

ENGINEERING DESIGN AND GRAPHICS WITH **SOLIDWORKS**[®] **2023**



JAMES D. BETHUNE
NATHAN BROWN

FREE SAMPLE CHAPTER |



***Engineering
Design and
Graphics with
SolidWorks® 2023***

***James D. Bethune
Nathan Brown***

Engineering Design and Graphics with SolidWorks® 2023

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Full-Service Project Management:
codeMantra
Composition: codeMantra
Proofreader: Jen Hinchliffe
Indexer: Timothy Wright

ScoutAutomatedPrintCode

Library of Congress Control Number: 2022951068

ISBN 10: 0-13-789952-1
ISBN 13: 978-0-13789952-4

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Preface

This book shows and explains how to use SolidWorks® 2023 to create engineering designs and drawings. Emphasis is placed on creating engineering drawings including dimensions and tolerances and using standard parts and tools. Each chapter contains step-by-step sample problems that show how to apply the concepts presented in the chapter.

The book contains hundreds of projects of various degrees of difficulty specifically designed to reinforce the chapter's content. The idea is that students learn best by doing. In response to reviewers' requests, some more difficult projects have been included.

Chapters 1 and 2 show how to set up a part document and how to use the SolidWorks **Sketch** tools. **Sketch** tools are used to create 2D part entities that can then be extruded into 3D solid models. The chapters contain an explanation of how SolidWorks' colors are used and of how shapes can be fully defined. The usage of mouse gestures, S key, and origins is also included. The two chapters include 44 exercise problems (18 in Ch1 and 26 in Ch2) using both inches and millimeters so that students can practice applying the various **Sketch** tools.

Chapter 3 shows how to use the **Features** tools. **Features** tools are used to create and modify 3D solid models. In addition, reference planes are covered, and examples of how to edit existing models are given.

Chapter 4 explains how to create and interpret orthographic views. Views are created using third-angle projection in compliance with ANSI standards and conventions. The differences between first-angle and third-angle projections are demonstrated. Seven exercise problems (P4-142 to P4-149) are included to help students learn to work with the two different standards. Also included are section views, auxiliary views, and broken views. Several of the projects require that a 3D solid model be drawn from a given set of orthographic views to help students develop visualization skills.

Chapter 5 explains how to create assembly drawings using the **Assembly** tools (**Mate**, **Exploded View**) and how to document assemblies using the **Drawing Documents** tools. Topics include assembled 3D solid models, exploded isometric drawings, and bills of materials (BOMs). Assembly numbers and part numbers are discussed. Both the **Animate Collapse/Explode** and **Motion Study** tools are demonstrated. In addition, the title, release, and revision blocks are discussed. An explanation of how to use **Interference Detection** is given.

Chapter 6 shows how to create and design with threads and fasteners. Both ANSI inch and ANSI metric threads are covered. The **Design Library** is presented, and examples are used to show how to select and size screws and other fasteners for assembled parts.

Chapter 7 covers dimensioning and is in compliance with ANSI standards and conventions. There are extensive visual examples of dimensioned shapes and features that serve as references for various dimensioning applications.

Chapter 8 covers tolerances. Both linear and geometric tolerances are included. This is often a difficult topic to understand, so there are many examples of how to apply and how to interpret the various types of tolerances. Standard tolerances as presented in the title block are demonstrated.

Chapter 9 explains bearings and fit tolerances. The **Design Library** is used to create bearing drawings, and examples show how to select the correct interference tolerance between bearings and housing, and clearance tolerances between bearings and shafts.

Chapter 10 presents gears. Gear terminology, gear formulas, gear ratios, and gear creation using the SolidWorks **Toolbox** are covered. The chapter relies heavily on the **Design Library**. Keys, keyways, and set screws are discussed. Both English and metric units are covered. There is an extensive sample problem that shows how to draw a support plate for mating gears and how to create an assembly drawing for gear trains. The projects at the end of the chapter include two large gear assembly exercises.

Chapter 11 will help students prepare for the CSWA certification exam. There are many sample questions and examples. Students should time how long it takes them to do each problem. This will help them get used to working under time pressure.

The **Appendix** includes fit tables for use with projects in the text. Clearance, locational, and interference fits are included for both inch and millimeter values.

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Acknowledgments

I would like to acknowledge the reviewers of this text: Peggy Condon-Vance, Penn State Berks; Lisa Richter, Macomb Community College; Julie Korfhage, Clackamas Community College; Max P. Gassman, Iowa State University; Paul E. Lienard, Northeastern University; and Hossein Hemati, Mira Costa College.

Thanks to my family—David, Maria, Randy, Sandra, Hannah, Will, Madison, Jack, Luke, Sam, and Ben.

A special thanks to Cheryl.

James D. Bethune

I would like to acknowledge the editors of this edition: Anshul Sharma, Patrice Rutledge, and Tonya Simpson. Thanks to my family: Amanda, Jovie, and Iris. And thanks to my mentor: Gina Bertocci.

Nathan Brown

Contents

Preface	v		
CHAPTER 1 Getting Started	1		
Chapter Objectives	1		
1-1 Introduction	1		
1-2 Starting a New Document	2		
Starting a New Part Document	2		
Selecting a Sketch Plane	3		
1-3 SolidWorks Colors	8		
1-4 Creating a Fully Defined Circle	8		
Changing an Existing Dimension	10		
Fully Defined Entities	11		
1-5 Units	14		
Changing Units	15		
1-6 Rectangle	15		
Sketching a Rectangle	15		
Exiting the Sketch Mode	17		
Reentering the Sketch Mode	17		
1-7 Moving Around the Drawing Screen	18		
Zooming the Rectangle	19		
Moving the Rectangle	19		
Reorientating the Rectangle	19		
1-8 Orientation	19		
Returning to the Top View Orientation—View Selector	19		
Returning to the Top View Orientation—Top View	20		
Returning to the Top View Orientation—Orientation Triad	20		
1-9 Sample Problem SP1-1	20		
Fixing a Line in Place	23		
Sketch Relations	24		
1-10 Creating 3D Models	25		
Creating a 3D Model	25		
1-11 Saving Documents	27		
Saving a Document	27		
1-12 Sample Problem SP1-2	28		
1-13 Holes	32		
Creating a Hole	32		
Chapter Project	37		
CHAPTER 2 Sketch Entities and Tools	43		
Chapter Objectives	43		
2-1 Introduction	43		
2-2 Mouse Gestures and the S Key	44		
Mouse Gestures	44		
Using Mouse Gestures	44		
Accessing Mouse Gestures Settings	45		
		Adding a Tool to a Mouse Gestures Wheel	46
		S Key	47
		Activating the S Key	48
		Customizing the S Key Shortcut Toolbar	49
		Removing a Tool from the S Key Toolbar	51
	2-3 Origins		51
		Showing the Origin	51
	2-4 Circle		52
		Sketching a Circle	52
		Sketching a Perimeter Circle Using Three Points	54
		Sketching a Perimeter Circle Tangent to Three Lines	55
	2-5 Rectangle		56
		Sketching a Center Rectangle	56
		Sketching a 3 Point Corner Rectangle	57
		Sketching a 3 Point Center Rectangle	58
		Sketching a Parallelogram	59
	2-6 Slots		61
		Sketching a Straight Slot	62
		Sketching a Centerpoint Straight Slot	63
		Sketching a 3 Point Arc Slot	64
		Sketching a Centerpoint Arc Slot	65
	2-7 Perimeter Circle		66
		Sketching a Perimeter Circle	66
	2-8 Arcs		67
		Sketching a Centerpoint Arc	67
		Sketching a Tangent Arc	68
		Sketching a 3 Point Arc	69
	2-9 Polygons		70
		Sketching a Hexagon	70
	2-10 Spline		72
		Sketching a Spline	72
		Editing a Spline	73
	2-11 Ellipse		73
		Sketching an Ellipse	74
		Sketching a Partial Ellipse	75
		Sketching a Parabola	76
		Conic Section	77
		Sketching a Conic	79
	2-12 Fillets and Chamfers		80
		Sketching a Fillet	81
		Sketching a Chamfer	82
		Sketching a Chamfer Using Distance-Distance—Equal Distance	82
		Sketching a Chamfer Using Angle-Distance	83

Sketching a Chamfer Using Distance-Distance— Not Equal Distance	84	Creating Inward Draft Sides	132
2-13 Sketch Text	84	Creating an Outward Draft	133
Adding Text	85	3-3 Sample Problem SP3-1	134
Changing the Font and Size of Text	85	3-4 Extruded Cut	137
Adding Text to a Feature	86	3-5 Hole Wizard	138
Creating Text that Wraps Around Two Features	87	3-6 Creating a Hole with the Circle and Extruded Cut Tools	141
2-14 Point	87	3-7 Blind Holes	143
2-15 Trim Entities	88	Creating a Blind Hole—Inches	143
Trimming Entities	88	Creating a Blind Hole—Metric	145
2-16 Extend Entities	89	3-8 Fillet	146
Extending Entities in a Sketch	89	Creating a Fillet with a Variable Radius	148
2-17 Offset Entities	90	Creating a Fillet Using the Face Fillet Option	150
Sketching an Offset Line	91	Creating a Fillet Using the Full Round Fillet Option	151
2-18 Mirror Entities	92	3-9 Chamfer	153
Creating a Mirror Entity	92	Defining a Chamfer Using an Angle and a Distance	153
2-19 Linear Sketch Pattern	95	Defining a Chamfer Using Two Distances	154
Creating a Linear Sketch Pattern	97	Defining a Vertex Chamfer	155
2-20 Circular Sketch Pattern	97	3-10 Revolved Boss/Base	156
Creating a Circular Sketch Pattern	98	3-11 Revolved Cut	159
2-21 Move Entities	99	3-12 Reference Planes	160
Moving an Entity	100	Creating a Reference Plane	161
2-22 Copy Entities	100	3-13 Lofted Boss/Base	165
Copying an Entity	102	3-14 Shell	168
2-23 Rotate Entities	102	3-15 Swept Boss/Base	170
Rotating an Entity	103	3-16 Draft	172
2-24 Scale Entities	103	3-17 Linear Sketch Pattern	174
Scaling an Entity	103	3-18 Circular Sketch Pattern	176
2-25 Stretch Entities	104	3-19 Mirror	177
Stretching an Entity	105	3-20 Helix Curves and Springs	179
2-26 Split Entities	106	Drawing a Helix	179
Splitting an Entity	106	Drawing a Spring From the Given Helix	180
2-27 Jog Lines	109	3-21 Compression Springs	181
Using the Jog Line Tool	110	Creating Ground Ends	183
2-28 Centerline	110	3-22 Torsional Springs	184
Using the Centerline Tool	111	Drawing a Torsional Spring	184
2-29 Sample Problem SP2-1	111	3-23 Extension Springs	187
2-30 Sample Problem SP2-2	114	Drawing an Extension Spring	188
2-31 Sample Problem SP2-3	116	3-24 Wrap	191
Chapter Projects	119	Creating Debossed Text	191
CHAPTER 3 Features	129	3-25 Editing Features	195
Chapter Objectives	129	Editing the Hole	195
3-1 Introduction	129	Editing the Cutout	196
3-2 Extruded Boss/Base	129	3-26 Sample Problem SP3-2	197
Using the Extruded Boss/Base Tool	130	Drawing a Cylinder	198

Creating a Slanted Surface on the Cylinder	200	5-6 Mate	311
Adding the Vertical Slot	201	Creating the First Assembly Using Mates	311
Adding the Ø8 Hole	203	Creating a Second Assembly	313
3-27 Sample Problem SP3-3	205	Creating a Third Assembly	315
3-28 Curve Driven Patterns	208	5-7 Bottom-up Assemblies	316
Using the Curve Driven Pattern Tool—Example 1	208	5-8 Creating an Exploded Isometric Assembly	321
Using the Curve Driven Pattern Tool—Example 2	211	5-9 Creating an Exploded Isometric Drawing	324
Chapter Projects	214	5-10 Assembly Numbers	326
 		5-11 Bill of Materials (BOM or Parts List)	328
CHAPTER 4 Orthographic Views	229	Editing the BOM	330
Chapter Objectives	229	Adding Columns to the BOM	332
4-1 Introduction	229	Changing the Width of a Column	333
4-2 Third- and First-Angle Projections	231	Changing the Width of Rows and Columns	334
4-3 Fundamentals of Orthographic Views	232	Changing the BOM's Font	334
Normal Surfaces	233	5-12 Title Blocks	335
Hidden Lines	234	Revision Letters	336
Precedence of Lines	235	Editing a Title Block	336
Slanted Surfaces	236	Release Blocks	338
Compound Lines	237	Tolerance Blocks	339
Oblique Surfaces	238	Application Blocks	339
Rounded Surfaces	238	5-13 Animate Collapse	339
4-4 Drawing Orthographic Views	240	5-14 Sample Problem SP5-1	341
Moving Orthographic Views	249	5-15 Using the Motion Study Tool	344
Creating Other Views	249	Viewing the Assembly Motion	346
4-5 Section Views	250	5-16 Editing a Part Within an Assembly	347
4-6 Drawing a Section View	252	5-17 Interference Detection/Clearance	
Changing the Style of a Section View	257	Verification	349
4-7 Aligned Section Views	258	Interference Detection	349
4-8 Broken Views	259	Detecting an Interference	350
Creating a Broken View	260	Verifying the Clearance	353
4-9 Detail Views	261	Removing the Interference	353
Drawing a Detail View	261	Verifying that a Clearance Exists	355
4-10 Auxiliary Views	262	Chapter Projects	357
Drawing an Auxiliary View	263	 	
4-11 First-Angle Projection	266	CHAPTER 6 Threads and Fasteners	381
Creating Three Orthographic Views Using		Chapter Objectives	381
First-Angle Projection	266	6-1 Introduction	381
Chapter Projects	269	6-2 Thread Terminology	381
 		Pitch	382
CHAPTER 5 Assemblies	305	6-3 Thread Callouts—ANSI Metric Units	382
Chapter Objectives	305	6-4 Thread Callouts—ANSI Unified	
5-1 Introduction	305	Screw Threads	383
5-2 Starting an Assembly	305	6-5 Thread Representations	384
5-3 Move Component	308	6-6 Internal Threads—Inches	384
5-4 Rotate Component	309	6-7 Threaded Blind Holes—Inches	387
5-5 Mouse Gestures for Assemblies	310	6-8 Internal Threads—Metric	388

6-9 Accessing the Design Library	390	7-13 Rounded Shapes—Internal	493
6-10 Thread Pitch	392	7-14 Rounded Shapes—External	494
6-11 Determining an External Thread Length—Inches	392	7-15 Irregular Surfaces	495
6-12 Smart Fasteners	398	7-16 Polar Dimensions	496
6-13 Determining an Internal Thread Length	401	7-17 Chamfers	497
6-14 Set Screws	404	7-18 Symbols and Abbreviations	498
6-15 Drawing a Threaded Hole in the Side of a Cylinder	405	7-19 Symmetrical and Centerline Symbols	499
6-16 Adding Set Screws to the Collar	409	7-20 Dimensioning to a Point	500
Chapter Projects	411	7-21 Dimensioning Section Views	501
CHAPTER 7 Dimensioning	447	7-22 Dimensioning Orthographic Views	501
Chapter Objectives	447	Dimensions Using Centerlines	502
7-1 Introduction	447	Chapter Projects	503
7-2 Terminology and Conventions—ANSI	448	CHAPTER 8 Tolerancing	519
Common Terms	448	Chapter Objectives	519
Dimensioning Conventions	449	8-1 Introduction	519
Common Errors to Avoid	449	8-2 Direct Tolerance Methods	519
7-3 Adding Dimensions to a Drawing	450	8-3 Tolerance Expressions	521
Controlling Dimensions	454	8-4 Understanding Plus and Minus Tolerances	522
Dimensioning Short Distances	455	8-5 Creating Plus and Minus Tolerances	522
Autodimension Tool	457	Adding Plus and Minus Symmetric Tolerances Using the Dimension Text Box	524
Creating Baseline Dimensions	459	8-6 Creating Limit Tolerances	525
Creating Ordinate Dimensions	460	8-7 Creating Angular Tolerances	526
7-4 Drawing Scale	460	8-8 Standard Tolerances	528
7-5 Units	461	8-9 Double-Dimensioning Errors	528
Aligned Dimensions	462	8-10 Chain Dimensions and Baseline Dimensions	530
Hole Dimensions	462	Baseline Dimensions	531
7-6 Dimensioning Holes and Fillets	466	8-11 Tolerance Studies	532
Dimensioning a Blind Hole	466	Calculating the Maximum Length of A	532
Dimensioning Hole Patterns	468	Calculating the Minimum Length of A	533
7-7 Dimensioning Counterbored and Countersunk Holes	469	8-12 Rectangular Dimensions	533
Counterbored Hole with Threads	473	8-13 Hole Locations	533
Dimensioning Countersink Holes	479	8-14 Choosing a Shaft for a Toleranced Hole	535
Dimensioning the Block	480	For Linear Dimensions and Tolerances	536
7-8 Angular Dimensions	480	8-15 Sample Problem SP8-1	537
Dimensioning an Evenly Spaced Hole Pattern	484	8-16 Sample Problem SP8-2	538
7-9 Ordinate Dimensions	485	8-17 Nominal Sizes	538
Creating Ordinate Dimensions	486	8-18 Standard Fits (Metric Values)	539
7-10 Baseline Dimensions	488	Clearance Fits	539
Creating Baseline Dimensions	488	Transitional Fits	539
Hole Tables	490	Interference Fits	540
7-11 Locating Dimensions	492		
7-12 Fillets and Rounds	493		

8-19 Standard Fits (Inch Values)	540	CHAPTER 9 Bearings and Fit Tolerances	619
Adding a Fit Callout to a Drawing	540	Chapter Objectives	619
Reading Fit Tables	542	9-1 Introduction	619
8-20 Preferred and Standard Sizes	543	9-2 Sleeve Bearings	620
8-21 Surface Finishes	544	Drawing a Sleeve Bearing	620
8-22 Surface Control Symbols	545	Using a Sleeve Bearing in an Assembly Drawing	621
8-23 Applying Surface Control Symbols	547	9-3 Bearings from the Toolbox	623
Adding a Lay Symbol to a Drawing	548	9-4 Ball Bearings	626
8-24 Design Problems	549	9-5 Fits and Tolerances for Bearings	628
Floating Condition	550	9-6 Fits—Inches	628
Fixed Condition	551	9-7 Clearance Fits	628
Designing a Hole Given a Fastener Size	553	9-8 Hole Basis	629
8-25 Geometric Tolerances	554	9-9 Shaft Basis	629
8-26 Tolerances of Form	554	9-10 Sample Problem SP9-1	629
8-27 Flatness	554	9-11 Interference Fits	630
8-28 Straightness	555	9-12 Manufactured Bearings	631
8-29 Straightness (RFS and MMC)	556	Clearance for a Manufactured Bearing	632
8-30 Circularity	559	Applying a Clearance Fit Tolerance	632
8-31 Cylindricity	560	Interference for a Manufactured Bearing	633
8-32 Geometric Tolerances Using SolidWorks	561	Applying an Interference Fit Tolerance	633
8-33 Datums	561	Applying Standard Fit Tolerances to an Assembly Drawing	634
Adding a Datum Indicator	563	9-13 Fit Tolerances—Millimeters	635
Defining a Perpendicular Tolerance	564	Chapter Projects	636
Defining a Straightness Value for Datum Surface A	565	CHAPTER 10 Gears	653
8-34 Tolerances of Orientation	566	Chapter Objectives	653
8-35 Perpendicularity	566	10-1 Introduction	653
8-36 Parallelism	569	10-2 Gear Terminology	654
8-37 Angularity	569	10-3 Gear Formulas	655
8-38 Profiles	570	10-4 Creating Gears	656
8-39 Runouts	572	Creating a Gear Assembly	657
8-40 Positional Tolerances	573	Animating the Gears	661
8-41 Creating Positional Tolerances	575	10-5 Gear Ratios	663
Creating the Positional Tolerance	575	10-6 Gears and Bearings	663
8-42 Virtual Condition	578	Adding Bearings	663
Calculating the Virtual Condition for a Shaft	579	10-7 Power Transmission—Shaft to Gear	666
Calculating the Virtual Condition for a Hole	579	10-8 Set Screws and Gear Hubs	666
8-43 Floating Fasteners	579	Adding a Threaded Hole to the Gear's Hub	668
8-44 Sample Problem SP8-3	581	10-9 Keys, Keyseats, and Gears	671
8-45 Sample Problem SP8-4	582	Defining and Creating Keyseats in Gears	671
8-46 Fixed Fasteners	582	Returning to the Assembly Drawing	674
8-47 Sample Problem SP8-5	583	Defining and Creating a Parallel Key	675
8-48 Design Problems	584	Creating a Keyseat in the Shaft	676
Chapter Projects	588		

Creating the Keyseat	678	Problem 11-15	729
Creating the Arc-Shaped End of a Keyseat	679	Problem 11-16	730
10-10 Sample Problem SP10-1	681	Problem 11-17	731
Determining the Pitch Diameter	681	Problem 11-18	732
Editing the Bill of Materials	683	Problem 11-19	733
10-11 Rack and Pinion Gears	687	Problem 11-20	734
Animating the Rack and Pinion	689	11-6 Drawing Auxiliary Views	735
10-12 Metric Gears	690	Problem 11-21	735
Creating a Metric Gear	690	Problem 11-22	736
Chapter Projects	692	Problem 11-23	737
 		11-7 Drawing Break Views	737
CHAPTER 11 CSWA Preparation	715	Problem 11-24	738
Chapter Objectives	715	Problem 11-25	738
11-1 Introduction	715	11-8 Drawing Section Views	739
11-2 Working with Cubes	716	Problem 11-26	739
Problem 11-1	716	Problem 11-27	740
11-3 Drawing Profiles	717	Problem 11-28	741
Problem 11-2	717	11-9 Drawing Detail Views	742
Problem 11-3	718	Problem 11-29	742
Problem 11-4	719	Problem 11-30	743
Problem 11-5	719	11-10 Drawing Lines and Views	744
Problem 11-6	721	Problem 11-31	744
11-4 Drawing Small 3D Objects	721	Problem 11-32	745
Problem 11-7	722	Problem 11-33	746
Problem 11-8	722	11-11 Creating Assemblies	747
Problem 11-9	723	Problem 11-34	747
Problem 11-10	724	Problem 11-35	749
Problem 11-11	725	11-12 Problem Answers	750
Problem 11-12	726		
11-5 Drawing Larger Objects	727	APPENDIX	751
Problem 11-13	727	Index	763
Problem 11-14	728		

7 chapter seven

Dimensioning

CHAPTER OBJECTIVES

- Dimension objects
- Learn ANSI standards and conventions
- Dimension different shapes and features
- Learn fundamentals of 3D dimensioning

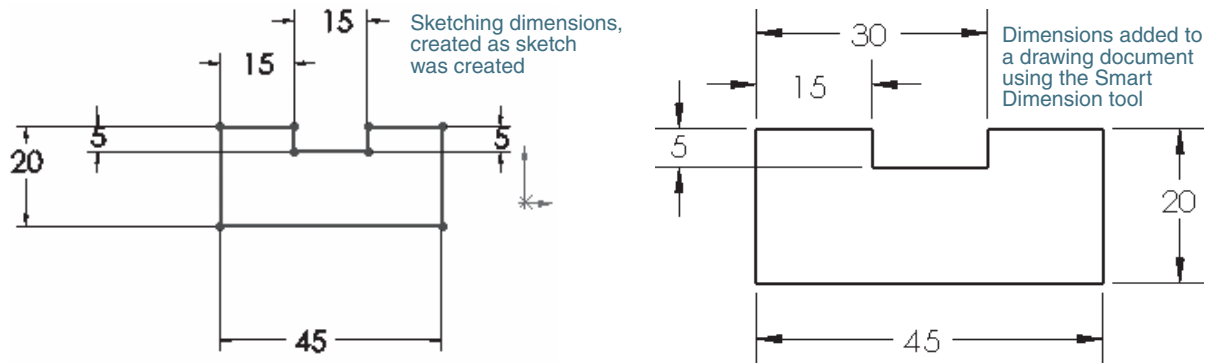
7-1 Introduction

Dimensions are added to SolidWorks on **Drawing** documents. Dimensions will appear in **Part** documents, but these are construction dimensions. These sketch dimensions are used to create a part and are used when a sketch is edited. They may be modified as the part is being created using the **Smart Dimension** tool. They will not appear on the finished model or in **Assembly** documents.

Figure 7-1 shows a dimensioned shape. The drawing on the left in Figure 7-1 shows the sketch dimensions that were used as the part was being created. The drawing on the right in Figure 7-1 shows dimensions that were created using the **Smart Dimension** tool in a **Drawing** document. These are defining dimensions and will appear on the working drawings. This chapter will show how to apply these types of dimensions.

SolidWorks has ANSI Inch and ANSI Metric dimensions available. Other dimensioning systems such as ISO also are available. This text is in compliance with ANSI standards.

Figure 7-1



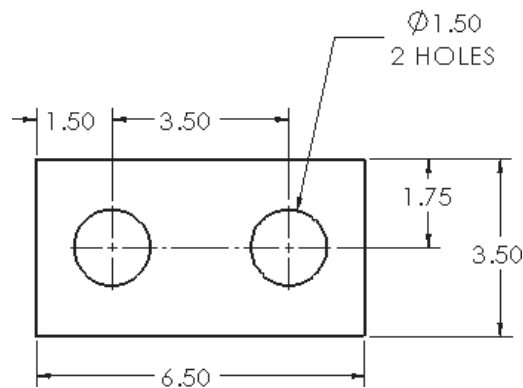
7-2 Terminology and Conventions—ANSI

Dimensions are added to drawings to define the part and guide manufacturing. General rules and conventions are used to dimension a drawing in a complete, orderly, and succinct manner.

Common Terms

Figure 7-2 shows both ANSI- and ISO-style dimensions. The terms apply to both styles.

Figure 7-2



Dimension lines: In mechanical drawings, lines between extension lines that end with an arrowhead and include a numerical dimensional value located within the line.

Extension lines: Lines that extend away from an object and allow dimensions to be located off the surface of an object.

Leader lines: Lines drawn at an angle, not horizontal or vertical, that are used to dimension specific shapes such as holes. The start point of a leader line includes an arrowhead. Numerical values are drawn at the end opposite the arrowhead.

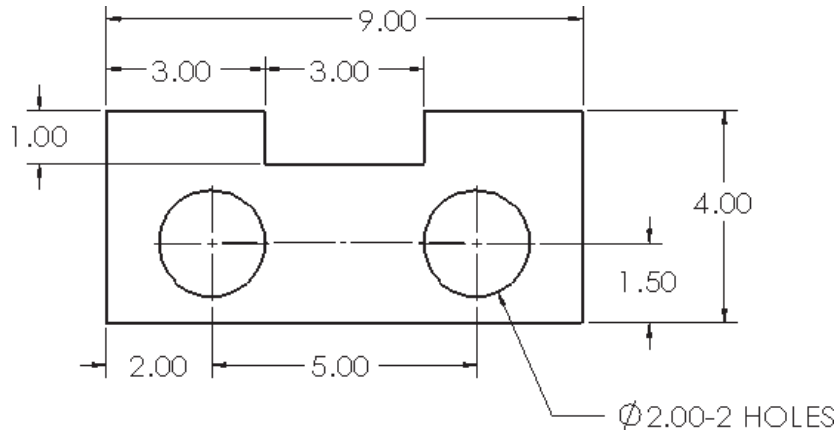
Linear dimensions: Dimensions that define the straight-line distance between two points.

Angular dimensions: Dimensions that define the angular value, measured in degrees, between two straight lines.

Dimensioning Conventions

There are general guidelines you should follow when dimensioning drawings. Figure 7-3 shows some of the following guidelines applied to a dimensioned part.

Figure 7-3



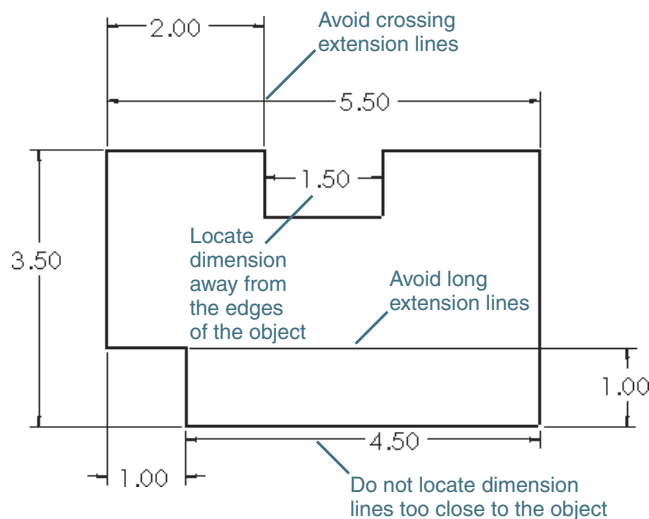
- Dimension lines should be drawn evenly spaced; that is, the distance between dimension lines should be uniform. A general rule of thumb is to locate dimension lines about 1/2in. or 15mm apart.
- There should be a noticeable gap between the edge of a part and the beginning of an extension line. This serves as a visual break between the object and the extension line. The visual difference between the line types can be enhanced by using different colors for the two types of lines.
- Leader lines are used to define the size of holes and should be positioned so that the arrowhead points toward the center of the hole.
- Centerlines may be used as extension lines. No gap is used when a centerline is extended beyond the edge lines of an object.
- Align dimension lines whenever possible to give the drawing a neat, organized appearance.

Common Errors to Avoid

See Figure 7-4.

Figure 7-4

Some common errors

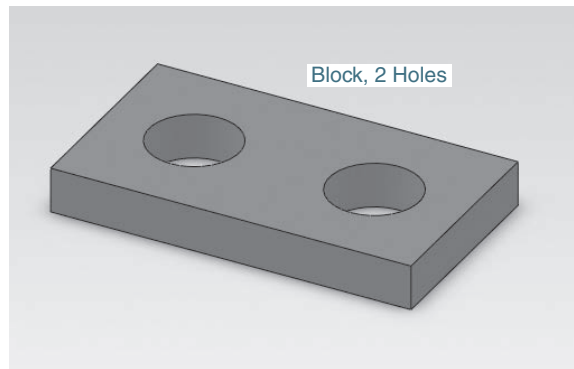


- Avoid crossing extension lines. Place longer dimensions farther away from the object than shorter dimensions.
- Do not locate dimensions within cutouts; always use extension lines.
- Do not locate any dimension close to the object. Dimension lines should be at least 1/2in. or 15mm from the edge of the object.
- Avoid long extension lines. Locate dimensions in the same general area as the feature being defined.

7-3 Adding Dimensions to a Drawing

Figure 7-5 shows a part that includes two holes. This section will explain how to add dimensions to the part. The part was drawn as a **Part** document and saved as **BLOCK, 2 HOLES**. See Figure 7-10 for the part's dimensions. The part is 0.50 thick. Save the part and start a new **Drawing** document.

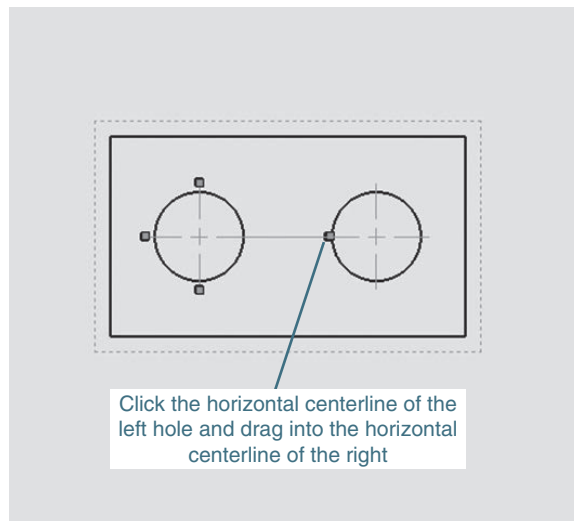
Figure 7-5



- 1 Click **New, Drawing**, and **OK** to start a new drawing. Use a **B (ANSI) Landscape** sheet size.
- 2 Click the **View Layout** tab, **Model View**, and create a top view of the **BLOCK, 2 HOLES** part.

In this example we will work with only one view. See Figure 7-6.

Figure 7-6

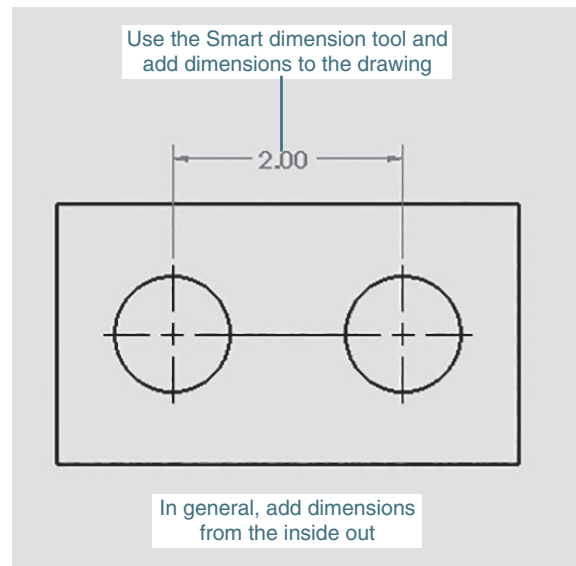


Extend the horizontal center mark from the left hole to the horizontal centerline of the right hole.

- 3 Click the horizontal centerline of the left hole. Small blue boxes will appear on the center mark.
- 4 Click and drag the horizontal centerline from the left hole to the right hole.

The holes now have the same horizontal centerline so only one vertical dimension can be used to define the hole's location. See Figure 7-7.

Figure 7-7



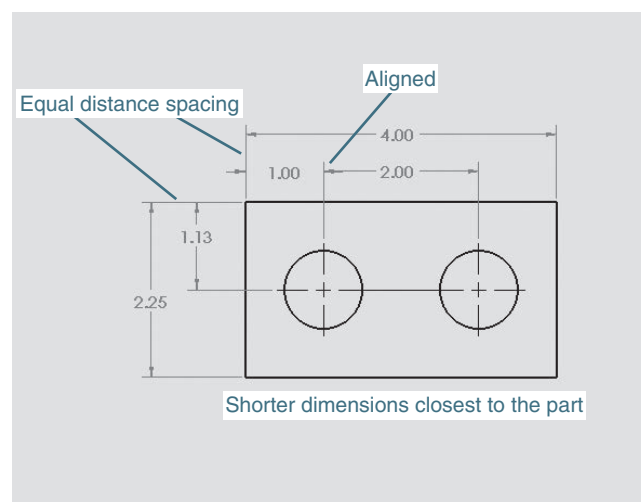
TIP

Centerlines can be extended by first clicking them and then dragging an endpoint to a new location.

- 5 Use the **Smart Dimension** tool and add the horizontal and vertical dimensions as shown.

See Figure 7-8.

Figure 7-8



Note that the dimension values for the vertical dimensions are written horizontally. This is in compliance with ANSI standards. For this example, the Century Gothic font was made bold with 14-point height.

RULE

Keep dimension lines aligned and evenly spaced.

- 6 Click the **Hole Callout** tool located on the **Annotation** panel, click the edge of the left hole, and move the cursor away from the hole.

Note that the leader arrow always points to the center of the hole.

- 7 Select a location off the surface of the part and click the mouse.

RULE

Never locate dimensions on the surface of the part.

See Figure 7-9. The word THRU is optional. Some companies require it and some do not.

