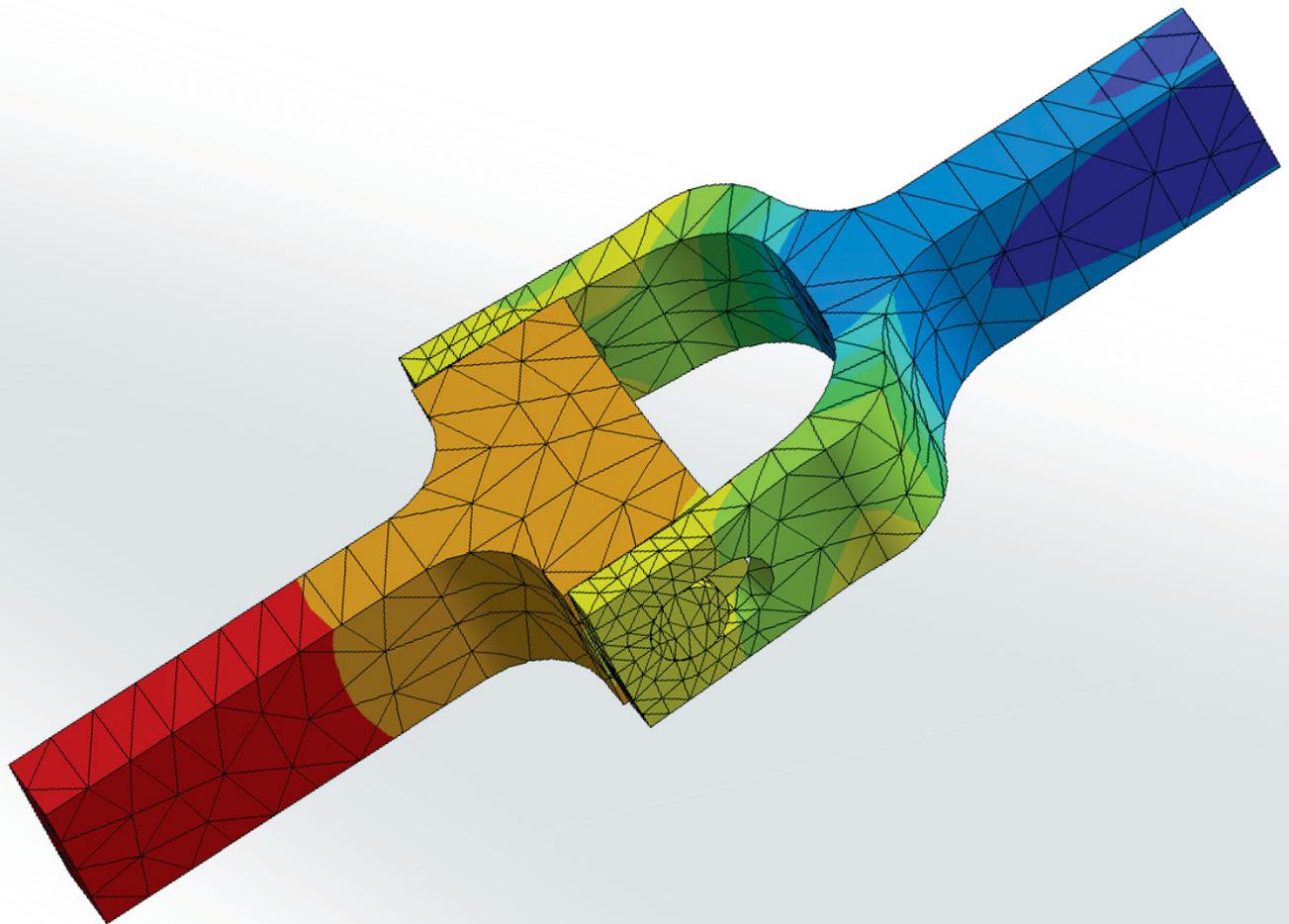


# ANSYS® Workbench™ Tutorial Release 14

Structural & Thermal Analysis Using  
the ANSYS Workbench Release 14  
Environment



Kent L. Lawrence

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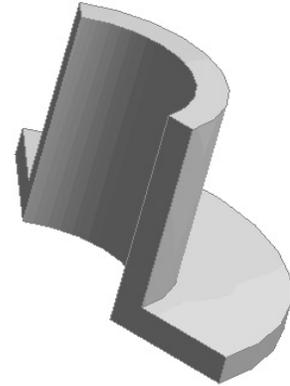
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# Chapter 1

## Solid Modeling Fundamentals

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### 1-1 OVERVIEW

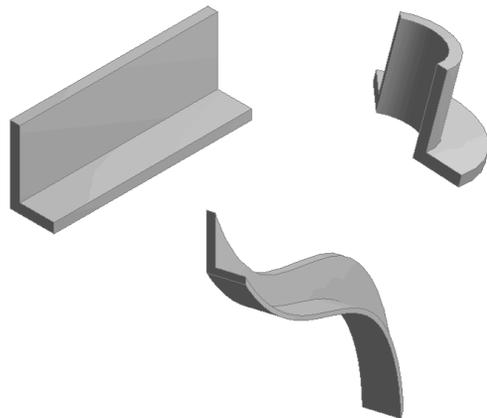
A simple **L-shaped cross section** is used to introduce basic solid modeling concepts with ANSYS DesignModeler. These tutorials explore solid modeling by:

- ◆ Extruding
- ◆ Revolving
- ◆ Sweeping

A number of additional parametric, feature-based modeling possibilities and formulations are demonstrated in this chapter.

### 1-2 INTRODUCTION

Solid modeling can be accomplished in a number of ways, and one favorite method involves starting with a two-dimensional shape and manipulating it to create a solid. That is the approach we will use for many of the object models created in this book. Figure 1-1 shows an L-shaped cross section that has been variously **extruded**, **revolved**, or **swept along a curve** to produce the solid object models shown.



**Figure 1-1** Extruding, revolving, sweeping an L-shaped section.

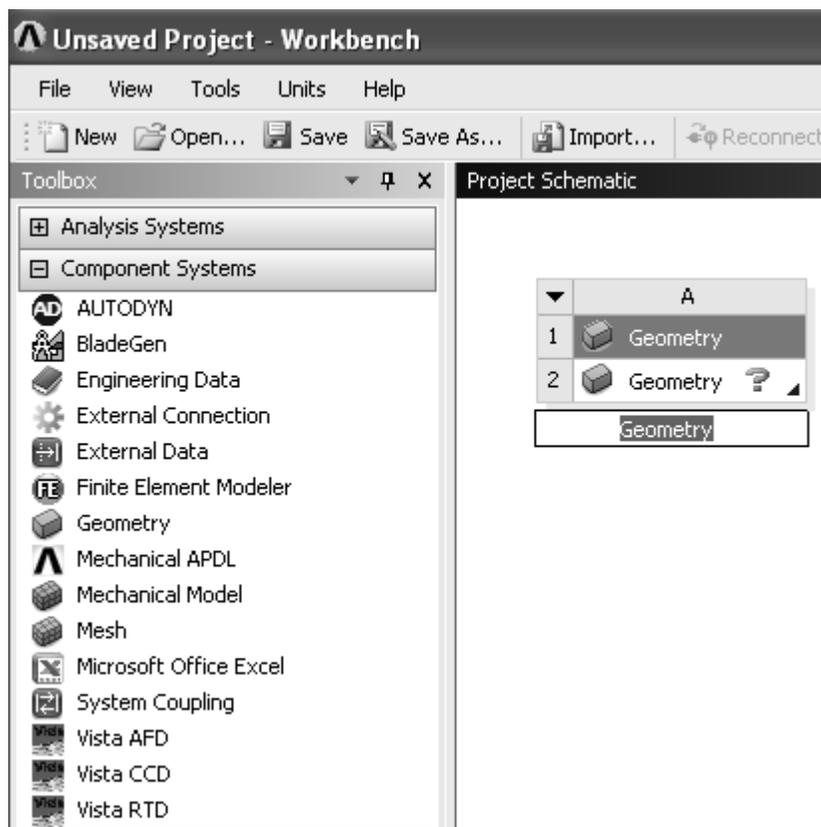
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In the following we use this simple L-shaped section as well as a circular section to illustrate the three fundamental solid modeling approaches mentioned above.

### 1-3 TUTORIAL 1A – EXTRUSION

Follow the steps below to create a **solid model** of an **extrusion** with an **L-shaped** cross section.

1. Follow the steps outlined in the previous chapter Figures I-1 through I-4 to **Start ANSYS Workbench**. **Double click Geometry** or **drag Geometry** into the **Project Schematic** as shown below.



