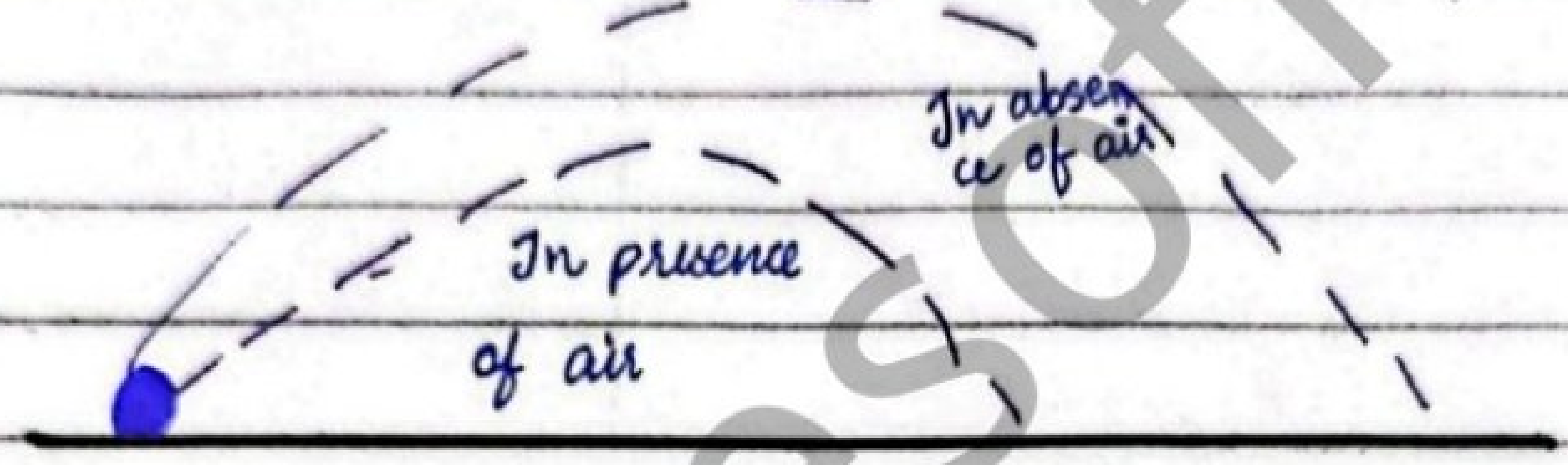
Putting in eq (1) we get,

$R = \frac{V_i}{g} \sin 2\theta$

$R = V_i^2/g \sin 2\theta$

Effect of air resistance on Projectile

Air resistance on projectile is just like friction. Air resistance decreases the horizontal and vertical component of the projectile consequently the time of flight (T), maximum height (H) and range of projectile decrease in presence of air friction. This is because, some kinetic energy of projectile is converted into heat, sound and other forces of energy.



Momentum:- The quantity of an object is called momentum. The product of mass and velocity of object is called momentum.

Momentum is a vector quantity. It is represented by $\vec{P}$. It is a vector quantity. It's direction is same as velocity