Figure 7-9

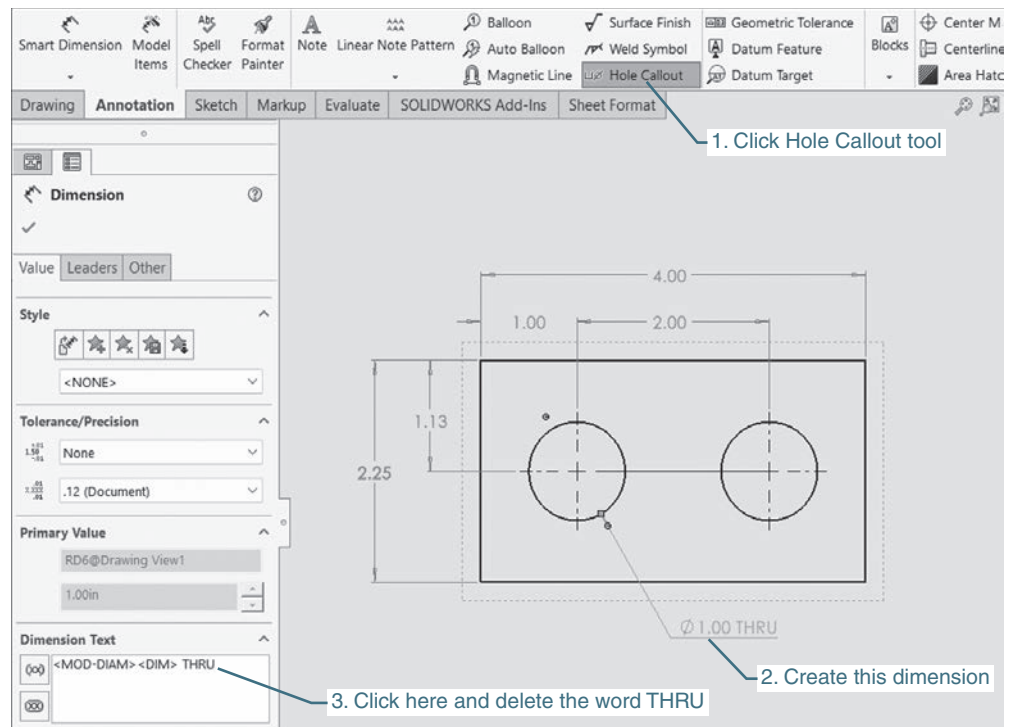
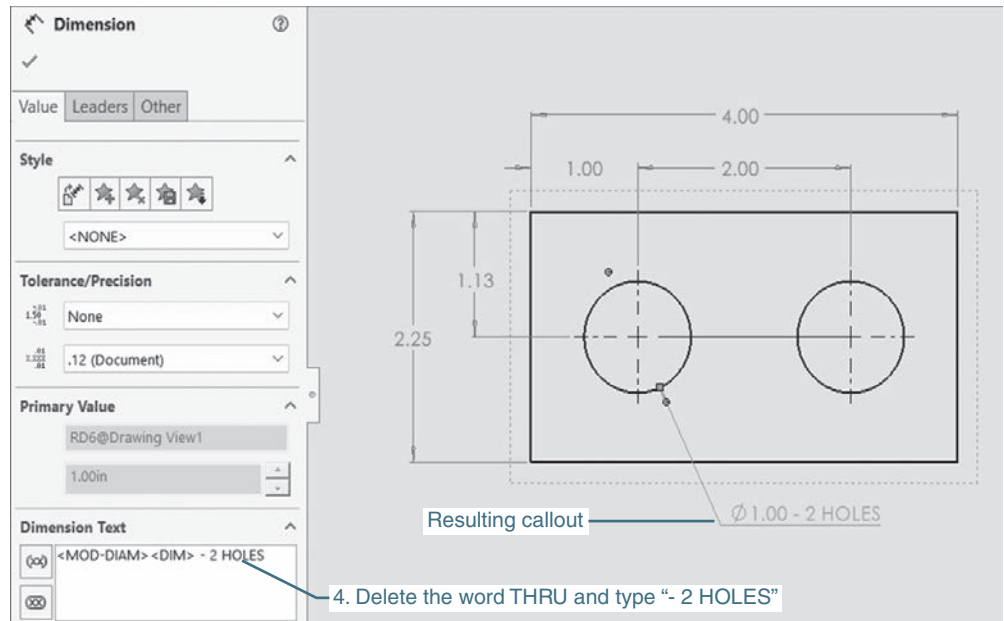


Figure 7-9
(Continued)



- 8** Go to the **Dimension PropertyManager** at the left of the screen, locate the cursor in the **Dimension Text** box, and delete the word THRU.

The text already in the box defines the hole's diameter.

- 9** Move the cursor to the end of the existing text line, and type **- 2 HOLES**.

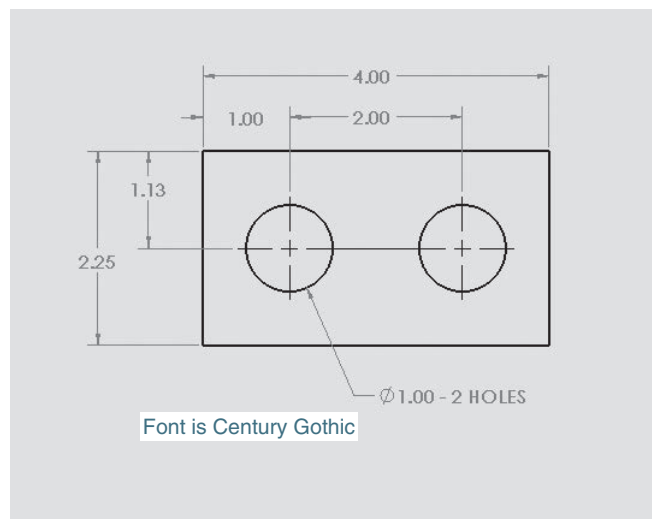
- 10** Click the green **OK** check mark.

Move the dimensions if needed to create neat, uniform dimensions.

See Figure 7-10.

- 11** Save the drawing.

Figure 7-10



TIP

Dimensions can be relocated by clicking and dragging the dimension text.

Controlling Dimensions

Various aspects of dimensions can be edited, such as text height, arrow location, and text values.

- 1 Click the **Options** tool at the top of the screen.

The **Documents Properties - Drafting Standard** dialog box will appear. See Figure 7-11.

- 2 Click the **Document Properties** tab.

- 3 Click the **Dimensions** option.

The **Document Properties - Dimensions** dialog box can be used to edit the style and form of dimensions. It can also be used to change the way arrows are applied.

- 4 Click the **Font** option.

The **Choose Font** dialog box will appear. See Figure 7-11. This dialog box can be used to change the font, font style, and height of dimension text. The height of text can be measured in inches, millimeters, or points. A *point* refers to a space that equals about 1/72 of an inch. (There are 12 points to a *pica*.)

Figure 7-11

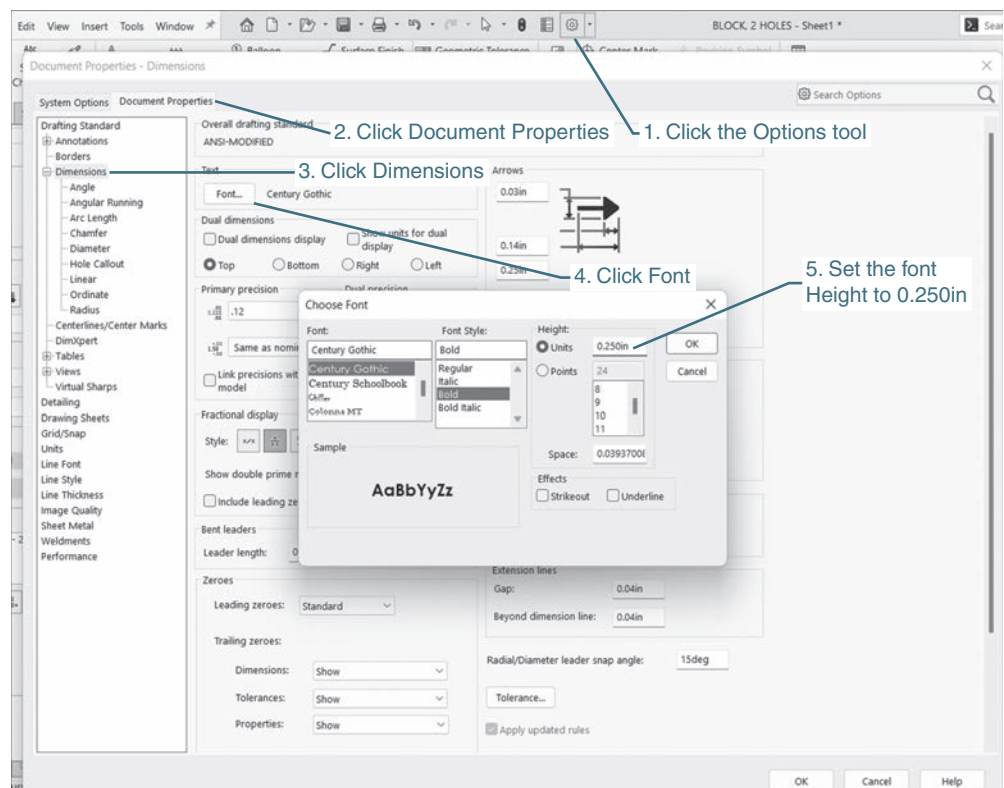
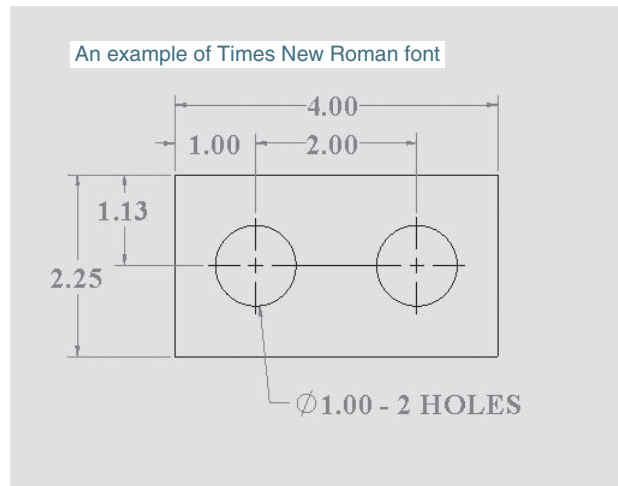


Figure 7-11
(Continued)



- 5** Click the **Height: Units** radio button and change the height to **0.250in.**

Note that the SolidWorks default font is Century Gothic.

- 6** Click **OK**, then **OK**.

Figure 7-11 shows dimensions created using the Times New Roman font. Fonts for drawings should always be easy to read and not too stylistic.

Dimensioning Short Distances

Figure 7-12 shows an object that includes several short distances. We will start by using the standard dimensions settings and show how to edit them for a particular situation.

- 1** Use the **Smart Dimension** tool and add dimensions to the drawing.

Note that the arrows for the .50 dimension are aligned with the arrows for the 1.00 dimensions. Dimensions that are aligned in a single row are called *chain dimensions*. Note that the .25 dimension is crowded between the two extension lines.

RULE

Never squeeze dimension values. Dimension values should always be presented clearly and legible.

There are several possible solutions to the crowded .25 value.

- 2** Click and drag the .25 dimension to the right outside the extension lines.
- 3** Add the **4.00** overall dimension.

Dimensions that define the total length and width of an object are called *overall dimensions*. In this example the dimension 4.00 defines the total length of the part, so it is an overall dimension. Overall dimensions are located farthest away from the edge of the part.

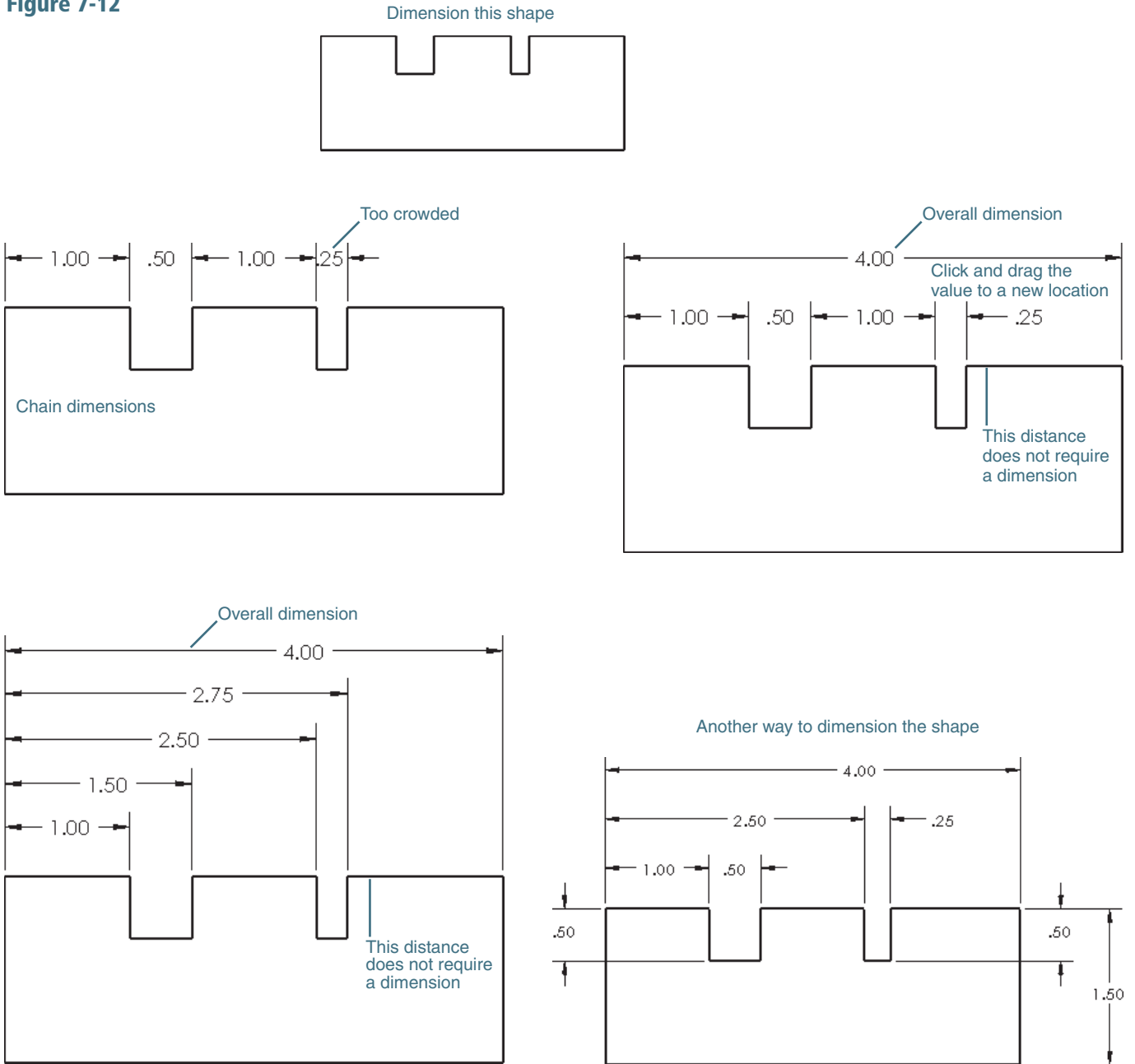
The right edge of the part, the section below the .25, does not need a dimension. The reason for this will be discussed in the next chapter on tolerancing.

TIP

To delete an existing dimension, click the dimension and press the key.

Figure 7-12 shows two other options for dimensioning. The first is the baseline method, in which all dimensions are taken from the same datum line. The second method is a combination of chain and baseline dimensions.

Figure 7-12



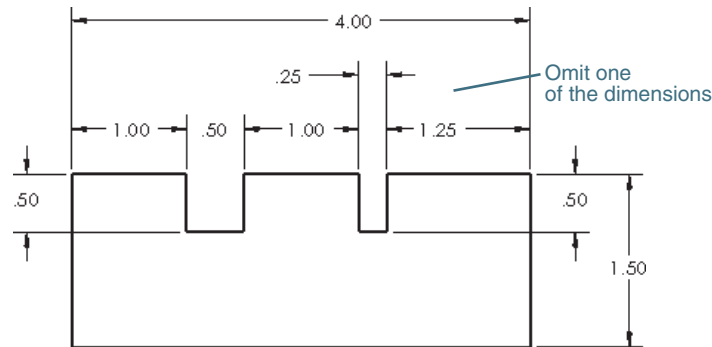
RULE

Never dimension the same distance twice. This is called *double dimensioning*.

Figure 7-13 shows an example of double dimensioning. The top edge distance is dimensioned twice: once using the 1.00 + .50 + 1.00 + .25 + 1.25 dimensions, and a second time using the 4.00 dimension. One of the dimensions must be omitted. Double dimensioning will be explained in more detail in Chapter 8.

Figure 7-13

ERROR—double dimensions



The top edge is dimensioned twice

Autodimension Tool

The **Autodimension** tool will automatically add dimensions to a drawing.

WARNING

The dimensions created using the **Autodimension** tool are not always in the best locations. The dimensions must be relocated to be in compliance with ANSI conventions.

Figure 7-14 shows a shape to be dimensioned using the **Autodimension** tool.

- 1** Click the **Annotation** tab, click the **Smart Dimension** tool, and click the **Autodimension** tab.
- 2** Select the **Chain Scheme**, define **Edge 1** and **Edge 2**, click the **Apply** box, and click the **OK** check mark.

SolidWorks will automatically pick edges 1 and 2. If it does not, or the edges selected are not the ones you want, click the **Edge** box, then click the edge. The word **Edge<1>** should appear in the box.

Figure 7-14 shows the dimensions applied using the **Autodimension** tool. They are not in acceptable positions.

- 3** Rearrange the dimensions to comply with standard conventions.

Figure 7-14

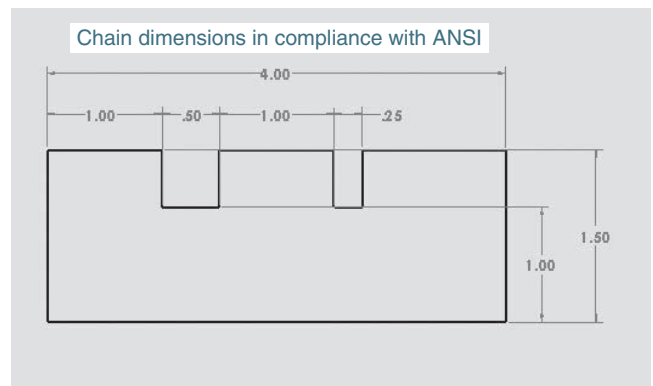
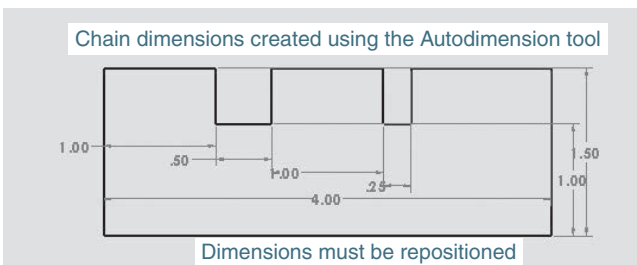
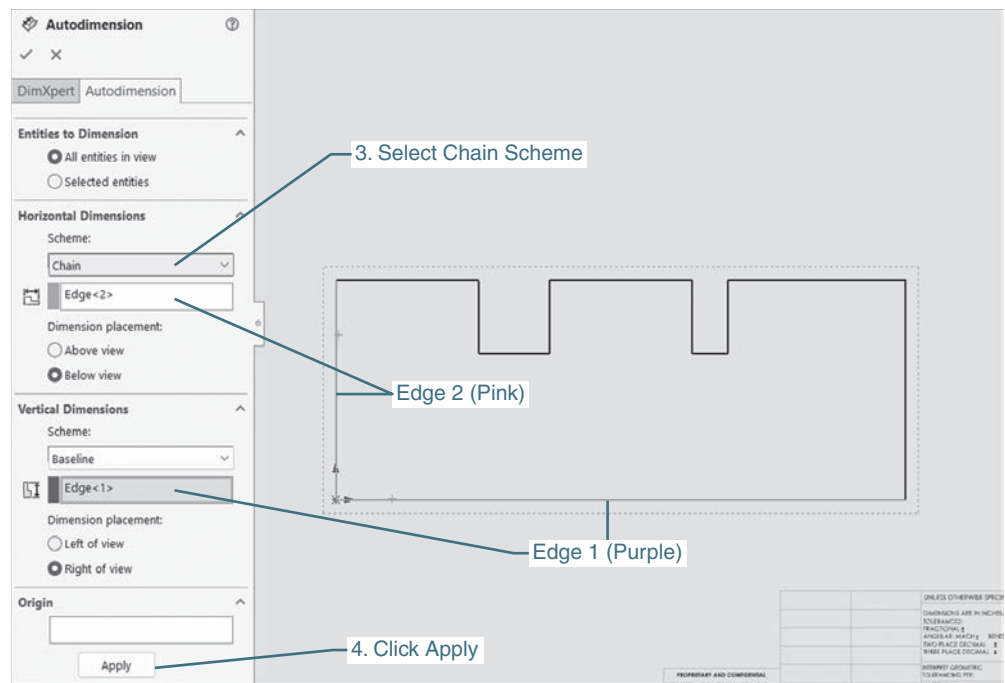
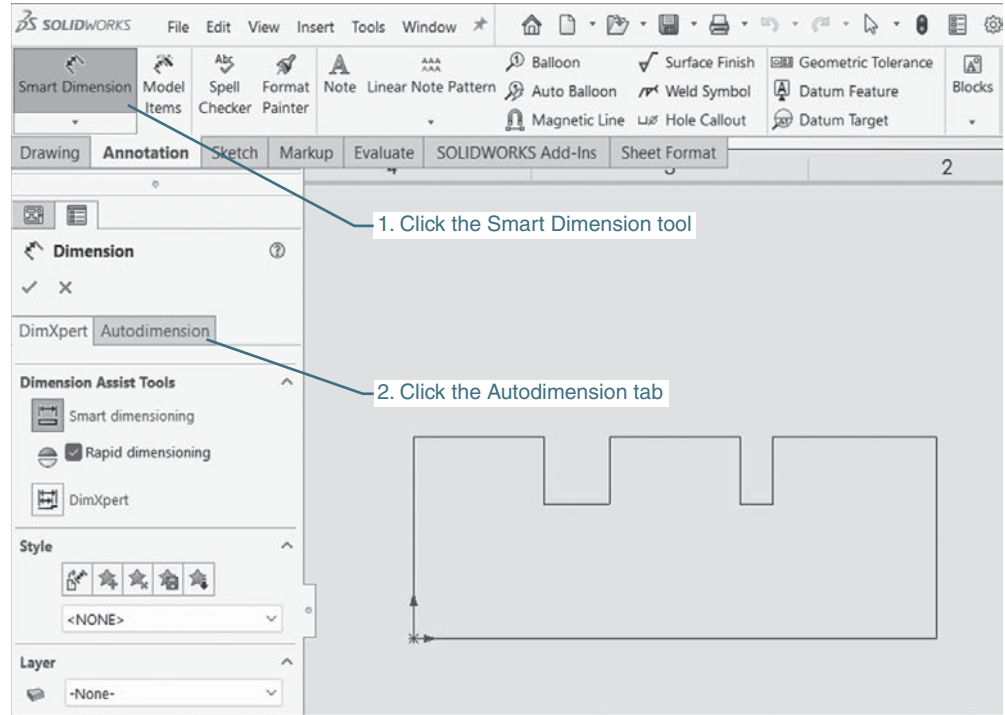
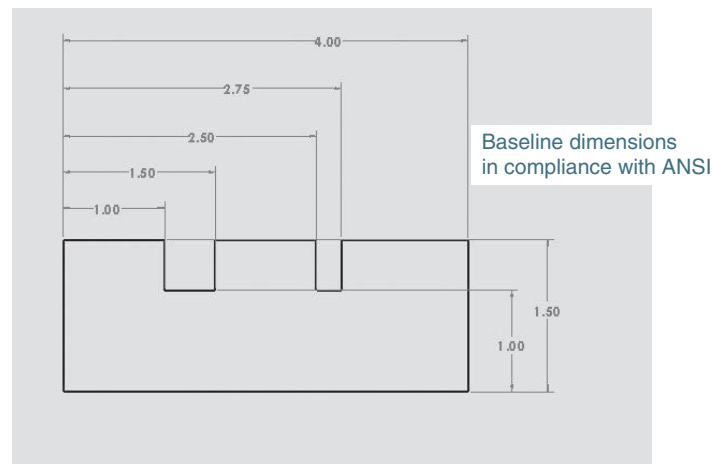
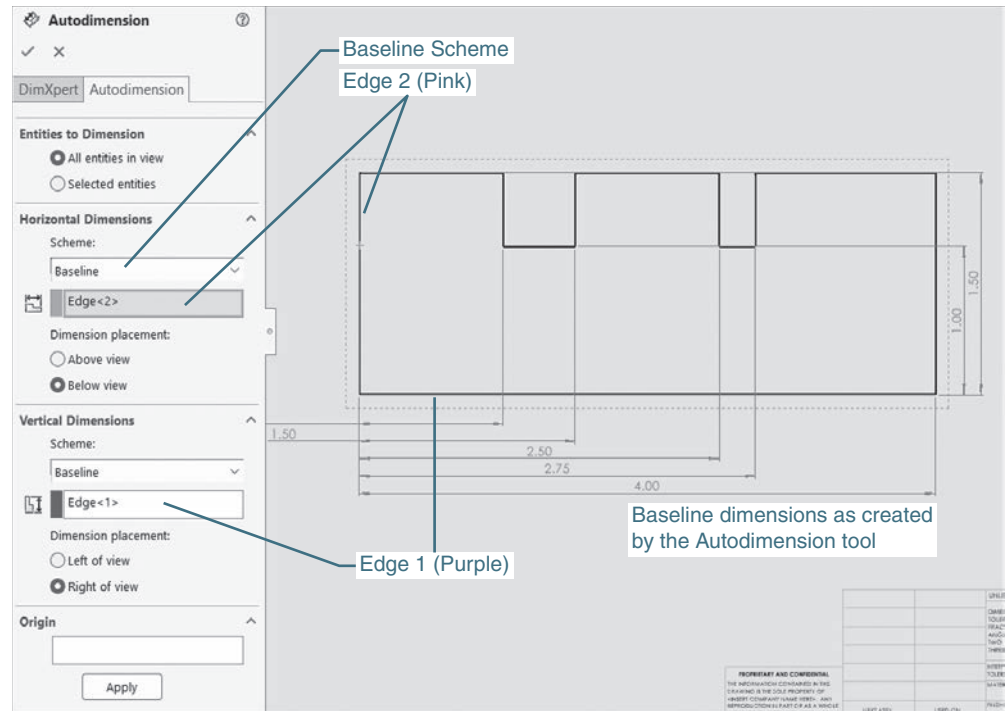


Figure 7-15 shows the shape shown in Figure 7-14 dimensioned using the baseline scheme, which is created as follows.

Figure 7-15



Creating Baseline Dimensions

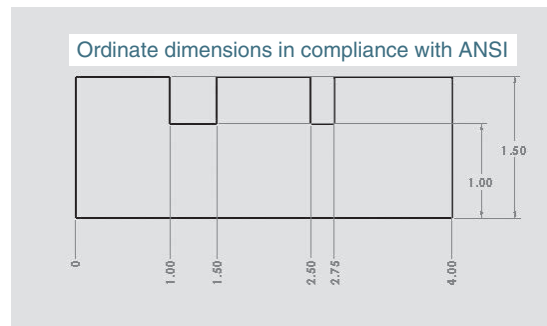
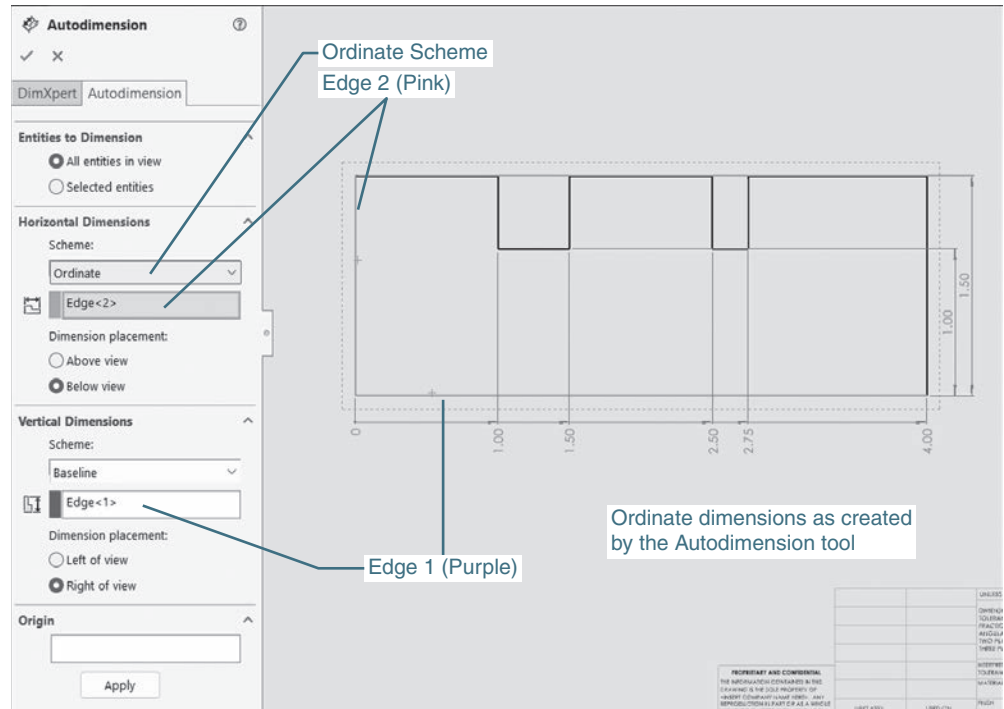
- 1 Access the **Autodimension** tool and select the **Baseline Scheme**.
- 2 Select **Edge 1** and **Edge 2**.
- 3 Click **Apply**.
- 4 Click the green **OK** check mark.

Figure 7-15 shows the dimensions created by the **Autodimension** tool and how the dimensions can be rearranged.

Creating Ordinate Dimensions

Figure 7-16 shows the object dimensioned using the **Ordinate Scheme** of the **Autodimension** tool. The **Autodimension** tool did better placing the ordinate dimensions in this instance, but if some of the created dimensions are located on the surface of the part, this would be a violation of the convention that dimensions should never be located on the surface of the part. Figure 7-16 shows how the ordinate dimensions were rearranged.

Figure 7-16



7-4 Drawing Scale

Drawings are often drawn “to scale” because the actual part is either too big to fit on a sheet of drawing paper or too small to be seen. For example, a microchip circuit must be drawn at several thousand times its actual size to be seen.

Drawing scales are written using the following formats:

SCALE: 1 = 1

SCALE: FULL

SCALE: 1000 = 1

SCALE: .25 = 1

In each example the value on the left indicates the scale factor. A value greater than 1 indicates that the drawing is larger than actual size. A value smaller than 1 indicates that the drawing is smaller than actual size.

Regardless of the drawing scale selected, the dimension values must be true size. Figure 7-17 shows the same rectangle drawn at two different scales. The top rectangle is drawn at a scale of $1 = 1$, or its true size. The bottom rectangle is drawn at a scale of $2 = 1$, or twice its true size. In both examples the 3.00 dimension remains the same.

Figure 7-17

SCALE: FULL

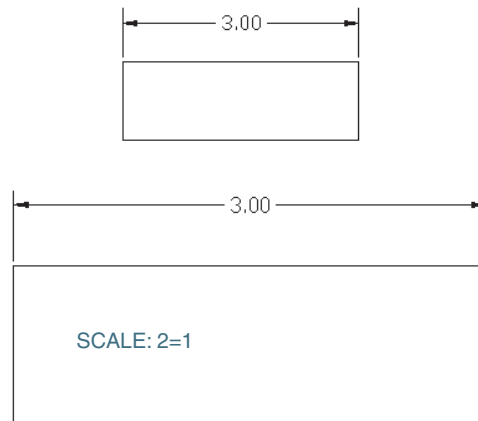


Figure 7-18

TOLERANCES UNLESS OTHERWISE STATED

X	± 1
.X	$\pm .1$
.XX	$\pm .01$
.XXX	$\pm .005$
X°	$\pm 1^\circ$
$.X^\circ$	$\pm .1^\circ$

7-5 Units

It is important to understand that dimension values are not the same as mathematical units. Dimension values are manufacturing instructions and always include a tolerance, even if the tolerance value is not stated. Manufacturers use a predefined set of standard dimensions that are applied to any dimensional value that does not include a written tolerance. Standard tolerance values differ from organization to organization. Figure 7-18 shows a chart of standard tolerances.

In Figure 7-19 a distance is dimensioned twice: once as 5.50 and a second time as 5.5000. Mathematically these two values are equal, but they are not the same manufacturing instruction. The 5.50 value could, for example, have a standard tolerance of $\pm .01$, whereas the 5.5000 value could have a standard tolerance of $\pm .0005$. A tolerance of $\pm .0005$ is more difficult and therefore more expensive to manufacture than a tolerance of $\pm .01$.

Figure 7-20 shows examples of units expressed in millimeters and in decimal inches. A zero is not required to the left of the decimal point for decimal inch values less than one. Millimeter values do not require zeros to the right of the decimal point. Millimeter and decimal inch values never include symbols; the units will be defined in the title block of the drawing.

Figure 7-19

These dimensions are not the same. They have different tolerance requirements.

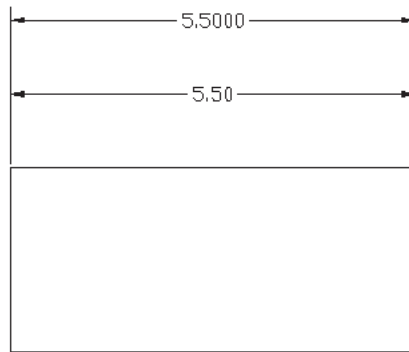


Figure 7-20

Millimeters

0.25	0.5	0.033
32	14.5	3

Zero required

Inches

.25	.05	.033
32.00	14.50	3.000

No zero required

Aligned Dimensions

Aligned dimensions are dimensions that are parallel to a slanted edge or surface. They are not horizontal or vertical. The units for aligned dimensions should be written horizontally. This is called *unidirectional dimensioning*.

Figure 7-21 shows the front, right-side, and isometric views of a part with a slanted surface. The dimensions were applied using the **Smart Dimension** tool. Note that the slanted dimension, aligned with the slanted surface, has unidirectional (horizontal) text. The hole dimension was created using the **Note** tool from the **Annotation** tab.

Hole Dimensions

Figure 7-22 shows an object that has two holes, one blind and one completely through. The object has filleted corners. In this section we will add dimensions to the views.

Figure 7-21

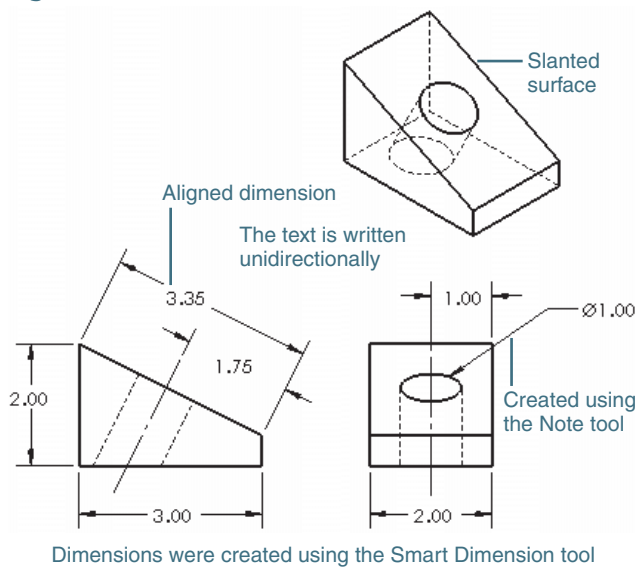
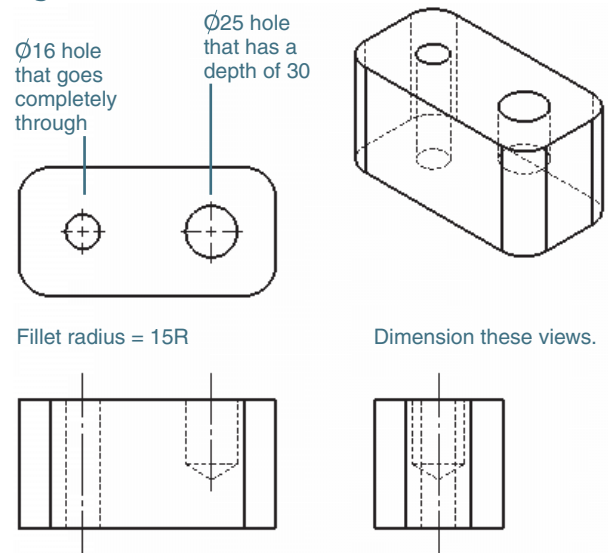


Figure 7-22



The holes were drawn using the **Hole Wizard** tool. The **Hole Wizard** tool will automatically create a conical point to a blind hole.

- 1 Use the **Smart Dimension** tool and locate the two holes.

See Figure 7-23. In general, dimensions are applied from the inside out; that is, starting with the features in the middle of the part and working out to the overall dimensions. Leader lines are generally applied last, as they have more freedom of location.

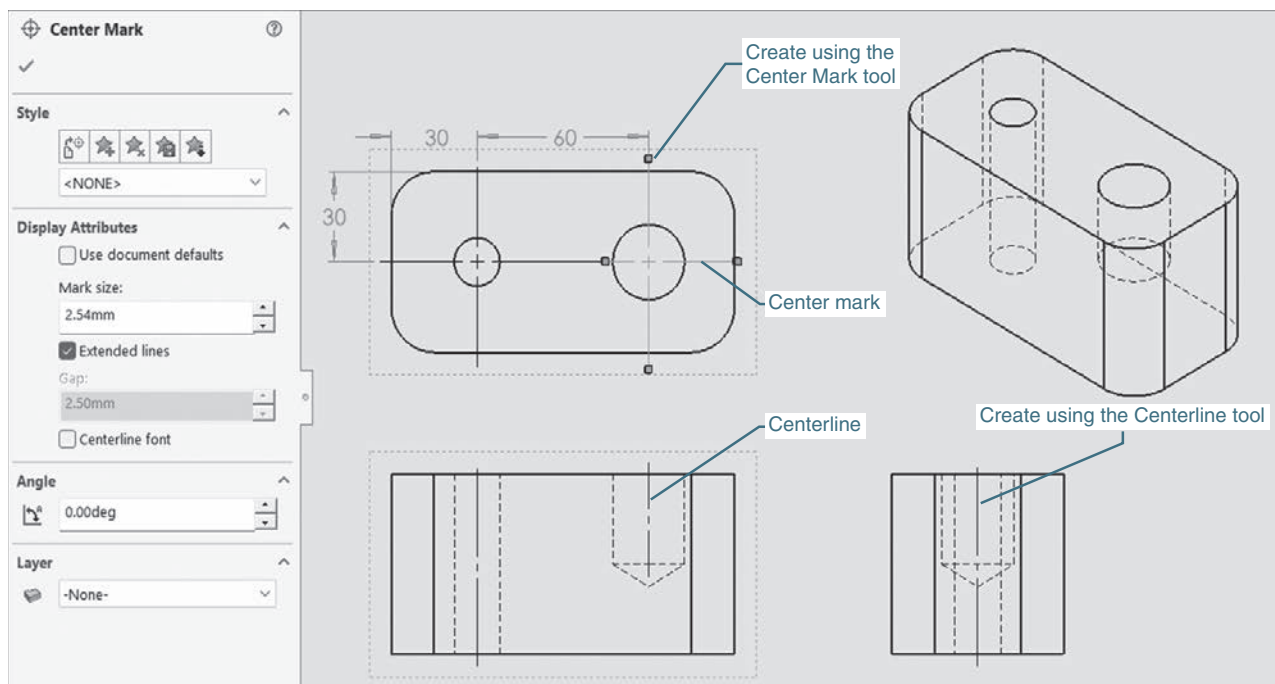
- 2 Use the **Linear Center Mark** tool to draw a centerline between the two holes and use the **Centerline** tool to add the vertical centerline in the front and side views.

