Gravity

This lesson may give you a sinking sensation but don't worry about it. It's only because we're talking about gravity. You can't go anywhere without gravity. Even though we deal with gravity on a constant basis, there are several misconceptions about it. Let's get to an experiment right away and I'll show you what I mean.

Experiment 1
Weight Doesn't Matter

You Need:
Two objects of different weights. A marble and a golf ball, or a tennis ball and a penny for example.
A sharp eye
A partner

1. Take a careful look at both objects and make a prediction about which object will hit the ground first if they are dropped from the same height.

2. Test your prediction. Hold both objects at the same height. Make sure the bottom of both objects are the same distance from the floor.

3. Let them go as close to the same time as possible. Sometimes it's helpful to roll them off a book.

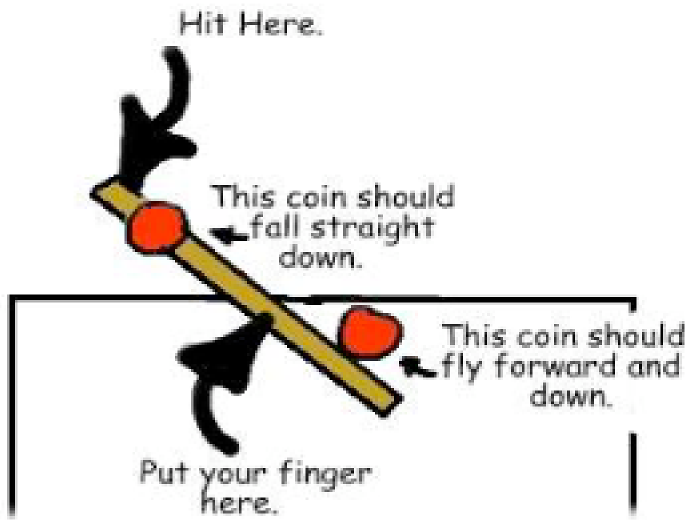
4. Watch carefully. Which hits the ground first, the heavier one or the lighter one? Try it a couple of times and watch carefully. It will be a little easier for the person who isn't dropping them to see what happens.

What you should see is that both objects hit the ground at the same time! Gravity accelerates both items equally and they hit the ground at the same time. Any two objects will do this, a brick and a Buick, a flower and a fish, a cumquat and a cow! "But," I hear you saying, "whoa Jim, if I drop a feather and a flounder, the flounder

will hit first every time!" Ok, you got me there. There is one thing that will change the results and that is air resistance. The bigger, lighter and fluffier something is, the more air resistance can effect it and so it will fall more slowly. Air resistance is a type of friction which we will be talking about later. In fact, if you removed air resistance, a feather and a flounder would hit the ground at the same time!!! Where can you remove air resistance? The moon!!! One of the Apollo missions actually did this (well, they didn't use a flounder they used a hammer). An astronaut dropped a feather and a hammer at the same time and indeed, both fell at the same rate of speed and hit the surface of the moon at the same time.
Ask someone this question. Which will hit the ground first, if dropped from the same height, a bowling ball or a tennis ball? Most will say the bowling ball. In fact, if you asked yourself that question 5 minutes ago, would you have gotten it right? It's conventional wisdom to think that the heavier object falls faster. Unfortunately, conventional wisdom isn't always right. Gravity accelerates all things equally. In other words, gravity makes all things speed up or slow down at the same rate. We will be discussing acceleration more in a later lesson. If you would like more details on the math of this, it will be at the end of this lesson in the Deeper Lesson section.

This is a great example of why the scientific method is such a cool thing. Many, many years ago, there was a man of great knowledge and wisdom named Aristotle. Whatever he said, most people believed to be true. The trouble was he didn't test everything that he said. One of his statements was that objects with greater weight fall faster than objects with less weight. Everyone believed that this was true. Hundreds of years later Galileo came along and said "Ya know...that doesn't seem to work that way. I'm going to test it" The story goes that Galileo grabbed a melon and an orange and went to the top of the Leaning Tower of Pisa. He said, "Look out below!" and dropped them! By doing that, he showed that objects fall at the same rate of speed no matter what their size. It is true that it was Galileo who "proved" that gravity accelerates all things equally no matter what their weight, but there is no real evidence that he actually used the Leaning Tower of Pisa to do it. Which is too bad, because it makes a great story and David Letterman would be proud!

