

**Practical Mathematics in Yurt Design;
A Detailed Discussion Following Project GRAD Kenai
Peninsula, Summer Learning Institute, 2004**

By Charles Lokey

**Project Grad Kenai Peninsula
P.O. Box 1725
Homer, AK 99603**

June 18, 2004

Contents

1	Introduction.....	2
2	Mathematics Used in Yurt Design.....	3
	2.1 Circles.....	3
	2.2 Similar Triangles.....	4
	2.3 The Pythagorean Theorem.....	5
	2.4 Linear Equations.....	5
	2.5 Surface Area.....	6
3	Yurt Frame Overview.....	9
	3.1 The Walls (Khanas).....	9
	3.2 Rafters, Center-ring, Door and Doorframe.....	11
	3.2.1 The Rafters and Center-ring.....	11
	3.2.2 The Door and Doorframe.....	11
	3.3 Assembling the Yurt.....	11
4	Problems and Exercises.....	12
	4.1 Problem 1.....	12
	4.2 Problem 2.....	12
	4.3 Problem 3.....	12
	4.4 Problem 4.....	12
	4.5 Problem 5.....	12
	4.6 Problem 6.....	13
	4.7 Problem 7.....	13
5	Solutions to Problems.....	14
	5.1 Solution 1.....	14
	5.2 Solution 2.....	14
	5.3 Solution 3.....	14
	5.4 Solution 4.....	15
	5.5 Solution 5.....	17
	5.6 Solution 6.....	18
	5.7 Solution 7.....	19
6	Suggested Lesson Plans.....	23
	References.....	24
	Appendix on Materials Lists.....	25

Practical Mathematics in Yurt Design; A Detailed Discussion Following Project GRAD Kenai Peninsula, Summer Learning Institute, 2004

By Charles Lokey

1 Introduction

On June 7, 2004, Project GRAD Kenai Peninsula began its first ever Summer Learning Institute, held in Homer, Alaska. The Summer Institute consisted of a two-week program where twenty-three high school freshmen participated in courses such as math, study and testing skills, workplace English, and resume writing. Among the courses offered, the math class was particularly novel. In this course, basic geometry and introductory algebra were used to analyze and build a circular, Mongolian style dwelling, called a yurt. This report discusses how the math course of the Summer Institute was developed and taught.

The math course consisted of constructing a 14-foot diameter yurt frame, while analyzing the design features of the structure. A total of nine 90-minute class sessions were devoted to the project, where each class session was divided between studying the relevant mathematics and building the yurt frame.

The hands on approach sparked remarkable interest in the students. Mathematics presented with applications following promptly, lessens the abstraction and promotes appeal.

The circular geometry of the yurt lends itself to teaching the concepts of radius, diameter, circumference and circular area, while the collapsible lattice walls are directly related to the study of similar triangles, the Pythagorean Theorem and linear equations.

Arguably, one could construct a yurt without any formal understanding of geometry or algebra. Nonetheless, if one chooses to explore these subjects, as applied to the yurt frame, a world of elegant mathematics is revealed.

The abilities and backgrounds of the entering students varied. However, all students were expected to possess competence in performing routine arithmetic operations (addition, subtraction, multiplication, and division) with real numbers. In addition to arithmetic, an understanding of basic algebra, such as manipulating first degree (linear) equations, and solving for unknown variables in such equations, was requisite. While no formal understanding of geometry was required, students with at least some exposure grasped the ideas more readily.

2 Mathematics Used in Yurt Design

This section is intended to briefly refresh the reader's knowledge of elementary geometry and algebra, which will be called upon in the following sections. It is not intended to be a complete discussion. A reader needing a more comprehensive treatment should consult any of a vast number of elementary geometry and/or algebra texts, such as (Lial) or (Aufman).

2.1 Circles

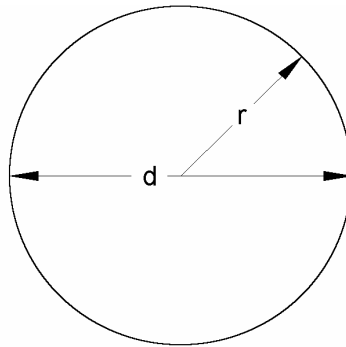


Figure 1

The radius r of a circle is the distance from the center to any point on the circle. The diameter d is the distance across the circle, through the center, to the other side (Figure 1). The diameter is related to radius by

$$d = 2 r. \quad (1)$$

The circumference C is the distance from any point on the circle, all the way around, and back to the same point. One can compute the circumference of a circle of radius r , and diameter d , by the formulae

$$C = 2 \pi r = \pi d, \quad (2)$$

where

$$\pi \approx 3.14.$$

The area A of a circle is the amount of two-dimensional space inside, and is calculated by

