

# Performance Based Learning and Assessment Task

## *Coal Silo Design Task*

### **I. ASSESSMENT TASK OVERVIEW & PURPOSE:**

The purpose of this activity is to assess the students' ability to calculate volume of a complex three dimensional object. Then using this information, the students will be responsible for using percentages to calculate data needed in the coal industry.

### **II. UNIT AUTHOR:**

**III.** Cindy Owens, Twin Valley Elementary/Middle School, Buchanan County, VA

### **IV. COURSE:**

Geometry

### **V. CONTENT STRAND:**

Geometry

### **VI. OBJECTIVES:**

Students will be able to: 1) Find the maximum volume of a concrete coal silo (an object that is comprised of two different three dimensional shapes), 2) Determine the amount of coal contained in the volume of the coal silo after a given amount of time, 3) Find the maximum volume of two concrete coal silos (both objects will be comprised of two different three dimensional shapes), 4) Determine the amount of coal contained in the volume of each coal silo after a given amount of time

### **VII. REFERENCE/RESOURCE MATERIALS:**

Students will need: Geometry SOL formula sheets, Calculators, Coal Silos: Storing Energy for The Future activity sheets, Pencils, Chart paper, Colored pencils or markers, Graph paper, Rulers, The pictures of coal silos (used in student work pages and were taken at the Buchanan Mine #1 in Mavisdale, VA. Buchanan Mine #1 is an underground coal mine that is owned and operated by CONSOL Buchanan Mine Company LLC.), Websites for background information on coal mining resources

### **VIII. PRIMARY ASSESSMENT STRATEGIES:**

The task includes an assessment component that performs two functions: (1) for the student it will be a checklist and provide a self-assessment and (2) for the teacher it will be used as a rubric

### **IX. EVALUATION CRITERIA:**

Students will complete the tasks found in the attached activity. Student performance on the tasks will be assessed by using the attached rubric(s)

### **X. INSTRUCTIONAL TIME:**

60 minutes instructional time.

# Coal Silo Design Task

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## Strand

Standard G.13

The student will use formulas for surface area and volume of three-dimensional objects to solve real-world problems.

## Mathematical Objective(s)

Students will be asked to:

- Find the maximum volume of a concrete coal silo. This will be an object that is comprised of two different three dimensional shapes such as a: cylinder, cone, rectangular prism, triangular prism, or square pyramid.
- Determine the percentage of coal contained in the volume of the coal silo.
- Create a scale drawing of the silo at full capacity. As well as modeling the percentage of the volume of the silo that would contain coal.
- Calculate the surface area of a complex three dimensional object.
- Determine and analyze building material needs and cost.

## NCTM Standards

- analyze properties and determine attributes of two- and three-dimensional objects
- explore relationships (including congruence and similarity) among classes of two- and three-dimensional geometric objects, make and test conjectures about them, and solve problems involving them
- draw and construct representations of two- and three-dimensional geometric objects using a variety of tools
- visualize three-dimensional objects and spaces from different perspectives and analyze their cross sections
- use geometric models to gain insights into, and answer questions in, other areas of mathematics;(in this case data)
- use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture
- understand and use formulas for the area, surface area, and volume of geometric figures, including cones, spheres, and cylinders

## Additional Objectives for Student Learning

Earth Science Standard:

- ES.6        The student will investigate and understand the differences between renewable and nonrenewable resources. Key concepts include:
- a) fossil fuels,
  - b) resources found in Virginia; and
  - c) environmental costs and benefits.

