FREE FALL

- On the surface of Earth, every object, no matter the size or shape, and neglecting air resistance, will accelerate downward at the same rate.

  This acceleration is about:

  22 mph every second

  or 9.8 m/s/s

  or 9.8 m/s² down

Gravity is always the same over-the-course of your experiments! (until we get to universal gravitation)

Gravity always acts downward at 9.8 m/s²!

Even when you throw a ball up, gravity always acts downward at 9.8 m/s²!

Note: If you choose up to be the positive direction, and you throw the ball up, you get:

\[ u_i = (t) \text{value} \quad \text{and} \quad a = -9.8 \text{ m/s}^2 \]
Kinematics Equations - Memorize These

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. \( \Delta x = \frac{1}{2} (v_i + v_f) t \)

You don't have to derive these, but you do have to fully understand them.

1. This is basically a restatement of the definition of acceleration:
   \[ \bar{a} = \frac{\Delta v}{\Delta t} \]
   \[ \bar{a} = \frac{v_f - v_i}{\Delta t} \]
   \[ \bar{a} \cdot \Delta t = v_f - v_i \]
   \[ v_f = v_i + \bar{a} \cdot \Delta t \]
   or \[ v_f = v_i + at \]

2. First, imagine motion at constant velocity (no acceleration): \( a = 0 \), so
   \[ \Delta x = v_i t + \frac{1}{2} at^2 \]
   so that \( \Delta x = v_i t \)
   or distance = velocity \cdot time
   this should look familiar.

* But I recommend deriving them anyway for your own edification.
2. (cont.) Next remember what the shape of the position graph looked like under constant acceleration?

\[
\begin{align*}
\text{area under the curve} & \quad \text{horizontal line} \\
\text{area under the curve} & \quad \text{upward sloping line}
\end{align*}
\]

Given that parabola are of the form \( y = Ax^2 \)
or rather: \( x = At^2 \) we know that under acceleration, position will vary parabolically with time, moreover, the value of \( A \) above is actually \( \frac{1}{2}a \). So if an object is accelerating under constant acceleration with no initial velocity

\[
\Delta x = \frac{1}{2}at^2
\]

Example: A ball dropped from a building.

After the first second, the ball will fall:

\[
\begin{align*}
a &= -9.8 \text{ m/s}^2 \\
t &= 1 \text{ s} \\
v_i &= 0
\end{align*}
\]

\[
\Delta x = v_i t + \frac{1}{2}at^2
\]

\[
\Delta x = (0)(1) + \frac{1}{2}(-9.8)(1)^2
\]

\[
\Delta x = -4.9 \text{ m}
\]

\[
\boxed{\Delta x = -4.9 \text{ m}}
\]
3. $v_f^2 = v_i^2 + 2a \Delta x$ is actually a combination of equations #1 and #4. Just memorize it, rather than deriving it each time.

- The equation is useful anytime you need $v_f$, $v_i$, $a$, and $\Delta x$ in the same equation.

4. This equation just restates the definition of average velocity: $\bar{v} = \frac{\Delta x}{\Delta t}$

where average velocity is $\bar{v} = \frac{v_i + v_f}{2}$

\[ \bar{v} = \frac{\Delta x}{\Delta t} \]
\[ \frac{1}{2} (v_f + v_i) = \frac{\Delta x}{\Delta t} \]
\[ \frac{1}{2} (v_f + v_i) \Delta t = \Delta x \]

or

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