(Kinematics and Dynamics)

This lecture covers the fundamental principles of classical mechanics, specifically focusing on how objects move and the causes of their motion.

Part I: Kinematics (The Description of Motion)

Kinematics focuses on describing motion using parameters such as position, ٥, and acceleration without considering the forces involved.

1. Reference Frames and Displacement

- **Position**: To describe motion, we must first define a coordinate system with a specific origin point.
- **Displacement**: Defined as the change in position of an object. If a particle moves from an initial position χ_i to a final position x_f the displacement is Delta

$$\Delta x = x_f - x_i$$

Vector Nature: Displacement is a vector quantity, meaning it has both a numerical magnitude and a direction.

2. Average and Instantaneous Velocity

- **Average Velocity**: This is the particle's displacement divided by the time interval during which that displacement occurs.
- **Instantaneous Velocity**: This represents the limit of the average velocity as the time interval approaches zero.
- **Mathematical Definition**: The instantaneous velocity equals the derivative of the position with respect to time.

3. Acceleration

- **Definition**: Acceleration is the rate of change of the velocity with respect to time.

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- **Instantaneous Acceleration**: This is the derivative of the velocity vector with respect to time.

4. Motion at Constant Acceleration

When acceleration is uniform, the following kinematic equations relate velocity, time, and displacement:

1- Velocity as a function of time : $v_{xf} = v_{xi} + a_x t$

2- **Position as a function of velocity and time**: $x_f = x_i + \frac{1}{2}(v_{xi} + v_{xf})t$

3- **Position as a function of time**: $x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$

4- Velocity as a function of position: $v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$

5. Freely Falling Objects

- **Gravity**: A freely falling object is any object moving freely under the influence of gravity alone, regardless of its initial motion.
- **Acceleration of Gravity**: All objects falling near the earth's surface in the absence of air resistance fall with a constant acceleration denoted by g (9.80 m/s^2).

6. Projectile Motion

- **Two-Dimensional Motion**: in the horizontal direction.
- **Independence**: The horizontal and vertical components of projectile motion are independent of each other.

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Part II: Dynamics (The Causes of Motion)

Dynamics involves the relationship between the motion of an object and the forces acting on it.

1. Force and Newton's Laws of Motion

- **The Concept of Force**: A force is an interaction that, when unopposed, will change the motion of an object.
- **Newton's First Law**: An object at rest remains at rest, and an object in motion continues in motion with a constant velocity unless acted upon by a net force.
- **Newton's Second Law**: The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass ($\sum F=ma$).
- **Newton's Third Law**: If two objects interact, the force exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force exerted by object 2 on object 1.

2. Collisions and Impulse

- **Linear Momentum**: The linear momentum of a particle is defined as the product of its mass and its velocity ($p=mv$).
- **Impulse**: The impulse of a force is equal to the change in the momentum of the particle.
- **Conservation of Momentum**: The total momentum of an isolated system (a system with no external forces) remains constant.

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Example 1 :- A ball is dropped from rest from the top of a building that is 50 meter high. Calculate its velocity just before it hits the ground

Sol.

Velocity initial

v_{yi} = Zero meter/s $\Delta y = -50$ m

$a_y = -9.8$ m/s^2

Choose Equation :- Use the equation that relates Velocity and displacement :-

$$v_{yf}^2 = v_{yi}^2 + 2a_y \Delta y$$

$$v_{yf}^2 = 2(-9.8)(-50) \Rightarrow 980$$

$$\therefore v_{yf} = \sqrt{980} = 31.3 \text{ m/s}$$

Example 2 :- A projectile is launched with an initial speed of 20 m/s at an angle of 30° above the horizontal. Find the maximum hight reached

Sol.

① find initial Vertical Velocity

$$v_{yi} = v_i \sin\theta = 20 \sin(30^\circ) = 10 \text{ m/s}$$

② maximum height, the Vertical Velocity $v_{yf} = 0$

③ Solve for height (y_{img})

$$19.6 \cdot y_{max} = 100 \Rightarrow y_{max} = 5.10$$

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Example 3 :- Newton's Second law with friction

Question :-

A 10 kg box is pulled on a horizantal surface with a force of 40 N. If the coefficient of kinetic friction μ_k is 0.3 . find the accelaration

Sol.

Normal force $(n) = mg \Rightarrow (10)(9.8) = 98\ N.$

$f_k = \mu_k \cdot n \Rightarrow (0.3)(98) = 29.4\ N$

$?F = ma?$

$F = F_{applied} - F_k \Rightarrow (40) - (29.4) \Rightarrow 10.6\ N$

$\therefore F = ma \Rightarrow (10.6) = (10)(a)$

$\therefore a = 1.06\ m/s^2$

Example 4 :- A soccer ball of mass 0.40 kg. is moving toward a player at a speed of 20 m/s. the player kicks the ball, and it rebounds in the opposite direction at a speed of 30 m/s if the Contact time between the foot and the ball is 0.01 s. Calculate the average force exerted by the Player on the ball?

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