$$A = \pi r^2. \quad (3)$$

2.2 Similar Triangles

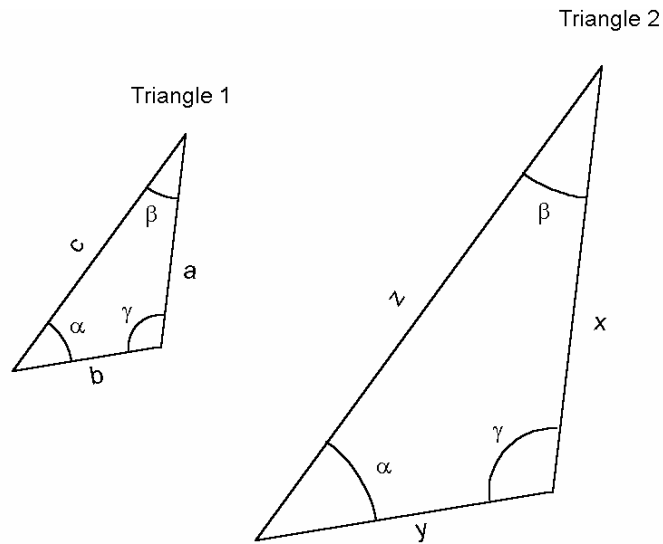


Figure 2

Two triangles are said to be similar if they have the same shape; more precisely, the triangles are similar if the corresponding angles of the two triangles are equal (Figure 2). Notice that both *Triangle 1* and *Triangle 2* have corresponding angles of α , β , and γ , which asserts that they are equal. That is,

$$\alpha = \alpha,$$

$$\beta = \beta,$$

and

$$\gamma = \gamma.$$

Because the corresponding angles are equal, *Triangle 1* and *Triangle 2* are similar. Notice that the sides need not be equal;

$$a \neq x,$$

$$b \neq y,$$

and

$$c \neq z,$$

Yet, the ratios of corresponding sides are. That is,

$$\frac{a}{x} = \frac{b}{y} = \frac{c}{z} \quad (4)$$

2.3 The Pythagorean Theorem

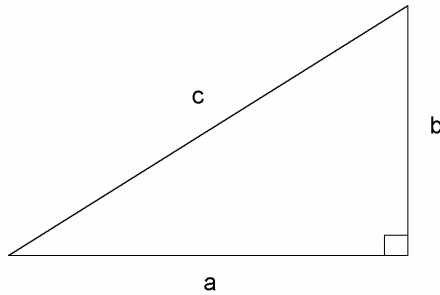


Figure 3

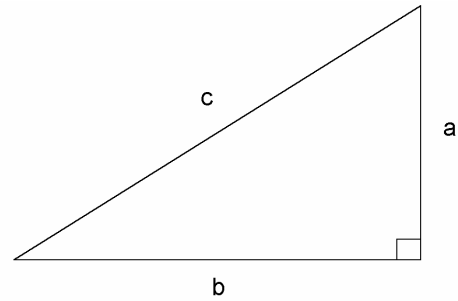


Figure 4

The Pythagorean Theorem states that the legs a and b of a right triangle are related to hypotenuse c by the formula

$$a^2 + b^2 = c^2. \quad (5)$$

Where the choice of assigning the variables a and b to the legs is arbitrary, but the hypotenuse is always c (Figures 3 and 4).

2.4 Linear Equations

The relationship between an independent variable x and a dependent variable y is said to be linear if it can be expressed in the form

$$y = m x + b. \quad (6)$$

Where m and b are constants, and represent the slope and the y -intercept of the line respectively. Equation (6) is called the slope-intercept form of the line.

Linear equations can also be written in point-slope form,

$$y - y_1 = m (x - x_1). \quad (7)$$

Where x_1 and y_1 are the x and y coordinates of the point (x_1, y_1) respectively. When writing the equation of a line, the choice between point-slope or slope-intercept form is determined by the information available. If both the slope and the y -intercept of a line are known, equation (6) can be written automatically. More commonly, if two points on the line are known, the slope can be calculated, and equation (7) should be employed.

Given any two points (x_1, y_1) and (x_2, y_2) on the line, the slope is found by writing the ratio of the change in vertical distance (the rise) to the change in horizontal distance (the run). That is,

$$m = \frac{\text{rise}}{\text{run}} = \frac{y_2 - y_1}{x_2 - x_1} \quad (8)$$

Linear equations are called linear because the graph represents a line. (Figure 5)

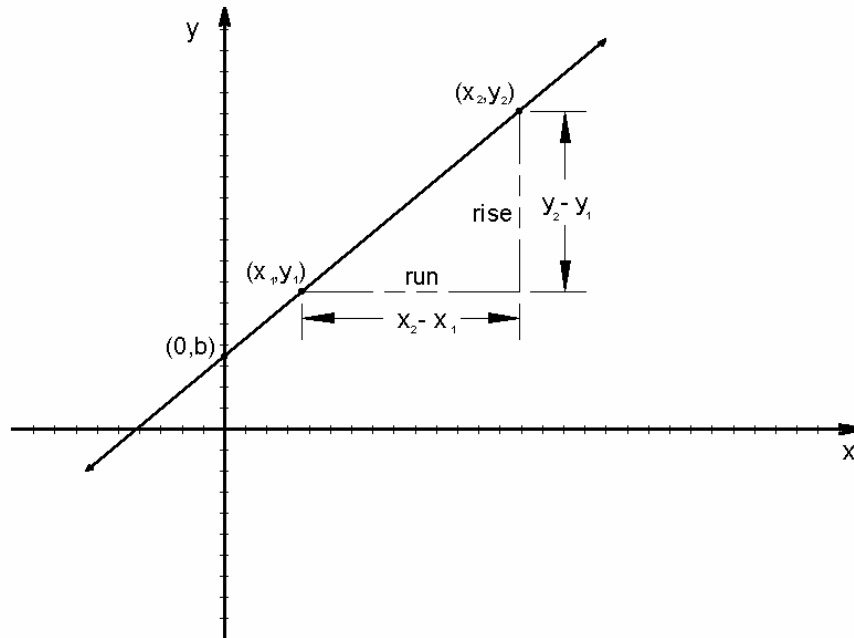


Figure 5

2.5 Surface Area

The above topics address two-dimensional shapes. When we encounter three-dimensional objects or solids, properties such as volume and surface area become important. In this class volume was merely mentioned, yet, the concept of surface area was used to hypothetically calculate the amount of canvas needed to cover the yurt. The formulae needed for the calculation are given below.

