CHAPTER 4 - LET'S LEARN A LITTLE MORE GEOMETRY!

Using Squares, Cubes, and Boxes to Make a House

If learning a little bit of geometry seems intimidating to you, I can only promise that this exercise, once mastered, will lead to some pretty impressive three-dimensional results: the construction of a cube, some box-making projects, and finally, a model house.

Compared to the equilateral triangle, the square may not seem quite so interesting, but the truth is, it works so well with other simple polygons to produce some very impressive results. Just look at its various applications in Chapter 6, Prisms and Antiprisms, and in Chapter 9, The Archimedean solids. The square also has a bit of symbolic history attached to it, representing the four corners of the earth (that is, when our ancestors thought the Earth was flat and square-shaped. Notice in Leonardo da Vinci's famous drawing of the Vitruvian man, that the figure is placed within a circle and a square.

Knowing how to draw a perpendicular to a line, the very foundation of the square will be a big help in any of a number of projects. The square is a cousin to the rectangle, and a distant relative to the trapezoid and the parallelogram. Knowing how to make a square will lead you well beyond the simplicity of the ordinary cube, and on to such projects as model designs for houses and barns, boxes of all types, and related projects.

Objective:
Gain an understanding of how to create three-dimensional shapes using nets

Vocabulary:
Arc
Chord
Compass
Cube
Equidistant
Equilateral
Gable
Hexagon
Horizontal
Intersect
Oblong
Perpendicular
Radius
Rectangular
Slope
Square
Vertical

Exercise 4

Materials needed:
Standard white paper
Several large sheets of 22 x 29-inch white poster-board (cut in half to the more manageable dimensions of 22 x 14 1/2-inches),
A straight-edge
Sharp No. 2 pencils
A precise compass
A pair of scissors
Cellophane tape
Glue
An eraser
1/2-inch x 3 1/2-inch white label strips (recommended)

Steps:

The Perfect Square

There are several ways to make a perfect square, two are presented below. Each requires great care in making perfect drawings, so make sure that your pencil is always sharp, and that your compass holds its setting. The first method—and the simplest and fastest—requires that you begin by constructing a perpendicular line on a horizontal line.

1. Use **Figure 4.1** to guide you in this process. Draw horizontal line AB. Set your compass at point O, and sweep out two small arcs on either side of point O that will intersect line AB at points C and D.

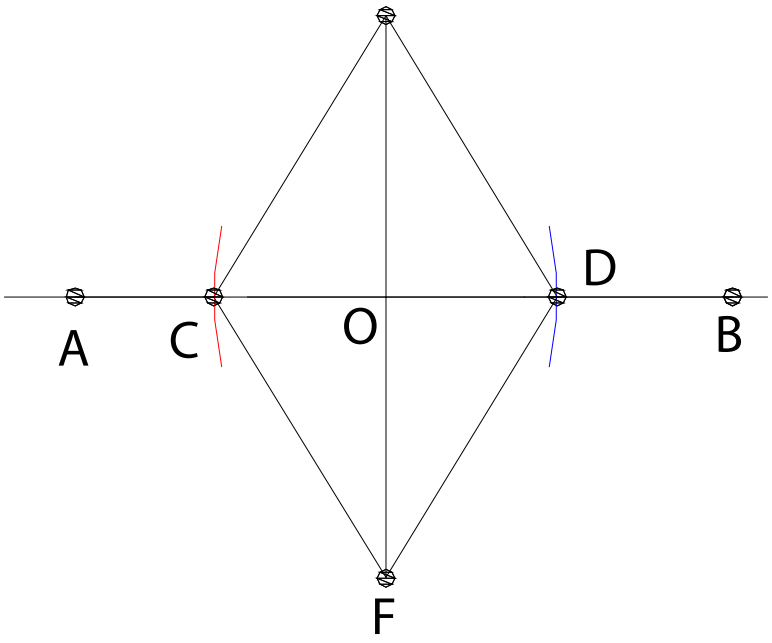

Figure 4.1

2. Then, widen your compass and set the tip on point C to sweep out arcs above and below line AB.

3. Do the same, setting the compass tip on point D.

4. Then connect points E and F. Line segment EF is a perfect perpendicular to line AB. Angle EOD is a perfect 90 degree angle, as are all four angles around point O.

