The Dayton Regional
STEM Center
Science, Technology, Engineering and Math

NDEP
NATIONAL DEFENSE EDUCATION PROGRAM
BUILDING AMERICAN STRENGTH IN SCIENCE AND ENGINEERING

Power & Propulsion and Air Vehicles

Compressed Air Vehicle

Grade Level: 4th

Academic Content Areas: Science, Technology, Engineering, & Mathematics

Topics: Science & Technology; Scientific Inquiry; Scientific Ways of Knowing; Geometry & Spatial Sense; Patterns, Functions, & Algebra; and Data Analysis & Probability

Recommended area of co-teaching for an AFRL Engineer or Scientist

Main Problem/Essential Question

How can balloon inflation predict the distance an air-propelled vehicle will travel?

Summary

This activity will introduce students to the use of compressed air as a means of propulsion. The goal is to allow students to discover the relationship between the amount of compressed air and the distance a vehicle is able to travel to determine the viability of compressed air for propulsion.

Jet engines, also known as ramjets operate on the same basic principle as a balloon propelled vehicle: compressed air from the atmosphere leaves the engine (as a force known as thrust) at a higher pressure (and therefore a higher speed) than the air surrounding it. A **scramjet** is a variation of a ramjet distinguished by supersonic combustion (**s**upersonic **c**ombustion **ramjet**). The scramjet essentially consists of a constricted tube through which air is collected from the atmosphere and compressed by the high speed of the vehicle; a combustion chamber through which the air flows to combust the fuel; and an exhaust nozzle to send the exhaust air out at a higher speed and temperature than the inlet air, effectively generating force/thrust. There are few or no moving parts.

Seeing its potential, organizations around the world are currently researching scramjet technology. The United States Air Force is developing supersonic ramjets and scramjets to obtain the ability to fly to China from New York in two hours; currently this takes thirteen to fifteen hours. Current research at Wright Patterson Air Force Base in this field can be explored through links provided in the additional resources section.

Students will investigate the essential question using proper tools of measurement, proper methods of recording, and maintaining the same conditions, while describing, illustrating, and evaluating the design process and then record and analyze data using a MS excel program.

Big Ideas / Focus

The release of compressed air (high pressure) from a latex balloon can propel a vehicle (when the air is released into a lower pressure environment) because it generates a force. The vehicle accelerates in the direction opposite this force (Newton's 2^{nd} Law regards motion and acceleration; Newton's 3^{rd} Law regards equal and opposite forces), or opposite the direction of the flow of released air (because every action has an opposite and equal reaction).

The more air inside the balloon at the start of deflation, the greater the acceleration and the longer the vehicle accelerates. The faster the top speed, the further the attached vehicle will travel. The amount of air in the balloon will be measured by counting the number of pump strokes pushed into the balloon by the air pump.

The force of friction between the tire/ground interface and the friction due to air resistance cause a vehicle to slow down and eventually stop because it acts opposite the direction of motion. Newton's 1^{st} Law of Motion states that, "Objects at rest will stay at rest and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force." In the case of a rolling vehicle, the object is in motion and it would stay in motion if it were not acted upon by the unbalanced force of friction between the tires and the ground.

It is important to control variables between experiments because we cannot make fair comparisons when all conditions are not kept the same.

We need to measure and record variables for replication and interpretation of our results as well as record results. A visual representation helps us form a picture in our mind that helps us interpret the meaning of the data.

Prerequisite Knowledge

Students should know how to use MS Excel to record data and create graphs; otherwise the teacher may need to assist them with this.

Standards Connections

Content Area: Science

Science and Technology Standard

Students recognize that science and technology are interconnected and that using technology involves assessment of the benefits, risks and costs. Students should build scientific and technological knowledge, as well as the skill required to design and construct devices. In addition, they should develop the processes to solve problems and understand that problems may be solved in several ways.

Grade 4: Benchmark B: Describe and illustrate the design process.	3. Describe, illustrate and evaluate the design process used to solve a problem.

Scientific Inquiry Standard

Students develop scientific habits of mind as they use the processes of scientific inquiry to ask valid questions and to gather and analyze information. They understand how to develop hypotheses and make predictions. They are able to reflect on scientific practices as they develop plans of action to create and evaluate a variety of conclusions. Students are also able to demonstrate the ability to communicate their findings to others.

Grade 4: Benchmark A: Use appropriate instruments safely to observe, measure, and collect data when conducting a scientific investigation.	1. Select the appropriate tools and use relevant safety procedures to measure and record length, weight, volume, temperature and area in metric and English units.

Grade 4: Benchmark C: Develop, design and safely conduct scientific investigations and communicate the results.	3. Develop, design and conduct safe, simple investigations or experiments to answer questions 4. Explain the importance of keeping conditions the same in an experiment. 5. Describe how comparisons may not be fair when some conditions are not kept the same between experiments.

Scientific Ways of Knowing Standard

Students realize that the current body of scientific knowledge must be base on evidence, be predictive, logical, subject to modification and limited to the natural world. This includes demonstrating an understanding that scientific knowledge grows and advances as new evidence is discovered to support or modify existing theories, as well as to encourage the development of new theories. Student are able to reflect on ethical scientific practices and demonstrate an understanding of how the current body of scientific knowledge reflects the historical and cultural contributions of women and men who provide us with a more reliable and comprehensive understanding of the natural world.

Grade 4: Benchmark C: Explain the importance of keeping records of observations and investigations that are accurate and understandable.	2. Record the results and data from an investigation and make a reasonable explanation. 4. Explain why keeping records of observations and investigation is important.

