Advanced Manufacturing and Materials

Design a Backpack

Grade Levels: 5th, 6th, & 8th

Academic Content Area: Mathematics, Technology, & Engineering

Topics: Measurement and Geometry & Spatial Sense

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

Main Problem

Design and build a backpack in the shape of a prism using only the available materials.

Summary

In this activity, students will be given a specific set of materials to use as they apply their knowledge of surface area and volume to design a net for a prism that could function like a small backpack. After a pre-activity discussion on surface area and volume, students will address design constraints and the engineering design challenge as they employ their mathematical skills.

Big Ideas / Focus

The surface area of a prism can be determined by finding the sum of the areas of each face of the prism.

The volume of a prism can be determined by multiplying the area of the base of the prism by the height of the prism.

Engineering is the application of scientific or mathematical principles to practical ends such as design. Based on material constraints, students will use their mathematical understanding and engineering skills to develop a backpack prototype in order to complete the engineering design challenge.

Military applications of efficient design are a constant concern, as many military efforts require mobility and safe transport of computers, armed systems, and housing. Whether it is a transportable computer/ communication device or living quarters, large engineering efforts have gone into the design based on established parameters. Efficient design equates to efficient costs and use of space, which are two of the most expensive constraints.

Prerequisite Knowledge

Students should be familiar with calculating surface area and volume of regular shapes.

Standards Connections

Content Area: Mathematics

Measurement Standard

Students estimate and measure to a required degree of accuracy and precision by selecting and using appropriate units, tools and technologies.

Grade 5 – Benchmark A: Select appropriate units to measure angles, circumference, surface area, mass and volume.	3. Demonstrate and describe the differences between covering the faces (surface area) and filling the interior (volume) of three-dimensional objects.
Grade 5 – Benchmark C: Identify appropriate tools and apply appropriate techniques for measuring angles, perimeter or circumference and area of triangles, quadrilaterals, circles and composite shapes, and surface area and volume of prisms and cylinders.	6. Use strategies to develop formulas for determining perimeter and area of triangles, rectangles and parallelograms, and volume of rectangular prisms.
Grade 6 – Benchmark A: Select appropriate units to measure angles, circumference, surface area, mass and volume.	1. Understand and describe the difference between surface area and volume.
Grade 6 – Benchmark C: Identify appropriate tools and apply appropriate techniques for measuring angles, perimeter or circumference and area of triangles, quadrilaterals, circles and composite shapes, and surface area and volume of prisms and cylinders.	4. Determine which measure (perimeter, area, surface area, volume) matches the context for a problem situation
Grade 8 – Benchmark B: Use formulas to find surface area and volume for specified three-dimensional objects accurate to a specified level of precision.	9. Demonstrate understanding of the concepts of perimeter, circumference and area by using established formula for triangles, quadrilaterals, and circles to determine the surface area and volume of prisms, pyramids, cylinders, spheres and cones.

Geometry and Spatial Sense Standard

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

Grade 5 – Benchmark H. Predict and describe results (size, position, orientation) of transformations of two-dimensional figures.	8. Predict what three-dimensional object will result from folding a two-dimensional net, and then confirm the prediction by folding the net.
Grade 8 – Benchmark E: Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools, such as straightedge, compass and technology.	6. Draw nets for a variety of prisms, pyramids, cylinders and cones.

Preparation for activity

Photocopy

- Appendix A: Pre-test / Post-test (2 copies / student)
- Appendix B: Rubric / Lab sheet

Collect materials for engineering design challenge

Bookmark websites for pre activity discussion and differentiation

Critical Vocabulary

Net – a jacket for a geometric solid that can be folded to create the surface of the solid. A net is a way of representing a polyhedron in two dimensions; this is a two-dimensional figure with indicated lines for folding that fold into a three-dimensional polyhedron.

Prism – a solid figure whose bases or ends have the same size and shape and are parallel to one another, and each of whose sides is a parallelogram.

Surface Area – is the sum of the number of square units that will exactly cover all of the faces of a three-dimensional figure.

Volume – the number of cubic units that will exactly fill a three-dimensional figure.

