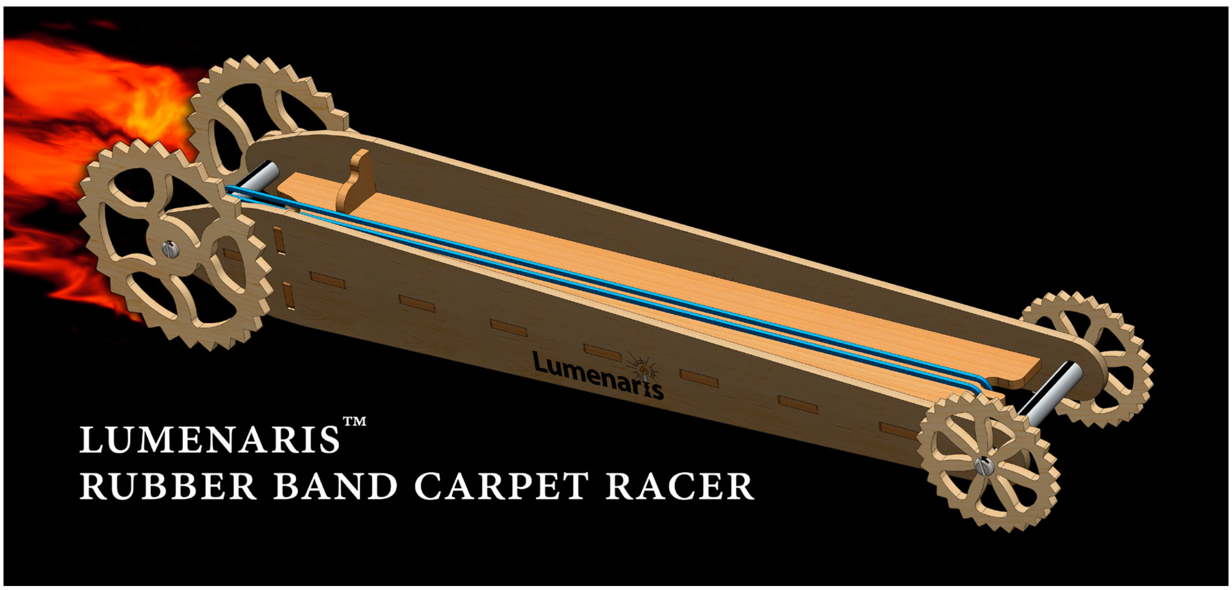
CARPET RACER LESSON PLAN

A lesson plan and suggested study items for your new Rubber Band Carpet Racer.



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How to Use this Lesson Plan

This lesson plan is divided into many different things that you can do with your Rubber Band Carpet Racer™. Some are things that you build, measure, or test, and some are things that you have to think or write about. Each encourages you to explore areas that you might not be familiar with. In each section there are questions that you can work on to answer with answers provided in the appendix as to how we would answer that question including an explanation as to why.

The lesson plan was designed so the section entitled Experiment can be printed or handed out separately. The theory section is study material that should be read and understood before starting the experiment.

ITEMS YOU MAY NEED

To do the experiments you'll need a few household items. If you don't have these at home, you should be able to find them at a hardware store, an office supply store, or even some grocery stores.

- glue — white or yellow (Titebond™ or Elmer's™)
- rubber bands of different sizes, thicknesses, and/or widths
- scissors
- pencils, pens, colored pens or pencils
- graph paper
- a spreadsheet program (such as Excel or OpenOffice.Org Calc)
- milk jug (half gallon or gallon, washed clean and empty)
- graduated measuring cup (in fluid ounces or cubic centimeters)
- wire (12 or 14 ga copper) — about 2 feet
- painters' tape (the kind that doesn't permanently stick to things)
- ruler or yardstick

The Racer

HISTORY

Do you know when the rubber band racer was invented? We have done a lot of research in this area and can't find the specific date. When you run into this problem, you can break it down into the technology components that are used in the item to figure out the earliest and latest it could have been invented. For example, in the racer, you need a wheel, axle, and rubber band.

The wheel and axle have been around since before the Egyptians, but the rubber band seems to be a newer invention. Let's research when the rubber band was first made. This would tell us that the racer has to be after that date.

The rubber band (also known as a binder, elastic, gummy, or gum band) was patented by Stephen Perry on March 17, 1845 in England. So, a rubber band powered racer has to be after March 1845 and before today. Searching on the internet you will find examples of rubber band racers going back to the 1970s. This places the date of possible invention somewhere between 1845 and 1970.

Q1: Research the history of rubber band racers to see if you can narrow down the date of when it was invented.

Q2: Can you find the text of the original patent of the rubber band?

RUBBER BANDS

What exactly is a rubber band and how is it made?

