Lesson 2: Newton Gets Me Moving

Grade Level: 4 (3-5) **Lesson #:** 2 of 6

Time Required: 15 minutes **Lesson Dependency:** None

Keywords: Newton, motion, rocket, action, reaction, acceleration, mass, force, energy

Summary: In this lesson, students will explore motion, rockets and rocket motion while assisting Spacewoman Tess, Spaceman Rohan and Maya in their explorations. They will first learn some basic facts about vehicles, rockets and why we use them. Then, the students will discover that the motion of all objects including the flight of a rocket and movement of a canoe is governed by Newton's three laws of motion.

Engineering Connection: Anytime an engineer is working on something that moves, they use Newton's laws of motion to help describe how it is going to move. This includes cars, trains, boats, airplanes and rockets. Really, Newton's laws of motion govern anything that is — simply — in motion. Knowing how a vehicle will move is very important when designing a successful vehicle. And, similarly, knowing how a rocket will move is obviously very important to designing a successful rocket. Newton's laws dictate how much fuel is needed, how big the rocket must be, how much the rocket can weigh, how long the rocket must burn, and even how fast the rocket will go.

Learning Objectives

After this lesson, students should be able to:

- Describe what a rocket is and what their purpose is.
- Identify and explain Newton's three laws of motion.
- Describe how Newton's laws relate to engineering, rockets and paddling.

Introduction/Motivation

What are vehicles and why do we need them? (With the students, discuss what their concept of a vehicle is. They should get to the conclusion that a vehicle is a device that allows something to move from one place to another quicker than if there was no vehicle at all.) Now, what is *motion*? What are some different ways a person can get from one place to another? (List the students' answers on the board. Possible answers include: walk, run, bicycle, skateboard, drive/ ride in a car, train, boat, airplane or rocket.) How do these objects move? You're right! Everything that moves should in one way or another involve a push or a pull, which engineers call a *force*. For example, an engine in a car causes the wheels to turn, which then push against the ground, while a sailboat is pulled along by the wind. Every single motion is caused by a force. If there were not a push or a pull, objects — or in this case, vehicles — would not go anywhere. This is an example of Newton's first Law, which states that an object at rest tends to stay at rest and an object in motion tends to stay in motion, unless a force acts upon that object.

Let's look at our list on the board again. Which of these objects move fast and which ones move slowly? Now that we have separated the list into fast and slow groups, let's think about the forces (pushes and pulls) acting on the objects. Are the forces acting on the faster objects more or less than the forces acting on the slower objects? (The students should realize that the faster objects are faster because there is a larger force acting on them.) This is an example of Newton's second law, which states that the force of an object is equal to its mass times its acceleration. Larger mass equals larger force.

Which vehicles will Maya and her family be using in their explorations? Tess and Rohan will need a rocket to carry their communications satellite into space. Maya has a canoe that she will paddle to explore uncharted waters. A rocket is large, and will take a large force to get it moving. A canoe is smaller and will need a smaller force to get it moving.

So how do we create a force to move an object? Let's think about Maya in her canoe. How will she move it? (Answer: She will only move if there is a force acting upon her canoe.) Maya needs a force to move, and that force may arrive in many different forms: Maya could use the movement of the water as a force to move her canoe if the water is going in the right direction; she could use a paddle to move or push her canoe; or, she could have a friend push her in the canoe. If Maya was holding a bowling ball in her canoe and threw it overboard, would she move? The answer is yes, throwing the bowling ball in one direction would cause Maya and her canoe to move in the opposite direction. Can you see that for every movement, there is some responding action happening in the opposite direction? This is an example of Newton's third law which states that every action has an equal and opposite reaction. (Note: You can demonstrate this using a skateboard or a rolling chair.)

So, what about Tess' rocket? What makes a rocket a rocket? A rocket is a device that burns fuel causing extremely hot gasses to be ejected from the rocket out the nozzle (the tailend). The action of all this hot gas moving in one direction causes the rocket to move in the opposite direction. Rockets usually burn either liquid or solid fuel. It takes a lot of engineers to build a modern rocket since they are so complicated. Figure 1 shows a diagram of a liquid fuel rocket.

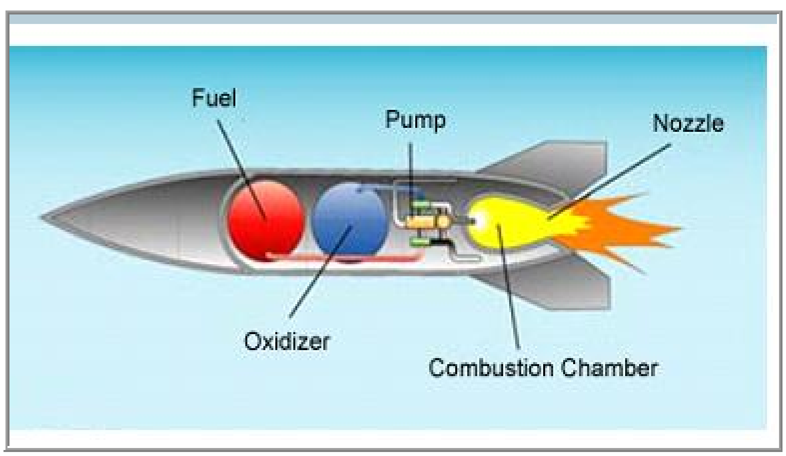


Figure 1. Diagram of a liquid fuel rocket

In a liquid fuel rocket, the fuel and oxidizer are pumped into a combustion chamber where the fuel and oxidizer burn to create super hot gas that is forced to escape through the nozzle. The rocket works on the same principle as Maya throwing the bowling ball while sitting in her canoe (do you remember: that for every action, there is an opposite reaction), but instead of throwing bowling balls the rocket is throwing hot gas. The rocket throws the hot gas down towards the Earth, which causes the rocket to move upward, away from the Earth. This does not seem like it would push the rocket very far, but the rocket is throwing so much hot gas at such a high speed that it can move very quickly. There are also rockets that use solid fuels. These are simpler rockets since there is no pump or oxidizer, but these rockets cannot be turned on and off. Typically, solid fuel rockets are not as efficient as liquid fuel rockets. Examples of liquid fuel rockets include the space shuttle's main engine as well as the Atlas, Titan and Delta rockets that are used to put satellites into space. Examples of solid fuel rockets include the solid rocket boosters on the space shuttle, rocket powered cars and bottle rockets. Figure 2 shows the liquid and solid fuel rockets on the space shuttle.