2.5.1 Right Cylinder

Extruding a circle of radius r uniformly through a distance h generates a right circular cylinder. The circumference of the circle is $2 \pi r$. The surface area is, therefore, the circumference of the circle times the length of extrusion. That is,

$$S = 2 \pi r h. \quad (9)$$

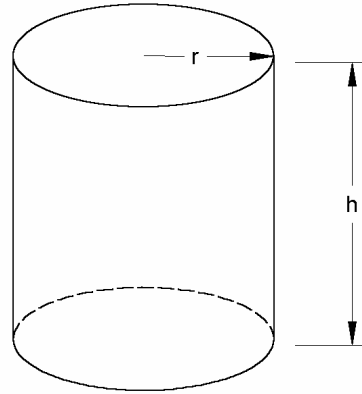


Figure 6

This equation gives the surface area of the outside portion of the cylinder, and not the ends. If we wish to include the ends, we need to add the area of the circles at top and bottom. The surface area for the entire object is

$$S = 2 \pi r h + 2 \pi r^2. \quad (10)$$

2.5.2 Cone

A cone is an example of a shape that does not remain constant as it is extruded. That is, as the circle is extruded through a distance h , the diameter of the circle reduces to a point. The formula for the surface area of a cone is

$$S = 2 \pi r l \quad (11)$$

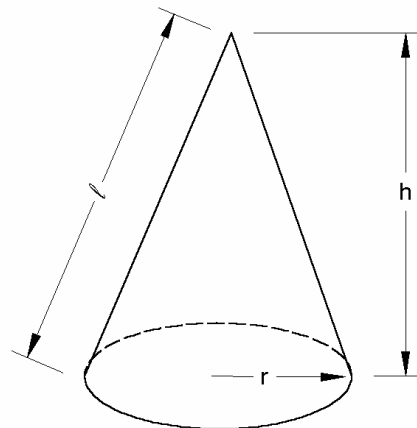


Figure 7

Notice that this expression does not involve the height h of the cone, but rather the side length l . By employing the Pythagorean Theorem, we can express the surface area in terms of the height. I leave this as an exercise.

As with the right circular cylinder, this expression also does not include the circular base of the cone. If we wish to include the base, we must add the area of the circle. That is,

$$S = 2 \pi r l + \pi r^2 \quad (12)$$

3 Yurt Frame Overview

In this section, I do not attempt to present detailed instructions on constructing the yurt frame. Rather, I will describe aspects of the design that we exploit in order to study the math. The reader is referred to (Blue) or (Charney) for complete instructions on building the yurt frame.

The yurt frame consists of lattice walls, rafters, a center ring, a door, a doorframe, and a tension cable (Figure 8). The top and side covering, typically canvas or synthetic fabric, were not included as part of the class. These features could complement the course well. For example, when dividing the class into groups to construct the door, the doorframe, and the center ring, a fourth group could work on the outside covering. This is especially true when enrollment exceeds eighteen students, and the size of each group is too large for effective learning.

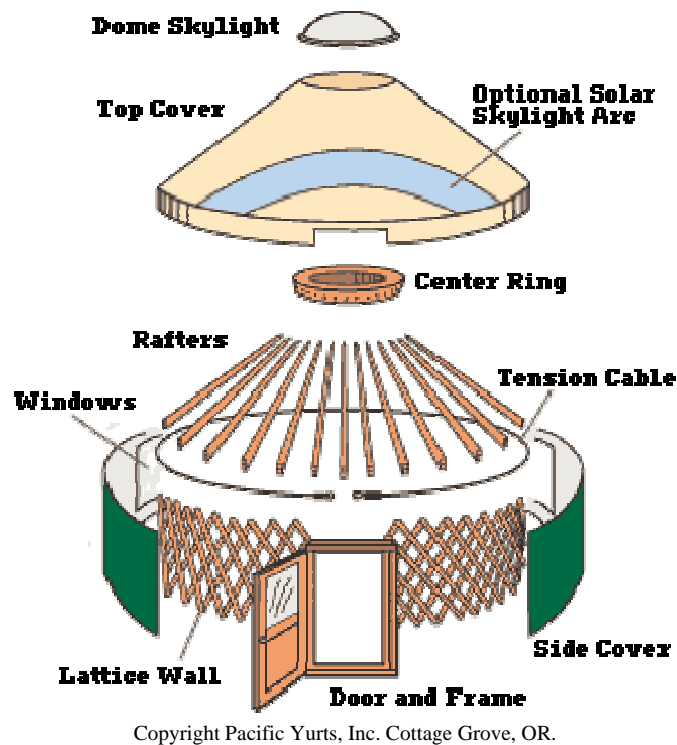
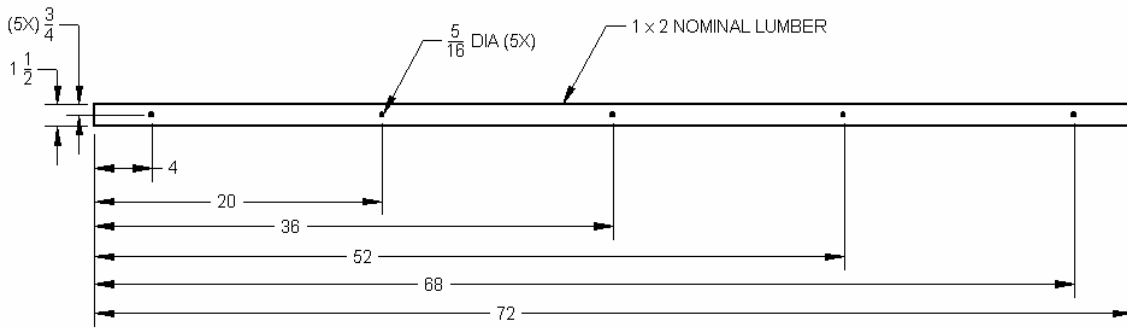


