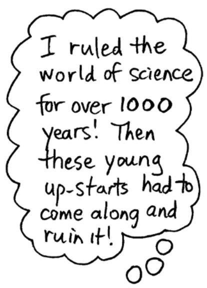
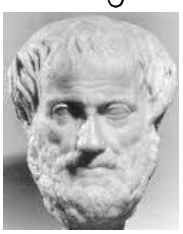
Adventure 4: Inertia with Newton
(Newton's 1st Law)

Oddly enough, this fourth adventure about motion starts out with people thinking about NOT moving. If you are not familiar with the word ***inertia***, it is pronounced like this: ***in-ER-shah***. The word inertia comes from the Latin word "inert," which means "lazy." Scientists all the way back to ancient Greece had noticed this tendency of stationary (non-moving) objects to stay put. They came up with various theories, but in the end, Aristotle's ideas won the day and were handed down for well over a thousand years. Aristotle believed that moving objects slowed down because they wanted to go back to being lazy and not moving.




Aristotle

In the 14th century (1300s), a scientist named Jean Buridan challenged Aristotle's idea and proposed that objects didn't slow down and stop because they wanted to, but because something was affecting them, causing them to slow down whether they wanted to or not. He also proposed that air was one of the things that made objects slow down. Buridan brought us one step closer to understanding intertia, though he didn't call it that. Buridan's research was continued by several of his students who refined his ideas and helped science make a few more steps in the right direction.

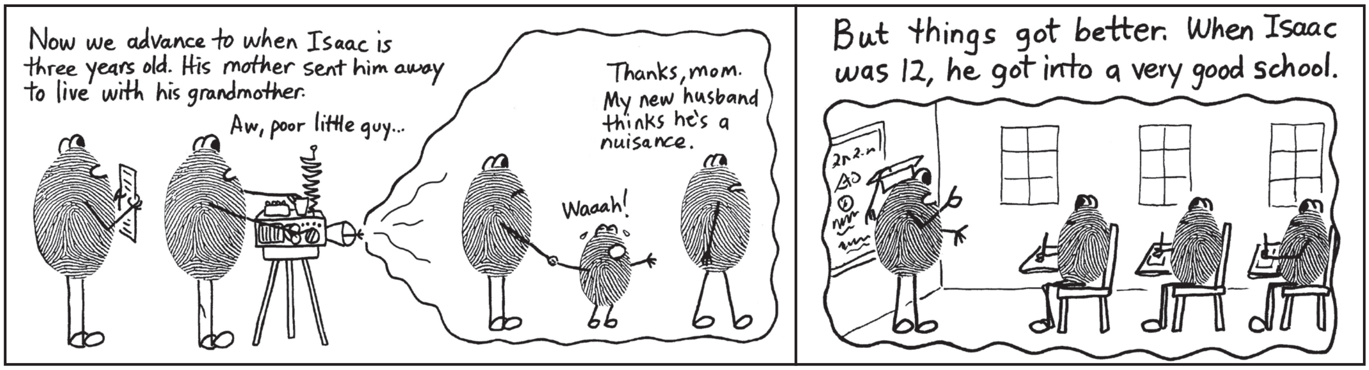
In the 1500s, an Italian scientist named Benedetti began studying motion and came to the conclusion that Aristotle had been wrong about many things and that although Buridan was on the right track, he had not discovered one important truth about motion—that the forces that pushed on objects and caused them to move only did so in straight lines. He believed that “pushing forces” could only push in one direction. Thus, when we see what looks like curved motion, such a ball following a curved path through the air, it is the result of more than one force affecting the object. This was quite a revolutionary thought!

Also in the 1500s, Copernicus and Galileo added their insights to the study of motion. Copernicus, who was an astronomer, pointed out that objects at rest (as we see them sitting on a table) are not really at rest at all because the table is sitting on planet Earth which is traveling through space at a very high speed, orbiting the Sun. This point did not turn out to be as helpful as Galileo's conclusion that “an object moving on a level surface will continue in the same direction at a constant speed unless disturbed.” Galileo later stated that he thought that motion is “relative,” meaning that whether or not something appears to be in motion depends on your viewpoint. (If you are riding in a car, everything inside the car—the steering wheel, the seats, your travel mug, your dog—looks stationary (not moving), while the landscape outside the car appears to be zooming past. However, to someone standing in that landscape, it is your car that appears to be moving.)

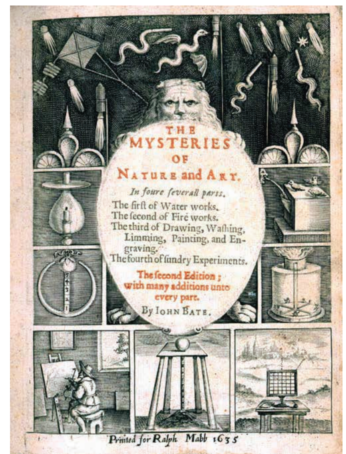
Finally, along came Isaac Newton, in the 1600s. Many people don’t realize that Newton wasn’t the first person to think about objects moving or being at rest. He knew about all of these previous scientists and their theories. He admitted that he was building on the work of scientists that had gone before him, and he once said, “If I have seen further, it is by standing on the shoulders of giants.”

Newton was born in December of 1642. Galileo had died in January of that year.

Isaac was born prematurely and was so small that no one thought he would survive. His mother wrote that newborn Isaac could have fit into a quart-size mug. Three years later, Isaac's mother decided to remarry.



