National Aeronautics and
Space Administration

OH, WHAT A PANE!

An inquiry based activity with a mathematical approach to investigating windows on Earth….and in space.

TEACHER GUIDE

ARES
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Space Administration

OH, WHAT A PANE!

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OH, WHAT A PANE!

5-E Activity – Teacher's Guide

Goal: Students will use mathematics to investigate windows and astronaut photographs.

Objectives: Students will:
- Identify shapes of windows and their functions.
- Investigate and calculate area, cost, and cost analysis for various window shapes.
- Analyze data from NASA astronaut photography.
- Interpret lens size and area of coverage information.
- Mathematically describe astronaut photographs.

Grade Level: 5 – 10 (Unit begins at a fifth grade level and the mathematics becomes progressively more difficult ending at the tenth grade level.)

Time Requirements: Unit does not have to be completed all at once. Teachers can be flexible with the time and use of the unit. Estimated total time of entire unit: 3 – 4 hours.

Materials:
- Student Guide Booklet
- Pattern Blocks or Tangrams
- *Oh, What A Vision!* handout
- *Oh, What A Cupola!* handout (optional extension)

National Mathematics Standards (NCTM) Addressed:

<u>Number and Operations:</u>
- Understand numbers, ways of representing numbers, and relationships among numbers.
- Compute fluently.

<u>Geometry:</u>
- Analyze characteristics and properties of two- and three-dimensional geometric shapes.
- Use visualization, spatial reasoning, and geometric modeling to solve problems.

<u>Measurement:</u>
- Apply appropriate techniques, tools, and formulas to determine measurements.

<u>Data Analysis:</u>
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
- Develop and evaluate inferences and predictions that are based on data.

<u>Connections:</u>
- Recognize and apply mathematics in contexts outside of mathematics.

Common Core State Mathematics Standards (CCSS) Addressed:

Grade 5

Number and Operations in Base Ten

- Perform operations with multi-digit whole numbers and with decimals to hundredths.

Measurement and Data

- Convert like measurement units within a given measurement system.

Geometry

- Classify two-dimensional figures into categories based on their properties.

Grade 6

The Number System

- Compute fluently with multi-digit numbers.

Geometry

- Solve real-world and mathematical problems involving area, surface area, and volume.

Grade 7

The Number System

- Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers.

Geometry

- Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

Grade 8

The Number System

- Know that there are numbers that are not rational, and approximate them by rational numbers.

Geometry

- Understand and apply the Pythagorean Theorem.

High School

Geometry

- Make geometric constructions.
- Apply geometric concepts in modeling situations.

Statistics and Probability

- Making inferences and justifying conclusions.

Useful Websites for Additional Background Knowledge:

- NASA Gateway to Astronaut Photography homepage: http://eol.jsc.nasa.gov
- NASA Earth Observatory webpage with featured articles, images, news, and global maps of Earth: http://earthobservatory.nasa.gov/
- NASA ARES Expedition Earth and Beyond webpage: http://ares.jsc.nasa.gov/ares/eeab/index.cfm
- The Art Glass Association: http://www.thestorefinder.com/glass/library/history.html

- Focal Length Information: http://www.photoaxe.com/understanding-the-lens-focal-length-and-aperture

References, Resources and Acknowledgements:

- Runco, M., Eppler, D., Scott, K.P., and Runco, S. *Earth Science and Remote Sensing Capabilities of the International Space Station: The Destiny Module Science Window and the Window Observational Research Facility.*
- Elm City Photo, Waterville, Maine
- Hammond Lumber Company, Belgrade, Maine

Printing Alternative: As your resources permit, you can download the pdf of the Student Guide on your student computers and have students fill in answers to questions, save their work, and continue each day without printing anything. You will need to have a program/software that will enable this. One recommendation is FoxIt Reader. FoxIt Reader allows you to open pdfs, type in answers, and save your work. It is a free download available at http://www.foxitsoftware.com/pdf/reader. You may want to check to make sure documents save correctly before students finish their work. Adobe reader will not save typed in work. Other alternatives may be available. For sketches, you might ask your students to hand draw those on a separate piece of paper or they can draw them on the computer using "Paint" and insert their sketch into the document.

Adaptations, Extensions, and Enrichment:

Oh, What Do You See?

- If there is not a lot of variety in windows in your locale, bring in pictures from magazines. You could also use the Internet to find pictures to have available.
- Traditionally windows in the US are sold in customary units. You might want to rework the initial part of this activity with dimensions for the windows being given in metric units.

Oh, But the Cost!

- Explore the costs of windows in your community. Visit a local business and compare the prices of windows. If you don't have that opportunity, you can explore pricing on-line.
- Students can create paper/tissue paper stained glass windows. Have them find the area of each color.
- Assign a cost per square unit, and have students calculate the cost of each color.

Oh, What a View!

- Visit the Gateway to Astronaut Photography of Earth website (http://eol.jsc.nasa.gov). Have students explore the website and discuss ways in which mathematical information is used.
- Have students conduct a mathematical investigation using astronaut photographs. As part of the Expedition Earth and Beyond program, students can conduct an investigation and request a new astronaut photograph as part of their investigation. For more information check out the Expedition Earth and Beyond website (http://ares.jsc.nasa.gov/ares/eeab/index.cfm)

Oh, What a Cupola! – OPTIONAL ACTIVITY INCLUDED AT THE END OF THE TEACHER GUIDE

- Using Google Earth, create a model of the Cupola.

Introduction and Background

Oh, What a Pane! offers a highly aligned mathematical supplement to the *Expedition Earth and Beyond* Program. The unit begins with mathematics concepts that fifth grade students would explore. The mathematics become progressively more difficult with each section. Towards the end of the unit concepts may challenge a more advanced learner.

The mathematical content for each section is outlined below:

- **Oh, What Do You See?** – shape recognition, data collection and analysis, patterns, area of rectangles (including squares which are special rectangles), circles, and octagons.
- **Oh, But the Cost!** – unit analysis, area, mathematical communication.
- **Oh, What a View!** – data analysis, percent, percent increase.
- **Oh, What a Vision!** – algebraic relationships.
- **Oh, What a Cupola! (extension)–** geometric models, technology.

NCTM Principles and Standards	Number and Operations	Algebra	Geometry	Measurement	Data Analysis and Probability	Problem Solving	Reasoning and Proof	Communication	Connections	Representation
Oh, What Do You See?	X			X	X	X		X	X	X
Oh, But the Cost!	X		X	X	X	X	X	X	X	X
Oh, What a View!	X	X			X	X	X	X	X	X
Oh, What a Vision!		X			X	X	X	X	X	
Oh, What a Cupola!			X	X	X	X			X	X

Common Core State Standards (Mathematics Domains)	Oh, What Do You See?	Oh, But the Cost!	Oh, What a View!	Oh, What a Vision!	Oh, What a Cupola!
Grade 5	5.NBT 5. MD 5.G	5.NBT 5.G	5.NBT		
Grade 6	6.NS	6.NS	6.NS		6.G
Grade 7	7.NS	7.NS 7.G	7.NS		6.G
Grade 8	8.NS 8.G				
High School				S-IC	G-CO G-MG

The mathematics content that is listed above is integrated throughout the 5-E Inquiry Model of Instruction. Each section of *Oh, What A Pane!* does not contain all parts of the 5-E model. The complete activity does incorporate all parts of the 5-E model. Each section can be given to students as an independent activity or as a total unit.

5-E INQUIRY MODEL OF INSTRUCTION

The 5-E model is an inquiry-based model of instruction based on a constructive approach to learning (learners build or construct ideas by comparing new experiences to their existing framework of knowledge). The 5-E model of instruction breaks this approach into 5 phases. The phases are: *Engagement, Exploration, Explanation, Elaboration,* and *Evaluation*. This model builds on prior knowledge and common experiences of students and teachers to construct or build meaning and connections to new concepts while also correcting any inaccuracies. This activity is designed as guided discovery to maintain a structure for learning for your students.

The table below breaks down each phase of the 5-E model. The table provides a general description of each phase and how the *Oh, What A Pane!* activity applies to each phase within the lesson.

