Final Assessment Module: Hot Air Balloon Project

FINAL PROJECT OVERVIEW

INCLUDED IN THIS PROJECT:

- **Overview and Daily Plan**
- **Hot Air Balloon PowerPoint** from the Teacher Resource CD to use as introduction of project. (Read through the *Final Project Senior Math*, *Teacher Notes* before showing the PowerPoint. Use the PowerPoint to give students a big picture view of what is expected in the project. There are some notes on the PowerPoint for you to use with each slide. Have students follow along on the student handout and follow along with the rubrics as you go through the slides.)
- **Final Project Hot Air Balloon, Teacher Notes**
- **Websites for FAA sample test**
- **FAA certification sample test**
- **Final Project Hot Air Balloon**
- **Rubric Part 1: Construction, Calculations, and Flying of Balloon**
- **Rubric Part 2: Data Collection, Analysis, and Final Paper**

SUPPLIES NEEDED FOR A SUCCESSFUL PROJECT:

- 13” Weber Grill (est. cost $30).
- Charcoal (natural wood charcoal burns at higher temp).
- Smoke Stack

  To assemble: 1 - 4’x8” Head Duct (est. cost $15)
  1 - 8”x12” Reducer (est. cost $6)
- Coat Hanger (1 for each team for the bottom of the balloons to help bend in shape).
- Tissue Paper (15 full sheets each for a team of 2).
- Elmer’s All-Glue (1 bottle per team).
- Scissors (1 per each team).

DAILY PLAN

Prior to Day 1:

- Schedule computer lab for Day 1. Upload the PowerPoint slideshow to website (or view on Google Docs).

Day 1:

- In a computer lab, show the PowerPoint presentation found on the Project TIME Teacher Resource CD. (Be sure that you have read through the teacher notes and the assignment before showing the PowerPoint). Use the PowerPoint to give students a big picture view of what is expected in the project. There are some notes on the PowerPoint for you to use with each slide. Have the students follow along on the student handout and follow along with the rubric as you go through the slides.
- Assign groups (two students in each group) and give each group a question to research from the FAA Hot Air balloon Certification: Sample Written Test.
- **HW:** Read through the project details.
  Prepare a 4 minute presentation explaining the question and answer for their assigned FAA test question.

Day 2:

- Have supplies and tissue paper set out for each team. Use container or shelf space for each team to keep project.
- Supplies needed for today: cardstock, rulers and scissors.
- Finish Step 3 and start on Step 4 of the project.
- Have groups report their findings from the FAA test questions.
- Begin construction of small model hot air balloon. Make necessary adjustments for the larger model. Talk about scaling factors. See if the students understand how scaling would impact the diameter of the neck of the balloon, the cross sectional area of the balloon and the volume of the balloon. Hopefully they will be able to use the information gained from the Gro-Beast project.
- **HW:** Students should be working on their final write-up as they create their balloon.

Day 3:

- Show a finished "cross section" and a finished small hot air balloon.
- Bring any students who have successfully finished Step 3 to the front of the room to demonstrate and show their progress (have the student explain in their own words what they did).
- Students should finish Steps #4-6. Set the expectation.

Day 4:

- Set expectation today: Finish the small hot air balloon. *This is important because students must keep up the pace or they won't be able to fly the large balloon.

- Check that the students understand the difference between their “first” (Labeled: Volume Cross-Section) and the Surface Area Cross-Section.
- Make sure that the students do not cut out 8 Volume Cross-Sections. Students must follow Steps #4-6 prior to cutting any tissue paper.
- Be sure that the students glue the cross-sections together in two’s then two two’s together, then fold inside out and carefully finish the last glue.

Days 5-6:

- Triple measurements of the Surface Area Cross-Section (which they used to trace and cut out the small balloon) and make a pattern on butcher paper. This large surface area cross-section will be traced onto tissue paper and cut out eight times.

Day 7:

- Calculate the SA/V (Surface Area & Volume) of the balloons (Steps #10-12).

Day 8:

- Fly the balloons. This needs lots of prep time to accomplish the flights successfully.

