

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 a wooden ball and a lead ball at the same time.
 - Both were the same size, but different masses.
- Down below an assistant watched for them to hit the ground.
 - They both hit the ground at the **same time**, even though Aristotle would say that the heavier metal ball should 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.

$$a_g = g = 9.81\text{m/s}^2$$

$a_g = g$ = 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**.



Examples of Calculations with Gravity

Example 1: A ball is thrown up into the air at an initial velocity of 26.3m/s. **Determine** its velocity after 1.80s 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.

$$a = \frac{v_f - v_i}{t}$$
$$v_f = v_i + at$$
$$v_f = 26.3 + (-9.81)(1.80)$$
$$v_f = 8.6 \text{ m/s}$$

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

Example 2: I throw a ball down from the top of a cliff so that it leaves my hand moving at 12m/s. **Determine** how fast is it going 3.47 seconds later.

Be careful! At the very start of the question I said that the ball is being thrown down. This means that any initial velocity it had must be negative.

$$a = \frac{v_f - v_i}{t}$$
$$v_f = v_i + at$$
$$v_f = -12 + (-9.81)(3.47)$$
$$v_f = -46 \text{ m/s}$$

In this example, the final velocity is bigger than the initial. That's because as it falls it will be going faster and faster. The negative sign simply means that the velocity is down.

Example 3: A rabbit jumps up into the air. As he leaves the ground he is traveling at 16.0 m/s. **Determine** how fast is he is going after 2.8s.

$$a = \frac{v_f - v_i}{t}$$
$$v_f = v_i + at$$
$$v_f = 16.0 + (-9.81)(2.8)$$
$$v_f = -11 \text{ m/s}$$

Why did I get a negative answer?

- The rabbit reached its maximum height, where it stopped (instantaneously for the briefest moment of time), and then started to fall down.
- Falling down means a negative velocity.

The Rules

There's a few rules that you have to keep track of. Let's look at the way an object thrown up into the air moves.

As the ball is going up...

1. It starts at the bottom at the maximum speed.
2. As it rises, it slows down because gravity is a negative acceleration.
3. It reaches its maximum height, where for a moment its instantaneous velocity is zero. This is exactly half ways through the flight time.

As the ball is coming down...

1. The ball begins to speed up, but downwards. Because gravity is negative, the velocity of the object increases in the negative direction.
2. When it reaches the same height that it started from (like the ground, or the person's hand), it will be going at the same speed down as it was originally moving up at. The only difference is that this velocity is negative because it is pointing down.
3. It takes just as much time to come down as it did to go up.

Applying these rules might seem complicated, but since they stay the same all the time you can get used to the problems by just practicing them over and over again.

Example 4: I throw my ball up (again) at a velocity of 12 m/s.

- a) **Determine** how much time does it take to reach its maximum height.

It reaches its maximum height when its velocity is zero. We'll use that as the final velocity. Also, if we define **up** as **positive**, we need to remember to define **down** (like **gravity**) as **negative**.

$$a = \frac{v_f - v_i}{t}$$

$$t = \frac{v_f - v_i}{a}$$

$$t = \frac{0 - 12}{-9.81}$$

$$t = 1.2 \text{ s}$$

- b) **Determine** how high it goes.

It's best to try to avoid using the number you calculated in part (a), since if you made a mistake, 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.

$$v_f^2 = v_i^2 + 2ad$$

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

$$d = \frac{0 - 12^2}{[2(-9.81)]}$$

$$d = 7.3 \text{ m}$$

c) **Determine** how fast it is going when it reaches my hand again.

Ignoring air resistance, it will be going as fast coming down as it was going up. This means its final velocity as it reaches my hand is -12m/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 9.81m/s^2 is equal to 9.81m/s^2 .
- During lift-off the astronauts in the space shuttle experience about 4 gee’s.
 - That works out to about $4 \times 9.81 = 39\text{m/s}^2$.

Example 5: Gravity on the moon is 1.67m/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.

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

Example 6: 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.

$$d = v_i t + 1/2 at^2$$
$$a = \frac{2d}{t^2} = \frac{2(0.157)}{0.500^2} = 1.26\text{ m/s}^2 \quad \text{changed into gee's} \quad \frac{1.26\text{ m/s}^2}{9.81\text{ m/s}^2} = 0.128\text{ gee 's}$$