5. Open your compass to the distance between points O and E and sweep out an entire circle using point O as the center and line segment OE as the radius. Label the intersection of the circle and line AB, point G. Now, you have drawn two sides of the square – line segments EO and OG. See **Figure 4. 2**.

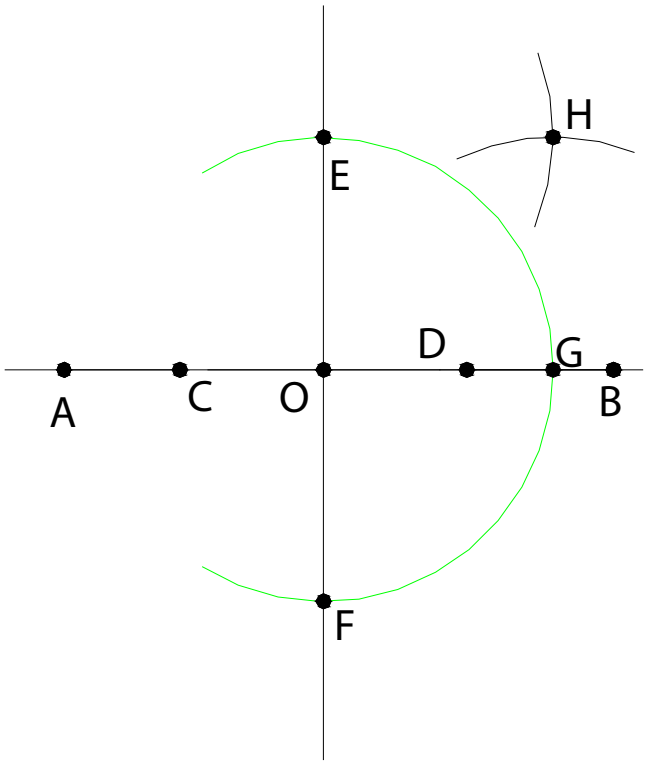

Figure 4.2

6. To complete the other two sides of the square, set the compass to the width of line segment EO at point E and sweep a small arc above point G. Keep the same compass width and do the same at point G, crossing the arc you just made from E, The intersection of these two small arcs will create point H.

7. Since Point H is equidistant from points E and G, a line drawn from E to H and from G to H will complete your square. **(Figure 4.3)**

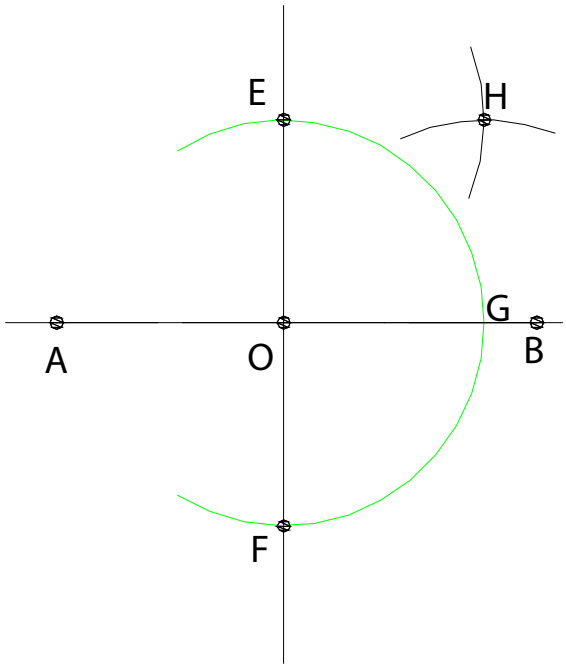

Figure 4.3

A Faster Way to Create a Square

A really fast way to make a perfect single square is shown in **Figure 4.4**. On a horizontal line, sweep out an entire circle from Point O near the center of the line. Label the intersections of the circle with the line, points A and B as shown. Construct a perpendicular line segment by placing the point of your compass on point A and sweeping out a small arc directly above and below the circle. Do the same from point B. By connecting the 2 points of intersection, you will have created a perfect perpendicular line to line AB, dividing the circle into four quarter sections. Label the intersection of the perpendicular line with the circle points C and D, as shown. Chords AC, CB, BD, and DA will form a perfect square, since all the internal angles are exactly 90 degrees and all sides are of equal length.