Formula:- By definition of momentum, we have

$$\vec{P} = m \times V$$

$$\vec{P} = mV$$

Unit:-

$$P = mV$$

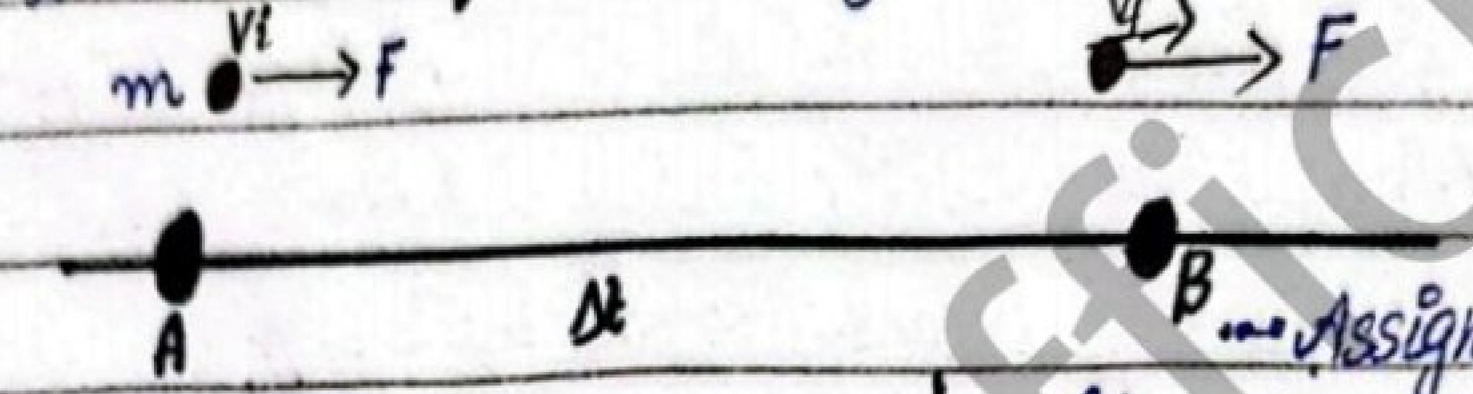
$$= kgms^{-1}$$

$$= kg\frac{m}{s} = kg\frac{m}{s} \times \frac{s}{s} = \left(\frac{kgm}{s^2}\right)$$

$$= (kgms^{-2})s = Ns$$

Relation b/w force and momentum

Consider a projectile of mass "m" moving with initial velocity "V_i". A constant force "F" acts on the projectile for time "Δt" and its velocity becomes "V_f". According to Newton 2nd law



...Assignment

$$F = ma$$

but

$$a = \frac{V_f - V_i}{\Delta t}$$

Put eq ② in ①

$$\vec{F} = ma$$

$$\vec{F} = m\left(\frac{V_f - V_i}{\Delta t}\right)$$

$$\vec{F} = \frac{\vec{P_f} - \vec{P_i}}{\Delta t} = \frac{\vec{\Delta P}}{\Delta t}$$

$$\vec{F} = \frac{\vec{\Delta P}}{\Delta t}$$

We know that

$$T = \frac{2V_i \sin\theta}{g}$$

$$T = 3.061s$$

$$H = \frac{V_i^2 \sin\theta^2}{2g}$$

$$H = 11.476\,m$$

$$R = \frac{V_i^2 \sin\theta}{g}$$

$$R = 79.533\,m$$

Rate of change of momentum of an object is equal to the net force acting on the object. This statement is called Newton 2nd law in terms of momentum.

Assignment:

DATA:

$V_i = 30\,ms^{-1}$

$\theta = 30°$

To find:

$H = ?$

$T = ?$

Examples-

Given Datas-

$V_{ix} = 12\,ms^{-1}$

$x = 24.6\,m$

To find-

$x = ?$

Calculations-

We know that

$x = V_i x \times t \rightarrow$ ①

$y = \frac{1}{2} g t^2$

$t = \sqrt{\frac{2y}{g}}$

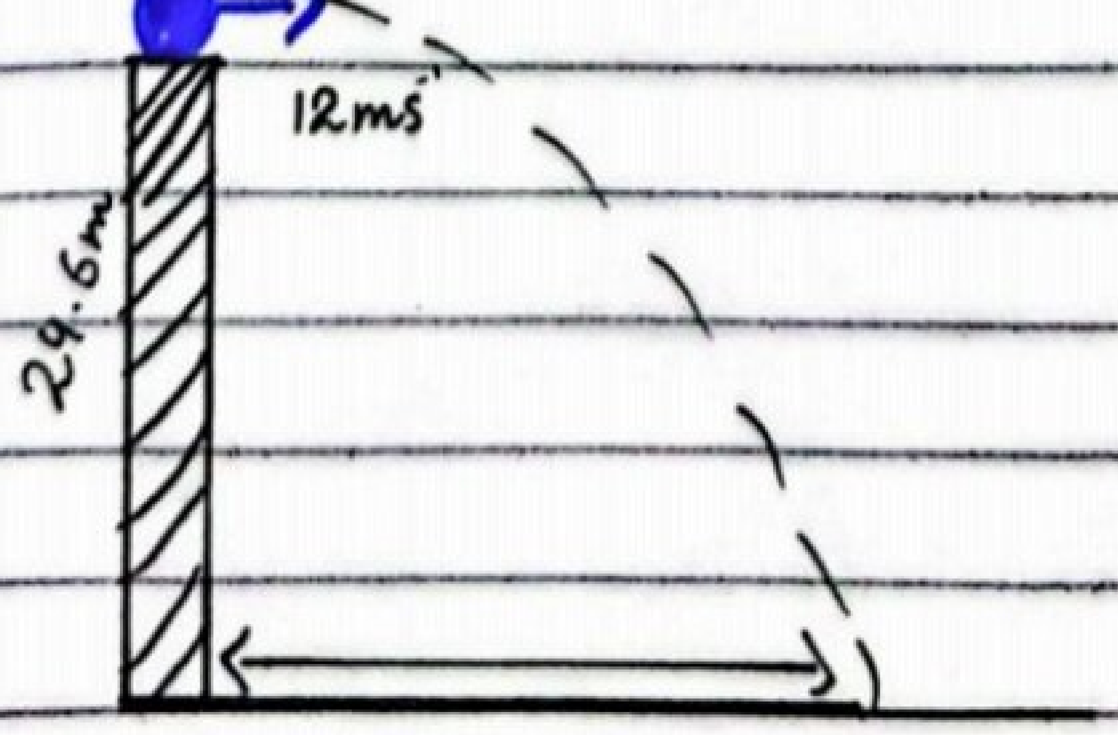
$t = \sqrt{\frac{2 \times 24.6}{9.8}} = 2.24$

