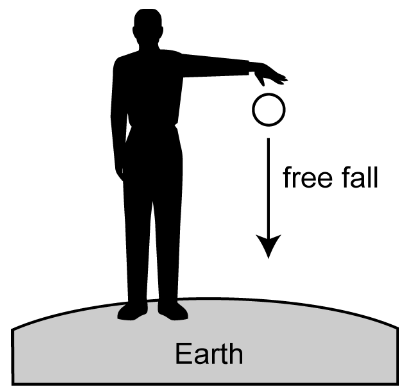
Name: ______________________

Skill Sheet 4.3 Acceleration Due to Gravity

One formal description of gravity is "The acceleration due to the force of gravity." The relationships among gravity, speed, and time are identical to those among acceleration, speed, and time. This skill sheet will allow you to practice solving acceleration problems that involve objects that are in free fall.

1. Gravity, velocity, distance, and time

When solving for velocity, distance, or time with an object accelerated by the force of gravity, we start with an advantage. The acceleration is known to be 9.8 meters/second/second or 9.8 m/sec^2. However, three conditions must be met before we can use this acceleration:



- The object must be in free fall.
- The object must have negligible air resistance.
- The object must be close to the surface of the Earth.

In all of the examples and problems, we will assume that these conditions have been met and therefore acceleration due to the force of gravity shall be equal to 9.8 m/sec^2 and shall be indicated by *g* Because the *y*-axis of a graph is vertical, change in height shall be indicated by *y*.

Remember that speed refers to "how fast" in any direction, but velocity refers to "how fast" in a specific direction. The sign of numbers in these calculations is important. Velocities upward shall be positive, and velocities downward shall be negative.

2. Solving for velocity

Here is the equation for solving for velocity:

final velocity = initial velocity + (the acceleration due to the force of gravity × time)

OR

$$v = v_0 + gt$$

Example:

How fast will a pebble be traveling 3 seconds after being dropped?

$$v = v_0 + gt$$

$$v = 0 + (-9.8 \text{ meters/sec}^{\cancel{2}} \times 3 \ \cancel{\text{sec}})$$

$$v = -29.4 \text{ meters/sec}$$

(Note that *gt* is negative because the direction is downward.)

3. Problems

1. A penny dropped into a wishing well reaches the bottom in 1.50 seconds. What was the velocity at impact?

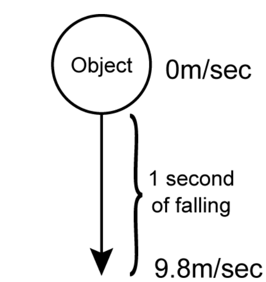
2. A pitcher threw a baseball straight up at 35.8 meters per second. What was the ball's velocity after 2.5 seconds? (Note that, although the baseball is still climbing, gravity is accelerating it downward.)

3. In a bizarre but harmless accident, Superman fell from the top of the Eiffel Tower. How fast was Superman traveling when he hit the ground 7.8 seconds after falling?

4. A water balloon was dropped from a high window and struck its target 1.1 seconds later. If the balloon left the person's hand at –5 meters/sec, what was its velocity on impact?

4. Solving for distance

Imagine that an object falls for one second. We know that at the end of the second it will be traveling at 9.8 meters/second. However, it began its fall at zero meters/second. Therefore, its average velocity is half of 9.8 meters/second. We can find distance by multiplying this average velocity by time. Here is the equation for solving for distance. Look to find these concepts in the equation:



$$\text{Average velocity} = \frac{9.8\text{m/sec} + 0\text{m/sec}}{2} = \frac{9.8\text{m/sec}}{2}$$

$$\text{distance} = \frac{\text{the acceleration due to the force of gravity} \times \text{time}}{2} \times \text{time}$$

OR

$$y = \frac{1}{2}gt^2$$

Example: A pebble dropped from a bridge strikes the water in exactly 4 seconds. How high is the bridge?

$$y = \frac{1}{2}gt^2$$

$$y = \frac{1}{2} \times 9.8 \text{ meters/sec} \times 4 \text{ sec} \times 4 \text{ sec}$$

$$y = \frac{1}{2} \times 9.8 \text{ meters/}\cancel{\text{sec}^2} \times 4\ \cancel{\text{sec}} \times 4\ \cancel{\text{sec}}$$

$$y = 78.4 \text{ meters}$$

Note that the terms cancel. The answer written with the correct number of significant figures is 78 meters. The bridge is 78 meters high.

5. Problems

1. A stone tumbles into a mineshaft and strikes bottom after falling for 4.2 seconds. How deep is the mineshaft?

2. A boy threw a small bundle toward his girlfriend on a balcony 10.0 meters above him. The bundle stopped rising in 1.5 seconds. How high did the bundle travel? Was that high enough for her to catch it?

3. A volleyball serve was in the air for 2.2 seconds before it landed untouched in the far corner of the opponent's court. What was the maximum height of the serve?

6. Solving for time

The equations demonstrated in Sections 2 and 3 can be used to find time of flight from speed or distance, respectively. Remember that an object thrown into the air represents two mirror-image flights, one up and the other down.

	Original equation	Rearranged equation to solve for time
Time from velocity	$v = v_0 + gt$	$t = \frac{v - v_0}{g}$
Time from distance	$y = \frac{1}{2}gt^2$	$t = \sqrt{\frac{2y}{g}}$

Try these:

1. At about 55 meters/sec, a falling parachuter (before the parachute opens) no longer accelerates. Air friction opposes acceleration. Although the effect of air friction begins gradually, imagine that the parachuter is free falling until terminal speed (the constant falling speed) is reached. How long would that take?

2. The climber dropped her compass at the end of her 240-meter climb. How long did it take to strike bottom?

3. For practice and to check your understanding, use these equations to check your work in Sections 2 and 3.