Physics 2204   **Worksheet #5**
Freefall-Acceleration due to Gravity

The equations of kinematics for uniform acceleration also apply to the special case of an object that is accelerating near the earth's surface. The gravitational pull of the earth on any object will cause it to accelerate towards the centre of the earth at a rate of 9.80 m/s^2, assuming air resistance is negligible. Thus, for any equations involving a body in free fall (something that is dropped or thrown) we can use the same problem solving skills we already have. There are a few unique features to solving freefall problems.

a)   acceleration is always constant at g = -9.80 m/s^2 (the negative is very important)
b)   at the top of its flight, an object has v = 0. (since it must stop before starting to come down again)
c)   keeping your sign conventions for direction is very important...all velocity directed down must be negative, and all velocity directed up must be positive.

1.   A tourist drops a rock from rest from a guard rail overlooking a valley. What is the velocity of the rock at 4.0 s? What is the displacement of the rock at 4.0 s?

2.   Suppose the tourist in question #1 instead threw the rock with an initial velocity of 8.0 m/s [down]. Determine the velocity and displacement of the rock at 4.0 s (Remember the v$_i$ is down and must become a -8.0 m/s)

3.   Suppose the tourist in question #1 instead threw the rock with an initial velocity of 8.0 m/s [up]. Determine the velocity and displacement of the rock at 4.0 s (Remember the v$_i$ is up and must become a +8.0 m/s)

4.   A college student wants to toss a textbook to his roommate who is leaning out of a window directly above him. He throws the book upwards with an initial velocity of 8.0 m/s. The roommate catches it while it is travelling at 3.0 m/s [up].
        a)   How long was the book in the air?
        b)   How far vertically did the book travel?
        c)   Redo the problem, and have the roommate catch the book as it is travelling 3.0 m/s [down]. What is the time and displacement now? Do you notice anything?

5.   A man is standing on the edge of a 20.0 m high cliff. He throws a rock vertically with an initial velocity of 10.0 m/s.
        a)   How high does the rock go? (Remember that at its max height v = 0 m/s)
        b)   How long does it take to reach its max height?

Solutions:

1.

Given: $v_i = 0$ m/s
        $a = g = -9.80$ m/s^2
        $t = 4.0$ s

Find: $v = ?$
        $d = ?$

Soln: $v_2 = v_1 + at$
        $v_2 = 0 + (-9.80 \text{ m/s}^2)(4.0 \text{ s})$
        $\boxed{v_2 = -39.2 \text{ m/s}}$

        $d = v_1 t + \frac{1}{2} at^2$
        $d = 0 + \frac{1}{2}(-9.80 \text{ m/s}^2)(4.0 \text{ s})^2$
        $\boxed{d = -78.4 \text{ m}}$

2.

Given: $v_i = -8.0$ m/s
        $a = g = -9.80$ m/s^2
        $t = 4.0$ s

Find: $v = ?$
        $d = ?$

Soln: $v_2 = v_1 + at$
        $v_2 = -8.0 \text{m/s} + (-9.80 \text{ m/s}^2)(4.0 \text{ s})$
        $\boxed{v_2 = -47.2 \text{ m/s}}$

        $d = v_1 t + \frac{1}{2} at^2$
        $d = (-8.0 \text{m/s})(4.0 \text{s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(4.0 \text{ s})^2$
        $\boxed{d = -110.4 \text{ m}}$

3.

Given: $v_i = +8.0$ m/s
        $a = g = -9.80$ m/s^2
        $t = 4.0$ s

Find: $v = ?$
        $d = ?$

Soln: $v_2 = v_1 + at$
        $v_2 = +8.0 \text{ m/s} + (-9.80 \text{ m/s}^2)(4.0 \text{ s})$
        $\boxed{v_2 = -31.2 \text{ m/s}}$

        $d = v_1 t + \frac{1}{2} at^2$
        $d = (8.0 \text{ m/s})(4.0 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(4.0 \text{ s})^2$
        $\boxed{d = -46.4 \text{ m}}$
        * this is smaller, because the object must travel up first, then down, so its net displacement is less.

4.

Given: $v_i = 8.0$ m/s [up]
        $v_2 = 3.0$ m/s [up]
        $a = g = -9.80$ m/s^2

Find: $t = ?$
        $d = ?$

Soln:
a) $\boxed{t = 0.51\text{s}}$

b) $\boxed{d = 2.80 \text{ m}}$

c)
Given: $v_i = 8.0$ m/s [up]
        $v_2 = 3.0$ m/s [down]
        $a = g = -9.80$ m/s^2

Find: $t = ?$
        $d = ?$

Soln:
        $\boxed{t = 1.12 \text{ s}}$

        $\boxed{d = 2.80 \text{ m}}$

*Notice that the time was longer, as the book went up past the roommate and was caught on the way down. The displacement was the same however...she caught it at the same net displacement.

5.

Given: $v_i = 10$ m/s
        $a = g = -9.80$ m/s^2
        $h = 20.0$ m

Find: $d = ?$
        $t = ?$

Soln: $v_2 = v_1 + at$
        $0 = 10 + (-9.80 \text{ m/s}^2)(t)$
        $\boxed{t = 1.02 \text{ s}}$

        $d = v_1 t + \frac{1}{2} at^2$
        $d = (10.0 \text{ m/s})(1.02\text{s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(1.02\text{s})^2$
        $\boxed{d = 5.10 \text{ m}}$