$\boxed{t = 2.24s}$

Put in equation ①

$x = 12 \times 2.24$

$x = 26.6m$



Example 3:5

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Given Data:-

$V_i = 30ms^{-1}$

$\theta = 30$

To find:-

$T = ?$

$H = ?$

$R = ?$

Calculation:-

We know that

① $T = \frac{2V_i \sin\theta}{g}$

$T = \frac{2 \times 30 \times \sin 30}{9.8}$

$T = 3.061s$

② $H = \frac{V_i^2 \sin^2\theta}{2g}$

$H = \frac{(30)^2 (\sin 30)^2}{2(9.8)}$

$H = 11.476\,m$

③ $R = \frac{V_i^2 \sin 2\theta}{g}$

$R = \frac{(300)^2 \times \sin 60}{9.8}$

$R = 79.533m$

Problem 3.2:-

Given data

$R = \frac{H}{2}$

To find:-

$V_x = ?$

Solution:-

According to given condition

$R = H$

$$\frac{2V_i \sin\theta \cos\theta}{g} = \frac{V_i^2 \sin^2\theta}{2g}$$

$$2\cos\theta = \frac{\sin\theta}{2}$$

$$4 = \frac{\sin\theta}{\cos\theta}$$

$\tan\theta = 4$

$\theta = \tan^{-1}(4)$

$\theta = 76°$

Complemtary angles

The angle whose sum is exactly 90° are called complementary angles

For example:-

(30°, 60°)
(70°, 20°)
(80°, 10°)

are called complementary angles. Range of projectile at complementary angle remains same range at:

