workbook

# PROMOTING CONCEPTUAL CHANGE IN PHYSICS USING SCIENTIFIC MODELS

**DAWSON COLLEGE** PAREA Funded Research Project 2005-07

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# Acknowledgment

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# Project 1 - Coaster Car Challenge

## Overall Goals:

Your overall goal for this project is to build a physical model of a Coaster Car (see building instructions, pages 3-5). Your model will demonstrate aspects of the mathematical model of **force** (f=ma). Your goal is to collect data on how <u>one feature</u> of your physical model affects its performance (i.e., how far and how straight it travels); and, to explain your results from this experiment in terms of the concept of force. In doing so, you will learn how your model allows you to visualize Newton's Second Law of motion.

### Activity:

In order to achieve your overall goal, each *team* will build and test one specific feature of a car's design, this will be the "challenge." To complete the goal, you will need to **<u>share</u>** your information with other *teams*. The aim is to design the car to go as far and as straight as possible.

## Procedure:

1. Your *team* will be assigned <u>one</u> **variable** to test, this is called the Independent Variable (i.e., a feature of the car that you can change in some way. For example, if the wheel surfaces can be your independent variable, you could tests different surfaces, such as (1) smooth surfaced wheels, (2) rubbery surfaced wheels, and (3) bumpy surfaced wheels. These would be considered the different **values** of the variable).

   **Helpful hint:** be sure to choose at least 3 different **values of your independent variable.** This way you will have "good" information to share with your classmates.
   If you do this right, there should be a pattern to the changes and/or increased by uniform amounts.

2. Proceed to the building instructions and start constructing your car. Keep in mind that you will be changing the independent variable in some way.

3. Use the "*Guide for Testing & Explanations Form*" (see page 6) to guide your discussion and decision making. Before starting your testing, answer items 1-3 and fill in the form.

   **Helpful Hint**: Be sure you know what a **scientific experiment** is before proceeding. If you don't ask your teacher. Also be sure you can answer these questions:

   - What are the main principles of the scientific method?
   - What is your independent variable and how do you plan to make this a fair test - i.e., control your variable and avoid unwanted sources of error in your testing.

4. Run your experiments and carefully collect data from these tests and record them in the "*Guide to Data Collection Form*" (see page 7).

5. Go back to the "*Guide for Testing & Explanations Form*" and fill out the remaining items.

***Summary of activities for Project 1:***

1. Plan your design of a research experiment which will allow you to accurately test the performance potential of the assigned feature.
2. Build a car based on this experiment. Be sure that can travel and as straight as possible after being released down a launching ramp.
3. Accurately collect data and record it on the sheets provided.
4. Answer the question: How can we explain the results using the concept of force?

- Remember to slow things down – (i.e., like frames in a film - cinema/ kinematic).
- Remember to use systems thinking (i.e., to see the connections & relationships between parts of a whole).Your ability to zoom between levels within the system.
- Remember to need to transform from one representation to another. (e.g., transforming from graph to calculus).

## Keep Developing These Skills:

Your **IMAGINATION**

Your scientific **INTUITION**

Your **CONFIDENCE**

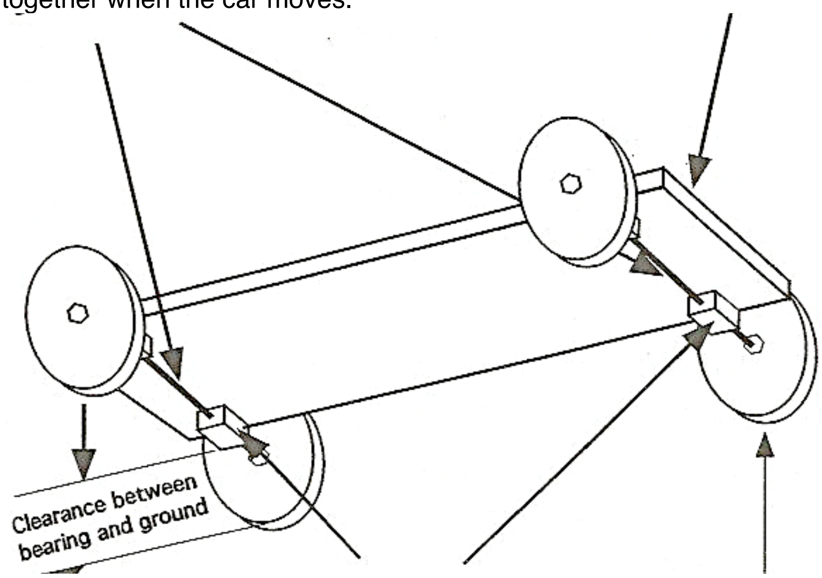
**NOTE: IMPORTANT FORMS FOR Project 1 ARE AT ON PAGES 6-7.**

# Coaster Car Building Instructions

The coaster car is a simple vehicle without a system for making it move - i.e., there is no propulsion system. It is made up of several important **features**: a flat board (a chassis) with wheels, 2 axles, and bearings (see image below). We will provide the basic materials (see following page) and you will assemble them using basic tools. Once your car is complete, you will conduct performance tests by releasing your coaster car down a launching ramp.

