Fantastic Elastic (Grades 2-3)

Unit Overview

This unit develops concepts of energy through design, construction and testing of two kinds of elastic powered vehicles: wind-ups and balloon cars. To operate each type, a user stores potential energy in an elastic medium, and then releases it, converting the energy to kinetic form, and thereby powering the vehicle. Wind-ups are the subject of the first six lessons, and balloon cars are the focus of the last six. In the wind-up sequence, students begin by looking at the operation of some sample wind-ups, and then think about how to make their own. As they create wind-ups, they record issues that arise, learn about troubleshooting, and write their own troubleshooting guides. Next they develop instruction manuals and descriptions of how a wind-up works, and finally apply what they have learned to redesign wind-ups to make them work the way they want. The balloon-car sequence follows a similar pattern, except that students are not shown samples at the outset. They begin by imagining what it would take to make a balloon power a car, and use these ideas as the basis for creating their own balloon cars. Otherwise, the balloon-car sequence is similar to that for wind-ups.

Table 1: Summary of Fantastic Elastic Curriculum

Lesson	Title	Summary
1	**What is a Wind-up?**	Observing home-made wind-up toys and starting to make them
2	**Make a Wind-up**	Completing first wind-ups & recording issues that arise
3	**Troubleshooting Wind-ups**	Developing the concept of troubleshooting; writing wind-up troubleshooting guides
4	**How to Build a Wind-up**	Writing instruction manuals for making wind-ups
5	**Redesign your Wind-up**	Investigating alternatives and creating final wind-ups
6	**How a Wind-up Works**	Exploring the principles behind wind-up operation
7	**How could a Balloon Power a Car?**	Imagining ways to get a balloon to power a car
8	**Make a Balloon Car**	Making initial balloon cars & recording issues that arise
9	**Troubleshooting Balloon Cars**	Writing balloon car troubleshooting guides
10	**How to Build a Balloon Car**	Writing instruction manuals for making balloon cars
11	**How a Balloon Car Works**	Exploring the principles behind balloon-car operation
12	**The Auto Show**	Making final design changes and presenting final wind-ups and balloon cars

Science Background

1. Energy is needed to make physical things happen.
2. Energy can take many forms. Types include energy of sound, light, heat, position and motion; as well as elastic, chemical, magnetic and electric energy.
3. Energy is often **transformed** from one form to another. Sometimes it also moves from one place to another, which is another way of saying it is **transported**.
4. Some energy is stored – it won't be used until something is released. Anything that "wants" to be different from the way it is – for example, it would start moving once something was released – has stored energy, which is also called **potential energy**. Examples are a wound-up rubber band or anything that's been lifted up off the floor or table. The rubber band "wants" to unwind, and the lifted object "wants" to fall down. Both have potential energy. Once something with potential energy is released, something will start moving. When something is moving it has **kinetic energy**.
5. Although energy is constantly changing form, it always starts from somewhere in some form, and goes somewhere in the same or another form. The form and location might change, but the amount of energy can't change. This is another way of saying that **energy is conserved**. For example, when something with potential energy is released, all of its potential energy gets converted into kinetic energy.
6. People and other animals get energy from the chemical energy contained in food, which consists of plants and animals. Plants use **photosynthesis** to turn light energy from the sun into chemical energy, which they can store.
7. **Elastic energy** is the kind of potential energy that is stored by twisting or stretching – and then holding – a rubber band or a balloon. When you let it go, the elastic energy turns into kinetic energy, because it causes something to move. Kinetic energy is also needed to wind up or stretch the elastic material in the first place.
8. A **vehicle** is something that can move on its own. Some ways that vehicles can **vary** are in how far they can go, how fast they can go, the kind of path they follow, how much weight they can carry, and how steep a hill they can climb. These can be affected by the way the vehicle is **designed,** and the way it is **operated**.
9. Some energy is useful for getting things done, but some is not. Any time energy is transformed or transported, some or all of it is changed to heat, which is not useful. The amount of energy doesn't change, but some of it is always being changed into a form that is not as useful.

Materials for Fantastic Elastic

Classroom Set of Materials for making Wind-ups, Lessons 1 - 6		
Item	**Detail**	**Qty**
Wooden barbecue skewers	8″	100
Masking tape *	¾ ″ wide roll	6
Rubber bands *	¼ lb. bag, assorted	1
Paper clips	Box of 100, small	1
cardstock	100 sheets, assorted colors	1
Pony beads		200
Plastic lids	4 ½″ – flat surface	100
Plastic lids	2 ½ ″ – nearly flat surface	60
Paper saucers	6 ″ diam.	100
Paper hot cups	8 oz.	100
Clear plastic cold cups	7 oz	50
Thin wire or fishing line	roll	1
Reclosable storage bag *	2 gallon	30
Classroom Set for Balloon Cars, Lessons 7 - 12		
Item	**Detail**	**Qty**
Wheels w/ 3 mm. holes	Pitsco black plastic	200
Wooden barbecue skewers	6 ″ & 8 ″ 100 of each	200
Masking tape *	¾ ″ wide roll	6
Rubber bands *	¼ lb. bag, assorted #511378	1
Straws	1 Box of 100, ¼ in. diam.; 1 Box of 100, 5/16 in. diam	2
cardstock	100 sheets, assorted colors	1
cardboard rectangles	4 ¼ ″ x 5 ½ ″ (¼ sheet)	30
Foam blocks (LDPE)	cut into 4 ″ x 3 ″ x 2 ″ blacks	30
Balloons	Assorted: 12″ Round, pear-shape, rocket	300
Balloon pump		6
Reclosable storage bag *	2 gallon	30

*shared between balloon cars & wind-ups

Craft supplies

Item	Detail	Qty	Lessons used in
Tissue paper	13″ x 20″ sheet, assorted colors	6	11-12
Cellophane	5″ x 25″ roll, assorted colors	2	
Google eyes	Small bagful, assorted sizes	1	
Feathers	Small bagful, assorted shapes & colors	1	
Yarn	24 ft., assorted colors	1	
Felt	9″ x 12″ sheet, assorted colors	5	
Construction paper	9″ x 12″ sheet, assorted colors	40	
Foam stickers	Small bagful, assorted shapes & colors	1	
Craft sticks	Assorted colors	30	
Ribbon	Roll	1	
Pipe cleaner	Assorted colors	30	
Cocktail umbrella	Assorted colors, 4″ diam.	30	

Lesson 1: What is a Wind-up?

Overview

Based on seeing a few prototypes, students identify materials, and describe what they plan to make. Students can then start making their own wind-ups.

Materials

- Three sample wind-ups: one that goes straight, another that goes around in a circle; and a third that spins in place.
- Materials for Making Wind-ups – see Materials List
- Two-gallon plastic bags for storing work-in-progress – one per student

Procedure

1. Looking at wind-ups: Gather students for a class meeting. Demonstrate each of the wind-ups. Ask students if they would like to make their own. Then compile a class list of materials that students think they will need to make a wind-up.

Science Notebook or Worksheet: 1. Write and draw what you plan to make. 2. What you will need to do to make it go? 3. Make a drawing showing of each of the materials you will need. Label each one.

2. Starting to make wind-ups: Provide students with materials. Most of the materials students have listed will probably be available. If any are not available, ask what materials could be substituted. Allow students to experiment freely with the materials, and record any problems that come up.
3. Clean-up: Allow adequate time for clean-up. Provide each student with a plastic bag for storing work-in-progress, and tape for putting his or her name on the bag.

Outcomes

- Students observe the winding up and subsequent motion of the device, and conclude that it needs to be wound up to make it go.
- Students notice the materials that a wind-up is made from, and develop interest in making one.

Name: ______________________ Date:________________

Lesson 1: My Wind-up

What I will make (draw and write)

	____________________________ ____________________________ ____________________________ ____________________________ ____________________________ ____________________________

What will you have to do to make it go ? _________________

____

Draw and label the parts you will need:

Troubleshooting (for teachers)

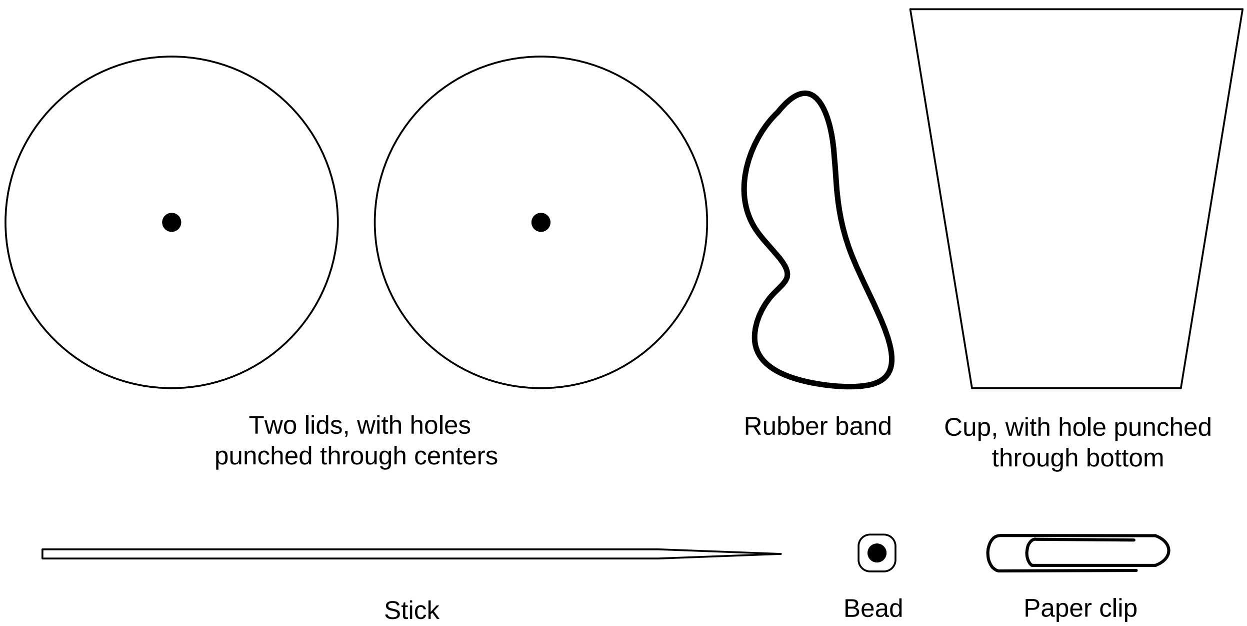
You will need three sample wind-ups to provide examples for students:

- One that travels in a fairly straight path;
- Another that travels in circles, and
- A third that spins in place or moves randomly.