FINAL PROJECT – HOT AIR BALLOON

Description

There are several key parts to making this a successful project:

- You will need approval from your administration. You will be using hot coals in a small container to create the necessary heat to fly the balloons. This means having the container hot and available when your class begins. There are definitely some logistics that are needed here. Begin talking with your administration early. Be sure to let them know that students gain much from this project as well as the fact that this is a final assessment. Some instructors may need to make arrangements to fly the balloons before and/or after the school date.

- There are many supplies needed to build and fly this project. Pre-planning is essential.

- Flying the balloon successfully requires a day with no rain and very little wind. This might be tricky in our climate! Consequently, you may wish to build the balloons and have the students work on their papers while you wait for the ideal weather. An alternative (if your administration agrees) is to try to fly the balloons inside of a high ceiling room with a cement floor like you might find in a trades classroom. Do not use charcoal briquettes if inside. Use natural wood.

Students will be working in pairs for the research, design, construction, and flying of the balloon. Ability to work with others and communication skills and respect are needed for this project.

Initially the students will research the ideas needed to make a hot air balloon fly. Have each group research one of the questions on the FAA Hot Air Balloon Certification Sample Test. Have groups report out to the class what they have found explaining their rationale and justifying their information with the website they use

Using cardstock the students will make a small model to see if their measurements work to make a balloon. After the small model is completed, have the students check with you before beginning the larger model. Check their measurements that they have scaled for the larger model.

Make sure that the students understand that the initial cross section outside edge is longer than the height of the balloon which is why they must use the string to create a new outside panel.

If the balloons all look similar, students might not be able to make any predictions on the relationship between SA/V and flight time. Encourage students to try different shapes. A long skinny balloon will help with the data as will a balloon that is nearly spherical. The larger the SA/V ratio the less time the balloon should fly, since there is a larger surface where the hot air can cool.

Some of the math concepts in this project are fairly complex when taken as a whole. An effort has been made to break steps down so that students will be successful.

- For the cross-section, the concept of a **piecewise** function is compounded with **translating** a ‘parent’ function to ensure **continuity**. You might want to define continuity by having the endpoints the same rather than the formal calculus definition.
- In addition, the idea of **arc length** on a circle = radius * theta is also used to produce the panels that will create the actual surface of the balloon. If you have calculus students in your class, you can discuss the idea of arc length and how the students might use calculus to determine the surface area of the balloon.
- To find the surface area and volume the students will use the small balloon with the **midpoint rule** (cylinders).
- The students then need to use the appropriate **proportionality** to determine the surface area and volume of the large balloon.

These topics may need additional discussion.

WEBSITES FOR FAA SAMPLE TEST INFORMATION

These are the sources from Russ Ballard used for the FAA test:

http://www.madsci.org/posts/archives/feb99/917586423.Eg.r.html

http://www.adventurenetwork.com/cgi-bin/adventurenetwork/Propane_Butane.html

http://travel.howstuffworks.com/hot-air-balloon6.htm

http://science.howstuffworks.com/question13.htm

http://www.weatherquestions.com/How_does_dew_form.htm

http://www.weatherquestions.com/What_is_an_unstable_air_mass.htm

http://travel.howstuffworks.com/hot-air-balloon2.htm

To assist students who are unable to locate their information, here is the annotated version:

❖ What are the least conditions under which a hot air balloon will float? It explains the factors that affect the effectiveness of flight.

  http://www.madsci.org/posts/archives/feb99/917586423.Eg.r.html

❖ Propane / Butane Fuel: The cold truth about performance. Compares and contrasts the properties and benefits of propane and butane.

http://www.adventurenetwork.com/cgi-bin/adventurenetwork/Propane_Butane.html

❖ How Hot Air Balloons Work: An extensive document that outlines the following: Balloon Design, Piloting, Launching and Landing, Wind and Weather, Air pressure + Gravity = Buoyancy, Lighter than Air, and Ballooning History.

  http://travel.howstuffworks.com/hot-air-balloon.htm

❖ What does it mean when a barometer is rising or falling? This gives a condensed explanation of the workings of the barometer.

  http://science.howstuffworks.com/question13.htm

- How does dew form? A brief explanation of the process and cause of dew formation

  http://www.weatherquestions.com/How_does_dew_form.htm

- What is an unstable air mass? This site outlines the causes and types of air masses, defining the stability of each.

  http://www.weatherquestions.com/What_is_an_unstable_air_mass.htm

FAA HOT AIR BALLOON CERTIFICATION:

Sample Written Test

For the question your group is assigned, choose the most complete answer. Write a short justification for your choice and present your solution to the class.

