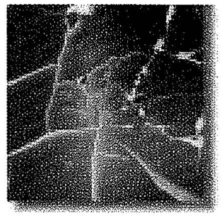
Drying By Design

Using Informed Design to Develop a Food Dehydration System

NYSCATE
NEW YORK STATE CURRICULUM
for Advanced Technology Education

Integrated MST Design Activities for High School and Community College Students



Overview of the Module and Design Challenge

Here's What You Will Do

In the NYSCATE module *Drying by Design,* you will work in a group to:

- understand and investigate possible solutions to a given problem;
- investigate that problem by completing Knowledge and Skill Builder (KSB) activities;
- use appropriate tools and materials to design a solution to the given problem;
- base your design and redesign upon scientific and mathematical concepts;
- see that your design meets specifications and constraints;
- collect, plot, and compare test data;
- use mathematical models, such as graphs and equations, to analyze your data;
- make improvements to your design based on your data analysis;
- develop and use a repeatable and reliable method for testing your design;
- propose improvements based on results of testing your design and related science and mathematics concepts.

Materials Needed

Your teacher or group may provide materials and tools. Any materials and tools provided by your group must be approved in advance by your teacher.

Problem Context

INTRODUCTION

A local elementary school group is planning a weekend hike during which they must carry everything, including their food and clothing. They are concerned about the heavy load each person will have to carry. Unable to think of ways to substantially reduce the weight of their backpacks, they have turned to you for advice.

DESIGN CHALLENGE

As part of a group, you will design, construct, and test a dehydrator that dries fruit as efficiently as possible while maintaining the quality of the foodstuff.

SPECIFICATIONS

Dehydrate the maximum weight of apple slices for a single dehydrating session. Dehydrating time will be set by the instructor. Teams must estimate their design's efficiency based on the data. Efficiency, e (grams/min), is defined in terms of the time it takes to achieve the specified weight loss.

e = (initial weight - final weight) / time

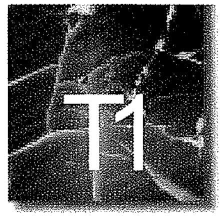
CONSTRAINTS

- You may use only approved materials.
- The drying surface must have an area no greater than 196 square inches.
- All apple slices must be from a single apple, with the exception of the end slices and core which may be discarded, before taking slices from another apple.
- Drying tray must be easily removable to faciltate weighing.

Student Requirements

You will be expected to:

- maintain a Design Activity Folio (DAF) in which you will gather and record information as you complete the design challenge for this module;
- complete a final Design Report/Presentation that summarizes your work and findings;
- be assessed on the quality of your work on MST Knowledge and Skill Builders (KSBs), your Design Activity Folio, and Design Report/Presentation.



The Informed Design Cycle

A method is shown (see Informed Design Cycle diagram) to achieve informed technological design. The cycle includes several phases. In this model, the phases together are referred to as the design cycle. The model involves repeatable phases that engage you in the design process.

You are to work in a manner similar to that of adult professionals who do engineering design for a living. Engineers and other designers rarely follow these phases in order. Instead, they move back and forth from one phase to another as needed. You also are not expected to go through the phases in the same order each time you design something. Additionally, some decisions are made without complete knowledge and as a result phases must be revisited later on. The designer arrives at solutions, monitoring performance against desired results and making changes as needed. Usually, following design criteria leads to trade-offs taking place. Seldom is true perfection obtained.

Further information on the phases of the informed design cycle follows:

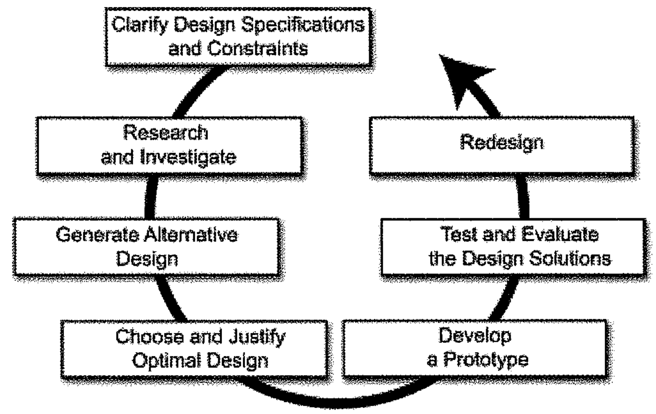
Clarify design specifications and constraints. Describe the problem clearly and fully, noting constraints and specifications. Constraints are limits imposed upon the solution. Specifications are the performance requirements the solution must meet.

