HOT-AIR BALLOONS

Teacher's Guide

STEM Curriculum for Hot-Air Balloons

PITSCO EDUCATION

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Creativity *Critical Thinking* *Communication* *Collaboration* *Back to Last Page Viewed* *Table of Contents*

WARNING: CHOKING HAZARD – Children under age 8 can choke or suffocate on uninflated or broken balloons. Adult supervision required. Keep uninflated balloons from children. Discard broken balloons at once.

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Activity Overview

Using the provided kit materials, students construct a hot-air balloon.

The *Hot-Air Balloons Teacher's Guide* contains both basic and advanced lesson plans. Basic lesson plans provide a more guided approach to instruction while advanced lesson plans are more open-ended. All lesson plans can be used to extend students' understanding of science, technology, engineering, and math concepts using the hot-air balloon.

Resource materials are provided to supplement students' understanding of core content. Resources include vocabulary, assessments, and content fact sheets.

Materials

This section lists required or optional materials and equipment for activities found in this guide. The first section lists materials and equipment needed for all activities. The second section lists optional materials and equipment, including class packs for replenishing consumables. If you are planning to complete only select activities, refer to the materials list located in each activity. Links are provided to Pitsco products for your convenience and offer at least one option. Other options might be available; to explore them, use the search box on Pitsco.com.

All Materials and Equipment Needed for All Activities

- Zoon Hot-Air Balloons – Getting Started Package: Pitsco.com/Hot-Air-Balloons-Getting-Started-Package
    - *Adventures in Lighter-Than-Air Flight* book: Pitsco.com/Adventures-in-Lighter-Than-Air-Flight
    - *Hot-Air Balloon* video: Pitsco.com/Hot-Air-Balloon-Video
    - Inflation Station: Pitsco.com/The-Inflation-Station-Hot-Air-Balloon-Launcher
    - Zoon Hot-Air Balloons: Pitsco.com/Hot-Air-Balloons-Getting-Started-Package
        - Glue sticks: Pitsco.com/Glue-Stic
        - Gore templates: Pitsco.com/Gore-Pattern
        - Mouth templates
        - Paper clips: Pitsco.com/Paper-Clips-Jumbo
        - Tissue paper: Pitsco.com/Tissue-Paper
        - *Zoon Balloon User Guides*: Pitsco.com/hot-air-balloons-getting-started-package#resources
- Calculator: Pitsco.com/Calculator-Sharp-EL-500
- Container large enough for water and inflated balloon
- Digital scale: Pitsco.com/CJ600-Digital-Scale
- Graph paper: Pitsco.com/Graph-Paper
- Ice water
- Latex balloons: Pitsco.com/Balloons
- Marker: Pitsco.com/Sharpie-Fine-Point-Markers
- Notebook
- Paper
- Pencil
- Propane canister: Pitsco.com/Propane-Canister-for-Balloon-Launcher
- Ruler: Pitsco.com/12-Flexible-Stainless-Steel-Ruler
- Scissors: Pitsco.com/Super-Sharp-Scissors-8
- Stapler: Pitsco.com/Stapler-Desktop
- Stopwatch: Pitsco.com/Pro-Survivor-Stopwatch
- Tape: Pitsco.com/Transparent-Tape
- Tape measure: Pitsco.com/30-Meter-Wind-Up-Tape-Measure
- Thermometer or thermocouple: Pitsco.com/Waterproof-Thermometer

Optional Materials and Equipment

- Gore pattern paper: Pitsco.com/Gore-Pattern
- Indoor Balloon Tester: Pitsco.com/Indoor-Balloon-Tester
- Modeling clay: Pitsco.com/Modeling-Clay

Activities with the following icons include opportunities for students to apply 21st-century skills in communication, collaboration, critical thinking, and creativity. If time is available, you might choose to focus on these skills in conjunction with the activities. These icons will appear in the Procedure sections of the Teacher Instruction. Additional icons might appear in the Note section that suggest how an additional skill can be addressed in the activity.

Communication	Sharing thoughts, questions, ideas, and solutions. Indicators: • Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts • Listen effectively to decipher meaning, including knowledge, values, attitudes and intentions • Use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade) • Utilize multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact • Communicate effectively in diverse environments (including multi-lingual)
Collaboration	Working together to reach a goal – putting talent, expertise, and smarts to work. Indicators: • Demonstrate ability to work effectively and respectfully with diverse teams • Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal • Assume shared responsibility for collaborative work, and value the individual contributions made by each team member
Critical Thinking	Looking at problems in a new way, linking learning across subjects and disciplines. Indicators: **Reason Effectively** • Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation **Use Systems Thinking** • Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems **Make Judgments and Decisions** • Effectively analyze and evaluate evidence, arguments, claims and beliefs • Analyze and evaluate major alternative points of view • Synthesize and make connections between information and arguments • Interpret information and draw conclusions based on the best analysis • Reflect critically on learning experiences and processes **Solve Problems** • Solve different kinds of non-familiar problems in both conventional and innovative ways • Identify and ask significant questions that clarify various points of view and lead to better solutions
Creativity	Trying new approaches to get things done equals innovation and invention. Indicators: **Think Creatively** • Use a wide range of idea creation techniques (such as brainstorming) • Create new and worthwhile ideas (both incremental and radical concepts) • Elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts **Work Creatively with Others** • Develop, implement and communicate new ideas to others effectively • Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work • Demonstrate originality and inventiveness in work and understand the real-world limits to adopting new ideas • View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes **Implement Innovations** • Act on creative ideas to make a tangible and useful contribution to the field in which the innovation will occur

Source: Partnership for 21st Century Skills: Pitsco.com/c-4cs-research

Standards Addressed

Standards were taken from the International Technology and Engineering Educators Association (ITEEA), the Next Generation Science Standards (NGSS), and the Common Core State Standards (CCSS).

NGSS

NGSS.MS.SPM Structure and Properties of Matter

NGSS.MS-PS1-4
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

NGSS.MS.FI Forces and Interactions

NGSS.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.

NGSS.MS-PS2-4
Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

NGSS.MS.E Energy

NGSS.MS-PS3-1
Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

NGSS.MS.ED Engineering Design

NGSS.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.

NGSS.MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

NGSS.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.

NGSS.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.

CCSS.MATH

Grade 6

CCSS.MATH.CONTENT.6.RP.A
Understand ratio concepts and use ratio reasoning to solve problems.

> CCSS.MATH.CONTENT.6.RP.A.1
> Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
>
> CCSS.MATH.CONTENT.6.RP.A.3
> Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.
>
>> CCSS.MATH.CONTENT.6.RP.A.3.C
>> Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means 30/100 times the quantity); solve problems involving finding the whole, given a part and the percent.
>>
>> CCSS.MATH.CONTENT.6.RP.A.3.D
>> Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.

CCSS.MATH.CONTENT.6.NS.B
Compute fluently with multi-digit numbers and find common factors and multiples.

CCSS.MATH.CONTENT.6.NS.B.2
Fluently divide multi-digit numbers using the standard algorithm.

CCSS.MATH.CONTENT.6.NS.B.3
Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation.

CCSS.MATH.CONTENT.6.NS.C
Apply and extend previous understandings of numbers to the system of rational numbers.

CCSS.MATH.CONTENT.6.NS.C.6
Understand a rational number as a point on the number line. Extend number line diagrams and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates.

CCSS.MATH.CONTENT.6.NS.C.6.C
Find and position integers and other rational numbers on a horizontal or vertical number line diagram; find and position pairs of integers and other rational numbers on a coordinate plane.

CCSS.MATH.CONTENT.6.NS.C.8
Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

CCSS.MATH.CONTENT.6.EE.A
Apply and extend previous understandings of arithmetic to algebraic expressions.

CCSS.MATH.CONTENT.6.EE.A.1
Write and evaluate numerical expressions involving whole-number exponents.

CCSS.MATH.CONTENT.6.EE.A.2
Write, read, and evaluate expressions in which letters stand for numbers.

CCSS.MATH.CONTENT.6.EE.A.2.C
Evaluate expressions at specific values of their variables. Include expressions that arise from formulas used in real-world problems. Perform arithmetic operations, including those involving whole-number exponents, in the conventional order when there are no parentheses to specify a particular order (Order of Operations).

CCSS.MATH.CONTENT.6.EE.C
Represent and analyze quantitative relationships between dependent and independent variables.

CCSS.MATH.CONTENT.6.EE.C.9
Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

CCSS.MATH.CONTENT.6.G.A
Solve real-world and mathematical problems involving area, surface area, and volume.

CCSS.MATH.CONTENT.6.G.A.4
Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems.

CCSS.MATH.CONTENT.6.SP.A
Develop understanding of statistical variability.

CCSS.MATH.CONTENT.6.SP.A.1
Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.

CCSS.MATH.CONTENT.6.SP.A.2
Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

CCSS.MATH.CONTENT.6.SP.B
Summarize and describe distributions.

CCSS.MATH.CONTENT.6.SP.B.4
Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

CCSS.MATH.CONTENT.6.SP.B.5
Summarize numerical data sets in relation to their context, such as by:

CCSS.MATH.CONTENT.6.SP.B.5.A
Reporting the number of observations.

CCSS.MATH.CONTENT.6.SP.B.5.B
Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.

CCSS.MATH.CONTENT.6.SP.B.5.C
Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

Grade 7

CCSS.MATH.CONTENT.7.RP.A
Analyze proportional relationships and use them to solve real-world and mathematical problems.

CCSS.MATH.CONTENT.7.RP.A.2
Recognize and represent proportional relationships between quantities.

CCSS.MATH.CONTENT.7.RP.A.2.A
Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.

CCSS.MATH.CONTENT.7.RP.A.2.C
Represent proportional relationships by equations.

CCSS.MATH.CONTENT.7.NS.A
Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers.

CCSS.MATH.CONTENT.7.NS.A.1
Apply and extend previous understandings of addition and subtraction to add and subtract rational numbers; represent addition and subtraction on a horizontal or vertical number line diagram.

CCSS.MATH.CONTENT.7.NS.A.1.D
Apply properties of operations as strategies to add and subtract rational numbers.

CCSS.MATH.CONTENT.7.NS.A.2
Apply and extend previous understandings of multiplication and division and of fractions to multiply and divide rational numbers.

CCSS.MATH.CONTENT.7.NS.A.2.C
Apply properties of operations as strategies to multiply and divide rational numbers.

CCSS.MATH.CONTENT.7.NS.A.3
Solve real-world and mathematical problems involving the four operations with rational numbers.

CCSS.MATH.CONTENT.7.EE.B
Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

CCSS.MATH.CONTENT.7.EE.B.4
Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

CCSS.MATH.CONTENT.7.EE.B.4.A
Solve word problems leading to equations of the form $px + q = r$ and $p(x + q) = r$, where p, q, and r are specific rational numbers. Solve equations of these forms fluently. Compare an algebraic solution to an arithmetic solution, identifying the sequence of the operations used in each approach.

CCSS.MATH.CONTENT.7.G.A
Draw, construct, and describe geometrical figures and describe the relationships between them.

CCSS.MATH.CONTENT.7.G.A.1
Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.

CCSS.MATH.CONTENT.7.G.A.2
Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.

CCSS.MATH.CONTENT.7.G.A.3
Describe the two-dimensional figures that result from slicing three-dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids.

CCSS.MATH.CONTENT.7.G.B
Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

CCSS.MATH.CONTENT.7.G.B.6
Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

CCSS.MATH.CONTENT.7.SP.A
Use random sampling to draw inferences about a population.

CCSS.MATH.CONTENT.7.SP.A.1
Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

CCSS.MATH.CONTENT.7.SP.A.2
Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions.

CCSS.MATH.CONTENT.7.SP.B
Draw informal comparative inferences about two populations.

CCSS.MATH.CONTENT.7.SP.B.3
Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability.

CCSS.MATH.CONTENT.7.SP.B.4
Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations.

Grade 8

CCSS.MATH.CONTENT.8.EE.B
Understand the connections between proportional relationships, lines, and linear equations.

CCSS.MATH.CONTENT.8.EE.B.5
Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways.

CCSS.MATH.CONTENT.8.F.A
Define, evaluate, and compare functions.

CCSS.MATH.CONTENT.8.F.A.1
Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output.

CCSS.MATH.CONTENT.8.F.A.2
Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

CCSS.MATH.CONTENT.8.F.B
Use functions to model relationships between quantities.

CCSS.MATH.CONTENT.8.F.B.4
Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

CCSS.MATH.CONTENT.8.G.C
Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres.

CCSS.MATH.CONTENT.8.G.C.9
Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.

CCSS.MATH.CONTENT.8.SP.A
Investigate patterns of association in bivariate data.

CCSS.MATH.CONTENT.8.SP.A.1
Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

CCSS.MATH.CONTENT.8.SP.A.2
Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.

ITEEA

ITEEA.9.H
Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.

ITEEA.11.H
Apply a design process to solve problems in and beyond the laboratory-classroom.

ITEEA.11.L
Make a product or system and document the solution.

ITEEA.13.F
Design and use instruments to gather data.

Construction Quick View

Students use kit materials to construct a hot-air balloon following the steps below.

Note: This Construction Quick View is based on the use of Pitsco's Dr. Zoon Hot-Air Balloon Kit. If using a different kit or materials, please alter these directions as necessary.

