Equations of Motion Workshop

Academic Resource Center
Presentation Outline

• Understanding Concepts
  • Displacement
  • Time
  • Velocity
  • Acceleration
  • Equations of Motion
• Example Problems
Understanding Concepts

• Displacement:
  • Definition: the vector distance between the initial and final point.

• Displacement (arrow) vs. distance traveled (dashed line)
Velocity

• Definition: the rate of change of displacement.
• Average Speed: the distance traveled over time
• Average Velocity: the displacement over time
Acceleration

• Definition: the rate of change of velocity, i.e., change of velocity over time.

• Average Acceleration: the change in velocity over time.

• If the average acceleration is constant, then the equations of motion can be applied.
Equations of Motion

• 4 Equations:

\[ x = x_0 + \frac{v_0 + v}{2} t \]
\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]
\[ v = v_0 + at \]
\[ v^2 = v_0^2 + 2a(x - x_0) \]

• Note: the subscript \( o \) denotes the initial/starting point. These equations are written for the x direction of motion but they can also be applied to the y direction.
Concept Check

• Consider a ball thrown which follows the path shown, \( h \) is the height and \( R \) is the horizontal distance traveled.

\[ \text{What is the displacement (horizontal & vertical) of the ball at each of the points (1, 2 & 3)?} \]
Example Problem 1

- A bullet is moving at a speed of 350 m/s when it embeds into a lump of moist clay. The bullet penetrates for a distance of 0.05 m. Determine the acceleration of the bullet while moving into the clay. (Assume a uniform acceleration.)
Solution Strategy

1. Understand the Problem
   - What is being asked? Make a sketch.

2. Translate into “Physics Language”
   - List the given quantities with their units.

3. Find equation/s to help you solve for the unknown.

4. Solve

5. Check and report your answers
   - A good practice is to check the units of all the calculations that have been done.
Solution

• Sketch

Bullet, initial velocity 350 m/s

Distance the bullet penetrates = 0.05 m
Solution (cont’d)

Given:
\( v_i = 350 \text{ m/s}, \ v_f = 0 \text{ m/s}, \ d = 0.05 \text{ m} \)

Find:
\( a = ?? \)

Which equation should we use to solve?
Solution Cont’d

\[ v_f^2 = v_i^2 + 2a d \]
\[ (0 \text{ m/s})^2 = (350 \text{ m/s})^2 + 2a(0.05 \text{ m}) \]
\[-(350^2 \text{ m}^2/\text{s}^2)/0.05 \text{ m} = a \]
a = -1.225 \times 10^6 \text{ m} /\text{s}^2

(The - sign indicates that the bullet slowed down.)
Example Problem 2

- Consider the ball problem from before; knowing the height \((h)\) of the ball and the horizontal distance traveled, what more can we learn about the ball’s motion?
Solution Problem 2

• Answer: Everything!

• Solution Strategy:
  • By knowing the height that the ball travels, we can solve for the \( y \) component of the velocity (velocity in the \( y \) or vertical direction).
  • Then, we can solve for the time it takes for the ball to reach its maximum height which will be half the time it takes to cover the horizontal distance \( R \).
  • Finally, we can solve for the horizontal component of velocity.
  • Furthermore, we can deduce the angle that the ball was launched at from knowing the initial components of the velocity in the \( x \) and \( y \) direction.