<u>Making a wind-up that goes straight</u>

We'll begin with the one that goes straight. The diagram below shows the parts you will need:

Materials for Making a Wind-up



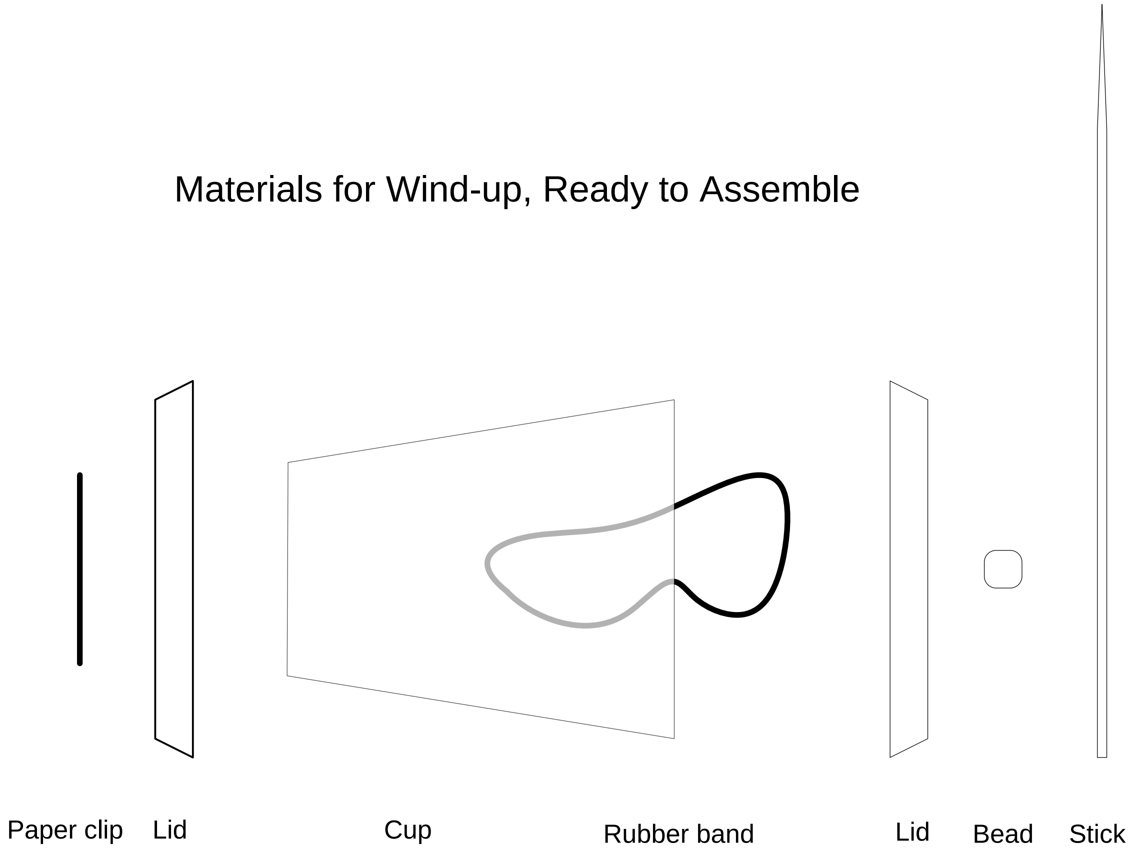
Before assembling the wind-up, you will need to make a small hole near the center of each lid, and another hole in the bottom of the cup. The holes should be big enough that you can get the rubber band through, but not so big that the paper clip or bead will fall through.

To assemble the wind-up, the rubber band will need to go through the two lids, cup, and bead. It will be held in place by going around the stick and paper clip. First place the parts in the order shown in the first diagram below.

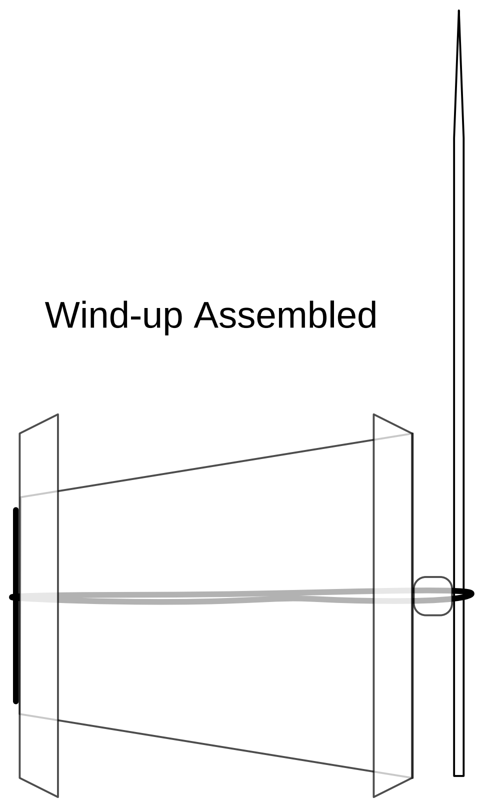
To assemble the wind-up, pull the rubber band through the hole in the lid on the left, and capture it with the paper clip. Then pull it in the other direction through the cup, the lid on the right, and the bead. If it's hard to get the rubber band through the holes, there are suggestions in the <u>Troubleshooting</u> section of Lesson 2.

After getting the rubber band through the bead, capture the open end of the rubber band by wrapping it around the stick. Adjust the stick so only one end of it is extending past the edge of the lid. The second diagram shows the assembled wind-up.

Materials for Wind-up, Ready to Assemble



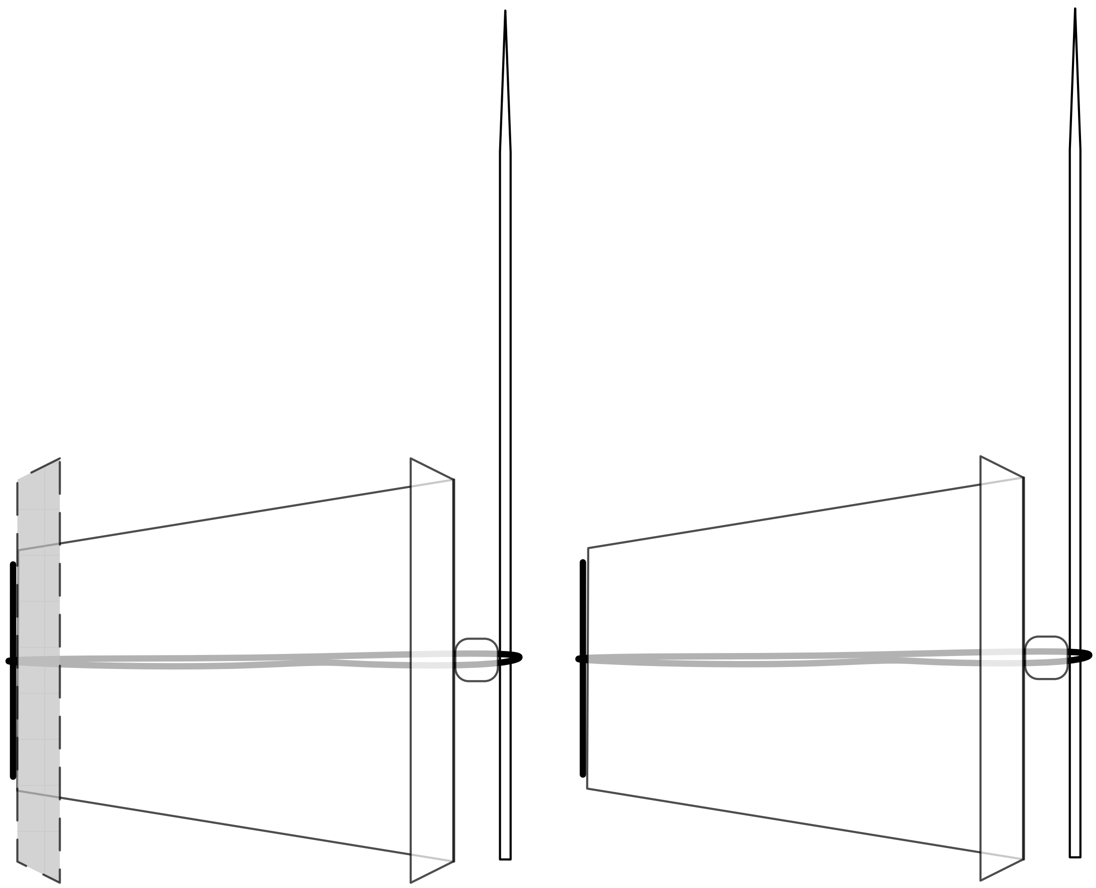
Wind-up Assembled



Now you are done! Just wind it up and let it go. If it doesn't work, consult the Troubleshooting section in Lesson 2. To understand why this type of wind-up goes straight, see Troubleshooting for Lesson 5.

Making a Wind-up that goes in Circles

The only difference between this wind-up and the one that goes straight is the size of one of the wheels. To go in circles, one wheel needs to be smaller than the other. Make a wind-up using a lid at the biog end of the cup, but no lid at the small end. Use the small end of the cup to hold the paper clip. The diagram below shows the difference between the two. On the left, the lid you do not want is shaded; on the right is the wind-up that goes in circles, because it has only one lid.



Make a new wind-up without the shaded lid

This wind-up will go in circles

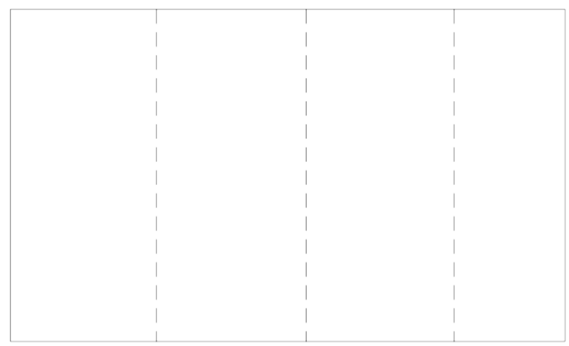
To understand why this type of wind-up goes in circles, see the Troubleshooting section of Lesson 5.

