FREE FALL

A FALLING POT

- A pot falls from a window.
- Before it fell, what was its speed?

  0 m/s
- What happened to its speed as it fell?

  It sped up or *accelerated*.
- What was happening to the speed the entire time it was falling?

  It kept increasing

- Since the initial speed was 0 m/s, the final speed can be expressed as :

$$v_f = at$$

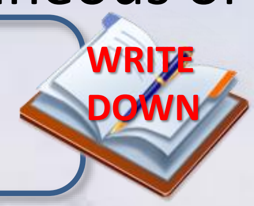
SPEED OF AN OBJECT IN FREE FALL

- The final speed of an object with a constant acceleration after a given amount of time has passed is also called the **instantaneous speed**.
  - It is, as we said, for an object with an initial speed of 0 m/s, $v_f = at$
- The acceleration of gravity, g, is 9.8 m/s^2
- For an object in free fall with an initial speed of 0 m/s, the final speed is:

$$v_f = gt$$

- If the initial speed of the falling object, v_i, is not zero, it needs to be added to get the instantaneous or final speed.

$$v_f = gt + v_i$$



(You may recall, this is the same as $v_f = at + v_i$ that we learned earlier.)

SAMPLE PROBLEM 1

A child drops a toy out of a window. It falls for 3.0 seconds. How fast is it going just before it hits?

- **Step 1:** Write the values of the variables
  - v_i = 0 m/s
  - t = 3 s
  - g = 9.8 m/s^2
- **Step 2:** Substitute values into the equation

$$v_f = gt + v_i$$

  - v_f = (9.8 m/s^2)(3 s) + 0 m/s = 29.4 m/s

SAMPLE PROBLEM 2

A child bounces a ball by throwing it down at 3.0 m/s. It hits the ground after 0.25 seconds. How fast is it going just before it hits?

- **Step 1:** Write the values of the variables
  - v_i = 3.0 m/s
  - t = 0.25 s
  - g = 9.8 m/s^2
- **Step 2:** Substitute values into the equation

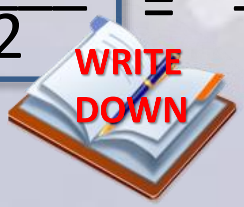
$$v_f = gt + v_i$$

  - v_f = (9.8 m/s^2)(0.25 s) + 3.0 m/s = 5.45 m/s

HOW FAR DOES IT FALL?

- In ***Sample Problem 1***, we calculated that an object that falls for 3.0 seconds with an initial speed of 0 m/s reaches a speed of 29.4 m/s.
  - $v_f = (9.8\ m/s^2)(3.0\ s) + 0\ m/s = 29.4\ m/s$
- Since the acceleration is constant, the average speed between any two measurements is the midpoint.
  - It is found by adding the two values and dividing by two.
  - The average speed of the falling object was:

$$v_{average} = \frac{v_f + v_i}{2} = \frac{29.4\ m/s + 0\ m/s}{2} = 14.7\ m/s$$



HOW FAR DOES IT FALL? (continued)

- Recall that average speed is *also* total distance divided by total time.

$$v_{average} = \frac{d_{total}}{t}$$

- This means that the distance fallen, d, can be determined as follows: $\boldsymbol{d = vt}$ (omitting the subscripts)
- At an average speed of 14.7 m/s for 3.0 s (last slide) this means: $\boldsymbol{d =}$ (14.7 m/s)(3.0 s) = **44.1 m**

HOW FAR DOES IT FALL? (finally done!)

- So, we determined that: ***d* =** (14.7 m/s)(3.0 s) = **44.1 m**
- Physicists have another equation obtained by some fancy math that gives the same result: $\boldsymbol{d = \frac{1}{2}at^2}$ or in this case $\boldsymbol{d = \frac{1}{2}gt^2}$
- d = ½(9.8 m/s^2)(3.0 s)^2 = 44.1 m
- Of course, if the object has an initial velocity, the distance it traveled due to that needs to be included:

$$d = v_i t + \frac{1}{2}at^2$$

SAMPLE PROBLEM 3

A penny falling from the Empire State Building hits the ground in 9.5 seconds. How far did it fall?

- **Step 1:** Write the values of the variables
  - $v_i = 0\ m/s$
  - $t = 9.5$ s
  - $a = g = 9.8$ m/s^2

- **Step 2:** Substitute values into the equation

$$d = v_i t + \frac{1}{2}at^2$$

  - $d = (0 \text{ m/s})(9.5 \text{ s}) + \frac{1}{2}(9.8 \text{ m/s}^2)(9.5 \text{ s})^2 = 442 \text{ m}$

SAMPLE PROBLEM 4

A child bounces a ball with a downward speed of 2.0 m/s. If it starts to bounce back after 0.20 s, how far down was it thrown?

- **Step 1:** Write the values of the variables
  - $v_i = 2.0\ m/s$
  - $t = 0.20$ s
  - $a = g = 9.8\ \text{m/s}^2$

- **Step 2:** Substitute values into the equation

$$d = v_i t + \frac{1}{2}at^2$$

  - $d = (2.0\ \text{m/s})(0.20\ \text{s}) + \frac{1}{2}(9.8\ \text{m/s}^2)(0.20\ \text{s})^2 = 0.60\ \text{m}$