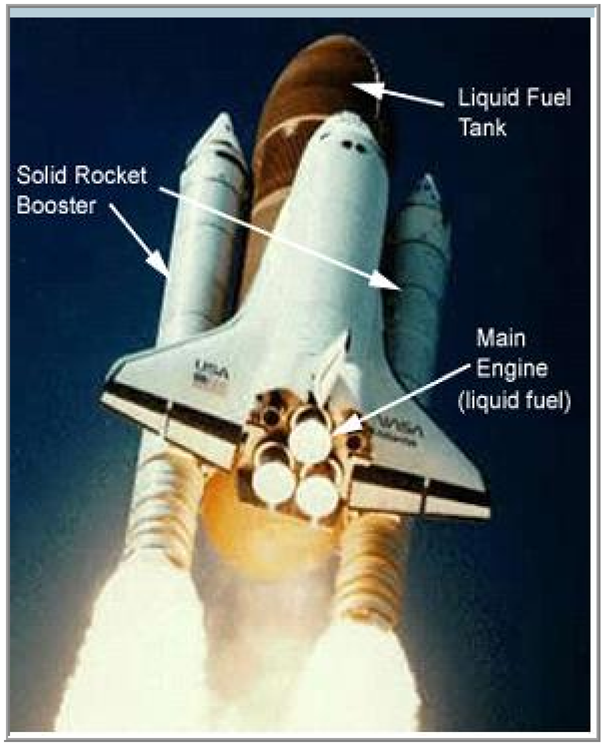


Figure 2. Liquid and solid rockets on the space shuttle. Copyright © http://nvo.gsfc.nasa.gov/astrodata/epohst-satellite.html (edited by Geoffrey Hill, University of Colorado, Boulder, 2005)

For what purpose do engineers design rockets? Well, we have already talked about designing rockets to go fast, but there are other reasons engineers design rockets. You may have heard or read that we often use rockets on spacecraft and satellites. That is because right now rockets are the only efficient way we have to move in space. Jets or propellers cannot be used to travel in space because they need air to work, and, as we know, there is no air in space. And, we cannot use a canoe to get around space because there is no water in which to paddle. Actually, we could get around in space if we had a bunch of bowling balls to throw. By throwing the bowling balls in one direction, we would successfully move in the opposite direction; however, throwing bowling balls is not the best way to move around in space, so we will stick to using rockets for now. Today, we are going to learn more about motion, engineering and about how a man named Isaac Newton formed three laws that tell us why objects — including rockets and canoes —move.

Lesson Background & Concepts for Teachers

Newton's Laws of Motion

The basic motion of any object is described by Isaac Newton's three laws of motion. His simple laws explain how objects move and, more specifically, how a rocket moves in the atmosphere and in space or how a canoe moves that is paddled in the water. (Note: For more reading on Sir Isaac Newton, see the accompanying reading material.)

Newton's First Law

Newton's First Law states that *an object at rest tends to stay at rest and an object in motion tends to stay in motion unless a force acts upon that object.* This means that for an object to speed up or slow down, there must be a force to push or pull on the object. Sometimes a force acting on an object causes that object to stay at rest or in motion. This is because there is another force that is canceling out the first force. For example, a person just standing on the ground has a force acting on him or her. This force is called gravity, but even though gravity is acting on this person, they are not actually moving. How can this be? Well, the reason is because the ground is actually pushing up on the person with the same force as the gravity that is pulling *down*. This upwards force cancels out gravity, and therefore, there is no change in motion. Engineers call two forces that cancel each other out *balanced forces*. If the floor was not present, gravity would no longer be canceled out by upward force, and the person would start to move (fall).

An object at rest stays at rest if the forces acting on that object are balanced or there are no forces acting on it. This is obvious for something that is not moving; but it also applies to moving objects in a vacuum. An object in motion stays in motion if balanced forces or no forces act on it. If a spaceship floating through deep space is moving at a constant velocity and has no forces acting on it (for example, gravity), then there is no change in motion, and the spaceship will keep moving in a straight line - forever! Continuous motion is not seen on Earth due to friction and other forces slowing things down.

Newton's Second Law

If a bowling ball and a soccer ball were both dropped at the same time from the roof of a tall building, which would hit the ground with greater force? Common sense picks the bowling ball because it is heavier. Might we believe this to be true because we naturally assume that the bowling ball will fall faster? This statement is actually NOT true. Gravity accelerates all objects at the same rate; therefore, both balls would hit the ground at the same time and with the same velocity. However, the bowling ball will indeed hit with greater force because it has a greater mass. Newton stated this relationship in his second law: *the force of an object is equal to its mass times its acceleration*.

This law of motion is a simple mathematical equation. The three parts of the equation are mass (m), acceleration (a), and force (F). Using the letters to symbolize each part, the equation can be written as follows:

F = m x a

To explain this law, consider a cannon as an example: when a cannon is fired, an explosion propels a cannonball out the open end of the barrel (top end of the cannon). It is propelled a kilometer or two to its target. At the same time, the cannon itself is pushed backward a meter or two. This is action and reaction at work (Newton's third law, which we will discuss shortly). Figure 3 shows a cannon and how Newton's laws of motion cause both the cannon ball and the cannon to move. The force acting on the cannon and the ball is the same force. What happens to the cannon and the ball is determined by the relative masses, according to the following equations:

Force on the cannon = mass (of cannon) x acceleration (of cannon)

Force on the ball = mass (of ball) x acceleration (of ball)

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation, the mass is the cannon ball and the acceleration is its movement. Because the force (exploding gun powder) is the same for the two equations, the equations can be set equal to each other and rewritten as:

mass (of cannon) x acceleration (of cannon) = mass (of ball) x acceleration (of ball)

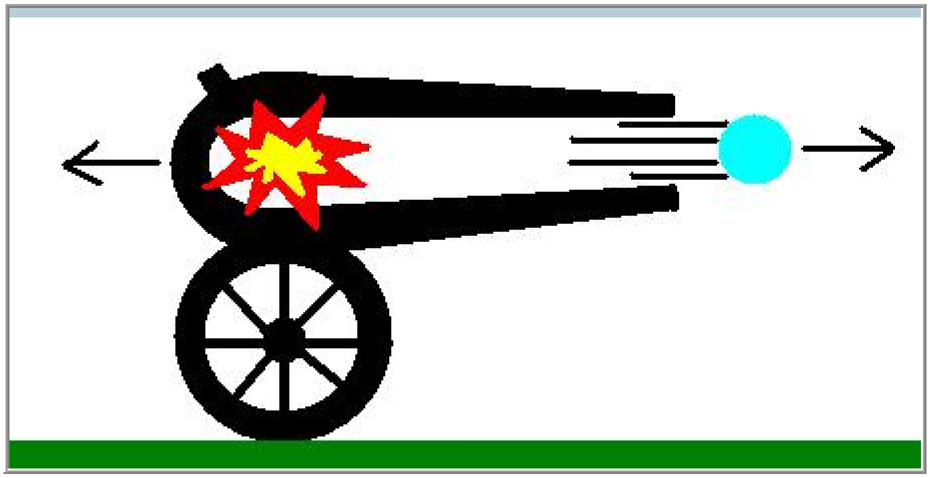


Figure 3. Cannon demonstrating Newton's laws of motion.

