University of Wisconsin-Milwaukee

Drawing Supplement

For Exploring Engineering

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1. Sketching and Drawing

Engineering drawings are one of the most common tools engineers use to communicate design and technical information. Imagine trying to completely describe an object using only words. How many words would it take to describe objects you use every day from a back pack to a cell phone? Now consider how much easier it would be to describe the same objects using pictures. We use engineering drawings to describe things that in many cases do not yet exist. Finally, an engineering drawing should so completely describe an object that a skilled technician should be able to make the object without having to ask any questions.

Engineering drawings start with one or more orthographic projections[1] of the object. They consist of one or more coordinated two dimensional views of an object along with dimensions and other information. Imagine a glass box surrounding the object you wanted to describe. The box is made up of three different planes: the frontal, horizontal, and profile. Now imagine straight lines emanating from every point on the object to each side of the glass box (Figure one).

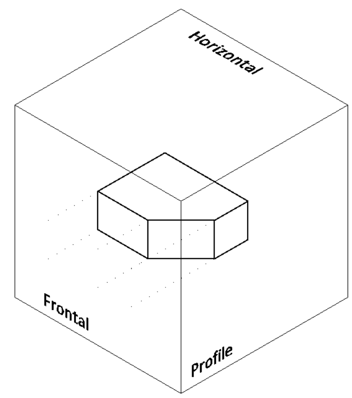


Figure 1

If you connect the ends of these straight lines, you create an orthographic view. In this view we can only see two dimensions. When looking at the front of an object, we can only see (measure) the width and height dimensions on the object as the depth dimension is perpendicular to our line of sight. We could repeat this procedure for all six sides of our box, but we will generally only use 3 views on a drawing. You will usually choose between a top or bottom view, a front or back view, and a right or left side view. Figure 2 shows the front, top and right side projections for this sample object.

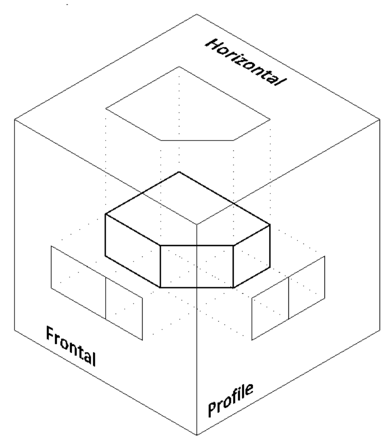


Figure 2

To create an engineering drawing of an object we will start by unfolding each side of the glass box until they lie in the same plane as the front. Each side of the glass box will be unfolded by an angle of 90^o around the line of intersection between the two sides of the box as in Figure 3.

[1] An orthographic projection is a two-dimensional graphic representation of a three-dimensional object in which the projecting lines are at right angles to the plane of the projection.

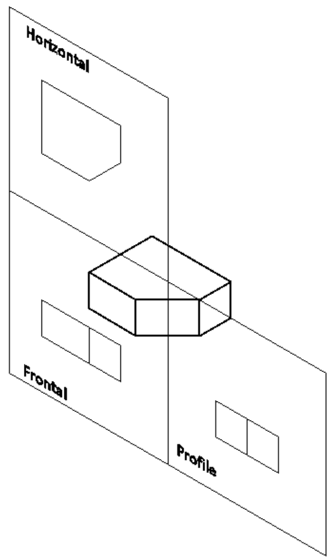


Figure 3

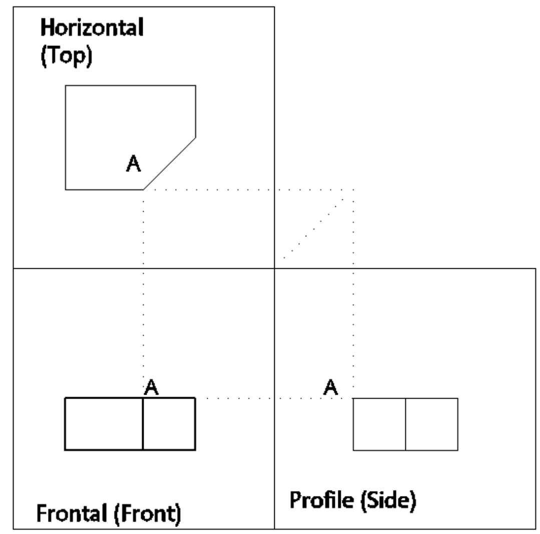


Figure 4

When we look directly at the unfolded glass box, we see the three principal views of the object (front, top, and side). We also see how the views are coordinated. Points can be projected between the front and top view using vertical lines. Similarly points can be projected between the front and side view using horizontal lines. Figure 4 shows how a single point "**A**" is located in our three principal views. When working with skilled technicians, the use of standard view positions is expected and enhances the readers' comprehension of the drawing.

2. Drawing Line Types

On an engineering drawing, different types of lines are used for different purposes. Figure 5 shows five of the most common line types we use in engineering drawings.

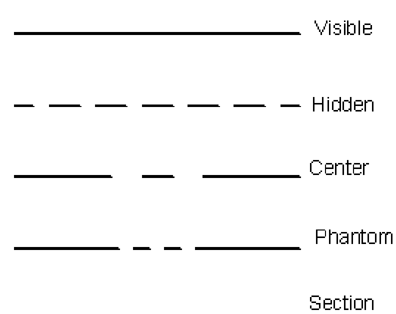


Figure 5

The most common line is the visible (also commonly referred to as the object) line. This line is drawn as a solid line about 0.7 mm in thickness. We use this line to represent edges on a drawing we can see from a given viewpoint.

The next most common line is the hidden line. The hidden line is thinner than the object line (0.5 mm approximately) and is drawn as a series of dashes. As a general rule the dashes should be about three-times longer than the spaces between the dashes. Hidden lines are used to show edges we cannot see from a given point of view.

The next most common line is the centerline. The centerline is the same thickness as the hidden line and drawn as alternating long and short dashes. The long dashes should be three to four times the length of the short dashes and the short dashes about three-times as long as the space between the dashes. Centerlines are used to show the centers of round features.

The cutting plane line is used when we create a sectional view of an object. It is a thick line (about 0.7 mm) and is drawn as a long dash followed by two short dashes with proportions similar to that of the centerline. The cutting plane line is used to show where we create an imaginary cut in the object in order to create the sectional view (more later).

Section lines are thin solid lines that are drawn about 0.5 mm in thickness. The section lines show where we have cut through solid material when creating a sectional view. Figure 6 shows the different types of lines being used in a simple drawing.

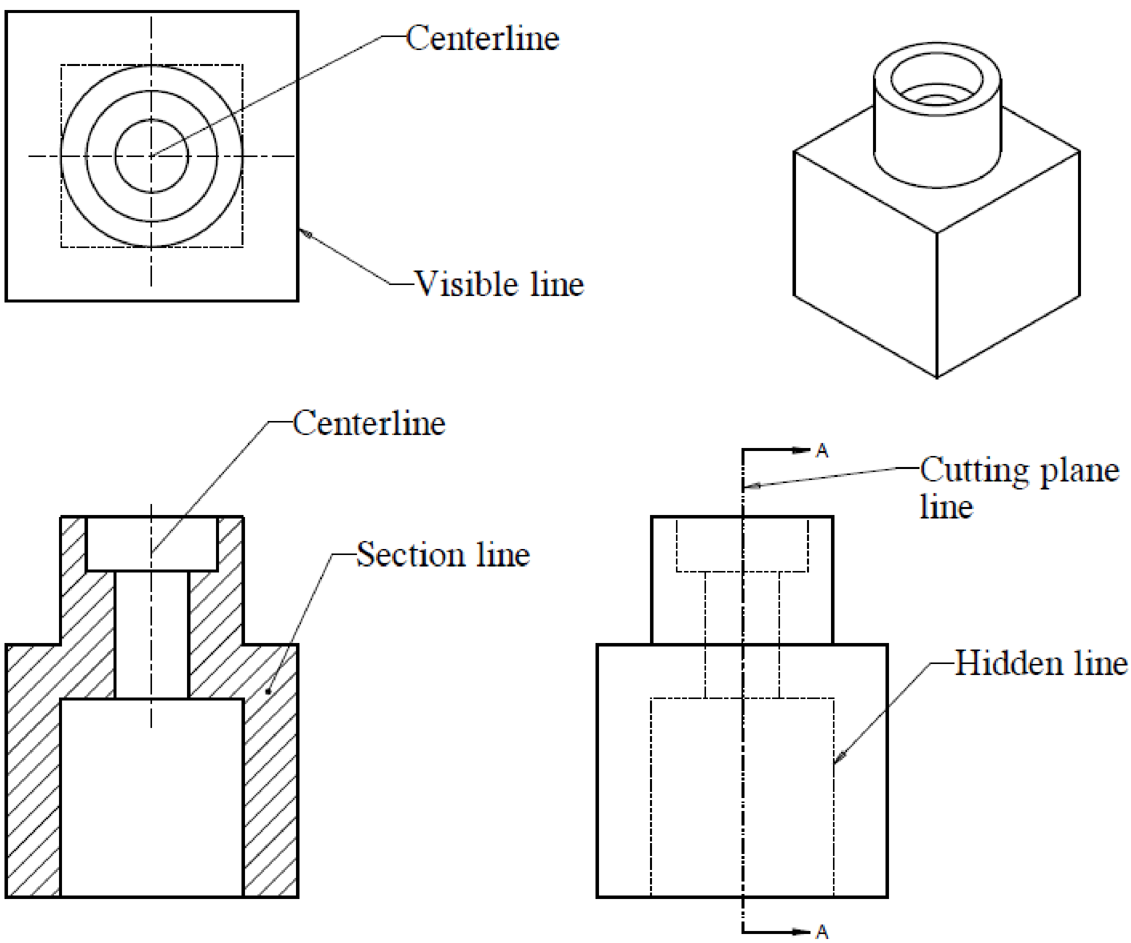


Figure 6

3. Hierarchy of Lines

There will be occasions when more than one type of line will want to occupy the same space in a drawing view. In those instances there is a hierarchy of lines that should be followed. Because the visible line shows edges we can see from a given point of view, it will always be drawn. Next because the hidden line represents actual edges on the object, it will be the second most important line. Finally, the centerline is third most important as it shows the center location for holes and other round features (see Figure 7).

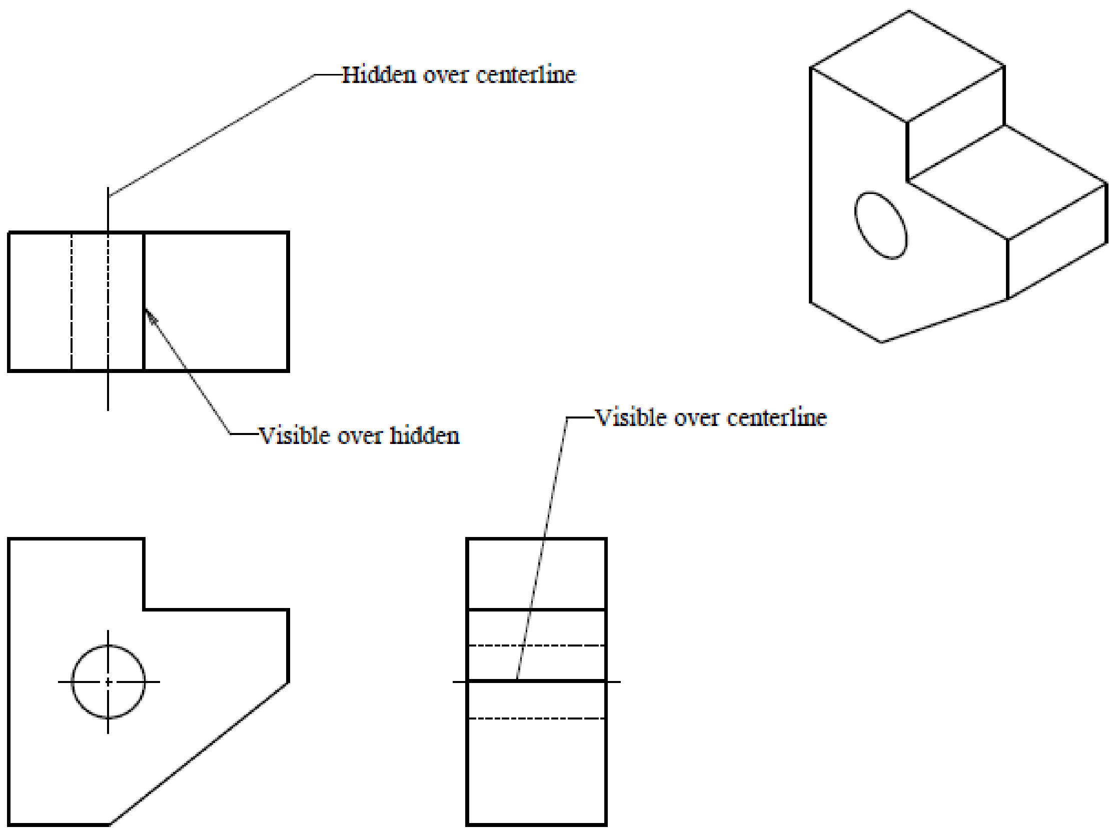


Figure 7

4. Sample Construction

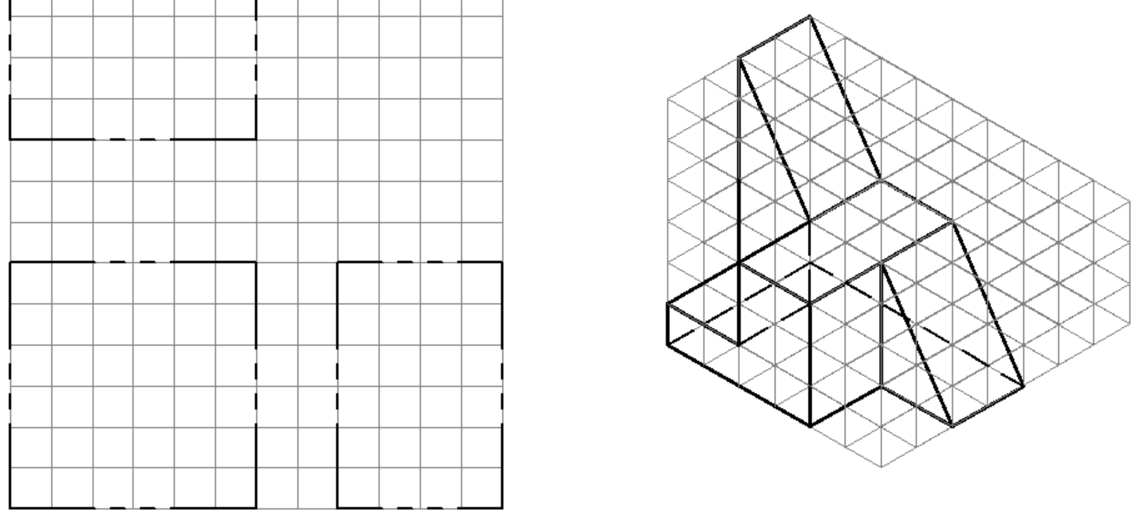


Figure 8

Let's sketch the orthographic views of a simple object shown in Figure 9. When drawing (sketching) orthographic views, you want to try to work systematically. Doing so will help reduce the likelihood of missing lines in the drawing. Our first step will be to lightly sketch boxes that will give the overall size of each orthographic view in their appropriate positions. For the front view we will create a box 6 unit wide by 6 units high; for the side view the box will be 6 units high by 4 units deep; and finally for the top view the box will be 6 units wide by 4 units deep.

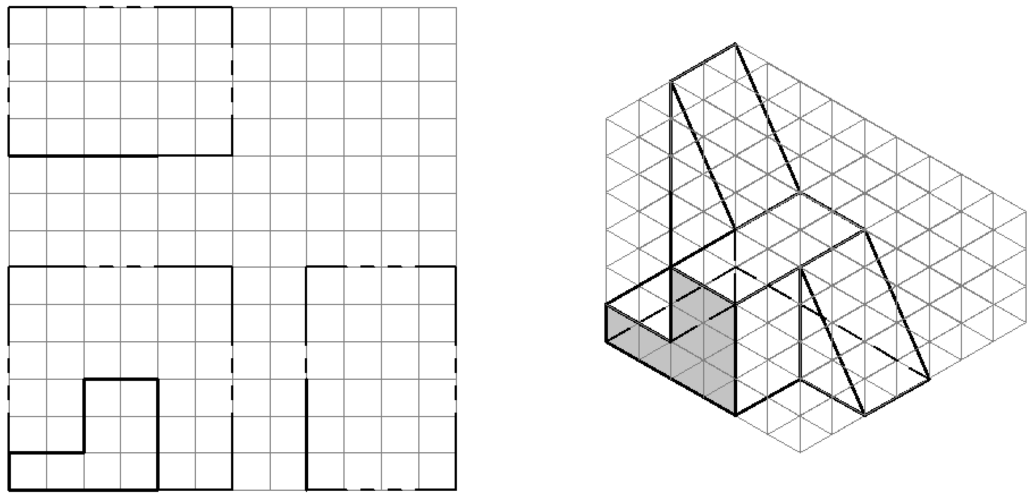


Figure 9

Next we will sketch individual surfaces in all the views. Remember that surfaces will look different in different views. Consider the front most surface on the object. When we look at the front of the piece, we will see the backwards “L” shape. However, since the points on this surface are all at the same depth, in the top and side views the surface will appear as an edge.

Working from the front to the back, lets sketch in the 2x8 unit horzontal surface next. Since all the points on this surface are at the same height, Figure 10 shows the retangular shape in the top view and horizontal lines in both the front and side views.

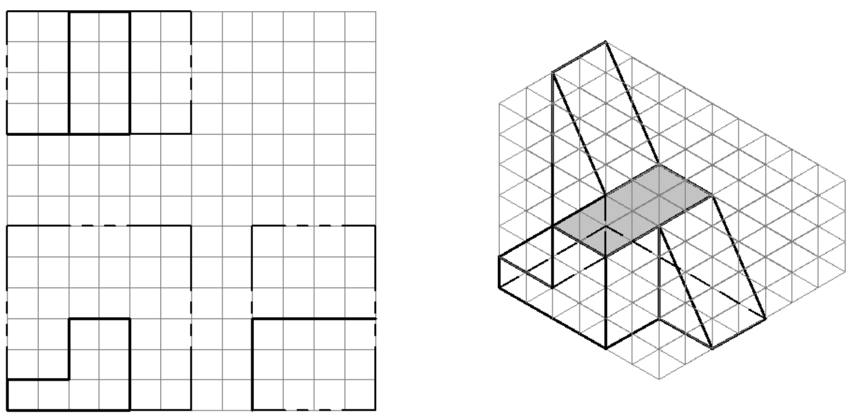


Figure 10

Also right off the front of the object is the 2x2 square that is one unit up from the bottom. Like the previous surface it will appear as a square in the top view and as a line in the front and side. However, since this surface wouldn’t be visible when looking at the object from the right side, in the side view we will sketch it as a hidden line as shown in Figure 11.

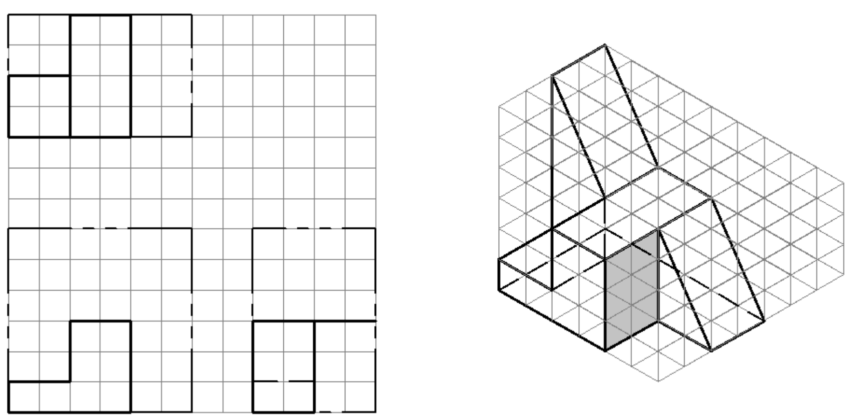


Figure 11

Continuing on our way toward the back of the object, the next surface we encounter is the 2x3 rectangle 4 units to the right from the left side of the object. Since all the points on this surface are at the same width, this surface will appear as a rectangle in the side view and as a vertical edge in both the front and top views as shown in Figure 12.

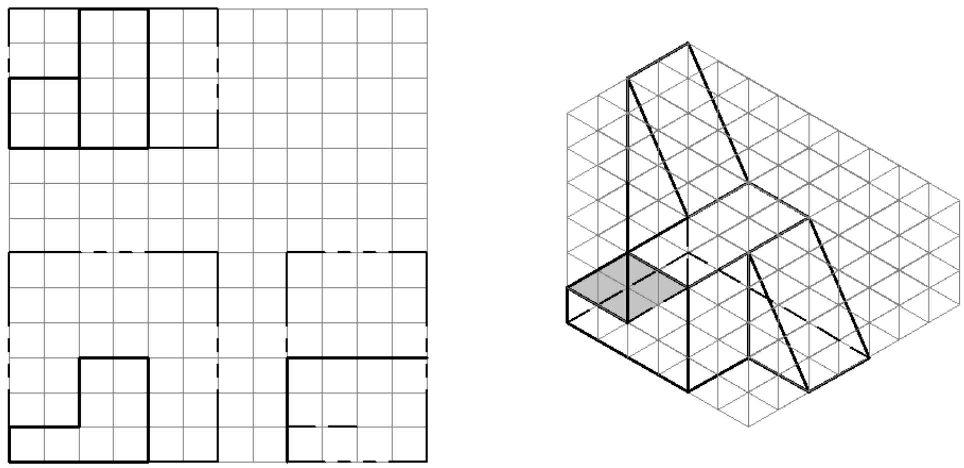


Figure 12

The next surface we will sketch is the truncated rectangle on the left side 2 units back. Like the first surface we sketched, we will see the truncated rectangle in the front view, a horizontal edge in the top view and a vertical edge in the side view. Part of the side view will be blocked from our sight, so it should be drawn as a hidden line. However, since this portion of a hidden line will take up the same space as one of the visible lines we just sketched in, we will keep the visible line on the sketch and not add the hidden line (see Figure 13).

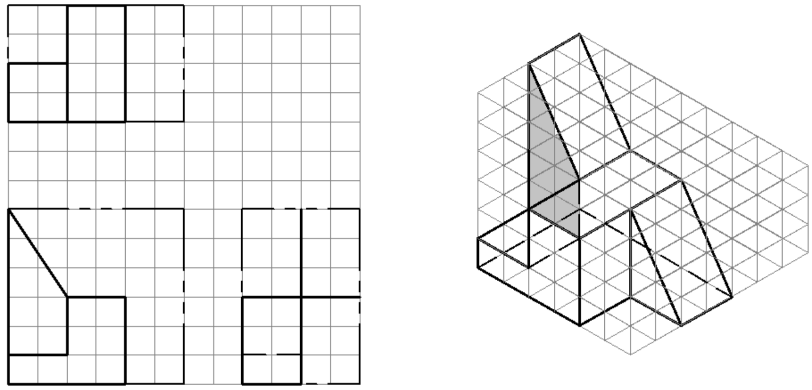


Figure 13

The last of the horizontal or vertical surfaces on the part is the triangle located on right side of the part. We will see this surface's triangular shape in the front view and it appears as a horizontal edge in the top view and a vertical edge in the side view, as in Figure 13. You should notice that you won't have anything to sketch in the side view, as the edge is coincident with lines we've already added sketched.

Our next two surfaces are different from the first surfaces we sketched in that they are not horizontal or vertical. These surfaces are at an angle to both the horizontal (top) and profile (side) planes. When we sketch these surfaces we will see a foreshortened (smaller than actual size) surface in the top and side views and an angled edge in the front view (see Figure 14).

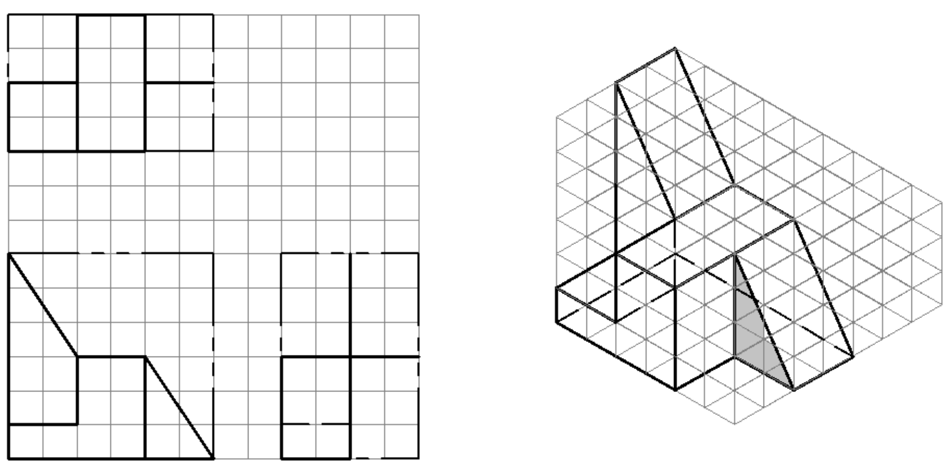


Figure 14

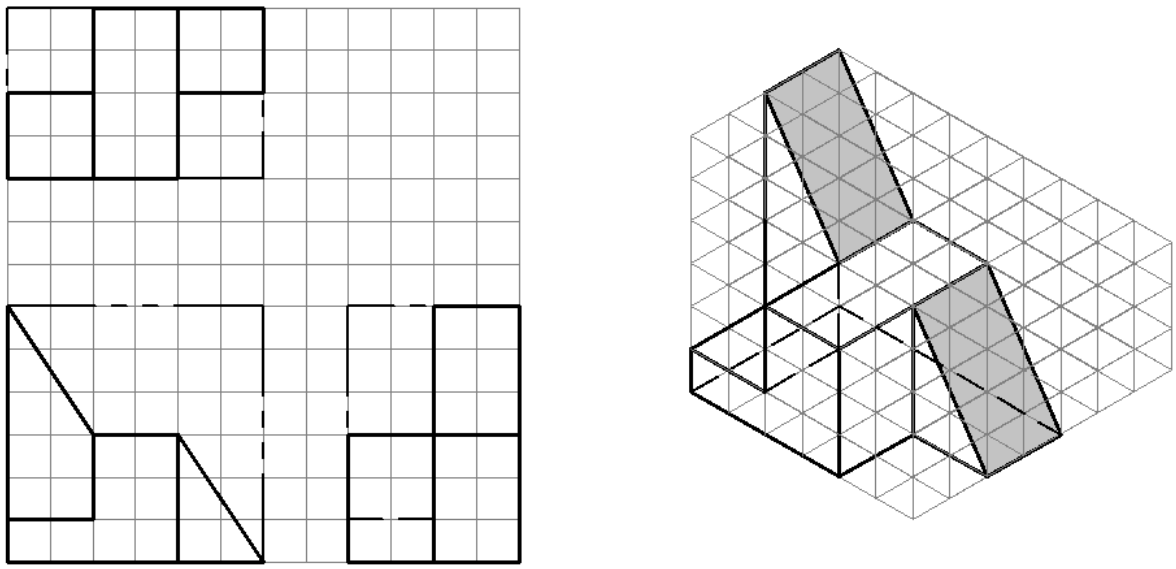


Figure 15

To finish up the sketch we erase any light construction lines.

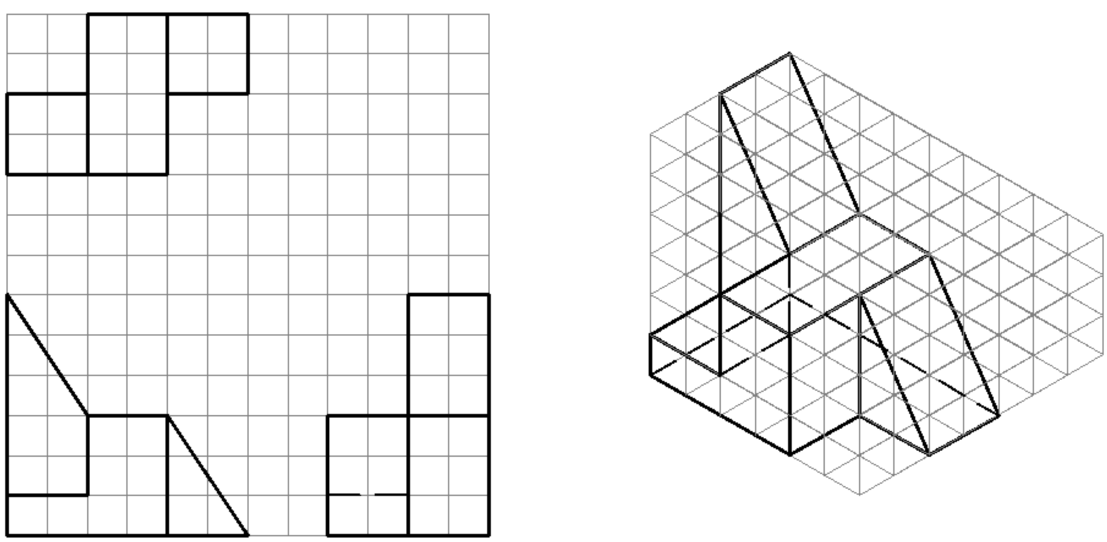


Figure 16

Here is a the blank copy you can use to work along with this example

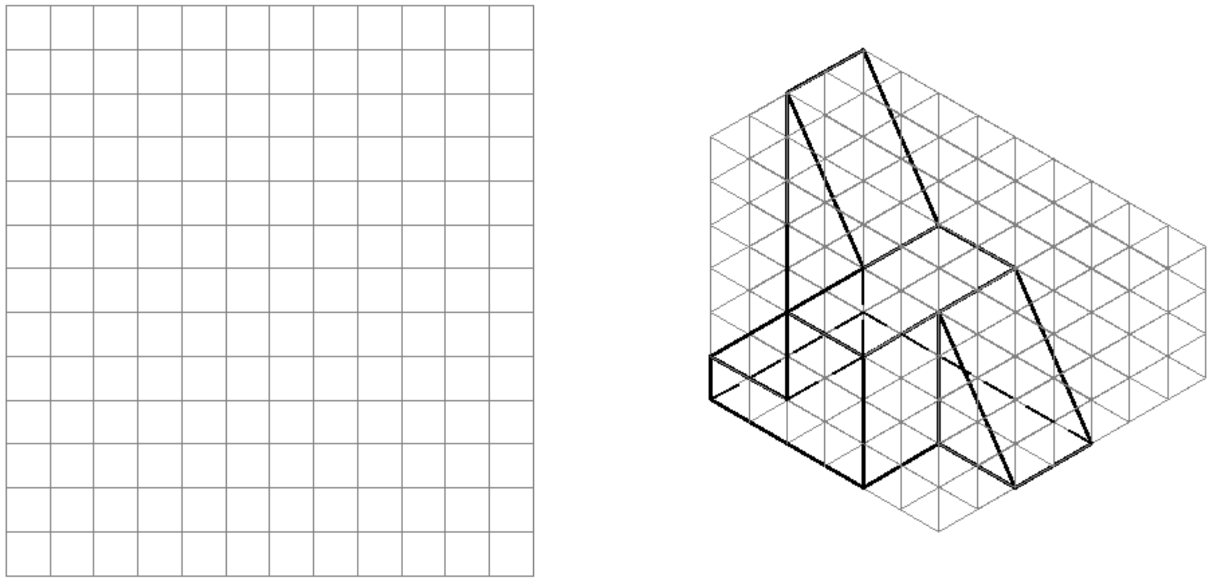


Figure 17

5. Sample Construction 2: Including curved elements

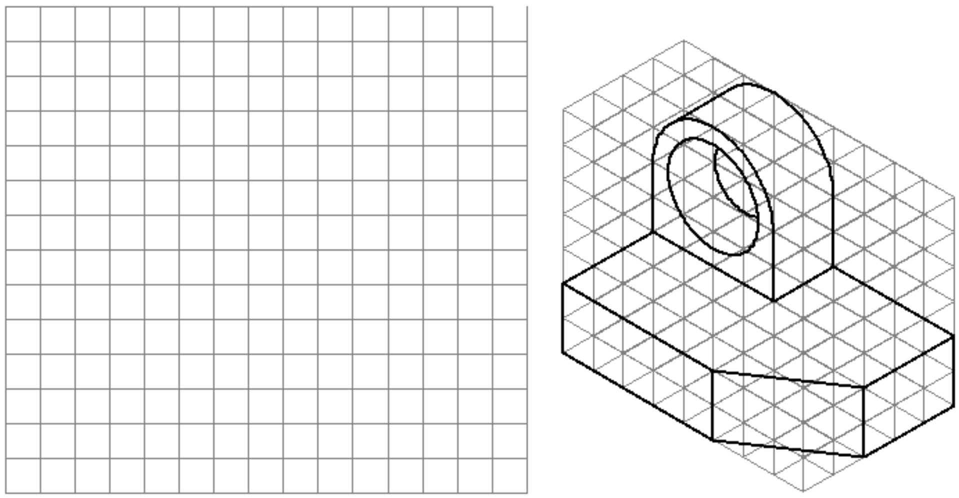


Figure 18

In addition to flat planar surfaces, objects we draw will also include curved surfaces. The most common curved surfaces include the cone, cylinder, torus and sphere. These pieces of geometry are often referred to as single curve surfaces. They are generated by moving a single curve, called an element, along a defined path in space (often a circle or ellipse). For example, a cylinder can be thought of as being generated by moving a straight line around a circular path, a cone as a angled line moved about a circular path, and so forth. There are then an infinite number of “elements” in any single curve surface. For the purposes of creating engineering drawings and sketches, we just draw the elements that define the boundaries, or limits, of the surface in a given view.