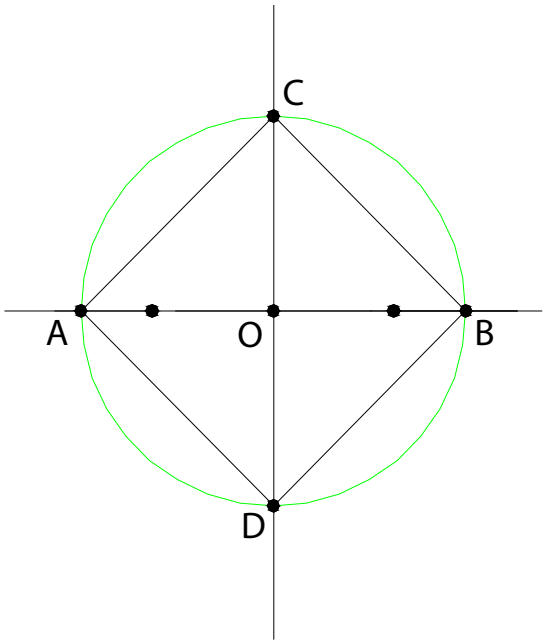

Figure 4.4

Square to Cube

To make a cube, you have only to cut out six of these squares using poster-board, and tape them together. But, there is an easier and faster way by making a "net" or pattern. A net can be designed on poster-board, scored with the point of your compass for easier folding and cutting. As you construct this net, try to make every square as perfect as you possibly can.

1. Start with a straight line, as in **Figure 4.5**, and construct a perpendicular at point O using the method in the previous section, steps 1 - 3.

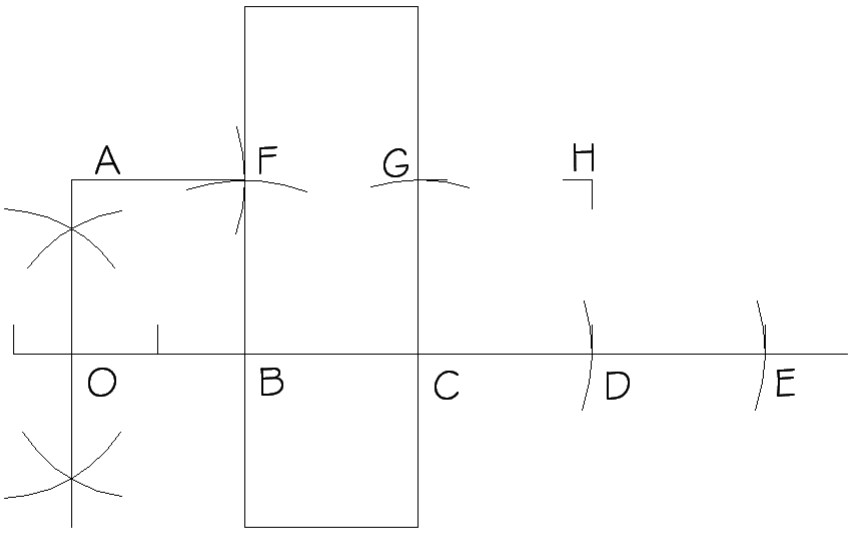

Figure 4.5

2. Decide how large a square or cube you want to make, for example, 2 inches on each side, and measure off this dimension both on the perpendicular line creating line segment OA, and also on the horizontal line creating line segment OB.

3. With your compass set at 2 inches on point B, strike off a small arc directly above, and do the same with the compass set at A, sweeping a small arc that will intersect with the first. Label the point of intersection, F. Lines drawn from A to F and from B to F will provide a true corner to your first square.