Research and investigate the problem. Search for and discuss solutions that presently exist to solve this or similar problems. Identify problems, issues, and questions that relate to addressing this design challenge.

Generate alternative designs. Don't stop when you have one solution that might work. Continue by approaching the challenge in new ways. Describe the alternative solutions you develop.

Choose and justify optimal design. Defend your selection of an alternative solution. Why is it the optimal choice? Use engineering, mathematical, and scientific data, and employ analysis techniques to justify why the proposed solution is the best one for addressing the design specifications. This chosen alternative will guide your preliminary design.

Develop a prototype. Make a model of the solution. Identify possible modifications that would lead to definement of the design, and make these modifications.



Test and evaluate the design solution. Develop a test to assess the performance of the design solution. Test the design solution, collect performance data, and analyze the data to show how well the design satisfies the problem constraints and specifications.

Redesign the solution with modifications. In the redesign phase, critically examine your design and note how other students' designs perform to see where improvements can be made. Identify the variables that affect performance and determine which science concepts underlie these variables. Indicate how you will use science concepts and mathematical modeling to further enhance the performance of your design.

Develop Your Understanding

1. Review the informed design cycle and explain how you might use the phases to guide efforts for your situation. Identify any procedural changes you would add, delete, or change. Defend your recommendation(s).
2. Pick one example of a product or system that was poorly designed. Explain possible reasons why the manufacturer might have allowed it to be produced with design flaws. Explain consequences (both positive and negative) that might result from a less-than-optimal design.
3. Provide an example of a product or system that you think could benefit from an improved design.

Dehydration Techniques

Use the World Wide Web or printed materials to investigate food dehydration techniques.

Develop Your Understanding

1. List the factors that are most important for the proper drying of food. Explain why each factor is important in the dehydration process.

Factor	Why Factor is Important in Dehydration

2. What dehydration techniques seem appropriate for the design challenge you have been asked to address?

3. Which of the appropriate techniques seems most important? Make a claim that explains its importance.

S1

KSBs

Science Knowledge and Skill Builders

Humidity and Evaporation

Use the World Wide Web or printed sources to answer the questions in the space provided.

1. What is humidity?

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2. How is humidity measured?

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3. What is the effect of the air's humidity on evaporation?

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4. What is the effect of air temperature on humidity?

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More on Humidity and Evaporation

In teama, discuss the following questions and answer in the space provided.

5. If you leave water in glass or on a plate, or in puddles after it rains, eventually it disappears. Where does it go? Explain.

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6. If you were to put damp clothes in a bathroom, hang them on the shower rod and close the door, would they dry? (assume there is no window or heat in the room)

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7. If you were to hang damp clothes on a clothes line under the following conditions,
   a) Cold, cloudy day
   b) Warm, sunny day
   c) Warm, sunny, windy day
   On which day would the clothes dry the fastest? Why?

8. How does a clothes dryer work?

Develop Your Understanding

9. Compose a paragraph relating the effects of temperature and evaporation on humidity.

Develop Your Understanding (cont.)

10. Explain why cold air holds less water vapor than warm air.

11. Would you use warm air or cool air to facilitate evaporation from the surface of fruit you intend to dry? Defend your choice, using the information in the paragraph you wrote for number 1.

12. Describe the effect of the movement of the air on evaporation. How might this affect the design of the fruit dehydrator?

M1

KSBs

Mathematics Knowledge and Skill Builders

Banana Data

The data below resulted from students dehydrating three different bananas.

Plot the data for each thickness on the same graph paper or spreadsheet.

Banana 1

1/8" Thick Slices	
time (hr)	weight (g)
0	36.9
0.5	28.3
1	22.1
1.5	18.5
2	14.7
2.5	12.3
3	11
3.5	9
4	8
4.5	8.6
5	7.4
5.5	7.4

Banana 2

1/4" Thick Slices	
time (hr)	weight (g)
0	30
0.5	26
1	22
1.5	19
2	16
2.5	14
3	12
3.5	11
4	10
4.5	8
5	7
5.5	6
6	6

Banana 3

3/8" Thick Slices	
time (hr)	weight (g)
0	30
0.5	28
1	27
1.5	26
2	25
2.5	24
3	23
3.5	21
4	20
4.5	18
5	17
5.5	16
6	15
6.5	13
7	12
7.5	11
8	10
8.5	9
9	8
9.5	8
10	8

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Develop Your Understanding

1. Use printed sources or the World Wide Web to search for the meaning of mathematical terms such as *linear* and *nonlinear*. Use the terms in a sentence to describe the relationships present in the three graphs.