The rubber in a rubber band comes from latex. Latex is the sap that comes from the rubber tree. The tree is scored on the outside to just nick the vessels that carry the sap. The sap will ooze out of the tree and is collected in buckets. If it is mixed with sulfur and heated it forms rubber. If it is not mixed with sulfur, the latex can dry but almost melts in hot weather and becomes brittle in cold weather. Not too useful. Sulfur and heat make it into a very new and useable material which is what we think of when we use the word rubber.

To make the rubber band, the manufacturer takes a pipe or long tube with a highly polished surface and dips it into the latex which is mixed with sulfur forming a coating on the tube. It may take several dippings to get the desired thickness. A tube or pipe is used because it is easy to heat from the inside with steam to cure the rubber. The rubber coating is then removed from the pipe and sliced into thin strips or rings forming the rubber band.

Rubber bands come in many different sizes, thicknesses, widths as well as types of rubber. Some rubber materials are very soft and stretchy while others are very hard and stiff. Today you will also find rubber bands made out of alternate materials including synthetic rubber, polyurethane, silicone rubber, and more.

HOW DOES THE RACER REALLY WORK?

The racer is a simple mechanism that turns energy stored in the stretch of the rubber band into forward motion. The rubber band causes the axle to turn which turns the wheels and moves the racer forward.

Let's take a closer look at the mechanism. To do this we are going to break it down into the following components:

- how a stretched rubber band stores energy
- how the rubber band makes the axle and wheel turn
- friction between the wheel and the floor
- the racer moving forward

If the racer were put on a carpet instead of on glass, would it perform differently? If the power wheels were smaller or larger would it perform differently? If the rubber band were shorter or longer, thinner or thicker, narrower or wider, would it perform differently?

All these things come together to make the racer work. If any of them change, the racer performs differently.

Energy Storage in a Rubber Band

When you stretch a rubber band in one direction, it pulls back in the opposite direction. The more you pull the larger the opposite force is. It takes energy to stretch the band and it releases energy when you let it return to its rest position. How can you figure out how much energy it stores?

THEORY – FORCE

A rubber band is like a spring.[1] The more you stretch it, the harder it pulls back. Likewise, the harder you pull, the more it stretches. There are three quantities here: how much the rubber band stretches (distance), how hard it's pulling back (force), and how strong the rubber band is (springiness). Distance is measured in units like inches, and force can be measured in units like ounces. To figure out the springiness of the rubber band requires some testing.

Let's say you take a rubber band and hook a 1 ounce weight to it, and the rubber band stretches to 0.5 inches long. Then you try a 2 ounce weight instead, and it stretches to 1 inch long. You try a 4 ounce weight, and it stretches to 2 inches long. Every time, the pulling force (in ounces) is 2 times the distance (in inches). This rubber band has a *spring constant* of 2 ounces per inch.

A large spring constant means the rubber band is very strong; it pulls with a lot of force when stretched a certain distance. A small spring constant means the rubber band stretches very easily; it pulls back with only a small force when stretched the same distance.

The relationship between the pulling force F, the spring constant k, and the distance stretched x can be shown as an equation:

$$F = kx$$

Remembering the units of measurement, this equation becomes:

$$F\text{[ounces]} = k\text{[ounces/inch]} \cdot x\text{[inches]}$$

Q3: How much force does a rubber band pull with when it's stretched 12 inches and it has a spring constant of 2 ounces/inch?

Q4: If a band with a spring constant of 0.5 ounces/inch is stretched 12 inches, how much force does it pull with?

THEORY – ENERGY

Energy is the ability to push against a force for a certain distance. If you hold a weight in your hand while resting your hand on the table, you can feel the force of the weight, but your hand isn't lifting anything. This expends

1 In physics, a *spring* is any elastic object that stores mechanical energy. Examples include a typical coiled metal spring, a rubber band, a metal ruler, an archer's bow, etc.

no energy. If you lift the weight up into the air, you're lifting while pushing against the force of the weight. This expends energy.

The energy it takes to lift a 1 ounce weight 10 inches is the same as the energy it takes to lift a 2 ounce weight 5 inches. The energy E is the product of the force F that you push against, times the distance x that you push it.

$$E = Fx$$

$$E[\text{inch-ounces}] = F[\text{ounces}] \cdot x[\text{inches}]$$

When you're holding a rubber band that isn't stretched at all, it isn't exerting any force on your hand. When you stretch it to its full length, the rubber band pulls back against your hand with a certain amount of force. To get the rubber band from 0% stretched to 100% stretched, you have to expend energy, pulling against the force of the rubber band. This energy gets stored in the rubber band, and can then be used to move an object, like a rubber band racer.