**Figure 1-2** DesignModeler in the Project Schematic.

The question mark indicates that **cell A-2** is incomplete.

2. Select the **small blue triangle** for additional information.
3. **Double click cell A-2 Geometry** to start **DesignModeler**. Select **millimeter** length units > **OK**.

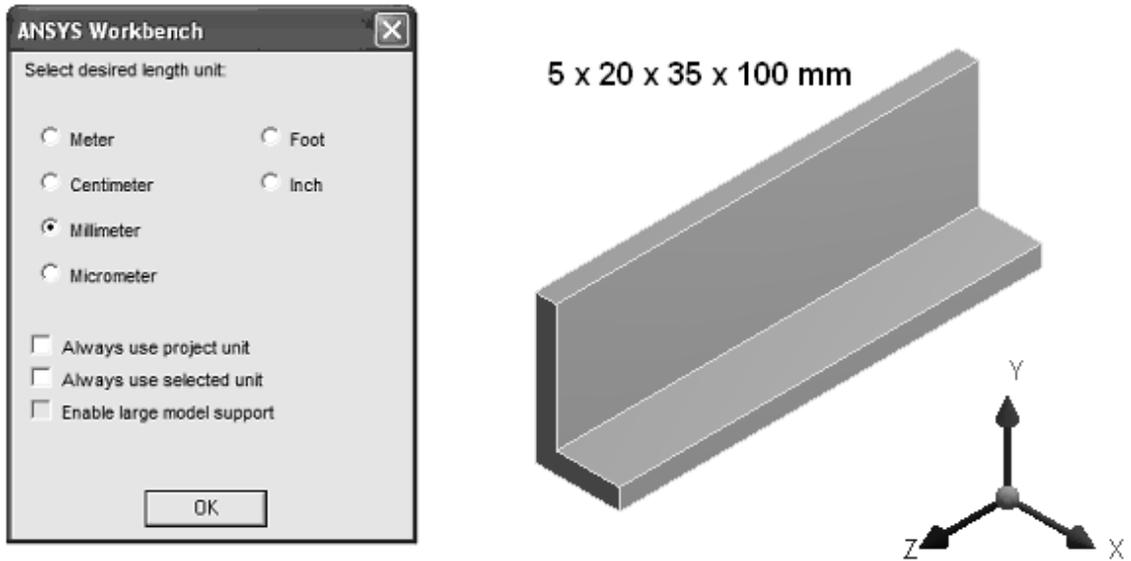


Figure 1-3 T1A solid.

We will **sketch** the L-shaped cross section on the XY Plane. Make it **35 mm high**, **20 mm wide** with **5 mm thick legs**.

4. **Select XYPlane** as in the figure below. Then **click** on the **Look at icon** to view the XYPlane.

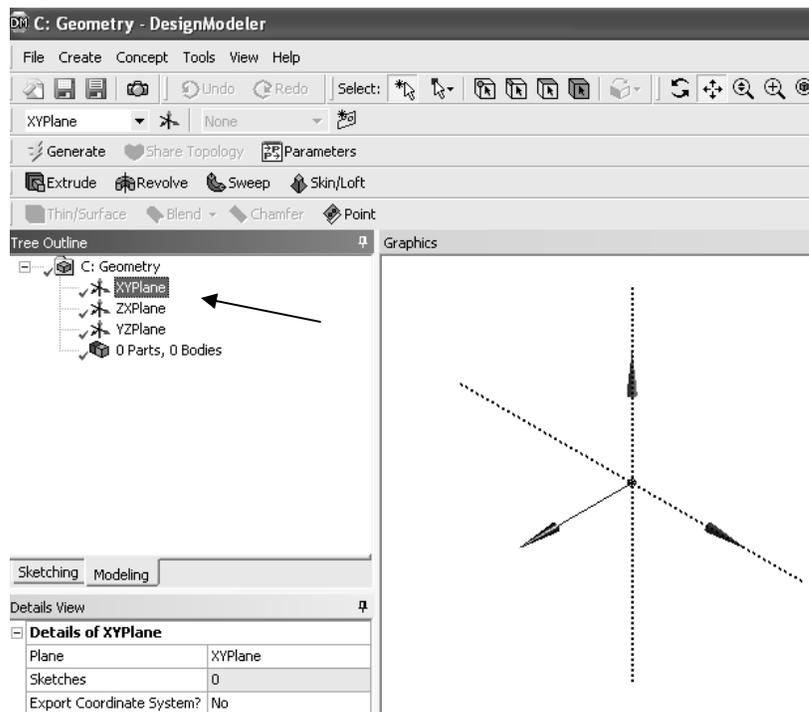


Figure 1-4 Select the sketching plane.

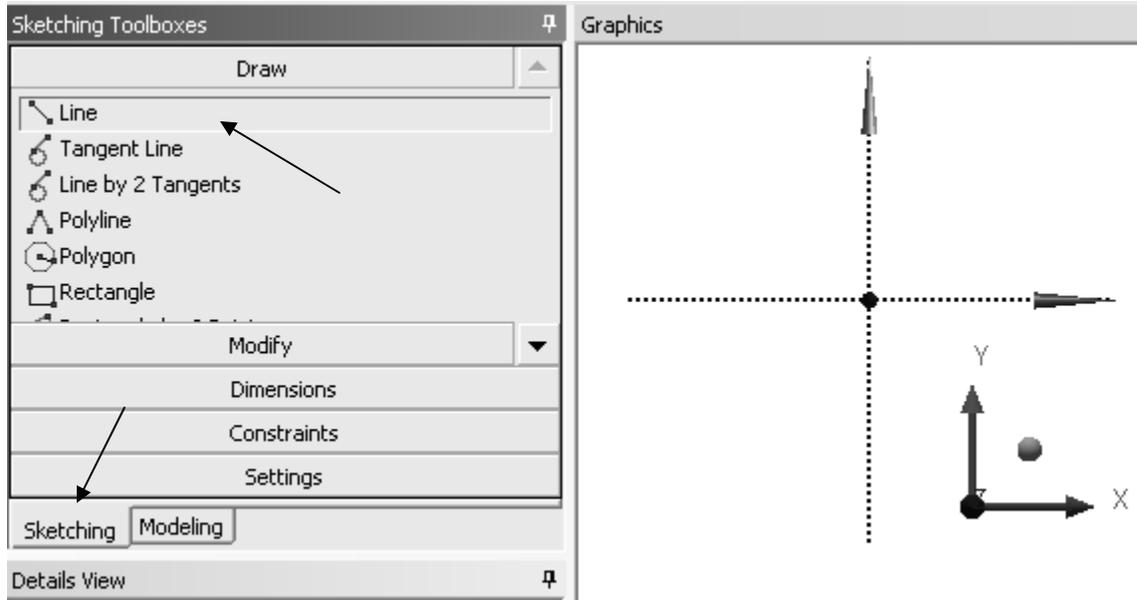


Figure 1-5 Sketching on the plane XY plane.

5. **Sketching.** Change from Modeling to Sketching by selecting the Sketching tab.

Select **Draw > Line**

6. Use the line drawing tool to draw the left vertical edge of the L-shape. Left click at the beginning and again at the end of the line. The **V** indicates that you've got it exactly **vertical**.

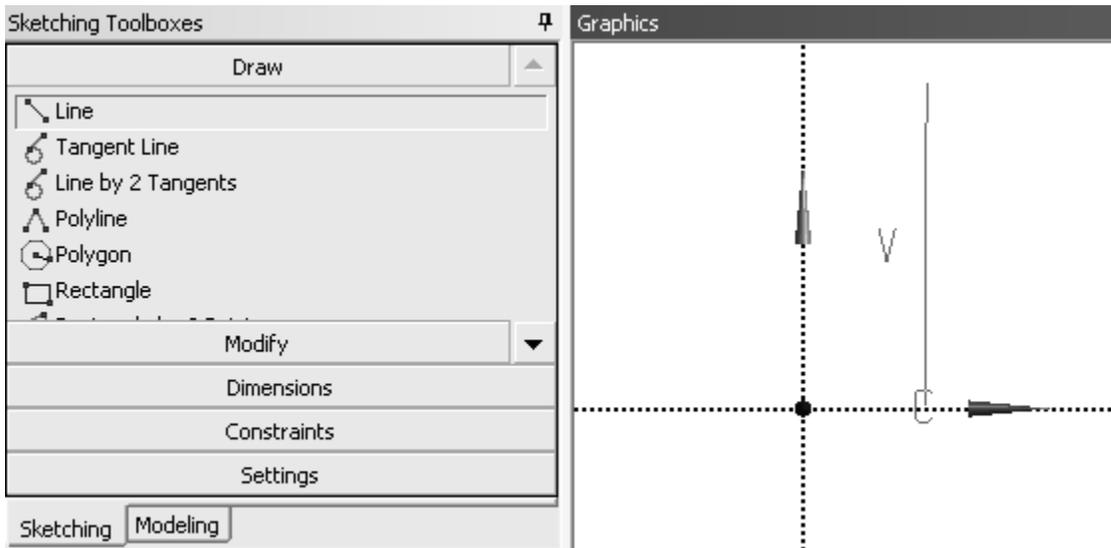


Figure 1-6 Left edge of the L-shape.