4. With your compass at B, you can now mark off C, D, and E. Arcs from F and C will give you the second complete square at G; G and D will give you H, etc. Lines connecting the appropriate points will give you four of the six squares required for your net.

5. By simply extending two vertical lines of any one square, say BF and CG above and below the line using the correct dimension will give you the full net for a cube shown in **Figure 4.6**.

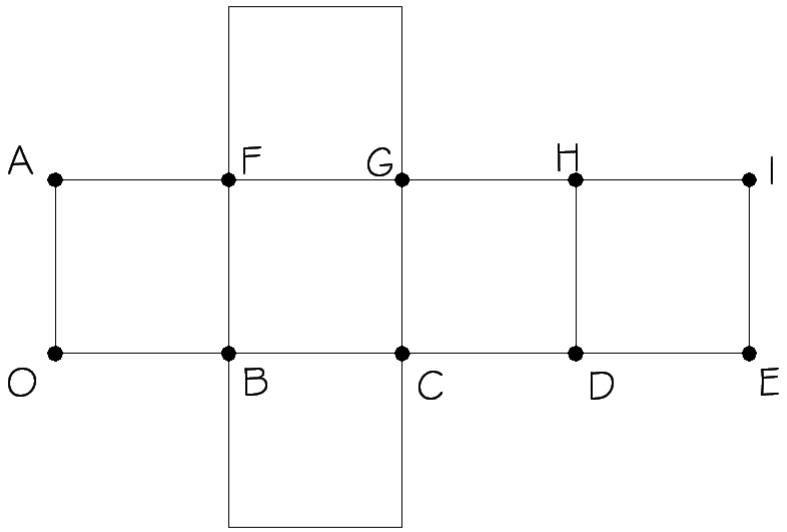

Figure 4.6

6. Before cutting out the completed net, go over all the lines between the connecting squares with the point of your compass guided by the straight-edge, and gently press in to "score" (pierce slightly) the board. This will facilitate folding along these lines. Hold the compass point at a 45 degree angle, not upright—to score. Don't press so hard that you cut through the poster-board. A slight groove is all you need.

7. Always fold away from a score--in other words, all your score markings on this cube should be on the outside. This is called a "ridge" or "hill" fold.

8. Cut out your cube, fold it, and tape it together either with cellophane tape or the white label strips.

Here is another quick method to achieve the same results. Working directly on a sheet of poster-board (22 x 14 ½ inches) and using **Figure 4.6** as a guide, create two horizontal parallel lines exactly four inches apart near the middle of the page. With these two parallel lines in place spaced exactly four inches apart, it will be very easy to design a series of squares in a row. Close to one end of the lower line, construct a perpendicular at point O which touches the upper line at A. Measure off four inches on the lower line creating points B, C, D, and E. Do the same on the upper line creating points F, G, H, and I. Connect points B and F, C and G, D and H, and E and I with straight lines. Four of the six squares necessary are completed. Again, by extending the perpendicular lines of any

one square exactly four inches above and four inches below and connecting these lines, as we've done with line segments BF and CG**,** the fifth and sixth squares are formed.

Here's an interesting question to consider at this time. Are there other net arrangements that will fold to make a cube? Cut out a supply of squares, and see just how many arrangements work.

The cube, or hexahedron (Greek for "six-sides"), is one of five shapes known as the Platonic Solids. Like all of the others in the series, it meets all of the qualifications required of a Platonic Solid: all faces are exactly identical to each other, all edges are equal, and all vertices (or corners) are of equal measure.

Let's Make a Box

Actually, we already made a box when we made the cube. Now, we want to make a box that is more practical--one that opens and closes, and has flaps to secure it. We can go back to our net for a cube and add the flaps needed to make it into a functional box. In fact, you might find it amusing to collect a few boxes of different shapes and sizes, carefully take them apart and lay them flat, and you will observe that each will match this grid in some respect. **Figure 4.7** provides a simple net for a cube shaped box.