The centerline between the two holes indicates that the vertical 30 dimension applies to both holes.

NOTE

Centerlines should extend beyond the edges of the part. Centerlines can be extended by first clicking the centerline. Blue end boxes will appear. Click and drag the blue end boxes to a point beyond the edges of the part.

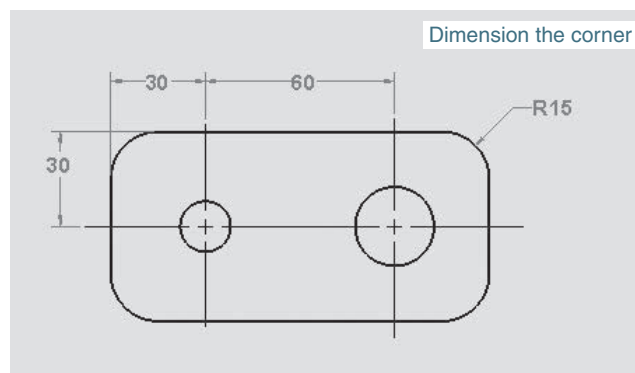
Figure 7-23



- 3 Use the **Smart Dimension** tool and add a dimension to one of the filleted corners.

See Figure 7-24.

Figure 7-24

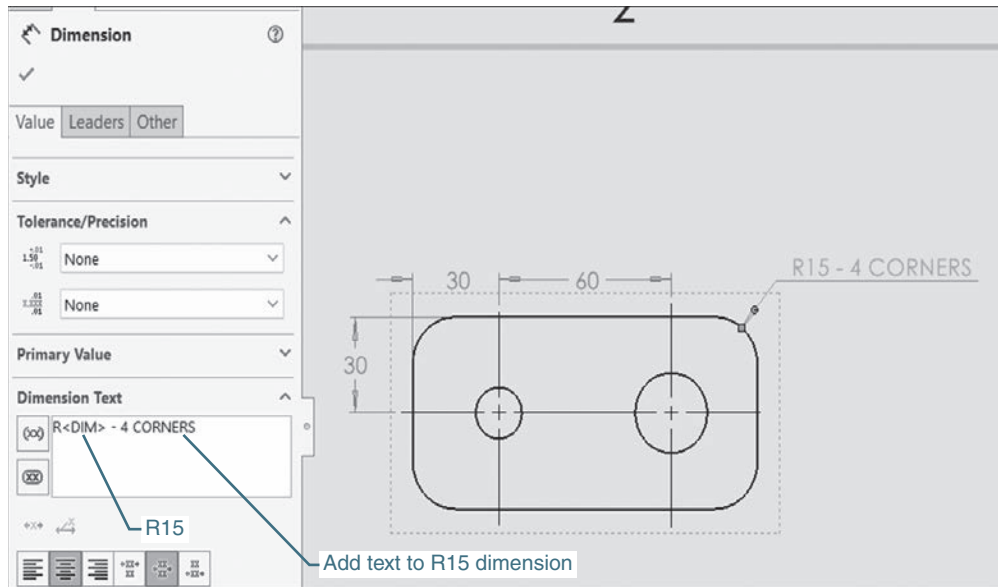


TIP

The dimension options found on the **Document PropertyManager** will change all dimensions. Clicking a dimension and using the **Dimension PropertyManager** allows you to change just that dimension.

- Click the fillet dimension again, go to the **Dimension Text** block on the **Dimension PropertyManager**, and type - **4 CORNERS** as shown in Figure 7-25.

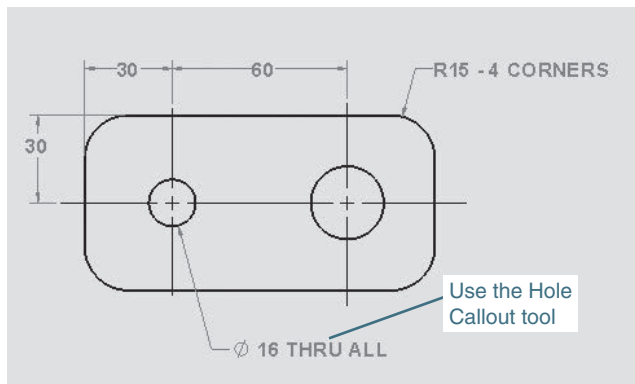
Figure 7-25



- Click **OK**, **Apply**, and **OK**.
- Use the **Hole Callout** tool on the **Annotation** panel and dimension the $\varnothing 16$ hole.

The $\varnothing 16$ hole goes completely through the part, so no depth specification is required. See Figure 7-26. The word THRU is optional and may be removed.
- Use the **Hole Callout** tool and **Dimension** the $\varnothing 25$ hole.

Figure 7-26



The hole callout will include the depth symbol (see Figure 7-27) and a depth value of **30** (see Figure 7-28).

Complete the dimensions.

See Figure 7-29.

Figure 7-27

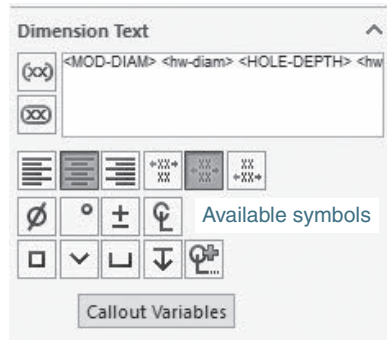


Figure 7-28

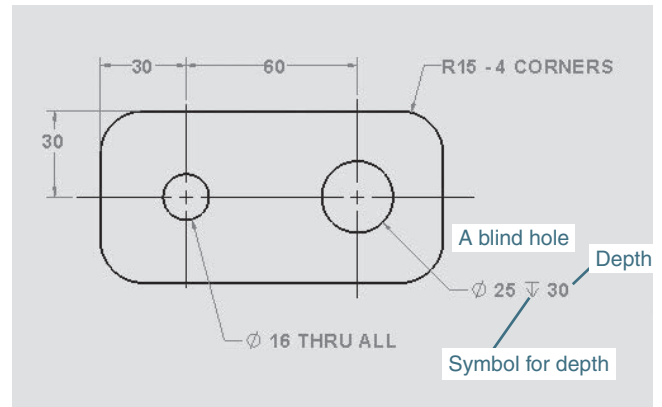
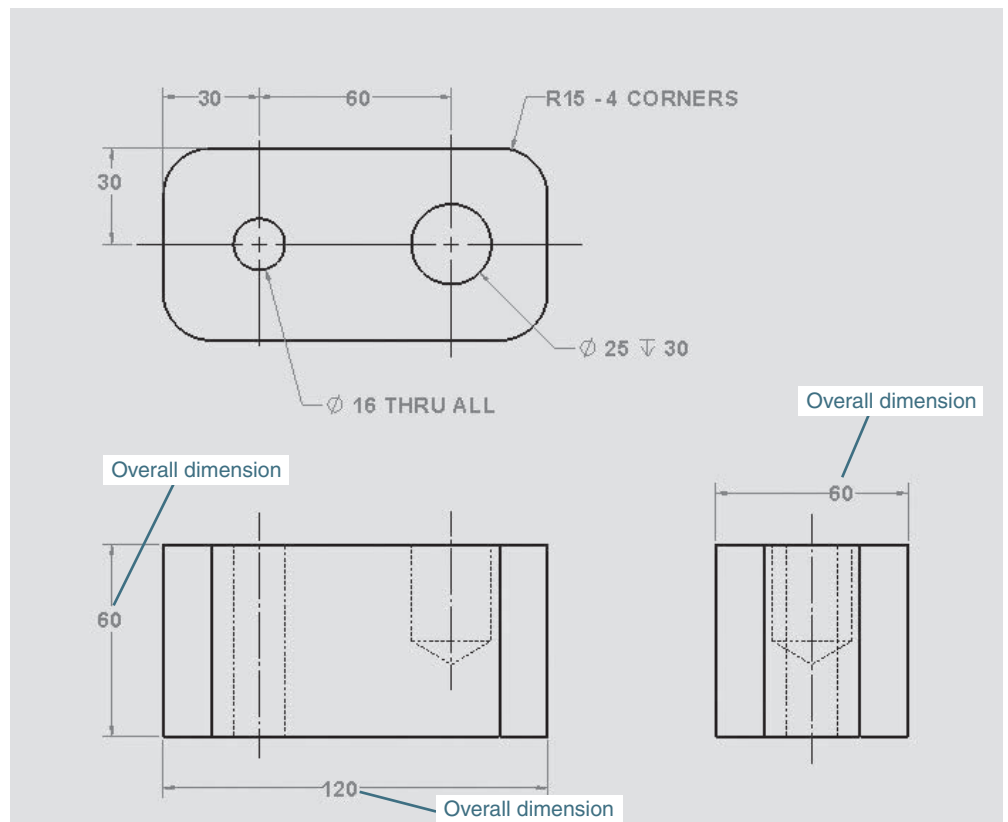


Figure 7-29



NOTE

If the **Smart Dimension** tool had been used, the dimension would have to be edited in the **Dimension Text** area and the depth symbol and a numerical value added.

7-6 Dimensioning Holes and Fillets

A *blind hole* is a hole that does not go completely through an object. It has a depth requirement. Figure 7-30 shows a $2.00 \times 2.00 \times 2.00$ cube with a blind $\text{Ø}.50 \times 1.18$ DEEP hole. It was created as follows.

Dimensioning a Blind Hole

- 1 Draw the block.
- 2 Click the **Hole Wizard** tool.

See Figure 7-30.

Figure 7-30

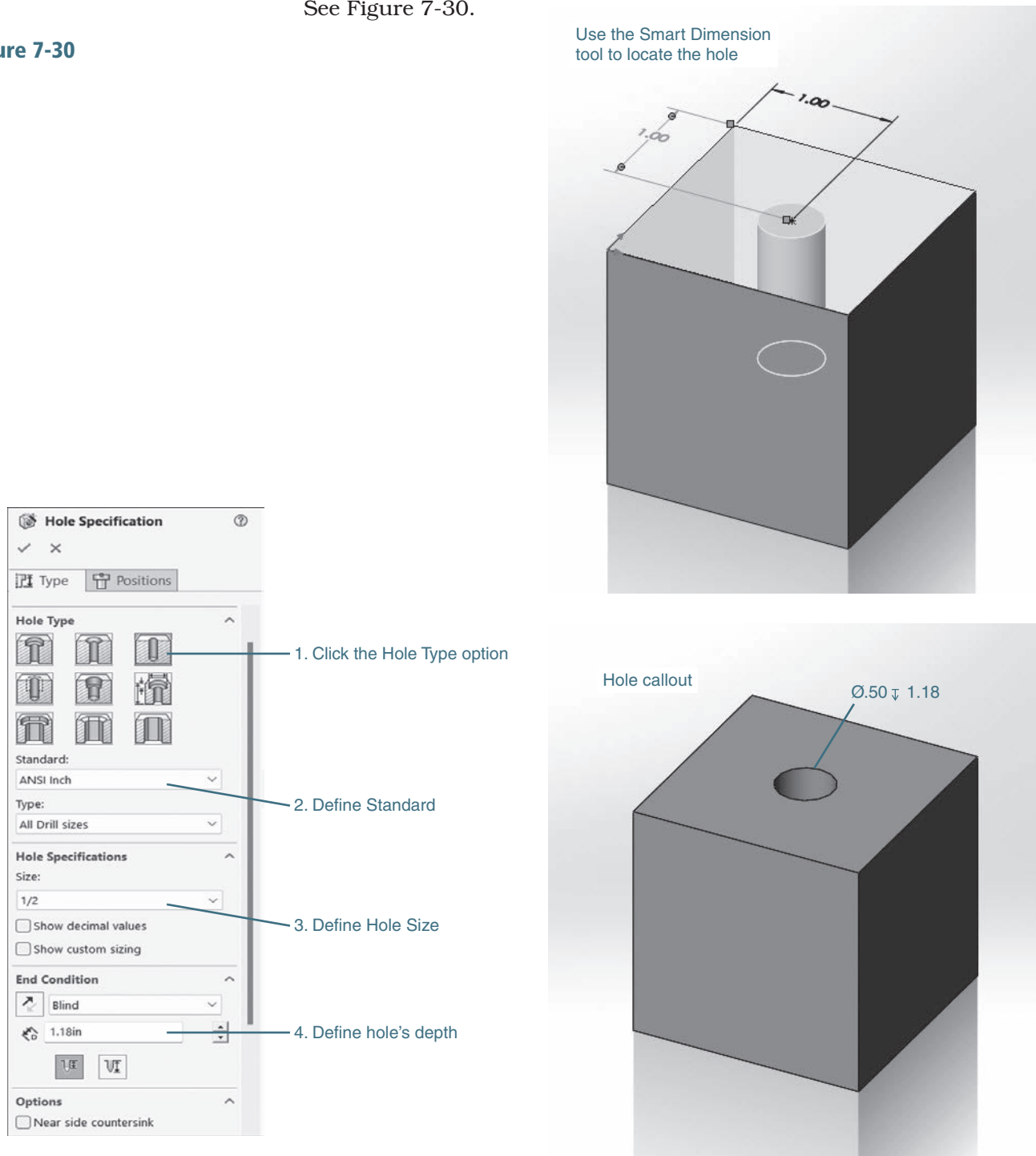
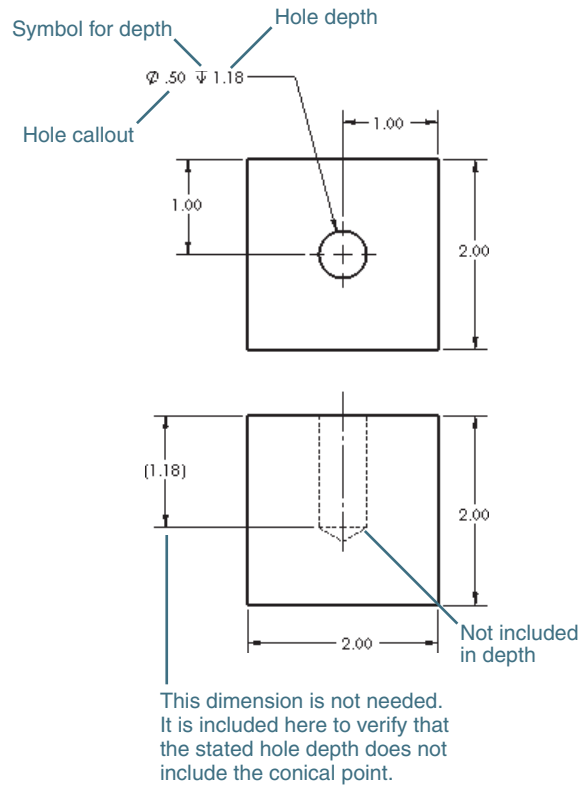


Figure 7-30
(Continued)



- 3** Click the **Hole** tool in the **Hole Type** box. Define the hole using the **ANSI Inch** standard with a **Size** of **1/2** and a **Blind Hole Depth** of **1.18in.**
- 4** Click the **Positions** tab.
- 5** Locate the hole as shown.

The initial location is an approximation. Use the **Smart Dimension** tool to specify the exact location of the hole's centerpoint.

- 6** Click the green **OK** check mark.
- 7** Save the drawing as **Block, Blind.**
- 8** Start a new **Drawing** document and create a front and a top orthographic view of the **Block, Blind.**
- 9** Add dimensions to the views.
- 10** Click the **Annotation** tab and click the **Hole Callout** option.
- 11** Click the edge of the hole, move the cursor away from the hole, define a location for the hole callout, and click the mouse. The hole callout dimension will initially appear as a rectangular box.

Change the height of the text font if necessary.

- 12** Save the drawing.

Note that the hole includes a conical point. Holes manufactured using twist drills will have conical points. The conical point is not included in the hole's depth dimension. A special drill bit can be used to create a flat-bottomed hole.

Figure 7-31 shows three different methods that can be used to dimension a blind hole.

Figure 7-31

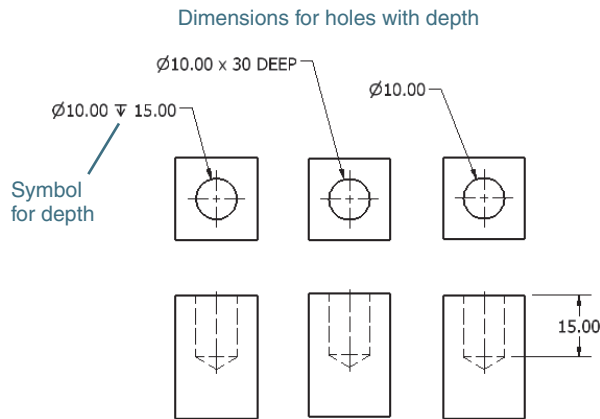


Figure 7-32

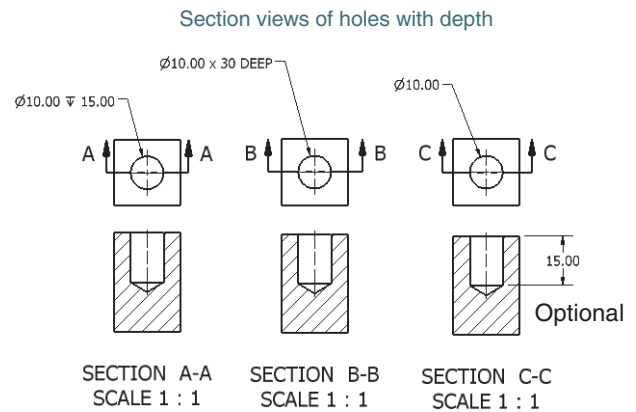


Figure 7-32 shows three methods of dimensioning holes in section views. The single line note version is the preferred method.

Dimensioning Hole Patterns

Figure 7-33 shows two different hole patterns dimensioned. The circular pattern includes the note **Ø10 - 4 HOLES**. This note serves to define all four holes within the object.

Figure 7-33 also shows a rectangular object that contains five holes of equal diameter, equally spaced from one another. The notation **5 × Ø10** specifies five holes of 10 diameter. The notation **4 × 20 (=80)** means four equal spaces of 20. The notation **(=80)** is a reference dimension and is included for convenience. Reference dimensions are explained in Chapter 9.

Figure 7-33

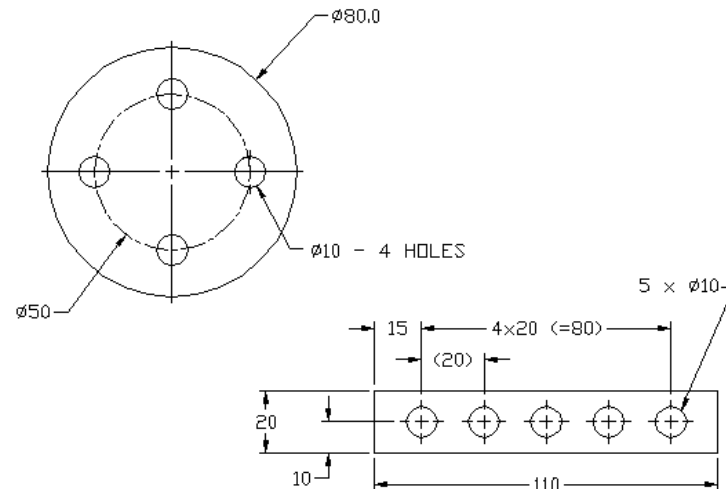


Figure 7-34 shows two additional methods for dimensioning repeating hole patterns. Figure 7-35 shows a circular hole pattern that includes two different hole diameters. The hole diameters are not noticeably different and could be confused. One group is defined by indicating letter **A**; the other is dimensioned in a normal manner.

Figure 7-34

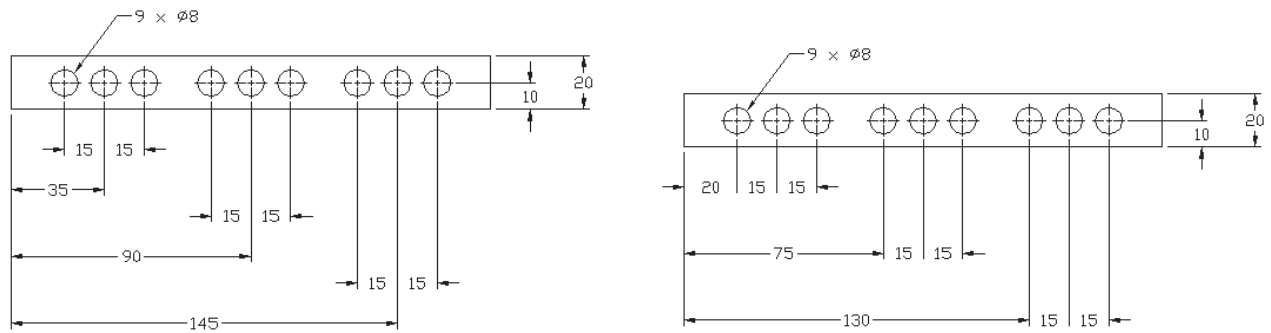
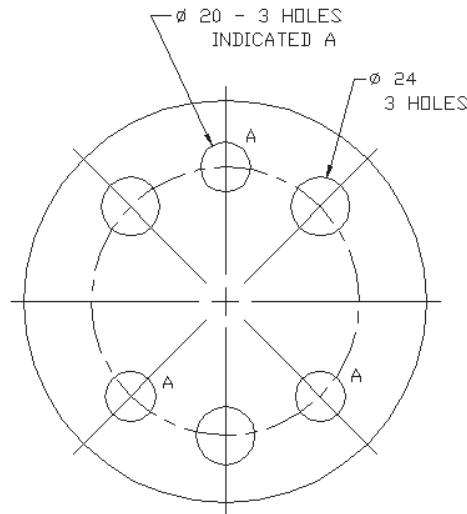


Figure 7-35



7-7 Dimensioning Counterbored and Countersunk Holes

Counterbored holes are dimensioned in the sequence of their manufacture. First the hole's diameter is given, then the counterbore diameter, then the depth of the counterbore.

Figure 7-36 shows a part that contains two counterbored holes; one goes completely through and the other is blind. Dimensions will be applied to both.

- 1 Create a **3.00 × 4.00 × 1.75** block.
- 2 Click the **Hole Wizard** tool, click the **Counterbore** option, and insert the counterbored hole that goes completely through.
- 3 Specify the **Standard** as **ANSI Inch**, the **Type** as **Hex Screw**, the **Size** as a **3/8** diameter, and the **End Condition** as **Through All**.

See Figure 7-37. SolidWorks will automatically select the diameter for the counterbored hole that will accommodate a Ø3/8 Hex Head Screw.

Depending on your default settings, the counterbored hole may have a small chamfer added. The countersink can be removed by removing the check mark in the **Options** box on the **Hole Specification** manager.

Figure 7-36

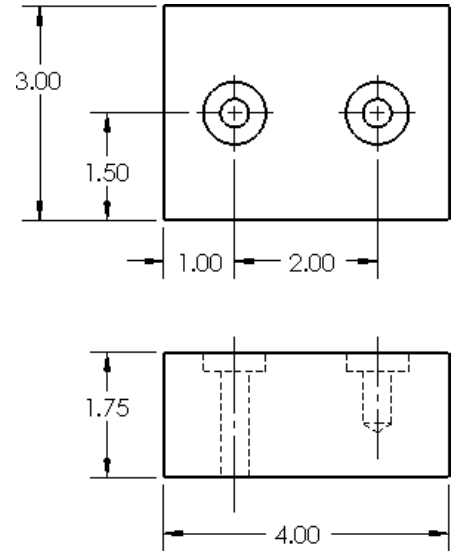
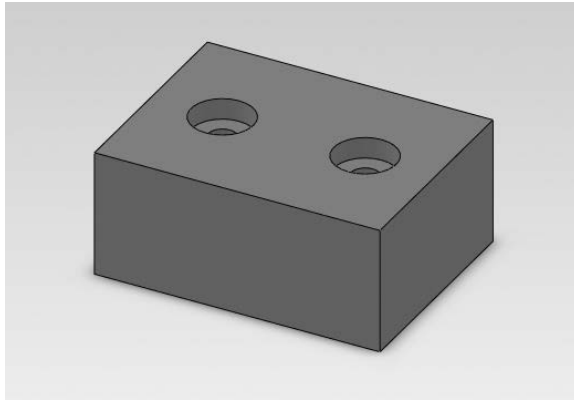


Figure 7-37

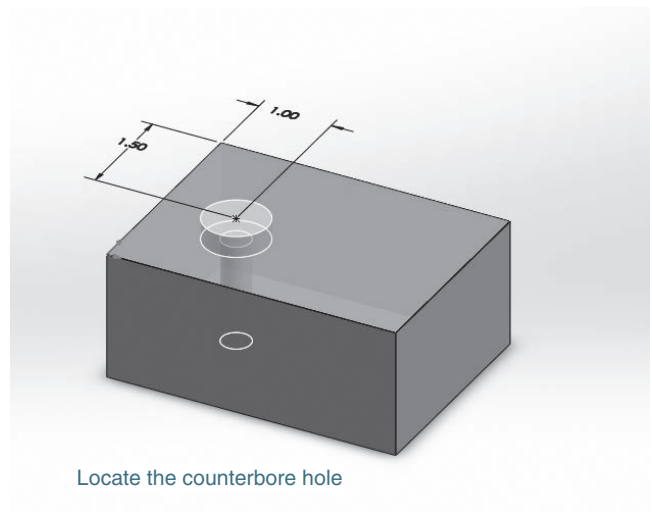
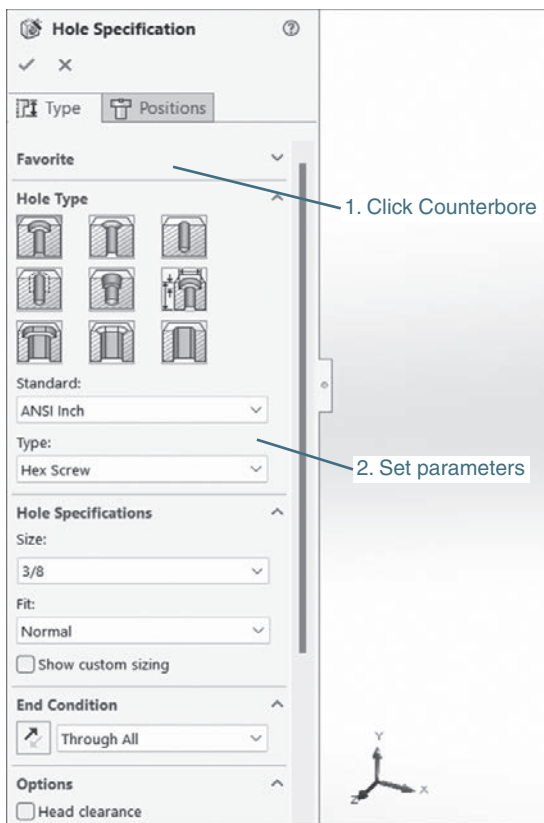
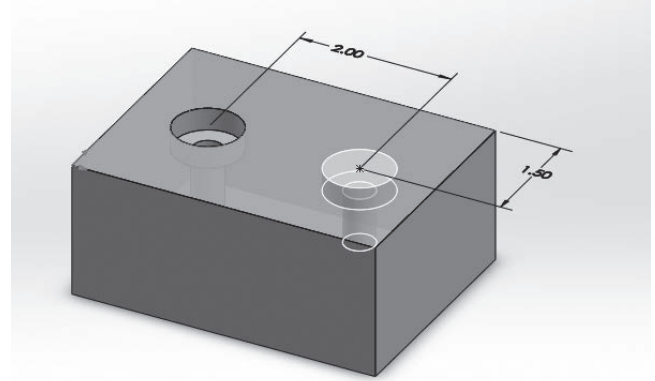
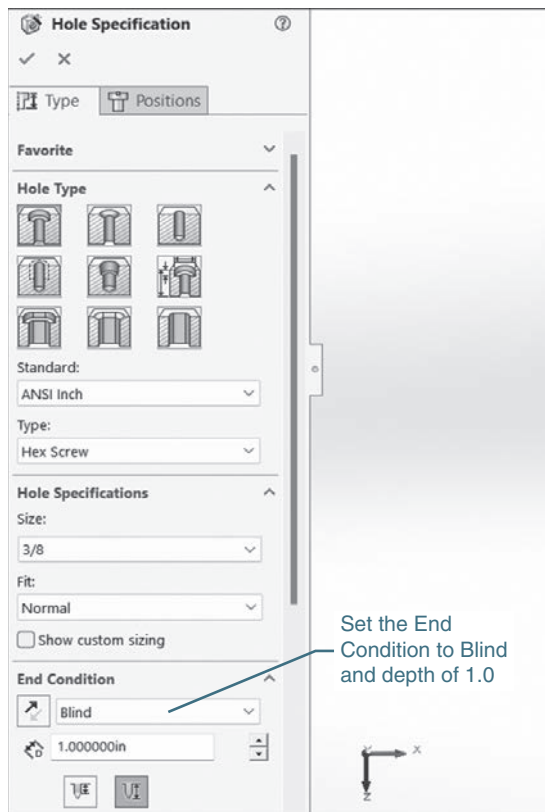
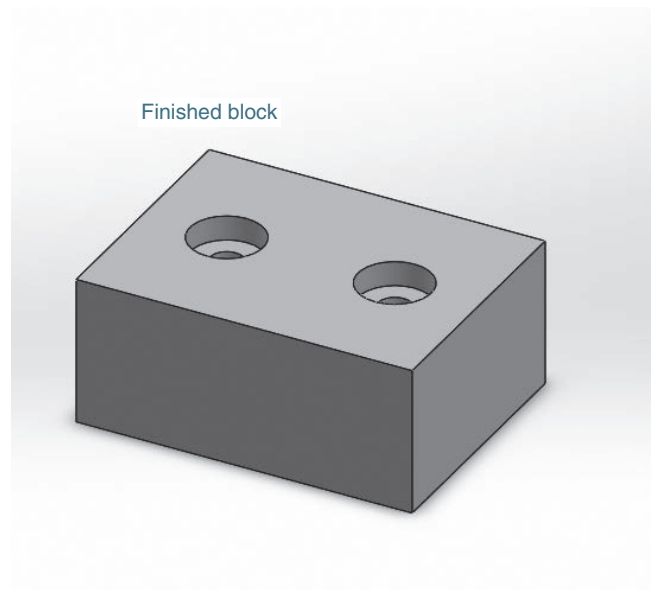


Figure 7-37

(Continued)



Position the second hole



Finished block

- 4 Position the hole using the given dimensions.
- 5 Add the second hole, setting the **End Condition** to **Blind** and **1.00** deep.
- 6 Position the hole using the given dimensions.
- 7 Save the block as **Block, Cbore**.
- 8 Start a new **Drawing** document and create a front and a top orthographic view of the **Block, Cbore**.
- 9 Click the **Annotation** tab and add all dimensions and centerlines other than the hole dimensions.
- 10 Click the **Hole Callout** tool.
See Figure 7-38.
- 11 Click the edge of each hole, move the cursor away from the hole, and click the mouse when a suitable location is found.

The counterbored hole's dimension note is interpreted as shown in Figure 7-38.

Figure 7-38

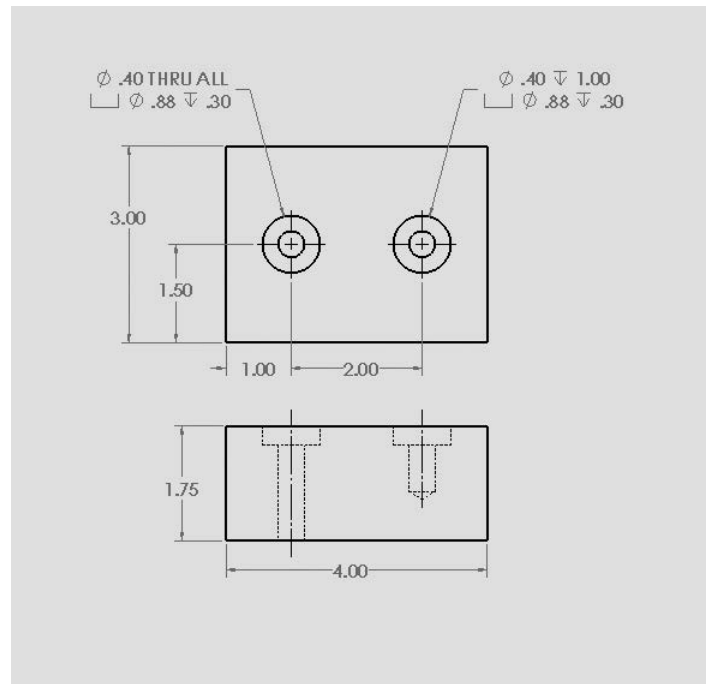
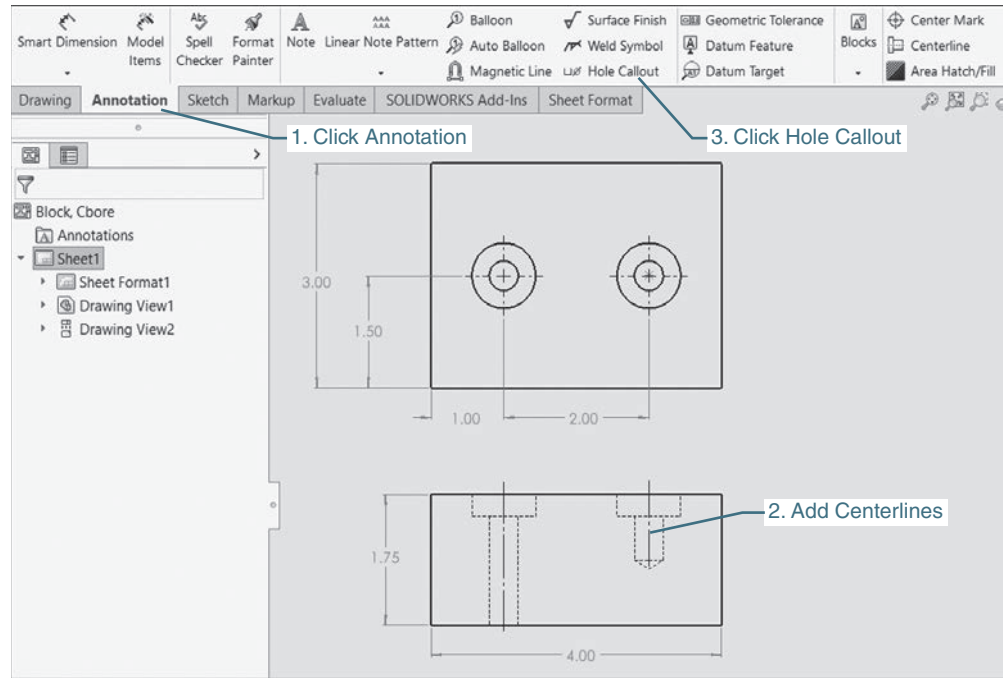


Figure 7-39 shows the **Block, Cbore** assembled with hex head screws inserted into the counterbored holes. SolidWorks will automatically generate the correct size counterbored hole for a specified screw. The counterbore depth will align the top of the screw head with the top surface of the part and will define a hole diameter that includes clearance between the fastener and the hole. In this example a clearance hole with a diameter of $\phi .40$ was generated. The hole is .02 larger than the specified .38 fastener diameter.

If clearance is required between the top of the screw and the top surface of the part, check the **Head clearance** box under **Options** in the **Hole Specification** section of the **Hole Wizard PropertyManager**. See Figure 7-40.

Figure 7-39

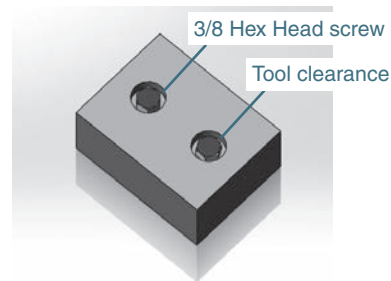
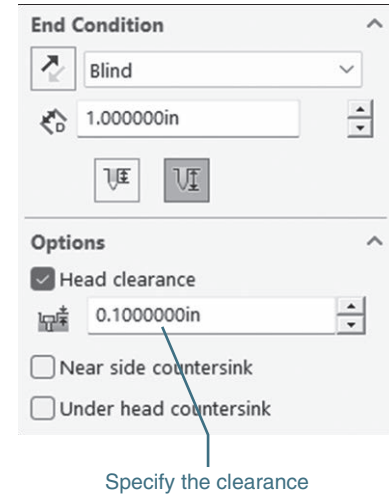


Figure 7-40

Click Hole Wizard and Hole Specification



The diameter of the counterbored hole can be made larger than the clearance generated by SolidWorks to allow for tool clearance. Tool clearance allowance increases the diameter of the counterbore so that it is large enough to allow a socket wrench to fit over the head of the fastener and still fit within the hole.