In order to keep the two sides of the equations equal, the accelerations must balance the masses. In other words, since the cannon's mass is large and the cannon ball's mass is small, the only way the equation will balance is if the cannon ball has a much larger acceleration than the cannon. This is why the cannon itself only rolls back a few feet and the cannon ball actually flies a long distance.

Now, apply this principle to a rocket. Replace the mass of the cannon ball with the mass of the gases (fuel) being ejected out of the rocket engine nozzle. Replace the mass of the cannon with the mass of the rocket moving in the other direction. The force is the pressure created by the controlled explosion taking place inside the rocket's engines (just like the gun powder explosion in the cannon). That pressure accelerates the fuel gases one way out the nozzle, which causes the rocket to move the other way.

Newton's Third Law

This law states that *every action has an equal and opposite reaction*. If you have ever run into anything in surprise or by accident, you should have a sense of this law.

Think about Maya in her canoe. Maya pushes the water back using a paddle, which creates a counterforce of similar size that propels the canoe forward. When Maya wants to move forward in the canoe, she paddles in a backward motion; when she wants to move backwards in the canoe (to avoid rocks or trees or animals), she would move the paddle in a forward motion. Figure 4 illustrates this idea.

As another example, imagine Spaceman Rohan alone at home with a skateboard. He and his skateboard are in a state of rest (not moving). Spaceman Rohan jumps off the skateboard. In Newton's third law, the act of jumping is called an *action*. The skateboard responds to that action by traveling some distance in the opposite direction. The skateboard's opposite motion is called a *reaction*. When the distance traveled by the rider and the skateboard are compared, it would appear that the skateboard has been affected by a much greater force than the rider, but this is not actually the case. The reason the skateboard has traveled farther is that it has less mass than the rider (see Newton's second law).

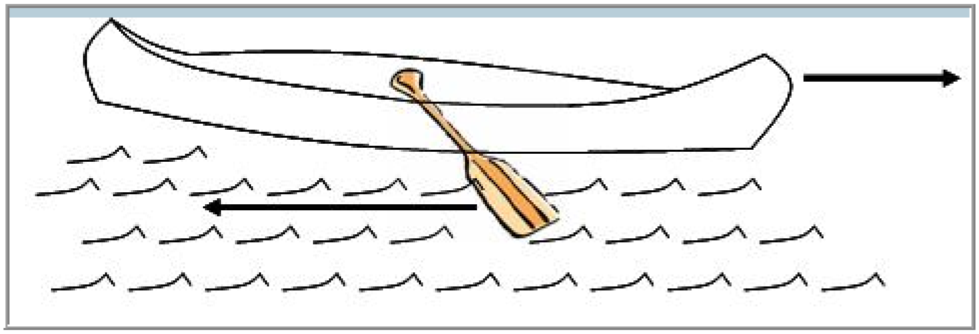


Figure 4. A canoe and paddle demonstrating Newton's laws of motion.

With rockets, the action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action (or thrust) from the engine must be greater than the downward acceleration of gravity on the mass of the rocket. In space, when the downward acceleration of gravity is balanced, even tiny thrusts will cause the rocket to change direction.

Rockets actually work better in space than they do in air. The surrounding air impedes the action-reaction. In the atmosphere, both the nose of the rocket and the exhaust gases leaving the rocket engine must push away the surrounding air; this uses up some of the energy of the rocket. In space, the exhaust gases can escape freely (*action*) and there is no air friction to slow the rockets *reaction* forward.

Vocabulary/Definitions

Acceleration:	How quickly the speed of an object is changing.
Force:	A push or pull that causes motion or change.
Rocket:	A vehicle that moves by ejecting mass.
Isaac Newton (b.1642 - d.1727):	An English mathematician and physicist who came up with three very important laws of motion.
Mass:	A measure of the amount of matter in an object.
Newton's First Law:	No forces = No change in motion. An object at rest tends to stay at rest, and an object in motion tends to stay in motion unless a force acts on the object.
Newton's Second Law:	Acceleration×Force = Mass
Newton's Third Law:	For every action, there is an equal and opposite reaction.
Rocket:	A vehicle that moves by ejecting mass.

Associated Activities

Newton Rocket Car - In this activity, students learn about Newton's laws of motion. They will build a small vehicle that moves by launching a mass backward.

Lesson Closure

Let's look around the room and find examples of balanced and unbalanced forces. Is there an air duct, a water faucet, a clock, or how about the students themselves? Anytime there is a change in motion, there is an unbalanced force. Anytime something encounters friction, that is actually a force acting upon that object. Every time there is a force, there is an equal and opposite force. A fan blade hitting an air molecule pushes it away (one force), but the air molecule also applies a reactive force to the fan and slows it down slightly (equal and opposite force). Can you think of examples from everyday life of actions and reactions? Do you think rockets would work without Newton's third law? (Answer: No way!) It is important to understand that a force is required for an object to start or stop moving. How fast an object speeds up (accelerates) is dependent on the mass of the object and the size of the force acting on it. Lastly, for every action there is always an equal and opposite reaction.

So, as we end this lesson, consider the fact that Spacewoman Tess and Spaceman Rohan need a rocket to put a communication satellite or two up in orbit in order to keep in contact with Maya as she goes on her journey. Since you all now understand the laws governing motion, you are capable of becoming engineers who will be in charge of helping build such a rocket.

Assessment

Pre-Lesson Assessment

Concept Quiz: Give students the What is a Rocket? Quiz. Do not give them any answers yet. Have the students work in groups of four. Sharing ideas should be encouraged.

Post Introduction Assessment

Vehicle Detectives: Break the students up into teams of three to four. Give the teams a specific vehicle (i.e., skateboard, toy car, toy train, bicycle, pogo stick, etc., but preferably vehicles from the list generated earlier in the lesson), and ask the students to describe the vehicle's motion using Newton's laws. Questions to ask:

- What sort of action is used to move the vehicle?
- What is the reaction to that action?
- Does the vehicle experience more or less friction depending on where it is used? Why?
- Is a vehicle that is already in motion more inclined to continue to be in motion? Why? Can you think of an example of one that is?
- What types of fuel are used to move the vehicle?
- Does the vehicle move fast or move slow? Why?