5-E Phase	General Description	Oh, What A Pane!
Engagement	Teachers engage students using an activity, image or discussion to focus students' thinking on the learning outcomes of an activity.	Students will observe windows, tally and count the various shapes, look for the most common type, and explore the purposes of various windows (Oh, What Do You See?).
Exploration	Students actively explore and make discoveries using hands-on materials. Students develop concepts, processes and skills to establish an understanding of content.	Students will investigate areas of the windows, find unit costs, and use data to answer questions (Oh, What Do You See?; Oh, But the Cost!; Oh, What a View!; Oh, What A Vision!).
Explanation	Students communicate and explain concepts they have been exploring. Students use formal language and vocabulary associated with content.	Based on the data, students will justify what they believe to be the "perfect" window (Oh, But the Cost!). Students will explain/justify how they match lens size with astronaut photographs (Oh, What A Vision!).
Elaboration	Students extend conceptual understandings to new problems or experiences. Students reinforce and develop a deeper understanding of concepts and skills.	Students will create stained glass windows and change the perspective of the unit rate to mathematically describe a window (Oh, But The Cost!). Students will mathematically describe astronaut photographs (Oh, What A Vision!). Students will apply their understanding of lens size to geographic area covered to solve problems (Oh, What A Vision!).
Evaluation	Teachers and students assess new knowledge and understanding of key concepts.	Students will complete a variety of tables with correct mathematics. They will also answer questions that are posed throughout the unit.

ACTIVITY PROCEDURE

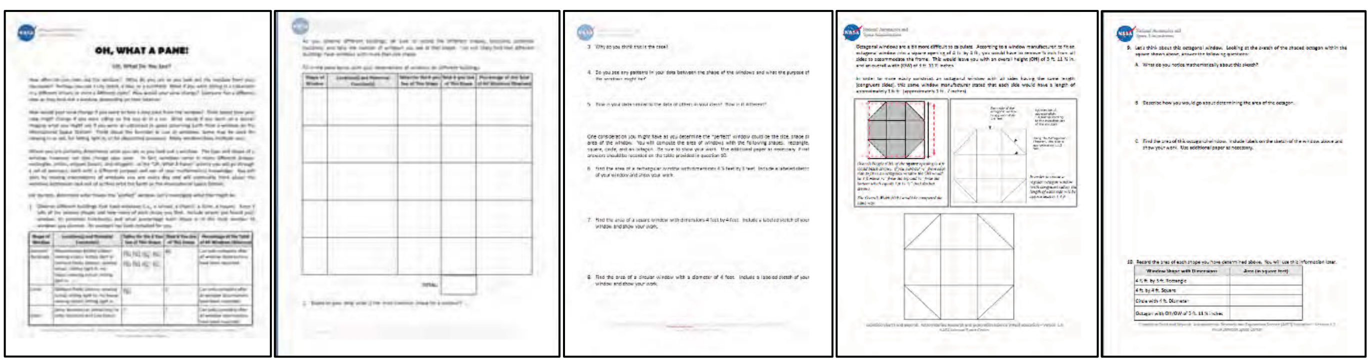
This activity procedure is provided as a suggested guide for the *Oh, What A Pane!* activity. This procedure includes sample answers and thumbnails of student pages for each section for your reference. The Student Guide is set up to allow a student(s) to work independently through the unit. You may decide to use the activity as a whole class activity, providing a myriad of discussion opportunities. You may have students work in pairs, small groups, or independently. Alternatively, you may consider using the activity as enrichment. Based on your student needs, feel free to provide additional instruction on finding the area of various shapes, additional work with unit cost and unit analysis, or other mathematical topics presented in the unit.

As students work through the activity, the first 2 sections (*Oh, What Do You See?* and *Oh, But The Cost!*), students will explore windows and determine the "perfect" window. As the activity progresses, students will make continual connections between mathematics, windows, and astronaut photographs.

Oh, What Do You See?

Overview of topics: Shape recognition, data collection and analysis, patterns, area.

Have students read through the introductory paragraphs on the first page of the activity. Have students use the sample shown in The Student Guide as a guide to how they should log information about windows they observe within the community. You might have students complete this tally prior to coming to class or provide pictures from magazines to have students log their observations.



1. Filling in Data Table
   Students will have their own answers. Rectangles, circles, semi-circles, hexagons, ovals, trapezoids, and octagons may be some of the shapes students observe. There are certainly other shapes for windows. You will need to check totals and the percentages students have calculated.

2. Based on your data, what is the most common shape for a window?
   Students probably saw more rectangular windows.

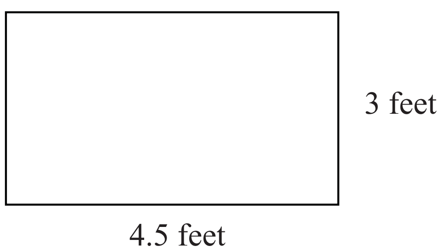
3. Why do you think this is the case?
   Students may mention cost, appealing shape, or popularity as reasons for the most common shapes, but other answers are acceptable.

4. Do you see any patterns in your data between the shape of the windows and what the purpose of the windows might be?
Students might find that homes have more rectangles, churches might have ovals, etc. Or they may find no patterns at all!

5. How is your data similar to the data of others in your class? How is it different?
Answers will vary. You might have the students discuss the amount of data collected and the location(s) the data was collected from.

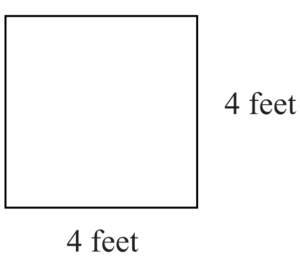
One consideration you might have as you determine the "perfect" window could be the size, shape, or area of the window. You will compute the area of windows with the following shapes: rectangle, square, circle, and octagon. Be sure to show your work and final answer labeled with the appropriate unit. Use additional paper as necessary. Final answers should be recorded on the table provided in question 10.

6. Find the area of a rectangular window with dimensions 4 ½ feet by 3 feet. Include a labeled sketch of your window and show your work.
Students should draw a rectangle with the length and width labeled. They should show the formula and calculation used to determine the area.



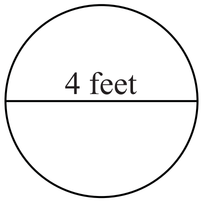
Example:
Formula For Area of a Rectangle: *A=bh or A = lw*
Calculation: *4.5 (4 ½) feet x 3 feet = 13.5 square feet*
Area: *13.5 square feet*

7. Find the area of a square window with dimensions 4 feet by 4 feet. Include a labeled sketch of your window and show your work.
Students should draw a square with the length and width labeled. They should show the formula and calculation used to determine the area.



Example:
Formula For Area of a Square: *A=bh or A = $(s)^2$*
Calculation: *4 feet x 4 feet = 16 square feet*
Area: *16 square feet*

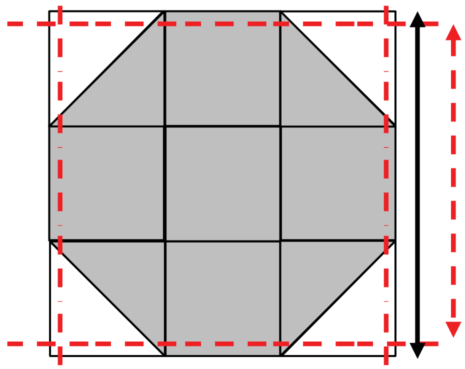
8. Find the area of a circular window with a diameter of 4 feet? Include a labeled sketch of your window and show your work.
Students should draw a circle with a 4 foot diameter labeled. They should show the formula and calculation used to determine the area.
Circle: Approximately 12.56 square feet (using 3.14 as pi).



Example:
Formula For Area of a Circle: *$A = \pi r^2$ (pi = 3.14)*
Calculation: *Diameter = 4 feet; Radius = 2 feet*
$3.14 \times (2)^2 = 3.14 \times 4 = 12.56$ square feet
Area: *≈ 12.56 square feet*

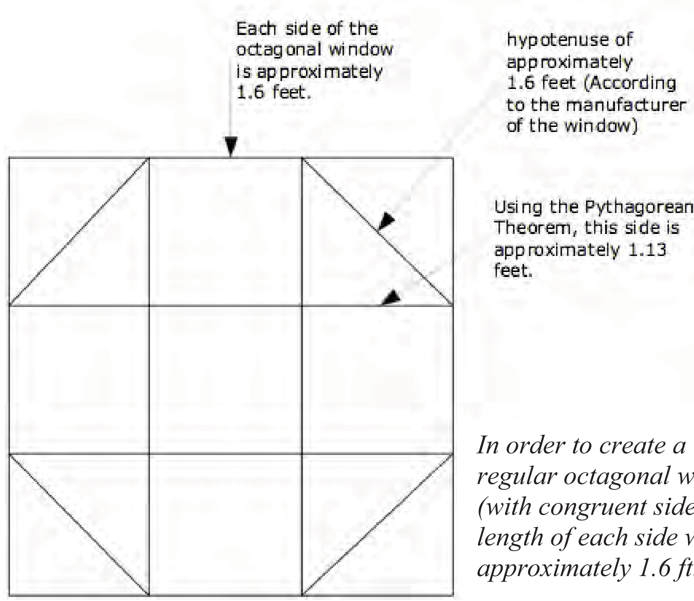
Octagonal windows are a bit more difficult to calculate. According to a window manufacturer, to fit an octagonal window into a square opening of 4 ft. by 4 ft., you would have to remove ¼ inch from all sides to accommodate the frame. This would leave you with an overall height (OH) of 3 ft. 11 ½ in. and an overall width (OW) of 3 ft. 11 ½ inches.