Content Area: Mathematics

Geometry and Spatial Sense Standard

Students identify, classify, compare and analyze characteristics, properties and relationships of one-, two-, and three-dimensional geometric figures and objects. Students use spatial reasoning, properties of geometric objects and transformations to analyze mathematical situations and solve problems.

Grade 4: Benchmark A. Provide rationale for groupings and comparisons of two-dimensional figures and three-dimensional objects.	2. Describe, classify, compare and model two and three-dimensional objects using their attributes.

Patterns, Functions and Algebra Standard

Students use patterns, relations and functions to model, represent and analyze problem situations that involve variable quantities. Students analyze, model and solve problems using various representations such as tables, graphs and equations.

Grade 4: Benchmark F. Construct and use a table of values to solve problems associated with mathematical relationships.	3. Construct a table of values to solve problems associated with a mathematical relationship.
Grade 4: Benchmark G. Describe how a change in one variable affects the value of a related variable.	6. Describe how a change in one variable affects the value of a related variable; e.g., as one increases the other increases or as one increases the other decreases.

Data Analysis and Probability Standard
Students pose questions and collect, organize, represent, interpret and analyze data to answer those questions. Students develop and evaluate inferences, predictions and arguments that are based on data.

Grade 4: Benchmark A. Gather and organize data from surveys and classroom experiments, including data collected over a period of time.	1. Create a plan for collecting data for a specific purpose.
Grade 4: Benchmark B. Read and interpret tables, charts, graphs (bar, picture, line, line plot), and timelines as sources of information, identify main idea, draw conclusions, and make predictions.	5. Propose and explain interpretations and predictions based on data displayed in tables, charts and graphs.
Grade 4: Benchmark C. Construct charts, tables, and graphs to represent data, including picture graphs, bar graphs, line graphs, line plots and Venn diagrams.	2. Represent and interpret data using tables, bar graphs, line plots and line graphs.

Preparation for activity
Create a classroom set of kits with the all the necessary construction materials for the balloon vehicle (enough for each group of 3-4 students to have their own)

Make necessary copies of documents for student inquiry and assessment including the
- Pre test
- Lab instructions (may also be displayed on Overhead or Electronic White Board)
- Post Test

Display the rubric/graded concepts for student access to verify assessment requirements.

Critical Vocabulary
Axis – one of two or more lines on which coordinates are measured on a graph or chart.

Distance – is the amount of space between two things or points.

Friction – is a force that resists movement between two surfaces that are touching one another.

Inflation – is to cause to swell by filling.

Intervals – at different points in time or space

Power – is a measure of the rate of the use of energy, usually to do work.

Pressure – is a force caused by one thing pushing against another.

Propulsion – is the force that moves something onward.

Thrust – is a force that propels a vehicle forward.

Wind – is the air that is moving over the earth.

Timeframe

Day	Time Allotment	Activities
1	approximately 60 minutes	Administer the pre-test. Pre-Activity discussion, demonstration, and journal writing.
2	approximately 60 minutes	Construct balloon-powered air vehicle and test it. Collect appropriate data and select the appropriate graph. Graph the collected data.
3-4	approximately 60 minutes each	Design and build a compressed air land vehicle and test it. Collect appropriate data and select the appropriate graph. Graph the collected data individually and on class graph. Group discussion and journal writing.
5	approximately 60 minutes	Re-design and modify the compressed air land vehicle and test it. Collect appropriate data and select the appropriate graph. Graph the collected data individually and on class graph.
6	approximately 60 minutes	Whole class discussion on the mathematical relationship between the balloon inflation amount and the distance each vehicle traveled; factors that affected vehicle performance; and how design improvements affected vehicle performance.
7	20 minutes	Administer the post-test.

Materials & Equipment

Vehicle Kit (1/group)
Keep in mind that it is important to control variables between experiments because we cannot make fair comparisons when all conditions are not kept the same. Therefore use of the same type/brand of materials for each group will ensure more accurate class comparisons.

2 Regular drinking straws
2 Wooden skewers
4 Plastic bottle caps (w/ pre-drilled nail-sized holes in center)
1 9” Latex Balloon
1 Small rubber band
1 16-20 oz. Plastic water bottle (with pre-cut slits)

Spool of nylon filament cord or fishing line (or provide a specific length)
Modeling clay
Duct tape or masking tape
Scissors
Balloon pump

Meter stick / tape measure
Stopwatch
Science journal

Safety & Disposal

Teacher should verify there are no students with latex allergies.

Students should use caution with scissors and the sharp end of the skewers.

Proper use of yard sticks and/or measuring tapes should be discussed with students.

Teachers Note: Pre-drilled holes in bottle caps and pre-cut slits in bottles preclude necessity of hammer, nails, and knife required in assembly instructions, steps 2 and 4.

Pre-Activity Discussion

Begin with a discussion of distance, time and rate using the specially created "Distance Finder" MS Excel program (and accompanying worksheet). Students gain an appreciation for the use of graphs as they change the variables and see the distance they could travel to various locations around the world.

Continue to harness their attention by showing the short video clip on the scramjet provided on the accompanying CD.