## **Materials/Resources**

- Geometry SOL formula sheets
- Calculators
- Coal Silos: Storing Energy for The Future activity sheets
- Pencils
- Chart paper
- Colored pencils or markers
- Graph paper
- Rulers
- The pictures of coal silos (used in student work pages) were taken at the Buchanan Mine #1 in Mavisdale, VA. Buchanan Mine #1 is an underground coal mine that is owned and operated by CONSOL Buchanan Mine Company LLC.
- Websites for background information on coal mining resources (these resources include information on coal mining in Buchanan County, VA): Cedar, Inc.: Coal Education Development and Resource <http://www.cedarinc.org>; Coal in Virginia <http://www.virginiaplaces.org/geology/coal.html>

## **Assumption of Prior Knowledge**

Students should be familiar with using:

- VA DOE Geometry formula sheet
- formulas to calculate the volume and surface area of a three dimensional object
- percentages to make calculations
- proportional reasoning and scale factors to draw similar three dimensional objects

## **Introduction: Setting Up the Mathematical Task**

### **Introduction**

Teachers should explain the following background information to the students:

Coal silos are used in the coal mining process to store earth that has been mined and brought to the surface. Coal silos are used to store both mined earth and prepped coal. When miners cut up sections of a coal bed other materials in the soil get mixed up with the coal that is being mined from the bed. This combination of earth, coal, and other minerals is brought to the surface and stored in a building called a silo. This conglomerate of earth, minerals, and coal will stay stored in the silo until it is moved to a prep plant that will ultimately separate the coal from the other material that was brought to the surface. Coal silos tend to be made up of concrete blocks reinforced with steel beams and are usually cylindrical in shape. In today's task you will investigate the attributes of a silo used to store mined earth to determine the amount of coal that has been mined.

Students will complete the tasks in groups of 2 or 3.

## **Student Exploration**

### **Individual Work**

Each individual student will be responsible for contributing to the necessary calculations and recording keeping needed to complete each task assigned.

### **Small Group Work**

Each task assigned will be completed in groups of 2 or 3 students. Groups are expected to work together on all necessary calculations and construction needed to complete the task assigned

### **Whole Class Sharing/Discussion**

Students will share their results with the class after completing the tasks. This would be a good time for the teacher to use any discrepancies in different group results to open mathematical discussions about the tasks performed in the activity.

### **Student/Teacher Actions**

#### **Silo Task #1**

Students will need to use the given data to calculate the maximum amount (or volume) of mined earth that the silo can hold. The teacher should be monitoring the groups to look for group collaboration and communication.

Questions that can be posed to students who are struggling on task #1:

How could you divide the silo into parts that may be easier to work with when trying to find volume?

#### **Silo Task #2**

Students will need to use given data to calculate the maximum amount that would be stored in the silo after just one day of production. The teacher should be monitoring the groups to look for group collaboration and communication. Questions that can be posed to students who are struggling on task #2: How could you use what you know about unit rates to help you complete this task?

#### **Silo Task #3**

Students will need to use their knowledge of percent of a whole to determine the amount of actual coal that is present in the silo. The teacher should be monitoring the groups to look for group collaboration and communication. Questions that can be posed to students who are struggling on task #2: What does it mean to find the percent of a whole? In this case what is the “whole” that we are trying to find a percent of?

#### **Silo Task #4**

Students will need to use the given data to calculate the maximum amount (or volume) of mined earth that each type of silo can hold (new and old). The teacher should be monitoring the groups to look for group collaboration and communication. Questions that can be posed to students who are struggling on task #1: How could you divide the silo into parts that may be easier to work with when trying to find volume?

#### Silo Task #5

Students will need to use given data to calculate the maximum amount of coal that would be stored in the two different silos after just one day of production. The teacher should be monitoring the groups to look for group collaboration and communication. Questions that can be posed to students who are struggling on task #5: How could you use what you know about unit rates to help you complete this task?

#### Silo Task #6

Students will need to use their knowledge of percent of a whole to determine the amount of actual coal that is present in each type of silo (new and old). The teacher should be monitoring the groups to look for group collaboration and communication. Questions that can be posed to students who are struggling on task #2: What does it mean to find the percent of a whole? In this case what is the “whole” that we are trying to find a percent of?