How much energy can the rubber band store? Remember, energy is force times distance, so we'll need to know two things: the force the rubber band pulls with (ounces), and the distance we'll be stretching it to (inches). The force a rubber band changes from unstretched to stretched, so we'll need the average pulling force.

To get the average force of the rubber band, we'll add together the minimum force and the maximum force, then divide by two. The minimum is zero (since an unstretched rubber band doesn't exert any pull), and the maximum is the band's spring constant k, multiplied by the distance x that we're stretching it to. In other words:

$$F_{\text{average}} = \tfrac{1}{2}kx$$

Now that we know the average force, we can figure out the total energy stored in the stretched rubber band. Energy is force times distance, so:

$$E = \tfrac{1}{2}kx^2$$

Since energy is force times distance, we measure it in inch-ounces. A single inch-ounce is enough energy to lift a 1 ounce object 1 inch, or a 2 ounce object 0.5 inches, or a 10 ounce object 0.1 inches — it's all the same amount of energy.

Learning Objectives

- how to measure the spring constant of the rubber band
- how to calculate the energy stored in the band

Skills You Will Develop

- measuring length and volume
- plotting data on a graph
- finding a best fit line for a set of data
- finding the slope of a line
- determining the spring constant and stored energy in a spring

EXPERIMENT – SPRING CONSTANT

In this experiment you have to measure the force that a rubber band exerts when stretched to a specific length. Then from this data you can calculate the spring constant. One way is to use a force gauge to measure this. An easier way is to simply hang some weight from the rubber band and measure its length. If you did a variety of weights, and measured the respective lengths, you could plot the data on a weight versus length chart and the slope of the line would be the spring constant k.

Using a milk jug as a container we can add water to it as the weight. The rubber band is hung from a wire loop suspended on a dowel rod. Water is added, the length is measured and you repeat this until the band is stretched to about its maximum. Water is a great substance to use for the weight since one liquid ounce is equal to one weight ounce. So if you can carefully measure one liquid ounce, you have a good one-ounce weight.

We will test 5 rubber bands to get an average spring constant for the lot. Each band needs to be the same.

Materials Needed

- 10 rubber bands about 2–3″ long and about 1/16″ to 1/8″ in width. They all need to be the same size.
- an empty milk jug
- a measuring cup - graduated in either ounces or liters
- some water
- a wooden dowel or broom stick handle, wire, painters tape, etc.
- measuring tape or yard stick
- graph paper or Excel™

Physical Setup

1. Take a wooden dowel and place it between two chair backs.
2. Take some painters' tape (the kind that does not permanently stick to surfaces) and anchor the dowel rod on both ends to the chair backs to keep it secure during this experiment.
3. Use a piece of wire as a hook to hang the rubber band from the dowel rod.
4. Make the wire into a double hook. Attach one end to the milk jug and the other end will be used to hang from the rubber band.
5. Hang a rubber band on the dowel rod hook and hang the jug hook on the band.

Data Recording Setup

1. Record your data in a table where one column is the weight in ounces and the next column is the length the band is stretched.
2. Add a new column for each band you test.
3. Make sure you record the date and time of the experiment

Experiment Procedure

1. Measure the length of the band.
2. Add 2 ounces of water to the jug and remeasure the band.
3. Continue adding water and measuring until the band breaks or you reach about 60 ounces of water.
4. Plot the data in Excel or on graph paper.
5. Find the best fit straight line the goes through most of the data points with an equal number of points above and below the line. You can do this in Excel by adding a trendline or on paper use a pencil and lay it so it is centered on the data, then draw the line.
6. To calculate the spring constant *k* all you need is the slope of the best fit line. You can get this by displaying the equation of the line in Excel or you can calculate the slope by hand. Just pick two data points that fall on the line and are spread apart. Find the value of each point in terms of the weight and distance. Subtract the two weights to get a delta weight. Subtract the two distances to get a delta distance. Divide the delta weight by the delta distance. This is the spring constant *k* which just so happens to be the slope of the line.
7. Repeat the experiment for 4 more rubber bands but stop at 90% of the length that the first one broke at. If the first one did not break do all of the weights until 60 ounces.
8. Average the 5 spring constants to find the value that represents the bands as a whole.
9. Calculate the energy that would be stored in this average rubber band if it were stretched to its maximum length just at breaking. Use the average spring constant and the distance from the band that broke.

Analysis

Let's try to figure out what we can learn from the data, graphs, and calculations we just finished.

When we started the experiment we never measured the weight of the milk container. This may seem funny but take a close look at how we measured the spring constant *k*.

Q5: Why does the weight of the milk container not matter in determining the spring constant?

We used wire hooks to hold the ends of the rubber band. We could have just draped the band over the dowel rod and wrapped it around the milk bottle neck. We choose to use something with a small diameter so almost all of the rubber band gets stretched. If we used the dowel rod, the part of the rubber band at the top of the dowel rod would not be stretched the same as that of the length of the band. This introduces some error in the measurement.