Making a Wind-up that Spins in Place or Moves Randomly

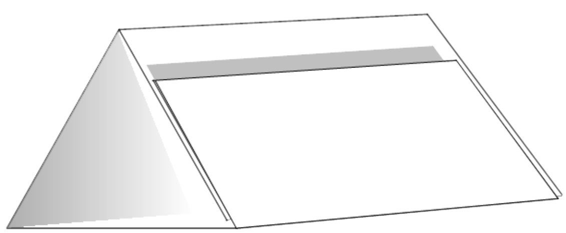
To make a wind-up that acts unpredictably, you need two small wheels. To understand why, consult the Troubleshooting section of Lesson 5.

Use the smallest lids instead of the larger ones. You can't use the cup to separate them, because the big end of the cup is too large to hold the small lid. Instead, you can make a separator by creating a triangular tube out of cardstock:

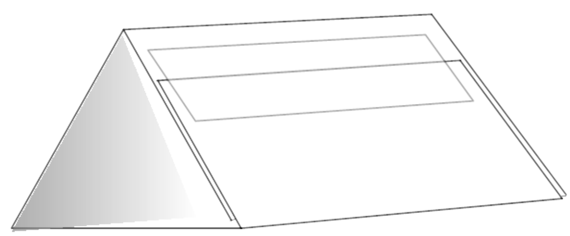
a) Cut a piece of cardstock about 3" x 5"



b) Make three folds, dividing it into four parts, one a little narrower than the others



c) Fold it into a triangular tube, with the narrower side overlapping one of the others



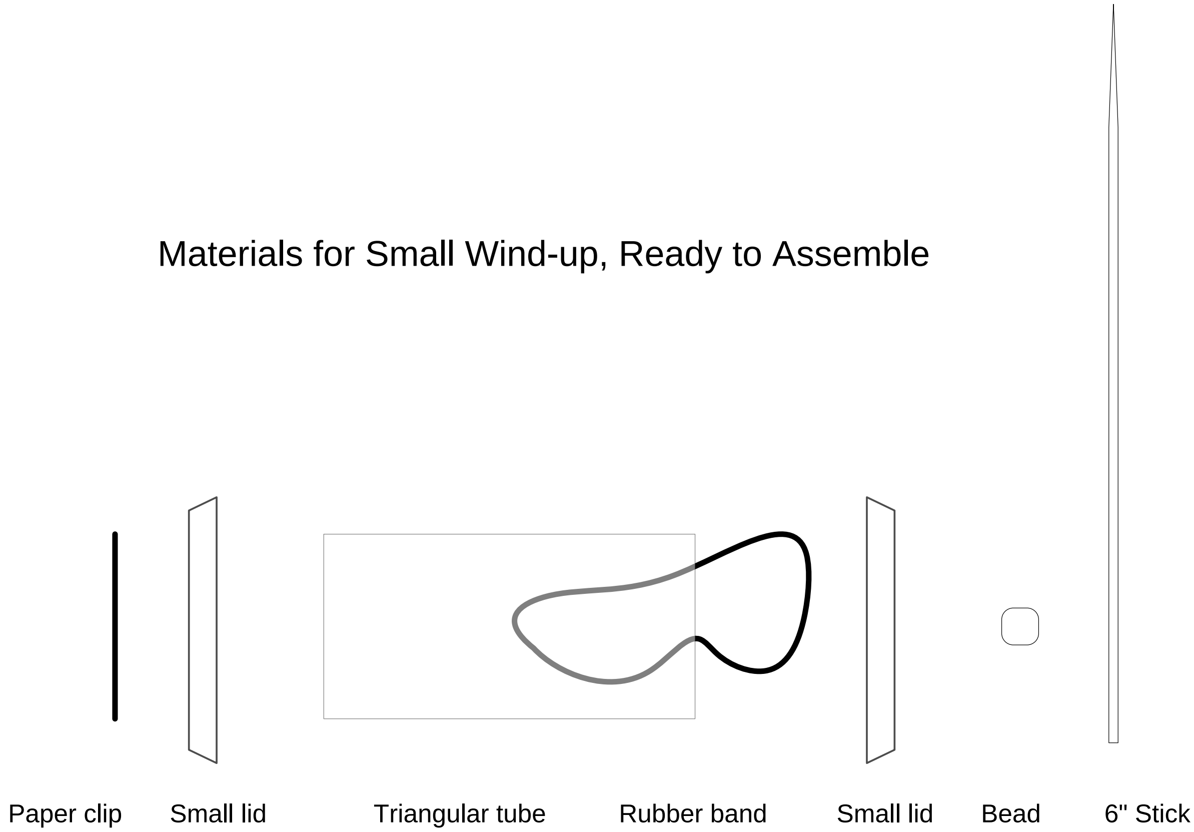
d) Tape the overlap to hold it in place

Now use the same materials as before except:

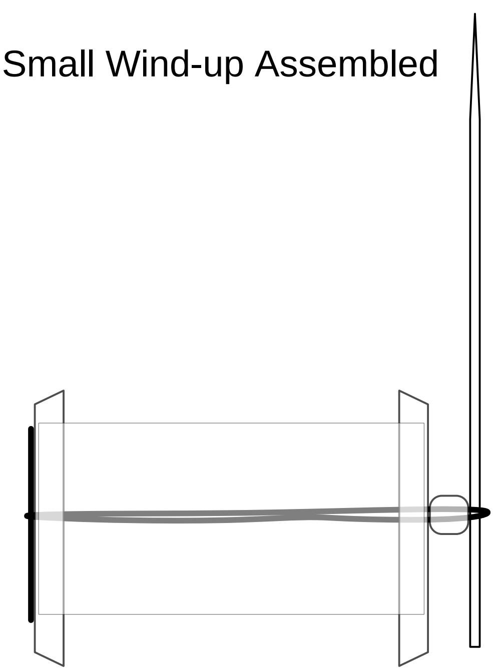
- Use the triangular tube instead of the cup,
- Use two small lids instead of two large ones, and
- Use the shortest stick available, such as a 6 ″ wooden skewer.

Use these parts to make a wind-up, the same way as before. The diagrams below show how it looks before and after assembly:

Materials for Small Wind-up, Ready to Assemble



Small Wind-up Assembled



Lesson 2: Make a Wind-up

Overview

Students continue working on their wind-ups, recording the issues that came up.

Materials

- Partially completed wind-ups from Lesson 1
- Materials for making wind-ups, for use as spare parts.

Procedure

Making wind-ups: Students continue working on their wind-ups. Students who have already made wind-ups can help others and/or make new ones of different types. As students are working, ask them to keep track of issues that arose. Post the issues on chart paper. As students ask for help with problems, identify these as issues, by adding them to the chart. Some examples of issues that are likely to come up:

- The rubber band won't go through the holes.
- The wind-up won't stay together.
- The wind-up does nothing at all.
- The wind-up moves but won't go in a straight line.
- The wind-up moves, but spins in place instead of traveling
- I would like the wind-up to go farther
- I would like the wind-up to go faster

Science Notebook:

1. Compile an **Issues List**, including anything that didn't work the way you wanted it to.
2. Describe what you did today.

Outcomes

Students learn to isolate problems. You can't usually solve a problem until you know what it is.

Troubleshooting (for Teachers)

Getting the wind-up to stay together

The initial problem in making a wind-up is to adjust the length of the rubber band and the cup or tube, so that when it is not stretched, the rubber band is only slightly shorter than the tube. If the rubber band is too long compared with the distance between the ends, the construction will not stay together. If the rubber band is as long as or longer than the tube or cup, you can:

- Use a shorter rubber band;
- Double the rubber band or wrap it around the stick a few times to make it shorter; or
- Keep ends farther apart by using a longer cup or tube.

Another reason the wind-up might not stay together is that the rubber band could slip through the hole in the wheel that was holding the paper clip. If the hole is too big, use a larger paper clip, or a cup or lid with a smaller hole.

Getting the rubber band through the holes

In making a wind-up, the rubber band has to be threaded through several holes. There is a hole through each wheel (which may be a lid or the bottom of the cup), and a hole in the bead, and the rubber band has to go through each of them. The holes in the wheels shouldn't be too big, because if they are, the bead or paper clip will fall through. Even so, these holes are not very deep, and not usually hard to negotiate. The biggest problem is getting the rubber band through the bead. Here are some ways to do this:

- Make a hook from a small paper clip, and use the hook to pull the rubber band through.
- Wrap a short length of stiff fishing line or thin wire around the rubber band, and use the line or wire to pull the rubber band through
- Use a stiff wire or barbecue skewer to push the rubber band through.

Getting the wind-up to move

For a wind-up to go, the rubber band has to be able to turn the wheels. This happens when the rubber band unwinds. In order to unwind, one end of the rubber band has to be fixed so the other end can rotate. In the sample wind-ups, the stick is prevented from turning by dragging on the floor. This provides a base for the rubber band to unwind against. The other end of the rubber band should be attached to one of the wheels (lids). This is the job of the paper clip in the sample wind-ups. A good way to troubleshoot a wind-up that won't go is to hold it off the floor or table, and see what happens after you wind up the stick. Three possibilities are:

1. The stick turns,
2. The stick and paper clip both rotate, or
3. Nothing turns.

Let's look at each of these cases separately.

1. The stick turns, but not the paper clip: If the stick turns when the wind-up is off the ground, but won't make the wind-up go when it is on the floor, it might just want to be wound up some more! Another possibility is that the stick is probably too short. Use a

longer stick, or adjust it so it extends past the edge of the lid on one side.

2. The paper clip and stick both turn: The problem here is that the paper clip isn't transmitting the motion to the lid. Use some tape to make sure the paper clip and the lid turn together.
3. Nothing turns: This is the hardest one to solve, because there are several possible causes.
   a) The first thing to look for is whether the stick is rubbing against the lid. If so, the **friction** between the two is probably what's preventing the stick from turning. Use a bead to separate the stick from the lid.
   b) Next, see if the rubber band is too short, and therefore too tight. If it is, this will also add to the friction. Test it by pulling the lid gently away from the cup or tube. If it is hard to do, the rubber band is probably too tight. The solution is to use a longer rubber band, to chain two rubber bands together, or to use a shorter cup or tube. When the rubber band is untwisted, it should be only slightly shorter than the tube or lid.
   c) The most obvious problem is that the stick just hasn't been wound up enough. The first thing to try is to wind it up some more, but not so much that the rubber band breaks!