7. **Continue sketching** until you have something like what is shown below. Left click at the beginning and again at the end of each line. (Notice that the top edge is not quite horizontal.) If you need to change something, use **Undo** to back up or use **New Selection, Edge** filter to select a line, press the delete key and redraw it. Also note that the cursor changes shape when it is **snapped** onto another point or axis.

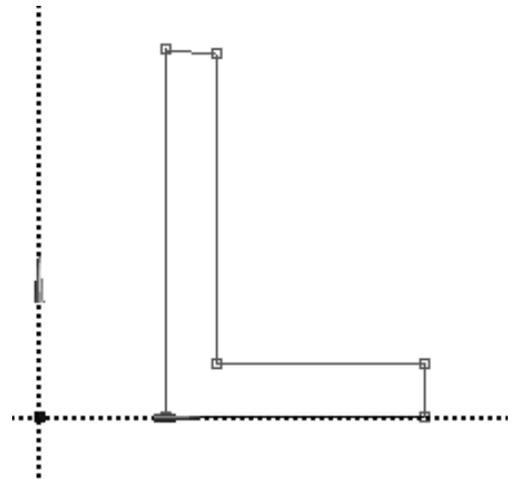
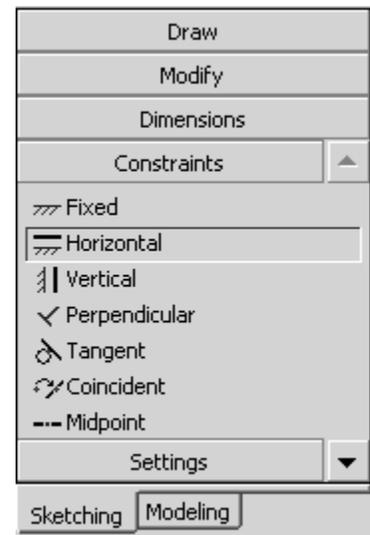


Figure 1-7 L-section sketch.

Use the **constraints** options **horizontal** to make the top edge horizontal and **equal length** to make sure that the vertical and horizontal legs of the L are of the same thickness.

8. **Sketching > Constraints > Horizontal** –  
Left click the top edge.

Figure 1-8 Sketching constraints.



9. **Sketching > Constraints > Equal length** –  
Left Click the top edge and then the right edge.

The figure is just a sketch so far, and a number of different dimensioning schemes could be used to produce the section we want. We will use the **Sketching > Dimensions** options to give it the desired properties.

10. **Sketching > Dimensions > General** –  
Left click and (hold down the button) on the left vertical edge of the section and drag the dimension to place.

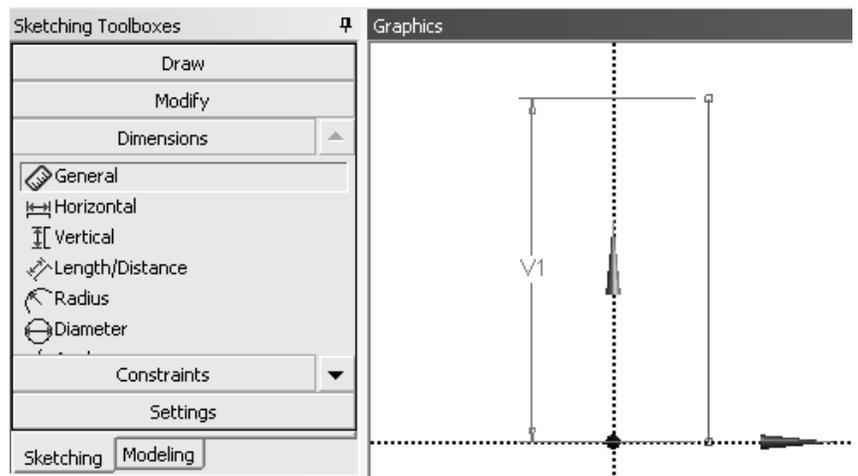


Figure 1-9 Left edge.

The V1 means this is the first vertical dimension for this sketch. Continue with General dimensioning to specify H3 and V2. Don't dimension the top edge; it has to be equal to V2. The bottom edge is located directly on the X axis but we need to locate the vertical edge with respect to the Y axis.

11. **Sketching > Dimensions > Horizontal** – Left click the left vertical edge then click the dotted Y axis and drag the H3 dimension to a convenient location.

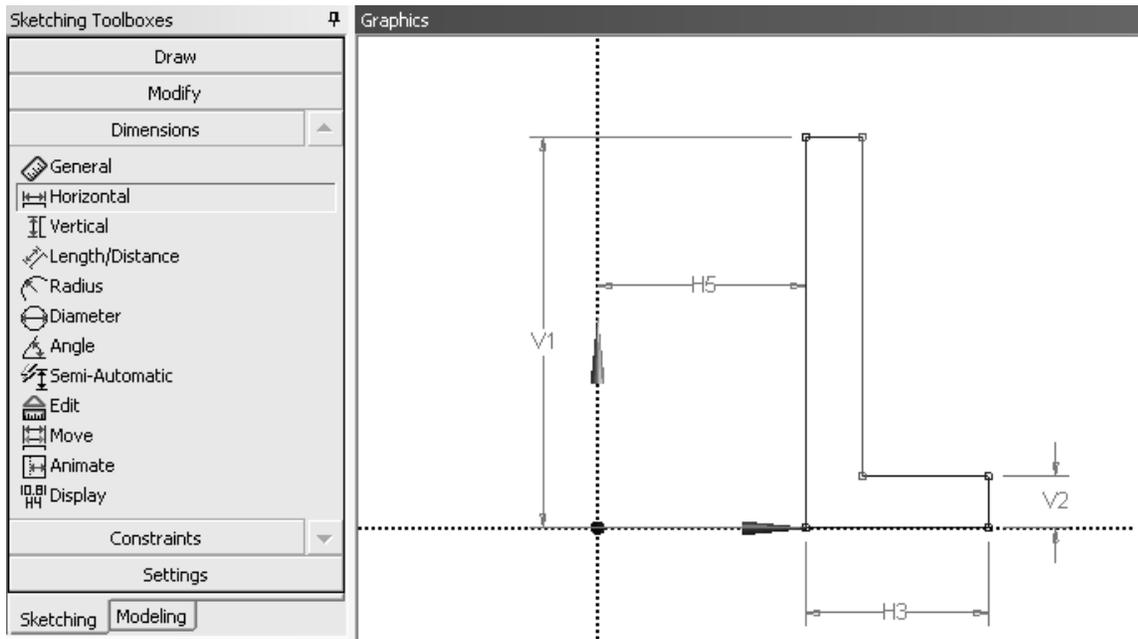


Figure 1-10 L-section sketch with all dimensions.

The current values for the dimensions depend upon the scale used in the sketching process, e.g., H3 = 21.126 mm in the **Details of Sketch1** box shown in figure above.

12. **Edit the dimensions to give them the desired values.** – Click on a value, enter the change and press return.