Materials

- Tissue paper
- Glue stick
- Tape measure/ruler
- Gore template
- Scissors
- Paper clips
- Mouth template
- Stapler

Construction

1. Locate six pieces of 20" x 30" tissue paper and a glue stick.
2. Lay one piece of tissue paper on a flat surface and make a line of glue 1/2" wide along one edge of its 30" sides. Take another piece of tissue paper and overlap the line of glue with one of its 30" sides. Be sure to press firmly to seal the papers together. Avoid gaps where air might escape. The result should be one large sheet of tissue paper (30" x 39-1/2") (Figure 1).
3. Repeat Steps 1 and 2 two more times. There should be a total of three large sheets of tissue paper.
4. Stack the three sheets on top of one another. Align the corners and sides. Fold the sheets lengthwise to create a rectangle measuring 15" x 39-1/2". Once again, align the corners and sides (Figure 2).
5. Fold the sheets lengthwise again to create a rectangle measuring 7-1/2" x 39-1/2". Set these folded sheets aside (Figure 3).
6. Locate the four sheets of paper in the Zoon Hot-Air Balloon Kit labeled A, B, C, and D. These pages are the gore template. Align the sheets in alphabetical order, lengthwise. On Sheets B, C, and D, trim the excess paper from Edges 2, 4, and 6. Take Sheet B and overlap Sheet A until the pattern is lined up. Glue the two sheets together at the overlap. Glue Sheet C to AB and Sheet D to ABC (Figure 4). Cut out the pattern along the lines on the curved outside edges of Sheets A, B, C, and D.

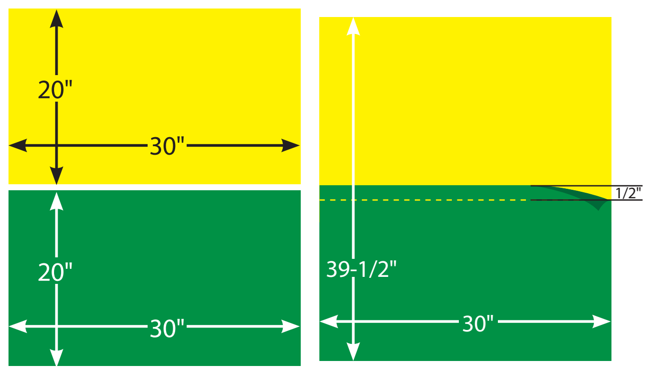


Figure 1

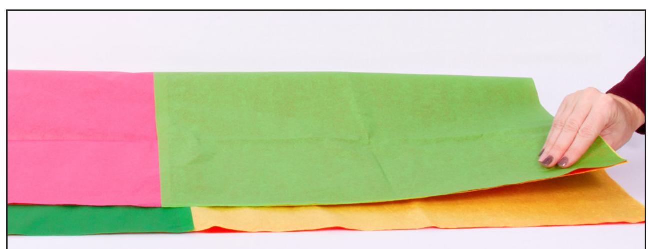


Figure 2

Figure 3

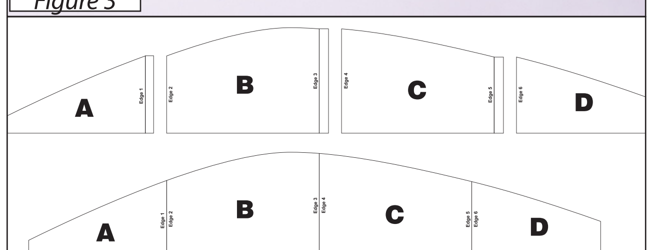


Figure 4

7. Locate the three paper clips, the folded tissue paper sheets, and the gore template. Align the flat edge of the gore template to the tissue paper along the side that has one long fold and no free edges. Attach using the three paper clips (Figure 5). Hold the template and the tissue paper firmly and cut the paper around the curved edge of the template. Do not cut along the edge with the paper clips. Save the excess tissue paper to repair tears in the balloon.
8. Remove the paper clips and the template. Unfold the gores while keeping them stacked together. There should be six gores. Some of the gores might be slightly larger than others. Size differences are acceptable as long as they are minor.
9. Set the stacked gores lengthwise in front of you. Take the top gore and slide it straight up 1/2". On the gore that was just moved, make a line of glue 1/2" wide along the bottom edge (the edge closest to you) (Figure 6).
10. Beginning at the center of the edge, fold 1/2" of the bottom edge of the second gore up and over the bottom of the first gore you just glued, fastening the two pieces together. Press firmly when gluing seams to ensure a tight seal. Apply more glue if needed. A tight seal will prevent air leaks. Do not overlap the gores more than 1/2".
11. Fold the top edge of the top gore down to the bottom edge, thus folding it in half without pressing the crease (Figure 7).
12. Slide the second gore straight down 1/2". On the gore you just moved, make a line of glue 1/2" wide along the top edge (the edge farthest from you). Beginning at the center of the edge, fold 1/2" of the top edge of the third gore down and over the top of the second gore, fastening the two pieces together (Figure 8).
13. Take the seam between the first and second gores and fold it up to the seam between the second and third gores. Once again, do not press the crease.
14. Repeat Steps 10-13 to fasten the remaining gores to one another. Do not fasten Gore 1 and Gore 6 to one another. For now, leave these two edges free.
15. Pick up the folded balloon, unfold it, and turn it inside out. Using the same process as before, glue the remaining two free edges together (Figure 9).
16. Locate the excess tissue paper. Take a large piece of the scrap paper and cut a 6" circle (Figure 10).

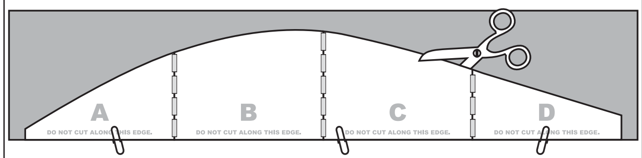


Figure 5

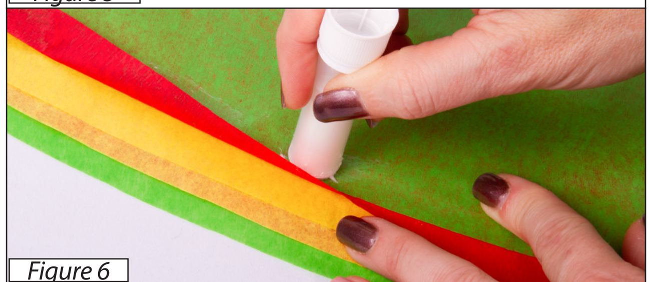


Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

17. There should be two holes in the balloon. The smaller hole is the top and the bigger hole is the bottom. Use a glue stick to completely cover the outer 2" of the circle with glue. Put one hand inside the balloon through the bottom. With the other hand, take the circle and press it over the hole at the top of the balloon. Ensure there is a tight seal (Figure 11). It is acceptable if the cap is not smooth as long as there are no gaps along the seams.
18. Locate the balloon mouth pattern and cut along the two lines labeled "Cut line." Overlap the pieces at the narrow ends 1/2" and attach the pieces together using glue or tape. Fold the entire length of the joined pieces at the fold line (Figure 12).
19. Insert the bottom of the balloon into the folded strip and staple the strip to the balloon (Figure 13). Staple approximately every 2". Overlap the ends of the strip if necessary.
20. Check all the gore seams and add more glue to any that are not sealed. You have completed a Zoon Balloon!


Figure 11

Figure 12


Figure 13

Teaching Tips

Safety

- Supervise students while the launcher is lit.
- Do not touch the grill near the chimney while the launcher is lit. It can be very hot.
- Do not lean over the launcher while it is lit. Clothing or hair could singe or ignite.
- Keep hands and fingers away from the direct blast of hot air coming from the mouth of the The Inflation Station – Hot-Air Balloon Launcher.
- Keep a fire extinguisher within easy reach when operating launcher.
- Store propane canisters away from sources of heat and sparks.
- Keep tissue paper away from the hot-air exhaust. Balloon tissue paper is flammable.
- Operate the launcher outdoors only.
- Keep students at least 10 feet from the launcher unless they are launching the balloon.
- Use low-profile propane canisters as they are more stable while sitting on the ground.

Construction Tips/Helpful Hints

- Press firmly when gluing seams to ensure a tight seal. A tight seal will prevent air leaks.
- Keep excess tissue paper to repair tears in the balloon.
- Some of the gores might be slightly larger than others. Size differences are acceptable as long as they are minor.
- Before gluing the seams of the gores, double-check the order of the colors to ensure this is the desired order. If necessary, rotate and flip the gores over to achieve the desired order.
- When gluing the gores, smooth the pieces as much as possible to create the best possible seal. Apply more glue if needed.
- Do not overlap the gores more than 1/2" as this will decrease the size of the bottom hole in the balloon and might prevent the launch.
- The cap of the balloon can be difficult to glue to the body of the balloon. If the cap is not smooth, it is acceptable as long as there are no gaps along the seams.
- The Inflation Station requires some assembly and must be completed prior to use. When assembling, double-check that all components are included and that all components fit together as instructed.
- When launching, place the launcher away from trees, structures, and power lines.
- An Indoor Balloon Tester is useful for testing the balloons indoors before launching them outside with the Indoor Balloon Launcher.
- To launch the balloon indoors, find a cool room with a high ceiling.
- Plug in Pitsco's Indoor Balloon Tester and let it run a couple minutes to warm up.
- Keep hands, fingers, and any other body parts away from the direct blast of hot air coming from the mouth of the Indoor Balloon Tester. Hold the mouth of the balloon over the tester for three to four minutes.
- Observe the seams of the balloons, looking for any gaps that need to be repaired. Release the mouth of the balloon and watch as it rises.
- Due to the high cost of shipping compressed gas, consider purchasing the propane fuel locally – anywhere that camping equipment is sold.

Troubleshooting

- If the balloon will not rise, check for gaps and tears. Make repairs if needed using glue and excess tissue paper.
- If the balloon will not rise after repairs have been made, check the temperature outside. The air must be much cooler than the air used to fill the balloon. If the temperature difference is not great enough, the balloon's weight might be too great for the warm air to rise.
- Before launching, check for gaps and tears. The balloon may be launched repeatedly. Be sure to check for tears and gaps after each launch. Repair any damage before launching the balloon again.
- Keep the balloon and tissue paper away from moisture or liquid of any kind. If the paper gets wet, it will disintegrate.
- Do not launch on rainy or foggy days.
- Be sure to let the launcher run a minute or two to warm up.
- Hold the mouth of the balloon over the launcher for three to four minutes to allow enough hot air to fill the balloon.

Quick View

Students design a hot-air balloon using a specified amount of material.

Time Required

45-90 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

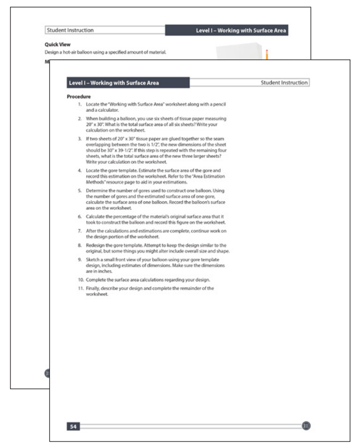
Vocabulary

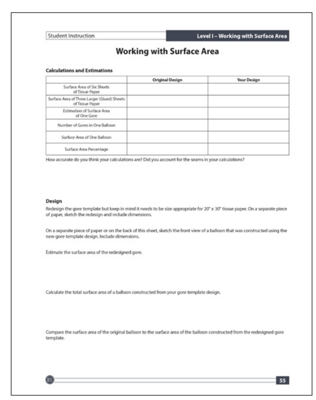
Glossary: Pitsco.com/c/hab-glossary.pdf

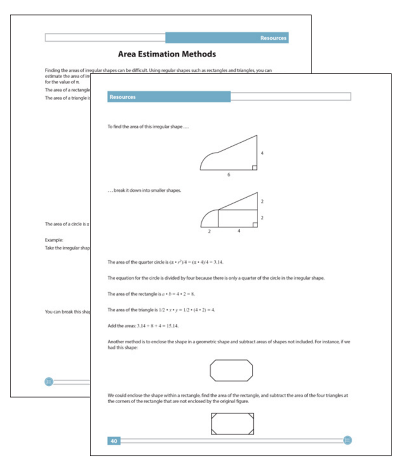
- design
- estimation
- gore
- surface area

Materials

- Paper
- Pencil
- Calculator
- Gore templates
- “Working with Surface Area” worksheet: Pitsco.com/c/hab-sp1.pdf
- “Area Estimation Methods” resource page: Pitsco.com/c/area-estimation.pdf
- Working with Surface Area Student Instruction: Pitsco.com/c/hab-sp3.pdf







Procedure

1. Locate the "Working with Surface Area" worksheet along with a pencil and a calculator.
2. When building a balloon, you use six sheets of tissue paper measuring 20" x 30". What is the total surface area of all six sheets? Write your calculation on the worksheet.
3. If two sheets of 20" x 30" tissue paper are glued together so the seam overlapping between the two is 1/2", the new dimensions of the sheet should be 30" x 39-1/2". If this step is repeated with the remaining four sheets, what is the total surface area of the new three larger sheets? Write your calculation on the worksheet.
4. Locate the gore template. Estimate the surface area of the gore and record this estimation on the worksheet. Refer to the "Area Estimation Methods" resource page to aid in your estimations.
5. Determine the number of gores used to construct one balloon. Using the number of gores and the estimated surface area of one gore, calculate the surface area of one balloon. Record the balloon's surface area on the worksheet.
6. Calculate the percentage of the material's original surface area that it took to construct the balloon and record this figure on the worksheet.
7. After the calculations and estimations are complete, continue work on the design portion of the worksheet.
8. Redesign the gore template. Attempt to keep the design similar to the original, but some things you might alter include overall size and shape.
9. Sketch a small front view of your balloon using your gore template design, including estimates of dimensions. Make sure the dimensions are in inches.
10. Complete the surface area calculations regarding your design.
11. Finally, describe your design and complete the remainder of the worksheet.

Note: (2) Be sure students understand the concept of area and the correct units used to measure area – inches squared.

Note: (4) The students might need to refer to the Construction Quick View to understand the construction process of creating a balloon, especially the folding steps prior to cutting out the gores.

Note: (7) Surface area calculations and estimations should be in inches squared unless students are working in metric. Then, units should be in centimeters squared.

Note: (9) Sketches can be freehand and the dimensions should be labeled correctly.

Note: (11) Grammar and punctuation need to meet grade-appropriate levels.

Quick View

Students construct and launch a balloon while analyzing the balloon's flight.