Several useful websites are listed at the end of the questions.

1. Under which atmospheric conditions is balloon lift off and climb the most difficult?
    a. Low temperature and low humidity
    b. High temperature and low humidity
    c. High temperature and high humidity

2. In hot air balloons, propane is preferred to butane or other hydrocarbons because
    a. It is less volatile
    b. It is slower to vaporize
    c. It has a lower boiling point

3. The lifting forces that act on a hot air balloons are primarily the result of the interior air temperature being
    a. Greater than ambient temperature
    b. Less than ambient temperature
    c. Equal to ambient temperature

4. While flying in 18 oC air, ice begins forming on the outside of the fuel tank in use but not on the reserve tank. This would most likely be caused by
    a. Water in the fuel
    b. A leak in the fuel line
    c. Vaporized fuel instead of liquid fuel being drawn from the tank into the main burner.

5. What would cause a gas balloon to start a descent if a cold air mass is encountered and the envelope becomes cooled?
    a. A density differential
    b. A barometric pressure differential
    c. The contraction of the gas

6. If a pilot changes the altimeter setting from 30.11” Hg to 29.96” Hg, what is the approximate change in gauge reading?

    a. Altimeter will indicate 0.15” Hg higher
    b. Altimeter will indicate 150’ higher
    c. Altimeter will indicate 150’ lower

7. What condition does a rising barometer indicate for balloon operations?
   a. Decreasing clouds and wind
   b. Chances of thunderstorms
   c. Approaching frontal activity

8. Clouds, fog, or dew will form when
   a. Water vapor condenses
   b. Water vapor is present
   c. Relative humidity reaches 100 percent

9. What would decrease the stability of an air mass?
   a. Warming form below
   b. Cooling from below
   c. Decrease in water vapor

10. It may be possible to make changes in the direction of flight in a hot air balloon by
   a. Flying a constant atmospheric pressure gradient
   b. Operating at different flight altitudes
   c. Operating above the friction level if there is no gradient wind.

Here are several websites you may find useful:

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FINAL PROJECT: HOT AIR BALLOON

PURPOSE:

- Demonstrate knowledge of graphing functions, types of functions, and volume and surface area by designing, constructing, and flying a hot air balloon.
- Gather information and data to find a relationship between flight time and surface area/volume ratio.

STEPS FOR CONSTRUCTION AND FLYING OF THE BALLOON:

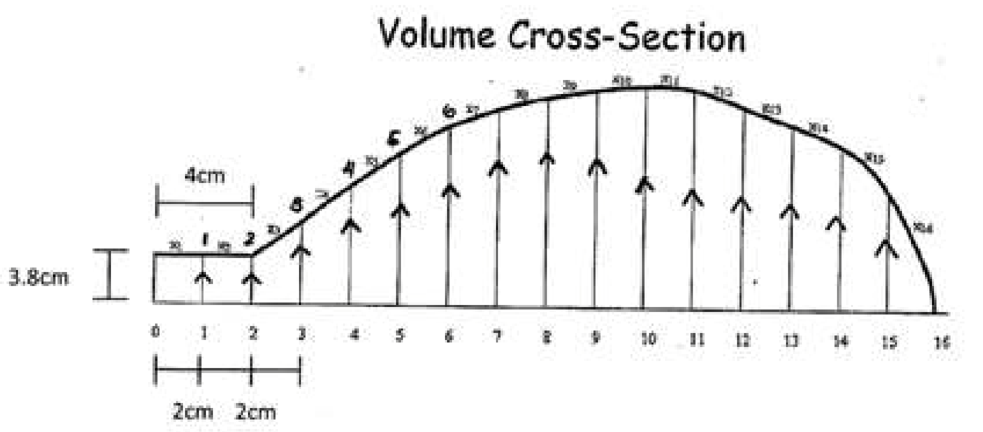
(See RUBRIC: FINAL PROJECT PART 1)

1. Research hot air balloons on the Internet to understand the physics of flying hot air balloons. Carefully look at various shapes of balloons.