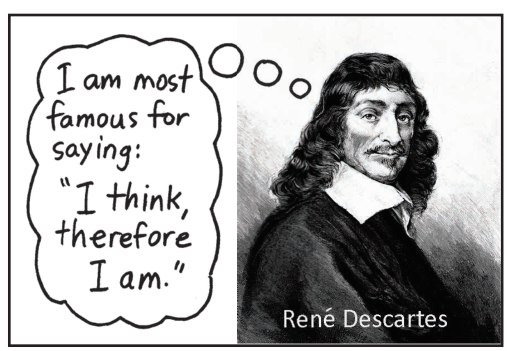
Although Isaac's mother had brought him home again (after the stepfather's death when Isaac was 11) this school was a distance from home, and therefore his mother arranged for him to live under the care of a gentleman who ran an apothecary shop. (Today we'd call him a pharmacist.) Isaac was fascinated as he watched the apothecary mix potions. When the apothecary saw Isaac's interest in science, he gave him permission to experiment with the chemicals. He also loaned Isaac a book called "The Mysteries of Nature and Art." This book had information about simple chemistry experiments, as well as instructions for building projects like kites and model windmills. The apothecary must have supplied young Isaac with building materials as well as chemicals, because we know that it was during this time that Isaac began building many kinds of models and simple machines. Perhaps he even tried out the book's instructions for making "fire drakes"—kites with firecrackers tied to their tails. Without any video games or social media to distract him, he had plenty of time for making inventions.



When Isaac graduated from this school at age 17, his mother brought him back home to help run the family farm. Isaac was much less successful as a farmer than as a student or an inventor. Fortunately, the head master at the school saw that Isaac was a very gifted learner and was able to persuade his mother to let him go to college. His uncle helped him get into Trinity College, Cambridge.

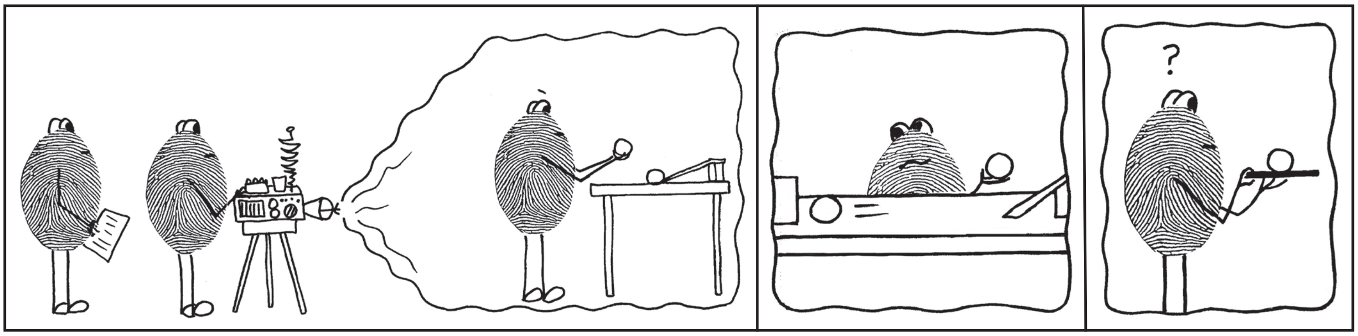
Many famous scientists have attended Trinity College, Cambridge, including the author's favorite scientist, James Clerk Maxwell.

Newton had to work his way through college, unlike most of his peers who were from rich families. He did not have time to go to college social events, but this did not bother him because he really preferred being alone with his books. One of his teachers introduced him to the writings of Galileo, Copernicus, and the famous French mathematician/philosopher René Descartes. *(Ren-ay Day-cart)* While reading Descartes's book, "La Geometrie," Newton fell in love with mathematics. By borrowing books from the college library, Newton taught himself (in only one year) almost everything that was known about math at that point in time. Upon graduation, he was all set to continue on as a graduate student, but in that year, 1665, the university had to close due to a plague epidemic. It remained closed for 18 months. Newton spent this time thinking and experimenting.



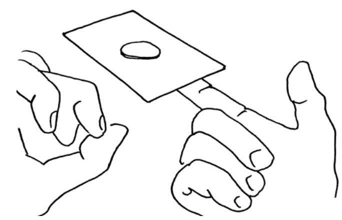
During this time at home, Newton made key discoveries about the nature of light and about gravity and motion. He also began inventing calculus. (Not *taking* calculus— *inventing* it!) It was also during this time that his famous observation of the falling apple supposedly took place, although some of his later writings, and the timing of them with respect to correspondence with famed scientist Robert Hooke, reveal that he probabaly did not completely realize the implications of gravity until about a decade after the apple incident.

Let's S.N.O.O.P. around in Newton's private workshop on a day when he is experimenting with moving and stationary objects, and doing some deep thinking about the concept of inertia.



You can do similar experiments to see the principles of inertia that Newton observed.

ACTIVITY 4.1: The coin and card trick



You will need: *a playing card (or index card) and a large coin*

1) Put the coin at the center of the card.
2) Balance this on the tip of one finger.
3) With your other hand, give the card a quick flick.

The coin should stay on your finger while the card goes flying off. The coin stays on your finger because of its inertia. It is at rest and wants to stay at rest. (Large coins work better than small ones because they have more inertia. Playing cards work best because they are very smooth.) The motion of the card underneath it happens so fast that the energy overcomes any friction and is not transferred to the coin. This is a small version of the classic "pulling the tablecloth out from under the dishes" trick. If you want to see this classic tablecloth trick, there is a video on the playlist.

ACTIVITY 4.2: The "drop the coin into the bottle" trick

You will need: *a small coin (such as a US dime), a bottle that has a neck just slightly larger than the coin, and a round hoop of some kind (hoop ideas: an embroidery hoop, a roll of masking tape, a circle cut from a large plastic bottle, or a strip of thin cardboard taped into a circle)*
NOTE: The larger the hoop, the more dramatic this trick looks!