Time Required

90-180 minutes (will vary with class size)

Content Areas

Primary: Math

Secondary: Science, technology, language arts

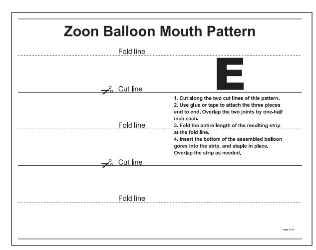
Vocabulary

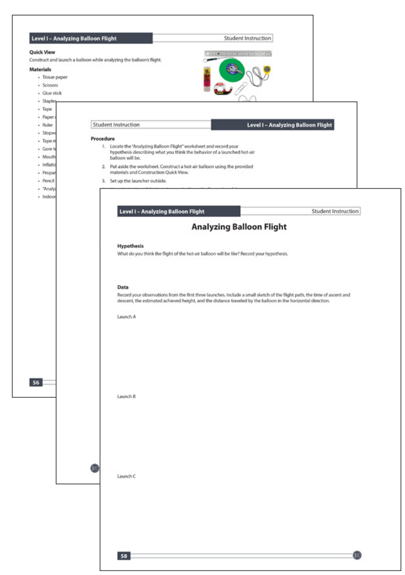
Glossary: Pitsco.com/c/hab-glossary.pdf

- analyze
- ascent
- descent
- flight
- gore
- hypothesis

Materials

- Tissue paper
- Scissors
- Glue stick
- Stapler
- Tape
- Paper clips
- Ruler
- Stopwatch
- Tape measure
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- "Analyzing Balloon Flight" worksheet: Pitsco.com/c/hab-sp4.pdf
- Analyzing Balloon Flight Student Instruction: Pitsco.com/c/hab-sp5.pdf
- Indoor Balloon Tester (optional)





Procedure

1. Locate the "Analyzing Balloon Flight" worksheet and record your hypothesis describing what you think the behavior of a launched hot-air balloon will be.

Note: (1) Middle school students should understand hypotheses. However, you might wish to explain that a hypothesis is a prediction based on prior knowledge or experience.

2. Put aside the worksheet. Construct a hot-air balloon using the provided materials and Construction Quick View.

Note: (2) It is a good idea to make several copies of the gore templates and mouth template so there are enough for all participants.

Using an Indoor Balloon Tester will enable students to test their balloons and make sure they are ready for an outside launch.

3. Set up the launcher outside.

Note: (3) Ideal conditions for a launch include little to no wind, no precipitation, and cool temperatures.

4. Have the igniter of the launcher ready. Open the flow valve of the propane canister until you can hear gas escaping. Squeeze the trigger of the igniter to light the gas within the launcher. Be sure to squeeze it in the center and not the top of the trigger. If the launcher does not light, open the flow valve more and try again. When it lights, push the Lock button above the trigger.

Note: (4) Be sure to caution students about keeping fingers away from the hot metal parts of the launcher and out of the flow of hot air directly over the launcher.

5. Open the flow valve completely after the gas ignites. Guide the balloon over the inflation guides.

Note: (5) Students might need to guide the mouth of the balloon over the tops of the inflation guides.

Keep the balloon approximately one inch from the top of the launcher with one hand holding the bottom and the other holding up the top of the balloon. A second person can help hold up the top of the balloon. If the balloon is too big for students to hold up, assist them.

6. Continue holding the balloon until it contains enough hot air to keep its shape.

Note: (6) Inflation times will vary depending on temperature and balloon size. Encourage the students to be patient.

7. When the pull from the hot air is steady and strong, release the balloon into the air.

8. Observe the flight and record your observations on the worksheet. Some of these observations need to include the overall flight path, the time of ascent, the time of descent, the greatest height the balloon achieves, and the distance the balloon travels from the launcher in the horizontal direction.

Note: (8) Students might need the help of a classmate to time the ascent and the descent and to observe the flight in general. The greatest height the balloon achieves can be estimated by comparing it to the height of objects around the launch, such as a tree or the height of a building. The distance traveled can be determined by using a tape measure.

9. Launch the balloon twice more. Record the observations for each launch.
10. When finished with the launches, completely shut off the flow valve of the propane canister and disconnect the propane from the launcher.
11. Complete the remainder of the worksheet.

Quick View

Students investigate various forces acting on a balloon throughout a launch.

Time Required

90-180 minutes (will vary with class size)

Content Areas

Primary: Science

Secondary: Math, technology, language arts

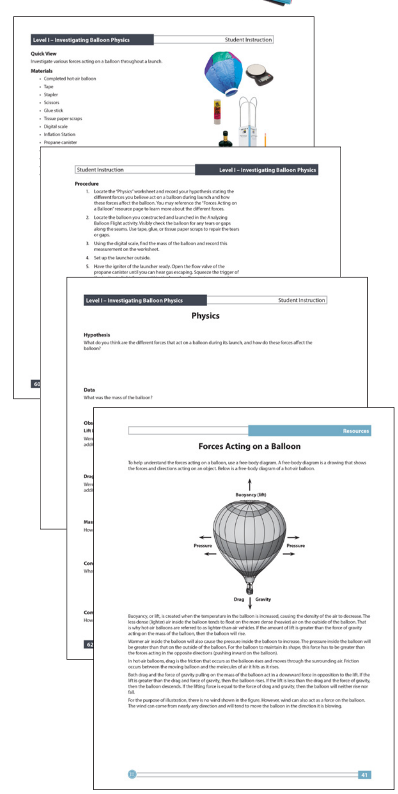
Vocabulary

Glossary: Pitsco.com/c/hab-glossary.pdf

- buoyancy
- density
- displacement
- drag
- force
- gore
- gravity
- hypothesis
- lift
- pressure
- seam

Materials

- Completed hot-air balloon
- Tape
- Stapler
- Scissors
- Glue stick
- Tissue paper scraps
- Digital scale
- Inflation Station
- Propane canister
- Pencil
- "Physics" worksheet: Pitsco.com/c/hab-sp7.pdf
- "Forces Acting on a Balloon" resource page: Pitsco.com/c/forces-balloon.pdf
- Investigating Balloon Physics Student Instruction: Pitsco.com/c/hab-sp6.pdf
- Indoor Balloon Tester (optional)



Procedure

The students are going to make necessary repairs and reuse the balloon they constructed for the Analyzing Balloon Flight activity. Due to this, this activity would be most effective if completed after the Analyzing Balloon Flight activity.

1. Locate the "Physics" worksheet and record your hypothesis stating the different forces you believe act on a balloon during launch and how these forces affect the balloon. You may reference the "Forces Acting on a Balloon" resource page to learn more about the different forces.
2. Locate the balloon you constructed and launched in the Analyzing Balloon Flight activity. Visibly check the balloon for any tears or gaps along the seams. Use tape, glue, or tissue paper scraps to repair the tears or gaps.

Note: (2) An Indoor Balloon Tester will enable students to identify repairs that might be needed.

3. Using the digital scale, find the mass of the balloon and record this measurement on the worksheet.
4. Set up the launcher outside.
5. Have the igniter of the launcher ready. Open the flow valve of the propane canister until you can hear gas escaping. Squeeze the trigger of the igniter to light the gas within the launcher. Be sure to squeeze it in the center and not the top of the trigger. If the launcher does not light, open the flow valve more and try again. When it lights, push the Lock button above the trigger.
6. Open the flow valve completely after the gas ignites. Guide the balloon over the inflation guides.
7. Continue holding the balloon until it contains enough hot air to keep its shape.
8. When the balloon is full of hot air and is steady and strong, release the balloon into the air.
9. During the first launch, observe how lift affects the balloon's flight. Record your observations on the worksheet.

Note: (9) The students might need to refer to the "Forces Acting on a Balloon" resource page.

10. Launch the balloon once more. During the second launch, observe the effects drag has on the balloon's flight. Record the observations for the launch.
11. When finished with the launches, completely shut off the flow valve of the propane canister and disconnect the propane from the launcher.
12. Complete the remainder of the worksheet.

Quick View

Students design and construct a hot-air balloon to achieve the maximum flight height possible.

Time Required

180-260 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

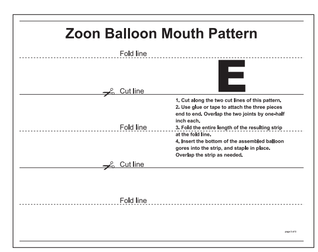
Vocabulary

Glossary: Pitsco.com/c/hab-glossary.pdf

- design
- flight
- gore
- hypothesis
- launch
- seam

Materials

- Graph paper
- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- Notebook
- Engineering Challenge I Student Instruction: Pitsco.com/c/hab-sp11.pdf
- Indoor Balloon Tester (optional)


Zoon Balloon Mouth Pattern

Fold line

E

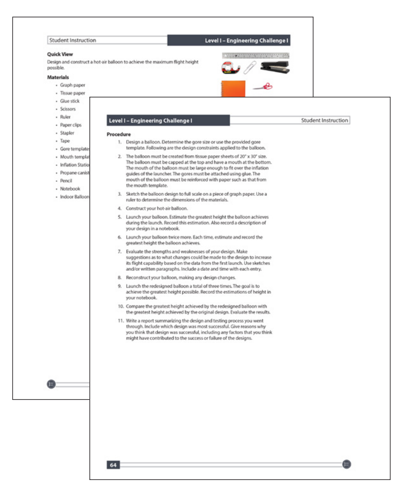
Cut line

1. Cut along the two cut lines of this pattern.
2. Use glue or tape to attach the three pieces end to end. Overlap the two joints by one-half inch each.
3. Fold the entire length of the resulting strip at the fold line.
4. Insert the bottom of the assembled balloon gores into the strip, and staple in place. Overlap the strip as needed.

Fold line

Cut line

Fold line



Procedure

At this point, students should have completed activities in which they have designed a balloon with surface area criteria, analyzed balloon flights, and observed the different forces acting on a balloon during flight. Students should use past data in designing the balloon.

1. Design a balloon. Determine the gore size or use the provided gore template. Following are the design constraints applied to the balloon.
2. The balloon must be created from tissue paper sheets of 20" x 30" size. The balloon must be capped at the top and have a mouth at the bottom. The mouth of the balloon must be large enough to fit over the inflation guides of the launcher. The gores must be attached using glue. The mouth of the balloon must be reinforced with paper such as that from the mouth template.
3. Sketch the balloon design to full scale on a piece of graph paper. Use a ruler to determine the dimensions of the materials.
4. Construct your hot-air balloon.
5. Launch your balloon. Estimate the greatest height the balloon achieves during the launch. Record this estimation. Also record a description of your design in a notebook.
6. Launch your balloon twice more. Each time, estimate and record the greatest height the balloon achieves.
7. Evaluate the strengths and weaknesses of your design. Make suggestions as to what changes could be made to the design to increase its flight capability based on the data from the first launch. Use sketches and/or written paragraphs. Include a date and time with each entry.
8. Reconstruct your balloon, making any design changes.
9. Launch the redesigned balloon a total of three times. The goal is to achieve the greatest height possible. Record the estimations of height in your notebook.
10. Compare the greatest height achieved by the redesigned balloon with the greatest height achieved by the original design. Evaluate the results.
11. Write a report summarizing the design and testing process you went through. Include which design was most successful. Give reasons why you think that design was successful, including any factors that you think might have contributed to the success or failure of the designs.

Note: (5) Help the students estimate the height of the launch. Depending on the level of the students, you might need to demonstrate some possibilities for keeping a log of designs and design modifications. One method would be to keep a notebook with sketches, data, materials, and explanations of changes with dates and times for each entry. You could create a structured format for students to do this, or you could give them an example and allow them to approach the record keeping in a more free-form style.

An Indoor Balloon Tester can be used by students to test their designs before the launch.

Note: (11) You might wish to give students a structured format to use for the report. They should identify the design problem, proposed solution, steps used to test the proposed solution, design modifications, retesting procedures, testing results, and evaluation of the design solution.

Note: To incorporate collaboration in this activity, have students work in pairs to design, build, and test their balloon. When students fill out their individual reports, have them include a reflection on their collaborative experience.

Quick View

Students determine the flight characteristics of balloons differing in size.

Time Required

45-90 minutes (will vary with class size)

Content Areas

Primary: Math

Secondary: Technology, science, language arts

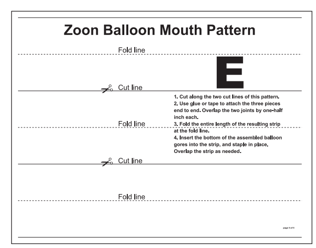
Vocabulary

Glossary: Pitsco.com/c/hab-glossary.pdf

- analyze
- cubic foot
- deflate
- function
- inflate
- sphere
- volume

Materials

- Graph paper
- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Paper
- Stopwatch
- Calculator
- Pencil
- "Volumes" worksheet: Pitsco.com/c/hab-sp13.pdf
- Varying Volumes Student Instruction: Pitsco.com/c/hab-sp19.pdf
- Indoor Balloon Tester (optional)


Zoon Balloon Mouth Pattern

Fold line

E

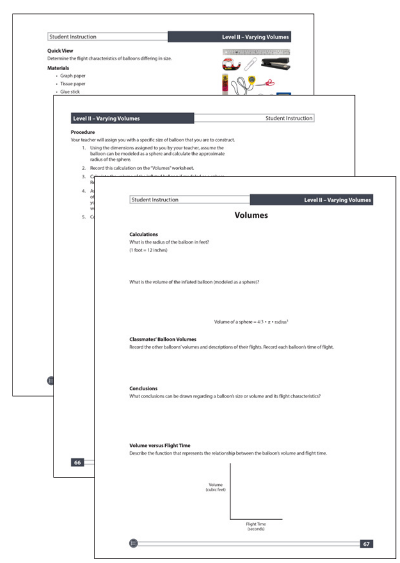
Cut line

1. Cut along the two cut lines of this pattern.
2. Use glue or tape to attach the three pieces end to end. Overlap the two joints by one-half inch each.
3. Fold the entire length of the resulting strip at the fold line.
4. Insert the bottom of the assembled balloon gores into the strip, and staple in place. Overlap the strip as needed.