In order to more easily construct an octagonal window with all sides having the same length (congruent sides), this same window manufacturer stated that each side would have a length of approximately 1.6 ft. (approximately 1 ft., 7 inches).



Overall Height (OH) of the ***square*** *opening is 4 ft (solid black arrow). If you subtract ¼" from each side to fit in an octagonal window the OH would be 4 ft minus ¼" from the top and ¼" from the bottom which equals 3 ft 11 ½" (red dashed arrow).*

The Overall Width (OW) would be computed the same way.



In order to create a regular octagonal window (with congruent sides), the length of each side will be approximately 1.6 ft.

9. Let's think about this octagonal window. Looking at the sketch provided of the shaded octagon within the square, answer the following questions:

   A. What do you notice mathematically about this sketch?
   Students may notice what appear to be 5 squares and 4 half squares (triangles). (Other answers are possible.) If students mention the squares, the teacher may want to dispel a misconception that these are actually squares. They are rectangles with one side approximately 1.6 feet and the other side approximately 1.13 feet. (See answer 10 for an explanation of the Pythagorean Theorem.)

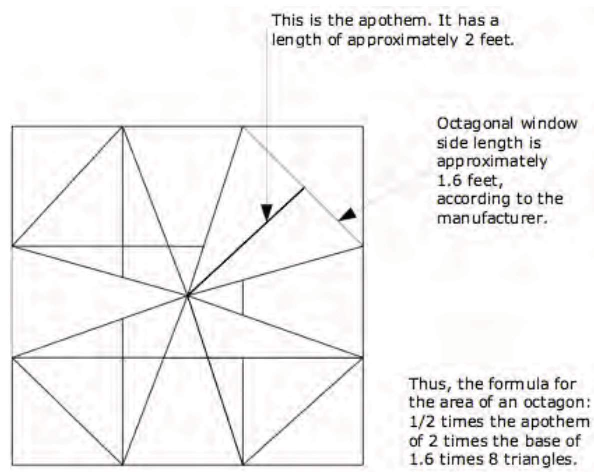
   B. Describe how you would go about determining the area of the octagon.
   Answers will vary based on how students view the above image.

C. Find the area of this octagonal window. Include labels on the sketch of the window provided and show your work. Use additional paper as necessary. (Students should label the sketch provided in the student guide as part of showing their work.)

Remind students that 1.6 feet is not 1 foot 6 inches. This is another misconception. There are several methods to find the approximate area of the octagonal window. Be sure students' explanations match the method they use to solve the problem.

- *Students can use the rectangle/triangle method. The four triangles joined together can make 2 rectangles with the same dimensions as the 5 rectangles. (1.13 * 1.6) (5 + 2) is approximately equal to* ***12.7 square feet****. They already used the Pythagorean Theorem to calculate the second dimension of each rectangle. Approximately 1.6 feet is the hypotenuse of the isosceles triangle. (*$a^2 + b^2 = c^2$ » $a^2 + b^2 = (1.6)^2$ » $a^2 + b^2 = 2.56$; $a = b$ » $2a^2 = 2.56$*, divide both sides by 2,* $a^2 = 1.28$*, so a is approximately 1.13 feet.*

- *Another method would be to use the formula for finding the area of a regular polygon which is A = ½ asn, where A = overall area of the polygon, a = the apothem or height of the triangles that form the polygon, s = the length of the sides, and n = the number of sides. A = ½ asn » A = .5(2)(1.6)(8). So the area is approximately* ***12.8 square feet****. (Hint: To find a (the apothem), take ½ the distance of one side of the window casement (OH/OW). Remember that 3 feet 11 ½ inches divided by two is approximately 2 feet.)*



- *Students may convert all measurements that were given in feet to inches. They would need to reconvert square inches to square feet at the end of the conversion process by dividing by 144 (144 square inches = 1 square foot; 12 inches * 12 inches = 144 square inches). Using A = ½ asn, students would get ½ (23.75) * 8 * (1.6 ft. * 12 in.) = 1824 square inches. Divide by 144 and you have approximately* ***12.67 square feet****. You can use the conversion to inches for other methods as well.*

- *Another way a student might look at solving the problem is to find the total area of the square casement (4 feet by 4 feet = 16 square feet). If students are approximating the area of the 9 sections created, they can divide 16 by 9, or multiply 1/9 by 16. Since four of the triangles represent 2 rectangles, find 7/9 of 16 square feet which would be the octagon within the square window casement. This gives approximately* ***12.4 square feet****.*

10. Record the area of each shape you have determined. You will use this information later.

Window Shape with Dimensions	Area (in square feet)
4 ½ ft. by 3 ft. Rectangle	*13.5 square feet*
4 ft. by 4 ft. Square	*16 square feet*
Circle with 4 ft. Diameter	*≈12.56 square feet*
Octagon with OH/OW of 3 ft. 11 ½ inches	*≈ 12.67 square feet (more than one answer is possible)*

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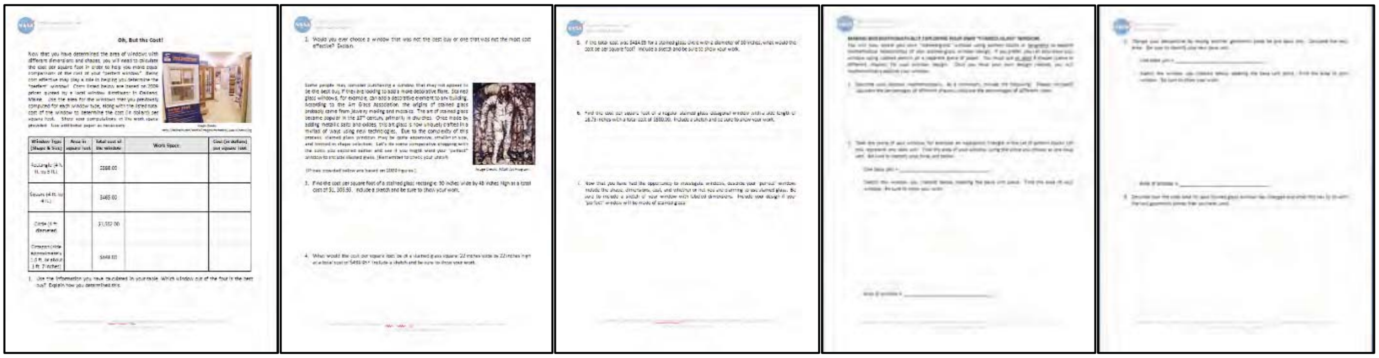
Oh, But the Cost!

Overview of topics: Unit analysis, area, mathematical communication.

For this part of the activity, students will use the area of each shape they calculated in the *Oh, What Do You See?* part of the activity. They will additionally compute costs of stained glass windows as part of their analysis of finding the “perfect” window.



Students should fill in the table as show below.

Window Type (Shape & Size)	Area in square feet	Total Cost of the Window	Work Space	Cost (in dollars) per square foot
Rectangle (4 ½ ft. by 3 ft.)	*13.5 square feet*	$588.00	*$588 / 13.5 square feet (Students should show their division.)*	*$43.56*
Square (4 ft. by 4 ft.)	*16 square feet*	$465.00	*$465 / 16 square feet (Students should show their division.)*	*$29.07*
Circle (4 ft. diameter)	*12.56 square feet*	$1,662.00	*$1662 / 12.56 square feet (Students should show their division.)*	*$132.33*
Octagon (side approximately 1.6 ft. or about 1 ft. 7 inches)	*12.67 square feet (more than one answer is possible)*	$648.00	*$648 / 12.67 square feet (Students should show their division.)*	*$51.15*

1. Use the information you have calculated in your table. Which window out of the four is the best buy? Explain how you determined this.
The best buy is the square window. You determine square footage by dividing the total cost by the area of each window.

2. Would you ever choose a window that was not the best buy, or one that was not the most cost effective? Explain.
   Students may have their own answers here. They might choose a more expensive window because it is more decorative. They may want a window that is unique. They might have a specific purpose or function for the window, such as a large, picture window that would give a scenic view.

