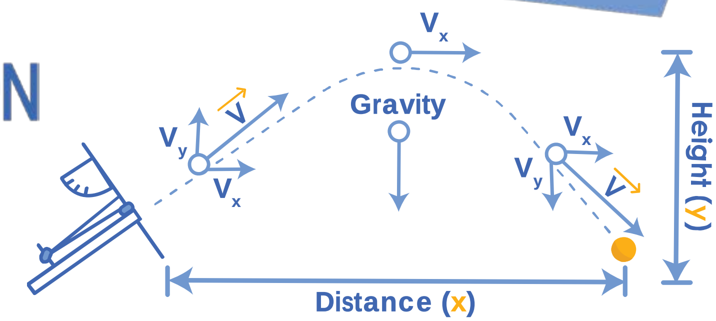
HOW TO HIT THE TARGET: KINEMATIC EQUATIONS

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 –

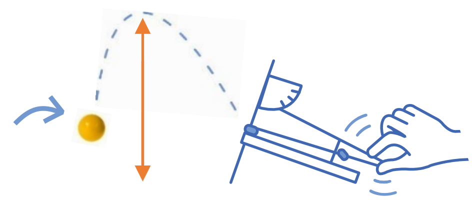
- **vertical** (how *high* the ball goes)
- **horizontal** (how *far* the ball goes)



This shows the **velocity** (speed) of the **ball** (v) at three points in its **trajectory**, separated into **x** and **y** directions (v_x and v_y.)

Y-AXIS: VERTICAL MOTION

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



$$d_y = v_i \times t + \tfrac{1}{2} \times a_y \times t^2$$

- **Y-Axis Vertical Distance** (Trajectory Height) — d_y
- **Initial Velocity** (Speed at Launch) — v_i
- **Time** — t
- **Vertical Acceleration** (Gravity = 9.8 m/s²) — a_y
- **Time** (How long the ball is in the air) — t^2

Kinematic Equation

Measure The Time

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

$$v_f = v_i + a \times t$$

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_y).

$$d_x = v_i \times t + \tfrac{1}{2} \times a_x \times t^2$$

- **X-Axis Horizontal Distance** (How far the ball goes, in meters) — d_x
- **Initial Velocity** (Speed at Launch) — v_i
- **Time** — t
- **Horizontal Acceleration** (Constant = 0 m/s²) — a_x
- **Time** (How long the ball is in the air) — t^2

Kinematic Equation

$$v_f = d \times t$$

Calculate X-Axis Velocity

- v_f = average (X-Axis) velocity (speed)
- t = time
- d = distance

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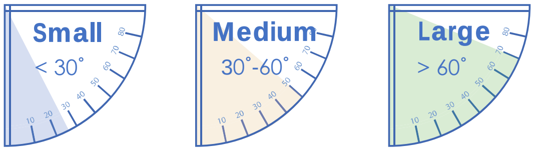
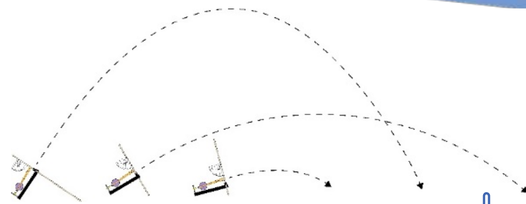
LAUNCH: GATHER YOUR DATA

Adjust your launcher's **angle** size <u>three</u> times, taking <u>three</u> shots for each angle.

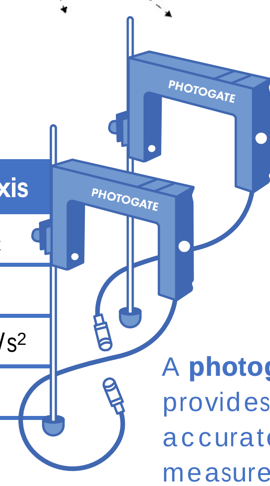




Take your best shot!

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

Variables	Y-Axis	X-Axis
Distance	d_y	d_x
Velocity	v_y	v_x
Acceleration	9.8 m/s²	0 m/s²
Time	t	t



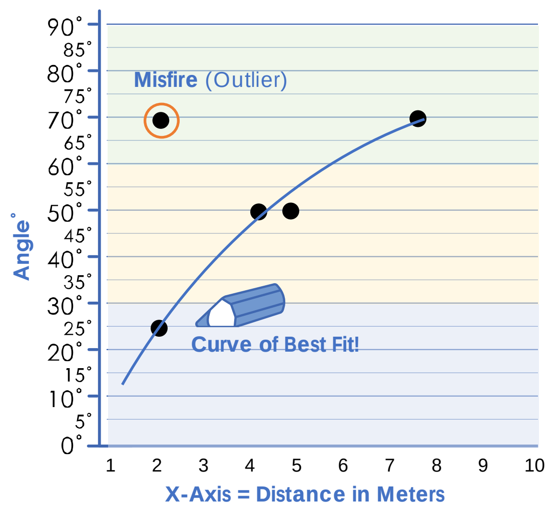
A **photogate** provides very accurate time measurements.

GRAPH: LINE OF BEST FIT

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

Sample Data		
25°	2 m	2 m
50°	4 m	5 m
70°	8 m	2 m

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



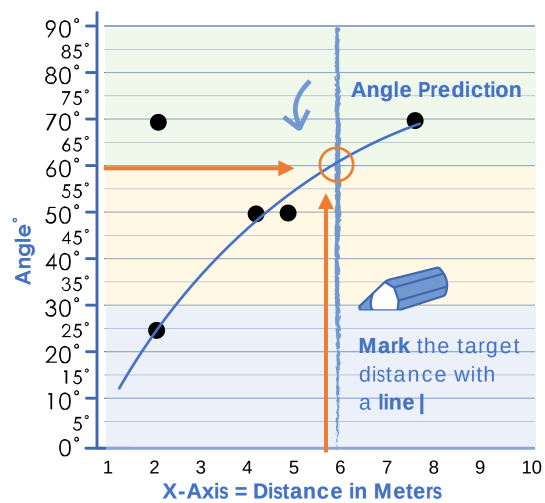
A **stopwatch** works as well, (less accurately.)

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 <u>three</u> 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.*

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