Fold line

Cut line

Fold line



Procedure

This activity can involve the class as a whole, possibly divided into teams. Depending on the number of teams, choose and assign different sizes of balloons for each team to construct. Each team will then complete the lesson plan using their assigned balloon size. During the launches, the students can observe other teams' balloons and compare worksheets when all the launches are complete.

1. Using the dimensions assigned to you by your teacher, assume the balloon can be modeled as a sphere and calculate the approximate radius of the sphere.
2. Record this calculation on the "Volumes" worksheet.
3. Calculate the volume of the inflated balloon if modeled as a sphere. Record this calculation in cubic feet.
4. As a class, take turns launching your balloons. Be sure to observe the other launches. Also obtain the volumes of the other balloons and share your balloon volume; this information will be needed to complete the worksheet.
5. Complete the worksheet.

Note: (1) Some students might not be familiar with the terms *sphere* and *radius*. The radius should be determined in the width of the balloon, not the length.

Note: (4) The students will need each launch's flight time. Assign one student the responsibility of timing every launch using the stopwatch. Share that information with each team.

Quick View

Students investigate the effects of temperature on pressure.

Time Required

90-135 minutes (will vary with class size)

Content Areas

Primary: Science

Secondary: Math, technology, language arts

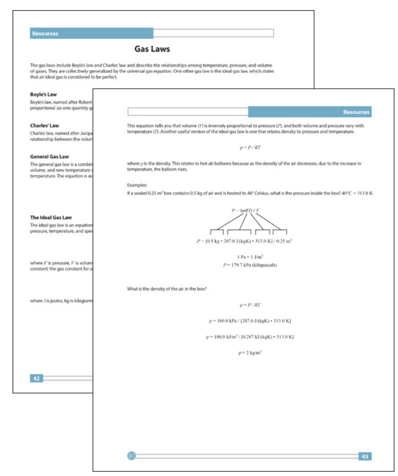
Vocabulary

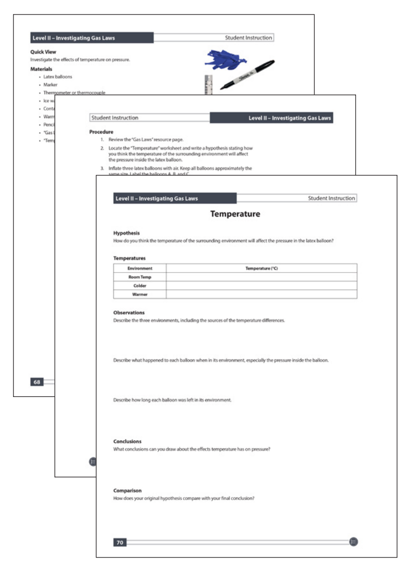
Glossary: Pitsco.com/c/hab-glossary.pdf

- fluid
- gas
- hypothesis
- pressure
- volume

Materials

- Latex balloons
- Marker
- Thermometer or thermocouple
- Ice water
- Container large enough for water and inflated balloon
- Warm environment
- “Gas Laws” resource page: Pitsco.com/c/gas-laws.pdf
- “Temperature” worksheet: Pitsco.com/c/hab-sp15.pdf
- Investigating Gas Laws Student Instruction: Pitsco.com/c/hab-sp16.pdf


Resources
Gas Laws


Level II – Investigating Gas Laws
Student Instruction
Temperature

Procedure

1. Review the "Gas Laws" resource page.
2. Locate the "Temperature" worksheet and write a hypothesis stating how you think the temperature of the surrounding environment will affect the pressure inside the latex balloon.
3. Inflate three latex balloons with air. Keep all balloons approximately the same size. Label the balloons A, B, and C.
4. Observe Balloon A in a room-temperature environment, specifically the pressure inside the balloon. Record the temperature of the environment. Record your observations on the worksheet.
5. Observe Balloon B in a colder environment. Record the temperature of this environment along with your observations.

   Note: (5) Ice water provides a suitable cold environment for this test. Submerge the balloon for several minutes.

6. Observe Balloon C in a warmer environment. Record the temperature of this environment along with your observations.

   Note: (6) If a warmer environment is not available, have the students make an inference as to what will happen to the balloon based on their observations from the colder environment and the room temperature environment.

7. Complete the worksheet.

Quick View

Students design and construct a balloon to hold the maximum payload possible and still maintain the capability to fly.

Time Required

90-180 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

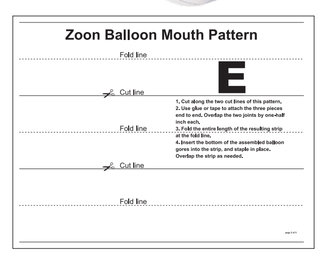
Vocabulary

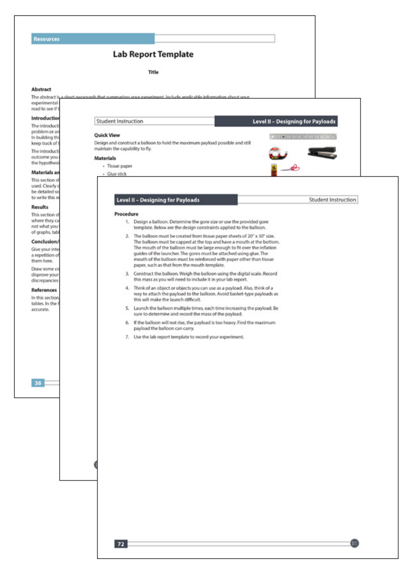
Glossary: Pitsco.com/c/hab-glossary.pdf

- buoyancy
- design
- flight
- gore
- gravity
- payload
- seam

Materials

- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- Digital scale
- "Lab Report Template" resource page: Pitsco.com/c/labreport.pdf
- Designing for Payloads Student Instruction: Pitsco.com/c/hab-sp17.pdf
- Indoor Balloon Tester (optional)





Procedure

1. Design a balloon. Determine the gore size or use the provided gore template. Below are the design constraints applied to the balloon.
2. The balloon must be created from tissue paper sheets of 20" x 30" size. The balloon must be capped at the top and have a mouth at the bottom. The mouth of the balloon must be large enough to fit over the inflation guides of the launcher. The gores must be attached using glue. The mouth of the balloon must be reinforced with paper other than tissue paper, such as that from the mouth template.
3. Construct the balloon. Weigh the balloon using the digital scale. Record this mass as you will need to include it in your lab report.
4. Think of an object or objects you can use as a payload. Also, think of a way to attach the payload to the balloon. Avoid basket-type payloads as this will make the launch difficult.
5. Launch the balloon multiple times, each time increasing the payload. Be sure to determine and record the mass of the payload.
6. If the balloon will not rise, the payload is too heavy. Find the maximum payload the balloon can carry.
7. Use the lab report template to record your experiment.

Note: (4) Suggestions for payloads would be paper clips attached to the mouth of the balloon or a combination of modeling clay and paper clips attached to the mouth of the balloon.

Note: (6) The maximum payload can be found by adding payload objects until the balloon hardly leaves the inflation guides.

Note: To incorporate collaboration in this activity, have students work in pairs to design, build, and test their balloon. When students fill out their individual reports, have them include a reflection on their collaborative experience.

Quick View

Students design and construct a hot-air balloon to achieve the greatest total flight time.

Time Required

225-550 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

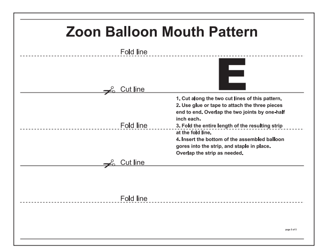
Vocabulary

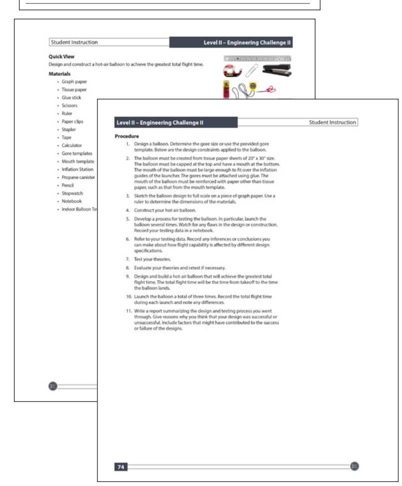
Glossary: Pitsco.com/c/hab-glossary.pdf

- design
- flight
- gore
- hypothesis
- launch
- seam

Materials

- Graph paper
- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Calculator
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- Stopwatch
- Notebook
- Engineering Challenge II Student Instruction: Pitsco.com/c/hab-sp18.pdf
- Indoor Balloon Tester (optional)





Procedure

1. Design a balloon. Determine the gore size or use the provided gore template. Below are the design constraints applied to the balloon.
2. The balloon must be created from tissue paper sheets of 20" x 30" size. The balloon must be capped at the top and have a mouth at the bottom. The mouth of the balloon must be large enough to fit over the inflation guides of the launcher. The gores must be attached using glue. The mouth of the balloon must be reinforced with paper other than tissue paper, such as that from the mouth template.
3. Sketch the balloon design to full scale on a piece of graph paper. Use a ruler to determine the dimensions of the materials.
4. Construct your hot-air balloon.
5. Develop a process for testing the balloon. In particular, launch the balloon several times. Watch for any flaws in the design or construction. Record your testing data in a notebook.

Note: (5) Students should record the testing procedure in a scientific format. They could follow a standard scientific method layout, or they could use a modified problem-solving format. It is important that the students clearly identify what specifications of the design they are testing, how they are testing the specs, and what the results of the tests are. You could have students bring a notebook, or you could duplicate and place templates from this guide in a binder. Students should get in the practice of keeping track of ideas, testing procedures, and data.

An Indoor Balloon Tester can be used by students to test their designs before the launch.

6. Refer to your testing data. Record any inferences or conclusions you can make about how flight capability is affected by different design specifications.

Note: (6) You might want to discuss with your students what inferences are, how they are made, and how to tell if they are reasonable. This should be fairly simple, but some students will need to be reminded how to make a reasonable inference from testing data.

7. Test your theories.

Note: (7) Students should test their inferences and/or conclusions using their original balloon. For example, if they infer that a smaller gore size increases the flight capability, then they should decrease the gore size and test this theory.

8. Evaluate your theories and retest if necessary.

Note: (8) Here students have the opportunity to evaluate what they thought to be true and retest if needed.

9. Design and build a hot-air balloon that will achieve the greatest total flight time. The total flight time will be the time from takeoff to the time the balloon lands.

Note: (9) For this part, students need to use the stopwatch to time the flight of the balloon. The time should be measured from the time the balloon leaves the launcher's guides to the time the balloon lands on the ground. This can be made into a mini competition or kept as an individual challenge.

10. Launch the balloon a total of three times. Record the total flight time during each launch and note any differences.

Note: (10) You could give a prize to the student whose balloon has the greatest flight time.

11. Write a report summarizing the design and testing process you went through. Give reasons why you think that your design was successful or unsuccessful. Include factors that might have contributed to the success or failure of the designs.

Note: (11) Students' reports should follow rules of grammar, punctuation, and spelling as well as being technically accurate.

Note: To incorporate collaboration in this activity, have students work in pairs to design, build, and test their balloon. When students fill out their individual reports, have them include a reflection on their collaborative experience.

Supplemental Lessons

Listed below are ideas for other lessons that can be developed to engage and challenge students with materials and equipment used in this teacher guide. Suggestions can be combined by you or the students to create a larger scope of study.

Design components of a balloon:

- Diameter
- Overall size
- Number of gores
- Mass
- Shape

Design a balloon for specific criteria:

- Design a balloon that has a specific mass.
- Design a balloon that can lift a specified payload.
- Design a balloon to reach a maximum altitude.
- Design a balloon to reach a maximum altitude with a specified payload.
- Design a balloon to reach a maximum range with a specified payload.

Class competition:

- Design a balloon that can lift a specified payload.
- Design a balloon that can lift the greatest payload.
- Design a balloon to achieve the greatest range.
- Design a balloon to achieve the greatest altitude.
- Design a balloon to achieve a specific range.
- Design a balloon to achieve the greatest flight time.

Vocabulary

analyze

ascent

buoyancy

cubic foot

deflate

density

descent

design

displacement

drag

estimation

flight

fluid

force

function

gas

gore

gravity

hypothesis

inflate

launch

lift

payload

pressure

seam

sphere

surface area

volume

Glossary

analyze: to examine methodically by separating into parts and studying their interrelations

ascent: the act or process of rising or going upward

buoyancy: the upward force on an object in a fluid, equal to the weight of the fluid displaced by the object

cubic foot: a volume equivalent to a cube with one-foot sides

deflate: to collapse by releasing contained air or gas

density: mass per unit volume; the characteristic of being crowded closely together; compact

descent: the downward movement of a rocket or object

design: the process of creating

displacement: the weight or volume of a fluid moved or shifted by a floating body

drag: the force that acts between a moving object and the fluid medium, slowing the motion of the object

estimation: the act of calculating approximately

flight: the motion of an object through Earth's atmosphere or through space

fluid: a gas or liquid that tends to take the shape of its container

force: the capacity to do work or cause physical change; energy, strength, or active power

function: a mathematical correspondence that assigns exactly one element of one set to each element of the same or another set

gas: the state of matter with no definite volume or shape

gore: a tapering piece of cloth or material forming a part of the envelope of a hot-air balloon

gravity: the natural force of attraction exerted by Earth upon objects, which tends to draw them toward the center of Earth

hypothesis: a prediction based on prior knowledge or previous experimental data

inflate: to fill an object with air or gas so as to make it swell

launch: to set or thrust (a self-propelled craft or projectile) in motion

lift: the act or process of rising or raising to a higher position

payload: the total weight of passengers and cargo carried by an aircraft

pressure: a force applied uniformly over a surface; measured as force per unit of area

seam: a line or ridge made by lapping and joining two sections along their edges

sphere: a ball-shaped or globular body

surface area: the extent of a two-dimensional surface enclosed within a boundary

volume: the amount of space occupied by a three-dimensional object or region of space, expressed in cubic units

Careers Related to Aerospace Engineering

The activities in this unit are a small part a larger field called aerospace. Careers in or concerning aerospace can be fun, challenging, and rewarding. Use the following links to see videos concerning aerospace-related careers. Then, explore the websites to learn more about other careers related to aerospace.