When you stretch the rubber band to near its breaking point, you will notice that the force in the last bit gets larger very quickly as you near that point. There is a kind of threshold just before it breaks where it no longer grows in length as quickly.

Q6: What happens to the end of the curve as the rubber band reaches its maximum length?

Latex rubber is not a perfect material. It works as a springy material because there are long coils of hydrocarbon chains the are partially cross-linked to their neighbors, but mostly free to be stretched. If one were to make many more bonds to their neighbors the material would become stiffer and stiffer. Some materials fatigue over time. Take a piece of wire and bend the wire back and forth at the same point. The wire will start to form some cracks and then fracture into two pieces. Latex is more flexible and can be bent or stretched many many more times, but the long coils of hydrocarbon chains are not perfect. Do an experiment where you put a new band on the test setup and hang about 90% of the weight you used for the earlier test (you don't want it to break). Measure the length, remove the band, replace the same band, replace the weight and remeasure. Do this for about 20 times.

Q7: What happens if the rubber band is stretched over and over? Does the spring constant remain the same, get higher, or get lower?

Since energy storage is proportional to x^2 what does the graph look like when you plot energy vs. band length?

Q8: How much energy is stored in the band when it is stretched to 25% of its breaking length? 50%? 75%? 100%?

Q9: Plot the energy stored in the band versus length. Is it linear (forming a straight line)?

You now have a good understanding of how a simple spring or rubber band works, how it can store energy and how the amount of stretch determines the force for a given spring constant.

Conclusion

Write a report of your experiment and summarize your results. What conclusions can you draw from the experiment?

Rubber Band Force to Racer Movement

The rubber band pulls on the circumference of the axle connected to the wheels. This creates a torque or twisting force in the axle. The axle then transfers this torque to the wheel. The wheel rotates and moves the racer forward by pushing on the carpet. However, the force that the rubber band exerts on the axle is much different in magnitude than the force the wheel exerts on the carpet. How can we figure out how much force pushes the racer forward?

THEORY – FORCE CONVERTER

The axle with a small diameter and the wheel with a large diameter act as a force converter. Here is how it works.

Instead of an axle, suppose we had a lever arm with a length the same as the radius of the axle to which the rubber band were hooked. The force in the band applied to the lever arm would create a twisting force in the axle. This twisting force is called torque.

The racer's axle is ¼″ in diameter, which means the lever arm or radius is half that: ⅛″ in length. The torque is simply the length of the lever times the force. If the force the rubber band exerted was 20 ounces, the the torque would be ⅛″ × 20 ounces: 2.5 inch-ounces.

To determine the force on the wheel, all we need to know is the wheel diameter. The large wheel has an average diameter of 2.75″ which means that its radius is half or 1.375″. So the force that the wheel produces is 2.5 inch-ounces divided by 1.375 inches which is 1.82 ounces. The wheel/axle combination acts as a force transformer. This combination changes the force of the rubber band into the force exerted by the wheel on the carpet by the ratio of their radii or 1.375:0.125 (which is the same as the ratio of their diameters) and it is 11:1. That is, the rubber band force is reduced by 11×. This lower force allows the energy to be expended over a longer distance of travel.

Learning Objectives

- how to measure the torque in an axle or wheel
- how to calculate forces which are transformed by an axle and wheel

Skills You Will Develop

- measuring skill in determining torque and the force a wheel exerts to push a vehicle forward
- graphical plotting skill
- determining the slope of the best fit line

EXPERIMENT – MEASURING WHEEL FORCE

In this experiment we will measure the force that the wheel would exert on the carpet caused by the rubber band. To do that we will make a temporary change to the racer. We will tape a toothpick to one of the large wheels with painters' tape so it acts as the lever arm from the above discussion. Then we will wind up a rubber band on the racer to near its maximum force. The milk jug is hung from the lever arm on the wheel with a piece of string and water is added to the jug until the force of the jug pulling on the lever arm exactly counter balances the force of the rubber band. We can then measure the water and have a good idea of the force at the wheel.

Materials Needed

- Rubber Band Racer™
- rubber bands
- toothpick
- painters' tape
- string — about 12 inches
- milk jug
- water
- measuring cup

Setup

1. Tie the string to the milk jug and put tie a loop in the free end.
2. Take a toothpick and tape it to the large wheel such that it looks like a spoke to act as the radius lever arm discussed above. The tip of the toothpick needs to stick out beyond the circumference of the wheel so the string and milk jug can hang on it.
3. Tape the racer to a table leaving the drive wheels overhang the edge of the table so they can spin freely. You will need to tape it very firmly and tightly to the wheel.
4. Load the racer with the rubber band (the same type you measured in the earlier experiment) and wind the wheels until the rubber band is at about its maximum tension.
5. Rotate the wheel with the toothpick until it is horizontal and hang the milk jug and string from the tip of the toothpick.
6. Add water to the milk jug until the force it exerts on the wheel counterbalances the force turning the wheel from the rubber band.
7. Measure the amount of water.