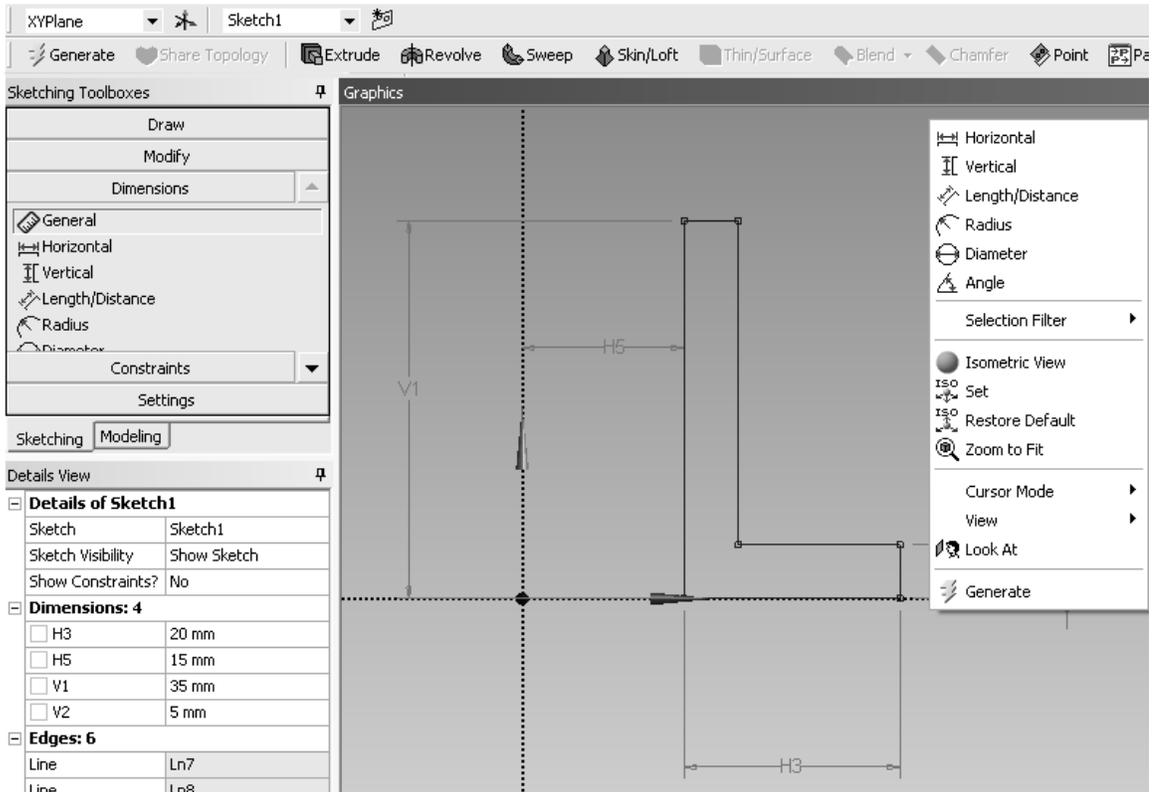
Details View	
[-] <b>Details of Sketch1</b>	
Sketch	Sketch1
Sketch Visibility	Show Sketch
Show Constraints?	No
[-] <b>Dimensions: 4</b>	
<input type="checkbox"/> H3	26.167 mm
<input type="checkbox"/> H5	14.807 mm
<input type="checkbox"/> V1	39.709 mm
<input type="checkbox"/> V2	5.2282 mm

Figure 1-11 Default dimension values.

13. **View > Ruler** (Top menu) to turn off the ruler display. Use the middle mouse roller to zoom in and out.

To reposition the section on the screen, **Right Click** in the graphics area of the display and select one of the following options: **Cursor Mode**, **View**, or **Zoom to Fit**.

The result is shown in the figure below.



**Figure 1-12** Edited dimension values.

To perform the extrusion, switch back from Sketching to Modeling. If it is not already highlighted, click **Sketch1** in the **Tree Outline** to highlight it.

#### 14. Modeling > Sketch1 > Extrude

The L-shaped section will be extruded along the positive Z axis by the amount specified in the **Depth** field shown in the **Details of Extrude1** box (Figure 1-14). **Edit this value** to give the solid an extrude **depth** of **100 mm**.

The tree structure shows the components from which the solid model is created.

#### 15. Click the **Generate** icon to complete creation of the extruded shape model.



In the graphics area of the display **Right click > View > Isometric** (or hold down the middle mouse button and rotate the object).

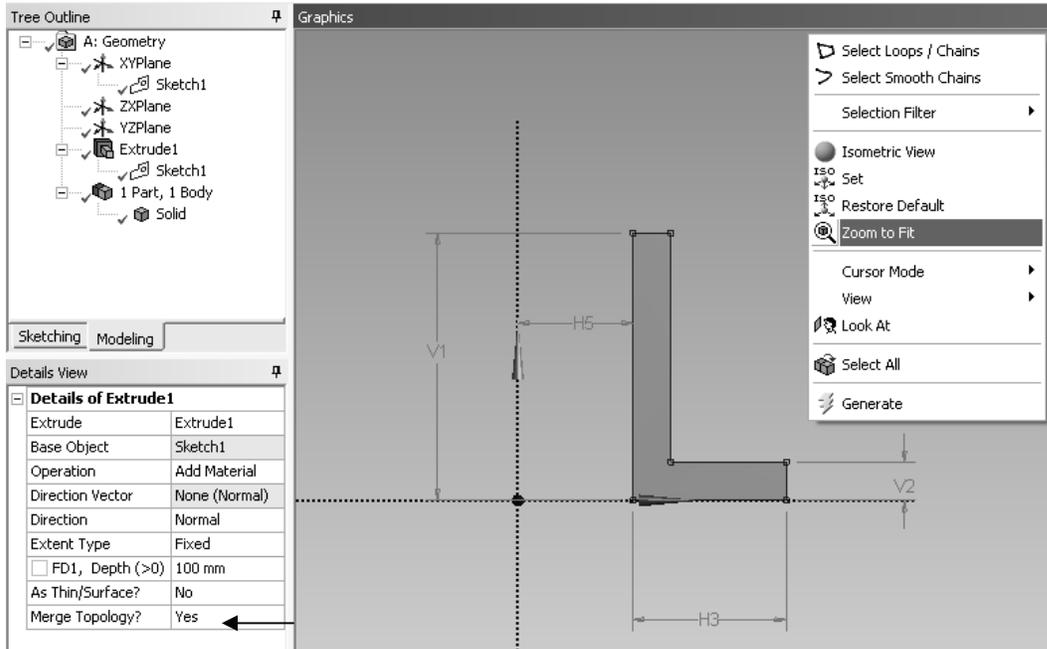


Figure 1-13 Extrusion.

16. Click on the **Display Plane** icon  to turn off the axes display and high-light the last item in the model tree (Solid) to display the volume, surface area, faces, edges and vertices in this model.

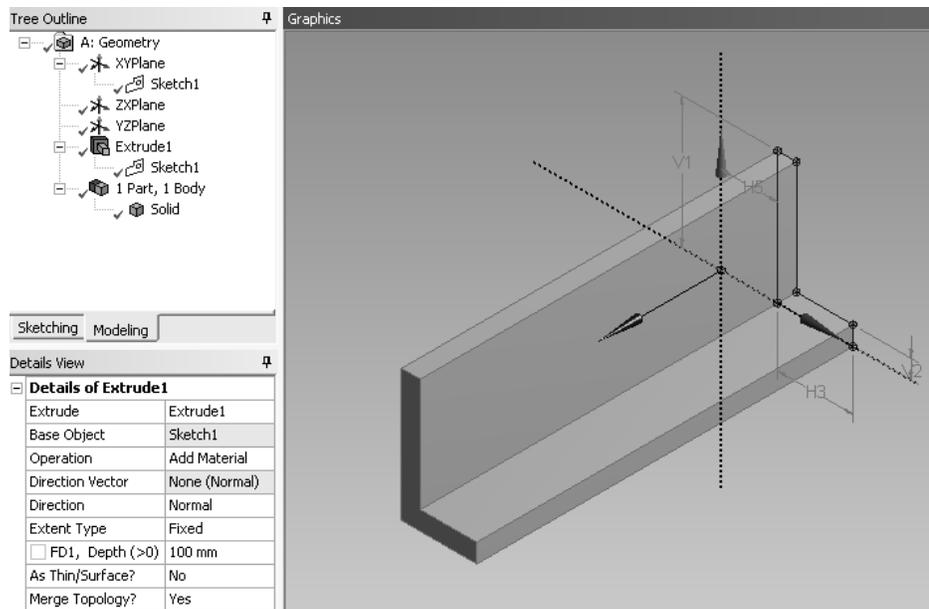


Figure 1-14 Extruded solid.

