

Mathematics 201: Geometry
Deerfield Academy
2017-2018

Problem Book

To MAT201 Students

Members of the Deerfield Academy, Emma Willard School and Phillips Exeter Academy Mathematics Department have created the material in this book. As you work through it, you will discover that algebra, geometry, and trigonometry have been integrated into a mathematical whole. There is no Chapter 5, nor is there a distinct section on right triangles. The curriculum is problem-based, rather than chapter-oriented.

A major goal of this course is have you practice thinking mathematically and to learn to become a more independent and creative problem solver. Problem solving techniques, new concepts and theorems will become apparent as you work through the problems, and it is your classroom community's responsibility to make these conclusions together. Your responsibility is to keep appropriate notes for your records — there are no boxes containing important theorems. There is no index as such, but the reference section at the end of the problems should help you recall the meanings of key words that are defined in the problems (where they usually appear italicized).

I. The Mathematical Thinking Process

1. Stay/Think/Say/Draw
 - a. Reading each question carefully and repeatedly is essential, especially since definitions, highlighted in italics, are routinely inserted into the problem texts. Check the reference section regularly.
 - b. It is important to make accurate diagrams whenever appropriate.
2. Talk/Use Resources
 - a. Talk out loud, speak to friends, ask questions, email your teacher
 - b. Your prior knowledge – what you know already or have forgotten that you know – is your best resource.
 - c. Use your notes, the internet
3. Estimate
 - a. Before you try any mathematical formulas at all, you should have some idea of what the answer should be – is really large like 3000? Or should it be something small like .05?
4. Mathematize
 - a. Formulas(Pythagorean theorem, quadratic formula, equations of lines), concepts (area, linear motion, what a triangle is, the sum of the angles in a triangle) and rules of mathematics (two points determine a line, all numbers squared are positive) can be used at this point in the process.
5. Try/Refine/Revise
 - a. If something does work, see why it didn't work
 - b. Change the method
 - c. Try something else!

- II. Problem Solving as Homework:** You should approach each problem as an **exploration**. **You are not expected to come to class every day with every problem completely solved. Your presentations in class are expected to be unfinished solutions.**
- Useful strategies to keep in mind are:
 - create an easier problem
 - guess and check
 - work backwards
 - make use of prior knowledge
 - recall a similar problem.
 - It is important that you work on each problem when assigned, since the questions you may have about a problem will likely motivate class discussion the next day. In other words, doing homework to get ahead is not a good idea since class discussion will help you prepare for future problems.
 - Try to justify each step you do – ask *why* not just *how*. Justification is more important than the answer on a nightly basis.
 - Problem-solving requires persistence as much as it requires ingenuity. When you get stuck, or solve a problem incorrectly, back up and start over. Keep in mind that you're probably not the only one who is stuck, and that may even include your teacher.
 - If you have taken the time to think about a problem, you should bring to class a written record of your efforts, not just a blank space in your notebook. There should be a diagram, equation, reference to similar problem, evidence of your work or questions you had on the problem. This is what will get you credit for doing your homework!!

The methods that you use to solve a problem, the corrections that you make in your approach, the means by which you test the validity of your solutions, and your ability to communicate ideas are just as important as getting the correct answer. You are not to spend more than the allotted time for that night's homework on any one nightly assignment, so please manage your study hall time carefully!

Most importantly, be patient with yourself – learning to problem solve independently takes time, courage and practice.

III. About technology: Many of the problems in this book require the use of technology (graphing calculators or computer software) in order to solve them. Moreover, you are encouraged to use technology to explore, and to formulate and test conjectures. Keep the following guidelines in mind:

- write before you calculate, so that you will have a clear record of what you have done
- store intermediate answers in your calculator for later use in your solution
- pay attention to the degree of accuracy requested
- be prepared to explain your method to your classmates, including bringing your laptop to class with the file on it (or emailing it to your teacher the night before) in order to project your solution to the class

IV. Keeping a Mathematics Journal:

As part of this curriculum you will be asked to write about your problem solving processes on a regular basis. This will help you to organize your thoughts around not only problem solving, but the content of the course. When you write your journal entries you should keep in mind a few things:

- Write in complete sentences as if you were explaining to yourself or to another student how to do the problem
- Justify the steps of your process and explain to yourself why you chose the methods you used in the problem
- Make connections between why you chose a certain step in the process and ideas that have been discussed in class
- Make connections between problems – see if patterns emerge in how the problems are laid out in the curriculum
- Draw diagrams that help you to understand the problem better, even if a student used that diagram in class and explain why it helped your understanding

At any time during the year, if you have questions about journal writing or want more feedback, do not hesitate to speak with your instructor, or see your instructor’s grading rubric for journal entries.

V. Classroom Contribution:

Learning in a PBL classroom is very different for most students for many different reasons. What is valued in the PBL classroom and what is considered successful takes time to understand, so most importantly you should come with an open mind and be ready to openly communicate. Be sure to communicate your learning needs to your teacher throughout the year. Here are some comments from past students:

About presenting homework solutions:

“The fact that we have to get up in front of the class helped in my learning”

“The accumulative mixture of problems the book had really helped me see the connections between concepts”

“I got more comfortable with taking mathematical risks”

“This curriculum has made me a better problem solver”

“It helped challenge me and taught me even if I didn’t think I was learning”

“Make sure you try all of the problems – even if you can’t get them.”

About doing journal writing:

“Keeping a journal has really helped make reviewing and preparing for tests very easy”

“Journals totally helped, although having them on the test is useless. Once you’ve done a journal you know the subject.”

“Although I never fully bought into keeping a journal, it gave me a good resource for studying.”

About communication in class:

“I loved being able to discuss issues with classmates”

“It helps when the teacher summarizes what we learn”

“I liked finding more than one way to do something”

About getting support:

“Meeting with my teacher really helped”

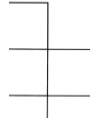
“Asking questions is sign of strength not weakness”

“I liked how it was focused on yourself figuring out the problem – though that was hard for me to adjust to – however it’s made me much more independent math-wise”

Becoming a better independent problem solver is not an easy journey, but it does need your whole-hearted curiosity and effort. The mathematics department is here to support you through this year so please make use of the support systems that are available if you feel you need them.

1. You are given the following figure created by squares. By drawing line segments, divide the given area in equal quarters. Be ready to discuss your method and justify that the areas you have created are equal. (from Dekker and Querrelle *Great Assessment Problems, Quarter the Cross*, <http://www.fi.uu.nl/catch>)

2. The Pythagorean Theorem is one of the most well-known geometric theorems in the world. It is so famous it was quoted in a movie – what movie? Watch the video that is posted on Canvas. What is wrong with the quote? Can you find a way to fix it?



3. *Some terminology:* In a right triangle, the *legs* are the sides adjacent to the right angle. The *hypotenuse* is the side opposite to the right angle. Given the two points $A(3, 7)$ and $B(5, 2)$ find C so that triangle ABC is a right triangle with the right angle at C . How long are legs? How long is the hypotenuse?
4. The length of a rectangle is $(3x - 4)$ and the width is $(2x + 1)$. Find the perimeter and area of this rectangle. What is your definition of a rectangle? Write out a sentence in your own words.
5. Let $A = (0, 0)$, $B = (7, 1)$, $C = (12, 6)$, and $D = (5, 5)$. Plot these points and connect the dots to form the *quadrilateral* $ABCD$. Verify that all four sides have the same length. Such a figure is called *equilateral*.
6. *Factor:* $x^2 - 5x + 6$. Write another factoring problem that has two different factors.
7. If the hypotenuse of a right triangle is 12 and one of the legs is 4, what is the length of the other leg? What is the simplest form in which you can express your answer?
8. In the book (and later movie) *Flatland*, by Edwin Abbott, we are introduced to a world and its inhabitants that take place in a *plane*. The main character's name is Arthur T. Square and all activities and actions happen in the plane. However, Arthur (who is a square) happens to run into the "King of Pointland" talking out loud about himself to himself. Here is an excerpt of what Arthur hears:

“Infinite beatitude of existence! It is; and there is none else beside It. It fills all space and It fills, It is. What It thinks, that It utters; and what It utters, that It hears; and It itself is Thinker, Utterer, Hearer, Thought, Word, Audition; it is the One and yet the All in All.” (*Flatland*, p.99)

Watch the Video Clip from *Flatland the Movie* where Arthur T. Square meets the King of Pointland here <https://www.youtube.com/watch?v=NeNvSCTbVVs> and answer these questions:

- a. Why does the King of Pointland talk the way he does?
- b. Why does he describe himself in the movie as zero-dimensional?
- c. Why does he describe himself in the book as “filling all space”?

1. Do all right triangles have integer side lengths? Using some examples, justify your answer.
2. The general notation in geometry is that points are labeled with capital letters. Given the two points $A(3,5)$ and $B(0,1)$, graph them on some graph paper. If triangle ABC is a right triangle with C being the right angle.
 - a. Find possible coordinates for point C keeping in mind that angle C is the right angle.
 - b. Describe how you would find the lengths of the sides BC and AC.
 - c. Now use a geometric idea you already know to find the length of the side AB.
3. Two different points on the line $y = 2$ are both exactly 13 units from the same point $(7, 14)$. Draw a picture of this situation, and then find the coordinates of these points.
4. Find the coordinates on a plane for the vertices of a quadrilateral that form a rectangle that is not a square. Can you find coordinates for vertices of a rectangle that does not lie horizontally or vertically?
5. Later in *Flatland*, Arthur T. Square meets the King of Lineland and has a whole conversation with him (this King can actually acknowledge others' presence). Here is some of Arthur's recounting of that meeting:

His subjects – of whom the small lines were men and the Points, women – were all alike confined in motion and eyesight to that single straight line, which was their world. It need scarcely be added that the whole of their horizon was limit to a point; nor could anyone ever see anything but a point. Man, woman, child, thing – each was a point to the eye of a Linelander. Only by the sound of the voice could sex or age be distinguished. Moreover, as each individual occupied the whole of the narrow path, so the speak, which constituted his universe, and no one could move to the right or left to make way for passers by, it followed that no Linelander could ever pass another. Once neighbors, always neighbors. (*Flatland*, p.59)

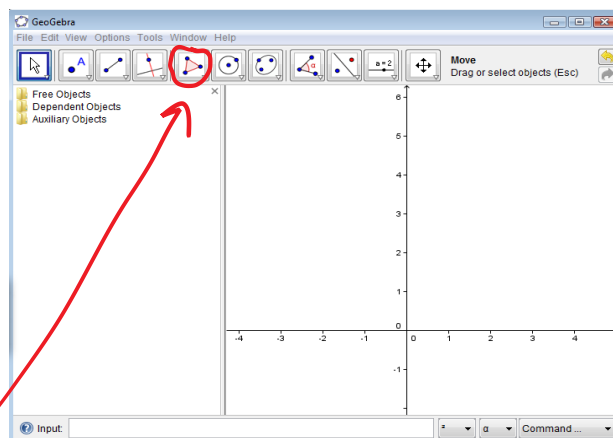
Listen to the conversation between Arthur and the King of Lineland in the movie version of Flatland at this link <https://www.youtube.com/watch?v=76IUZR6z3OQ> and then answer these questions:

- a. What does it mean that “each individual occupied the whole of the narrow path”?
 - b. Why does the King say that “length and space are the same”?
 - c. Is dimension the same as direction?
 - d. How many dimensions does the line have?
6. In algebra you spent a great deal of time learning to describe lines in the plane. How many points do you need to write the equation of a line? Justify your answer. Give an example.

1. Give an example of a point that is the same distance from $(3, 0)$ as it is from $(7, 0)$. Find lots of examples. Describe the configuration of all such points. In particular, what types of triangles are formed?
2. The general notation in geometry is that points are labeled with capital letters and coordinates are defined with lowercase letters. Given the two points $A(x_1, y_1)$ and $B(x_2, y_2)$ what do the subscripts on x and y represent? If triangle ABC is right triangle with C being the right angle.
 - d. Find possible coordinates for point C in terms of $A(x_1, y_1)$ and $B(x_2, y_2)$.
 - e. How could you express the length of the sides BC and AC ?
 - f. Now use a geometric idea you already know to find an expression for side AB .
3. Find two points on the line $x=3$ that are 5 units away from the point $(6, 2)$.
4. *Some terminology:* When two angles fit together to form a straight angle (a 180-degree angle, in other words), they are called *supplementary angles* and either angle is the *supplement* of the other. When an angle is the same size as its supplement (a 90-degree angle), it is called a *right angle*. When two angles fit together to form a right angle, they are called *complementary angles* and either angle is the *complement* of the other. Two lines that form a right angle are said to be *perpendicular*. Draw a diagram for each definition.
5. Verify that the hexagon formed by $A = (0, 0)$, $B = (2, 1)$, $C = (3, 3)$, $D = (2, 5)$, $E = (0, 4)$, and $F = (-1, 2)$ is equilateral. Is it also *equiangular*?
6. Draw a 20-by-20 square $ABCD$. Mark P on AB so that $AP = 8$, Q on BC so that $BQ = 5$, R on CD so that $CR = 8$, and S on DA so that $DS = 5$. Find the lengths of the sides of quadrilateral $PQRS$. Is there anything special about this quadrilateral? Explain.
7. Given the two points $A(-2, 1)$ and $B(4, 7)$ describe two different methods to find the distance between A and B . Which method do you prefer and why?
8. You may have learned in the past that the sum of the angles in any triangle is 180° . We will prove this more rigorously later on. For now, given this, what can we say about the two non-right angles of a right triangle?

GeoGebra Lab #1

If you have never used a dynamic software program before, you should be aware of the difference between properties and objects that are “constructed” (using either a tool or a CONSTRUCT command) rather than “drawn” freehand with a tool. To observe this difference, complete the following activity



Undo Icon

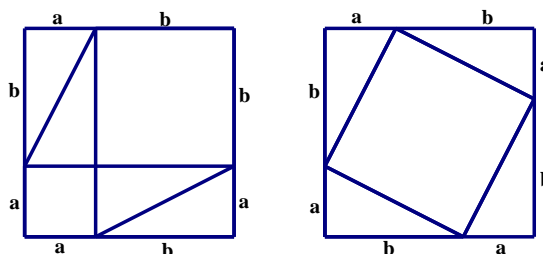
- A. Right click in what’s called “the Graphics view” (where the axes are) and select Axes in the pop-up window. This will hide the axes.
- B. Click on the polygon tool. It is 5th from the left and looks like a triangle. It is circled in the above diagram.
- C. You are going to *draw* a triangle that looks right by doing the following: click somewhere on the drawing space (Graphics View) to start drawing the triangle, then click three more times (two more points) to draw a triangle that looks like a right triangle, finishing it by clicking on the first point you placed.
- D. Press Escape (ESC), or click on the selection tool (the one that looks like an arrow) and click on any endpoint of a segment and move the triangle around. You will notice that the triangle changes, and is no longer a right triangle. You can undo, if you like, by pressing the yellow arrow at the top right of the screen.
- E. Now you will *construct* a right triangle. In the bottom right-hand corner of the 3rd toolbox from the left (pictured at right) click on the bottom right corner of the button to expand it (the corner looks a little like a tiny white triangle, but changes to red when you can click it). Choose the tool that says “Segment between two points.” Click once for each endpoint of the segment you want to create.
- F. Now choose the 4th toolbox (pictured at right) which is the Perpendicular Line. Click on an endpoint of the segment and the segment itself.
- G. Place a point on the perpendicular line using the Point tool (pictured at right), 2nd from the left. When you are on the line, it is highlighted.
- H. Choose the Polygon tool and connect your three points, clicking on each point, and making sure to again click the first point you choose at the end.
- I. At the left-side of your screen you have a list of what is on your Graphics View. This section of your screen is called the Algebra View. Find the line equation – it will have y in it. Click on the circle to the left of the equation to hide the line. Bonus: Right-click the equation and you can turn it from Standard Form to $y = mx + b$ form.
- J. Drag the vertices of this right triangle. How is this right triangle different from the one you drew in part C? What do you think is the difference between drawing and constructing objects in GeoGebra?



- How would you proceed if you were asked to verify that $P = (1, -1)$ is the same distance from $A = (5, 1)$ as it is from $B = (-1, 3)$? It is customary to say that P is *equidistant* from A and B . Find two more points that are equidistant from A and B . By the way, to “find” a point means to find its *coordinates*. Can points equidistant from A and B be found in every *quadrant*?

- Alex was given the number $\sqrt{112}$ but knew there was another way to write it in a simpler form. Remembering that the number inside the square root can be split up into factors, Alex decided to try to write 112 as the product of two numbers, one that was at perfect square. Find the numbers and simplify the radical in the way that Alex might have.

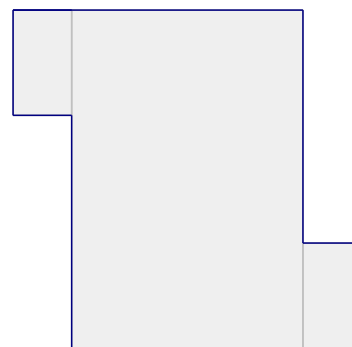
- The two-part diagram at right, which shows two different dissections of the same square, was designed to help *prove* the Pythagorean Theorem. Provide the missing details.



- Find both points on the line $y = 3$ that are 10 units from $(3, -3)$.

- On a number line, where is $\frac{1}{2}(p + q)$ in relation to p and q ? Try it with some values first.

- Some terminology: Figures that have exactly the same shape and size are called *congruent*. Dissect the region shown at right into two congruent parts using only one cut. How many different ways of doing this can you find?



- Let $A = (2, 4)$, $B = (4, 5)$, $C = (6, 1)$, $T = (7, 3)$, $U = (9, 4)$, and $V = (11, 0)$. Triangles ABC and TUV are specially related to each other in some way. Make calculations to discover and justify the relationship that you claim. Write a few words to describe what you discover.

- If you were writing a geometry book, and you had to define a mathematical figure called a *kite*, how would you word your definition? Draw some examples and be as specific as possible in your definition.

- Can you design a figure constructed with other familiar shapes (i.e. squares, rectangles, triangles) that has rotational symmetry?

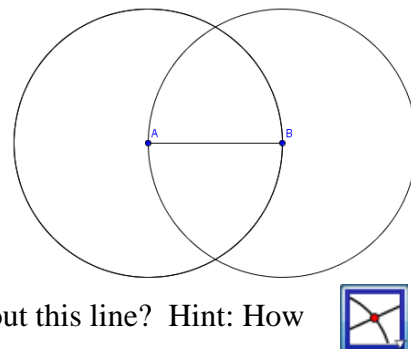
- A triangle that has at least two sides of equal length is called *isosceles*. Make up an example of an isosceles triangle, one of whose vertices is $(3, 5)$. Give the coordinates of the other two vertices. Try to find a triangle that does not have any horizontal or vertical sides.

1. Let $A = (1, 5)$ and $B = (3, -1)$. Show that the point $P = (8, 4)$ is equidistant from A and B . Find at least two more points that are equidistant from A and B . How could you describe all such points?
2. Find two different rectangles with perimeter 26. Find a general way of writing the sides of the rectangle.
3. When simplifying the radical $\sqrt{80}$, Quinn simplified to $5\sqrt{16}$ which was the same as 5 times 4 which equaled 20. “Hmm,” Quinn said, “that doesn’t make sense because 20 squared is 400.” Explain what mistake Quinn made.
4. Find two points on the y -axis that are 9 units from $(7, 5)$.

GeoGebra Lab #2

In this lab, you will explore the various ways to create circles.

- A. First, click the x in the top right corner of the Algebra View. This will close it, and give you more space to draw. You can re-open it in the View menu. Also, right click in the Graphics View window and select Axes to turn them off.
- B. The tools to create circles are in the toolbox with the circle icon. It is right next to the polygon toolbox. Try out the “Circle with Center Through Point” tool by following the instructions it gives you, at the top right part of your screen. Press ESC or select the Move tool (looks like small axes) and move the two points around to see what happens. Is there any way to move the circle that doesn’t change it?
- C. Right-click on the circle itself, select Object Properties, and notice that this gives you its name and how it was constructed. It also gives you several other options. Rename this circle “Circle_1.” Notice that this creates a subscript.
- D. Select Object Properties again. Explore some of the options in the box that pops up. Especially look through the Style tab.
- E. Now, try the Circle with Center and Radius tool. How is it different? Name this circle, “Circle_2” and change its color.
- F. Right-click Circle₁ and choose Show Object. Do the same thing for Circle₂. This should hide the circles. Do this for any other objects on the screen.
- G. Construct a segment. With the Compass tool, the third Circle tool, click on one endpoint of the segment, then the other endpoint to set the compass radius, then select one of the endpoints of this segment as the center of the circle. Repeat, using the other endpoint of the segment as its center. Your diagram should look like this:
- H. Create the intersection points using the Intersect Two Objects tool in the Point toolbox (pictured at right). Then, connect these intersections with a line. What do you think is special about this line? Hint: How do the points on the line relate to the endpoints of the segment?
- I. Find a way to check your conjecture.