1) Balance the coin on top of the hoop, then balance the hoop on top of the bottle, as shown.
2) Put your finger inside the hoop, then pull the hoop out of the way, moving your hand very quickly.
3) The coin should drop right through the neck of the bottle. If the neck of the bottle is just slightly bigger than the coin, this make the trick more amazing.
4) Try the trick again, but this time put your hand outside the hoop instead of inside. Does it still work? (If your hoop is very stiff, putting your finger outside the hoop might not make any difference.)

The fact that you had to balance the coin on top of the hoop ensured that the coin was directly over the neck of the bottle. Gravity is a great help in getting things vertically straight ("plumb"). When you pulled quickly on the inside of the hoop, the energy from the moving hoop did not have time to get transferred to the coin, so the coin was unaffected by the motion of the hoop. Thus, the coin stayed directly over the neck of the bottle and gravity pulled it straight down into the bottle.

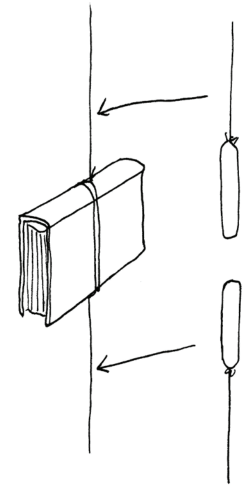
If you push the hoop from the outside, your finger bends the hoop inward (assuming you have a flexible hoop) and ruins the perfect circle shape. It was this perfect circular shape that helped to keep the coin lined up. If the shape of the hoop is distorted, the coin loses its perfect alignment and therefore drops slightly off center.

The playlist has a version of this trick using an egg instead of a coin, and a glass of water instead of a bottle.

ACTIVITY 4.3: “Hanging by a Thread”

You will need: *two pieces of thread (each about a meter [yard] long) and a heavy book.*

1) Tie the end of one piece of thread around the book. Adjust the loop of thread so the book hangs balanced.
2) Tie the end of the other piece of thread around the book, but so that it hangs off on the other side.
3) Hold one of the threads so that the book hangs in the air with the other thread dangling beneath it.
4) Predict which thread will break if you yank very hard on the bottom thread.
5) Yank! Which thread broke?



You'd think the that top thread would break because it already has a lot of weight pulling down on it. It might not be able to take any more weight, right? But the book has a lot of inertia and doesn't want to be pulled down. Just like we witnessed in our two previous demonstrations, a quick motion isn't enough to overcome the object's inertia.

Inertia also applies to objects that are in motion, not just stationary objects. The principle of inertia says that objects want to do what they are already doing. If they are sitting still, they will keep sitting still until something forces them to move. However, if an object is already moving, Newton concluded that it will keep on moving unless a force stops it. Often, this force is friction. Friction is when two things rub together, slowing motion.

ACTIVITY 4.4: An object in motion keeps on going

You will need: a cylindrical object (such as a battery), a book (or block), a length of floor space

1) Set the battery on top of the book. (or whatever objects you are using)
2) Start sliding the book very slowly so that the battery goes along with it and does not roll off.
3) Once the book is moving quickly, suddenly stop pushing it. What happens?

The battery should go rolling off the front of the book, continuing in motion. You didn't push the battery off the book. The inertia of the battery overcame the friction between it and the book and made it keep on moving.

ACTIVITY 4.5: A thought experiment

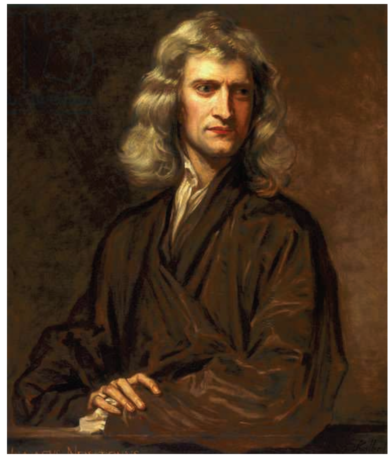
Imagine yourself riding in a car. Hopefully you have your seatbelt on, because the car is going to stop very quickly. Something darts across the car's path and the driver slams on the breaks. Wham! What happens to your body? Do you jolt forward suddenly? That's your inertia in action. As you were riding along, you were going the same speed as the car. It felt like you were sitting still because everything inside the car looked stationary to you. But when the car slowed down, your body kept on going until it hit the seatbelt. Your body was in motion and would have continued forward had it not been for the seatbelt. Bodies in motion (you, in this case) will continue in motion unless acted upon by an outside force (the restraining power of the seatbelt).

ACTIVITY 4.6: Watch Episode 1 in the "Eureka" series (on inertia)

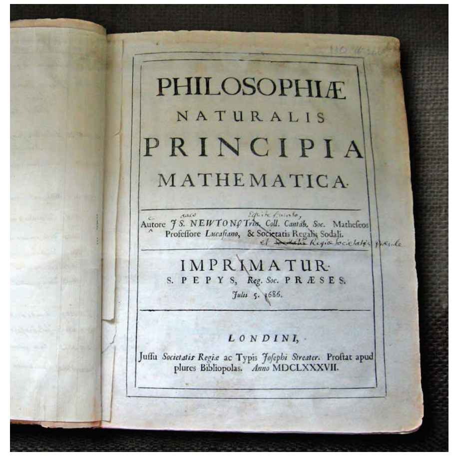
Use the playlist, or simply search for Eureka episode 1.

Newton did not write about his discoveries right away. In fact, that was an issue that would create problems for him later in life. He was interested in science mostly to satisfy his own curiosity and cared very little if anyone else knew what he did. (Little did he know, but someone else was also working on inventing calculus at the same time as he was. The two men would eventually get into an argument that lasted for years. If Newton had published his ideas right after he had thought of them, this dispute would probably never have happened.) So Newton's laws of motion did not appear in writing until 1687, when, at the insistence of a friend, he finally published his work in a book known as ***Principia***. (Newton said *Prin-chip-ia*, Latin scholars say *Prin-kip-ia* and most scientists say *Prin-sip-ia*. Take your pick!) This book as been called the most influence science book ever written.