Data Recording Setup

1. Record your data in a table where the first column is the length the rubber band was stretched before winding. The second column is the calculated force in the rubber band, and the third column is the weight of water to counterbalance the wheel force.
2. Make sure you record the date and time of the experiment.

Experiment Procedure

When winding the rubber band on the racer, there are two techniques that can be used. First is to simply hook the rubber band on the peg and finger and then rotate the wheels until the rubber band is at maximum tension. The second is to hook the rubber band on the axle peg and stretch it to its maximum length, then wind it on the axle and finally hook the other end on the finger. For this experiment we will use the latter.

1. Wind the rubber band onto the axle, stretching it to its maximum length.
2. Hang the jug and add water until the force from the jug balances the force from the wheel. Record this data.
3. Repeat this for the rubber band stretched to 75%, 50%, and 25% of its length and record the results.
4. Calculate the force in the rubber band for each of the lengths you used (25%, 50%, 75%, and 100%).

Q10: Plot the force in the rubber band versus the weight of water. Both are in ounces.

Q11: What is the shape of the plot?

Q12: What is the slope of the line?

Analysis

Let's try to figure out what this all means.

The force that the wheel exerts should be smaller than the force the rubber band exerts by the ratio of the wheel diameter to the axle diameter.

Q13: If the shape of the plot of force vs water weight were not linear, what things in this experiment might cause this?

Q14: What would happen if the small wheel were swapped with the large wheel? What would the ratio of the force conversion be? What would the force at the wheel be if the same 20 ounces of force were supplied by the rubber band?

Q15: Would the racer go farther using the smaller wheel versus the larger wheel as the drive wheel?

Conclusion

Write a report of your experiment and summarize your results. What conclusions can you draw from the experiment?

Friction Forces between the Wheel and the Carpet

How is the force the wheel exerts to move the racer forward affected by friction? What exactly is friction?

THEORY – FRICTION

Friction is a force that resists motion. It occurs in sliding bodies, rolling bodies, and spinning bodies; and it prevents bodies from moving. It happens any time two things touch, even if one of the things is air. If there were no friction in the world and you bumped something on your desk it would simply slide off. You would not be able to walk or run.

We will focus on two main types of friction for the racer: static friction and rolling friction.

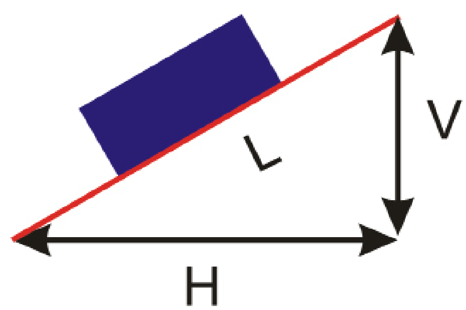
Theory – Static Friction

Imagine a large ice chest or cooler that is full of water and sitting on a floor. If we tried to pull it across the floor, there would be a strong resistance to any motion. As the force we exerted increased, we would reach a point where the cooler would break free and start moving. The force which was resisting our pulling was static friction. It is related to the area of contact between two objects and a factor that represents the surfaces called the coefficient of friction. Two surfaces that are smooth and slippery like the material a plastic cutting board is made of (High Density Polyethelyene: HDPE) have a low coefficient of friction of around 0.28, while 200 grit sandpaper on wood is about 0.75. It is the ratio of the force in the direction of the sliding motion (tangential) divided by the force pressing the two objects together (normal).

$$\mu = F_{\text{tangential}} \,/\, F_{\text{normal}}$$

If the ice chest weighed 100 lbs and the force we needed to get it to move were 100 lbs, the coefficient of friction μ would be 0.5.

A simple way to measure this coefficient of friction is to place the object on an inclined surface (like a board) and tilt the surface until it starts to move. Knowing the weight of the object and the angle of the tilt, the normal force and the tangential force can be calculated and the coefficient of friction determined.



The coefficient of static friction is the ratio of the vertical distance the board is raised to the horizontal projection of the board on the table. Since we know L, the length of the board, we can calculate the angle the board is raised by the equation:

$$\theta = \sin^{-1}(V/L)$$

and, the coefficient of static friction is:

$$\mu = V/H$$

then in terms of V and L, the coefficient is:

$$\mu = \tan(\theta) = \tan(\sin^{-1}(V/L))$$

Our racer has a coefficient of friction for the static friction that can be determined using this method.

