the kinematics equations for two-dimensional projectile motion

***x* equation** (constant v_x)	***y* equations** (constant a_y, changing v_y)	**missing variables**
$x_f = x_i + v_x \Delta t$	$y_f = y_i + v_{iy} \Delta t + \frac{1}{2} a_y (\Delta t)^2$	v_{fy}
	$v_{fy} = v_{iy} + a_y \Delta t$	y_i, y_f
	$v_{fy}^2 = v_{iy}^2 + 2a_y (y_f - y_i)$	Δt

how to solve two-dimensional projectile-motion problems

1. Check that the problem involves **projectile motion**. "Projectile motion" occurs when the only force on the object is the force of the Earth's gravity.

2. Check that all given units are **SI units**.

3. For a symbolic problem, write down **the "given" symbols**.

4. Begin your sketch by drawing the object's **path** of motion. The path for two-dimensional projectile motion is a parabola. Build any given **distance** information into your sketch.

5. Label the key **points in time** in your sketch (t_0, t_1, etc.). Usually, set $t_0 = 0$.

6. Write down your **axes,** pointing up and (usually) right.

7. Write down an **origin** for position. Your origin should usually be located at the furthest left x-coordinate and furthest down y-coordinate of the object, during the interval of projectile motion.

8. Label the **coordinates for position** (x_0, y_0, x_1, y_1, etc.), for each of the key points in time in your sketch. When possible, write down a specific value or symbol for each coordinate.

9. Identify the **question** with a "?". When convenient, represent what the question is asking you for with a *symbol*. When convenient, build the question into the sketch.

10. If you are given the **velocity** for a point in time, draw the velocity vector at that point in time, break the velocity vector into **components**, and build the components into your sketch.
If relevant, build into the sketch that the ***vertical* velocity at the peak** of the trajectory is 0.

11. Choose **"initial" and "final"** positions on the path. *Label* these positions *i* and *f*. The "initial" and "final" points are the two points that you plan to substitute into your kinematics equations.

12. Write down your **"setup"** for solving the projectile motion problem:

$$x_f = x_i + v_x \Delta t \qquad \Delta t,\ \ y_i,\ \ y_f,\ \ v_{iy},\ \ v_{fy},\ \ \underset{-9.8\,\frac{m}{s^2}\text{ or } -g}{a_y}$$

13. In the setup from step 12, indicate the **question** with a "?"—or, indicate **what you need** to answer the question with the word "need".

14. In the setup from step 12, write down a **specific number or symbol** for each variable**.**

15. When you know values for three of the four *x*-variables, you can **solve** the

$$x_f = x_i + v_x \Delta t$$

equation for the remaining variable.

15. When you know values for four *y*-variables, you can **choose an equation** to solve for one of the unknowns: Identify the variable you don't care about, and choose the equation that is missing that variable. Plug in and **solve**. You may need the quadratic formula:

If $a(\Delta t)^2 + b\,\Delta t + c = 0$, then $\Delta t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

For two-dimensional problems, you will usually need to use one component to **find Δ*t*, then use this value for the other component**.

16. **Check** that you have answered the right question, and have answered all parts of the question.
Check that your results makes sense. For a numeric answer, **check** that you included units.
For a symbolic answer, **check** that your answer includes only the "given" symbols.