Lesson Summary Assessment

Concept Quiz: Have students redo their What is a Rocket? Quiz. Discuss the attached answers and have students correct each other's papers.

Informal Discussion: Solicit, integrate and summarize student responses.

- Ask the students to explain how rocket motion is different from car, airplane or canoe motion and reference Newton's third law (for every action there is an equal and opposite reaction).
- Ask the students to explain Newton's second law (Force = mass x acceleration). Students should understand that many different combinations of mass and acceleration can give you the same final force using F=m x a:

12 = 1 x 12

12 = 2 x 6

12 = 3 x 4

Human Matching: On ten pieces of paper, write either the term or the definition of the vocabulary words. Ask for volunteers from the class to come up to the front of the room, and give each person one of the pieces of paper. One at a time, have each volunteer read what is written on his/her paper. Have the remainder of the class match term to definition by voting. Have student "terms" stand by their "definitions." At the end, give a brief explanation of the concepts.

Lesson Extension Activities

Try going into the gym and have students sit on a skateboard (with their feet off the ground!) while throwing heavier balls at them. Have students discuss among themselves whether or not they think this is an efficient way to travel. Is it? (Answer: probably not)

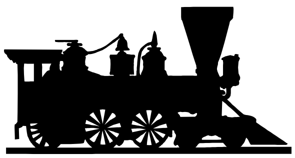
Attachments

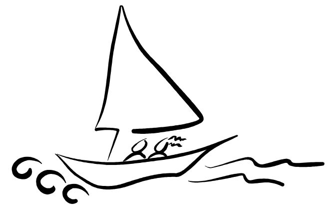
- What is a Rocket? Quiz
- What is a Rocket? Quiz - Answer Sheet

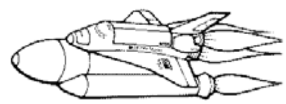
Name: ______________________________________ Date: ________________________

Lesson 2: Newton Gets Me Moving –
What is a Rocket? Quiz

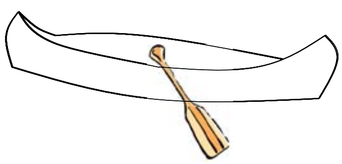
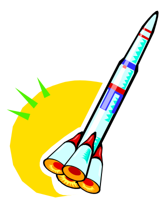
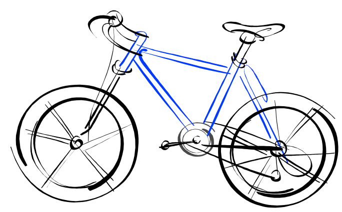
Circle the pictures that use rocket power to move:





Circle the pictures that do not use fuel power to move:

Circle True or False:

True or False : Every force has an equal and opposite force.

True or False : A ball sitting on a table creates a force on the table.

True or False : The table does not create a force on the ball.

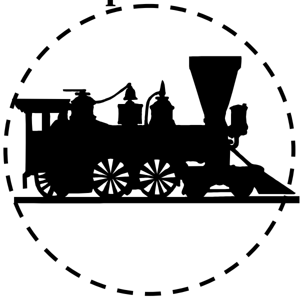
True or False : An airplane can fly in space.

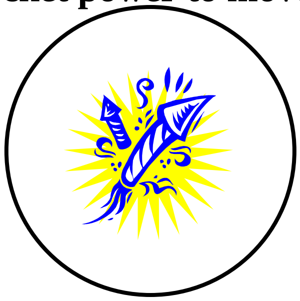
List two uses of rockets:

______________________________ ________________________________

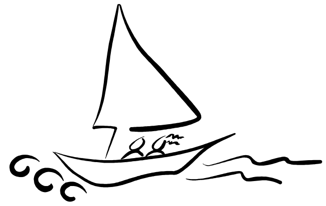
Lesson 2: Newton Gets Me Moving –
What is a Rocket? Quiz – Answers

Circle the pictures that use rocket power to move:

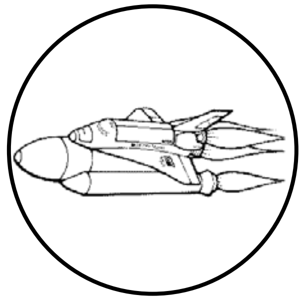




Fireworks – Yes!



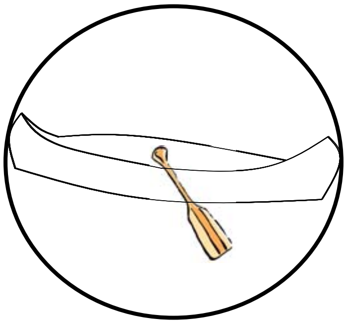
Wind - No



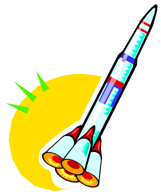
Space Shuttle – Yes!

Steam Trains, Airplanes, and Cars use it indirectly.
They use fuel explosions or heat to eventually turn propellers and wheels.
Could be okay for older kids who understand this.

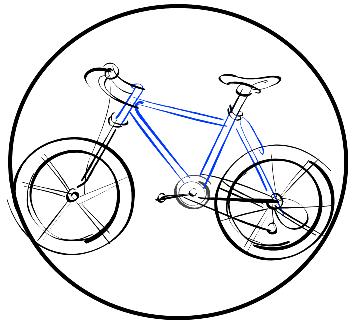
Circle the pictures that do not use fuel power to move:



Canoe – Yes!



Rocket – No



Bicycle – Yes!

Circle True or False:

True or False : Every force has an equal and opposite force.

This is Newton's Third Law of motion.

True or False : A ball sitting on a table creates a force on the table.

Gravity is pulling the ball down and therefore the ball is push down on the table.

True or False : The table does not create a force on the ball.

The table pushes up on the ball because if it didn't the only force would be gravity and therefore the ball would have to move.

True or False : An airplane can fly in space.

Airplanes require air in order to operate.