Theory – Rolling Friction

The coefficient of rolling friction is generally much smaller than the static friction coefficient. It is due to things that deform like a soft car tire on a road, which has higher rolling friction that a properly inflated tire. Considering the weight of the racer and the stiffness of the birch wood wheels and a typical home carpet, we are going to assume this is zero.

Static Friction on a Micro Scale

Sometimes friction is good, sometimes it is bad. Image if you wanted to cross an ice skating ring in your shoes and that there was no friction between your shoes and the ice. What would happen?

The racer has static friction between the teeth on the wheel and the carpet it runs on. If the wheel is turned with too much force, the wheel will break free and spin on the carpet. We don't want to reduce this friction as it allows the wheel to push against the carpet and move the racer forward.

The racer also has static friction between the axle and the wood bearing it rides in. This absorbs energy and limits how far the racer will travel. We can reduce this by putting a lubricant on the axle in the bearing. A good lubricant for the racer is paraffin or candle wax. A small amount rubbed on the axle will allow the racer to travel farther.

Learning Objectives

- How to measure static friction of the racer

Skills You Will Develop

- Measuring skill in determining static friction

EXPERIMENT – STATIC FRICTION

In this experiment we will measure the static friction of the racer wheels to the carpet. To do this we will place the racer on a piece of carpet (use a towel if you don't have a carpet) which is laying on a board. We will then tilt the board up until the racer just starts to move being very careful not to bump the board. We want the static coefficient not the rolling coefficient.

Materials Needed

- 2 feet of carpet (a towel can be used if a piece of carpet is not available)
- double-faced tape
- racer
- board — at least 2 feet long
- ruler

Setup

1. Attach the carpet to a board so the board can be tilted up to about 45 degrees without the carpet coming loose.
2. Measure the length of the board, L.

Data Recording Setup

1. Record the height V the board was raised at which the racer begins to roll.
2. Calculate the coefficient of static friction.

Experiment Procedure

1. Place the racer on the carpeted board.
2. Raise one end of the board until the racer begins to move. Be very careful not to bump the board or jiggle the racer when raising the board.
3. Measure the height of the raised end.
4. Calculate μ, the coefficient of static friction.

Analysis

1. Examine the data and try to determine other areas to explore.

Q16: Does the coefficient of friction change if the surface is smooth like a board or if a higher pile carpet is used?

Q17: Is the coefficient of friction the same if the car is aiming one way or the other?

Conclusion

Write a report of your experiment and summarize your results. What conclusions can you draw from the experiment?

Lesson Plan – Racing the Racer

RUBBER BAND RACER EXPERIMENTS

In the process of testing and racing the racer many options come to mind. You could use a single car and mark the farthest distance using tape on the floor. You could race multiple racers simultaneously to determine the winner.

The winner could be determined by whose car went the farthest, whose rubber band went the farthest, or by who reached the finish line first.

This part is always the most fun in any project. When all of the parts finally come together and you can see it work, understand why it works, and find some new surprises in the data that cause you to think — that's where the excitement comes from.

Learning Objectives

- how to develop a plan and test it to reach an objective

Skills You Will Develop

- logic skills in figuring out your best options to win

Learning Objectives

- racing the racer
- data collection
- analyzing the data

EXPERIMENT – THE RUBBER BAND DISTANCE TEST

In running a race, you could try various ideas to get the racer and rubber band to travel the farthest. These may include:

- narrow vs. wide rubber bands
- hooking two rubber bands side-by-side vs. end-to-end
- stretching the band all the way before winding it up vs. winding it to stretch it
- using large wheels as the drive wheels vs. using small wheels
- using the rear wheels to push the racer vs. using the front wheels to pull
- adding weight to the car (currently 2.57 ounces)
- rolling the racer back and forth in the carpet before starting

Your job is to pick which combination or set of combinations you think will do best and then test them.

Materials Needed

- racer and rubber bands
- painters' tape
- ruler or tape measure
- candle wax

Setup

1. Find a long stretch of carpet that you can use for the race. It should be about 10-16 feet long.
2. Get permission to use the area for the race.
3. Mark a starting line with the painters' tape.
4. Prepare the racer by lubricating the axles with parrifin or candle wax. Run a few trial races to burnish it in to the bearings.
5. Develop your experiment test matrix. Pick at least three techniques from the above list or new ones you may have thought of and run each three times to determine which will do best. We will call each of these a test case that is run three times.

Data Recording Setup

1. Record the distance traveled and the conditions you used for that iteration of the race.

Experiment Procedure

1. Choose your test case.
1. Place the racer on the carpeted board.
2. Run the race.
3. Mark the location of where the racer stopped.
4. Mark the location of where the rubber band stopped.
5. Measure both and record the data.
6. Repeat for each test case.