#### Silo Task #7

Students will need to calculate the surface area of a complex three dimensional object. Students will need to calculate the amount of building material needed to build a new silo design. Then, determine how much it would cost the company to produce their new silo design.

#### Silo Task #8

Students will need to create a chart/poster that will compare the two different silos based upon the following criteria: maximum storage capability after a given amount of time, amount of coal that could be shipped by railway, amount of profit for the company after just one day of production, and building costs. Students will need to use the list of websites provided to determine the profit that can be made by using the two different silo designs (the old and new)

#### **Monitoring Student Responses**

The teacher should monitor group progress as they work on each assigned task. The teacher should not give answers to working groups. Instead he/she should propose guiding questions to struggling student groups to help them come to a reasonable conclusion.

## Assessment List and Benchmarks

Students' tasks will be assessed by using the following rubric. Rubric may be used by teacher and student.

<b>Task Assessed:</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>0</b>
<b>Silo Task #1</b> Calculating the volume of the coal silo.	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank
<b>Silo Task #2</b> Find the amount of mined earth (on average) that the silo would have after just one day of production.	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank
<b>Silo Task #3</b> Find the amount of mined earth stored in the silo after just one day's production that is actual coal that can be sold to power or steel plants. (in Tons)	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank
<b>Silo Task #4</b> Students will need to use the given data to calculate the maximum amount (or volume) of mined earth that each type of silo can hold.	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect:	Task not completed: left blank
<b>Silo Task #5</b> Student will need to use given data to calculate the maximum amount of coal that would be stored in the two different silos after just one day of production.	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank
<b>Silo Task #6</b> Students will need to use their knowledge of percent of a whole to determine the amount of actual coal that is present in each type of silo. (in Tons)	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank
<b>Silo Task #7</b> Students will need to calculate the surface area the new and old silo.	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank
<b>Silo Task #7</b> Students will need to calculate the total amount of building material needed and cost of material for both the new and old silos.	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank
<b>Silo Task #8</b> Students will need to calculate the amount of coal that could be shipped for a profit for both the new and old silos.	All calculations are shown, complete, and accurate	Partial calculations are shown, complete, and accurate	Attempted to complete tasks but calculations were incorrect	Task not completed: left blank

## Rubric for Silo Task #8 Chart/Poster

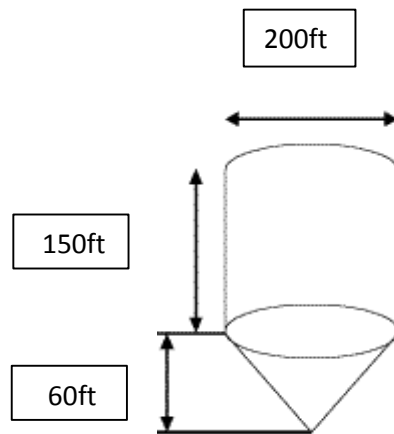
<b>Task #8: Chart/Poster</b>	<b>Points</b>	<b>Student</b>	<b>Teacher</b>
Maximum storage capacity of mined earth for both silos. (correct)	<b>5</b>		
Amount of coal that could be shipped off to the prep plant for profit. (correct)	<b>5</b>		
Total amount of profit after selling the coal that was stored in the silo. (correct)	<b>5</b>		
The total amount of building materials needed to produce each silo. (correct)	<b>5</b>		
The total cost of building materials to produce each silo. (correct)	<b>5</b>		
Chart/Poster is complete.	<b>5</b>		
All work is written neatly and work is organized.	<b>5</b>		
Student show good communication and collaboration while working on poster.	<b>5</b>		
Poster shows good use of illustrations to represent required information.	<b>5</b>		

## Coal Silos: Storing Energy for Tomorrow Part 1

You work as an employee at the local mining plant here in town. As part of the statistics department it is your responsibility to provide management with the data needed to help keep production moving steadily. When you arrive to work today you are asked to determine the percentage of coal that is stored in the silo after a mining crew's eight hour shift. This data will help the sales department determine how much coal they can offer to their clients in a sales contract after a day's time.