List two uses of rockets:

Fireworks, space shuttle, missiles, satellite thrusters, jet packs, rocket launchers, bottle rockets, science rockets, model rockets, etc…

Activity 2: Newton Rocket Car

Grade Level: 4 (K-5)

Group Size: 4

Time Required: 50 minutes

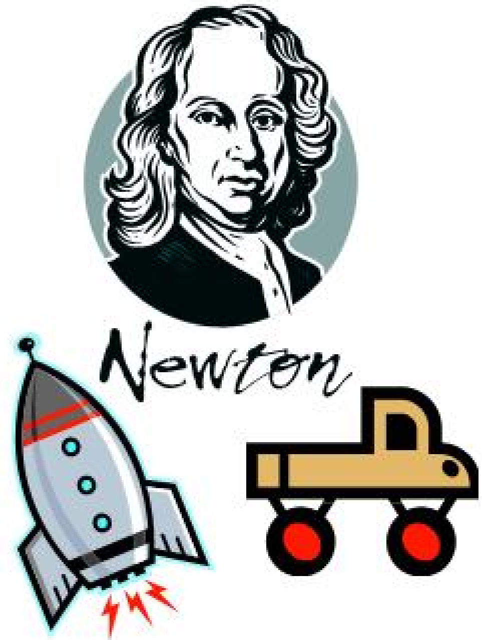
Activity Dependency: None

Expendable Cost Per Group: US$ 3

Keywords: Newton, motion, third law of motion, rocket car, action, reaction, acceleration, mass, force

Summary: The purpose of this activity is to demonstrate Newton's third law of motion — which states that every action has an equal and opposite reaction — through a small wooden car. The Newton cars show how action/reaction works and how the mass of a moving object affects the acceleration and force of the system. Subsequently, the Newton cars provide students with an excellent analogy for how rockets actually work.

Engineering Connection: Engineers will often build a model to demonstrate and study a law of science. An engineer working on a rocket could even look at a small wooden car to understand Newton's third law of motion. Such a car must obey the laws of motion, just as a rocket must. Observing how a toy, wooden car moves forward when a small block is launched off the back of it is analogous to a rocket moving forward when hot gases are expelled from the back of the rocket. By studying the similarities and differences between a small model and an actual rocket, engineers can successfully build a rocket using information obtained during their demonstrations.



Learning Objectives

After this activity, students should be able to:

- Explain Sir Isaac Newton's three law of motion.
- Describe what happens to motion if the mass or acceleration is increased.
- Collect and analyze distance data gathered in a Newton car activity.
- Explain why engineers need to know about Newton's laws of motion.

Materials List

If doing this activity as a demonstration for younger students, only one set of supplies/equipment is needed.

Each group needs:

- 1 wooden block about 10x20x2.5 cm (Note: any size block will work as long as it is bigger than the fuel block, described below.)
- 1 wooden block about 7.5x5x2.5 cm (as shown in Figure 1; the smaller wooden piece with holes drilled into it)
- 1 3-inch No. 10 wood screw (round head)
- 2 1-inch No. 10 wood screws (round head)
- 3 rubber bands (all the same size and thickness)
- Several pieces of 3-5 inch cotton string
- 2 lead fishing sinkers or similar weights (about 1/2 ounce each)
- 1 pair scissors
- 1 meter stick
- Masking tape
- Legos®, Tinker® toys, or similar building toys with wheels (each group needs a total of 4 wheels)
- Note: If using Legos® wheels is not possible, the Newton Rocket Car can simply be placed on short cylindrical wooden dowels (roughly ½" -3/4" in diameter and the same length as the width of the car). This creates a relatively low-friction rolling surface for the Newton Rocket Car.

- If desired, the wooden weight blocks may be prepared ahead of time. Supplies needed:
    - Drill and bit (the bit size is determined by the diameter of the fishing sinkers or weights and screws)
    - Screwdriver

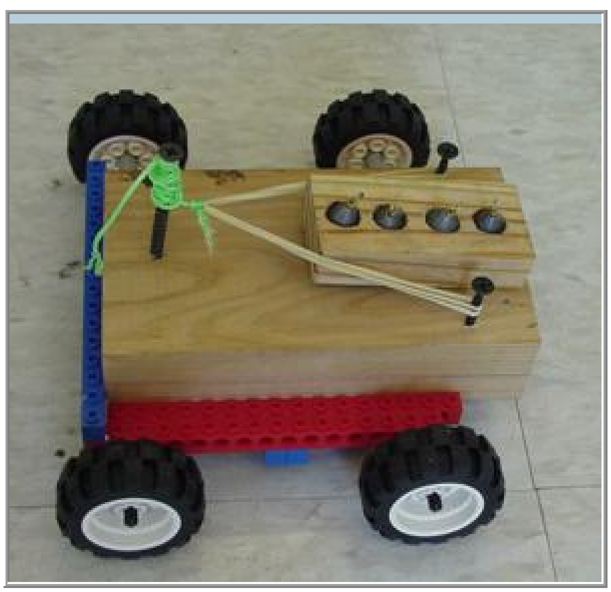


Figure 1. A Newton rocket car.
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

Introduction/Motivation

This activity will provide us with an excellent demonstration of Sir Isaac Newton's three laws of motion. Can you name the three laws? Previously we learned that *a force (push or pull) must act on an object for the object to either start or stop moving*. This is Newton's first law of motion, and it simply means that for a rocket to start moving there must be a force involved. We have also learned that *the force required to move an object depends on the mass of the object and how fast we want the object to move*. This relationship comes from Newton's second law of motion. Finally, we learned that *for every action there is an equal and opposite reaction*. In a rocket, for example, the action is the hot gasses escaping in one direction, while the reaction is the rocket moving in the opposite direction. This is a good example of Newton's third law of motion.

In the following activity, we will be using Newton Rocket Cars to demonstrate Newton's laws of motion. Engineers need to know Newton's laws when deigning a rocket to understand how it will get into space and move once it is there. The Newton Rocket Car moves on the same principle as a real rocket, but instead of "throwing" hot gasses like a rocket, the Newton Rocket Car throws a weighted block of wood. From the following experiments, we will see how Newton's laws of motion dictate the motion of our model rocket cars.

Why would an engineer need to build a model car like this? Well, engineers will often build a model to demonstrate and study a concept in science before they build the real thing. By studying the similarities and differences between a small model and an actual rocket, engineers can build a more successful rocket.

Tess and Rohan want to use a satellite to help communicate with their daughter, Maya, on her canoe trip. As Rohan and Tess' engineers, your models should help us build an understanding of the motion of rockets, and what may be needed to better design and build the rocket for getting Tess' communications satellite into space. Since the laws of motion are universal, the understanding of this model will also help Maya understand her canoeing motion.

Procedure

Before the Lesson

Preparing the blocks and string:

1. Screw two 1-inch screws into each side of one end of the large wood blocks with enough room for the smaller block to slide between them. See Figure 2.
2. Screw one 3-inch screw into the center of the other end of each of the large wood blocks, as shown in Figure 2. (Note: try to keep the distance between screws equal on all blocks.)
3. Place each of the short pieces of wood into a vice and drill 3-4 holes so that a sinker (or other small weight) can fit in it, as shown is Figure 1.
4. Cut the cotton string into 50 equal (~3") pieces (tie knots in the ends if the string begins to fray).