**Axle** - is the rod that holds the wheels, which are attached to it (in this case, the long screws). In some cars, the axle stays still while the wheels rotate. In others, the wheels are fixed to the axle, and both rotate together when the car moves.

**Chassis** - the body of the car. It is the main structure or frame to which other parts of the car are attached.

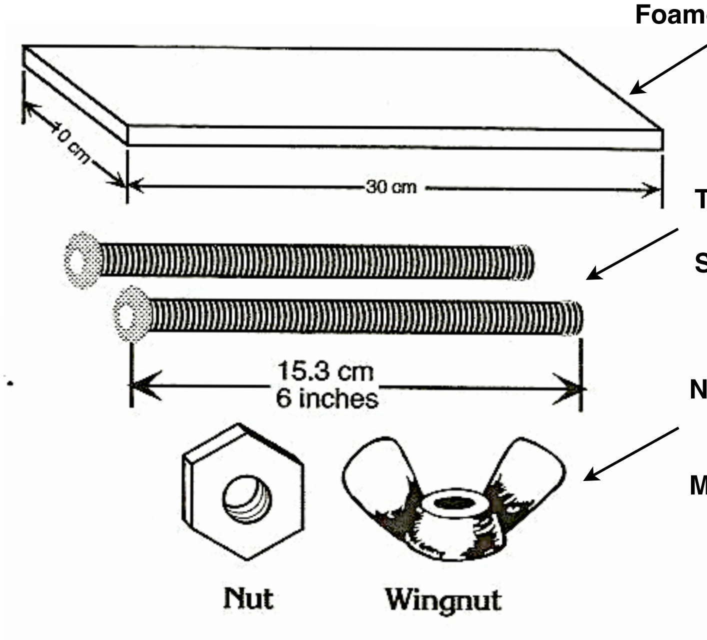



**Clearance** - the distance separating two things. The distance between the lowest part of the car (chassis) and the floor is the clearance of the car with the ground.

**Bearings** - hold things like the axles in place , while allowing them to rotate with little friction (in this case, the straws).

**Wheels** - the round discs that allow the vehicle to roll rather than slide on the floor.

# Coaster Car Materials




Foamcore board - as chassis

Threaded rod (screw) - as an axle

Straw - as a bearing

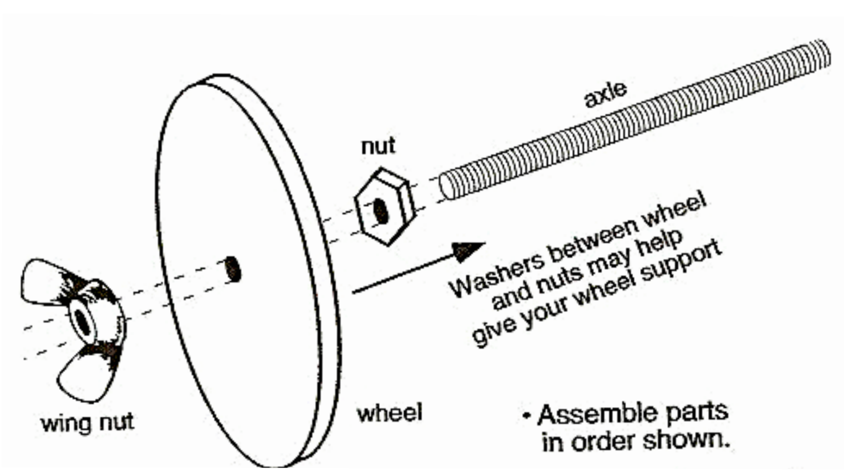
Nuts & wingnuts - to secure wheels to axle

Masking tape - to secure the wheel system

### *Connecting the Wheels to the Axle*

You will be attaching the wheel to the axle by using a nut on one side of the wheel and a wingnut on the other to keep the wheel tightly fastened on the threaded axle (see image below). Directions to attach the first outside wheel:

1. Thread a regular nut along the length of the screw.
2. Slide a wheel into place on the axle so that it rest tightly against the nut.
3. Screw on the wingnut until it too is fitting tightly beside the wheel (like a wheel sandwich).




4. Check that the wheel is firmly held so that the axle and wheel turn together.
5. Do <u>not</u> attach the other wheel until bearings are attached (see instructions following).

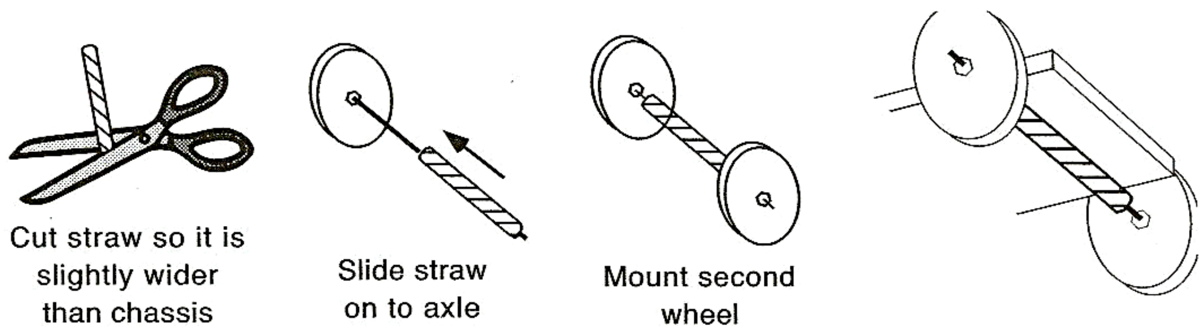
**Helpful hint**: Though wingnuts can be tightened with fingers, you will probably want to use pliers to hold the nut in place while you turn the wingnut to tighten it.