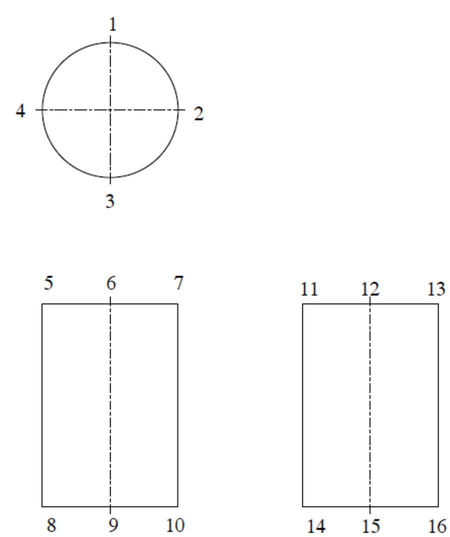


Figure 19

Consider the simple cylinder shown in the Figure 19. If we project the lines 5-8 and 7-10 that define the limits of the front view to the top view, they line up with points 2 and 4. If we take the lines 11-14 and 13-16 from the side view and transfer their location to the top view, we see they coincide with points 1 and 3 respectively.

When dealing with complete surfaces, this distinction is not that important. However, when we make cuts into the curved surface or combine it with other surfaces (either curved or planar) this becomes very important. Let's add a simple cut to our cylinder. In the Figure 20 we see that the angled surface defined by the points ***a*** and ***b*** in the top view is defined by points c-f in the front view and g-j in the side view. Just as importantly, notice the points 6 and oneone move down to the bottom of the cut.

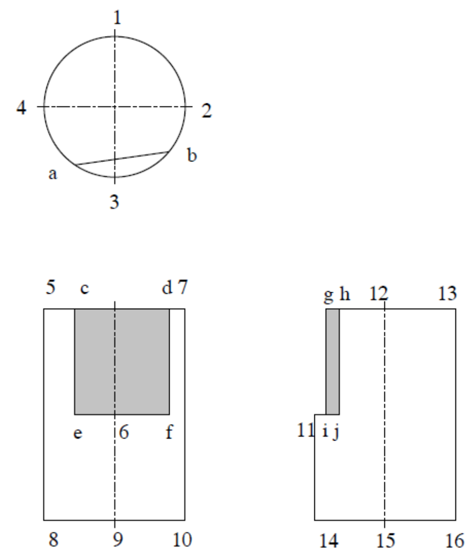


Figure 10

Let's create a 3 view sketch of the object in Figure 21 that includes some curved surfaces. In the figure above we have a prismatic base and a semi-circular upright that contains a counter-sunk hole (a cylinder intersected with a cone). We start as we did in the first example, by laying three boxes that define the overall size of each view in their appropriate positions as in Figure 22.

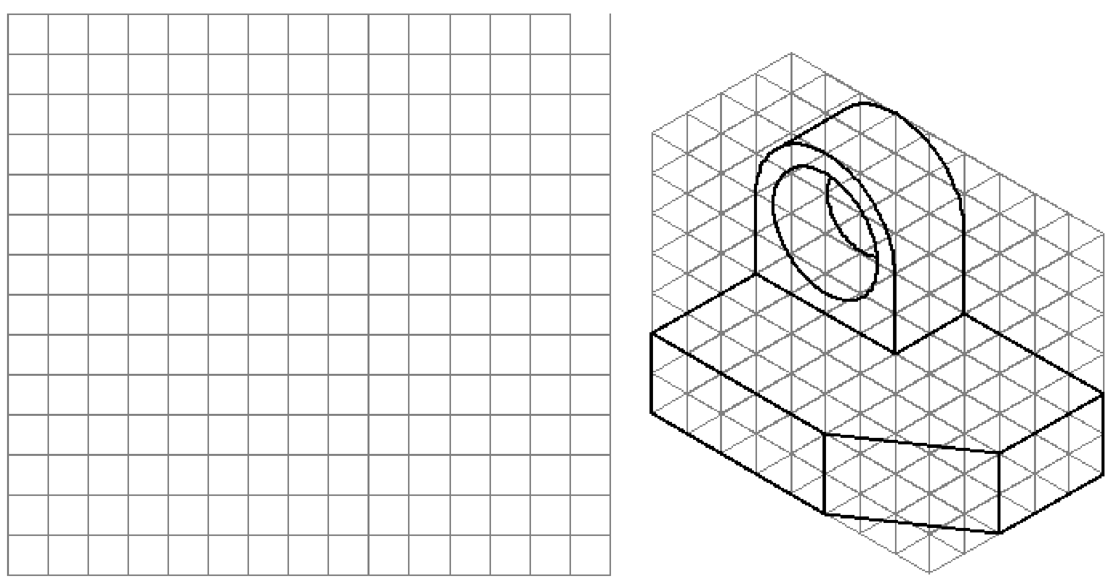


Figure 21

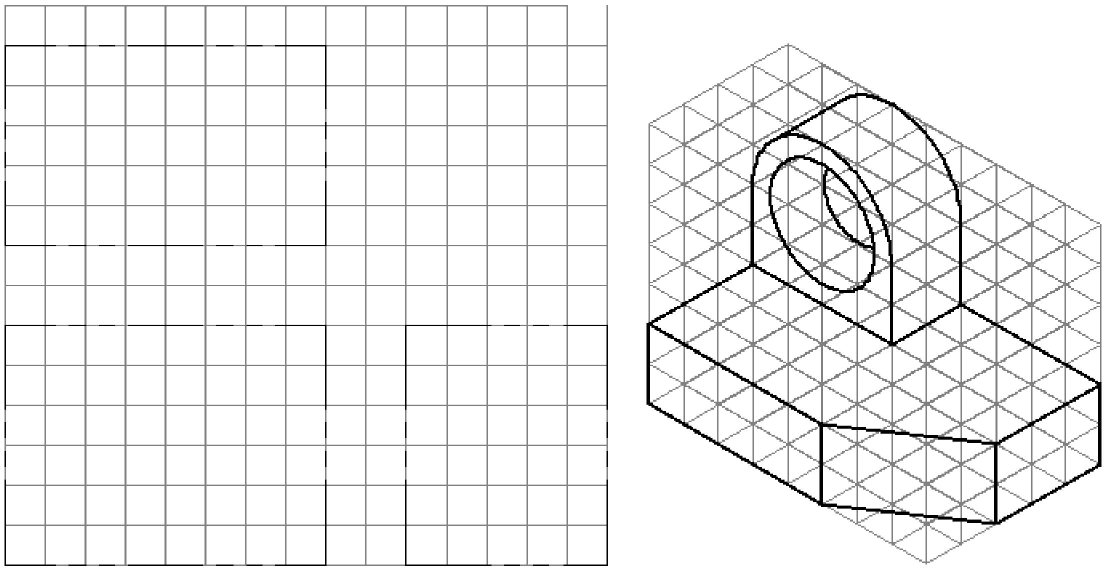


Figure 22

Using the same procedure that we used with the first example, you should be able to draw the top, front and side views of the prismatic base of this object as in Figure 23.

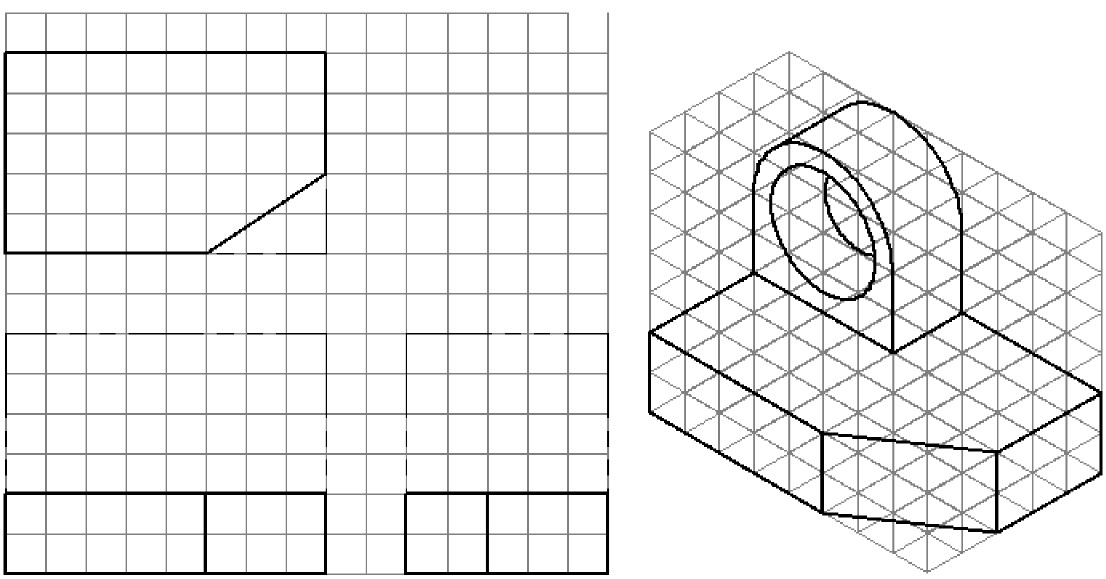


Figure 23

When developing the views of the curved upright, we again use the same techniques as in our first example. The front most face on this portion of the object appears as a horizontal edge in the top view, a vertical edge in the side view, and we will see the shape in the front view as in Figures 24 and 25.

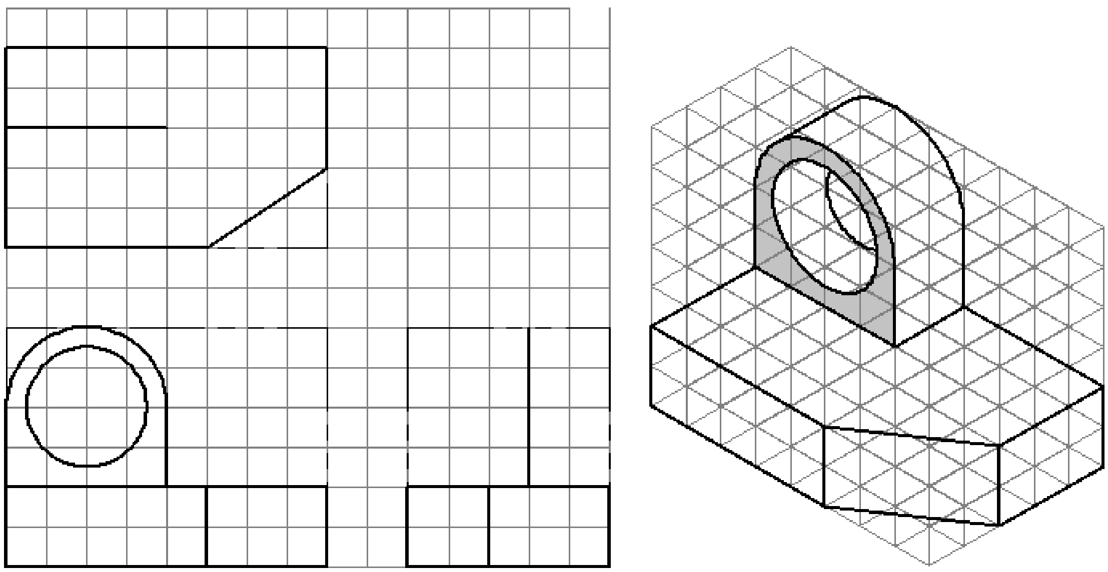


Figure 24

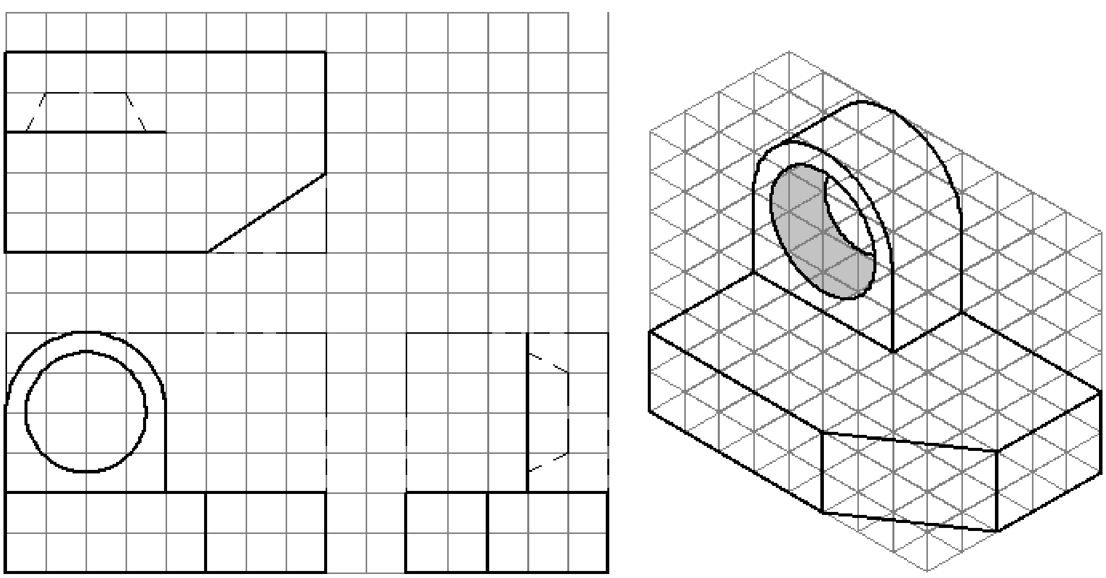


Figure 25

As we move back along the feature, the next item we will encounter is the conical portion of the countersunk hole. Hidden angled edges will define the outline of this feature in the top and side views.

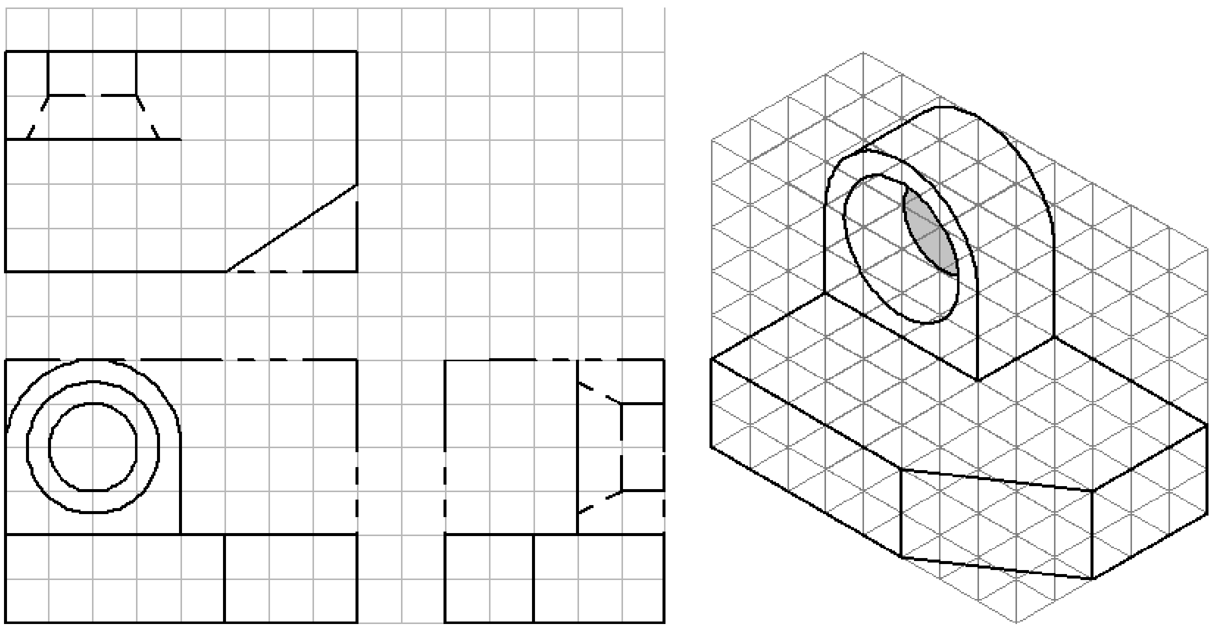


Figure 26

In the front view in Figure 26 we see a circle that is concentric to the outer circle and the "base" of the conic. This circle is coincident (concentric) with the cylinder portion of the countersunk hole. The limiting elements of the hole are shown as parallel horizontal lines in the side view and parallel vertical lines in the top view.

To finish this feature we need to represent the outer curved surface. Like the simple cylinders discussed earlier, the outer surface will appear as a rectangle in both the top view and side views. Notice that in the side view of Figure 27 we do not include a line between the planar vertical face and the semi-cylindrical part. As a general rule, when a curved surface meets another surface (whether curved or planar) and is tangent to that surface, we do not show a line of intersection between the surfaces. The idea is to communicate the "smooth" transition between the two surfaces.

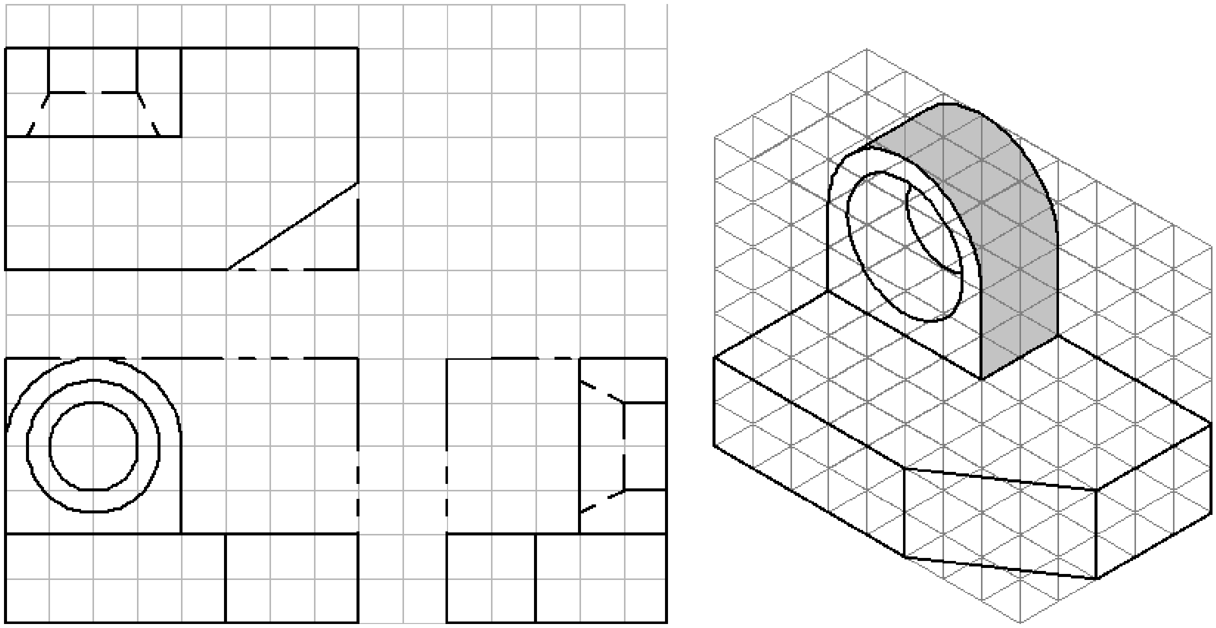


Figure 27

6. Pictorial Sketching

While engineers will use orthographic drawings and sketches to communicate highly technical information, they will also use pictorial sketches, drawings (and yes CAD models) to communicate quickly with a wider audience. The two most common types of pictorial sketches engineers use are the oblique and isometric. In general, a pictorial drawing will try to emulate three dimensions on a two dimensional medium (a sheet of paper or computer screen for example) by having angled lines representing one or more dimensions going into the page.

Figure 28 shows an example of both an oblique box and an isometric box. With the oblique box the depth dimension is shown going into the page along the angled lines. The height is shown with vertical lines and width with horizontal lines. In the isometric box we see that both the depth and width dimensions are shown along angled lines while the height is shown along vertical lines.

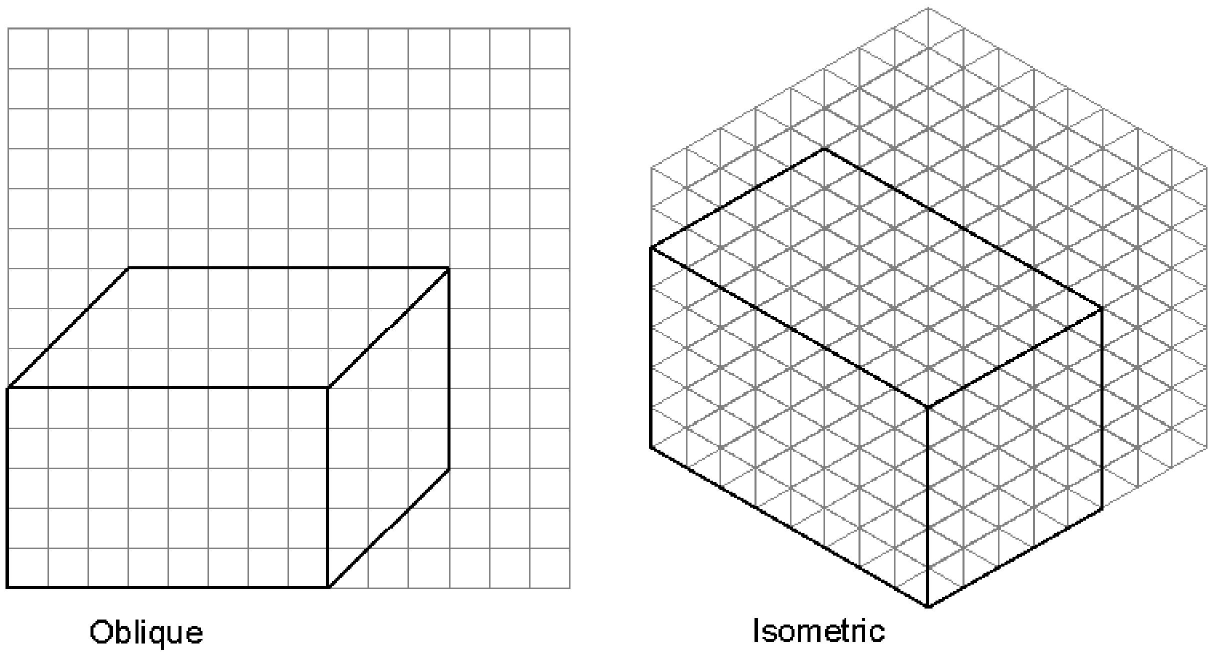


Figure 28

7. Oblique Sketching

An oblique sketch is a quick way to get an idea onto paper quickly. With only one dimension going into the page, oblique sketches are generally quicker to make for two reasons. First, oblique sketching lends itself to the use of readily available rectangular grid graph paper. Secondly, if we can

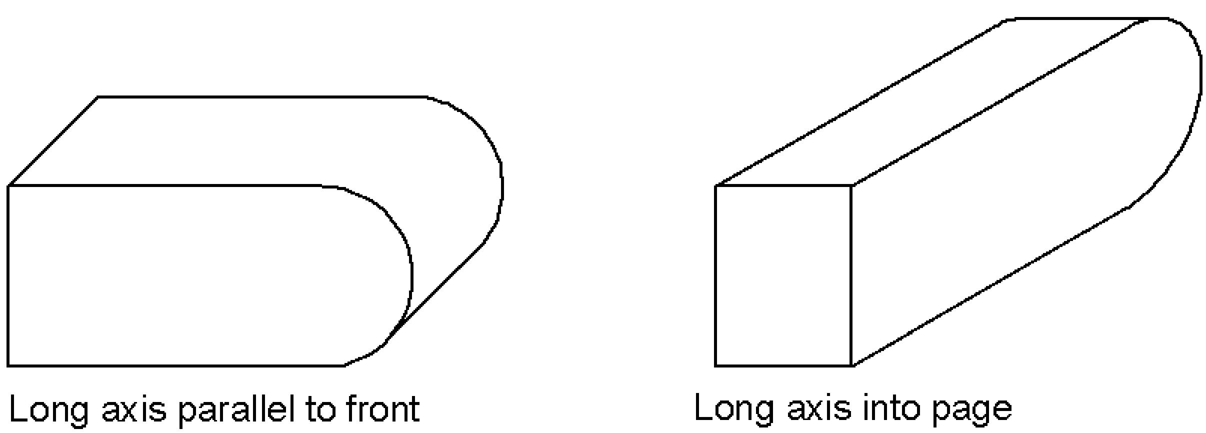


Figure 29

keep round features parallel to the front face, we can sketch them as circles instead of ellipses. Figure 29 shows 2 oblique pictorials on the left we see the long axis and round features parallel to the frontal plane; on the right we can see the distortion that occurs when these features are drawn along the receding axis.

There are two ways we can minimize the amount of distortion we see in an oblique drawing. The first is to vary the angle of the receding axis. The second is to change the scaling along the receding axis. In Figure 30 we see three oblique cubes drawn using three different scales along the receding axis.

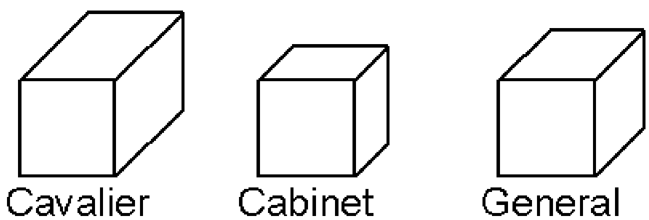


Figure 30

The leftmost cube shows a "cavalier" oblique and has the depth at full scale along the receding axis. This type of drawing will tend to over exaggerate features parallel to the top and side and is most often used when sketching objects with a relatively small depth dimension. The middle oblique is a "cabinet" oblique. In this type of drawing, the scale along the depth axis is ½ of the scale of the other two. The rightmost picture is a "general" oblique. The general oblique will use a scale somewhere between ½ and full. In the example above, we are using ¾ scale on the depth axis. The general is commonly used with drawings where the overall dimensions are about the same.

The other technique we have to minimize distortion in an oblique drawing is to vary the angle of

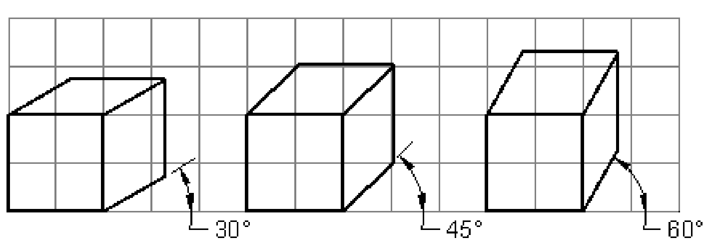


Figure 31

the receding axis. Figure 31 shows our cube drawn as a general oblique (¾ scale) using angles of 30°, 45°, and 60° along the receding axis. Notice that as the angle of the receding axis increases, the emphasis shifts from the side features to the top features. When using the 45° angle, we will then show about the same amount of detail on the top and side surfaces.

8. Oblique Sketching Example

In our first couple of examples we sketched orthographic views of an object using a given pictorial view. In this example we will sketch an oblique pictorial using the information given in the top and front views of an object as shown in Figure 33.

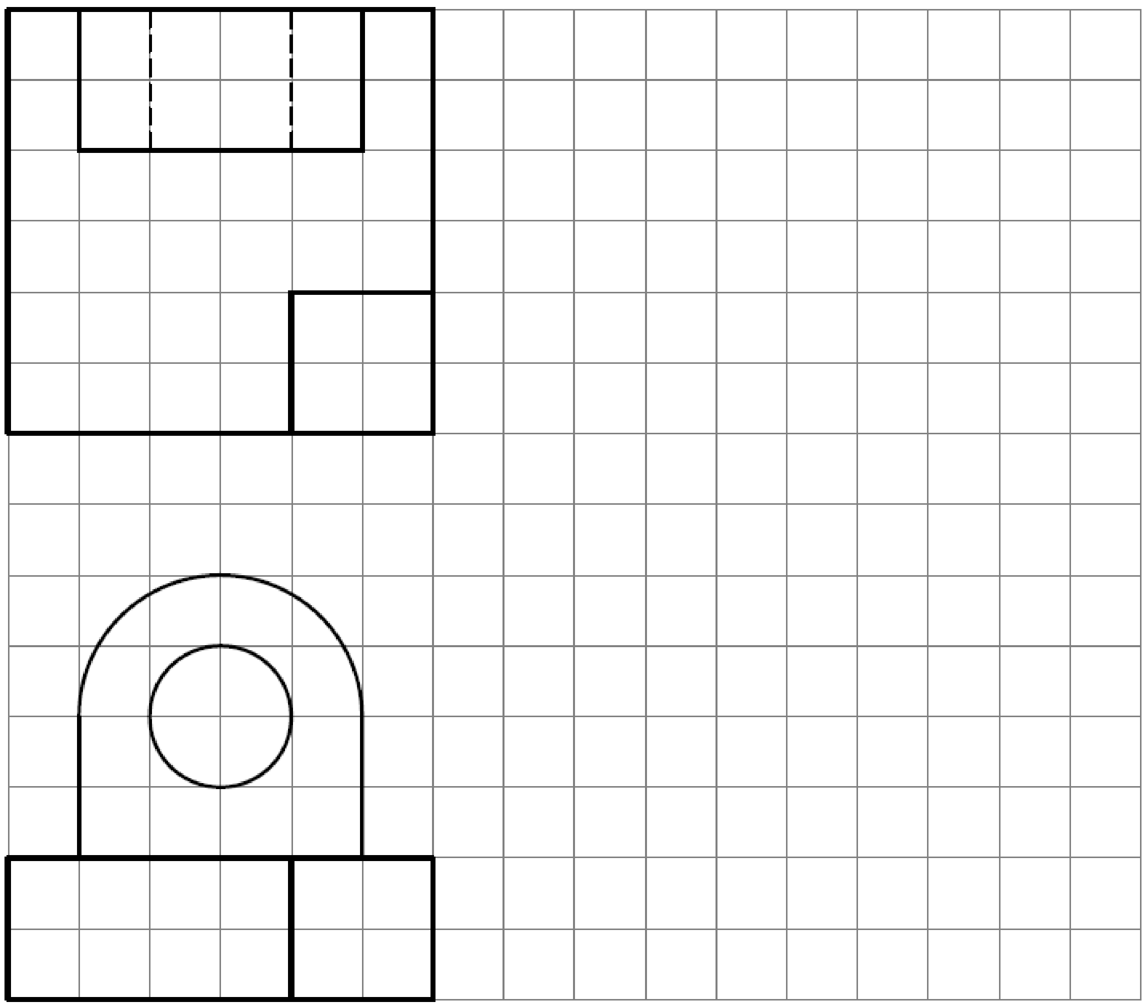


Figure 33

Like our previous examples we are going to start by sketching an oblique box that should completely enclose our final view. Examining Figure 33 we see that our object is 6 squares high by 6 squares wide by 6 squares deep. Based on our earlier discussion, we would want to draw this object as a general oblique. When sketching on graph paper, you can use a quick math trick to sketch a general oblique. What we do is divide the depth distance by 2 and then use that many diagonals along the receding axis. Since each diagonal is the $\sqrt{2}$ times the side length of each square, we end up with a scale factor $\sqrt{2}/2$ (~70.7%) along our receding axis. Remember, sketch this square lightly so it will be easier to erase when we are finished (Figure 34).