1. Using GeoGebra, plot the points $P(3, 5)$, $Q(0, 0)$ and $R(-5, 3)$. Measure angle PQR , being careful to select the points in a clockwise manner. Create the segments PQ and QR . Use the Slope tool in the same toolbox as the Angle tool to find the slope of segment PQ . Do the same thing for segment QR . Make a conjecture about how these slopes are related. Verify by calculating the slopes by hand.
2. A *lattice point* is a point whose coordinates are *integers*. For example, $(2, 3)$ is a lattice point, but $(2.5, 3)$ is not. Find two lattice points that are 5 units apart but do not form a horizontal or vertical line.
3. Find a point that is 13 units away from $(-1, 4)$. Describe your interpretation of “13 units away.”
4. Graph the lines $2x - y = 5$ and $x + 2y = -10$ on a piece of graph paper on the same set of axes. Using a protractor or GeoGebra, measure the angle of intersection. What do you notice?
5. Given that $2x - 3y = 17$ and $4x + 3y = 7$, and without using paper, pencil, or calculator, find the value of x . (notice that the signs of the y terms are opposite).
6. Blair is walking along the sidewalk and sees a bird walking along the telephone wire that passes over the street. Draw a picture of this scenario. Are their paths *parallel*? Why or why not?
7. The point on segment AB that is equidistant from A and B is called the *midpoint* of AB . For each of the following, find coordinates for the midpoint of AB :
 (a) $A = (-1, 5)$ and $B = (-1, -7)$ (b) $A = (-1, 5)$ and $B = (2, -7)$
8. A unique line exists through any two points. In one form or another, this statement is a fundamental *postulate* of Euclidean geometry – accepted as true, without proof. Taking this for granted, then, what can be said about three points that lie in a plane?
9. A river bank runs along the line $x = 3$ and a dog is tied to a post at the point $D = (10, 5)$. If the dog’s leash is 25 units long (the same units as the coordinates), and if a fence were going to be placed at the edge of the river along $x = 3$, name the two coordinates along the river where it would be safe for the fence to end so that the dog could not fall in the river even though he is tethered at D . How long would the fence be?
10. Think back to problem 1 on page 6. A geometric way to describe all of the points that are equidistant from two given points is to say that they lie on the perpendicular bisector of the segment made by the two given points. For example, plot $A = (0, 2)$ and $B = (0, -4)$. Plot some points that should look like they are equidistant from A and B . Draw segment AB . What do you see is the relationship between the line that goes through all of the points you drew and the segment AB ?

GeoGebra Lab #3

In this lab you will explore some of the graphing and measurement features of GeoGebra for segments and angles. Answer all questions in a text box in your ggb file.

- A. Open GeoGebra. Notice that a coordinate axes does not always appear in the Graphics View. Right-click and choose Axes or Select Axes from the View Menu. Currently the x and y axes are in a 1:1 ratio meaning that the scales are equal.
- B. Press and hold down the shift key and click on the y axis simultaneously. A label will appear stating the scale “x:y = 1:1”. Now drag the y axis up and down. What happens to that scale definition? To return the scale definition to 1:1 you can simply right click on the graphic window and choose **x axis: y axis -> 1:1**.
- C. Now, click on the small triangle in front of the word Graphics, click on the icon that looks like a magnet and now choose “snap to grid”. This will allow drawn points to snap to lattice points.
- D. With your cursor, click on the Input Command Line and simply type (4, 5) and press enter. The point (4, 5) should be plotted and labeled A.
- E. Plot the points (7, 3) and (1, 0) in the same way. GeoGebra automatically labels in alphabetical order and also keeps a record of your objects in the Algebra View to the left. If the Algebra View is not there, select Algebra View from the View menu.
- F. Select the Move tool (farthest to the right) and move the Graphics View down so that the first quadrant is in full view in the window.
- G. Press shift and select the y axis (as described in part B). What happens to points A, B and C? Is this what you expected? Do the coordinates of A, B and C change?
- H. Construct the sides of triangle ABC using the Segment between Two Points tool which is the second tool in the Line toolbox.
- I. What type of triangle does ABC appear to be? Measure the angles of triangle ABC using the Angle tool (fourth from the right, pictured at right). Select the three points in a clockwise order with the vertex of the angle to be measured as the second point.
- J. What information is provided in the Algebra View at this time?
- K. You can easily rotate your triangle when you know a center of rotation and an angle. With the point tool, draw a point on the Graphics View. Choose the Rotate tool from the Transformation Toolbox (third from the right) and follow the directions to do the rotation using your new point D as the center. When prompted for the angle of rotation use 70 degrees and be sure to include the degree symbol in the notation. If you accidentally erase the given degree symbol, you can find it in the first drop down menu. In what direction does the rotation take your triangle?
- L. Repeat step K choosing -40 degrees for your angle of rotation. Which direction does it rotate now?



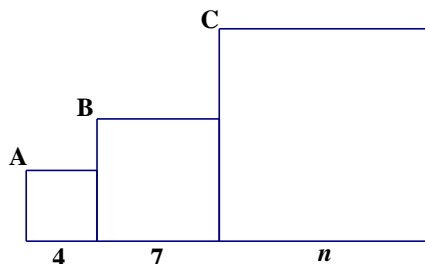
1. Find the slope of the line through:
 - (a) (3, 1) and (-7, -4)
 - (b) (2, y) and (x, 10).
2. If you needed to find the point of intersection of $y=-2x+3$ and $y=5x+3$ without your calculator or graph paper, what would you do?

- Factor: **(a)** $x^2 - 16$; **(b)** $x^2 + 8x + 16$; **(c)** $x^2 + 6x - 16$. Describe any patterns that you see.
- In GeoGebra, plot the points $A=(2,1)$ and $B=(6,-1)$. Use the Perpendicular Bisector Tool (fourth toolbox, third tool down) to construct the *perpendicular bisector of AB*. What point is guaranteed to be on the perpendicular bisector of AB ? Name some other points that are on the perpendicular bisector.
- Let $P = (a, b)$, $Q = (0, 0)$, and $R = (-b, a)$, where a and b are positive numbers. Prove that angle PQR is right, by introducing two congruent right triangles into your diagram by connecting points P and Q to the x -axis. Using these two triangles, verify that the slope of segment QP is the *opposite reciprocal* of the slope of segment QR .
- How would you find the midpoint of the two points with coordinates $A = (m, n)$ and $B = (k, l)$.
- Find the point of intersection of the lines $3x + 2y = 1$ and $-x + y = -2$. Choose a method that is new to you.
- The sides of a triangle are formed by the graphs of $3x + 2y = 1$, $y = x - 2$ and $-4x + 9y = 22$. Use technology to discover if the triangle is isosceles. How do you know?
- Consider the linear equation $y = 3.5(x - 1.3) + 2$.
 - What is the slope of this line?
 - What is the value of y when $x = 1.3$?
 - This equation is written in *point-slope* form. Explain the terminology.
 - Use your calculator to graph this line.
 - Find an equation for the line through $(4.2, -2.5)$ that is parallel to this line. Leave your answer in point-slope form.
 - Describe how you would graph by hand a line that has slope -2 and that goes through the point $(-7, 3)$.
- Given the points $A = (-2, 7)$ and $B = (3, 3)$, find two points P that are on the perpendicular bisector of AB . In each case, what can be said about the triangle PAB ?
- We live in a three dimensional world (3D) but drawings exist on a two dimensional plane (2D). Artists have the challenge of making 2D drawings look 3D. Look at this drawing and describe how the artist might have used certain techniques to help the city look 3D.
- (continuation) Can you find two lines that are in the same 3D plane that intersect? Can you find two lines that are in the same plane that do not intersect? Can you find two lines that are not in the same plane?



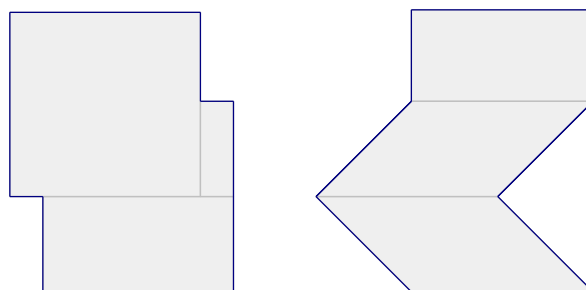
1. A slope can be considered to be a rate of change (how one quantity changes in relation to another). Explain this interpretation and give an example. Explain the difference between a line that has *undefined slope* and a line whose slope is zero.
2. A five-foot tall Deerfield student casts a shadow that is 40 feet long while standing 200 feet from a streetlight. How high above the ground is the lamp?
3. (Continuation) How far from the streetlight should the student stand in order to cast a shadow that is exactly as long as the student is tall?

4. Three squares are placed next to each other as shown. The vertices A , B , and C are *collinear*. Find the dimension n .



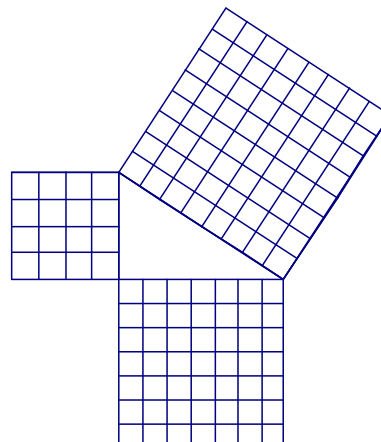
5. An airplane 27000 feet above the ground begins descending at the rate of 1500 feet per minute. Assuming the plane continues at the same rate of descent, how long will it be before it is on the ground?
6. (Continuation) Graph the line $y = 27000 - 1500x$, using an appropriate window on your calculator. With the preceding problem in mind, explain the significance of the slope of this line and its two intercepts.
7. In a dream, Blair is shrunken down to the size of a pixel and is confined to a coordinate plane on a computer screen, moving along a line with a constant speed. Blair's position at 4 am is $(2, 5)$ and at 6 am it is $(6, 3)$. What is Blair's position at 8:15 am when the alarm goes off?
8. Find a way to show that points $A = (-4, -1)$, $B = (4, 3)$, and $C = (8, 5)$ are collinear.

9. Find as many ways as you can to dissect each figure at right into two congruent parts.



10. In another dream, Blair is cycling down the street and rides underneath an overpass over which a friend, Alex is strolling. Are the two friends' paths coplanar? Do the two friends' paths ever intersect? Draw a diagram of this situation. Two lines that are non-coplanar and therefore do not intersect are called *skew*.


- An airplane is flying at 36000 feet directly above Lincoln, Nebraska. A little later the plane is flying at 28000 feet directly above Des Moines, Iowa, which is 160 miles from Lincoln. Assuming a constant rate of descent, predict how far from Des Moines the airplane will be when it lands.
- Is there enough evidence in the given diagram at the right to conclude that the triangle is right? Explain why or why not?



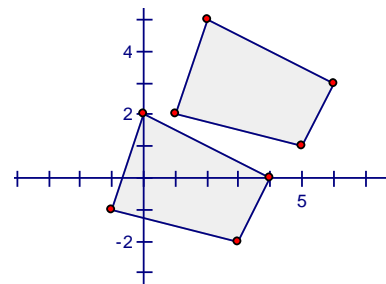
- Golf balls cost \$0.90 each at Leonard's Club, which has an annual \$25 membership fee. At Alex & Taylor's sporting goods store, the price is \$1.35 per ball for the same brand. Where you buy your golf balls depends on how many you wish to buy. Explain, and illustrate your reasoning by drawing a graph.
- Given the line $y = \frac{3}{4}(x+3) - 2$ and the point (9, 2). Using point-slope form, write equations for the lines parallel and perpendicular to this line through the given point.
- Show that the triangle formed by the lines $y = 2x - 7$, $x + 2y = 16$, and $3x + y = 13$ is isosceles. Show also that the lengths of the sides of this triangle fit the Pythagorean equation. Can you identify the right angle just by looking at the equations?
- A clock takes 3 seconds to chime at 3 pm, how long does it take to chime at 6 pm? Hint: The answer may be based on your interpretation of the question.
- For each of the following questions, fill in the blank with always true (A), never true (N), or sometimes true (S). Please write a few sentences explaining your choice. Recall that italicized words are defined in the reference section.
 - Two parallel lines are _____ *coplanar*.
 - Two lines that are not coplanar _____ intersect.
 - Two lines parallel to the same plane are _____ parallel to each other.
 - Two lines parallel to a third line are _____ parallel to each other.
 - Two lines perpendicular to a third line are _____ perpendicular to each other.
- A triangular plot of land has boundary lines of 45 meters, 60 meters, and 70 meters. The 60 meter boundary runs north-south. Is there a boundary line for the property that runs due east-west?
- Using GeoGebra, plot the points $A = (-5, 0)$, $B = (5, 0)$, and $C = (2, 6)$, then the points $K = (5, -2)$, $L = (13, 4)$, and $M = (7, 7)$. Find the lengths of each side and the measure of each angle of the triangles ABC and KLM. It is customary to call two triangles *congruent* when all corresponding sides and angles are the same.

GeoGebra Lab #5

Using GeoGebra, you can facilitate visualization of translations in the coordinate plane.

- A. Open a new GeoGebra file and hide the axes in the Graphics View.
- B. Select the regular polygon tool (fifth toolbox, second tool) from the polygon toolbox and construct a small regular pentagon.
- C. Using the “vector” tool (third toolbox, sixth tool), draw a vector somewhere else in the Graphics View. This vector is going to serve as the signal for the direction and slope for a translation of the regular pentagon, so the length of the vector will be how far the polygon is moved and the slope of the vector is the slope it will be moved by. The direction of the vector is denoted by the arrow at its head. 
- D. Now select the “Translate by vector” tool from the Transformation toolbox (fourth toolbox from the right, fifth tool) and follow the directions you will see if you hover over the translate icon to translate the regular pentagon by the vector you had drawn.
- E. Now press escape (to give you back the Move tool) and drag the original vector by the point at the head (arrow) end. What happens to the translated pentagon? Does anything happen to the original pentagon? Why or why not?

1. Let $A = (1, 2)$, $B = (5, 1)$, $C = (6, 3)$, and $D = (2, 5)$. Let $P = (-1, -1)$, $Q = (3, -2)$, $R = (4, 0)$, and $S = (0, 2)$. What is the relationship between quadrilateral $ABCD$ and $PQRS$?



2. Let $A = (2, 4)$, $B = (4, 5)$, and $C = (6, 1)$. Draw three new triangles as follows:

- (a) $\triangle PQR$ has $P = (11, 1)$, $Q = (10, -1)$, and $R = (6, 1)$;
- (b) $\triangle KLM$ has $K = (8, 10)$, $L = (7, 8)$, and $M = (11, 6)$;
- (c) $\triangle TUV$ has $T = (-2, 6)$, $U = (0, 5)$, and $V = (2, 9)$.

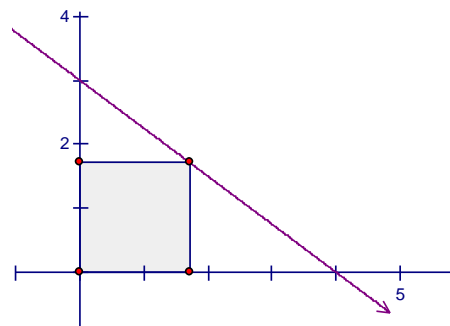
These triangles are not obtained from ABC by applying a translation. Instead, each of the appropriate transformations is described by one of the suggestive names *reflection*, *rotation*, or *glide-reflection*. Decide which is which and explain your answers.

3. The senior grass can be approximated by the triangle seen in the picture at the right. The juniors are jealous of the seniors and they want to copy the senior grass onto the lawn behind the MSB. They have a limited amount of time so they measure one of the sides and create a congruent segment on the lawn. If they do not do any more measurements does this guarantee that the junior triangle will be congruent to the senior triangle? Sketch a diagram of this scenario. Another group measured only one angle and created a congruent angle on the field. If they do not do any more measurements does this guarantee that the junior triangle will be congruent to the senior triangle? Sketch a diagram.



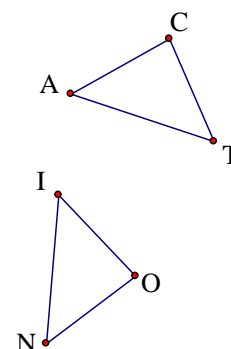
1. In baseball, the bases are placed at the corners of a square whose sides are 90 feet long. Home plate and second base are at opposite corners. How far is it from home plate to second base to two decimal places?
2. Let $A = (0, 0)$, $B = (2, -1)$, $C = (-1, 3)$, $P = (8, 2)$, $Q = (10, 3)$, and $R = (5, 3)$. Plot these points. Angles BAC and QPR should look like they are the same size. How would you argue that these angles are the same size without measuring them?
3. The juniors realize that copying a single measurement will not guarantee an exact copy of the senior triangle. They decide to try measuring two parts (i.e two angles or one side and one angle, etc.). Are there any combinations of two measurements that ensure that the copy will be congruent to the original?
4. An equilateral quadrilateral is called a *rhombus*. A square is a simple example of a rhombus. Find a non-square rhombus whose *diagonals* and sides are *not* parallel to the rulings on your graph paper. Use coordinates to describe its vertices. Write a brief description of the process you used to find your example.
5. Plot points $K = (0, 0)$, $L = (7, -1)$, $M = (9, 3)$, $P = (6, 7)$, $Q = (10, 5)$, and $R = (1, 2)$. Show that the triangles KLM and RPQ are congruent. Describe how one triangle has been transformed into the other.
6. What is the slope of the line $2x+3y=9$? Find an equation for the line through the origin that is perpendicular to the line $ax + by = c$.
7. Realizing that one or two corresponding parts do not ensure congruent triangles the juniors conjecture that they must use three parts to create a new junior triangle. Create a table of the possibilities. Which do you think will work and why?
8. (Continuation) Access the GeoGebra Book from your Canvas site called MAT202 Deerfield GeoGebra and go to Chapter 2 on Triangle Congruence. For each combination of three parts of a triangle answer the following questions:
 - a. Do you believe that this combination of three parts of a triangle is enough to create a unique triangle? If yes, why and if no, why not?
 - b. How does this GeoGebra applet help justify your conjecture?
9. Two of the sides of a right triangle have lengths 360 and 480. Find the possible lengths for the third side.
10. If two figures are congruent, then their parts *correspond*. In other words, each part of one figure has been matched with a definite part of the other figure. Given congruent triangles KLM and RPQ , in the triangle RPQ , which angle corresponds to angle M ? Which side corresponds to KL ? In general, what can be said about corresponding parts of congruent figures? How might you confirm your hunch experimentally?

1. A nice acronym to shorten the statement about corresponding parts of congruent triangles can be written as CPCTC. What do you think these letters represent?
2. The diagram at right shows the graph of $3x + 4y = 12$. The shaded figure is a square, three of whose vertices are on the coordinate axes. The fourth vertex is on the line. Find
 - (a) the x - and y -intercepts of the line;
 - (b) the length of a side of the square.



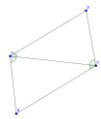
3. A triangle has six principal parts – three sides and three angles. The SSS criterion states that three of these items (the sides) determine the other three (the angles). What other combinations of three parts determine the remaining three? In other words, if the class is given three measurements with which to draw and cut out a triangle, which three measurements will guarantee that everyone's triangles will be congruent?
4. Blair is in another dream on the coordinate plane and is walking along the line $y=3x-2$. A bug starts walking towards Blair perpendicularly from the point $(5, 3)$. What is the equation of the line that describes the bug's path?
5. Plot the three points $P = (1, 3)$, $Q = (5, 6)$, and $R = (11.4, 10.8)$. Verify that $PQ = 5$, $QR = 8$, and $PR = 13$. What is special about these points?
6. Sidney calculated three distances of the collinear points A , B , and C . She reported them as $AB = 29$, $BC = 23$, and $AC = 54$. What do you think of Sidney's data, and why?
7. After drawing the line $y = 2x - 1$ and marking the point $A = (-2, 7)$, Kendall is trying to decide which point on the line is closest to A . The point $P = (3, 5)$ looks promising. To check that P really is the point on $y = 2x - 1$ that is closest to A , what would help Kendall decide? Is P closest to A ?
8. Let $A = (1, 4)$, $B = (0, -9)$, $C = (7, 2)$, and $D = (6, 9)$. Prove that angles DAB and DCB are the same size. Can anything be said about the angles ABC and ADC ?
9. When two lines intersect, four angles are formed. It is not hard to believe that the nonadjacent angles in this arrangement are congruent. If you had to prove this to a skeptic, what reasons would you offer? These pairs of angles are called *vertical angles*.
10. Let $A = (2, 9)$, $B = (6, 2)$, and $C = (10, 10)$. Verify that segments AB and AC have the same length. Use GeoGebra to measure angles ABC and ACB . On the basis of your work, propose a general statement that applies to any triangle that has two sides of equal length.
11. A line goes through the points $(2, 5)$ and $(6, -1)$. Let P be the point on this line that is closest to the origin. What does it mean for the point on the line to be closest to a point not on the line? Calculate the coordinates of P .