Experiment 2
The Fling's the Thing



You Need:
2 rulers or paint sticks. Any thing wide and flat
2 coins or poker chips
A sharp eye and ear
A partner is good for this one too

1. Place one of the rulers flat so that it is diagonal across the edge of a table with half the ruler on the table and half sticking off.

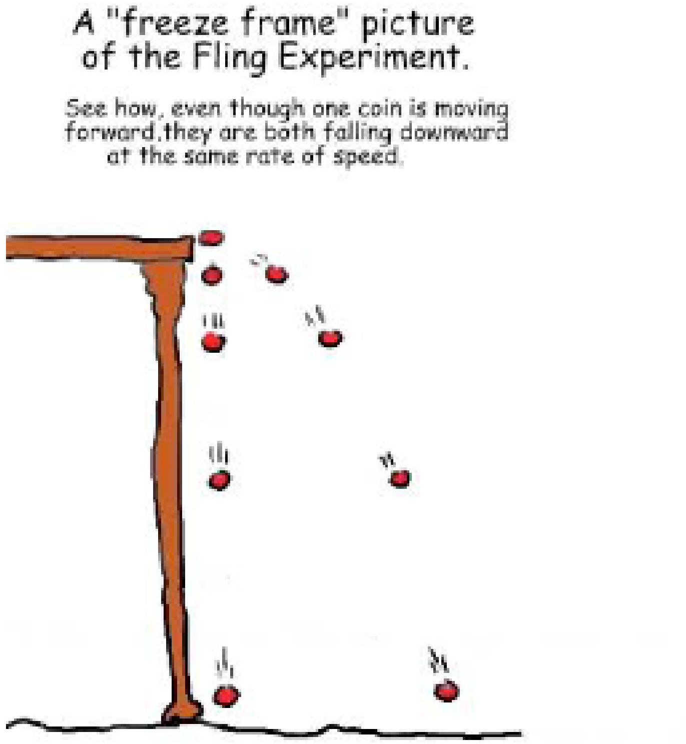
2. Place one coin on the table, just in front of the ruler and just behind the edge of the table. Place the other coin on the ruler on the side where it's off the table.

3. Put your finger right in the middle of the ruler on the table so that you are holding it in such a way that it can spin a bit under your finger. Now with the other ruler you are going to smack the end of the first ruler so that the first ruler pushes the coin off the desk and the coin that's resting on the ruler falls to the ground.

4. Now, before you smack the ruler, make a prediction. Will the coin that falls straight down or the coin that is flying forward hit the ground first?

5. Try it. Do the test and look and listen carefully to what happens. It's almost better to use your ears here than your eyes. Do it a couple of times.

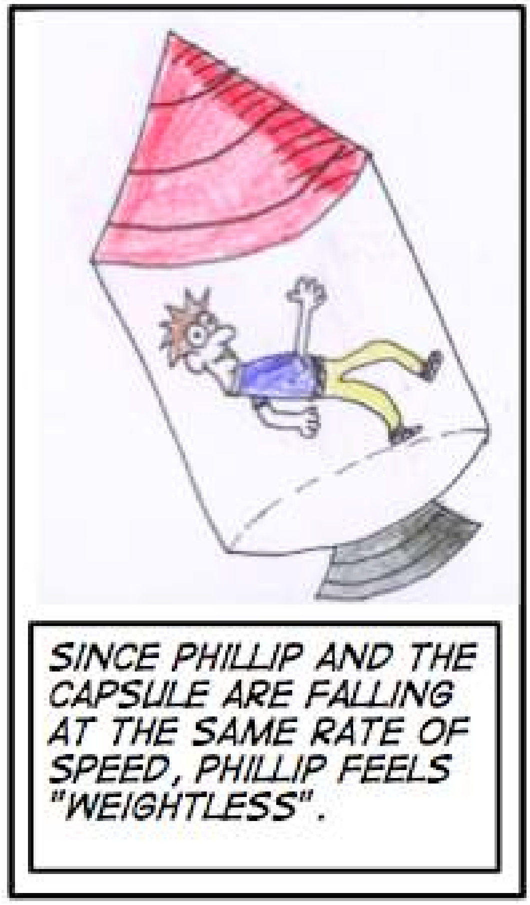
Are you surprised by what you see, and/or hear? Most people are. It's not what you would expect. The coins hit the ground at the SAME time. Is that odd or what? Gravity doesn't care if something is moving or not. Everything falls at the same rate of speed. A bullet fired parallel to the ground from a gun and a bullet dropped from the same height at the same time will both hit the ground at the same time! Even though one may be a mile away! It seems incredible, but it's true. Gravity doesn't care what size something is or whether or not it is moving, it treats all things equally and accelerates them downward with equal rates.