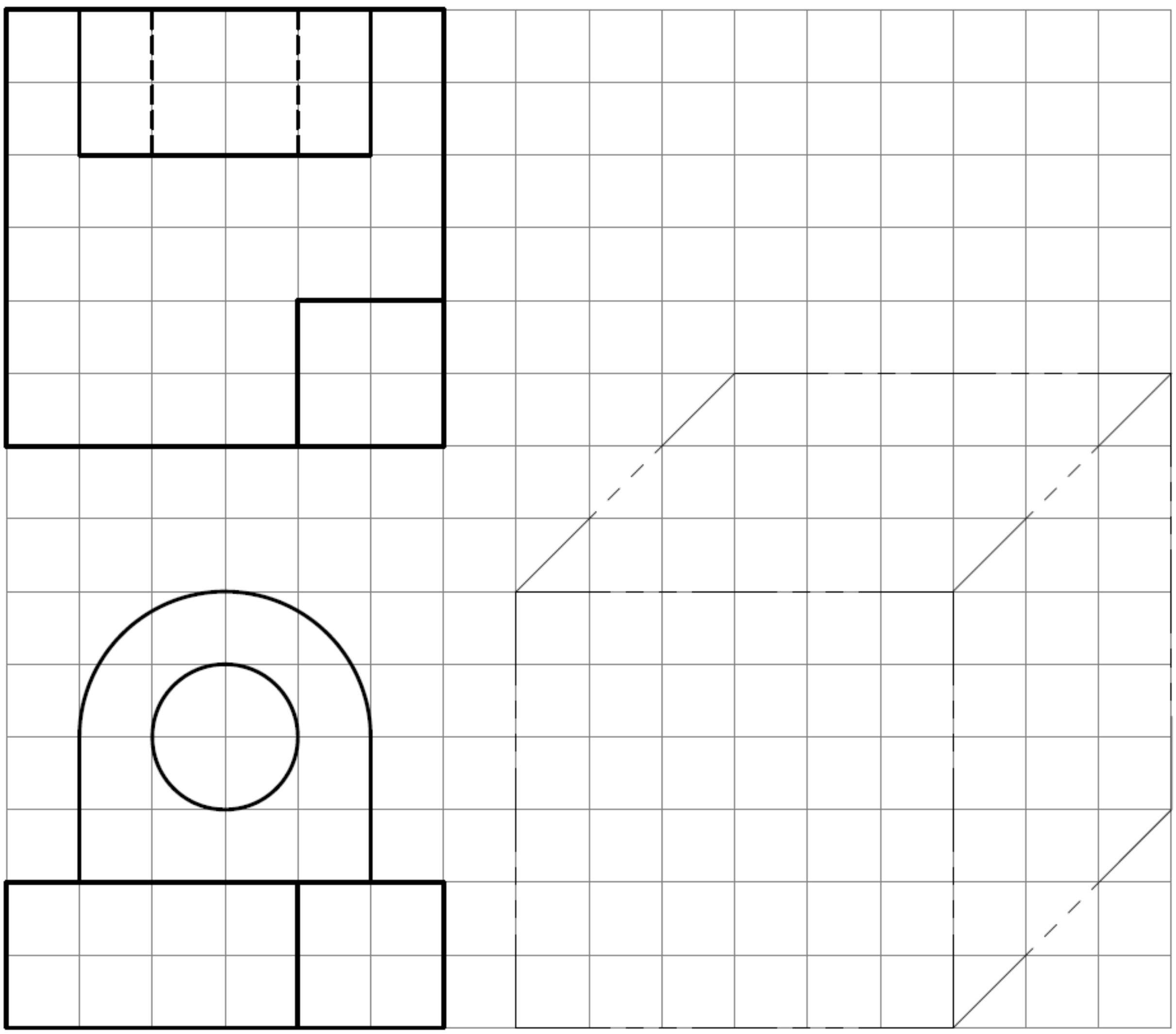


Figure 34

Like our orthographic drawings we want to approach sketching pictorial views in a systematic way. Let's start with the 4x2 rectangle in the lower left corner of the front view (Figure 35). If we project the width of this rectangle to the top view, we will see that it is on the very front of the object. Therefore we can sketch a rectangle 4 squares wide by 2 squares high on the front of our oblique box.

As we keep moving from front to back on the object, the next feature we come across is the 2x2 box we see in both the front and top views. This surface is at an angle to both the front and top views of

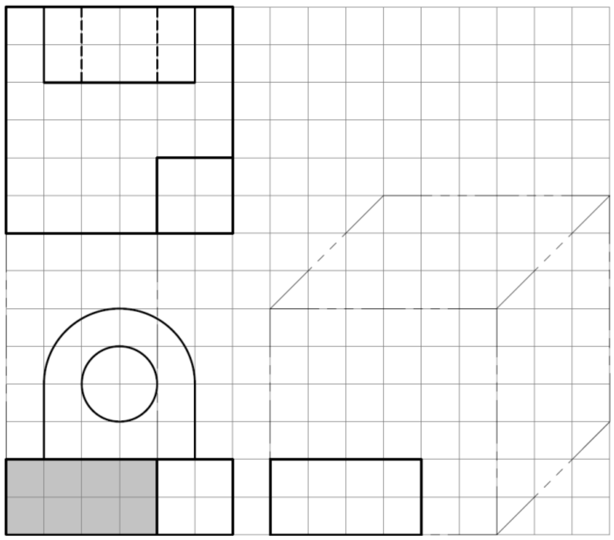


Figure 35

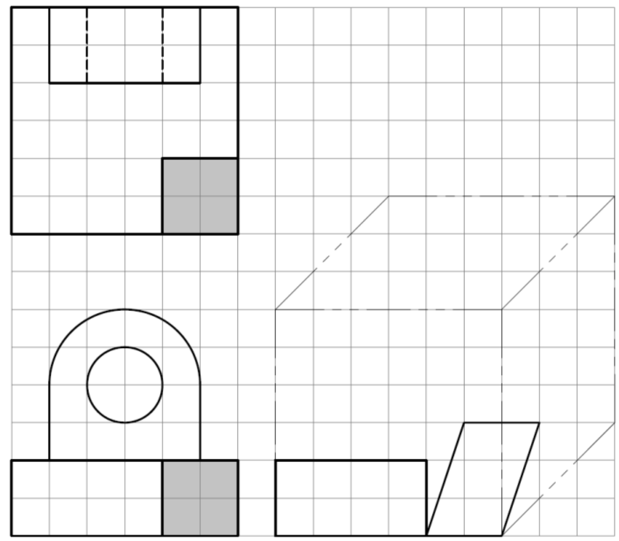


Figure 36

the object. Its front edge is on the bottom of the part. The upper edge is 2 squares up and 2 squares back from the front. So in our oblique view we will sketch this edge 2 squares up and one diagonal back (Figure 36).

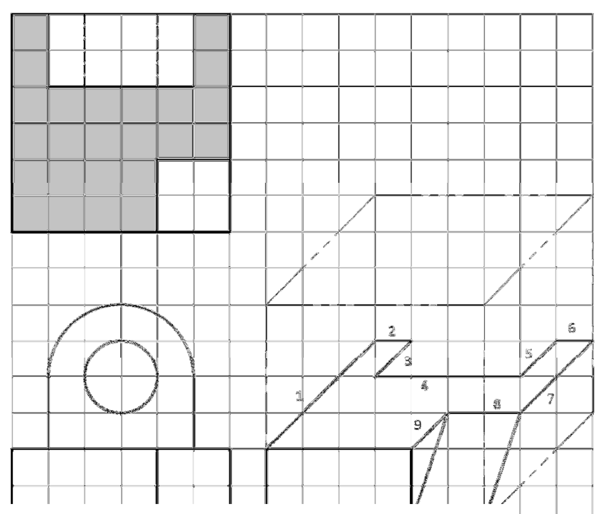


Figure 37

Next we can deal with the large irregular surface in the top view. Once again projecting the points on this surface to the front view we see that the surface is horizontal. To sketch this surface starting at the upper left corner of the first rectangle we sketched we:

1. Go back 3 diagonals
2. Go to the right one square
3. Go forward one diagonal
4. Go to the right 4 squares
5. Go back one diagonal
6. Go to the right one square
7. Go forward 2 diagonals

8. Go to the left 2 squares (already there)
9. Go forward one square (Figure 37)

As we continue to work our way back along the part, the next feature we encounter is the vertical upright with the semi-circular top. Since the round features are parallel to the front face of the object, we will be able to draw them as circles. The base of this feature has already been sketched in step 4 from above. When we add this feature it overlaps with the lines drawn in steps 2 and 3. Since the objective of a pictorial view is to show how something looks, *we will not use hidden lines* when drawing/sketching pictorial views (Figure 38).

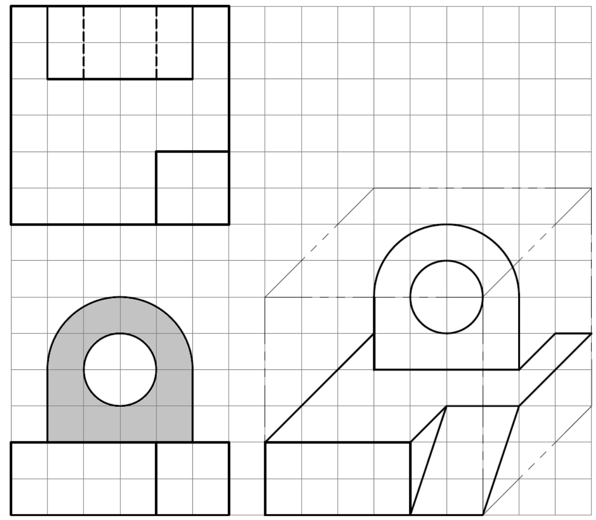


Figure 38

The next feature to add to our sketch is the back of the vertical upright. Portions of this feature will be visible while others will not. A good starting practice is to sketch the entire feature lightly and then darken in just the visible feature. Looking at Figure 39, we can see how much of the back surface is visible and that we are able to see a little of the back of the hole.

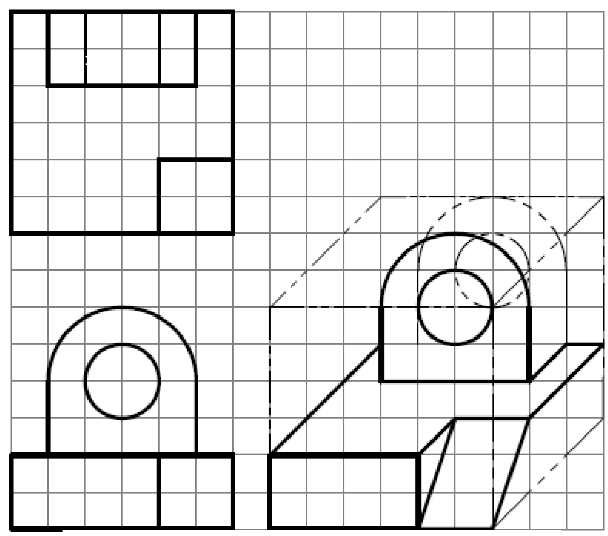


Figure 39

Next, darken in the portions of the lines and arcs we can see from Figure 39, add a tangent line between the front and back arcs, and darken in the two lines to complete the left side of the part (Figure 40). Finally we erase the bounding box and any other construction lines left on our drawing.

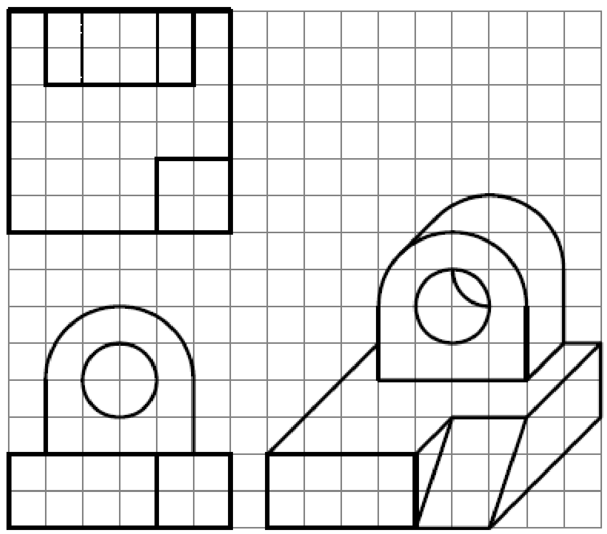
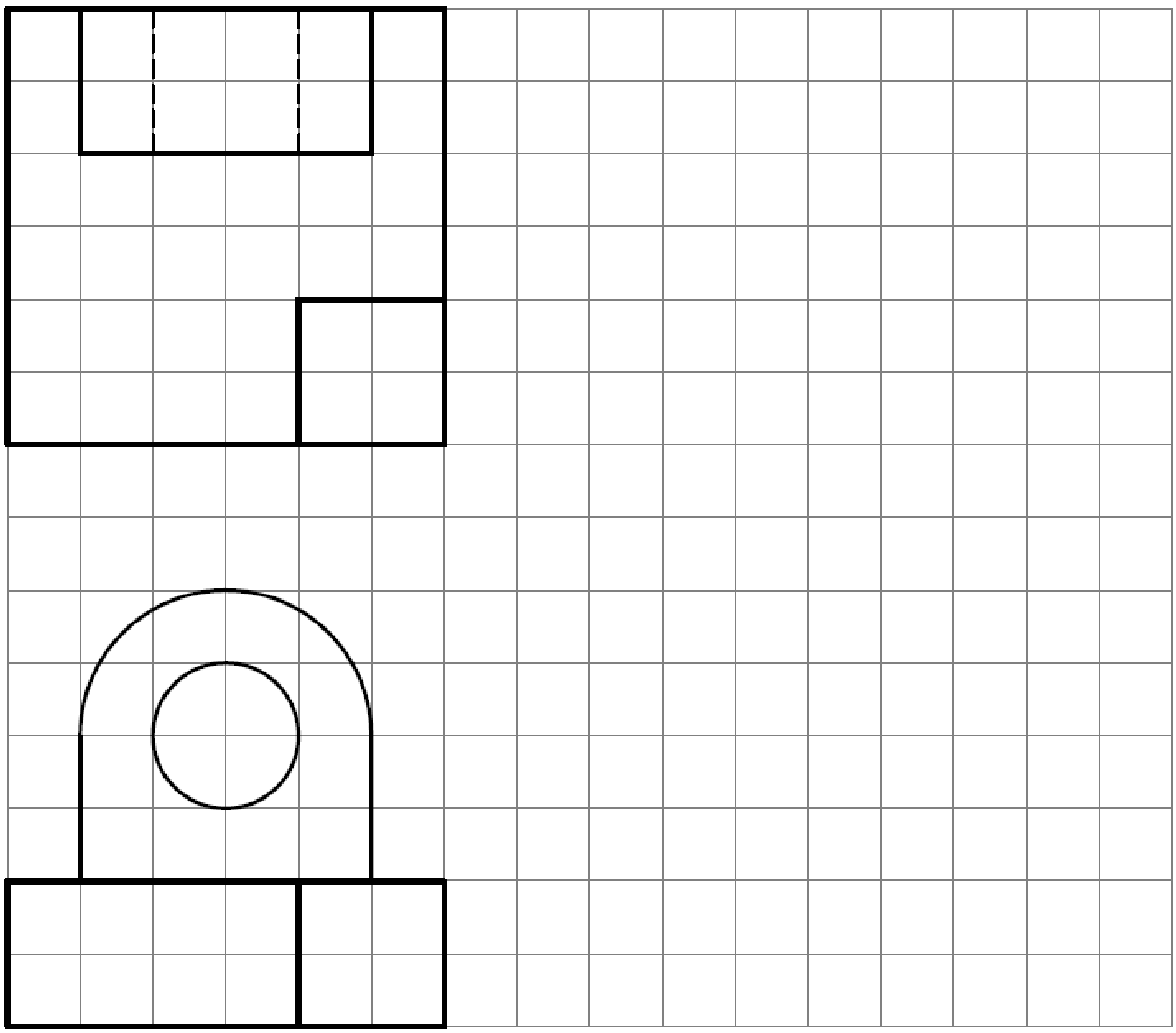


Figure 40

Here is a the blank copy you can use to work along with this example



9. Isometric Sketching

The other common pictorial sketch engineers regularly make is the isometric. The isometric drawing is actually one type of a drawing from the category called axonometric. This type of drawing shows 2 dimensions (width and depth) along angled lines. The different types of axonometric drawings are the isometric, dimetric and trimetric (Figure 41). These drawings are differentiated by the angles used for the receding axes. In an isometric the angles between the three axes are all equal (iso is the Greek prefix for equal). In the dimetric there are two equal angles and one is different (di is the Greek prefix for two). In the trimetric all three angles between the axis are different (tri is the Greek prefix for

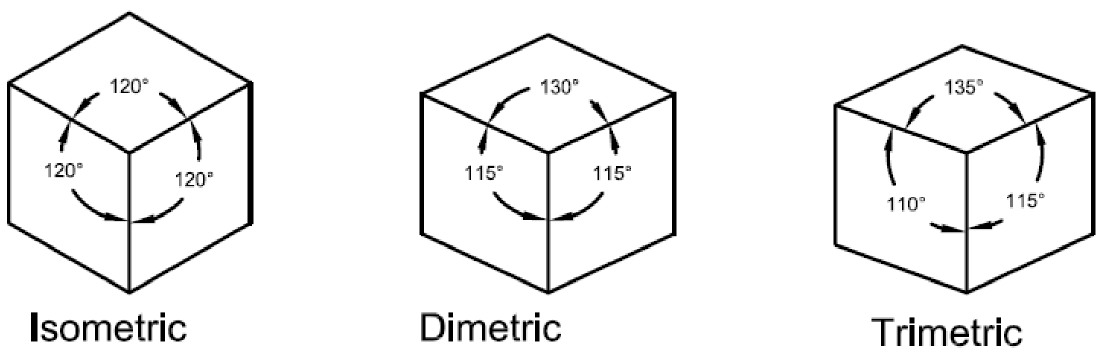


Figure 41

three). Of the three types of axonometric pictorials, the isometric is the most commonly used because it shows about the same amount of detail and the availability of isometric grid graph paper.

When working with round features in an isometric drawing, we need to sketch or draw these features as ellipses. One of the easiest ways to create an ellipse is to use the four corner method. In this method we start by sketching an isometric square to with each side equal to the diameter of the ellipse. Then from the two corners along the minor axis we sketch lines to the midpoints of the opposite sides (Figure 42). From each end of the minor axis we can sketch (or draw) an arc with a radius equal to the length of the line from the endpoint of the minor axis to the midpoint

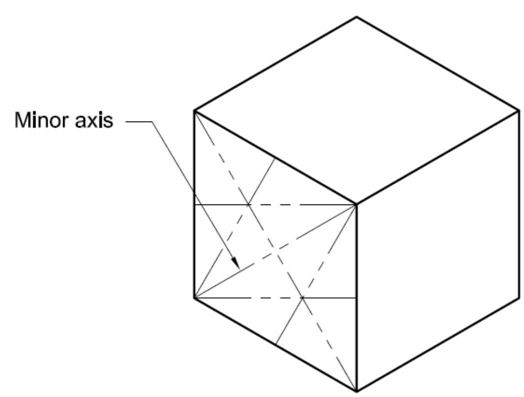


Figure 42

of the opposite side as shown in Figure 43. To complete the ellipse we sketch/draw an arc from where our diagonals cross the major axis with a radius equal to the line length from where the diagonal crosses the major axis to the midpoint of the bounding box as shown in Figure 44.

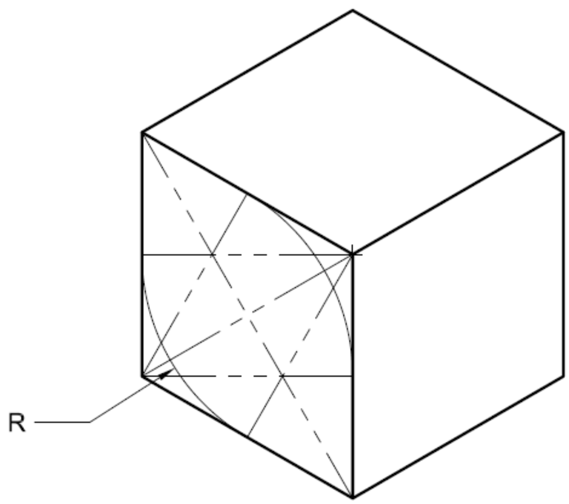


Figure 43

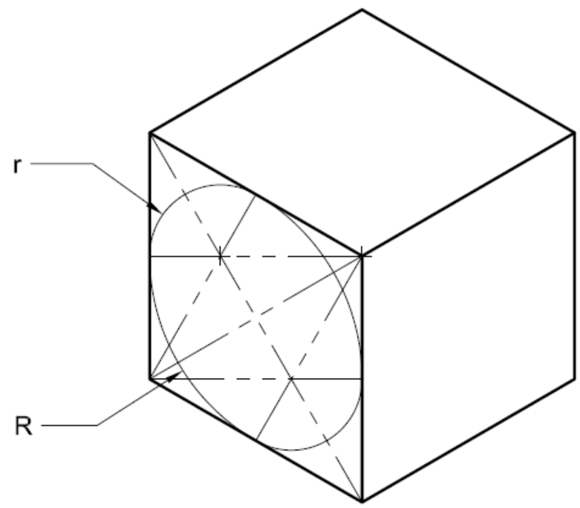


Figure 44

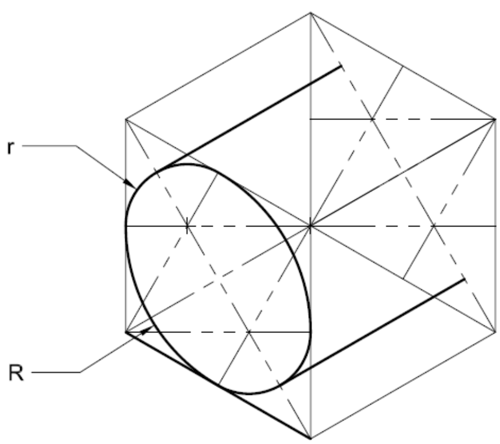


Figure 45

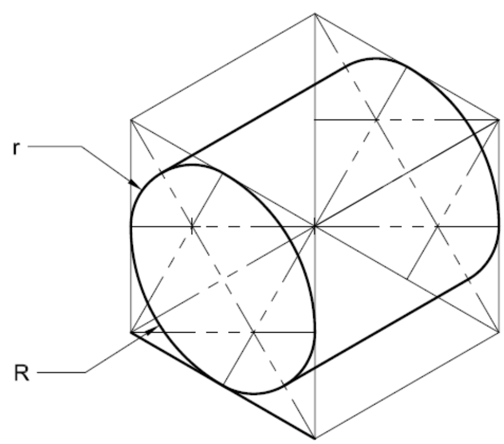


Figure 46

An addition benefit of this construction technique can be found when we extend our ellipse into an elliptical cylinder. The locations for the edges that will define the outline of the cylinder are located where the small arc (r) crosses the major axis. In Figure 45 we see the 4 corner construction on the opposite face of the ellipse we've just created. The lines parallel to the box edge and through the point where the small arc (r) cross the major axis define the limits for this ellipse (Figure 46).

10. Example Construction

For this sample construction, let's change things a bit and sketch an isometric using a given front and right side view as shown in Figure 47. In Figure 47 we've already laid out an isometric box that will define the 8x7x8 size limits for our sketch.

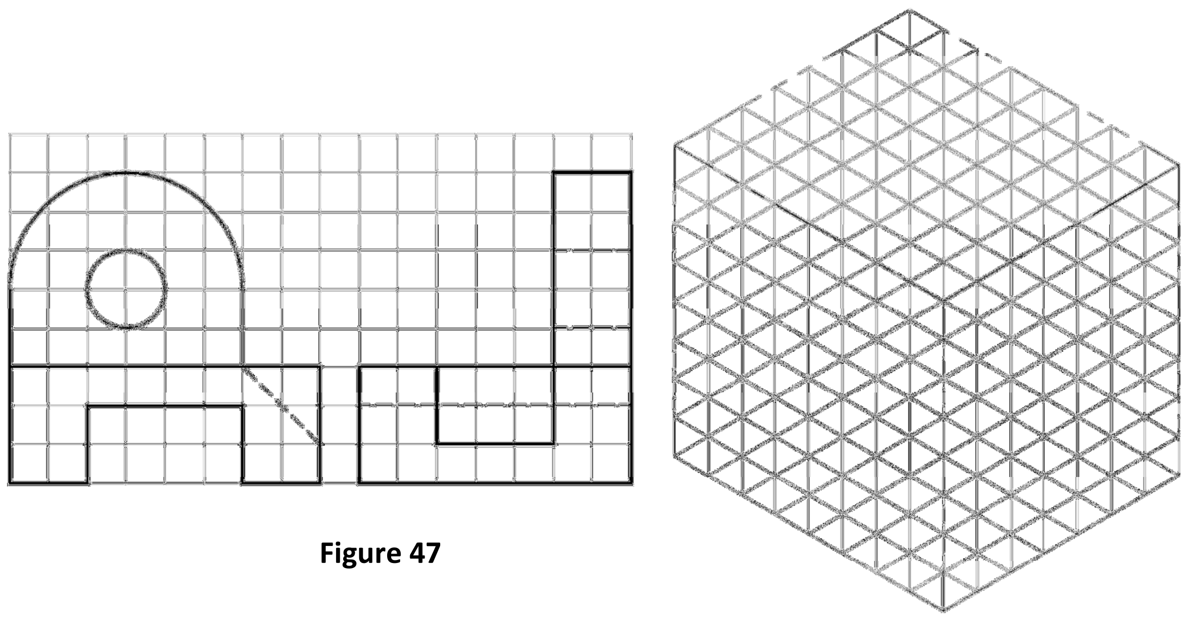


Figure 47

If we start on the front of the object we should notice the front most surface is a vertical edge in the side view, and will appear on the front of our enclosing box as shown in Figure 48.

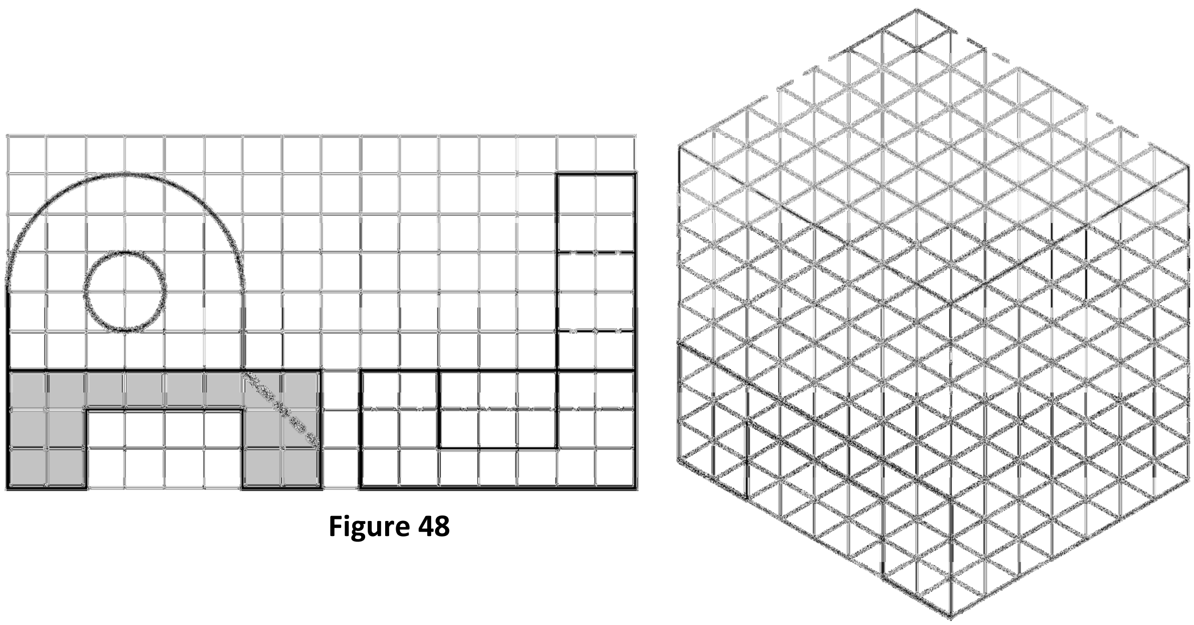


Figure 48

Since we do not have a top view, let's next deal with the first surface in the right side view. You should notice by now that this surface is the right most vertical edge in the front view, and can be drawn along the side of our isometric box as shown in Figure 49.

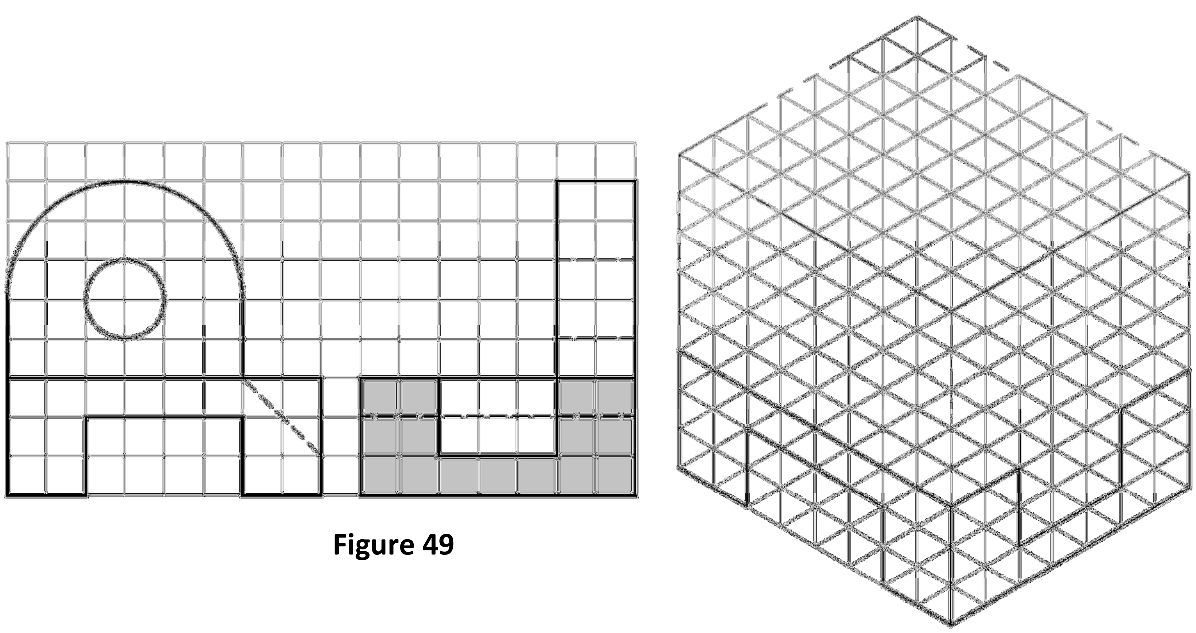


Figure 49

Next let's deal with the small rectangular surface in the side view. When we project its location over to the front view, we see it is represented by an angled hidden line. We will want to sketch this feature in lightly to start since all of it will not be visible when we are finished (Figure 50). Next, connect the top edge of the inclined surface to the vertical surface on the far right side (Figure 5one).