- We have conjectured that in an Isosceles Triangle the angles opposite the congruent sides seem to always be congruent. Write an argument supporting this assertion, which might be called the *Isosceles Triangle Theorem*.
- Let $A = (-6, -4)$, $B = (1, -1)$, $C = (0, -4)$, and $D = (-7, -7)$. Show that the opposite sides of quadrilateral $ABCD$ are parallel. Such a quadrilateral is called a *parallelogram*.
- Let $A = (0, 0)$, $B = (4, 2)$, and $C = (1, 3)$, find the exact size of angle CAB . Justify your answer without your protractor or the use of technology.
- Show that the lines $3x - 4y = -8$, $x = 0$, $3x - 4y = 12$, and $x = 4$ form the sides of a rhombus.
- Given the points D , A , and Y with the property $DA = 5$, $AY = 7$, and $DY = 12$. What can be said about these three points? What would be true if DY is less than 12?
- You know that a triangle with sides of 3, 4 and 5 is a right triangle. What would happen if the third side changed from 5 to 4? From 5 to 2? From 5 to 1? Can it be less than 1?
- Describe a transformation that carries the triangle with vertices $(0, 0)$, $(13, 0)$, and $(3, 2)$ onto the triangle with vertices $(0, 0)$, $(12, 5)$, and $(2, 3)$. Where does your transformation send the point $(6, 0)$? If you cannot find the exact coordinates make your best guess or use GeoGebra to help.
- Suppose that triangle ACT has been shown to be congruent to triangle ION , with vertices A , C , and T corresponding to vertices I , O , and N , respectively. It is customary to record this result by writing $\triangle ACT \cong \triangle ION$. Notice that corresponding vertices occupy corresponding positions in the equation. Let $B = (5, 2)$, $A = (-1, 3)$, $G = (-5, -2)$, $E = (1, -3)$, and $L = (0, 0)$. Using only these five labels, find as many pairs of congruent triangles as you can, and express the congruences accurately.
- (Continuation) How many ways are there of arranging the six letters of $\triangle ACT \cong \triangle ION$ to express the two-triangle congruence?
- What can be concluded about triangle ABC if it is given that
(a) $\triangle ABC \cong \triangle BCA$? (b) $\triangle ABC \cong \triangle ACB$? (two separate situations)
- Plot points $K = (-4, -3)$, $L = (-3, 4)$, $M = (-6, 3)$, $X = (0, -5)$, $Y = (6, -3)$, and $Z = (5, 0)$. Show that triangle KLM is congruent to triangle XZY . What type of transformation does it look like was used to transform KLM onto XZY with respect to the line $y = 2x$.

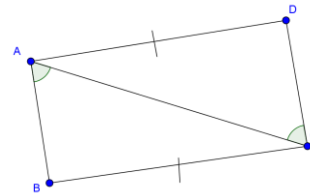


For the following pairs of triangles, state which triangle congruence criteria might help you conclude that the two triangles are congruent, if any. Then state the congruence (the names of the triangles that are congruent, if there are any).

1)



2)



3)



4)



5)



6)



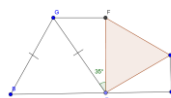
GeoGebra Lab #7**Altitudes**

In this lab you will construct the altitudes (or heights) of a triangle and investigate their properties.

- A. Open a new GeoGebra file on your computer. Turn on the axes in the Graphics View.
 - B. With the polygon tool, draw an arbitrary triangle ABC (nothing special about it).
 - C. With the angle tool, measure all three angles by clicking on the triangle. Make sure that ABC is an acute triangle. If it is not, press escape and move the vertices until all three angles are acute.
 - D. An *altitude* of a triangle is a segment that joins one of the three vertices *perpendicularly* to a point on the line that contains the opposite side. To construct the line that contains the altitude to AB, select the perpendicular line tool (fourth from the left) and select point C and segment AB.
 - E. Do the same for the other two altitude lines to their respective sides. Press escape when finished.
 - F. Notice that the equations of three lines have appeared in the Algebra View to the left. As you click on each equation, the lines in the Graphic View should turn bold to denote which line the equation is representing. If you would rather have the altitude equations in slope/intercept form, right click on the equations and choose Equation $y = mx + b$. This will be a helpful way for you to check your answers in other problems.
 - G. What do you notice about the three altitude lines? Construct the point of intersection of these lines with the Intersect Two Objects tool in the Point Toolbox.
 - H. Change the name of the point (it should be automatically named D) by right clicking on the point of intersection and selecting Object Properties from the drop-down menu. In the field entitled "name" change D to Orthocenter (which is the name for the intersection of the altitudes of a triangle).
 - I. Save this sketch as GeoGebra Altitude Lab on your computer.
 - J. **Answer the following questions in a textbox on your graphics view:**
 1. Make a conjecture about the three altitudes of a triangle. What do you think is always true?
 2. Test your conjecture by dragging one or more vertices around the sketch screen. What do you observe? Does this support your conjecture?
 3. What do you observe when the triangle is obtuse?
 4. What do you observe when the triangle is right?
 5. What do you observe when the triangle is acute?
1. How would you convince someone that the two acute angles in a right triangle are complementary?
 2. In Geogebra, draw a triangle and using the measure tool, measure the lengths of the three sides. Make a conjecture about what must be true about the two sides in comparison to the third side in order for the triangle to exist?

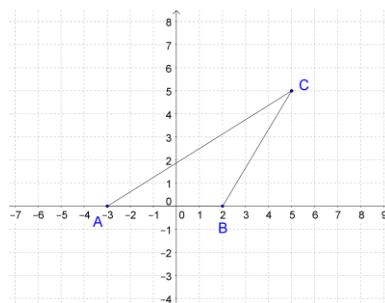
- Let $A = (0, 0)$, $B = (1, 2)$, $C = (6, 2)$, $D = (2, -1)$, and $E = (1, -3)$. Show that angle CAB is the same size as angle EAD . You may want to use Geogebra to help you solve this problem.
- In the diagram at the right, Triangle BGD is isosceles, Triangle DFE is equilateral and angle BDE is 150 degrees. Find the following measures:

- $\angle FDE$
- $\angle BDG$
- $\angle BGD$
- $\angle B$



- What is true about all of the points that lie on the perpendicular bisector of a segment?
- How would you write the geometric definition of a square? Is a square a rectangle?
- Triangle Inequality Theorem*: What must be true about the three sides of a triangle for it to exist?
- An *altitude* of a triangle is a segment that joins one of the three vertices to a point on the line that contains the opposite side, the intersection being *perpendicular*. For example, consider the triangle whose vertices are $A = (0, 0)$, $B = (8, 0)$, and $C = (4, 12)$.
 - Find the length of the altitude from C to side AB .
 - Find an equation for the line that contains the altitude from A to side BC .
 - Find an equation for the line BC .
 - Find coordinates for the point where the altitude from A meets side BC .
 - Find the length of the altitude from A to side BC .
 - As a check on your work, calculate BC and multiply it by $\frac{1}{2}$ times your answer to part (e). You should be able to predict the result.
 - It is possible to deduce the length of the altitude from B to side AC from what you have already calculated. Show how.
- Find the point on the line $x + 2y = 8$ that is closest to the point $(3,0)$. Describe the method you used.
- What do you think of this statement – if a quadrilateral is equilateral, then its diagonals must be perpendicular. If you think it's true, draw a diagram and try to show that it's false. If you think it's false, draw a diagram and try to come up with a reason why it must be true.
- Let $A = (-2, 3)$, $B = (6, 7)$, and $C = (-1, 6)$.
 - Find an equation for the perpendicular bisector of AB .
 - Find an equation for the perpendicular bisector of BC .
 - Find coordinates for a point K that is equidistant from A , B , and C .

1. What are the lengths of the base and the altitude of the triangle defined by the coordinates $A(3,2)$, $B(6,2)$ and $C(4,6)$? Find an alternative coordinate for C so that ABC has the same area but is now obtuse.
2. Take a regular piece of $8\frac{1}{2}$ by 11 inch of paper (regular printer paper). By only folding, how could fold the piece of paper into a perfect square? Try it.
3. What is true about the diagonals of a rhombus? What past concept that we have discussed is used in your justification?
4. Find the area of the triangle defined by $E(-2, 8)$, $W(11, 2)$, and $S(-2, -4)$. Now, find the area of triangle WLS where L is $(-2, 0)$.
5. Take a piece of paper that is in the shape of a square. Find a way to fold the square to construct a square with exactly $\frac{1}{4}$ the area of the original square. Convince a partner that it is a square and has $\frac{1}{4}$ of the area.
6. A segment from one of the vertices of a triangle to the midpoint of the opposite side is called a *median*. Consider the triangle defined by $A = (-2, 0)$, $B = (6, 0)$, and $C = (4, 6)$.
 - (a) Find an equation for the line that contains the median drawn from A to BC .
 - (b) Find an equation for the line that contains the median drawn from B to AC .
 - (c) Find coordinates for G , the intersection of the medians from A and B .
 - (d) Let M be the midpoint of AB . Determine whether or not M , G , and C are collinear.
7. The line $3x + 2y = 16$ is the perpendicular bisector of the segment AB . Find coordinates of point B , given that $A = (-1, 3)$. What would you call this geometric transformation?
8. A rhombus has 25-cm sides, and one diagonal is 14 cm long. How long is the other diagonal?
9. Prove that one of the diagonals of a kite is bisected by the other.
10. Let $A = (1, 4)$, $B = (8, 0)$, and $C = (7,8)$. Find the area of triangle ABC .
11. Every triangle has three altitudes. Draw the three altitudes of triangle ABC in the following diagram at the right.



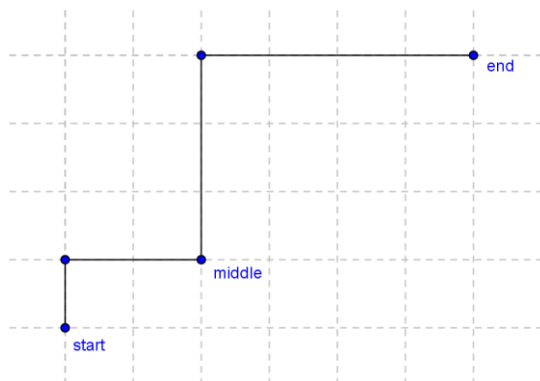
GeoGebra Lab #8

Medians

- A. Open a new Geogebra file and draw an arbitrary triangle.
- B. Using the Midpoint tool from the Point toolbox, construct the midpoint of each side of the triangle. Right-click one of the midpoints, and in Object Properties, change the color of each midpoint.
- C. A *median* of a triangle is a segment that connects a vertex to the midpoint of the side opposite to it. Construct the medians of this triangle with the segment tool.
- D. Construct the intersection of the medians. Remember to use the Intersect Two Objects tool. This point is called the *centroid* of the triangle. Right-click to rename this point G (if it is not already named this).

Answer the following questions:

1. What can be said about the three medians of a triangle?
 2. Do the properties that you observed for the orthocenter hold true for this point? Test your conjecture by making the triangle right, obtuse and acute.
-
1. Triangle ABC is isosceles, with $AB = BC$, and angle BAC is 56 degrees. Find the remaining two angles of this triangle.
 2. Terry walked one mile due north, two miles due east, then three miles due north again and then once more east for 4 miles. How far is Terry from the starting point? Which distance is farther – Terry’s distance from the starting point or the sum of the two direct distances walked?
 3. Find the area of the triangle whose vertices are $A = (-2, 3)$, $B = (6, 7)$, and $C = (0, 6)$.
 4. Write the equation of the line that goes through the point $(-3,5)$ and is perpendicular to the line $y = 2x + 6$.
 5. Take a piece of paper that is in the shape of a square again. Find a way to fold the square to construct a triangle with exactly $\frac{1}{4}$ the area of the original square. Convince a partner that it has $\frac{1}{4}$ of the area.
 6. Let $A = (-4, 0)$, $B = (0, 6)$, and $C = (6, 0)$.
 - (a) Find equations for the three lines that contain the altitudes of triangle ABC .
 - (b) Show that the three altitudes are *concurrent*, by finding coordinates for their common point. The point of concurrence is called the *orthocenter* of triangle ABC .



1. Triangle ABC is isosceles, with $AB = BC$, and angle ABC is 56 degrees. Find the remaining two angles of this triangle.
2. If ABC is a right triangle with B the right angle, $A=(-3,2)$ and $B=(2,5)$, find possible coordinates for C .
3. Take a piece of paper in the shape of a perfect square. Find a way to fold the square to construct a square with exactly $\frac{1}{2}$ the area of the original square. Convince your partner that it is a square and has $\frac{1}{2}$ of the area.
4. Let $A = (-4, 0)$, $B = (0, 6)$, and $C = (6, 0)$.
 - (a) Using algebra, find equations for the three medians of triangle ABC .
 - (b) Show that the three medians are concurrent, by finding coordinates for their common point. The point of concurrence is called the *centroid* of triangle ABC .
5. Given points $A = (0, 0)$ and $B = (-2, 7)$, find coordinates for C and D so that $ABCD$ is a square.
6. Let $A = (0, 12)$ and $B = (25, 12)$. Find coordinates for a point $P(x,0)$ on the x -axis that makes angle APB a right angle.
7. The lines $3x + 4y = 12$ and $3x + 4y = 72$ are parallel. Explain why, and then find the distance that separates these lines. You will have to decide what “distance” means in this context.
8. Give an example of an equiangular polygon that is not equilateral.
9. On a separate sheet of paper, draw parallelogram $PQRS$ with vertices at $P(0, 0)$, $Q(1, 3)$, $R(6, 2)$, and $S(5, -1)$. Cut out your parallelogram (REALLY). By making one cut through the parallelogram, show how a rectangle can be formed by the two pieces that you now have. What can you conclude about how to find the area of a parallelogram?
10. Prove that a diagonal of a square divides it into two congruent triangles.
11. Given the points $A = (0, 0)$, $B = (7, 1)$, and $D = (3, 4)$, find coordinates for the point C that makes quadrilateral $ABCD$ a parallelogram. What if the question had requested $ABDC$ instead?
12. Find an equation for the line through point $(7, 9)$ that is perpendicular to a line with slope of $\frac{2}{5}$.

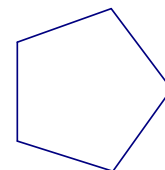
GeoGebra Lab #9

Perpendicular Bisectors

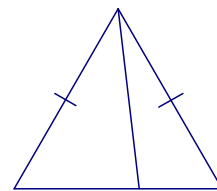
1. Open a new Geogebra file and draw an arbitrary triangle.
2. Select the Perpendicular Bisector Tool from the construction toolbox (4th from the left), and click on each side of the triangle.
3. Construct the intersection point of all of the perpendicular bisectors. Change the name of the point to “Circumcenter.”
4. Save this sketch as GeoGebra Perpendicular Bisector Lab on your computer.

Answer the following questions in a textbox on your graphics view:

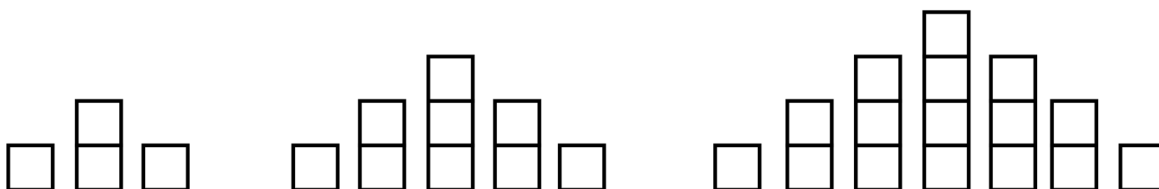
1. Move your triangle around observe what happens to the circumcenter. What happens to this point when the triangle is right? Obtuse? Acute?
 2. The circumcenter also has another interesting property. Recall the property of perpendicular bisectors discussed in class. The intersection of the perpendicular bisectors then has that property for both segments. So what do you think is true of the circumcenter?
 3. Check your conjecture by selecting the circle tool. With the cursor click on the circumcenter and drag the mouse to one of the vertices of the triangle (it doesn't matter which one – why not?). Describe the circle in relation to the triangle.
-
1. What do you need to write the equation of the perpendicular bisector of the points D (3, -1) and A (5, 3)? Do so.
 2. Plot all points that are 3 units away from the x -axis. Describe the configuration algebraically and in words. What definition of distance are you using in this problem?
 3. A polygon that is both equilateral and equiangular is called *regular*. Prove that all diagonals of a regular *pentagon* (five sides) have the same length.
 4. Plot all of the points that are 5 units away from the line $x=3$. Describe these points algebraically and in words.
 5. Considering a Pythagorean definition of distance in the plane, plot all of the points 3 units from (5, 4) and describe their configuration algebraically and in words.
 6. Let $A = (3, 4)$, $B = (0, -5)$, and $C = (4, -3)$.
 - a. Find equations for the perpendicular bisectors of segments AB and BC .
 - b. Find the coordinates for their intersection point K .
 - c. Calculate lengths KA , KB , and KC .
 - d. Why is K also on the perpendicular bisector of segment CA ?
 7. (Continuation) A *circle* centered at K can be drawn so that it goes through all three vertices of triangle ABC . Explain why. This is why K is called the *circumcenter* of the triangle. In general, how do you locate the circumcenter of a triangle?



1. Find coordinates for the point equidistant from $(-1, 5)$, $(8, 2)$, and $(6, -2)$.
2. Use the diagram at right to help you explain why SSA evidence is not by itself sufficient to justify the congruence of triangles. The tick marks designate segments that have the same length.
3. Find an equation for the line through point $(7, 9)$ that is perpendicular to a line with slope of $\frac{2}{5}$.

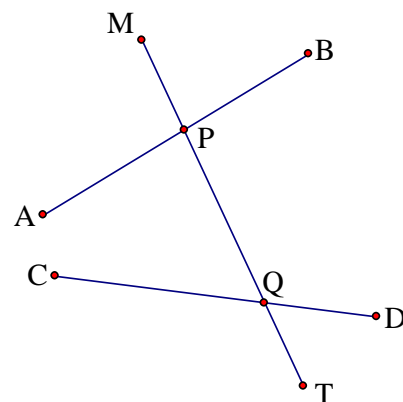


4. A triangle that has a 13-inch side, a 14-inch side, and a 15-inch side has an area of 84 square inches. Accepting this fact, find the lengths of all three altitudes of this triangle. Remember that area is equal to $\frac{1}{2}$ the base multiplied by the height.
5. Find the lengths of *all* the altitudes of the triangle whose vertices are $(0, 0)$, $(3, 0)$, and $(1, 4)$.
6. The *converse* of a statement of the form “If A then B ” is the statement “If B then A .” Write the converse of the statement “If it is Tuesday, we have sit down lunch.”
7. (Continuation) “If point P is equidistant from the coordinate axes, then point P is on the line $y = x$ ”. Is this a true statement?
 - (a) Write the converse of the given statement. Is it true?
 - (b) Give an example of a true statement whose converse is false.
 - (c) Give an example of a true statement whose converse is also true.
8. Given the following three objects, write a description of how you see the objects growing. Be as detailed as possible and be prepared to describe your thoughts to the class.



9. Let $P = (2, 7)$, $B = (6, 11)$, and $M = (5, 2)$. Depending on the coordinates of point D what types of quadrilaterals can you make of quadrilateral $PBMD$? Find different examples of the coordinates of point D for as many types of quadrilaterals as you can.

- The diagram at right shows lines APB and CQD intersected by line $MPQT$, which is called a *transversal*. There are two groups of angles: one group of four angles with vertex at P , and another group with vertex at Q . There is special terminology to describe pairs of angles – one from each group. If the angles are on different sides of the transversal, they are called *alternate*, for example, angles APM and PQD . Angle BPQ is an *interior* angle because it is between the lines AB and CD . Thus, angles APQ and PQD are called *alternate interior*, while angles QPB and PQD are called *Same Side Interior*. On the other hand, the pair of angles MPB and PQD – which are non-alternate angles, one interior, and the other exterior – is called *corresponding*. Refer to the diagram and name
 - the other pair of alternate interior angles;
 - the other pair of same side interior angles;
 - the angles that correspond to CQT and to TQD .

