Kinematics - Study of Motion

Types of Motion

1. Constant Motion (Uniform)
   - Same Motion - Same Direction
   - Same Speed

2. Non-Constant Motion (Accelerated)
   - Changing Motion - Change Direction
   - Change Speed
   - Change Both

Definitions of Motion

(distance, displacement, position, speed, velocity, acceleration, gravity, free fall)

Position \((x, y, z)\) - Where an object is located.

Distance \((d)\) - How far an object has traveled.

Displacement \((\Delta x, \Delta y, \Delta z)\) - Change in position.

- How far an object is from where it started.
- In what direction.

Position Diagram:

- \(C\) to \(D\): \(\Delta x = 4\) units \(\Delta x^2 + 4\) units
- \(D\) to \(B\): \(\Delta x = 8\) units \(\Delta x^2 = 0\) units
- \(A\) to \(C\): \(\Delta x = 5\) units \(\Delta x^2 = 5\) units
- \(B\) to \(D\) to \(A\) to \(B\):
- \(A\) to \(B\): \(\Delta x = 6\) units \(\Delta x^2 = 2\) units

Speed \((s)\) - Rate at which an object covers distance.
- How fast?

Velocity \((v)\) - Rate at which position is changed.
- # in direction (vector).
- How fast in what direction.

Sample Problem: Runner A runs the 100m dash at 15 m/s. Runner B at 10 m/s. By how many meters did Runner A beat Runner B?

Time for A: \(s = \frac{d}{t}\) \(t = \frac{100m}{15m/s} = 6.667\) sec.

Distance traveled by B: \(s = \frac{d}{t}\) \(d = \frac{3}{10Y} = 10\) sec.

\(t = \frac{3}{10Y}\) sec.

He was beat by 25.04 m.

\(s = \frac{d}{t}\)
ACCELERATION (a) - RATE AT WHICH AN OBJECT CHANGES VELOCITY
- HOW FAST THE NEEDLE ON SPEEDOMETER CHANGES (COMPASS)

IMPORTANT TOPIC
SECRETELY TRICKY
* VISUALIZE SPEEDOMETER NOT THE CAR

\[ a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t} \]

UNITS: \( \text{mph}/s \), \( \text{km/h}/s \), \( \text{m/s}^2 \rightarrow \text{m/s} \)

SAMPLE: A CAR GOES FROM 0 - 60 MPH IN 5 SEC. WHAT IS THE ACCELERATION?

\[ v_i = 0 \quad v_f = 60 \text{ MPH} \quad t = 5 \text{ SEC} \]

\[ a = \frac{\Delta v}{t} = \frac{60 \text{ MPH} - 0}{5 \text{ SEC}} = 12 \text{ MPH}/\text{SEC} \]

KINEMATICS EQUATIONS

1. \( v_f = v_i + at \)
2. \( \Delta x = v_i t + \frac{1}{2} at^2 \)
3. \( v_f^2 = v_i^2 + 2a\Delta x \)
4. \( \Delta x = \frac{1}{2}(v_f + v_i)t \)

TIPS:
1. WRITE DOWN GIVEN'S + UNKNOWN
2. MAKE SURE UNITS MATCH-UP
3. DO THE MATH W/ THE UNITS TO CHECK

\[ v_i = 0 \quad v_f = 60 \text{ MPH} \rightarrow 26.9 \text{ m/s} \]
\[ t = 5 \text{ SEC} \]

\[ \Delta x = \frac{1}{2}(v_f + v_i)t \]
\[ = 67 \text{ m} \]

HARD SAMPLE PROBLEM: "CATCHING UP"

A SPEEDER SETS CRUISE CONTROL AT 100 MPH. A POLICE OFFICER STARTS FROM REST AND ACCELERATES AT A RATE OF 5\( \text{ MPH}/\text{SEC} \) TO CATCH THE SPEEDER. 8) HOW MUCH TIME TILL THE SPEEDER IS CAUGHT? 9) HOW FAR TILL CAUGHT?