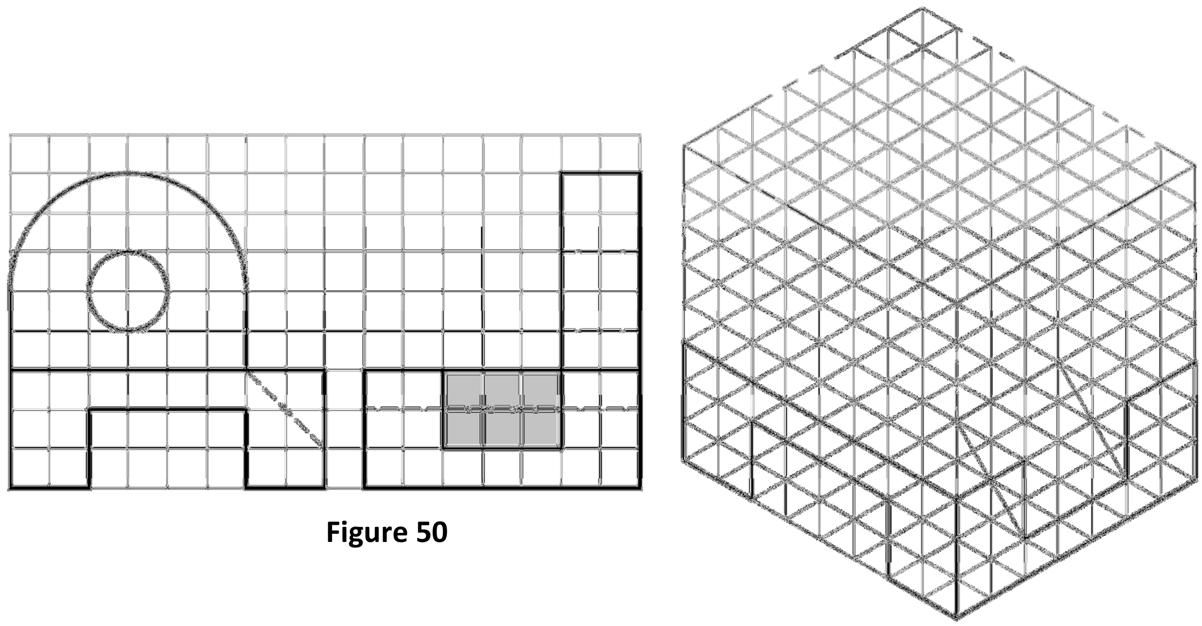


Figure 50

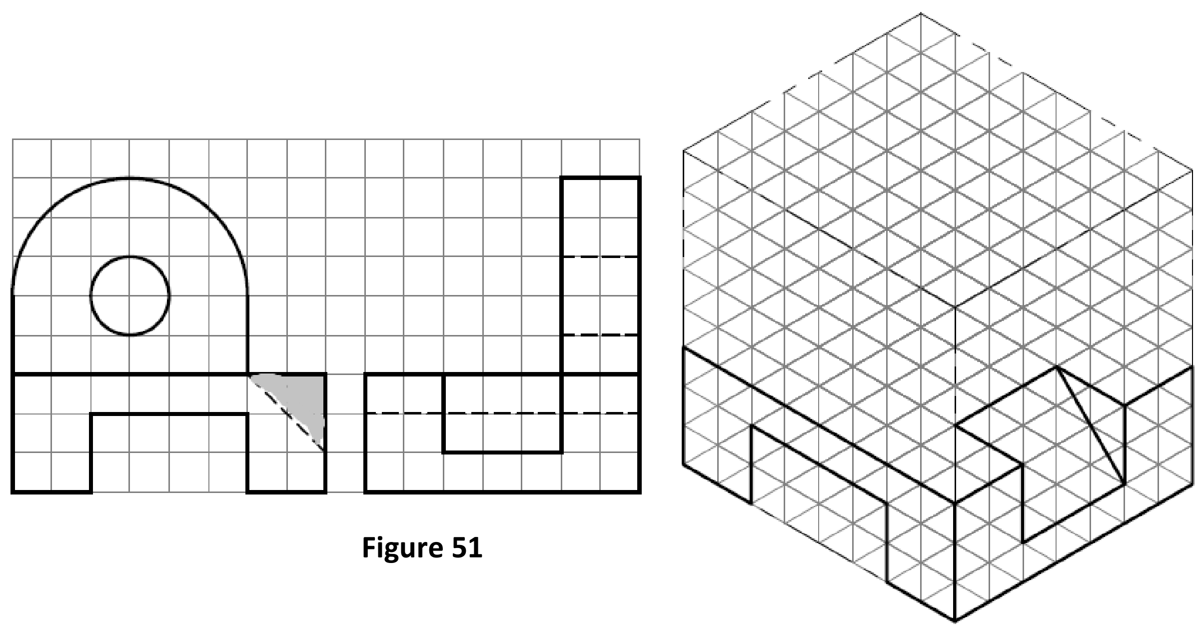


Figure 51

By working surface to surface, hopefully you can start to "see" the horizontal surface we would normally see in a top view. By working with adjacent surfaces, we have already created 6 edges along this surface. To complete this horizontal surface, we will:

1. Starting from the left corner 3 squares up, go back 5 squares.
2. Go to the right 6 squares (along the front edge of the vertical upright).
3. Go back 2 squares
4. Go to the right 2 squares.

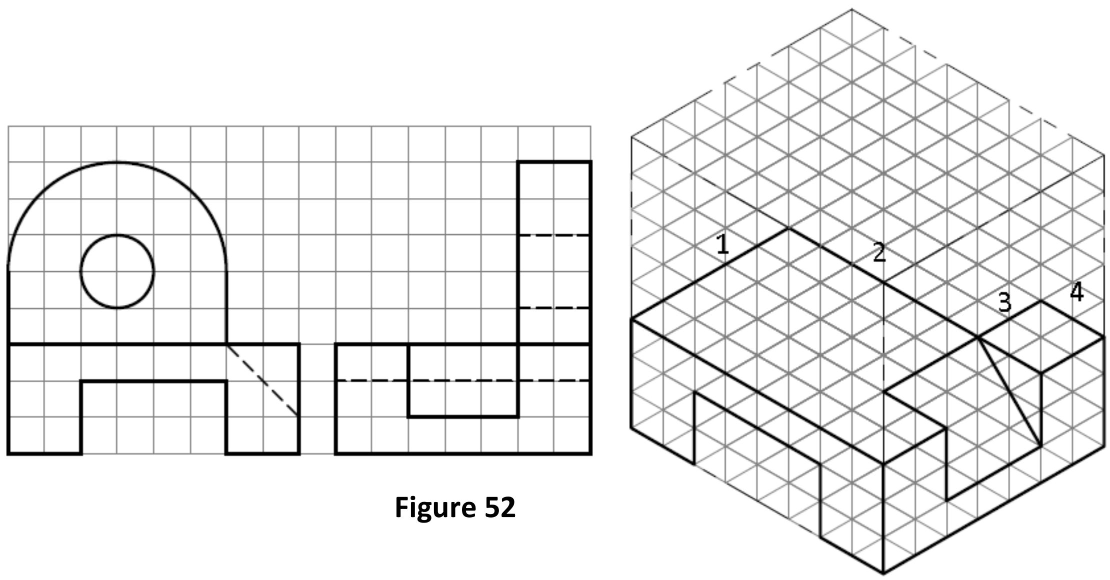


Figure 52

The finished horizontal surface is shown in Figure 52. Our next step will be to tackle the vertical upright with the semi-circular top. Starting at the front of this feature we can add the 2 square tall uprights and lightly sketch the enclosing boxes for the semi-ellipse and the through hole. Figure 53 also shows the construction lines needed for sketching the ellipses using the 4 corner method described earlier.

Because the bigger arc is a semi-ellipse, we only need to sketch two of the four construction lines.

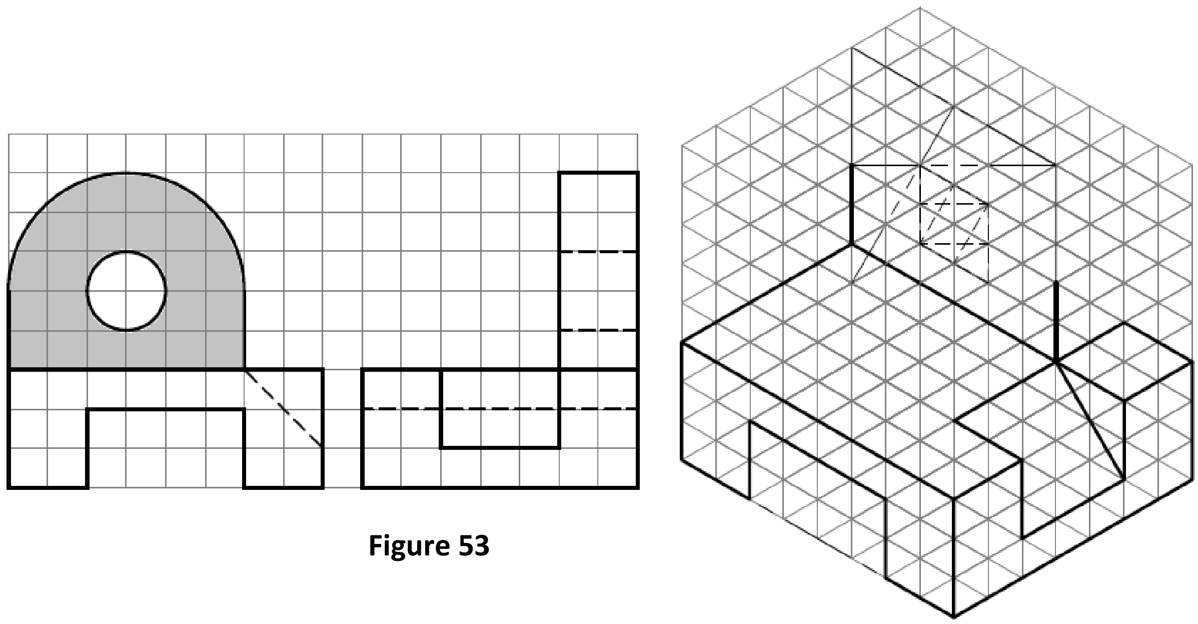


Figure 53

We should then be able to sketch in the semi-ellipse and small center ellipse (Figure 54). Our second to last step in this construction will be to complete the backside of the vertical upright. To start create the construction lines for the semi-ellipse and center ellipse back two squares as shown in Figure 55. We can also add the back left vertical 2 squares high. Figure 55 shows us that we do not see any portion off the back of the through hole. Starting with a line going back 2 squares from where the major axis crosses the semi-ellipse, we should then be able finish the vertical upright as shown in Figure 56.

To complete this sketch we need to show a small portion of the channel running from front to back as highlighted in Figure 57. Since we will not use hidden lines when drawing pictorial views, we only show the small portion of the line that we see in Figure 57.

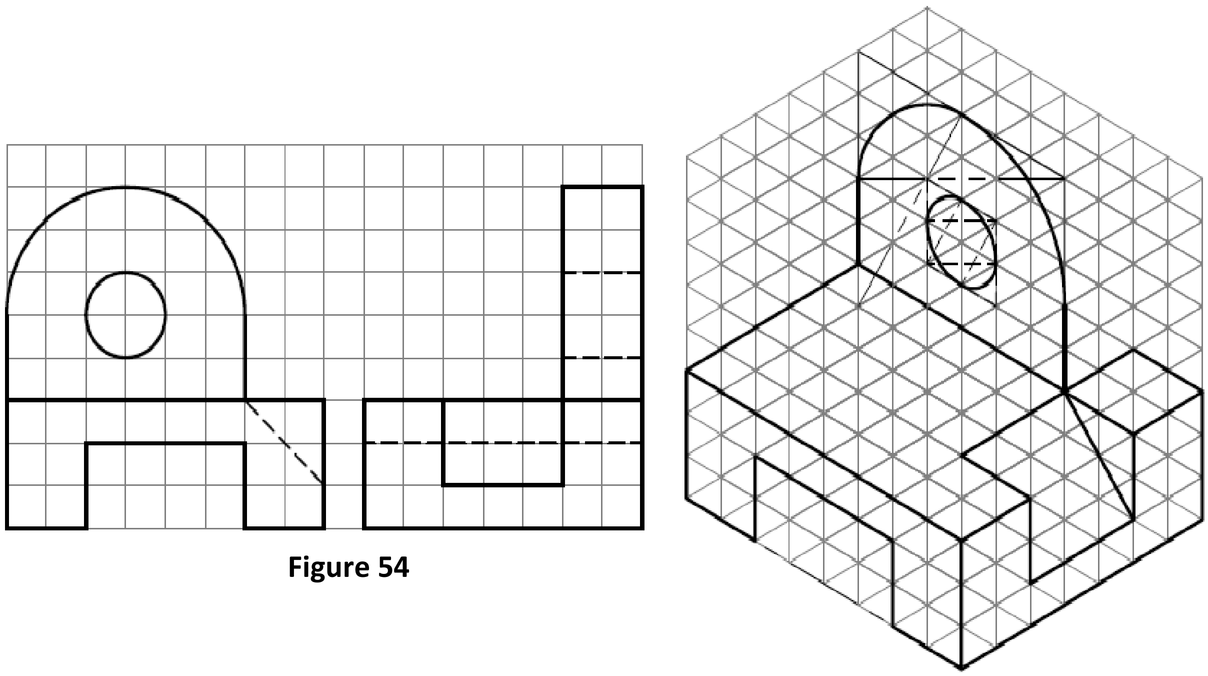


Figure 54

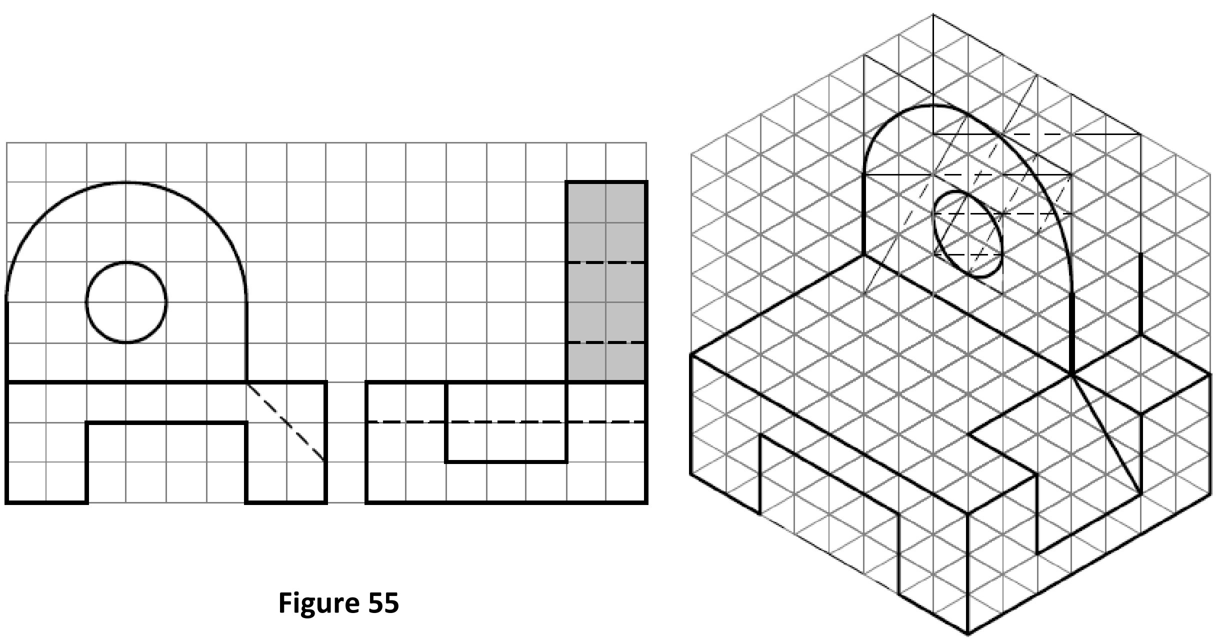


Figure 55

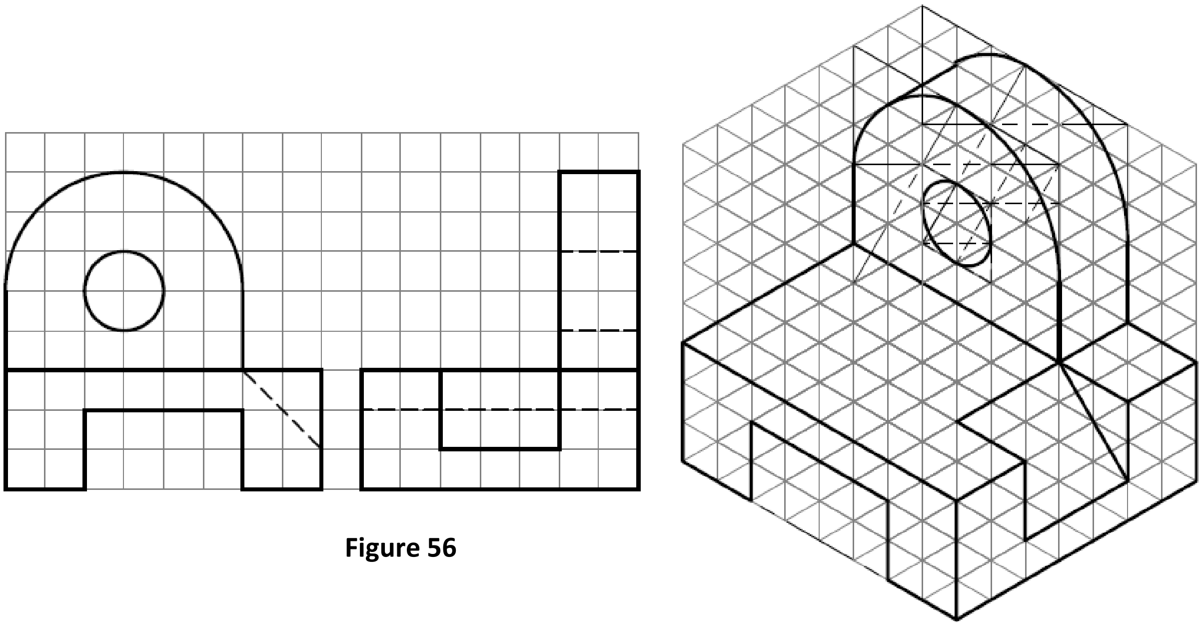


Figure 56

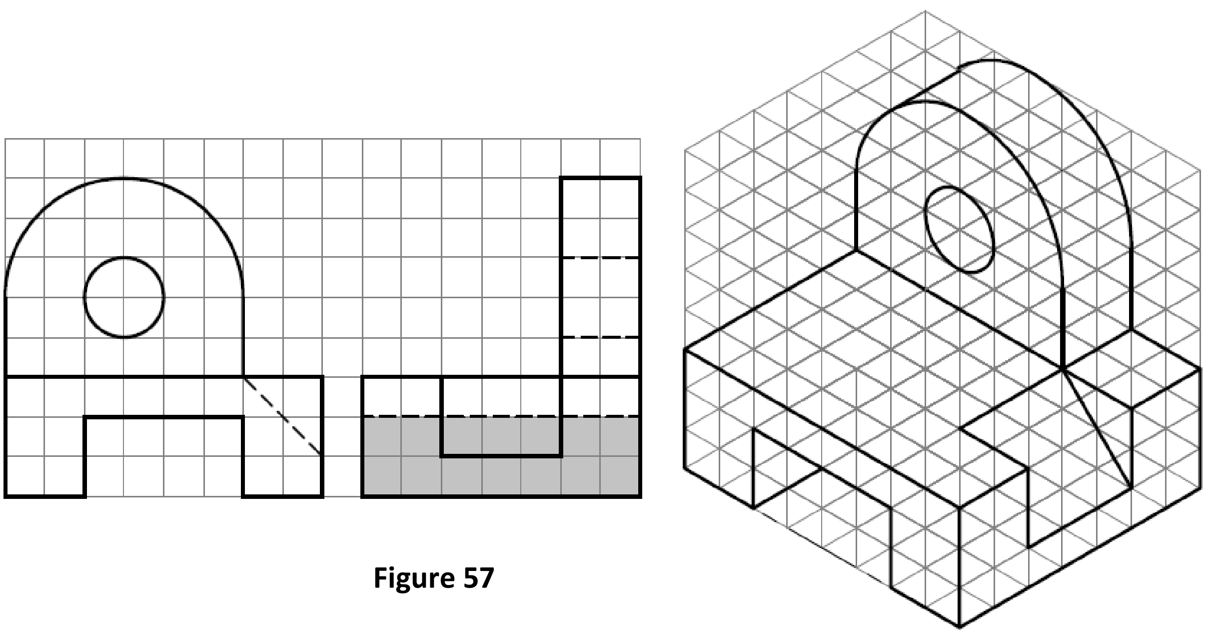


Figure 57

11.Section Views

Section views are a special type of drawing we use to clarify details on a drawing we cannot clearly see a regular orthographic view. These details can include interior features we would normally show using hidden lines and complex exterior contours. The theory behind section views is pretty straight forward; we make an imaginary cut in an object so we can “look inside” to see the desired details more clearly. Consider the top, front and right side views shown in Figure 58, the middle cylindrical features are shown using only hidden lines in the front and side views. If we could cut this piece in half, we could then see the interior detail using visible lines. Figure 59 shows an isometric rendering of this imaginary cut.

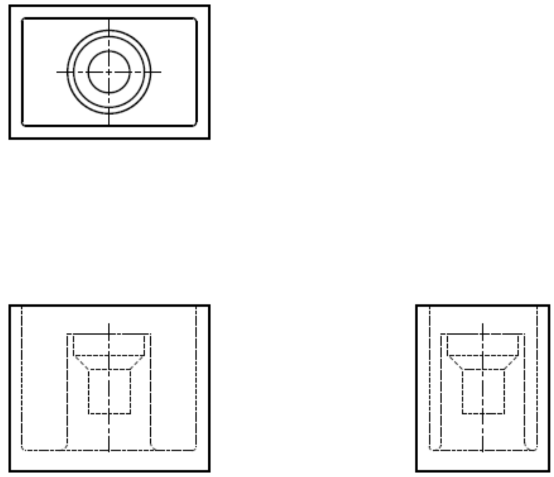


Figure 58

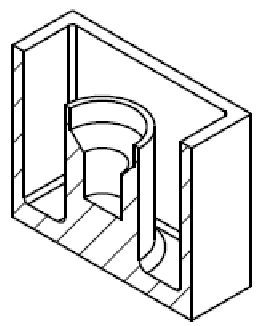


Figure 59

We can cut objects in different ways to show different features and create the different types of section views. There are seven different types of sectional views. We differentiate these views by how we make this imaginary cut.

The first type of sectional view is the **full section**. In the full section, *the cutting plane passes fully through the object*. Figure 59 is an example of a full section.

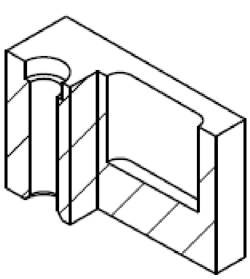


Figure 6one

The **half section** is a sectional view where *the cutting plane passes half way through the object*. With a half section, we will be able to see both interior and exterior shapes in the same view. Figure 60 is an example of a half section.

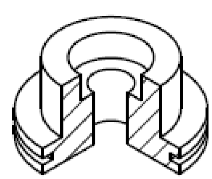


Figure 60

The **offset section** is another type of full section. The

offset section has *90^o bends in the imaginary cutting plane* so that it can go through features that do not lie along a straight line. Figure 61 shows an example of an offset section.

The **revolved section** is always used with orthographic drawings. We use this type of section to

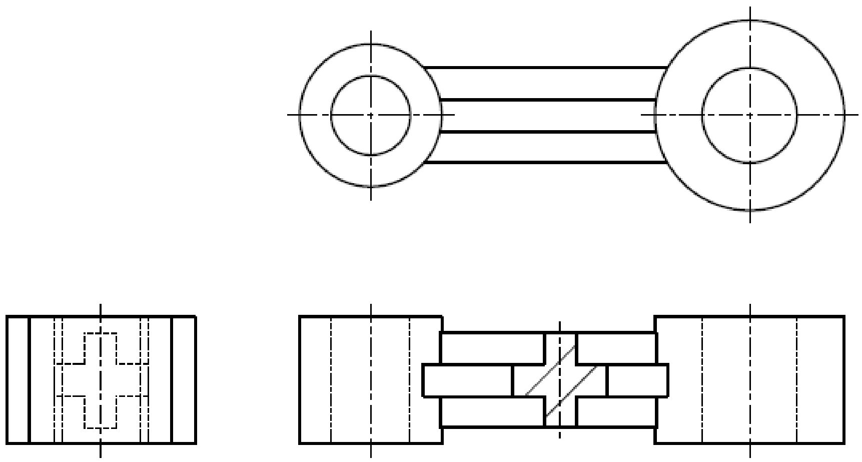


Figure 62

show a contour (exterior shape) that cannot be shown using visible lines. Consider the drawing in Figure 62. While we can see the "+" cross section in the side view, it is shown completely using hidden lines. The revolved section (shown in the front view) is created by passing the imaginary cutting plane through the object and then rotating it into the plane of the display.

The **removed section** is similar to the removed section, the main difference being in where the section is placed. Figure 63 shows a removed section. The removed section, the cut cross section is moved off the view as to prevent the lines in each view from overlapping.

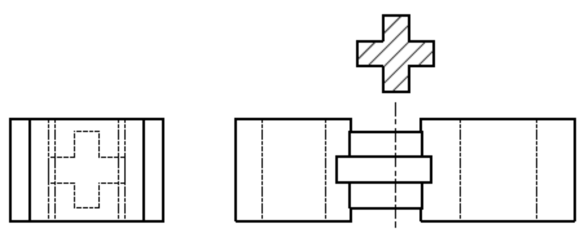


Figure 63

The **aligned section** is drawn when features are at a radial distance from a center. This type of section will allow us to see the features at their radial distance. Consider the hub shown in Figure 64; it has three counterbored holes equally spaced at 120^o about the center of the piece. If we were to draw this part in orthographic views, we would show the holes separated by 180^o in the section view as shown in Figure 65. The idea behind

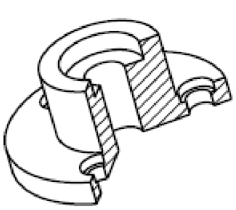


Figure 64

this rule bending is that in the aligned position, the regular orthographic view and the section view will more clearly communicate the overall symmetry of the part.

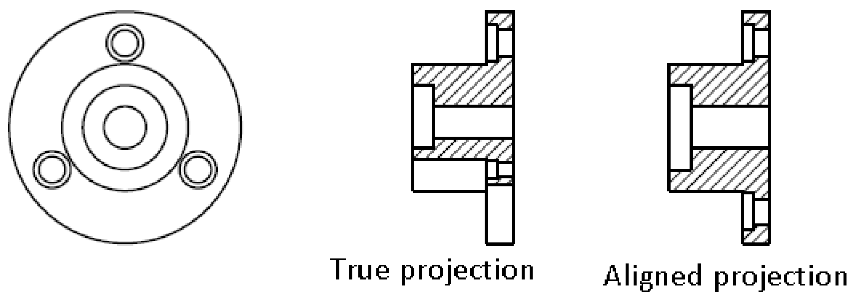


Figure 65

The last type of section view is the **broken-out section**. We use this type of section when we want to show only a small portion of an object in section. When we draw a broken-out section (Figure 66) we will define the boundary of the sectioned area using a irregular (short) break line. The other difference between the broken-out section and other sectional views is that we will use hidden lines in the rest of the view.

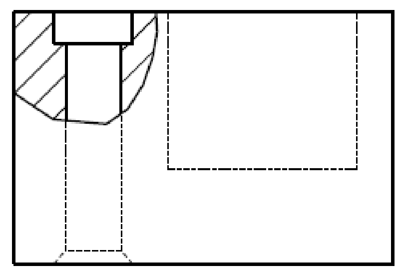
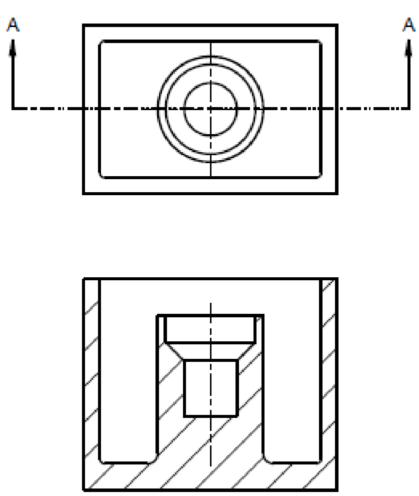


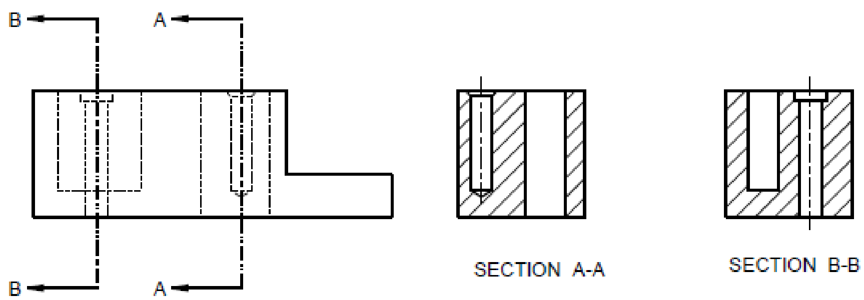
Figure 66



12. Cutting Plane Lines and Section Lines

We show the reader of our drawings that we are using a sectional view by the use of the cutting plane line and section lines. The cutting plane line is a bold line (~ 0.7 mm thick) that represents an edge view of the imaginary cut made through the object. The cutting plane line appears in a view adjacent to the sectioned view. There will be arrows at each end of the cutting plane line. These arrows show our line of sight at the object after we've made the imaginary cut. In Figure 67 we have the front and top views of the example object we used when describing the full section. In the top view we see the cutting plane line running fully through the object. The arrows at the end of the cutting plane line show us that we will be looking from the front to the back of the object to see the section view.

You also should have noticed the A's at each end of the cutting plane line. For more complicated objects, it may be necessary to create more than one sectional view to clearly and completely describe its shape. When this happens, we differentiate the different section views by



labelling them alphabetically. Figure 68 shows an object with two full sectional views. Notice how both the cutting plane lines and the views are labeled and that the section lines in each view are at the same angle and going in the same direction. When a drawing has only one sectional view, labelling the sectional view itself is unnecessary.

The other way a section view is differentiated on a drawing is by the use of *section lining*. Section lines are also commonly referred to as cross-hatching. Section lines are thin (~0.5 mm) lines drawn at an angle (45^{o} commonly) and represent where our imaginary cut has passed through material.

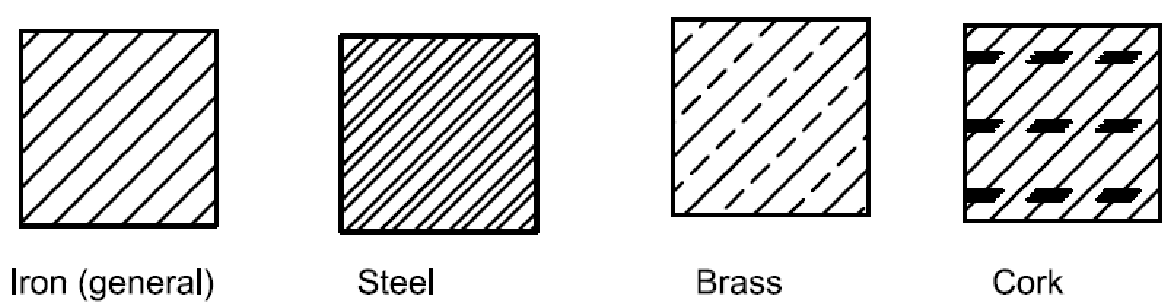


Figure 69

If we wanted, we can use different patterns of section lines to represent different materials. Figure 69 shows four different material patterns. When sketching a section, we generally stick to the iron (general) section lining pattern.

12. Example Construction one – Full Section

Drawing or sketching a section view is not very different than drawing a normal orthographic view, but there are a couple of differences to remember. First, when drawing or sketching section views we generally not include hidden lines in the view since one of the main purposes of a section view is to clarify hidden interior details. The exception to this rule is the broken-out section as previously mentioned. The second difference is that we project points starting at the cutting plane line into the new view since this is where we are making the imaginary “cut” into the object.