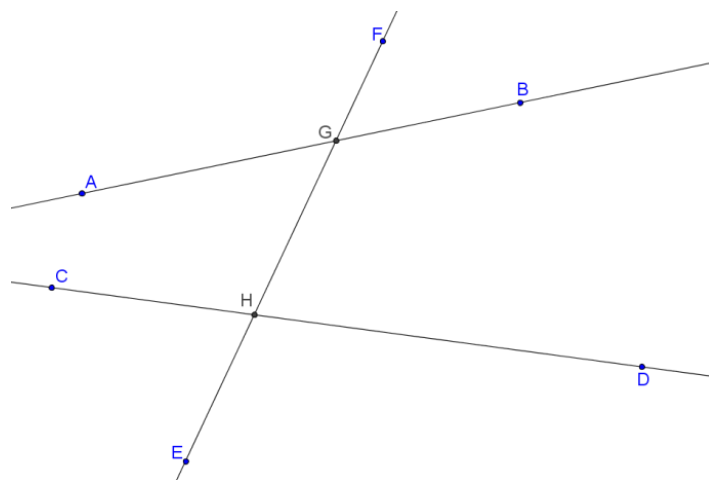


- The diagonals of quadrilateral $ABCD$ intersect perpendicularly at O . What can be said about quadrilateral $ABCD$?

GeoGebra Lab #11

In this lab, we will discover properties of angles formed by two lines (or segments) cut by a transversal.

- Open a GeoGebra file and turn off the axes in the Graphics View.
- Draw two **lines**, not necessarily parallel, and a transversal, as in the diagram. Construct the intersection points and label as shown in the diagram
- Measure all eight of the angles using the Angle tool. Recall that in order to measure an angle, you need to select the three points that define that angle in a clockwise order.
- Move all angle measurement labels so that they are readable.
- Press escape and select a point on either line (not the intersection). All angle measure labels should remain in view, but the measure of the angles should change.
- In the Algebra View, make sure the equations of the lines AB and CD are in slope/intercept form and compare the slopes.
- Drag one of the lines so that they are parallel to each other.
- Fill in the chart below. Name a pair of each type of angle given and state the angle measurement that you observe in your Graphics View when the lines are parallel. Finally, state the relationship that exists (if any) between the angles in that pair.

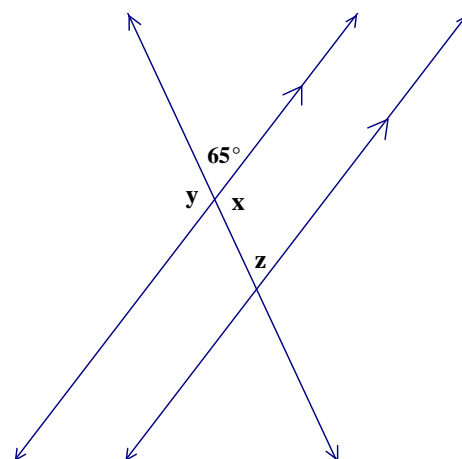


Angle Type	First Pair name and angle measurement	Second Pair name and angle measurement	Relationship?
Corresponding			
Alternate Interior			
Same Side Interior			

- I. For each type of angles, make a conjecture about the relationship of the lines. What is the requirement for your conjectures to be true?
 J. Are the converses of these statements true?

1. You have recently seen that there is no generally reliable SSA criterion for congruence. If the angle part of such a correspondence is a *right* angle, however, the criterion *is* reliable. Justify this so-called *hypotenuse-leg* criterion (which is abbreviated HL).

2. For the diagram at the right, find the measure of the angles indicated. Notice the custom of marking arrows on lines to indicate that they are known to be parallel.



3. It is a postulate (assumed without proof) that given two parallel lines cut by a transversal, corresponding angles are congruent. Given two parallel lines cut by a transversal, why would any pair of alternate interior angles also be congruent as well?

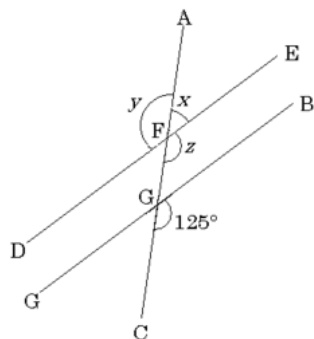
4. What do you call (a) an *equiangular quadrilateral*? (b) an *equilateral quadrilateral*? (c) a *regular quadrilateral*?

5. Given isosceles triangle ABC where $AB = BC = 10$ and the altitude from B has length 4. Find the length of the base. Leave your answer in simplest radical form.

6. You probably know that the sum of the angles of a triangle is the same as the measure of a straight angle. One way to confirm this is to draw a line through one of the vertices, parallel to the opposite side. This creates some alternate interior angles. Complete the proof and include a visual representation.

7. If it is known that one pair of alternate interior angles are congruent, what can be said about (a) the other pair of alternate interior angles? (b) any pair of corresponding angles? (c) either pair of same side interior angles?

1. In the following diagram if ED and BG are parallel lines, state the reason why you should be able to state that



$\angle z = 125 ?$

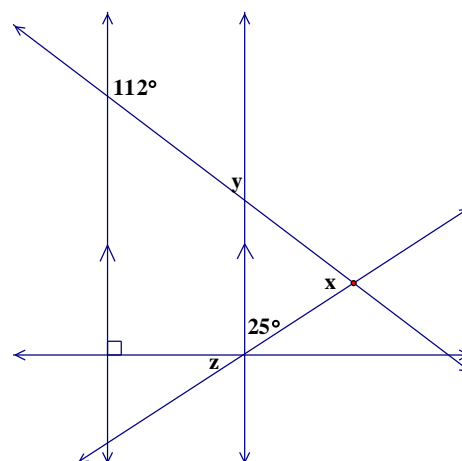
$\angle y = 125 ?$

$\angle x = 55 ?$

Is there sometimes more than one reason?

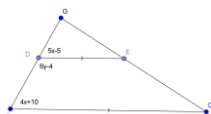
2. Suppose that $ABCD$ is a square and that CDP is an equilateral triangle, with P outside the square. What is the size of angle PAD ?
3. Recall that a quadrilateral that has two pairs of parallel opposite sides is called a *parallelogram*. What relationships exist between the interior angles of a parallelogram?

4. For the diagram at the right, find the measure of the angles indicated.

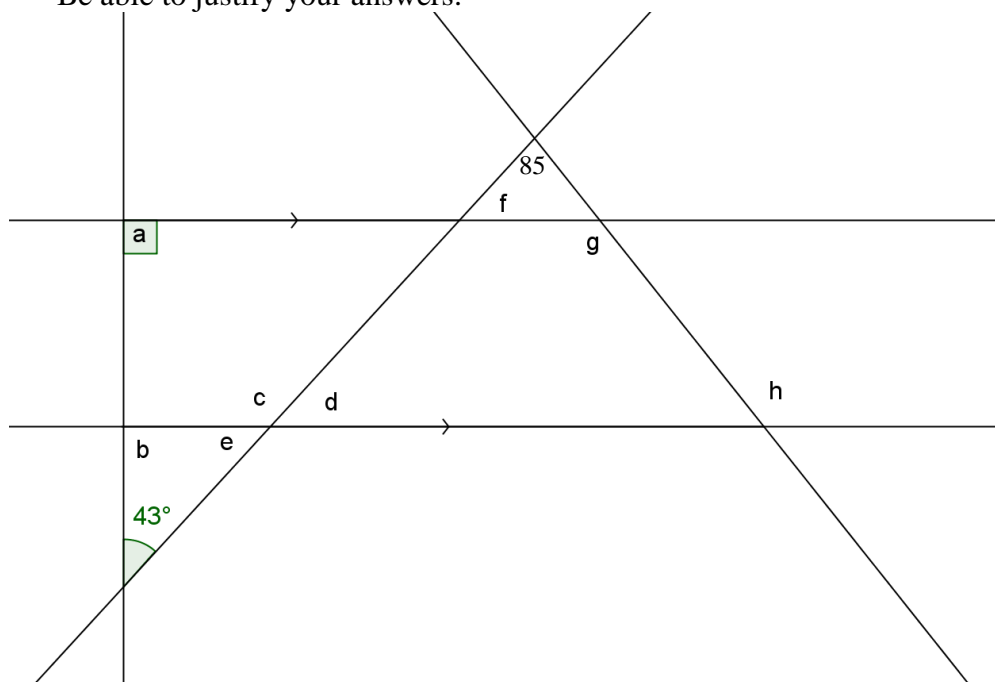


5. What is the sum of the interior angles of any square? What about a rectangle? What about a parallelogram? Rhombus? Arbitrary quadrilateral? Explain your conjectures.
6. Given parallelogram $PQRS$, let T be the intersection of the bisectors of angles P and Q . Without knowing the sizes of the angles of $PQRS$, calculate the size of angle PTQ . Recall that the diagonals of a parallelogram are not necessarily the angle bisectors.

7. Given the diagram below and the segments that are denoted as parallel, solve for the variables and give the reason for the equation(s) that you set up.



1. In the diagram below, find the measurements of all angles labeled with lowercase letters. Be able to justify your answers.

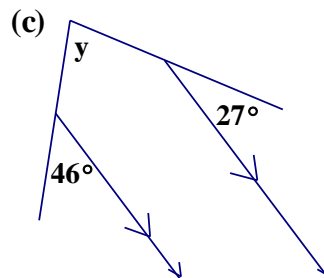
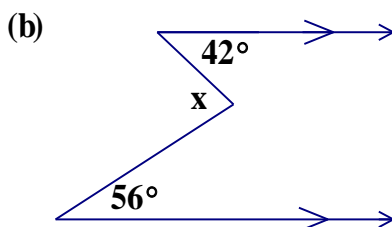
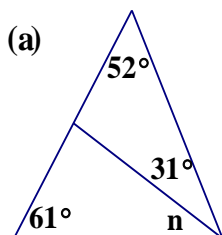
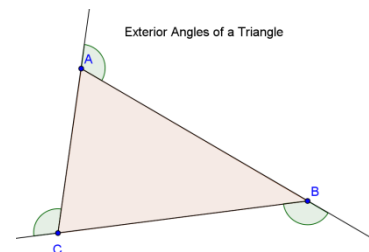


GeoGebra Lab #12

The Exterior Angle Theorem

- Open GeoGebra and draw an arbitrary triangle ABC. It's helpful to turn off the Axes and Grid so that your drawing space is cleaner.
- Using the ray tool in the Segment toolbox, extend side AB past B.
- Place a point, D, on ray AB past B so that B is between A and D.
- Measure angle DBC, this is called an *exterior angle* of this triangle. Also measure angles BAC, BCA which are called the *remote interior angles* to angle DBC. Why do you think these angles are named this way?
- You will use the Input bar create a measurement that is the sum of these two angle measures. First, find the first remote interior angle on the Algebra view. Right click it and rename it p (so that you do not have to deal with the Greek letter assigned it). Rename the other remote interior angle as q and the exterior angle as e. Then, in the input bar, type: $\text{sum} = p + q$.
- Create a text box. In the box, type Exterior Angle = , then notice that under where you are typing are some drop down menus. Select the category Objects, and select "e", the name of your exterior angle. The preview of your text will show up in the bottom of the window. Finally, click OK to close the text box window.
- Create another text box and type Sum of Remote Interior Angles = and then select sum from the drop down list of Objects.
- Drag one of the vertices of the triangle. What do you observe?
- What do you think the relationship between the exterior angle and one of its remote interior angles would be if this was an isosceles triangle? Why?

- Given an arbitrary triangle, what can you say about the *sum* of the three exterior angles, one for each vertex of the triangle?
- In the diagrams below, the goal is to find the sizes of the angles marked with letters, using the given numerical information.

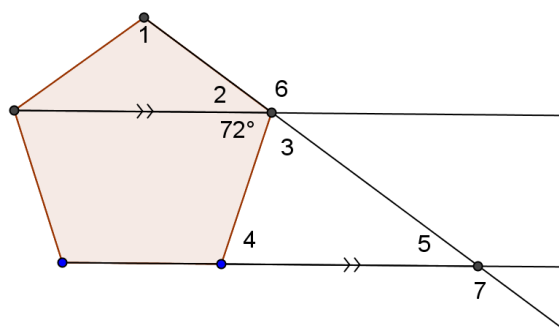


- Write the Pythagorean Theorem in if...then form. State the converse of the Pythagorean Theorem.

4. Fill in the following table

Number of sides of polygon	3	4	5	6	7	8	...	n
Number of non-overlapping triangles	1	2					...	
Total sum of the interior angles	180°	360°					...	
One Angle in a regular n -sided polygon							...	

- In the figure at right, find the sizes of the angles indicated by numbers if the pentagon is regular and the lines indicated are parallel.

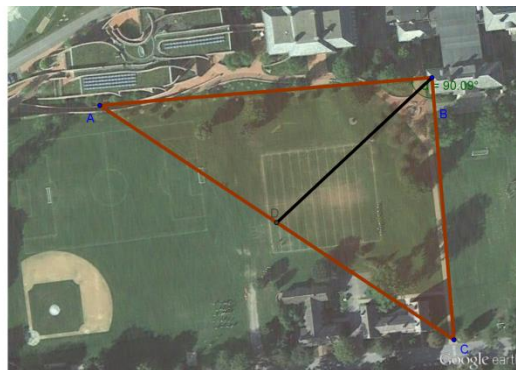


- Mark the point P inside square $ABCD$ that makes triangle CDP equilateral. Calculate the size of angle PAD .
- If a quadrilateral is a parallelogram, then both pairs of opposite angles are congruent. What is the converse of this statement? Is the converse true?
- Consider triangle MAC with vertices $M(7,-1)$, $A(-5,5)$ and $C(5,-5)$.
 - Find the circumcenter of MAC .
 - How far are all the vertices from the circumcenter?
 - Make a conjecture about the midpoint of the hypotenuse of a right triangle. Explain.

1. Find the measure of an interior angle of a regular decagon.
2. If ABC is any triangle, and TAC is one of its exterior angles, then what can be said about the size of angle TAC , in relation to the other angles of the figure? Draw your own triangle and assign reasonable angle measures to the interior angles and confirm that the exterior angle TAC is the sum of the two remote interior angles.
3. In regular pentagon $ABCDE$, draw diagonal AC . What are the sizes of the angles of triangle ABC ? Prove that segments AC and DE are parallel.
4. The sides of an equilateral triangle are 12 cm long. How long is an altitude of this triangle? The altitude divides the triangle into two right triangles. What are the measures of the angles in these right triangles? How does the short side of this right triangle compare with the other two sides? Please leave your lengths in simplest radical form.
5. If a quadrilateral is a parallelogram, then both pairs of opposite sides are congruent. Explain. What is the converse of this statement? Is it true?
6. In triangle ABC , it is given that angle A is 59 degrees and angle B is 53 degrees. Draw the altitude from B to side AC . Draw a line through A that is parallel to side BC . Extend the altitude from B to AC until it intersects that line through A that is parallel to segment BC . Call that intersection point K . Calculate the size of angle AKB .
7. Given square $ABCD$, let P and Q be the points outside the square that make triangles CDP and BCQ equilateral. Segments AQ and BP intersect at T . Find angle ATP .
8. Friday runs along the boundary of a four-sided plot of land, writing down the number of degrees turned at each corner. (Picture yourself doing this and the angle you would turn through.) What is the sum of these four numbers?
9. If the diagonals of a quadrilateral bisect each other, then the figure is a parallelogram. What about the converse statement? Do you think the converse is true? Why or why not?
10. Jackie walks along the boundary of a five-sided plot of land, writing down the number of degrees turned at each corner. What is the sum of these five numbers?
11. Marty walks along the boundary of a seventy-sided plot of land, writing down the number of degrees turned at each corner. What is the sum of these seventy numbers?
12. The preceding two questions illustrate the *Sentry Theorem*. What does this theorem say, and why has it been given this name?
13. A rectangle with area 540 has one side of length 15. Find the length of the other side and the diagonals.

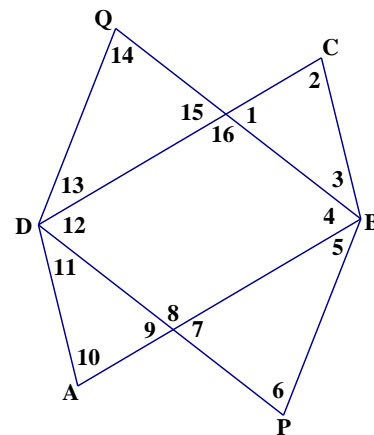
- The *midsegment* of a triangle is a segment that connects the midpoints of two sides of the triangle. Given a triangle with coordinates $A(1, 7)$, $B(5, 3)$ and $C(-1, 1)$ find the coordinates of the midpoints of sides AB and AC , label the midpoints M and N , respectively. Draw the midsegment MN .
 - Find the length of the midsegment MN and compare it to the length of BC .
 - What can be said about the lines containing segments BC and MN ?
- Given rectangle $ABCD$, let P be the point outside $ABCD$ that makes triangle CDP equilateral, and let Q be the point outside $ABCD$ that makes triangle BCQ equilateral. What do you think can be said about triangle APQ ? Why?

- Ber is walking directly from the Koch Center to the crosswalk across Albany Rd. Lee plans to leave the Hess and intercept Ber exactly halfway along the straight path which happens to be the hypotenuse of a right triangle. They continue walking together to the crosswalk by Hitchcock to go on to lunch. If the Koch is 160 m away from the Hess and the Hess is 120 m away from the crosswalk, how far does each person walk in total?



- A regular, n -sided polygon has 18-degree exterior angles. Find the integer n .
- Triangle FLB has a perimeter of 23 and $BF = \frac{1}{2} LB$. The midsegment parallel to $LB = 4$. Find the lengths of the three sides of this triangle.

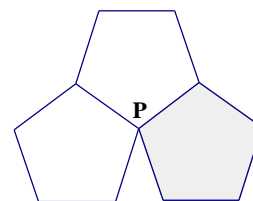
- In the figure at right, it is given that $ABCD$ and $PBQD$ are parallelograms. Which of the numbered angles must be the same size as the angle numbered 1? Give a reason for each angle.
- Triangle PQR has a right angle at P . Let M be the midpoint of QR . Draw the altitude from P to QR and let F be the point where that altitude meets QR . Given that angle FPM is 18 degrees, find the sizes of angles Q and R .



- Given that $ABCDEFGH \dots$ is a regular n -sided polygon, with angle $CAB = 12$ degrees, find n .
- Midsegment (Midline) Theorem*: State the properties of the segment that connects the midpoints of two sides of a triangle.
- Draw triangle ABC so that angles A and B are both 42 degrees. Why should AB be longer than BC ? Why do you think so?

- (Continuation) Extend CB past B to E , so that $CB = BE$. Mark D between A and B so that $DB = BC$, then draw the line ED , which intersects AC at F . Find the size of angle CFD .

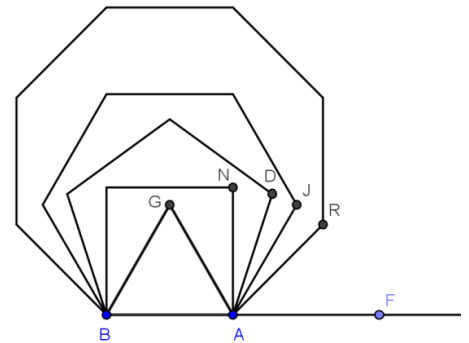
- The diagram at right shows three congruent regular pentagons that share a common vertex P . The three polygons do not quite surround P . Find the size of the uncovered acute angle at P .



- (Continuation) If the shaded pentagon were removed, it could be replaced by a regular n -sided polygon that would exactly fill the remaining space. Find the value of n that makes the three polygons fit perfectly.
- How can one tell whether a given quadrilateral is a parallelogram? In other words, how much evidence is needed to be sure of such a conclusion? Hint: There are six ways to definitively show that a quadrilateral is a parallelogram.
- We have seen that pentagons cannot *tessellate* (tile without space between the same polygons). Why is it that pentagons cannot fit evenly flat in the plane? Give a mathematical reason.
- In triangle ABC , $\angle A = 100^\circ$ and $\angle B = 57^\circ$. List the sides of the triangle in order of increasing length. Justify your answer.
- In mathematics, a *counterexample* is used to show that a statement is false. Can you find a counterexample to show that the following statement is false? If $ab = 5$ then either $a = 1$ and $b = 5$ OR $b = 1$ and $a = 5$.
- Mark Y inside regular pentagon $PQRST$, so that PQY is equilateral. Is RYT straight? Explain.
- We have discussed medians, perpendicular bisectors, altitudes, midsegments and angle bisectors of triangles.
 - Which of these *must* go through the vertices of the triangle?
 - Is it possible for a median to also be an altitude? Explain.
 - Is it possible for an altitude to also be an angle bisector? Explain.
 - Is it possible for a midsegment to be a median? Explain.
 - Is it possible for a perpendicular bisector to be an altitude?
- The diagonals of a rhombus have lengths 18 and 24. How long are the sides of the rhombus?
- A *trapezoid* is a quadrilateral with exactly one pair of parallel sides. If the non-parallel sides have the same length, the trapezoid is *isosceles*. Make a diagram of an isosceles trapezoid whose sides have lengths 7 in, 10 in, 19 in, and 10 in. Find the *altitude* of this trapezoid (the distance that separates the parallel sides), then find the enclosed area.