NOTE: Additional issues, such as getting a wind-up to go straight, go faster or go further, are addressed in the Troubleshooting section of Lesson 5.

Lesson 3: Troubleshooting Wind-ups

Overview

Students meet to discuss the issues on their lists from Lesson 2. Next they develop some ideas about how to **troubleshoot**: find out what's preventing something from working, and change that one thing. They use each others' troubleshooting ideas to fix their wind-ups. Finally, they record what they have learned by each writing a **Troubleshooting Guide.**

Materials

- Chart paper **Issues list** from Lesson 2
- Wind-ups already made by students
- Materials for making wind-ups, for use as spare parts

Procedure

1. <u>Class meeting</u>: Select one of the issues from the chart, such as "Wind-up falls apart," and ask:

    - If something doesn't work the way you want it to, what should you do?

    Develop the idea that it doesn't make sense to start over, because most of what you made is probably OK. Also, if you start over, you might just run into the same issue again! It makes much more sense to:

    - Find out exactly what is preventing it from working, and
    - Then solve <u>only</u> that problem.

    In engineering, this way of addressing issues is called **troubleshooting**.

    Make a chart with the heading, "Troubleshooting," write down an issue from the list and under it two columns labeled "Cause" and " Fix." Ask students what they think is causing one of the items on the "Issues" list, and record it in the "Cause" column. Model one or two entries on this chart, like the one below: Then ask what they did or could do about that problem, and put the answer under "Fix." Sometimes it's easier to go the other way – Figure out the "Fix" first, and then decide what the "Cause" was. Model this process, by creating one entry on the chart, something like this:

Wind-up Troubleshooting Chart

Issue: Wind-up falls apart	
Cause	Fixes
Rubber band is too long	Use a shorter rubber band
	Double the rubber band to make it shorter.
	Keep ends farther apart by using longer cup or tube
Paper clip or bead falls thru hole	Start with another lid; this time make a smaller hole

2. Troubleshooting Guide: Distribute worksheets. Based on the example you have just shown, ask each student to create a **Troubleshooting Guide** showing how to deal with each issue that has been resolved**.**
3. Using one another's Troubleshooting Ideas: Ask students to present some of the issues that have come up with their wind-ups. After each issue is presented, ask if anyone has figured out a way to solve that particular problem. Then provide time for students to get their wind-ups to work, based on one another's suggestions for troubleshooting.

Outcomes

- Students learn to find out what's causing a problem, rather than become frustrated by it.
- Students develop the concept of **troubleshooting**, and see the benefit of identifying the cause of a problem and solving only that problem.
- Students learn troubleshooting ideas from one another.
- Students learn that friction can prevent things from moving, and find ways to reduce friction.

Troubleshooting (for Teachers)

See Troubleshooting section in Lesson 2 for suggestions about how to fix a wind-up

Name: ______________________ Date:_____________

Lesson 3: Wind-up Troubleshooting Guide

Issue:	
Cause: ________________	Fix:__________________________
________________________	______________________________
________________________	______________________________
________________________	______________________________
________________________	______________________________

Issue:	
Cause: ________________	Fix:__________________________
________________________	______________________________
________________________	______________________________
________________________	______________________________
________________________	______________________________

Issue:	
Cause: ________________	Fix:__________________________
________________________	______________________________
________________________	______________________________
________________________	______________________________
________________________	______________________________

Lesson 4: How to Build a Wind-up

Overview

Based on the steps actually followed in making one, each student writes an illustrated **Instruction Manual** that could show someone how to make a wind-up. The teacher and other students test each student's manual by following each step literally.

Materials

- Wind-ups already made by students
- Materials for making wind-ups, for use as spare parts.
- Instruction manuals from furniture, electronics, Legos™, etc. (if available)

Procedure

1. Class meeting: Students may already be familiar with How-to Books. An engineering term for a How-to Book is an **Instruction Manual**. Meet with students to discuss what an instruction manual is and how it can be used:
    - Someone else might want to make what you made, and you might not be around to show them. Your Instruction Manual will tell them how to make one.
    - You might want to make one yourself at a later date, but by then you might have forgotten how to do it. Your Instruction Manual will remind you about what to do.
2. What should an instruction manual have? Discuss how an instruction manual could provide information:
    - Where have you seen instruction manuals? What do they help you to make or do?

    Students will probably identify manuals supplied with Legos™, electronic products, unassembled furniture, etc. Provide examples of instruction manuals you have collected.

    - What do these manuals use to tell someone what to do?

    All of these are likely to use pictures at least as much as words.

    - What would somebody need to see in order to follow your instructions?

    Develop the idea that – like instruction manuals they have seen – their manuals should include drawings as well as words.
3. Creating drawings: Students may claim that they can't draw. Using a lid, coffee cup or stick as an example, show how to use simple shapes to represent objects. See the Troubleshooting section for suggestions about how to get students started in making drawings.
4. Writing instruction manuals: Provide time for each student to write his or her own Instruction Manual. They can do it in the Science Notebook or on the Worksheet.

Science Notebook or Worksheet
Write an illustrated **Instruction Manual** showing how to make a wind-up. Number the steps and make a diagram and write a description for each step.

5. Testing instruction manuals. After students have finished writing, demonstrate how to test an Instruction Manual. Select an instruction that is vague, such as “Make a hole in the cup,” and deliberately misinterpret it; for example, by making the hole on the side of the cup rather than the end. Ask students:

    - What could happen if someone tries to follow an instruction that does not give enough information?

    Then ask students to exchange manuals in their groups, and test them to see if they give all the information that’s needed.

6. Revising instruction manuals. Ask students to revise their instruction manuals to provide all the information that is needed. This could be a homework assignment.

Outcomes

- Students develop ideas about how instruction manuals are useful, and why they need to include diagrams as well as text.
- Students develop strategies for creating diagrams.
- Students explain procedures they have invented through diagrams and text.
- Students come to see the limitations of writing that is vague or lacking in detail.
- Students revise their own writing to make it more specific.

Name: ______________________ Date:_____________

Lesson 4: Instruction Manual for Making a Wind-up

Number each step. Use more pages if necessary

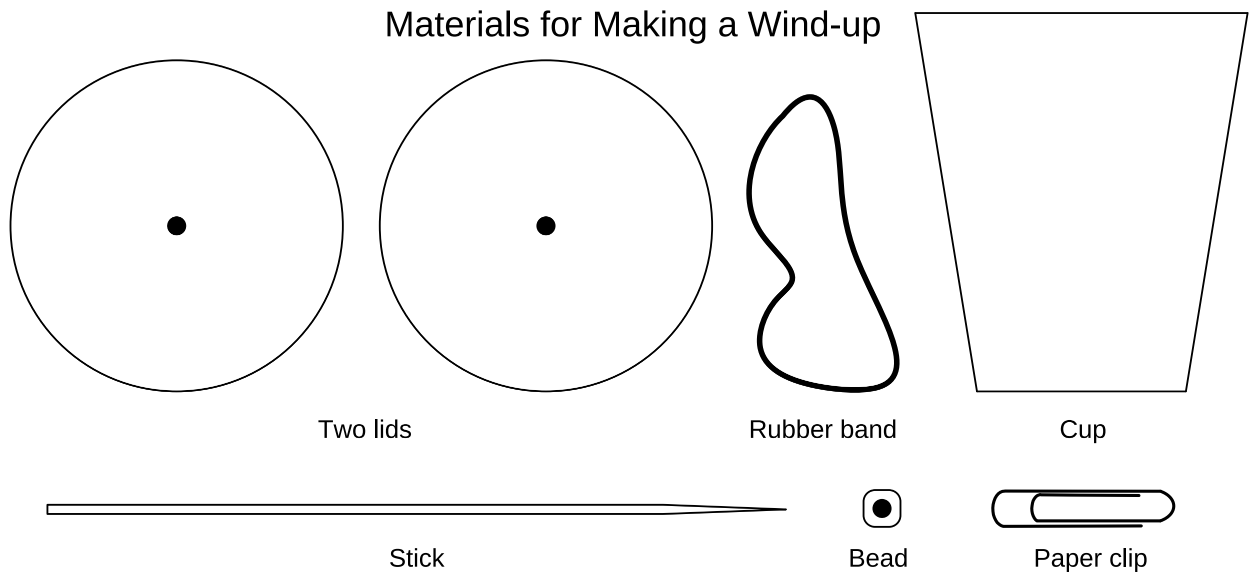
___	___________________________ ___________________________ ___________________________ ___________________________ ___________________________ ___________________________

___	___________________________ ___________________________ ___________________________ ___________________________ ___________________________ ___________________________

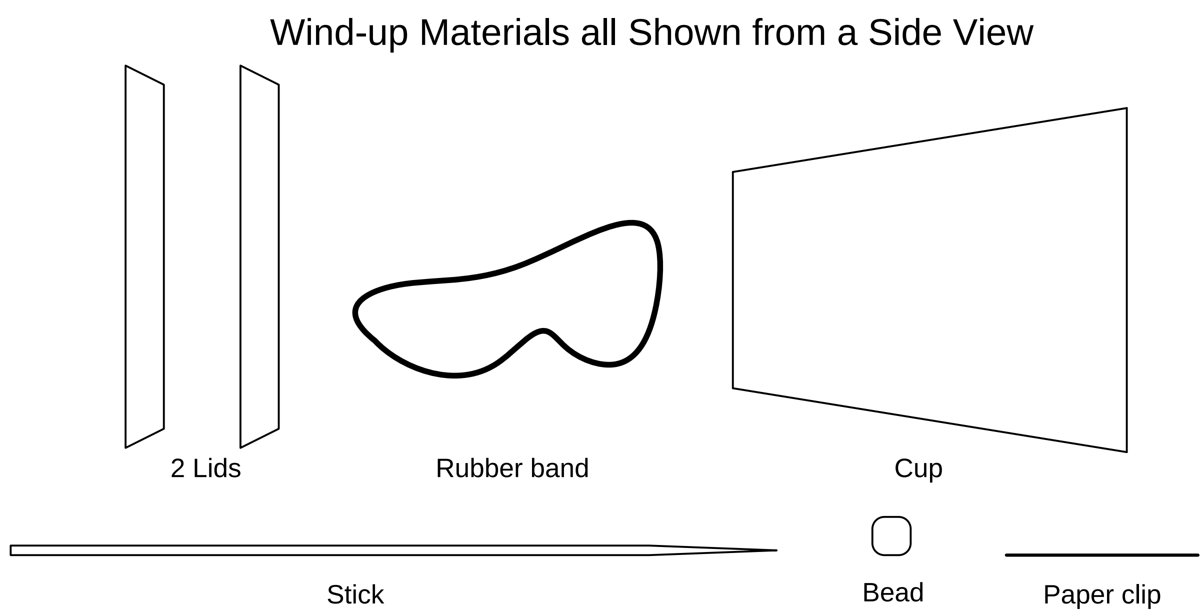
___	___________________________ ___________________________ ___________________________ ___________________________ ___________________________ ___________________________