Range at 30°:-

$$R = \frac{V_i^2 \sin 2\theta}{g}$$

$$R_{30} = \frac{V_i \sin^2 (30)}{9.8}$$

$$R = \frac{v_i^2 \sin (60)}{g}$$

$$R = \frac{V_i^2 (0.866)}{g} \rightarrow \text{equation } 1$$

Range at 60°:-

$$R_{60} = \frac{V_i \sin^2 \theta}{g}$$

$$R_{60} = V_i \sin 2(60)$$

$$R_{60} = \frac{V_i^2 \sin (120)}{g}$$

$$R_{60} = \frac{V_i^2 (0.866)}{g}$$

$$R_{60} = 0.866 \frac{V_i^2}{g} \rightarrow \text{equation } 2$$

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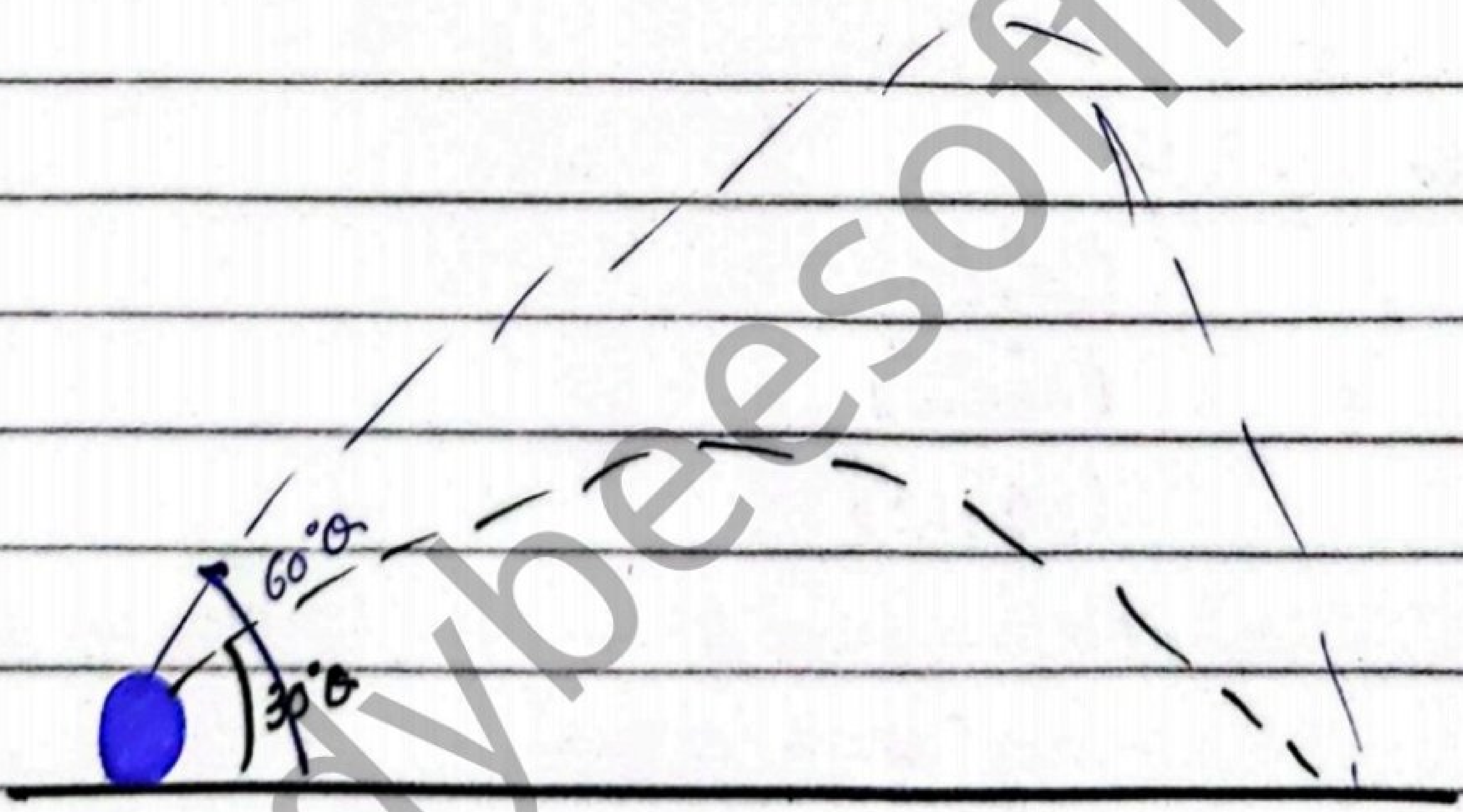
Compairing eq ① and ②

$R_{30} = R_{60}$

Thus, range of projectile of complemantary angles remains same



System of Particle:-

If two or more than two particles are moving dependently or independently, they are correctly known as system of particles

Isolated System:-

Any system of particles that is not affected by its surrounding is called isolated system. If no external force is acting on system of particles is zero then system is said to be isolated.