- Which regular polygons can tessellate? Be sure to use mathematical evidence in your answer.
- A trapezoid has a 60-degree angle and a 45-degree angle. What are the other angles?
- An n -sided polygon has the property that the sum of the measures of its exterior angles is equal to the sum of the measures of its interior angles. Find n .
- Trapezoid $ABCD$ has parallel sides AB and CD , a right angle at D , and the lengths $AB = 15$, $BC = 10$, and $CD = 7$. Find the length DA .
- A trapezoid has a 60-degree angle and a 120-degree angle. What are the other angles?
- An equilateral triangle has side lengths of 12. Find the length of its median.

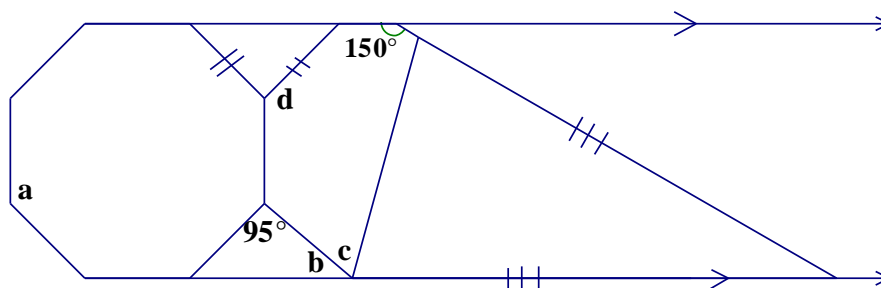
- In the diagram at right, \overline{AGB} is an equilateral triangle, \overline{AN} is the side of a square, \overline{AD} is the side of a regular pentagon, \overline{AJ} is the side of a regular hexagon, and \overline{AR} is the side of a regular octagon. \overline{AB} is a side shared by all of the regular polygons. Find
 (a) $\angle GAF$ (b) $\angle NAR$ (c) $\angle JAF$ (d) $\angle GAJ$



- A line of positive slope is drawn so that it makes a 60-degree angle where it intersects the x -axis. What is the slope of this line?
- What can be said about quadrilateral $ABCD$ if it has supplementary consecutive angles?
- If $MNPQRSTU$ is a regular polygon, then how large is each of its interior angles? If lines through the sides MN and QP are extended to meet at A then how large is angle PAN ?
- Is it possible for the sides of a triangle to be 23, 19, and 44? Explain.
- Consider the following “trapezoids” and midlines (keeping in mind the definition of a trapezoid):
 - A “trapezoid” with top base of length 0 and bottom base of length 10. What is the length of its midline? (In actually what is this “trapezoid” and how would find the length of its “midline”?)
 - A “trapezoid” with top base of length 10 and bottom base of length 10. What is the length of its “midline”?
 - A trapezoid with top base of length 6 and bottom base of length 10. From the following two examples, how might you conjecture to find the length of the midline? Try to justify your answer.

- Let $ABCD$ be a parallelogram, with M the midpoint of DA , and diagonal AC of length 36. Let G be the intersection of MB and AC and draw in diagonal DB . What is the length of AG ?
- Draw the lines $y = 0$, $y = \frac{1}{2}x$, $y = x$, $y = 2x$ and $y = 3x$. Use GeoGebra to measure the angle that each line makes with the x -axis. Using your intuition, make a guess what the angle is that the line $y = 4x$ makes with the x -axis. Now measure it. Try to predict any pattern that you think exists.
- The parallel sides of trapezoid $ABCD$ are AD and BC . Given that sides AB , BC , and CD are each half as long as side AD , find the size of angle D .
- Dana buys a piece of carpet that measures 20 square yards. Will Dana be able to completely cover a rectangular floor that measures 12 ft. 4 in. by 16 ft. 8 in.?
- The altitudes of an equilateral triangle all have length 12 cm. How long are its sides?
- The sides of a square have length 10. How long are the diagonal of the square? Keep your answer in simplest radical form. What would your answer be if the side had been 6?
- In triangle ABC , let M be the midpoint of AB and N be the midpoint of AC . Suppose that you measure MN and find it to be 7.3 cm long. How long would BC be, if you measured it?
- In Geogebra, use the “Segment of given length” tool to create a triangle with sides of 5, 12, and 13. What type of triangle must it be? Keep the lengths of the sides that are 5 and 12 constant but delete the one that is 13. Connect the ends of these two with a segment of variable length by just drawing in a segment. How does the triangle change if the hypotenuse is lengthened to 15 from 13? 17 from 13? 19 from 13? What types of triangles do you get in each case?

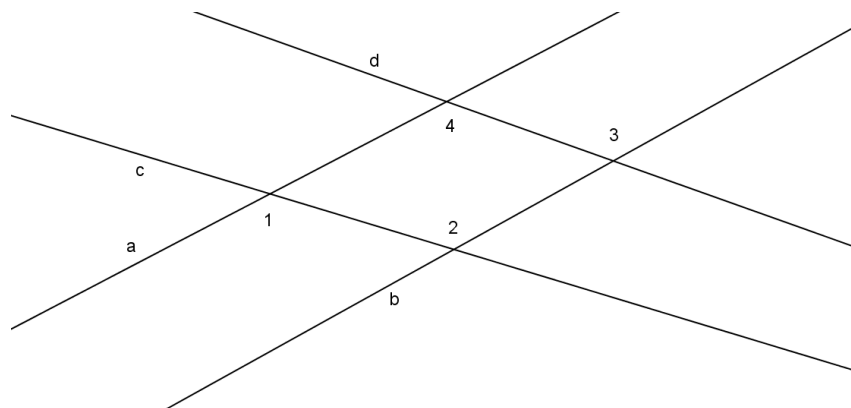
- In the diagram at the right, the octagon is regular. Find the measures of the angles labeled a , b , c , and d .



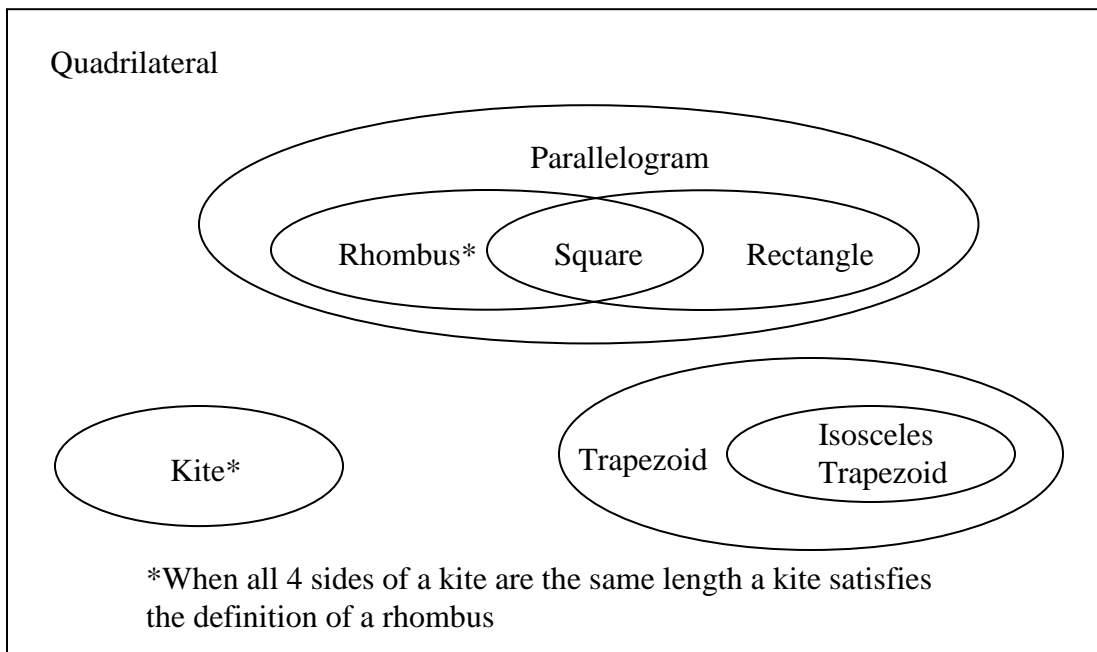
- Given regular hexagon $BAGELS$, show that SEA is an equilateral triangle.

1. Mark $A = (0, 0)$ and $B = (10, 0)$ in GeoGebra and use the “Angle with a given size” tool to draw the line of positive slope through A that makes a 25-degree angle with AB . Approximate the slope of this line by looking at some coordinates on the line.
2. (Continuation) Turn on your calculator, press the MODE button, and select the *Degree* option for angles. Return to the home screen, and press the TAN button to enter the expression $\text{TAN}(25)$, then press ENTER. You should see that the display agrees with your answer to the preceding item.
3. What would happen to a 5-12-13 triangle if the hypotenuse was shortened to 12 while the sides of 5 and 12 stayed constant? What if the hypotenuse were shortened to 7? What about 5?
4. (Continuation) Under what conditions would a triangle with two sides of 5 and 12 be acute?
5. Given $A = (0, 6)$, $B = (-8, 0)$, and $C = (8, 0)$, find coordinates for the circumcenter of triangle ABC .
6. Rearrange the letters of *doctrine* to spell a familiar mathematical word.
7. In the following diagram, if you know the given angles are congruent, which lines can you say are parallel?
 - i. If $\angle 1 \cong \angle 2$?
 - ii. If $\angle 2 \cong \angle 3$?
 - iii. If $\angle 4 \cong \angle 2$?

Be sure to justify your conjectures.



Justify the following Venn diagram and check the properties that each type of quadrilateral holds.



Property	Parallelogram	Rectangle	Rhombus	Square	Kite	Trapezoid	Isosceles Trapezoid
Opposite sides are parallel							
Opposite sides are congruent							
Exactly one pair of opposite sides is parallel							
Opposite angles are congruent							
Exactly one pair of angles is congruent							
Consecutive angles are supplementary							
Base angles are congruent							
Diagonals bisect each other							
Diagonals are congruent							
Diagonals are perpendicular							
Diagonals bisect opposite angles							
Exactly one diagonal is the perpendicular bisector of the other							

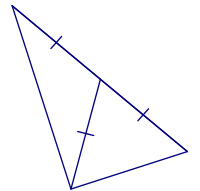
- The parallel bases of a trapezoid have lengths 12 and 18 cm. Find the lengths of the two segments into which the *midline* of the trapezoid is divided by one diagonal. (Hint: look for some triangles!)
- How does the value of the tangent of an angle change as an angle increases from 0 to 90 degrees? Is there a direct relationship between the slope and the angle measure?
- Standing 50 meters from the base of a fir tree, Rory measured an *angle of elevation* of 33° to the top of the tree with a protractor. The angle of elevation is the angle formed by the horizontal ground and an ant's line-of-sight ray to the top of the tree. How tall was the tree?
- You are building a tent for a sleepover. You have a 36 ft tarp that you are going to use to hang it over a clothesline symmetrically. Looking at it from the side, what are the possible base lengths of the cross-section of your tent? What realistic assumptions are you making?
- Standing on a cliff 380 meters above the sea, Pocahontas sees an approaching ship and measures its *angle of depression*, obtaining 9 degrees. How far from shore is the ship?
- (Continuation) Now Pocahontas sights a second ship beyond the first. The angle of depression of the second ship is 5 degrees. How far apart are the ships?
- Let $A = (0, 0)$, $B = (4, 0)$, and $C = (4, 3)$. Measure angle CAB with your protractor (you must use a protractor for this). What is the slope of AC ? Use your calculator to compare the tangent of the angle you measured with the slope. By trial-and-error, find an angle that is a better approximation of the measure of angle CAB .
- (Continuation) On your calculator, ENTER the expression $\text{TAN}^{-1}(0.75)$. Compare this answer with the approximation you obtained for the measure of angle CAB . What does the TAN^{-1} button do? (TAN^{-1} is said as "inverse tangent.")
- When the Sun has risen 32 degrees above the horizon, Sandeep casts a shadow that is 9 feet 2 inches long. How tall is Sandeep, to the nearest inch?
- A five-foot Deerfield student casts an eight-foot shadow. How high is the Sun in the sky? This is another way of asking for the angle of elevation of the Sun.
- An isosceles trapezoid has sides of lengths 9, 10, 21, and 10. Find the distance that separates the parallel sides then find the length of the diagonals. Finally, find the angles of the trapezoid, to the nearest tenth of a degree.



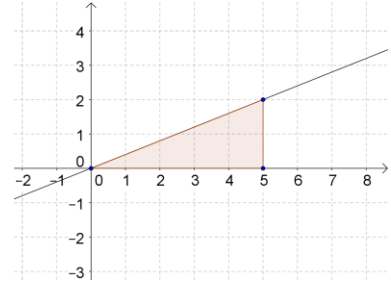
<http://www.rockabyebabymusic.com/blog/tag/tent/>

In the following list of true statements, find **(a)** the four pairs of statements whose converses are also in the list; **(b)** the statement that is a definition; **(c)** the statement whose converse is false; **(d)** the Sentry Theorem; **(e)** the Midsegment Theorem; Note: Not all statements are used.

- A. If a quadrilateral has two pairs of parallel sides, then its diagonals bisect each other.
- B. If both pairs of opposite angles of a quadrilateral are congruent, then the quadrilateral must be a parallelogram.
- C. If a quadrilateral is equilateral, then it is a rhombus.
- D. If both pairs of opposite sides of a quadrilateral are congruent, then the quadrilateral is a parallelogram.
- E. If a quadrilateral has two pairs of equal adjacent sides, then its diagonals are perpendicular.
- F. If one of the medians of a triangle is half the length of the side to which it is drawn, then the triangle is a right triangle.
- G. If a segment joins two of the midpoints of the sides of a triangle, then it is parallel to the third side, and is half the length of the third side.
- H. Both pairs of opposite sides of a parallelogram are congruent.
- I. The sum of the exterior angles of any polygon – one at each vertex – is 360 degrees.
- J. The median drawn to the hypotenuse of a right triangle is half the length of the hypotenuse.
- K. If two lines are intersected by a transversal so that alternate interior angles are equal, then the lines must be parallel.
- L. If the diagonals of a quadrilateral bisect each other, then the quadrilateral is in fact a parallelogram.
- M. If two opposite sides of a quadrilateral are both parallel and equal in length, then the quadrilateral is a parallelogram.
- N. Both pairs of opposite angles of a parallelogram are congruent.
- O. An exterior angle of a triangle is the sum of the two nonadjacent interior angles.



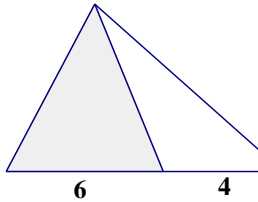
1. If a right triangle were placed on the x -axis, how could the sides of the triangle represent the slope of a line?
2. One day at the beach, Kelly flies a kite, whose string makes a 37-degree elevation angle with the ground. Kelly is 130 feet from the point directly below the kite. How high above the ground is the kite, to the nearest foot?



3. Hexagon $ABCDEF$ is regular. Show that segments AE and ED are perpendicular.
4. What angle does the line $y = \frac{2}{5}x$ make with the x -axis?
5. Suppose that $PQRS$ is a rhombus, with $PQ = 12$ and a 60-degree angle at Q . How long are the diagonals PR and QS ?
6. Given a rectangular card that is 5 inches long and 3 inches wide, what does it mean for another rectangular card to have the *same shape*? Describe a couple of examples.
7. *The Varignon quadrilateral.* A quadrilateral has diagonals of lengths 8 and 10. The midpoints of the sides of this figure are joined to form a new quadrilateral. What is the perimeter of the new quadrilateral? What is special about it?
8. The hypotenuse of a right triangle is twice as long as one of the legs. How long is the other leg? What is the size of the smallest angle?
8. Alex wants to measure the width of the Deerfield River. Standing under a tree T on the river bank, Alex sights a rock at the nearest point R on the opposite bank. Then Alex walks to a point P on the river bank that is 50.0 meters from T , and makes RTP a right angle. Alex then measures RPT and obtains 76.8 degrees. How wide is the river?
9. The legs of an isosceles right triangle have a length of s . What is the length of the hypotenuse with respect to s ?
10. How tall is an isosceles triangle, given that its base is 30 cm long and that both of its base angles are 72 degrees?

11. A triangle has sides in the ratio $1:2:\sqrt{3}$. Draw a triangle with this scale. What can you say about this triangle?
12. In Hawley State Forest near Buckland, MA there is a very old structure that was once used as a kiln for heating wood into coal. Here is a picture of the triangular structure (with Mr. Day, Mr. Thiel, Dr. Hagamen and Mr. Friends in front with their mountain bikes). If the outline of this structure is approximately an equilateral triangle with base of 18 feet across, in simplest radical form, how tall is the structure?



1. What are the angle sizes in a trapezoid whose sides have lengths 6, 20, 6, and 26?
2. In a Deerfield Freshman class there are 105 students, and the day: boarder ratio is approximately 1:5.
 - a. How many students in that class are boarders?
 - b. How many day students would you expect to find in a freshman English class of fifteen students? Explain. What realistic assumptions are you making?
3. Find the equation of a line passing through the origin that makes an angle of 52 degrees with the x -axis.
4. *What are all of the special right triangles?* In geometry it is very useful to know many right triangles that have special properties. Which right triangles so far this year have been helpful in our work? Explain as many as you can think of and why they have been “special” in their own way. Be as specific as possible.
5. In the figure at right, the shaded triangle has area 15. Find the area of the unshaded triangle.
 
6. To the nearest tenth of a degree, how large are the congruent angles of an isosceles triangle that is exactly as tall as it is wide? (There is more than one interpretation).
7. An estate of \$362880 is to be divided among three heirs, Alden, Blair, and Cary. According to the will, Alden is to get two parts, Blair three parts, and Cary four parts. How much money in dollars and cents does each heir receive?
8. What is the relationship between the length of the hypotenuse and the length of the legs in a 45-45-90 triangle?
9. The area of a parallelogram can be found by multiplying the distance between two parallel sides (the height, or altitude) by the length of either of those sides. Explain why this formula works. Draw a picture and explain why the phrase “two parallel sides” was used in this problem instead of “base.”
10. Using GeoGebra, plot the points $A = (0, 0)$, $B = (4, -3)$, $C = (6, 3)$, $P = (-2, 7)$, $Q = (9, 5)$, and $R = (7, 19)$. Measure the angles of triangles ABC and PQR . Create ratios of the lengths of the corresponding sides. Find justification for any conclusions you make. (If you choose not to use technology, leave all answers in simplest radical form.)
11. The perimeter of a square is 36, what is the length of a diagonal of the square? How many squares can you come up with that have a perimeter of 36?
12. Draw a diagram of a right triangle ABC , with B the right angle and BK the altitude drawn to the hypotenuse. Give an argument as to why all three triangles, AKB , ABC and BKC would have the same angle measurements. Try to be as precise as possible.

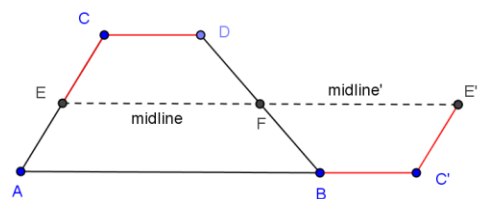


1. A drawbridge has the shape of an isosceles trapezoid. The entire length of the bridge is 100 feet while the height is 25 feet. If the angle at which the bridge meets the land is approximately 60 degrees, how long is the part of the bridge that opens?
2. One figure is *similar* to another figure if the points of the first figure can be matched with the points of the second figure in such a way that corresponding distances are proportional. In other words, there is a *ratio of similarity*, k , such that every distance on the second figure is k times the corresponding distances on the first figure.
 - a. Open GeoGebra and plot the points $K = (1, -3)$, $L = (4, 1)$, $M = (2, 3)$, $P = (6, 5)$, $Q = (2, 5)$ and $R = (7, -2)$.
 - b. Is triangle KLM similar to triangle RPQ ? Justify with measurements from GeoGebra.
 - c. Would it be correct to say that triangle MKL is similar to triangle RQP ?
3. Draw a right triangle that has a 15-cm hypotenuse and a 27-degree angle. To the nearest tenth of a cm, measure the side opposite the 27-degree angle, and then express your answer as a percentage of the length of the hypotenuse. Compare your answer with the value obtained from your calculator when you enter $\text{SIN } 27$ in degree mode.
4. (Continuation) Repeat the process on a right triangle that has a 10-cm hypotenuse and a 65-degree angle. Try an example of your choosing. Write a summary of your findings.
5. In triangle ABC , points M and N are marked on sides AB and AC , respectively, so that $AM : AB = 1 : 3 = AN : AC$. Why are segments MN and BC parallel?
6. One way to find the area of a trapezoid is by multiplying its altitude (the distance between the parallel sides) by the average of the bases ($A = h \times \frac{1}{2}(b_1 + b_2)$). What is a geometric way to justify this formula? In other words, how could you redraw the trapezoid so that the $\frac{1}{2}(b_1 + b_2)$ represents something with respect to the trapezoid?
7. What is the length of an altitude of an equilateral triangle with perimeter 36?
8. *The Right Triangle Similarity Theorem.* Draw an arbitrary right triangle. Why does the altitude drawn from the right angle vertex to the hypotenuse create three right triangles? Try to justify your answer in a few sentences and a diagram.
9. To actually draw a right triangle that has a 1-degree angle and measure its sides accurately is difficult. To get the sine ratio for a 1-degree angle, however, there is an easy way – just use your calculator. Is the ratio a small or large number? How large can a sine ratio be?
10. How long is the altitude drawn to the hypotenuse in a right triangle with two legs that are 5 and 12?