Principia Mathematica contains not only Newton's laws of motion and gravity, but also how they can be applied to astronomy. Newton was able to explain the motion of the planets in a way that solved many of the problems that astronomers were having with their calculations. But more on that later. Right now we want to highlight the very first law of motion that appeared in *Principia*.

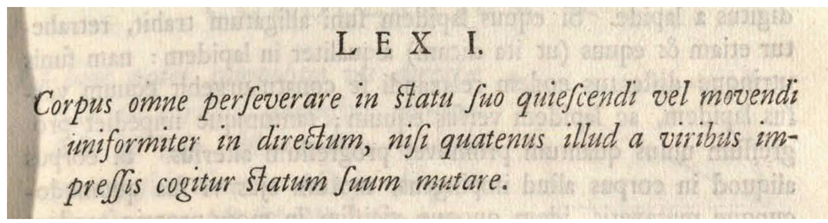


Portrait of Newton from 1689



Newton's own copy of his book, with all his hand-written corrections.

The book was written in Latin, which was the language of scholars in that day. Latin was used because at that time, scientists in every country could read Latin. The Latin word for law is "lex," so Newton's first law was written as LEX I. The Latin says: "Every body perseveres in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed thereon." In simpler English:


LEX I.

Corpus omne perſeverare in ſtatu ſuo quieſcendi vel movendi uniformiter in directum, niſi quatenus illud a viribus impreſſis cogitur ſtatum ſuum mutare.

This is how Newton's first law looks in the first edition of Principia.

A body at rest will stay at rest, and a body in motion will stay in motion, until an external force acts upon it.

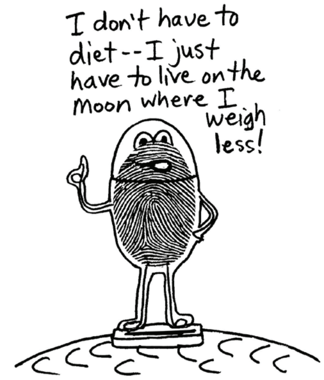
The idea that motion is essentially always in a straight line did not originate with Newton. Robert Hooke had already proposed that motion which appears to be curved (like the path of a ball thrown into the air) is actually a combination of two or more straight-line motions. (We saw this happening in the harmongraph patterns in the last chapter. In a two-pendulum harmongraph, you have only two back-and-forth (straight) motions happening. Yet if you connect the two motions with rods that have a pen attached, the pen will draw circular and oval patterns.) Hooke had written a letter to Newton asking his opinion about this idea, particularly as it related to the path of the moon around the earth.

After the publication of *Principia*, Newton instantly became famous. He went from being a recluse (loner) surrounded by books to attending dinners hosted by kings and queens. He gradually became used to being around people and eventually learned to enjoy being the center of attention. But enough of Newton's social life, let's get back to the science...

Are all objects equally "lazy"? Do they all have the same amount of inertia? In the "Eureka!" video we saw the cartoon character try to move a large boulder. It had too much inertia and he could not make it budge. Is there a way we can measure inertia?

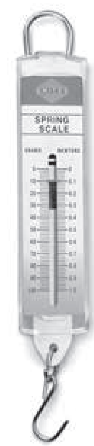
The amount of inertia something has can be measured by finding its ***mass***. The word "mass" comes from Greek and means "a barley cake or lump of dough." Mass is usually measured using a ***scale***, or ***balance***. The earliest scales we know of are seen in ancient Egyptian paintings. In this painting we see the god Anubis weighing a human soul with a "pan balance." The soul sits in one pan (inside the little jar) and an ostrich feather is placed on the other pan. The ostrich feather was a symbol of Ma'at, the goddess of truth and justice. If the pan with the soul in it went down, the person went to an unpleasant afterlife. If the pan with the soul stayed even or went up, this would indicate that the soul was not weighed down with bad deeds, but had the lightness of truth and justice, and therefore the soul would be rewarded with a pleasant afterlife.

Many of us have a flat scale in our bathrooms or bedrooms. This type of scale has a mechanism that can detect and measure the amount of pressure that is pressing down on top of it. Gravity pulls us down onto the scale. The bigger you are, the more "stuff" there is for gravity to pull on. More stuff registers as "heavier." These gravity-based scales are fine as long as everything that you weigh is on planet earth. Since most of us rarely leave the earth, this isn't a problem. However, if you were to take your bathroom scale to the moon, you would find that your scale will tell you that you weigh about 1/6 as much as you do on earth. This is because the gravity of the moon is about 1/6 that of earth. Gravity is directly related to how much mass something has, and the moon has much less mass than the earth. (Oddly enough, various parts of the moon have varying amounts of mass, so your weight on the moon would depend on where you put your scale. For maximum weight, you'd put your scale on one of those dark gray splotches. Those areas have more mass because they've been hit with giant meteors. We think that perhaps at least some of that extra meteoritic mass still lies below the moon's crust.)



This brings us to an important difference between the words "mass" and "weight." Your mass did not change when you went to the moon; your body remained the same. The scale on the moon is telling you how much you weigh *while on the moon*. For someone born and raised in a moon colony, their moon weight would be their normal weight, and they would be fascinated by the heavier readings on their scale when they visited the earth. So which scale is correct? The moon colonists would think their scales are right. We'll have to think about this problem and see if there is a way to measure mass without relying on gravity. But first, let's meet one more type scale.

A scale you often meet in physics classes is the "spring scale." (We met this scale briefly in activity 2.5.) The spring inside the scale is just stretchy enough to be able to measure the weight of small to medium-sized objects. For small (or lightwieght) objects, you need a scale that measures up to 100 grams. For objects that weigh as much as a soup can or a pineapple, you can use scales that measure up to 1,000- 5,000 grams.