Figure 70 shows an isometric representation as well as a given top and side view for an object. Our goal is to sketch the front view as a full section. We begin just like we are drawing any other view

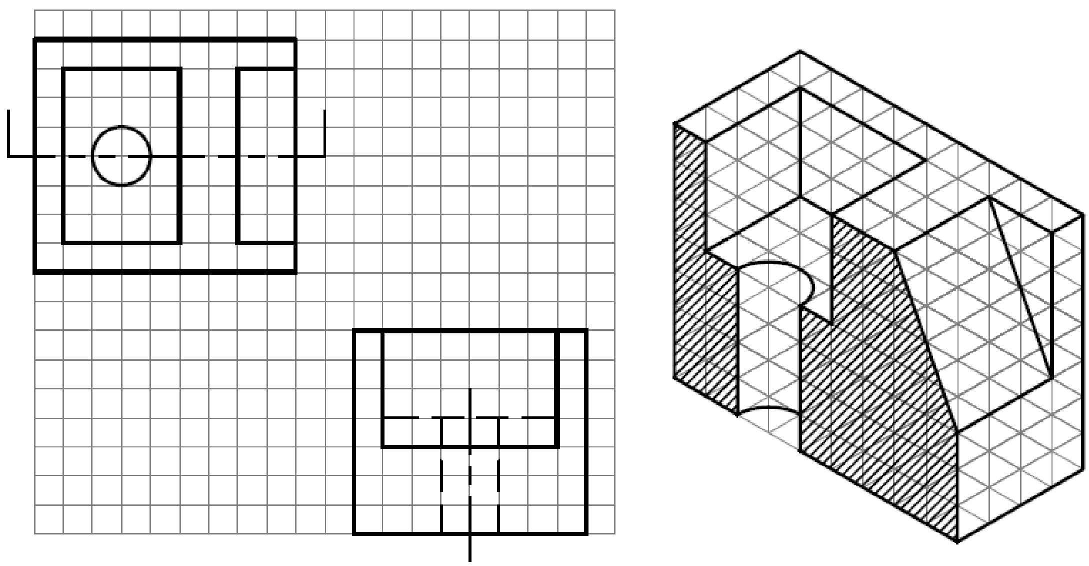


Figure 70

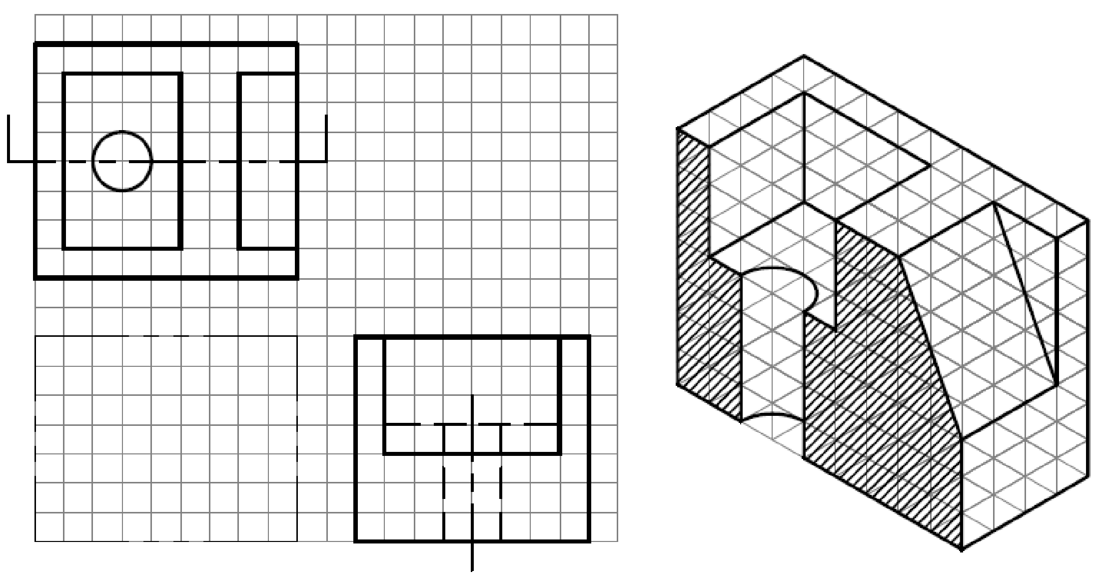


Figure 71

of an object by creating a box that will enclose the front view we are about to draw (Figure 71).

Working along the cutting plane from left to right, we will sketch the area to the left of the hole first. Points 1 through 6 in Figure 72 show the outline of this area. Since we are cutting through solid

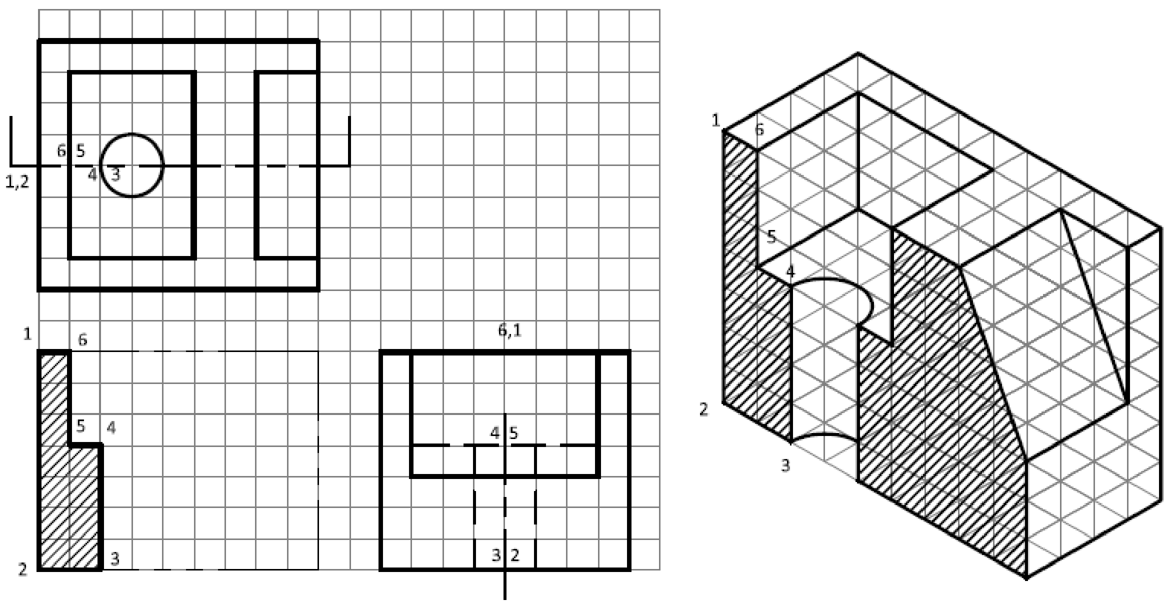


Figure 72

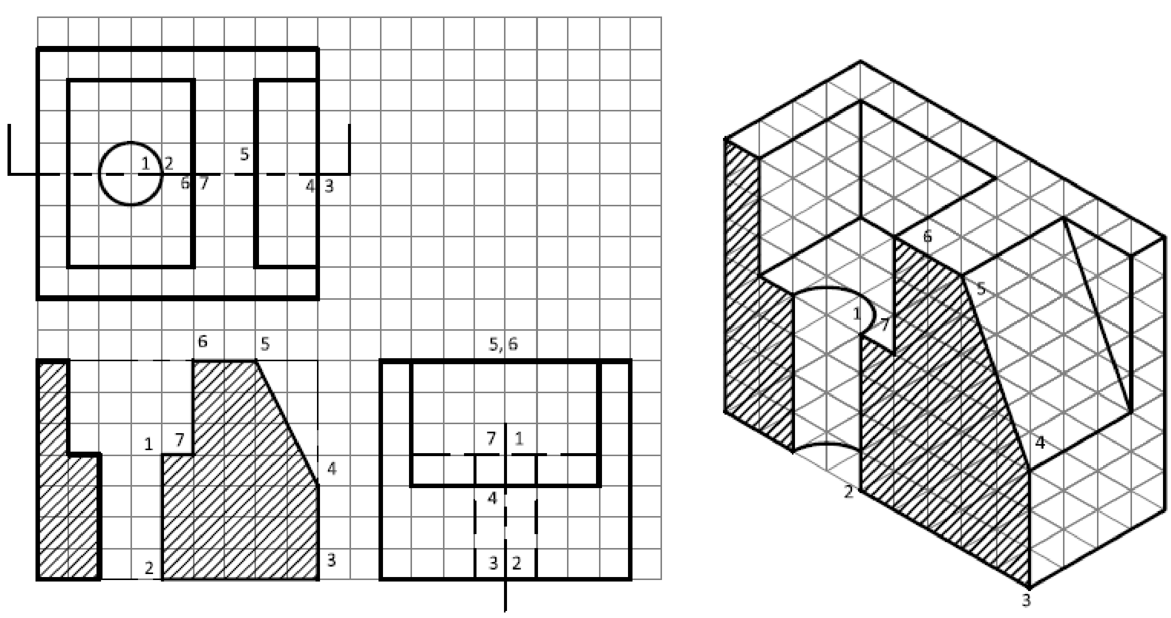


Figure 73

material in this region, we will add the section lining (cross-hatching) to this area.

Moving to the right, the next solid area is to the right of the hole in the piece. As shown in Figure 73, the region we will be drawing is defined by points 1 through 7. Once again, because our imaginary cut is going through material, we add section lining to this area. The section lining we add here should be at the same angle and in the same direction as the first area.

As we move back from the cutting plane line, we encounter features we need to draw that the cutting plane does not pass through but would still be visible in the view. For example, our cutting plane goes through the center of the hole in the piece so when we pull the front half of the part away to create the full section, we would be able to see the back half of the hole as shown in figure 74. Similarly

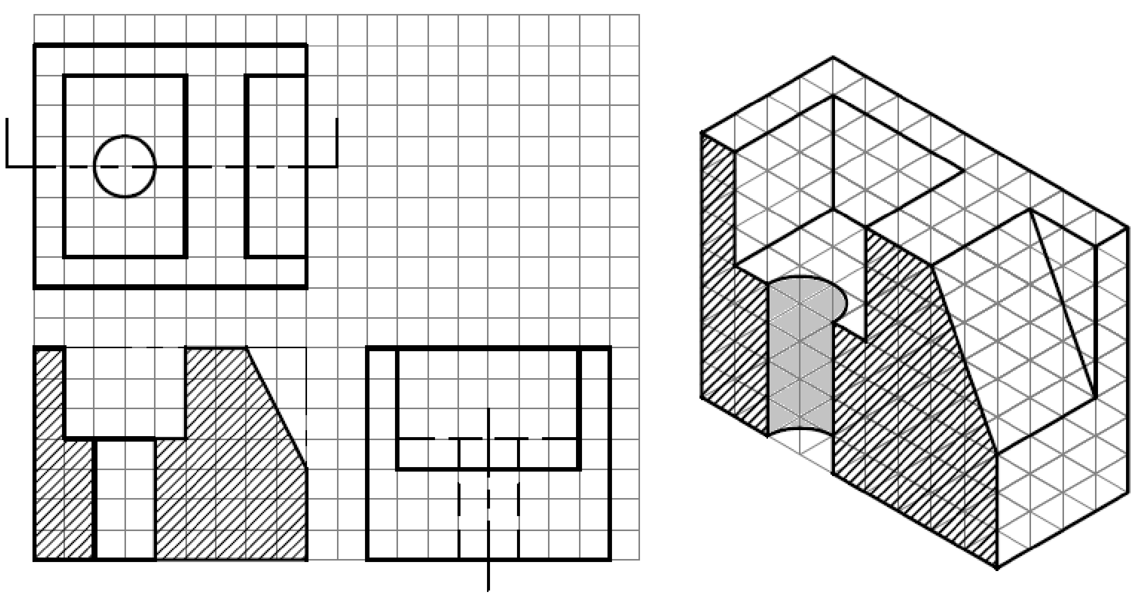


Figure 74

the square and triangular surfaces highlighted in Figure 75 should be shown in the sectional view, but since they are not cut by the cutting plane, those areas do not include section lining.

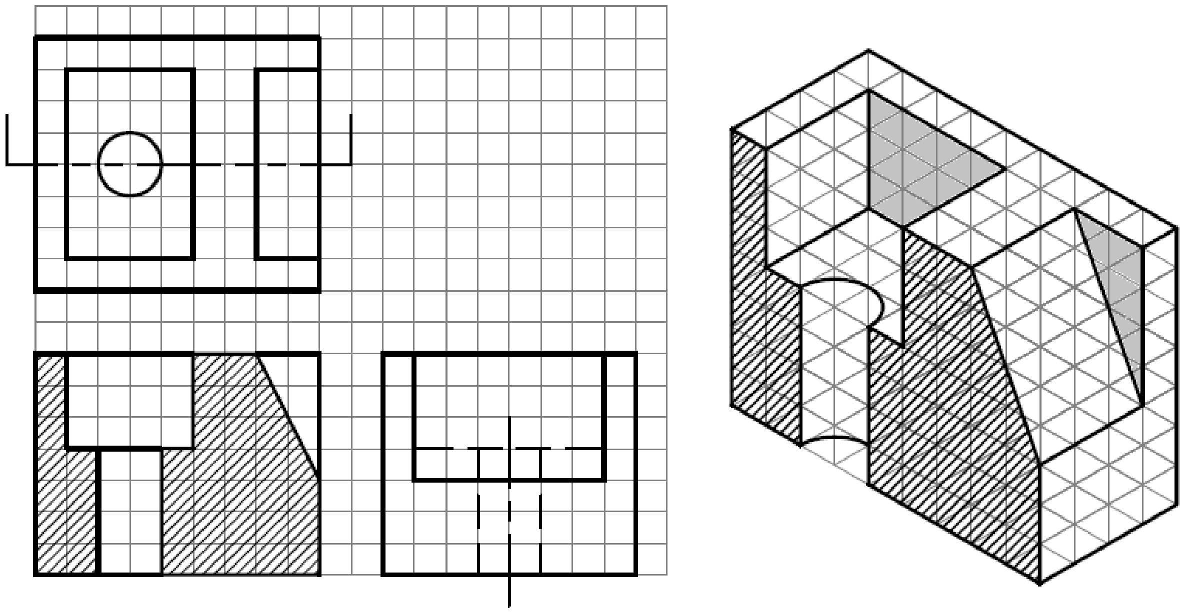


Figure 75

13. Example Construction 2 – Half Section

The half section is another commonly used sectional view. This view is commonly used with parts that are axisymmetric. Using this type of section view, we can show both the exterior shape of a

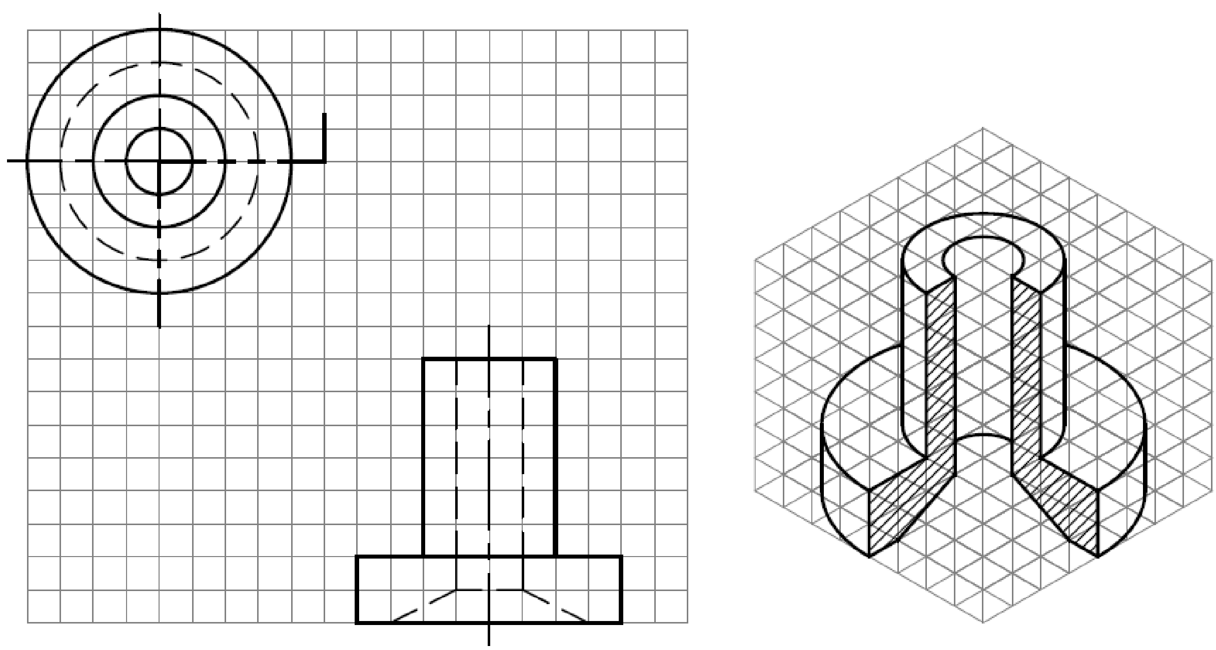
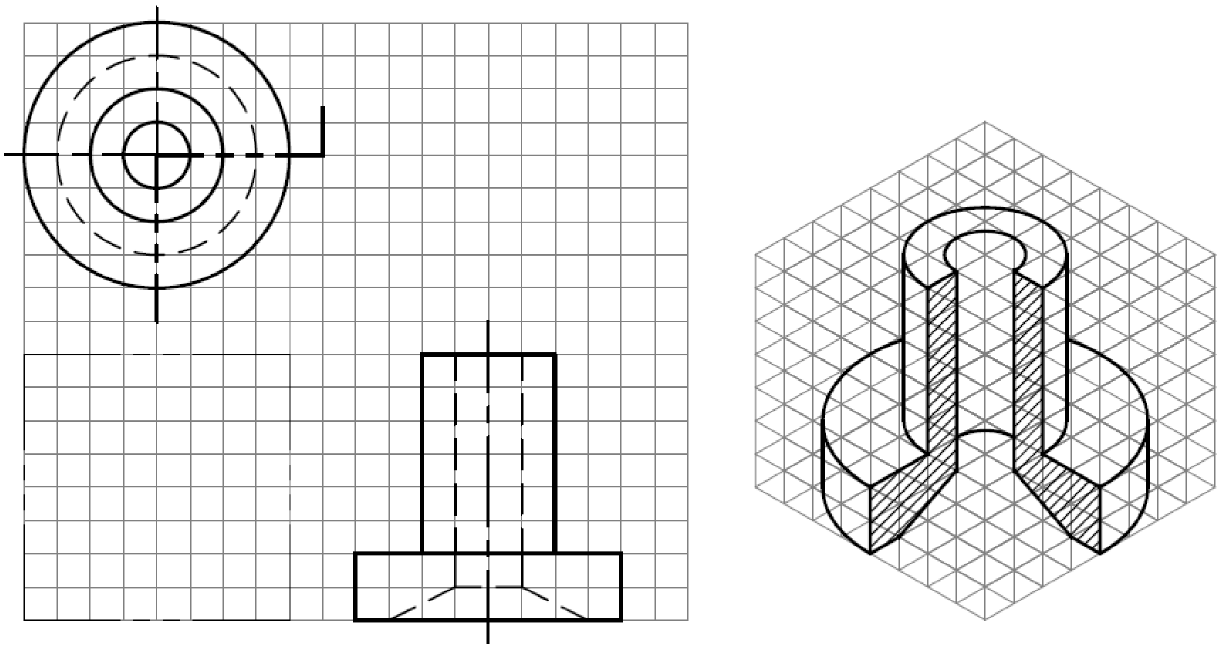


Figure 76

piece and the hidden interior detail in a single view. Figure 76 show the sample half section we will be sketching in this example.

Following our standard practice to this point, we lightly sketch a box that defines the overall size of the front view (Figure 77). Next, for the portion to the left of the cutting plane line in the top view,



we sketch the front view as normal, except we will not include any hidden lines. Where we reach the cutting plane line we draw a center line (Figure 78). It is standard drawing practice to separate the sectioned and unsectioned halves of a half section using a centerline. We do this whether or not the

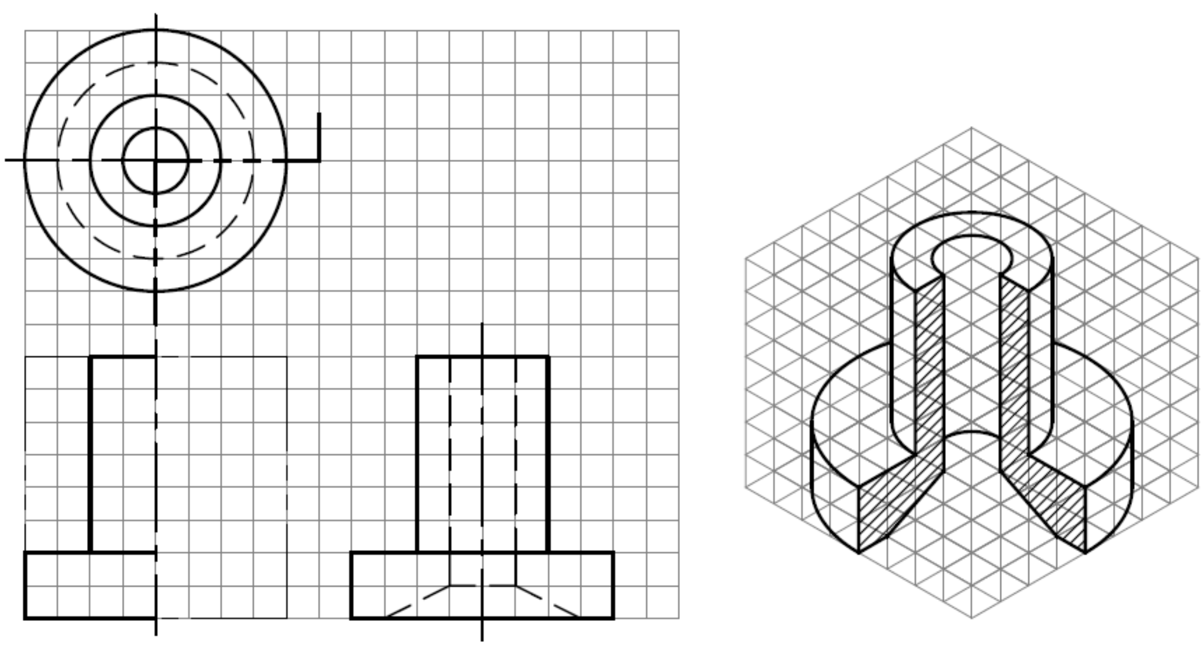


Figure 78

piece being drawn is cylindrical in shape or not.

Sketching the surface cut by the horizontal portion of the cutting plane line results in a view as shown in Figure 79. Moving toward the back we would encounter the back of the hole where the large counter sink intersects with the hole (Figure 80).

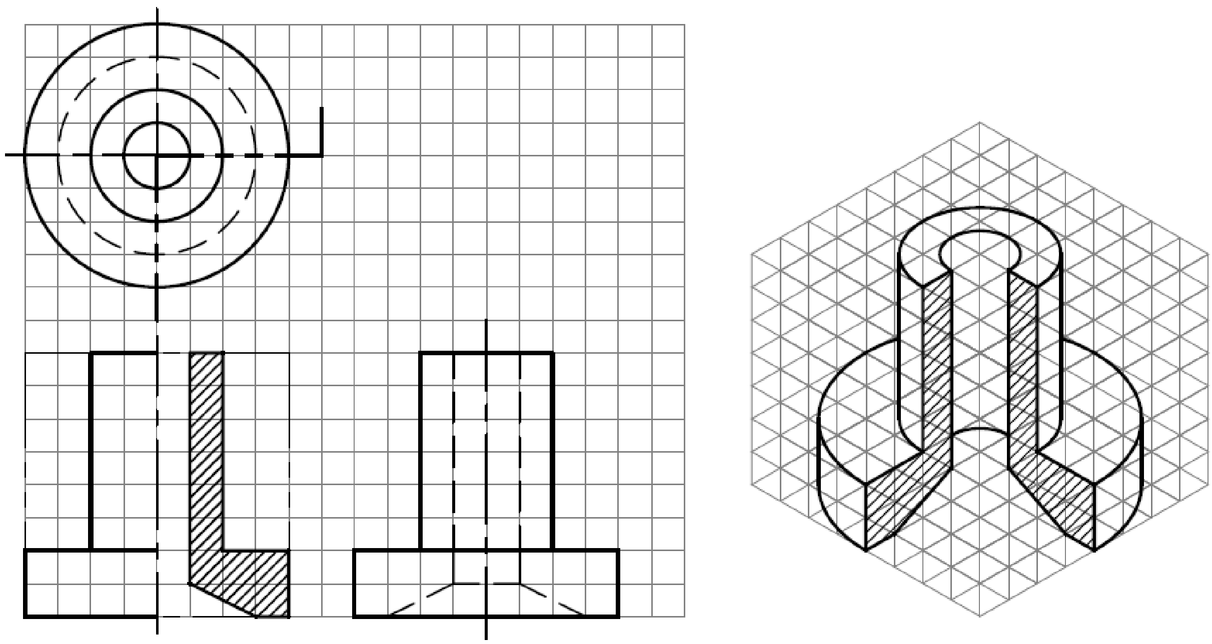


Figure 79

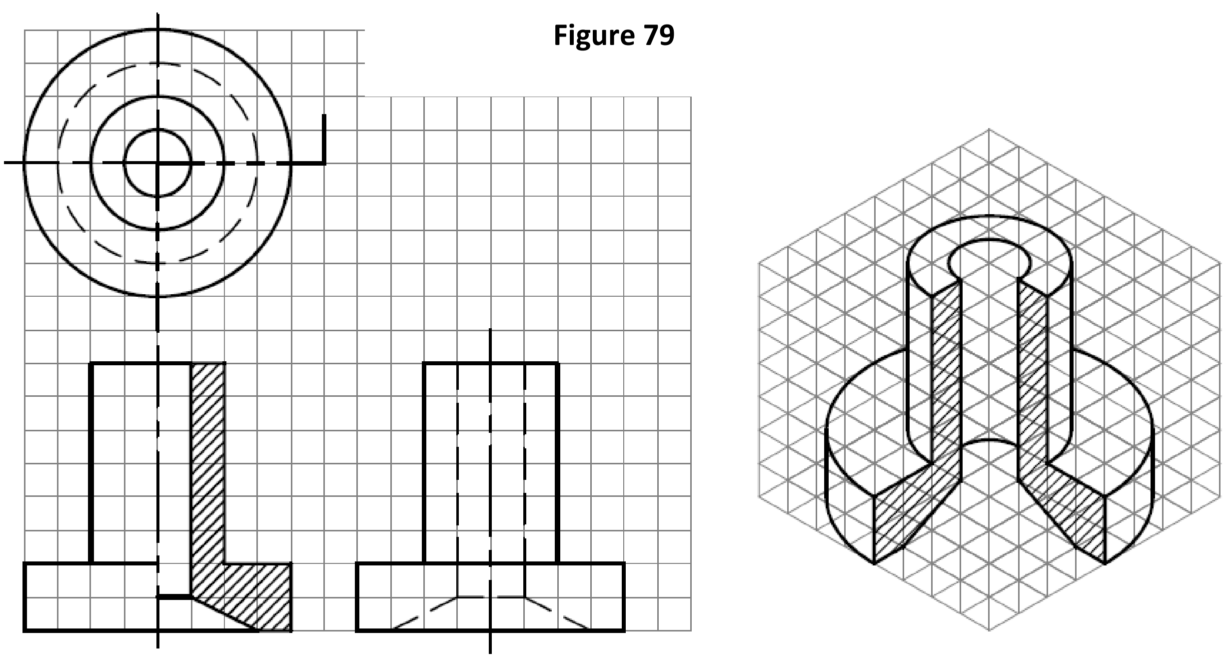


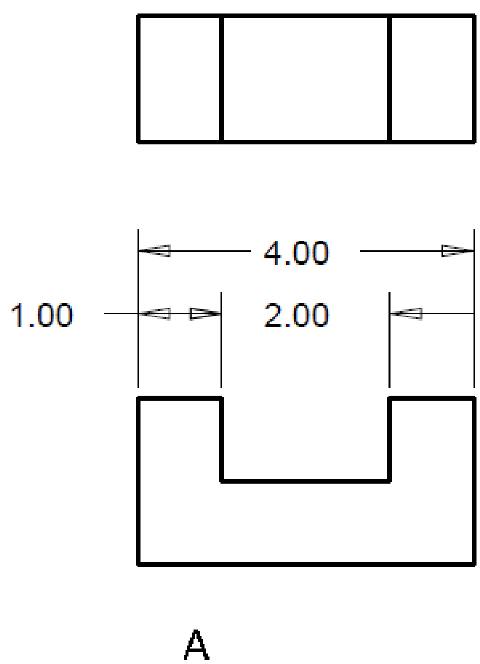
Figure 80

14. Dimensioning

Because the purpose of engineering drawings is to communicate technical information, choosing the correct views to describe an object is only half of the job. We will also need to communicate where and how big the features are on the part we are drawing. We accomplish this by annotating the drawing using dimensions and other notes. In theory, dimensioning should be one of the easiest tasks to accomplish. When dimensioning, there are some basic “rules of thumb” to make the process easier.

Contour Dimensioning

Contour dimensioning is simply to place the dimensions in the view that best shows the shape, or contour, of the feature being illustraded. Consider the three width dimensions associated with the block shown in Figure 81. On the left side (A), the dimensions are in the front view where the reader can “see” the notch that is cut out of the block. On the right side (B), the dimensions are numerically correct and show the same information, but are not as clear.



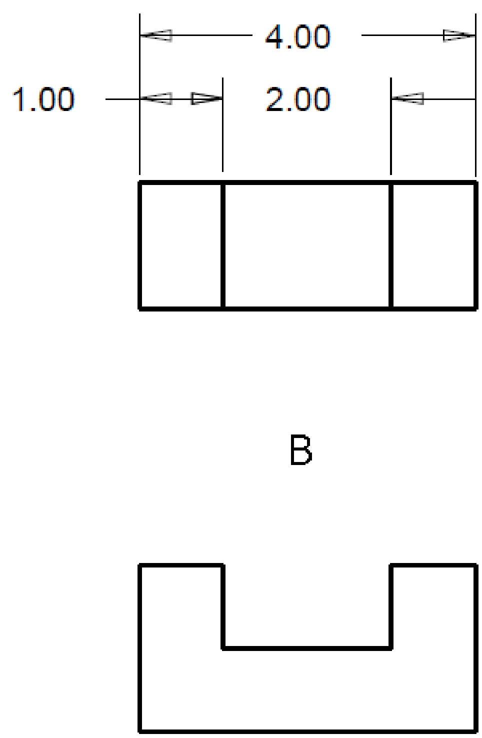


Figure 81

As the shapes we need to describe become more complicated, so does applying this rule of contour. Consider simple cylindrical shapes for example. When we want to tell the drawing reader where the circular shape is located, we will do this in the view where we see the circular shape (Figure 82). We give the three dimensions that will locate the post and the hole in the front view where they appear circular in shape. Also notice that when placing the dimensions we extend the centerline out to show at least one limit of the dimension. This allows the drawing's reader to quickly recognize that the dimensions are to the center of an object.

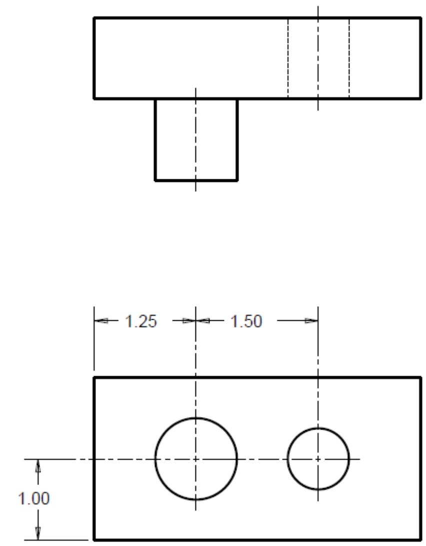


Figure 82

When we place the dimensions to give the size of the circular features we need to know if the shape is a solid (i.e. shaft) or negative (i.e. hole). Where the shape is a solid, we dimension its size as a diameter in the view where we see a rectangle. This way the dimension would reflect what a machinist would "see" if making the solid cylinder on a machine tool such as a lathe. For negative cylinders, we place the diameter dimension in the view where we see the circular shape. This would reflect what a machinist would see when creating a hole using a tool such as a drill press (Figure 83).