Types of conservation of momentum:-

According to relationship between force and momentum,

$$\vec{F} = \frac{\vec{\Delta P}}{\vec{\Delta t}}$$

if $\vec{F} = 0$

Then,

$$0 = \frac{\vec{\Delta P}}{\Delta t}$$

$$\frac{\vec{\Delta P}}{\Delta t} = 0$$

$$\Delta P = 0$$

$$\vec{P_f} - \vec{P_i} = 0$$

$$P_f = P_i$$

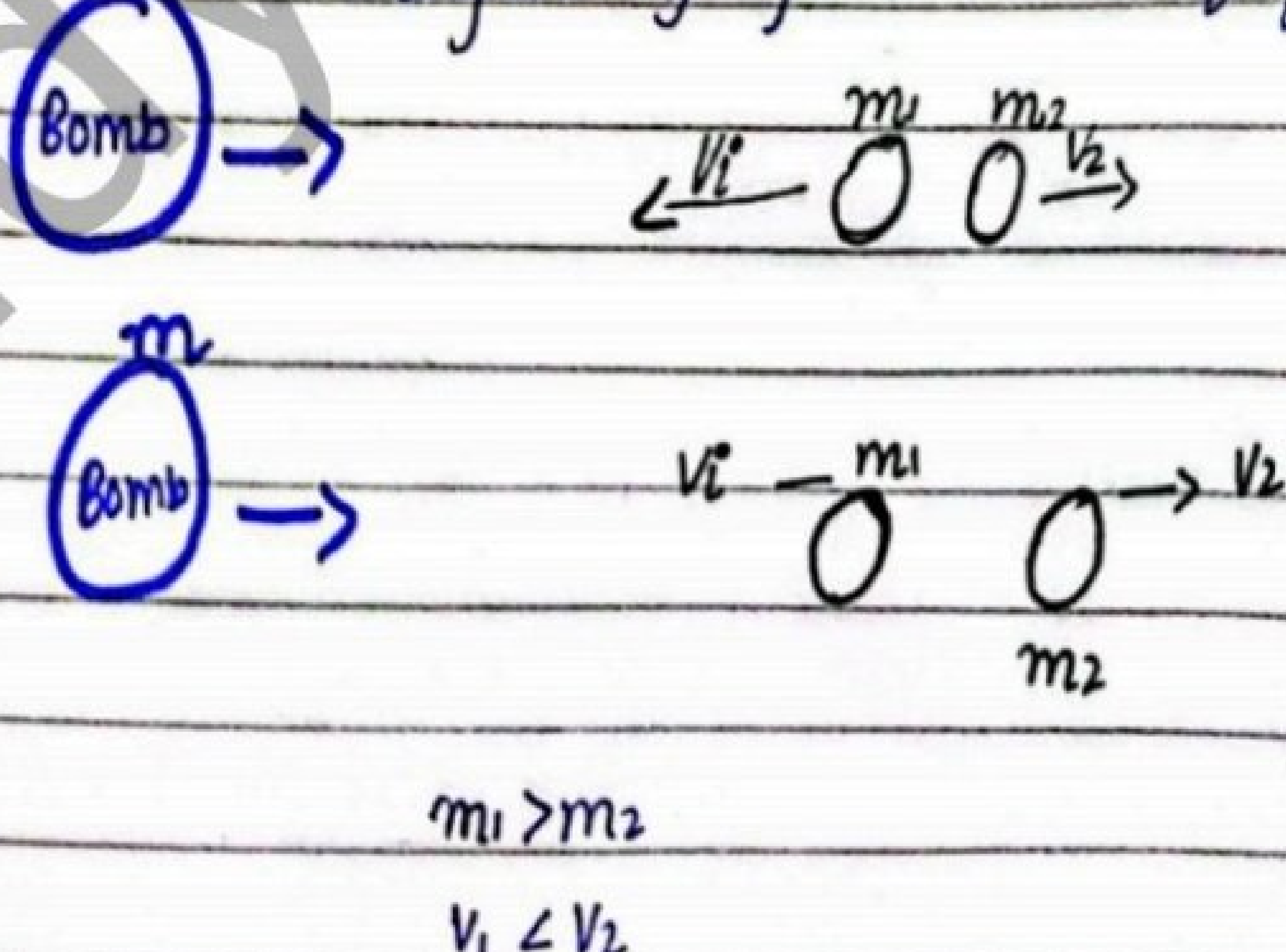
If no external force is acting on a particle or system of particles is zero (i.e. system is isolated), the momentum remains conserved.

Then Total momentum of particles or system of particles remains Zero:-

(Assignment)*
Application:-

A). Conservation of momentum during explosion:-

During an explosion, chemical energy of system is converted into kinetic energy of the fragments of system. Since, system is isolated (as no external force is involved), Total momentum of system after and before explosion must remain constant/same. System is initially at rest ($P_i = 0$) after explosion fragment move in opposite direction with same or different velocities depending upon masses of fragments