Notice, that I say gravity accelerates all things equally, not gravity pulls on all things equally. Gravity does pull harder on some things than on other things. This is why I weigh more than my dog Tarzana. I am made of more stuff than Tarzana, so gravity pulls on me more. Weight is nothing more than a measure of how much gravity is pulling on you. This is why you can be "weightless" in space. You are still made of stuff, but there's no gravity to pull on you so you have no weight. The larger a body is, the more gravitational pull or in other words the larger a gravitational field, it will have. The Moon has a fairly small gravitational field, the Earth's field is fairly large and the Sun has a huge gravitational field. As a matter of fact, Tarzana and I both have gravitational fields! Since we are both bodies of mass we have a gravitational field which will pull things towards us. All bodies have a gravitational field. However, my mass is sooooo small that the gravitational field I have is miniscule. Something has to be very massive before it has a gravitational field that noticeably attracts another body.

So what's the measurement for how much stuff you're made of? Mass. Mass is basically a measure of how much matter makes you you. Tarzana is made of a fairly small amount of stuff so she has a small mass. I am made of more stuff, so my mass is greater then hers. Your house is made of even more stuff so its mass is greater still. So, here's a question. If you are "weightless" in space, do you still have mass? Yes, the amount of stuff you're made of is the same on Earth as it is in your space ship. Mass does not change but since weight is a measure for how much gravity is pulling on you, weight will change.

Did you notice that I put weightless in quotation marks? Wonder why? Weightlessness is a myth! Believe it or not, one is never weightless. A person can be pretty close to weightless in very deep space but the astronauts in a space ship actually do have a bit of weight. Think about it for a second. If a space ship is orbiting the Earth what is it doing? It's constantly falling! If it wasn't moving forward at 10's of thousands of miles an hour it would hit the Earth. It's moving fast enough to fall around the curvature of the Earth as it falls but, indeed, it's falling as the Earth's gravity is pulling it to us. Otherwise the ship would float out to space. So what is the astronaut doing? She's falling too! The astronaut and the space ship are both falling to the Earth at the same rate of speed and so the astronaut feels weightless in space. If you were in an elevator and the cable snapped, you and the elevator would fall to the Earth at the same rate of speed. You'd feel weightless! (Don't try this at home!)



Either now, or at some point in the future you may ask yourself this question, "How can gravity pull harder (put more force on some things, like bowling balls) and yet accelerate all things equally?" When we get into Newton's laws in a few lessons you'll realize that doesn't make any sense at all. More force equals more acceleration is basically Newton's Second law. Well, I don't want to take too much time here since this is a little deeper then we need to go but I do feel some explanation is in order to avoid future confusion. The explanation for this is inertia. When we get to Newton's First law we will discuss inertia. Inertia is basically how much force is needed to get something to move or stop moving. Now, lets get back to gravity and acceleration. Let's take a look at a bowling ball and a golf ball. Gravity puts more force on the bowling ball than on the golf ball. Soooo the bowling ball should accelerate faster since there's more force on it. However, the bowling ball is heavier soooo it is harder to get it moving. Vice versa, the golf ball has less force pulling on it but it's easier to get moving. Do you see it? The force and inertia thing equal out so that all things accelerate due to gravity at the same rate of speed!