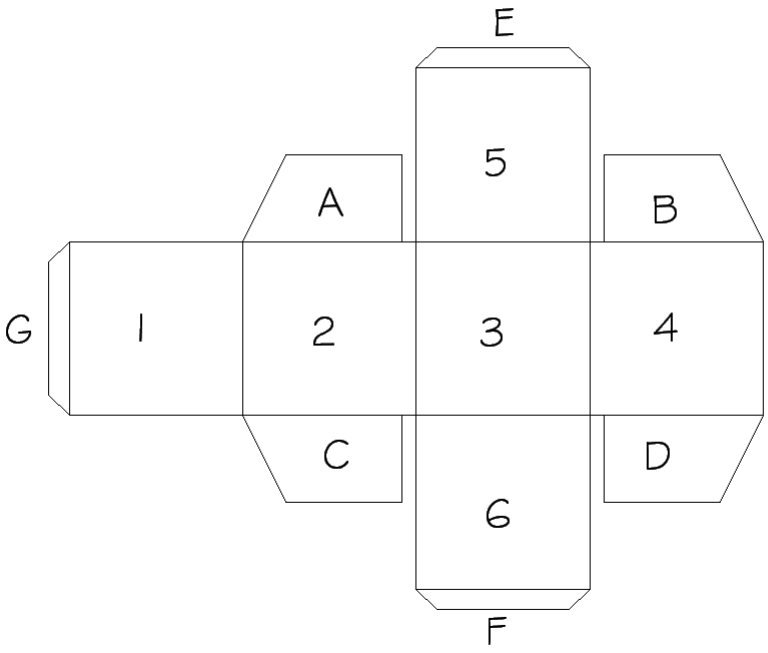

Figure 4.7

1. In this representation, flaps A, B, C, and D fold completely into the box before the lid (1) is closed. G is the tab that holds the lid in place when the box is closed. Square #3 should be on the bottom of the box. You can make the tabs longer if you like and use glue to secure the structure.

2. Do you want to make an oblong box instead? The same principle used above holds true here, except that we must now think of our box as having a long side, and a short side, as in **Figure 4.8.**

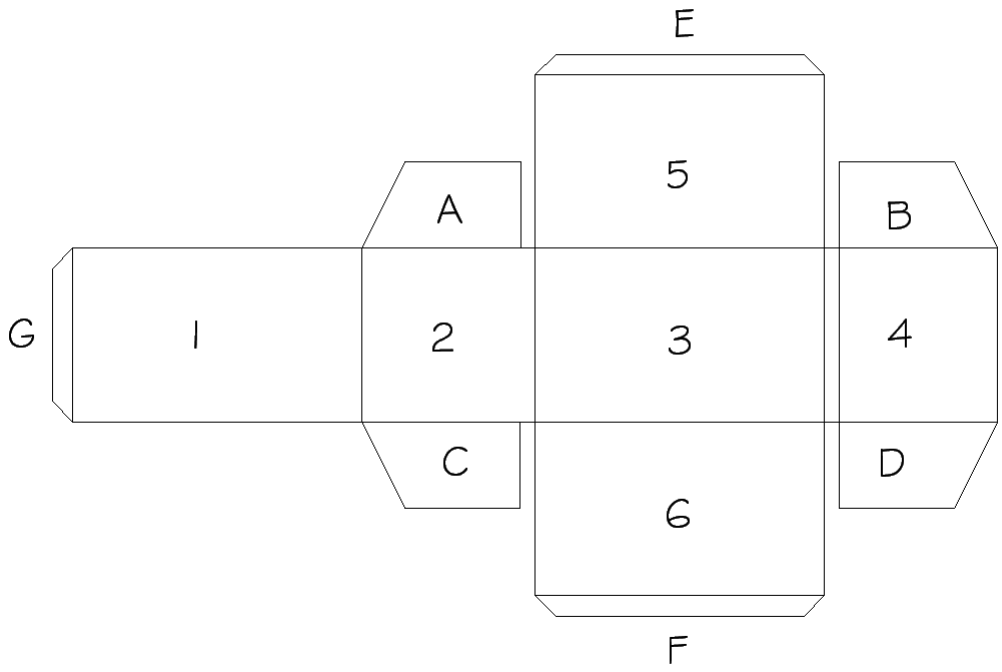

Figure 4.8

3. Depending on how you want your box to open, #1 can be the front of the box, #3 the back, and 2 and 4 the sides. The lid is #5, and the bottom #6. **Figure 4.9** shows the folded box. This box can also be made to open in a different manner. **Figure 4.10** shows an alternative opening.

