Lesson Plan for the Ultimate Speed Challenge

A Middle School Physical Science Lesson
Featuring Engineering Design

*Lesson Summary:*

**Grade Level:** 6-8 **Preparation Time:** 15-30 min

**Cost:** $160 - $250 initial cost **Activity Time:** 100 minutes
$5 - $10 recurring cost

**Key Vocabulary:** **Clean-up Time:** 5-10 min
Chassis, Gravity, Inertia, Gravitational Potential Energy, Friction, Air Resistance, Trade-off, Newton’s 2nd Law, and Prototype

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# 1—Lesson Overview

## 1.1—Introduction

In this engineering lesson, students will design and build prototype soapbox cars also known as coaster cars. Their ultimate goal is to build the fastest car possible. The lesson is divided into three parts

* **Part 1, Reading,** which familiarizes students with the history of soapbox racing in America as well as explaining the physics of the cars.
* **Part 2, Exploration,** where students will perform investigations to better understand the relationship between force, friction, and speed in coaster cars.
* **Part 3, Design.** Using the data they collect in Part 2, students will design, build and evaluate their own coaster cars. This part ends with a simulated soapbox race, where groups, using their best prototype, compete for the title of Ultimate Racer.

## 1.2—Lesson Breakdown with Engineering Design

|  |  |  |  |
| --- | --- | --- | --- |
| **Engineering Design Steps** | **Activity** | **Handout** | **Product** |
| 1. Define a problem that addresses a need | **Part 3:** Design | *Design Activity Handout* | Design worksheet |
| 2. Identify criteria, constraints, and priorities | **Part 3:** Design | *Design Activity Handout* | Design worksheet |
| 3. Describe relevant scientific principles and knowledge | **Part 1:** Reading  | *Article Handout* and *Vocab Alert Handout*  | Vocab Alert! worksheet |
| **Part 2:** Exploration | *Exploration Activity Handout* or *Short Exploration Activity* | Coaster car physics paragraph and data analysis questions |
| 4. Investigate possible solutions | **Part 3:** Design | *Design Activity Handout* | Labeled sketches |
| 5. Design and construct a proposed solution | **Part 3:** Design | *Design Activity Handout* | Prototypes |
| 6. Test a propose solution and collect relevant data | **Part 3:** Design | *Design Activity Handout* | Data table and/or graphs |
| 7. Evaluate a proposed solution in terms of design and performance criteria, constraints, priorities, and trade-offs | **Part 3:** Design | *Design Activity Handout* | Evaluation Paragraphs  |
| 8. Identify possible design improvements | **Part 3:** Design | *Design Activity Handout* | Evaluation Paragraphs |

## 1.3—Pre-Requisite Knowledge

Students should be familiar with the concept of gravity including gravitational potential energy.

# 2—Teacher Background Information

## 2.1—Glossary of Terms

**Note:** The following terms are not in the *Article Handout*: Constraint, Criteria, Gravitational Potential Energy, Priority, Prototype. Explain these terms via teacher instruction or class discussion prior to doing part 2 of the Vocab Alert exercise.

**Air Resistance** – Friction created by air molecules.

**Chassis** – The frame of a car.

**Constraint** *–* Limits on possible solutions. When we solve a practical problem we usually have limits on how big the solution can be, how much it can cost, how much it can weigh, etc.

**Criteria**– The things a solution should do or be. Engineering problems are usually described in terms of a set of goals that become the criteria against which we judge possible solutions.

**Force** – A push or a pull.

**Friction**– A force which opposes motion.

**Gravitational Potential Energy** – Stored energy due to height.

**Gravity** – The pulling attraction all objects exert on all other objects.

**Inertia** – The tendency of an object to resist changes in motion, equal to its mass.

**Priority** – The relative importance of the criteria and constraints. Usually some criteria are more important than others; likewise for constraints.

**Prototype** – An early sample or model built to test an idea before it is put into production.

**Soapbox Car** – A gravity-driven car which coasts down a hill and does not use a motor or engine, and which carries one passenger.

**Speed** –A rate of motion. Speed equals distance divided by time.

**Trade-off –** Practical problems almost always have many possible solutions. When we compare one solution to another, doing a better job of achieving one criterion often means doing less well on another criterion. In other words, we are forced to trade off one criterion for another.