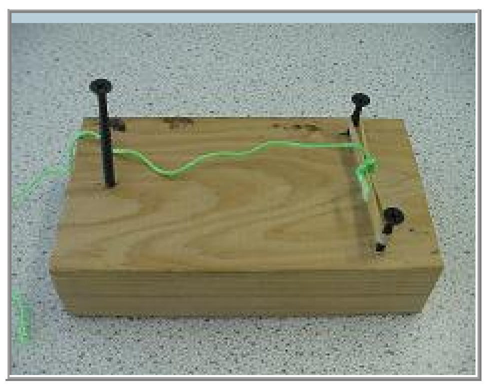


Figure 2. Construction Phase 1.
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

With the Students

1. Give each group a large piece of wood with the screws attached, a small block of wood with the holes drilled in it (do not hand out sinkers/weights until it is time for that portion of the activity), 3 rubber bands, 1 piece of string, and a meter stick.
2. Have each group place the rubber band over the two shorter screws on the end of the large wood block. Tie one end of the string to the center of the stretched rubber band. Using the string, pull the rubber band back like a slingshot and wrap the string around the third (larger) screw, stretching the rubber band tightly (see Figure 3). Wrap the string up high on the third screw.

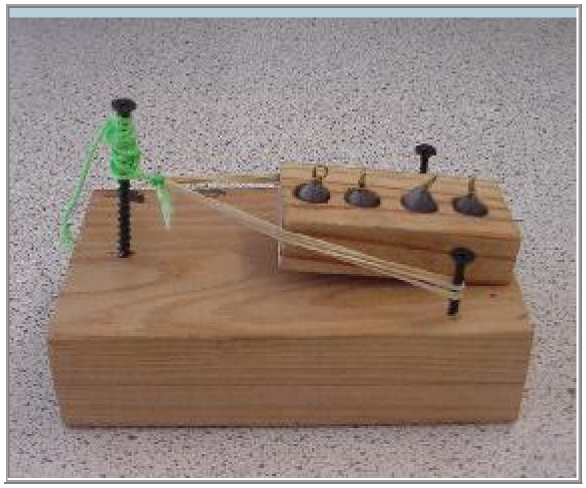


Figure 3. A finished Newton car body.
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

3. Have the students create a wheel-frame for the platform to rest on. An easy example is shown below in Figure 4. The lighter the frame, the faster their cars will go. If LEGO® blocks/wheels are not available, use the dowel rods discussed in the materials list. Lining up 4 or 5 dowels under and in front of the car will allow it to slide smoothly across the floor/desk.

4.

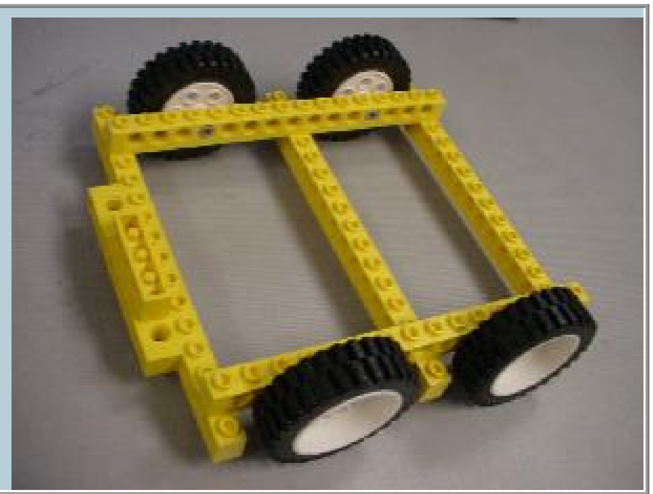


Figure 4. A finished Newton Car chassis.
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

5. Have the students place their platform (larger block) onto the wheel frame.
6. On the floor/desk, have students make a masking tape starting line. Place the car on the starting line with its back wheel on the tape line. (Note: make sure all cars are placed the same direction from the line.)
7. Next, have the students carefully place the smaller block into the slingshot.
8. Using scissors cut the string and quickly pull the scissors away. When the string is cut, the rubber band will throw the block off the car and the car will roll in the other direction. Measure how far the car travels along the tabletop or floor with the meter stick and record this on the Newton Rocket Car Data Sheet.
9. Add a second rubber band, and attach a new string as before. Again, cut the string and record how far the car travels.
10. Reset the equipment and try again with 3 rubber bands. Then try again with one rubber band and one sinker, two rubber bands and 1 sinker, etc. To shorten the activity, use fewer variations of the Newton Car (i.e., test the car using only one rubber band or only two different weight setups).

Attachments

- Newton Rocket Car Data Sheet
- Newton Rocket Car Data Sheet Page 2 (for 4th and 5th grade only)
- Grades K-1 Color Graph Worksheet

- Grades 2-3 Bar Graph Worksheet
- Grades 4-5 Line Graph Worksheet

Safety Issues

Since the students need to cut the string and then move the scissors out of the way quickly, it is very important that they are reminded to be very careful with the scissors. For very young students, it is recommended that the teacher does the experiment while the students watch and record the data.

Troubleshooting Tips

Cut many pieces of string ahead of time (for the full worksheet, you will need 6 strings per group of students plus some extras. Ideally make all the strings the same size (~ 3 in).

A good way to secure your string to the tall screw is to wrap it around the screw many times and include a couple of single hitches. The single hitch tightens on itself against the pull of the rubber bands. This is best done with someone else holding the rubber bands in place while the single hitch knots are added (see Figure 5).