The spring in a 1,000 gram scale will be much stiffer than the spring in a 100 gram scale. This means that the larger scales are much less sensitive to tiny amounts of weight. You would not want to measure something very light using a larger scale. You must choose the correct spring scale for the object you want to weigh.

Spring scales can do something that regular scales can't do—they can also measure force. Often, they will be labeled not only in grams (g) but also in units called newtons (N). **One newton is equal to about 100 grams.** But first, how much is a gram, anyway?

ACTIVITY 4.7: Measuring grams using your spring scale

This activity assumes that you have been able to buy or borrow a spring scale. If you don't have one, you can watch Spring Scale Lab 1 on the playlist.

You will need: *your spring scale and various objects you want to weigh*

1) Your spring scale probably has a hook on the end. This is because very often physics labs use weights that have rings on their tops. To use the spring scale with something that does not have a ring, you can either wrap a rubberband around the ojbect and slip the hook under the rubberband, or you can make a "sling" out of a scrap of cloth. Sew or tie a piece of string to each corner of the cloth and the tie the strings together.

2) Weigh various objects and record their weight in both grams and kilograms. 1 kg = 1,000 g

object	g	kg

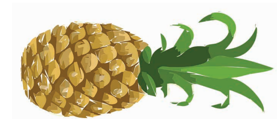
object	g	kg

Here are some approximations to help you remember how much a gram is. Some of you might already be very familiar with grams, but others might not. The metric system is used by all scientists around the world. Since it is based on the number 10, calculations are much easier that using a system based on the number 12.

A gram is about the weight of one paper clip.

A pencil weighs about 10 grams

An apple weighs about 100 grams



A kilogram is about the weight of a pineapple.

Let's take time right now to watch two more episodes in the "Eureka!" series.

In episode 2, you will be reminded that it is just has hard to stop a moving object as it was to get it moving. A memorable example of this is when an airplane lands. To slow the speed of the plane after landing on the runway, the engines have to work just as hard in reverse as they did in forward mode during take-off. In this second episode, you will also be introduced to one of the "standards" that scientists use to define their units of measurement. There is one special platinum block, (held in a very secure place), that is the "official" kilogram weight. All other weights are compared to this one. The study of standards is its own branch of science. Also, governments of large countries usually have an entire department devoted to standard. They monitor weights and measures of all kinds, making sure that scales and other measuring devices are accurate. Next time you are at a gas (petrol) station, look for a stamp that shows how recently someone has been there to make sure the pump is dispensing accurate gallons or liters.

In episode 7, they will review the difference between mass and weight. You will see and hear them say that gravity is pulling down at 10 meters per second, per second. Don't worry about this for now —we will get to this eventually. You don't need to understand this in order to understand the episode. You will see the cartoon character go to the moon to decrease his weight as shown on a spring scale that measures in newtons. You will also see an old-fashioned balance (sort of like the Egyptian one) showing that this type of scale works the same on the moon as it does on earth, proving that mass does not change, only weight as measured by gravity.

ACTIVITY 4.8: Watch episodes 2 and 7 from the "Eureka!" series

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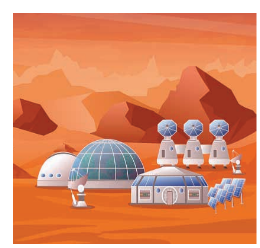
The videos helped us to understand that your weight is determined by the gravitational field you are in. Your weight varies from planet to planet. On Jupiter you'd weigh so much that your bones and muscles would barely be able to keep you standing up. On Mars, you'd weigh only about one third of your earth weight. But the mass of an object does not change as it goes from planet to planet, only its weight does. So, if you need gravity to measure how much something weighs, how would an astronaut in a weightless environment measure an object's mass? Would they ever need to measure mass? Is there another way to measure mass?



Mars colonists would experience less gravity.

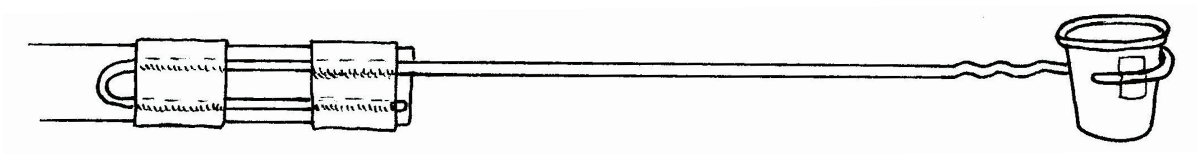
ACTIVITY 4.9: Measure mass *without* using gravity (using an *inertial balance*)

You will need: *a hanger, a small plastic cup (or a sturdy paper one), several dozen coins (all the same kind, pennies are perfect), duct tape, and your stopwatch*

(Note: An alternate way to make the arm of this balance is to use a hacksaw blade. Clamp the end of the blade to a table leg. The wide, flat shape of the blade will prevent the arm from bending down as much as the coat hanger will.)