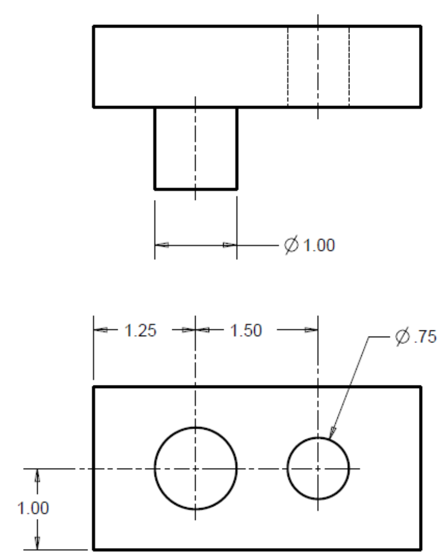


Figure 83

<u>Use Symbols Instead of Words</u>

One way a drawing can be more easily understood by a broader audience is to replace commonly used words with symbols. One example of these symbols is shown in Figure 83 with the use of the ∅ to represent a diameter. It was previously considered acceptable to use either the DIA abbreviation or, if applicable, DRILL notation. Some of the other commonly used dimensioning symbols are shown in Table 1.

Text	Symbol	Text	Symbol
Counterbore or C'BORE	⌴	DEEP	↧
Countersink or C'SINK	⌵	Reference or REF	()
Diameter	∅	Radius	R

Table 1

Minimize Dimensions to Hidden Features

This rule of thumb goes hand-in-hand with the contour dimensioning rule. Generally, hidden details on a drawing are more difficult to understand than those shown using visible lines. We should therefore avoid dimensioning to the hidden view of a feature. If you find yourself placing a good number of dimensions to the hidden view of a feature, you should consider using a sectional view on

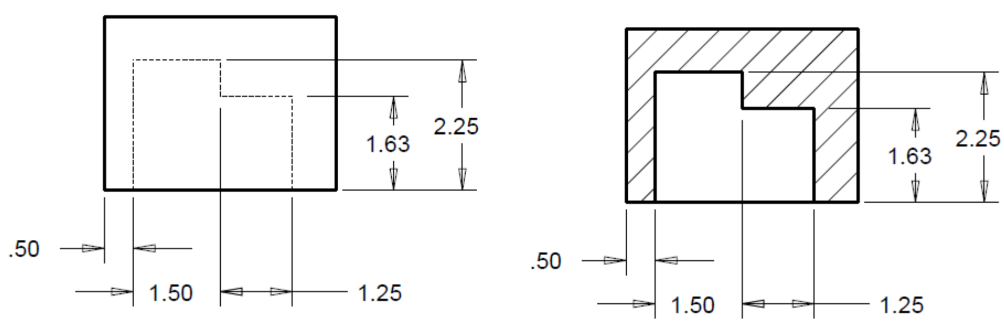


Figure 84

your drawing to clear up those hidden details (Figure 84).

Dimensioning Technique Consistency

There are two general techniques for placing dimensions on a drawing. The first is called *string dimensioning*. In string dimensioning we will locate features sequentially (or from one feature to the next). The 1.25, 1.50 and 4.00 dimensions shown in Figure 85 are a simple example of a string dimension. In string dimensioning one dimension in the string is left off and the overall dimension is given. In Figure 85 for example, we leave off the 2.25 distance from the hole to the right edge

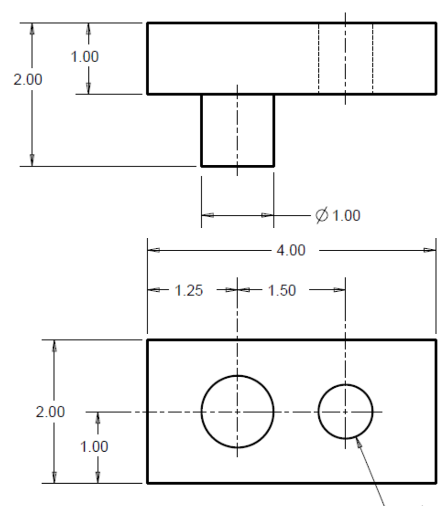


Figure 85

and put in the 4.00 overall distance instead.

The second technique for placing dimensions on a drawing is called *datum dimensioning*. In this system all the dimensions of a particular type (i.e. height, width or depth) will be given from a common reference, or datum. Figure 86 shows the same part with the width dimensions given using the datum technique.

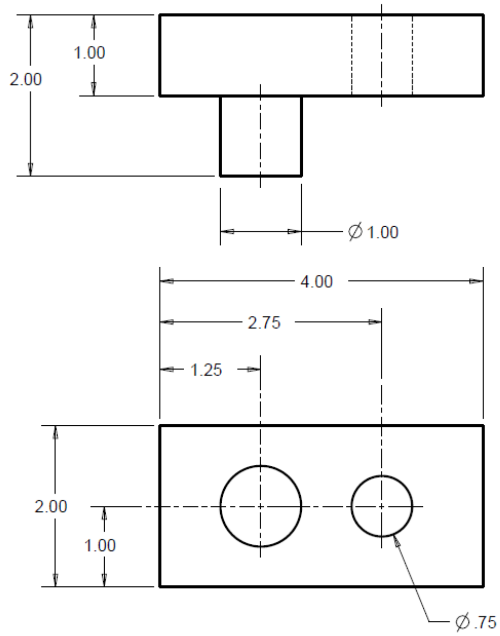


Figure 86

While using the datum technique is considered to be more accurate, the string technique can still be useful when dealing with repeated features of the same type. For example, the string technique would be appropriate when showing where to drill a series of the same size holes into a part.

<u>Keep Dimensions Organized and Off of Views</u>

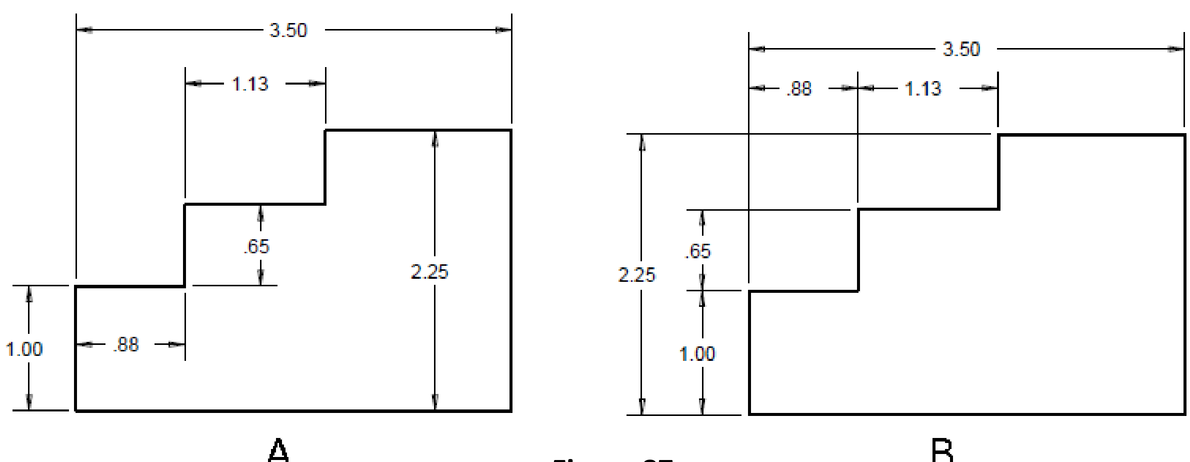


Figure 87

Once we start adding annotations to a drawing, the time it will take the drawing's reader to interpret the print will increase exponentially. In order to make the drawing easier to read, you will want to group your dimensions according to some simple guidelines:

- Keep dimensions off the view

- Place smaller dimensions closer to the view
- Keep strings of dimensions at same distance off view
- Keeps strings of dimensions close to each other
- Allow extension lines to simply cross

In Figure 87 we have two identical views dimensioned using the same dimensions. Notice while view (A) gives all the same information, view (B) is more organized and easier to interpret.

Dimensioning Round Features

We have already mentioned a few general rules with respect to dimensioning round features; locate the centers of round features in the view where we see a circle; dimension hole diameters (negatives) in the view where we see the circle; and dimension shaft diameters in the rectangular view. There are a few other general rules that we follow when dimensioning round features.

A. Features that are completely circular should be dimensioned as a diameter
B. Features that are not completely circular should be dimensioned as a radius
C. For arcs that span an angle that is a multiple of 90°, we do not need to locate the center of the arc
D. For an object with a rounded end, you can locate center of round, give end radius, and skip overall dimension.

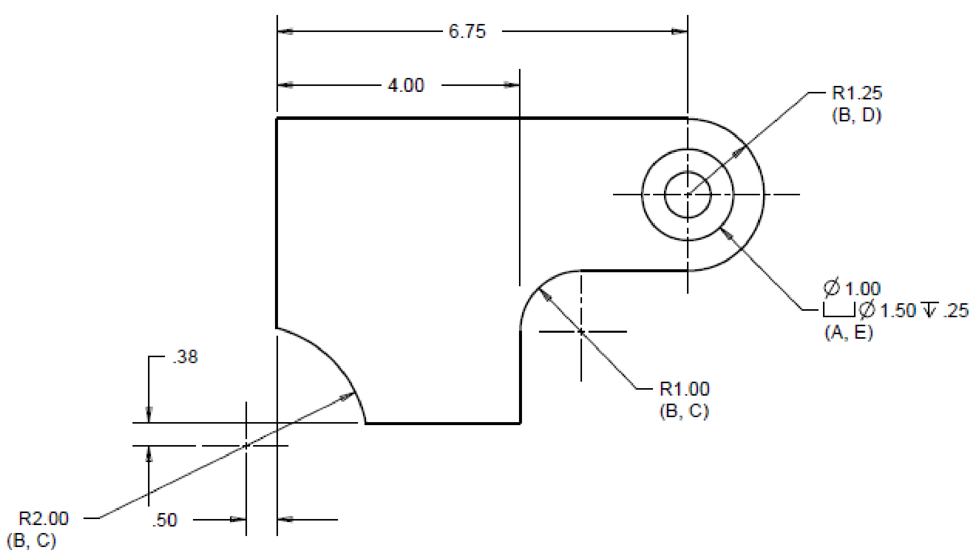


Figure 88

E. For counterbored, countersunk, and threaded holes, the hole note should reflect the steps used in making the hole. For holes that do not go completely through the object, add the depth to the note.

These concepts are illustrated in Figure 88. The letters in parentheses correspond to the list items.

<u>Dimensioning Angles</u>

When dimensioning an angle, you have two primary methods to choose from. First you can give the angle and an edge length as shown in Figure 89 (A). Secondly you can dimension the two sides that would be the legs of a right triangle (Figure 89 (B)). What you ***<u>do not want to do is</u>*** dimension the length of the cut edge itself (Figure 89 (C)). This length is not used in making the angled feature, but is usually a by-product of making the angled feature, so would not be of any use to a technician making a piece.

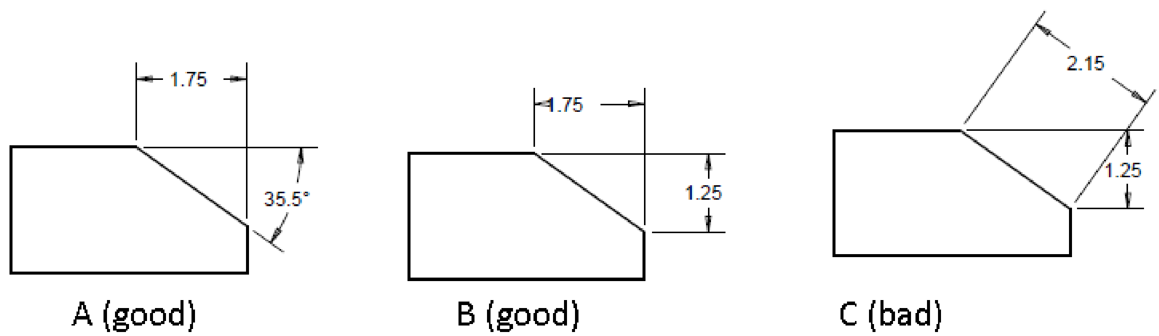


Figure 89

<u>Dimensioning Units</u>

When dimensioning prints we will generally use decimal inches or millimeters (even though whole units on most metric scales are in centimeters) as our base unit of measurement. In civil engineering and architectural environments you will also often see dimensions in feet or meters. The only other difference is that when dimensioning in millimeters, sizes less than one will start with a zero (e.g. 0.1). When dimensioning in inches, this leading zero is omitted (e.g. .375).

When using inches for dimensioning there is one exception. We will still use number or fractional sizes when dimensioning drilled holes. Since the tools used to create these features are commonly referred to by their number or fractional size, we still use these sizes on engineering drawings.

The thing you should always be aware of when dimensioning is the number of decimal places you put into each dimension. Even with today's technology, making parts to the exact size on a print is not possible. On most engineering prints you will see a tolerance block that specifies how much

<u>UNLESS SPECIFIED ALL:</u>

.XX = ±.0one
.XXX = ±.002
.XXXX =±.0005
ANGULAR = = ±.2°

Figure 90

variation is allowed in dimensions based on the number of decimal places as shown in Figure 90. By adding more decimal places to the drawing, you will require more machining operations and as a result higher costs.

<u>Dimensioning Example 1</u>

Let's examine the dimensioned drawing shown in figure 9one; it contains several common errors in dimensioning. When "proof reading" a drawing, there are several things you will want to look for:

- Consistency in dimensioning technique
- Duplicate dimensions
- Missing dimensions
- Dimensions to hidden features
- The rule of contour

Deciding on a dimensioning technique before starting to dimension a drawing will help you recognize where you have duplicate and missing dimensions. Let's take our given dimensions in Figure 9one and rearrange them using a datum technique such that:

- Height dimensions go from the bottom up
- Width dimensions go from left to right
- Depth dimensions go from the front to back.

One of the easiest mistakes to make is to place more dimensions on a drawing than are needed. When making drawings, “better safe than sorry” is not the case. In figure 92 some of the duplicate dimensions are easy to spot.

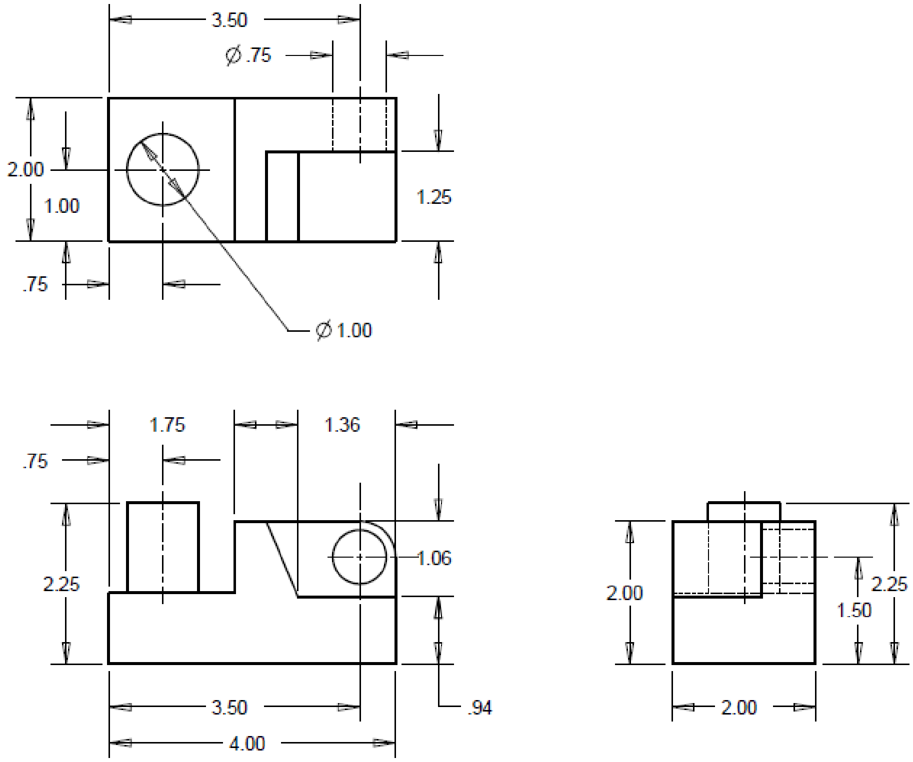


Figure 9one

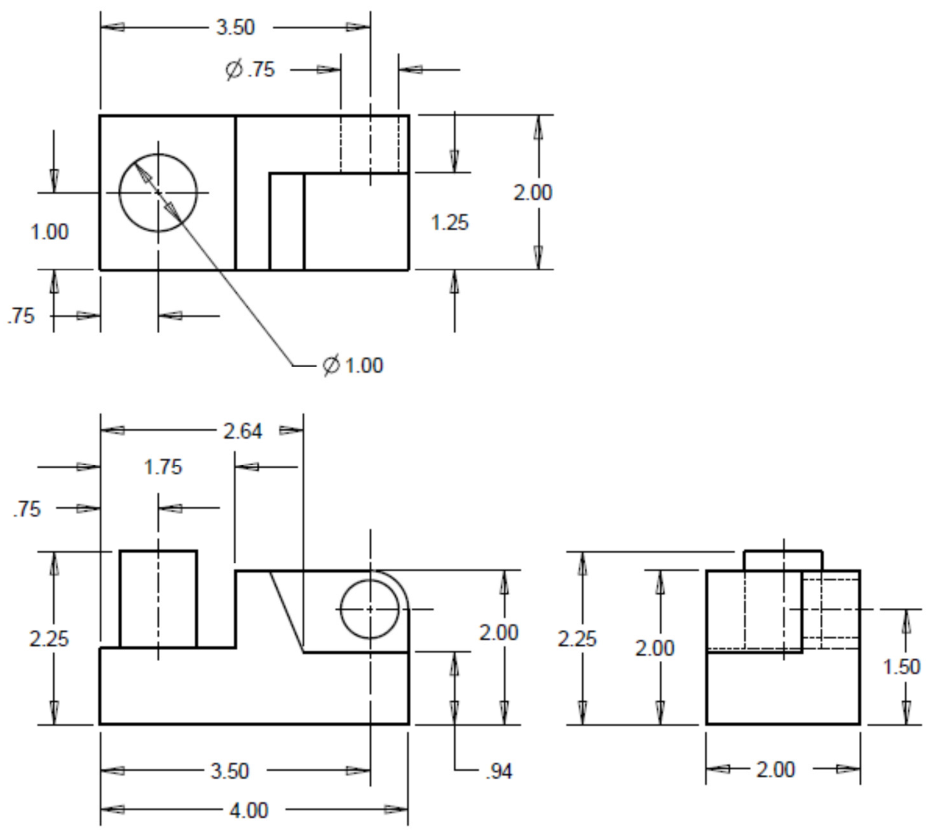


Figure 92

- The 2.00" overall depth is shown in both the top and side views
- The 2.00" height on the right side is shown in both the front and side views
- The 2.25" overall height is shown in both the front and side views
- The 3.50" dimension from the left side to the center of the .75 diameter hole is shown in both the front and top views.
- The .75" dimension from the left side to the center of the one.00" diameter post is shown in both the top and front views

To fix these issues, we can remove the two 2.00 and 2.25 dimensions from the side view. The 3.50 and

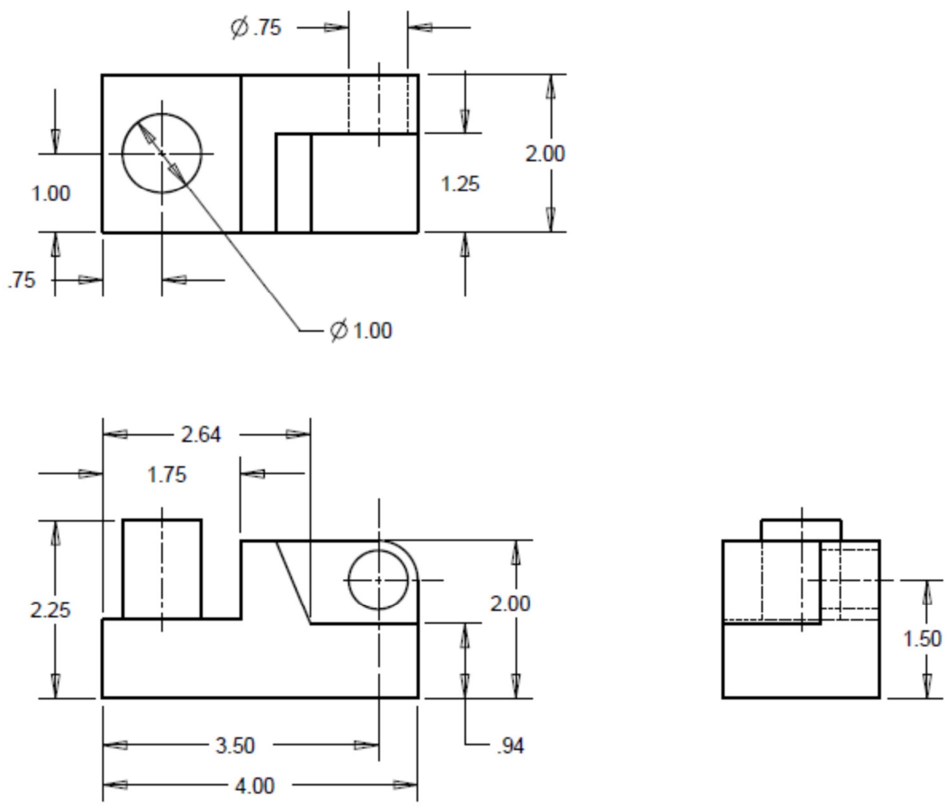


Figure 93

.75 dimensions from the top view (remember we want to locate the centers' of cylindrical features in their circular view).

In figure 93 we should now be able to notice the dimension we have excluded from the drawing. We

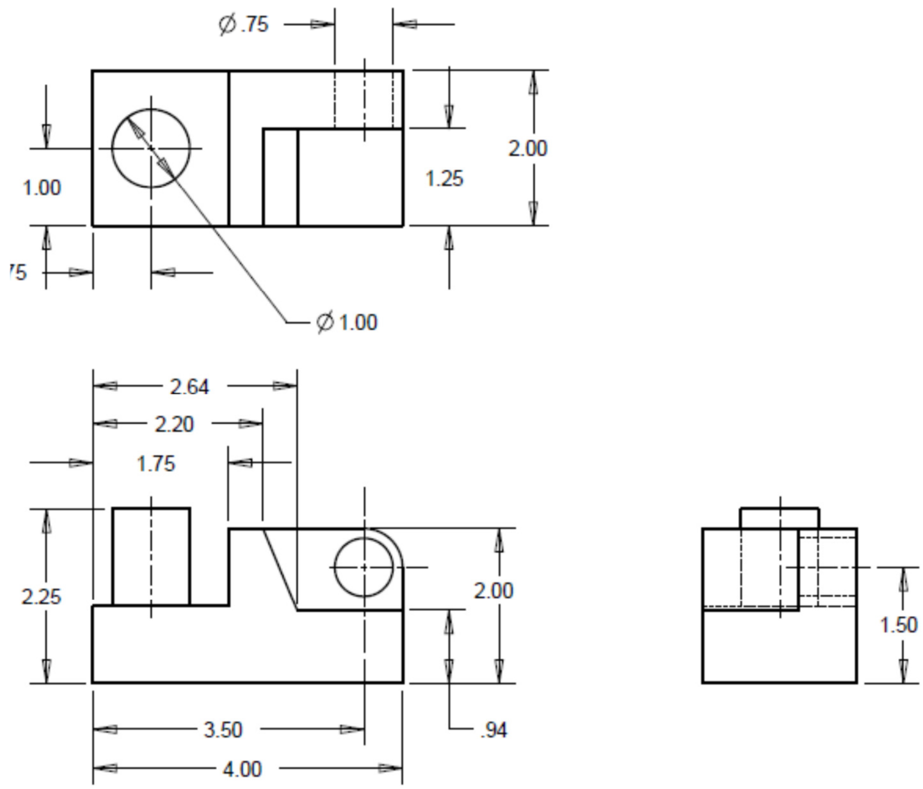


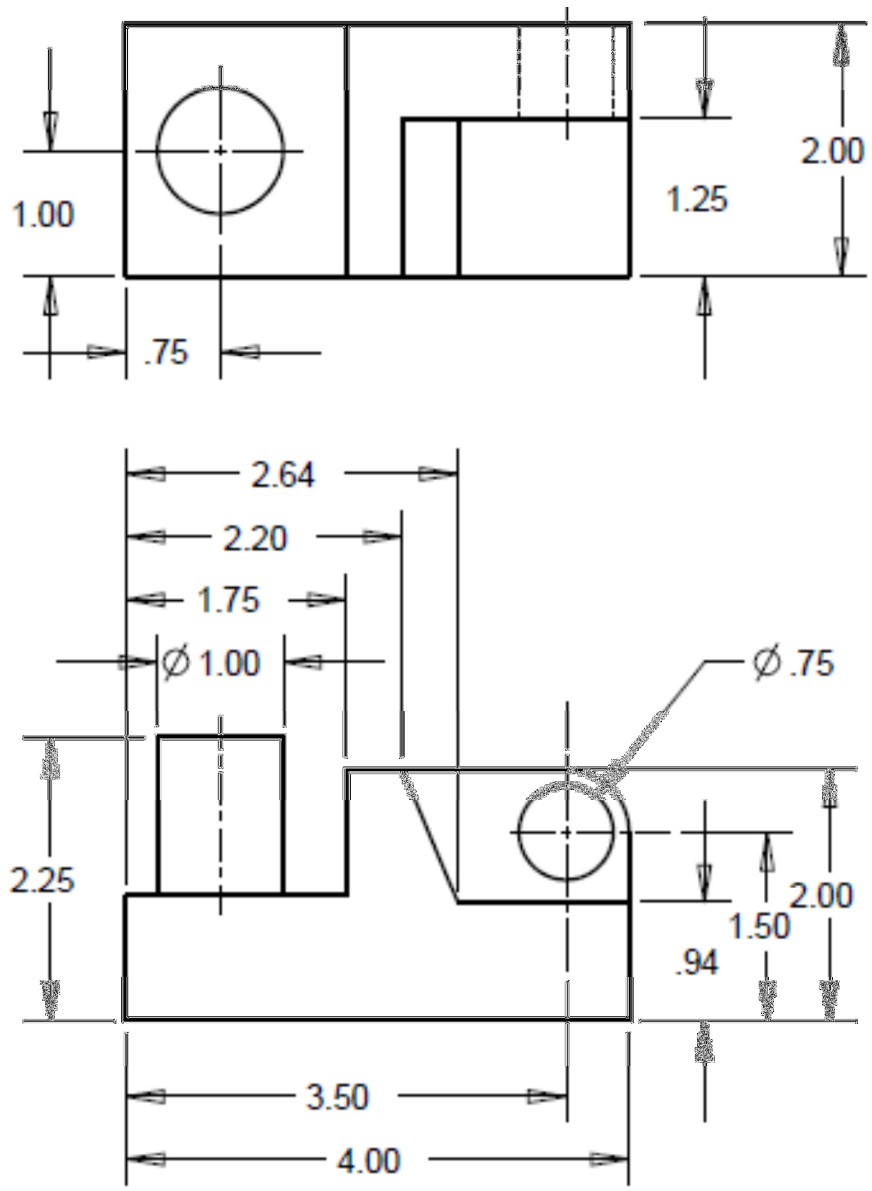
Figure 94

see the 2.64 distance to the right end of the angled cut, but do not have a location for its left end. After adding this dimension (figure 94) we will want to look for dimensions to hidden features and where we can apply the rule of contour.

In the side view we see the height to the center of the hole, we should move this dimension to the front view. In the top view we give the diameters for the one.00" post and the .75" hole. Both these dimensions should be moved to the front view. Remember we will want to show hole diameters in the view where we see a circle and post (solid cylinder) diameters in the view where we see a rectangle (figure 95).

After moving these dimensions, you should notice there are no dimensions left in the side view. As a general rule, if a view does not have any dimensions in it, it can probably be eliminated from the drawing. Doing so will allow us to make the drawing to a larger scale; providing more room for dimensions; and making the drawing easier to read overall.

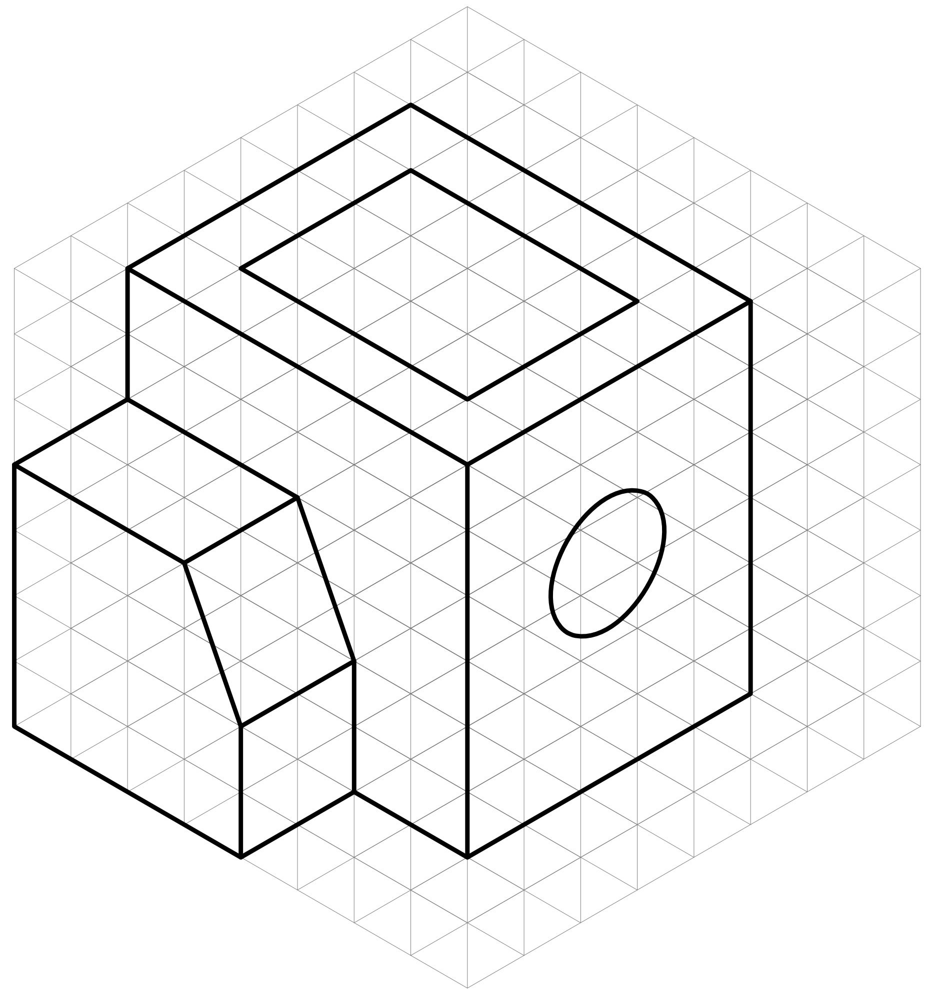
Figure 95



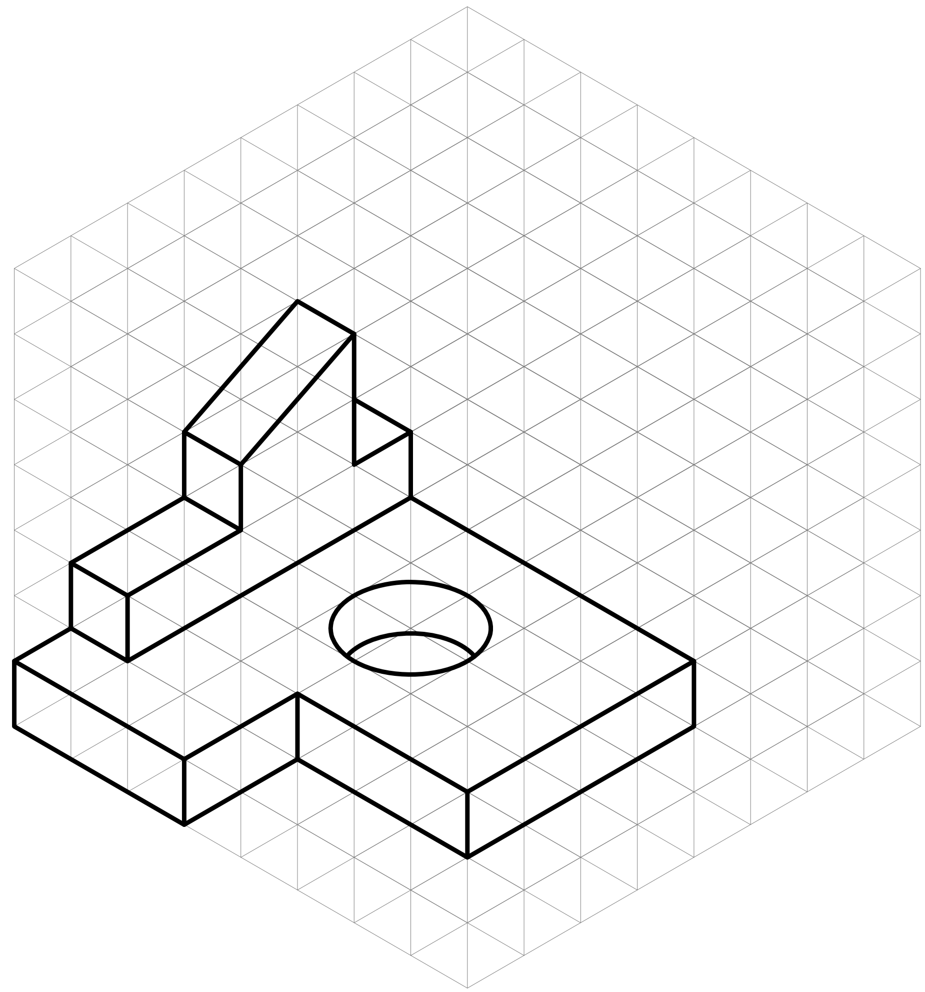
Sample Problems:

1. Sketch front, top and right side view from given isometric
2. Sketch front, top and right side view from given isometric
3. Sketch right side view given front and top view
4. Sketch missing lines in given front, top and right side views *(Hint: 2 of the views are complete)*
5. Given a front and top view, sketch an oblique pictorial
6. Given a front and top view, sketch an oblique pictorial
7. Given a front and top view, sketch an oblique pictorial
8. Given front, top and right side views, sketch an isometric pictorial
9. Given front and top views, sketch an isometric pictorial
10. Given front and right side views, sketch an isometric pictorial
11. Given top and right side views, sketch front view as a full section
12. Given front and right side views, sketch top view as full section
13. Given top and right side views, sketch the front view as an offset section
14. Given the top and right side views, sketch the front view as a half section
15. Cross out 6 duplicate or incorrect dimensions in the given views.
16. For the next 3 dimensioning problems do not measure, just sketch in extension, dimension and leader lines. Note diameter dimensions with a Øsymbol, radii with a R.