Timeframe

Day	Time Allotment	Activities
1	50 minutes	Pre-test and pre-activity discussion
2	50 minutes	Engineering Design Challenge
3	50 minutes	Redesign and Lab sheet completion
4	50 minutes	Presentations and post-activity discussion
5	20 minutes	Post-test

Materials & Equipment

Each student will need access to:

4 sheets of 12” x 18” construction paper: (1 for net, 1 for backpack, 1 for redesign, 1 extra)
1 Index card
Markers
Tape
Glue sticks
Scissors

Teacher Note: A large sheet of grid paper (from grid paper on a roll) is an additional option for students in need of differentiation. This is available at:
https://www.hand2mind.com/Search?fulltext=roll%20of%20grid%20paper

Safety & Disposal

Students should be cautioned on the safe use of scissors.

Pre-Activity Discussion

Teacher Note: Use the Internet, electronic white board, and projector to complete the pre-activity discussion. If these technologies are not available, use of a school computer lab or classroom Internet and projector are suitable alternatives. Additional links are provided in the additional resources section for differentiation.

1. View the Boston Dynamics video on the BigDog robot that is capable of carrying 340 lbs and walking on rough terrain. Although the primary objective of this robot was for it to walk on rough terrain, it is easy to see how beneficial the robot is for carrying backpacks through that rough terrain. Have students pay particular attention to the packs the robot is carrying (especially when it slips on the ice) and how they are designed.

2. View teacher tube link on finding the surface area of a prism to solidify concept: https://www.teachertube.com/video/surface-area-of-a-rectangular-prism-287329
3. Explore http://www.learner.org/interactives/geometry/3d_prisms.html to discuss nets and different prisms.
4. Discuss how to create a net for a prism:
   a. Sketch the prism including all three dimensions.
   b. Label the dimensions.
   c. Sketch the base of the prism with the correct corresponding side measures.
   d. Sketch the attached sides to the base using the correct corresponding side measures.
   e. Sketch the top face of the prism attached to one of the side faces using the correct corresponding side measures.
5. Discuss that volume is the number of cubic units that will exactly fill a three-dimensional box. For visual assistance in discussing volume explore the following link with the class. http://illuminations.nctm.org/ActivityDetail.aspx?ID=6

Teacher Note: While reviewing the pre-test, make note of students who are not able to find surface area and/or volume. Plan to differentiate instruction for these students by providing small group instruction and/or developing media or activity centers that focus on re-teaching surface area and volume of prisms. These students should be encouraged to make their backpacks in the shape of rectangular prisms.

Teacher Instructions

Day 1: Refer to PowerPoint

1. Administer pre-test
2. Conduct pre-activity discussion
3. Introduce the engineering design challenge:

The Engineering Design Challenge:
You are commissioned to design a cool new backpack that kids would want to buy. Design and create a net for your backpack prototype that can be made from one sheet of 12" x 18" piece of construction paper. Your backpack must be a prism with no dimension less than 2".

The manufacturer will use the net as a scale prototype and enlarge it to fit their size requirements.

a. Discuss how backpacks are designed based on what they will be used to carry. Have students complete a Think-Pair-Share showing purposes and uses of backpacks. Hikers want a backpack that will hold a sleeping bag, eating utensils, and water. Students want a backpack that will hold books, pens and pencils, a calculator, and possibly a computer. In all cases, the backpack needs to be as compact and lightweight as possible.

b. An AFRL Engineer/Scientist from the Human Performance BATMAN group can speak to the students about the equipment soldiers must carry. Engineers must consider human capability when designing the backpack and the carrier for the critical items carried on their chests, otherwise known as "prime real estate" for a soldier. Refer back to the BigDog video from the Pre-Activity and how this new technology can help the soldiers carry the necessary equipment.

c. **OPTIONAL**: Show a 4:58 minute video from Defined STEM (formerly The Futures Channel) entitled "How engineering design applies to consumer products." In this video, Columbia Sportswear Designer Chris Araujo combines innovation with design to create backpacks for one of the largest outdoor apparel companies in the world. Whether he's measuring the straps for comfort or designing the shape of the front pouch, math is essential to his designs. This will help to inspire students to engage in this activity as well as to inform them of how this content can be used in a STEM career. (Refer to Additional Resources at the end of this document for more information.)

d. Discuss how everyday products that students use are developed using the Engineering Design Process (defining a problem/need, researching how others have solved it, brainstorming hypotheses and choosing one, creating and testing a prototype, redesigning the solution based on tests, finalizing drawing or prototype, and presenting the best solution to the client).