2. On scratch paper, sketch some shapes as a possible design for the hot air balloon.

3. On a large piece of cardstock, use a straight edge to label the bottom of the longer edge as the *x*-axis (this will represent the height at the center of balloon). Mark off 1 cm units on this axis. 0 represents the bottom of the balloon. The cross section should be about 25-30 cm from top to bottom (L to R).

Label the left side of the card stock as the y-axis. Mark off 1 cm units on the *y*-axis. Draw ½ of the cross-section (due to symmetry, you will only sketch ½ of the cross-section). Make sure that the mouth of the balloon cross section is 3.8 cm high for the first 4 cm along the *x*-axis. This will make the final balloon fit over the stovepipe when filling it up with hot air.



Make sure when you draw the connecting lines from 0 to x1 and 1 to x2, etc... The lines are parallel (^) to each other and equidistant from each other. This is very important, only in the first “Volume Cross-Section”.

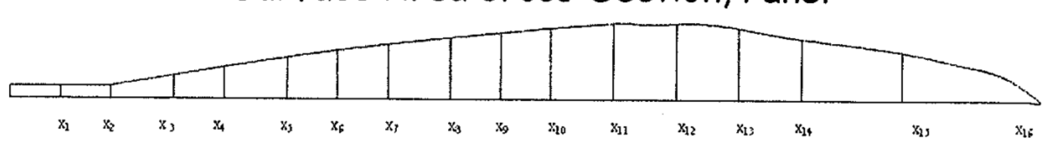
4. **Construction of the cross-section:** Determine a function or set of functions that give a similar shape to the top curve you have sketched for the outside edge of the cross section of the hot air balloon. Note: the piece-wise function for the cross-section must be continuous. This means that when you draw your piecewise function there will be no jumps or breaks in the graph. Be sure to record what functions you have used. It is sometimes easier to try functions centered at the origin and then shift them horizontally and vertically from the ‘parent’ function so that the outside edge given by your piecewise function is continuous.

5. **Measurements for the panels:** The actual balloon will be made with 8 panels that will represent the surface of the balloon between the outside edges of the cross-sections. The construction of the panel is a bit tricky. It will help to keep your data in a tabular format.

On your cardstock cross-section mark on the curve the corresponding f(x) value for every inch along the *x*-axis. Measure and record these f(x) (or *y*-values). These measurements represent the radii of the balloon at each point on the center axis.

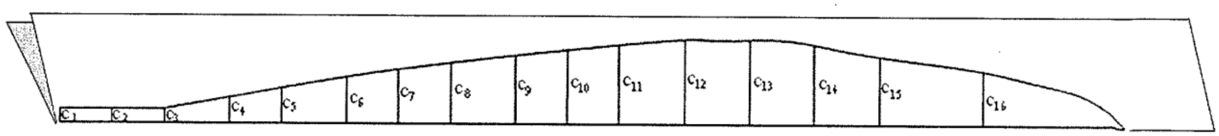
The center axis of the **panel** is not the same length as the center axis of the **balloon** since the panel edge is measure along the outside curve of your drawing. With a string accurately measure the length of the outside edge of the cross section. Mark on the string every f(x) point you have marked along the edge of the cross-section.

Surface Area Cross-Section, Panel



6. **Construction of the panels:** Stretch out the string along a new *x*-axis on the fold of a piece of butcher or construction paper (this represents the center of the outside panel from bottom to top of the balloon). The pen marks will not be at even intervals.

Recall that arc length on a circle is calculated by r*the angle (s = r*angle). The radii are the f(x) values and the angle is found to be 1/8 of 2*Pi since we will have 8 panels around the balloon. At every pen mark measure out ½ (1/8 * r*2*Pi) or ½ (1/8 * f(x)*2*Pi). This is ½ of 1/8 of the circumference of the balloon at that point. We use ½ because the paper for the panel model is folded in half and the *x*-axis is on the fold.