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2. By looking at the plots generated, predict which thickness results in weight loss in the shortest amount of time. Justify your answer.

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3. For each thickness, calculate the weight of the banana slices representing 30% of the initial weight provided for that thickness. Using the graphs, predict the time it would take to dry banana slices of each thickness (1/8", 1/4", and 3/8") to the weight calculated. For example, if we were looking for the weight representing 50% of the initial weight for the 1/4" slices, the answer would be 15g and it would take 2.25 hours.

Slice Thickness	Initial Weight (g)	30% of Initial Weight (g)	Drying Time (hours)
1/8"			
1/4"			
3/8"			

4. For each thickness, calculate the weight of the banana slices representing 20% of the initial weight provided for that thickness. Using the graphs, predict the time it would take to dry banana slices of each thickness (1/8", 1/4", and 3/8") to the weight calculated. Note that you will need to extrapolate beyond the last data point to determine an answer for the 3/8" thickness.

Slice Thickness	Initial Weight (g)	20% of Initial Weight (g)	Drying Time (hours)
1/8"			
1/4"			
3/8"			

Develop Your Understanding (cont.)

5. Was the prediction you made in question 2 above correct? If not, what was misleading about the graph that led you to wrong conclusion?

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More with Banana Data

Comparison of the curves plotted using the banana data provided on page 1 is difficult because the banana slices have different initial weights. The tables provided here were created by dividing the weight readings by the initial weight for that sample. In this way, the data has been "normalized" to the equivalent experimental situation where the initial weight is identical, regardless of thickness.

Plot all three sets of "normalized" data on one sheet of graph paper or use a spreadsheet to generate the graph.

Banana 1

1/8 " Thick	
time (hr)	normalized weight (g/g)
0	36.9/36.9 = 1
0.5	28.3/36.9 = 0.767
1	0.599
1.5	0.501
2	0.398
2.5	0.333
3	0.298
3.5	0.244
4	0.217
4.5	0.233
5	0.2
5.5	0.2

Banana 2

1/4 " Thick	
time (hr)	normalized weight (g/g)
0	30/30 = 1
0.5	26/30 = 0.867
1	0.733
1.5	0.633
2	0.533
2.5	0.466
3	0.4
3.5	0.366
4	0.333
4.5	0.267
5	0.233
5.5	0.2

Banana 3

3/8 " Thick	
time (hr)	normalized weight (g/g)
0	30/30 = 1
0.5	28/30 = 0.933
1	0.9
1.5	0.867
2	0.833
2.5	0.8
3	0.767
3.5	0.7
4	0.667
4.5	0.6
5	0.567
5.5	0.533
6	0.5
6.5	0.433
7	0.4
7.5	0.366
8	0.333
8.5	0.3
9	0.267
9.5	0.267
10	0.267

Develop Your Understanding (cont.)

6. Using the graph generated, for each thickness, how much time did it take to dry the banana slices to 50%, 30% and 20% of the initial weight. (Note that the plot generated from the 3/8" data indicates that drying banana slices of this thickness will likely not result in slices that are 20% of their initial weight.)

Slice Thickness	Time to Dry to 50% of Initial Weight (hours)	Time to Dry to 30% of Initial Weight (hours)	Time to Dry to 20% of Initial Weight (hours)
1/8"			
1/4"			
3/8"			

7. It should have been easier to determine drying times using the "normalized" data and graph, rather than using the original data and graph. Why? (Hint: There is a connection between "normalizing" the data and percentages).

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8. The normalized plots allow easier comparison between samples. Using the normalized plots, compare the rates of weight loss for each thickness. Justify your comments with the data. (Hint: look at the steepness of the initial slope for each thickness).

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9. Based on the banana drying data, predict which thickness (1/8", 1/4", 3/8") of apple slice would result in the shortest drying time? Justify your answer with the data.

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10. The design challenge asks you to efficiently dry a maximum weight of apples with a limited drying area of 196 square inches. Predict whether thinner slices help you maximize the weight of apples dried. Explain. *An investigation of area will be performed in* KSB - M2.

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<u>INTRODUCTION</u>

The amount of apple area that is exposed will affect the rate at which apple slices dry. Using a commonly practiced strategy employed in technical fields, this activity helps you approximate how much exposed area is created by slicing the apple. The strategy is to use <u>mathematical models</u> to describe parts or functions of a product or system. Since apples vary in size and shape, using an actual apple to predict the exposed area of the sliced apple would be complicated. A reasonable approximation would be to model the apple as a perfect sphere!