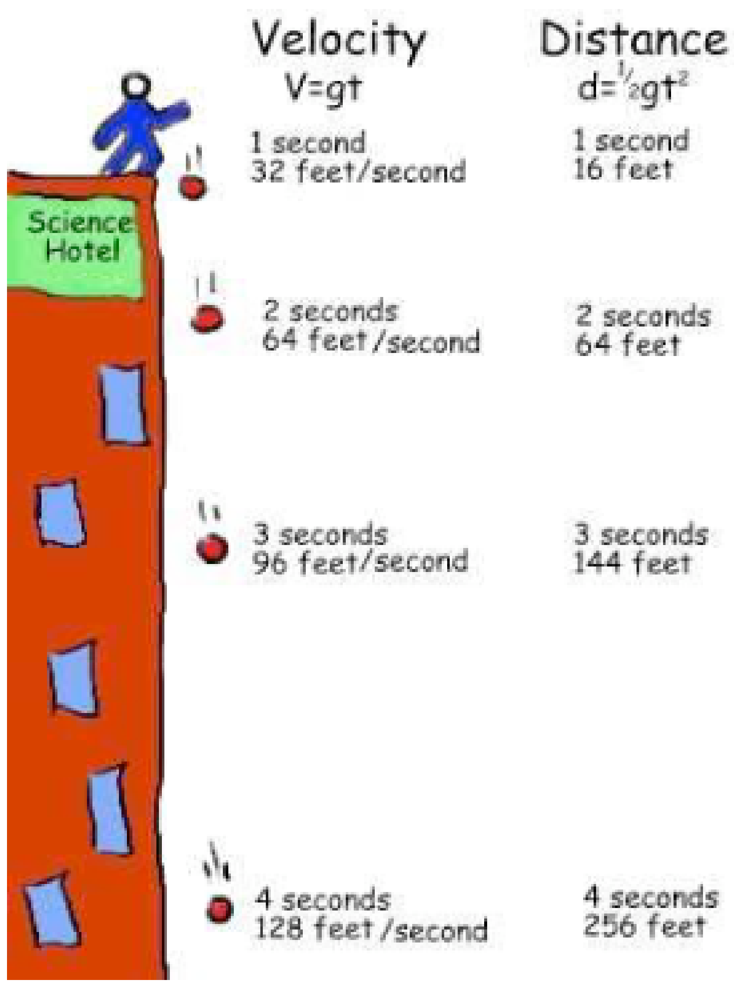
Gravity had to be one of the first scientific discoveries. Whoever the first guy was to drop a rock on his foot, probably realized that things fall down! However, even though we have known about gravity for many many years, it still remains one of the most elusive mysteries of science. At this point, nobody knows what makes things move towards a body of mass. Why did the rock drop towards the Earth and on that guys foot? We still don't know. We know that it does, but we don't know what causes a gravitational attraction between objects. Gravity is also a very weak force. Compared to magnetic forces and electrostatic forces, the gravitational force is extremely weak. How come? No one knows. A large amount of amazing brain power is being used to discover these mysteries of gravity. Maybe it will be you who figures this out!

Deeper Lesson

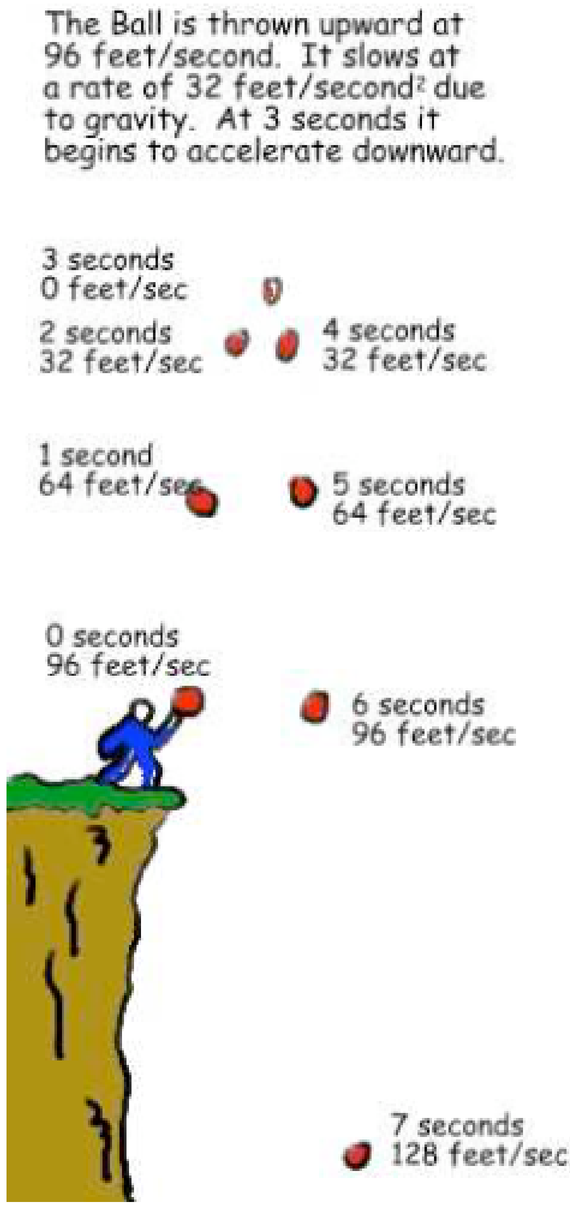
You have just taken in a nice bunch of information about the wild world of gravity. This next section is for folks who want to go even deeper. There's a lot of great stuff here but there's a lot of math as well. If you're not a math person, feel free to pass this up. You'll still have a nice understanding of the concept. However, I'd recommend giving it a try. There are some fun things to do and if you're not careful, you might just end up enjoying it!