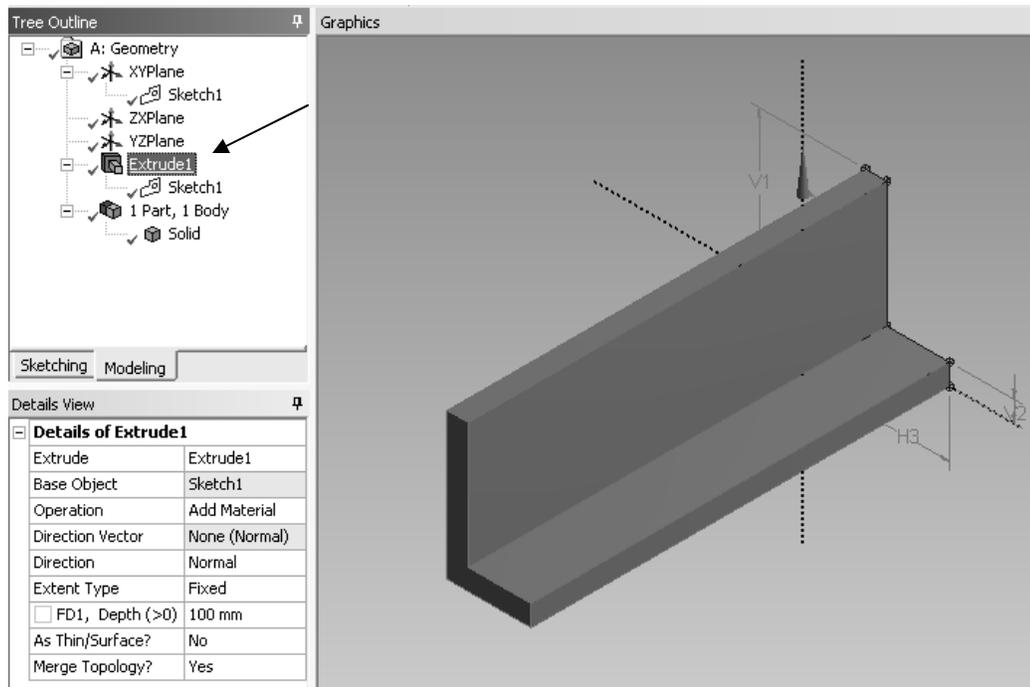
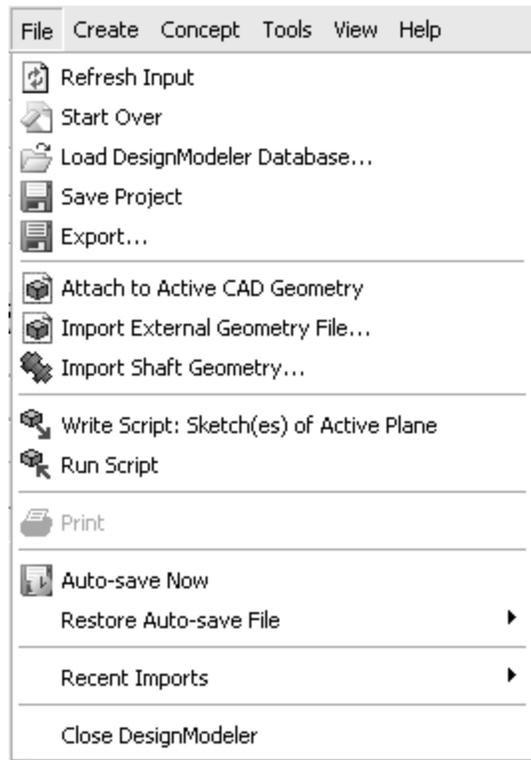
17. **Save your work** – Use the **Save As** option to save the extrusion using a name (e.g. T1A) and location of your choice.

**Figure 1-15** File menu.

Basic solid modeling notions have been used thus far to demonstrate creating a solid by extruding a two-dimensional section. In the next tutorial we will revolve the same L-shape to create a solid of revolution.

#### 1-4 TUTORIAL 1B – REVOLUTION

We can reuse the extrusion model from the previous tutorial after it has been safely saved. Start from the screen shown below if the extrusion is still in memory, or start Workbench and reload the extrusion. First modify the tree structure.



**Figure 1-16** Select the extrusion.

1. Click on **Extrude1** and press **Delete**. Click **Yes** to the query. The extrusion is deleted and the new tree structure shows 0 Parts and 0 Bodies.

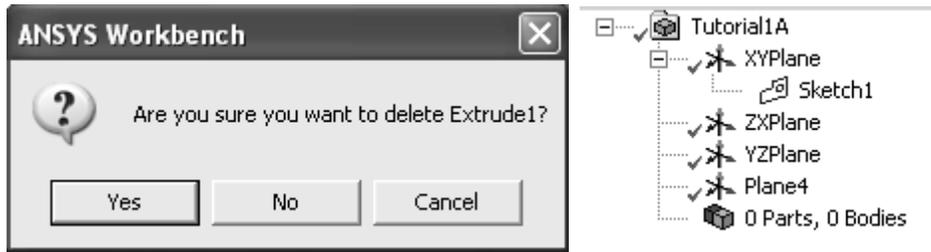


Figure 1-17 Delete the extrusion.

2. Return to the **Project Schematic** and use **Save As** to save this work using a **new file name**, say **Tutorial1B**.



3. Click on **Sketch1**, the **Display Plane** icon  and the **Look at Plane** icon .

We obtain the view of the same sketch we had earlier.

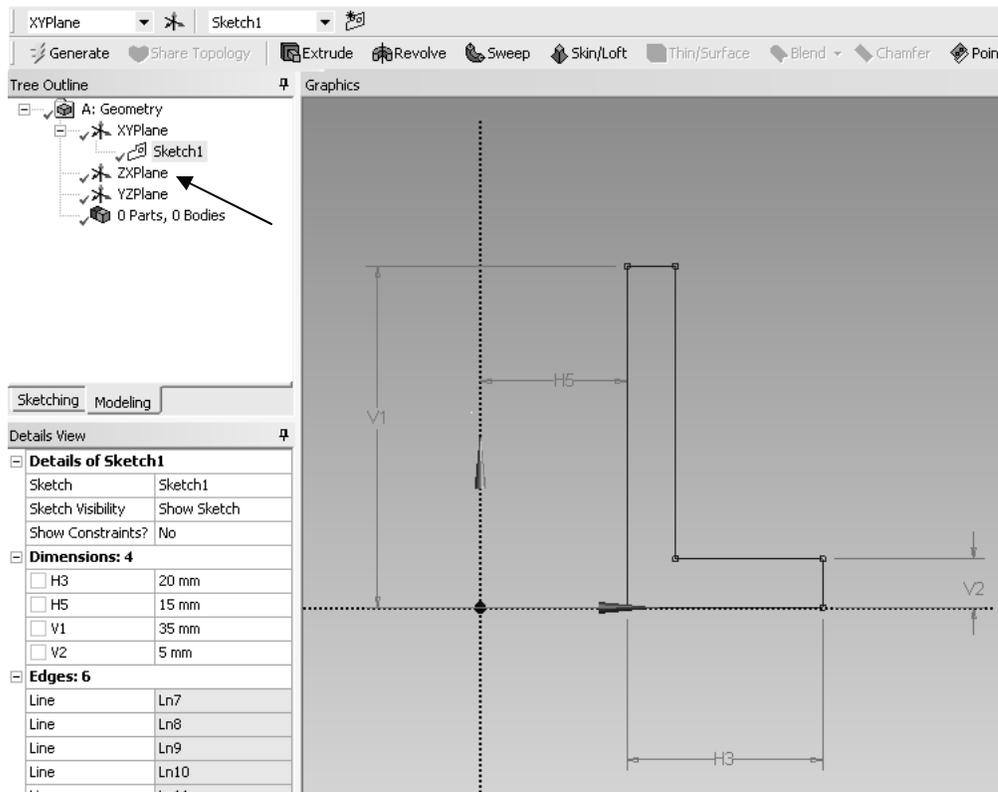


Figure 1-18 Select the sketch.

4. Be sure **Sketch1** is highlighted and Click **Revolve**. 
5. Click **Axis** > **Select the Y axis** > **Apply** in **Details of Revolve1** box.
6. **Select Angle** > **Enter 120 deg.**
7. **Click Generate.** 

The L-shaped section is rotated about the Y axis by 120 degrees to create the solid of revolution shown next. **Direction** options change the rotation direction.

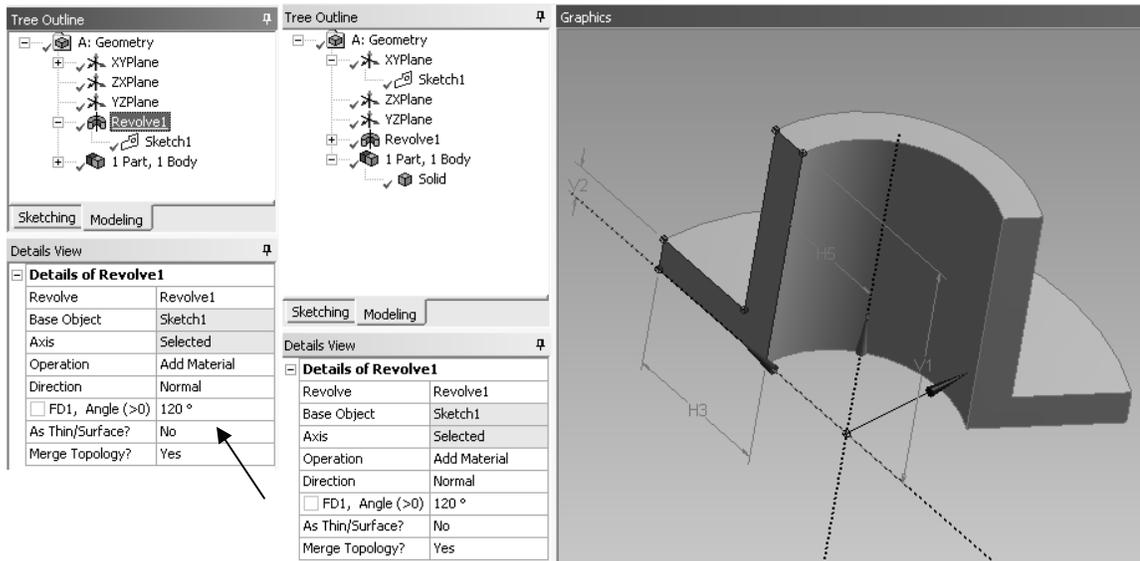


Figure 1-19 Solid of revolution.