## 2.2—Scientific Concepts and Disciplinary Core Ideas

See the *Article Handout* for the scientific concepts covered in this lesson.

**Note:** For a complete list of scientific concepts and disciplinary core ideas covered in this lesson, see **Appendix 1**.

## 2.3—Lesson Timeline

### 2.3.1—Overview Timeline

This lesson consists of three activities (Reading, Exploration, and Engineering Design) which will take approximately two hours of in-class time. The whole lesson can be conducted in one session, or split into multiple class sessions.

*2.3.2—Part 1 Timeline (30 minutes)*

This activity will take an estimated total of thirty minutes, during which the teacher will do the following:

1. Distribute materials to all students
2. Vocab Alert exercise, part 1
3. Have students read the *Article Handout*
4. Vocab Alert exercise, part 2

*2.3.3—Part 2 Timeline (45 minutes)*

This activity will take an estimated total of forty-five minutes. During this time, the teacher will do the following:

1. Distribute materials to all students
2. Review the *Article Handout* with students
3. Guide students through the *Exploration Handout*
4. Help students fill out the *Class Data Table*

**Note:** If a teacher chooses to skip Part 2, he or she will do the following:

1. Distribute materials to all students
2. Guide students through the *Short Exploration Activity Handout* using the *Short Exploration Activity Answer Key Resource*.

*2.3.4—Part 3 Timeline (45 minutes)*

This activity will take an estimated total of forty-five minutes, during which the teacher will do the following:

1. Distribute materials to all students
2. Have students design and build their coaster cars
3. Have students race their cars
4. Discuss results and have students complete the *Design Activity Handout*.

## 2.4—Lesson Materials

**Note:** For a complete and up-to-date listing of materials in a printable shopping list format, see **Appendix 2: Complete Materials Listing**.

# 3—Preparation

## 3.1—Preparation Part 1: Reading

### 3.1.1—Printed Materials

* *Vocab Alert Handout*—(one per student)
* *Article Handout*—(one per student)

### 3.1.2—Activity Materials

#### *None.*

### 3.1.3—Preparation Steps

1. Make student copies of the *Article Handout* and *Vocab Alert Handout*.

## 3.2—Preparation Part 2: Exploration

### 3.2.1—Printed Materials

* *Exploration Activity Handout*—(one for each student)
* *Class Data Table Resource*—(one for the teacher)
* *Car Building Instructions Handout*—(one for each group)
* **Optional:** *Short Exploration Activity Handout*—(one for each student)
	+ *used if skipping Part 2*
* **Optional:** *Short Exploration Activity Answer Key Resource*—(one for the teacher)
	+ *used if skipping Part 2*

### 3.2.2—Activity Materials

* MDF Particle Board (2 32-inch 1x6 pieces make one ramp)
* Books (lifts for the ramp)
* Ruler or measuring tape
	+ - *1 per group*
* Masking Tape
	+ - *1 foot per group*
* Craft Sticks (car chassis) in two lengths
	+ - *2 per group*
* Straws (axle bearings)
	+ - *1 per group*
		- *0.25” diameter*
* LEGO 6M axles
	+ - *2–3 per group*
* LEGO 12-tooth wheels
	+ - *4–6 per group*
* LEGO 20-tooth wheels
	+ - *4–6 per group*

### 3.2.3—Preparation Steps

**Note:** This next part of the lesson is **optional**. If you do not have the time, instead of having your students perform the exploration, give them a copy of the *Short Exploration Activity Handout*

1. Make student copies of the *Exploration Activity Handout*. Make group copies of the *Car Building Instructions Handout* and *Swerve Guide Handout*. Make an overhead of the *Class Data Table Resource*.
2. Plan to have students work in groups of three or four.
3. Build ramps built from pairs of boards according to *How to Build A Ramp for The Ultimate Speed Challenge*

**Note:** Two student groups (6 to 8 students) should be assigned to share a ramp. So if you have a class of 30, you will need to build five ramps.