Okay, let's see where we can go here. Gravity accelerates all things equally...what does that mean! All things accelerate at 32 feet per second squared due to gravity. In metric, it accelerates 9.8 meters per second squared. What that means is, every second something falls, its speed increases by 32 feet/second or 9.8 meters/second. Believe it or not, that's about 22 miles per hour!! Gravity will accelerate something from 0 to 60 mph in about 3 seconds. Faster then all but the fastest sports cars!

So what is acceleration anyway? Well speed is the amount of distance something travels in a certain amount of time. Five Miles per hour, for example, tells you that something can travel five miles in an hour. Acceleration is how much the speed changes over time. So acceleration would be miles per hour per hour or feet per second per second. Acceleration is a rate of change of speed or, in other words, how fast is the speed is changing. Feet per second per second is the same as ft/s/s which is the same as ft/s². (I told you we were going deeper!) Let's say you're riding your bicycle at a positive acceleration (your getting faster) of 5 ft/s². That means in 1 second you're moving at a speed of 5 ft/s. After 2 seconds you're



moving at a speed of 10 ft/s. After 3 seconds you're now clipping along at 15 ft/s (about 10 mph). So you can see that as long as you accelerate, you will be getting faster and faster. The formula for this is v=at where v is velocity, a is acceleration and t is time. (We will be doing more with acceleration in a future lesson.)



If we want to find out how fast something is going after it has been dropped, we use the formula v=gt. The letter "v" stands for velocity (which basically means speed.) "g" stands for the gravitational constant and "t" stands for time. If we want to find out how fast a golf ball is dropping after it falls for 3 seconds we multiply 3 seconds by 32 feet/second squared and that equals 96 feet/second. So, if I dropped a golf ball off a building, it would be going 96 feet per second after 3 seconds of dropping. The formula looks like this when we fill in the numbers:

$v=3s \times 32\ ft/s^2$

If we do more math, we'll see that after one second something will be -going 32 ft/s, after 2 seconds it will be going 64 ft/s, after 3 seconds 96 ft/s after 4 seconds 128 ft/s. Get it? Anything dropped will be going that speed after that many seconds because gravity accelerates all things equally (air resistance will effect these numbers so you won't get exactly the numbers in practice that you will mathematically).

All right, lets go even deeper. We now know how to calculate how fast something will be going if it is dropped, but what happens if we throw it up? Well, which way does gravity go? Down right? Gravity accelerates all things equally so, gravity will slow things down as they travel up by $32\ ft/s^2$. If a ball is thrown up at 64 ft/s how long will it travel upwards? Well, since it is negatively accelerating (in physics there's no such thing as deceleration) after the first second the ball will be traveling at 32 ft/s and after 2 seconds the ball will come to a stop, turn around in midair, and begin to accelerate downwards at $32\ ft/s^2$. Using this, you can tell how fast you can throw by using nothing more then a timer. Let's try it.

Experiment 3
Fast Ball

You Need:
- A ball (a tennis ball or baseball would be perfect)
- A stopwatch
- Pencil and paper
- A friend
- A calculator

1. Go outside and pick one person to be the thrower and another to be the timer.

2. Have the timer say "Ready, Set, Go!" and at go he or she should start the stop-watch.

3. When the timer says go, the thrower should toss the ball as high as he or she can.

4. The timer should stop the stopwatch when the ball hits the ground.

5. Write down the time that the ball was in the air.

6. Let each person take a couple of turns as timer and thrower.

7. Now, come back inside and do a bit of math.

Ok, let's see how you did. Let's say you threw the ball into the air and it took 3 seconds to hit the ground. The first thing you have to do is divide 3 in half. Why? Because your ball traveled 1.5 seconds up and 1.5 seconds down! (By the way, this isn't completely accurate because of two things. One, air resistance and two, the ball falls a little father then it rises because of the height of the thrower.) Now, take your formula and figure out the speed of the throw.

$v=gt$,

so $v=32\ ft/s^2 \times 1.5\ sec$ or

$v = 48\ ft/s$.

So, if that's how fast it left your hand...how fast was it going when it hit the ground? Yup, 48 ft/s. It has to be going the same speed because it had just as much time to speed up as it had to slow down, 1.5 seconds. Try that with your time and see how fast your throw was.