Teacher Note: For this challenge, students will focus on the last four steps of brainstorming hypotheses and choosing one, creating and testing a prototype, redesigning the solution based on tests, finalizing drawing or prototype, and presenting the best solution to the client.

1. Hand out lab sheet and discuss design parameters as well as the grading rubric.
2. Have students identify the purpose for their backpack design and draw a sketch of what they want their backpack to look like.

Day 2:

Provide supplies and offer scaffolding for individual students throughout the engineering design challenge.

Day 3:

1. Redesign: As a class discuss how designs can be redesigned/improved for a better product. Allow students time to complete the redesign. Students should have two prototypes to share with the class for their presentation. Remind students to save all of their wasted paper for the challenge question on the lab sheet. Once their second prototype is complete, students will create a net of their second prototype using construction paper or graph paper.
2. Allocate 15 minutes at the end of class for cleanup and calculations.
3. Remind students that there are still 15 points to earn in the post-discussion presentations.

Day 4:

1. Student Presentations (refer to rubric)
2. Post-discussion.

Day 5:

Administer post-test.

Background Information

Engineers and inventors are always constrained by the materials that are available either due to availability or cost. An example of design constraints is the situation Apollo XIII mission faced as engineers had to help the astronauts solve a problem with only the available materials in the space capsule.

Instructional tips

Encourage students to draw a labeled diagram (with dimensions) of their backpack and complete the index card with surface area and volume first. Drawing a diagram (with dimensions) of what their net will look like will allow them to be sure it will fit on their construction paper.

Students can design a template for their backpack and then trace it on cardboard to determine the minimal size polygon that will surround the template for purposes of cutting material. They can then find the wasted space by subtracting the area of the template from the area of the surrounding polygon needed to cut the material. They can also determine the percent of waste to the manufacturer and the exact amount lost if they know the cost of the bulk material. This will include unit conversions from a scale drawing.

Assignment of Student Roles and Responsibilities

Students will all assume the same role:

Role Name	Brief Description
Designer	Design 1st and 2nd generation prototypes following provided specification in the engineering design rubric.

Student Instructions

Day 1:

1. Complete pre-test
2. Participate in pre-activity discussion
3. Engineering Design Challenge:
   You are commissioned to design a cool new backpack that kids would want to buy. Design and create a net for your backpack that can be made from one sheet of 12" x 18" piece of construction paper. Your backpack must be a prism with no dimension less than 2".

Day 2:

Design your first prototype using the lab sheet and rubric.

Day 3:

Redesign your prototype. Save the wasted paper for the lab sheet challenge question.

Day 4:

Participate in backpack presentations and post-activity discussion.

Day 5:

Complete post-test

Formative Assessments

As students work, look for those who have difficulty sketching the net on the unlined construction paper. Provide large sheets of grid paper for students to make an initial net which they can trace onto the construction paper.

Engineering Design Challenge Rubric:
The Backpack Challenge (printable version provided in Appendix B for student use)

Category	5 points	3 points	1 point
Engineered Net	Exhibits: Accurate 2D design Includes all faces Includes all folding lines	Exhibits 2 of the following: Accurate 2D design Includes all faces Includes all folding lines	Exhibits 1 of the following: Accurate 2D design Includes all faces Includes all folding lines
Net Storage	Net is folded flat and inside student's 3-D backpack.	Net is folded flat OR inside student's 3-D backpack.	Net is present but neither folded or inside the student's backpack.
Backpack Structure	A prism with no gaps or overlaps.	A prism with minor gaps or overlaps.	Either not a prism OR has large gaps OR overlaps.
Backpack Stability	Adhesives are neatly applied and effectively holding the backpack together.	Adhesives are holding the backpack together.	Adhesives are insufficiently holding the backpack together.