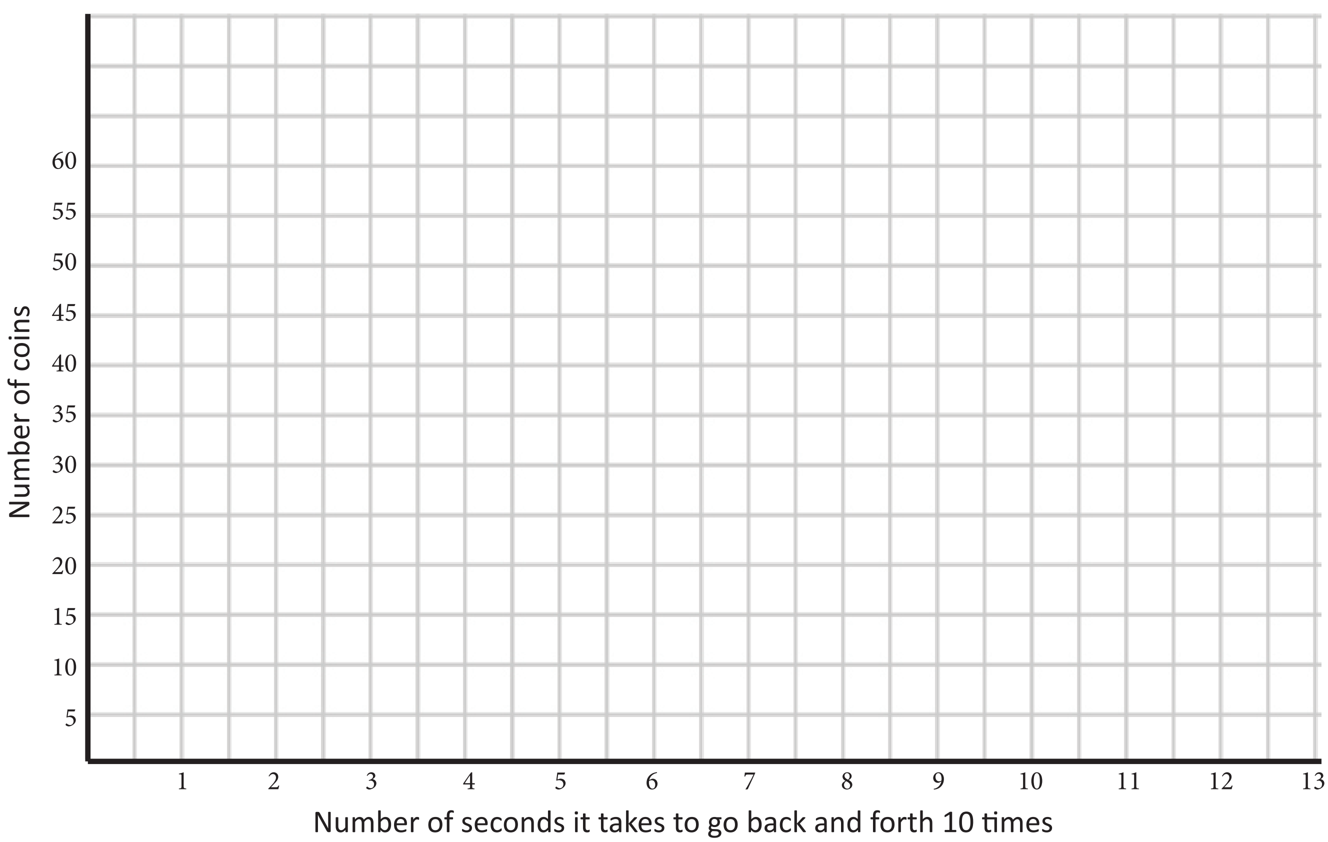
TIP: It will help if you have someone to operate the stopwatch for you. They can call out "Go!" when the start the watch, and then they can stop it when you call out "10!"

1) Unwrap the coiled part of the hanger near the hook. Straighten it out, then bend a long loop at then end opposite the hanger hook. Make the loop at a 90 degree angle from the hanger hook.
2) Tape the small cup into the hanger hook.
3) Duct tape (or clamp) this contraption to the edge of a table so that the cup end is dangling way out from the edge. Make sure it is securely fastenend. You should be able to "twang" the cup back and forth without the base coming off the table.



What you have made is called an <u>inertial balance</u>. Yours isn't nearly as accurate as a real one, but it will be good enough for this experiment.

5) Put 5 coins into the cup. Then pull the cup back about 10 cm (5 inches) or so and then let go. Count how many seconds it takes for the balance to go back and forth 10 times. (Count how many times the cup comes back to you.)
6) Now put 5 more coins into the cup, for a total of 10. Pull the wire back the same distance you did before and let it go. Again, count how many seconds it takes for the cup to come back to you 10 times. (If you have trouble estimating how far back to pull the spring each time, you can put the back of a chair right at that spot. Then you just pull the spring back until it touches the chair. This will ensure that you pull it the same distance every time.)
7) Add 5 more coins and count again. Then 5 more. Then 5 more.
8) Keep adding coins until your wire bends down too much.
9) Make a graph of this experiment, with one axis being the number of coins and the other being the number of seconds.
10) When your results are all recorded, draw a "best -fit" straight line showing the general trend of the data.



11) Do some extrapolation.
How many seconds for a number 10 greater than the highest number of coins on your graph? ________
What about for 50 more coins, instead of 10 more? _____
Which number are you more sure of: 10 greater, or 50 greater? __________

This lab allowed us to discover the true definition of "mass." ***Mass is the measure of an object's resistance to a change in velocity***. This definition makes no sense at all unless you have worked with an interial balance. Now that you have used one, you can see how this definition is possible.

The force you applied to the wire each time you pulled it back was always (approximately) the same. When the cup contained very little mass, it was happy to change directions many times per second. The more mass we put into the cup, the more interita it had, making it better at resisting a change in direction, and thus, giving us slower swings back and forth.

This method of measuring mass would work in space, as long as you securely tied your weights to the end of the spring. This is how things are weighed on the International Space Station. Astronauts have to keep track of their weight (their mass) if they are in a weightless environment for a long time because being weightless can lead to loss of muscle mass. Also, some experiments that are done on the space station require finding mass. For example, they might want to find out how fast an experimental plant was growing.

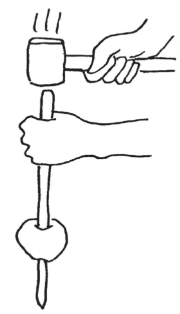
ACTIVITY 4.10: Watch astronauts using inertial balances on the ISS

If you go to the playlist, you can watch an astronaut weighing himself in the space station using an inertial balance that bobs up and down. There is also a short video clip of an researcher putting a sample into a digital inertial balance. (If the videos are not there, just search for "astronuts weigh things in space.")