Troubleshooting (for Teachers)

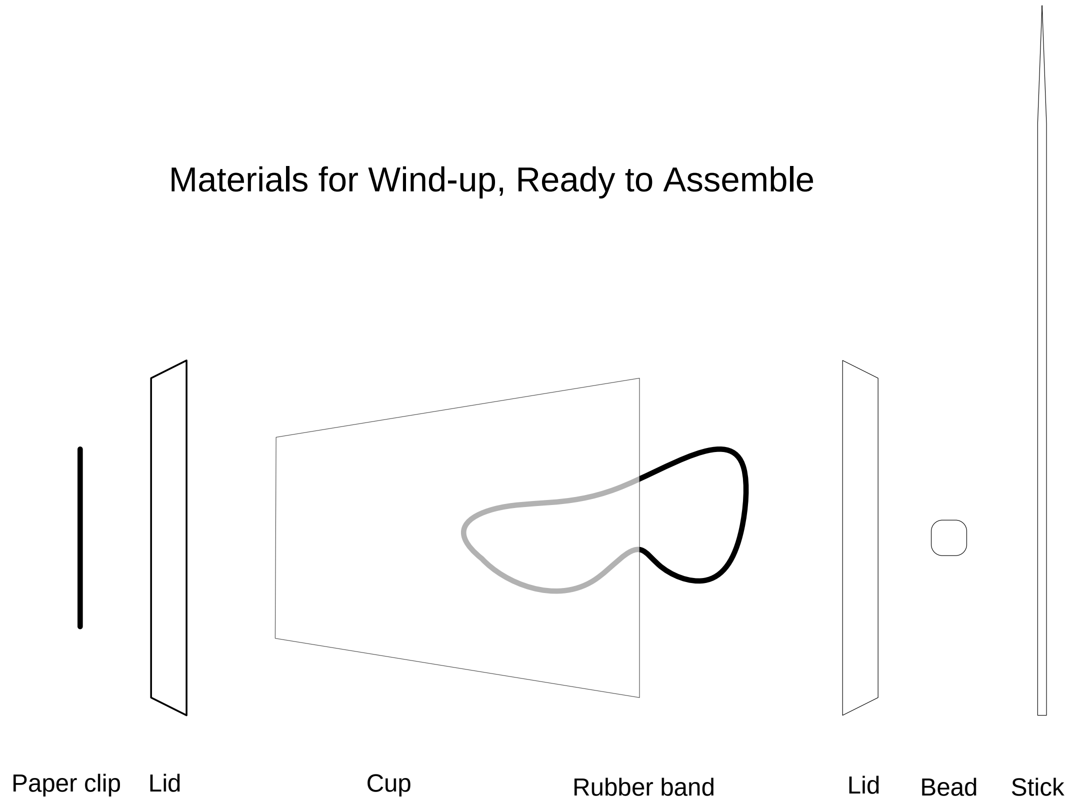
For students are reluctant to make drawings, provide individual or group instruction in basic drawing skills. Begin by showing them a lid, and asking what shape they see. Then ask them to draw a circle. Continue in a similar way with each of the other wind-up parts. The diagram below shows how each part – except the paper clip – can be represented by a very simple shape or line drawing:



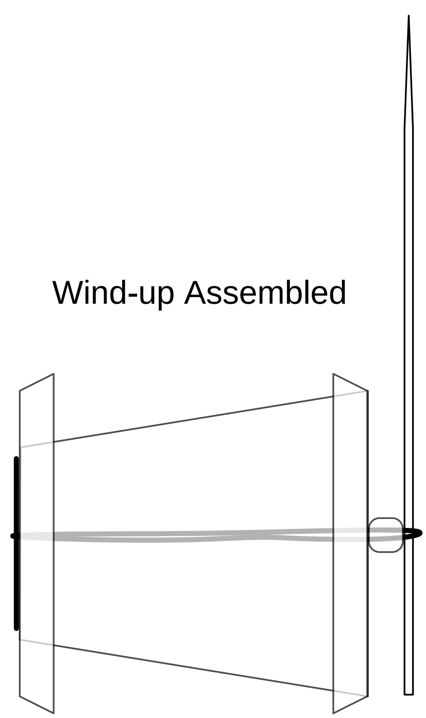
In this diagram, all of the parts are seen head-on, which is not how they would all look when assembled into a wind-up. Ask students to draw a lid as it is seen from the side. It no longer looks like a circle! The next step is to show the parts from the view you would see when looking at an assembled wind-up. The diagram below shows the wind-up parts from a side view:



The previous diagram shows the parts from a wind-up, all in the same view, but not in the order you would have to put them in order to assemble a wind-up. The next step is to show how they would be laid out in the correct positions, just before assembly. See the diagram below:



The last step is to show how the parts come together to make a wind-up:



Lesson 5: Redesign your Wind-up

Overview

The class brainstorms differences among the ways various wind-ups work. Students sort wind-ups according to their characteristics, such as: wind-ups that go straight, those that go in circles, those that spin in place. They then look at how that the design of a wind-up could change the way it works. Finally they redesign their wind-ups to make them work the way they want.

Materials

- Wind-ups made in previous lessons
- Materials for making wind-ups, for spare parts
- Markers, crayons and craft materials for decorating wind-ups

Procedure

1. Class meeting: Conduct a brief meeting about the differences among the wind-ups students have made. Here are three possible sets of categories:

   According to shape of path
   - Wind-ups that go nearly straight,
   - Wind-ups that go around in circles
   - Wind-ups that spin in place.

   If students have conducted wind-up races, they may have noticed another set of categories among wind-ups that travel in more-or-less straight paths. In order to notice these differences, students would need some experience in controlling variables.

   Far vs. Fast
   - Wind-ups that go far, but not very fast
   - Wind-ups that go faster, but not as far

   Another set of categories applies to wind-ups that go in circles. They might notice:

   Size of circle
   - Wind-ups that go in large circles
   - Wind-ups that go in small circles

2. Sorting wind-ups: Ask students to sort their wind-ups according to the categories they have noticed in #1. Depending on the number of wind-ups available, this could be a whole-class or a group activity.

3. Finding patterns: Ask students what they noticed about the wind-up in each category. Then ask:

   - How could you use this information in designing a wind-up to make it work the way you want?

The Worksheet, Part 1 provides space for recording their conclusions.

4. Instruction manual: Ask each student to create new instruction manual for making the redesigned wind-up. They can use the second page of the Worksheet. Copy additional blank pages as needed. Remind students to number each step on each page.

> Science Notebook:
>
> Explain how you redesigned your wind-up to make it work differently. Use diagrams to show what you did.
>
> How did it work?

Outcomes

- Students learn how to identify sets of categories and sort objects into the categories they have chosen.
- Student observe the differences in design between the objects in different categories.
- Students develop an understanding about how changing the design of something can cause a change in performance.

Name: ________________________ Date:_______________

Lesson 5, Part 1: Redesign your Wind-up

1. How can you make a wind-up that will go straight ?

   ____

   How can you make it go faster? ________________________

   ____

   How can you make it go further? _______________________

   ____

2. How can you make a wind-up that will go in circles?

   ____

   How can you make it go in larger circles? ________________

   ____

   How can you make it go in smaller circles? _______________

   ____

3. How can you make a wind-up that will spin in place?

   ____

4. How can you make a wind-up that will jump?

   ____

5. What else would you like your wind-up to do?

   ____

   What did it do differently after you redesigned it?

   ____

Name: ______________________ Date:_____________

Lesson 5, Part 2: Manual for Building a New Wind-up

How to Make a Wind-up that __________________

___	________________________ ________________________ ________________________ ________________________ ________________________ ________________________

___	________________________ ________________________ ________________________ ________________________ ________________________ ________________________

___	________________________ ________________________ ________________________ ________________________ ________________________ ________________________

Troubleshooting (for Teachers)

The sorting and pattern-finding activities get at the relationship between design and performance. The design of a wind-up affects how it will work. This is another example of a cause-and-effect relationship. Here, the cause arises from your own design.

The first set of categories looks at the shape of a wind-up's path. In order to go straight, a wind-up needs to have two wheels of the same size. If one wheel is bigger than the other, the larger wheel will rotate around the smaller one, because its circumference is larger, and therefore it will go further than the small wheel each time the rubber band unwinds through a full revolution. The smaller wheel is also more likely to spin in place, which makes the circle even smaller. A wind-up that has two small wheels is likely to spin in place, because the both wheels have less contact with the floor, and therefore less friction. Therefore they are more likely to slip, and less likely to grab the road. This problem can sometimes be solved by putting rubber bands (tires) around the wheels. The table below summarizes the categories and patterns.

Wind-ups sorted according to shape of path

Operation	**Design**	**Explanation**
Travels in a straight path	Two large wheels, same size	Each wheel goes the same distance
Travels in a circle	One small, one large wheel	Larger wheel has to go further than small wheel
Spins in place	Two small wheels	Insufficient friction to grab the road

The second set of categories compares wind-ups that travel in a straight line, and therefore have the same size wheels (see the Table above). Suppose you have two wind-ups, each with two same-size wheels, but one wind-up has bigger wheels than the other. For a fair test between them, all the other design elements would have to be the same: type of rubber band, length of tube or cup, type of bead, etc. also, they would have to be wound up the same number of times. In other words, wheel size should be the only variable. Under these conditions, the wind-up with smaller wheels will go faster, but not as far; while the one with larger wheels will go further but not as fast. Why? If a wheel is larger, its circumference is longer, and it will travel further each time the rubber band unwinds through a full revolution. However, it will not go as fast, because it will have to cover a longer distance in about the same amount of time. The reverse is true for a wind-up with smaller wheels.