Figure 8

3.1 The Walls (Khanas)

The lattice walls consist of 68 identical 1 x 2s, 6-ft long, with 5/16” holes drilled in precise locations (Figure 9). The 1 x 2s were pre-drilled for the class, allowing more time to focus on the design elements. The students were given a copy of Figure 9, which was used to carry out one of the homework problems (See Problem 4, Section 4).



- NOTES:
- 1) DIMENSIONS ARE IN INCHES.
 - 2) DO NOT SCALE DRAWING.
 - 3) TOLERANCE ON HOLE LOCATIONS ±1/16.

Figure 9

When assembling the wall, the class divided into four groups, with each group taking approximately one-fourth of the pre-drilled boards. They assembled the boards with nuts, bolts and washers in a linear (non-circular) fashion (Figure 10).

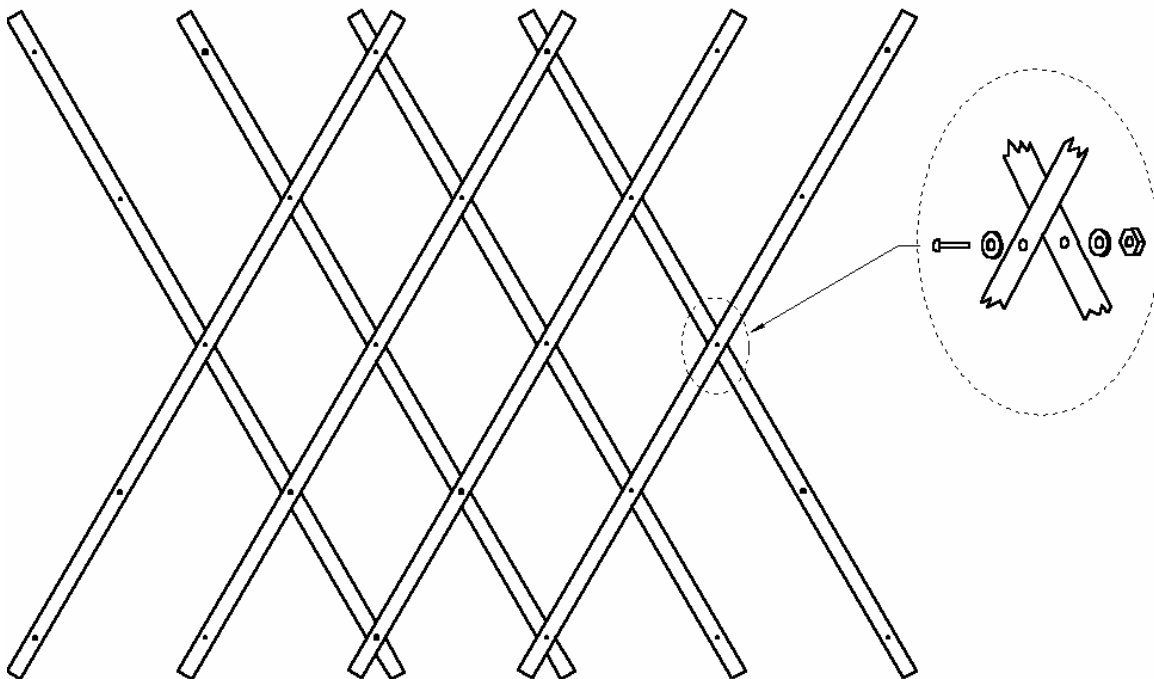


Figure 10

When complete, each group possessed a roughly identical section of the wall. The groups completed their sections in less than 30 minutes, and were ready to fasten the sections together.

Once the wall was completely assembled, we observed the collapsible nature of the lattice wall. We notice that we can pull the ends away and then back together, similar to an accordion. As the length of the wall increases, the height decreases, and as the length of the wall decreases, the height increases. Could this be a linear relationship?

We take measurements and record data. When the wall is completely collapsed, the length is x_1 and the height is y_1 . When we extend the wall to a length of x_2 , the height is y_2 (Problem 5, Section 4).

3.2 Rafters, Center-ring, Door, and Doorframe

To construct the remaining components of the yurt frame, the class broke into groups. One group for the rafters and the center-ring, one group for the door, and one group for the doorframe. Due to the size of the class, we added a fourth group that did not work on the yurt, but completed a workshop on graphing calculators. All students joined together for the final assembly.

3.2.1 The Rafters, the Center-ring

The rafters also require machining. This machining requires some layout, and is less mundane than the drilling for the walls, for this reason, the students inherited the task. The rafters, made from 2 x 2s, extend from the walls to the center ring. A notch in one end of each rafter receives the tension cable, while a hole in the other end accepts a bolt from the center ring bracket (Blue 77).