ACTIVITY 4.11: One last demo about inertia

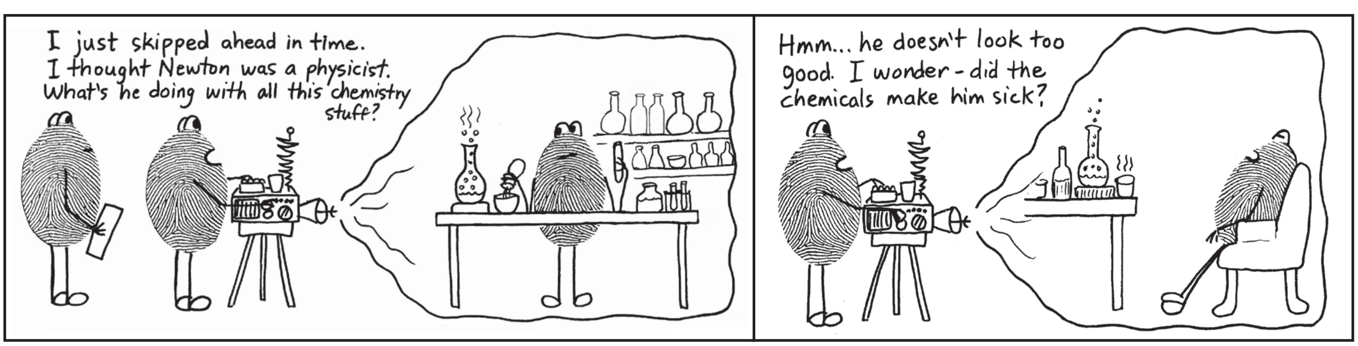
NOTE: There is a video of this demo on the playlist.

You will need: *an apple, a hammer, a dowel rod with one end sharped to a point (does not have to be sharp!)*



1) Push the sharpened end of the dowel rod through the apple, going straight through the core.
2) Position the apple at the bottom of the rod while holding it near the top.
3) Bang on the top of the dowel rod with the hammer. Does the apple start creeping up the rod? (If not, loosen the apple just a bit and try again.)
4) Try hitting the bottom of the rod on the floor. Does the apple go back down again?

The apple, like all objects, has inertia and wants to keep on doing what it is doing. When you hit the top of the rod with the hammer, you forced the rod to go down suddenly. The apple's inertia caused it to want to remain in place. As the rod jerked down bit by bit, it looked like the apple was going up, but it was simply staying in place while the rod moved down. When you banged the rod on the floor, you caused the apple to be in motion, headed down towards the floor. When the rod hit the floor, it stopped, but the apple tried to obey Newton's first law and stayed in motion. The friction between the apple and the rod soon overcame the downward force of the moving apple, however, and caused it to stop moving.



Turn the page and you can find out what is going on here.

ACTIVITY 4.12: More about Newton's life

1771 painting of an alchemist discovering the element phosphorus.

Newton had been fascinated with chemistry since childhood. You might remember that he lived with an apothecary while attending school. After the publication of *Principia* in 1687 (when he was 45), he achieved enough financial success that he had money he could spend on leisure activities. He decided to spend more of his time and money studying "alchemy," which was a mix of superstition and actual chemistry, and something he had dabbled with since early adulthood. Alchemists of previous centuries tried to find a magic elixir of life that could give immortality. They also were famous for trying to turn things into gold. We don't know exactly what Newton's goals were, but we do know from his notes that many of his experiments involved tasting the chemicals. We also know that his lab was stocked with many substances that we now know are toxic, including lead, arsenic, antimony and mercury. In his notes, he wrote that mercury tasted "strong, sourish, and ungrateful."

All this tasting of chemicals took its toll, and by 1693 (when he was about 50 years old) he became ill. He had many neurological symptoms consistent with the symptoms of heavy metal poisoning. He almost destroyed his genius brain. For a year, he suffered from insomina, confusion, memory problems and depression. No one at that time connected his illness to his chemicals. They just chalked it up to the fact that he was an odd person to begin with. Amazingly, he managed to recover from this terrible bout of poisoning, and became functional again, though he never regained the brilliance of his youth.

In that day, it was customary for someone who had achieved academic greatness to be given prestigious appointments at a universtity or in the government. Newton had received a few promotions, but some of this friends thought he should have received more. One of his supporters was able to have him appointed as Warden of the Royal Mint in 1696. The Mint was where all the English coins were manufactured. Newton took his new job more seriously than anyone had anticipated. He knew that counterfeiting ad become a serious problem. It was all too easy for someone to make coins that looked just like the real ones. It is estimated that by the early 1690s, 10 percent of all coins in the realm were counterfeit. Newton vowed to end this scandal. His knowledge of chemistry and math helped him to find solutions to the coinage problems. The result was the Great Recoinage of 1696. All old coins were recalled and replaced by new ones. Newton also decided to go after counterfeiters with more intensity that others before him had done. Technically, the punishment for making fake coins was death, but catching and convicting someone was very difficult. Newton decided to play detective and personally gathered evidence against 28 counterfeiters. One of these counterfeiters was particularly notorious and had devised massive schemes to fool even people at the Mint. Newton saw through his schemes and was able to get him arrested. When the counterfeiter's friends were able to get him released from prison on the grounds that the evidence had not been conclusive enough, Newton was able to gather even more evidence and have him arrested a second time. This time the conviction stuck and the man was publicly executed. The Mint was then put under Newton's complete control and he remained in charge of the Mint until his death in 1727.

Newton's portraits usually show him wearing a wig. That was the fashion of his day. It is believed that perhaps this fashion came about because of head lice. Men would keep their heads shaved so that lice had no place to live, then they would powder the wigs to prevent lice from living in the wig. Both of these portraits are from later in Newton's life. The one on the right definitely shows him in a wig. Do you think the portrait on the left shows his natural hair or a wig?

