1.3.3 In Class or Homework Exercise

1. A sportscar is advertised to be able to stop, from a speed of 100. *km/h*, within 45 *m*. What is its acceleration in m/s^2? How many *g*'s is this?

$\vec{v}_i = 100\ km/h = 27.8 m/s$

$\vec{v}_f = 0$

$\Delta\vec{d} = 45m$

$\vec{a} = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}}$$

$$45 = \frac{0 - 27.8^2}{2\vec{a}}$$

$$\vec{a} = \boxed{-8.6 m/s^2}$$

$$\frac{8.6}{9.8} = \boxed{0.88 g's}$$

2. A brick is dropped from a height of 80.0 m.
   a. How long does it take a brick to reach the ground?

Using down as +,

$\vec{v}_i = 0$

$\Delta\vec{d} = 80.0m$

$\vec{a} = 9.80 m/s^2$

$t = ?$

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$

$$80.0 = 0 + \tfrac{1}{2}(9.80)t^2$$

$$t = \boxed{4.04s}$$

   b. What will be its velocity when it reaches the ground?

$\vec{v}_i = 0$

$\Delta\vec{d} = 80.0m$

$\vec{a} = 9.80 m/s^2$

$\vec{v}_f = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}}$$

$$80.0 = \frac{v_f^2 - 0}{2(9.80)}$$

$$\vec{v}_f = \pm 39.6 m/s$$

$$= \boxed{39.6 m/s}$$

3. A ball is thrown vertically into the air with a speed of 24.7 *m/s*. How high does it go? How long does it take to return to the ground?

Using up as +,

$\vec{v}_i = 24.7 m/s$

$\vec{a} = -9.80 m/s^2$

$\vec{v}_f = 0$

$\Delta\vec{d} = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}}$$

$$= \frac{0 - 24.7^2}{2(-9.80)}$$

$$= \boxed{31.1m}$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$-9.80 = \frac{0 - 24.7}{t}$$

$t = 2.52s$ **(half of the trip)**

So it reached a height of 31.1 m and was in the air a total of $\boxed{5.04 s}$

4. A kangaroo jumps to a vertical height of 2.8 *m*. How long was it in the air before returning to earth?

This problem is easiest if we look at the trip down (and use down as +)

$\vec{v}_i = 0$

$\vec{a} = 9.80\, m/s^2$

$\Delta\vec{d} = 2.8m$

$t = ?$

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$
$$2.8 = 0 + \tfrac{1}{2}(9.80)t^2$$
$$t = 0.76\, s$$

Since this is only half of the time (the trip down) the total time is $\boxed{1.52\, s}$

5. A trout jumps a waterfall 2.5 *m* high. With what minimum speed did it leave the water below to reach the top?

Using up as +,

$\Delta\vec{d} = 2.5m$

$\vec{v}_f = 0$

$\vec{a} = -9.80\, m/s^2$

$\vec{v}_i = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}}$$
$$2.5 = \frac{0 - v_i^2}{2(-9.80)}$$
$$\vec{v}_i = \pm 7.0 m/s$$
$$= \boxed{7.0 m/s}$$

6. A stuntman is on a bridge 3.8 *m* above a road. He wants to be able to jump into an approaching truck on the road below that is travelling at 60.0 *km/h*. How far away should the truck be when the stuntman steps off of the bridge? (assume the stuntman's initial speed is zero and ignore the height of the truck)

Using down as + for the stuntman,

Stuntman

$\vec{v}_i = 0$

$\vec{a} = 9.80 m/s^2$

$\Delta\vec{d} = 3.8m$

$t = ?$ **(the stuntman and the truck will have the same time)**

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$
$$3.8 = 0 + \tfrac{1}{2}(9.80)t^2$$
$$t = 0.88s$$

Truck

$\vec{v}_t = 60.0 km/h = 16.7 m/s$

$t = 0.88 s$

$\Delta\vec{d}_t = ?$

$$\vec{v}_t = \frac{\Delta\vec{d}_t}{t}$$

$$16.7 = \frac{\Delta\vec{d}_t}{0.88}$$

$$\Delta\vec{d}_t = \boxed{15m}$$

Since the truck will travel 15m in the time it will take the stuntman to fall, he should start falling when the truck is 15m away.

7. You are standing on a bridge that is 15.0 *m* high. You throw a rock off of the bridge and it hits the water below in 2.2 *s*. With what speed did you throw the rock and in what direction was it thrown?