The third set of categories compares wind-ups that go around in circles, and therefore have different sized wheels (see the Table above). What controls the size of the circle they travel around? If the two wheels are closer in size, the circle will be larger. If there is a big difference in size, the circle will be smaller.

Lesson 6: How a Wind-up works

Overview

Students first examine their wind-ups closely to explore how they work, and do some mini-experiments to see what role each part plays. Next, there are some focusing questions that help develop concepts of energy. Finally, they write descriptions about how wind-ups work.

Materials

- Wind-ups already made by students
- Materials for making wind-ups, for spare parts and for doing experiments

Procedure

1. Class meeting. Ask students what they have noticed about the way a wind-up works. Chart their observations. Here are some focusing questions that might help to structure the discussion:

   - What changes happen when you wind up the stick?
   - What would happen if you replaced the rubber band by a piece of string?

   Students should be able to answer this question immediately, but you can provide a length of string to each group in case students want to try this experiment.

   - When you let the stick go, what parts are turning, and what parts are not?

   This is hard to answer without seeing inside the cup or tube. Provide a transparent plastic cup to each group in case students want to see for themselves.

   - What is making some parts turn?
   - What is keeping other parts from turning?

2. Wind-up Experiments. Here are three simple demonstrations that you or the students can do to reveal more about how wind-ups work:

   a) Put a stick on each side, instead of just on one side.

      - What happens?
      - Why doesn't it work?
      - When the rubber band unwinds, what does it need to do, in order to make the wind-up go?

   b) Remove the second stick, so you are back to your original wind-up, with only one stick. Make the stick shorter (by breaking it) so it can't touch the floor or table.

      - What happens now?
      - What does the stick have to do to allow the wind-up to go?
      - Why does the stick need to touch the floor?

c) Replace the broken stick with a new stick that can touch the ground, so you have your original wind-up. On the side with the paper clip, slip the rubber band through a bead, to keep the paper clip away from the wheel.

   - What do you notice about the paper clip?
   - What does the paper clip need to do to make the wind-up work?
   - What's preventing the paper clip from doing its job?

3. Class meeting. The class then meets to piece together the information from these experiments. Help them break down the entire sequence of steps that occurs between windup up the stick, and the wind-up traveling on its own. What is the job of each part? (See Technical Background for details.)

   This is also a good place to introduce the concept of **energy**, which comes in two major categories. After it's wound up, but before is released, **potential energy** is what makes the wind-up "want" to go. The kind of potential energy is called **elastic**, which means that it is contained in something "springy" that is stretched or twisted, but would "like" to go back to its original shape. After the wind-up is released and moving across the floor, it has **kinetic energy**, which is the energy of motion. Some focusing questions about energy are:

   - Where does the energy come from that's needed to wind it up?
   - Where do you get energy from?
   - What energy changes take place as you wind it up?
   - What happens to the energy when you let it go?
   - What happens to the energy of the wind-up as it slows down and stops?

4. Homework or extension activity: Conduct a scavenger hunt at home or in the classroom for elastic-powered devices. Example include anything with a return spring that makes it come back to its original shape when you let it go: keyboard keys, door knobs, wind-up toys, snack food clips, clothespins, bulldog clips, tweezers, salad tongs, automatic door closers, staplers, push button switches (for example on a computer mouse), etc.

Outcomes

- Students look at a wind-up closely to uncover its principles of operation.
- Students use the results of simple experiments to draw conclusions about how a wind-up works.
- Students develop a series of cause-and-effect relationships linked together in a causal chain.
- Students develop concepts of potential and kinetic energy, and see how one is transformed into the other, using wind-ups as examples.

Name: ______________________ Date:_____________

Lesson 6: How a Wind-up Works

In your wind-up…

1. What happens to the rubber band when you wind up the stick? _______________________________________
2. What happens to the rubber band when you let the stick go? ____
3. After you let the stick go, which parts of the wind-up are turning? _____________________________________
4. Which parts are not turning?______________________
5. What happens if the paper clip is not attached to the wheel ? _______________________________________
6. What makes the wheel turn? ______________________
7. Make a diagram showing how energy takes different forms in a wind-up. Include the energy you need to wind it up:

Troubleshooting (for teachers)

How a Wind-up Works

The way a wind-up works is not obvious. The experiments are designed to reveal some of its secrets. Here is a blow-by-blow description of what the experiments tell us about how it works. Table 1 provides a summary.

1. **Twisting the rubber band**: When you wind the stick, you are twisting the rubber band. It "wants" to untwist, but you are preventing it from doing so by holding the stick with one hand and the body of the wind-up with the other.
2. **What is actually turning**: By looking closely at a wind-up as it is operating, students should notice that:
   - The stick does not turn. The floor or table should prevent it from doing that.
   - The bead may or may not turn. Its job is to allow the stick to stay fixed while the wheel turns.
   - The rubber band untwists.
   - The paper clip and both wheels turn.
3. **Untwisting the rubber band:** The rubber band can't untwist unless it is stopped at one end and allowed to rotate freely at the other end. The stick will stop the rubber band from turning at its end, unless the stick is too short to rest on the floor, as in Experiment 2 b). Then the rubber band won't have anything to stop it from turning at either end, so it won't be able to untwist reliably. If there is a stick at each end, as in Experiment 2 a), and both sticks are touching the floor, the rubber band won't be able to turn either one and won't be able to unwind at all.
4. **Turning the wheel**: Let's suppose the stick touches the floor, so it holds the rubber band at one end, and the rubber band is attached to a paper clip at the other end, which can turn freely. The rubber band will then unwind, taking the paper clip with it. What will the paper clip do as it turns? If it is fastened to one of the wheels, the friction between the two will make the wheel turn too, and that will make the wind-up go. In Experiment 2 c), the paper clip is not fastened to the wheel, because there is a bead in between them. In that case, the paper clip will rotate, but it won't carry the wheel with it, and the wind-up will not go.
5. **Making the wind-up go**: In order to work well, the paper clip has to be fastened to one wheel. Sometimes, the rubber band will be strong enough to press it against the wheel. If not, a little tape will do the job. As the rubber band unwinds, it turns the paper clip, which turns the wheel it is fastened to. The whole wind-up is held together by the rubber band. That includes both wheels, the tube and other parts. The paper clip should be fastened to one of the wheels, which may be a lid or the end of a cup. If the rubber band can turn one of the wheels through the paper clip, that wheel will turn the rest of the wind-up as a unit.

The whole process is subtle, because the side you wind up – the stick, is opposite the side that actually makes the wind-up go. The wind-up is powered as the unwinding rubber band turns the paper clip, which turns one wheel, which turns the entire vehicle.

Table 1: Explaining the Wind-up Experiments

Experiment	Set-up at each wheel		Situation at each wheel		Outcome
2 a)	stick	stick	Stick can't turn	Stick can't turn	Rubber band can't unwind, because it is held at both ends
2 b)	Short stick	paper clip	Stick can turn	Paper clip can turn	Rubber band unwinds unpredictably, because it is not held at either end
2 c)	stick	paper clip not attached to wheel	Stick can't turn	Paper clip turns, but doesn't turn wheel	Rubber band unwinds but doesn't drive the wind-up, because the paper clip isn't making wheel turn
Working wind-up	Stick	paper clip attached to wheel	Stick can't turn	Paper clip turns and makes wheel turn	One wheel turned by paper clip makes the wind-up go

Energy relationships in a wind-up

Like almost any vehicle, the operation of a wind-up provides rich examples of how **energy can be stored and converted** from one form to another, but never created nor destroyed. This last principle is called the **Law of Conservation of Energy**. The energy transformations in a wind-up are summarized in Table 2.

Let's begin with the winding of the stick. It takes energy to do that. The energy of anything in motion is called **kinetic** or **mechanical energy**. Where do we get that energy from? Working backwards, all of the energy we have comes from food and beverages, which store **chemical energy** in a form that our bodies can make use of. Energy that is stored is available for use later, but not now. Another word for stored energy is **potential energy**. The energy stored in food or beverages originates from plants, even if we eat meat, whose energy came originally from the plants eaten by an animal. The chemical energy that is stored in plants is the result of **photosynthesis**, which converts **solar (or light) energy** from the sun into chemical energy. Ultimately, we are all solar-powered!

Next, let's look forward in the process. What happens as we exert energy into winding the stick? The rubber band converts this energy into a form called **elastic energy**, which is the energy of something that is twisted, stretched or squashed, but "wants" to come back to its original shape. Elastic energy is a form of **potential energy**, because it is being saved up for later. The Homework is a scavenger hunt for devices other than wind-ups that store elastic energy, usually in some kind of spring. Energy is stored in the rubber band until the wind-up is released. At that point, as the rubber band turns the wheel through the paper clip, the stored energy is converted into the energy of motion, which we have already identified as **kinetic** or **mechanical energy**.

Eventually, the wind-up will stop rolling. What happens to its energy? When the wind-up stops, it has no kinetic energy any more, which seems to suggest that its energy was lost – but the Law of Conservation of Energy says that can't happen. What actually happens is very subtle. The energy of the wind-up is not destroyed, but it is changed from kinetic energy to a form that cannot be used. What slows the wind-up down is **friction**, the enemy of all moving things.

Table 2: Energy relationships involved in wind-up operation

Action	**Energy transformation**	**Outcome**
Sun shines on plants	Light energy from the sun is converted to chemical energy via photosynthesis	Plants store chemical energy
People eat food	Stored chemical energy is added to our bodies	People store chemical energy
Food is metabolized	Chemical energy becomes available to muscles, which convert it to kinetic energy	People can move their body parts
A person turns the stick of a wind-up	Kinetic energy gets converted into elastic energy in the rubber band	The rubber band stores potential energy, for later use
The person releases the wind-up	The elastic energy of the rubber band gets converted into kinetic energy of the wind-up	The wind-up travels across the floor
The wind-up slows down	The kinetic energy is gradually transformed into heat energy, due to friction between the wind-up, and the floor and air	The wind-up eventually stops. The floor, wind-up and surrounding air all heat up very slightly.