Release an inflated balloon in the classroom with students observing the movement and uncontrolled flight path

Open a discussion on **compressed air** as a means of **propulsion**. (i.e. How was the air harnessed? *It was held in the balloon.* How was the air used for propulsion? *When the air was allowed to escape, it pushed the balloon in the direction opposite the motion of the air.)*

Discuss how this means of propulsion (harnessed air) could be used to move things. (i.e. So far, the balloon, which held the air, is the only thing the air moved. What else could the air move, and how? *If we taped a coin to the balloon, then the air would be moving the coin*.) Perhaps lead students to consider the balloon like a zeppelin or blimp. (i.e. Consider if the coin we taped to the balloon were a basket or compartment that could hold cargo or people. Now what would you have*? An air balloon that can move but not stay suspended because it does not have hydrogen or helium. So we would have a means of propulsion, but not necessarily lift.)*

Discuss how to control the flight path of the balloon and keep it suspended without using helium or hydrogen. Set the scenario that you only want to cross the distance less than the width of the classroom. *Lead students to an idea similar to attaching a straw to the balloon, running a line through the straw, suspending the line from one end of the room to the other (or whatever distance you have determined), and releasing the inflated balloon. Once students have come up with this as a possible scenario, let them know that this will be one of the experiments that they will get to do.*

Assign journal writing homework. In your science journal describe how you, can:

1. Harness and compress air. *The air was harnessed by the balloon and it was compressed as more was added to the balloon.*

2. Use that harnessed air to propel a quarter through the air. *Tape the quarter to the inflated balloon and release it.*

3. Propel lunch money from your side of the classroom to your friend on the other side of the classroom (you have a specific target). *Tape the lunch money to the balloon, attach a straw to the balloon, run a line through the straw, suspend the line from you on one end of the room to your friend on the other side of the room, and release the inflated balloon.*

Teacher Instructions

Use of the lab worksheet in Appendix B will help lead students through the entire lab including all 3 experiments.

1. Test five different balloon inflation amounts (as determined by the number of pumps of air pushed into the vehicle) on the air vehicle experiment discussed above. *Watch to see that they are not adding extra pumps of air. If they are, question them until they understand that they should not be doing this. Do not simply tell them not to do it.*
2. Collect appropriate data to show the relationship between the number of pumps of air pushed into the balloon and the distance the air vehicle travels. *Students should record distances traveled for each balloon inflation test. Teacher must be certain each group has a minimum of 3 trials for each balloon inflation (suggestion: 1 trial per group member per inflation).*
3. Select the appropriate graph to represent the data that was collected to show the relationship between the number of pumps of air pushed into the balloon and the distance the air vehicle travels. Students should average their data and then transfer it into MS Excel. *A line graph is the best choice. The average distance from the three trials will be the data point used for graphing. The line of best fit should show a direct linear relationship. Teacher must facilitate to be certain students have created a line graph before moving on to collecting data on the land vehicle.*
4. Design and build a land vehicle that uses the release of compressed air to propel it. *Allow students the opportunity to design their own vehicle.* ***If students are unable to design a land vehicle of their own, provide them with the instructions given in the "Instructional Tips" section.***

   Teachers Note: Provide students with a list of materials readily available for use. Another alternative is that some students may want to bring in a ready-made toy vehicle and add the necessary components to it so it will be propelled by the compressed air. If needed or desired provide students with a vehicle design, (one suggested example is in the instructional tips section).
5. Collect and analyze all the necessary data to show the relationship between the number of pumps of air pushed into the balloon and the distance the land vehicle travels. *Students should record distances traveled and times for each balloon inflation Teacher must again be certain each group has a minimum of 3 trials for each balloon inflation. The average of these three trials will be the data point used for graphing.*
6. Students should record their data in the class MS excel program and plot their data on the class graph. *Teacher should have a data table and a line graph prepared and available for students to enter their data and plot their data points. This will be used in a whole group discussion to demonstrate the mathematical relationship between the number of pumps of air pushed into the balloon and the distance the land vehicle traveled.*

7. Group discussion questions: *Students should discuss these with their group and then write their own responses (in their own words) in their science journals (perhaps as homework).*

   A. How were you able to control the direction of each vehicle's movement to minimize veering astray of a straight-line forward progress versus the uncontrolled balloon flight path*? In each case, a straw was attached to the vehicle and a line was run through the straw and then suspended from one point to another to guide the vehicle along a straight line path.*

   B. Discuss the role friction played in your data and results for each vehicle. *Friction played a minor role in the air vehicle because only the line and the straw were in contact with each other. In the land vehicle, on the other hand, the friction between the wheels and the ground is added to the friction between the line and the straw. This frictional force (between the wheels and the ground) is more significant and will cause the vehicle to slow and eventually stop. Since the frictional force is greater on the land vehicle than on the air vehicle, the distances measured for each balloon inflation are not as easily comparable.*

   C. Discuss the importance of accurately measuring the balloon diameter and vehicle distance traveled. *Since the data is being graphed and used to determine a mathematical relationship, it is important to measure the balloon inflation amount and vehicle distance as accurately as possible. Accuracy makes it easier to determine the mathematical relationships and to compare data between groups.*

   D. Discuss how you could improve on the design of your land vehicle. *Student answers will vary depending on the vehicle they designed and built. This is a critical component of the lesson. Students must have the opportunity to re-design their vehicles for improvements. This is a very important part of the engineering design process.*

8. Students should discuss their improvements within their small groups and decide on which to incorporate into their land vehicle design. They should then re-design these improvements into the land vehicle and re-run the tests.