3. Find the cost per square foot of a stained glass rectangle: 30 inches wide by 48 inches high at a total cost of $1, 306.95. Include a sketch and be sure to show your work.
   Students should show their labeled sketch and show their work.
   *Stained glass rectangle: $1,306.95/10 square feet is approximately $130.70 per square foot. Conversion from square inches to square feet: 30*48=1440 square inches; 1440 square inches/144 (square inches in a square foot) = 10 square feet.*

4. What would the cost per square foot be of a stained glass square: 22 inches wide by 22 inches high at a total cost of $439.95? Include a sketch and be sure to show your work.
   Students should show their labeled sketch and show their work.
   *Stained glass square: $439.95/3.36 square feet is approximately $130.94 per square foot. [Conversion from square inches to square feet: 22*22=484 square inches; 484 square inches/144 (square inches in a square foot) ≈ 3.36 square feet.]*

5. If the total cost was $414.95 for a stained glass circle with a diameter of 30 inches, what would the cost be per square foot? Include a sketch and be sure to show your work.
   Students should show their labeled sketch and show their work.
   Stained glass circle: $414.95/4.91 square feet is approximately $84.52 per square foot.
   [Conversion from square inches to square feet: πr^2=3.14(15 inches)^2=706.5 square inches; 706.5 square inches/144 (square inches in a square foot) ≈ 4.91 square feet.]

6. Find the cost per square foot of a regular stained glass octagonal window with a side length of 18.75 inches with a total cost of $500.00. Include a sketch and be sure to show your work.
   Students should show their labeled sketch and show their work.
   Stained glass octagon: This problem requires the use of the Pythagorean Theorem due to the limited data provided.
   - *We only have the length of the side of the regular octagon. There are five squares with sides of 18.75 inches.*
   - *The area of the corner triangles can be found once you calculate the length of the legs of the triangle using the Pythagorean Theorem. Area of the squares = 5(18.75)^2=1757.8 square inches (approximately).*
   - *The length of the legs of the triangles: $a^2+a^2=18.75^2$ (remember the legs are equal in length). So, $2a^2=18.75^2$; $2a^2=351.5625$; $a^2= 351.5625/2$; $a^2=175.78125$; a=13.258 inches (approximately).*
   - *(Students may discover that they do not need to find the actual length of the legs because of the relationship between the 4 triangles and the Pythagorean Theorem). $2a^2$ is equal to the area of all four triangles. Therefore you could simply add the area of the 5 squares to $2a^2$ giving you: $5(18.75)^2 + 18.75^2= 6(18.75)^2$=2109.375 square inches.*

Remember to divide by 144 square inches to convert to square feet; 2109.375/144=14.65 square feet. To find the cost per square foot divide: $500/14.65 square feet = ***$34.13 per square foot (approximately).***

7. Now that you have had the opportunity to investigate windows, describe which of these would be your "perfect" window. Include the shape, dimensions, cost, and whether or not you are planning to use stained glass. Be sure to include a sketch of your window with labeled dimensions. Also describe the purpose of your "perfect" window.
   Students will have their own individual descriptions of their windows.

MAKING AND MATHEMATICALLY EXPLORING YOUR OWN "STAINED-GLASS" WINDOW

1. Describe your window mathematically. At a minimum, include the following: Shapes used, calculate the percentages of different shapes, calculate the percentages of different colors.
   Students create their own windows. You would need to give suggestions on the types of mathematics you wish for the students to give and check their answers individually.

2. Take one piece of your window, for example an equilateral triangle in the set of pattern blocks. Let this represent one base unit. Find the area of your window, using the piece you choose as one base unit. Be sure to identify your base unit below.

   One base unit = ___________________________________

   Sketch the window you created below, labeling the base unit piece. Find the area of your window. Be sure to show your work.

   Area of window = ___________________________________

   Answers will vary based on student window design and base unit used.

3. Change your perspective by having another geometric piece be one base unit. Calculate the new area. Be sure to identify your new base unit.

   One base unit = ___________________________________

   Sketch the window you created below, labeling the base unit piece. Find the area of your window. Be sure to show your work.

   Area of window = ___________________________________

   Answers will vary based on student window design and base unit used.

4. Describe how the total area for your stained glass window has changed and what this has to do with the two geometric pieces that you have used.
   If students chose a larger piece for the base unit, their overall area would be less. If they chose a smaller piece for the base unit, their overall area would increase.

SAMPLE STAINED GLASS WINDOW EXAMPLE:

Description:

My stained glass window was designed using four pattern block shapes: 6 yellow regular hexagons, 8 red isosceles trapezoids, 10 blue parallelograms, and 4 green equilateral triangles.

Shape Percentages: Hexagons ≈ 15%; Triangles ≈ 15%; Trapezoids ≈ 31%; Parallelograms ≈ 39%.

Color Percentages: Yellow ≈ 33 ⅓ %; Red ≈ 33 ⅓ %; Blue ≈ 27 $\frac{7}{9}$ %; and green is 5 $\frac{5}{9}$ %

One Base Unit = the equilateral triangle

Determining the area: If the equilateral triangle is equal to one base unit, the hexagon is 6 base units, the trapezoid is 3 base units, and the parallelogram is 2 base units. To find the total area of the stained glass window, multiply the number of each type of shape by its base area. There are four hexagons that are 6 base units (total of 24 base units), 8 trapezoids multiplied by an area of 3 base units each (total of 24 base units), 10 parallelograms of 2 base units each (20 base units), and 4 equilateral triangles with a base unit each (total of 4 base units).

ONE BASE UNIT = GREEN EQUILATERAL TRIANGLE

1 Yellow Hexagon = 6 triangles

4 hexagons x 6 = 24 base units

Red Trapezoids = 3 triangles

8 trapezoids x 3 = 24 base units

Blue Parallelograms = 2 triangles

10 x 2 parallelograms = 20 base units

Green Triangles = 1 triangle

4 triangles x 1 = 4 base units

TOTALS
24 base units (hexagons)
24 base units (trapezoids)
20 base units (parallelograms)
4 base units (triangles)
----
72 base units

THE ENTIRE STAINED GLASS WINDOW HAS AN AREA OF **72 BASE UNITS.**

National Aeronautics and
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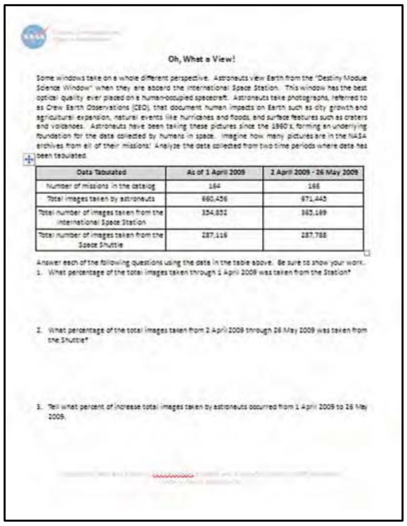
Oh, What a View!

Overview of topics: Data analysis, percent, percent increase.

For this part of the activity, students will analyze data related to astronaut photographs taken during given time periods.


Oh, What a View!

Some windows take on a whole different perspective. Astronauts view Earth from the "Destiny Module Science Window" when they are aboard the International Space Station. This window has the best optical quality ever placed on a human-occupied spacecraft. Astronauts take photographs, referred to as Crew Earth Observations (CEO), that document human impacts on Earth such as city growth and agricultural expansion, natural events like hurricanes and floods, and surface features such as craters and volcanoes. Astronauts have been taking these pictures since the 1960's, forming an underlying foundation for the data collected by humans in space. Imagine how many pictures are in the NASA archives from all of their missions! Analyze the data collected from two time periods where data has been tabulated.

Data Tabulated	As of 1 April 2009	2 April 2009 - 26 May 2009
Number of missions in the catalog	164	166
Total images taken by astronauts	660,456	671,445
Total number of images taken from the International Space Station	354,852	365,169
Total number of images taken from the Space Shuttle	287,116	287,788

Answer each of the following questions using the data in the table above. Be sure to show your work.