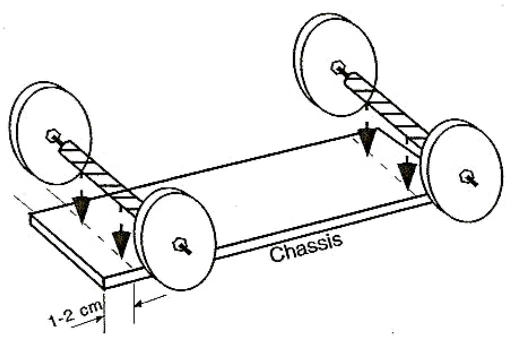
## *Attaching the Bearings to the Chassis*

A bearing holds something in place while allowing it to move freely in certain ways (i.e., rotating freely). You will be using a straw for your bearings (see image below). As you test your car, you will probably find it necessary to modify the length of your bearings to improve your car's performance. Directions:

1. Your bearings will be already cut to an appropriate size. Simply slip them onto the axle before you mount the second wheel.

2. You're now ready to attach your wheel system (axle, bearing and wheel) to the chassis. Do this carefully paying attention to make sure that the straight alignment of the axle and bearing.




Attach bearing to chassis using masking tape

**Helpful hint**: Before attaching the wheel system measure the distance from the edge of the chassis and draw a line, which you can use to align your axle.

# Form #1: Guide for Testing & Explanation - Project 1 Coaster Car

### Test Variable, Data and General Explanations

| **Type of Vehicle:** | | | |
|---|---|---|---|
| **State the variable tested:** (variables are things that you choose to test) | | | |
| **Record the values of the test variable:** (Remember the example of values for the independent variable of "wheel surface" were: (1) smooth, (2) rubbery, & (3) bumpy). | **Value 1:**<br>**Value 2:**<br>**Value 3:** | | |
| **State your prediction about the affect of the variable. Speculate why** (i.e., give an explanation) | | | |
| **List things that you can't control but may be affecting the performance of the vehicle** (i.e., rule out alternative explanations) | | | |
| **Data:** (in the boxes to the right, enter the data from the other recording sheet related to the variable tested) | **Value 1**<br>**Ave distance:**<br>**Ave speed:** | **Value 2**<br>**Ave distance:**<br>**Ave speed:** | **Value 3**<br>**Ave distance:**<br>**Ave speed:** |
| **State observations related to this data for each level of the variable:** (what happened when you ran test for each value?) | **Value 1:**<br>**Value 2:**<br>**Value 3:** | | |
| **State what you learned from these tests that would help in designing a better performing vehicle:** (what does your data tell you about the variables tested?) | | | |
| **In your own words, explain how these observations and data relate to a general law of mechanics:** | | | |

# Form #2: Guide for Data Collection - Project 1 Coaster Car

| Variable tested: | Trials | General Observations | DATA COLLECTED | | | |
|---|---|---|---|---|---|---|
| | | | Distanc | Time | Speed | Acceleration |
| **Value of variable tested:** | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |
| | | AVERAGE | | | | |
| **Value of variable tested:** | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |
| | | AVERAGE | | | | |
| **Value of variable tested:** | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |
| | | AVERAGE | | | | |

# Project 1 - Notes & Drawings

**Hint: Try to always include the answers to these questions in your reflections.**

- What did you learn? Summarize your knowledge in a full explanation of your data.
- What is your model?
- How is the model working in this instance? i.e., what is the “mechanism” (how do the parts interact).
- How does it relate to what you already know?
- Think up another example, similar to your experiment and try to solve it as “thought experiment.”

# Project 2 - Propulsion System Car Challenge

## Overall Goals:

Your overall goal for this project is to add a **propulsion system** to the coaster car. In other words, you will create a simple engine for your car (see Balloon Car or Rubber Band Car building instructions). This new model shows features of the mathematical model of **forces in pairs** (Newton's Third Law). Once again, your goal is to collect data on how your independent variable affects the performance of your car (ie.g., how straight it travels) and explain your results from this experiment in terms of the concept of force. In doing so, you will learn how your model allows you to visualize Newton's Third Law, Net Force and Acceleration.

## Activity:

In order to achieve your overall goal, each *team* will build and test your independent variable of the car's design, this will be the "challenge." To complete the goal, you will need to **share** your information with other *teams*. The aim is to design the car to go as far and as straight as possible.

## Procedure:

1. Once again, your team will be assigned one **variable** to test (i.e., a feature of the propulsion system that you can vary). These would be equivalent to having different horsepower engines, or front or rear mounted engines (e.g., Honda Civic vs. VW Beetle).

2. Design an experiment to tests at least 3 different **values** of your assigned variable. Remember that **values** are qualitative or quantitative differences of a variable that may affect how the system behaves (e.g., numbers of balloon engines, number of rubber bands, location of the engine).