9. Collect and analyze all the necessary data to show the relationship between the amount of air pumped into the balloon and the distance the land vehicle travels. *Students should record the number of times they pumped the balloon pump. (Students may also decide to record times for each distance traveled to determine speed.) Students may decide to collect more (or different) data than they did with their first land vehicle. This is a good thing because they are not only improving their vehicle design, but also their experimental design. Teacher must again be certain each group has a minimum of 3 trials for each balloon inflation amount. The average of these three trials will be the data point used for graphing.*

10. Students should record their data in MS excel. *Teacher should have a data table and a line graph prepared and available for students to enter their data and plot their data points. This will be used in a whole group discussion to demonstrate the mathematical relationship between the inflation amount of the balloon and the distance the land vehicle traveled.*

Background Information

Jet Engine Theory – by the Aviation History On-Line Museum (http://www.aviation-history.com/engines/theory.htm)

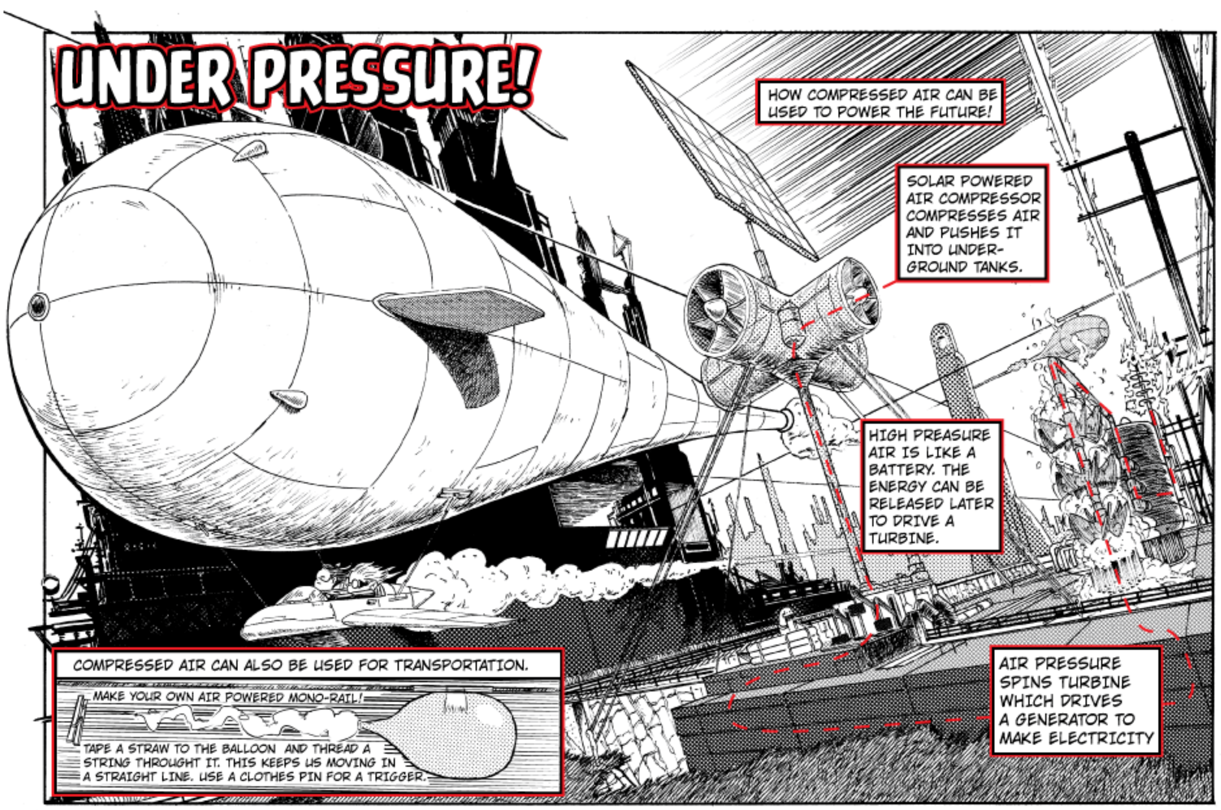
Over the course of the past half a century, jet-powered flight has vastly changed the way we all live. However, the basic principle of jet propulsion is neither new nor complicated.

Centuries ago in 100 A.D., Hero, a Greek philosopher and mathematician, demonstrated jet power in a machine called an "aeolipile." A heated, water filled steel ball with nozzles spun as steam escaped. Why? The principle behind this phenomenon was not fully understood until 1690 A.D. when Sir Isaac Newton in England formulated the principle of Hero's jet propulsion "aeolipile" in scientific terms. His Third Law of Motion stated: "Every action produces a reaction ... equal in force and opposite in direction."

The jet engine of today operates according to this same basic principle. Jet engines contain three common components: the compressor, the combustor, and the turbine. To this basic engine, other components may be added, including:

- A nozzle to recover and direct the gas energy and possibly divert the thrust for vertical takeoff and landing as well as changing direction of aircraft flight.
- An afterburner or augmenter, a long "tailpipe" behind the turbine into which additional fuel is sprayed and burned to provide additional thrust.
- A thrust reverser, which blocks the gas rushing toward the rear of the engine, thus forcing the gases forward to provide additional braking of aircraft.
- A fan in front of the compressor to increase thrust and reduce fuel consumption.
- An additional turbine that can be utilized to drive a propeller or helicopter rotor.

Here is an idea illustration from HowToons.com that relates to this activity:



http://www.howtoons.com/wp-content/uploads/2009/05/air.png

Instructional tips

Ensure that the suspended line remains taut throughout testing in order to maximize the distance the vehicle travels.