Backpack Redesign	2nd generation backpack shows visible improvement from the initial prototype in two of the following qualities: shape (more difficult prism), structure (less gapping or overlapping), or stability (adhesives).	2nd generation backpack shows visible improvement from the initial prototype in either shape (more difficult prism), structure(less gapping or overlapping), or stability (adhesives).	2nd generation backpack is attempted but does not exhibit a measurable improvement in any of the following categories: shape (more difficult prism), structure(less gapping or overlapping), or stability (adhesives).
Surface Area Calculations	Math is shown for surface area and calculations appear to be accurate (all sides and measurements are accounted for).	Math is shown for surface area however calculations are incorrect either because one side is not accounted for or multiplication is incorrect.	Surface area calculations are visibly incomplete. (More than one side is unaccounted for, math is incomplete, or there are multiple multiplication errors)
Volume Calculations	Volume calculations are complete multiplication is correct and answer is cubed.	Only two of the following requirements have been met: Volume calculations are complete, multiplication is correct OR answer is cubed.	Only one of the following requirements have been met: Volume calculations are complete, OR multiplication is correct OR answer is cubed.
Extra Credit:	Backpack is not a rectangular prism.	----------	----------
Extra Credit:	3-D backpack is neatly and creatively decorated.	----------	----------
Presentation: Intended use	Student explains the intended use (ex. hiking backpack) for their backpack including how the design benefits the intended use (ex. boxy design ensures room for sleeping bag and mess kit or thick straps for carrying heavy loads).	Student explains the intended use for their backpack but does not include how the design benefits the intended user.	Student refers to product as a backpack but does not elaborate on it intended use.
Presentation: Percentage of waste	Student provides written calculations on percentage of waste and shares the percentage during their presentation.	Student shares the percentage of calculated waste during their presentation but does not provide written calculations.	Student provides estimate of waste but has not calculated the exact amount of waste. OR calculations are clearly incorrect but the math was attempted.

Presentation: Importance of Redesign	Student provides an example of what aspect of their backpack improved from the redesign. Referring specifically to either shape (more difficult prism), structure (less gapping or overlapping), or stability (adhesives).	Student provides an example of what aspect of their backpack improved from the redesign. However it was neither shape (more difficult prism), structure (less gapping or overlapping), or stability (adhesives) improvements.	Student states that their redesign is an improvement from their first design but does not provide any specific examples of improvements.
Total Score: _____/ 50 possible points			

Post-Activity Discussion

Teacher Note: If possible, display the finished products in the classroom.

Class discussion:

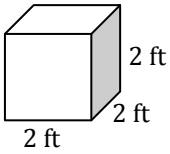
A. Have each student present their backpack and describe its intended use (design challenge), provide their percentage of waste, and explain why the redesign is better than their first prototype.

B. With the remaining class time elicit student responses to:

1. Which do they think has the largest volume? The smallest? *(students' work on index cards would give you the answers)*
2. What would be the advantages/disadvantages of having a large or small volume? *(Largest would hold probably hold the most; smallest might be easier to store in locker)*
3. Which appears to have the largest surface area? The least? *(students' work on index cards would give you the answers)*
4. What are the advantages/disadvantages of having a large or small surface area? *(Smallest would use least material to manufacture)*
5. Discuss which parts of the challenge were most difficult and what strategies students used to help them with their solution.

Pre-Test / Post-Test

Here is a rectangular storage box:



1. Determine the area of the base of the storage box.

   4 ft^2 (four square feet)

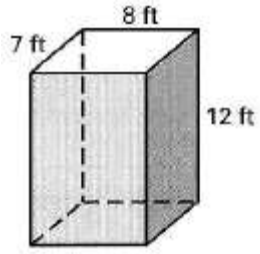
2. Determine the volume of the storage box.

   8 ft^3 (eight cubic feet)

3. Determine the surface area of the storage box.

24 ft² (twenty-four square feet)

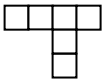
4. Determine the volume and surface area of the following figure:

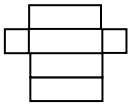


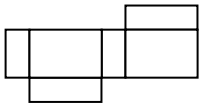
Answer: surface area: (2 x 7 x 8) + (2 x 7 x 12) + (2 x 8 x 12) = 472 ft²

volume: (7 x 8 x 12) = 672 ft³

5. For each of the following, tell if the nets can be folded along the lines to form a box. If yes, explain how. If no, explain why not.

a) 

b) 

c) 

Answer:

a – No, some squares would overlap

b- Yes, Vertical squares form top, bottom, front and back; 2 "flap" squares form sides

c – Yes, horizontal rectangles form top, bottom, front, and back; 2 "flap" rectangles form sides.