You are provided with the following information from the building manager.

Diagram of silo:



After talking to the crew shift manager you are able to obtain the following information:

- During an eight hour shift a crew can mine and fill (on average) 360 skips (equipment used to transfer the mined earth to the silo). Each skip is filled to maximum capacity before being transported to the silos. One skip can hold 25 tons of mined earth.
- Approximately 25% of the mined earth brought to the surface during a crew's shift is considered to be "reject" (or a non-coal substance). One ton of this particular type of coal bed material is approximately 40 cubic feet.

For each task be sure to show the methods you used to find your calculations and record your results.

**Silo Task #1:**

Find the maximum amount of mined earth that the silo can hold if completely filled.

**Silo Task #2:**

Find the amount of mined earth (on average) that the silo would have after just one day of production.

**Silo Task #3:**

Find the amount of mined earth stored in the silo after just one day's production that is actual coal that can be sold to power or steel plants.

## Coal Silos: Storing Energy for Tomorrow Part 2

You work as an architect for the local coal mining company. The CEO of the coal company has asked you to create a new coal silo design that will be more profitable to the company over a 24 hour period. After creating the design and making your calculations you will need to present your findings to the company's board of directors. You must prove to the board of directors that your new silo design will be able to store more mined earth (and thus more coal) that the company can sell to power plants and/or steel factories.

### Requirements:

You must use two different three dimensional shapes in the design of your new silo. You can pick from the following shapes: rectangular prism, triangular prism, cylinder, cone, square pyramid, or triangular pyramid. The new silo must have the same total height as the original silo and cannot take up more than 40,000 square feet of land.

For each task be sure to show the methods you used to find your calculations and record your results. You will need to use your calculations that you completed from the previous task (Coal Silos: Storing Energy for Tomorrow Part 1) to compare your results.

### Silo Task #4:

Sketch a scale model of the original silo and your new silo design on graph paper. Be sure to include your scale.

Find the maximum amount of mined earth that each silo can hold if completely filled.

Old Silo	New Silo

### Silo Task #5:

Find the amount of mined earth (on average) that the silo would have after just one day of production (24 hours).

Old Silo	New Silo

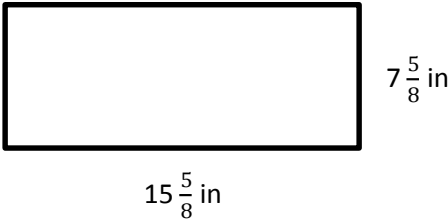
**Silo Task #6:**

Find the amount of mined earth stored in each type of silo after just one day’s production that is actual coal that can be sold to power or steel plants.

Old Silo	New Silo

**Silo Task #7:**

The coal company you work for uses concrete blocks for their silo construction. You are provided with the following information about the type of concrete blocks that are approved for construction.



Calculate the total surface area of both types of silo (new and old). Then, determine the amount of concrete blocks you would need to construct each type of silo. The concrete blocks will cost the company \$1.58 a block to purchase. How much will the company have to spend to purchase concrete blocks for each silo?

Old Silo	New Silo

**Silo Task #8:**

For this task you will need to use the websites we talked about in class to find additional information to help you calculate the company's profit.

Create a chart/poster that will compare the two different silos based upon the following criteria:

After 24 hours of production:

- maximum storage capacity of mined earth
- amount of coal that could be shipped off to the prep plant for profit
- total amount of profit after selling the coal that was stored in the silo
- the total amount of building materials needed to produce each silo
- the total cost of building materials to produce each silo

# Sample of Student's Work

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Coal Silos: Storing Energy for Tomorrow pg. 1

## Silo Task #1:

Silo information:

Cylinder:

$$d = 200 \text{ ft}$$

$$h = 150 \text{ ft}$$

$$r = 100 \text{ ft}$$

To find the maximum volume I must find the volume of the cylinder and cone.