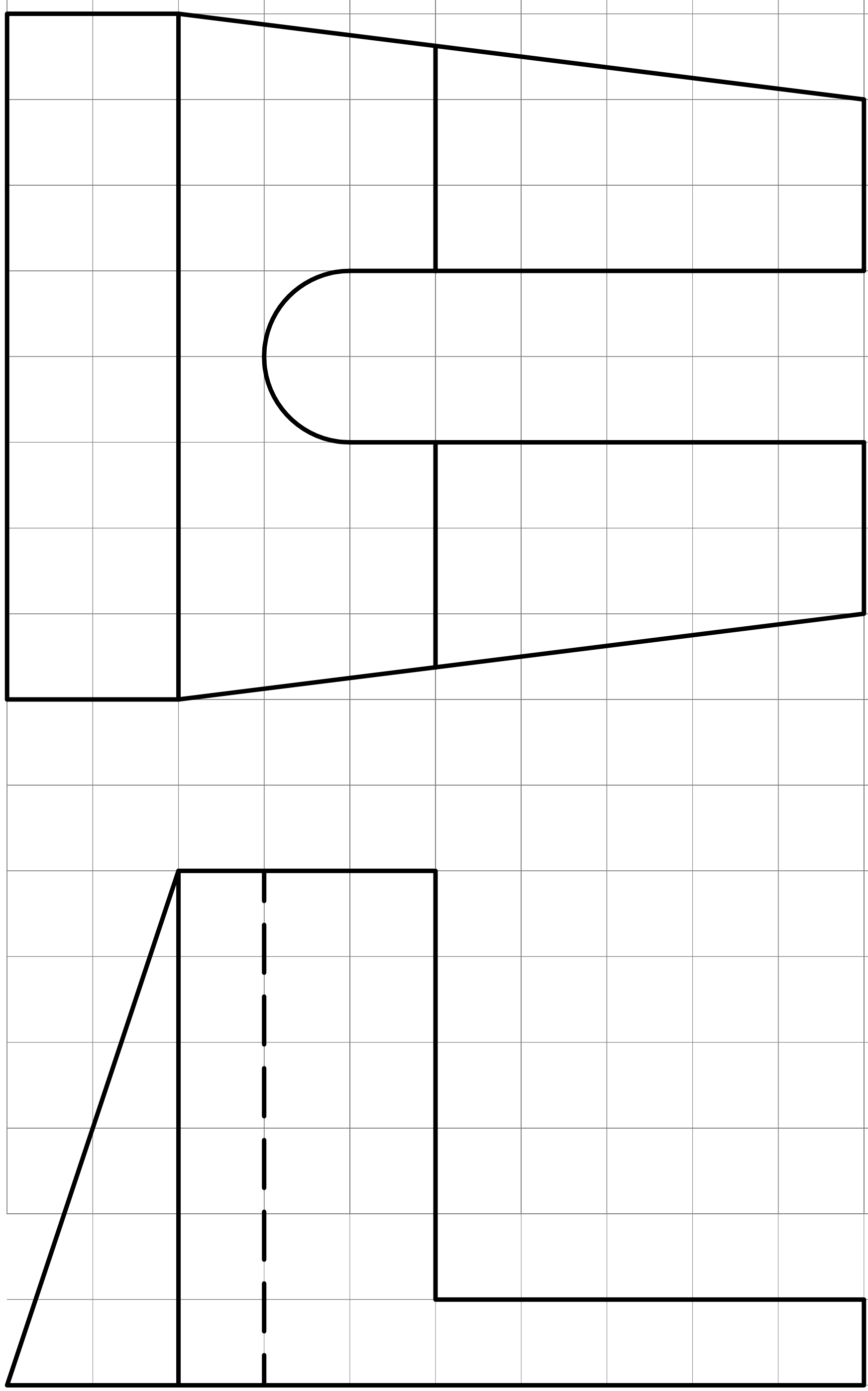
Sketch the front, top and right side views of the object.



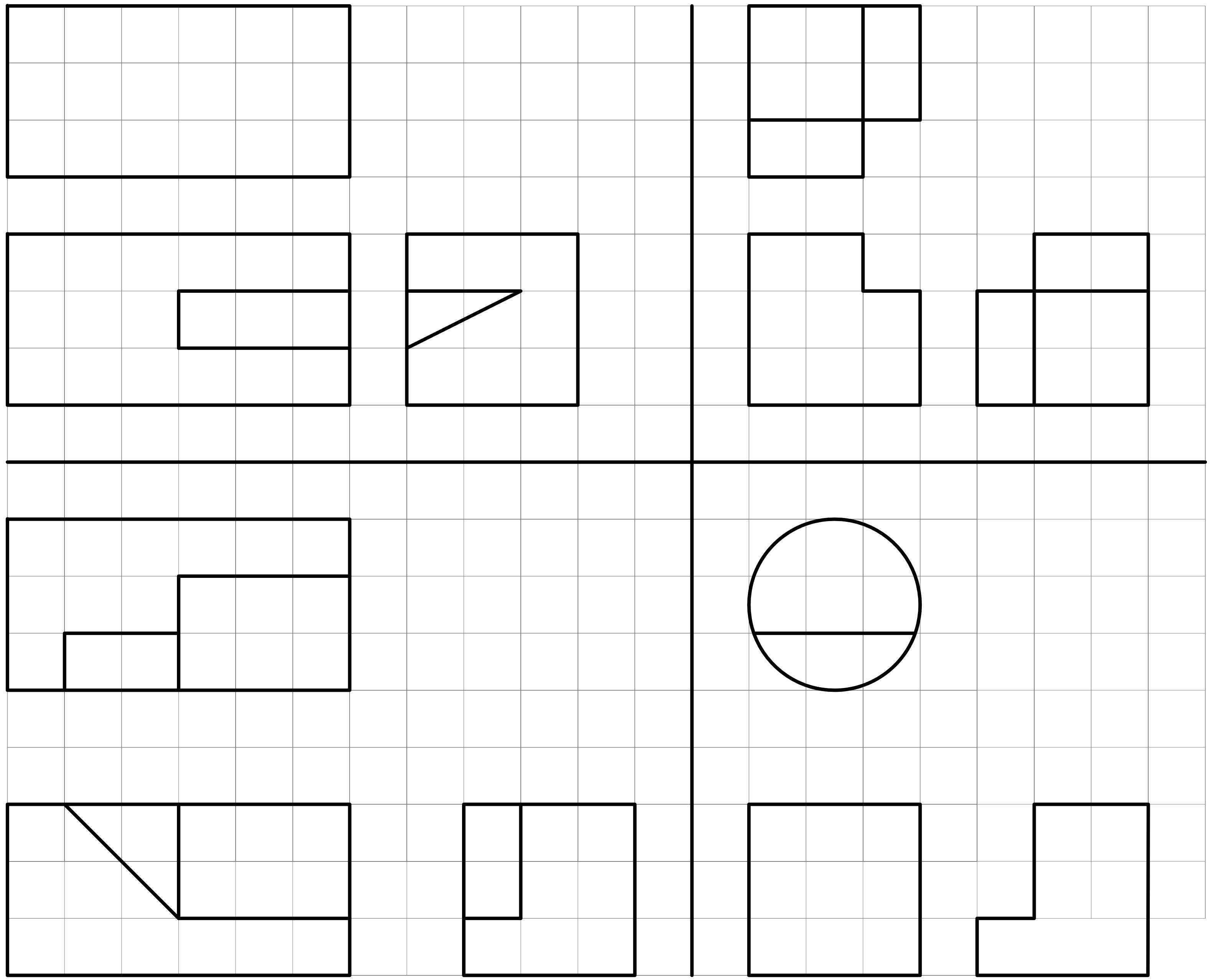
Sketch the front, top and right side views of the object.



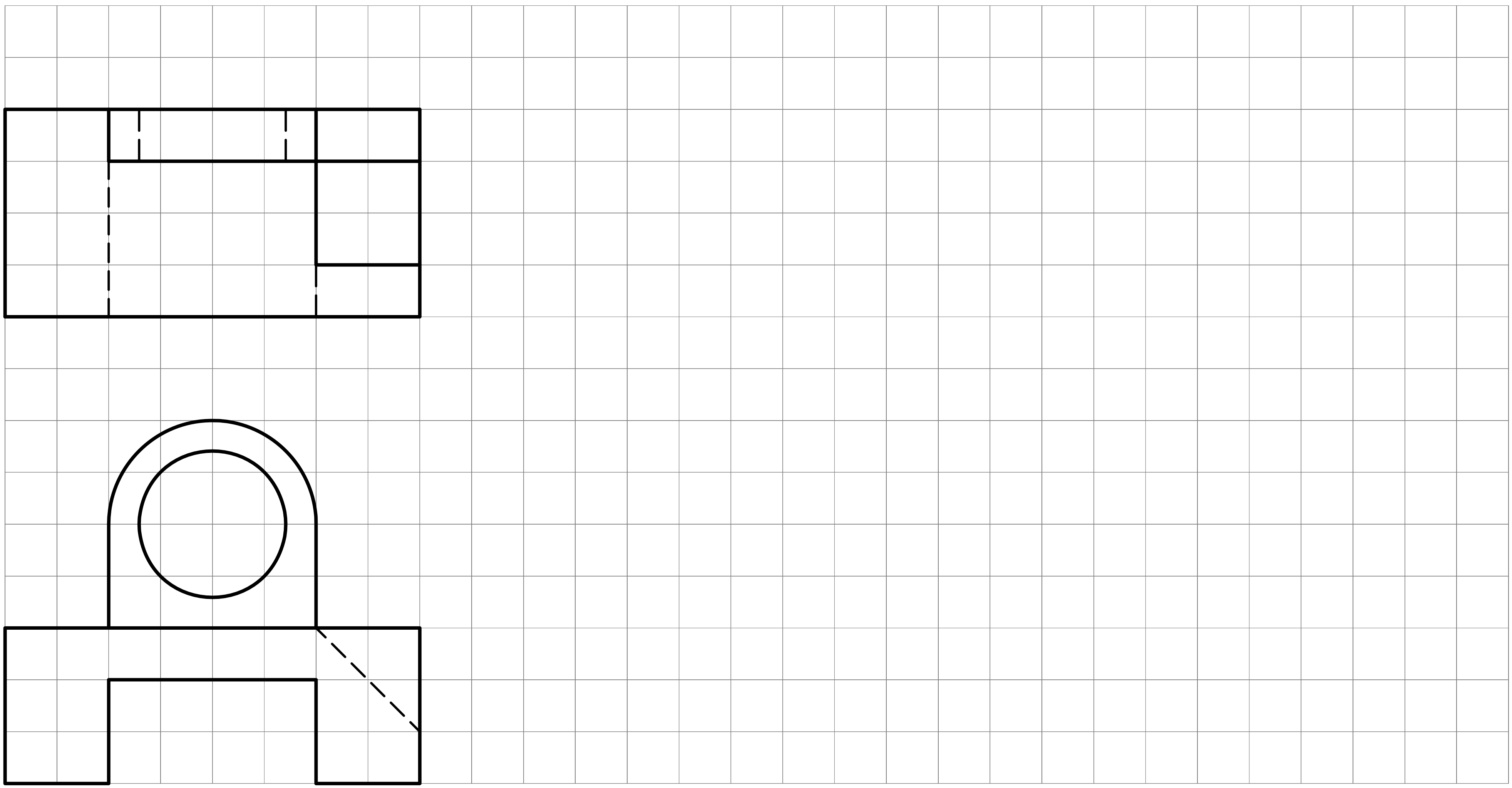
Given the top and front views, sketch the missing right side view.



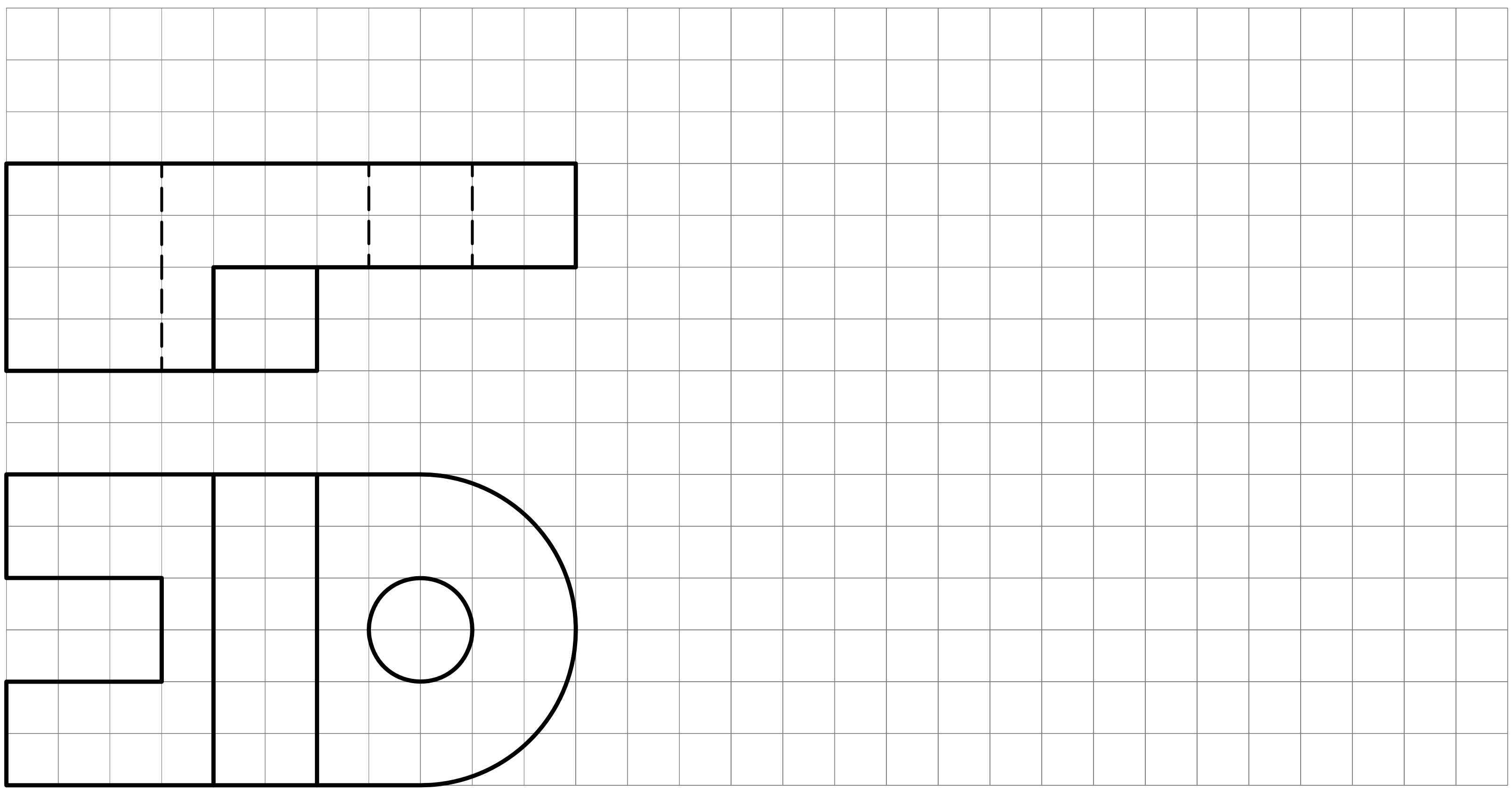
For each problem find the view with one or more missing lines and sketch them in.



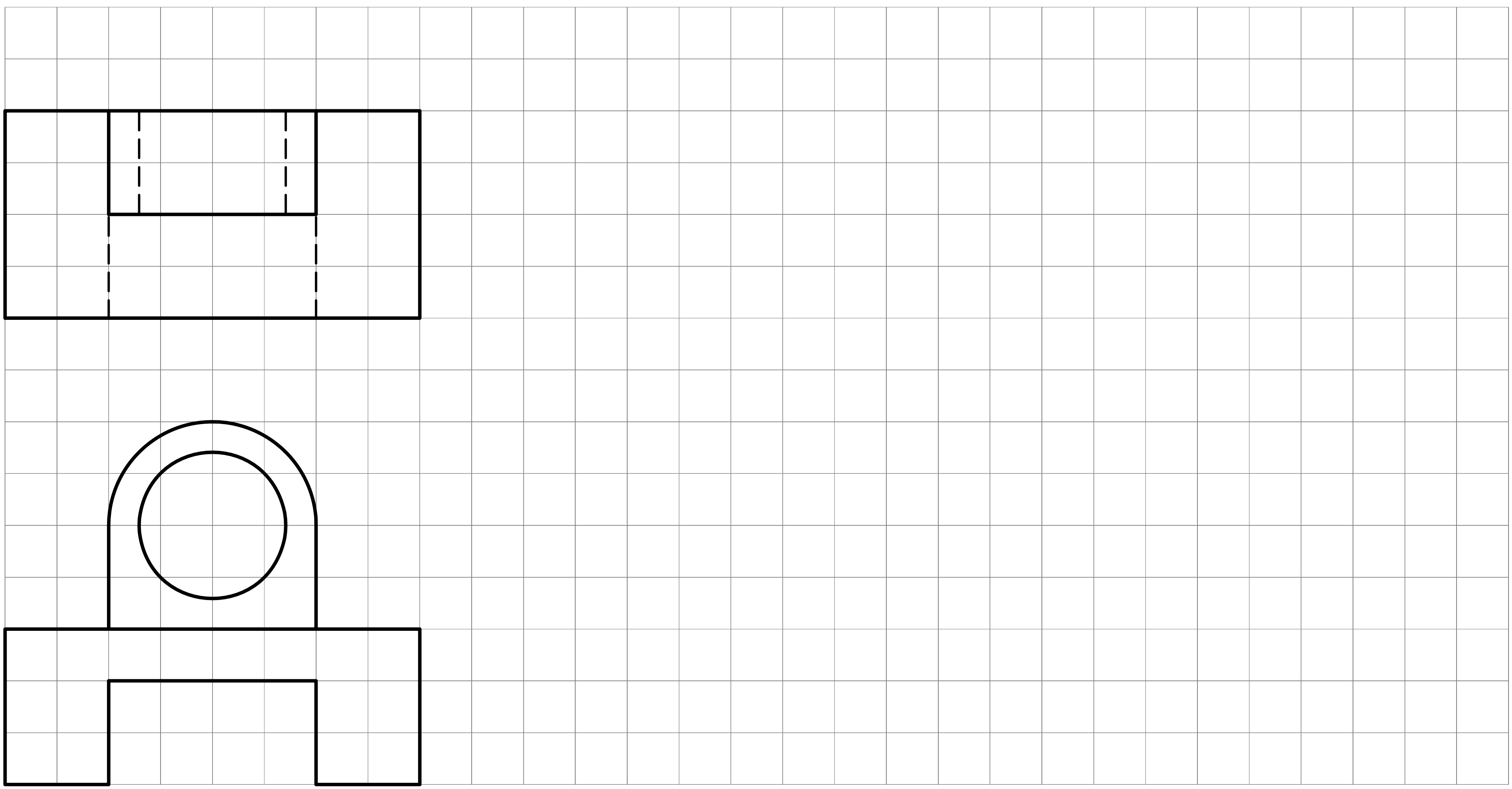
Using front and top views, sketch an oblique pictorial of the given object.



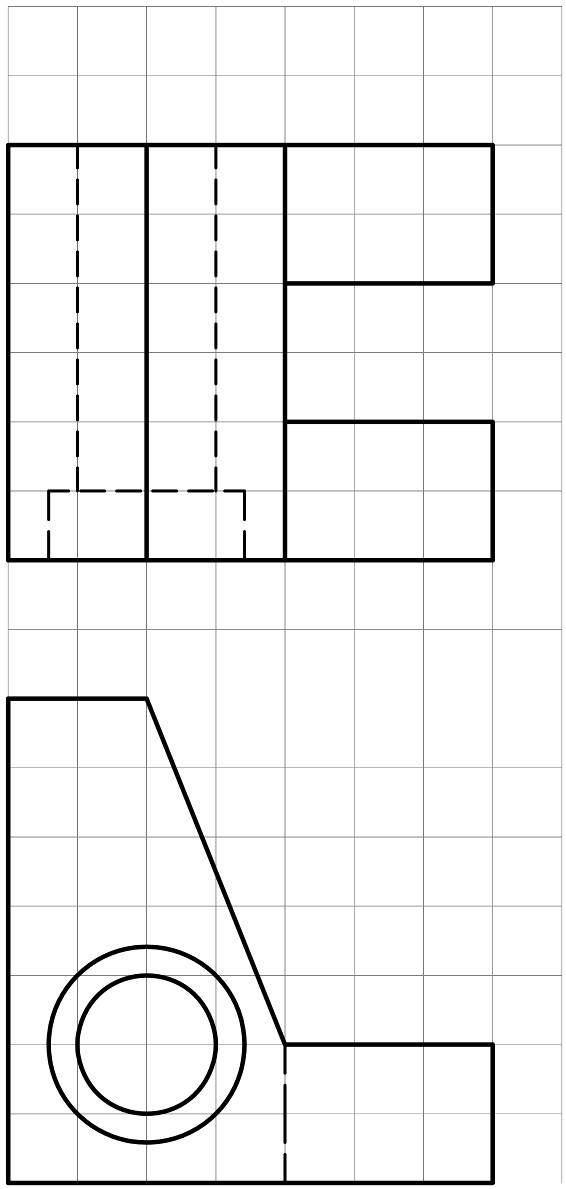
Using front and top views, sketch an oblique pictorial of the given object.

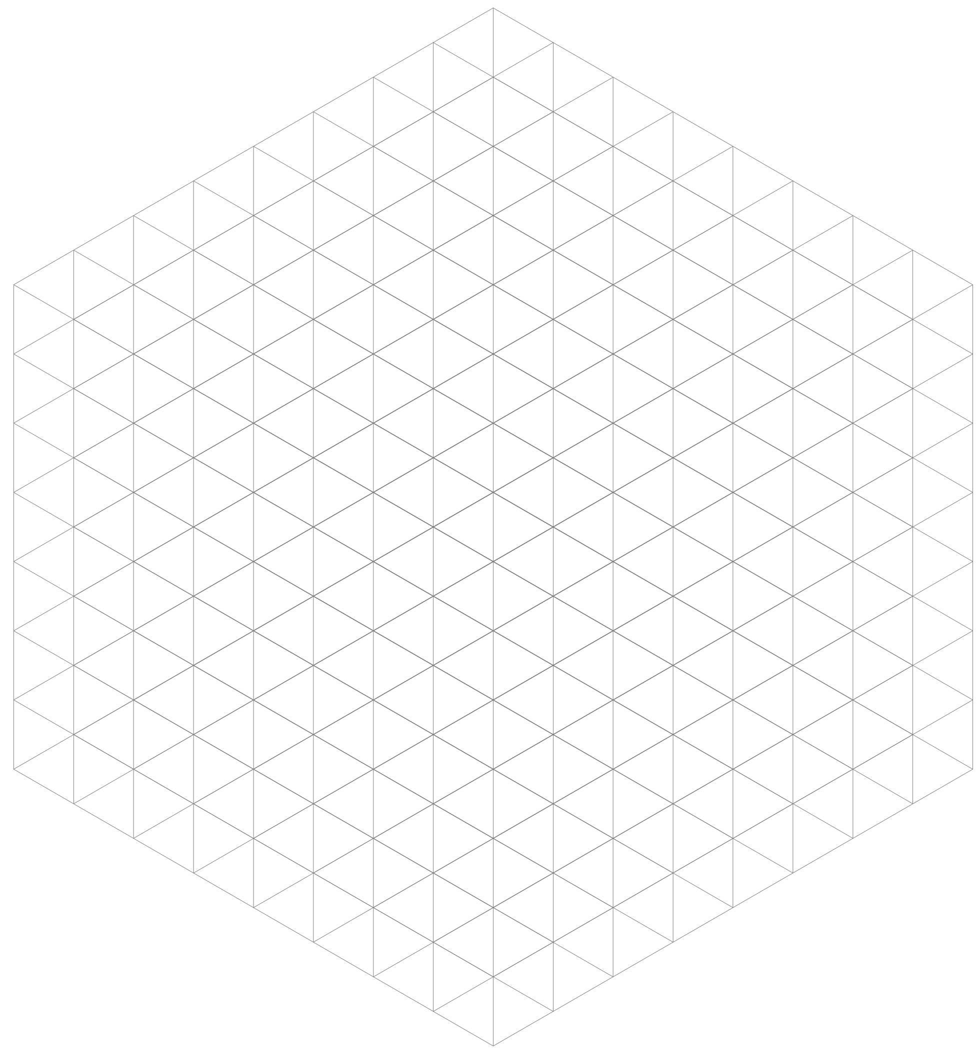


Using front and top views, sketch an oblique pictorial of the given object.

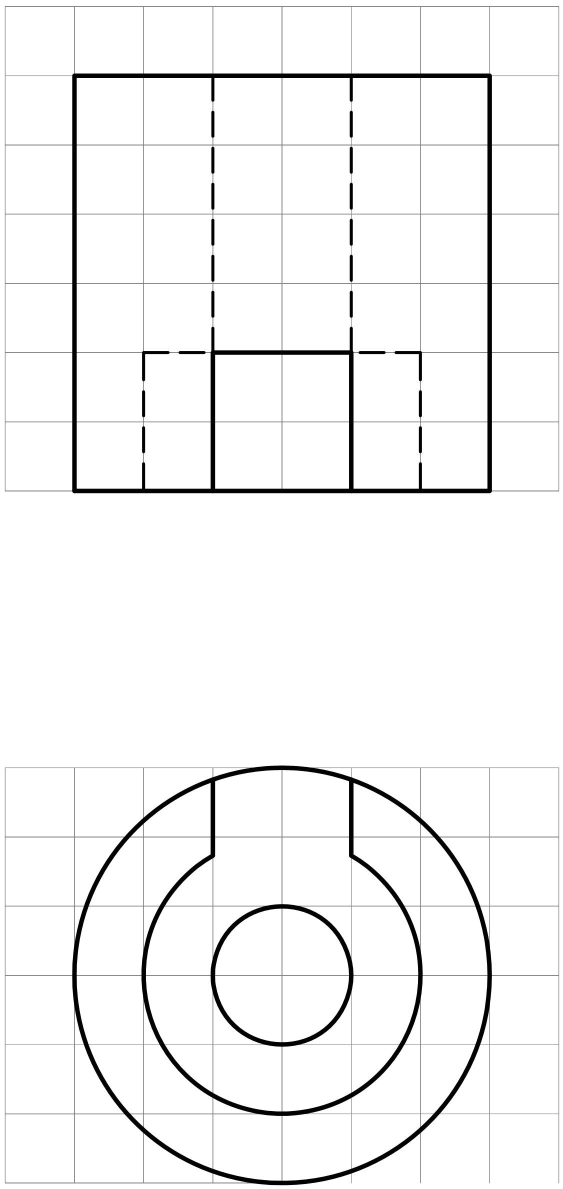


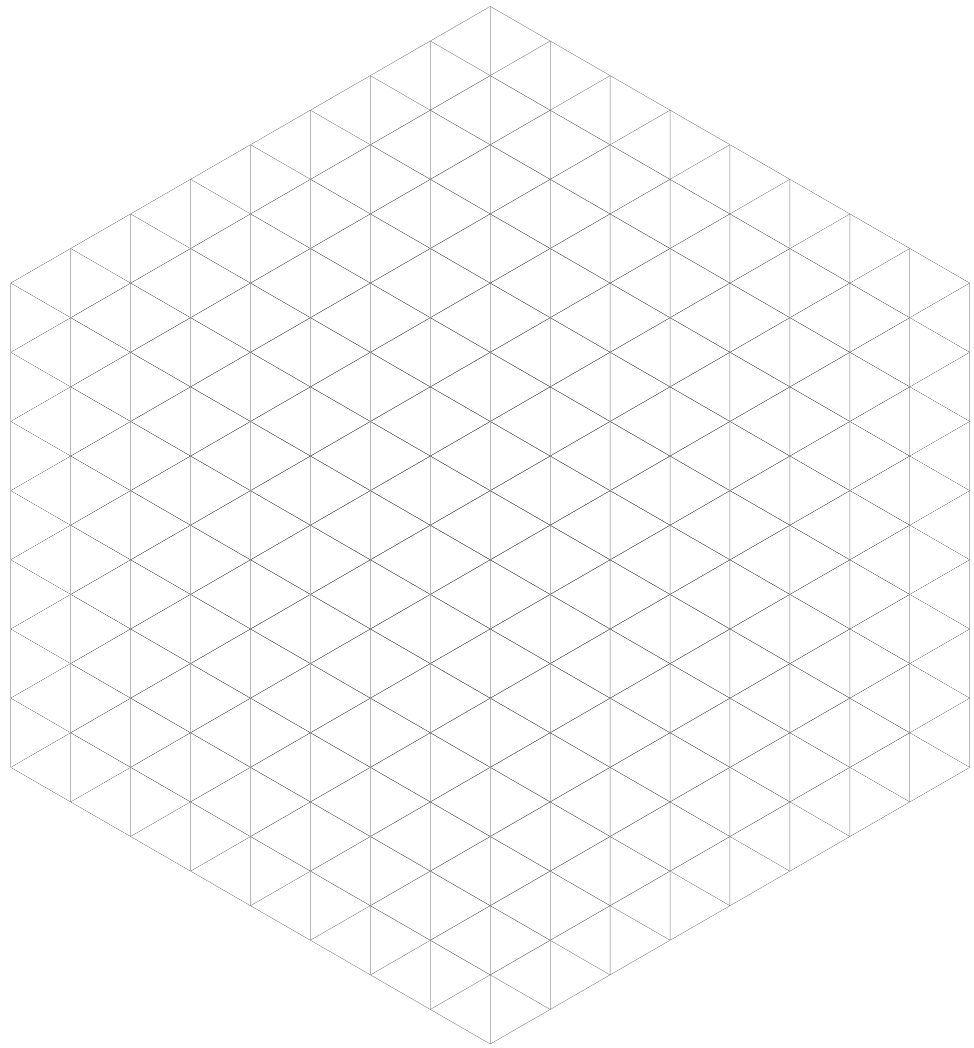
Given the front and top views, sketch an isometric pictorial.



