Lesson 12: Gravity

Aristotle

From the time of Aristotle (384-322 BC) until the late 1500's, gravity was believed to act differently on different objects.

- This was based on Aristotle's observations of doing things like dropping a metal bar and a feather at the same time. Which one hits the ground first?
    - Obviously, common sense will tell you that the bar will hit first, while the feather slowly flutters to the ground.
- In Aristotle's opinion, this was because the bar was being pulled harder (and faster) by gravity because of its physical property of having more mass.
- Because everyone could see this when they dropped different objects, it wasn't questioned for almost 2000 years.

Galileo

Galileo Galilei was the first major scientist to refute (prove wrong) Aristotle's theories.

- In his famous (at least to Physicists!) experiment, Galileo *supposedly* went to the top of the leaning tower of Pisa and dropped two balls from the top at the same time.
    - Both were the same material, but different sizes so also different masses.
- Down below people watched for them to hit the ground.
    - They both hit the ground at the ***same time***, even though Aristotle would say that the heavier ball should have hit first.

Galileo had shown that the different rates at which some objects fall is due to air resistance, a type of friction.

- Get rid of friction (air resistance) and all objects will fall at the same rate.
- Galileo said that the acceleration of any object (in the absence of air resistance) is the same.
- To this day we follow the model that Galileo created.

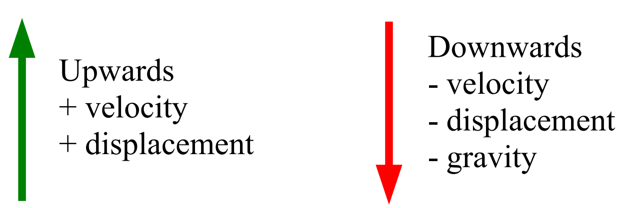
$$a_g = g = 9.81 m/s^2$$

$a_g = g$ = acceleration due to gravity

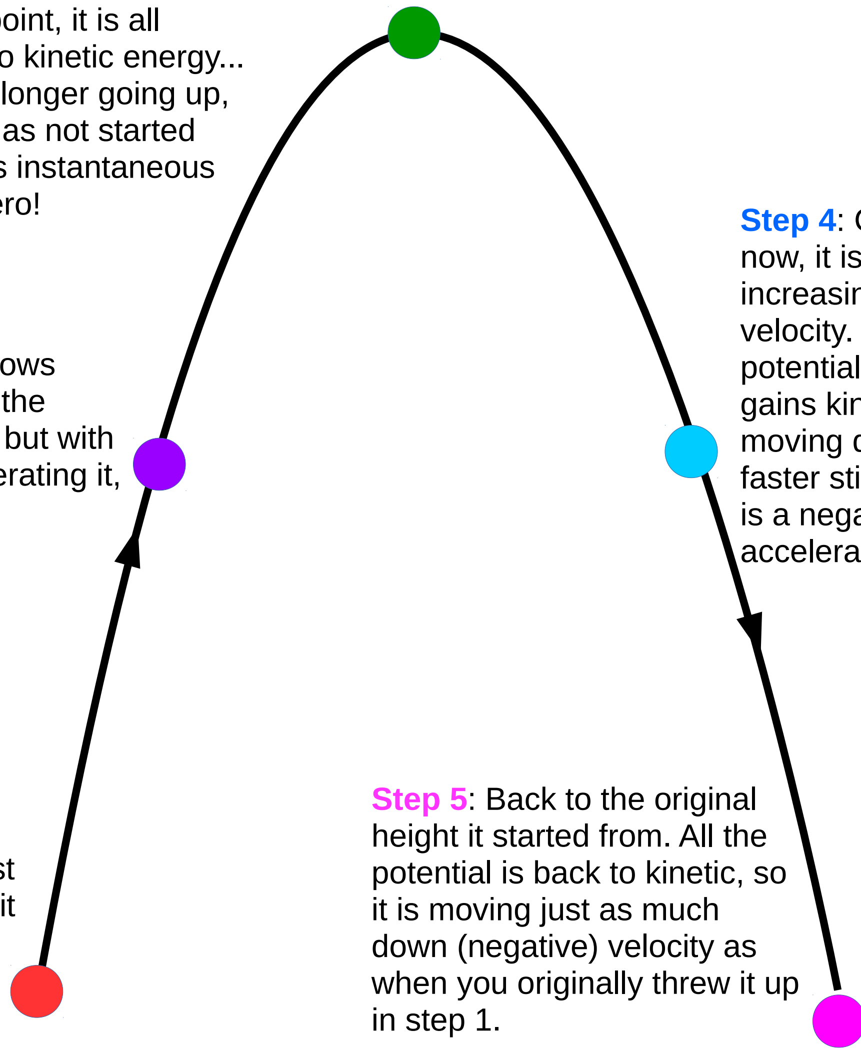
Warning!
In any of the questions we will do, we must assume that the entire problem happens near the surface of the Earth. We will learn in later chapters that the acceleration due to gravity does decrease as you move further away from the centre of the Earth.