8. **Save** to archive your work.

Next we will take a **circular cross section** and **sweep it along a circular path** to illustrate the third kind of modeling discussed in this chapter.

### 1-5 TUTORIAL 1C – SWEEP

1. **Start DesignModeler. Sketch a 2 mm diameter circle on the XYPlane** as before. We get the **sketch1** figure shown. Save this file as **T1C** or something convenient.

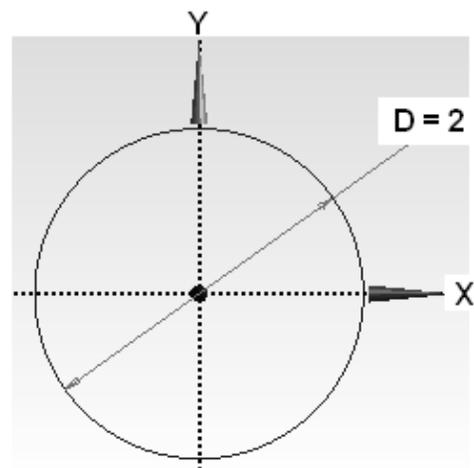


Figure 1-20 Cross section, sketch1.

We now want to sketch a path along which the circular shape will be swept to produce a solid. We will use a simple curve to define this path.

2. **Select the YZPlane and Select Sketching.**
3. Use the **Circle** and **Trim** options to sketch a **semi-circle of Radius 20 mm** in the **YZPlane** as shown below. Note that at the origin of the path, sketch2, is perpendicular to the cross section, sketch1.

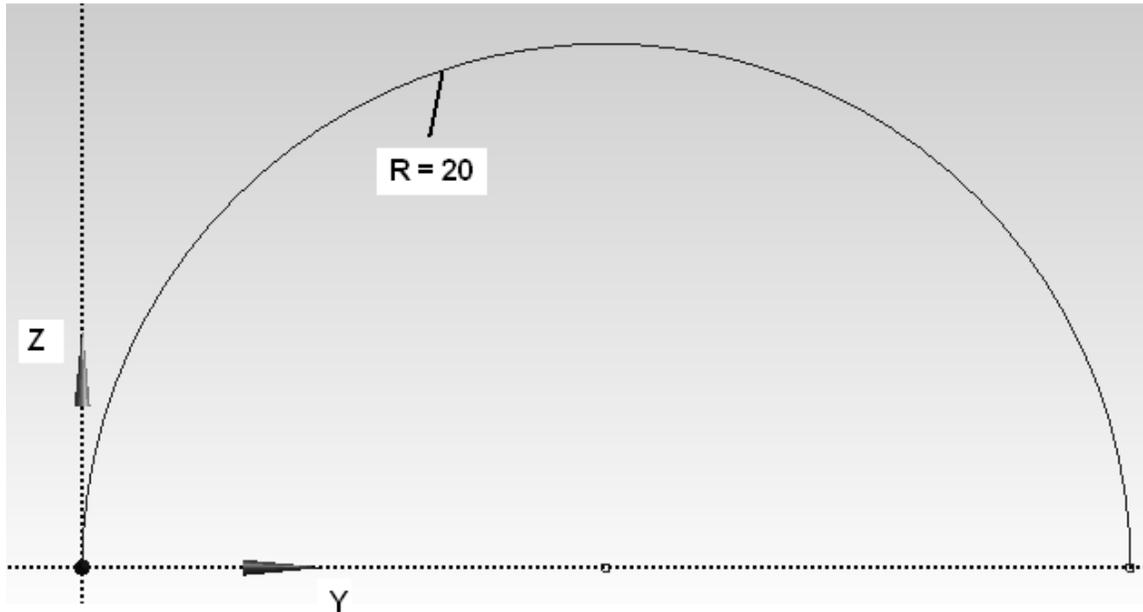
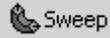


Figure 1-21 Path of sweep, sketch2.

4. **Select Sweep** to create the solid. 

We need to specify the **Profile** (cross section) of the solid and the **Path** along which the profile will be swept.

5. In the Tree Outline Click **Sketch1**, then in **Details of Sweep1** > Click on **Profile** > **Apply**.
6. In the Tree Outline Click **Sketch2**, then in **Details of Sweep1** > **Path** > **Apply**.

See Figure 1-22.

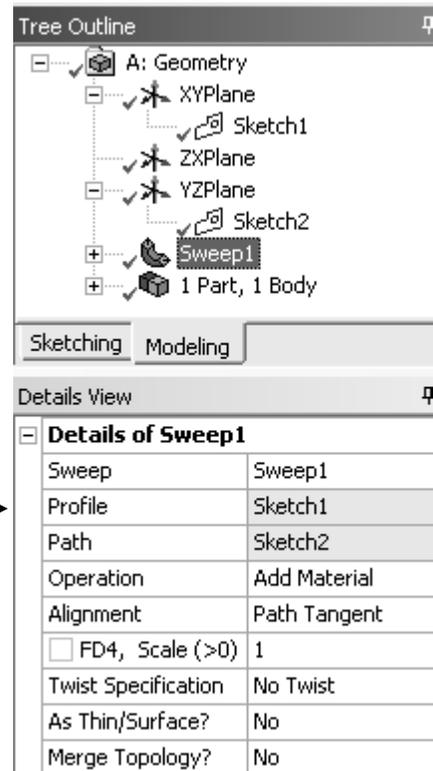
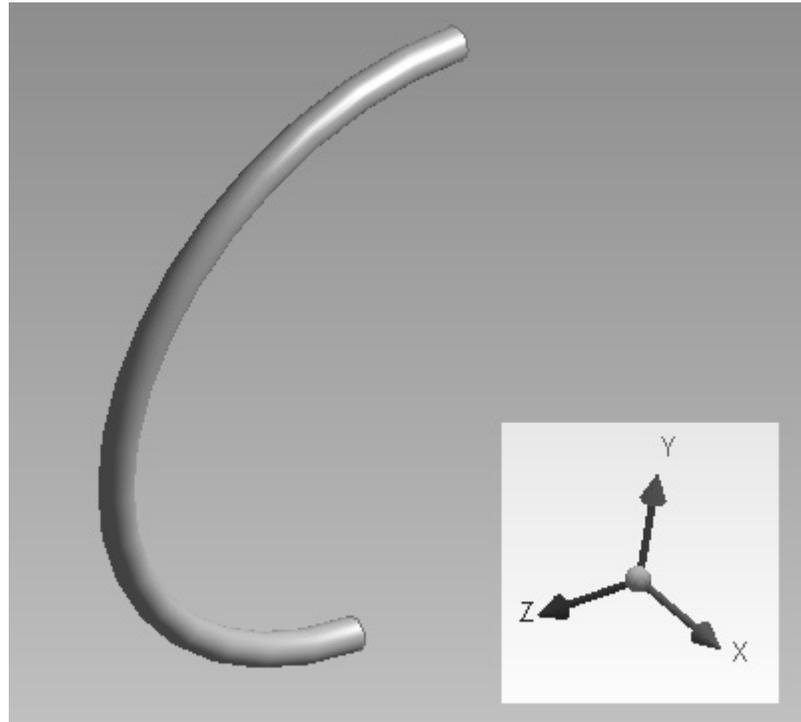


Figure 1-22 Profile and path selection.

7. **Generate** to obtain the solid shown next. 