Counterbored Hole with Threads

Figure 7-41 shows a $3.00 \times 4.00 \times 2.00$ block with two counterbored holes. Both holes are threaded.

- 1 Create the block.
- 2 Click the **Hole Wizard** tool, select the **Straight Tap** option, and specify a **3/8-16 UNC** thread that goes completely through.
- 3 Click the **Positions** tab and locate the hole.
- 4 Click the green **OK** check mark.

This will locate a 3/8-16 UNC thread hole in the block. Now, we add the counterbore.

- 5 Click the top surface of the block and click the **Sketch** option.
- 6 Click the **Circle** tool and draw a $\varnothing.88$ circle on the top surface centered on the same centerpoint as the $\varnothing 3/8$ -16 hole.

The dimensions for this example came from Figure 7-38.

Figure 7-41
(Continued)

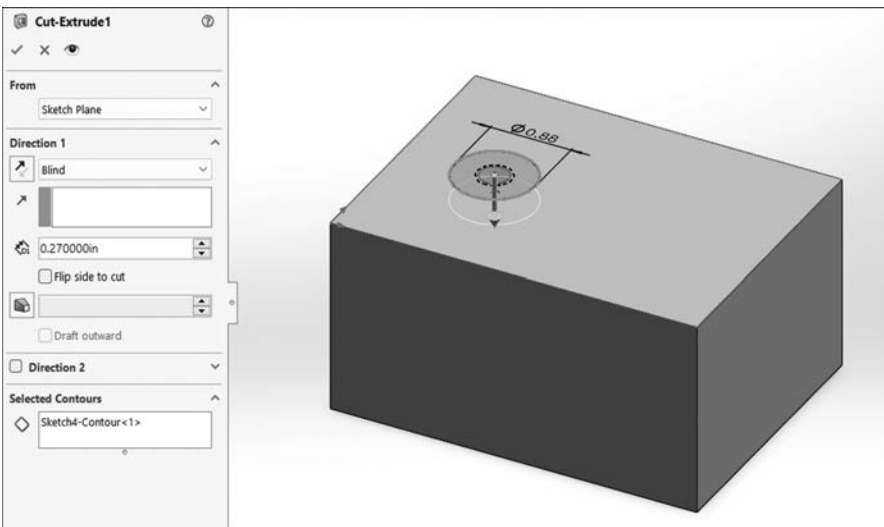
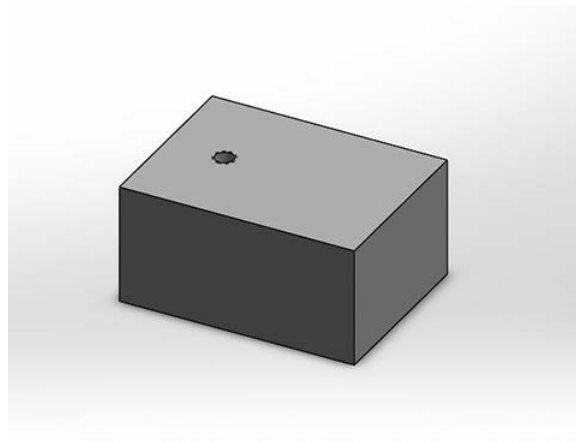
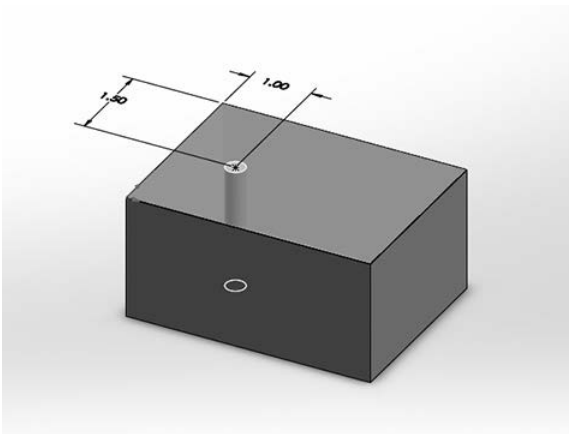
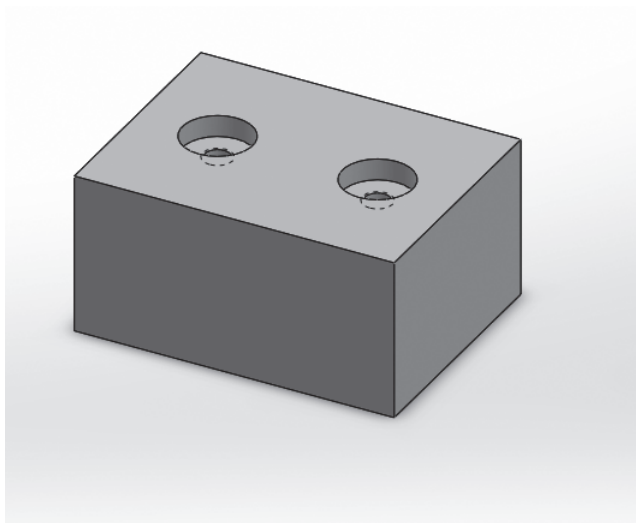
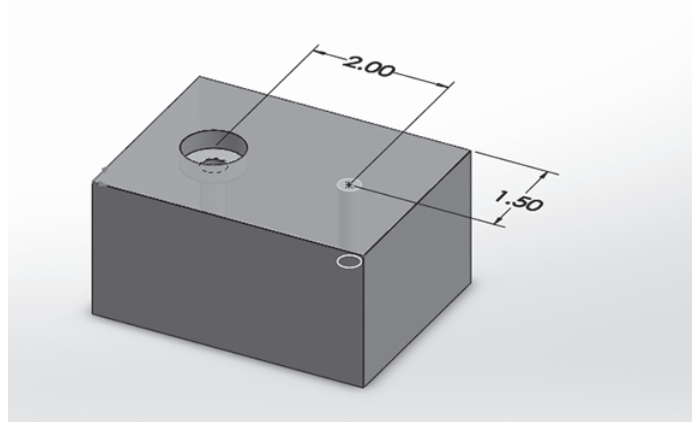
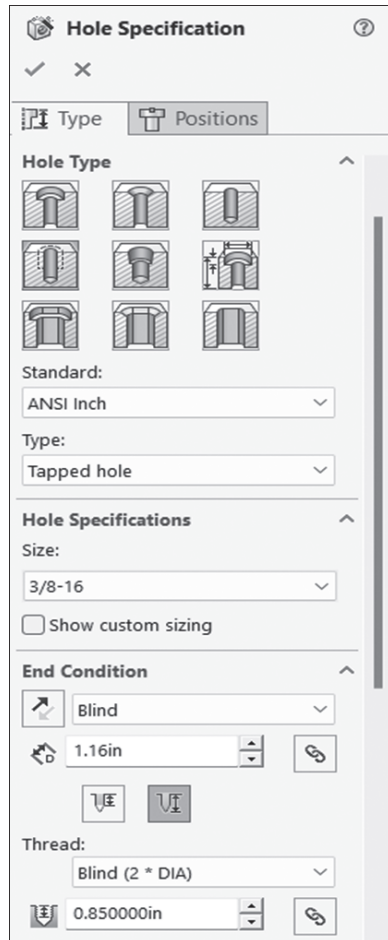


Figure 7-41
(Continued)



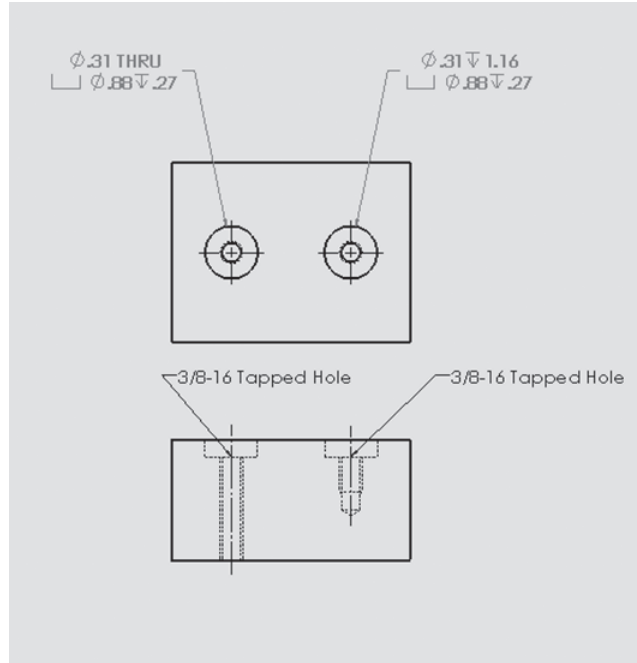
- 7** Click the **Features** tab, click the **Extruded Cut** tool, and specify a cut depth of **0.27**.
- 8** Click the green **OK** check mark.
- 9** Repeat the procedure, adding a second hole with a thread to a depth of **0.85**.

TIP

For an internal thread, the thread depth is measured from the top surface of the part.

See Figure 7-42.

Figure 7-42



- 10** Save the block as **Block, Threads**.
- 11** Create a new **Drawing** document and create front and top orthographic views of the **Block, Threads**.
- 12** Add centerlines to the front view and add dimensions as shown.

See Figure 7-43.

- 13** Use the **Hole Callout** tool and click the left threaded hole.

Do not click the outside of the counterbored hole. This will generate a note that includes only the counterbore. In Figure 7-42 the callouts 3/8-16 Tapped Hole appear on the front view. Remove the callouts from view by right-clicking the callouts and selecting the **Hide** option. The thread information will be included in the counterbore hole callout.

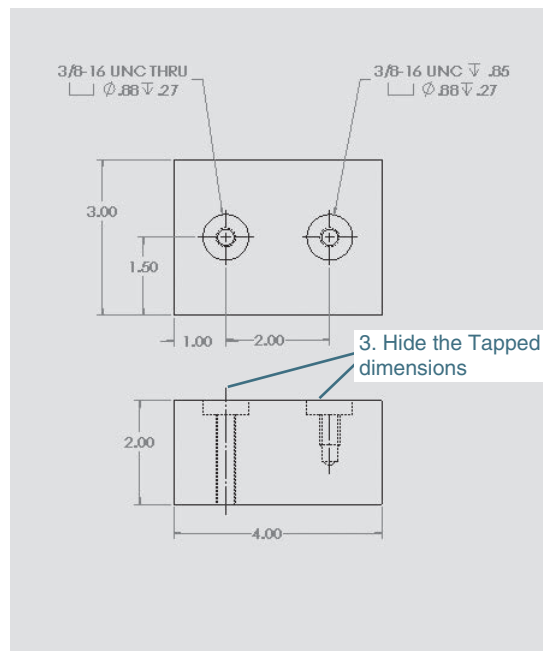
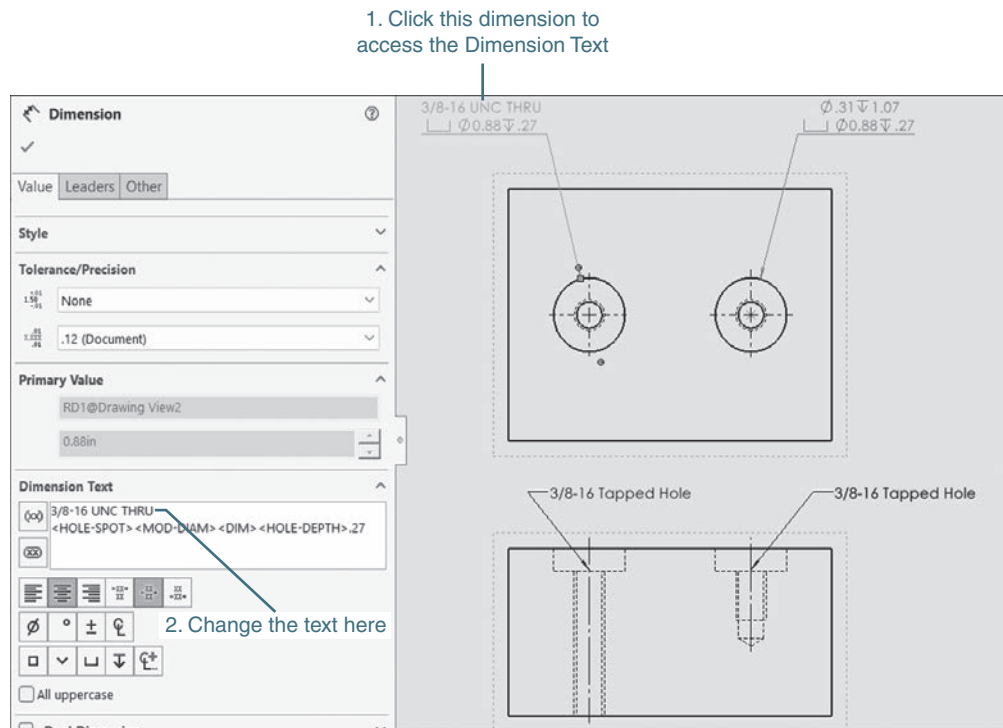
- 14** Locate the text and click the mouse.

The initial note may show the counterbore callout above the thread callout. Convention calls for the note to read in the sequence of manufacture. The threaded hole is cut first and then the counterbore is added; therefore, the thread callout should come before the counterbore callout.

- 15** Modify the callout to list the thread callout above the counterbore callout.

Access the **Dimension Text** box on the **Dimension Manager** by clicking the **.31 THRU ALL** dimension, delete the first line of text, and replace the dimension with a new dimension, **3/8-16 UNC THRU**.

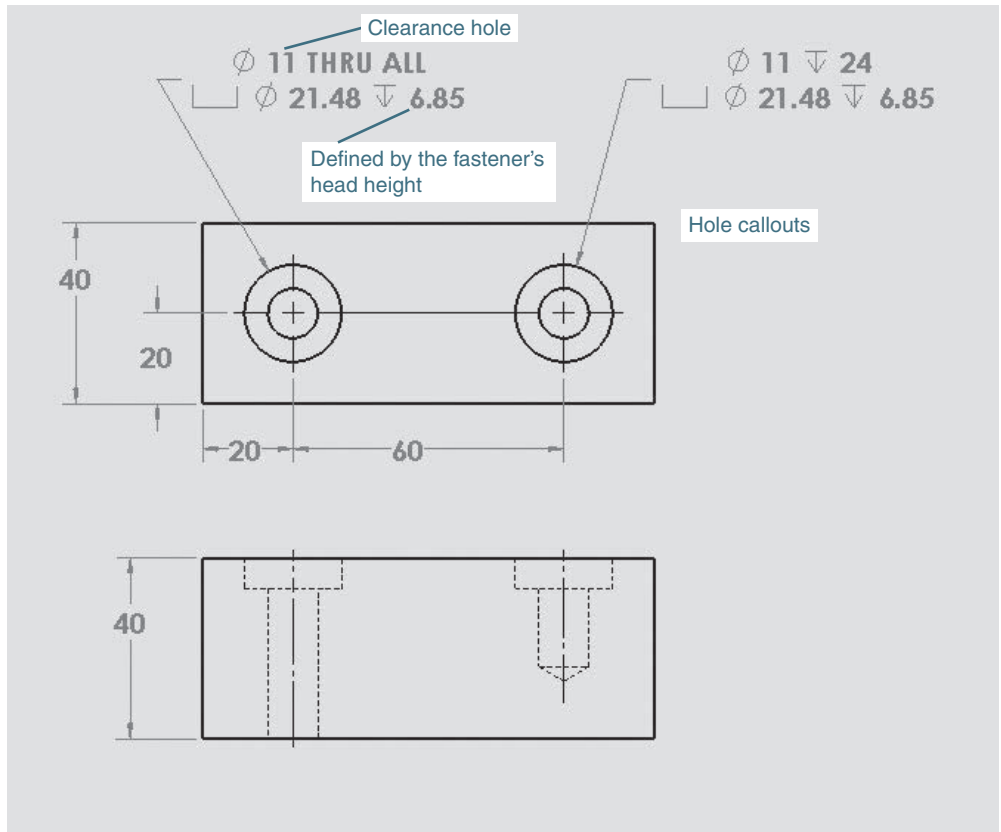
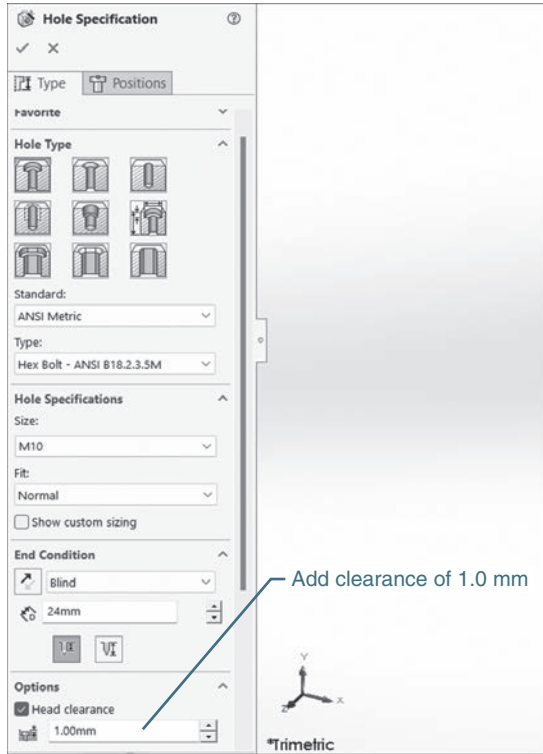
Figure 7-43



- 16 Click the green **OK** check mark.
- 17 Click the threaded portion of the right hole.
- 18 Locate the text and click the mouse.
- 19 Modify the callout as shown.

Figure 7-44 shows dimensioned counterbored holes using metric units. The **Hole Callout** tool was used to dimension the counterbored holes. Note that the hole's diameter is listed as $\text{\O}11$. The fastener size was specified as M10, and the $\text{\O}11$ hole is a clearance hole.

Figure 7-44

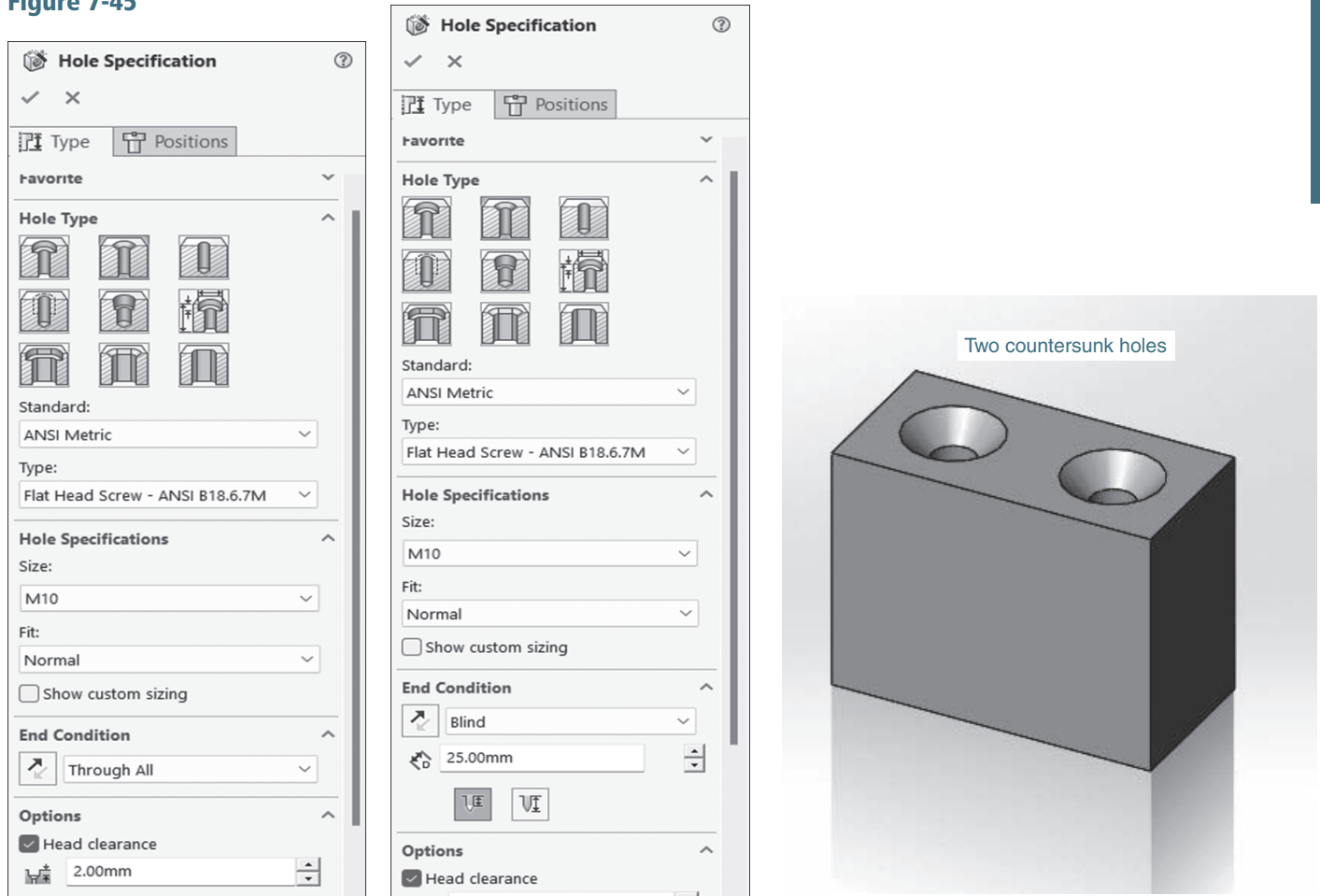


Dimensioning Countersink Holes

Countersink holes are used with flat head screws to create assemblies in which the fasteners do not protrude above the surfaces.

Figure 7-45 shows a part with two countersunk holes; one goes completely through, the other has a depth specification.

Figure 7-45



- 1 Draw a 40 × 80 × 60 block.
- 2 Use the **Hole Wizard** tool, click the **Countersink** type, specify the **ANSI Metric** standard, select an **M10** size for a flat head screw, and specify a hole that goes all the way through. Define a head clearance of **2.00mm**.
- 3 Click the **Positions** tab and position the countersink hole's center-point as shown using the **Smart Dimension** tool.
- 4 Click the green **OK** check mark.
- 5 Click the **Hole Wizard** tool, click the **Countersink** type, specify the **ANSI Metric** standard, select an **M10** size for a flat head screw, and specify a depth requirement of **25.00mm** for a **Blind** hole. Define a head clearance of **2.00mm**.

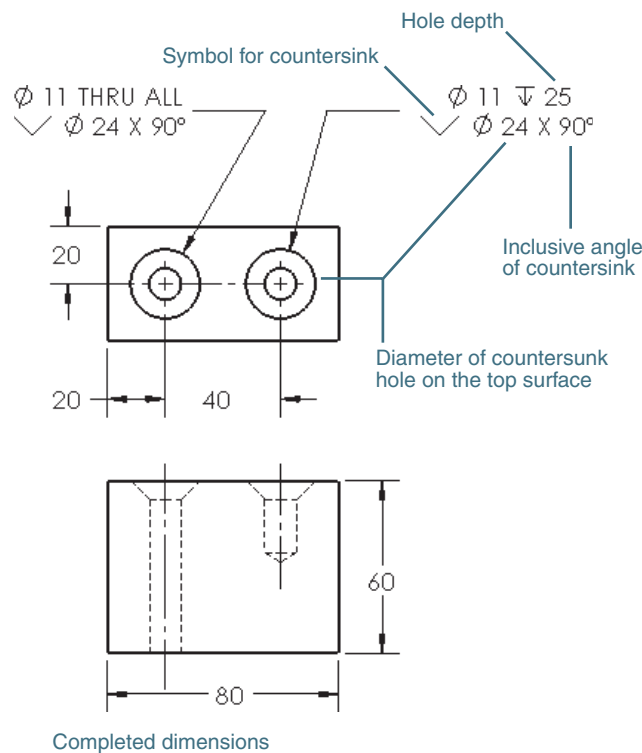
- 6 Click the **Positions** tab and locate the hole as shown.
- 7 Click the green **OK** check mark.
- 8 Save the drawing as **Block, CSink**.

Dimensioning the Block

- 1 Create a new **Drawing** document with a front and a top orthographic view of the **Block, CSink**.
- 2 Use the **Smart Dimension** tool and add the appropriate dimensions.
- 3 Use the **Center Mark** tool to add a centerline between the two holes indicating they are aligned.
- 4 Click the **Annotation** tab, click the **Hole Callout** tool, and dimension the two countersunk holes.

See Figure 7-46.

Figure 7-46



7-8 Angular Dimensions

Figure 7-47 shows a model that includes a slanted surface and dimensioned orthographic views of the model. The dimension values are located beyond the model between two extension lines. Locating dimensions between extension lines is preferred to locating the value between an extension line and the edge of the model.

Figure 7-47

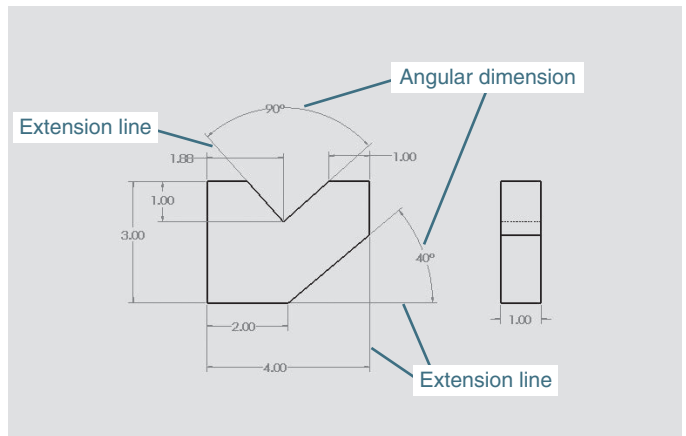
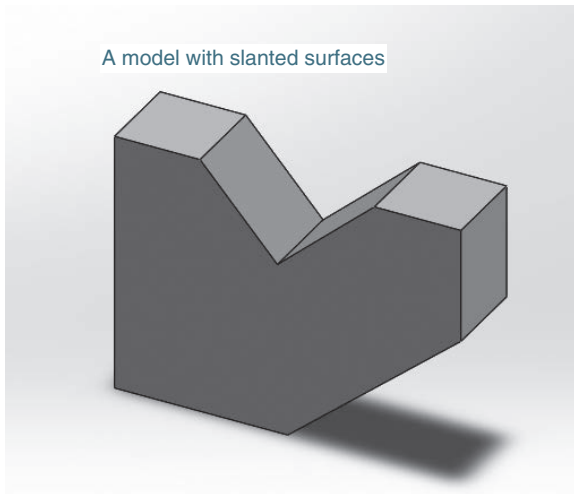
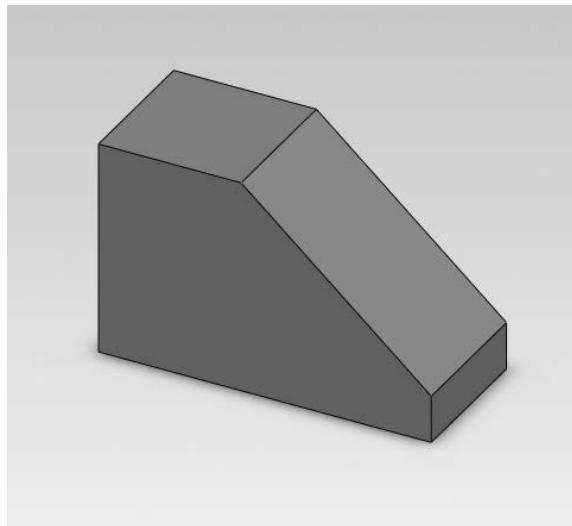
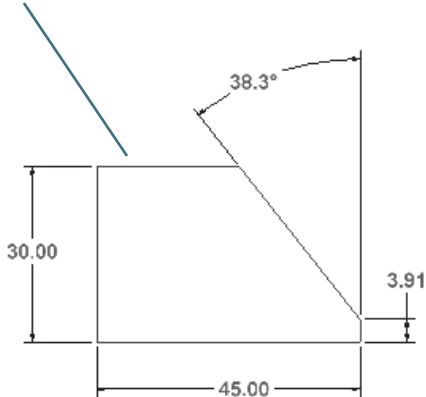


Figure 7-48 shows a shape that includes a slanted surface dimensioned in two different ways. The shape on the left uses an angular dimension; the one on the right does not. Both are acceptable.

Figure 7-48



No dimension here



There are different ways to dimension the same model. Do not include more dimensions than are needed.

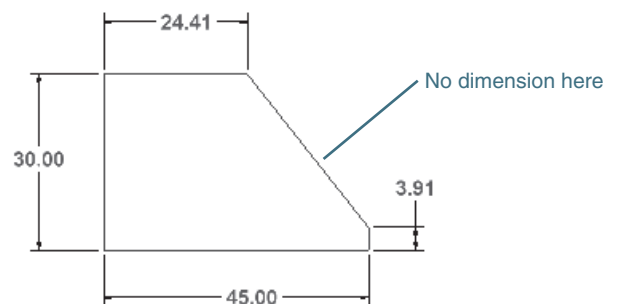


Figure 7-49 shows two objects dimensioned using angular dimensions. One has an evenly spaced hole pattern; the other has an uneven hole pattern.

Figure 7-49

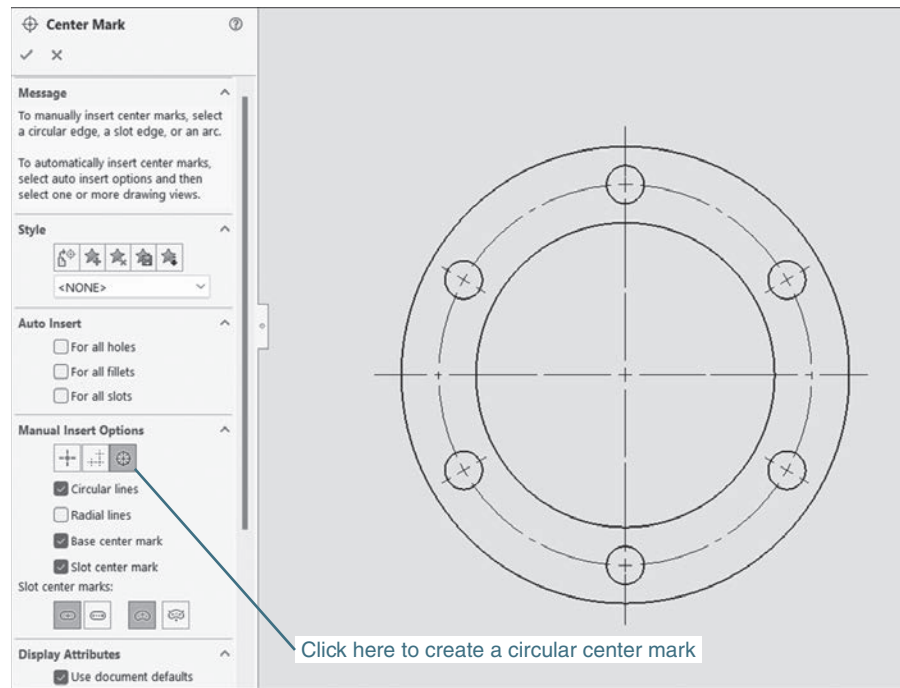
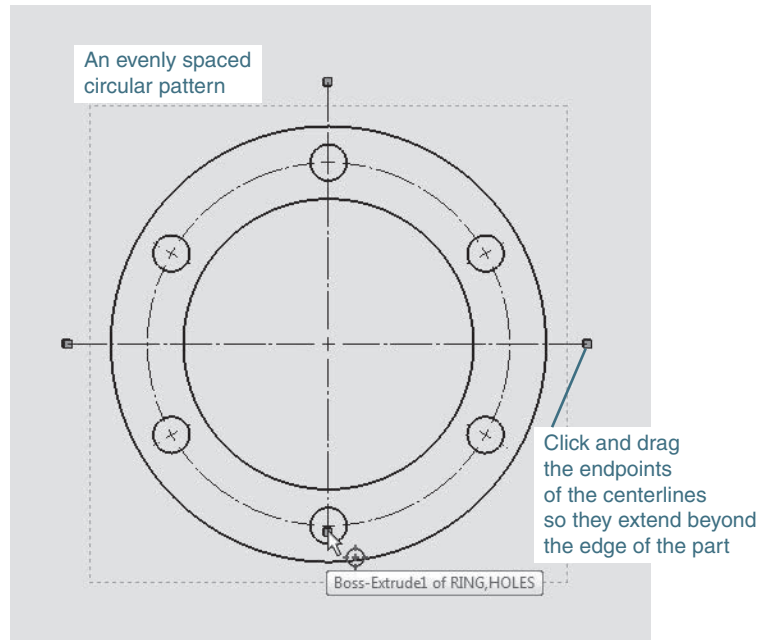


Figure 7-49
(Continued)

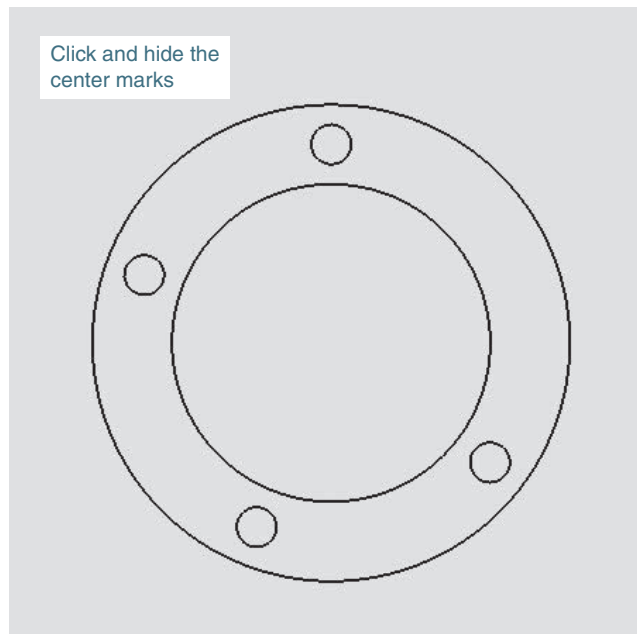
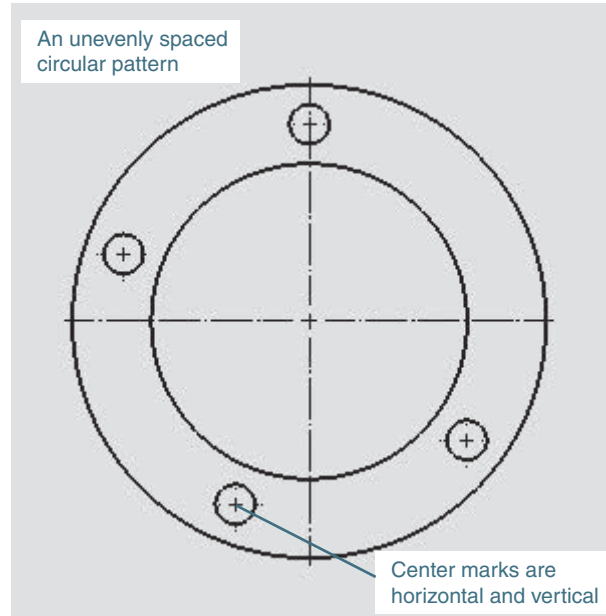
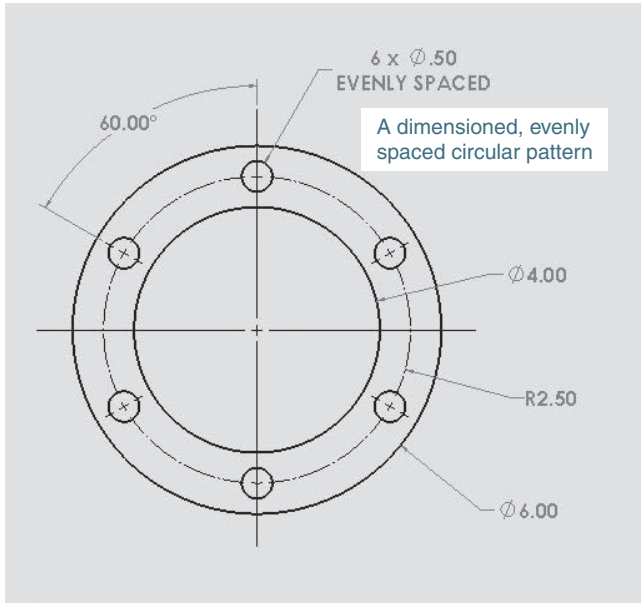
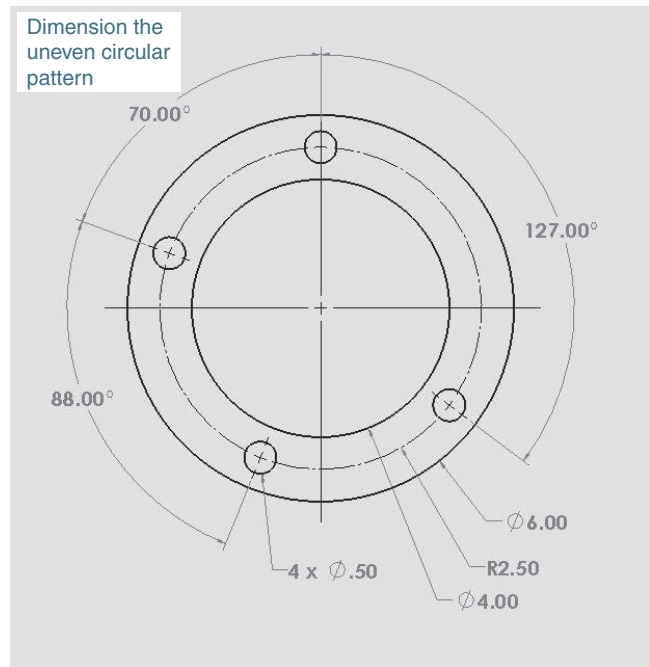
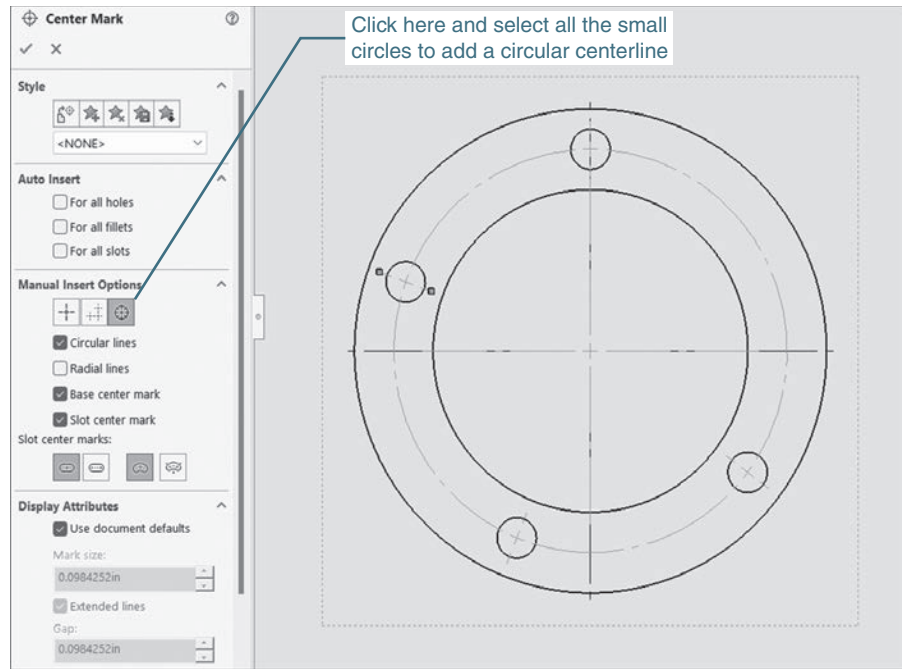


Figure 7-49
(Continued)



Dimensioning an Evenly Spaced Hole Pattern

- 1 Start a new drawing of the object and create a view as shown in Figure 7-49.