3. Use the "*Guide for Testing & Explanations Form"* (see page 16) to guide your discussion and decision making. Before starting your testing, answer items 1-3 and fill in the form.

4. Run your experiments and carefully collect data from these tests and record them in the "*Guide to Data Collection Form*" (see page 17).

5. Go back to the "*Guide for Testing & Explanations Form*" and fill out the remaining items.

6. Try to explain the data (results from the 3 values of the assigned variable) by seeing how it fits (or not) the anticipated theoretical model of Newtonian physics. Your explanation should account for the things that may have affected the performance of your car.

**Summary of activities for Project 2:**

1. Build a car with a propulsions system that allows it to move on its own, and goes as straight as possible.
2. Design a research experiment which will allow you to accurately test the performance potential of the assigned feature.
3. Accurately collect data and record it on the sheets provided.
4. Answer the question: How can we explain the results using the concept of **force**?

- Remember to slow things down – (i.e., like frames in a film - cinema/kinematic).
- Remember to use systems thinking (i.e., to see the connections & relationships between parts of a whole).
    - Your ability to zoom between levels within the system.
- Remember to need to transform from one representation to another. (e.g., transforming from graph to calculus).

## Keep developing these skills:

Your **IMAGINATION**

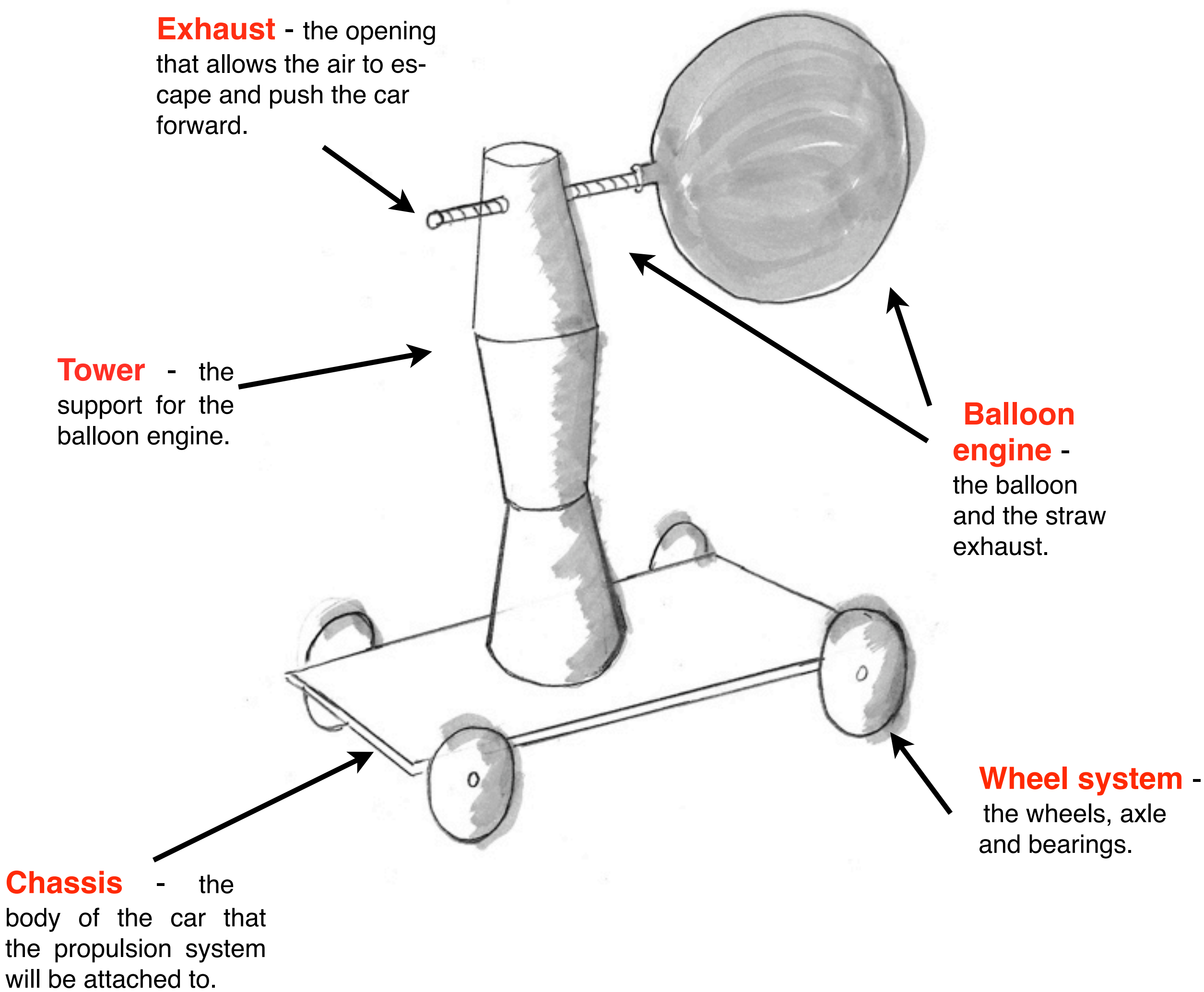
Your scientific **INTUITION**

Your **CONFIDENCE**

**NOTE: IMPORTANT FORMS FOR Project 2 ARE AT ON PAGES 16-17.**

# Balloon Car Building Instructions

The balloon car is a simple vehicle with a system for making it move on its own. It is made up of several important **sub-systems**: a chassis, wheel system (wheel, axles, and bearings), balloon engines, and an engine support system (a tower). We will provide the basic materials (see following page) and you will assemble them. Once your car is complete, you will conduct performance tests by releasing your balloon car.