Using down as +,

$\Delta\vec{d} = 15.0m$

$\vec{a} = 9.80 m/s^2$

$t = 2.2s$

$\vec{v}_i = ?$

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$

$$15.0 = \vec{v}_i(2.2) + \tfrac{1}{2}(9.80)(2.2)^2$$

$$\vec{v}_i = \boxed{-4.0 m/s}$$

Since the initial velocity is negative and we chose down as positive, it was thrown upward.

8. A stone is thrown vertically upward with a speed of 18.0 *m/s*.

a. How fast is it moving when it reaches a height of 16.0 *m*?

Using up as +,

$\vec{v}_i = 18.0 m/s$

$\Delta\vec{d} = 16.0m$

$\vec{a} = -9.80 m/s^2$

$\vec{v}_f = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}}$$

$$16.0 = \frac{v_f^2 - 18.0^2}{2(-9.80)}$$

$$\vec{v}_f = \boxed{\pm 3.22 m/s}$$

b. At what time is the stone at this height?

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$

$$16.0 = 18.0t + \tfrac{1}{2}(-9.80)t^2$$

$$0 = -4.90t^2 + 18.0t - 16.0$$

$t = \boxed{1.51s \textbf{ or } 2.17s}$ **(using quadratic formula)**

c. Why are there two answers to (a) and (b)?

There are two answers because the stone is at the height twice – on the way up and on the way down. Note that if you used the final velocity from (a) to calculate (b), you would have to do two calculations – one with the positive velocity and one with the negative velocity. Both are possible answers.

9. A stone is dropped from the roof of a high building. A second stone is dropped 1.00 *s* later. How far apart are the stones when the second one has reached a speed of 23.0 *m*/*s*?

Using down as +,

Stone 1

$\vec{v}_i = 0$

$\vec{a} = 9.80 m/s^2$

$t_1 = t_2 + 1.00$

$\Delta\vec{d}_1 = ?$

Stone 2

$\vec{v}_i = 0$

$\vec{a} = 9.80 m/s^2$

$\vec{v}_f = 23.0 m/s$

$t_2 = ?$

$\Delta\vec{d}_2 = ?$

Since we know more about stone 2, we will start with that object; we can find both $\Delta\vec{d}_2$ and t_2:

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$
$$9.80 = \frac{23.0 - 0}{t}$$
$$t_2 = 2.35 s$$

$$\Delta\vec{d}_2 = \frac{v_f^2 - v_i^2}{2\vec{a}} = \frac{23.0^2 - 0}{2(9.80)} = 27.0 m$$

Looking at stone 1 now,

$$t_1 = t_2 + 1.00$$
$$t_1 = 2.35 + 1.00$$
$$t_1 = 3.35 s$$

$$\Delta\vec{d}_1 = \vec{v}_i t_1 + \tfrac{1}{2}\vec{a}t_1^2 = 0 + \tfrac{1}{2}(9.80)(3.35)^2 = 55.0 m$$

$$x = \Delta\vec{d}_1 - \Delta\vec{d}_2 = 55.0 - 27.0 = \boxed{28.0 m}$$

10. A stone is dropped into the water from a bridge 44 *m* above the water. Another stone is thrown downward 1.0 *s* after the first one was dropped. Both stones strike the water at the same time. What was the initial velocity of the second stone?

Using down as +,

Stone 1

$\vec{v}_i = 0$

$\vec{a} = 9.80 m/s^2$

$t_1 = ?$

$\Delta\vec{d}_1 = 44m$

Stone 2

$\vec{v}_i = ?$

$\vec{a} = 9.80 m/s^2$

$t_2 = t_1 - 1.0$

$\Delta\vec{d}_2 = 44m$

Starting with stone 1,

$$\Delta\vec{d}_1 = \vec{v}_i t_1 + \tfrac{1}{2}\vec{a}t_1^2$$
$$44 = 0 + \tfrac{1}{2}(9.80)t_1^2$$
$$t_1 = 3.0s$$

so

$$t_2 = t_1 - 1.0$$
$$= 3.0 - 1.0$$
$$= 2.0s$$

Now for stone 2

$$\Delta\vec{d}_2 = \vec{v}_i t_2 + \tfrac{1}{2}\vec{a}t_2^2$$
$$44 = \vec{v}_i(2.0) + \tfrac{1}{2}(9.80)(2.0)^2$$
$$\vec{v}_i = \boxed{12.2 m/s}$$

11. The acceleration due to gravity on the moon is about one-sixth what it is on earth. If an object is thrown upward on the moon, how many times higher will it go as compared to the earth assuming the same initial velocity of 5.0 *m*/*s*?