Analysis

1. Which combination of factors produced the best results? Why do you think it worked that way?

Conclusion

Write a report of your experiment and summarize your results. What conclusions can you draw from the experiment?

Art

Cartoon of the Race

You are responsible for the cartoons in your local magazine. Draw a cartoon of 4 to 5 cells that show the progress of the race and how the race was won. Use your imagination to show, with simple characters and drawings, the following items or emotions:

- winning
- losing
- excitement
- disappointment
- the grand prize
- speed

Writing

At the Race

You are a reporter at the Rubber Band Racer Race championship for your state. Write a one-column news story covering the race. Put yourself in the place of each person at the race to picture what it was like. Make sure to describe or answer the following:

- Where was it held?
- Who was there?
- Who sponsored the race?
- What difficulties did each finalist go through in building, tuning, and decorating their racer?
- What did the winner feel like when he or she won?
- What did it feel like to those who did not win?
- What did each person learn in the process of racing in the championship?
- What expections did they have before they started and how did their expectations change?

Practice a race between yourself and a friend and use their thoughts to help you write this news story.

Vocabulary

Write definitions of each of the following terms used in this lesson plan:

- friction
- coefficient of friction
- static friction
- rolling friction
- force
- energy
- spring constant
- weight
- area
- graph

Answers to Questions

Q1: Research the history of rubber band racers to see if you can narrow down the date of when it was invented.

Q2: Can you find the text of the original patent of the rubber band?

March 17, 1845 - Patent #13880.1845 - Stephen Perry of Woodland's place, St. John's-wood, County of Middlesex London- Invented the rubber band to hold papers or envelopes together.[2]

British Patent No. 13880 (1845)

Specification of the Patent granted to Stephen Perry, of Woodland's-place, St. John's-wood, in the County of Middlesex, Gentleman, and Thomas Barnabas Daft, of Birmingham, Manufacturer, for Improvements in Springs to be applied to Girths, Belts, and Bandages, and Improvements in the Manufacture of Elastic Bands. —Sealed March 17, 1845.

Q3: How much force does a rubber band pull with when it's stretched 12 inches and it has a spring constant of 2 ounces/inch?

$F = kx = 2 \times 12 = 24$ ounces

Q4: If a band with a spring constant of 0.5 ounces/inch is stretched 12 inches, how much force does it pull with?

$F = kx = 0.5 \times 12 = 6$ ounces

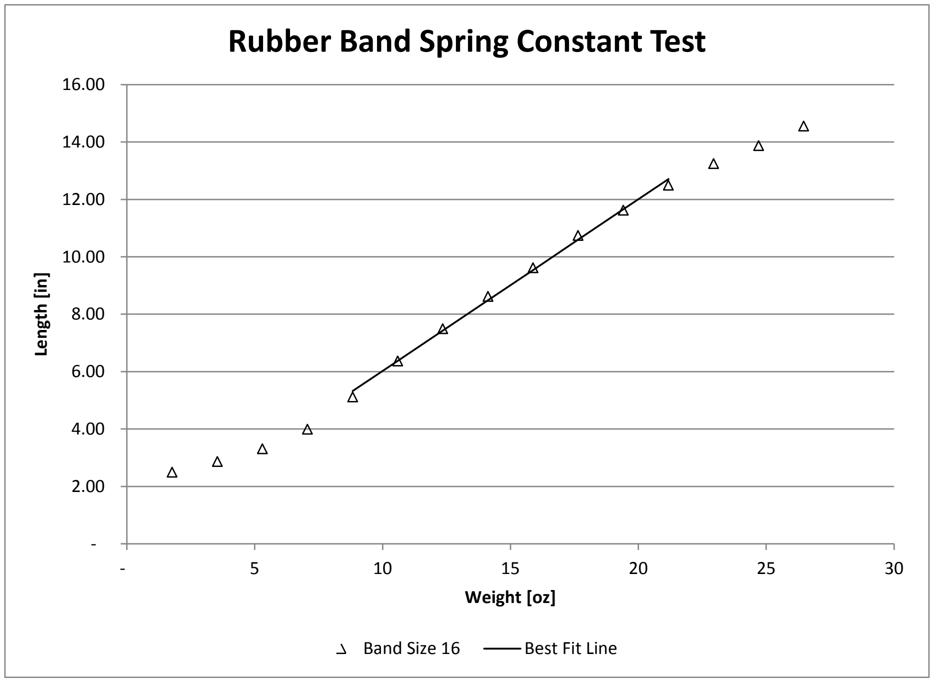
Q5: Why does the weight of the milk container not matter in determining the spring constant?

It does not matter because only the slope of the line matters. If the line shifted up or down but did not change in slope the result would be the same. As long as the weight of the container without water is constant it has no effect.