The center-ring is made from 5/8" plywood with 10 strong-tie brackets attached. The brackets join the center-ring to the rafters. The students scribed the 2' diameter circle on the plywood, and the instructor cut out the circle with a jigsaw. The students calculated the spacing between the brackets by computing circumference of the circle, and dividing by ten.

First the rafters are fastened to the center ring, and they are free to swing vertically. It is the position of the yurt wall (yurt diameter) that determines the angle of the rafters. While trigonometry could be employed here, the Pythagorean Theorem is just as effective, and more appropriate for the student's skill level (Problem 6).

3.2.2 The Door and Doorframe

The door and doorframe require careful measurement and layout; they also need to be square. The students used the Pythagorean Theorem, combined with carpentry squares, to ensure right angles on the corners of both the door and the doorframe.

3.3 Assembling the Yurt

All of the students were involved in assembling the yurt. (see Blue pg 96 - 100)

4 Problems and Exercises

The problems and exercises employ topics from Section 2. The exercises focus on routine mechanics, and are intended to bring a basic level of understanding to the students. Exercises are taken directly out of texts such as (Lial) and are not repeated here.

The problems are more difficult and are intended to challenge the students. They are intended to get the students to think about the concepts in different contexts, as is typical in applied mathematics or engineering. Some problems are rudimentary and are posed in order to lure the student into using the proper math on the more difficult problems. Rudimentary problems are marked[†].

The more challenging problems, in some cases, proved to be too difficult for some students. However, if the student was diligent in his attempts, he positioned himself well to understand the solution when presented.

4.1 Problem 1[†]

Seabiscuit is racing around a circular track. If the radius of track is 700 feet, how far does Seabiscuit run in 2 complete laps?

4.2 Problem 2

If the diameter of the yurt is to be 14', and the door opening is 43", how long should the yurt wall be?

4.3 Problem 3[†]

Cement tiles measuring 3' x 1½' are used to create a 3' wide walkway. If the walkway is to be 100' long, how many tiles are needed for the job?

4.4 Problem 4

Use the wall length calculated in Problem 2, and a desired wall height of 5'4", to find the number of 1 x 2 boards needed to construct the walls. Show your work!

4.5 Problem 5

When the yurt wall is fully collapsed to a length of 48", the height is 70", and when the yurt wall is extended to a length of 336", the height is 46". What is the height of the yurt wall when the length is 168"? What is height of the yurt wall when the length is 400"? Assume the relationship is linear. You may use pictures, words, or numbers to answer this problem. Show your work!

[†] Rudimentary Problem.

4.6 Problem 6

If the wall height is 5'4", the center ring diameter is 2', and the rafter length is 10'. How high will the yurt stand?

4.7 Problem 7

Now that we have calculated the dimensions of the yurt, we can calculate the amount of canvas needed to cover the structure. Assuming no canvas is needed for the floor or the center-ring, calculate the minimum amount of canvas needed to cover the yurt, using the following dimensions:

Yurt Diameter:	14'
Wall Height:	5'4"
Center-ring Diameter:	2'
Rafter Length:	7'6"
Yurt Height:	9'10"

Hint: A picture tells a thousand words.

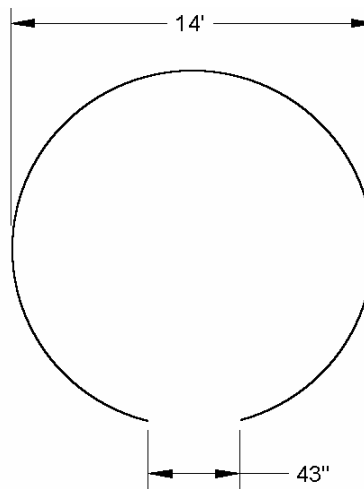
5 Solutions to Problems

5.1 Solution 1

Problem 1 amounts to finding the circumference of a circle of radius 700-feet, and multiplying by 2.

$$\begin{aligned}r &= 700 \text{ ft,} \\C &= 2 \pi r \\2C &= 2 (2 \pi r) \\2C &= 2 (2) (3.14) 700 \text{ ft} = 8792 \text{ ft}\end{aligned}$$

5.2 Solution 2



First we calculate the circumference of a 14-foot diameter circle, and then we subtract a 43-in opening to get the length of the wall. However, we need to be careful with the units. That is

$$d = 14 \text{ ft} = (12 \text{ in/ft}) (14 \text{ ft}) = 168 \text{ in}$$

$$C = \pi d = (3.14)(168 \text{ in}) = 527.52 \text{ in}$$

$$C - 43 \text{ in} = 527.52 \text{ in} - 43 \text{ in} = 484.52 \text{ in}$$

The wall needs to be 484.5 inches long.

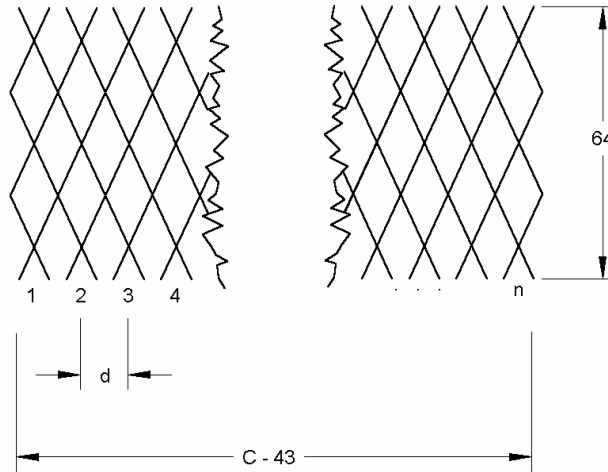
5.3 Solution 3

If we position the tiles so that the 3' dimension is the width, each tile extends a length of $1\frac{1}{2}'$. To cover a distance of 100', we need

$$100 \div 1.5 = 66.67 \text{ or } 67 \text{ tiles.}$$

5.4 Solution 4

A picture is usually a good place to start.