ACTIVITY 4.13: Review word puzzle

Fill in the blanks with the correct letters, then use the number code to spell out two famous quotes by Newton.

1) The title of Newton's book: ____ ____ ____ ____ ____ ____ ____ ____ ____
31 89 22 34 43 108 49 109 33

2) A baseball bat is a ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ lever.
16 29 91 2 111 43 11 44 15 25

3) He said, "I think, therefore I am." ____ ____ ____ ____ ____ ____ ____ ____ ____
107 8 95 43 73 94 21 18 37

4) The technical word for going up and down, or back and forth: ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
23 84 43 13 32 50 83 28 41 47 24

5) When something vibrates at its natural frequency: ____ ____ ____ ____ ____ ____ ____ ____ ____
86 30 56 55 45 33 99 43 35

6) A machine that makes circular patterns using pendulums: ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
54 73 2 19 74 99 75 1 94 12 72 59

7) The tendency of something to keep on doing what it is already doing: ____ ____ ____ ____ ____ ____ ____
52 71 48 93 6 90 33

8) The measure of an object's resistance to a change in velocity: ____ ____ ____ ____
69 12 76 110

9) "You can always trade distance for a gain in ____ ____ ____ ____ ____."
27 70 2 43 57

10) The wave shape that records harmonic motion: ____ ____ ____ ____ wave
77 67 78 106

11) The number of pendulum swings per minute (or second) is called its ____ ____ ____ Q ____ ____ ____ ____ ____
97 94 60 101 98 14 43 7

12) Newton spent the last part of his life as head of this governmental office: ___ ___ ___ ___ ___ ___ ___ ___ ___
2 20 80 44 11 102 5 46 36

13) These were used to decipher writing on the Antikythera mechanism (page 35): ___ - ____ ____ ____ ____
9 104 83 81 66

14) The pivot point in a lever: ____ ____ ____ ____ ____ ____ ____
85 87 62 43 86 39 96

15) The weight at the end of a pendulum: ____ ____ ____
38 70 88

16) Foucault set up his famous pendulum at the Paris ____ ____ ____ ____ ____ ____ ____ ____
10 51 71 40 17 92 55 68

17) To decrease something's energy or activity level: ____ ____ ____ ____ ____ ____
100 3 79 61 105 53

18) If you wrap an inclined plane around an axle you get a ____ ____ ____ ____ ____
58 43 2 93 112

19) Simple machines give you mechanical ____ ____ ____ ____ ____ ____ ____ ____ ____
63 100 4 3 64 42 12 103 65

20) The curved shape a ball makes after you throw it into the air. (pg. 13) ____ ____ ____ ____ ____ ____ ____ ____
61 82 89 82 88 26 62 33

Famous quotes by Isaac Newton:

1) ___ ___ ___ ___ ___ ___ ___   ___ ___ ___ ___ ___ ___ ___ ___   ___ ___ ___   ___ ___ ___ ___ ___ ___ ___
1 2 3 4 5 6 7   8 9 10 11 12 13 14 15   16 17 18   19 20 21 22 23 24 25

___ ___   ___ ___ ___   ___ ___ ___ ___ ___ ___ ___   ___ ___ ___   ___ ___   ___ ___ ___ ___ ___ ___
26 27   28 29 30   31 32 33 34 35 36 37   38 39 40   41 42   43 44 45 46 47 36

___ ___ ___ ___ ___ ___ ___   ___ ___ ___   ___ ___ ___ ___   ___ ___ ___   ___ ___ ___ ___ ___ ___ ___
48 9 49 50 51 52 53   112 54 55   56 57 16 58   21 59 60   61 62 63 64 65 42 66

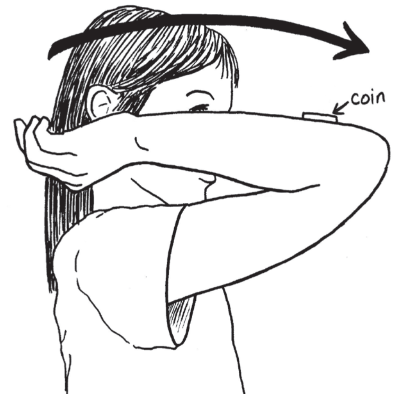
___ ___   ___ ___ ___ ___ ___ ___.
67 68   69 70 36 13 26 71

2) ___ ___ ___ ___ ___   ___ ___   ___ ___   ___ ___ ___ ___ ___ ___,   ___ ___ ___ ___ ___ ___ ___ ___ ___   ___ ___
72 11 73 40 74   5 76   79 80   85 89 90 92 78 111   82 94 91 77 6 75 21 11 93   67 95

___ ___   ___ ___ ___ ___ ___ ___.   ___ ___ ___   ___ ___   ___ ___ ___ ___ ___ ___ ___ ___   ___ ___ ___ ___ ___ ___
96 80   97 93 13 98 99 100   88 87 16   102 81   103 104 105 83 6 106 84 36   27 86 109 8 46 107

___ ___   ___ ___ ___ ___ ___. (Written in his notebook while still a teenger)
108 110   40 2 101 42 29

ACTIVITY 4.14: Just for fun: "Catch-the-coin" inertia trick



You will need: *a coin*

1) Place the coin on your elbow as shown in the pictture.
2) Drop your elbow very quickly and catch the coin in your hand. (as shown by arrow)
3) This trick works because the inertia of the coin causes it to stay in place just long enough that you can catch it.

ACTIVITY 4.15: Optional: Watch a video documentary about Newton's life

If you like documentaries, check out the 45-minute video on the "Biography" channel on YouTube. "Sir Isaac Newton: Unhappy Scientific Genius | Full Documentary | Biography"