Before we talk about the energy lost to friction, let's look at some other examples from wind-ups, showing the many faces of friction (see Table 3):

- The bead is used to reduce friction: In the Troubleshooting section of Lesson 2, we explained that the bead is needed between the stick and the wheel to reduce the friction between them. If there stick is too tight against the wheel, there will be too much friction and the stick and wheel will not be able to move independently.
- The paper clip and lid require friction to keep them together An example – where friction is a good thing – is the attachment of the paper clip to the other wheel. Here they need to move together, or the turning paper clip won't make the car go.
- Some friction is needed between the wheel and the floor. If the wheels are small, they will slip on the floor, and the wind-up will spin in place rather than travel forward. See Lesson 6. Like a car wheel, something rough is needed to make the wheel "grab the road." A car uses a rubber tire to increase the friction between the wheel and the road. Of course, too much friction will not work, which is why wheels should not be square.

As the wind-up is rolling, there is some friction between the wheels and the floor, between the whole wind-up and the surrounding air, and also between the stick and the bead. All of this rubbing causes everything to heat up ever so slightly – probably much less than you can notice – but accounting for all the energy the was previously kinetic. Energy "lost to friction" is not actually being destroyed – it is being converted from mechanical energy to heat energy, which is "lost" only in the sense that it can no longer be used.

Table 3: Some of the Many Faces of Friction

Surfaces in contact	Possible Problem	Amount of friction	Solution
Stick and wheel	Stick rubs against wheel, preventing wheel from turning freely	Too much	Put a bead between the stick and the wheel to reduce friction
Paper clip and wheel	Paper clip turns, but doesn't make wheel turn	Not enough	Use tape or tighter rubber band to increase friction
Wheel and floor	Wheel slips on floor; wind-up won't move forward	Not enough	Add a tire around the wheel to increase friction, or use a larger wheel
Wind-up, floor and air	Wind-up eventually slows down and stops	unavoidable	No solution – this is happens to every moving thing unless additional energy is supplied to make up for friction

Lesson 7: How could a Balloon Power a Car?

Overview

Students are introduced to the idea of designing and making a car that uses a balloon as its energy source. They are challenged to think about how a balloon car would be similar to a wind-up and how they would be different. Finally, they create concept drawings and materials lists for their balloon cars.

Materials

- Materials for making balloon cars

Procedure

1. Class meeting. Show the class a balloon. Blow it up and then release it. Ask:
   - When I blow this up, what changes do you see?
   - How is this different from stretching a rubber band? How is it similar?
   - How is the energy of the balloon changing as I blow it up?
   - Where is the energy coming from to make the balloon's energy change?
   - Where do I get the energy to blow it up?
   - Where does the energy of the balloon go when I release it?

   Ask students to think about how you could use a balloon to make something similar to a wind-up:
   - Earlier, we made wind-ups. What made them go?
   - How could you make a car that uses a balloon as its energy source?
   - What materials would you need?

Science Notebook or Worksheet:
What do you think a balloon car will look like?
Predict the direction it will go in.
Draw and label the materials you will need.

2. Starting to make balloon cars: Provide students with materials. Most of the materials students have listed will probably be available. If any are not available, ask what materials could be substituted. Provide each group with a balloon pump. Allow students to experiment with the materials, and record any problems that come up.

SAFETY NOTE: To avoid spreading infections, do not allow students to blow balloons up by mouth. Each student should always use a balloon pump to blow up a balloon.

Name: _______________________ Date:________________

Lesson 7: My Balloon Car

What I will make (draw and write)

	______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________

What will you have to do to make it *go* ? __________________

____

Use an arrow to show the direction you think it will *go*.

Draw and label the parts you will need:

Outcomes

- Students review their work with wind-ups, by considering a related, but different problem.
- Student apply the concepts of potential and kinetic energy, and energy conservation, in a context similar to wind-ups.
- Students try to imagine a new design without the benefit of a sample.

Troubleshooting (for Teachers)

A balloon is similar to a rubber band in that each one can store elastic energy. When either one is stretched, they have potential energy. This energy comes from the person who blows up the balloon or stretches the rubber band. See Technical Background for Lesson 5.

A balloon and a rubber band differ in the number of dimensions available for useful expansion. For all practical purposes, a rubber band is like a **one-dimensional line**: it can only get longer or shorter. A balloon has a **surface** that can **expand** (get bigger) or **contract** (get smaller) in **two dimensions.** The surface of a balloon encloses a **volume** that can expand or contract in **three dimensions**.

When a balloon is blown up and held, its energy is stored in the elastic energy of the rubber surface. When it is released, the surface can only go back to its original shape by pushing all the air out. The air flow out of the neck of the balloon pushes the balloon in the opposite direction, much the same way that a rocket pushes itself up by forcing an exhaust gas down. Students may be surprised to discover that the direction of the balloon car is the opposite of the direction of the air flow!

Lesson 8: Make a Balloon Car

Overview

Students complete their balloon cars, keeping track of issues as they come up.

Materials

- Partially completed balloon cars from Lesson1
- Materials for making balloon cars, for use as spare parts.

Procedure

Making balloon cars: Students continue working on their balloon cars. Students whose balloon cars are completed can help others. As students are working, ask them to keep track of issues that arose. Post the issues on chart paper. As students ask for help with problems, identify these as issues, by adding them to the chart. Some examples of issues that are likely to come up:

- Wheels fall off
- Balloon won't hold air
- Balloon won't stay on car
- Car won't go at all
- Car won't go straight
- Car topples over

Science Notebook:

1. Compile an **Issues List**, including anything that didn't work the way you wanted it to.
2. Describe what you did today.

Outcomes

Students gain further practice in isolating problems. You can't usually solve a problem until you know what it is.

Troubleshooting (for Teachers)

A balloon car is not a wind-up

When students first try to make balloon cars, they may simply begin with a wind-up, and somehow try to add a balloon to it. Ask them what will make a balloon car go. If it has a balloon, what role will be left for the stick and rubber band? Encourage them to see this as a new design problem. They will have to creative in solving it, and not just copy something they did before.

Things fall apart

Once students realize that they will need to build a car to mount the balloon on, they will likely run into some relatively straightforward construction problems. The wheels fall off the car. The balloon won't stay on the car. There's nothing to direct the air flow from the balloon. These problems are mostly solved using tape and/or rubber bands. To channel the air flow, and make it easy to keep the balloon in place, tape or tie a straw to the end of the balloon. Then use a rubber band or tape to attach the straw to the body of the car. If the wheels are loose on the axles, tape, rubber bands or clay will hold them in place.

What if the car won't go?

An important principle in troubleshooting is to isolate causes. There are two independent kinds of problem that could prevent a balloon car from working:

1. Friction is preventing the car from rolling freely, and/or
2. The balloon can't drive the car.

The first step is to make a car that can roll easily, before even worrying about the balloon. It's easy to test a car to see if it can roll easily: push the car a little and see what happens. If it doesn't move freely, the balloon won't be able to make it go either.

1. **Making it roll.** The wheels need to be able to turn. There are two ways this can happen:
   a) **Axles fixed to body, wheels spin on axles**. This is usually the easier solution, because it doesn't require any special way of attaching the axles to the body. The axles can simply be taped or jammed through the body, but the holes in the wheel need to be big enough so that the wheels can rotate on the fixed axles. This leads to the problem of the wheels falling off, which can be solved using tape, rubber bands or clay (see Things Fall apart, above). Another problem is to make sure the wheels are touching the floor. Sometimes the axles so high that the wheels aren't actually touching, and therefore can't roll. Hold the car up, in the horizontal position, and look at it from the end to see if the bottoms of the wheels are actually below the body. If not, you will have to move the axles to a lower position on the body.
   b) **Wheels fixed to axles, axles spin on body**. While a little harder to make, this solution is generally more reliable. Something that allows an axle to rotate, while keeping it attached to the body, is called a **bearing**. A simple way to make a bearing is to cut a little piece of straw, and tape it to the underside of the car body. Slide the axle through and attach the wheels to the axle. The straw will keep the axle and wheels on the body, while allowing them to rotate.

2. **Getting the car to go.** If the car can roll easily, but the balloon won't make it go, the first thing to check for is a leak. If there is no leak, investigate the direction of the flow. If the flow is in the right direction and the balloon holds air, the solution might be to use a better balloon.

    a) **Does the balloon hold air?** Blow up the balloon, and pinch the end of the straw. Does the balloon stay inflated? If not, use your finger to check for air leaks. The most likely spot for a leak is where the balloon is attached to the straw.

    b) **Which way does the air go?** In order to power the car, the air has to be able to go in the reverse direction of the car. Roll the car forwards to see which way it wants to go. Then make sure the straw is pointing in a parallel direction, backwards. To the extent it is going sideways, up or down, at least part of the air flow will not make the car go at all.

    c) **Is the car too heavy?** The heavier the car, the harder it is to make it go. Sometimes, just removing some of the material, or making the car smaller, will be all that's needed to make it go.

    d) **Is the balloon up to the task?** Some balloons just can't stretch enough to store the energy needed to push a car. 12 ″ round party balloons usually work quite well, but cylindrical balloons for making balloon animals are not usually effective. If the air flow is in right direction, and the balloon and straw are air tight, and the car still won't go, you might try a different kind of balloon.

<u>Balloon car topples over</u>

This problem has to do with the way weight is distributed. If most of the weight is in the front, the back of the vehicle will tend to flip over the front, like a bicycle going downhill./ The back is heavier, the front wheels will lift off the ground. If rearranging the parts doesn't solve this problem, you can add weight to the sides that are too light. Almost anything metal will do as a weight: coins, large paper clips, nails, washers. However, be careful in adding weight, because too much additional weight may make the car too heavy to drive; see 2 c), above.

Lesson 9: Troubleshooting Balloon Cars

Overview

Students meet to discuss the issues on their lists from Lesson 8. Next they revisit the concept of **troubleshooting** from Lesson 3. They use each others' troubleshooting ideas to fix their balloon cars. Finally, they record what they have learned by each writing a **Troubleshooting Guide.**

Materials

- Chart paper **Issues list** from Lesson 8
- Balloon cars already made by students
- Materials for making balloon cars, for use as spare parts

Procedure

1. Class meeting: Select one of the issues from the chart, such as "Balloon won't hold air," and ask:

   - When our wind-ups didn't work, what did we do?

   Review the concept of troubleshooting, and ask how it would apply to the issue you have selected.