Since gravity is just an acceleration like any other, it can be used in any of the formulas that we have used so far.

- Just be careful about using the correct sign (positive or negative) for the variables in the problem. I would strongly suggest you always stick with **up** being **positive,** and **down** being **negative.**



Throwing a ball up into the air...



Step 1: When it first leaves your hand, it is going at its very fastest velocity. Think of how it has maximum kinetic energy at this point.

Step 2: As it rises, it slows down. It's still going in the positive (up) direction, but with negative gravity accelerating it, it slows down.

Step 3: At its highest point, it is all potential energy and no kinetic energy... it has stopped! It is no longer going up, but for a split second has not started coming down either. Its instantaneous velocity at the top is zero!

Step 4: Coming down now, it is moving with an increasing *negative* velocity. It's losing its potential energy as it gains kinetic. A ball moving down faster and faster still means gravity is a negative acceleration.

Step 5: Back to the original height it started from. All the potential is back to kinetic, so it is moving just as much down (negative) velocity as when you originally threw it up in step 1.

Examples of Calculations with Gravity

***** For Examples 1 to 5, we are starting with a ball that is thrown up into the air at 16.3 m/s. *****

Example 1: **Determine** its velocity after 0.80s have passed.

In the question the velocity upwards is positive, and we'll keep it that way. That just means that we have to make sure that we use gravity as a negative number, since gravity always acts down.

$$a=\frac{v_f-v_i}{t}$$
$$v_f=v_i+at$$
$$v_f=16.3+(-9.81)(0.80)$$
$$v_f=8.452=8.5\,m/s$$

This value is still positive, just smaller. That means it's still going up, it's just not moving as fast as it was originally.

Example 2: **Determine** how fast it is going 2.5s after you threw it up into the air..

Just to be clear, this isn't adding 2.5s to the previous question. I just want to know how fast it's moving 2.5 s after it left your hand.

$$a = \frac{v_f - v_i}{t}$$
$$v_f = v_i + at$$
$$v_f = 16.3 + (-9.81)(2.5)$$
$$v_f = -8.225 = -8.2 m/s$$

In this example, the final velocity is negative. That means that it must have already passed its highest point is on its way back down.

Example 3: **Determine** how much time it took for the ball to reach its maximum height.

It must be some time before 2.5s, since by then we know it was already on its way back down. We do know that at its maximum height its instantaneous velocity is zero, so...

$$a = \frac{v_f - v_i}{t}$$
$$t = \frac{v_f - v_i}{a}$$
$$t = \frac{0 - 16.3}{-9.81}$$
$$t = 1.6615698 = 1.66 s$$

Notice that I have 3 sig digs, because I only used numbers with three sig digs.

Example 4: Determine how high the ball goes.