Use a small rubber band to hold the air seal where the balloon is attached to the straw.

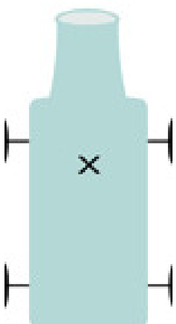
If students cannot create or find a car body of their own, here is a procedure for them to make one from a water bottle:

To be used at Teacher discretion. Taken from Home Science Tools' "Balloon Rocket Car" at http://www.hometrainingtools.com/articles/balloon-rocket-car-project.html

Teachers Note: It is recommended that the teacher prepare bottle caps as described in step 2 and cut the two necessary slits described in step 4. Tools needed for these two parts are not included in the materials list.

Procedure

The water bottle forms the chassis, or body, of your balloon car. You can start by mounting the wheels on this body.



1. Cut a drinking straw into two pieces as long as the water bottle is wide. Use strips of tape to attach them to the bottle - one near the front and one near the back. The axles for the wheels will run through these straws, so line them up carefully so the wheels won't be crooked.

2. Use a hammer and a small nail to poke holes through the center of four bottle caps. Cut two pieces of a wooden skewer about an inch-and-a-half longer than the pieces of straw you taped to the bottle. Push one end of each skewer through the hole in the center of a bottle cap. If the cap doesn't fit snugly on the skewer, use some modeling clay to hold it in place. Next, thread the skewers through the straws on the bottle and attach the other wheels to the other ends. Make sure your car rolls smoothly.

3. Stretch out a large balloon by blowing it up and then letting the air out of it a few times. Next, make a nozzle. The size of the nozzle is very important. If it is too small, the air can't escape with enough force to propel the car forward. If it is too big, the air will escape too fast and the car won't go very far. Create the nozzle by taping four drinking straws together (*one very large/ fat straw can replace these 4 straws and will minimize the escape of air between the nozzle and the balloon).* Insert the straws into the mouth of the balloon and seal the opening by wrapping a strip of duct tape around it several times.

4. To mount the balloon/nozzle on the car, use a knife to cut two perpendicular slits (to make an X) in the top of the car about 10-cm back from the mouth of the bottle. Thread the nozzle through this opening and out through the mouth of the bottle. Leave about 2-½ cm of the nozzle sticking out of the mouth.

   * *Add to the assembly a regular sized drinking straw placed parallel along underbelly of the vehicle after complete assembly. It should be attached with masking or duct tape and will serve to guide the balloon along nylon filament cord when balloon is released.*

5. Find a hard surface, like a long table, linoleum floor, or sidewalk. Blow up the balloon through the straws at the mouth of the bottle. Pinch the base of the balloon to prevent the air from escaping too soon. Set the car down, let go of the balloon, and watch it go!

Assignment of Student Roles and Responsibilities

Every student in each small group is responsible for performing experimental tests, manipulating equipment safely & properly, recording data, writing results and conclusions. In addition, each student will be assigned one of the following roles:

Role Name	Brief Description
Recorder	Responsible for the lab report, including properly documenting the recorded measurements and group answers to lab questions. Will work closely with the measurement specialist/mathematician and computer specialist.
Lead Engineer	Responsible for overseeing the construction and testing of the vehicle. Responsible for carefully completing the design steps determined by the group. Is also responsible for making sure all members of his/her group help construct the vehicle and test it.
Measurement Specialist/ Mathematician	Works directly with the recorder by carefully measuring test results and providing the measurements to the recorder. This individual is also in charge of overseeing all calculations.
Computer Specialist	In charge of data input for chart creation and analysis. Will work closely with the recorder and measurement specialist/mathematician.

Student Instructions

In your science journal describe how you can:

1. Harness and compress air.
2. Use that harnessed air to propel a quarter through the air.
3. Propel lunch money from your side of the classroom to your friend on the other side of the classroom (you have a specific target)
4. Use lab worksheet to complete assigned experiments.

Formative Assessments

Students will be working cooperatively in their groups as the teacher (facilitator) walks about the room to observe them.

Use the following rubric to assess students individually.

CATEGORY	4	3	2	1
Design Implementation **(Compare to students design diagram in experiment 2)**	The vehicle is neat, and exhibits all design details accurately.	Construction was careful and accurate but 1-2 details have been left out or incorrectly implemented.	Construction accurately followed the plans, but 3-4 details have been left out or incorrectly implemented.	Construction appears careless and many details have been left out or incorrectly implemented.

Function	Structure functions well, it holds up through distance testing. Structure shows no wear at the end of testing.	Structure functions well, it holds up through distance testing. Structure shows little wear at the end of testing.	Structure functions, but deteriorates during distance testing and requires slight modification to continue testing (e.g. piece of tape or reattach wheel).	Fatal flaws in function with complete failure under typical stresses. Multiple modifications had to be made to complete testing.
Contributions/ Team Work	Routinely provides useful ideas when participating in the group or classroom discussion. Contributes a lot of effort. A positive member of the team.	Usually provides useful ideas when participating in the group or classroom discussion. A strong group who shows effort! A positive member of the team.	Sometimes provides useful ideas when participating in the group or classroom discussion. A satisfactory group member who does only what is required. A positive member of the team.	Rarely or never provides productive ideas when participating in the group or classroom discussion. A hindrance to team performance.
Scientific Knowledge	Explanations indicate an accurate understanding of scientific principles underlying the propulsion to distance relationship (including the relationship of variables: friction, air pumps, & distance traveled).	Explanations indicate a basic understanding of scientific principles underlying the propulsion to distance relationship.	Explanations indicate an incomplete understanding as to the principles underlying the propulsion to distance relationship however student still understands there is a relationship	It is inconclusive that student understands the principles underlying the propulsion to distance relationship or that there is even a connection, however student still participated.
Diagrams	Provided an accurate labeled diagram to illustrate their design.	Provided an accurate diagram that was partially labeled to illustrate their design.	Provided diagram without labels.	Did not provide a diagram OR the diagram was quite incomplete
Data Collection & Measurement	Data was collected in a careful manner resulting in measurements within the range of acceptability.	Data was collected carelessly however measurements are still within the range of acceptability.	Data not within the range of acceptability however an attempt was made to document findings.	No data was provided.