6. Give the dimensions of three different rectangular prisms that have the volume of 24 cubic centimeters. _____ _____ _____

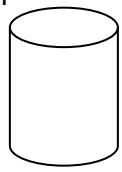
Answer: Any of the following: (1 x 1 x 24); (1 x 2 x 12); (1 x 3 x 8); (1 x 4 x 6); (2 x 3 x 4)

7. What is the difference between surface area and volume?

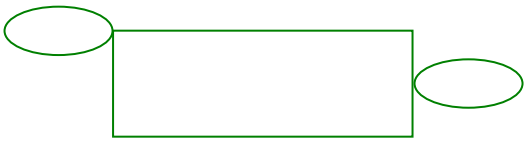
Answer: Surface area is the total area of all the faces combined where as volume is the amount of space the 3-dimensional object takes up. Surface area is denoted as #² whereas volume is #³.

Questions 8-10 are for the Post-Test only:

8. Draw a net for this shape:



Answer:



9. If farmer Ben wants to install a fence around his property he would need to calculate the:

a) Area

b) Perimeter

c) Volume

d) Surface area

10. If Lindsey the aerospace engineer is designing a satellite and needs to make sure her satellite will fit in the space capsule she need to be concerned with:

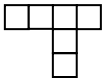
a) Area
b) Perimeter
c) Volume
d) Surface area

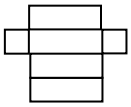
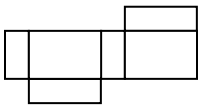
Teacher Note: Questions 8-10 are for the post test only. A printable version of the pre/post test is provided at the end of this document. (Appendix A)

Pre- Test/ Post-Test Rubric

1. Determine the area of the base of the storage box. ***Answer: 4 ft^2 or (four square feet)***		
3 points - Student provides correct numerical value, shows work and provides correct units	*2 points* - Student provides 2 of the following 3: correct numerical value, shows work, or provides correct units.	*1 point* - Student provides 1 of the following 3: correct numerical value, shows work, or provides correct units.
2. Determine the volume of the storage box. ***Answer: 8 ft^3 or (eight cubic feet)***		
3 points - Student provides correct numerical value, shows work and provides correct units	*2 points* - Student provides 2 of the following 3: correct numerical value, shows work, or provides correct units.	*1 point* - Student provides 1 of the following 3: correct numerical value, shows work, or provides correct units.
3. Determine the surface area of the storage box. ***Answer: 24 ft^{2}or (twenty-four square feet)***		
3 points - Student provides correct numerical value, shows work and provides correct units	*2 points* - Student provides 2 of the following 3: correct numerical value, shows work, or provides correct units.	*1 point* - Student provides 1 of the following 3: correct numerical value, shows work, or provides correct units.

4. Determine the volume and surface area of the provided figure: ***Answer: surface area is 472 ft^2 and volume is 672 ft^3***			
4 points Correct numerical values provided for both surface area and volume, work is shown, and units are correct for both calculations.	*3 points* 4 of the 5 are provided: Correct numerical values provided for both surface area and volume, work is shown, and units are correct for both calculations.	*2 points* 3 of the 5 are provided: Correct numerical values provided for both surface area and volume, work is shown, and units are correct for both calculations.	*1 point* 2 of the 5 are provided: Correct numerical values provided for both surface area and volume, work is shown, and units are correct for both calculations.

5**. For each of the following, tell if the nets can be folded along the lines to form a box. If yes, explain how. If no, explain why not.**		
a)  ***No, some squares would overlap***	*2 points* Correct answer and explanation	*1 point* Correct answer, no explanation.

b)  ***Yes, Vertical squares form top, bottom, front and back; 2 "flap" squares form sides***	*2 points* Correct answer and explanation	*1 point* Correct answer, no explanation.
c)  ***Yes, horizontal rectangles form top, bottom, front, and back; 2 "flap" rectangles form sides.***	*2 points* Correct answer and explanation	*1 point* Correct answer, no explanation.