This means I want to know its maximum height. It's best to try to avoid using the time you calculated in Example 3, since if you made a mistake there this answer will be wrong also. If you are working on a problem where you ***must*** use your previous answer (there's no other formula), then you just have to. That's not the case here, since...

$$v_f^2 = v_i^2 + 2ad$$
$$d = \frac{v_f^2 - v_i^2}{2a}$$
$$d = \frac{0 - 16.3^2}{[2(-9.81)]}$$
$$d = 13.5417940877 = 13.5 m$$

Example 5: **Explain** how fast it is going when it reaches your hand again.

I'm asking you to explain, not calculate, this. Ignoring air resistance, it will be going as fast coming down as it was going up. This means its final velocity as it reaches your hand is -16.3m/s (**negative** because it is coming **down**).

Gee's

You might have heard people flying fighter jets or rockets in movies say how many "gee's" they were feeling.

- All this means is that they are comparing the acceleration they are feeling to regular gravity.

So, right now just sitting in a chair, you are experiencing 1 gee… regular gravity.

- This just means that you are experiencing one times the acceleration of gravity. One times $9.81 m/s^2$ is equal to $9.81 m/s^2$.
  - During lift-off the astronauts in the space shuttle experienced about 5 g.
    - That works out to about 5 x 9.81 = 49.1 m/s^2.
  - Early rocket launches in the 1960's caused the astronauts to experience about 9 g maximum. Special training, lying on their backs, and their flight suits allowed them to keep from passing out in these extreme conditions.
    - That works out to about 9 x 9.81 = 88.3 m/s^2.
  - Colonel John Stapp was a U.S. Air Force officer and doctor who studied the effects of extreme acceleration on the human body. Using rocket sleds, he eventually exposed himself to an acceleration of 46.2 g and survived.
    - That works out to about 9 x 9.81 = 453 m/s^2.

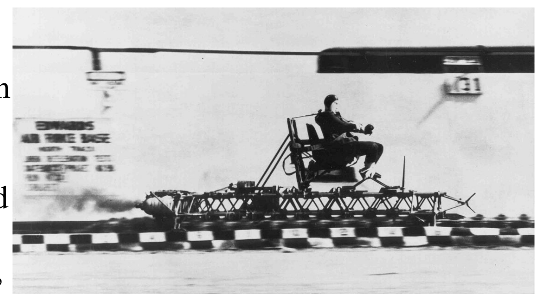


Illustration 1: Colonel Stapp on his rocket sled at Edwards Air FOrce Base.

Example 6: Gravity on the moon is $1.67 m/s^2$. **Determine** how many gee's this is.

This is just a quick easy way to compare the acceleration due to gravity on the moon to the value you feel from day to day here on Earth.

$$\frac{1.67\, m/s^2}{9.81\, m/s^2} = 0.170\, gee's$$

Example 7: A space probe sent to one of Jupiter's moons, Callisto, is taking pictures with a digital camera that records one picture every tenth of a second (measured to a precision of three sig digs). While doing this, a small screw falls off a part of the probe right in front of the camera and can be seen to start falling past the camera as it takes the pictures. Over a series of six pictures, the screw can be seen to fall 15.7 cm starting from rest. **Determine** how many gee's there are on this moon.

To figure out the gee's, we'll first need to figure out the actual acceleration due to gravity on this moon. Then we can convert it into gee's.

We also need to remember to use 0.500 s as the time. Six pictures were taken in total, but the first one is t = 0 just as the screw starts to fall from rest. The next five pictures (0.500 s) record its fall of 0.157 m.

$$d = v_i t + 1/2\, a t^2$$
$$a = \frac{2\text{d}}{t^2}$$
$$a = \frac{2(0.157)}{0.500^2}$$
$$a = 1.256 = 1.26\, m/s^2$$

changed into gee's $\frac{1.26\, m/s^2}{9.81\, m/s^2} = 0.1280326 = 0.128\, gee's$

Homework

p.63 All even from #4 – 14