# Balloon Car Materials

The Balloon Car is made up of three basic sub-systems:

- *a coaster car (used before).*
- *styrofoam cups attached to the chassis of the coaster car - the tower.*
- *a balloon engine attached to the tower.*

# Putting Your Balloon Car Together

The Balloon Car works by blowing up the balloon and then allow the released air to push the car forward.

***Checking the Balloon Engine***

The balloon engines have been made ahead of time. Always check to make sure that the seal between the balloon and the straw is airtight. If your balloon is limp while being blown up, or seems to deflate quickly, you probably have a problem with the seal between the balloon and the straw, or a hole in the balloon. In either case, you should change for a new balloon engine immediately.

***Inflating the Balloon Engine***

Use the balloon pump supplied. Insert the air pump's tube into the opening in the straw exhaust. After inflating your engine be sure to prevent the air from escaping, but be careful not to crush the tip of the straw. This will affect the air flow when you are conducting your experiments. Instead of crushing the tip of the straw, simply place your finger over the tip.

***Attaching the Balloon Engine to the Tower***

The balloon engine works best if it securely attached to the tower structure. To do so, follow these directions:

1. Make 2 holes in the styrofoam cup. Use a pencil or sharp object to do so, making sure the holes are lined up straight (level).
2. Attach the cup to the chassis using masking tape.

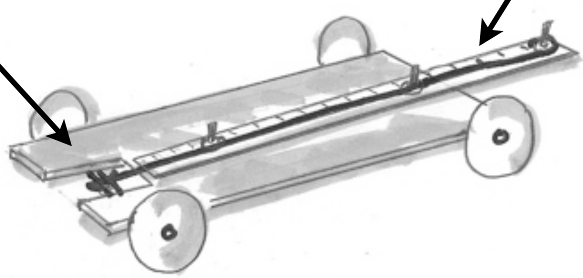
# Rubber Band Car Building Instructions

The rubber band car is another simple vehicle with a system for making it move on its own. This time the important **sub-systems are**: a chassis, wheel system (wheel, axles, and bearings), and a rubber band engine. We will provide the basic materials (see following page) and you will assemble them. Once your car is complete, you will conduct performance tests by releasing your rubber band car.

**Rubber Band Engine System** - is made up a ruler, screws & nuts, wing nut and a rubber band.

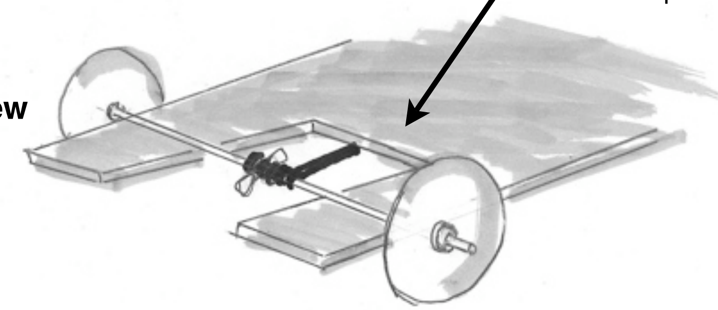
**Rear Axle**- note that a hole is cut out of the rear chassis to allow for the rear axle to be exposed so that the rubber band can be wound up.

**Top View**



**Winding Up** - note that the rubber band is wound around the rear axle around the X-post made up of 2 wing-nuts held in place.

**Bottom View**



# Rubber Band Car Materials

The rubber band car described below has four basic sub-systems:

- *a coaster car*
- *ruler (for extending the rubber band), with mounting machine screws and nuts*
- *rubber band*
- *X-post for attaching rubber band to the rear axle*

# Putting Your Rubber Band  Car Together

Like the balloon car, the rubber band car uses the force exerted by the stretched elastic material to make the car move. Instead of sending pressurized air out the back of the exhaust, as with the balloon car, this new model uses a stretched rubber band attached directly to the rear axle to make the axle spin around. By winding the rubber band around the axle, as the rubber band stretches, it applies force on the axle. When released, the wheels turn, more like what happens with a real car.

The rubber band car is easy to assemble and operate. Your finished car will have a ruler attached firmly to its chassis using nuts and screws. A post will be attached to the front of the ruler to hold one end of the rubber band. The other end of the rubber band gets attached to a X-shaped hook on the rear axle. By turning the wheels backwards, you stretch the rubber band and “wind up” the car. When released, the car moves forward.

***Operating Your Rubber-Band Car***

*When you are ready to wind up your rubber band car and begin experiments, follow the instructions below:*

> *1. Place one end of a long rubber band around the front post and the other around the X-post.(You might eventually choose to discard the X-post and simply wrap the rubber band along the axle).*
>
> *2. Turn the wheels of the car backwards so that the rubber band winds around the axle. As the rubber band begins to stretch, watch to make sure it winds around without binding (i.e., getting caught up on itself). Be careful not to wind it too far!*
>
> *3. When the rubber band is tight, put the wheels of your car firmly to the ground You are now ready to release your car and send it off down your test track.*

***Checking the Chassis***

You may find that with use your car’s chassis may become bent or weaken. Be sure to check that this does not affect the performance of your car. If it appears to, you should change or reinforce your chassis immediately.