1. What percentage of the total images taken through 1 April 2009 was taken from the Station?

2. What percentage of the total images taken from 2 April 2009 through 26 May 2009 was taken from the Shuttle?

3. Tell what percent of increase total images taken by astronauts occurred from 1 April 2009 to 26 May 2009.

Data Tabulated	As of 1 April 2009	2 April 2009 - 26 May 2009
Number of missions in the catalog	164	166
Total images taken by astronauts	660,456	671,445
Total number of images taken from the International Space Station	354,852	365,169
Total number of images taken from the Space Shuttle	287,116	287,788

1. What percentage of the total images taken through 1 April 2009 was taken from the Station?
   354,852 / 660,456 = Approximately 53.7%

2. What percentage of the total images taken from 2 April 2009 through 26 May 2009 was taken from the Shuttle?
   287,788 / 671,445 = Approximately 42.9%

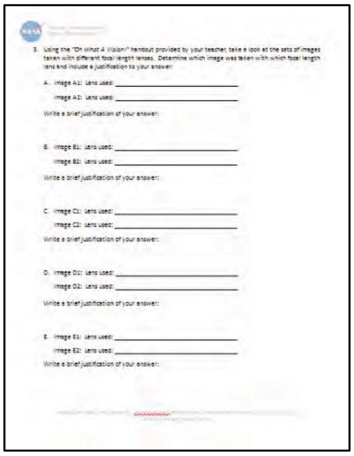
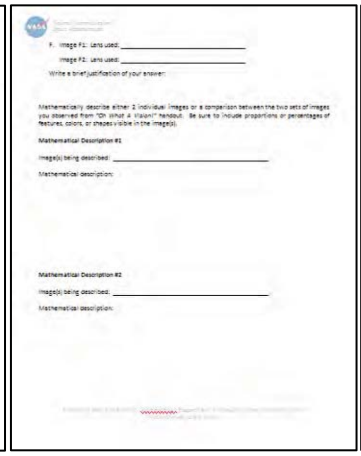
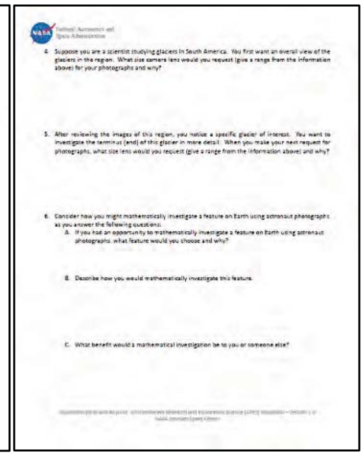
3. Look at the increased number of total images taken by astronaut from 1 April 2009 to 26 May 2009. What is the percent of increase?
   (671,445 - 660,456) / 660,456 = Approximately 1.66 % increase

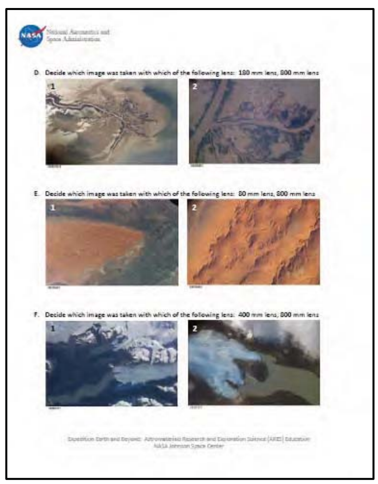
Oh, What a Vision!

Overview of topics: Algebraic relationships, application of lens size/area relationship to solve scientific problems.

For this part of the activity, students will analyze the inverse relationship between lens size and area covered in an image. Students will apply their understanding of lens size to geographic area covered to solve scientific problems.

RESOURCE NEEDED: *Oh, What A Vision*! handout

These two pages are the "Oh, What A Vision!" handout used to answer questions 3 – 6.

1. Based on the information above, what type of mathematical relationship explains the lens size and area of coverage?

   An inverse variation

2. The International Space Station's (ISS) inclination (or angle) of orbit was increased from 28.5 degrees to 51.6 degrees, significantly increasing the area of the Earth that would be visible to the astronauts through the Destiny Window. What type of mathematical relationship does this describe?

   A direct variation

3. Using the handout provided by your teacher, take a look at the sets of images taken with camera lenses of different focal lengths. Match the camera lens with the acquired astronaut photograph. Include a justification of your answer.

   A. Image A1: Lens used: ___*400 mm*________________________________

      Image A2: Lens used: ___*180 mm*________________________________

   Write a brief justification of your answer:

   Answers will vary but should include details regarding aspects such as: the higher the focal length/lens, the less area shown in the image; or the higher the focal length/lens, the more detail is shown in the image (or vice versa).

   B. Image B1: Lens used: ___*400 mm*________________________________

      Image B2: Lens used: ___*800 mm*________________________________

   Write a brief justification of your answer:

   Answers will vary but should include details regarding aspects such as: the higher the focal length/lens, the less area shown in the image; or the higher the focal length/lens, the more detail is shown in the image (or vice versa).

   C. Image C1: Lens used: ___*800 mm*_______________________________

      Image C2: Lens used: ___*80 mm*________________________________

   Write a brief justification of your answer:

   Answers will vary but should include details regarding aspects such as: the higher the focal length/lens, the less area shown in the image; or the higher the focal length/lens, the more detail is shown in the image (or vice versa).

   D. Image D1: Lens used: ___*180 mm*_______________________________

      Image D2: Lens used: ___*800 mm*_______________________________

   Write a brief justification of your answer:

   Answers will vary but should include details regarding aspects such as: the higher the focal length/lens, the less area shown in the image; or the higher the focal length/lens, the more detail is shown in the image (or vice versa).

   E. Image E1: Lens used: ___*80 mm*________________________________

      Image E2: Lens used: ___*800 mm*_______________________________

   Write a brief justification of your answer:

Answers will vary but should include details regarding aspects such as: the higher the focal length/lens, the less area shown in the image; or the higher the focal length/lens, the more detail is shown in the image (or vice versa).

F. Image F1: Lens used: ___*400 mm*_______________________________

Image F2: Lens used: ___*800 mm*_______________________________

Write a brief justification of your answer:

Answers will vary but should include details regarding aspects such as: the higher the focal length/lens, the less area shown in the image; or the higher the focal length/lens, the more detail is shown in the image (or vice versa).

Mathematically describe either 2 individual images or a comparison between the two sets of images you observed from *"Oh What A Vision!"* handout. Be sure to include proportions or percentages of features, colors, or shapes visible in the image(s).

Mathematical Description #1

Image(s) being described: ____

Mathematical description:

Answers will vary.

Mathematical Description #2

Image(s) being described: ____

Mathematical description:

Answers will vary.

4. Suppose you are a scientist studying glaciers in South America. You first want an overall view of the glaciers in the region. What size camera lens would you request (give a range from the information provided) for your photographs and why?
Students should indicate a request of a short (or small) lens size (between 70 mm and 180 mm) to get the largest area of coverage due to the inverse relationship of the lens size and area covered.

5. After reviewing the images of this region, you notice a specific glacier of interest. You want to investigate the terminus (end) of this glacier in more detail. When you make your next request for photographs, what size lens would you request (give a range from the information provided) and why?
Students should indicate a request of a longer (or larger) lens size (between 200 mm and 800 mm) to get the smallest area of coverage to help target the specific area of interest in greater detail, based on the inverse relationship of the lens size and the area covered.

6. Consider how you might mathematically investigate a feature on Earth using astronaut photographs as you answer the following questions:
    a. If you had an opportunity to mathematically investigate a feature on Earth using astronaut photographs, what feature would you choose and why?

    Answers will vary.

    b. Describe how you would mathematically investigate this feature.

    Answers will vary.

    c. What benefit would a mathematical investigation be to you or someone else?

    Answers will vary.

Teacher Note: This last question is a perfect lead in to potentially having your students conduct research through the Expedition Earth and Beyond Program. For additional information contact Paige Graff at paige.v.graff@nasa.gov.

Oh, What a Cupola! (Optional Extension)

Overview of topics: Geometric models, technology.

For this part of the activity, students will create a model of the Cupola, a recent addition to the International Space Station using Google SketchUp. The Cupola includes one circular window and six trapezoid shaped windows.

RESOURCES NEEDED: Google SketchUp and *Oh, What a Cupola!* Handout.

Oh, What a Cupola!

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Oh, What A Vision!

Take a look at the follow sets of astronaut photographs. Each image was taken of the same area with camera lenses of different focal lengths. Your task is to match the camera lens with the acquired astronaut photograph.

A. Match each of the following lenses with the images below: **180 mm lens, 400 mm lens**

ISS014E13613

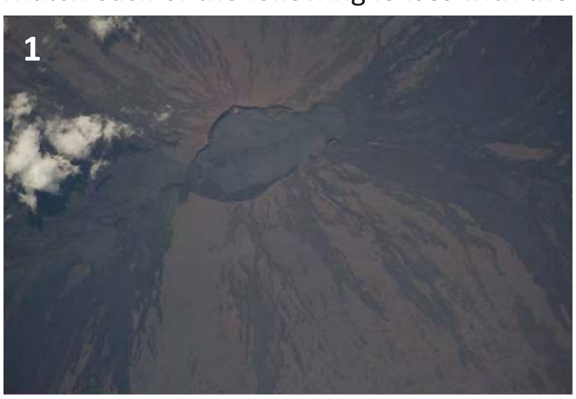
ISS007E05698

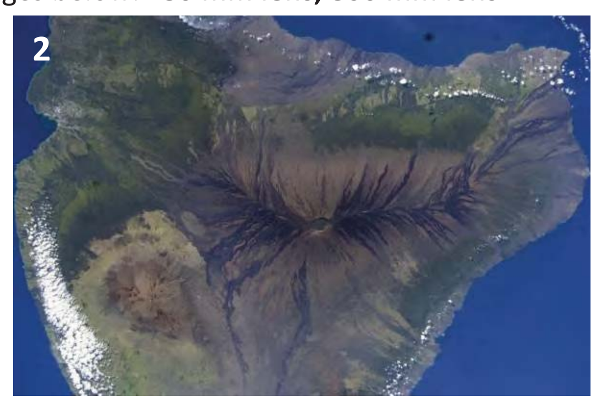
B. Match each of the following lenses with the images below: **400 mm lens, 800 mm lens**