   Make a Troubleshooting Chart, as in Lesson 3, and remind students how to fill it in, by listing the Issue, Cause and possible Fixes. See example below:

   Balloon Car Troubleshooting Chart

Issue: Balloon won't hold air	
Cause	Fixes
Balloon is broken	Use a new balloon
Leaks where balloon is taped to straw	Use more tape or tighten rubber band
Can't pinch straw easily after balloon is blown up	Use longer straw or move balloon and straw further back

2. Troubleshooting Guide: Based on the example you have just shown, ask each student to create a **Troubleshooting Guide** showing how to deal with each issue that has been resolved**.**

Science Notebook or Worksheet
Write a **Troubleshooting Guide,** showing the **cause** and the **fix** for each issue.

3. Using one another's Troubleshooting Ideas: Ask students to present some of the issues that have come up with their balloon cars. After each issue is presented, ask if anyone has figured out a way to solve that particular problem. Then provide time for students to get their balloon cars to work, based on one another's suggestions for troubleshooting.

Outcomes

- Students learn to find out what's causing a problem, rather than become frustrated by it.

- Students develop the concept of **troubleshooting**, and see the benefit of identifying the cause of a problem and solving only that problem.
- Students learn troubleshooting ideas from one another.
- Students learn ways to address problems such as friction, air leaks, and air flow direction.

Troubleshooting (for Teachers)

See Troubleshooting section in Lesson 8 for suggestions about how to fix a balloon car.

Name: ______________________ Date:_____________

Lesson 9: Balloon Car Troubleshooting Guide

Issue:	
Cause: ___________________ ___________________________ ___________________________ ___________________________ ___________________________	Fix:______________________________ ___________________________________ ___________________________________ ___________________________________ ___________________________________

Issue:	
Cause: ___________________ ___________________________ ___________________________ ___________________________ ___________________________	Fix:______________________________ ___________________________________ ___________________________________ ___________________________________ ___________________________________

Issue:	
Cause: ___________________ ___________________________ ___________________________ ___________________________ ___________________________	Fix:______________________________ ___________________________________ ___________________________________ ___________________________________ ___________________________________

Lesson 10: How to Build a Balloon Car

Overview

Based on the steps actually followed in making one, each student writes an illustrated **Instruction Manual** that could show someone how to make a balloon car. The teacher and other students test each student's manual by following each step literally.

Materials

- Balloon cars already made by students
- Materials for making balloon cars, for use as spare parts.

Procedure

1. Class meeting: Review the purpose and format of an **Instruction Manual**, based on Lesson 4.
2. Writing instruction manuals. Provide time for each student to write his or her own Instruction Manual. They can do it in the Science Notebook or on the Worksheet.

> Science Notebook or Worksheet:
>
> Write an illustrated **Instruction Manual** showing how to make a balloon car. Number the steps and make a diagram and write a description for each step.

3. Testing instruction manuals. After students have finished writing, demonstrate how to test an Instruction Manual. Select an instruction that is vague, such as "Attach the wheels to the car" and deliberately interpret it in a way that is obviously wrong; for example, by taping the wheels on top of the body, rather than to the axles. Review the need to be precise in giving instructions. Then ask students to exchange manuals in their groups, and test them to see if they give all the information that's needed.
4. Revising instruction manuals. Ask students to revise their instruction manuals to provide all the information that is needed. This could be a homework assignment.

Outcomes

- Students develop ideas about why instruction manuals are useful.
- Students explain procedures they have invented through diagrams and text.
- Students come to see the limitations of writing that is vague or lacking in detail.
- Students revise their own writing to make it more specific.

Name: _______________________ Date:______________

Lesson 10: Instruction Manual for Making a Balloon Car

___	____________________________ ____________________________ ____________________________ ____________________________ ____________________________ ____________________________

___	____________________________ ____________________________ ____________________________ ____________________________ ____________________________ ____________________________

___	____________________________ ____________________________ ____________________________ ____________________________ ____________________________ ____________________________

Lesson 11: How a Balloon Car Works

Overview

Students first examine their balloon cars closely to explore how they work, and do some mini-experiments to see what role each part plays. Next, there are some focusing questions that help to review and develop energy concepts related to balloon cars. Finally, they write descriptions about how balloon cars work.

Materials

- Balloon cars already made by students
- Materials for making balloon cars, for spare parts and for doing experiments

Procedure

1. Class meeting. Ask students what they have noticed about the way a balloon car works. Chart their observations. Here are some focusing questions that might help to structure the discussion:
    - What is changing as you blow up the balloon? What does it "want" to do? How are you preventing it?
    - Blow up the balloon, release the straw, but hold the car so it can't go. What comes out of the straw? What direction does it go and why?
    - Now blow it up again, but this time let the car go. What is making it go?
2. Balloon car Experiments. Here are three simple experiments that reveal more about how balloon cars work:
    a) Adjust the balloon and straw so the straw doesn't point towards the back of the car, but is instead angled towards one side. Try the car.
        - What happens?
        - Why doesn't it work?
        - Where is the air going?

    b) Replace the straw so it is again pointing backwards. Adjust the front axle so it is at an angle with the rear axle, instead of parallel to it. Try the car.
        - What happens now?
        - What controls the direction of the car?
3. Class meeting. The class then meets to piece together the information from these experiments. Help them break down the entire sequence of steps that occurs between winding up the stick, and the wind-up traveling on its own. What is the job of each part? (See Technical Background for details.)

    This is also a good place to review the concept of **energy**.

    - A wind-up stores **potential energy** in the **rubber band**, when you wind it up. When and where does a balloon car store energy?

- What happens to this energy? When?
- A balloon car won't work unless someone blows up the balloon. Where do we get the energy from that we need to blow up the balloon?

Outcomes

- Students look at a balloon car closely to uncover its principles of operation.
- Students use the results of simple experiments to draw conclusions about how a balloon car works.
- Students develop a series of cause-and-effect relationships linked together in a causal chain.
- Students review concepts of potential and kinetic energy and apply them to balloon cars.

Name: ______________________ Date:_____________

Lesson 11: How a Balloon Car Works

In your balloon car…

1. What happens to the balloon when you blow it up?
   ____
2. What happens when you let it go? __________________
   Where does the air go? ___________________________
3. What makes the car go? _________________________
4. To make the car go fast, what direction should the air be going? _______________________________________
5. What happens if the axles are not parallel?
   ____
6. Make a diagram showing how energy takes different forms in a balloon car. Include the energy you need to blow it up:

Troubleshooting (for teachers)

A balloon car stores energy in the balloon, when you blow it up. The energy you use to blow it up is the kinetic energy you put into the balloon pump. You convert this energy from the chemical energy stored in food, which is turn was originally converted from solar energy by photosynthesis. See Technical Background for Lesson 5.

When you blow up the balloon, potential energy gets stored in two ways, both elastic. One form of potential energy is that the balloon stretches, similar to the rubber band getting twisted in a wind-up. The other form is more subtle: the air inside the balloon gets compressed it a little. The stretching of the balloon is elastic, because it “wants” to go back to its original shape. The air inside the balloon is elastic too, but in a way that we can’t see. The air gets compressed into a slightly smaller volume than it had originally. It “wants” to expand to its original volume, so the air stores energy elastically too.

Letting the balloon go does two things. The air inside is at slightly higher pressure than the air surrounding, so some of it leaves the balloon to make the pressures equal. At the same time, and more important, the balloon goes back to its original size, because it doesn’t “like” being stretched. This forces more air out, because the original size was smaller, and can’t hold nearly as much air. Unless there is a leak, the only path available for the air to leave by is through the straw.

Unless there is something stopping the car from moving (such as friction, or an obstacle), the motion of the air out the straw has to be balanced by motion in the opposite direction. This is the same principle that explains why a rocket has to go up, when it is pushing exhaust gas out the bottom; or why the exhaust out the back of a jet engine makes the plane go forward. Some lawn sprinklers work this way too: pushing water out the back makes the sprinkler turn in the opposite direction. When air rushes out the back of the straw, it tries to propel the car in the forward direction. The potential energy that was stored in the balloon changes into the kinetic energy of the motion of the air, and then the car.

The car can go forward only if there isn’t something holding it back. Friction will prevent the car from moving, except in the direction that the wheels can roll. The car won’t go unless the airflow pushes it in the direction where the wheels can roll. If the straw is pointed any other way (such as up, down or sideways), the air flow will be wasted fighting against friction, and won’t make the car go.

Lesson 12: The Auto Show

Overview

The class brainstorms differences in the ways different balloon cars work. Some go straight, some curve, some go faster. Students present their final designs of wind-ups and balloon cars, and what they have learned from making them.

Materials

- Balloon cars made in previous lessons
- Materials for making balloon cars, for spare parts
- Markers, crayons and craft materials for decorating balloon cars

Procedure

1. Class meeting: Conduct a brief meeting about the differences among the balloon cars students have made. They have probably noticed that some go straight, while others don't. If students have conducted balloon car races, they may have noticed that some go faster than others. Develop and chart these differences.
2. Redesigning balloon cars: Provide time for students to redesign their balloon cars to make them work the way they want. Some challenges are:
    - Make it jump.
    - Make it the locomotive of a train – see how many train cars it can pull
    - Make it go faster (for example by adding a second balloon)
    - Use two balloons to make it rotate in place
    - Make a balloon car that has only three wheels.
    - Make a balloon car that has only two wheels.
    - Make a balloon sled that has no wheels at all.

> Science Notebook:
>
> Explain how you redesigned your balloon car to make it work differently. Use diagrams to show what you did.
>
> How well did your new design work?

3. The car show: Provide a format and audience for students to present their work. The presentation should include notebooks and worksheets, as well as finished products. The show could take any of several forms:
    - Creating a museum display;
    - Giving oral presentations of their work to an audience;
    - Presenting their work informally to visitors, "science-fair" style

Outcomes

- Students learn how the design of a balloon car affects its performance.
- Students redesign their vehicles to make them work the way they want.
- Students present their work before an audience.

Name: ________________________ Date:_______________

Lesson 12: Redesign your Balloon Car

1. How can you make a balloon car that will go straight ?

   ____

   How can you make it go faster? ________________________

   ____

2. How can you make a balloon car that will go in circles?

   ____

   How can you make it go in larger circles? ________________

   ____

   How can you make it go in smaller circles? _______________

   ____

3. How can you make a balloon car the locomotive of a train?

   ____

4. How can you make a balloon car that will jump?

   ____

5. What else would you like your balloon car to do?

   ____

   How did you redesign it? ______________________________

   ____

   What did it do differently after you redesigned it?

   ____