The object will automatically include circular centerlines. The circular centerline is called a *bolt circle*. Note that the center marks are not horizontal and vertical but point at the centerpoint of the pattern.

Circular centerlines and center marks can be created using the **Manual Insert Options** located on the **Center Mark PropertyManager**.

2 Add dimensions to the pattern and the object.

The six holes are evenly spaced and are all the same size, so only one angular dimension and a note are needed, as shown. All the holes are the same distance from the centerpoint, so the circular centerline needs only one dimension that will include the six holes.

The size and text position of the angular dimension can be edited using the **System** tool, **Document Properties**, **Dimensions**, **Angle**, and entering edits.

Figure 7-49 shows a similar object but with an uneven hole pattern. Each hole must be dimensioned separately.

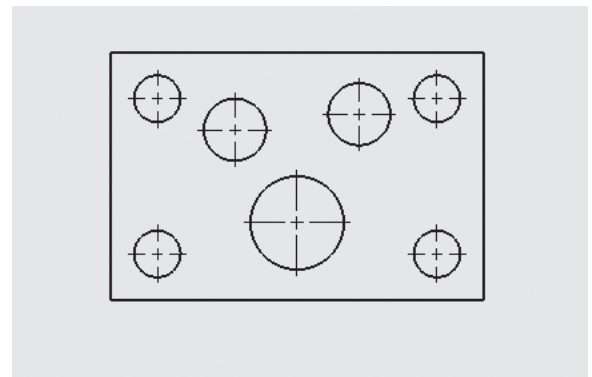
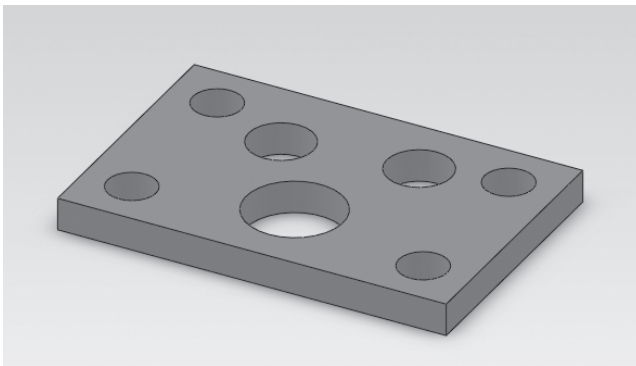
When the drawing view first appears on the screen, all the center marks are horizontal and vertical. A circular centerline pattern is preferred. Click each center mark and **Hide** the mark. Click the **Center Mark** tool and the **Circular Center Mark** tool located under the **Manual Insert Options**, and click each hole. A circular centerline pattern will appear. The shape can then be dimensioned using the circular pattern.

7-9 Ordinate Dimensions

Ordinate dimensions are dimensions based on an XY coordinate system. Ordinate dimensions do not include extension lines, dimension lines, or arrowheads but simply horizontal and vertical leader lines drawn directly from the features of the object. Ordinate dimensions are particularly useful when dimensioning an object that includes many small holes.

Figure 7-50 shows a part that is to be dimensioned using ordinate dimensions. Ordinate dimensions' values are calculated from the XY origin, which, in this example, is the lower-left corner of the front view of the model.

Figure 7-50



Creating Ordinate Dimensions

See Figure 7-51.

- 1 Start a new **Drawing** document and create a top orthographic view of the part.

Use the dimensions shown in Figure 7-52 to create the drawing.

- 2 Click and extend the center marks and draw centerlines between the four corner holes.

Figure 7-51

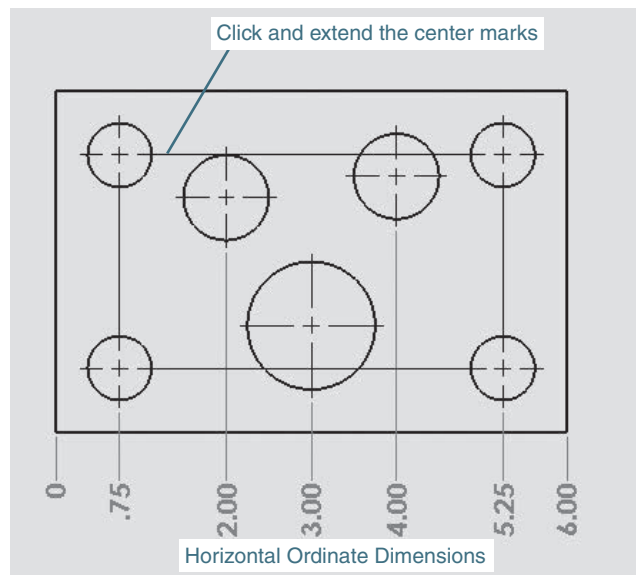
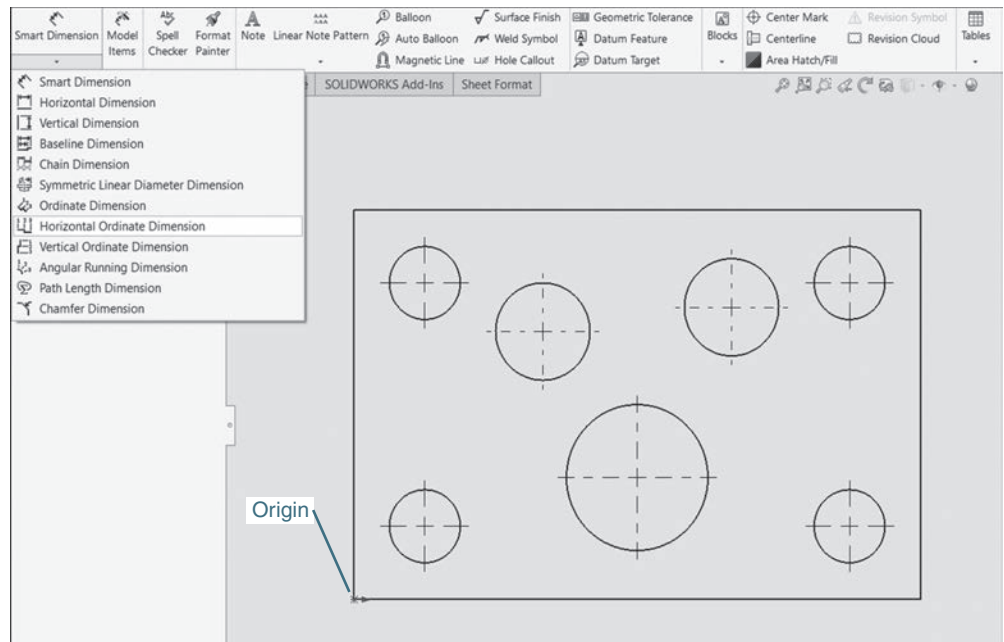
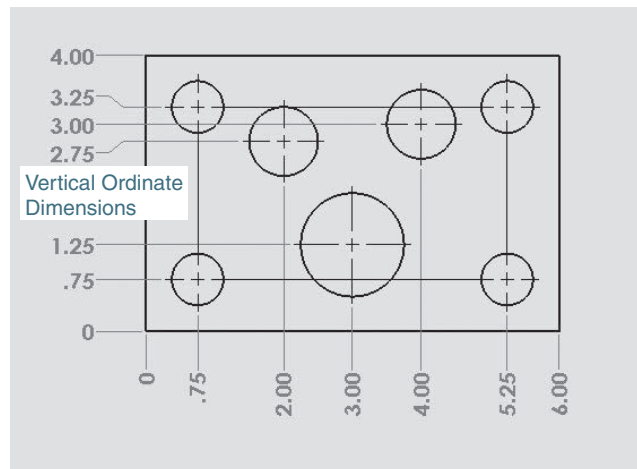
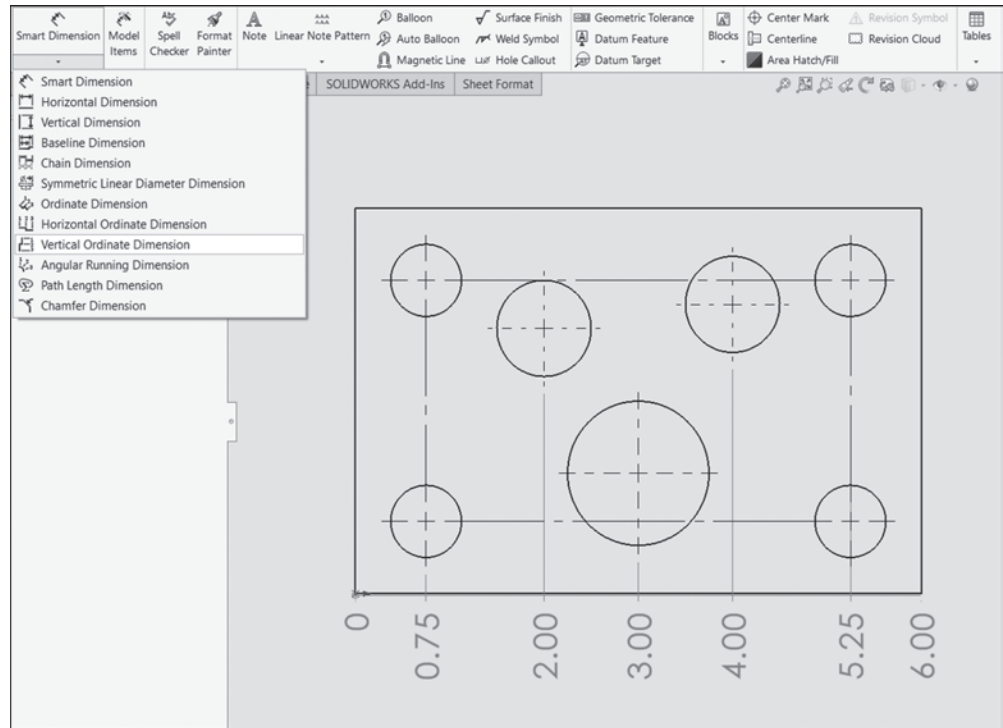


Figure 7-51
(Continued)

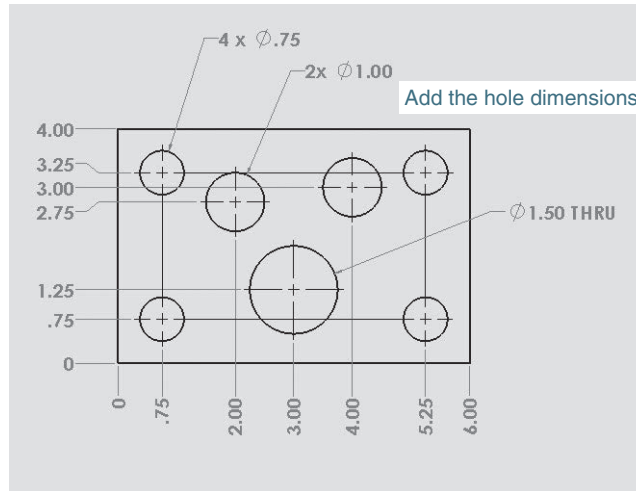


- 3** Click the arrowhead located under the **Smart Dimension** tool and click the **Horizontal Ordinate Dimension** option.
- 4** Click the lower-left corner of the part to establish the origin for the dimensions.
- 5** Move the cursor away from the origin and define a location for the “0” dimension.
All other horizontal dimensions will align with this location.
- 6** Click the lower portion of each hole’s vertical centerline and the lower-right corner of the part.
- 7** Click the arrowhead located under the **Smart Dimension** tool and click the **Vertical Ordinate Dimension** option.
- 8** Click the lower-left corner of the part to establish the origin for the dimensions.

- 9 Click the left portion of each hole's horizontal centerline and the upper-left corner of the part.
- 10 Add dimensions for the holes.

Figure 7-52 shows the dimensioned part.

Figure 7-52



7-10 Baseline Dimensions

Baseline dimensions are a series of dimensions that originate from a common baseline or datum line. Baseline dimensions are very useful because they help eliminate the tolerance buildup that is associated with chain-type dimensions.

Creating Baseline Dimensions

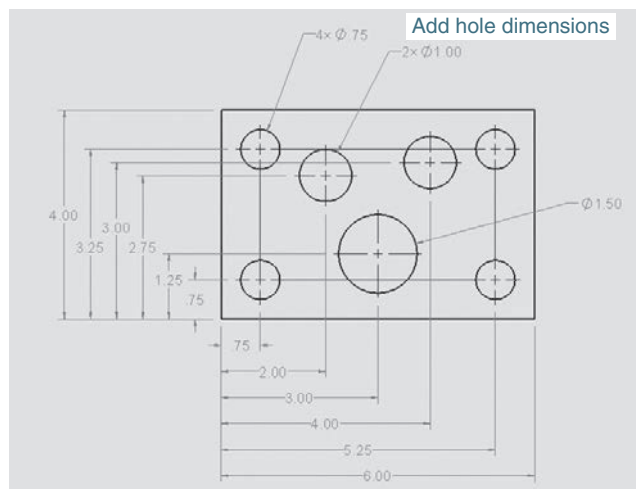
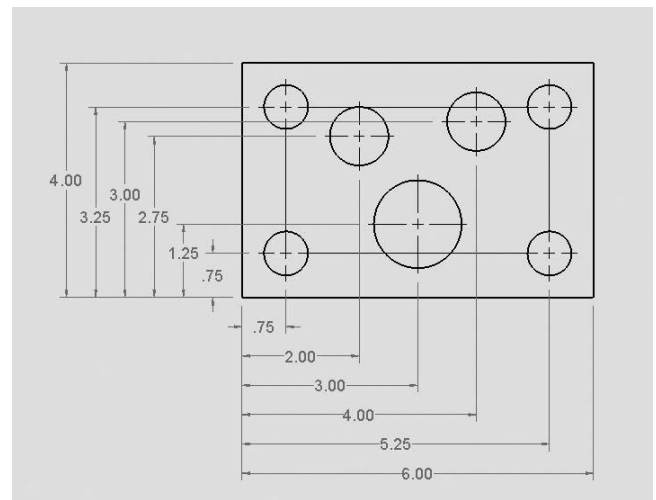
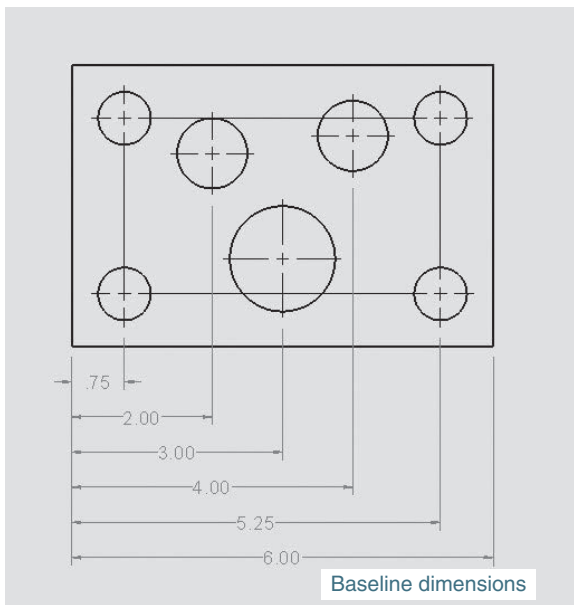
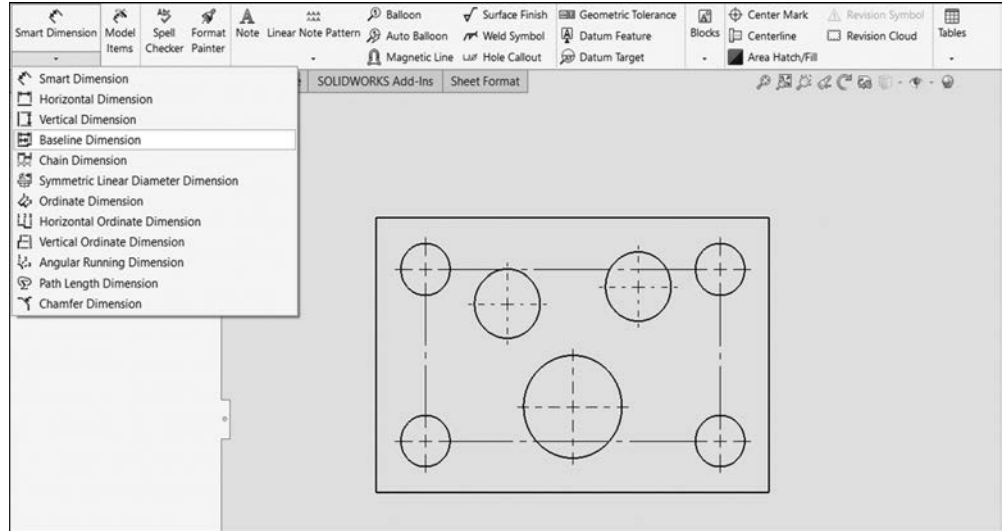
See Figure 7-53.

- 1 Start a new **Drawing** document and create a top orthographic view of the part.
- 2 Use the **Linear Center Mark** tool and add connection centerlines between the four corner holes.
- 3 Click the arrowhead under the **Smart Dimension** tool and click the **Baseline Dimension** option.
- 4 Click the left vertical edge of the part and the lower portion of the first vertical centerline.

This will establish the baseline.

- 5 Click the lower portion of each vertical centerline and the right vertical edge line and locate the dimensions.

Figure 7-53



NOTE

The distance between the dimension lines can be changed in the **Offset distances** box under **Dimensions** on the **Document Properties** tab of the **Options** tool.

- 6 Click the arrowhead under the **Smart Dimension** tool and click the **Baseline Dimension** option.
- 7 Click the lower horizontal edge of the part and the left end of the first horizontal centerline.
- 8 Click the left end of each horizontal centerline and the right top horizontal edge line.

The alignment of the vertical dimension lines can be changed by right-clicking the individual dimension and selecting the **Break Alignment** option.

- 9 Add the hole dimensions.

Hole Tables

Hole tables are a method for dimensioning parts that have large numbers of holes where standard dimensioning may be cluttered and difficult to read. See Figure 7-54.

Figure 7-54

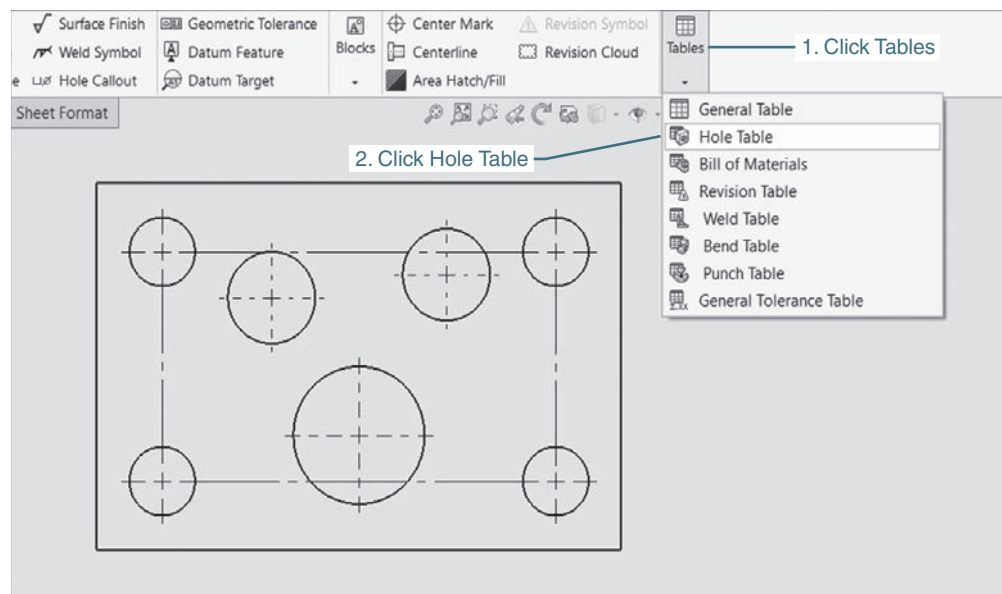
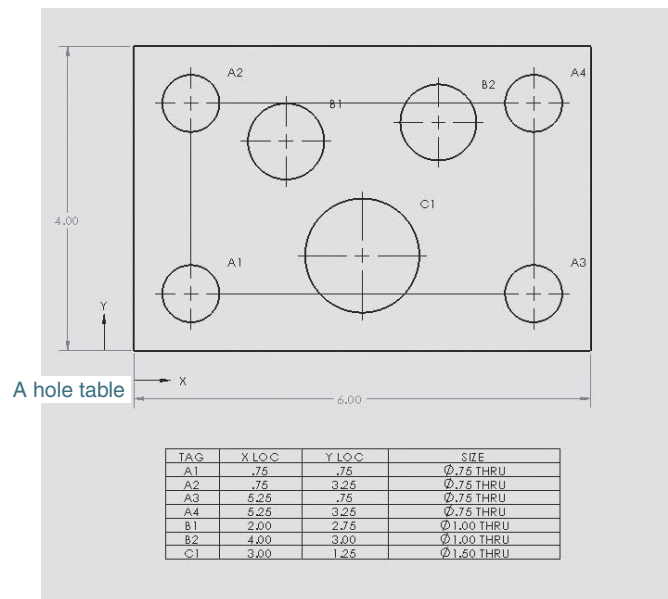
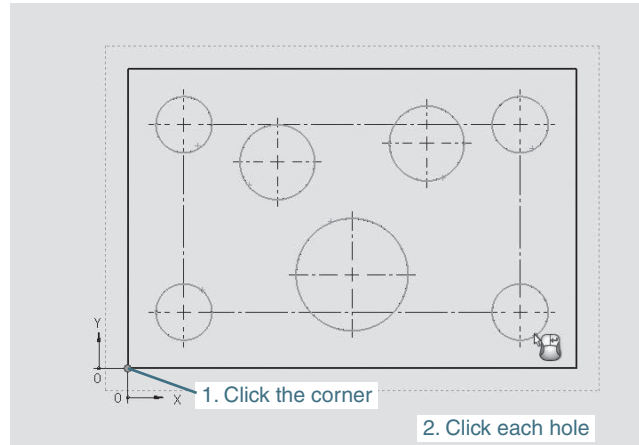


Figure 7-54
(Continued)



- 1** Start a new **Drawing** document and create a top orthographic view of the part.
- 2** Use the **Linear Center Mark** tool and add connection centerlines between the four corner holes.
- 3** Click the **Annotation** tab, click **Tables**, and click **Hole Table**.
- 4** Click the lower-left corner of the part to establish an origin.
- 5** Click each hole.

As the holes are clicked they should be listed in the **Holes** box located in the **Hole Table PropertyManager**.

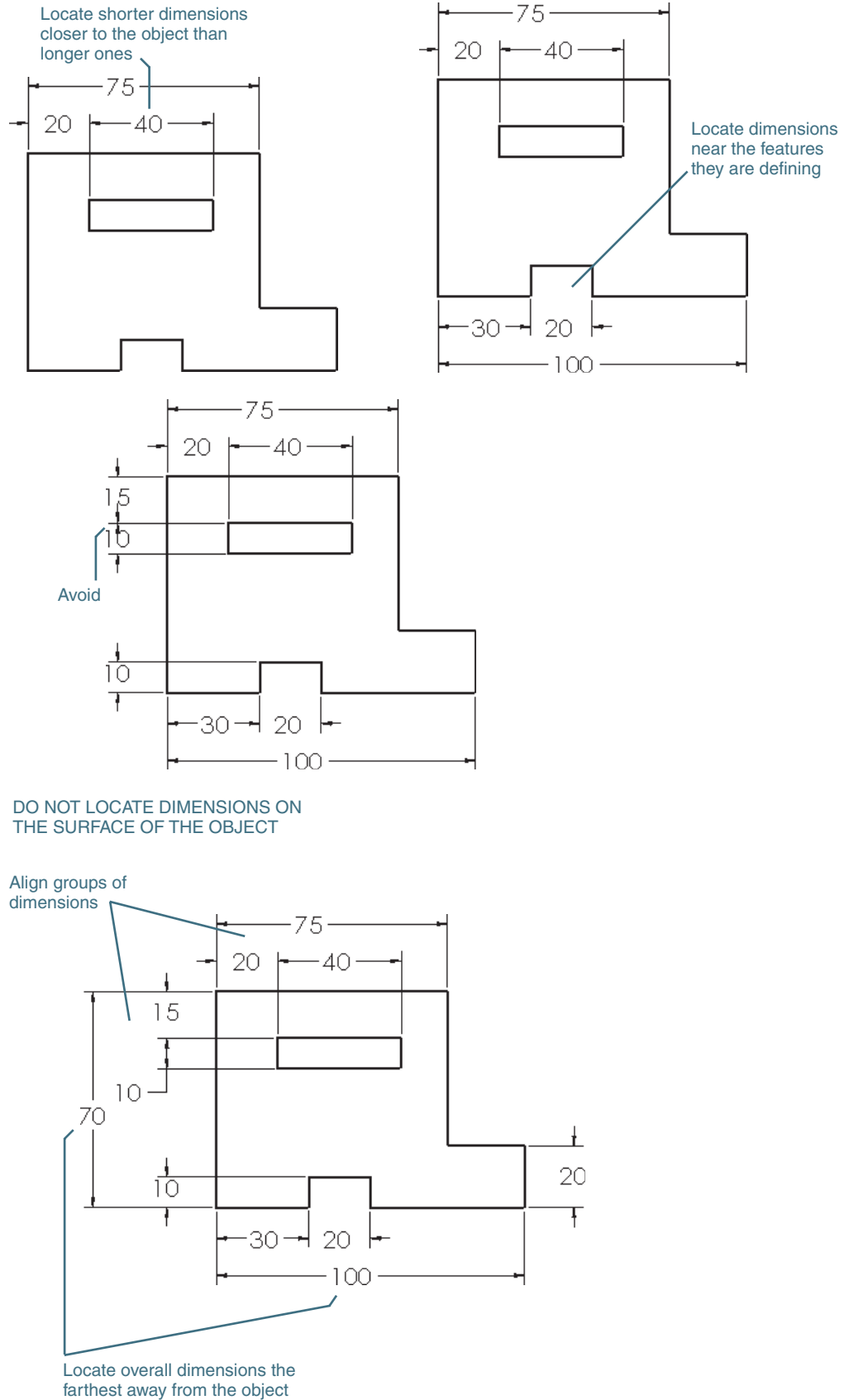
- 6** Click the green **OK** check mark and locate the hole table.
- 7** Add the overall dimensions.
- 8** Move the hole tags as needed to present a clear, easy-to-read drawing.

In this example all tags were located to the upper-right of the holes they define. Tables can be edited using the instructions presented in Section 5-11 for BOMs.

7-11 Locating Dimensions

There are eight general rules concerning the location of dimensions. See Figure 7-55.

Figure 7-55



- 1 Locate dimensions near the features they are defining.
- 2 Do not locate dimensions on the surface of the object.
- 3 Align and group dimensions so that they are neat and easy to understand.
- 4 Avoid crossing extension lines.

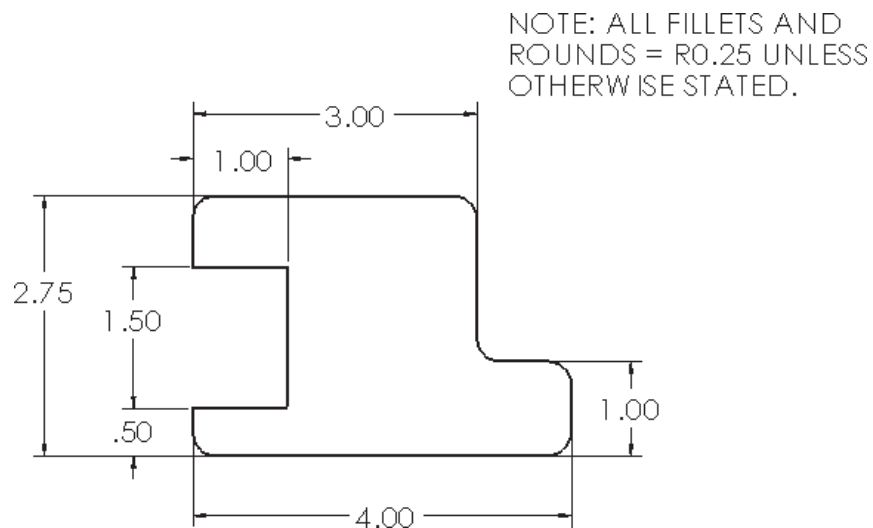
Sometimes it is impossible not to cross extension lines because of the complex shape of the object, but whenever possible, avoid crossing extension lines.

- 5 Do not cross dimension lines.
- 6 Locate shorter dimensions closer to the object than longer dimensions.
- 7 Always locate overall dimensions the farthest away from the object.
- 8 Do not dimension the same distance twice. This is called *double dimensioning* and will be discussed in Chapter 8 in association with tolerancing.

7-12 Fillets and Rounds

Fillets and rounds may be dimensioned individually or by a note. In many design situations all the fillets and rounds are the same size, so a note as shown in Figure 7-56 is used. Any fillets or rounds that have a different radius from that specified by the note are dimensioned individually.

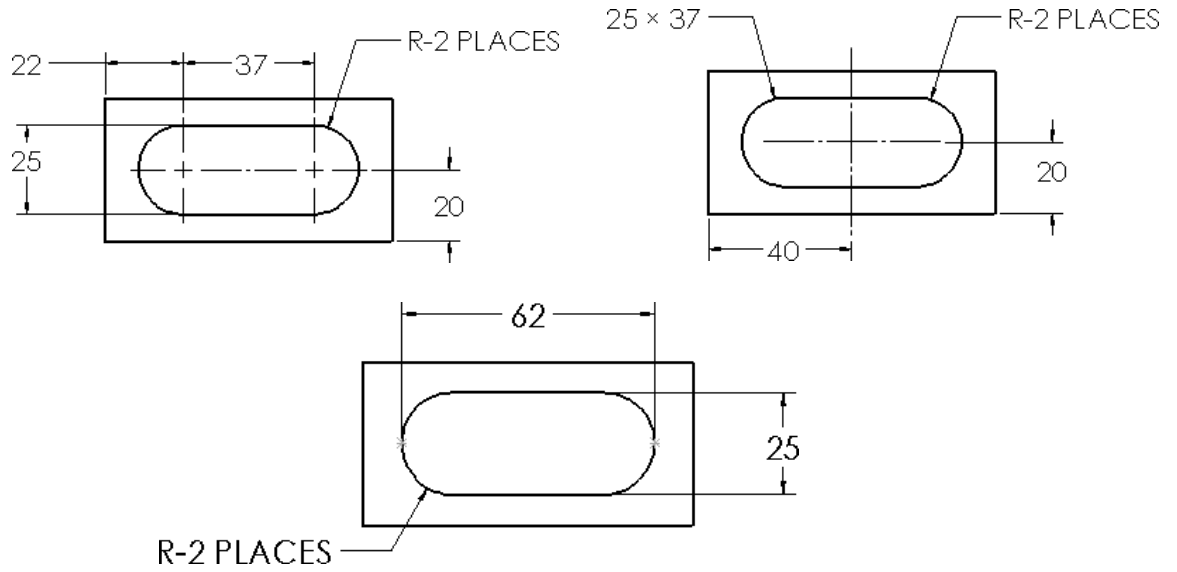
Figure 7-56



7-13 Rounded Shapes—Internal

Internal rounded shapes are called *slots*. Figure 7-57 shows three different methods for dimensioning slots. The end radii are indicated by the note **R-2 PLACES**, but no numerical value is given. The width of the slot is dimensioned, and it is assumed that the radius of the rounded ends is exactly half of the stated width.

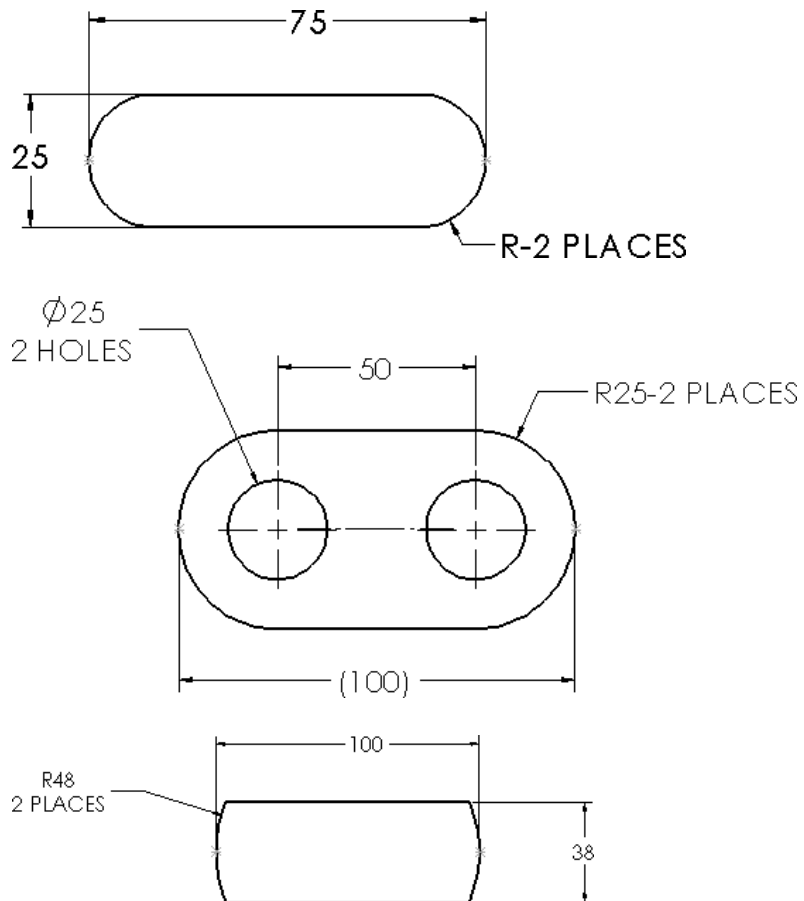
Figure 7-57



7-14 Rounded Shapes—External

Figure 7-58 shows two shapes with external rounded ends. As with internal rounded shapes, the end radii are indicated, but no value is given. The width of the object is given, and the radius of the rounded end is assumed to be exactly half of the stated width.

Figure 7-58



The second example shown in Figure 7-58 shows an object dimensioned using the object's centerline. This type of dimensioning is done when the distance between the holes is more important than the overall length of the object; that is, the tolerance for the distance between the holes is more exact than the tolerance for the overall length of the object.