- Aerospace Engineering and Operations Technicians: Pitsco.com/c-cv17-3021-00
- Aerospace Engineers: Pitsco.com/c-cv17-2011-00
- Aviation Inspectors: Pitsco.com/c-cv53-6051-01
- Secondary School Teachers: Pitsco.com/c-cv25-2031-00
- Transportation Managers: Pitsco.com/c-cv11-3071-01

Military Careers

Students may search the following sites for potential careers within the military related to aerospace:

- Air Force: Pitsco.com/c-cv-mc-air-force
- Army: Pitsco.com/c-cv-mc-army
- Coast Guard: Pitsco.com/c-cv-mc-coast-guard
- Marine Corps: Pitsco.com/c-cv-mc-marine-corps
- National Guard: Pitsco.com/c-cv-mc-national-guard
- Navy: Pitsco.com/c-cv-mc-navy

Additional information about each career can be found by exploring the following websites:

- *Occupational Outlook Handbook:* Pitsco.com/c-ooh
- O*NET – Occupational Information Network: Pitsco.com/c-onet

Activity Suggestion

Have students create an "Aerospace Careers" pamphlet detailing career information such as skills required, nature of work, and level of education needed. Students should include information about at least two careers.

Careers

Pitsco.com/c/career.pdf

Students can use the "Careers" worksheet to help them gather information about a career by using the *OOH* and O*NET websites. They might find other related careers of interest they would like to explore. Print extra "Careers" worksheets if needed.

Careers

Occupational Outlook Handbook Research

Career Title: ______________________________

Career Summary			
Median Pay	**$**	**Current Number of Jobs**	
Lowest 10% Pay	**$**	**Projected Job Growth %**	
Highest 10% Pay	**$**		
What do people in this career do?			

What are the pros and cons of a career in this field? Justify your answer using information from the *OOH*.

Would you consider a career in this field? State the reasons for your decision. Cite evidence from the *OOH* that supports your decision. (For example: *I would not consider a career in this field. One of the reasons is that I do not like cold weather and the* OOH *states that these jobs exist only in regions close to the Arctic Circle.*)

Lab Report Template

Title

Abstract

The abstract is a short paragraph that summarizes your experiment. Include applicable information about your experimental subjects, materials and methods, results, and conclusions. The abstract is the part of the report that others will read to see if they are interested in the topic.

Introduction

The introduction should give background information on the experiment. It should include an explanation of the general problem or area being investigated. The introduction should outline what information is already known about the problem. In building this part of your report, you might want to consult references or, at the very least, reread the text. Be sure to keep track of the information and list all references used.

The introduction should also present the question you are trying to answer or the hypothesis you are testing. Include what outcome you expect and how it would support or disprove your hypothesis or answer your question. Distinguish between the hypothesis and the experiment you will do to test the hypothesis.

Materials and Methods

This section should include a concise, step-by-step numbered description of the materials, procedures, and equipment you used. Clearly describe the experimental situation, the control situation, and the type of observations you made. This should be detailed so that someone else could repeat your work. Do not include the rationale for your work in this section. Be sure to write this report as a past event, not as a set of instructions for the reader.

Results

This section should describe what happened. Include your raw data sheets or refer to the reference section of the report where they can be found. Present your findings in a logical order, not a chronological order. Give the results that you found, not what you think you should have found. Do not explain your results in this section. Results can be reported in the form of graphs, tables, or drawings. Be sure that the data recorded are single readings or averages.

Conclusion/Discussion

Give your interpretations of the data and relate them to the questions posed in the introduction. Avoid making this section a repetition of the introduction. If you have data to explain or a new hypothesis of why the results were unexpected, list them here.

Draw some conclusions, supporting them with your data. Did the results answer your question? Did they support or disprove your hypothesis? What is the significance of your results? Should further experiments be performed to clear up discrepancies or ambiguities in your results?

References

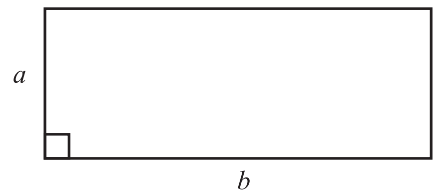
In this section, list the data that was concluded during the experiment. This could include graphs, charts, drawings, or data tables. In the Results section, you explained what happened; in this section, provide quantitative proof that your results are accurate.

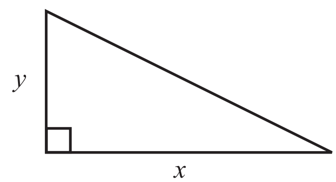
Area Estimation Methods

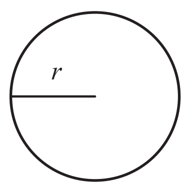
Finding the areas of irregular shapes can be difficult. Using regular shapes such as rectangles and triangles, you can estimate the area of irregular shapes. In the following formulas, the • stands for multiplication. Use 3.14 in your calculations for the value of π.

The area of a rectangle is $a \cdot b$.

The area of a triangle is $1/2 \cdot x \cdot y$.



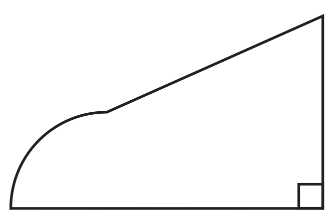




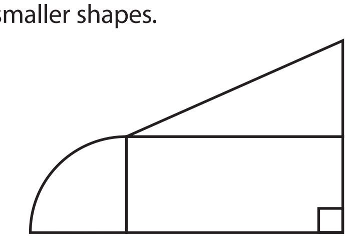
The area of a circle is $\pi \cdot r^2$.

Example:

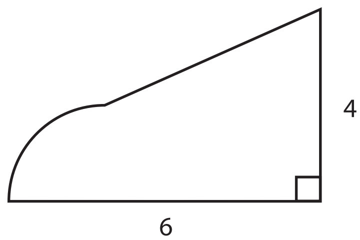
Take the irregular shape found below.



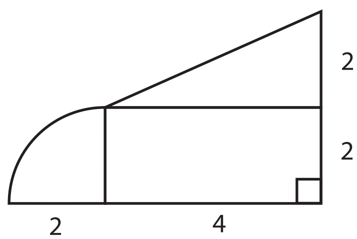
You can break this shape down into several smaller shapes.



To find the area of this irregular shape . . .



. . . break it down into smaller shapes.



The area of the quarter circle is $(\pi \cdot r^2)/4 = (\pi \cdot 4)/4 = 3.14$.

The equation for the circle is divided by four because there is only a quarter of the circle in the irregular shape.

The area of the rectangle is $a \cdot b = 4 \cdot 2 = 8$.

The area of the triangle is $1/2 \cdot x \cdot y = 1/2 \cdot (4 \cdot 2) = 4$.

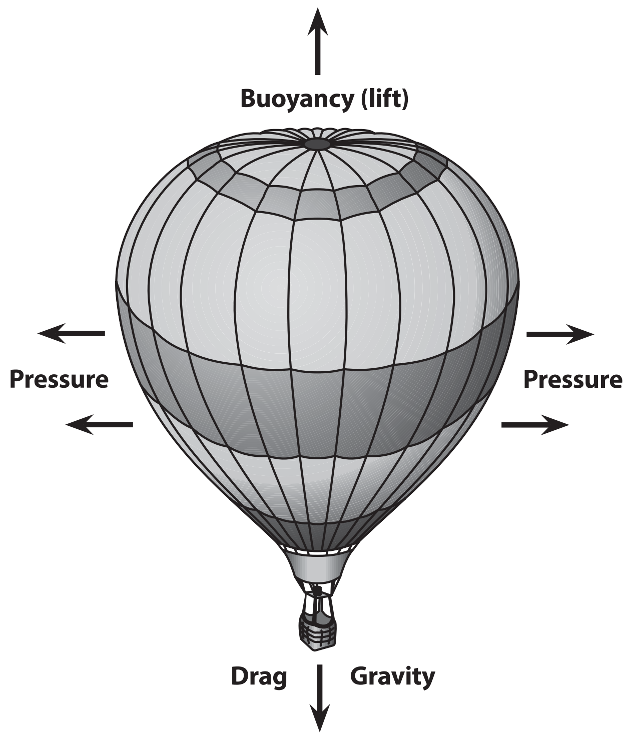
Add the areas: $3.14 + 8 + 4 = 15.14$.

Another method is to enclose the shape in a geometric shape and subtract areas of shapes not included. For instance, if we had this shape:

We could enclose the shape within a rectangle, find the area of the rectangle, and subtract the area of the four triangles at the corners of the rectangle that are not enclosed by the original figure.

Forces Acting on a Balloon

To help understand the forces acting on a balloon, use a free-body diagram. A free-body diagram is a drawing that shows the forces and directions acting on an object. Below is a free-body diagram of a hot-air balloon.



Buoyancy, or lift, is created when the temperature in the balloon is increased, causing the density of the air to decrease. The less dense (lighter) air inside the balloon tends to float on the more dense (heavier) air on the outside of the balloon. That is why hot-air balloons are referred to as lighter-than-air vehicles. If the amount of lift is greater than the force of gravity acting on the mass of the balloon, then the balloon will rise.

Warmer air inside the balloon will also cause the pressure inside the balloon to increase. The pressure inside the balloon will be greater than that on the outside of the balloon. For the balloon to maintain its shape, this force has to be greater than the forces acting in the opposite directions (pushing inward on the balloon).

In hot-air balloons, drag is the friction that occurs as the balloon rises and moves through the surrounding air. Friction occurs between the moving balloon and the molecules of air it hits as it rises.

Both drag and the force of gravity pulling on the mass of the balloon act in a downward force in opposition to the lift. If the lift is greater than the drag and force of gravity, then the balloon rises. If the lift is less than the drag and the force of gravity, then the balloon descends. If the lifting force is equal to the force of drag and gravity, then the balloon will neither rise nor fall.

For the purpose of illustration, there is no wind shown in the figure. However, wind can also act as a force on the balloon. The wind can come from nearly any direction and will tend to move the balloon in the direction it is blowing.

Gas Laws

The gas laws include Boyle's law and Charles' law and describe the relationships among temperature, pressure, and volume of gases. They are collectively generalized by the universal gas equation. One other gas law is the ideal gas law, which states that an ideal gas is considered to be perfect.

Boyle's Law

Boyle's law, named after Robert Boyle, states that the volume occupied by a gas at a constant temperature is inversely proportional (as one quantity gets bigger the other quantity gets smaller) to the pressure applied.

Charles' Law

Charles' law, named after Jacques Charles, states that under conditions of constant pressure and quantity, there is a direct relationship between the volume and absolute temperature for an ideal gas.

General Gas Law

The general gas law is a combination of Boyle's law and Charles' law. It states that the product of the initial pressure, initial volume, and new temperature of an enclosed gas is equal to the product of the new pressure, new volume, and initial temperature. The equation is as follows:

$$P_1 \bullet V_1 \bullet T_2 = P_2 \bullet V_2 \bullet T_1 \text{ or } (P_1 \bullet V_1) / T_1 = (P_2 \bullet V_2) / T_2$$

The Ideal Gas Law

The ideal gas law is an equation of state for substances in a gas phase. An equation of state is any equation that relates pressure, temperature, and specific volume. The ideal gas law can take many forms but one of the most well known is

$$PV = mRT$$

where P is pressure, V is volume, m is mass, R is the gas constant, and T is the temperature. All gases have their own gas constant; the gas constant for air is

$$R_{\text{air}} = 287 \text{ J/(kgK)}$$

where J is joules, kg is kilograms, and K is degrees Kelvin.

This equation tells you that volume (*V*) is inversely proportional to pressure (*P*), and both volume and pressure vary with temperature (*T*). Another useful version of the ideal gas law is one that relates density to pressure and temperature.

$$\rho = P / RT$$

where ρ is the density. This relates to hot-air balloons because as the density of the air decreases, due to the increase in temperature, the balloon rises.