# Form #1: Guide for Testing & Explanation - Project 2 Balloon Car or Rubber Band Car

## Test Variable, Data and General Explanations

| Type of Vehicle: | | | |
|---|---|---|---|
| **State the variable tested:** (variables are things that you choose to test) | | | |
| **Record the values of the test variable:** (Remember the example of values for the independent variable of "wheel surface" were: (1) smooth, (2) rubbery, & (3) bumpy). | **Value 1:**<br>**Value 2:**<br>**Value 3:** | | |
| **State your prediction about the affect of the variable. Speculate why** (i.e., give an explanation) | | | |
| **List things that you can't control but may be affecting the performance of the vehicle** (i.e., rule out alternative explanations) | | | |
| **Data:**<br>(in the boxes to the right, enter the data from the other recording sheet related to the variable tested) | **Value 1**<br>**Ave distance:**<br>**Ave speed:** | **Value 2**<br>**Ave distance:**<br>**Ave speed:** | **Value 3**<br>**Ave distance:**<br>**Ave speed:** |
| **State observations related to this data for each level of the variable:** (what happened when you ran test for each value?) | **Value 1:**<br>**Value 2:**<br>**Value 3:** | | |
| **State what you learned from these tests that would help in designing a better performing vehicle:** (what does your data tell you about the variables tested?) | | | |
| **In your own words, explain how these observations and data relate to a general law of mechanics:** | | | |

# Form #2: Guide for Data Collection - Project 2
# Balloon Car or Rubber Band Car

| **Variable tested:** | **Trials** | **General Observations** | **DATA COLLECTED** | | | |
|---|---|---|---|---|---|---|
| | | | Distanc | Time | Speed | Acceleration |
| **Value of variable tested:** | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |
| | | AVERAGE | | | | |
| **Value of variable tested:** | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |
| | | AVERAGE | | | | |
| **Value of variable tested:** | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |
| | | AVERAGE | | | | |

# Project 2 - Notes & Drawings

**Hint: Try to always include the answers to these questions in your reflections.**

- What did you learn? Summarize your knowledge in a full explanation of your data.
- What is your model?
- How is the model working in this instance? i.e., what is the "mechanism" (how do the parts interact).
- How does it relate to what you already know?
- Think up another example, similar to your experiment and try to solve it as "thought experiment."

# Project 3 - Transformation Challenge

## Overall Goals:

Your overall goal for this project is to use the table provided (*Motion storyboard form* - next page) to help you explain your results from the physical models you've been working with. This is considered transforming your model from one representation to another. In this project you will once again be learning how to understand and explain your model and deepen your understanding of Newton's Laws.

## Activity:

In order to achieve your overall goal, you will work together to complete the Motion storyboard form. To complete the goal, you will need to use the findings and explanations obtained from the other *teams*.

| **Reflections on the activity:** What did you learn? |
| --- |
| |

## Motion storyboard Modeling – bridging between 2D representations of motion

| Time-state | $T_0$ (start) | $T_1$ (speeding up) | $T_2$ (slowing down) | $T_3$ (end) |
|---|---|---|---|---|
| Pictorial | | | | |
| Dots | | | | |
| F | ● | ● | ● | ● |
| $F_{net}$ | | | | |
| Velocity | | | | |

| | | | | |
|---|---|---|---|---|
| **A Graph** n<br>0 | 0 | 0 | 0 | |
| **V Graph** n<br>0 | | | | |
| **Mathematical Equation** | | | | |

# Project 4 - SIMCARS Challenge

## Overall Goals:

Your overall goal for this project is to explain how the cars you choose to build, using the computer model SIMCARS, work. In doing so, you will look at the graphs your model car produces and explain how the features of the car might produce such graphs. In this project you will once again be learning how to understand and explain models that are based on Newton's Laws. You will also answer the question, How does this compare to the physical model?

### Activity:

In order to achieve your overall goal, each *team* will select specific features of a car's design, this will be the "challenge." To complete the goal, you will need to **share** your findings and explanations with other *teams*.

## Procedure:

1. First read the following pages that introduce you to the SIMCARS software. This will help to familiarize you with the software. When ready, there is a full PowerPoint presentation available on line.

2. Open the SIMCARS and start by selecting Coaster Car.

3. Choose one feature (variable).

4. Use the "*Guide for SIMCAR Form*" (see page 26) to guide your discussion and decision making. Before starting your testing, answer items 1-3 and record these in writing on the form.

5. Run your test and return to answering and filling in the remaining questions on the "Guide for SIMCAR Form".

6. Try to explain the results in light of Newton's Laws.

7. Try to explain how the models represented in the simulation differs from the real physical models you have been working with.

8. Select another car (Balloon Car or Rubber Band Car). Once again choose one feature to investigate.

# SIMCARS Instructions

The software you will be using is called SIMCARS™. It is to be used together with the Guide for Running SIMCARS form (see following pages). It was developed by researchers at Georgia Institute of Technology in Atlanta, Georgia (Vattam & Kolodner, 2005), and pilot tested by Dawson College science students. A full introduction is available as a PowerPoint presentation and will be online (see below for highlights to get you started).