The overall length of the object is given as a reference dimension (100). This means the object will be manufactured based on the other dimensions, and the 100 value will be used only for reference.

Objects with partially rounded edges should be dimensioned as shown in Figure 7-58. The radii of the end features are dimensioned. The center-point of the radii is implied to be on the object centerline. The overall dimension is given; it is not referenced unless specific radii values are included.

7-15 Irregular Surfaces

There are three different methods for dimensioning irregular surfaces: tabular, baseline, and baseline with oblique extension lines. Figure 7-59 shows an irregular surface dimensioned using the tabular method. An XY axis is defined using the edges of the object. Points are then defined relative to the XY axis. The points are assigned reference numbers, and the reference numbers and XY coordinate values are listed in chart form as shown.

Figure 7-59

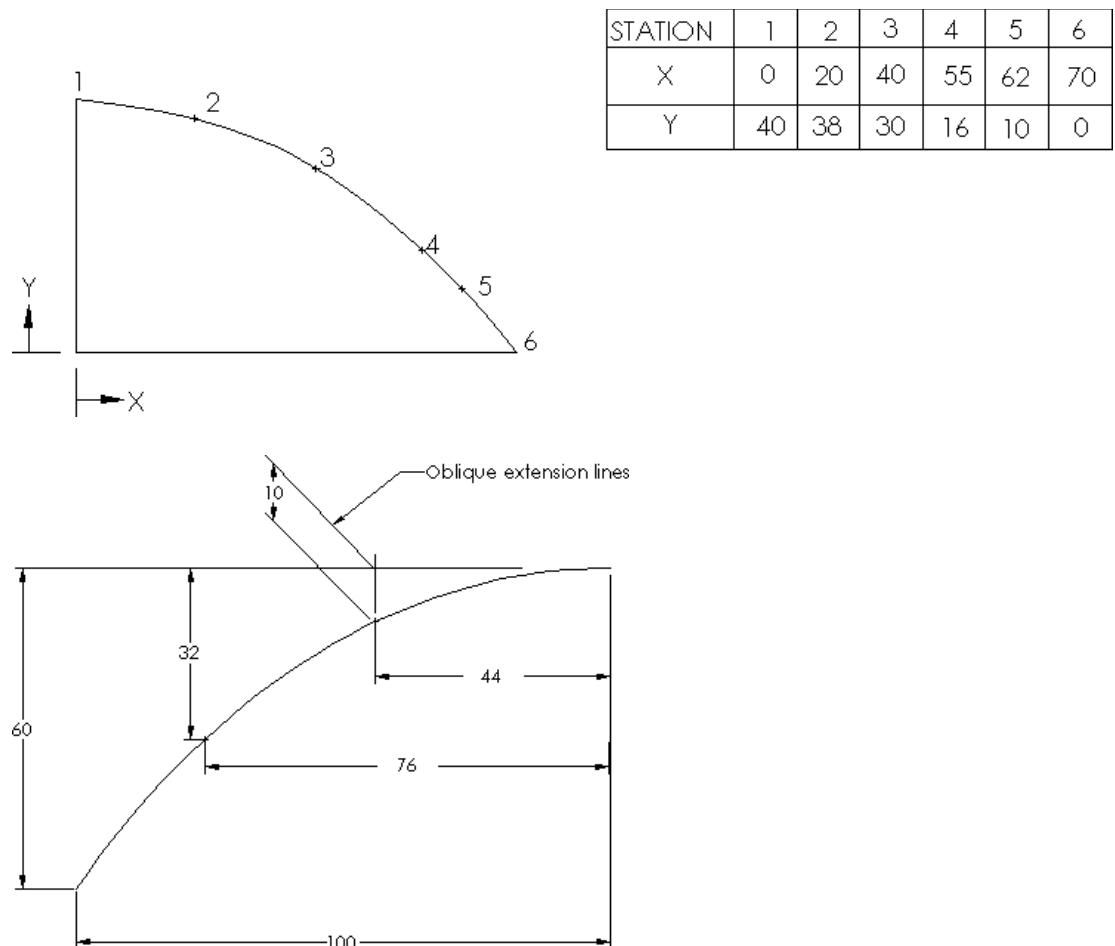
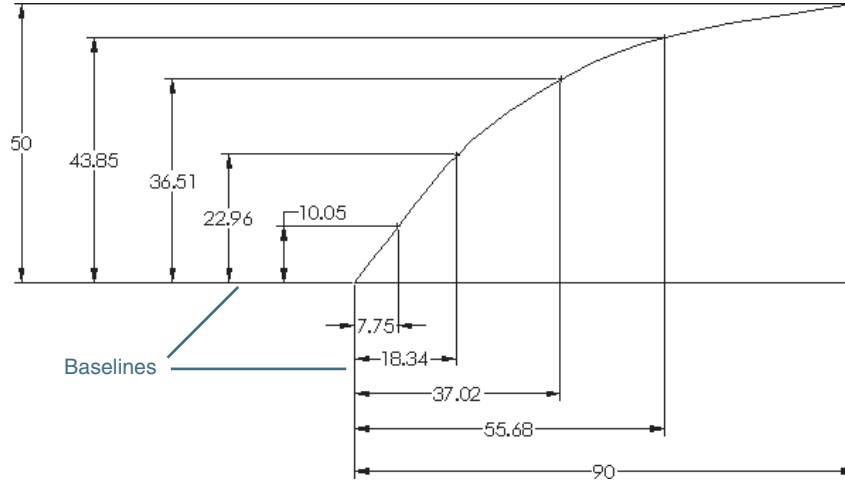


Figure 7-60 shows an irregular curve dimensioned using baseline dimensions. The baseline method references all dimensions to specified baselines. Usually there are two baselines, one horizontal and one vertical.

Figure 7-60



It is considered poor practice to use a centerline as a baseline. Centerlines are imaginary lines that do not exist on the object and would make it more difficult to manufacture and inspect the finished objects.

Baseline dimensioning is very common because it helps eliminate tolerance buildup and is easily adaptable to many manufacturing processes.

7-16 Polar Dimensions

Polar dimensions are similar to polar coordinates. A location is defined by a radius (distance) and an angle. Figure 7-61 shows an object that includes polar dimensions. The holes are located on a circular centerline, and their positions from the vertical centerline are specified using angles.

Figure 7-61

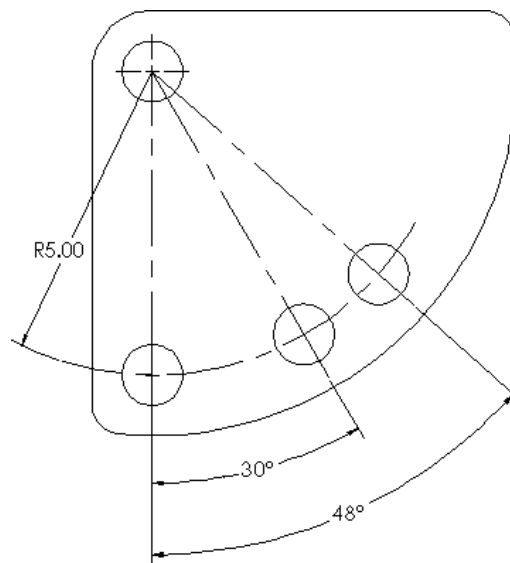
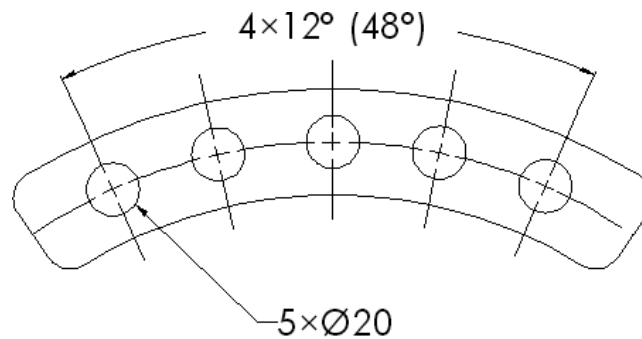


Figure 7-62 shows an example of a hole pattern dimensioned using polar dimensions.

Figure 7-62



7-17 Chamfers

Chamfers are angular cuts made on the edges of objects. They are usually used to make it easier to fit two parts together. They are most often made at 45° angles but may be made at any angle. Figure 7-63 shows two objects with chamfers between surfaces 90° apart and two examples between surfaces that are not 90° apart. Either of the two types of dimensions shown for the 45° dimension may be used. If an angle other than 45° is used, the angle and setback distance must be specified.

Figure 7-63

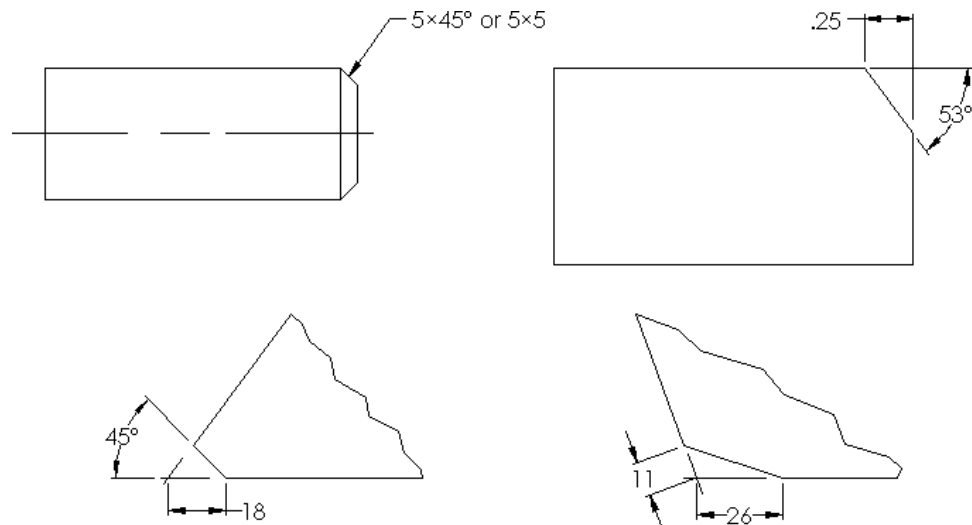
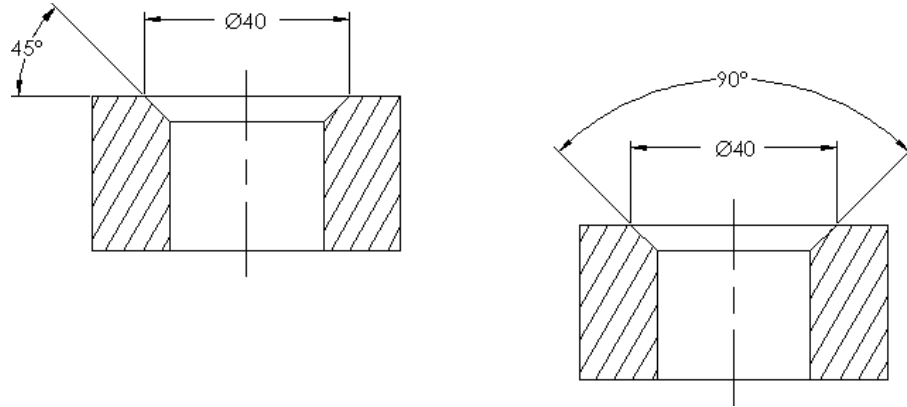


Figure 7-64 shows two examples of internal chamfers. Both define the chamfer using an angle and diameter. Internal chamfers are very similar to countersunk holes.

Figure 7-64



7-18 Symbols and Abbreviations

Symbols are used in dimensioning to help accurately display the meaning of the dimension. Symbols also help eliminate language barriers when reading drawings.

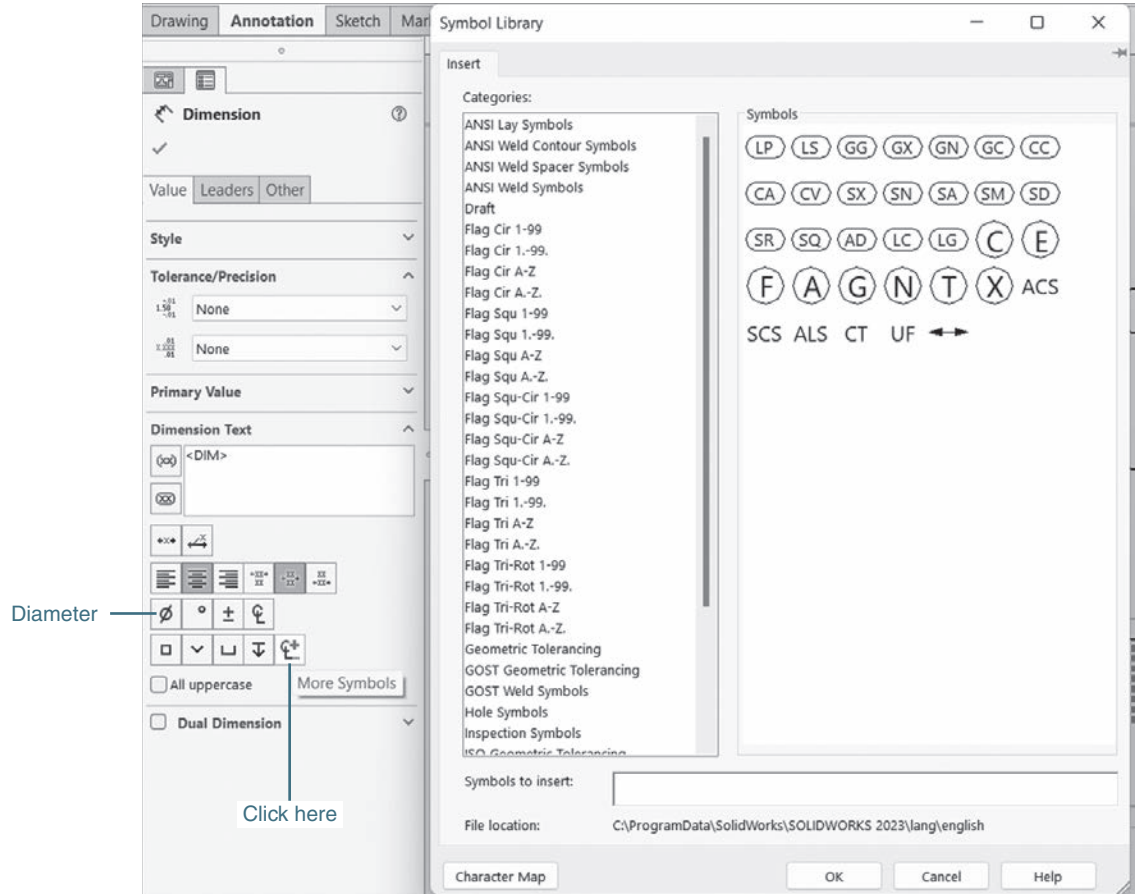
Abbreviations should be used very carefully on drawings. Whenever possible, write out the full word, including correct punctuation. The **Dimension PropertyManager Value** tab includes a group of symbols and words commonly used on technical drawings. Figure 7-65 lists several standard abbreviations used on technical drawings.

Figure 7-65

AL = Aluminum
CBORE = Counterbore
CRS = Cold Rolled Steel
CSK = Countersink
DIA = Diameter
EQ = Equal
HEX = Hexagon
MAT'L = Material
R = Radius
SAE = Society of Automotive Engineers
SFACE = Spotface
ST = Steel
SQ = Square
REQD = Required

Figure 7-66 shows a list of symbols available in the **Dimension PropertyManager Value** tab.

Figure 7-66



TIP
To access the **Dimension PropertyManager Value** tab, click an existing dimension.

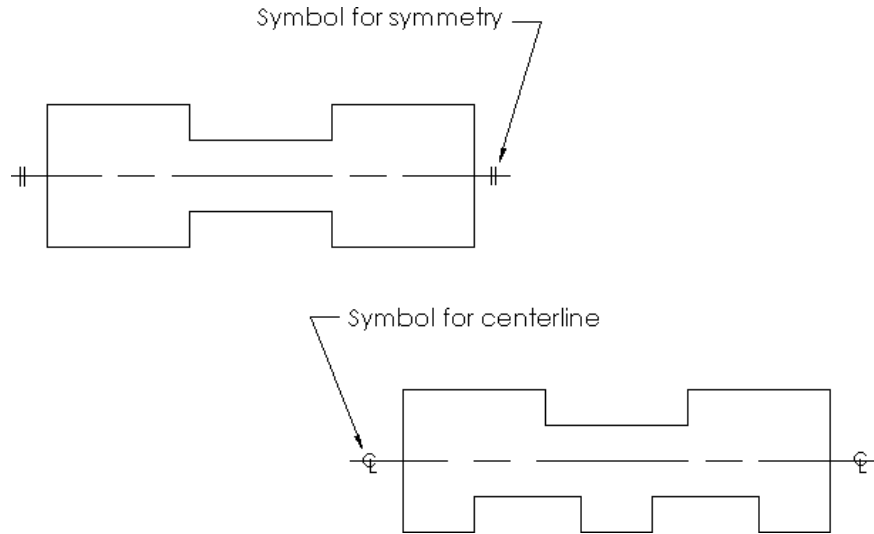
More symbols are available by clicking the **More** box. A list of available symbols will appear. Click a new symbol. A preview of the selected symbol will appear. Click **OK** and the symbol will appear on the drawing next to the existing symbol.

7-19 Symmetrical and Centerline Symbols

An object is symmetrical about an axis when one side is the exact mirror image of the other. Figure 7-67 shows a symmetrical object. The symbol of two short parallel lines or the note OBJECT IS SYMMETRICAL ABOUT THIS AXIS (centerline) may be used to designate symmetry.

If an object is symmetrical, only half the object needs to be dimensioned. The other dimensions are implied by the symmetry note or symbol.

Figure 7-67



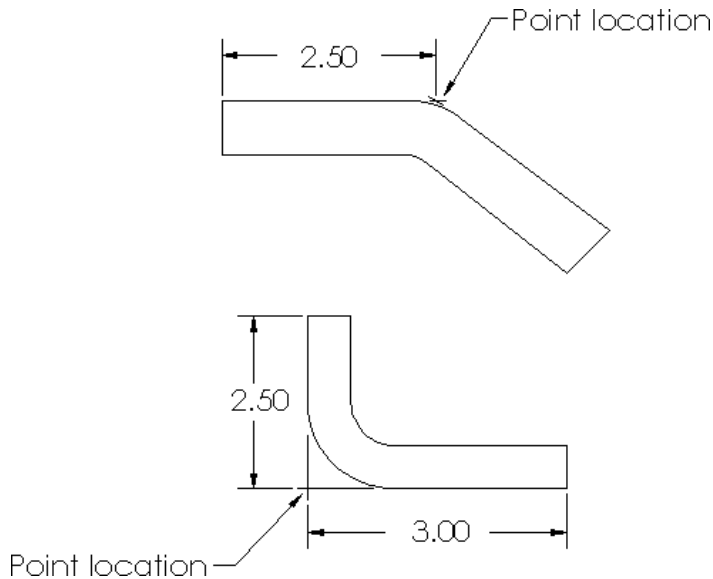
The centerline is slightly different from the axis of symmetry. An object may or may not be symmetrical about its centerline. See Figure 7-67. Centerlines are used to define the center of both individual features and entire objects. Use the centerline symbol when a line is a centerline, but do not use it in place of the symmetry symbol.

7-20 Dimensioning to a Point

Curved surfaces can be dimensioned using theoretical points. See Figure 7-68. There should be a small gap between the surface of the object and the lines used to define the theoretical point. The point should be defined by the intersection of at least two lines.

There should also be a small gap between the extension lines and the theoretical point used to locate the point.

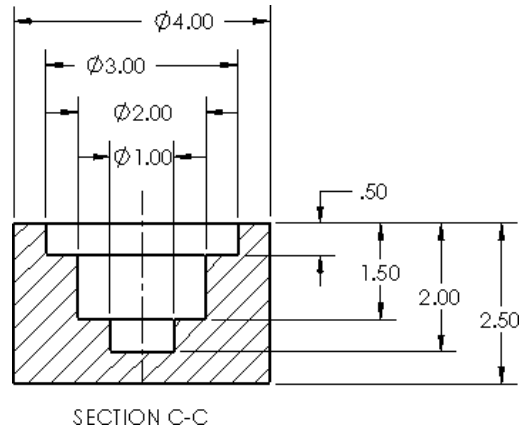
Figure 7-68



7-21 Dimensioning Section Views

Section views are dimensioned. See Figure 7-69. The section lines should be drawn at an angle that allows the viewer to clearly distinguish between the section lines and the extension lines.

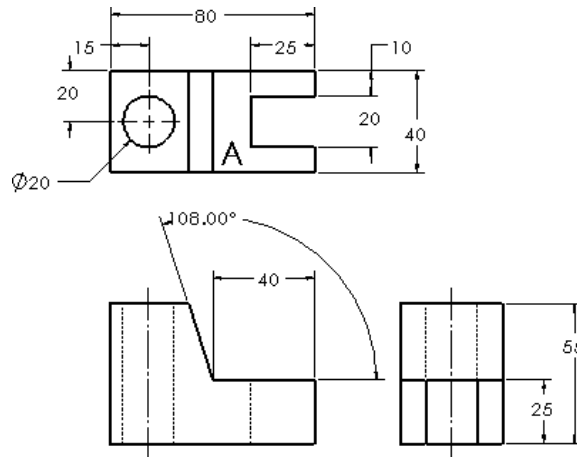
Figure 7-69



7-22 Dimensioning Orthographic Views

Dimensions should be added to orthographic views where the features appear in contour. Holes should be dimensioned in their circular views. Figure 7-70 shows three views of an object that has been dimensioned.

Figure 7-70



The hole dimensions are added to the top view, where the hole appears circular. The slot is also dimensioned in the top view because it appears in contour. The slanted surface is dimensioned in the front view.

The height of surface A is given in the side view rather than run along extension lines across the front view. The length of surface A is given in the front view. This is a contour view of the surface.

It is considered good practice to keep dimensions in groups. This makes it easier for the viewer to find dimensions.

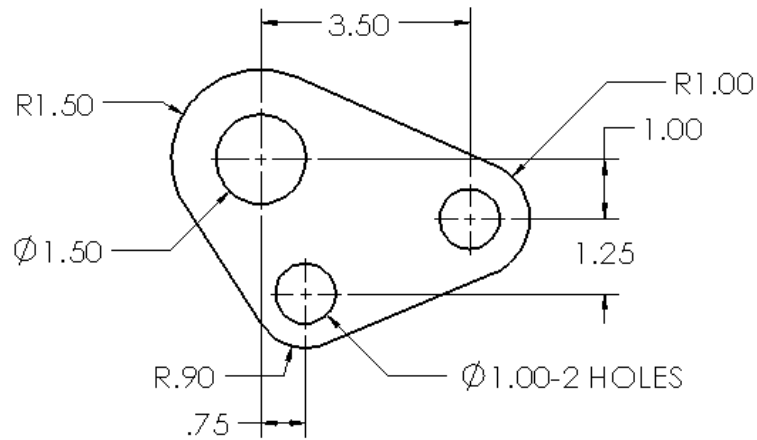
Be careful not to double dimension a distance. A distance should be dimensioned only once. If a 30 dimension were added above the 25 dimension on the right-side view, it would be an error. The distance would be

double dimensioned: once with the 25 + 30 dimension, and again with the 55 overall dimension. The 25 + 30 dimensions are mathematically equal to the 55 overall dimension, but there is a distinct difference in how they affect the manufacturing tolerances. Double dimensions are explained more fully in Chapter 8.

Dimensions Using Centerlines

Figure 7-71 shows an object dimensioned from its centerline. This type of dimensioning is used when the distance between the holes relative to each other is critical.

Figure 7-71



Chapter Projects

Project 7-1:

Measure and redraw the shapes in Figures P7-1 through P7-24. The dotted grid background has either .50in. or 10mm spacing. All holes are through holes. Specify the units and scale of the drawing. Use the **Part** template to create a model. Use the grid background pattern to determine the dimensions. Use the **Drawing** template to create the orthographic view shown. Use the **Smart Dimension** tool to dimension the view.

- A. Measure using millimeters.
- B. Measure using inches.

All dimensions are within either .25in. or 5mm. All fillets and rounds are R.50in., R.25in. or R10mm, R5mm.

Figure P7-1

THICKNESS:
40mm
1.50in.

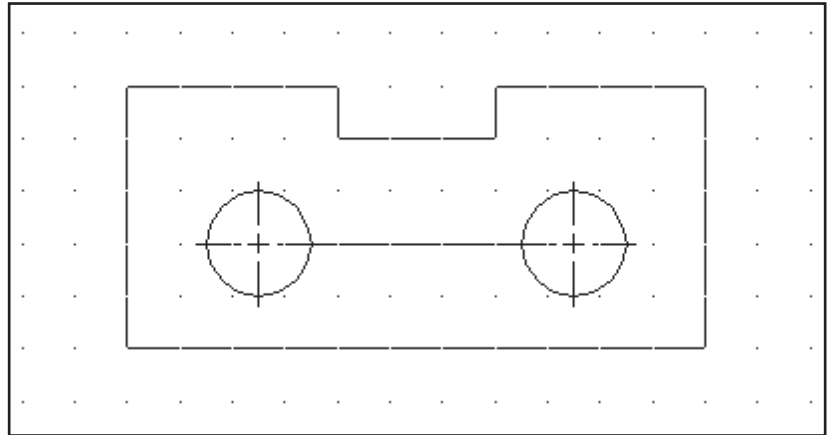


Figure P7-2

THICKNESS:
20mm
.75in.

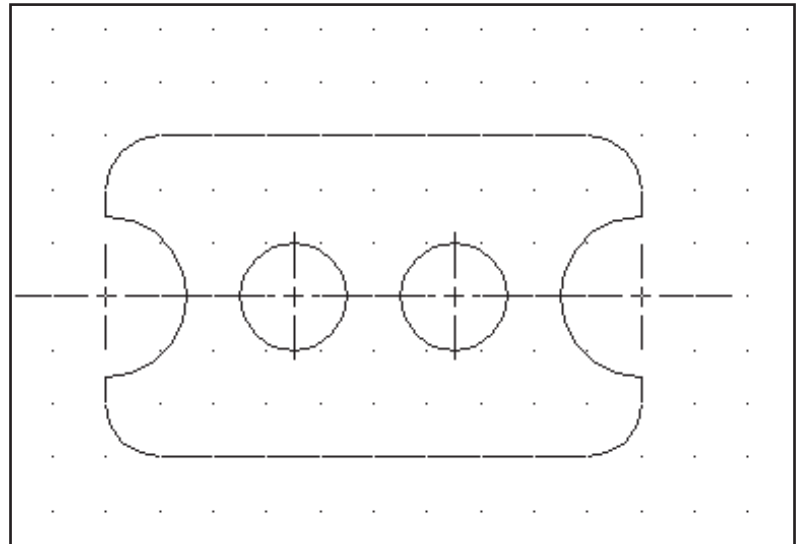
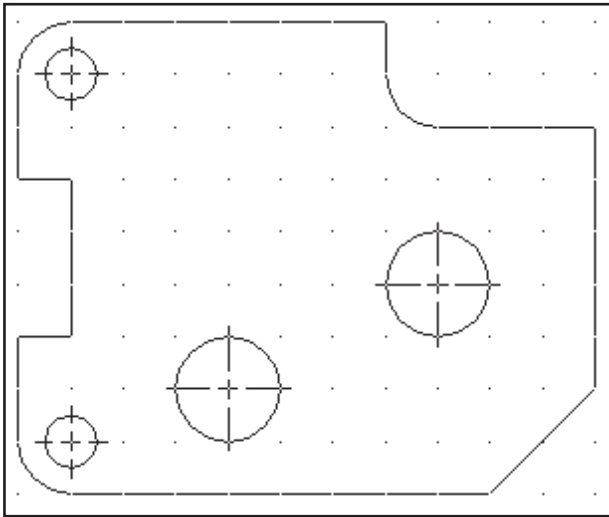
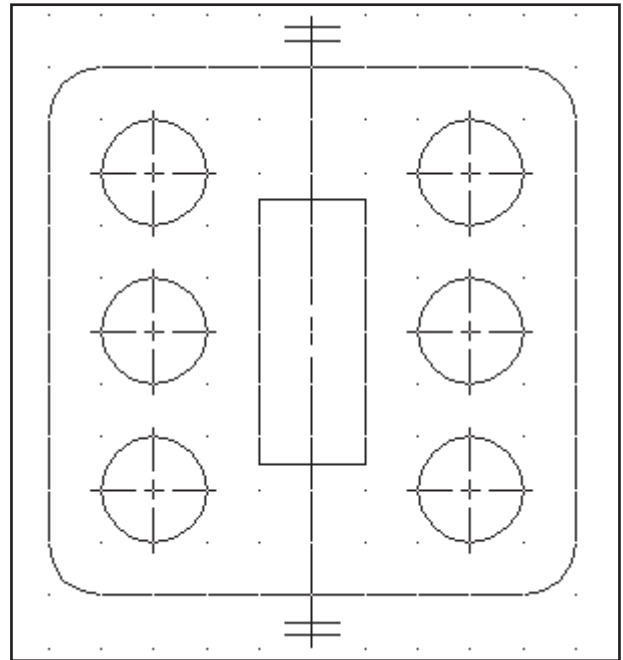


Figure P7-3



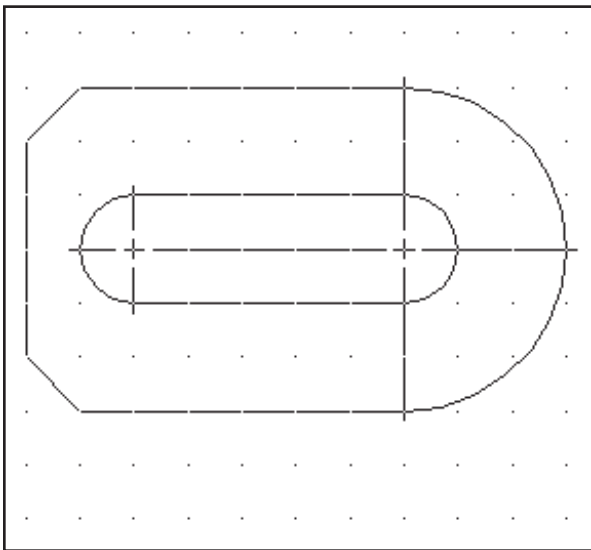
THICKNESS:
35mm
1.25in.

Figure P7-4



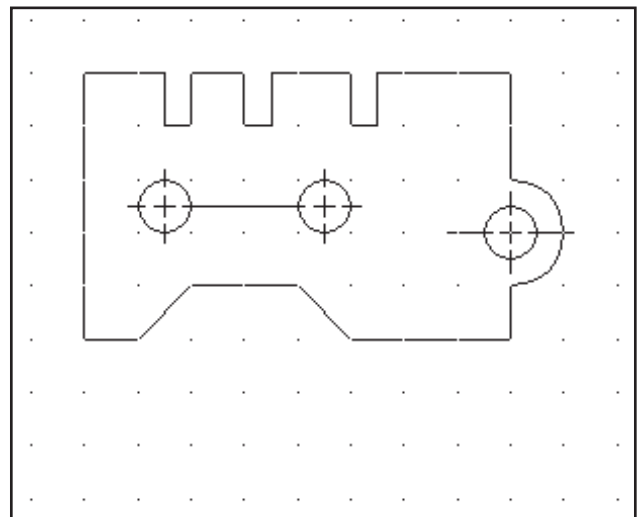
THICKNESS:
15mm
.50in.

Figure P7-5



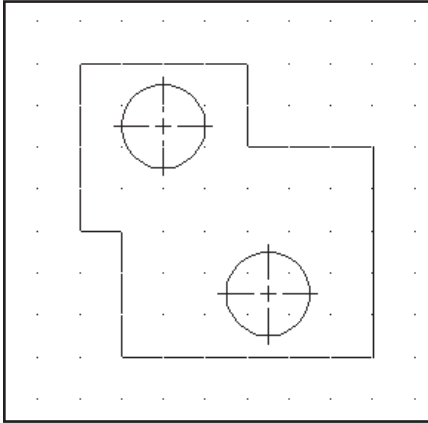
THICKNESS:
10mm
.50in.

Figure P7-6



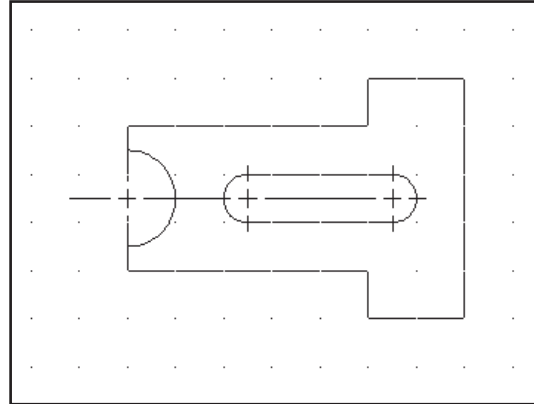
THICKNESS:
5mm
.25in.

Figure P7-7



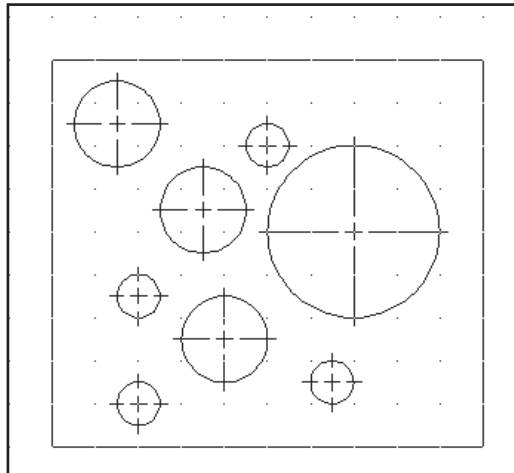
THICKNESS:
12mm
.50in.

Figure P7-8



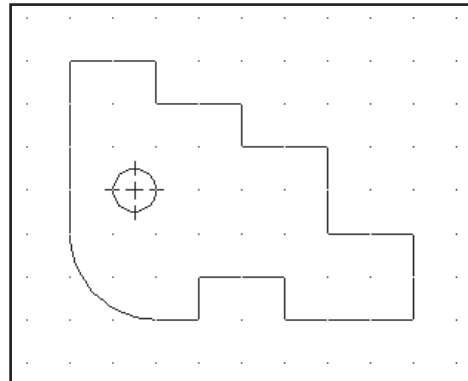
THICKNESS:
25mm
1.00in.

Figure P7-9



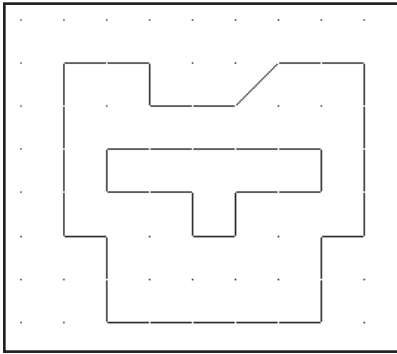
THICKNESS:
5mm
.25in.

Figure P7-10



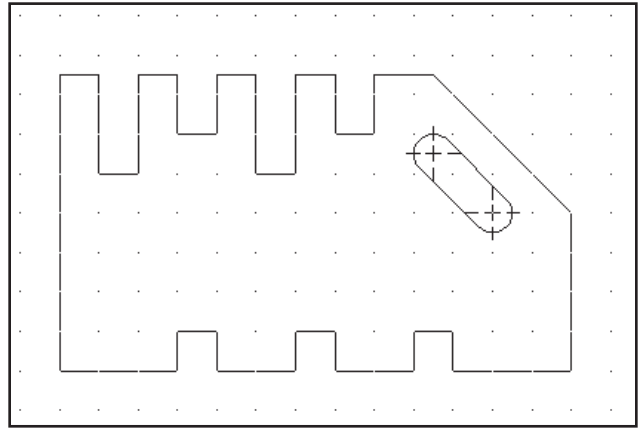
THICKNESS:
20mm
.75in.

Figure P7-11



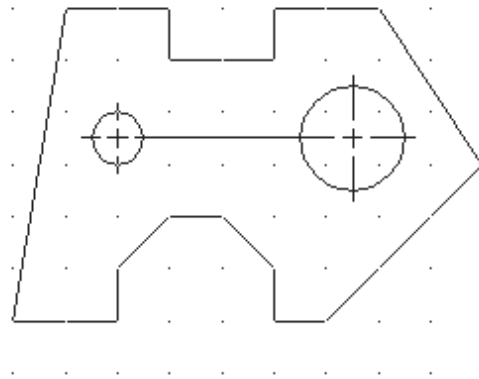
THICKNESS:
18mm
.625in.

Figure P7-12



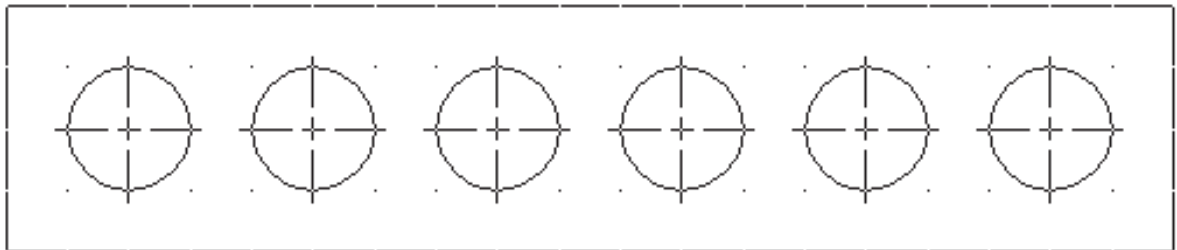
THICKNESS:
24mm
1.00in.