6. Give the dimensions of three different rectangular prisms that have the volume of 24 cubic centimeters. _____ _____ _____

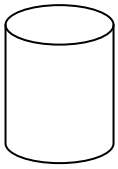
Answer: Any of the following: (1 x 1 x 24); (1 x 2 x 12); (1 x 3 x 8); (1 x 4 x 6); (2 x 3 x 4)

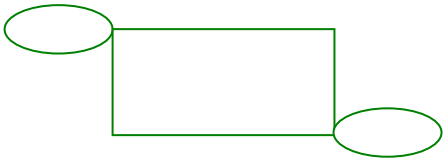
3 points Student provides 3 correct solutions.	*2 points* Student provides 2 correct solutions.	*1 point* Student provides 1 correct solution.

7. What is the difference between surface area and volume?

Example Answer: Surface area is the total area of all the faces combined where as volume is the amount of space the 3-dimensional object takes up. Surface area is denoted as #^{2} whereas volume is #^{3}.

3 points Student provides accurate comparison of surface are and volume based on classroom definitions.	*2 points* Student provides partially accurate comparison of surface are and volume based on classroom definitions. However it is clear that student grasps the basic concepts of both terms.	*1 points* Student provides partially accurate comparison of surface are and volume based on classroom definitions. It is clear that student grasps the basic concepts of one of these terms.

8. Draw a net for this shape: 

Answer: 

3 points Correct drawing of the net is provided.	*2 points* Net drawing is provided but one aspect is incorrect.

9. If farmer Ben wants to install a fence around his property he would need to calculate the:

a) Area **b) Perimeter**

c) Volume **d) Surface area**

2 points- correct answer is chosen.

10. If Lindsey the aerospace engineer is designing a satellite and needs to make sure her satellite will fit in the space capsule she need to be concerned with:	
a) Area	**b) Perimeter**
c) Volume	**d) Surface area**
2 points- correct answer is chosen.	

Technology Connection

The **ADISC** Model of technology created by ITEL:

Integration Model	Application Description
Technology that supports students and teachers in **adjusting, adapting, or augmenting** teaching and learning to meet the needs of individual learners or groups of learners	Computer Internet (provided websites) Electronic white board Projector
Technology that supports students and teachers in conducting **inquiry**, including the effective use of Internet research methods	Computer Internet (provided websites) Electronic white board Projector
Technology that supports students and teachers in **simulating** real world phenomena including the modeling of physical, social, economic, and mathematical relationships	Computer Internet (provided websites) Electronic white board Projector

Interdisciplinary Connection:

This lesson can serve as an extension to a 5th grade social studies economics unit.

In Language Arts, students could write narratives involving their backpack such as describing where their backpack is going to go, writing from the point of view of the backpack, describing a backpack trip through a region of any country or writing journal entries from a backpacking trip. Students could also create an advertisement persuading students to purchase their backpack.

Home Connection

Students and parents can explore different types of backpacks their family owns and report back to the class on their general shape and specific functions (parents can help their child differentiate the pros and cons to each bag).

Differentiated Instruction

Product Differentiation: Students who need review of surface area and/or volume can relearn and practice with interactive Spy Guys lessons:
http://www.learnalberta.ca/content/mesg/html/math6web/math6shell.html

Content Differentiation: Students who need more structure can be given more constraints for their backpack, such as: grid paper to assist them in determining the surface area and correct measurements.

Content Differentiation: Students can be given two pieces of construction paper for the first prototype and challenged to use only one piece on the second prototype.

Content Differentiation: Students who need more challenge should be encouraged (or required) to make a prism that does not have rectangular bases. Additional links are provided in the additional resources section (ex. http://www.learner.org/interactives/geometry/3d_prisms.html)

Content Differentiation: Students can create 3-D models of their backpacks using Google Sketch-Up.

Extension

Arrange for an engineer or physicist from AFRL Air Vehicles directorate to speak to the class on ongoing design challenges in their air vehicle development and reasons why they need to calculate surface area such as stealth coatings and wing spans.
(Teacher Note: Make sure you provide your guest speaker with clear expectations of their visit including talking points and a brief overview of your student's academic level.)

Career Connection

Design engineers, fashion designers, material scientists and engineers as well as, manufacturing engineers, product designers, quality controllers, and industrial engineers are all concerned with surface area and volume. Calculations for materials needed for manufacturing and shipping of new goods rely on these precise measurements to keep waste of materials at a minimum and to ensure enough materials are available for the creation of their product.