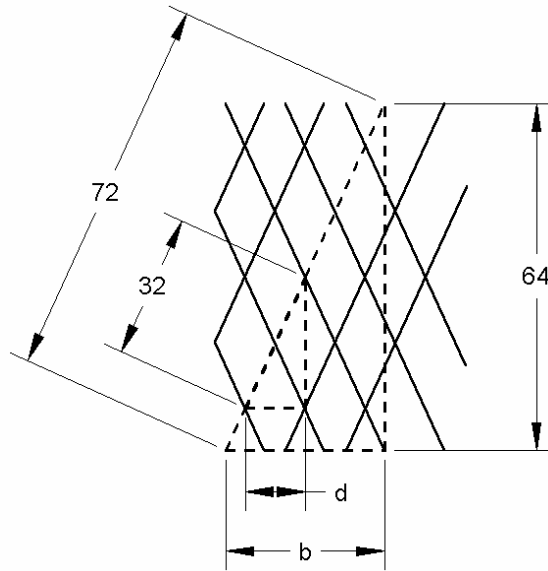
From Problem 2, we found the length of the wall is the circumference of the yurt minus the door opening,

$$C - 43 = 484.5 \text{ inches.}$$

If we wish to count the boards, we note that there are two boards at every bottom vertex. By counting the number of vertices, and multiplying by 2 (2 boards per vertex), we count all of the board needed for the wall. The number of vertices is

$$n = \frac{C - 43}{d} + 1$$

Where d is the distance between vertices and the $+1$ counts the 2 boards on the upper ends that do not reach the bottom. The question is how can we find d ? Taking a closer look, and applying data from Figure 2 of Section 3, we see similar right triangles.



To find b , we apply the Pythagorean Theorem,

$$a^2 + b^2 = c^2$$

$$b^2 = c^2 - a^2$$

$$b = \sqrt{(72)^2 - (64)^2} = 33.0 \text{ inches}$$

To find d , we set up the proportions derived from similar triangles and solve for d .

$$\frac{32}{72} = \frac{d}{b}$$

$$\frac{32}{72} = \frac{d}{33}$$

$$d = \frac{(32) \times (33)}{72} = 14.7 \text{ inches}$$

Finally,

$$n = \frac{C - 43}{d} + 1$$

$$= \frac{484.5 \text{ in}}{14.7 \text{ in}} + 1$$

$$n = 34.0$$

and so, $N = 2n = 68$ boards.

68 boards are required for the walls.

5.5 Solution 5

Because the relationship is linear, the unknowns can be determined by writing the linear equation. The solution can be determined either graphically or analytically. Most students chose a graphical solution. The analytical approach is presented here.

Two points define a line. The two points are

$$(x_1, y_1) = (48, 70)$$

and,

$$(x_2, y_2) = (336, 46).$$

The slope can be determined from Equation (8) of Section 2.

$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{70 - 46}{48 - 336} = -\frac{1}{12}$$

We choose the point-slope form, Equation (7), Section 2.

$$y - y_1 = m(x - x_1)$$

$$y - 70 = -\frac{1}{12}(x - 48)$$

$$y = -\frac{1}{12}x + 74$$

Now that the linear equation is defined, we can determine the yurt height y for any yurt length x . When $x = 168$ inches,

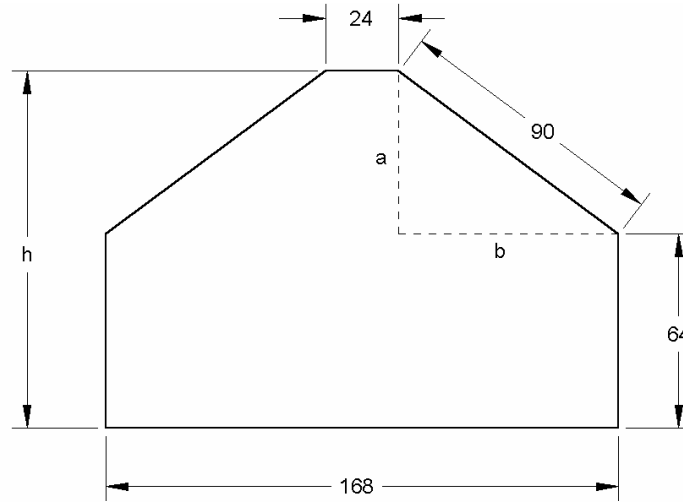
$$y = -\frac{1}{12}(168) + 74 = -14 + 74 = 60 \text{ inches}$$

and when $x = 400$ inches,

$$y = -\frac{1}{12}(400) + 74 = -33.3 + 74 = 40.7 \text{ inches}$$

5.6 Solution 6

We begin with a cross sectional view of the yurt, labeled with known and unknown dimensions.