ISS014E14065

ISS013E40727

C. Match each of the following lenses with the images below: **80 mm lens, 800 mm lens**



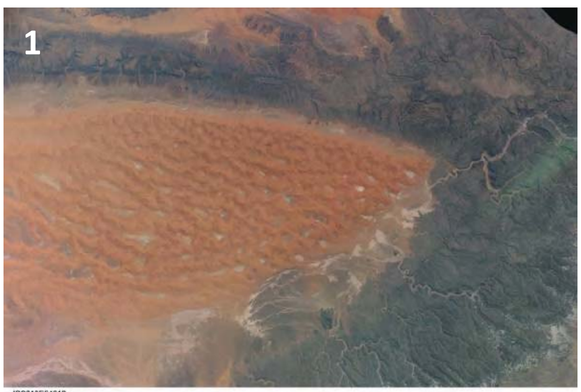


D. Match each of the following lenses with the images below: **180 mm lens, 800 mm lens**

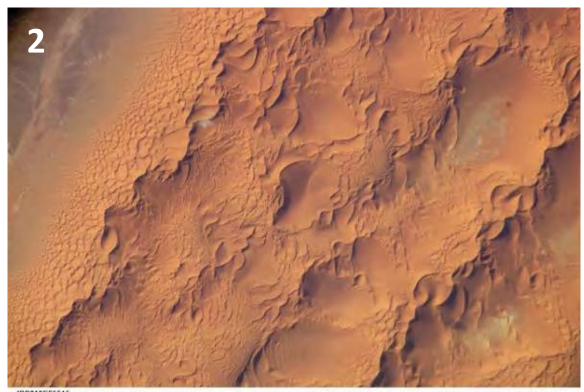
ISS016E030714

ISS006E46015

E. Match each of the following lenses with the images below: **80 mm lens, 800 mm lens**



ISS013E64612



ISS013E65515

F. Match each of the following lenses with the images below: **400 mm lens, 800 mm lens**

ISS006E07071

ISS015E10704

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Oh, What a Cupola!

According to NASA news in 2010, "The crew of the International Space Station (ISS) is about to get a new 'eye-pod'." A dome unlike any other window ever flown in space was launched on February 8, 2010 and attached to the Tranquility Module (also known as Node 3). This dome, called the Cupola, has seven windows for observing Earth, space, and the marvelous expanse of the ISS itself." With an approximately 70 centimeter diameter, the center circular window of the Cupola will allow astronauts stunning views of Earth processes, panoramic views of Earth, and spectacular pictures of the cosmos. The Cupola is also intended for operational purposes such as monitoring spacecraft docking as well as the use of the manipulator arm.

Image courtesy of NASA

Before NASA contracts to have a piece of the International Space Station built, engineers create a 3D scale model from a blueprint. Using Google SketchUp (http://sketchup.google.com/download/), you too will create a 3D scale model of the Cupola. Note: Do not include the window coverings included in the image below in your 3D design.

Image Credit: European Space Agency (ESA)

Cupola Design Specifications

- Overall Height: 1.5 meters
- Base Diameter: 2 meters
- Maximum Diameter: 2.9 meters
- Top Circular Window Diameter: 70.6 cm
- Trapezoid-Shaped Windows:
  - Height = 40.5 cm
  - Short side length: 40.0 cm
  - Long side length: 64.4 cm

For more details on the Cupola, check out:
http://esamultimedia.esa.int/docs/hsf_research/Climate_change_ISS_presentations/Cupola_Deloo.pdf

Hints when using Google SketchUp

- Program can be downloaded for free and is available for Macs or PC's platforms. http://sketchup.google.com/download/
- Once you have downloaded the program, consider the following recommendations:
  1. Allow students some time to explore the program and become familiar with the tools.
  2. Encourage students to watch some of the training videos.
  3. Have students choose a template for their model. A suggestion is to use: Architectural Design Millimeters.
  4. Have students go to View, and customize the toolbar to add any additional tools they may wish to use.

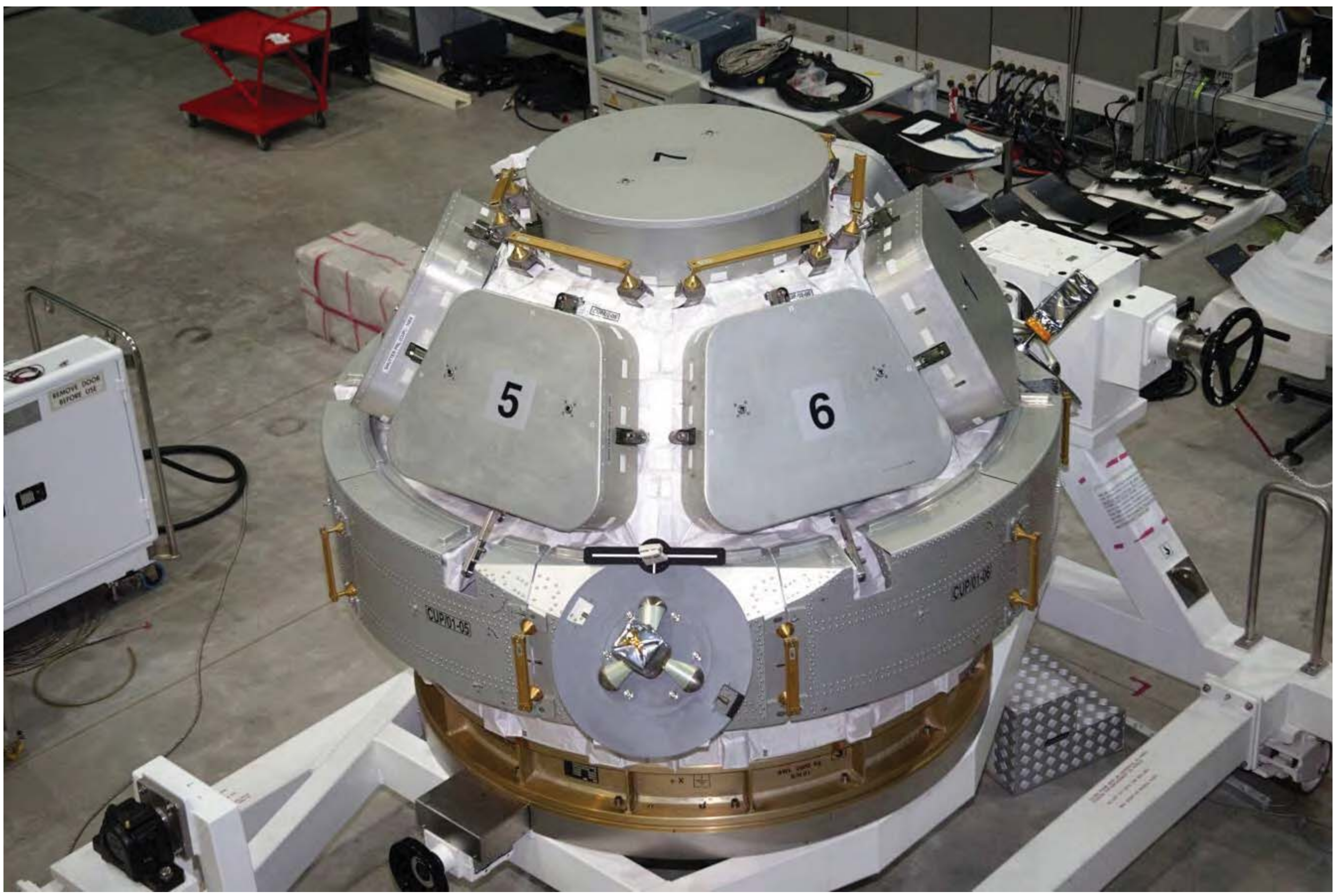

Image Credit: European Space Agency (ESA)

National Aeronautics and
Space Administration

OH, WHAT A PANE!

An inquiry based activity with a mathematical approach to investigating windows on Earth....and in space.

STUDENT GUIDE

ARES
Astromaterials Research & Exploration Science

National Aeronautics and
Space Administration

OH, WHAT A PANE!

Written and Developed for the Expedition Earth and Beyond Education Program
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ARES Education Program, NASA Johnson Space Center
JACOBS - Engineering Science Contract Group (ESCG)

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ARES
Astromaterials Research & Exploration Science

Front Cover Images courtesy of NASA

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OH, WHAT A PANE!