In the aircraft design phases, electrical engineers and physicisits need to be able to calculate the surface area of modern day fighters and bombers so they can apply stealth coatings to make the air craft "invisible" to radar. Since the coating material is very expensive percise measurements help to ensure little waste of this material. This specific research in conducted in the Air Vehicles Branch of the Wright Patterson Air Force Research Laboratory.

Aerospace engineers, technicians, and physicists have to design satelites that will fit inside the ferrings of space launch vehicles. Volume and mass are major constraints as satelites with improper dimensions will not fit on top of the rocket and therefore stay earth bound. Creating nets, as studied in this lesson, for satelites help scientists create a more space efficient satelite design. The more space saving the design the more room for sensors, electronics, or ground communication capabilities.

Additional Resources	Purpose and Application
http://www.learner.org/interactives/geometry/3d_prisms.html	Explore & Play with Prisms on this interactive website with geometry 3D shapes.
http://thefutureschannel.com/backpack-press/	**Defined Learning (formerly The Futures Channel) The Backpack Designer** - Columbia Sportswear Designer Chris Araujo combines innovation with design to create backpacks for one of the largest outdoor apparel companies in the world. Whether he's measuring the straps for comfort or designing the shape of the front pouch, math is essential to his designs. Defined Learning is the sole provider of The Futures Channel videos. They have added curriculum content and have made STEM connections between all the videos. The cost in March 2010 was $2/student.
https://www.thefutureschannel.com/pdf/algebra/strap_stress.pdf	**The Futures Channel: Strap Stress** (Activity in PDF format) – Algebra for grades 7-10 – When force is applied to a the futures chmaterial, it will usually cause the material to change shape, even if just a little bit. In such a situation, the force that is applied is called “stress,” and the change of shape of the material is called “strain.”

Credits

Bonnie Thompson – Primary author
Nicole Erwin – Contributing author
Patricia Deaton – Contributing author
Diane Fox – Contributing author
Leesa Folkerth – Contributing author
Norma Howell – Contributing author, Editor
Sandra Preiss – Contributing author, Editor

Teacher Reflections

Were students focused and on task throughout the lesson?

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

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

Did the students learn what they were supposed to learn?

How do you know?

How did students demonstrate that they were actively learning?

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

What were they?

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

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

Are there better items that can be used next time?

Which ones worked particularly well?

Additional Comments

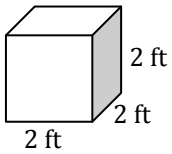
Appendix A

Name _____

Design a Backpack Test

Directions: Answer the following questions and show your work.

Questions 1-3: Here is a rectangular storage box

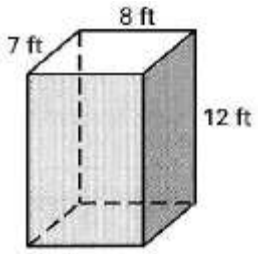


1. Determine the base of the storage box.

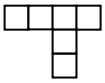
2. Determine the volume of the storage box.

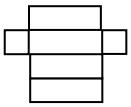
3. Determine the surface area of the storage box.

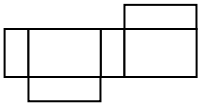
4. Determine the volume and surface area of the following figure:



5. For each of the following, tell if the nets can be folded along the lines to form a box. If yes, explain how. If no, explain why not.

a) 

b) 

c) 

a)

b)

c)

6. Give the dimensions of <u>three</u> different rectangular prisms that have the volume of 24 cubic centimeters.

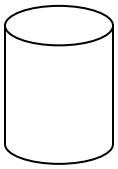
_____

_____

_____

7. What is the difference between surface area and volume?

8. Draw a net for this shape:



9. If farmer Ben wanted to install a fence around his property he would need to calculate the:

a) Area b) Perimeter

c) Volume d) Surface area

10. If Lindsey the aerospace engineer is designing a satellite and needs to make sure her satellite will fit in the space capsule she need to be concerned with:

a) Area b) Perimeter

c) Volume d) Surface area

Appendix B

Name _____

Lab Sheet/Rubric

Engineering Challenge:

You are commissioned to design a cool new backpack prototype that kids would want to buy. Design and create a net for your backpack prototype that can be made from one sheet of 12" x 18" piece of construction paper. Your backpack must be a prism with no dimension less than 2". The manufacturer will use the net as a scale prototype and enlarge it to fit their size requirements. You will need to decide a specific purpose for your backpack and calculate how much material waster you have from your 12" x 18" piece of paper.