Math Calculations (Refer to experiments 1, 2, &3)	Averages calculated were at least 90% correct.	Averages calculated were at least 80% correct.	Averages calculated were at least 70% correct.	Averages calculated were less than 70% correct.
Graphs	Students produced line graphs that correctly represented their data on all three experiments.	Students produced line graphs that correctly represented their data on at least two experiments.	Students produced graphs that were not line graphs but did correctly represent their data.	Graphs produced did not represent data collected.

Post-Activity Discussion

Discussion should include but not be limited to:

a. The mathematical relationship between the balloon inflation amount and the distance each vehicle traveled*. The line graph should be a straight diagonal line, indicating direct proportion, up to a point and then plateau out because the vehicle slows and stops*.

b. Factors that affected vehicle performance. *(i.e., friction, design/construction, air escaping prior to intended release of the balloon, and possible balloon inflation level.)*

c. How design improvements affected vehicle performance. *Student responses will vary depending on the vehicle they designed and built as well as the improvements they made to their vehicles.* This is a critical component of the lesson because it is a very important part of the engineering design process. Students need the opportunity to re-design their vehicles for improvements and the opportunity to see how effective their improvements were by re-testing. *Be sure to discuss how engineers are always improving designs and testing their re-designs.*

Pre-Test / Post-Test

Appendix A is the pre-test/post-test. Administer the first page for the pre test and both pages for the post test. Use the pre-test/post-test rubric for grading.

1. How does the release of air from inside the balloon propel the vehicle? Mention at least one of Newton's Laws of Motion in your response. *The release of tightly packed air (high pressure) generates a force that propels the vehicle (when the air is released into a lower pressure environment. The vehicle moves in the opposite direction of the flow of released air because every action has an opposite and equal reaction. This is Newton's 3rd Law.*

Teachers Note: The release of the higher pressure air generates a force. The vehicle accelerates in the opposite direction of the flow of released air because every action has an opposite and equal reaction (Newton's 3rd Law) and force divided by mass is acceleration (Newton's 2nd Law).

2. What does the amount of air in the balloon have to do with moving/propelling the vehicle? *The more strokes with the balloon pump cause more air inside the balloon and a greater pressure on that air. More compressed air inside the balloon means more air to escape providing more force to move the vehicle.*

3. Why does the vehicle stop without hitting a wall or barrier? Mention at least one of Newton's Laws of Motion in your response. *The force of friction eventually stops the vehicle. Newton's 1st Law of Motion states that, "Objects at rest will stay at rest and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force." In this case the object is in motion and it would stay in motion except that it is acted upon by the unbalanced force of friction between the tires and the ground and the air particles. The force of friction acts opposite the direction of motion, causing the vehicle to slow down and eventually stop. Newton's Law says that it will decelerate proportionally to the force and inversely proportional to the mass.*

4. Why is it important to control variables between experiments? *We cannot make fair comparisons when some conditions are not kept the same. For example, we cannot determine if the amount of air in the balloon affects vehicle travel distance if we make variances to any condition of the experiment other than the amount of air pumped into the balloon.*

5. Why is it important for us to measure and record variables such as the amount of air added to the balloon and distance traveled? *Records are important for replication and interpretation of our results. It helps us decide what we have learned from our investigation, compare our results to our peers, and communicate our findings.*

Post-Test Question only:
6. Why is it important to graph our data? *A visual representation helps us form a picture in our mind that helps us interpret the meaning of the data.*

Pre-Test / Post-Test Rubric

1. How does the release of air from inside the balloon propel the vehicle? Mention at least one of Newton's Laws of Motion in your response.

4	Response states in a clear and accurate manner that the release of compressed air in the balloon generates a force that propels the vehicle. The vehicle moves in the opposite direction of the flow of released air because every action has an opposite and equal reaction. This is Newton's 3rd Law.
3	Response states in a clear and accurate manner that the release of compressed air in the balloon generates a force that propels the vehicle. The vehicle moves in the opposite direction of the flow of released air because every action has an opposite and equal reaction.
2	Response states that the release of compressed air in the balloon generates a force that propels the vehicle. The vehicle moves in the opposite direction of the flow of released air.
1	Response states that the release of compressed air in the balloon generates a force that propels the vehicle.

2. What does the amount of air in the balloon have to do with moving/propelling the vehicle?

4	Explanation indicates a clear and accurate understanding that more pumps pushed into the balloon means more compressed air inside the balloon, thus more force to move the vehicle.
3	Explanation indicates an understanding that more pumps pushed into the balloon means more compressed air inside the balloon, thus more force to move the vehicle.
2	Explanation indicates some understanding that more pumps pushed into the balloon means more compressed air inside the balloon, thus more force to move the vehicle.