1. Make a test kit for each student group. A test kit should include a stopwatch, a meter stick, the materials needed to make a control car (regular craft stick, four large (20-tooth) wheels, 2 axles, and 1 straw) and the materials needed to make one of the five modifications below:
* A: **Smaller Wheels**: Include four small 12-tooth wheels in this kit.
* B: **Larger Chassis**: Include a large, longer craft stick in this kit.
* C: **More Wheels**: Include two extra 20-tooth wheels and one more axle in this kit.
* D: **Dual-Size Wheels**: Include two small 12-tooth wheels in this kit.
* E: **Short Wheel Base**: Include more masking tape for students to move the bearings.
* F: **More Mass**: Include two pennies in this kit.
1. Have masking tape and scales available for student use.

## 3.3—Preparation Part 3: Engineering Design

### 3.3.1—Printed Materials

* *Class Data Table Resource—*(one per student)
	+ - *must be copied from the overhead which will be made by the class, during Part 2 of the lesson*
* *Car Building Instructions Handout*—(one per group/one for the teacher)
* *Ramp Building Instructions Handout*—(one for the teacher)
* *Design Activity* *Handout*—(one per student)
* *Swerve Guide* *Handout*—(one per group)

### 3.3.2—Activity Materials

* Craft Sticks (car chassis) in two lengths
	+ - *2 per group*
* Straws (axle bearings)
	+ - *1 per group*
		- *0.25” diameter*
* LEGO 6M axles
	+ - *2–3 per group*
* LEGO 12-tooth wheels
	+ - *4–6 per group*
* LEGO 20-tooth wheels
	+ - *4–6 per group*
* Pennies or something similar to use as weights
	+ - *3–4 per group*
* Meter sticks
	+ - *1 per group*
* Scale for weighing cars
	+ - *1 per 2–4 groups; 1 per class also OK*

### 3.3.3—Preparation Steps

1. Make student copies of the *Design Activity Handout*.
2. Make note that you or the teacher will have to make copies of the completed *Class Data Table Resource* overhead—one for each student. This must be done after executing Part 2.
3. On a counter or table top, lay out the materials you have available for the coaster cars. Also put out scales, scissors, tape, and any other construction tool you want the students to have the option of using.
4. Set up ramps according to step #2 of the Part 2 preparation instructions.
5. Have copies of the *Car Building Instructions Handout* and *Swerve Guide Handout* available for student reference.
6. If you want your students to be able to decorate their cars, put out markers and/or craft supplies. You may want to wait until close to the end of the activity to do this, otherwise student groups might focus on the decorating to the detriment of the rest of the activity.

# 4—Activity Instructions

## 4.1—Part 1: Reading (30 minutes)

1. Pass-out the *Vocab Alert Handout*, and have students rate their knowledge of the upcoming article’s key vocabulary.
2. Pass-out the *Article Handout* for students to read. Discuss important concepts and vocabulary.
3. Once students are finished with the article they should re-rate their knowledge of the key vocabulary words on their *Vocab Alert Handout*, and write in a few words, phrases, or pictures to help them remember what the word means.

## 4.2—Part 2: Exploration (45 minutes)

**Note:** This part of the lesson is **optional**. If you do not have the time, instead of having your students perform the exploration give them a copy of *Car Building Instructions Handout, Swerve Guide Handout* and *Short Exploration Activity Handout*. Have students look at the six different cars in the *Car Building Instructions Handout*. Have students read *Swerve Guide Handout* to understand how swerve was determined. Before looking at the data table, students should write down their predictions in the space provided on the handout. After they make predictions, they should use the data table to answer the analysis questions. Discuss the answers to these questions as a class before starting part 3.

If you have time for the students to complete the Exploration Activity, proceed as follows:

1. Pass out a copy of the *Exploration Activity Handout* to each student. Explain to students that before they design and build their own coaster cars, they first need to explore how the different parts of the car affect its motion.
2. Students should write down four key pieces of information about coaster car physics from the *Article Handout.* They should then turn these notes into a background paragraph about coaster car physics.
3. Arrange students into groups of 3 or 4. Pass out *Car Building Instructions Handout* and *Swerve Guide Handout* to each group. Have students look at the six different cars that will be tested in the *Car Building Instructions Handout*. Have students read the *Swerve Guide Handout* to understand how swerve will be determined. Next, they should fill out their predictions in the space provided on the *Exploration Activity Handout*.
4. Go over the procedure for the activity with the students as described in their student handout. Pass out test kits and assign each group one of the five modifications.

