HOW TO HIT THE TARGET: KINEMATIC EQUATIONS

PREDICTING PROJECTILE MOTION

How can you predict a projectile's path?
When you launch a ping pong ball, its trajectory (path) moves in two directions –
  ◆ **vertical** (how high the ball goes)
  ◆ **horizontal** (how far the ball goes)

Y-AXIS: VERTICAL MOTION

The **highest** point of the ball’s trajectory is the **vertical distance** \(d_y\).

\[
\begin{align*}
\text{Vertical Distance} & = d_y \\
\text{Initial Velocity} (\text{speed at launch}) & = v_i \\
\text{Time} & = t \\
\text{Vertical Acceleration} (\text{Gravity} = 9.8 \text{ m/s}^2) & = a_y \\
\text{Kinematic Equation} & = \frac{1}{2} a_y t^2 \\
\end{align*}
\]

**Measure The Time**

Use a stop watch or photogate to time how long the ball is in the air.

\[
v_f = v_i + a_x t
\]

**Calculate Y-Axis Velocity**

- \(v_f\) = average (Y-Axis) velocity
- \(v_i\) = initial velocity
- \(t\) = time
- \(d\) = distance (height!)

If you have the other variables, calculating the velocity is easy!

X-AXIS: HORIZONTAL MOTION

How far the bar is launched is the **horizontal distance** \(d_x\).

\[
\begin{align*}
\text{Horizontal Distance} & = d_x \\
\text{Initial Velocity} (\text{speed at launch}) & = v_i \\
\text{Time} & = t \\
\text{Horizontal Acceleration} (\text{Constant} = 0 \text{ m/s}^2) & = a_x \\
\text{Kinematic Equation} & = \frac{1}{2} a_x t^2 \\
\end{align*}
\]

**Calculate X-Axis Velocity**

- \(v_f\) = average (X-Axis) velocity
- \(v_i\) = initial velocity
- \(t\) = time
- \(d\) = distance
LAUNCH: GATHER YOUR DATA

Adjust your launcher’s angle size three times, taking three shots for each angle.

Collect data for the y-axis and x-axis. Graph the distance each shot landed - a new graph for each launch angle.

Graph: Line of Best Fit

Draw a curve or line of best fit that follows (fits) your data’s path.

Sample Data

<table>
<thead>
<tr>
<th>Angle (°)</th>
<th>Distance (X-axis)</th>
<th>Distance (Y-axis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>2 m</td>
<td>2 m</td>
</tr>
<tr>
<td>50</td>
<td>4 m</td>
<td>5 m</td>
</tr>
<tr>
<td>70</td>
<td>8 m</td>
<td>2 m</td>
</tr>
</tbody>
</table>

Some shots misfire. These outliers are too far from the line of best fit to include.

Predict: Hit a Target

Using the graph, predict which angle will hit a target distance.

Launch with the predicted angle. Repeat with more predictions - refine the line/curve of best fit!

Use these distances to find other variables in the kinematic equations - how does launch angle affect velocity?

This angle prediction should hit the target distance. If it doesn’t land after three shots, launch and graph the curve of best fit again.

Remember! Each time you re-design your launcher, make another graph. New designs need to test new data.