To assist with the construction of the large balloon, it would be helpful to create a table of values of the position of each point along the string and the corresponding radii: Here is an example:

Number of the point	**Distance from the origin**	**Radii**
0	0	3.8 cm
1	1	3.8 cm
2	--	--

7. **Construct the small balloon:** Connect the points you marked in (5). Carefully cut along this curve and unfold the paper to form the pattern for one of the 8 panels for your hot air balloon. Using the pattern, cut out 8 panels of tissue paper. Leaving a little ¼ inch border around the panel gives you a seam allowance so the panels can be glued together. Make a small balloon with the 8 panels. Use the small balloon to find out if any of the measurements are off.

8. **Construct the large balloon:** Using your table, triple the dimensions of the panel model to find the measurements for the panels for the large balloon. Follow the directions from (5) and (6) with these new measurements. Using the pattern, cut out 8 new panels using colored tissue paper. Put the balloon together by gluing the seams with Elmer's Glue and using copper wire (or heavy duty florist wire) around the mouth of the balloon.

9. Fly the balloon twice if possible and find the time aloft.

10. **Calculate the surface area:** To calculate the surface area, we will be using a technique called the mid-point rule. Essentially, it finds a fairly good estimate for surface area (and volume) when no geometric formula can be used.

From the data on your small balloon, use the 1-inch intervals along the *x*-axis to find the f(x) value at a midpoint (i.e. 0.5, 1.5, 2.5, …). Find and record the f(x) value at each of these midpoints. You might want to use a spreadsheet to record your data. Here is an example of a table you might form:

Point	**f(x) value**
0.5	f(0.5)
1.5	f(1.5)
2.5	f(2.5)

Imagine that we could lay the balloon on its side and make a series of slices perpendicular to the central axis of the balloon. These slices would look like flat cylinders. The height of each cylinder is 1 inch and the radius of each cylinder is f(x). This allows us to calculate an estimate for the surface area for each cylinder. Summing these values gives a good estimate of the small balloon's surface area.

11. **Calculate the volume:** Do the same work to calculate the volume of the small balloon. Find the volume of the each cylinder. Then sum these values to get an approximation of the volume of the small balloon.

12. Using appropriate proportions calculate approximations of the surface area and volume of the large balloon.

GATHERING AND ANALYZING FLIGHT DATA:

(RUBRIC: FINAL PROJECT PART 2)

13. Graph data from the entire class to find a possible relationship between SA/V and Time Aloft. The SA/V ratio is the independent variable and Time Aloft is the dependent variable. Your balloon will give you two data points if you can fly the balloon twice.

14. Can the data be represented by a linear model (or other function)? If so what is the relationship between SA/V and flight time? Why do you think this relationship exists?

15. Write a one to two page paper explaining the process you went through on choosing a design, what functions you used and how the functions you used are related to their parent functions.

For example:
If $f(x) = -1/2\ x^2 - 3\ x + 5$ then vertex form is $f(x) = -1/2\ (x - 3)^2 + 19/2$. So f(x) is related to the parent function $y = x^2$ in the following way: the vertex is shifted to the right 3 spaces and up 19/2 spaces, it opens downward, it is wider or less steep than the parent. When describing how your functions relate to the parent (for convenience and speed) round your functions' coefficients to 1 decimal place. Your piecewise function should be

continuous, justify the continuity of your function. Include a sketch of what your balloon looked like when it was inflated.

16. Describe in the paper the relationship between the cross section, SA and volume of the small balloon and the large balloon, and why different proportional relationships work for each of those measurements.

17. Include in your paper the data sheet or excel spreadsheet with the calculations for surface area and volume of the small balloon and how you used those values to find the surface area and volume of the big balloon. Be sure to include the surface area and volume of both the large and small balloons in the paper.

18. Include the scatter plot of SA/V ratio vs. flight time data that was gathered from the entire class.

19. Summarize your paper with a description of the flight of your balloon and any relationship you saw in the flight data for the class. Finally conclude with any relationship you saw between SA/V and flight time and what you think is the cause of this relationship.

20. Include with your write-up:
- a personal evaluation (look at rubric part 2)
- a team evaluation on your own balloon
- an evaluation on the project as an assessment tool.