Using up as +,

On Earth

$\vec{v}_i = 5.0 m/s$

$\vec{v}_f = 0$

$\vec{a} = -9.80 m/s^2$

$\Delta\vec{d} = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}}$$
$$= \frac{0 - 5.0^2}{2(-9.80)}$$
$$= 1.28m$$

On Moon

$\vec{v}_i = 5.0 m/s$

$\vec{v}_f = 0$

$\vec{a} = -1.63 m/s^2$

$\Delta\vec{d} = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}}$$
$$= \frac{0 - 5.0^2}{2(-1.63)}$$
$$= 7.67m$$

So the ratio is $\frac{\Delta\vec{d}_m}{\Delta\vec{d}_E} = \frac{7.67m}{1.28m} = \boxed{6.0 \textbf{ times higher}}$

12. A foolish student, wanting to measure the acceleration due to gravity, walks off of a skyscraper 320 *m* high and starts his free fall (zero initial velocity). 5.0 seconds later, Superman dives off the roof to save the student. What must Superman's initial velocity be in order to catch the student just before reaching the ground? (Assume Superman is in free fall)

Using down as +,

Student

$\vec{v}_i = 0$

$\vec{a} = 9.80 m/s^2$

$\Delta\vec{d} = 320 m$

$t = ?$

$\Delta\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$

$320 = 0 + \frac{1}{2}(9.80)t^2$

$t = 8.1 s$

Superman

$\vec{a} = 9.80 m/s^2$

$\Delta\vec{d} = 320 m$

$t_2 = t_1 - 5.0 = 8.1 - 5.0 = 3.1 s$

$\Delta\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$

$320 = \vec{v}_i(3.1) + \frac{1}{2}(9.80)(3.1)^2$

$\vec{v}_i = \boxed{88 m/s}$

13. At a height of 120 *m* above the earth, a package is released from the window of a helicopter that is ascending vertically with a speed of 8.00 *m/s*. How long does it take the package to reach the ground?

Using up as +,

$\vec{v}_i = 8.00 m/s$

$\Delta\vec{d} = -120 m$

$\vec{a} = -9.80 m/s^2$

$t = ?$

$\Delta\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$

$-120 = 8.00t + \frac{1}{2}(-9.80)t^2$

$0 = -4.90t^2 + 8.00t + 120$

$t = -4.2 s$ **or** $\boxed{5.8 s}$ **(using quadratic formula)**

14. A falling stone takes 0.30 *s* to pass a window that is 2.4 *m* long. From what height above the top of the window did the stone fall?

It is necessary to break this problem up into 2 parts, above the window and next to the window:

Using down as +,

Next to the window

$t = 0.30s$

$\Delta\vec{d} = 2.4m$

$\vec{a} = 9.80m/s^2$

$\vec{v}_i = ?$

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$
$$2.4 = \vec{v}_i(0.30) + \tfrac{1}{2}(9.80)(0.30)^2$$
$$\vec{v}_i = 6.53m/s$$

Since the initial speed at the top of the window is the same as the final speed for the part of the trip above the window"

Above the window

$\vec{v}_i = 0$

$\vec{v}_f = 6.53m/s$

$\vec{a} = 9.80m/s^2$

$\Delta\vec{d} = ?$

$$\Delta\vec{d} = \frac{v_f^2 - v_i^2}{2\vec{a}} = \frac{6.53^2 - 0}{2(9.80)} = \boxed{2.2m}$$

So the stone was released from a height of 2.2 m above the window.

15. Pelicans tuck their wings and free fall straight down when diving for fish. Suppose a pelican starts its dive from a height of 20.0 *m* and cannot change its path once committed. If it takes a fish 0.10 *s* to perform evasive action, at what minimum height must it spot the pelican to escape?

Using down as +,

$\vec{v}_i = 0$

$\vec{a} = 9.80m/s^2$

$\Delta\vec{d} = 20.0m$

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$
$$20.0 = 0 + \tfrac{1}{2}(9.80)t^2$$
$$t = 2.02s$$

So the pelican will take 2.02 s to reach the water; since the fish needs 0.10 s to escape, the pelican can only fall for 2.02-0.10=1.92 s

$\vec{v}_i = 0$

$t = 1.92s$

$\vec{a} = 9.80m/s^2$

$\Delta\vec{d} = ?$

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2 = 0 + \tfrac{1}{2}(9.80)(1.92)^2 = 18.1m$$

Since the pelican is falling from a height of 20.0 m, and can fall 18.1 m, the fish must spot him at a minimum height of $\boxed{\mathbf{1.9m}}$.