1. If two sides of a triangle are 5 and 10, what is the range of values for the third side?
2. We have discussed the formula for the area of a trapezoid

as $A = h \times \frac{1}{2}(b_1 + b_2)$ where you can multiply the height

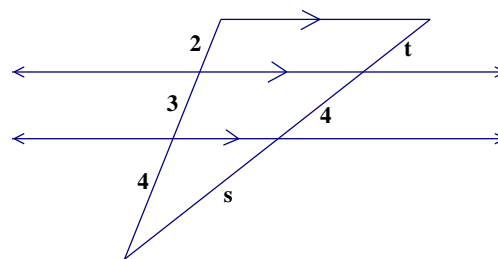
by the average of the bases. Find another way to represent the area of a trapezoid by looking at this diagram:



3. What is the size of the acute angle formed by the x -axis and the line $3x + 2y = 12$?
4. If triangle ABC has a right angle at C , the ratio $AC : AB$ is called the *sine ratio of angle B*, or simply the *sine of B*, and is usually written $\sin B$. What should the ratio $BC : AB$ be called? Without using your calculator, can you predict what the value of the sine ratio for a 30-degree angle is? How about the sine ratio for a 60-degree angle?
5. Write an equation using the distance formula that says that an arbitrary point $P = (x, y)$ is 5 units from $(0, 0)$. Plot several such points. What is the configuration of all such points called? How many are lattice points?
6. (Continuation) Explain how you could use the Pythagorean Theorem to obtain the same result. How are right triangles related to circles?
7. What is the length of a side of an equilateral triangle whose altitude is 16? How do you describe the length of the side in terms of the altitude?
8. When you take the sine of 30 degrees using your calculator you get 0.5. What do you think $\text{SIN}^{-1}(0.5)$ is? Use your calculator to test your conjecture. Find $\text{SIN}^{-1}(0.3)$ and $\text{SIN}^{-1}\left(\frac{3}{5}\right)$.
What do these values represent?
9. When triangle ABC is similar to triangle PQR , with $A, B,$ and C corresponding to $P, Q,$ and R , respectively, it is customary to write $ABC \sim PQR$. Suppose that $AB = 4, BC = 5, CA = 6,$ and $RP = 9$. Find PQ and QR .
10. One triangle has sides that are 5 cm, 7 cm, and 8 cm long; the longest side of a similar triangle is 6 cm long. How long are the other two sides?
11. According to Skiing Magazine's website (<http://www.skinet.com/skiing/2001/12/how-steep-is-steep>)
"A 45-degree pitch is equivalent to a 100-percent grade, and both mean that a run descends one vertical foot for each horizontal foot. (Steepness can be presented in percent or degrees, with ski professionals using degrees.) In perspective, a very steep highway-pass road is approximately 7 percent or about 4 degrees."
Explain what this means in terms of tangent.

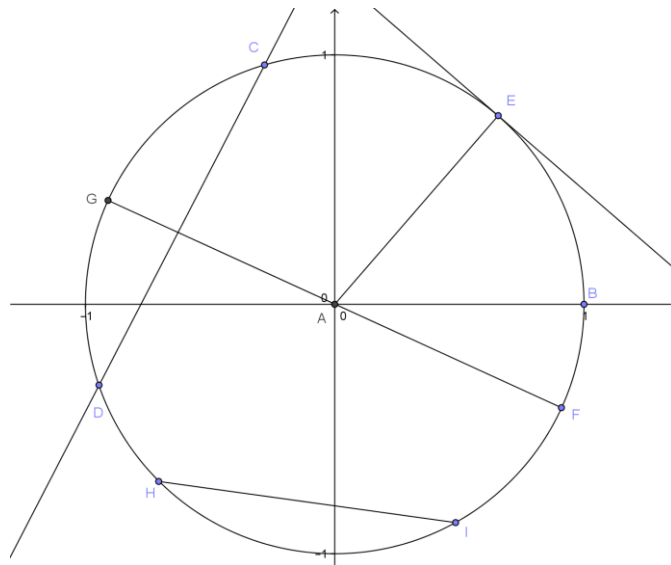
1. The floor plan of a house is drawn with a ratio of $1/8$ inch = 1 foot. On the plan, the kitchen measures 2 in. by $2\frac{1}{4}$ in. What are the dimensions of the kitchen?
2. If an altitude is also the side of a triangle, what do you know about the triangle?
3. If two polygons are similar, explain why the corresponding angles are the same size. What is the converse of this statement? Is it true?
4. To the nearest tenth of a degree, find the sizes of the acute angles in a 5-12-13 triangle and in a 9-12-15 triangle. Put these two triangles together (side-by-side) by matching up the sides that are 12 long. By doing this, answer the question: what are the angles in a 13-14-15 triangle?
5. *AA Similarity Postulate*: If two corresponding angles of a triangle are equal in size to the angles of another triangle, then the triangles are similar. Justify this statement. State the converse of this statement. Is it true?

6. In the diagram at the right, find t and s . In what way are the parallel lines helpful?



7. Is it possible to draw a triangle with the given sides? If it is possible, state whether it is acute, right, or obtuse. If it is not possible, say no and sketch why.
 (a) 9, 6, 5 (b) $3\sqrt{3}$, 9, $6\sqrt{3}$ (c) 8.6, 2.4, 6.2
8. The area of an equilateral triangle with m -inch sides is 8 square inches. What is the area of a regular hexagon that has m -inch sides?
9. A parallelogram has 10-inch and 18-inch sides and an area of 144 square inches.
 (a) Find the altitude between the 18-inch sides?
 (b) Find the altitude between the 10-inch sides? (notice that it is not necessarily the same)
 (c) Find the angles of the parallelogram?

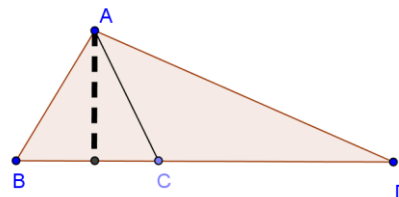
1. In the following diagram choose which objects you think fulfill the definitions of the terms that relate to a circle from your previous experience with circles, common sense or resources that you have - *radius*, *diameter*, *secant line*, *chord*, *tangent line*, *point of tangency*, *minor arc*, *major arc*, *central angle*



2. Write an equation that describes all the points on the circle whose *center* is at the origin and whose *radius* is (a) 13; (b) 6; (c) r .
3. If the lengths of the midsegments of a triangle are 3, 4, and 5, what is the perimeter of the triangle?
4. When moving a lot of plates, the dining hall packs our round plates in square boxes with a perimeter of 36 inches. If the plates fit snugly in one stack in the box, one plate per layer, what is the circumference of each plate?
5. (Continuation) Each dining hall saucer has a circumference of 12.57 in. Can four saucers fit on a single layer in the same square box? Justify your answer.
6. Graph the circle whose equation is $x^2 + y^2 = 64$. What is its radius? What do the equations $x^2 + y^2 = 1$, $x^2 + y^2 = 40$, and $x^2 + y^2 = k$ all have in common? How do they differ?
7. Taylor lets out 120 meters of kite string then wonders how high the kite has risen. Taylor is able to calculate the answer after using a protractor to measure the 63-degree angle of elevation that the string makes with the ground. How high is the kite, to the nearest meter? What (unrealistic) assumptions did you make in answering this question?
8. Find the sine of a 45-degree angle. Use your calculator *only to check your answer*.
9. You are making lemonade and the recipe calls for a ratio of lemon juice to water of 1:4. You want to make 2 gallons of lemonade. How much of each ingredient do you need?
10. If the central angle of a slice of pizza is 36 degrees, how many pieces are in the pizza?
11. (Continuation) A 12 inch pizza is evenly divided into 8 pieces. What is the length of the crust of one piece?
12. The vertices of triangle ABC are $A = (-5, -12)$, $B = (5, -12)$, and $C = (5, 12)$. Confirm that the circumcenter of ABC lies at the origin. What is the equation for the *circumscribed circle*?

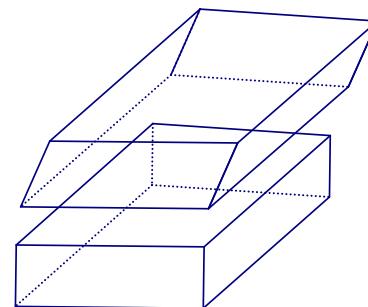
1. If the sides of a triangle are 13, 14, and 15 cm long, then the altitude drawn to the 14-cm side is 12 cm long. How long are the other two altitudes? Which side has the longest altitude?
2. (Continuation) How long are the altitudes of the triangle if you double the lengths of its sides?
3. Let $A = (6, 0)$, $B = (0, 8)$, $C = (0, 0)$. In triangle ABC , let F be the point of intersection of the altitude drawn from C to side AB .
 - a. Explain why the angles of triangles ABC , CBF , and ACF are the same.
 - b. Find coordinates for F and use them to calculate the exact lengths FA , FB , and FC .
 - c. Compare the sides of triangle ABC with the sides of triangle ACF . What do you notice?
4. What happens to the area of a triangle if its dimensions are doubled?
5. A rectangular sheet of paper is 20.5 cm wide. When it is folded in half, with the crease running parallel to the 20.5-cm sides, the resulting rectangle is the same shape as the unfolded sheet. Find the length of the sheet, to the nearest tenth of a cm. (In Europe, the shape of notebook paper is determined by this similarity property).
6. Write an equation that describes all the points $P(x,y)$ that are 5 units away from the point $C(1,-4)$. What set of points does this describe?

7. What is the ratio of the areas of $\triangle ABC$ and $\triangle ADC$ in the following diagram if $BC=5$ and $CD=8$?



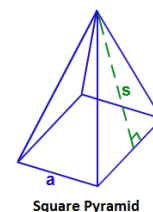
8. A regular polygon is *inscribed* in a circle – all vertices of the polygon lie on the circle. (We can also say that the circle is *circumscribed* around the polygon). Go to the website <http://www.mathopenref.com/polygoncircumcircle.html> and increase the number of sides of the regular polygon. What happens to the polygon as the number of sides increases?
9. Sketch the circle whose equation is $x^2 + y^2 = 100$. Using the same system of coordinate axes, graph the line $x + 3y = 10$, which should intersect the circle twice – at $A = (10, 0)$ and at another point B in the second quadrant. Estimate the coordinates of B . Now use technology to find them exactly. Segment AB is called a *chord* of the circle.
10. (Continuation) Find coordinates for a point C on the circle that makes chords AB and AC have equal length.
11. A 25 foot ladder is leaning against a wall and makes a 57.32° angle with the floor. How far from the wall is the base of the ladder? Without using trigonometry try to predict how far from the floor a step on the ladder would be that is half way up the ladder? 8 feet up the ladder? Now use trigonometry to confirm your answers.
12. What is the radius of the smallest circle that surrounds a 5-by-12 rectangle?

1. Baking Powder is made up of Baking Soda, Cream of Tartar and sometimes Corn Starch in a ratio of 1:2:1. If you need 2 Tablespoons of Baking Powder, how much of each ingredient do you need?
2. Without doing any calculation, what can you say about the tangent of a k -degree angle, when k is a number between 90 and 180? Explain your response, then check with your calculator.
3. Ask your calculator for the sine of a 56-degree angle, then for the cosine of a 34-degree angle. Ask your calculator for the sine of a 23-degree angle, then for the cosine of a 67-degree angle. The word *cosine* is an abbreviation of *sine of the complement*. Explain the terminology.
4. (Continuation) How can you represent the cosine of an angle in terms of a ratio?
5. A right triangle has a 123-foot hypotenuse and a 38-foot leg. To the nearest tenth of a degree, what are the sizes of its acute angles?
6. The line $y = x + 2$ intersects the circle $x^2 + y^2 = 10$ in two points. Call the third quadrant point R and the first-quadrant point E , and find their coordinates on GeoGebra. Let D be the point where the line through R and the center of the circle intersects the circle again. The chord DR is an example of a *diameter*. Show that triangle RED is a right triangle.
7. To the nearest tenth of a degree, find the angles of the triangle with vertices $(0, 0)$, $(6, 3)$, and $(1, 8)$. Use your protractor to *check* your calculations, and explain your method.
8. Playing cards measure 2.25 inches by 3.5 inches. A full deck of fifty-two cards is 0.75 inches high. What is the volume of a deck of cards? If the cards were uniformly shifted (turning the bottom illustration into the top illustration), would this volume be affected?
9. In a right triangle, the 58-cm hypotenuse makes a 51-degree angle with one of the legs. To the nearest tenth of a cm, how long is that leg? Once you have the answer, find some other ways to calculate the length of the other leg. They should all give the same answer, of course.
10. An equilateral triangle ABC is inscribed in a circle centered at O . The portion of the circle that lies above chord AB is called an *arc*. In geometry, arcs have two types of measurement, arclength (which is length measurement) and arc angle which is an angular size in degrees. If $AB = BC = AC$, what is the angular size of AB ? AB is called a *minor arc* and ACB is called a *major arc*. Why do you think they are called this? How are AB and ACB related?



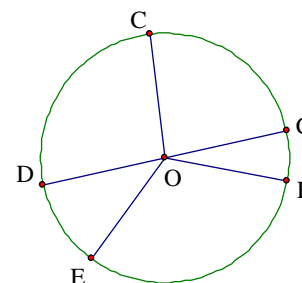
- (Continuation) *Some Terminology:* A *central angle* is an angle whose vertex is at the center of a circle and whose sides are radii. What is the measure of angle AOB ? What is the relationship between a central angle and the arc it intercepts?
- What is the angular size of an arc that a diameter intercepts? This arc is called a *semicircle*.
- If the ratio of the areas of two triangles is 18: 8, what is the ratio of similarity?
- Draw a circle and label one of its diameters AB . Choose any other point on the circle and call it C . What can you say about the size of angle ACB ? Does it depend on which C you chose? Justify your response.

- A square *pyramid* is a pyramid with a square base and four triangular lateral faces. The slant height, s , is the distance from the vertex of the pyramid along a *lateral face* to the midpoint of a base edge. If the slant height is 10 and an edge of the square is 12, what is the altitude of this pyramid?



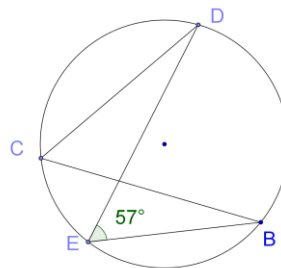
- A regular pentagon can be dissected into 5 isosceles triangles whose vertex angle is at the center of the pentagon. The height of the triangles is 10 cm. Find the area of this pentagon.

- Circle O has diameter DG and central angles $COG = 86^\circ$, $DOE = 25^\circ$, and $FOG = 15^\circ$. Find the angular size of minor arcs CG, CF, EF and major arc DGF .

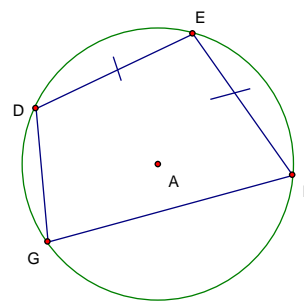


- If two chords in the same circle have the same length, then the minor arcs formed by those chords have the same length, too. True or false? Explain. What about the converse statement? Is it true? Why or why not?
- The sides of a triangle are found to be 10 cm, 14 cm, and 16 cm long, while the sides of another triangle are found to be 15 in, 21 in, and 24 in long. On the basis of this information, what can you say about the angles of these triangles?
- Many people think that pyramids only exist in Egypt, but there are pyramids in China as well. The Great White Pyramid is standing in Shaanxi, China and has an approximate square base with edges of 357 meters. Its height was 76 meters but has fallen since it was built. (For our purposes we will assume this is a pyramid with a vertex, currently this pyramid has a flat top!) Calculate the slant height of The Great White Pyramid.
- In mathematical discussion, a *right prism* is defined to be a solid figure that has two parallel, congruent polygonal bases, and rectangular *lateral faces*. How would you find the volume of such a figure? Explain your method.

- In triangle ABC , it is given that angle BCA is right. Let $a = BC$, $b = CA$, and $c = AB$. Using a , b , and c , express the sine, cosine, and tangent ratios of acute angles A and B .
- The sine of a 38-degree angle is some number r . Without using your calculator, you should be able to identify the angle size whose cosine is the same number r from what you know about right triangles.
- *On a circle whose center is O , using your protractor or GeoGebra, mark points P and A so that minor arc PA is a 46-degree arc. What does this tell you about angle POA ? Extend PO to meet the circle again at T . What is the size of angle PTA ? This angle is *inscribed* in the circle, because its vertex is on the circle. The arc PA is *intercepted* by the angle PTA . Make a conjecture about arcs intercepted by inscribed angles.
- *(Continuation) Confirm your conjecture about inscribed angles and the arcs they intercept using GeoGebra. To measure the arc, select one endpoint, then the center of the circle, then the final endpoint, making sure to go clockwise with respect to the vertices.
- Given lengths of three sides of an isosceles triangle, describe the process you would use to calculate the sizes of its angles. How does your method compare to your classmates'?
- *If P and Q are points on a circle, then the center of the circle must be on the perpendicular bisector of chord PQ . Explain. Which point on the chord is closest to the center? Why?

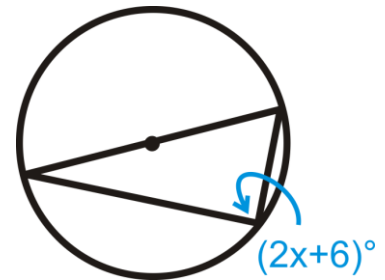


- *In the circle at the right, what is the relationship between $\angle DEB$ and arc DB ? Find the measure of $\angle DCB$ and justify your answer.
- *Why are there many isosceles triangles in a circle? What do they have in common? How are they possibly different?
- *Quadrilateral $DEFG$ is inscribed in circle A . $ED \cong EF$, $\angle E = 100^\circ$ and $\angle F = 70^\circ$. Find the measures of the four minor arcs.
- Given that triangle ABC is similar to triangle PQR , write the three-term proportion that describes how the six sides of these figures are related.
- A circle of radius 5 is **circumscribed** about a regular hexagon. By any method, find the area of the hexagon.



1. *Draw a circle with a 2-inch radius, mark four points randomly (not evenly spaced) on it, and label them consecutively G , E , O , and M . Measure angles GEO and GMO . Could you have predicted the result? Name another pair of angles that would have produced the same result.
2. A regular hexagon has an **inscribed** circle of radius 4. Find the area of the hexagon.
3. *A circular park 80 meters in diameter has a straight path cutting across it. It is 24 meters from the center of the park to the closest point on this path. How long is the path?
4. *Triangle ABC is inscribed in a circle. Given that AB is a 40-degree arc and $\angle ABC$ is a 50-degree angle, find the sizes of the other arcs and angles in the figure.
5. A triangle has a 3-inch side, a 4-inch side, and a 5-inch side. The altitude drawn to the 5-inch side cuts this side into segments of what lengths?
6. By using the triangle whose sides have lengths 1, $\sqrt{3}$ and 2, you should be able to write non-calculator expressions for the sine, cosine, and tangent of a 30-degree angle. Do so. You can use your calculator to check your answers, of course.
7. Find all the angles in a 5-12-13 triangle.

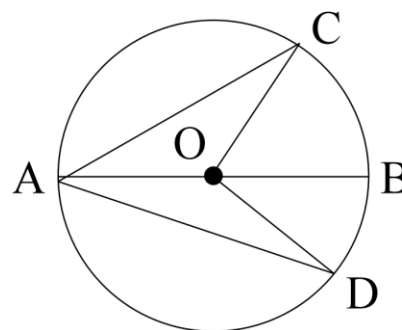
8. Quinn was taking the SATs and saw this diagram. Knowing that the goal was to solve for x , what idea about circles could Quinn use to solve for the value of x ?



9. You are at the scenic overlook at Mt. Sugarloaf in South Deerfield looking through the panoramic viewer that is looking straight ahead. By what degree measure must you rotate the viewer directly downward to see the Mullins Center at UMass, which you know to be 8 miles away if the scenic overlook is 600 feet high?
10. Can the diagonals of a kite bisect each other? Why or why not?
11. Draw trapezoid $ABCD$ so that AB is parallel to CD and the diagonals of the trapezoid. Label the intersection as E . Show that triangles ABE and CDE are similar.
12. The area of an equilateral triangle is $100\sqrt{3}$ square inches. How long are its sides?
13. *Points E , W , and S are marked on a circle whose center is N . In quadrilateral $NEWS$, angles S and W are found to be 54° and 113° , respectively. What are the other two angles?
14. *The points $A = (0, 13)$ and $B = (12, 5)$ lie on a circle whose center is at the origin. Show that the perpendicular bisector of AB goes through the origin.