	Components	Comments
Think	Demonstrates clear understanding of designing a cross-section pattern, modeling data with piece-wise functions, building a small and large balloon. Accurate computations of area under the curve, surface area and volume.	
Designing	❑ Cross section sketch of balloon ❑ Data Points and Regressions on calculator (observation) ❑ Continuous Piece-wise Function to model data ❑ Small balloon panel	
Calculations	❑ Excel spread sheet with measurements needed for area under curve (in cross section), surface area and volume of small balloon ❑ Calculations for approximate area under curve of small balloon cross section and for full cross section of large balloon ❑ Calculations for approximate SA of small and large balloons ❑ Calculations for approximate volume of small and large balloons ❑ Description of why certain proportions are used for finding area, surface area, and volume of large balloons	
Building	❑ Diagram of cross section and corresponding diagram of panel for small balloon ❑ Construction of small balloon ❑ Construction of large balloon ❑ **Get Help on the construction?** What kind of help? How did it help you? If not, why didn't you need it?	
Flying	❑ Large balloon finished on time ❑ Balloon flew once or twice ❑ Data collected for class	

Components are scored as **E**ssentially correct, **P**artially correct, or **I**ncorrect

1: Design All categories are clearly and completely provided.

E – All four categories | P – Only 3 | I – Two or less

2: Calculations Complete description of the steps taken by the students in the process of finding area under curve, SA, and volume of both balloons.

E – All 5 requirements | P – Only 4 or 3 | I – Fewer than 3

3: Building Neat construction of both balloons

E – All four requirements | P – Only 3 | I – Two or less

4: Flying Balloon flies and data sheet for class completed.

E – All three requirements | P – Only 2 | I – 1 or 0

Scoring

- ❑ E's count as 1 point, P's count as a 1/2 point, I's count as 0 points
- ❑ Rubric 1 Score = sum of components; Grade: 4 = 100%, 3.5 = 95%, 3 = 90%, etc.

Name: ______________________________________ Balloon Part 1 Score:__Grade:______________

	Components	Comments
Think	Demonstrates with a written paper a clear understanding of designing and constructing a hot air balloon and of analyzing flight information of a hot air balloon.	
Write–Up Includes	❑ Written paper describing design, construction, and analysis of flight data ❑ Data sheet or excel program used when enlarging small balloon to large ❑ Class data on SA/V to flight ❑ Team evaluations of balloon and paper with project rubrics ❑ Personal reflection on balloon project	
Components of Paper	❑ Description of piece wise function and how two component sections are related to their parent function (choose any two sections) ❑ Description of why piecewise function is continuous ❑ Description of how the dimensions of the small balloon helped you with the building of the large (why certain ratios were used) ❑ Description of flight of balloon and observations of trends in class data	
Analysis	❑ Analysis of class data is clearly described ❑ Line of best fit shown (or why there is no line of best fit) ❑ Reasoning of why relationship exists or should exist is correct	
Reflection	**Reflection (At least one paragraph):** ❑ Includes what was learned ❑ Possible applications of concepts covered in this project (at least 2) **Evaluation:** ❑ Team evaluation of project (with rubrics) ❑ Team evaluation of how this balloon assessment could be improved and/or strengths of balloon project	

<u>Components are scored as **E**ssentially correct, **P**artially correct, or **I**ncorrect</u>

1: Write-Up All categories are clearly and completely provided.
E – All five categories | P – Only 4 | I – Three or less

2: Components Descriptions in the paper are clear and complete
E – All four requirements | P – Only 3 or 2 | I – Fewer than 2

3: Analysis Complete, clear, correct and justified analysis is provided.
E – All three requirements | P – Only 2 | I – One or none

4: Extension and Evaluation Conclusions are genuine and insightful
E – All four requirements | P – Only 3 or 2 | I – Fewer than 2

Scoring

- ❑ E's count as 1 point, P's count as a 1/2 point, I's count as 0 points
- ❑ POW Score = sum of components; Grade: 4 = 100%, 3.5 = 95%, 3 = 90%, etc.

Name: ______________________________________ Final Part 2 Score: ____ Grade: ___________