Examples:

If a sealed 0.25 m^3 box contains 0.5 kg of air and is heated to 40° Celsius, what is the pressure inside the box? 40°C = 313.0 K

$$P = (mRT) / V$$

$$P = [0.5\ \text{kg} \cdot 287.0\ \text{J/(kgK)} \cdot 313.0\ \text{K}] / 0.25\ \text{m}^3$$

$$1\ \text{Pa} = 1\ \text{J/m}^3$$

$$P = 179.7\ \text{kPa (kilopascals)}$$

What is the density of the air in the box?

$$\rho = P / RT$$

$$\rho = 180.0\ \text{kPa} / [287.0\ \text{J/(kgK)} \cdot 313.0\ \text{K}]$$

$$\rho = 180.0\ \text{kJ/m}^3 / [0.287\ \text{kJ/(kgK)} \cdot 313.0\ \text{K}]$$

$$\rho = 2\ \text{kg/m}^3$$

Additional Resources

Digital Resources

Hot-Air Balloon Video: Pitsco.com/c/v-hot-air-balloon.mp4

Hot-Air Balloon Video – Introduction: Pitsco.com/c/v-hot-air-balloon-intro.mp4

Hot-Air Balloon Video – Tissue Sheet Preparation: Pitsco.com/c/v-hot-air-balloon-sheet-prep.mp4

Hot-Air Balloon Video – Preparing the Gore Template: Pitsco.com/c/v-hot-air-balloon-gore-prep.mp4

Hot-Air Balloon Video – Balloon Construction: Pitsco.com/c/v-hot-air-balloon-construction.mp4

Hot-Air Balloon Video – Balloon Mouth Installation: Pitsco.com/c/v-hot-air-balloon-mouth-install.mp4

Hot-Air Balloon Video – Indoor Testing: Pitsco.com/c/v-hot-air-balloon-indoor-testing.mp4

Hot-Air Balloon Video – Outdoor Launching: Pitsco.com/c/v-hot-air-balloon-outdoor-launching.mp4

Hot-Air Balloon Video – Flight Analysis: Pitsco.com/c/v-hot-air-balloon-flight-analysis.mp4

Hot-Air Balloon Video – Balloon Physics: Pitsco.com/c/v-hot-air-balloon-balloon-physics.mp4

Printable Resources

"Area Estimation Methods" resource page: Pitsco.com/c/area-estimation.pdf

"Forces Acting on a Balloon" resource page: Pitsco.com/c/forces-balloon.pdf

"Gas Laws" resource page: Pitsco.com/c/gas-laws.pdf

"4Cs" resource page: Pitsco.com/c/4cs.pdf

Career Video Links: Pitsco.com/c/hab-career.pdf

Vocabulary List: Pitsco.com/c/hab-vocab.pdf

Pretest I: Pitsco.com/c/hab-pre1.pdf

Pretest I Answer Key: Pitsco.com/c/78671.pdf

Pretest II: Pitsco.com/c/hab-pre2.pdf

Pretest II Answer Key: Pitsco.com/c/32765.pdf

Posttest I: Pitsco.com/c/hab-post1.pdf

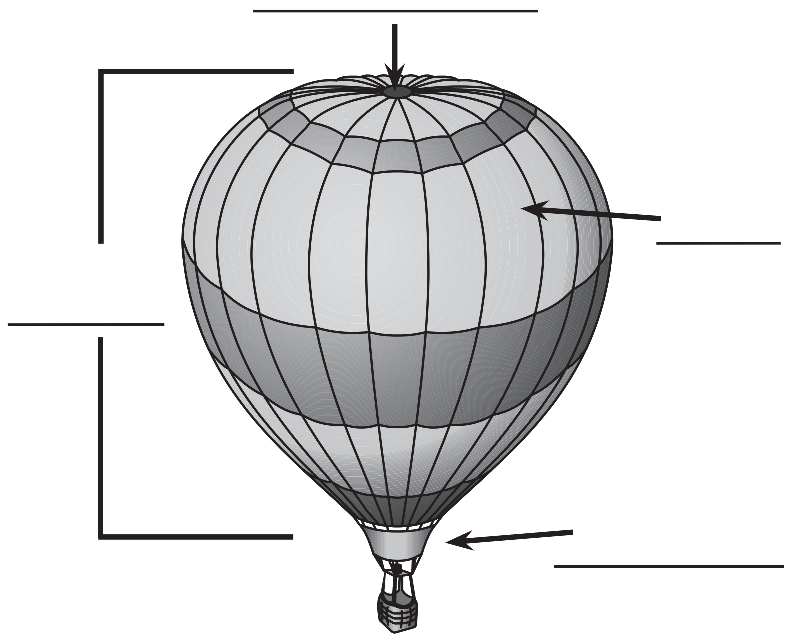
Posttest I Answer Key: Pitsco.com/c/44950.pdf

Posttest II: Pitsco.com/c/hab-post2.pdf

Posttest II Answer Key: Pitsco.com/c/58464.pdf

1-4. Match the following parts of a hot-air balloon with the appropriate parts of the graphic.

1. gore
2. basket hoop
3. cooling vent (cap)
4. envelope



5. A circle has a diameter of 10 feet. What is the area of the circle?

6. One side of a cube has a length of 30 inches. What is the surface area of the cube in cubic feet?

7. As a balloon is rising, what force is helping it do so?

A. weight
B. lift
C. drag
D. pressure

8. Define *buoyancy*.

9. A balloon was in flight for 25 seconds. It took the balloon 7 seconds to reach its maximum height. How long was the balloon's time of descent?

10. Which of the following would provide the greatest amount of lift for a hot-air balloon?

A. cold air inside with cold air outside
B. hot air inside with hot air outside
C. cold air inside with hot air outside
D. hot air inside with cold air outside

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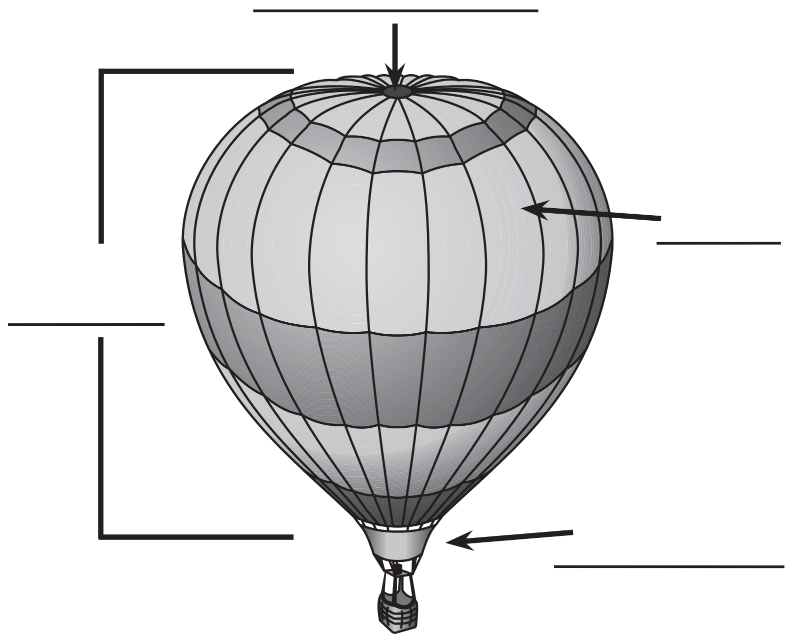

5. A circle has a diameter of 4 feet. What is the area of the circle?

6. One side of a cube has a length of 18 inches. What is the surface area of the cube in cubic feet?

7. As a balloon is rising, what force is helping it do so?

A. weight
B. lift
C. drag
D. pressure

8. Define *buoyancy*.

9. A balloon was in flight for 20 seconds. It took the balloon 7 seconds to reach its maximum height. How long was the balloon's time of descent?

10. Which of the following would provide the greatest amount of lift for a hot-air balloon?

A. cold air inside with cold air outside
B. hot air inside with hot air outside
C. cold air inside with hot air outside
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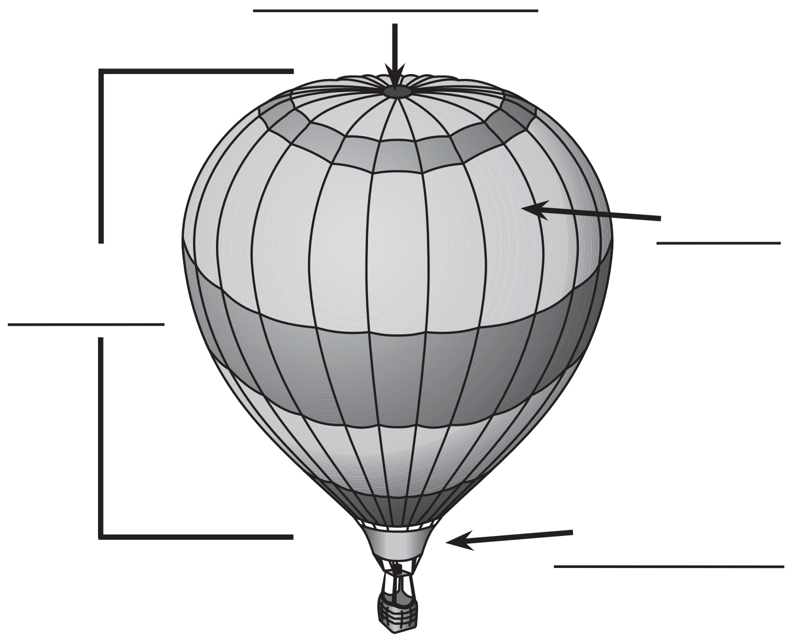

5. True or false: Volume is measured in squared units.

6. A sphere has a radius of 7.5 inches. What is the volume of the sphere?

7. Balloon A is carrying a payload of 15 grams and rises 25 feet. Balloon B is carrying a payload of 12 grams. Assume Balloon A and B are identical other than their payload. Will Balloon B rise higher than Balloon A?

8. A gas law is an equation that shows the relationship among which of the following?

A. time, volume, temperature
B. volume, temperature, pressure
C. weight, time, temperature
D. pressure, volume, time

9. Define *ascent*.

10. When a balloon is filled with air, it is _______.

A. deflated
B. heavy
C. inflated
D. cold

1-4. Match the following parts of a hot-air balloon with the appropriate parts of the graphic.

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2. basket hoop
3. cooling vent (cap)
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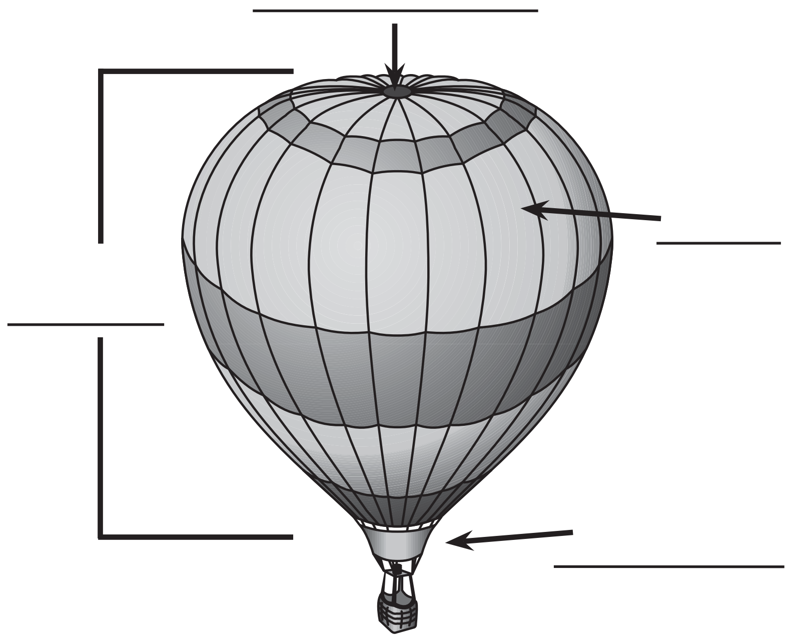

5. True or false: Volume is measured in squared units.

6. A sphere has a radius of 6 inches. What is the volume of the sphere?

7. Balloon A is carrying a payload of 15 grams and rises 25 feet. Balloon B is carrying a payload of 7.5 grams. Assume Balloon A and B are identical other than their payload. Will Balloon B rise higher than Balloon A?

8. A gas law is an equation that shows the relationship among which of the following?

A. time, volume, temperature
B. volume, temperature, pressure
C. weight, time, temperature
D. pressure, volume, time

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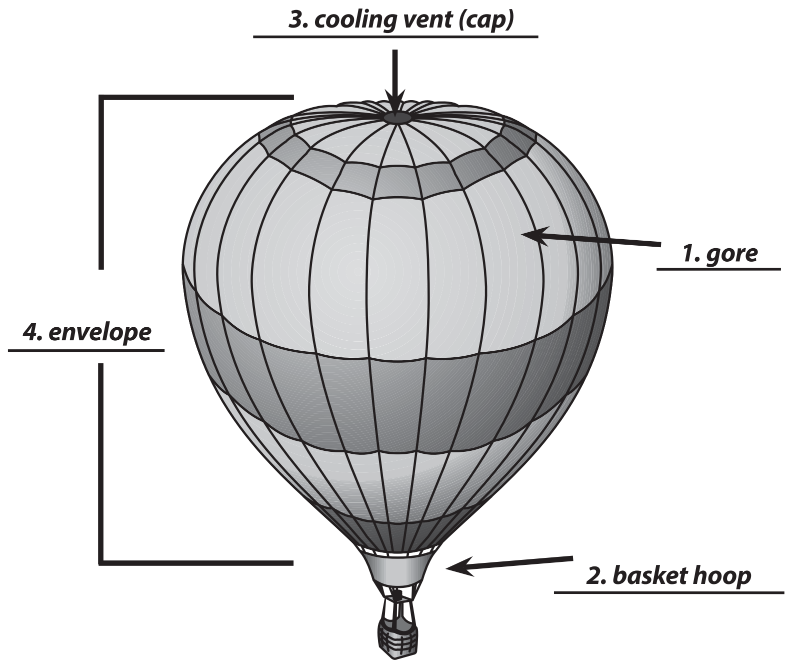

5. A circle has a diameter of 10 feet. What is the area of the circle?

78.5 square feet

6. One side of a cube has a length of 30 inches. What is the surface area of the cube in cubic feet?

37.5 square feet

7. As a balloon is rising, what force is helping it do so?

A. weight
B. lift
C. drag
D. pressure

8. Define *buoyancy*.

the upward force on an object in a fluid, equal to the weight of the fluid displaced by the object

9. A balloon is in flight for 25 seconds. It took the balloon 7 seconds to reach its maximum height. How long was the balloon's time of descent?