Oh, What Do You See?

How often do you look out the window? What do you see as you look out the window from your classroom? Perhaps you see a city street, a lake, or a cornfield. What if you were sitting in a classroom in a different school, or even a different state? How would your view change? Everyone has a different view as they look out a window, depending on their location.

How would your view change if you were to take a step back from the window? Think about how your view might change if you were riding on the bus or in a car. What about if you were on a plane? Imagine what you might see if you were an astronaut in space observing Earth from a window on the International Space Station! Think about the function or use of windows. Some may be used for viewing in or out, for letting light in, or for decorative purposes. Many windows have multiple uses.

Where you are certainly determines what you see as you look out a window. The type and shape of a window, however, can also change your view. In fact, windows come in many different shapes: rectangles, circles, ellipses (ovals), and octagons. In the "Oh, What A Pane!" activity you will go through a set of exercises, each with a different purpose and use of your mathematical knowledge. You will start by making observations of windows you see every day and will eventually think about the windows astronauts look out of as they orbit the Earth on the International Space Station.

For starters, determine what makes the "perfect" window. Let's investigate what that might be.

1. Observe different buildings that have windows (i.e., a school, a church, a store, a house). Keep a tally of the various shapes and how many of each shape you find. Include where you found each window, its potential function(s) and what percentage each shape is of the total number of windows you observe. An example has been included for you.

Shape of Window	Location(s) and Potential Function(s)	Tallies for the # You See of This Shape	Total # You See of This Shape	Percentage of the Total of All Windows Observed
Example: Rectangle	*Messalonskee Middle School: viewing in/out, letting light in; Oakland Public Library: viewing in/out, letting light in; my house: viewing in/out, letting light in.*		40	Can only complete after all window observations have been recorded.
Circle	*Oakland Public Library: viewing in/out, letting light in; my house: viewing in/out, letting light in.*		5	Can only complete after all window observations have been recorded.
Other	*Same locations as above and/ or other locations and function(s)*	?	?	Can only complete after all window observations have been recorded.

As you observe different buildings, be sure to record the different shapes, locations, potential functions, and tally the number of windows you see of that shape. You will likely find that different buildings have windows with more than one shape.

Fill in the table below with your observations of windows on different buildings.

Shape of Window	Location(s) and Potential Function(s)	Tallies for the # You See of This Shape	Total # You See of This Shape	Percentage of the Total of All Windows Observed
		TOTAL:		

2. Based on your data, what is the most common shape for a window?

3. Why do you think this is the case?

4. Do you see any patterns in your data between the shape of the windows and what the purpose of the windows might be?

5. How is your data similar to the data of others in your class? How is it different?

One consideration you might have as you determine the "perfect" window could be the size, shape, or area of the window. You will compute the area of windows with the following shapes: rectangle, square, circle, and octagon. Be sure to show your work and final answer labeled with the appropriate unit. Use additional paper as necessary. Final answers should be recorded on the table provided in question 10.

6. Find the area of a rectangular window with dimensions 4 ½ feet by 3 feet. Include a labeled sketch of your window and show your work.

7. Find the area of a square window with dimensions 4 feet by 4 feet. Include a labeled sketch of your window and show your work.

8. Find the area of a circular window with a diameter of 4 feet. Include a labeled sketch of your window and show your work.

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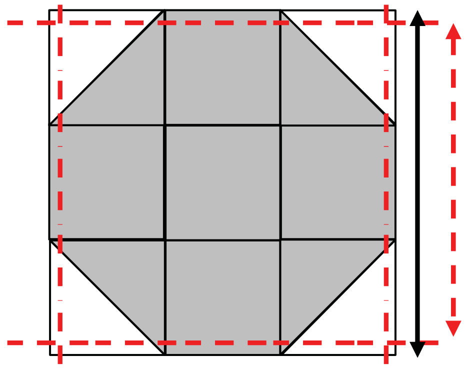
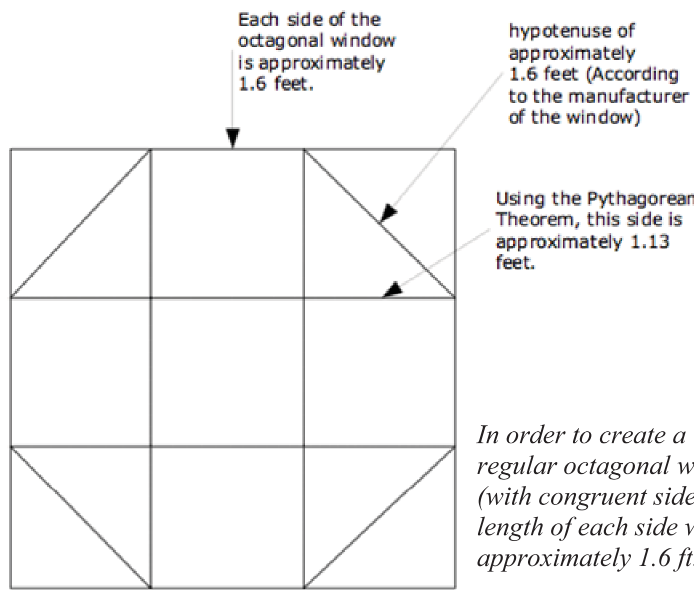
Octagonal windows are a bit more difficult to calculate. According to a window manufacturer, to fit an octagonal window into a square opening of 4 ft. by 4 ft., you would have to remove ¼ inch from all sides to accommodate the frame. This would leave you with an overall height (OH) of 3 ft. 11 ½ in. and an overall width (OW) of 3 ft. 11 ½ inches.

In order to more easily construct an octagonal window with all sides having the same length (congruent sides), this same window manufacturer stated that each side would have a length of approximately 1.6 ft. (approximately 1 ft., 7 inches).

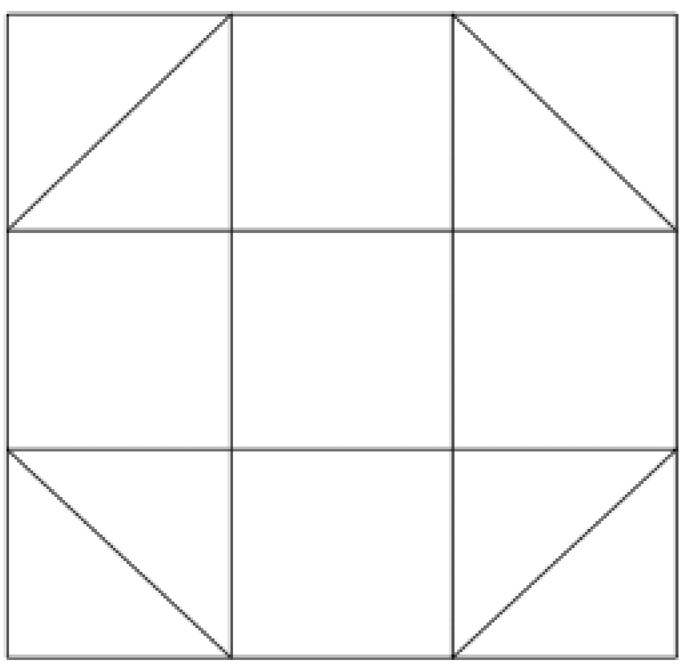


Overall Height (OH) of the ***square*** *opening is 4 ft (solid black arrow). If you subtract ¼" from each side to fit in an octagonal window the OH would be 4 ft minus ¼" from the top and ¼" from the bottom which equals 3 ft 11 ½" (red dashed arrow).*

The Overall Width (OW) would be computed the same way.



In order to create a regular octagonal window (with congruent sides), the length of each side will be approximately 1.6 ft.



9. Let's think about this octagonal window. Looking at the sketch provided of the shaded octagon within the square , answer the following questions:

   A. What do you notice mathematically about this sketch?

   B. Describe how you would go about determining the area of the octagon.

   C. Find the area of this octagonal window. Include labels on the sketch of the window provided and show your work. Use additional paper as necessary.

10. Record the area of each shape you have determined. You will use this information later.

Window Shape with Dimensions	Area (in square feet)
4 ½ ft. by 3 ft. Rectangle	
4 ft. by 4 ft. Square	
Circle with 4 ft. Diameter	
Octagon with OH/OW of 3 ft. 11 ½ inches	

Oh, But the Cost!

Now that you have determined the area of windows with different dimensions and shapes, you will need to calculate the cost per square foot in order to help you make equal comparisons of the cost of your “perfect" window. Being cost effective may play a role in helping you determine the “perfect” window! Costs listed below are based on 2009 prices quoted by a local window distributor in Belgrade, Maine. Use the area for the windows that you previously computed, along with the listed total cost of the window to determine the cost (in dollars) per square foot. Show your computations in the work space provided. Use additional paper as necessary.