Ok, hold your breath, just a little deeper now. Let's talk about distance. If something starts from rest you can tell how far it drops by how long it has dropped. This formula is $d=1/2gt^2$ or distance equals one half the gravitational constant multiplied by time squared. Let's try it. If I drop a ball and it drops 3 seconds how far has it dropped?

$d=1/2\ 32ft/s^2 \times 32$ or

$d = 16\ ft/s \times 9s^2$ or

$d=144$ ft So it has dropped 144 ft.

Now try this with your time. What's the first thing you have to do? Divide your time in half again, right. It took your ball half the time to go up and half the time to come down. Now plug your numbers into $1/2gt^2$ and find out how high you threw your ball! Is Major League Baseball in your future?!

In a Nutshell

Gravity is a force that attracts things to one another.

All bodies (objects) have a gravitational field.

The larger a body is, the greater the strength of the gravitational field.

Bodies must be very, very large before they exert any noticeable gravitational field.

Gravity accelerates all things equally. Which means all things speed up the same amount as they fall.

Gravity does not care what size things are or whether things are moving. All things are accelerated towards the Earth at the same rate of speed.

Gravity does pull on things differently. Gravity is pulling greater on objects that weigh more.

Weight is a measure of how much gravity is pulling on an object.

Mass is a measure of how much matter (how many atoms) make up an object.

Did You Get It

1. Of the following objects, which ones are attracted to one another by gravity?
A. Apple and Banana
B. Beagle and Chihuahua
C. Earth and You
D. All of the above

2. Gravity accelerates all things differently...True or False??

3. Gravity pulls on all things differently...True or False??

4. If I drop a golf ball and a golf cart at the same time from the same height, which hits the ground first?

5. There is a monkey hanging on the branch of a tree. A wildlife biologist wants to shoot a tranquilizer dart at the monkey to mark and study him. The biologist very carefully aims directly at the shoulder of the monkey and fires. However, the gun makes a loud enough noise that the monkey gets scared, lets go of the branch and falls directly downward. Does the dart hit where the biologist was aiming or does it go higher or lower then he aimed? (This, by the way, is an old thought problem.)

6. Why don't a feather and a brick hit the ground at the same time?

Answers

1. D. All bodies are attracted to other bodies by gravity. But a body has to be really stinkin' big before it's noticeable.

2. FALSE!!! Gravity accelerates all things at the same rate. All things fall at the same rate of speed no matter what (ignoring air resistance, that is).

3. True. That's why some things weigh more then other things. Gravity pulls more on the big stinky guy sitting next to me on the bus, then it does on me.

4. They hit the ground at the same time. Gravity accelerates all things equally.

5. The monkey and the dart fall downward at the same rate of speed. So the dart would hit exactly where the biologist aimed! In fact, if the monkey didn't let go, the dart would have hit lower then the biologist aimed.
6. They do...if you're on the moon! On Earth, the friction between the air and the feather causes the feather to slow down and the brick to win the race.

Problems

Phew, now take a deep breath. We're done. Would you like to try out your new formulas? All right, give these problems a try. Don't worry about air resistance for these.

Since you are finding velocity use this formula for these problems, $v=gt$. v is velocity, g is the gravitational constant (32 ft/sec^2), t is time.

1. **You dropped a ball off a building 3 seconds ago. How fast is it going now?**

2. **6 seconds have passed since your meat ball rolled off the roof. How fast is it going?**

3. **If you shoot a model rocket into the air and it takes 8 seconds before it hits the ground how fast was it going when it left the launch pad?**

Now for these you're looking for distance, so use the formula $d=1/2gt^2$. d is distance, g is the gravitational constant, and t is time.

4. **If you dropped a ball off the edge of the roof of your house to your buddy on the ground and it took 5 seconds to get to your friend, how tall is your house?**

5. **If you're in the outfield and a fly ball takes 3 seconds to go from the highest point of the hit to your mitt, how high was the ball hit?**

Answers for Problems:

I've converted feet/second to miles/hour for you so that you can get more of a feel for the speed.

1. 96 ft/s which is 64 mph

2. 192 ft/s or 131 mph (thatsa fasta meata balla!)

3. 128 ft/s or 87 mph (remember that you have to half the time. It took 4 seconds to go up and 4 seconds to fall down.

4. 400 ft. Ok, so, you have a big house!

5. 144 ft Nice catch!