From the picture, we see that, in order to find the height h , we must find the leg a of the right triangle. That is,

$$h = 64 + a$$

In order to find a , we must solve the right triangle. However, there are two unknowns a and b , so first we must find b . If we exploit symmetry, we can logically and algebraically deduce that

$$2b + 24 = 168$$

$$2b = 144$$

$$b = 72$$

With $b = 72$ and $c = 90$, we solve the Pythagorean Theorem for a .

$$a^2 + b^2 = c^2$$

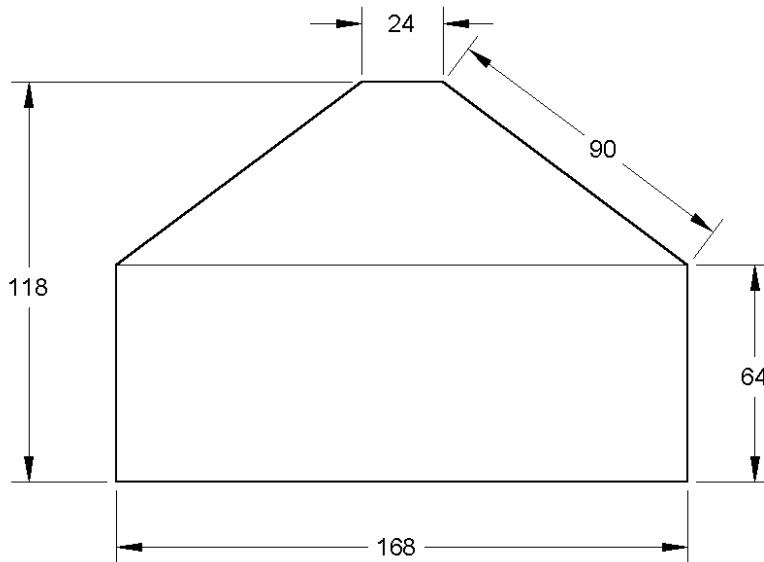
$$a^2 = c^2 - b^2$$

$$a = \sqrt{(90)^2 - (72)^2} = 54 \text{ inches}$$

So, $h = 64 + a = 64 + 54 = 118$ inches = 9' 10".

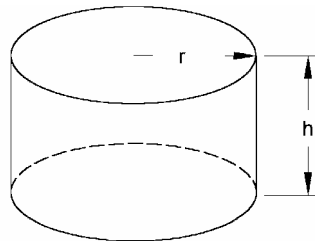
5.7 Solution 7

In order to find the minimum amount of canvas needed for the yurt, we must find the surface area. Begin with a picture, labeled with known dimensions.



The problem requires finding the surface area of two shapes: a cylinder with no ends, and a cone with a chopped off top (truncated cone). The surface area of the cylinder is (Equation 9, Section 2).

$$S_{cylinder} = 2 \pi r h$$



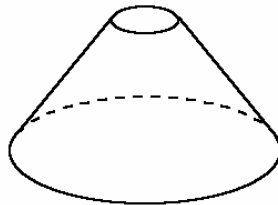
Where $r = 84$ inches (half of the yurt diameter) and $h = 64$ inches (yurt wall height).

$$S = 2 (3.14) (84) (64) = 33761.3 \text{ in}^2$$

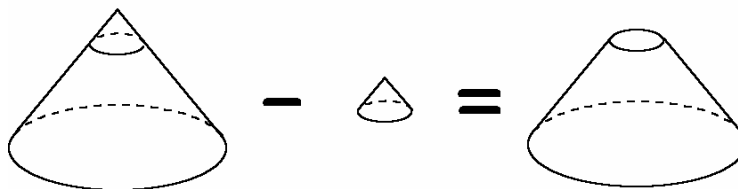
or

$$S_{\text{cylinder}} = 234.5 \text{ ft}^2$$

Next we find the surface area of the truncated cone.



However, we are not equipped with a formula for this shape. But, if we consider the truncated cone a large cone with a smaller cone subtracted from the top,



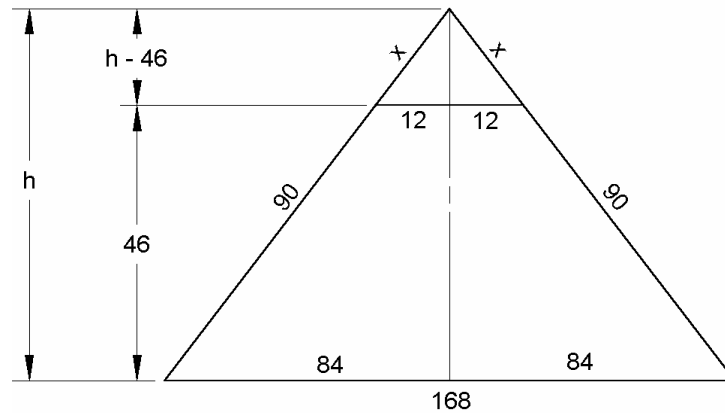
the surface area is the difference of the surface area of the two cones. Call the surface area of the large cone S_{lc} , the surface area of the small cone S_{sc} , and the surface area of the truncated cone S_{tc} . Algebraically,

$$S_{tc} = S_{lc} - S_{sc}$$

Now the problem is reduced to finding the surface area of the small and large cones. The formula for the surface area of a cone is (Equation 11, Section 2)

$$S = 2 \pi r l$$

The question is, do we have the information needed to use the formula? To answer, draw a schematic with known dimensions and unknown variables.