2 http://todayinsci.com/Events/Misc/Perry-ElasticBandsPatent.htm Manufacturing Elastic Bands

Q6: What happens to the end of the curve as the rubber band reaches its maximum length?

The rubber band runs out of the ability to stretch linearly and starts to fail. The curve bends because the elastic limits of the latex rubber are being reached.



Q7: What happens if the rubber band is stretched over and over? Does the spring constant remain the same or get higher or get lower?

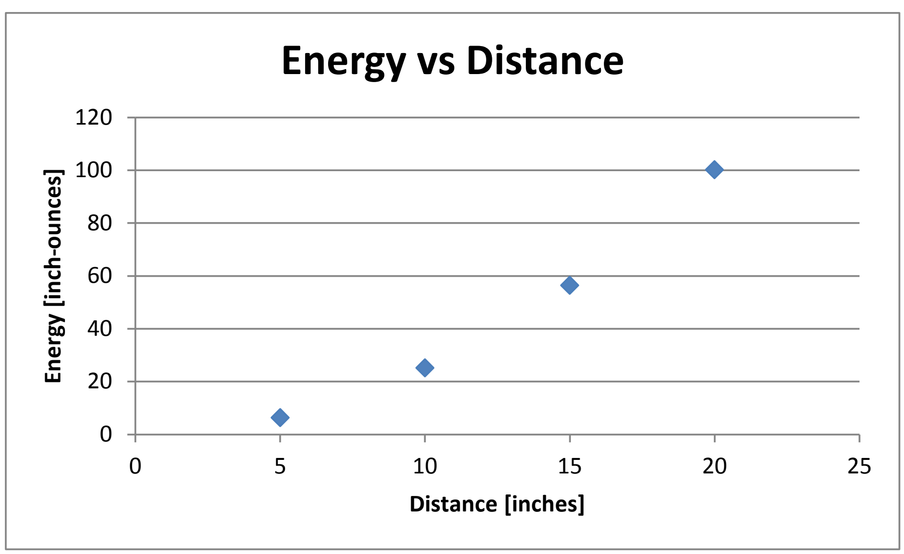
If the rubber band is stretched over and over, it gets softer. The spring constant goes down in value.

Q8: What is the energy stored in the band when it is 25% of its breaking length? 50%? 75%? 100%?

The energy stored is $E = ½kx^2$. You will need to use the k factor you found (should be about 0.5) and the length the band stretched (in the range of 20 inches) to find these values. Assuming that k is 0.5 and that the maximum length was 20 inches, then the energy stored at 25% is 6.25 inch-ounces; 50% is 25 inch-ounces, 75% is 56.25 inch-ounces, and 100% is 100 inch-ounces

Q9: Plot the energy stored in the band versus length. Is it linear (forms a straight line)?

The plot is not linear. It is a function of x^2.



Q10: Plot the force in the rubber band versus the weight of water. Both are in ounces.

The plot forms a straight line.

Q11: What is the shape of the plot?

The shape of the plot is a line. Any variations from a straight line are usually due to measurement error or experiment setup error.

Q12: What is the slope of the line?

The slope of the line is the ratio of the wheel diameter to the axle diameter.

Q13: If the shape of the plot of force vs. water weight were not linear, what things in this experiment might cause this?

The rubber band may be stretched too far, near its breaking point. The tension in the rubber band may not be uniform which happens if it is not stretched and held extended to the desired length before it is wound on the axle.

Q14: What would happen if the small wheel were swapped with the large wheel? What would the ratio of the force conversion be? What would the force at the wheel be if the same 20 ounces of force were supplied by the rubber band?

If the small wheel were swapped replacing the large wheel, it would deliver more force into the carpet based on the ratio of its diameter (which is smaller) to the axle's diameter.

The small wheel is 1.562″ in diameter, the axle is 0.250″ diameter, so the ratio is 6.2 to 1.

The force would be 20 ounces divided by 6.2 (3.20 ounces) to push the racer forward which is higher than that of the larger wheel.

Q15: Would the racer go farther using the smaller wheel versus the larger wheel as the drive wheel?

Now this is a good question. The answer is it depends. The energy being released is the same, so in theory it should not matter. However, if too much force is delivered by the drive wheel into the carpet and the wheel slips (which usually happens if you use a rubber band that is 2 or 3 times the width of the 1/16″ band) then it falls far short.

Q16: Is the coefficient of friction the same if the car is aiming one way or the other?

The simple answer is that it should be. You may find some small differences in the value you determine but it should not matter.

Q17: Does the coefficient of friction change if the surface is smooth like a board or if a higher pile carpet is used?

Yes. It can change a lot. The smoother or slicker a surface is the lower the coefficient becomes. The thicker the carpet is the higher it becomes.