To warm up to this task, let's do some practice with measuring the dimensions and calculating the area of various shapes.

1) Use a ruler to measure the dimensions of the shapes on the following page and determine their areas (in square inches). Provide your answers in the space provided with each shape.

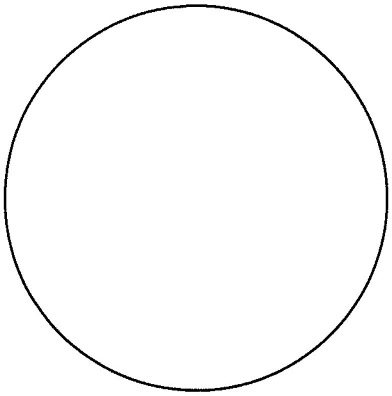
The following formulas might be useful to you to decide what dimensions to measure and how to use those to calculate area.

Area of a Circle = $\pi \times r^2$ where π is approximately 3.14 and r is the radius of the circle which is half of the diameter.

Area of a Triangle = $\frac{1}{2} \times b \times h$ where b is the length of the base of the triangle and h is the height of the triangle.

Area of a Rectangle = $l \times w$ where l is the length of the rectangle and w is the width of the rectangle. Note that a square is a special case of the rectangle where the length and width are equal.

2) Combine at least two of the shapes provided on the following page to create a new shape with area approximately equal to 5 square inches. ***Sketch*** the new shape in the area provided below:



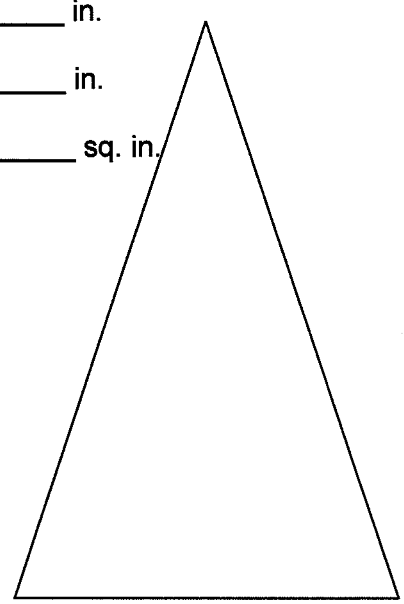
Diameter __________ in.

Area _____________ sq. in.

Base _________ in.

Height ________ in.

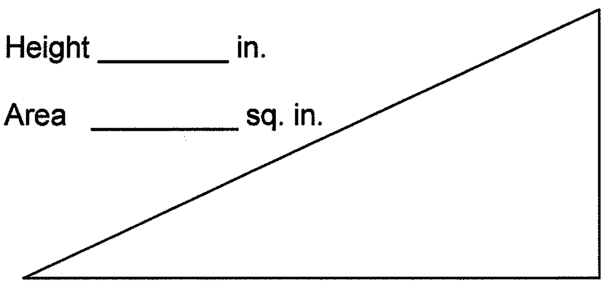
Area _________ sq. in.

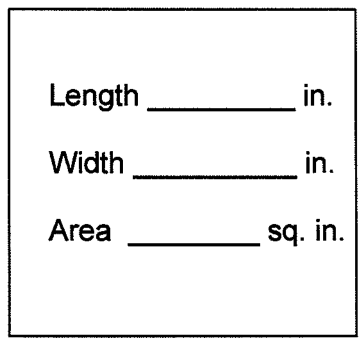


Base _________ in.

Height ________ in.

Area _________ sq. in.

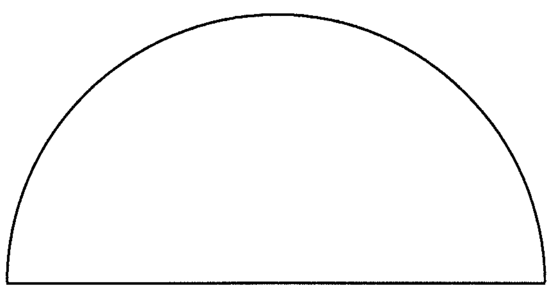




Length _________ in.

Width __________ in.

Area ________ sq. in.