Cone:

$$d = 200 \text{ ft}$$

$$h = 60 \text{ ft}$$

$$r = 100 \text{ ft}$$

Cylinder:

$$V = \pi r^2 h$$

$$V = \pi (100^2) (150)$$

$$V = 4,712,388.98 \text{ ft}^3$$

Cone:

$$V = \frac{1}{3} \pi r^2 h$$

$$V = \frac{1}{3} \pi (100^2) (60)$$

$$V = \frac{1}{3} \pi (10,000) (60)$$

$$V = 62,8318.5307 \text{ ft}^3$$

$$\begin{aligned} \text{Total volume} &= 4,712,388.98 + 62,8318.5307 \\ &= 5,340,707.511 \text{ ft}^3 \end{aligned}$$

The silo could hold 5,340,707.511 ft<sup>3</sup> of mined earth if completely filled.

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pg. 2

Silo Task #2:

8 hr shift produces Fills 360 skips

1 skip = 25 Tons

1 ton = 40 ft<sup>3</sup>

$$360 \times 25 = 9,000 \text{ tons}$$

$$\text{skips} \times \text{tons} =$$

$$\frac{1 \text{ ton}}{40 \text{ ft}^3} = \frac{9,000 \text{ tons}}{x}$$

$$x = 360,000 \text{ ft}^3$$

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One 8 hr shift produces 360,000 ft<sup>3</sup> of mined earth. It would take three 8 hr shifts to complete 1 day of production.

$$\text{So, } 3 \times 360,000 \text{ ft}^3 = 1,080,000 \text{ ft}^3$$

1,080,000 ft<sup>3</sup> of mined earth could be produced after just one day of production.

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## Silo Task .it3

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The amount of actual coal after 1 day of product would be 810,000 ft<sup>3</sup>

## Silo Task #4

Sketch of new silo design:

Total height of original silo = 210ft

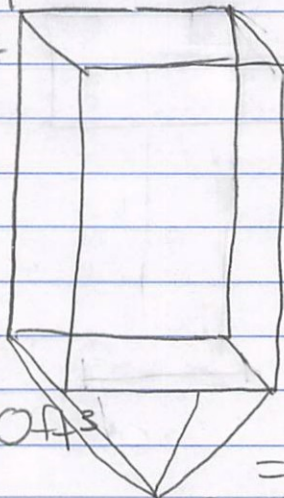
rectangular prism + square pyramid  
h = 170ft h = 40ft  
l = 200ft l = 200ft  
w = 200ft w = 200ft  
B = 40,000ft<sup>2</sup>

Volume of prism

$$V = lwh$$

$$V = (170)(200)^2$$

$$V = 6,800,000 \text{ ft}^3$$



$$V = \frac{1}{3} Bh$$

$$V = \frac{1}{3} (40,000)(40)$$

$$V = 533,333.3 \text{ ft}^3$$

$$\text{Total } V = 6,800,000 \text{ ft}^3 + 533,333.3 \text{ ft}^3 = 7,333,333.3 \text{ ft}^3$$

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Silo Task #4 continued

Maximum amount of mined earth:

Old SiloNew Silo5,340,707.5 ft<sup>3</sup>7,333,333.3 ft<sup>3</sup>

So, the new silo design could hold 1,992,625.8 ft<sup>3</sup> more mined earth than the old silo design.

Silo Task #5

The amount that the silo would have after just one day of production would be the same. Both silos would have 1,080,000 ft<sup>3</sup> of mined earth after 1 day. The design of the silo would not effect the mining production.

Silo Task #6

Both silos would contain 810,000 ft<sup>3</sup> of actual coal. The silo design would not effect the mining production.