18 seconds

10. Which of the following would provide the greatest amount of lift for a hot-air balloon?

A. cold air inside with cold air outside
B. hot air inside with hot air outside
C. cold air inside with hot air outside
D. hot air inside with cold air outside

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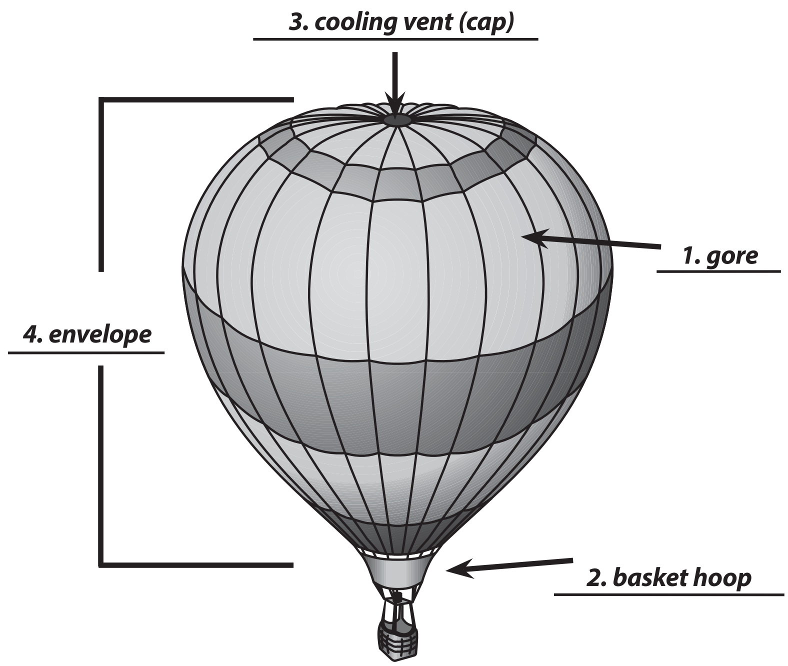

5. A circle has a diameter of 4 feet. What is the area of the circle?

   12.6 square feet

6. One side of a cube has a length of 18 inches. What is the surface area of the cube in cubic feet?

   13.5 square feet

7. As a balloon is rising, what force is helping it do so?

   A. weight
   B. lift
   C. drag
   D. pressure

8. Define *buoyancy*.

   the upward force on an object in a fluid, equal to the weight of the fluid displaced by the object

9. A balloon was in flight for 20 seconds. It took the balloon 7 seconds to reach its maximum height. How long was the balloon's time of descent?

   13 seconds

10. Which of the following would provide the greatest amount of lift for a hot-air balloon?

    A. cold air inside with cold air outside
    B. hot air inside with hot air outside
    C. cold air inside with hot air outside
    D. hot air inside with cold air outside

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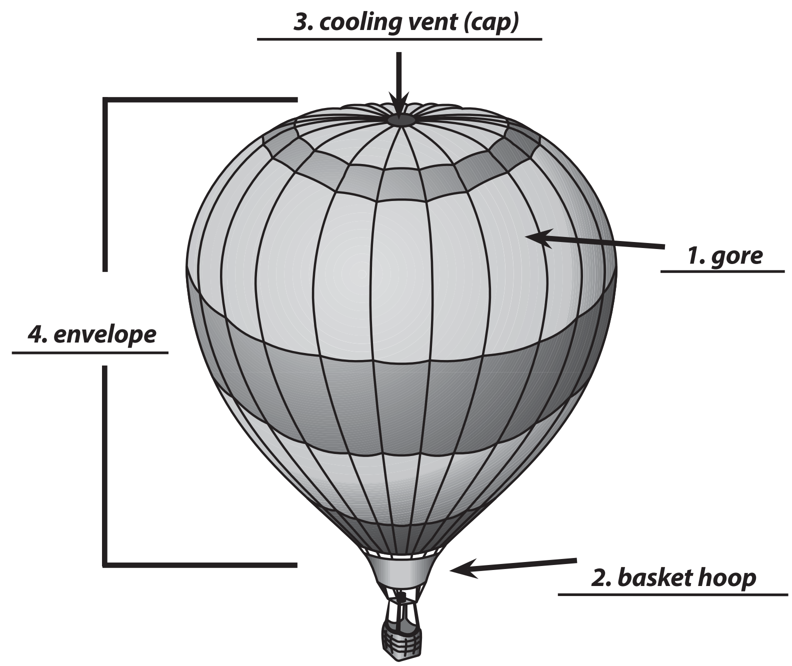

5. True or false: Volume is measured in squared units.

false

6. A sphere has a radius of 7.5 inches. What is the volume of the sphere?

1766.3 cubic inches

7. Balloon A is carrying a payload of 15 grams and rises 25 feet. Balloon B is carrying a payload of 12 grams. Assume Balloon A and B are identical other than their payload. Will Balloon B rise higher than Balloon A?

yes

8. A gas law is an equation that shows the relationship among which of the following?

A. time, volume, temperature
B. volume, temperature, pressure
C. weight, time, temperature
D. pressure, volume, time

9. Define *ascent*.

the act or process of rising or going upward

10. When a balloon is filled with air, it is _______.

A. deflated
B. heavy
C. inflated
D. cold

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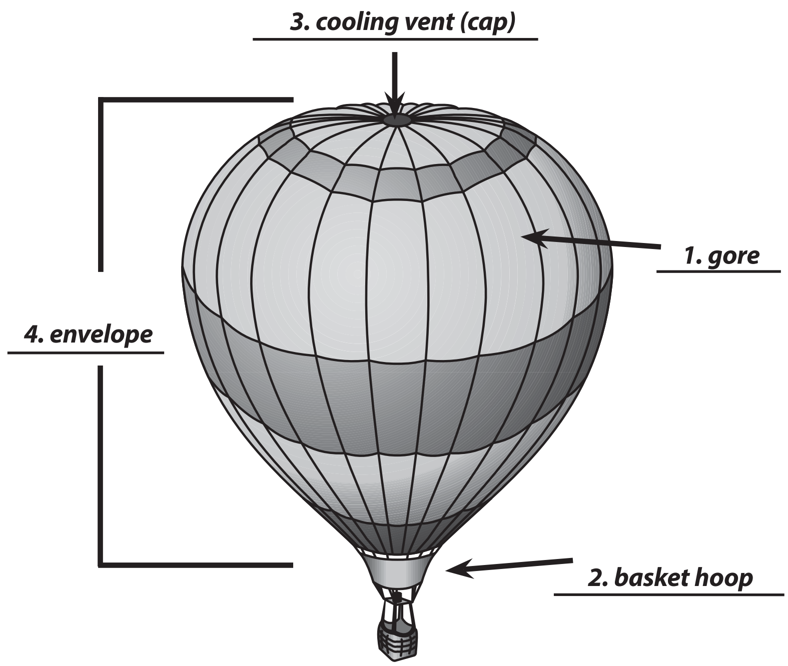
3. cooling vent (cap)
4. envelope



5. True or false: Volume is measured in squared units.

   false

6. A sphere has a radius of 6 inches. What is the volume of the sphere?

   904.3 cubic inches

7. Balloon A is carrying a payload of 15 grams and rises 25 feet. Balloon B is carrying a payload of 7.5 grams. Assume Balloon A and B are identical other than their payload. Will Balloon B rise higher than Balloon A?

   yes

8. A gas law is an equation that shows the relationship among which of the following?

   A. time, volume, temperature
   B. volume, temperature, pressure
   C. weight, time, temperature
   D. pressure, volume, time

9. Define *ascent*.

   the act or process of rising or going upward

10. When a balloon is filled with air, it is _______.

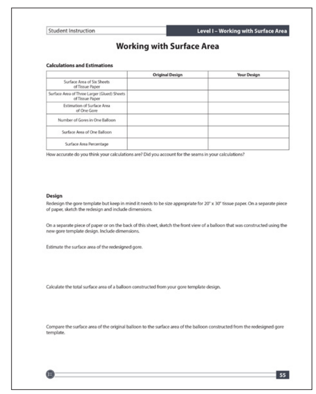
    A. deflated
    B. heavy
    C. inflated
    D. cold

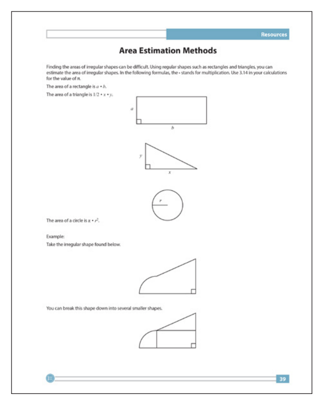
Quick View

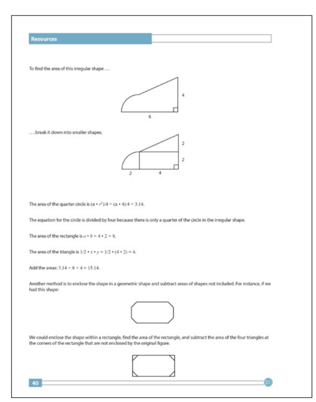
Design a hot-air balloon using a specified amount of material.

Materials

- Paper
- Pencil
- Calculator
- Gore templates
- "Working with Surface Area" worksheet
- "Area Estimation Methods" resource page







Procedure

1. Locate the "Working with Surface Area" worksheet along with a pencil and a calculator.
2. When building a balloon, you use six sheets of tissue paper measuring 20" x 30". What is the total surface area of all six sheets? Write your calculation on the worksheet.
3. If two sheets of 20" x 30" tissue paper are glued together so the seam overlapping between the two is 1/2", the new dimensions of the sheet should be 30" x 39-1/2". If this step is repeated with the remaining four sheets, what is the total surface area of the new three larger sheets? Write your calculation on the worksheet.
4. Locate the gore template. Estimate the surface area of the gore and record this estimation on the worksheet. Refer to the "Area Estimation Methods" resource page to aid in your estimations.
5. Determine the number of gores used to construct one balloon. Using the number of gores and the estimated surface area of one gore, calculate the surface area of one balloon. Record the balloon's surface area on the worksheet.
6. Calculate the percentage of the material's original surface area that it took to construct the balloon and record this figure on the worksheet.
7. After the calculations and estimations are complete, continue work on the design portion of the worksheet.
8. Redesign the gore template. Attempt to keep the design similar to the original, but some things you might alter include overall size and shape.
9. Sketch a small front view of your balloon using your gore template design, including estimates of dimensions. Make sure the dimensions are in inches.
10. Complete the surface area calculations regarding your design.
11. Finally, describe your design and complete the remainder of the worksheet.

Working with Surface Area

Calculations and Estimations

	Original Design	Your Design
Surface Area of Six Sheets of Tissue Paper		
Surface Area of Three Larger (Glued) Sheets of Tissue Paper		
Estimation of Surface Area of One Gore		
Number of Gores in One Balloon		
Surface Area of One Balloon		
Surface Area Percentage		

How accurate do you think your calculations are? Did you account for the seams in your calculations?

Design

Redesign the gore template but keep in mind it needs to be size appropriate for 20" x 30" tissue paper. On a separate piece of paper, sketch the redesign and include dimensions.

On a separate piece of paper or on the back of this sheet, sketch the front view of a balloon that was constructed using the new gore template design. Include dimensions.

Estimate the surface area of the redesigned gore.

Calculate the total surface area of a balloon constructed from your gore template design.

Compare the surface area of the original balloon to the surface area of the balloon constructed from the redesigned gore template.

Quick View

Construct and launch a balloon while analyzing the balloon's flight.

Materials

- Tissue paper
- Scissors
- Glue stick
- Stapler
- Tape
- Paper clips
- Ruler
- Stopwatch
- Tape measure
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- "Analyzing Balloon Flight" worksheet
- Indoor Balloon Tester (optional)

Procedure

1. Locate the "Analyzing Balloon Flight" worksheet and record your hypothesis describing what you think the behavior of a launched hot-air balloon will be.
2. Put aside the worksheet. Construct a hot-air balloon using the provided materials and Construction Quick View.
3. Set up the launcher outside.
4. Have the igniter of the launcher ready. Open the flow valve of the propane canister until you can hear gas escaping. Squeeze the trigger of the igniter to light the gas within the launcher. Be sure to squeeze it in the center and not the top of the trigger. If the launcher does not light, open the flow valve more and try again. When it lights, push the Lock button above the trigger..
5. Open the flow valve completely after the gas ignites. Guide the balloon over the inflation guides.
6. Continue holding the balloon until it contains enough hot air to keep its shape.
7. When the pull from the hot air is steady and strong, release the balloon into the air.
8. Observe the flight and record your observations on the worksheet. Some of these observations need to include the overall flight path, the time of ascent, the time of descent, the greatest height the balloon achieves, and the distance the balloon travels from the launcher in the horizontal direction.
9. Launch the balloon twice more. Record the observations for each launch.
10. When finished with the launches, completely shut off the flow valve of the propane canister and disconnect the propane from the launcher.
11. Complete the remainder of the worksheet.

Analyzing Balloon Flight

Hypothesis

What do you think the flight of the hot-air balloon will be like? Record your hypothesis.

Data

Record your observations from the first three launches. Include a small sketch of the flight path, the time of ascent and descent, the estimated achieved height, and the distance traveled by the balloon in the horizontal direction.

Launch A

Launch B

Launch C

Analysis

How do the three launches compare?

What was the average time of ascent of the three launches?

What was the average time of descent?

What was the average height achieved?

What was the average distance traveled?

Conclusion

What conclusions can you make about the behavior of a hot-air balloon after it has been launched?

Comparison

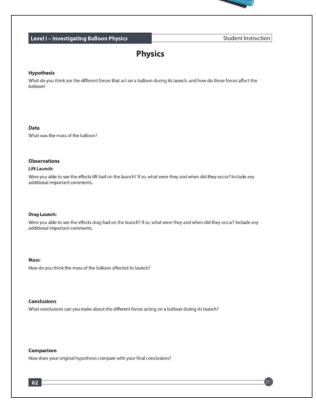
How do your conclusions compare to your original hypothesis?

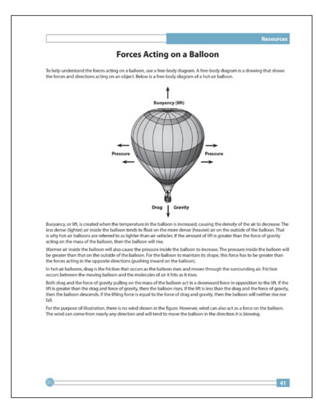
Quick View

Investigate various forces acting on a balloon throughout a launch.

