Lecture 2

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Newton's First Law of Motion

- **An object subject to no external forces moves at a constant velocity.**
- Equation of predicting an object at constant velocity: $\vec{x}_f = \vec{x}_i + \vec{v} \cdot (t_f - t_i)$
  - $\vec{x}_f$ is the final position (m)
  - $\vec{x}_i$ is the initial position (m)
  - $\vec{v}$ is the velocity ($\frac{m}{s}$)
  - t_f is the final time (s)
  - t_i is the initial time (s)
- Example of finding the final position of an object at constant velocity:
  - What is $\vec{x}_f$ if $\vec{x}_i = (-4, 6, -8)$, $\vec{v} = (2, \frac{-4}{3}, 2)$, $t_f = 3$, and $t_i = 0$?
    - $\vec{x}_f = \vec{x}_i + \vec{v} \cdot (t_f - t_i)$
    - $\vec{x}_f = (-4, 6, -8) + (2, \frac{-4}{3}, 2) \cdot (3)$
    - $\vec{x}_f = (-4, 6, -8) + (6, -4, 6)$
    - $\vec{x}_f = (2, 2, -2)$

Newton's Second Law of Motion

- **The acceleration that an object experiences is equal to the net force exerted on it divided by the object's mass.**
- Equation of predicting the acceleration of an object: $\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$
  - $\vec{a}$ is the acceleration ($\frac{m}{s^2}$)
  - $\vec{F}_{\text{net}}$ is the net force ($N \cdot m$ *Newton meters*)
  - m is the mass of the object (kg)
- Equation of predicting an object's final velocity: $\vec{v}_f = \vec{v}_i + \vec{a} \cdot (t_f - t_i)$
  - $\vec{v}_f$ is the final velocity ($\frac{m}{s}$)

- $\vec{v}_i$ is the initial velocity ($\frac{m}{s}$)
- $\vec{a}$ is the acceleration ($\frac{m}{s^2}$)
- t_f is the final time (s)
- t_i is the initial time (s)

- Thus, the equation of finding the final position of an object is $\vec{x}_f = \vec{x}_i + \vec{v}_i \cdot (t_f - t_i) + \frac{1}{2}\vec{a} \cdot (t_f - t_i)^2$
- In three-dimensional motion, we often need to consider the motion in each direction separately. For example, the motion in the z direction can be described similarly to the motion in the x and y directions. The equation for the final velocity in the z direction is:
  - $\vec{v}_z f = \vec{v}_i + \vec{a} \cdot (t_f - t_i)$
    - $\vec{v}_z f$ is the final velocity in the z direction ($\frac{m}{s}$)
    - $\vec{v}_i$ is the initial velocity ($\frac{m}{s}$)
    - $\vec{a}$ is the acceleration ($\frac{m}{s^2}$)
    - t_f is the final time (s)
    - t_i is the initial time (s)
  - ***This is less important than the other two equations in this section.***
- Equation for finding the average velocity of an object: $\vec{v}_{\text{avg}} = \frac{\vec{v}_i + \vec{v}_f}{2}$
  - $\vec{v}_{\text{avg}}$ is the average velocity ($\frac{m}{s}$)
  - $\vec{v}_i$ is the initial velocity ($\frac{m}{s}$)
  - $\vec{v}_f$ is the final velocity ($\frac{m}{s}$)
- To find the final position of an object, we can use the average velocity and the time interval. The average velocity can be expressed as: $\vec{v}_{\text{avg}} = \vec{v}_i + \frac{\vec{a} \cdot (t_f - t_i)}{2}$
- By integrating the average velocity over the time interval, we get the equation for the final position: $\vec{x}_f = \vec{x}_i + \vec{v}_i \cdot (t_f - t_i) + \frac{1}{2}\vec{a} \cdot (t_f - t_i)^2$
  - $\vec{x}_f$ is the final position
  - $\vec{x}_i$ is the initial position
  - $\vec{v}_i$ is the initial velocity
  - $\vec{a}$ is the acceleration
  - t_f is the final time
  - t_i is the initial time
- ***We will not be tested on derivation. To derive these equations you need calculus. Rather I include each step to show the steps in derivation***

Gravitational Force

Force	Symbol	Description	Direction
Gravitational	$\vec{F}_g$ or $\vec{w}$ = $\vec{\text{weight}}$	The force of attraction between two masses. $\vec{F}_g = (0, 0, -9.8\frac{m}{s^2})$	Towards the center of the Earth (downwards)
Frictional	$\vec{F}_f$	The force that opposes the motion of an object.	Opposite to the direction of motion
Normal	$\vec{F}_N$	The support force exerted by a surface perpendicular to the object.	Perpendicular to the surface (upwards)
Drag	$\vec{F}_d$	The force that opposes the motion of an object through a fluid.	Opposite to the direction of motion

- The *equivelence principle* states that the force of gravity is equivalent to the force of acceleration. This is why objects in free fall experience weightlessness.
- When dropping an object from a height, the object will accelerate downwards at a rate of $9.8\frac{m}{s^2}$.
  - Putting that into a formula gives us $\vec{x}_f = \vec{x}_i + \vec{v}_i \cdot (t_f - t_i) + \frac{1}{2}\vec{a} \cdot (t_f - t_i)^2$
    - $\vec{X}_i = (0, 0, h)$
    - $\vec{v}_i = (0, 0, 0)$
    - $\vec{a} = \vec{g} = (0, 0, -9.8\frac{m}{s^2})$
  - Rearranging, $h = \frac{1}{2} \cdot 9.8 \cdot t^2$
- Example: If an object is dropped from a height of 100 meters, how long will it take to hit the ground?
  - $t_f = \sqrt{\frac{2 \cdot 100}{9.8}} \approx 4.52s$

Important Equations

Name	Equation
Newton's First Law of Motion	$\vec{x}_f = \vec{x}_i + \vec{v} \cdot (t_f - t_i)$
Newton's Second Law of Motion	$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$
	$\vec{v}_f = \vec{v}_i + \vec{a} \cdot (t_f - t_i)$
	$\vec{x}_f = \vec{x}_i + \vec{v}_i \cdot (t_f - t_i) + \frac{1}{2}\vec{a} \cdot (t_f - t_i)^2$
Gravitational Force	$\vec{F}_g = (0, 0, -9.8\frac{m}{s^2})$

PollEV Answers

1. *D* (2, 2, -2)

- What is $\vec{x}_f$ if $\vec{x}_i = (-4, 6, -8)$, $\vec{v} = (2, \frac{-4}{3}, 2)$, $t_f = 3$, and $t_i = 0$?