Image Credit:
http://doitbest.com/media/images/members/2244-window.jpg

Window Type (Shape & Size)	Area in square feet	Total Cost of the Window	Work Space	Cost (in dollars) per square foot
Rectangle (4 ½ ft. by 3 ft.)		$588.00		
Square (4 ft. by 4 ft.)		$465.00		
Circle (4 ft. diameter)		$1,662.00		
Octagon (side approximately 1.6 ft. or about 1 ft. 7 inches)		$648.00		

1. Use the information you have calculated in your table. Which window out of the four is the best buy? Explain how you determined this.

2. Would you ever choose a window that was not the best buy or one that was not the most cost effective? Explain.

Some people may consider purchasing a window that may not appear to be the best buy, if they are looking to add a more decorative flair. Stained glass windows, for example, can add a decorative element to any building. According to the Art Glass Association, the origins of stained glass probably came from jewelry making and mosaics. The art of stained glass became popular in the 10th century, primarily in churches. Once made by adding metallic salts and oxides, this art glass is now uniquely crafted in a myriad of ways using new technologies. Due to the complexity of this process, stained glass windows may be quite expensive, smaller in size, and limited in shape selection. Let's do some comparative shopping with the costs you explored earlier and see if you might want your "perfect" window to include stained glass. (Remember to check your units!)

Image Credit: NASA Art Program

(Prices provided below are based on 2009 figures.)

3. Find the cost per square foot of a stained glass rectangle: 30 inches wide by 48 inches high at a total cost of $1, 306.95. Include a sketch and be sure to show your work.

4. What would the cost per square foot be of a stained glass square: 22 inches wide by 22 inches high at a total cost of $439.95? Include a sketch and be sure to show your work.

5. If the total cost was $414.95 for a stained glass circle with a diameter of 30 inches, what would the cost be per square foot? Include a sketch and be sure to show your work.

6. Find the cost per square foot of a regular stained glass octagonal window with a side length of 18.75 inches with a total cost of $500.00. Include a sketch and be sure to show your work.

7. Now that you have had the opportunity to investigate windows, describe which of these would be your "perfect" window. Include the shape, dimensions, cost, and whether or not you are planning to use stained glass. Be sure to include a sketch of your window with labeled dimensions. Also describe the purpose of your "perfect" window.

MAKING AND MATHEMATICALLY EXPLORING YOUR OWN "STAINED-GLASS" WINDOW

You will now create your own "stained-glass" window using pattern blocks or tangrams to explore mathematical relationships of your stained-glass window design. If you prefer, you can also draw your window using colored pencils on a separate piece of paper. You must use at least 6 shapes (same or different shapes) for your window design. Once you have your own design created, you will mathematically explore your window.

1. Describe your window mathematically. At a minimum, include the following: Shapes used, calculate the percentages of different shapes, calculate the percentages of different colors.

2. Take one piece of your window, for example an equilateral triangle in the set of pattern blocks. Let this represent one base unit. Find the area of your window, using the piece you choose as one base unit. Be sure to identify your base unit below.

   One base unit = ___________________________________

   Sketch the window you created below, labeling the base unit piece. Find the area of your window. Be sure to show your work.

   Area of window = ___________________________________

3. Change your perspective by having another geometric piece be one base unit. Calculate the new area. Be sure to identify your new base unit.

   One base unit = ___________________________________

   Sketch the window you created below, labeling the base unit piece. Find the area of your window. Be sure to show your work.

   Area of window = ___________________________________

4. Describe how the total area for your stained glass window has changed and what this has to do with the two geometric pieces that you have used.

Oh, What a View!

Some windows take on a whole different perspective. Astronauts often view Earth from the "Destiny Module Science Window" when they are aboard the International Space Station. This window has the best optical quality ever placed on a human-occupied spacecraft. Astronauts take photographs, broadly referred to as "Earth Observations", that document human impacts on Earth such as city growth and agricultural expansion, natural events like hurricanes and floods, and surface features such as craters and volcanoes. Astronauts have been taking these pictures since the 1960's, forming an underlying foundation for the data collected by humans in space. Imagine how many pictures are in the NASA archives from all of their missions! Analyze the data collected from two time periods where data has been tabulated.

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Answer each of the following questions using the data in the table above. Be sure to show your work.

1. What percentage of the total images taken through 1 April 2009 was taken from the Station?

2. What percentage of the total images taken from 2 April 2009 through 26 May 2009 was taken from the Shuttle?

3. Look at the increased number of total images taken by astronauts from 1 April 2009 to 26 May 2009. What is the percent of increase?

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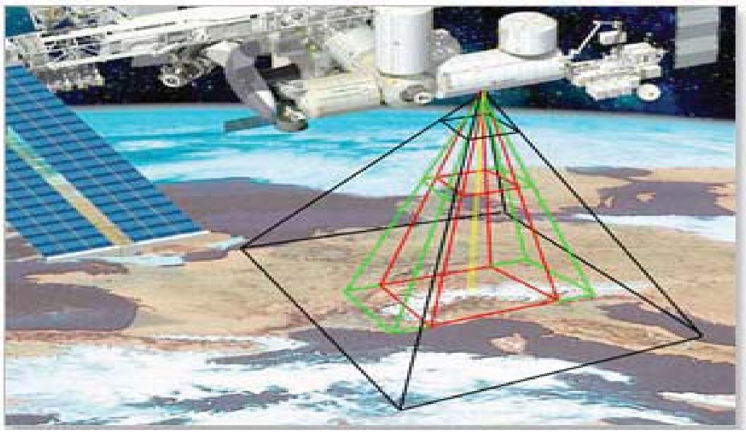
Space Administration

Oh, What a Vision!

As you might have determined from the previous exercise, astronauts take a lot of images from space! They have actually used off-the-shelf film and digital cameras to take these images. So let's think about what we see with our eyes, compared to what a camera and lens enables us to see. Field of view or field of vision is the extent of what we can see at any given moment. Our eyes provide us with a field of vision. Once you put a camera up to your eye, your field of view changes. The camera lens now acts as our eyes. The focal length of the lens determines an area of coverage, or extent of what you can capture in an image. Astronauts select different camera lens sizes (shorter or longer lenses) based on how much area they wish to capture in the photograph.

This image is illustrating the area of coverage viewed when looking through different camera lenses.



Area of Coverage for a 70-300 mm Lens
70 mm = largest area of coverage
100 mm = large area of coverage
200 mm = small area of coverage
300 mm = smallest area of coverage

Image Credit: http://winearth.terc.edu/

1. Based on the information above, what type of mathematical relationship explains the lens size and area of coverage?

2. The International Space Station's (ISS) inclination (or angle) of orbit was increased from 28.5 degrees to 51.6 degrees, significantly increasing the area of the Earth that would be visible to astronauts looking through the Destiny Window. What type of mathematical relationship does this describe?

3. Using the handout provided by your teacher, take a look at the sets of images taken with camera lenses of different focal lengths. Match the camera lens with the acquired astronaut photograph. Include a justification of your answer.

A. Image A1: Lens used: ____________________________________

Image A2: Lens used: ____________________________________

Write a brief justification of your answer:

B. Image B1: Lens used: ____________________________________

Image B2: Lens used: ____________________________________

Write a brief justification of your answer:

C. Image C1: Lens used: ____________________________________

Image C2: Lens used: ____________________________________

Write a brief justification of your answer:

D. Image D1: Lens used: ____________________________________

Image D2: Lens used: ____________________________________

Write a brief justification of your answer:

E. Image E1: Lens used: ____________________________________

Image E2: Lens used: ____________________________________

Write a brief justification of your answer:

F. Image F1: Lens used: ______________________________________

Image F2: Lens used: ______________________________________

Write a brief justification of your answer:

Mathematically describe either 2 individual images or a comparison between the two sets of images below. Be sure to include proportions or percentages of features, colors, or shapes visible in the image(s).

Mathematical Description #1
Image(s) being described: ____

Mathematical description:

Mathematical Description #2
Image(s) being described: ____

Mathematical description:

4. Suppose you are a scientist studying glaciers in South America. You first want an overall view of the glaciers in the region. What size camera lens would you request (give a range from the information provided) for your photographs and why?

5. After reviewing the images of this region, you notice a specific glacier of interest. You want to investigate the terminus (end) of this glacier in more detail. When you make your next request for photographs, what size lens would you request (give a range from the information provided) and why?

6. Consider how you might mathematically investigate a feature on Earth using astronaut photographs as you answer the following questions:
   A. If you had an opportunity to mathematically investigate a feature on Earth using astronaut photographs, what feature would you choose and why?

   B. Describe how you would mathematically investigate this feature.

   C. What benefit would a mathematical investigation be to you or someone else?