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Silo Task #7:

Cost : \$1.58 per block

Surface Area of Old Silo :cylinder:

$d = 200 \text{ ft}$

$h = 150 \text{ ft}$

$r = 100 \text{ ft}$

$S.A. = 2\pi r^2 + 2\pi rh$

$S.A. = 2\pi(100^2) + 2\pi(100)(150)$

$S.A. = 20,000\pi + 30,000\pi$

$S.A. = 157,079.63 \text{ ft}^2$

cone:

$d = 200 \text{ ft} \quad l = ?$

$h = 60 \text{ ft}$

$r = 100 \text{ ft}$

$S.A. = \pi r^2 + \pi rl$

To find the slant height of the cone:

$l^2 = h^2 + r^2$

$l^2 = 3600 + 10,000$

$l^2 = 13,600$

$\sqrt{l^2} = \sqrt{13,600}$

$l = 116.6 \text{ ft}$

$S.A. = \pi r^2 + \pi rl$

$S.A. = \pi(100^2) + \pi(100)(116.6)$

$S.A. = 10,000\pi + 36630.97$

$S.A. = 68,046.9 \text{ ft}^2$

$\text{Total S.A.} = 157,079.63 \text{ ft}^2 + 68,046.9 \text{ ft}^2$

$S.A. = 225,126.53 \text{ ft}^2$

Old silo surface area is:  
 $225,126.53 \text{ ft}^2$

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Silo Task #7

Surface Area of New Silo design:

rectangular prism

$h = 170 \text{ ft}$

$l = 200 \text{ ft}$

$w = 200 \text{ ft}$

$S.A. = 2lw + 2wh + 2lh$

$S.A. = 2(40,000) + 2(34,000) + 2(34,000)$

$S.A. = 86,000 + 68,000 + 68,000$

$S.A. = 216,000 \text{ ft}^2$

square pyramid

$h = 40 \text{ ft}$

$l = 200 \text{ ft}$

$w = 200 \text{ ft}$

$B = 40,000 \text{ ft}^2$

$p = 4(200) = 800 \text{ ft}$

To find the slant height:

$\frac{1}{2} \text{ base of } 200 = 100$

$100^2 + 40^2 = l^2$

$11,600 = l^2$

$\sqrt{11,600} = \sqrt{l^2}$

$107.7 \text{ ft} = l$

$S.A. = \frac{1}{2}lp + B$

$S.A. = \frac{1}{2}(107.7)(800) + 40,000$

$S.A. = 43,086 + 40,000$

$S.A. = 83,086 \text{ ft}^2$

Total Area of new silo design would be:

$216,000 \text{ ft}^2 + 83,086 \text{ ft}^2$

$= 299,086 \text{ ft}^2$

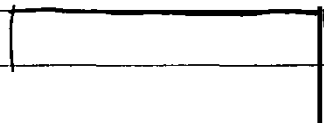
## Silo Task #7 continued:

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Surface Area of old silo:  
 $225,126.53 \text{ ft}^2$

Surface Area of new silo:  
 $299,080 \text{ ft}^2$

Block dimensions:



$7\frac{5}{8} \text{ in}$

$$A = lw$$

$$A = (15\frac{5}{8} \text{ in})(7\frac{5}{8} \text{ in})$$

$$A = 119.14 \text{ in}^2$$

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$$119.14 \div 12^2 = 0.827361 \text{ ft}^2$$

Each block give  $\approx 0.8 \text{ ft}^2$  of area

Number of blocks needed for each type of silo:

Old Silo

$$225,126.53 \div 0.8$$
$$= 281,408.16$$

Old Silo would need  
 $\approx 281,409$  blocks

Costs of blocks:

$$281,409 \cdot \$1.58 =$$
$$\$444,626.22$$

Cost to build old silo

New Silo:

$$299,080 \div 0.8$$
$$= 373,850$$

New Silo would need 373,850 blocks

Costs of Blocks:

$$373,850 \cdot \$1.58 =$$
$$\$590,683$$

Cost to build new silo