**Figure 1-23** Swept solid.

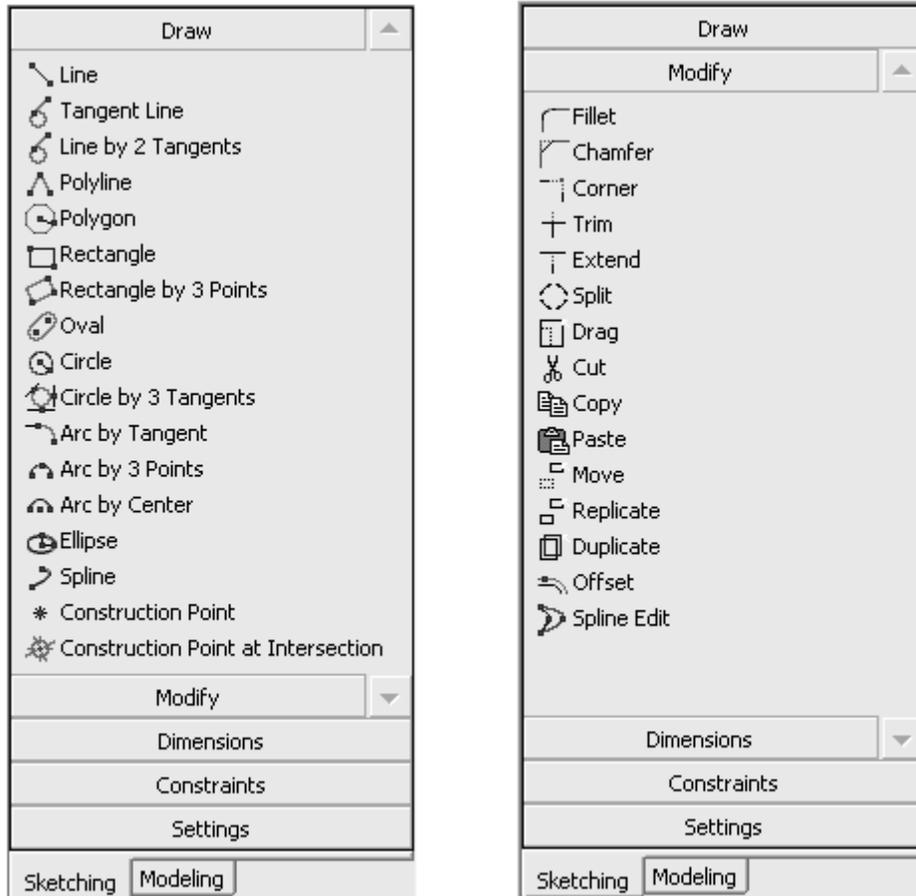
Notice that the profile is perpendicular to the path as when we used Extrude to create a solid. Also the path can be a more complex curve as in the example of Figure 1-1 where a spline was used for the path.

## 1-6 SKETCHING

A wide variety of sketching tools are available to help in creating two-dimensional sections. We used the line drawing option and the equality constraint option in the tutorials above. Some of the other sketching features are shown below.

The next illustration shows the **Draw** and **Modify** options. The **Draw** menu includes **Line**, **Tangent Line**, **Line by two Tangents**, **Polyline**, **Polygon**, **Rectangle**, **Oval**, **Circle**, **Arc**, **Ellipse**, **Spline** and **Construction Point**.

The **Modify** menu includes **Fillet**, **Chamfer**, **Trim**, **Extend**, **Split**, **Drag**, **Cut**, **Copy**, **Paste**, **Move**, **Replicate** and **Offset**.



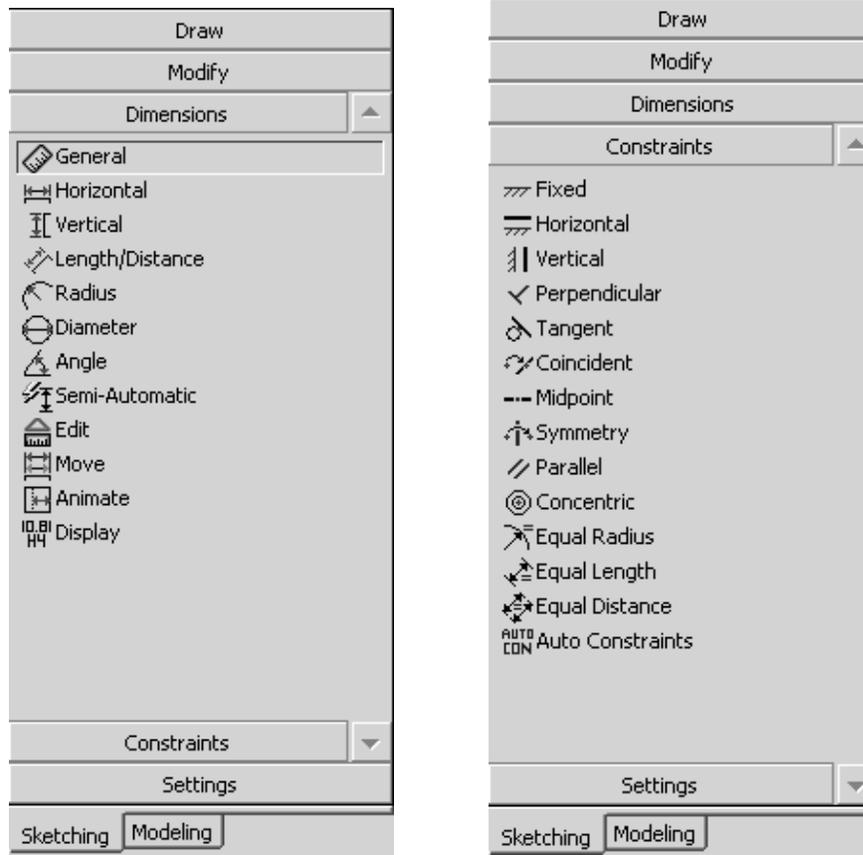
**Figure 1-24** Draw and Modify sketching options.

We will have the occasion to illustrate the use of many of these options in what follows. Menu selections for assigning **Dimensions** and enforcing **Constraints** are shown in the next figure.

In addition to a **General** dimension specification, dimensions can be assigned which are **Horizontal**, **Vertical**, **Length/Distance**, **Radius/Diameter**, or an **Angle**. Select **Semi-Automatic Dimensioning** if you want DesignModeler to select a dimensioning scheme automatically. You then have the option to accept, add or delete dimensions to meet your specific design needs.

**Constraints** that can be enforced for sketching entities include **Horizontal**, **Vertical**, **Perpendicular**, **Tangent**, **Coincident**, **Midpoint**, **Symmetric**, **Parallel**, **Concentric**, **Equal Radius**, **Equal Length** and **Equal Distance**.

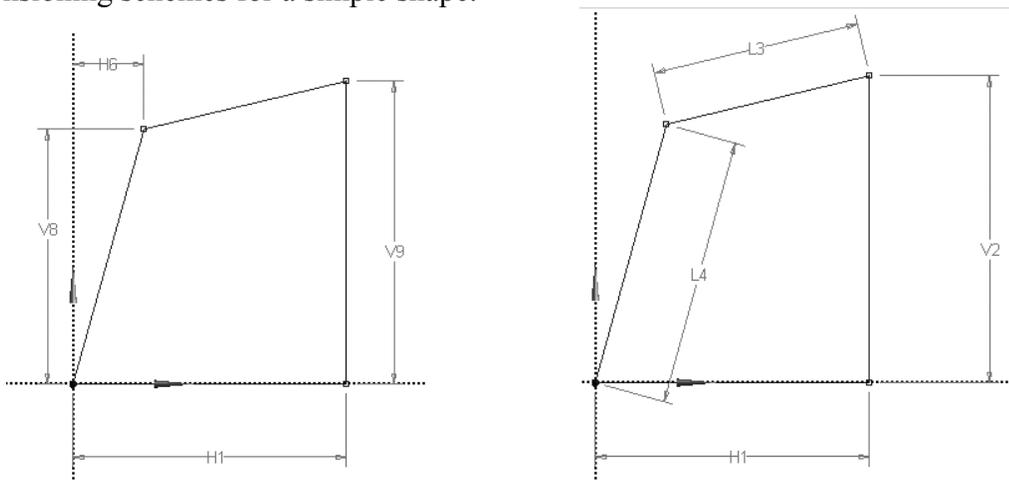
As sketching proceeds DesignModeler will attempt to detect and enforce constraints that seem to be part of the design intent of the sketch. The **Auto Constraints** option allows you to turn these on and off as desired. **Cursor** triggered constraints are local, while **Global** constraints relate to all entities in the sketching plane.