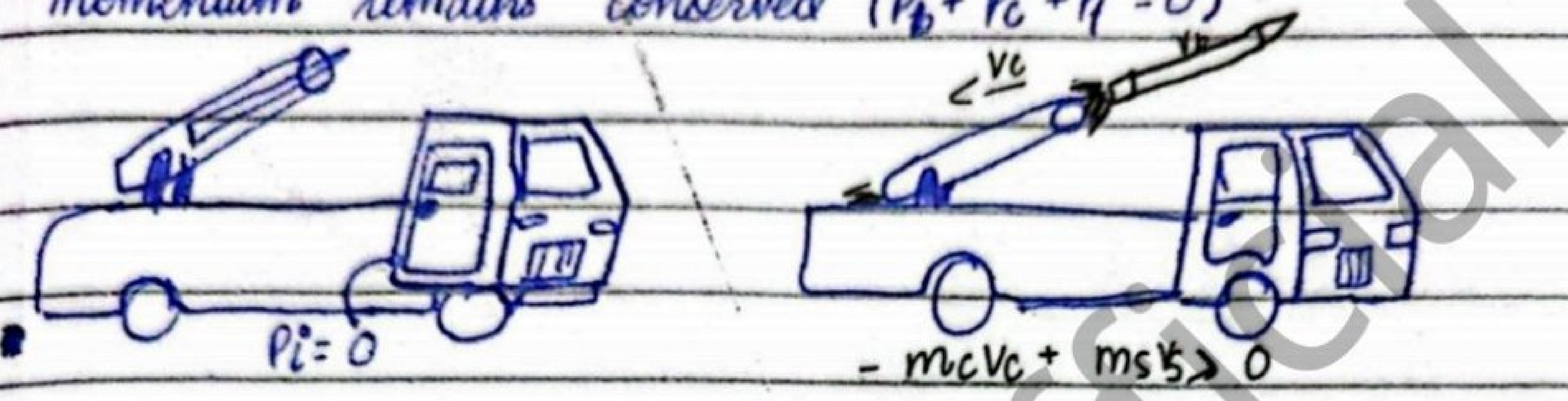


$m_1 > m_2$

$V_1 < V_2$

B). Conservation of momentum during firing in Canon:-

Common- bullet is an isolated system and momentum of this system remains conserved. Before firing both are at rest ($P_i > 0$). After firing both are at rest $(P_i > 0)$. After firing, bullet moves forward (P_b) and cannon moves backward i.e recoils $(P_c > 0)$ such that momentum remains conserved $(P_b + P_c + P_f = 0)$



c). Momentum conservation during collision of cars/vehicles

During any collision of system of particle, then momentum of system remains constant some of momentum of particles of system before collision is equal to the sum of momentum of system of particles after collision

d) Momentum conservation during collision of cricket ball and cricket bat :-

During the collision between a cricket bat and ball, momentum of system remains conserved/constant/same. Before collision between bat and ball sum of momentum of ball and bat. after collision is same as momentum before collision.

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Collisions:

If velocity and momentum of one particle affected by higher / another particle, we can say that there is a collision between particles.

Types:-

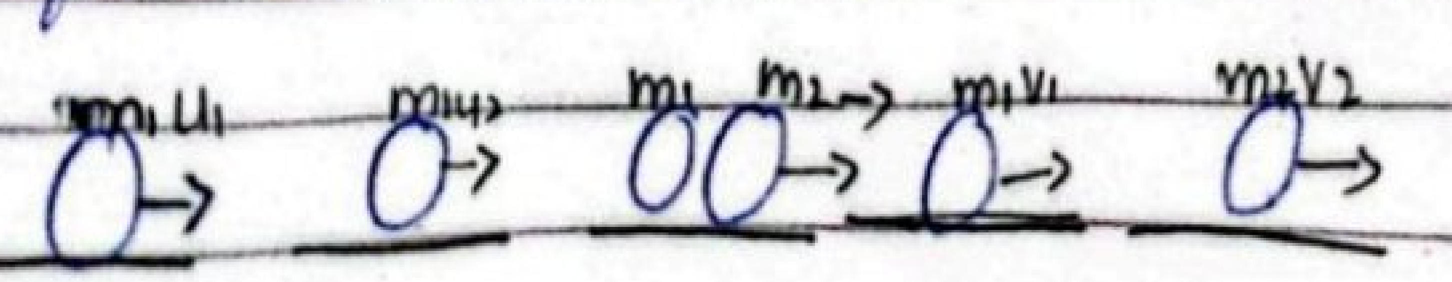
There are Two types of collision:

i). Elastic collision
ii). Inelastic collision

Inelastic collision:- A type of collision in which kinetic energy of colliding particle does not remain conversed constant / same. A part of kinetic energy of particle is converted into sound heat, demostration and other types of energy

Elastic collision:- A type of collision in which kinetic energy of colliding particle remains conserved before and after. The collision. No part of kinetic energy of colliding particle is converted into heat, sound and other forms of energy K·E of colliding particles before collision is equal to after collision

Explanation:- Consider a system of two particles of masses m_1 and m_2 moving with initial velocity u_1 and u_2 such that $u_1 > u_2$. After collision their velocities become v_1 and v_2



25th September, 2025 Thursday

Mathematically:- Since, system of particles under consideration is isolated, therefore momentum of system is conserved;

$$(P_i)_{system} = (P_f)_{system}$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$m(u_1 + v_2) = m_2(v_2 - u_2) \quad - (A)$$

Since, collision is elastic, K.E of colliding particle is conserved.

$$(K.E_i)\ system = (K.E_f)\ system$$

$$\frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2v_2^2 = \frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2$$

$$\frac{1}{2} (m_1u_1^2 + m_1u_2^2) = \frac{1}{2} (m_1v_1^2 + m_2v_2^2)$$

$$m_1u_1^2 + m_2u_2^2 = m_1v_1^2 + m_2v_2^2$$

$$m_1u_1^2 + m_1v_1^2 = m_2v_2^2 - m_2u_2^2$$

$$m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$$

$$m_1(u_1 + v_2)(u_1 - v_1) = m_2(v_2 + u_2)(v - u_2) \quad - (b)$$

$\div$ (b) by (A) we get,

$$\frac{m_1(u_1 + v_1)(u_1 - v_1)}{m_1(u_1 - v_1)} = \frac{m_2(v_2 + u_2)(v_2 - u_2)}{m_2(v_2 - u_2)}$$

$$u_1 + v_1 = v_2 + u_2$$

$$u_1 - v_2 = v_2 - v_1$$

$$u_1 - u_2 = -(v_1 - v_2)$$

- This equation says that, velocity of approach of particles is equal to the velocity of separation of particles after collision.