Materials

- Completed hot-air balloon
- Tape
- Stapler
- Scissors
- Glue stick
- Tissue paper scraps
- Digital scale
- Inflation Station
- Propane canister
- Pencil
- “Physics” worksheet
- “Forces Acting on a Balloon” resource page
- Indoor Balloon Tester (optional)





Procedure

1. Locate the "Physics" worksheet and record your hypothesis stating the different forces you believe act on a balloon during launch and how these forces affect the balloon. You may reference the "Forces Acting on a Balloon" resource page to learn more about the different forces.
2. Locate the balloon you constructed and launched in the Analyzing Balloon Flight activity. Visibly check the balloon for any tears or gaps along the seams. Use tape, glue, or tissue paper scraps to repair the tears or gaps.
3. Using the digital scale, find the mass of the balloon and record this measurement on the worksheet.
4. Set up the launcher outside.
5. Have the igniter of the launcher ready. Open the flow valve of the propane canister until you can hear gas escaping. Squeeze the trigger of the igniter to light the gas within the launcher. Be sure to squeeze it in the center and not the top of the trigger. If the launcher does not light, open the flow valve more and try again. When it lights, push the Lock button above the trigger.
6. Open the flow valve completely after the gas ignites. Guide the balloon over the inflation guides.
7. Continue holding the balloon until it contains enough hot air to keep its shape.
8. When the balloon is full of hot air and is steady and strong, release the balloon into the air.
9. During the first launch, observe how lift affects the balloon's flight. Record your observations on the worksheet.
10. Launch the balloon once more. During the second launch, observe the effects drag has on the balloon's flight. Record the observations for the launch.
11. When finished with the launches, completely shut off the flow valve of the propane canister and disconnect the propane from the launcher.
12. Complete the remainder of the worksheet.

Physics

Hypothesis

What do you think are the different forces that act on a balloon during its launch, and how do these forces affect the balloon?

Data

What was the mass of the balloon?

Observations

Lift Launch:

Were you able to see the effects lift had on the launch? If so, what were they and when did they occur? Include any additional important comments.

Drag Launch:

Were you able to see the effects drag had on the launch? If so, what were they and when did they occur? Include any additional important comments.

Mass:

How do you think the mass of the balloon affected its launch?

Conclusions

What conclusions can you make about the different forces acting on a balloon during its launch?

Comparison

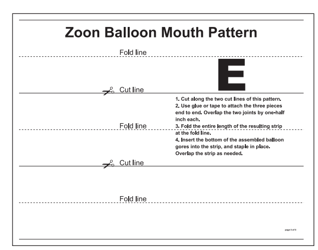
How does your original hypothesis compare with your final conclusions?

Quick View

Design and construct a hot-air balloon to achieve the maximum flight height possible.

Materials

- Graph paper
- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- Notebook
- Indoor Balloon Tester (optional)



Procedure

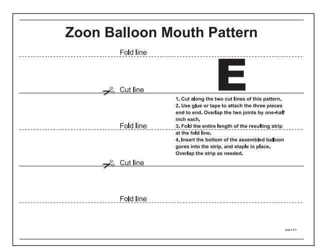
1. Design a balloon. Determine the gore size or use the provided gore template. Following are the design constraints applied to the balloon.
2. The balloon must be created from tissue paper sheets of 20" x 30" size. The balloon must be capped at the top and have a mouth at the bottom. The mouth of the balloon must be large enough to fit over the inflation guides of the launcher. The gores must be attached using glue. The mouth of the balloon must be reinforced with paper such as that from the mouth template.
3. Sketch the balloon design to full scale on a piece of graph paper. Use a ruler to determine the dimensions of the materials.
4. Construct your hot-air balloon.
5. Launch your balloon. Estimate the greatest height the balloon achieves during the launch. Record this estimation. Also record a description of your design in a notebook.
6. Launch your balloon twice more. Each time, estimate and record the greatest height the balloon achieves.
7. Evaluate the strengths and weaknesses of your design. Make suggestions as to what changes could be made to the design to increase its flight capability based on the data from the first launch. Use sketches and/or written paragraphs. Include a date and time with each entry.
8. Reconstruct your balloon, making any design changes.
9. Launch the redesigned balloon a total of three times. The goal is to achieve the greatest height possible. Record the estimations of height in your notebook.
10. Compare the greatest height achieved by the redesigned balloon with the greatest height achieved by the original design. Evaluate the results.
11. Write a report summarizing the design and testing process you went through. Include which design was most successful. Give reasons why you think that design was successful, including any factors that you think might have contributed to the success or failure of the designs.

Quick View

Determine the flight characteristics of balloons differing in size.

Materials

- Graph paper
- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Paper
- Stopwatch
- Calculator
- Pencil
- "Volumes" worksheet
- Indoor Balloon Tester (optional)



Zoon Balloon Mouth Pattern

Fold line

E

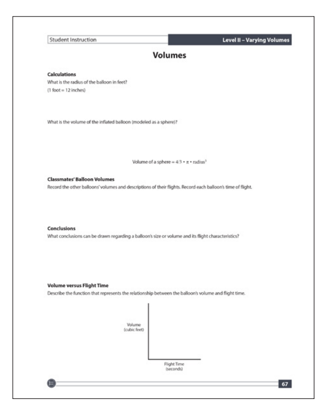
Cut line

1. Cut along the two cut lines of this pattern.
2. Use glue or tape to attach the three pieces end to end. Overlap the two joints by one-half inch each.
3. Fold the entire length of the resulting strip at the fold line.
4. Insert the bottom of the assembled balloon gores into the strip, and staple in place. Overlap the strip as needed.

Fold line

Cut line

Fold line



Student Instruction | Level II – Varying Volumes

Volumes

Calculations

What is the radius of the balloon in feet?
(1 foot = 12 inches)

What is the volume of the inflated balloon (modeled as a sphere)?

Volume of a sphere = $4/3 \cdot \pi \cdot \text{radius}^3$

Classmates' Balloon Volumes

Record the other balloons' volumes and descriptions of their flights. Record each balloon's time of flight.

Conclusions

What conclusions can be drawn regarding a balloon's size or volume and its flight characteristics?

Volume versus Flight Time

Describe the function that represents the relationship between the balloon's volume and flight time.

Volume (cubic feet)

Flight Time (seconds)

67

Procedure

Your teacher will assign you with a specific size of balloon that you are to construct.

1. Using the dimensions assigned to you by your teacher, assume the balloon can be modeled as a sphere and calculate the approximate radius of the sphere.
2. Record this calculation on the "Volumes" worksheet.
3. Calculate the volume of the inflated balloon if modeled as a sphere. Record this calculation in cubic feet.
4. As a class, take turns launching your balloons. Be sure to observe the other launches. Also obtain the volumes of the other balloons and share your balloon volume; this information will be needed to complete the worksheet.
5. Complete the worksheet.

Volumes

Calculations

What is the radius of the balloon in feet?

(1 foot = 12 inches)

What is the volume of the inflated balloon (modeled as a sphere)?

Volume of a sphere = $4/3 \cdot \pi \cdot \text{radius}^3$

Classmates' Balloon Volumes

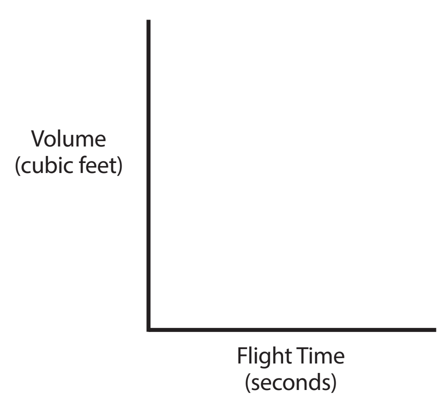
Record the other balloons' volumes and descriptions of their flights. Record each balloon's time of flight.

Conclusions

What conclusions can be drawn regarding a balloon's size or volume and its flight characteristics?

Volume versus Flight Time

Describe the function that represents the relationship between the balloon's volume and flight time.

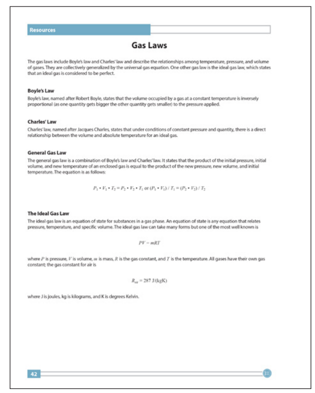


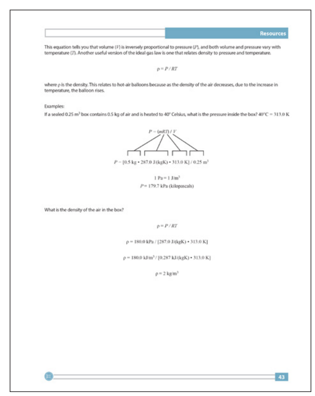
Quick View

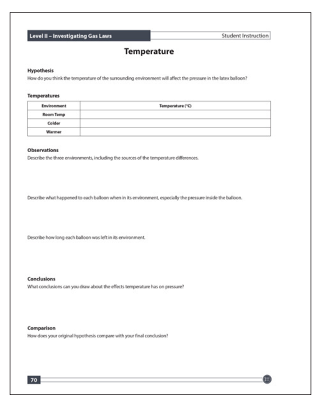
Investigate the effects of temperature on pressure.

Materials

- Latex balloons
- Marker
- Thermometer or thermocouple
- Ice water
- Container large enough for water and inflated balloon
- Warm environment
- Pencil
- “Gas Laws” resource page
- “Temperature” worksheet


Gas Laws




Temperature

Procedure

1. Review the "Gas Laws" resource page.
2. Locate the "Temperature" worksheet and write a hypothesis stating how you think the temperature of the surrounding environment will affect the pressure inside the latex balloon.
3. Inflate three latex balloons with air. Keep all balloons approximately the same size. Label the balloons A, B, and C.
4. Observe Balloon A in a room-temperature environment, specifically the pressure inside the balloon. Record the temperature of the environment. Record your observations on the worksheet.
5. Observe Balloon B in a colder environment. Record the temperature of this environment along with your observations.
6. Observe Balloon C in a warmer environment. Record the temperature of this environment along with your observations.
7. Complete the worksheet.

Temperature

Hypothesis

How do you think the temperature of the surrounding environment will affect the pressure in the latex balloon?

Temperatures

Environment	Temperature (°C)
Room Temp	
Colder	
Warmer	

Observations

Describe the three environments, including the sources of the temperature differences.

Describe what happened to each balloon when in its environment, especially the pressure inside the balloon.

Describe how long each balloon was left in its environment.

Conclusions

What conclusions can you draw about the effects temperature has on pressure?

Comparison

How does your original hypothesis compare with your final conclusion?

Quick View

Design and construct a balloon to hold the maximum payload possible and still maintain the capability to fly.

Materials

- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- Digital scale
- "Lab Report Template" resource page
- Indoor Balloon Tester (optional)

Procedure

1. Design a balloon. Determine the gore size or use the provided gore template. Below are the design constraints applied to the balloon.
2. The balloon must be created from tissue paper sheets of 20" x 30" size. The balloon must be capped at the top and have a mouth at the bottom. The mouth of the balloon must be large enough to fit over the inflation guides of the launcher. The gores must be attached using glue. The mouth of the balloon must be reinforced with paper other than tissue paper, such as that from the mouth template.
3. Construct the balloon. Weigh the balloon using the digital scale. Record this mass as you will need to include it in your lab report.
4. Think of an object or objects you can use as a payload. Also, think of a way to attach the payload to the balloon. Avoid basket-type payloads as this will make the launch difficult.
5. Launch the balloon multiple times, each time increasing the payload. Be sure to determine and record the mass of the payload.
6. If the balloon will not rise, the payload is too heavy. Find the maximum payload the balloon can carry.
7. Use the lab report template to record your experiment.

Quick View

Design and construct a hot-air balloon to achieve the greatest total flight time.

Materials

- Graph paper
- Tissue paper
- Glue stick
- Scissors
- Ruler
- Paper clips
- Stapler
- Tape
- Calculator
- Gore templates
- Mouth template
- Inflation Station
- Propane canister
- Pencil
- Stopwatch
- Notebook
- Indoor Balloon Tester (optional)

Procedure

1. Design a balloon. Determine the gore size or use the provided gore template. Below are the design constraints applied to the balloon.
2. The balloon must be created from tissue paper sheets of 20" x 30" size. The balloon must be capped at the top and have a mouth at the bottom. The mouth of the balloon must be large enough to fit over the inflation guides of the launcher. The gores must be attached using glue. The mouth of the balloon must be reinforced with paper other than tissue paper, such as that from the mouth template.
3. Sketch the balloon design to full scale on a piece of graph paper. Use a ruler to determine the dimensions of the materials.
4. Construct your hot-air balloon.
5. Develop a process for testing the balloon. In particular, launch the balloon several times. Watch for any flaws in the design or construction. Record your testing data in a notebook.
6. Refer to your testing data. Record any inferences or conclusions you can make about how flight capability is affected by different design specifications.
7. Test your theories.
8. Evaluate your theories and retest if necessary.
9. Design and build a hot-air balloon that will achieve the greatest total flight time. The total flight time will be the time from takeoff to the time the balloon lands.
10. Launch the balloon a total of three times. Record the total flight time during each launch and note any differences.
11. Write a report summarizing the design and testing process you went through. Give reasons why you think that your design was successful or unsuccessful. Include factors that might have contributed to the success or failure of the designs.

HOT-AIR BALLOONS

Teacher's Guide

STEM Curriculum for Hot-Air Balloons

HAVE QUESTIONS?

There are a variety of ways to get in touch with us:

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Email us at orders@pitsco.com.
Chat with us on Pitsco.com/support.

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