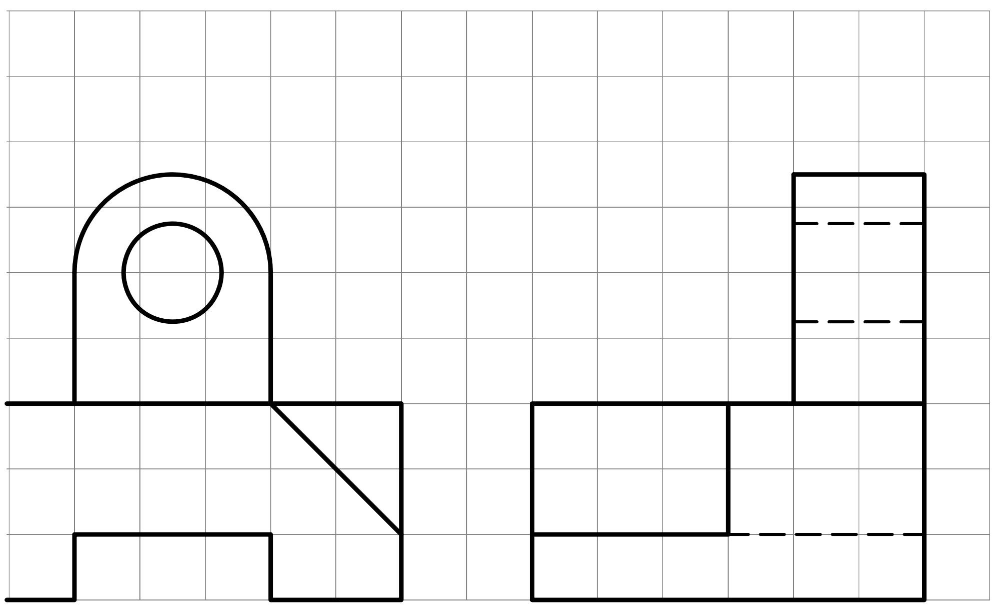


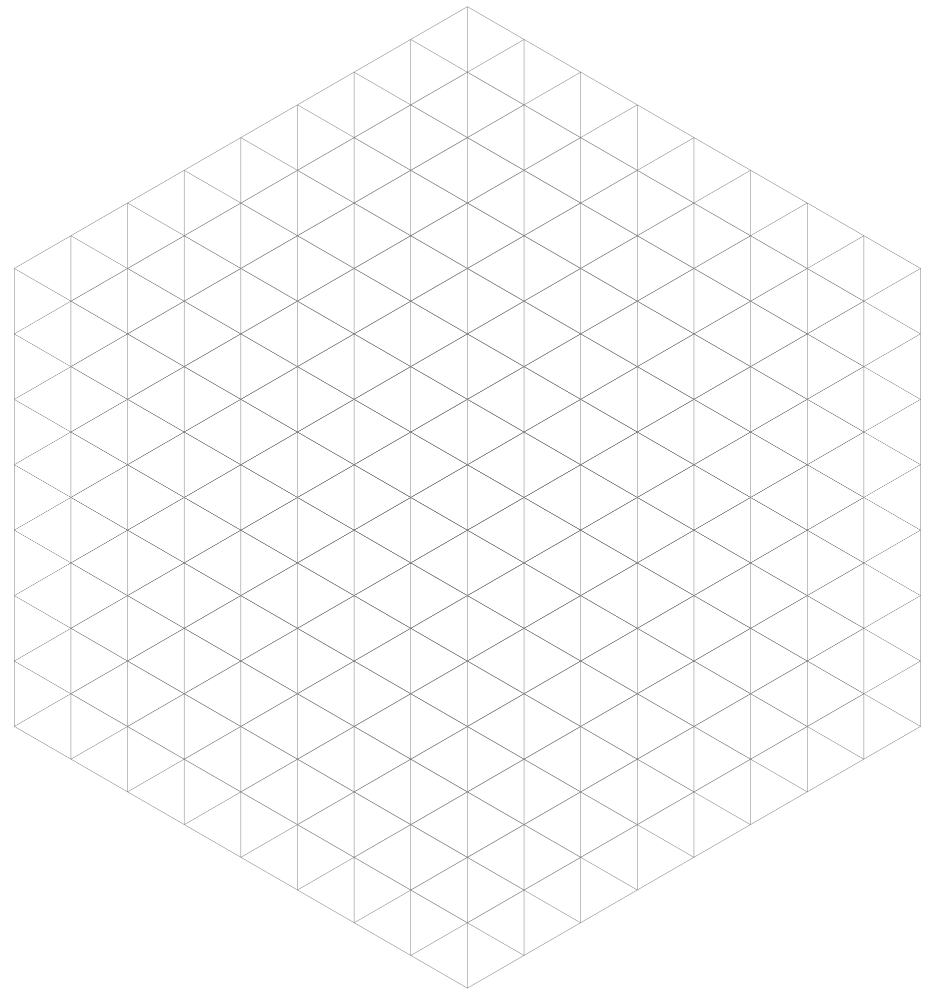
Using the given front and top views, sketch an isometric view.



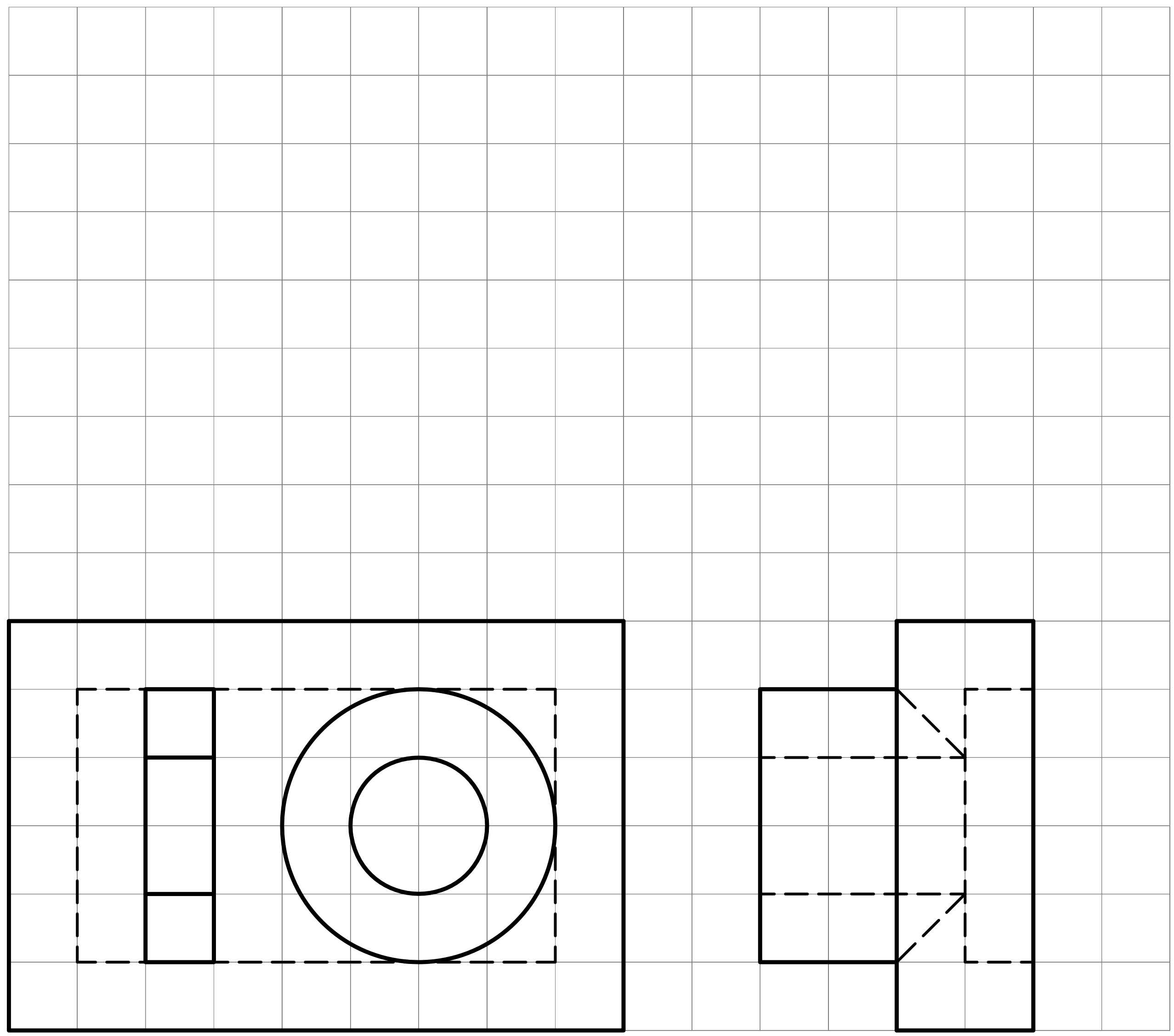


Given the front and right side views, sketch an isometric of the part

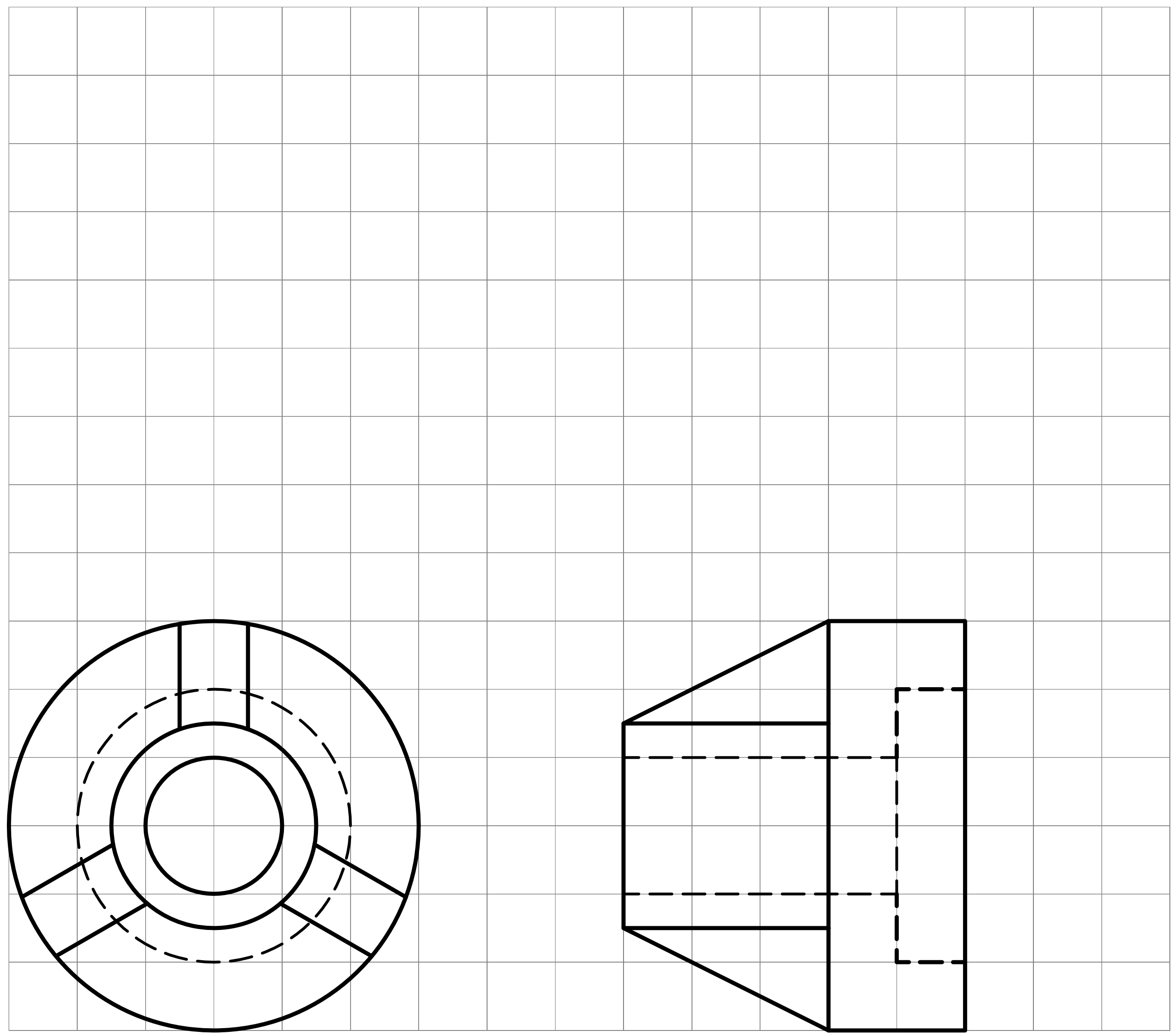




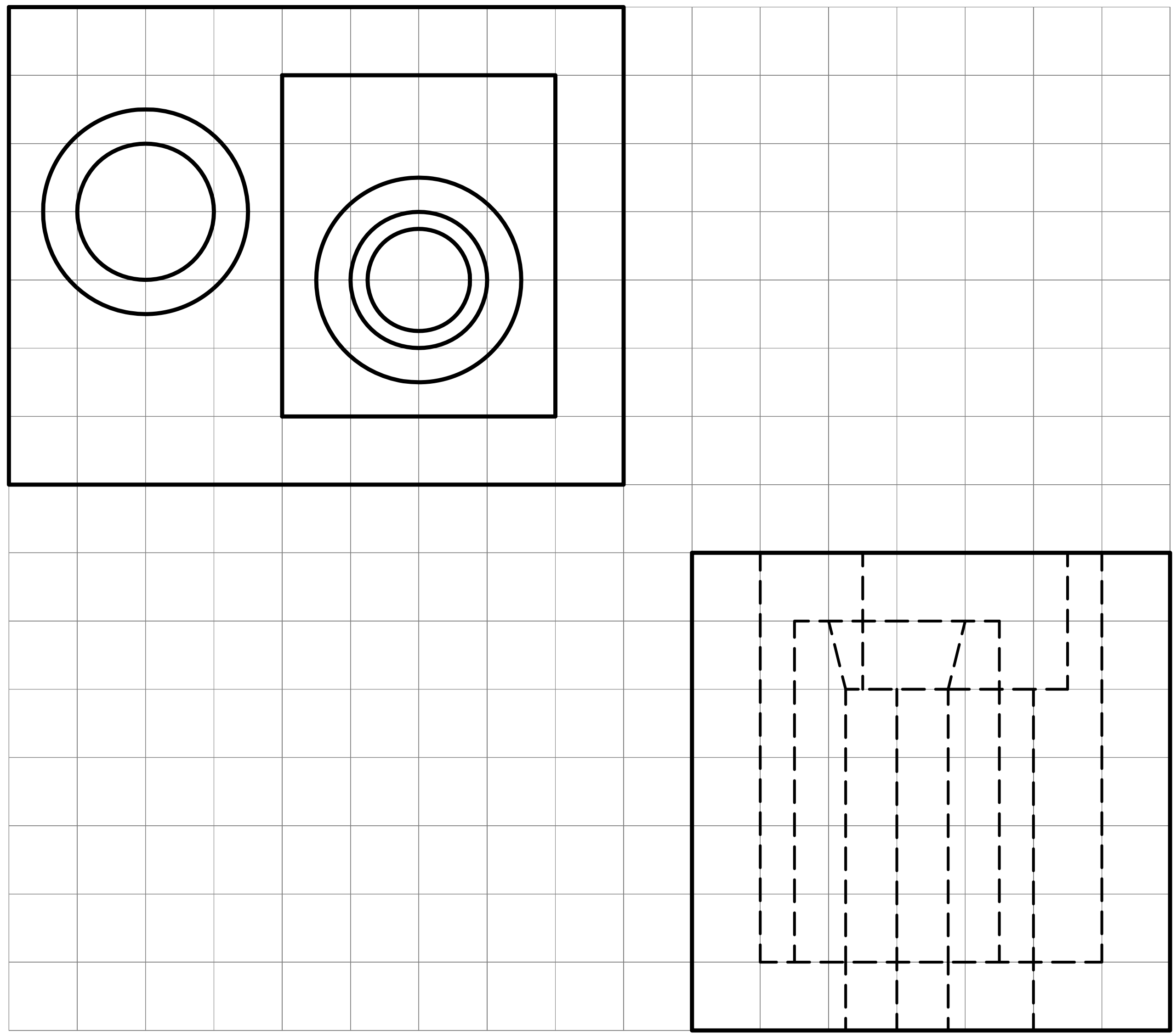
Sketch the top view as a full section, add cutting plane line in front view



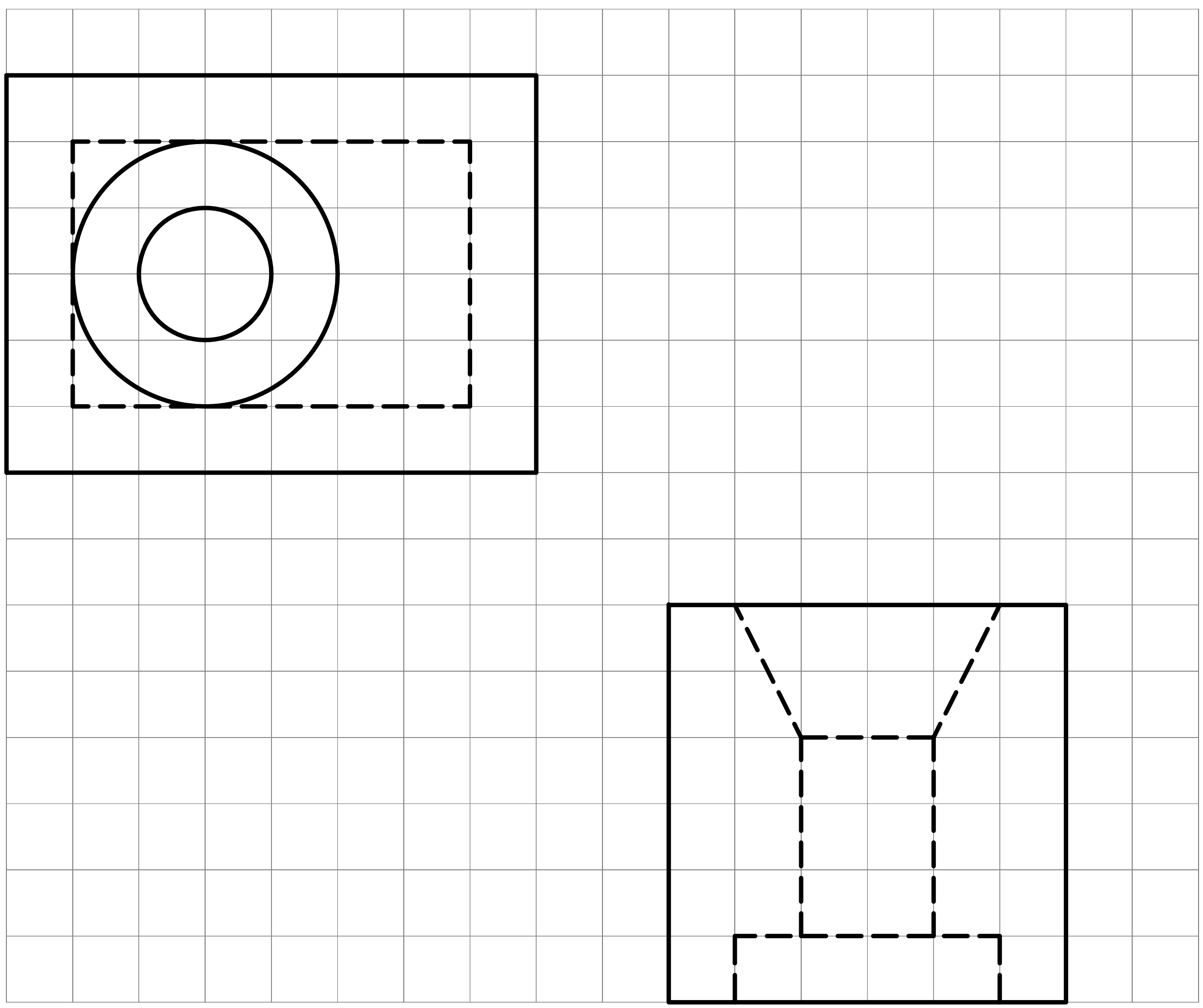
sketch the top view as a full section. Be sure to follow all conventional drawing practices.



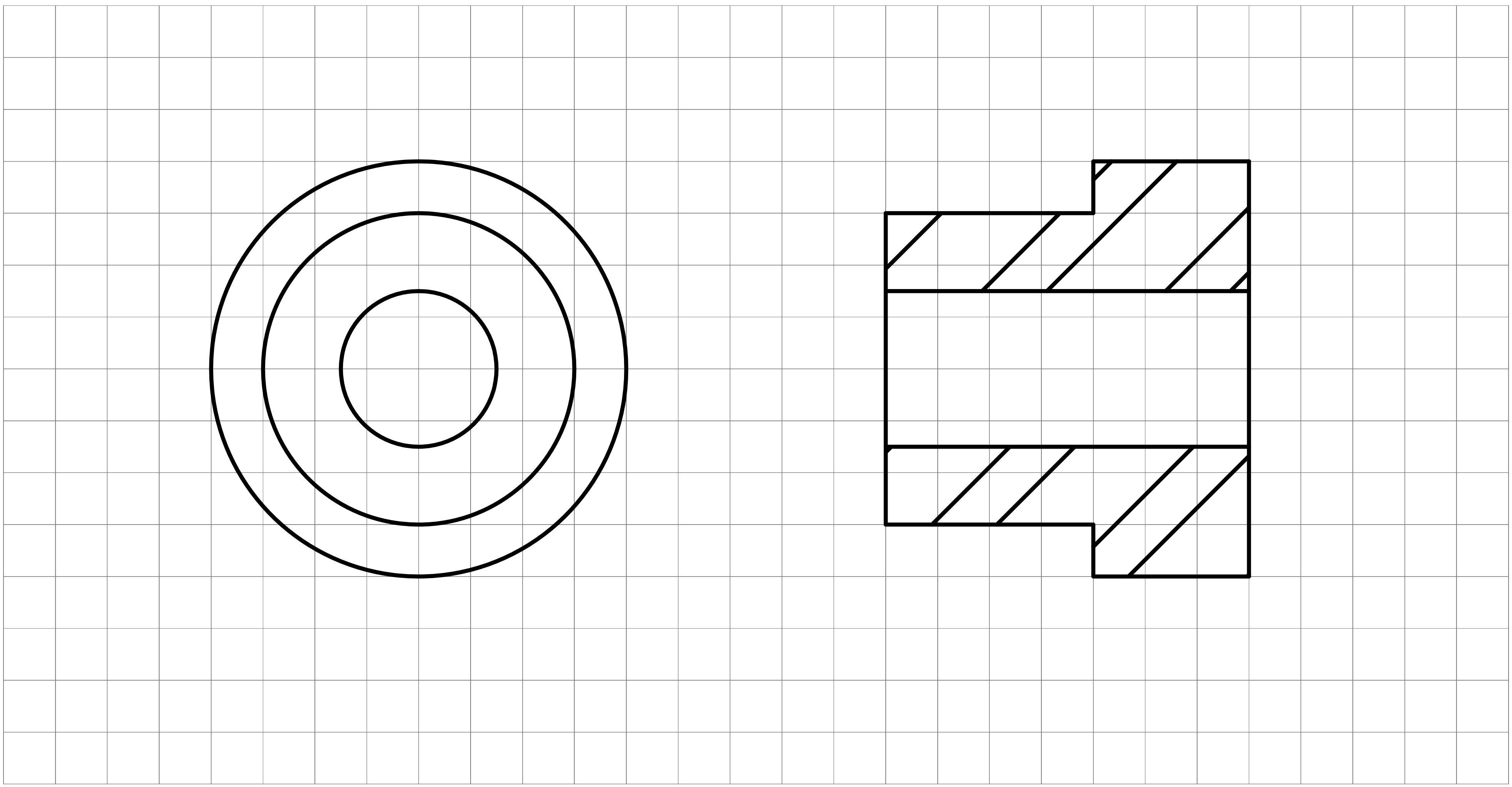
sketch the front view as an offset section. Sketch the cutting plane line in the top view.



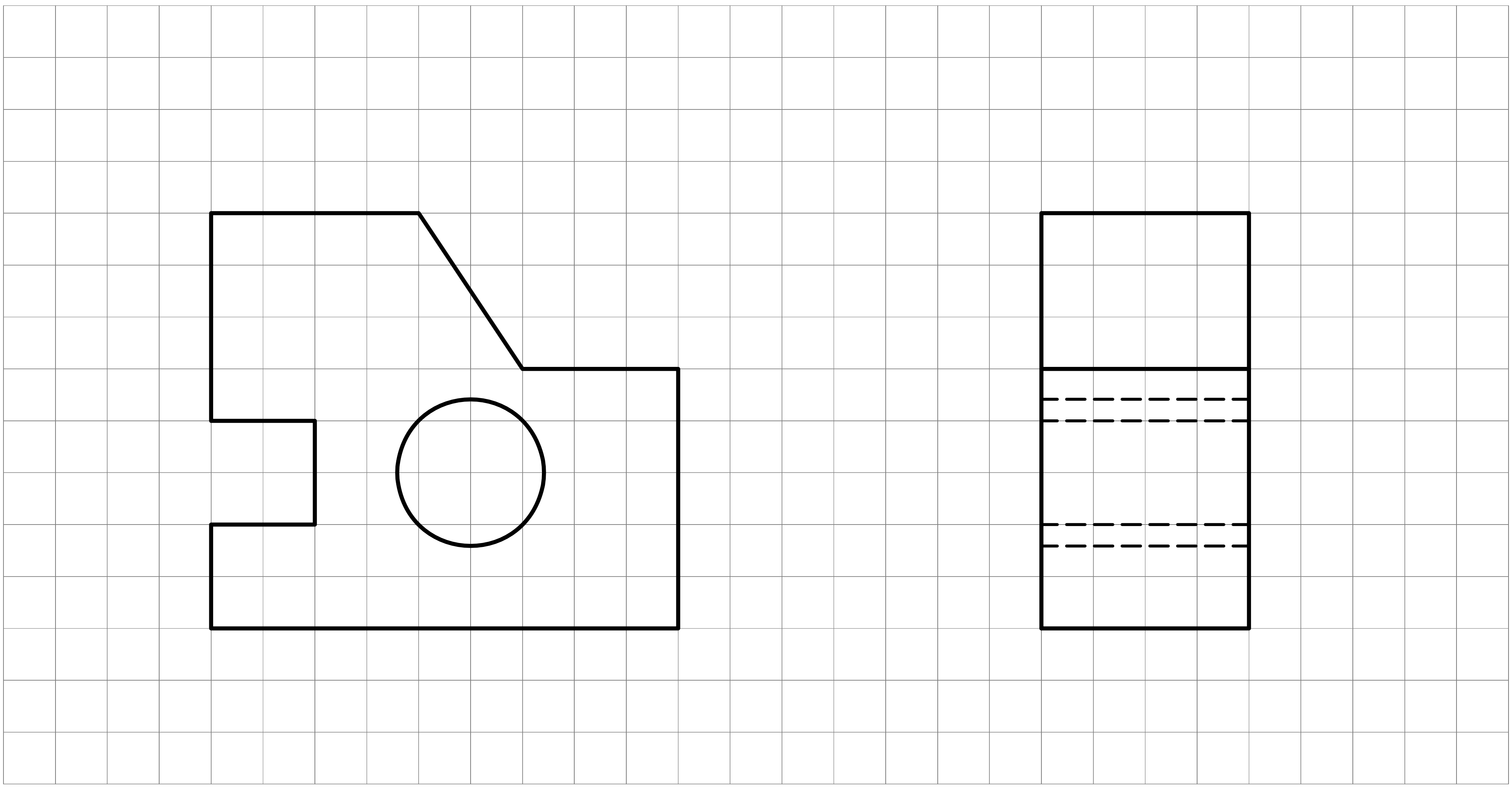
Using side and top views, sketch the front view as a full section



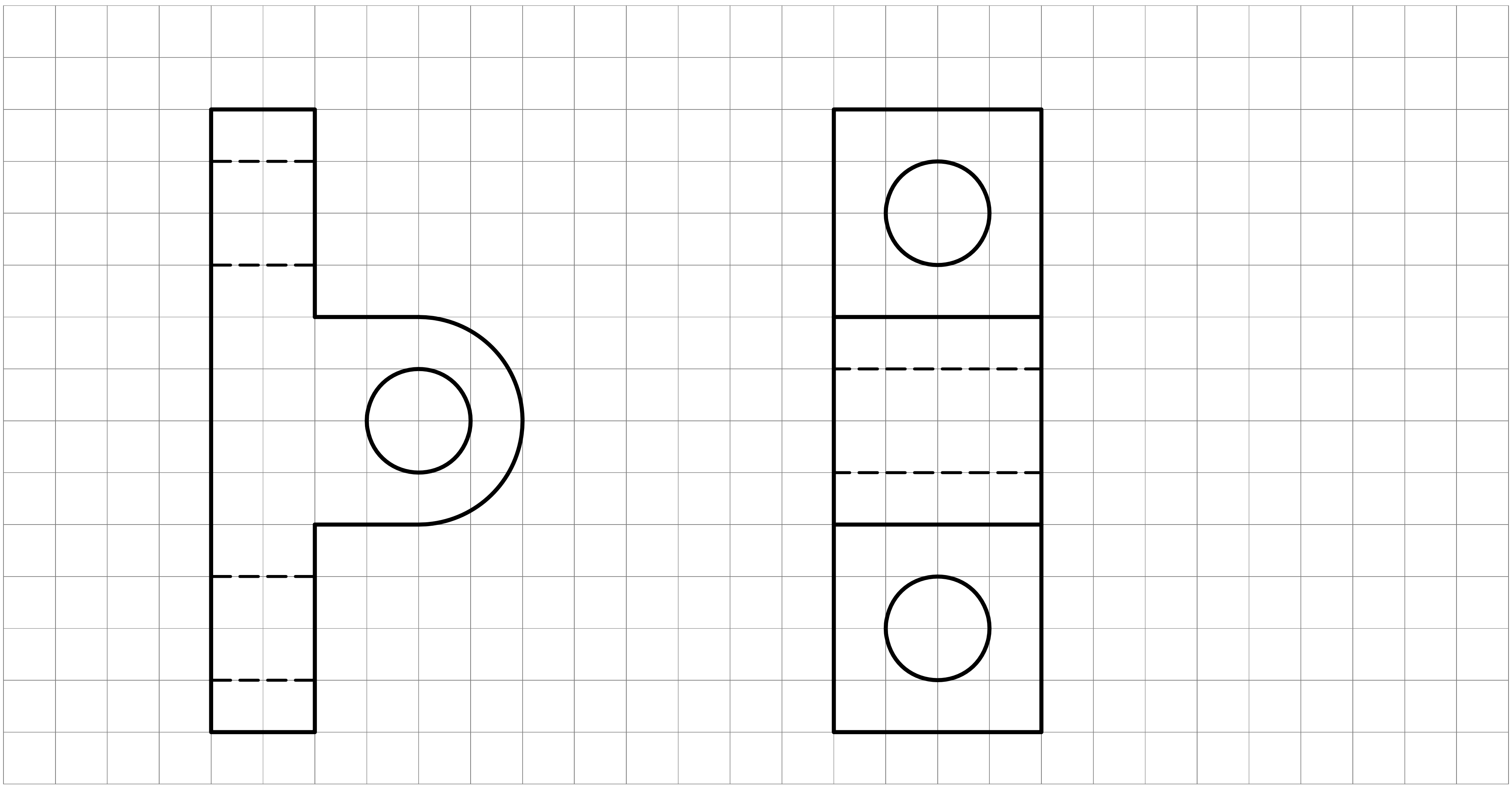
Neatly sketch in the centerlines, dimension lines, extension lines and leaders you would use to dimension the given views.



Neatly sketch in the centerlines, dimension lines, extension lines and leaders you would use to dimension the given views.



Neatly sketch in the centerlines, dimension lines, extension lines and leaders you would use to dimension the given views.



FIND 6 DUPLICATE OR INCORRECT DIMENSIONS IN THE GIVEN DRAWING. CIRCLE THESE DIMENSIONS.