ACCELERATED

\[ v_i = 0 \quad a = 5\text{ MPH}/\text{SEC} \]
\[ \Delta x = \frac{1}{2}a t^2 \quad \Delta x = 5\text{ t}^2 \]

\[ \Delta x = \frac{1}{2} (5\text{ t})^2 = 25 \text{ t}^2 \]

\[ 44.7 = \frac{\Delta x}{t} \rightarrow 44.7 = \frac{1}{2}(5\text{ t})^2 \]

\[ 44.7 = 25\text{ t} \]

\[ t = 1.8 \text{ SEC} \]

CONSTANT

\[ v = 44.7 \text{ MPH} \quad a = 0 \]

\[ v = \frac{\Delta x}{t} \]

\[ \Delta x = 44.7 \text{ MPH} \]

\[ \Delta x = \frac{1}{2} (44.7\text{ MPH}) \]

\[ \Delta x = 44.7 \text{ MPH} \]
What is the difference between...

- Constant Velocity & Constant Acceleration?
- Same Speed + Same Direction
- Car on Cruise Control in same direction

Graphing motion

- When an object moves, its motion can be defined by an equation.
- Tells the story of an object's motion during a time frame.

3 Measurements of Motion:
1. Position at some period of time (x vs. t)
2. Velocity at some period of time (v vs. t)
3. Acceleration at some period of time (a vs. t)

3 Things to do from a graph:
1. Read points on the graph
2. Find the slope of a line
3. Find area under line

Shapes on a graph:
- No slope
- Constant + slope
- Constant - slope
- Changing slope (o → big +)
- Changing slope (big → o)
- Changing slope (o → big)

Position vs. Time (x vs. t)
- Slope → Velocity
- Area → Displacement

Velocity vs. Time (v vs. t)
- Slope → Acceleration
- Area → Displacement (Δx)

Acceleration vs. Time (a vs. t)
- Slope → Nothing
- Area → Δv
FREE FALL & THE ACCELERATION OF GRAVITY

FREE FALL: WHEN THE ONLY FORCE ACTING ON AN OBJECT IS THE FORCE OF GRAVITY

EX: FALLING ROCK, THROWN BALL, AIRPLANE, FRICTION

WHEN AN OBJECT IS IN FREE FALL → CHANGING MOTION
← VELOCITY IS CHANGING (SPEED UP OR SLOWING DOWN)

ALL OBJECTS IN FREE FALL EXPERIENCE THE SAME RATE OF ACCELERATION.

ACCELERATION OF GRAVITY (g)

WHAT IS THE RATE ACCELERATION FOR GRAVITY? FOR ALL OBJECTS

\[ g = 9.8 \text{ m/s}^2 \]

\[ g = 22 \text{ mph/s} \]

<table>
<thead>
<tr>
<th>( t )</th>
<th>( v_0 )</th>
<th>( v )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5s</td>
<td>0 m/s</td>
<td>( v )</td>
</tr>
<tr>
<td>1 s</td>
<td>9.8 m/s</td>
<td>( v )</td>
</tr>
<tr>
<td>2 s</td>
<td>19.6 m/s</td>
<td>( y )</td>
</tr>
<tr>
<td>3 s</td>
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<td>( y )</td>
</tr>
<tr>
<td>4 s</td>
<td>39.2 m/s</td>
<td>( y )</td>
</tr>
</tbody>
</table>

VELOCITY IS A FUNCTION OF TIME

\[ v = v_0 + at \]

\[ \Delta y = y_f - y_i = \frac{1}{2} at^2 \]

POSITION IS A FUNCTION OF TIME

UP/DOWN PROBLEMS

1. BREAK UP MOTION INTO AN "UP" HALF & A "DOWN" HALF
2. USE BASIC INFO
   - MOTION IS SYMMETRIC
   - \( v_f = v_{i, \text{down}} + \frac{1}{2} at_{\text{total}} \)
   - \( \Delta y_{\text{up}} = -\Delta y_{\text{down}} \)
   - \( v_{\text{top}} = 0 \text{ m/s} \)
   - \( a = 9.8 \text{ m/s}^2 \downarrow \)

ASSUME \( \text{down} \) = \( -9.8 \text{ m/s}^2 \)