Figure P7-13



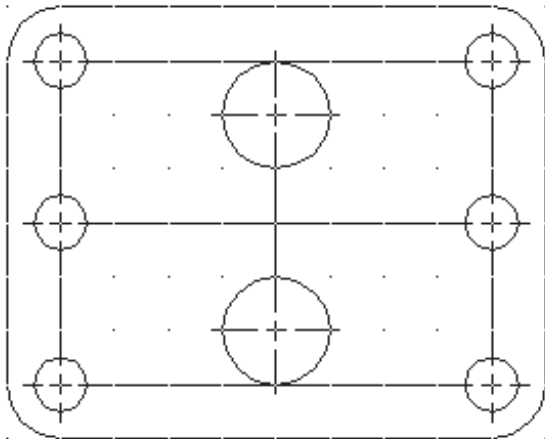
THICKNESS:
10mm
.25in.

Figure P7-14



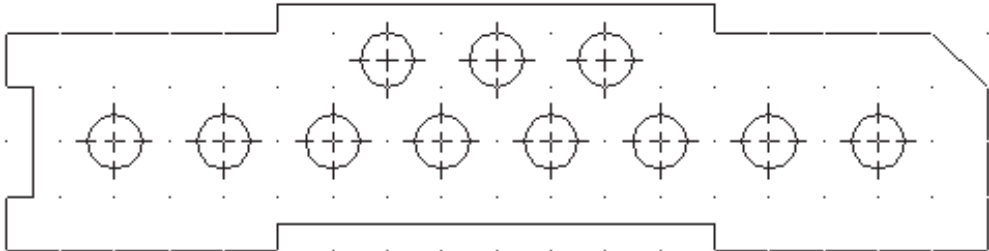
THICKNESS:
8mm
.25in.

Figure P7-15



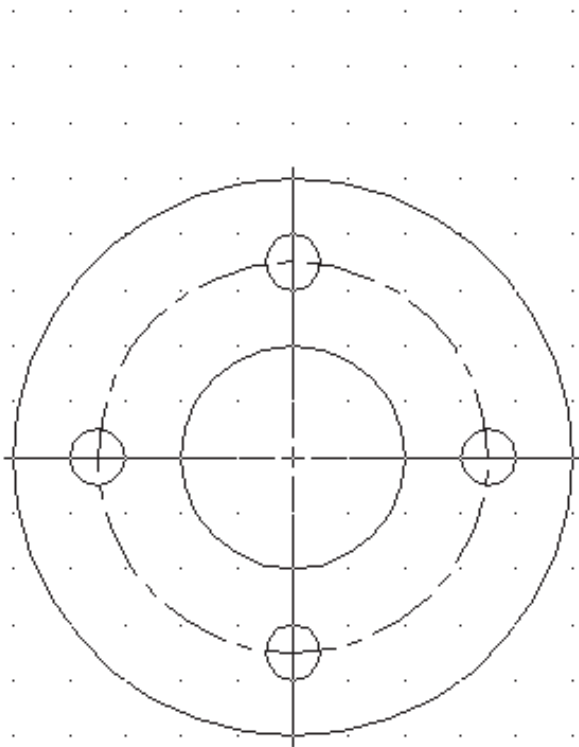
THICKNESS:
20mm
.75in.

Figure P7-16



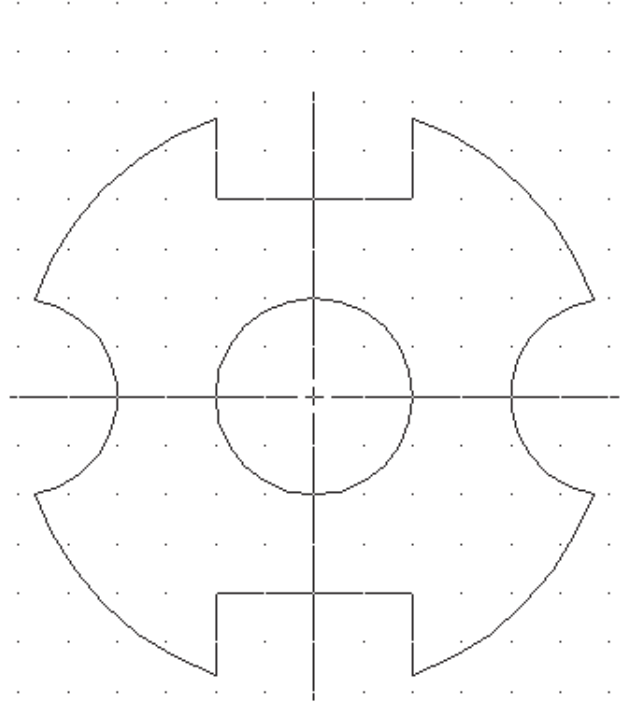
THICKNESS:
20mm
.75in.

Figure P7-17



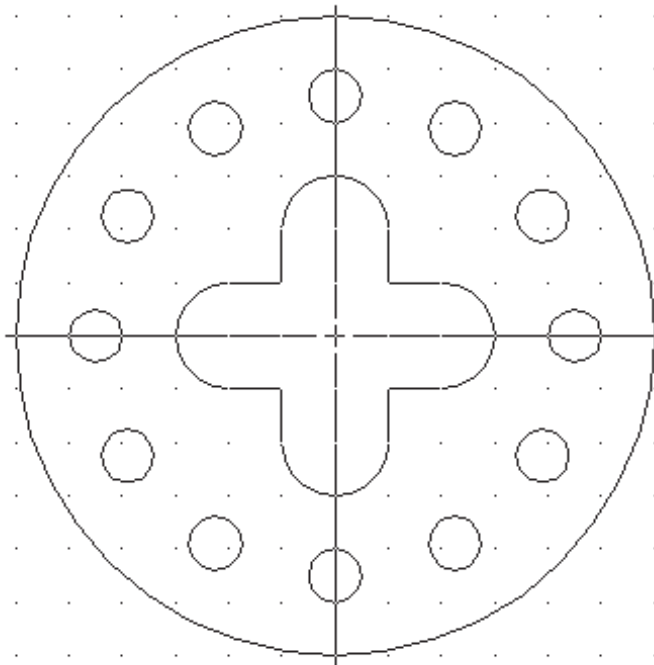
THICKNESS:
20mm
.75in.

Figure P7-18



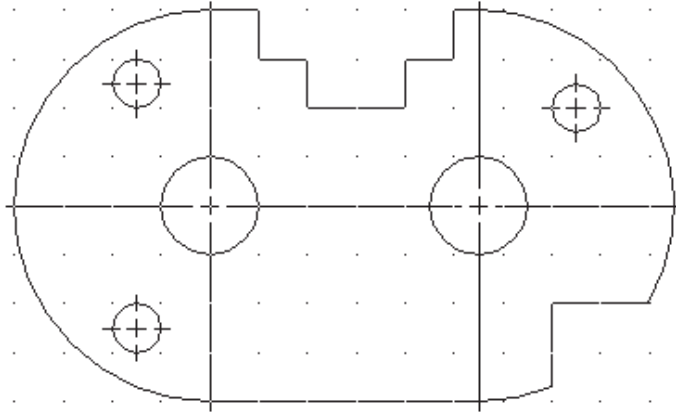
THICKNESS:
30mm
1.375in.

Figure P7-19



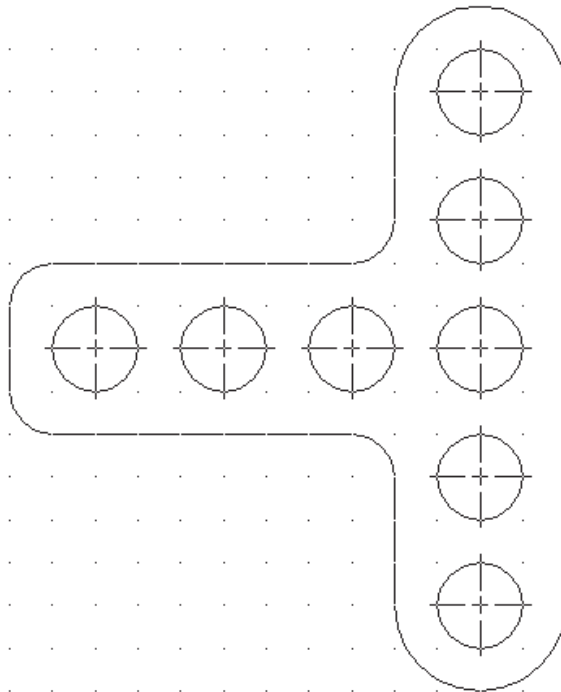
THICKNESS:
12mm
.30in.

Figure P7-20



THICKNESS:
5mm
.125in.

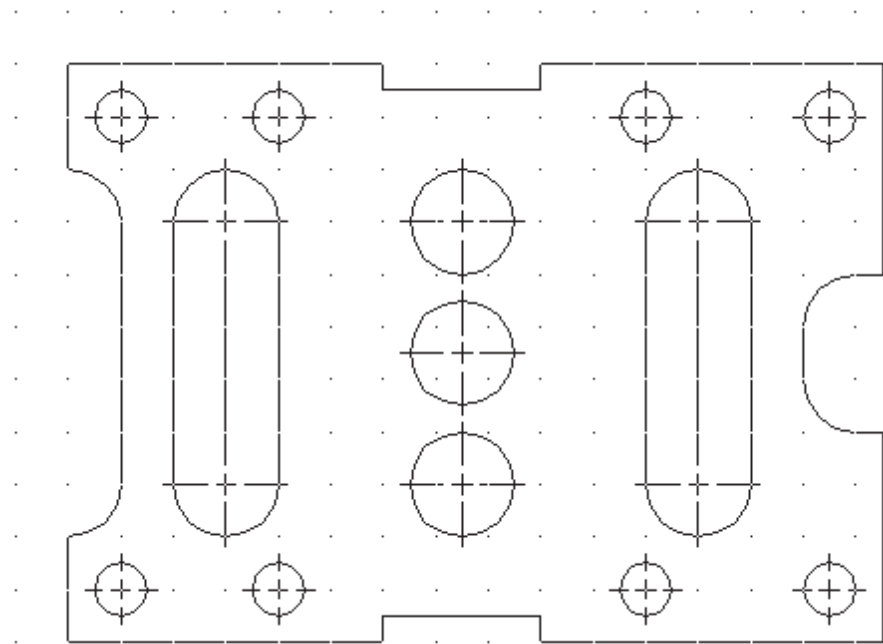
Figure P7-21



THICKNESS:
10mm
.25in.

Dimension using baseline dimensions

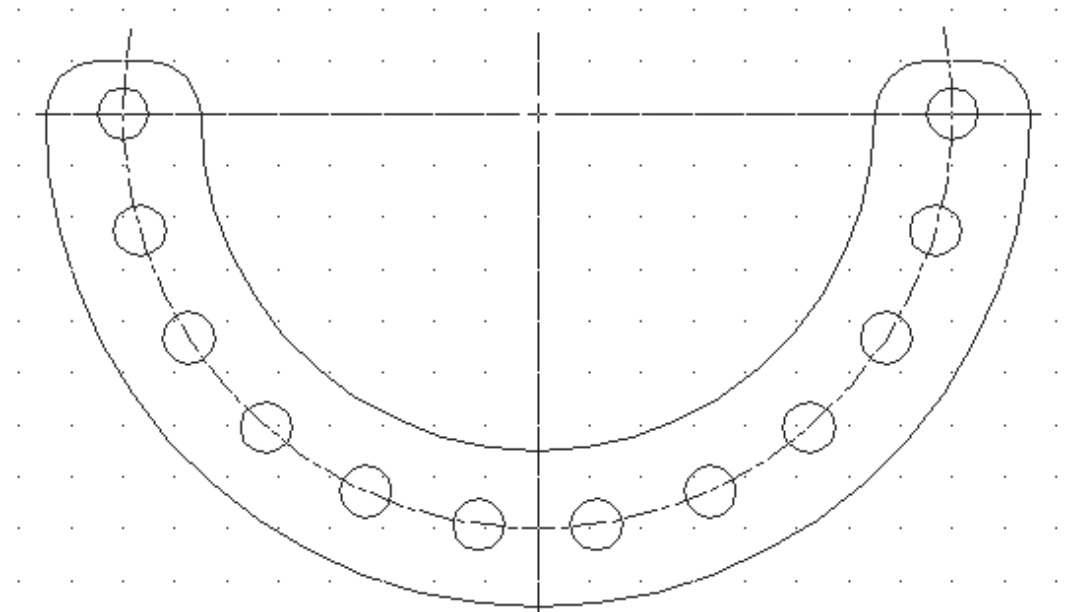
Figure P7-22



THICKNESS:
15mm
.50in.

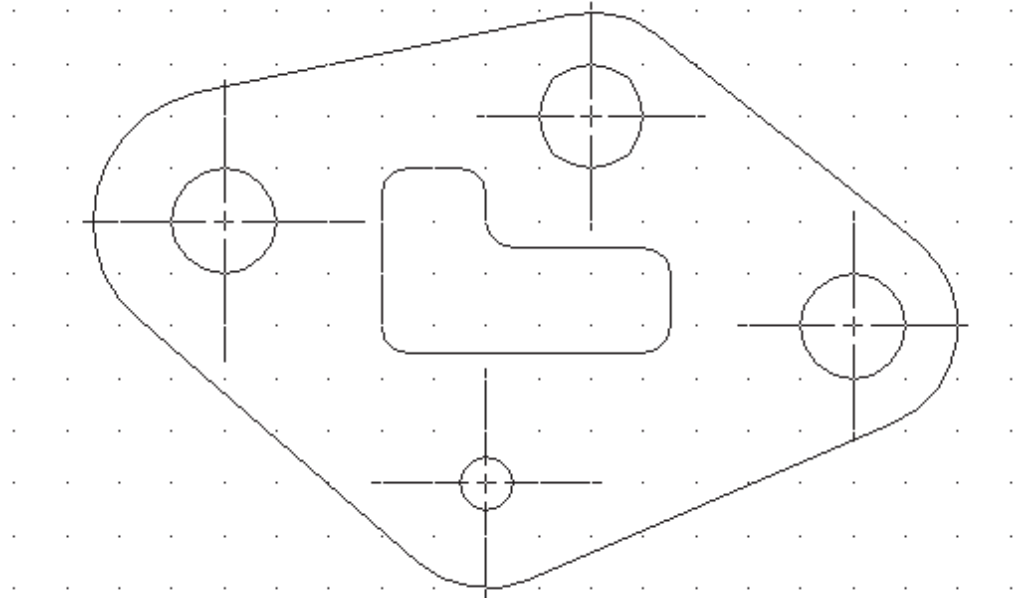
Dimension using
A. Baseline dimensions C. Chain dimensions
B. Ordinate dimensions D. Hole table

Figure P7-23



THICKNESS:
5mm
.19in.

Figure P7-24



THICKNESS:
15mm
.625in.

Project 7-2:

Use the **Part** template to draw models of the objects shown in Figures P7-25 through P7-42.

1. Create orthographic views of the objects. Dimension the orthographic views.
2. Create 3D models of the objects. Dimension the 3D models.

Figure P7-25
MILLIMETERS

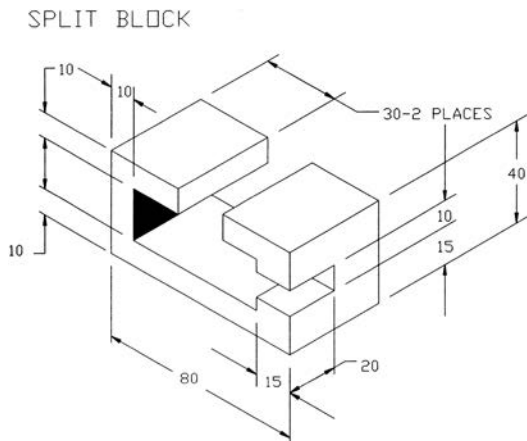


Figure P7-26
MILLIMETERS

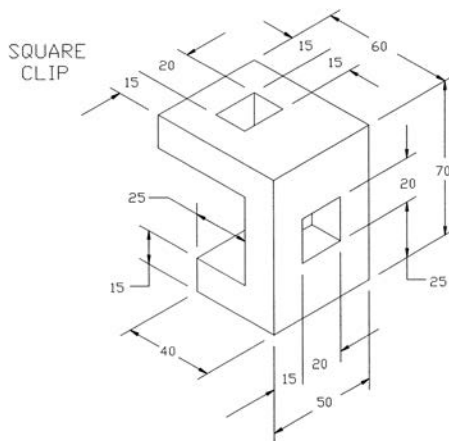


Figure P7-27
INCHES

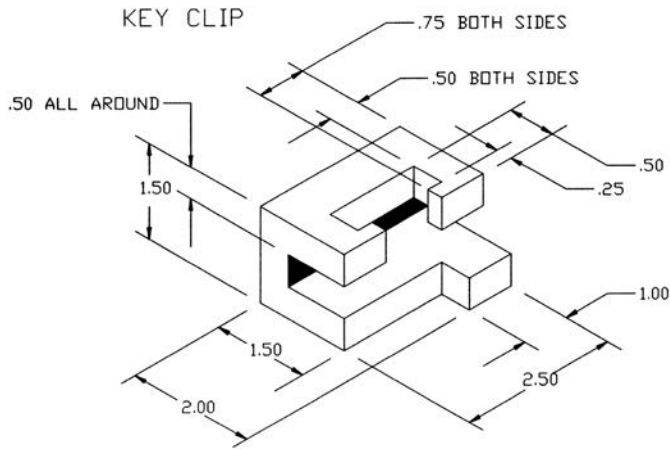


Figure P7-28
MILLIMETERS

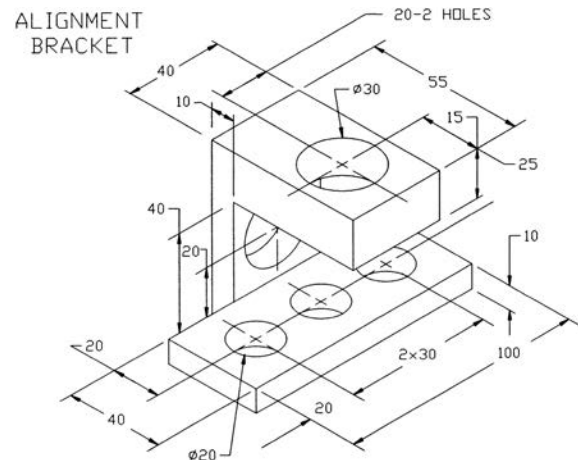


Figure P7-29
MILLIMETERS

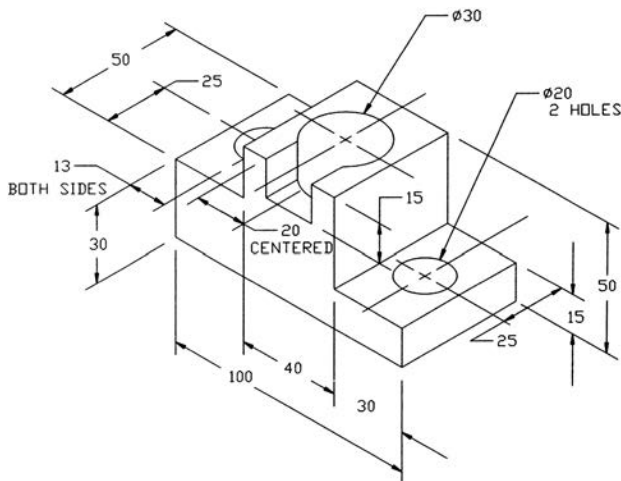


Figure P7-30
INCHES

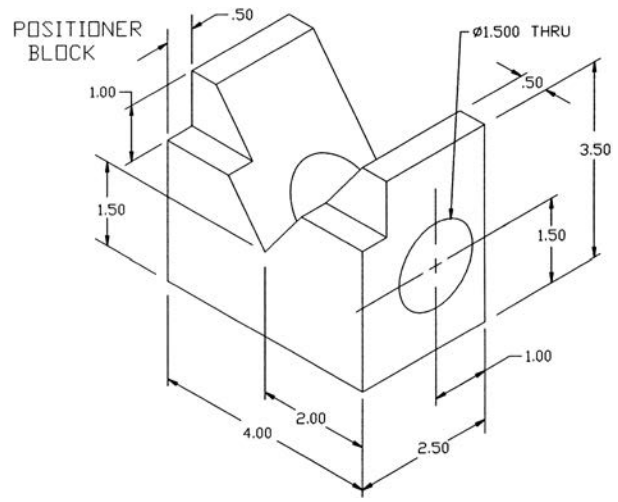


Figure P7-31
MILLIMETERS

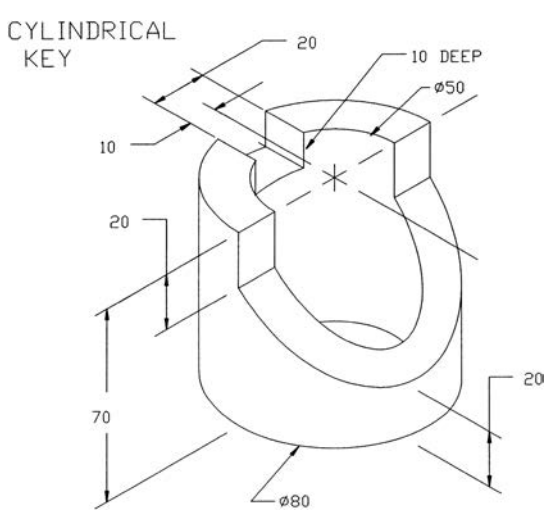


Figure P7-32
INCHES

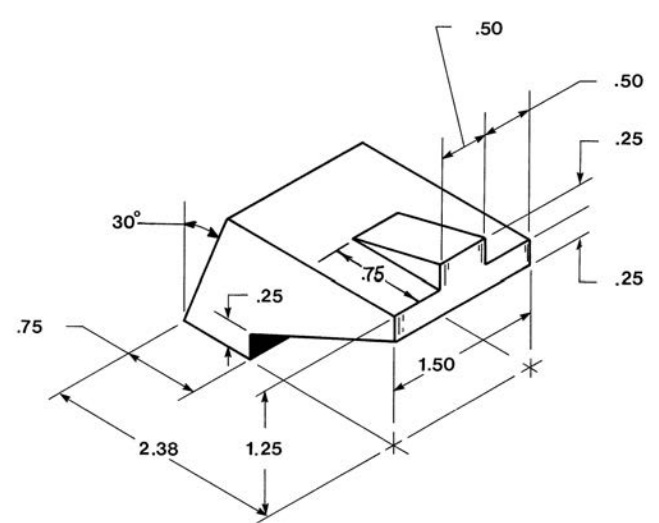


Figure P7-33
MILLIMETERS

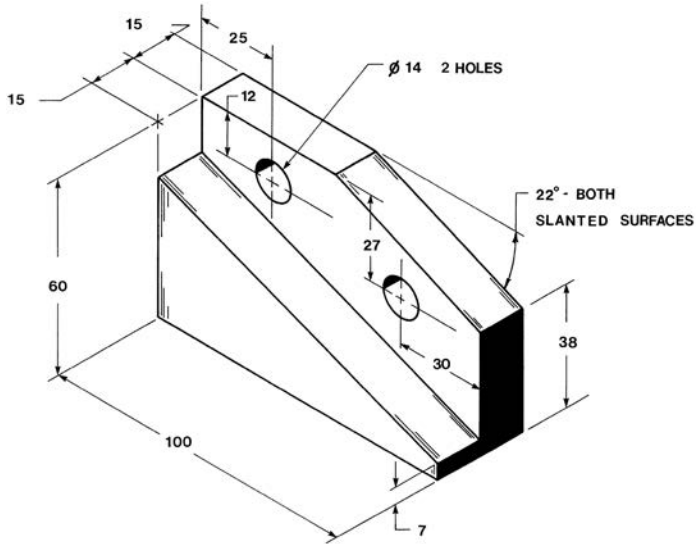


Figure P7-34
INCHES

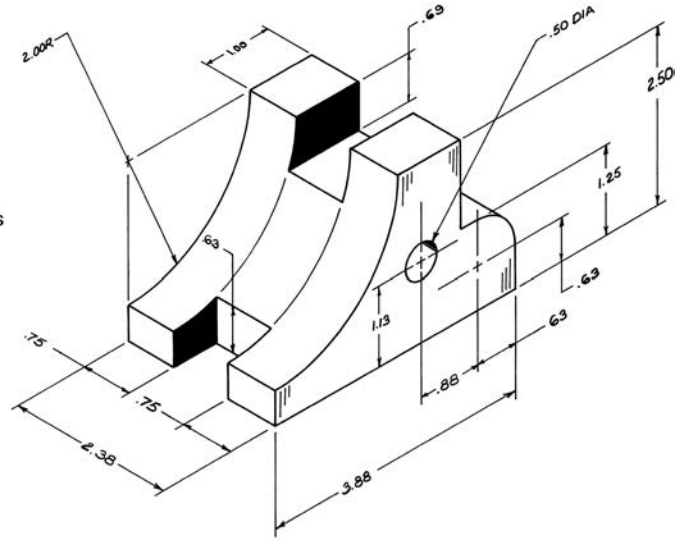


Figure P7-35
MILLIMETERS

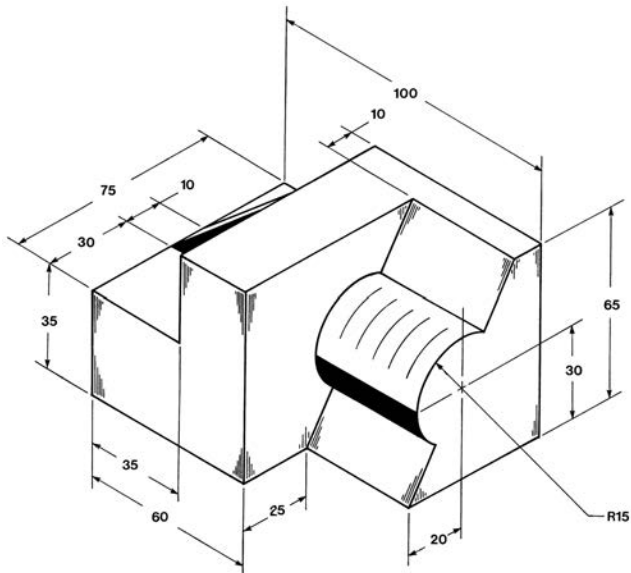


Figure P7-36
MILLIMETERS

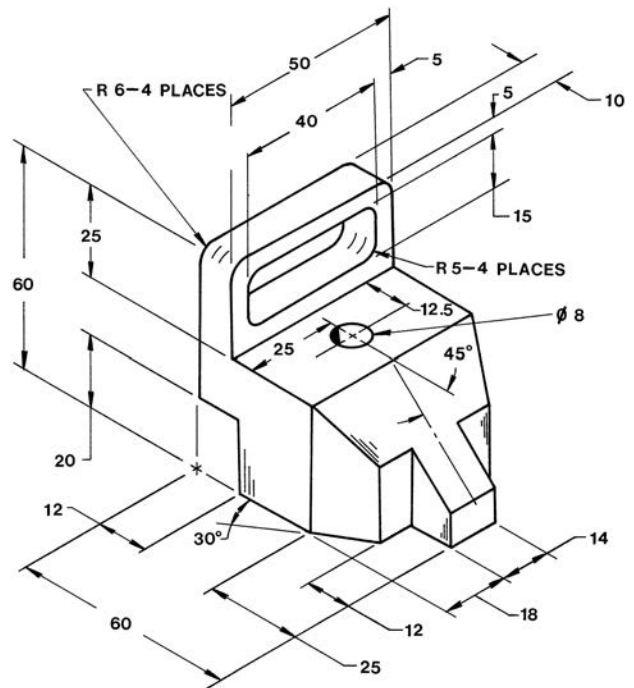


Figure P7-37
INCHES

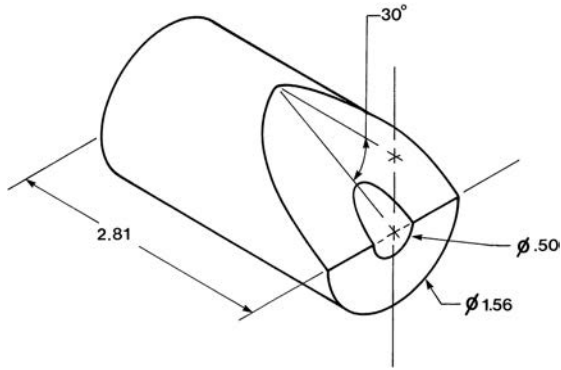
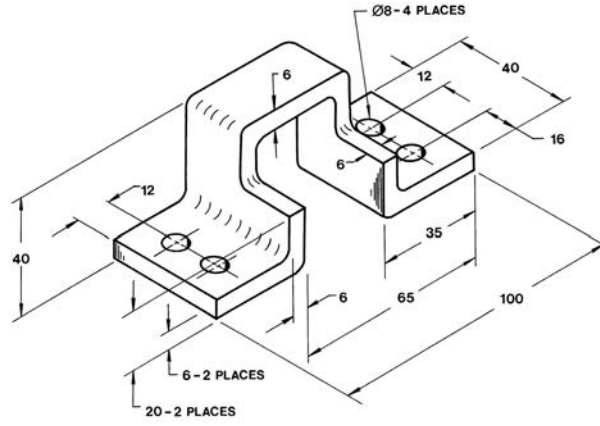


Figure P7-38
MILLIMETERS



NOTE: ALL FILLETS AND ROUNDS=R3

Figure P7-39
MILLIMETERS

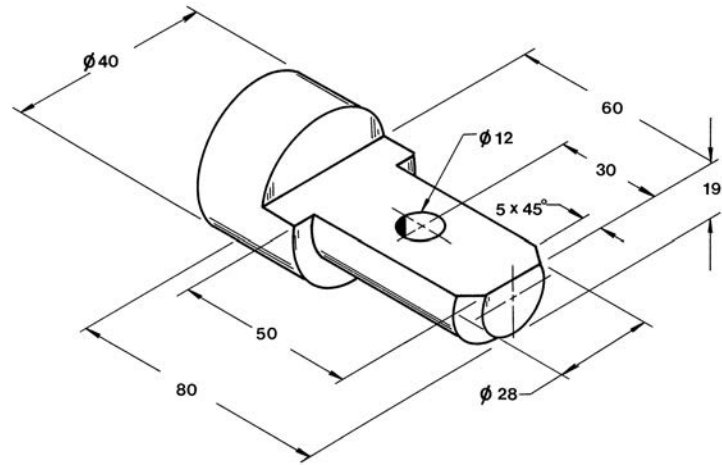
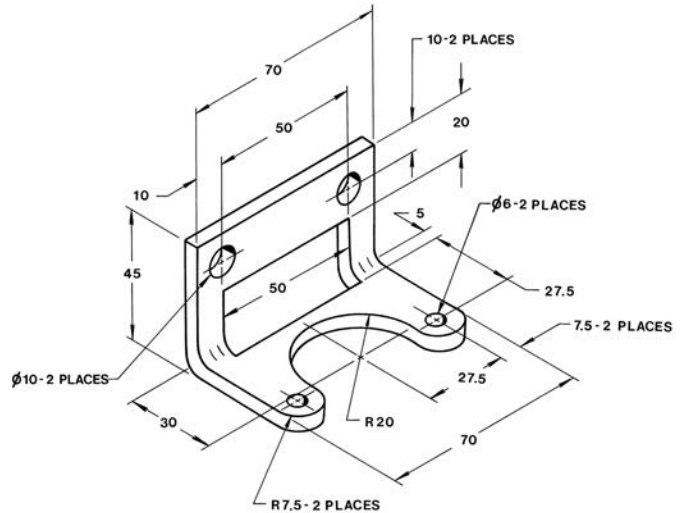


Figure P7-40
MILLIMETERS



ALL FILLETS AND ROUNDS=R5
MATL 5 THK

Project 7-3:

1. Draw a 3D model from the given top orthographic and section views in Figure P7-43.
2. Draw a top orthographic view and a section view of the object and add dimensions.

Figure P7-43
MILLIMETERS

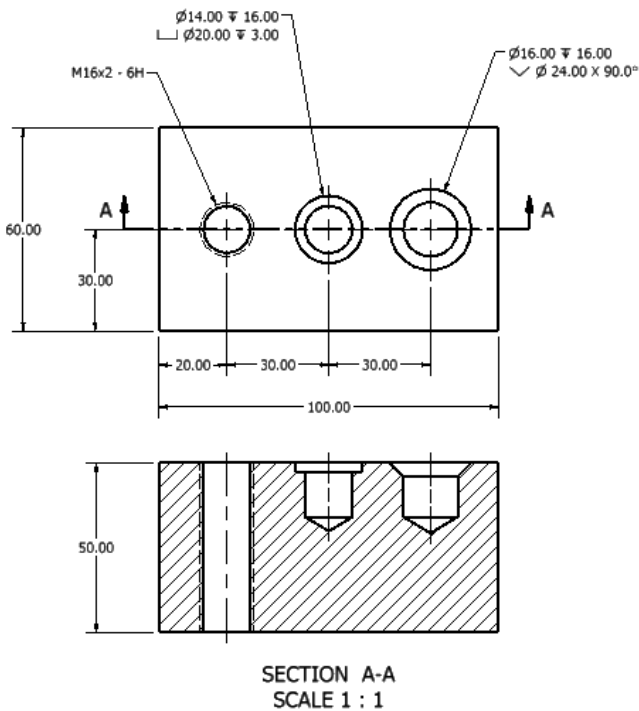
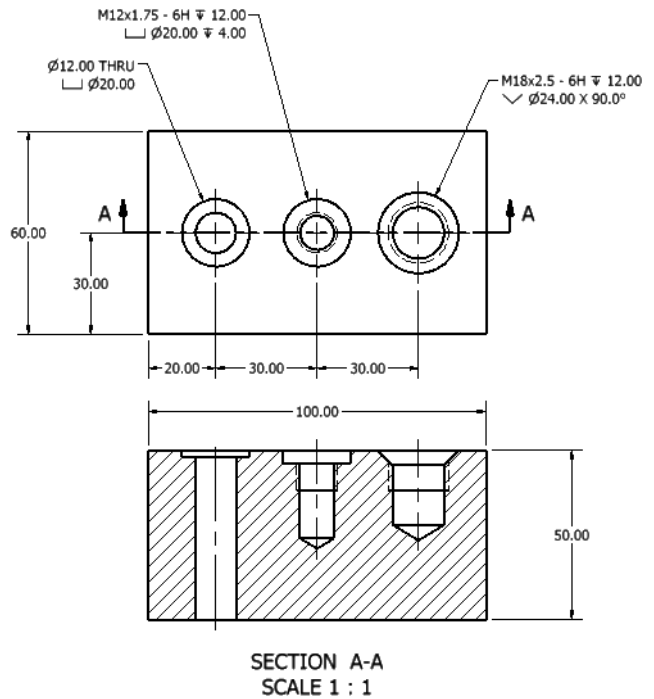


Figure P7-44
MILLIMETERS



Project 7-4:

1. Draw a 3D model from the given top orthographic and section views in Figure P7-44.
2. Draw a top orthographic view and a section view of the object and add dimensions.

Project 7-5:

1. Draw a 3D model from the given top orthographic and section views in Figure P7-45.
2. Draw a top orthographic view and a section view of the object and add dimensions.

Project 7-6:

1. Draw a 3D model from the given top orthographic and section views in Figure P7-46.
2. Draw a top orthographic view and a section view of the object and add dimensions.

Figure P7-45
INCHES

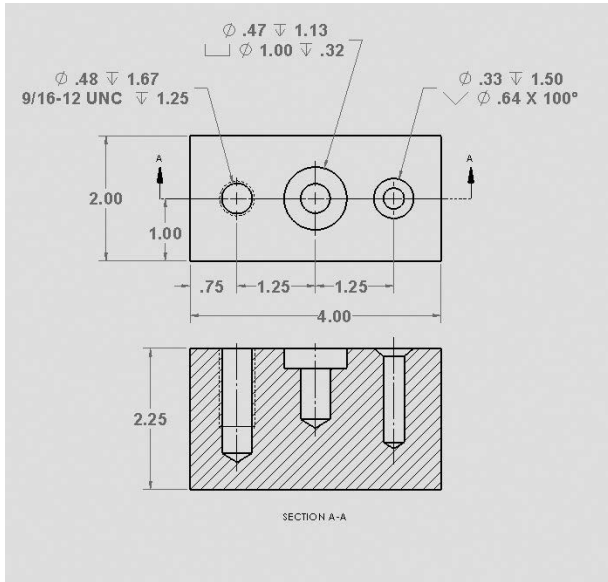
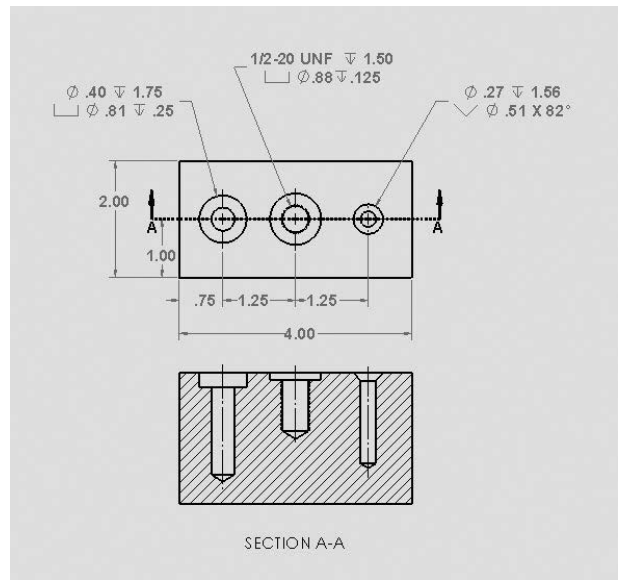


Figure P7-46
INCHES



Project 7-7:

Redraw the given shapes in Figures P7-47 through P7-49 and dimension them using the following dimension styles.