1. Draw a 30-60-90 triangle of any size and include lengths of all three sides. Using the ratios that you know, write expressions for $\sin(30)$ and $\cos(60)$. What do you notice? Write a sentence or two to justify what you notice.
2. The areas of two similar triangles are 24 square cm and 54 square cm. The smaller triangle has a 6-cm side. How long is the corresponding side of the larger triangle?
3. Find the perimeter of a regular 36-sided polygon inscribed in a circle of radius 20 cm.
4. Find the sine and cosine of two angles that are complements of each other. Do you see any patterns?
5. If the ratio of similarity between two triangles is 3: 5, what is the ratio of the areas of these triangles?
6. How much evidence is needed to be sure that two triangles are similar?
7. Trapezoid $ABCD$ has parallel sides AB and CD , of lengths 8 and 24, respectively. Diagonals AC and BD intersect at E , and the length of AC is 15. Find the lengths of AE and EC .
8. A regular octagon has a perimeter of 64. Find its area.
9. *Fill in the chart below based on the circle diagram given. Be sure you can justify your answers.

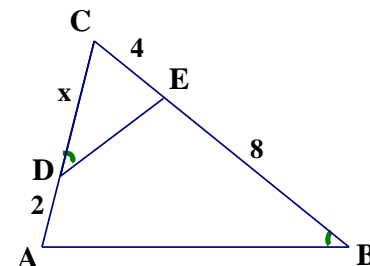
$m\widehat{C B}$	70	60	66	60	p
$m\widehat{B D}$	30	28	?	?	q
$m\angle COD$?	?	100	?	?
$m\angle CAD$?	?	?	52	?



10. *A *cyclic* quadrilateral is a quadrilateral whose vertices are points on a circle. Draw a cyclic quadrilateral $SPAM$ in which the size of angle SPA is 110 degrees. What is the size of angle AMS ? Would your answer change if M were replaced by a different point on major arc SA ?
11. If $A = (3, 1)$, $B = (3, 4)$, and $C = (8, 1)$ find the measure of angle B .

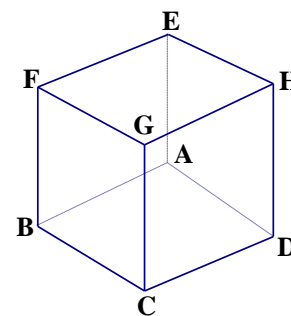
1. A 20-inch chord is drawn in a circle with a 12-inch radius. What is the *angular size* of the minor arc of the chord? What is the *length* of the arc, to the nearest tenth of an inch?
2. In a certain building, there are two large regular octagonal pillars. The edges are 6.5 in and they are 9 feet tall. How much granite was needed to build these pillars?
3. *Quadrilateral *WISH* is *cyclic*. Diagonals *WS* and *HI* intersect at *K*. Given that arc *WI* is 100 degrees and arc *SH* is 80 degrees, find the sizes of as many angles in the figure as you can. Note: *K* is not the center of the circle.

4. Refer to the figure, in which angles *ABE* and *CDE* are equal in size and various segments have been marked with their lengths. Find *x*.
5. *Quadrilateral *BAKE* is cyclic. Extend *BA* to a point *T* outside the circle, thus producing the exterior angle *KAT*. Why do angles *KAT* and *KEB* have the same size?



6. Use GeoGebra to graph $y = 2x - 5$ and the circle $x^2 + y^2 = 5$. Show that these graphs touch at only one point. It is customary to say that a line and a circle are *tangent* if they have exactly one point in common.
7. (Continuation) Find the slope of the segment that joins the point of tangency to the center of the circle and compare your answer with the slope of the line $y = 2x - 5$. What do you notice?

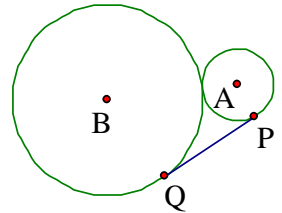
8. Given that *ABCDEFGH* is a cube (shown at right), what is the relationship between the volumes of the cube and the three square pyramids *ADHEG*, *ABCDG*, and *ABFEG*? (note: the square pyramids are not necessarily congruent).
9. The parallel sides of a trapezoid have lengths 9 cm and 12 cm. Draw *one* diagonal, dividing the trapezoid into two triangles. What is the ratio of their areas? If the other diagonal had been drawn instead, would this have affected your answer?



10. On the next page there are two dimensional networks that you should print, cut out and attempt to fold up and tape into three oblique pyramids (you will need to print one extra) that will help you to visualize pyramids *ADHEG*, *ABCDG* and *ABFEG*. Attempt to put them together and form the cube *ABCDEFGH* once again and justify the volume formula of a pyramid. Why do you conjecture is volume of a pyramid that has the same base area and height as a cube? Bring your cubes to class.
11. Drawn in a circle whose radius is 12 cm, chord *AB* is 16 cm long. Calculate the angular size of minor arc *AB*.

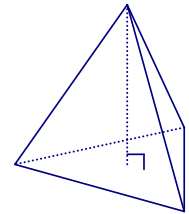
1. Show that the line $y = 10 - 3x$ is tangent to the circle $x^2 + y^2 = 10$. Find an equation for the line perpendicular to the tangent line at the point of tangency. Show that this line goes through the center of the circle.
2. Let $A = (4, 6)$, $B = (6, 0)$, and $C = (9, 9)$. Find the size of angle BAC .
3. Segment AB , which is 25 inches long, is the diameter of a circle. Chord PQ meets AB perpendicularly at C , where $AC = 16$ in. Find the length of PQ .

4. A circle with a 4-inch radius is centered at A and a circle with a 9-inch radius is centered at B , where A and B are 13 inches apart. There is a segment that is tangent to the small circle at P and to the large circle at Q . It is a common external tangent of the two circles. What kind of quadrilateral is $PABQ$? What are the lengths of its sides?



5. **Two Tangents Theorem.* From any point P outside a given circle, there are two lines through P that are tangent to the circle. Explain why the distance from P to one of the points of tangency is the same as the distance from P to the other point of tangency. What special quadrilateral is formed by the center of the circle, the points of tangency, and P ?

6. The altitude of a regular triangular pyramid is the segment connecting a vertex to the centroid of the opposite face. A regular triangular pyramid has edges of length 6 in. How tall is such a pyramid, to the nearest hundredth of an inch?



7. **A 72-degree arc AB is drawn in a circle of radius 8 cm. How long is chord AB ?*

8. It is not hard to believe that a 360-sided polygon is very close to looking like a circle. Find the perimeter of a regular 360-sided polygon that is inscribed in a circle of radius 5 inches. If someone did not remember the formula for the circumference of a circle, how could that person use a calculator's trigonometric functions to find the circumference of a circle with a 5-inch radius?

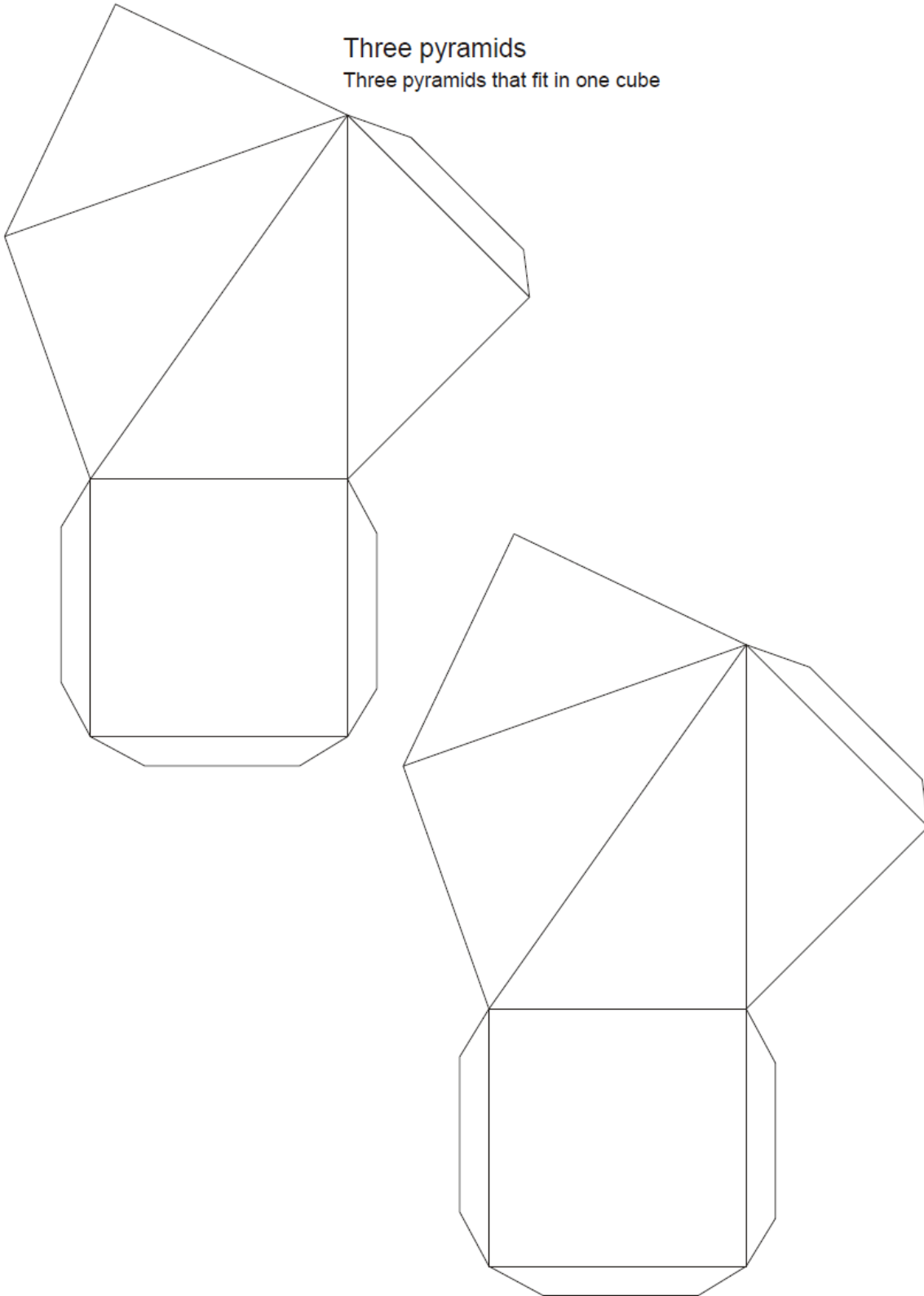
9. **The segments GA and GB are tangent to a circle with center O at A and B , and AGB is a 60-degree angle. Given that $GA = 12\sqrt{3}$ cm, find the distance GO . Find the distance from G to the nearest point on the circle.*

10. **A circle T has two tangents that intersect at 54° at point M . The points of tangency are A and H . What is the angular size of AH ?*

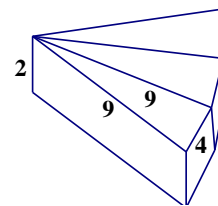
11. The Great Pyramid at Giza was originally 483 feet tall, and it had a square base that was 756 feet on a side. It was built from rectangular stone blocks measuring 7 feet by 7 feet by 15 feet. Such a block weighs seventy tons. Approximately how many tons of stone were used to build the Great Pyramid? The volume of a pyramid is one third the base area times the height.

1. In a group of 12 students, only 4 of them like olives on their pizza. If they are sharing a 16-in pizza what is the area of the part the pizza covered with olives?
2. *A triangle that has a 50-degree angle and a 60-degree angle is inscribed in a circle of radius 25 inches. The circle is divided into three arcs by the vertices of the triangle. To the nearest tenth of an inch, find the lengths of these three arcs. An accurate diagram is useful here.
3. Stacy wants to decorate the side of a cylindrical can by using a rectangular piece of paper and wrapping it around the can. The paper is 21.3 cm by 27.5 cm. Find the two possible diameters of the cans that Stacy could use. (Assume the paper fits exactly).

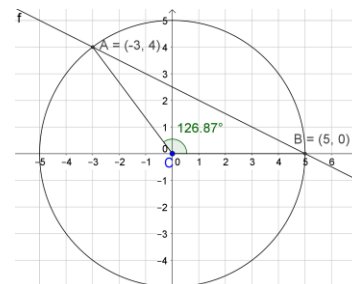
Three pyramids
Three pyramids that fit in one cube



1. A wedge of cheese is 2 inches tall. The triangular base of this right prism has two 9-inch edges and a 4-inch edge. Several congruent wedges are arranged around a common 2-inch segment, as shown. How many wedges does it take to complete this wheel? What is the volume of the wheel, to the nearest cubic inch?



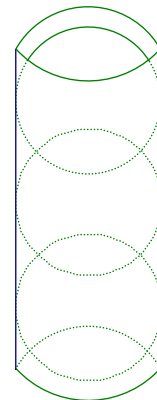
2. The circle $x^2 + y^2 = 25$ and the line $x + 2y = 5$ intersect at the two points shown in the diagram, A and B, therefore dividing the circle into two arcs. Find the lengths of the arcs.



3. (Continuation) A *sector* is a region formed by two radii and an arc of a circle. Find the area of the smaller sector. Justify your method.
4. The equation of a circle is $x^2 + y^2 = 50$, find the area of the circle.
5. If the area of a circle centered at the origin is 40π , write the equation for this circle.
6. Write the equation of the circle that passes through the vertices of the triangle defined by $(-1, -7)$, $(5, 5)$, $(7, 1)$.
7. All triangles have circumscribed circles. Why? What property must a given quadrilateral hold in order to have a circumscribed circle? Explain.
8. Pyramid $TABCD$ has a square base $ABCD$ with 20-cm base edges. The lateral edges that meet at T are 27 cm long. Make a diagram of $TABCD$, showing F , the point of $ABCD$ closest to T . To the nearest 0.1 cm, find the height TF . Find the volume of $TABCD$, to the nearest cm^3 .
9. (Continuation) Find the slant height of pyramid $TABCD$. The slant height is the height of the *lateral face*.
10. From the top of Mt Washington, which is 6288 feet above sea level, how far is it to the horizon? Think of the height of Mt. Washington as a small extension relative to the radius off the earth and draw a diagram looking at the earth from space. Label the distance you are looking for as “ x .” Assume that the Earth has a 3962-mile radius, and give your answer to the nearest mile.
11. What is the minimum amount of wrapping paper needed to wrap a box with dimensions 20 cm by 10 cm by 30 cm?
12. Which polygons can have circumscribed circles? Explain.
13. A paper towel tube has a diameter of 1.7 inches and a height of 11 inches. If the tube were cut and unfolded to form a rectangle, what would be the area of the rectangle?

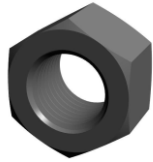
1. Find the area of a kite whose longer diagonal is divided into two parts that are 4 and 12 and whose shorter side is 5.
2. The area of a sector of a circle with radius 12 is $16\pi \text{ cm}^2$. What is the central angle of this sector?
3. The lateral edges of a regular hexagonal pyramid are all 20 cm long, and the base edges are all 16 cm long. To the nearest cm^3 , what is the volume of this pyramid? To the nearest square cm, what is the combined area of the base and six lateral faces?
4. *Surface area of a Sphere:* The surface area of a sphere is found using the formula $4\pi r^2$. Find the surface area of the Earth, given that its diameter is 7924 miles.
5. For any pyramid, the volume is $\frac{1}{3} \cdot \text{base area} \cdot \text{height}$. A cone is a pyramid with a circular base. Find the volume of a cone with a slant height of 13 and a diameter of 10.
6. The radius of the Sun is 109 times the radius of the Earth. Find the surface area of the Sun.
7. Suppose that the lateral faces VAB , VBC , and VCA of triangular pyramid $VABC$ all have the same height drawn from V . Let F be the point in base ABC that is closest to V , so that VF is the altitude of the pyramid. Does this imply that $AB \cong BC \cong CA$?
8. Schuyler has made some glass prisms to be sold as window decorations. Each prism is four inches tall, and has a regular hexagonal base with half-inch sides. They are to be shipped in cylindrical tubes that are 4 inches tall. What radius should Schuyler use for the tubes? Once a prism is inserted into its tube, what volume remains for packing material?
9. A conical cup has a 10-cm diameter and is 12 cm deep. How much can this cup hold?
10. (Continuation) Water in the cup is 6 cm deep. What percentage of the cup is filled?
11. A sphere of ice cream is placed on an ice cream cone. You can assume the volume of a sphere is $V = \frac{4}{3}\pi r^3$ and the volume of a cone is $V = \frac{1}{3}\pi r^2 h$. Both have a diameter of 8 cm. The height of the cone is 12 cm. Will all the ice cream, if pushed down into the cone, fit?

6. The base radius of a cone is 6 inches, and the cone is 8 inches tall. If the cone is cut along its slant height and unrolled flat, what shape is created? What questions can you answer about this shape?
7. Three tennis balls fit snugly inside a cylindrical can. What percent of the available space inside the can is occupied by the balls?
8. Fill in the following proportion relating the sectors of circles to the whole circle. Why does this proportion hold true?



$$\frac{\text{sector area}}{?} = \frac{\text{central } \angle}{?} = \frac{?}{2\pi r}$$

9. Find the perimeter of the semicircle with radius 10.
10. A squash ball fits snugly inside a cubical box whose edges are 4 cm long. Guess the percentage of the box's volume that the ball occupies, then calculate that percentage. (This is an example of a *sphere inscribed in a cube*.)
11. There is a park, 27 feet wide, that is between two buildings whose heights are 123 ft and 111 ft. Two Deerfield teachers, Mr. Barnes and Ms. Schettino are standing on top of the shorter building looking at a rare bird perched on top of the taller building. If Mr. Barnes is 77 inches tall and Ms. Schettino is 62 inches tall who has the smaller angle of elevation while looking at the bird? Explain your answer.
12. As a spherical gob of ice cream that once had a 2-inch radius melts, it drips into a cone of the same radius. The melted ice cream exactly fills the cone. What is the height of the cone?
13. Two similar triangles have medians in a ratio of 5: 6, what is the ratio of their areas?
14. A 10 cm tall cylindrical glass 8 cm in diameter is filled to 1 cm from the top with water. If a gold ball 4 cm in diameter is dropped into the glass, will the water overflow?
15. An *annulus* is defined as the region lying between two *concentric* circles. If the diameter of the larger circle is 20 in and the radius of the smaller circle is 8, find the area of the annulus.
16. A Reese's Big Cup has a diameter of two inches and a height of 0.8 inches. A Reese's bar has dimensions 4 inches by 0.8 inches by 0.5 inches. Using approximations, which candy has more peanut butter?
17. (Continuation) Assuming a uniform chocolate thickness, which candy has more chocolate?
18. Ice cream scoops are often 6 cm in diameter. How many scoops should you get from a half-gallon of ice cream? A half-gallon container can be approximated by a cylinder with a diameter of 12 cm and a height of 14 cm.

1. A spherical globe, 12 inches in diameter, is filled with spherical gumballs, each having a 1-inch diameter. Estimate the number of gumballs in the globe, and explain your reasoning.
2. The altitudes of two similar triangles are 6 cm and 9 cm. If the area of the larger triangle is 36 cm^2 , what is the area of the smaller triangle?
3. Seventy percent of the Earth's surface is covered in water. Find the approximate surface area of the Earth that is dry land.
4. The ratio of similarity of two triangular prisms is 3: 5. What is the ratio of their surface areas?
5. The figure at right shows a metal hex nut with two regular hexagonal faces and thickness of 1 cm. The length of each side of a hexagonal face is 2 cm. A hole with a diameter of 2 cm is drilled through the nut. The density of the metal is 7.9 grams per cubic cm. What is the mass of this nut, to the nearest gram? (Density is mass divided by volume.)  <http://www.daleengineering.com/e-commerce/hex-nuts.shtml>
6. The sum of the lengths of the two bases of a trapezoid is 22 cm and its area is 946 cm^2 . Find the height of this trapezoid.
7. Find the point that is equidistant from the points (0, 4), (2, 3), and (5, 9). (Hint: this is a special point)
8. The surface areas of two cubes are in the ratio of 49: 81. If the volume of the smaller cube is 20, what is the volume of the larger cube?
6. Charlie built a treasure box. Lucy built a treasure box with dimensions twice as large as Charlie's. If it takes one-half gallon of paint to cover the surface of Charlie's box, how many gallons of paint would it take to paint Lucy's box? How many times more volume will Lucy's box hold than Charlie's?
7. Find the area of the regular polygon whose exterior angle is 45° and whose sides are 3.5 inches.
8. Suppose that *DRONE* is a regular pentagon and that *DRUM*, *ROCK*, *ONLY*, *NEAP*, and *EDIT* are squares attached to the outside of the pentagon. Show that decagon *ITAPLYCKUM* is equiangular. Is this decagon equilateral?
9. A 20-inch chord is drawn in a circle with a 12-inch radius. What is the *angular size* of the minor arc of the chord?
10. Find the lengths of both altitudes in the parallelogram determined by [2, 3] and [-5, 7].