Determination of velocity after collision:

By using equation (c) we have

$$u_1 + v_1 = v_2 + u_2$$

$$v_1 = u_2 + v_2 - u_1$$

Put in equation ③ we get:

$$m_1u_1 + m_2u_2 = m_1(u_2 + v_2 - u_1) + m_2v_2$$

$$m_1u_1 + m_2u_2 = m_1u_1 + m_1v_1 + m_1v_1 - m_1u_1 + m_2v_2$$

$$m_1u_1 + m_2u_2 + m_1u_1 - m_1u_2 = v_2(m_1 + m_2)$$

$$2m_1u_1 + (m_2 - m_1)u_2 = v_2(m_1 - m_2)$$

$$v_2(m_1 + m_2) = 2m_1u_1 + (m_2 - m_1)u_2$$

$$v_2 = \frac{2m_1u_1}{m_1} - \frac{(m_1 - m_2)u_2}{m_1 + m_2}$$

Determination of velocity of m_2 after collision

We know that

$$u_1 - u_2 = -(v_1 - v_2)$$

$$u_1 - u_2 = -v_1 + v_2$$

$$u_1 - u_2 + v_1 = v_2$$

Put in equation ①

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2(u_1 - u_2 + v_1)$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2u_1 = (m_1 + m_2)v_2$$

$$m_1u_1 + m_2u_1 + 2m_2u_2 = (m_1 + m_2)v_1$$

$$(m_1 - m_2)u_1 + 2m_2u_2 = (m + m_2)v_1$$

$$v_1 = \frac{2m_2u_2}{m_1 + m_2} + \frac{(m_1 - m_2)}{(m_1 + m_2)}u_1 \rightarrow Ⓐ$$

Example / Numerical 3.6:

Given data:-

$m_1 = m \quad m_2 = m$

$u_1 = 2ms^{-1}, \quad u_2 = 2ms^{-1}$

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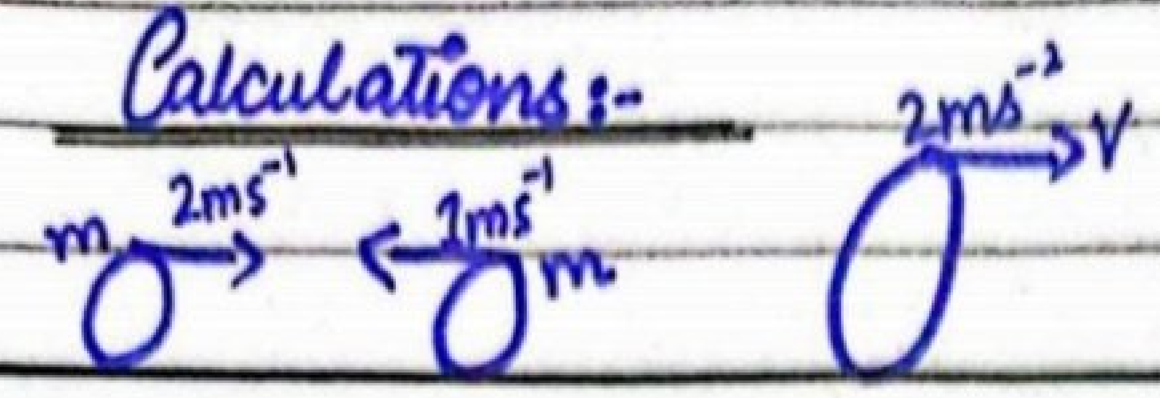
To find:-

$V = ?$

Calculations:-



$$(P_i)\ system = (P_f)\ system$$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)V$$

$$V = \frac{m_1u_1 + m_2u_2}{m_1 + m_2}$$

$$V = \frac{2m - m}{2m}$$

$$V = \frac{m}{2m}$$

$$V = \frac{1}{2}$$

$$\boxed{V = 0.5ms^{-1}}$$ - Answer....