Directions:

Note: save all scraps from you construction paper!!!

- Make two nets for your backpack – fold and tape one of them into a 3-D backpack. Fold the other net flat and place it inside your 3-D backpack.
- On a 3" x 5" index card, determine the surface area and volume of your backpack. Put your calculations and result for surface area on one side of the card and the calculations and result for volume on the other side of the index card. Place this index card inside your 3-D backpack.
- Fold your scoring guide and place it inside your 3-D backpack. Be sure your name is on it!
- To excel at this project, you could make a prism that is not a rectangular prism or use your materials creatively decorate or enhance your 3-D backpack.

Student Grading Rubric

Category	5 points	3 points	1 point
Engineered Net	Exhibits: Accurate 2D design Includes all faces Includes all folding lines	Exhibits 2 of the following: Accurate 2D design Includes all faces Includes all folding lines	Exhibits 1 of the following: Accurate 2D design Includes all faces Includes all folding lines
Net Storage	Net is folded flat and inside student's 3-D backpack.	Net is folded flat OR inside student's 3-D backpack.	Net is present but neither folded or inside the student's backpack.
Backpack Structure	A prism with no gaps or overlaps.	A prism with minor gaps or overlaps.	Either not a prism OR has large gaps OR overlaps.
Backpack Stability	Adhesives are neatly applied and effectively holding the backpack together.	Adhesives are holding the backpack together.	Adhesives are insufficiently holding the backpack together.
Backpack Redesign	2nd generation backpack shows visible improvement from the initial prototype in two of the following qualities: shape (more difficult prism), structure (less gapping or overlapping), or stability (adhesives).	2nd generation backpack shows visible improvement from the initial prototype in either shape (more difficult prism), structure(less gapping or overlapping), or stability (adhesives).	2nd generation backpack is attempted but does not exhibit a measurable improvement in any of the following categories: shape (more difficult prism), structure(less gapping or overlapping), or stability (adhesives).
Surface Area Calculations	Math is shown for surface area and calculations appear to be accurate (all sides and measurements are accounted for).	Math is shown for surface area however calculations are incorrect either because one side is not accounted for or multiplication is incorrect.	Surface area calculations are visibly incomplete. (More than one side is unaccounted for, math is incomplete, or there are multiple multiplication errors)
Volume Calculations	Volume calculations are complete multiplication is correct and answer is cubed.	Only two of the following requirements have been met: Volume calculations are complete, multiplication is correct OR answer is cubed.	Only one of the following requirements have been met: Volume calculations are complete, OR multiplication is correct OR answer is cubed.
Extra Credit:	Backpack is not a rectangular prism.	----------	----------
Extra Credit:	3-D backpack is neatly and creatively decorated.	----------	----------

Presentation: Intended use	Student explains the intended use (ex. hiking backpack) for their backpack including how the design benefits the intended use (ex. boxy design ensures room for sleeping bag and mess kit or thick straps for carrying heavy loads).	Student explains the intended use for their backpack but does not include how the design benefits the intended user.	Student refers to product as a backpack but does not elaborate on it intended use.
Presentation: Percentage of waste	Student provides written calculations on percentage of waste and shares the percentage during their presentation.	Student shares the percentage of calculated waste during their presentation but does not provide written calculations.	Student provides estimate of waste but has not calculated the exact amount of waste. OR calculations are clearly incorrect but the math was attempted.
Presentation: Importance of Redesign	Student provides an example of what aspect of their backpack improved from the redesign. Referring specifically to either shape (more difficult prism), structure (less gapping or overlapping), or stability (adhesives).	Student provides an example of what aspect of their backpack improved from the redesign. However it was neither shape (more difficult prism), structure (less gapping or overlapping), or stability (adhesives) improvements.	Student states that their redesign is an improvement from their first design but does not provide any specific examples of improvements.
Total Score: _____/50 possible points			

How much waste did you have from your provided paper to your 2nd prototype? (Show your work)

What part of the challenge was most difficult for you?