From the schematic, we can see that the radius of the large cone is 84 inches, and the side length is $(90 + x)$ inches. The radius of the small cone is 12 inches, and the side length is x inches. Furthermore, the triangles are similar. Therefore, we can set up the ratios described in Section 2.5. For these triangles,

$$\frac{12}{84} = \frac{x}{(90 + x)}$$

Solving for x , the proportion becomes

$$12 (90 + x) = 84 x .$$

$$1080 + 12 x = 84$$

$$1080 = 72 x$$

$$x = 15$$

Now we have all of the information needed to compute the surface area of the small and large cones.

$$S_{lc} = 2 \pi r l$$

Where $r = 84$ inches, and $l = 90 + x = 90 + 15 = 105$ inches. Therefore,

$$S_{lc} = 2 (3.14) (84) (105) = 55389.6 \text{ in}^2$$

and

$$S_{sc} = 2 \pi r l$$

Where $r = 12$ inches, and $l = x = 15$ inches. So,

$$S_{sc} = 2 (3.14) (12) (15) = 1130.4 \text{ in}^2$$

Finally, the surface area of truncated cone is

$$S_{tc} = S_{lc} - S_{sc} = 55389.6 - 1130.4 = 54259.2 \text{ in}^2,$$

or,

$$S_{tc} = 376.8 \text{ ft}^2$$

The very last step of this problem is to add the surface area of the cylinder to the surface area of the truncated cone.

$$S_{cylinder} + S_{tc} = 234.5 \text{ ft}^2 + 376.8 \text{ ft}^2 = 611.3 \text{ ft}^2$$

Thus the amount of canvas needed to cover the yurt is 611.3 ft^2 .

6 Suggested Lesson Plans

The problems from the last two sections vary in complexity; yet, the topics from algebra and geometry are fairly fundamental. As is typical of math instruction, concepts are first presented in their simplest, most unencumbered forms, and mastery of the idea comes through repetition. When the context changes, and the basic principals are less pronounced, and the problems become more complex. Real life application problems tend to be more difficult for this reason. And while problems such as 7 may involve too many steps for students follow through on their own, with proper guidance, they should be able to understand the process. The following lesson plans are suggested to bring a level of coherence to the group.

Day	Lecture	Building
1	<ul style="list-style-type: none">▪ Introductions▪ General description of yurts▪ Circles	<ul style="list-style-type: none">▪ Present materials and tools
2	<ul style="list-style-type: none">▪ Follow-up discussion on circles▪ Discuss wall assembly▪ Introduce the Cartesian plane	<ul style="list-style-type: none">▪ Layout yurt footprint▪ Construct walls
3	<ul style="list-style-type: none">▪ Introduce linear equations▪ Introduce similar triangles	<ul style="list-style-type: none">▪ Record data on walls for linear equations▪ Break into groups and distribute materials
4	<ul style="list-style-type: none">▪ Develop similar triangles▪ Discuss Group activities	<ul style="list-style-type: none">▪ Groups; door doorframe, center-ring
5	<ul style="list-style-type: none">▪ Pythagorean theorem▪ Discuss group activities	<ul style="list-style-type: none">▪ Groups; door doorframe, center-ring
6	<ul style="list-style-type: none">▪ Follow-up Pythagorean theorem	<ul style="list-style-type: none">▪ Groups; door doorframe, center-ring
7	<ul style="list-style-type: none">▪ Linear equations▪ Discuss group activities▪ Discuss yurt assembly	<ul style="list-style-type: none">▪ Wrap-up door doorframe, center-ring
8	<ul style="list-style-type: none">▪ Surface area▪ Discuss yurt assembly	<ul style="list-style-type: none">▪ Yurt assembly
9	<ul style="list-style-type: none">▪ Discuss final assembly	<ul style="list-style-type: none">▪ Final assembly

References

Aufmann, Richard, Barker, Vernon, and Lockwood, Joanne. Prealgebra. Houghton Mifflin Company. New York 2002.

Blue Evening Star. Building Tipis and Yurts. Lark Books & Sterling Publishing Company. New York. 1995.

Charney, Len. Build a Yurt. Sterling Publishing Company. New York. 1974.

Lial, Margaret, Hornsby, John and McGinnis, Terry. Introductory Algebra. Addison Wesley. 2002.

Pearson, David. Circle House. Chelsea Green Publishing Company. Vermont. 2001.

Appendix on Materials (Materials List)

QTY	DESCRIPTION
75	FIR (PINE), 1" x 2" x 6', BOARDS SHOULD BE STRAIGHT AND FREE FROM LARGE KNOTS
12	FIR (PINE), 2" x 2" x 7'6", BOARDS SHOULD BE STRAIGHT AND FREE FROM LARGE KNOTS
4	FIR (PINE), 2" x 4" x 8', BOARDS SHOULD BE STRAIGHT AND FREE FROM LARGE KNOTS
1 SHT	PLYWOOD, 5/8", EXTERIOR
25	6' STAKES, LATH OR ANY SUITABLE STAKING MATERIAL
200	HEX BOLT, 1/4" x 2"
400	WASHER, 1/4"
200	NUTS, 1/4"
4	HEX BOLT, 1/4" x 3"
10	STRONG TIE H1 BRACKET, SIMPSON OR EQUIVALENT BRAND
58'	STEEL CABLE, 3/16"
1 LB	1" DRYWALL SCREW
40	2" FLAT-HEAD WOOD SCREW
20	#6 x 1-1/2" FLAT-HEAD SCREW
8 OZ	WOOD GLUE, EXTERIOR
2	5" INTERNAL ANGLE MENDING PLATE
2	5" RECTANGULAR MENDING PLATE
3	WOOD EYELET SCREW, 1/2" HOLE X 1-1/2"
200'	NYLON ROPE, ANY