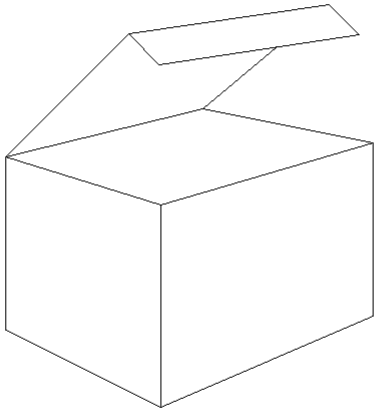

Figure 4.9

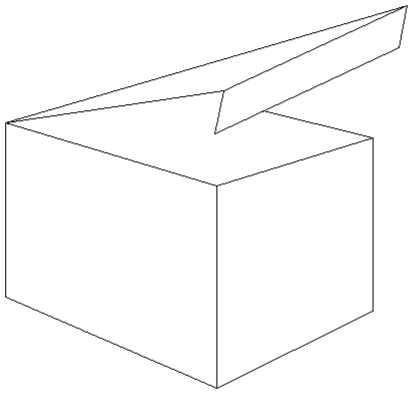

Figure 4.10

You can continue to play with the net design to discover additional possibilities. See **Figures 4.11 and 4.12**.

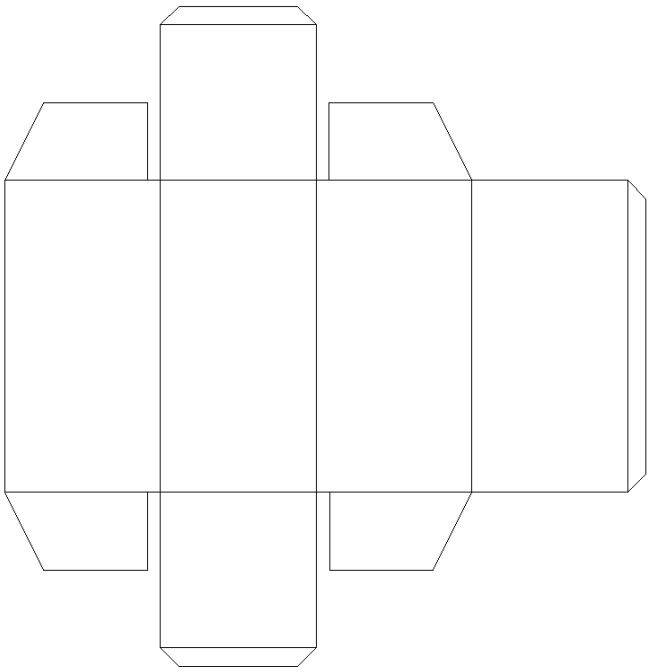

Figure 4.11

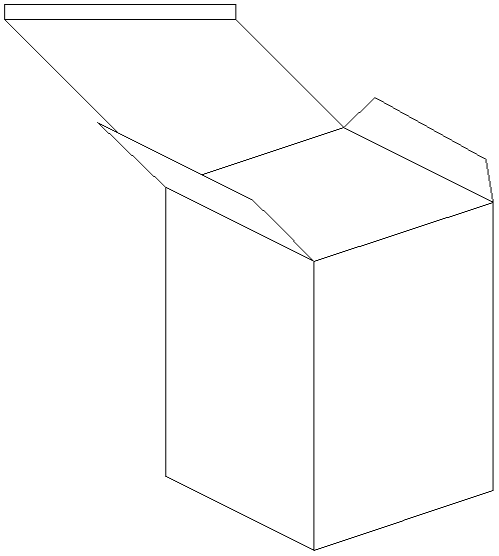

Figure 4.12

Let's Make a House!