**Note**: If, during testing, a car swerves off the ramp the students should redo that trial.

**Note**: If a car continually swerves off the ramp it is probably because the bearings are not straight.

1. After students have finished building and testing their cars, they should copy their results onto the *Class Data Table Resource*.
2. Once the *Class Data Table Resource* is complete either have students copy the set from the overhead or otherwise hand out the data.
3. Students should use the data set to answer the analysis questions on their *Exploration Activity Handout*. Discuss answers with students before starting part 3 of the lesson.

## 4.3—Part 3: Engineering Design (45 minutes)

1. Organize the class into groups of 3 or 4 students.
2. Pass out the *Design Activity Handout* to each student. Hand out copies of *Car Building Instructions Handout* and *Swerve Guide Handout* to each group. Read the scenario, then have students either as a class or within their groups identify the problems, criteria, priorities, and constraints associated with designing and building coaster cars. Push the students to write down specific answers. For example, instead of writing “fast” students should set a travel time goal for their design.
3. Next, student groups should brainstorm two car designs. Once you approve their ideas, they should build and test both designs according to the instructions on their handout. Time permitting, there is also space on their handout to design, build, and test two more solutions.

**Note**: Only one designated student in each group should collect needed materials and students should only collect the materials they need for one design solution at a time.

1. To prepare for the Ultimate Speed Challenge, set up the ramps side by side (remember that each ramp is made of two pieces). Groups should pick their best design to represent them in the race. You could run the race in a few different ways. One way is to line up all the ramps and divide the groups into two heats. Then winners or top cars from each heat would then race together for the title. Another option is to set up fewer ramps and have more heats such as a quarter final and semi-final leading up to the grand finale. This set up would reward designs that are consistently straight. A third option is to model the race after the real Ultimate Speed Challenge, where they have three lanes and each car does three timed runs, one in each lane. The fastest single run is the winner.
2. After the final race students should use the data they collected on their designs to write two paragraphs which evaluate the effectiveness of their solutions according to the instructions on their handout. Scoring rubrics for these paragraphs can be found at <http://www.ode.state.or.us/search/page/?=32>.

# Appendix 1A: 2009 Standards that Relate to This Lesson

### Science Content Standards

**7.2P.1** Identify and describe types of motion and forces and relate forces qualitatively to the laws of motion and gravitation.

* **Students will develop an understanding that for a fixed distance, a shorter time corresponds to a faster speed.**
* **Students will be able to explain how wheel or axle friction affects speed.**
* **Students will be able to explain how the shape and surface area of a coaster car affects its air resistance.**

Extensions:

* **Given time and distance, students will be able to calculate speed.**

### Engineering Design Standards

**6.4D.1** Define a problem that addresses a need and identify science principles that may be related to possible solutions.

**7.4D.1** Define a problem that addresses a need and identify constraints that may be related to possible solutions.

**8.4D.1** Define a problem that addresses a need, and using relevant science principles investigate possible solutions given specified

criteria, constraints, priorities, and trade-offs.

* **Students will identify the problems their coaster cars should address.**
* **Students will identify criteria, priorities, constrains, and trade-offs of possible coaster car solutions.**
* **Students will read a background article on coaster cars and conduct exploration of aspects of coaster car designs to they can determine potential coaster car design solutions.**

**6.4D.2** Design, construct, and test a possible solution to a defined problem using appropriate tools and materials. Evaluate

proposed engineering design solutions to the defined problem.

**6.4D.3** Describe examples of how engineers have created inventions that address human needs and aspirations.

**7.4D.2** Design, construct, and test a possible solution using appropriate tools and materials. Evaluate proposed solutions to identify

how design constraints are addressed.

**8.4D.2** Design, construct, and test a proposed solution and collect relevant data. Evaluate a proposed solution in terms of design

and performance criteria, constraints, priorities, and trade-offs. Identify possible design improvements.

