PHYS11 CH3:

Acceleration and Motion

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Introduction

- Understanding motion is crucial in physics
- Acceleration: a fundamental concept
- Key topics:
    - Average acceleration
    - Kinematic equations
    - Graphical analysis
    - Vector directions

Acceleration: Definition

- Acceleration: rate of change of velocity with time
- Vector quantity (magnitude and direction)
- Formula:

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

  where:

  - $\vec{a}$ is acceleration
  - $\Delta \vec{v} = \vec{v} - \vec{v}_0$ is change in velocity
  - $\Delta t = t - t_0$ is change in time

Average Acceleration

- Average acceleration over a time interval:

$$\vec{a}_{\text{avg}} = \frac{\vec{v} - \vec{v}_0}{t - t_0}$$

- Useful for calculating overall change in motion

Kinematic Equations for Uniform Acceleration

For constant acceleration:

$$\vec{v} = \vec{v}_0 + \vec{a}t$$
$$\vec{x} = \vec{x}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$$
$$v^2 = v_0^2 + 2a(x - x_0)$$

where:

- $\vec{v}$: final velocity
- $\vec{v}_0$: initial velocity
- $\vec{a}$: acceleration
- t: time
- $\vec{x}$: final position
- $\vec{x}_0$: initial position

Graphical Analysis: Velocity vs. Time

- Slope represents acceleration
- Straight line: constant acceleration
- Curved line: changing acceleration

Graphical Analysis: Displacement vs. Time

- Slope represents velocity
- Straight line: constant velocity (zero acceleration)
- Curved line: changing velocity (non-zero acceleration)

Vectors and Direction

- Acceleration, velocity, and displacement are vector quantities
- Direction is significant:
  - Positive acceleration: vector points in positive direction
  - Negative acceleration: vector points in negative direction
  - Positive and negative vectors are 180° apart
- **Important note:** We use "negative acceleration" instead of "deceleration"
  - This emphasizes that acceleration is a vector quantity
  - It reinforces the concept that slowing down is just acceleration in the opposite direction
  - Helps avoid misconceptions about the nature of acceleration

Example 1: Calculating Average Acceleration

Problem: Velocity increases from 0 to 20 m/s in 10 s. What is the average acceleration?
Solution:

$$\begin{aligned}\vec{a}_{\text{avg}} &= \frac{\vec{v} - \vec{v}_0}{t} \\ &= \frac{20\,\text{m/s} - 0\,\text{m/s}}{10\,\text{s}} \\ &= 2\,\text{m/s}^2\end{aligned}$$

Answer: The average acceleration is $2\,\text{m/s}^2$.

Example 2: Interpreting Velocity vs. Time Graphs

Problem: Show that the acceleration of a jet car is $5.0\,\mathrm{m/s^2}$ at any point on the graph.

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Figure: Velocity vs. Time Graph for a Jet Car

- Slope of v-t graph represents acceleration
- Straight line indicates constant acceleration
- Slope $= \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}}{t} = 5.0\,\mathrm{m/s}^2$

Answer: The acceleration is $5.0\,\mathrm{m/s}^2$ at any point on the graph.

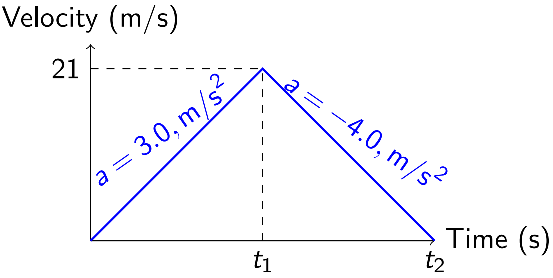
Car Acceleration Problem: Two-Phase Motion

Problem Statement: A car undergoes two-phase motion:

- Phase 1: Accelerates from rest at $3.0, \text{m/s}^2$ to $21.0, \text{m/s}$
- Phase 2: Decelerates at $4.0, \text{m/s}^2$ until stopping

Question: Find the total time of travel.

Solution: Total Time and Visualization



Solution: Phase 1 - Acceleration

Phase 1 (Acceleration):

- Initial velocity: $v_0 = 0, \mathrm{m/s}$
- Final velocity: $v = 21.0, \mathrm{m/s}$
- Acceleration: $a = 3.0, \mathrm{m/s}^2$

Using the equation: $v = v_0 + at_1$

$$21 = 0 + 3t_1 \;\; t_1 \qquad = \frac{21}{3} = 7.0, \mathrm{s}$$

Time for Phase 1: $7.0, \mathrm{s}$

Solution: Phase 2 - Deceleration

Phase 2 (Deceleration):

- Initial velocity: $v_0 = 21.0, \text{m/s}$
- Final velocity: $v = 0, \text{m/s}$
- Deceleration: $a = -4.0, \text{m/s}^2$

Using the equation: $v = v_0 + at_2$

$$0 = 21 + (-4)t_2 \quad 4t_2 \qquad = 21 \quad t_2 = \frac{21}{4} = 5.25, \text{s}$$

Time for Phase 2: $5.25, \text{s}$
Total time:

$$t_{\text{total}} = t_1 + t_2 \qquad = 7.0, \text{s} + 5.25, \text{s} \quad = 12.25, \text{s}$$

Answer: The total time of travel is $12.25, \text{s}$ (approximately $12, \text{s}$)

Conclusion

- Understanding acceleration is essential in physics
- Key concepts covered:
  - Definition of acceleration
  - Average acceleration
  - Kinematic equations
  - Graphical analysis
  - Vector directions
- These concepts help analyze real-world situations
- Practice with examples to master the material
- Remember: "Negative acceleration" instead of "deceleration" emphasizes the vector nature of acceleration