**Figure 1-25** Dimension and Constraint sketching options.

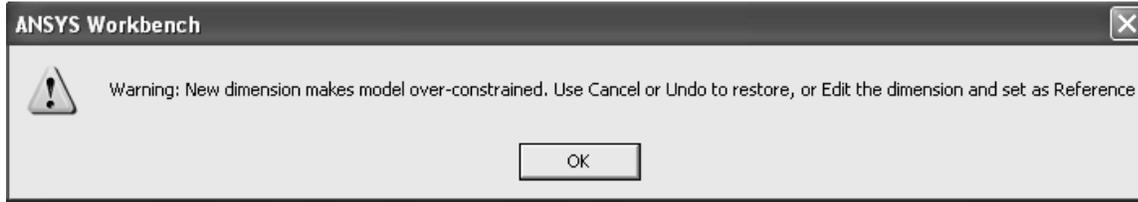
Dimensioning is the process of defining how geometry is to be constructed.

In that regard, sketches must be **unambiguously** defined; that is, they cannot have too many dimensions or too few dimensions specified. The figure below shows two different dimensioning schemes for a simple shape.



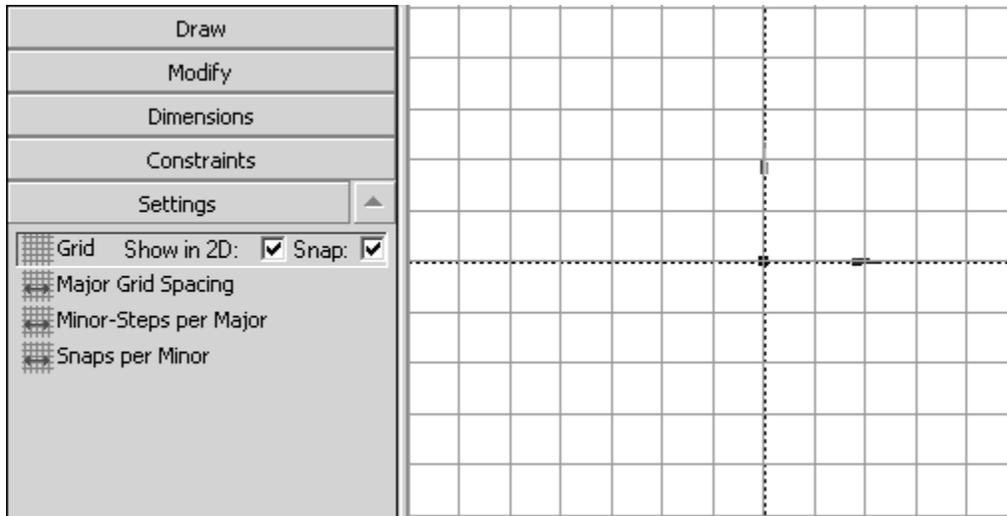
**Figure 1-26** Two different dimensioning schemes.

If you over-dimension a sketch, DesignModeler will issue the following warning:



**Figure 1-27** Over-constraint message.

Finally, the **Settings** option provides a **grid** sketching aid that allows you create drawing entities placed at vertices of the grid as indicated in the next figure.



**Figure 1-28** Settings options and a sketching grid.

## 1-7 SUMMARY

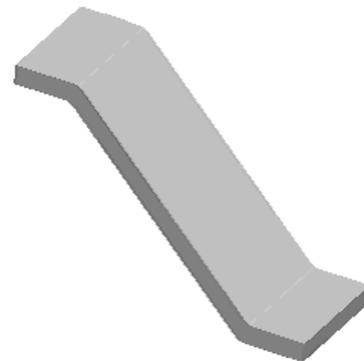
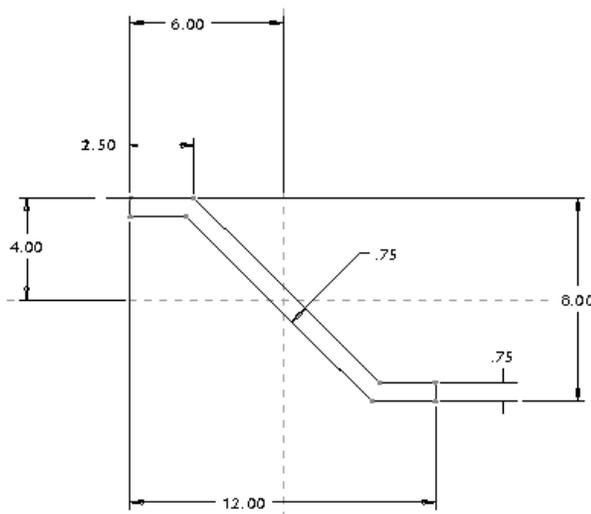
Three tutorials in Chapter 1 introduce basic solid model creation in ANSYS DesignModeler and provide examples from which more complex shapes can be developed. In the next chapter we will extend these ideas and introduce additional modeling features.

**1-8 PROBLEMS**

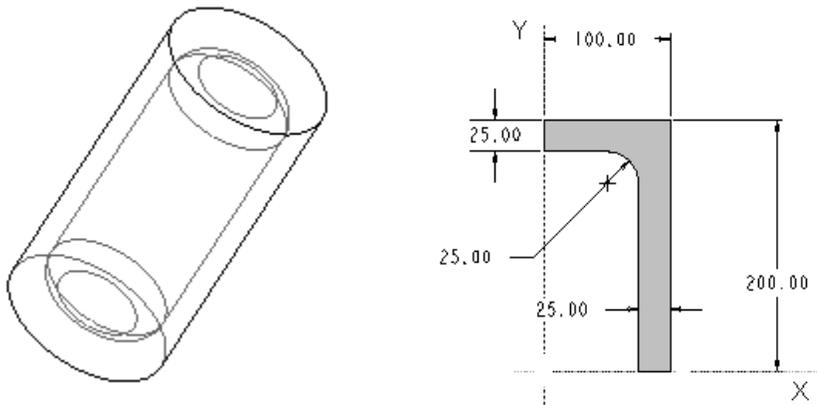
- 1-1** Identify some common objects (such as an unsharpened pencil, drinking glass, etc.) and develop models of them using the ideas presented in this chapter.
- 1-2** Use a “T” shaped section to create a solid by extrusion, another by revolving, and another by sweeping. Select your own units and dimensions.
- 1-3** Measure the exterior dimensions of a light bulb, estimate the wall thickness of the glass and base, and create a model by revolving the sketch.
- 1-4** Create the shape shown and extrude it to form a solid. Choose your own dimensions. Use the Sketching **Trim** option to help in the sketch development. Save it and we’ll use it in a simulation problem later in the text.

**Figure P1-4****Figure P1-5**

- 1-5** A 20 inch diameter cylinder has an 8 in square hole with 1.0 inch radius corner fillets. The thickness is 0.75 inch. Create the solid model shown.
- 1-6** Use an extrusion to create the solid model shown below.

**Figure P1-6**

- 1-7 The cross section of the upper half of a flat-topped cylinder is shown below. The dimensions are in millimeters. Create a solid model of the cylinder.

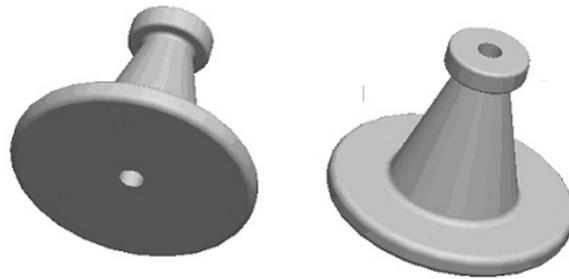


**Figure P1-7**

- 1-8 Create the solid model shown in P1-6 by using a sweep operation.



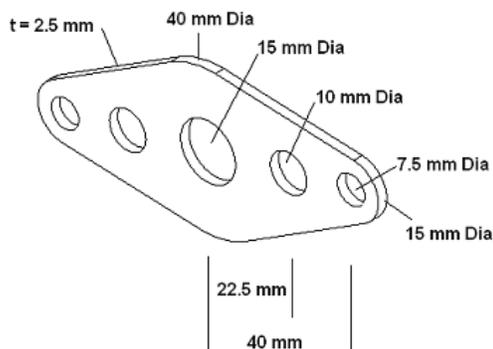
**Figure P1-8**



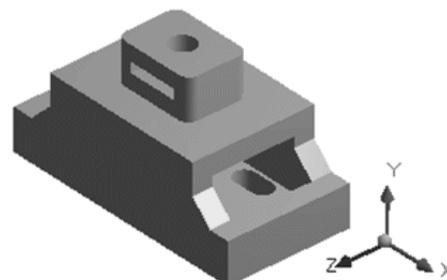
**Figure P1-9**

- 1-9 Select dimensions and create the solid model shown in P1-9 by using a revolve operation.

- 1-10 Create the solid model shown in P1-10.



**Figure P1-10**



(Image from ANSYS VMDM001)

**Figure P1-11**

- 1-11 Create the solid model shown in P1-11 and described in VMDM001.