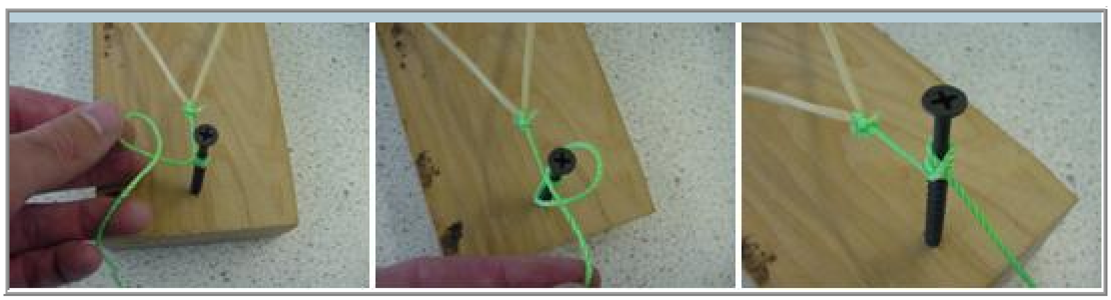


Figure 5. Tying a single hitch knot

Assessment

Pre-Lesson Assessment

Poll: Before the lesson, ask all students the same question. Have students raise their hand to answer the question. Write answers (or key facts) on the board, and summarize (in percentages or actual number of students) who answered the same or similarly. Ask students:

- Which of Newton's laws of motion states that for every action there is an equal and opposite reaction? (Answer: Newton's third law) Can you give an example of this law?
- Which of Newton's laws of motion states that an object at rest stays at rest while an object in motion stays in motion unless there is a force acting upon the object? (Answer: Newton's first law) Can you give an example of this law?
- Which of Newton's laws of motion states that a force depends on the mass and the acceleration? (Answer: Newton's second law) Can you give an example of this law?

Prediction: Have students predict the outcome of the activity before the activity is performed. Students should predict which will move farther: the Newton car or the small weighted block.

Activity Embedded Assessment

Data Recording: As directed in the Procedure section, each time another rubber band or small weight is added to the setup, have the students measure the distance the Newton car travels from the masking tape starting line. Have them record this data on the Newton Rocket Car Data Sheet.

Group Question: During the activity, ask the groups:

- How far does the car move compared to the wood block? Is this surprising? Can you use Newton's second law of motion to explain this discrepancy?

Post-Lesson Assessment

Graphing: Have students work individually or in pairs on the age appropriate Graph Worksheet. After students finish the worksheet, have them compare answers with a peer or another pair, giving all students time to finish the worksheet.

Question/Answer: Ask the students and discuss as a class:

- How does the number of rubber bands influence the distance the car traveled? (Answer: The students should see that the car moves further as more rubber bands are added).
- Why is this (that the cars move further with more rubber bands added)? (Answer: Newton's second law of motion tells us that a larger force causes a larger acceleration. Also, Newton's third law of motion tells us that a larger action will cause a larger reaction.)
- How does the weight of the block influence the distance the car traveled? (Answer: The students should see that the car moves further as more weight is added.)
- Why is this? (Answer: Newton's second law states that a larger mass causes a larger force.)
- Why do engineers need to know Newton's laws of motion when designing a rocket? (Answer: Newton's laws of motion help explain what will happen when a rocket is in motion and how to get a rocket into motion. By understanding Newton's laws, engineers can design better and safer rockets.)

Activity Extensions

Have the students compete as to who can get their car to go the furthest. This involves maximizing the amount of weight that is thrown off the car (i.e., the weight block) and in turn also maximizing the force with which it is thrown off (i.e., the rubber bands).

Activity Scaling

For K and 1st grade students, do activity as a demonstration. Have students complete the Grades K-1 Color Graph Worksheet.

For 2nd and 3rd grade students, have them record distances and make bar graphs of the distance the car traveled. Have student complete the Grades 2-3 Bar Graph Worksheet. Also, the instructor can make a line graph on the board for the students to see and discuss.

For 4th and 5th grade students, have them complete the 2nd page of the Newton Rocket Car Data Sheet. Have students complete the Grades 4-5 Line Graph Worksheet. They can graph their results and discuss trends in each variable.

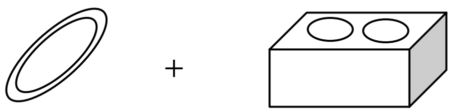
Name: ______________________________________ Date: ________________________

Newton Rocket Car Activity —
Newton Rocket Car Data Worksheet

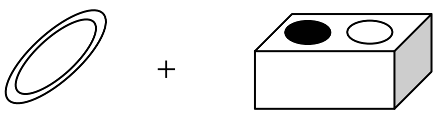
Instructions

Write down how far the Newton Rocket Car traveled for each test.

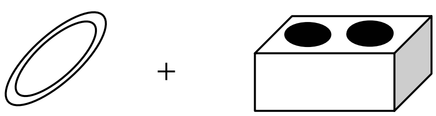
1 Rubber Band and **0 extra weights:**


= ____________ (distance traveled – in cm)

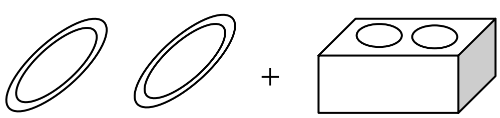
1 Rubber Band and **1 extra weight:**


= ____________ (distance traveled – in cm)

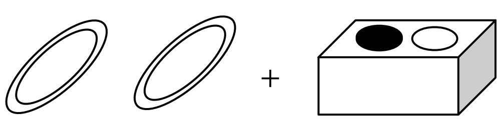
1 Rubber Band and **2 extra weights:**


= ____________ (distance traveled – in cm)

2 Rubber Bands and **0 extra weights:**


= ____________ (distance traveled – in cm)

2 Rubber Bands and **1 extra weight:**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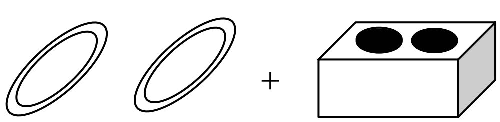
2 Rubber Bands and **2 extra weights:**


= ____________ (distance traveled – in cm)

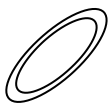
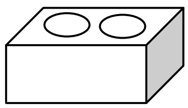
Name: ______________________________________ **Date:** _________________________

Newton Rocket Car Activity —
Newton Rocket Car Data Worksheet – Page 2

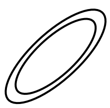
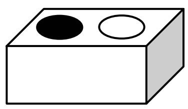
Instructions

Write down how far the Newton Rocket Car traveled for each test.

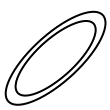
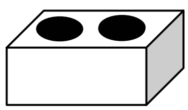
3 Rubber Band and **0 extra weights:**

 +  = _____________ (distance traveled – in cm)

3 Rubber Band and **1 extra weight:**

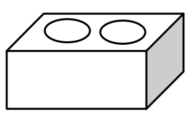
 +  = _____________ (distance traveled – in cm)

3 Rubber Band and **2 extra weights:**

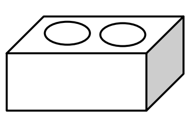
 +  = _____________ (distance traveled – in cm)

If you have extra time, make up your OWN combination…

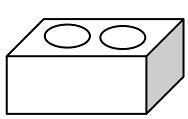
__ Rubber Bands and **__ extra weights:**

+  = _____________ (distance traveled – in cm)

__ Rubber Bands and **__ extra weights:**

+  = _____________ (distance traveled – in cm)

__ Rubber Bands and **__ extra weights:**

+  = _____________ (distance traveled – in cm)

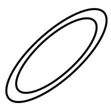
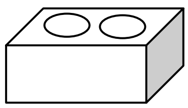
Name: ____ **Date:** __________________________

Newton Rocket Car Activity — Grades K – 1 Color Graph Worksheet

Instructions

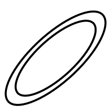
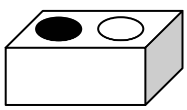
Color in the boxes to show how far the Newton Rocket Car traveled for each demonstration.