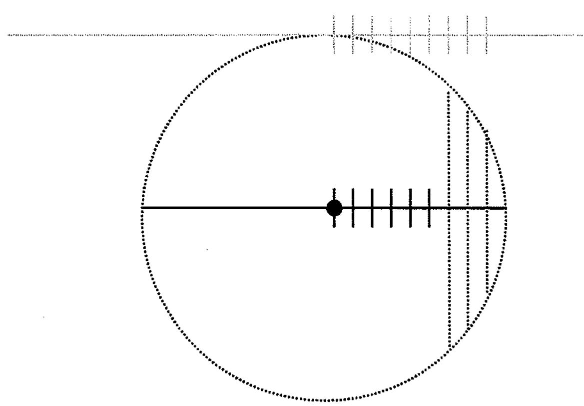
Diameter __________ in.

Area _____________ sq. in.

3) Draw a circle with a diameter of 3 inches to represent a side or top view of our model 3" spherical apple (spheres look the same from all sides). We have given you the center and a diameter of the circle to get you started. What do you know about circles that will help you complete it accurately?

4) Divide the circle into 1/8 inch slices by drawing lines perpendicular to the line above at each of the notches. Make sure the lines are neatly drawn parallel to one another. Then, make a small mark every 1/8 inch on the left half of the diameter line above to indicate those slices.

Below is a model of how to draw the lines to show the slices (**drawing is not to scale**).



How many apple slices will there be altogether?

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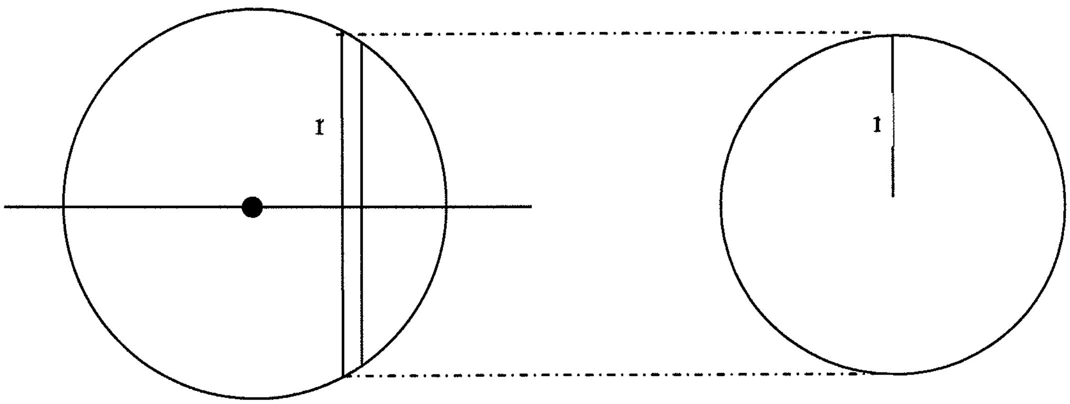
5) Next, you need to determine the total area of the slices. Since the apple is a sphere, the slices you drew are circles when viewed from a different angle. If you measure the length of each line, that will give you the diameter of each circular apple slice.



A cutaway view of the apple with one slice marked

That slice, turned 90°

Do you need to measure the diameters of every slice, or is there a shortcut? What shortcut might you use?

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Measure and record the diameter of each slice, then divide by 2 to find the radius. Write the radius as a decimal rounded to the nearest hundredth.

Diameter	Radius

6) Now make a model of each apple slice by cutting a circle of the correct size out of available paper. Use a compass to make a circle with each of the radii you recorded above. You should make 24 circles to represent the entire apple. Why 24 circles?

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7) Next, you should calculate the area of each circle.
The formula for the area of a circle is: $A = \pi \times r^2$ ($\pi = 3.14$)

For each slice, write in the radius and then calculate the area. We have filled in the first row for you. Round your answers to the nearest hundredth.

r* = *radius	r^2	*x* π	*= A*
(inches)	(square inches)		(square inches)
1.50	2.25	3.14	7.07
		3.14	
		3.14	
		3.14	
		3.14	
		3.14	
		3.14	
		3.14	
		3.14	
		3.14	
		3.14	
		3.14	
		Total Area = (sum area column)	

This represents the area for half the apple. What is the total area of the apple slices for the whole apple?

Total Area of Apple Slices = ______________ sq. in.

8) As part of your design process, you will need to consider how to shape your drying area, which is limited to 196 square inches, and also how to arrange the apple slices to maximize the weight of apple being dried.

Is the total area of the apple slices, as calculated above, greater than, less than or equal to the allowable limit of 196 square inches?