Going from a box design to that of a simple rectangular house is not very difficult. After all, such a house would have four sides, two long and two short. But most houses have a gabled roof, and in order to accommodate this, we will have to adapt our original net for a rectangular box somewhat. **Figure 4.13** provides a sketch of the kind of a simple house design. As you can see, the gable occurs on the short sides. The longer sides of the net will be rectangles, and both of the short sides will accommodate the gable.

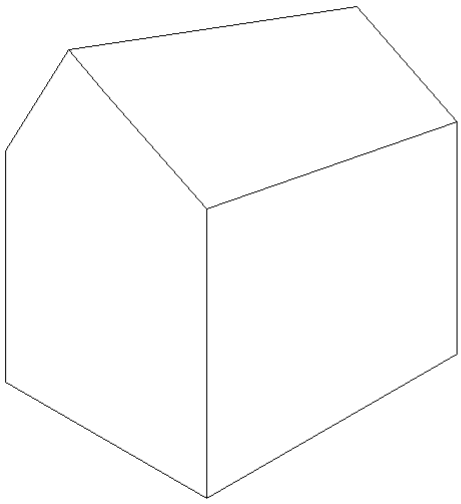

Figure 4.13

1. A good way to design this net is to draw a net for an oblong box, eliminating the top flap, as in **Figure 4.14.** In this case, sides 1 and 3 are the long sides of the house, 2 and 4 are the short sides, and 5 is the bottom.

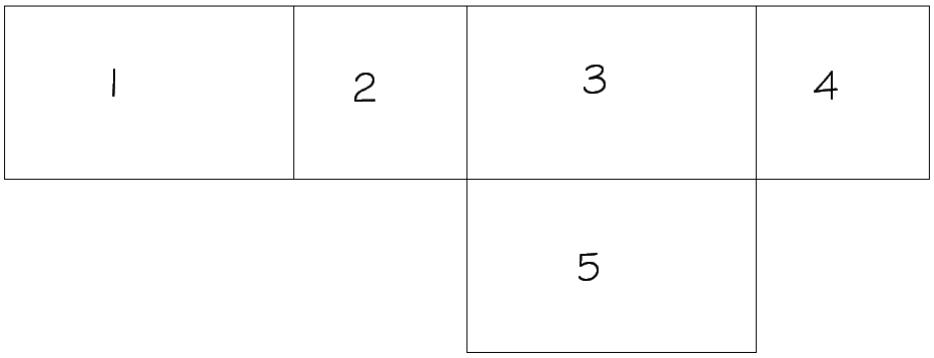

Figure 4.14

2. To create the gabled roof, we must set our compass to the desired length, depending on how steep we want our roof to be. A closer look at side 2 is provided in **Figure 4.15**, upon which we will construct a gable. Set the compass point on one of the vertices on the dotted edge of side 2. Sweep an arc above the dotted edge. Then, do the same from the other vertex. This will create the peak of the roof.

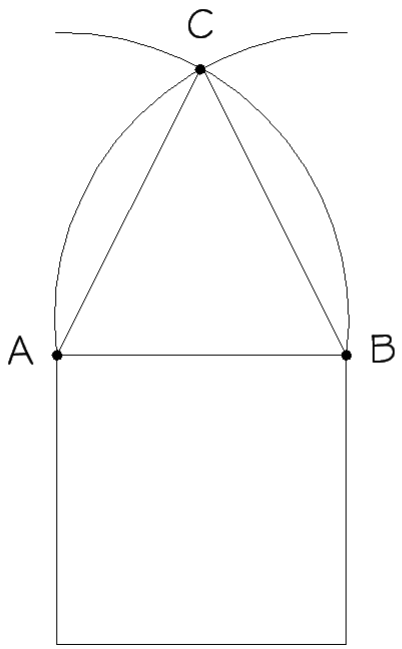

Figure 4.15

3. Connect the points creating a triangle.

4. Repeat this process from the dotted edge of side 4 to complete your house design.

5. **Figure 4.16** shows the net with "glue" tabs to secure the roof which we will create separately. The roof is made as a separate piece, since it normally overhang all sides of the house.