Numerical 3.3)-

Given data:-

$V_i = 100ms^{-1}$, $V_f = 0$, $a = -6ms^{-2}$

To find:-

$t = ?$, $S = 0$

Calculations:-

$$t = \frac{V_f^2 - V_i^2}{a}$$

$$t = \frac{0 - 100}{-5} = \frac{-100}{-5}$$

$$t = 20s$$

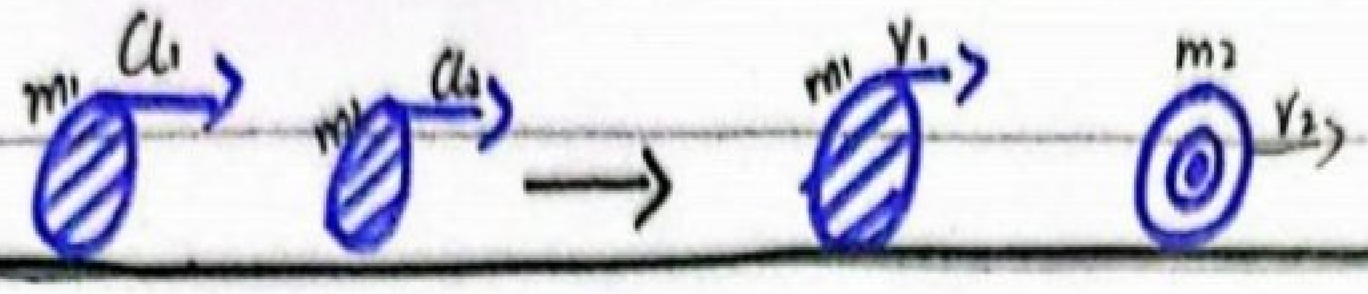
$$S = V_it + \frac{1}{2}at^2$$

$$S = (100)(20) - \frac{5}{2} \times 200$$

$$S = 2000 - 1000\,m$$

$$S = 1000m$$

$$S = 1km$$



$$V_1 = \frac{2m_2u_2}{m_1+m_2} + \left(\frac{m_1-m_2}{m_2-m_2}\right)u_1$$

$$V_2 = \frac{2m_1u_1}{m_1+m_2} - \frac{(m_1-m_2)}{(m_1+m_2)}u_2$$

Cases-01

If $m_1 = m_2 = m$

$$V_1 = \frac{2mU_2}{m_1+m} + \frac{(m-m_2)}{m+m}u_1$$

$$V_1 = \frac{2mu_2}{2m}$$

$$V_1 = u_2$$

$$V_2 = \frac{2m_1u_1}{m+m} - \left(\frac{m-m}{m+m}\right)u_2$$

$$V_2 = \frac{2m_1u_1}{2m}$$

$$V_2 = u_1$$

Case 02:-

If $m_1 = m_2 = m$, $u_2 = 0$

$$V_1 = \frac{2m(0)}{m+m} + \frac{m-m}{m+m}u_1$$

$$V_1 = 0$$

$$V_2 = \frac{2m_1u_1}{m+m} - \left(\frac{m-m}{m+m}\right)(0)$$

$$V_2 = \frac{2mu_1}{2m}$$

$$V_2 = u_1$$

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$m_1 + m_2 \qquad (m_1 + m_2)$

Case #01:- $m_1 = m_2 = m$

$V_1 = U_2$

$V_2 = U_1$

Case 02:- $m_1 = m_2 = m$

$U_2 = 0$

$V_1 = 0$

$V_2 = U_1$

Case 03:-

$m_1 >> m_2 \qquad V_1 = 0 \qquad V_2 = 0$

$U_2 = 0 \qquad V_2 = ? \qquad V_1 = -U_1$

$$V_1 = \frac{2m_2(0)}{0 + m_2} + \frac{(0 - m_2)}{0 + m_2} U_1$$

$$V_1 = 0 - \frac{m_2}{m_2} U_1$$

$$V_1 = -U_1$$

Now $$V_2 = \frac{2(0)(U_1)}{0 + m_2} - \left(\frac{0 - m_2}{0 + m_2}\right)(0)$$

$$V_2 = 0$$

Case 4:-

$m_1 >>> m_2$

$u_2 = 0$

$m_1 + m_2 = m_1$

$m_1 - m_2 = m_1$

$$V_1 = \frac{2m_2(0)}{m_1} + \frac{m_1}{m_1}u_1$$

$$V_1 = u_1$$

$$V_2 = \frac{2m_1u_1}{m_1} - \left(\frac{m_1}{m_1}\right)(0)$$

$$V_2 = 2u_1$$