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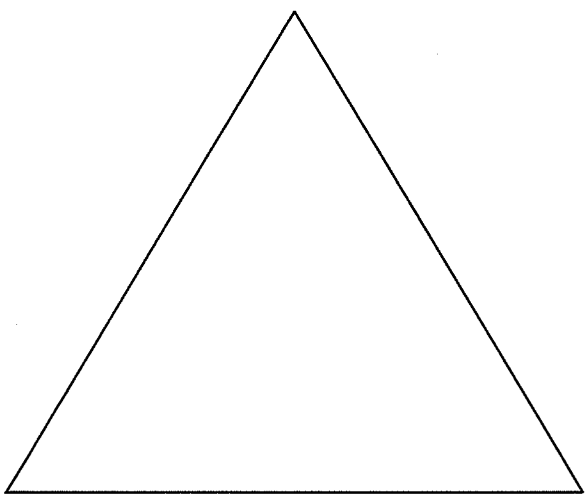
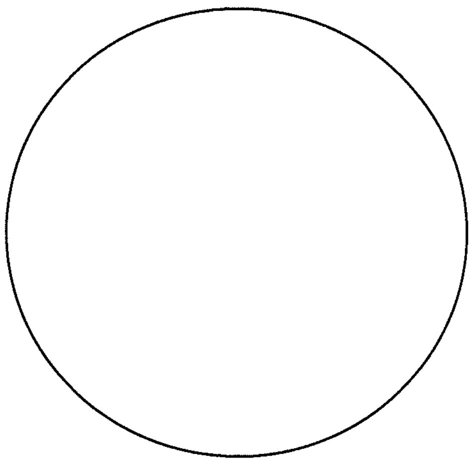
Using the model apple slices cut from paper, arrange the apple slices on three different templates: a square template, an equilateral triangle template, and a circular template. Each template is to have an area of 196 square inches.

Draw a sketch of how you arranged the model apple slices on each template.





How well do the apple slices from one whole 3" apple fit on each template? Does one template allow for more room than the others?

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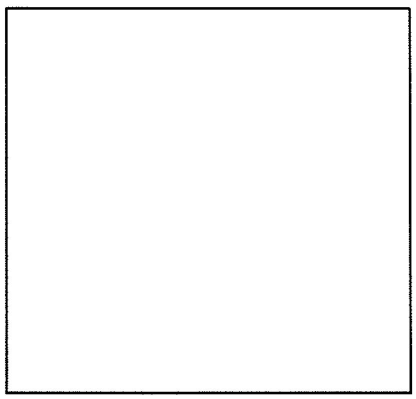

If you were to perform this exercise again with ¼" thick slices, would the area covered by the apple slices be greater than, less than, or equal to the area of the apple that was cut in to 1/8" slices? Why?

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The design challenge asks you to maximize the grams of apples that are being dried. Therefore, you need to fit the maximum grams of apples placed on the drying area. Generate at least three ideas on how you could reduce the area required by the apple slices so that more slices could be placed on the drying area. Describe your ideas in the space provided below. What are the advantages and disadvantages of each idea?

Idea 1:

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Advantages: ____

Disadvantages: ____

Idea 2:

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Advantages: ____

Disadvantages: ____

Idea 3:

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Advantages: ____

Disadvantages: ____

3. Generate Alternative Designs

Sketch two of your possible alternative solutions to the design problem. Remember to consider the specifications and constraints. Include a description of what you consider to be each solution's strengths and weaknesses. Use additional sheets of paper if necessary.

4. Choose and Justify the Optimal Solution

Choose your preferred solution. Explain how your solution meets the specifications and constraints. What makes this alternative better?

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What tradeoffs if any, did you make in selecting this alternative?

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5. Develop a Prototype

Construct a scale model of your design. Include an isometric drawing, orthographic drawings, or a photograph of your model.

6. Test and Evaluate

Did your design meet the initial specifications and constraints? Indicate the tests you conducted and the experiments you performed to verify this.

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Besides the initial specifications, did your particular design include any other specifications? Describe the testing procedure and explain how the design meets all the specifications. Include any data from testing.

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7. Redesign the Solution

What problems did you encounter that would influence a redesign of your solution? Did you change your original design concept? Why?
If you had to redesign your model, what changes would you recommend in your new design? Explain your reasoning. What additional tradeoffs, in any, would you have to make?

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8. Communicate Your Achievements

Describe the plan you will use to present your solution to your class, and show what handouts you will use. (You make include Power Point slides).