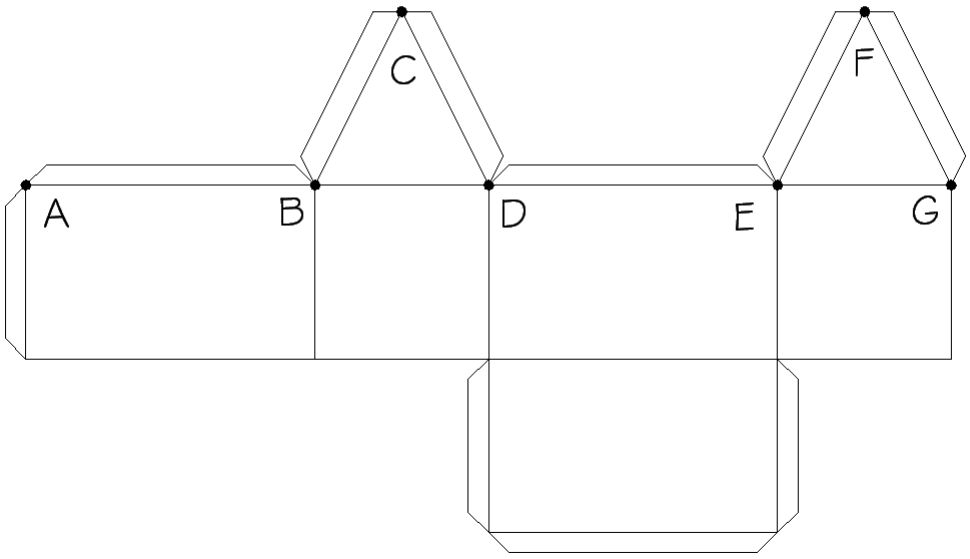

Figure 4.16

6. To make the folded roof as a single piece, measure the length of the slope of the roof gable you have designed in between points A and C, and use this measurement, along with the width of the side of the house, as your two measurements for the roof. Remember, there are two sides to a roof, so you must design two connected rectangles with a scored line between them. Remember also that the roof normally overhangs in the front, back and sides of the house, so you should add 1/4-inch or more all the way around the four sides of the two-paneled roof, as we have done in **Figure 4.17.**

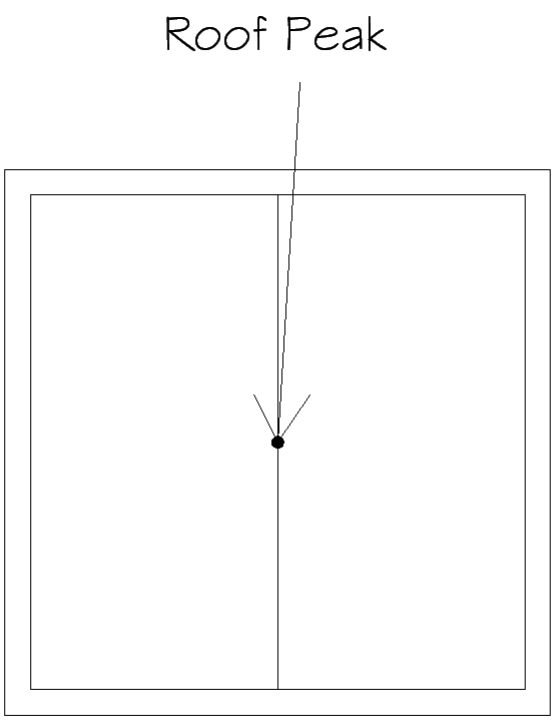

Figure 4.17

7. When completely designed, score all the inside lines of the model, cut it out, and fold it. All folds will be in the same direction as ridge folds. Glue all the tabs in place, and attach the roof.

NOTE: Attaching the roof to the in-folding tabs may be difficult, so here is a suggestion. While designing the net for the house, make the tabs on the two gable ends the same width as the roof overhang. Make tiny holes in the poster-board with your compass point at the ends of each of these lines--these will be your scoring reference points to guide your straight-edge on the opposite side. Then, when the model is cut out, fold these flaps outward and align them with the edge of the roof on all sides. Glue in place, and trim off any excess.