* **Students will design, build, and test two coaster car design solutions.**
* **Students will evaluate their solutions in terms of performance criteria, constrains, priorities, and trade-offs.**
* **Students will identify possible design improvements.**

# Appendix 1B: 2014 (NGSS) Standards that Relate to This Lesson

## Alignment to Next Generation Science Standards

### Performance Expectations

* MS-PS2-2. Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton’s First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton’s Second Law), frame of reference, and specification of units.]
* MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
* MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
* MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
* MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

### Disciplinary Core Ideas

##### PS2.A: Forces and Motion

* For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton’s third law). (MS-PS2-1)
* The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
* All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

### Scientific and Engineering Practices

1. Asking questions (for science) and *defining problems (for engineering)*

3. Planning and carrying out investigations

4. Analyzing and interpreting data

5. Using mathematics and computational thinking

6. Constructing explanations (for science) and *designing solutions (for engineering)*

8. Obtaining, evaluating, and communicating information

# Appendix 2: Complete Materials Listing

The purpose of this section is for lesson preparation—a teacher, assistant, or volunteer who already has all of the materials required for the lesson, and must only gather the materials for the lesson itself. If you are reading this section, you are probably working from **Section** **3—Preparation** of this lesson.

Items are sorted into four lists: materials that must be printed/collated for all parts of the lesson; activity materials needed for part 1; activity materials needed for part 2; activity materials needed for part 3. Items are arranged in the order used in the lesson.

## Printed Materials

### Part 1: Reading Activity

* *Vocab Alert Handout*—(one per student)
* *Article Handout*—(one per student)

### Part 2: Exploration Activity

* *Exploration Activity Handout*—(one for each student)
* *Class Data Table Resource*—(one for the teacher)
* *Car Building Instructions Handout*—(one for each group)
* **Optional:** *Short Exploration Activity Handout*—(one for each student)
	+ *used if skipping Part 2*
* **Optional:** *Short Exploration Activity Answer Key Resource*—(one for the teacher)
	+ *used if skipping Part 2*

### Part 3: Engineering Design Activity

* *Class Data Table Resource—*(one per student)
	+ - *must be copied from the overhead which will be made by the class, during Part 2 of the lesson*
* *Car Building Instructions Handout*—(one per group/one for the teacher)
* *Ramp Building Instructions Handout*—(one for the teacher)
* *Design Activity* *Handout*—(one per student)
* *Swerve Guide* *Handout*—(one per group)

## Activity Materials

### Part 1: Reading Activity

#### *None.*

### Part 2: Exploration Activity

* MDF Particle Board (2 pieces make one ramp)
* Books (lifts for the ramp)
* Ruler or measuring tape
	+ - *1 per group*
* Masking Tape
	+ - *1 foot per group*
* Craft Sticks (car chassis) in two lengths
	+ - *2 per group*
* Straws (axle bearings)
	+ - *1 per group*
		- *0.25” diameter*
* LEGO 6M axles
	+ - *2–3 per group*
* LEGO 12-tooth wheels
	+ - *4–6 per group*
* LEGO 20-tooth wheels
	+ - *4–6 per group*

### Part 3: Engineering Design Activity

* Craft Sticks (car chassis) in two lengths
	+ - *2 per group*
* Straws (axle bearings)
	+ - *1 per group*
		- *0.25” diameter*
* LEGO 6M axles
	+ - *2–3 per group*
* LEGO 12-tooth wheels
	+ - *4–6 per group*
* LEGO 20-tooth wheels
	+ - *4–6 per group*
* Pennies or something similar to use as weights
	+ - *3–4 per group*
* Meter sticks
	+ - *1 per group*
* Scale for weighing cars
	+ - *1 per 2–4 groups; 1 per class also OK*