1	Explanation indicates very little understanding that more pumps pushed into the balloon means more compressed air inside the balloon, thus more force to move the vehicle.

3. Why does the vehicle stop without hitting a wall or barrier? Mention at least one of Newton's Laws of Motion in your response.

4	Response states in a clear and accurate manner that the force of friction eventually stops the vehicle because it resists the motion of the tires contacting the ground. Response includes explanation of Newton's 1st Law of Motion.
3	Response states in a clear and accurate manner that the force of friction eventually stops the vehicle because it resists the motion of the tires contacting the ground.
2	Response states that the force of friction stops the vehicle because it resists the motion of the tires contacting the ground.
1	Response states that the force of friction stops the vehicle.

4. Why is it important to control variables between experiments? Provide examples from your experiment.

4	Student correctly explains that we cannot make fair comparisons when most conditions are not kept the same; student provides examples from experiment to illustrate point.
3	Student correctly explains that we cannot make fair comparisons when most conditions are not kept the same.
2	Student explains that we cannot make fair comparisons when some conditions are not kept the same.
1	Student explains that we cannot make fair comparisons unless we keep one condition the same.

5. Why is it important for us to measure and record variables such as the amount of air added to the balloon and distance traveled?

4	Explanation indicates a clear and accurate understanding that the larger diameter means more compressed air inside the balloon, thus more force to move the vehicle.
3	Explanation indicates an understanding that the larger diameter means more compressed air inside the balloon, thus more force to move the vehicle.
2	Explanation indicates some understanding that the larger diameter means more compressed air inside the balloon, thus more force to move the vehicle.
1	Explanation indicates very little understanding that the larger diameter means more compressed air inside the balloon, thus more force to move the vehicle

6. Why is it important to graph our data? (only on post-test)

4	Student correctly explains that a visual representation helps us form a picture in our mind that helps us interpret the meaning of the data.
2	Student explains that a graph provides information but does not imply the importance of a visual representation.

Technology Connection

Integration Model	**Application Description**
Technology that supports students and teachers in **adjusting, adapting, or augmenting** teaching and learning to meet the needs of individual learners or groups of learners	Electronic White Board Projector
Technology that supports students and teachers in **dealing effectively with data**, including data management, manipulation, and display	MS Excel Meter sticks Stopwatches Printer
Technology that supports students and teachers in **simulating** real world phenomena including the modeling of physical, social, economic, and mathematical relationships	The Ramjet/Scramjet Engine by the Aviation History On-Line Museum http://www.aviation-history.com/engines/ramjet.htm
Technology that supports students and teachers in **communicating and collaborating** including the effective use of multimedia tools and online collaboration	MS Word MS Excel Printer

Interdisciplinary Connection

Literacy Connections (for concept introduction or student reading)

Adams, Adrienne. *The Great Valentine's Day Balloon Race*. New York. Charles Scribner's Sons. 1980.

Curtis, Jamie Lee. *Where Do Balloons Go?* New York. Harper Collins Publishers. 2000.

Davies, Kay. *My Balloon.* New York. Doubleday. 1990.

Owen, David. *Lighter Than Air.* Edison, NJ. Chartwell Books. 1999.

Priceman, Marjorie. *Hot Air.* New York. Antheneum Books. 2005.

Woelfle, Gretchen. *The Wind at Work: An Activity Guide to Windmills.* Chicago Review Press. 1997.

Home Connection

Students can show family members how to “do work” with their straws by attempting to move things by blowing through their straws (moving paper, change, pencils, stacked plastic cups).

Students can sign out a working model of the balloon-powered vehicle from their group to bring home. With their personalized straw, they can demonstrate for family members the inflation of the balloon, release of air, and propulsion of the vehicle. They can also explain to family members how inflating the balloon with varying amounts of air can affect the distance the vehicle will travel.

Students can have family members help them design other “vehicles” propelled by pressurized air.

Differentiated Instruction

Make focus questions into science journal questions or a class game where the teacher quizzes groups of students for the answer in order to obtain points for a reward

Vehicles can be preassembled

Inquiry can be more or less teacher-guided

Vehicles can be checked out with lab for inquiry at home

Students can be challenged to create other means of propulsion for their vehicles

Students can be challenged to create another vehicle to be used for propulsion testing

Students can construct mathematically accurate “blue prints” of their vehicle

Assessment can be group based versus individually measured

Extension

Discuss or research swamp boats that use large fans to move across the swampy surface.

Discuss or research ramjets (a jet engine with no mechanical compressor, consisting of specially shaped tubes or ducts open at both ends. The air necessary for combustion is shoved into the duct and compressed by the forward motion of the engine.) On June 15, 2007, the US Defense Advanced Research Project Agency (DARPA), in cooperation with the Australian Defense Science and Technology Organization (DSTO), announced a successful scramjet flight at Mach 10 using rocket engines to boost the test vehicle to hypersonic speeds.

You can arrange for an air force aerospace engineer or physicisit from the propulsion and power directorate, RZS to come in and talk to your students about one of these cutting edge technologies. If a visit is not an option, arrange for a teleconference or videoconference. Use article links in additional resources section, to help prepare your class for the presenter. Teachers Note: Make sure you provide your guest speaker with clear expectations of their visit including talking points and a brief overview of your student’s academic level.

Career Connection

Aeronautical engineers research and design scramjet technology.

Automotive design engineers work cooperatively as teams to design fuel efficient, high performance vehicles. They consider aerodynamics, structural materials and other factors in designing high tech automobiles for the future.