1 Rubber Band and **0 extra weights.**

 +  =

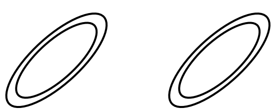
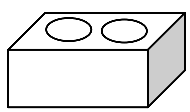
1	2	3	4	5

1 Rubber Band and **1 extra weight:**

 +  =

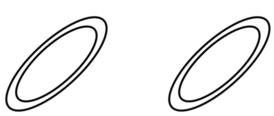
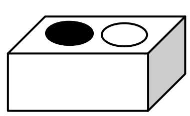
1	2	3	4	5

2 Rubber Bands and **0 extra weights:**

 +  =

1	2	3	4	5

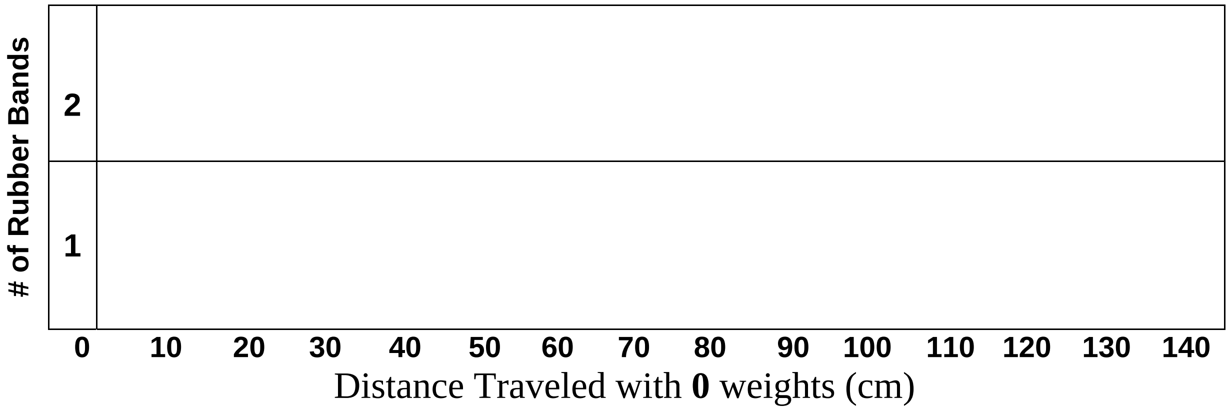
2 Rubber Bands and **1 extra weight:**

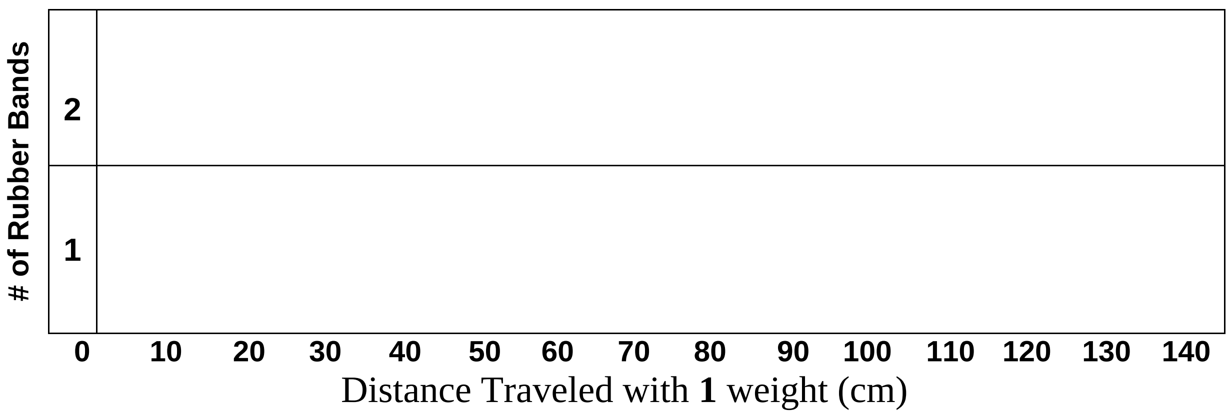
 +  =

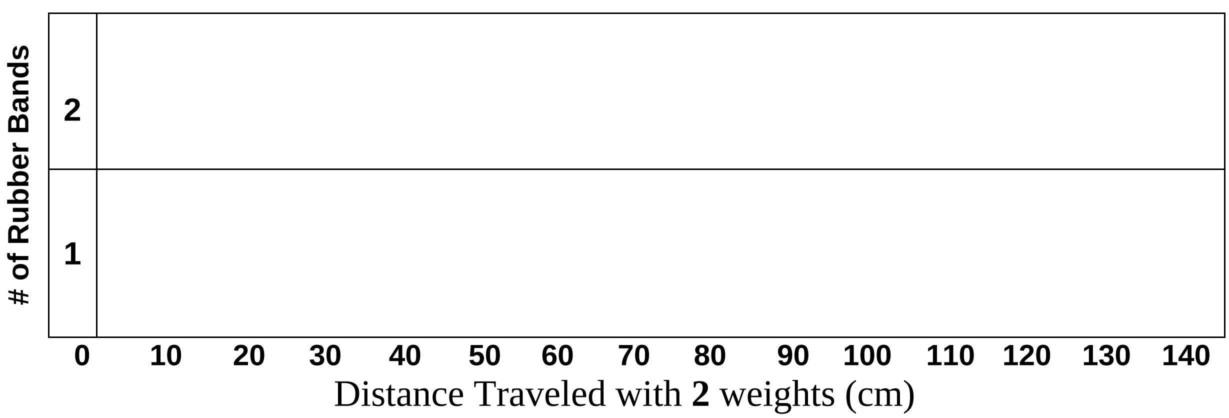
1	2	3	4	5

Name: ________________________ Date: ________________

Newton Rocket Car Activity — Grades 2-3 Bar Graph Worksheet







Name: ______________________ Date: ______________

Newton Rocket Car Activity — Grades 4-5 Line Graph Worksheet