> ***Note**: some aspects of the software may appear to work slower than computer games (e.g., the time it takes to draw a graph). But this is intentional, the software calculates the actual time it takes for the cars to run. Also note that the software is intended to promote deep level discussions of physics, though it may look somewhat simple because of the Comic Sans font and graphics.*

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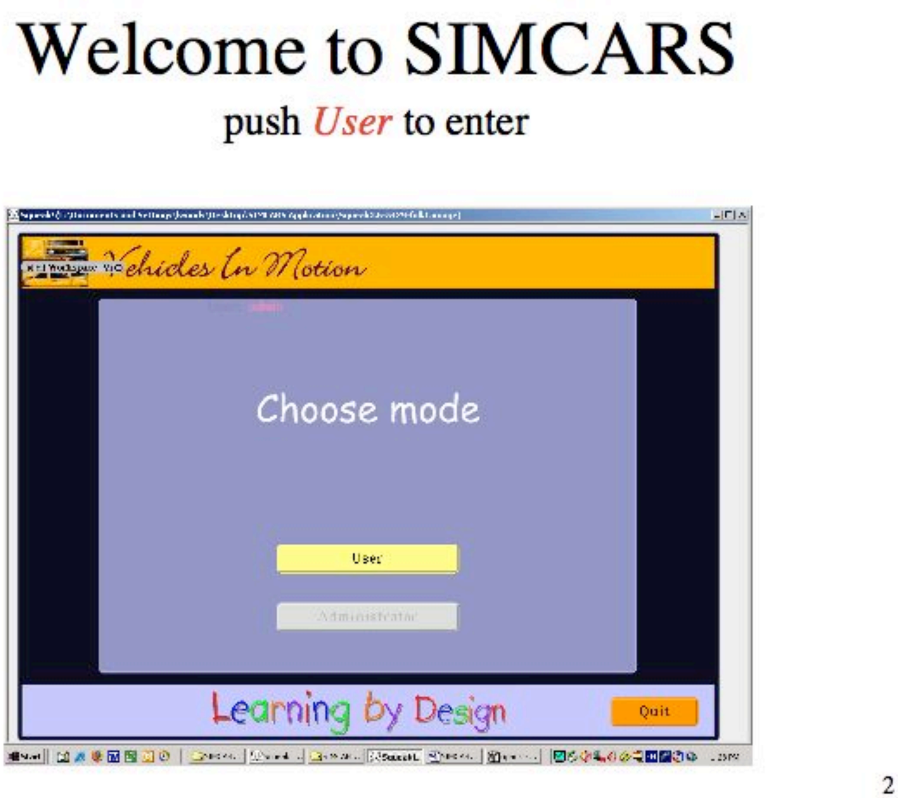


# Start by selecting

*Coaster Car*


3

---

# Select

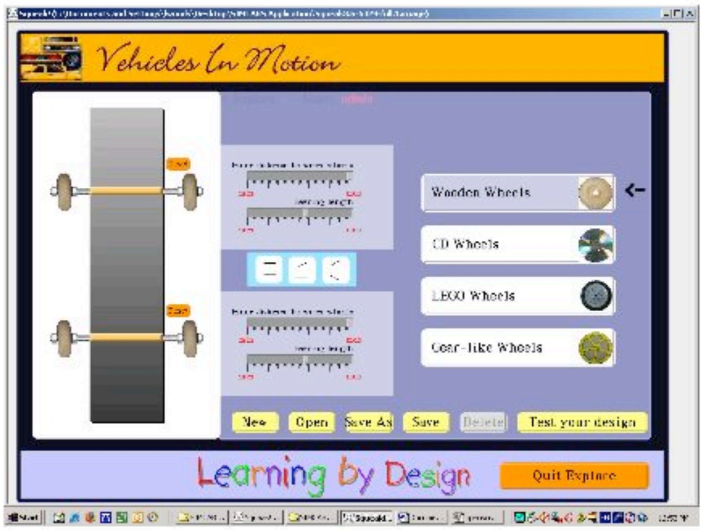
*New*

this will allow you to start designing a coaster car


4

# The different features of the car.

You may select to change *wheels types*, *length of bearings*, *distance between wheels*, and *direction of wheels*




5

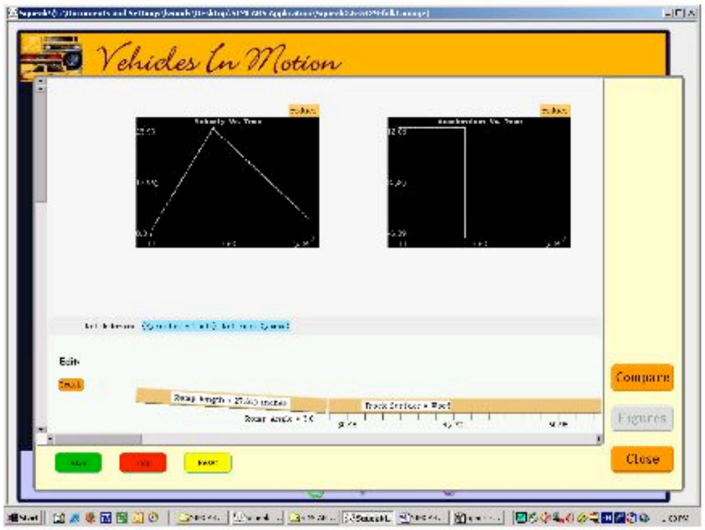
# Test you design

Push *run* to test this saved design. Wait to see the results come up on the graphs and the distance readout. Note that these are currently reported in "feet" (imperial measure) and not "meters" (metric measures).