1. Triangle ABC has $AB = AC$. The bisector of angle B meets AC at D . Extend side BC to E so that $CE = CD$. Triangle BDE should look isosceles. Is it? Explain.
2. Can a circle always be drawn through three given points? If so, describe a procedure for finding the center of the circle. If not, explain why not.
3. Suppose that $PEANUT$ is a regular hexagon, and that $PEGS$, $EACH$, $ANKL$, $NUMB$, $UTRY$, and $TPOD$ are squares attached to the outside of the hexagon. Decide whether or not dodecagon $GSODRYMBKLCH$ is regular and give your reasons.
4. A kite has an 8-inch side and a 15-inch side, which form a right angle. Find the length of the diagonals of the kite.
5. Point P is marked inside regular pentagon $TRUDY$ so that triangle TRP is equilateral. Decide whether or not quadrilateral $TRUP$ is a parallelogram and give your reasons.
6. Find the equation of the line that contains all of the points equidistant from the points $A(-2, 7)$ and $B(3, 6)$.
7. A triangle with sides 6, 8, and 10 and a circle with radius is r are drawn so that no part of the triangle lies outside the circle. How small can r be?
8. Diagonals AC and BD of regular pentagon $ABCDE$ intersect at H . Decide whether or not $AHDE$ is a rhombus, and give your reasons.
9. Let $A = (3, 1)$, $B = (9, 5)$, and $C = (4, 6)$. Your protractor should tell you that angle CAB is about 45 degrees. Explain why angle CAB is in fact exactly 45 degrees.
10. The sides of a polygon are cyclically extended to form *rays*, creating one exterior angle at each vertex. Viewed from a great distance, what theorem does this figure illustrate?
11. The midpoints of the sides of a quadrilateral are joined to form a new quadrilateral. For the new quadrilateral to be a rectangle, what must be true of the original quadrilateral?
12. The parallel sides of a trapezoid are 12 inches and 18 inches long. The non-parallel sides meet when one is extended 9 inches and the other is extended 16 inches. How long are the non-parallel sides of this trapezoid?
13. The altitude drawn to the hypotenuse of a right triangle divides the hypotenuse into two segments, whose lengths are 8 inches and 18 inches. How long is the altitude?
14. In the middle of the nineteenth century, octagonal barns and sheds (and even some houses) became popular. How many cubic feet of grain would an octagonal barn hold if it were 12 feet tall and had a regular base with 10-foot edges?

1. The diagonal of a rectangle is 15 cm, and the perimeter is 38 cm. What is the area? It is possible to find the answer without finding the dimensions of the rectangle – try it.
2. A triangle that has a 5-inch and a 6-inch side can be similar to a triangle that has a 4-inch and an 8-inch side. Find all possible examples. Check that your examples really *are* triangles.
3. What is the radius of the circumscribed circle for a triangle whose sides are 15, 15, and 24 cm long?
4. A kite has a 5-inch side and a 7-inch side. One of the diagonals is bisected by the other. The bisecting diagonal has length 8 inches. Find the length of the bisected diagonal.

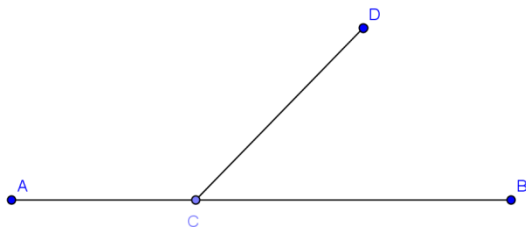
Reference

AA similarity: Two *triangles* are sure to be similar if at least two of their angles are equal in size.

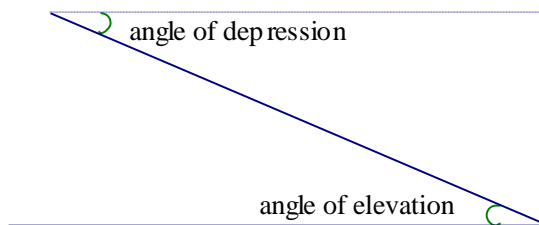
adjacent angles: Two angles with a common vertex that share a side but have no common interior points.

altitude: In a triangle, an altitude is a line through one of the vertices, perpendicular to the opposite side. In obtuse triangles, it may be necessary to extend a side to meet the altitude. The *distance* from the vertex to the point of intersection with the line containing the opposite side is also called an altitude, as is the distance that separates the parallel sides of a trapezoid.

angles can often be identified by a single letter, but sometimes three letters are necessary. The angles shown can be referenced as C , ACD , or BCD .



angle of depression: Angle formed by a horizontal ray and a line-of-sight ray that is below the horizontal. See the diagram at right.



angle of elevation: Angle formed by a horizontal ray and a line-of-sight ray that is above the horizontal. See the diagram at right.

Angle-Angle-Side (corresponding): When the parts of one triangle can be matched with the parts of another triangle, so that two pairs of corresponding angles have the same sizes, and so that one pair of corresponding sides has the same length, then the triangles are congruent. This rule of evidence is abbreviated to AAS.

angle bisector: Given an angle, this ray divides the angle into two equal parts.

Angle Bisector Theorem: The bisector of any angle of a triangle cuts the opposite side into segments whose lengths are proportional to the sides that form the angle.

Angle-Side-Angle: When the parts of one triangle can be matched with the parts of another triangle, so that two pairs of corresponding angles have the same sizes, and so that the (corresponding) shared sides have the same length, then the triangles are congruent. This rule of evidence is abbreviated to ASA.

angular size of an arc: This is the size of the central angle formed by the radii that meet the endpoints of the arc. Also called the measure of the arc.

arc: A section of the perimeter of a circle. Can be a *minor arc* (measure less than 180 degrees) or *major arc* (measure greater than 180 degrees). The portion of a circle that lies to one side of a chord is also called an *arc*.

arc length: The linear distance along the circle from one endpoint of the arc to the other. Given a circle, the length of any arc is proportional to the size of its central angle.

areas of similar figures: If two figures are similar, then the ratio of their areas equals the *square* of the ratio of similarity.

bisect: Divide into two equal parts.

central angle: An angle formed by two radii of a circle.

centroid: The medians of a triangle are concurrent at this point, which is the balance point (also known as the *center of gravity*) of the triangle.

chord: A segment that joins two points on a circle is called a *chord* of the circle.

circle: The set of all points equidistant from a given point, called the *center*. The common distance is the *radius* of the circle. A segment joining the center to a point on the circle is also called a *radius*.

circumcenter: The perpendicular bisectors of the sides of a triangle are concurrent at this point, which is equidistant from the vertices of the triangle.

circumscribed circle: When possible, the circle that goes through all the vertices of a polygon.

collinear: Three (or more) points that all lie on a single line are *collinear*.

common chord: A segment that joins the points where two circles intersect.

complementary: Two angles that fit together to form a right angle are called complementary. Each angle is the *complement* of the other.

concentric: Two figures that have the same center are called *concentric*.

concurrent: Three (or more) lines that go through a common point are *concurrent*.

conyclic: Points that all lie on a single circle are called *conyclic*.

congruent: When the points of one figure can be matched with the points of another figure, so that corresponding parts have the same size, then the figures are called *congruent*, which means that they are considered to be equivalent.

converse: The converse of a statement of the form “if [something] then [something else]” is the statement “if [something else] then [something].”

convex: A polygon is called *convex* if every segment joining a pair of points within it lies entirely within the polygon.

coordinates: Numbers that describe the position of a point in relation to the origin of a coordinate system.

coplanar: objects that are within the same plane

corresponding: They are parts of polygons that are in the same position relative to each other. Corresponding describes parts of figures (such as angles or segments) that could be matched by means of a transformation. In congruent polygons, if the polygons were superimposed, the corresponding parts would be right on top of one another.

cosine ratio: Given a right triangle, the cosine of one of the acute angles is the ratio of the length of the side *adjacent* to the angle to the length of the hypotenuse. The word cosine is a combination of *complement* and *sine*, so named because the cosine of an angle is the same as the sine of the complementary angle.

counterexample: an example used to show that a statement is false.

CPCTC: *Corresponding Parts of Congruent Triangles are Congruent.*

cyclic: A polygon, all of whose vertices lie on the same circle, is called *cyclic*. Also called an *inscribed polygon*.

decagon: A polygon that has ten sides.

diagonal: A segment that connects two nonadjacent vertices of a polygon.

diameter: A chord that goes through the center of a circle is called a *diameter*.

distance formula: The distance from (x_1, y_1) to (x_2, y_2) is $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$. This formula is a consequence of the *Pythagorean Theorem*.

dodecagon: A polygon that has twelve sides.

dynamic: A figure is dynamic if it is not fixed in the plane.

equiangular: A polygon all of whose angles are the same size.

equidistant: A shortened form of *equally distant*.

equilateral: A polygon all of whose sides have the same length.

Euclidean geometry (also known as plane geometry) is characterized by its parallel postulate, which states that, *given a line, exactly one line can be drawn parallel to it through a point not on the given line*. A more familiar version of this assumption states that *the sum of the angles of a triangle is a straight angle*.

Euler line: The centroid, the circumcenter, and the orthocenter of any triangle are collinear.

exterior angle: An angle that is formed by a side of a polygon and the extension of an adjacent side. It is supplementary to the adjacent interior angle.

Exterior Angle Theorem: An exterior angle of a triangle is the sum of the two nonadjacent interior angles.

function: A function is a rule that describes how the value of one thing is determined uniquely by the value of another thing.

glide-reflection: An transformation created by a translation and reflection.

Greek letters appear often in mathematics. Some of the common ones are α (alpha), β (beta), Δ or δ (delta), θ (theta), Λ and λ (lambda), μ (mu), π (pi), and Ω or ω (omega).

hexagon: a polygon that has six sides.

Hypotenuse-Leg: When the hypotenuses of two right triangles have the same length, and a leg of one triangle has the same length as a leg of the other, then the triangles are congruent. This rule of evidence is abbreviated to HL.

image: The result of applying a transformation to a point P is called the *image of P* , often denoted P' . One occasionally refers to an *image segment* or an *image triangle*.

incenter: The angle bisectors of a triangle are concurrent at this point, which is equidistant from the sides of the triangle.

included angle: The angle formed by two designated segments.

inscribed angle: An angle formed when two chords meet at a point on the circle. An inscribed angle is *half* the angular size of the arc it intercepts. In particular, an inscribed angle that intercepts a semicircle is a *right* angle.

inscribed polygon: A polygon whose vertices all lie on the same circle; also called a *cyclic polygon*.

integer: Any whole number, whether it be positive, negative, or zero.

intercepted arc: The part of an arc that is found inside a given angle.

isometry: A geometric transformation that preserves distances. The best-known examples of isometries are *translations*, *rotations*, and *reflections*.

isosceles triangle: A triangle that has two sides of the same length. The word is derived from the Greek *iso* + *skelos* (equal + leg)

Isosceles Triangle Theorem: If a triangle has at least two sides of equal length, then the angles opposite the congruent sides are also the same size.

isosceles trapezoid: A trapezoid whose nonparallel sides have the same length.

kite: A quadrilateral that has two pairs of congruent adjacent sides.

labeling convention: Given a polygon that has more than three vertices, place the letters around the figure in the order that they are listed.

lateral face: Any face of a pyramid or prism that is not a base.

lattice point: A point whose coordinates are both integers.

lattice rectangle: A rectangle whose vertices are all lattice points.

leg: The perpendicular sides of a right triangle are called its legs.

linear equation: Any straight line can be described by an equation in the form $Ax + By = C$.

linear pair: Two adjacent angles whose sum is 180 degrees; Two angles that form a straight angle.

major/minor arc: A non-diameter chord of a circle divides a circle into two parts. Of the two arcs, the smaller one is called *minor* (less than 180 degrees), and the larger one is called *major* (more than 180 degrees). Often, a major arc is described with a label that has 3 letters and a minor arc is described with 2 letters.

median of a triangle: A segment that joins a vertex of a triangle to the midpoint of the opposite side.

midline of a trapezoid: This segment joins the midpoints of the non-parallel sides. Its length is the average of the lengths of the parallel sides, to which it is also parallel. Also known as the *median* in some books.

Midsegment Theorem: A segment that joins the midpoints of two sides of a triangle is parallel to the third side, and is half as long.

midpoint: The point on a segment that is equidistant from the endpoints of the segment.

If the endpoints are (a, b) and (c, d) , the midpoint is $\left(\frac{a+c}{2}, \frac{b+d}{2}\right)$

Mirror line: In a reflection, the mirror line is the perpendicular bisector of the segments that connect the initial point (pre-image) and its reflected point (image).

Negative (opposite) reciprocal: One number is the negative reciprocal of another if the product of the two numbers is -1 .

octagon: a polygon that has eight sides.

opposite: Two numbers are opposite if they differ in sign. For example, 17.5 is the opposite of -17.5

orthocenter: The altitudes of a triangle are concurrent at this point.

parallel: Coplanar lines that do not intersect. When drawn in a coordinate plane, they are found to have the same slope, or else no slope at all. The shorthand $//$ is often used.

parallelogram: A quadrilateral that has two pairs of parallel sides.

pentagon: a polygon that has five sides.

perpendicular: Coplanar lines that intersect to form a right angle.

perpendicular bisector: Given a line segment, this is the line that is perpendicular to the segment and that goes through its *midpoint*. The points on this line are all *equidistant* from the endpoints of the segment.

point-slope form: A non-vertical straight line can be described by $y - y_0 = m(x - x_0)$ or by $y = m(x - x_0) + y_0$. One of the points on the line is (x_0, y_0) and the slope is m .

postulate: A statement that is accepted as true, without proof.

prism: A three-dimensional figure that has two congruent and parallel *bases*, and parallelograms for its remaining *lateral faces*. If the lateral faces are all rectangles, the prism is a *right prism*. If the base is a regular polygon, the prism is also called *regular*.

Proof by Contradiction (Indirect Proof): method of mathematical proof in which the mathematician assumes the opposite of what they are attempting to prove in the hope of coming

up with a contradiction of already known fact. This contradiction thereby proves that the assumption that the statement must have been false.

proportion: An equation that expresses the equality of two *ratios*.

pyramid: A three-dimensional figure that is obtained by joining all the points of a polygonal *base* to a *vertex*. Thus all the lateral faces of a pyramid are triangles. If the base polygon is regular, and the lateral edges are all congruent, then the pyramid is called *regular*.

Pythagorean Theorem: The area of the square with a side equal to the hypotenuse of a right triangle equals the sum of the areas of the squares whose sides are the lengths of the legs of the right triangle. If a and b are the lengths of the legs of a right triangle, and if c is the length of the hypotenuse, then these lengths fit the Pythagorean equation $a^2 + b^2 = c^2$.

quadrant: one of the four regions formed by the coordinate axes. Quadrant I is where both coordinates are positive, and the other quadrants are numbered (using Roman numerals) in a counterclockwise fashion.

quadratic formula: $x = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$ and $x = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$ are the two solutions to $ax^2 + bx + c = 0$.

quadrilateral: a four-sided polygon.

ratio of similarity: The ratio of the lengths of any two corresponding segments of similar figures.

ray: A ray is a line bounded at one end and infinite at the other.

rectangle: An equiangular quadrilateral.

reflection: A reflection maps points on one side of the *mirror line* to the other side. If the point is on the mirror line, then it maps onto itself.

regular: A polygon that is both equilateral and equiangular.

rhombus: An equilateral quadrilateral.

right angle: An angle that is its own supplement, in other words, an angle that is 90 degrees.

rotation: A transformation in a plane that moves a figure about a single fixed point. The fixed point is called the *center of rotation*.

SAS similarity: Two triangles are certain to be similar if two sides of one triangle are proportional to two sides of the other, and if the included angles are equal in size.

Same Side interior angles – angles formed by two parallel lines and a transversal which are non-adjacent, interior angles (i.e. they do not share a vertex and are both interior to the parallel lines).

scalene: A triangle that has 3 different side lengths.

segment: That part of a line that lies between two designated points.

Sentry Theorem: The sum of the exterior angles (one per vertex) of any polygon is 360 degrees.

Shared Altitude Theorem: If two triangles share an altitude, then the ratio of their areas is proportional to the ratio of the corresponding bases.

Shared Base Theorem: If two triangles share a base, then the ratio of their areas is proportional to the ratio of the corresponding altitudes.

Side-Angle-Side: When the parts of one triangle can be matched with the parts of another triangle, so that two pairs of corresponding sides have the same lengths, and so that the (corresponding) angles they form are also the same size, then the triangles are congruent. This rule of evidence is abbreviated to just SAS.

Side-Side-Angle: Insufficient grounds for congruence. See *Hypotenuse-Leg*, however.

Side-Side-Side: When the parts of one triangle can be matched with the parts of another triangle, so that all three pairs of corresponding sides have the same lengths, then the triangles are congruent. This rule of evidence is abbreviated to just SSS.

similar: Two figures are similar if their points can be matched in such a way that all ratios of corresponding lengths are proportional to a fixed *ratio of similarity*. Corresponding angles of similar figures must be equal in size.

sine ratio: Given a right triangle, the sine of one of the acute angles is the ratio of the length of the side *opposite* the angle to the length of the hypotenuse.

skew lines: Non-coplanar lines that do not intersect.

slope: The slope of the segment that joins the points (x_1, y_1) and (x_2, y_2) is $\frac{y_2 - y_1}{x_2 - x_1}$.

slope-intercept form: Any non-vertical straight line can be described by an equation that takes the form $y = mx + b$. The slope of the line is m , and the y -intercept is b .

SSS similarity: Two triangles are *similar* if their corresponding sides are proportional.

square: A regular quadrilateral.

supplementary: Two angles whose measures add up to 180 degrees and could be fit together to form a straight line are called *supplementary*. Each angle is the *supplement* of the other.

tangent ratio: Given a right triangle, the tangent of one of the acute angles is the ratio of the side opposite the angle to the side adjacent to the angle.

tangent and slope: When an angle is formed by the x -axis and a ray through the origin, the *tangent* of the angle is the *slope* of the ray. Angles are measured in a counterclockwise sense, so that rays in the second and fourth quadrants determine negative tangent values.

tangent to a circle: A line that has one and only one intersection with a circle. This intersection is called the *point of tangency*. Such a line is perpendicular to the radius drawn to the point of tangency.

tessellate: To fit non-overlapping tiles together to cover a planar region.

transformation: A *function* that maps points to points.

translate: To slide a figure by moving each of its coordinates horizontally and vertically the same distances.

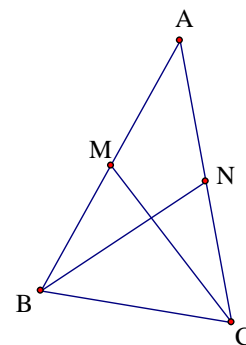
transversal: A line that intersects two other lines in a diagram.

trapezoid: A quadrilateral with exactly one pair of parallel sides. If the non-parallel sides have the same length, the trapezoid is called *isosceles*.

triangle inequality: The sum of the lengths of two sides of a triangle is greater than the length of the third side.

two-column proof: A way of outlining a geometric deduction. Steps are in the left column, and supporting reasons are in the right column. For example, here is how one might show that an isosceles triangle ABC has two medians of the same length. It is given that $AB = AC$ and that M and N are the midpoints of sides AB and AC , respectively. The desired conclusion is that medians CM and BN have the same length.

$AB = AC$	given
$AM = AN$	M and N are midpoints
$\angle MAC = \angle NAB$	shared angle
$\triangle MAC \cong \triangle NAB$	SAS
$CM = BN$	CPCTC



Two Tangent Theorem: From a point outside a circle, there are two segments that can be drawn tangent to the circle. These segments have the same length.

unit circle: This circle consists of all points that are 1 unit from the origin, O , of the xy -plane. Given a point P on this circle, the coordinates of P are the *cosine* and the *sine* of the counterclockwise angle formed by segment OP and the positive x -axis.

unit square: Its vertices are $(0, 0)$, $(1, 0)$, $(0, 1)$, and $(1, 1)$.

Varignon parallelogram: Given any quadrilateral, this is the figure formed by connecting the midpoints of consecutive sides.

vertex: A labeled point in a figure. The plural is *vertices*, but “vertice” is not a word. The point on a parabola that is closest to the focus is also called the vertex.

vertical angles: Two non-adjacent angles that share a vertex and are formed by the intersection of two lines.

volume of a prism: This is the product of the *base area* and the *height*, which is the distance between the parallel base planes.

volume of a pyramid: This is one third of the product of the *base area* and the *height*, which is the distance from the vertex to the base plane.

volumes of similar figures: If two three-dimensional figures are similar, then the ratio of their volumes equals the *cube* of the ratio of similarity.