Environmental and mechanical engineers study wind and the use of wind turbines as an alternative energy source.

Researchers, scientists, mathematicians, and engineers in all fields must produce repeatable experiments in order to prove the validity of their research. Their data must be accurately recorded and easy for their peers to understand. Sharing your findings is what helps better our community!

Additional Resources

Resources	**Purpose and Application**
www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Air_Engines.html	NASA For Educators Classroom Activity, "Air Engines"
http://www.hometrainingtools.com/articles/balloon-rocket-car-project.html	Reference to detailed assembly of Home Science Tools' "Balloon Rocket Car"
http://www.eia.doe.gov/	Energy Information Administration - Government site for energy consumption in the US.
http://www.bwea.com/energy/how.html	How a wind turbine takes kinetic energy and creates electrical energy.
http://www.aviation-history.com/engines/ramjet.htm	The Ramjet/Scramjet Engine by the Aviation History On-Line Museum
http://www.time.com/time/2002/inventions/tra_scramjet.html	Time – 2002 Best Inventions: Scramjet
http://www.abc.net.au/science/slab/hyshot/default.htm	ABS News – On the Trail of the Scramjet
http://www.popsci.com/military-aviation-space/article/2007-12/hypersonic-age-near	Popular Science On-line – The Hypersonic Age is Near
http://www.futurepundit.com/archives/002019.html	An unmanned supersonic ramjet test vehicle soared to 95,000 feet and Mach 7, 2009 (about 5,000 mph)
http://www.airforcetimes.com/news/2009/05/ap_airforce_supersonic_engine_test_051109/	AF plans X-51 supersonic engine flight test. Current research in Dayton, Ohio.

Credits

Gregg Powell – Main Author
Sandra Preiss – Contributing Author, Editor
Norma Howell – Contributing Author, Editor
Emily Bowers – Contributing Author
Mary Kate Broerman – Contributing Author
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Teacher Reflection

Were students focused and on task throughout the lesson?

If not, what improvements could be made the next time this lesson is used?

Were the students led too much in the lesson or did they need more guidance?

Did the students learn what they were supposed to learn?

How do you know?

How did students demonstrate that they were actively learning?

Did you find it necessary to make any adjustments during the lesson?

What were they?

Did the materials that the students were using affect classroom behavior or management?

What were some of the problems students encountered when using the …?

Are there better items that can be used next time?

Which ones worked particularly well?

Additional Comments

Appendix A: Test

NAME ______________________________

DATE ______________________________

1. How does the release of air from inside the balloon propel the vehicle? (Mention at least one of Newton's Laws of Motion in your response.)

2. What does the amount of air in the balloon have to do with moving/propelling the vehicle?

3. Why does the vehicle stop without hitting a wall or barrier? (Mention at least one of Newton's Laws of Motion in your response.)

4. Why is it important to control variables between experiments?

5. Why is it important for us to measure and record variables such as the amount of air added to the balloon and distance traveled?

6. Why is it important to graph our data?

Appendix B: Compressed Vehicle Lab

NAMES ____

____

DATE __________________________________

Directions: Complete the following questions and steps.

1. How can compressed air be used as a means of propulsion?

____

____

____

Experiment 1: Balloon Powered Air Vehicle

Attach a straw to the balloon.

Run a string through the straw.

Suspend the string from two teacher-determined points in the classroom. (Hint: make sure the string is taut)

Test 5 different amounts of air pumps and track the distance traveled. (Use the table below to record your findings.)

# of Pumps	Distance in Trial 1	Distance in Trial 2	Distance in Trial 3

Average your data for each # of pumps (Use the table below to record your calculations.)

# of Pumps	Average Distance

Use the table above to create a graph in Microsoft Excel to show the relationship between number of pumps and the average distance traveled. (Hint: You must first decide what type of graph you will create).

2. I will create a ____ graph.

Print graph and attach to this lab packet.

Experiment 2: Compressed Air Land Vehicle

Use the space below to design a land vehicle that uses the release of compressed air to propel it. (Hint: Use only materials that your teacher lists as possible supplies.)

Label your design.

Build your design.

Test 5 different amounts of air pumps and track the distance traveled. (Use the table below to record your findings.)

# of Pumps	Distance in Trial 1	Distance in Trial 2	Distance in Trial 3

Average your data for each # of pumps (Use the table below to record your calculations.)

# of Pumps	Average Distance

Use the table above to create a graph in Microsoft Excel to show the relationship between number of pumps and the average distance traveled. (Hint: You must first decide what type of graph you will create).

3. I will create a ____ graph.

Print graph and attach to this lab packet.

Experiment 3: Redesign Compressed Air Land Vehicle

Use the space below to redesign your land vehicle. (Hint: Use only materials that your teacher lists as possible supplies.)

Label your design.

4. What changes will you make and why?

____

____

____

____

Build your design.

Test 5 different amounts of air pumps and track the distance traveled. (Use the table below to record your findings.)

# of Pumps	Distance in Trial 1	Distance in Trial 2	Distance in Trial 3

Average your data for each # of pumps (Use the table below to record your calculations.)

# of Pumps	Average Distance

Use the table above to create a graph in Microsoft Excel to show the relationship between number of pumps and the average distance traveled. (Hint: You must first decide what type of graph you will create).

Print graph and attach to this lab packet.

5. I will create a ____ graph.

6. What variable affected the distance the vehicle traveled?

____

____