7

# Results of your tests

Make a record of your results and answer the questions on the forms provided.




8

# Comparing Tests

Now you can test this car and any others you have saved. Push *compare*, then select another car you wish to test against the current one (last one you designed - it will be at the top).


10

# Comparing Tests

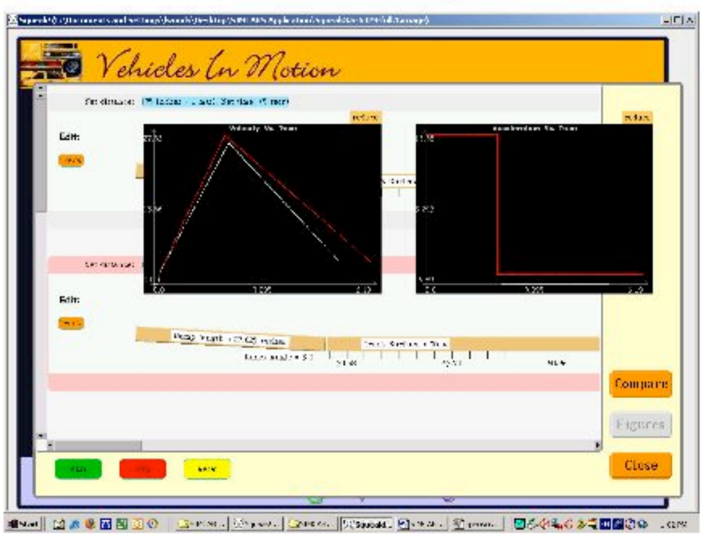
Push *run*, and you are now ready to compare your 2 designs.




---

# Comparing Tests

The graphs will show both results, grey, top car, red, bottom car. You can add more cars using the same method.



### Reading the Graphs in SIMCARS

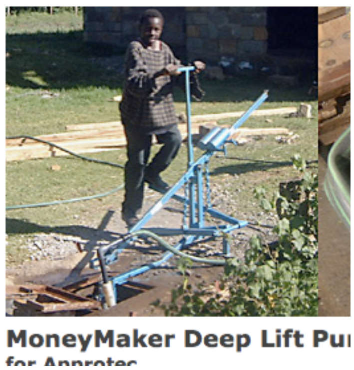
| | | |
|---|---|---|
| | **Type of Vehicle:** | |
| 1. | **State the variable you plan to test:** (variables are things that you choose to test) | |
| | **Before running your test:** | |
| 2. | **Describe what you think will happen to the velocity:** | |
| 3. | **Describe what you think will happen to the acceleration:** | |
| | **After running your test:** | |
| 4. | **Describe the velocity graph:** | |
| 5. | **Describe the acceleration graph:** | |
| 6. | **Explain the motion seen in your velocity graph to forces:** | |
| 7. | **Explain the motion seen in your acceleration graph to forces:** | |

**Hint: Try to always include the answers to these questions in your reflections.**

- What did you learn? Summarize your knowledge in a full explanation of your data.
- What is your model?
- How is the model working in this instance? i.e., what is the “mechanism” (how do the parts interact).
- How does it relate to what you already know?
- Think up another example, similar to your experiment and try to solve it as “thought experiment.”

# Project 5 - Design Challenge

Imagine you are member of a design team for the prestigious design company “IDEO”(http://www.ideo.com/). This innovative technology based company designs products from human-powered pumps for non-profit projects in Kenya, to new heat-resistant products that use chemical solutions such as BASF’s Ultrason polymer.



Many of IDEO’s clients are energy and environmental conscious companies. Your team has been asked to come up with the design for a new vehicle. The design must use non-conventional propulsion systems as well as meet other criteria (to be given later). You will have to convince the client that your design CAN work!

### **Overall Goals**:

Your overall goal for this project is to bring together (synthesize) all that you and your team have learned. You will need to use your imagination, scientific intuitions and confidence to make a proper presentation.

### **Activity**:

In order to achieve your overall goal, each team will plan the design of the best vehicle which operates within specified criteria and constraints. This will be a paper and pencil exercise including drawings and whatever media deemed appropriate. The design must be explained in terms of the physics involved and a how you plan to test the effectiveness of your design. Hint: you should be thinking of how you can create a model of this design.

## Project 5 - Notes & Drawings

# Create Your Own Glossary

a) **Acceleration**:

b) **Force**:

c) **Gravity**:

d) **Model**:

e) **Net Force**:

f) **Newton's Laws**:

- First Law:
- Second Law:
- Third Law:

g) **Speed**:

h) **Terminal Velocity**:

i) **Velocity**:

j)

k)

l)

# Glossary Continued.

**What is a Model?**

**How can I use models to help me explain physics problems?**