## Buyer’s Guide

|  |  |  |  |
| --- | --- | --- | --- |
| **Item Information** | **Quantity: Class size of…** | **Local Retail Ext Costs: Class size of…** | **Online Ext Costs: Class size of…** |
| **Item to Purchase** | **Re usable** | **Where Found** | **30** | **40** | **Ea.** | **30** | **40** | **Ea.** | **30** | **40** |
| "MDF" Particle board (ramps) nominal 1x6x32 (actual 5.5" x 5/8" x 32: or 5.5" x 11/16" x 32") | yes | Home Improvement; Hardware; some variety | 12 | 15 | $2.67 | $32.00 | $40.00 | $0.00 | $0.00 | $0.00 |
| Stop watch or timer with count up from 0 function in hundredths | yes | Variety; science supply; PE supply | 12 | 15 | $6.00 | $12.00 | $15.00 | $6.42 | $77.04 | $96.30 |
| Regular-sized (popsicle) and Jumbo-sized wooden craft sticks, variety of colors preferred. | yes | Craft, variety, grocery | 2 | 2 | $0.02 | $0.06 | $0.06 | $0.03 | $0.06 | $0.06 |
| Straws (bearings) straight straws will have less waste than flexible ones; variety of colors is good | yes | Dollar, Craft, Grocery | 1 | 1 | $0.01 | $0.01 | $0.01 | $0.03 | $0.03 | $0.03 |
| Masking tape | no | 0 | 0 | 0 | $1.79 | $0.00 | $0.00 | $1.79 | $0.00 | $0.00 |
| **Subtotal** | **$0.00** | **$44.07** | **$55.07** | **$0.00** | **$77.13** | **$96.39** |
|   |   |   |   |   |   |   |   |   |   |   |
| LEGO 20-tooth black double conical wheels (Product ID: W970623) | yes | LEGO Education Website | 2 | 3 | $0.00 | $0.00 | $0.00 | $10.00 | $20.00 | $30.00 |
| LEGO 12-tooth black double conical wheels (Product ID W991327) | yes | LEGO Education Website | 1 | 2 | $0.00 | $0.00 | $0.00 | $10.00 | $10.00 | $20.00 |
| Lego axles size 6M (Product ID W970614) | yes | LEGO Education Website | 1 | 2 | $0.00 | $0.00 | $0.00 | $10.00 | $10.00 | $20.00 |
| **Subtotal** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$40.00** | **$70.00** |
| **Shipping** | LEGO ed; <$99 -- $8; <$500 -- 7% | $0.00 | $0.00 | $0.00 | $0.00 | $8.00 | $8.00 |
| www.flowerfactory.com -- <$20 = $6.60; <$35 = $8.80; <$50 = $9.90 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| **Total Retail** | **$0.00** | **$92.07** | **$133.07** | **$0.00** | **$0.00** | **$0.00** |
| **Total Online** | **$0.00** | **$0.00** | **$0.00** | **$0.00** | **$125.13** | **$174.39** |

## Buyer’s Guide Notes

|  |  |
| --- | --- |
| **Item to Purchase** | **Notes** |
| "MDF" Particle board (ramps) nominal 1x6x32 (actual 5.5" x 5/8" x 32: or 5.5" x 11/16" x 32") | Buy 8-foot boards and have the store pre-cut them into thirds -- giving you 3 ramps of about 32 inches each. Class of 30 needs 12 ramps. Class of 40 needs 15. No reasonable online alternative found. |
| Stop watch or timer with count up from 0 function in hundredths | many digital lab timers have hundredths; most stopwatches have hundredths |
| Regular-sized (popsicle) and Jumbo-sized wooden craft sticks, variety of colors preferred. | The craft sticks will serve as the body of the chassis. For a little extra money you can get colored sticks. Buy one pack of each size |
| Straws (bearings) straight straws will have less waste than flexible ones; variety of colors is good | These will be the bearings. Try to get multi-colored straws for the reason stated above. Online www.flowerfactory.com; www.drugstore.com |
| Masking tape | Dollar store masking tape substandard, don't buy. |
| Subtotal | none |
| LEGO 20-tooth black double conical wheels (Product ID: W970623) | http://www.legoeducation.us/eng/product/20\_tooth\_double\_conical\_wheels/865  |
| LEGO 12-tooth black double conical wheels (Product ID W991327) | These are the small wheels. http://www.legoeducation.us/eng/product/12\_tooth\_black\_double\_conical\_wheels/1320 |
| Lego axles size 6M (Product ID W970614) | http://www.legoeducation.us/eng/product/detail/2233?sku=W970614 -- sizes 5M or 7M also work |
| Shipping | LEGO ed; <$99 -- $8; <$500 -- 7% |
| www.flowerfactory.com -- <$20 = $6.60; <$35 = $8.80; <$50 = $9.90 |
| Total Retail | Assumes LEGO bought online, all else local |
| Total Online | none |