1. Baseline
2. Ordinate
3. Hole Table

Figure P7-47
MILLIMETERS

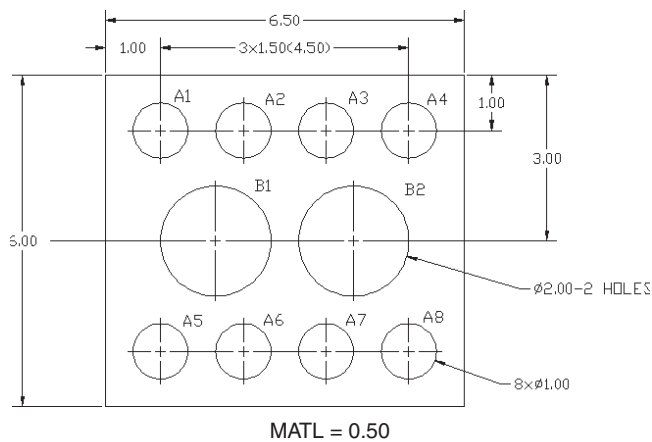


Figure P7-48
MILLIMETERS

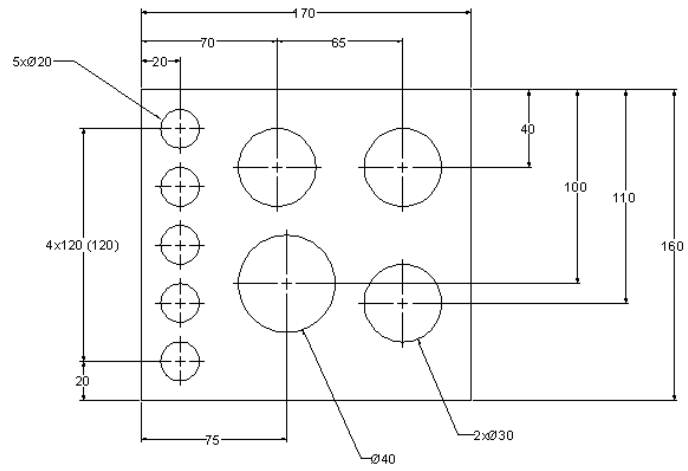
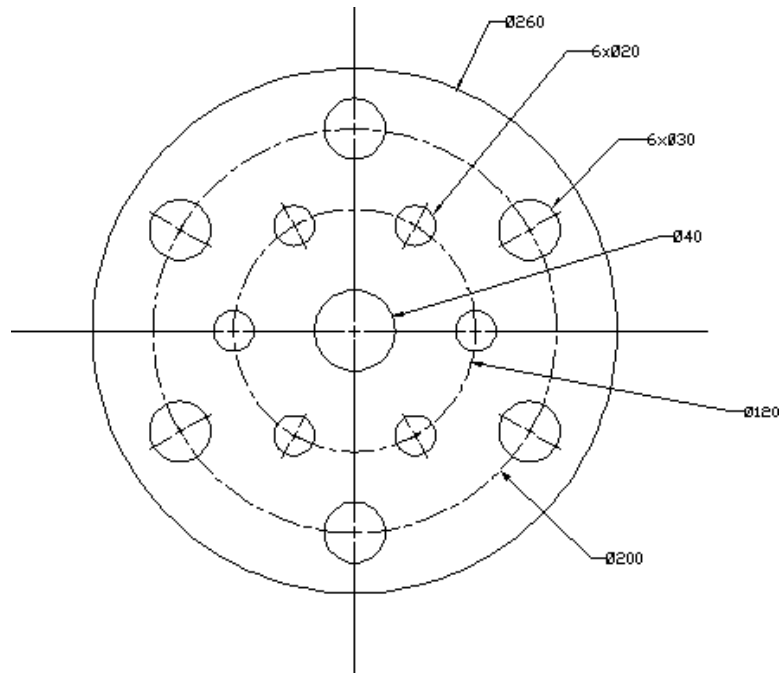


Figure P7-49
INCHES



Index

Numerics

2D shape

- creating, 28–31
- drawing, 20–23
- 3 point arc, sketching, 69–70
- 3 point arc slot, sketching, 64
- 3 Point Arc Slot tool, 64
- 3 point center rectangle, sketching, 58–59
- 3 point corner rectangle, sketching, 57–58
- 3D model, creating, 25–26

A

- abbreviations, 498–499
 - accessing
 - Design Library, 390–392
 - Mouse Gestures settings, 45–46
 - activating, S Key, 48
 - addendum, 655
 - adding
 - columns to a BOM (bill of materials), 332–333
 - datum indicator, 563–564
 - dimensions to a drawing, 450–454
 - plus and minus tolerances, 524–525
 - screw sets to a collar, 409–410
 - text, 85
 - text to a feature, 86
 - aligned dimensions, 462
 - aligned section view, 258–259
 - angular dimensions, 448, 480–484
 - angular tolerance, creating, 526–528
 - angularity tolerances, 569–570
 - Animate Collapse tool, 339–340
 - animating, gears, 661–662, 689–690
 - Annotation tools
 - Auto Balloon, 327
 - Autodimension, 457–459
 - creating baseline dimensions, 459
 - creating ordinate dimensions, 460
 - Balloon, 326–328
 - Datum Feature, 563, 564
 - Geometric Tolerance, 565–566
 - Note tool, 337–338
 - Smart Dimension, 6, 8, 11–12, 17, 23, 387, 451, 457
 - ANSI (American National Standards Institute). *See also* English units; inch values; metric units
 - dimensioning terminology and conventions, 448–449
 - orthographic view standards, 229
 - thread standards, 383–384
 - threads, 381, 392
- application blocks, 339
 - applying, surface control symbols, 547–549
- arcs

- 3 point, sketching, 69–70
 - centerpoint, sketching, 67–68
 - tangent, sketching, 68–69
- Assembly tools
 - Animate Collapse, 339–340
 - Clearance Verification, 353, 355–356
 - Exploded View, 321–324
 - Interference Detection, 349–350
 - Mate, 311–316, 318–320
 - Motion Study, 344–346
 - Mouse Gestures, 310–311
 - Move Component, 308–309
 - Rotate Component, 309–310
 - assembly/ies
 - application blocks, 339
 - BOM (bill of materials), 328–329
 - adding columns, 332–333
 - changing the font, 334–335
 - changing the width of columns and rows, 333–334
 - editing, 330–331
 - bottom-up, 316–321
 - exploded isometric, creating, 321–324
 - Fix option, 308
 - gear, 674–675
 - adding bearings, 663–666
 - animating the gears, 661–662
 - creating, 657–661
 - interference
 - detecting, 350–352
 - removing, 353–355
 - motion, viewing, 346
 - numbers, 326–328
 - origin, 307
 - parts, editing, 347–349
 - release block, 338
 - revision letters, 336
 - Rotator, 341–344
 - sleeve bearings, 621–622
 - standard fit tolerance, applying, 634–635
 - starting, 305–308
 - title block, 335, 336–338
 - assigning
 - tolerances, 549–550
 - tools to the Mouse Gestures wheel, 46–47
 - Auto Balloon tool, 327
 - Autodimension tool, 457–459
 - auxiliary views, drawing, 262–266

B

- backlash, 655
- ball bearings, 619, 626–628
- Balloon tool, 326–328
- baseline dimensions, 459, 488–490, 529–532
- basic dimensions, 574
- bearings, 628
 - adding to gear assemblies, 663–666

- applying a clearance fit tolerance, 632–633
 - ball, 619, 626–628
 - clearance fits, 628–629
 - fits, 628
 - hole basis, 629
 - interference fit, 630–631
 - manufactured, 631–632
 - clearance fit, 632
 - interference fit, 633
 - shaft basis, 629–630
 - sleeve, 619, 620
 - drawing, 620–621
 - using in an assembly drawing, 621–622
 - from the Toolbox, 623–626
 - bilateral tolerance, 519–520
 - blind holes, 205, 466
 - creating, 143–146
 - dimensioning, 466–471
 - threaded, inch values, 387–388
 - bolt threads, 396
 - BOM (bill of materials), 328–329
 - adding columns, 332–333
 - changing the font, 334–335
 - changing the width of columns and rows, 333
 - editing, 330–331, 683–686
 - bottom-up assemblies, 316–321
 - broken views, 259–261
- ## C
- callouts
 - ball bearings, 626
 - fit, 540–541
 - thread, 382–383
 - CD (center distance), 655
 - center rectangle, sketching, 56–57
 - Centerline tool, 110–111
 - centerlines
 - dimensions, 502
 - extending, 463
 - symbol, 500
 - centerpoint arc, sketching, 67–68
 - centerpoint arc slot, sketching, 65–66
 - centerpoint straight slot, sketching, 63
 - Centerpoint Straight Slot tool, 63
 - chain dimensions, 529–531
 - Chamfer tool, 153
 - defining a chamfer using an angle and a distance, 153–154
 - defining a chamfer using two distances, 154–155
 - defining a vertex chamfer, 155–156
 - chamfer/s
 - dimensioning, 497–498
 - sketching, 82
 - using angle-distance, 83
 - using distance-distance – equal distance, 82

- using distance-distance – not equal distance, 84
- vertex, 155–156
- changing
 - existing dimension, 10–11
 - style of a section view, 257
 - text font and size, 85–86
 - units, 15
- Circle tool, 9, 52–54, 141–142
- circle/s
 - changing an existing dimension, 10–11
 - under defined, 11
 - defining the diameter, 53–54
 - fully defined, creating, 8–10
 - locational value, 11
 - perimeter
 - sketching, 66–67
 - sketching tangent to three lines, 55–56
 - sketching using three points, 54–55
 - sketching, 52–54
- circular pitch, 655
- Circular Sketch Pattern tool, 176–177
- circular sketch patterns, creating, 97–99
- circular thickness, 655
- circularity tolerance, 559–560
- class, threads, 383–384
- clearance, 655
- clearance fit, 539, 628–629, 632–633
- Clearance Verification tool, 353, 355–356
- closed spline, 72
- Coincident relation icon, 5
- colors, 8
- Column Width dialog box, 333
- column/s
 - adding to BOM (bill of materials), 332–333
 - width, changing on a BOM (bill of materials), 333
- compound lines, 237
- compression springs, 181–182
- Concentric relation icon, 23
- conic section, sketching, 79–80
- controlling, dimensions, 454–455
- copying, entities, 100–102
- counterbored holes, dimensioning, 469–478
- countersink holes, dimensioning, 479–480
- creating
 - 2D shapes, 28–31
 - 3D models, 25–26
 - angular tolerances, 526–528
 - baseline dimensions, 459, 488–490
 - broken views, 260–261
 - exploded isometric drawings, 324–326
 - fillets, with variable radius, 148–149
 - gears, 656–657, 690–691
 - ground ends, 183–184
 - holes, 32–36, 141–142
 - blind, 143–146
 - inward draft sides, 132–133
 - keyseats, 671–674, 678–679
 - limit tolerances, 525–526
 - linear sketch pattern, 95–97
 - mirror entities, 92–94
 - ordinate dimensions, 460, 486–488

- outward draft, 133–134
- plus and minus tolerances, 522–523
- positional tolerance, 575–578
- reference plane, 161–165
- crest, 381
- Curve Driven Pattern tool, 208–213
- curved surfaces, dimensioning to a point, 500
- Customize dialog box, 45, 49
- customizing, S Key toolbar, 49–51
- cutout, editing, 196–197
- cylinders. *See also* sleeve bearings
 - creating a slanted surface, 200
 - drawing, 198–200
 - hole, adding, 203–205
 - straightness tolerance, 556
 - threaded holes, adding, 405–409
 - vertical slot, adding, 201–203
- cylindricity tolerance, 560

D

- datum, 561–563
 - indicator, adding, 563–564
 - surfaces, 545
- Datum Feature tool, 563, 564
- debossed text, creating, 191–194
- dedendum, 655
- under defined entities, 11
- Design Library, 381
 - accessing, 390–392
 - Limits and Fits option, 539
 - nuts, 394–396
 - threads, 383
 - washers, 393–394
- detail view, drawing, 261–262
- detailed representation, threads, 384
- detecting, interference, 350–352
- dialog box
 - Column Width, 333
 - Customize, 45, 49
 - Documents Properties - Drafting Standard, 454
 - Formatting, 330, 336
 - Make Dimension Driven?, 13
 - Modify, 10, 29
 - New SolidWorks Document, 240, 672
 - Properties/Geometric Tolerance, 564
 - S Key, 47
 - Smart Fastener, 399
- diameter
 - calculating, 535–538
 - clearance fit, 539
 - defining, 53–54
 - fixed condition, 551–552
 - floating condition, 550–551
 - interference fit, 539, 540
 - major, 382
 - minor, 381
 - outside, 655
 - pitch, 655, 681–683
 - root, 655
 - transition fit, 539
- diametral pitch, 655
- Dimension Property Manager, 464
- Dimension Text box, adding plus and minus symmetric tolerances, 524–525

- dimensions and dimensioning, 1, 7.
 - See also* tolerances
 - adding to a drawing, 450–454
 - aligned, 462
 - angular, 448, 480–484
 - baseline, 459, 488–490, 529–532
 - basic, 574
 - blind holes, 466–471
 - chain, 529–531
 - chamfers, 497–498
 - changing, 10–11
 - circle, 12–13
 - common errors to avoid, 449–450
 - controlling, 454–455
 - conventions, 449
 - counterbored holes, 469–478
 - countersink holes, 479–480
 - datum, 561–563
 - designing a hole given a fastener size, 553
 - double, 457, 493, 528–529
 - drawing scale, 460–461
 - driving, 13
 - evenly spaced hole pattern, 484–485
 - extension lines, 448, 449
 - hole patterns, 468–469
 - hole tables, 490–491
 - holes, 462–466
 - irregular surfaces, 495–496
 - leader lines, 448, 449
 - linear, 448
 - lines, 448
 - locating, 492–493
 - nominal size, 535–537, 549
 - ordinate, 460, 485, 486–488
 - orthographic views, 501–502
 - overall, 455
 - to a point, 500
 - polar, 496–497, 535
 - rectangular, 533
 - reference, 13, 495
 - section views, 501
 - short distances, 455–457
 - slots, 493–494
 - standard tolerances, 461
 - symbols and abbreviations, 498–499
 - unidirectional, 462
 - units, 14–15, 461–462
 - using centerlines, 502
 - values, 455, 461
- document/s
 - part
 - sketch plane, selecting, 3–8
 - starting, 2–3
 - saving, 27–28
- Documents Properties - Drafting
 - Standard dialog box, 454
- double dimensioning, 457, 493, 528–529
- Draft tool, 172–173
- drawing/s. *See also* assembly/ies
 - 2D shape, 20–23
 - abbreviations, 498–499
 - adding dimensions, 450–454
 - auxiliary view, 262–266
 - callouts, thread, 382–383
 - cylinders, 198–200
 - detail views, 261–262

- fit callout, adding, 540–541
 - helix, 179–180
 - lay symbol, adding, 548–549
 - orthographic view, 240–248
 - scale, 460–461
 - section views, 252–257
 - sheet sizes, 241
 - sleeve bearings, 620–621
 - springs, 180–181
 - extension, 187–191
 - torsional, 184–187
 - symbols, 498–499
 - threads
 - blind holes, 387–388
 - internal, 384–387
 - driving dimension, 13
- E**
- editing, 195
 - BOM (bill of materials), 330–331, 683–686
 - cutout, 196–197
 - dimensions, 454–455
 - holes, 195–196
 - parts within an assembly, 347–349
 - splines, 73
 - title block, 336–338
 - ellipse
 - conic section, sketching, 79–80
 - partial, sketching, 75–76
 - sketching, 74–75
 - English units, 14–15, 542. *See also* metric units
 - entities
 - center, 110–111
 - copying, 100–102
 - under defined, 11
 - extending, 89–90
 - fully defined, 11–13
 - mirror, creating, 92–94
 - moving, 18, 99–100
 - rotating, 102–103, 151–153
 - scaling, 103–104
 - Sketch Relations, 24–25
 - splitting, 106–109
 - stretching, 104–106
 - trimming, 88
 - evenly spaced hole pattern,
 - dimensioning, 484–485
 - exam preparation, 715
 - creating assemblies, 747–749
 - drawing auxiliary views, 735–737
 - drawing break views, 737–738
 - drawing larger objects, 727–734
 - drawing lines and views, 744–747
 - drawing profiles, 717–721
 - drawing section views, 739–741, 742–743
 - drawing small 3D objects, 721–726
 - working with cubes, 716–717
 - Exit Sketch mode icon, 17
 - exploded isometric assembly, creating, 321–324
 - exploded isometric drawing, creating, 324–326
 - Exploded View tool, 321–324, 622
 - extending
 - centerlines, 463
 - entities, 89–90
 - extension lines, 448, 449
 - extension springs, drawing, 187–191
 - Extrude Boss/Base tool, 129–132, 134–136
 - creating an outward draft, 133–134
 - creating inward draft sides, 132–133
 - extrusion depth, defining, 132
 - Extruded Cut tool, 137–138, 141–142, 203
- F**
- face width, 655
 - fasteners, 399–400, 553
 - fixed, 582–584
 - fixed condition, 551–552
 - floating, 579–582
 - floating condition, 550–551
 - screw sets, 404–405
 - features, text
 - adding, 86
 - wrapping, 87
 - Features tools, 3
 - Chamfer, 153
 - defining a vertex chamfer, 155–156
 - defining using an angle and a distance, 153–154
 - defining using two distances, 154–155
 - Circular Sketch Pattern, 176–177
 - Curve Driven Pattern, 208–213
 - Draft, 172–173
 - Extrude Boss/Base, 129–132, 134–136
 - creating an outward draft, 133–134
 - creating inward draft sides, 132–133
 - extrusion depth, defining, 132
 - Extruded Cut, 137–138, 203
 - Fillet, 146–148
 - creating a fillet with a variable radius, 148–149
 - Face Fillet option, 150–151
 - Full Round Fillet option, 151–153
 - Hole Wizard, 138–142, 462, 466–471
 - creating a blind hole, 143–146
 - dimensioning counterbored and countersunk holes, 469–480
 - internal threads, drawing, 384–387
 - threaded blind holes, drawing, 387–388
 - threaded hole, drawing on the side of a cylinder, 406–409
 - Linear Sketch Pattern, 174–175
 - Lofted Boss/Base, 165–168
 - Mirror, 177–179
 - Revolved Boss/Base, 156–159
 - Revolved Cut, 159–160
 - Shell, 168–169
 - Swept Boss/Base, 170–172
 - Wrap, 191–194
 - Fillet tool, 146–148
 - Face Fillet option, 150–151
 - Full Round Fillet option, 151–153
 - fillets, 146–148
 - creating with a variable radius, 148–149
 - dimensioning, 493
 - sketching, 81
- first-angle projection, orthographic views, 229–230, 243, 266–268
- fit/s, 628
 - callout, adding to a drawing, 540–541
 - clearance, 539, 628–629, 632–633
 - interference, 539, 540, 630–631
 - locational, 630
 - metric, 635
 - press, 633
 - standard, 540, 634–635
 - tables, 542
 - transition, 539
- fixed condition, 551–552
- fixed fasteners, 582–584
- flatness tolerances, 554–555
- floating condition, 550–551
- floating fasteners, 579–582
- font
 - changing, 85–86
 - changing on a BOM (bill of materials), 334–335
- Formatting dialog box, 330, 336
- formulas, gear, 655
- fully defined entities, 8–10, 11–13
- G**
- gear/s
 - addendum, 655
 - animating, 689–690
 - assemblies, 674–675
 - adding bearings, 663–666
 - animating the gears, 661–662
 - creating, 657–661
 - backlash, 655
 - CD (center distance), 655
 - circular pitch, 655
 - circular thickness, 655
 - clearance, 655
 - creating, 656–657
 - dedendum, 655
 - diametral pitch, 655
 - face width, 655
 - formulas, 655
 - hub
 - adding, 666–667
 - threaded hole, adding, 668–671
 - keyseat
 - creating, 671–674, 678–679
 - creating in the shaft, 676–678
 - creating the arc-shaped end, 679–680
 - metric, 690–691
 - module, 655
 - number of teeth, 655
 - outside diameter, 655
 - parallel keys, 675–676
 - pitch diameter, 655, 681–683
 - preferred pitch, 655
 - pressure angle, 655
 - rack and pinion, 687–689
 - ratios, 663
 - root diameter, 655

- set screws, 666–667
- spur, 681
- train, 663
- whole depth, 655
- working depth, 655

Geometric Tolerance tool, 565–566

geometric tolerances, 554, 561, 584–587

ground ends, creating, 183–184

H

helix, drawing, 179–180

hexagon, sketching, 70–72

hidden lines, 234–235

Hole Callout tool, 477

Hole Wizard tool, 32, 138–142, 462, 466–471

- internal threads, drawing, 384–387
- threaded blind holes, inches, 387–388
- threaded hole, drawing on the side of a cylinder, 406–409

hole/s, 32, 203–205

- basis, 629–630
- blind, 143, 205, 466
 - dimensioning, 466–471
 - threaded, 387–388
- counterbored, dimensioning, 469–478
- countersink, dimensioning, 479–480
- creating, 32–36, 141–142
- designing given a fastener size, 553
- dimensions, 462–466
- editing, 195–196
- evenly spaced pattern, dimensioning, 484–485
- locations, 533–535
- patterns, dimensioning, 468–469
- shaft tolerance, calculating, 535–537
- tables, 490–491
- threaded
 - adding to a gear's hub, 668–671
 - adding to the side of a cylinder, 405–409
 - tolerance, calculating, 538
 - virtual condition, 579

hub, gear, 666–667, 668–671

I

icon/s

- Coincident relation, 5
- Concentric relation, 23
- Design Library, 391
- Exit Sketch mode, 17
- Line, 6
- origin, hiding/showing, 321
- Sketch toolbar, 3

inch values

- standard fits, 540
- threaded blind holes, 387–388
- zero limit, 521

interference

- detecting, 350–352
- fit, 539, 540, 630–631, 633
- removing, 353–355

Interference Detection tool, 349–350

internal threads

- inches, 384–388
- length, 401–404
- metric, 388–390

- threaded blind holes, 387–388

irregular surfaces, dimensioning, 495–496

isometric drawing, creating, 324–326

J-K

Jog Line tool, 110

keys, 671, 675–676

keyseat, 671

- creating, 671–674, 678–679
- creating in the shaft, 676–678
- creating the arc-shaped end, 679–680

L

lay symbol, adding to a drawing, 548–549

leader lines, 448, 449

length

- internal thread, 401–404
- thread, 392–397

limit tolerance, 525–526

Line tool, 5, 22, 28, 43–44

linear dimensions, 448

Linear Sketch Pattern tool, 174–175

linear sketch patterns, creating, 95–97

linear tolerance, 533

lines

- compound, 237
- hidden, 234–235
- offset, sketching, 91–92
- precedence, 235–236

locating dimensions, 492–493

locational fit, 630

locational tolerance, 567

locational value, 11

Lofted Boss/Base tool, 165–168

M

major diameter, 382

Make Dimension Driven? dialog box, 13

Make Fixed tool, 24

manufactured bearings, 631–632, 633

Mate tool, 311–316, 318–320

metric units, 14–15, 635

- fit tables, 542
- gears, 690–691
- threads, 382, 388–390

minor diameter, 381

mirror entities, creating, 92–94

Mirror tool, 177–179

MMC (maximum material condition), 557–559

Model View tool, 252–253

Modify dialog box, 10, 29

module, 655

Motion Study tool, 344–346

Mouse Gestures, 44

- accessing settings, 45–46
- for assemblies, 310–311
- assigning a tool to the wheel, 46–47

Move Component tool, 308–309

moving

- entities, 18, 99–100
- orthographic views, 249
- rectangles, 19

N

New SolidWorks Document dialog box, 240, 672

nominal size, 549

non-parametric modeler, 1

normal surfaces, orthographic views, 233–234

Note tool, 337–338

numbers, assembly, 326–328

nuts, 394–396

O

oblique surfaces, 238

offset line, sketching, 91–92

open spline, 72

ordinate dimensions, 460, 485, 486–488

orientation

- returning to original
 - using the Orientation Triad, 20
 - using the Top View tool, 20
 - using the View Selector, 19–20
- tolerances, 566
- Top view, 19

Orientation Triad, 20

origin, 5, 51

- assembly, 307
- icons, 321
- showing, 51–52

orthographic views, 229

- ANSI standards, 229
- compound lines, 237
- dimensioning, 501–502
- drawing, 240–248
- first-angle projection, 229–230, 243, 266–268
- hidden lines, 234–235
- moving, 249
- normal surfaces, 233–234
- oblique surfaces, 238
- precedence of lines, 235–236
- side view orientations, 231–232
- slanted surfaces, 236–237
- third-angle projections, 229–230, 231, 243

outside diameter, 655

overall dimensions, 455

P

parabola

- conic section, sketching, 79–80
- sketching, 76–77

parallel keys, 675–676

parallelism tolerances, 569

parallelogram, sketching, 59

Parallelogram tool, 59

parametric modeler, 1

part document

- sketch plane, selecting, 3–8
- starting, 2–3

partial ellipse, sketching, 75–76

parts list, 328–329

patterns

- circular, 97–99
- hole, dimensioning, 468–469
- linear, 97

perimeter circle, sketching, 66–67

tangent to three lines, 55–56

- using three points, 54–55
- Perimeter Circle tool, 54–56, 66–67
- perpendicular tolerance, 564–565
- perpendicularity tolerances, 566–568
- pitch, 382
 - circular, 655
 - diameter, 655
 - diametral, 655
 - preferred, 655
 - thread, 392
- pitch diameter, 681–683
- plane. *See also* sketch plane
 - conic section, 77–78
 - reference, creating, 161–165
 - selecting, 3–8
- plus and minus tolerances, 519, 520, 522
 - adding, 524–525
 - creating, 522–523
- points, 87
- polar dimensions, 496–497, 535
- polygons, hexagon, sketching, 70–72
- positional tolerances, 573–575
 - creating, 575–578
 - design problems, 584–587
- power transmission, 653. *See also* gear/s
 - shaft to gear, 666
 - adding a threaded hole to the gear's hub, 668–671
 - keys, 671
 - keyseat, creating, 676–680
 - keyseats, 671–674
 - parallel keys, 675–676
 - set screws and gear hubs, 666–667
- precedence of lines, 235–236
- preferred pitch, 655
- preferred sizes, 543–544
- press fit, 633
- pressure angle, 655
- profile tolerances, 570–572
- Projected View tool, 249–250
- Properties/Geometric Tolerance dialog box, 564

Q-R

- rack and pinion gears, 687–689
- rectangle/s, 15
 - 3 point center, sketching, 58–59
 - 3 point corner, sketching, 57–58
 - center, sketching, 56–57
 - dimensions, 533
 - hole locations, 533–535
 - moving, 19
 - reorienting, 19
 - sketching, 15–17
 - zooming, 19
- reentering, Sketch mode, 17–18
- reference dimension, 13, 495
- Reference Geometry tool, 161, 168, 177, 183, 191, 200, 203, 208
- reference plane, creating, 161–165
- release block, 338
- removing, interference, 353–355
- reorienting, entities, 19
- Revolved Boss/Base tool, 156–159

- Revolved Cut tool, 159–160
- RFS (regardless of feature size), 556–559
- root, 381
- root diameter, 655
- Rotate Component tool, 309–310
- rotating, entities, 102–103, 151–153
- Rotator assembly, 341–344
- rounded shapes
 - external, 494–495
 - internal, 493–494
- rounded surfaces, 238–240
- rows, width, changing on a BOM (bill of materials), 334
- runout tolerance, 572–573

S

- S Key, 47
 - activating, 48
 - dialog box, 47
 - toolbar
 - customizing, 49–51
 - removing a tool from, 51
- saving, documents, 27–28
- scaling, entities, 103–104
- schematic representation, thread/s, 384
- screw sets, 404–405, 409–410
- section views, 250–251
 - aligned, 258–259
 - changing the style, 257
 - dimensioning, 501
 - drawing, 252–257
 - set screws, 666–667
- settings, Mouse Gestures, accessing, 45–46
- shaft. *See also* gear/s; hole/s
 - basis, 629–630
 - clearance fit, 539
 - interference fit, 539, 540, 630–631
 - keyseat, creating, 676–678
 - MMC (maximum material condition), 557
 - nominal size, 535–537
 - tolerances, 535–537
 - transition fit, 539
 - virtual condition, calculating, 579
- Shell tool, 168–169
- short distances, dimensioning, 455–457
- side view orientations, orthographic views, 231–232
- simplified representation, threads, 384
- Sketch mode
 - exiting, 17
 - reentering, 17–18
- sketch plane
 - origin, 5
 - returning to original orientation, 19–20
 - using the Orientation Triad, 20
 - using the Top View tool, 20
 - using the View Selector, 19–20
 - selecting, 3–8
- Sketch Relations, 24–25
- Sketch toolbar, icons, 3
- sketching
 - arcs
 - 3 point, 69–70

- centerpoint, 67–68
- tangent, 68–69
- chamfer, 82
 - using angle-distance, 83
 - using distance-distance – equal distance, 82
 - using distance-distance – not equal distance, 84
- circles, perimeter, 66–67
- conic section, 79–80
- fillets, 81
- hexagons, 70–72
- parabolas, 76–77
- parallelograms, 59
- rectangles, 15–17
 - 3 point center, 58–59
 - 3 point corner, 57–58
 - center, 56–57
- slots
 - 3 point arc, 64
 - centerpoint arc, 65–66
 - centerpoint straight, 63
 - straight, 61–62
- splines, 72–73
- Sketching tools, 110–111
 - 3 Point Arc Slot, 64
 - Centerline, 110–111
 - Centerpoint Arc, 67–68
 - Centerpoint Arc Style, 65–66
 - Centerpoint Straight Slot, 63
 - Chamfer, 82, 83
 - Circle, 52–54
 - Circular Sketch Pattern, 97–99
 - Copy Entities, 102
 - Ellipse, 73
 - Extend Entities, 89–90
 - Fillet, 81
 - Jog Line, 110
 - Line, 5, 22, 28
 - Linear Sketch Pattern, 95–97
 - Mirror Entities, 92–94
 - Move Entities, 100
 - Offset Entities, 90–92
 - Parabola, 76–77
 - Parallelogram, 59
 - Partial Ellipse, 75–76
 - Perimeter Circle, 66–67
 - Point, 87
 - Polygon, 71–72
 - Rotate Entities, 103
 - Scale Entities, 103–104
 - Spline, 73
 - Split Entities, 106–109
 - Straight slot, 61–62
 - Stretch Entities, 104–106
 - Tangent Arc, 68–69
 - Text, 84–87
 - Trim Entities, 88
- slanted surfaces, 236–237
- sleeve bearings, 619, 620
 - drawing, 620–621
 - tolerances, 1
 - using in an assembly drawing, 621–622
- slots

- 3 point arc, sketching, 64
- centerpoint arc, sketching, 65–66
- centerpoint straight, sketching, 63
- dimensioning, 493–494
- straight, sketching, 61–62
- Smart Dimension tool, 6, 8, 11–12, 17, 23, 387, 451, 455–457
- Smart Fastener dialog box, 399
- Smart Fasteners tool, 398–400
- solid modeler, 1
- spline, 72
 - editing, 73
 - sketching, 72–73
- splitting, entities, 106–109
- springs
 - compression, 181–182
 - drawing, 180–181
 - extension, drawing, 187–191
 - ground ends, creating, 183–184
 - torsional, drawing, 184–187
- spur gears, 681
- Standard 3 View tool, 249
- standard fit, 540, 634–635
- standard sizes, 543–544
- standard tolerances, 461, 528
- starting
 - assemblies, 305–308
 - new part document, 2–3
- straight slot, sketching, 61–62
- Straight slot tool, 61–62
- straightness
 - tolerances, 555–559
 - value, defining, 565–566
- stretching, entities, 104–106
- style, section views, changing, 257
- surface/s
 - control symbols, 545–547
 - applying, 547–548
 - lay, 548–549
 - datum, 545, 565–566
 - finish, 544–545
 - hidden lines, 234–235
 - irregular, dimensioning, 495–496
 - lay, 545
 - normal, orthographic views, 233–234
 - oblique, 238
 - profile tolerances, 570–572
 - roughness, 545
 - rounded, 238–240
 - slanted, 236–237
 - texture, 545
- Swept Boss/Base tool, 170–172
- symbols, 498–499
 - centerline, 500
 - datum, 564
 - surface control, 545–547
 - applying, 547–548
 - lay, 548–549
 - symmetrical object, 499
- symmetric tolerances, 524–525

T

- tangent arc, sketching, 68–69
- text
 - adding, 85
 - adding to a feature, 86
 - changing font and size, 85–86

- debossed, creating, 191–194
- wrapping, 87
- third-angle projection, orthographic
 - views, 229–230, 243
- threaded hole, drawing on the side of a
 - cylinder, 405–409
- thread/s
 - ANSI callout, 383–384
 - bolt, 396
 - classes, 383
 - counterbored holes, dimensioning, 473–478
 - crest, 381
 - depth, 476
 - detailed representation, 384
 - display styles, 392
 - external length, inch values, 392–397
 - form specification, 383
 - internal, 384
 - inches, 384–388
 - length, 401–404
 - metric, 388–390
 - threaded blind holes, 387–388
 - length, 382
 - major diameter, 382
 - metric, 382
 - minor diameter, 381
 - pitch, 382, 392
 - preferred sizes, 383
 - root, 381
- title block, 335, 336–338
- tolerance/s, 519. *See also* fit/s
 - angular, 526–528
 - angularity, 569–570
 - assigning, 549–550
 - bilateral, 519–520
 - circularity, 559–560
 - cylindricity, 560
 - datum, 561–563
 - designing a hole given a fastener size, 553
 - double-dimensioning errors, 528–529
 - expressions, 521
 - fit, 628, 635
 - fixed condition, 551–552
 - fixed fasteners, 582–584
 - floating condition, 550–551
 - floating fasteners, 579–582
 - of form, 554
 - flatness, 554–555
 - straightness, 555–559
 - geometric, 554, 561, 584–587
 - hole, 538
 - hole locations, 533–535
 - interference fit, 633–634
 - limit, 525–526
 - linear, 533
 - locational, 567
 - manufactured bearings, 631–632
 - MMC (maximum material condition), 557–559
 - of orientation, 566
 - parallelism, 569
 - perpendicular, 564–565
 - perpendicularity, 566–568
 - plus and minus, 519, 520, 522
 - adding, 524–525

- creating, 522–523
- positional, 573–578, 584–587
- profile, 570–572
- RFS (regardless of feature size), 556–559
- runout, 572–573
- shaft, 535–537
- shaft basis, 629–630
- standard, 528
- standard fit, applying to an assembly
 - drawing, 634–635
- studies, 532
 - maximum length, calculating, 532
 - minimum length, calculating, 533
- symmetric, 524–525
- unilateral, 519–520
- virtual condition, 578–579
 - calculating for the hole, 579
 - calculating for the shaft, 579
- zero limit, 521
- tolerances, bilateral, 520
- toolbar, S Key
 - customizing, 49–51
 - removing a tool from, 51
- Toolbox, bearings, 623–626
- tool/s
 - Annotation
 - Auto Balloon, 327
 - Autodimension, 457–460
 - Balloon, 326–328
 - Datum Feature, 563, 564
 - Geometric Tolerance, 565–566
 - Note, 337–338
 - Smart Dimension, 6, 8, 11–12, 17, 23, 387, 451, 457
 - Assembly, 305
 - Animate Collapse, 339–340
 - Clearance Verification, 353, 355–356
 - Interference Detection, 349–350
 - Mate, 311–316, 318–320
 - Motion Study, 344–346
 - Move Component, 308–309
 - Rotate Component, 309–310
 - assigning to the Mouse Gestures
 - wheel, 46–47
 - Circle, 9
 - Exploded View, 321–324, 622
 - Features, 3, 129
 - Chamfer, 153–156
 - Circular Sketch Pattern, 176–177
 - Curve Driven Pattern, 208–213
 - Draft, 172–173
 - Extrude Boss/Base, 129–136
 - Extruded Cut, 137–138, 203
 - Fillet, 146–153
 - Hole Wizard, 138–142, 143–146, 384–387, 462, 466–471
 - Linear Sketch Pattern, 174–175
 - Lofted Boss/Base, 165–168
 - Mirror, 177–179
 - Revolved Boss/Base, 156–159
 - Revolved Cut, 159–160
 - Shell, 168–169
 - Swept Boss/Base, 170–172
 - Wrap, 191–194
 - Hole Callout, 477
 - Hole Wizard, 32

- Line, 5, 22, 28
- Make Fixed, 24
- Model View, 252–253
- Perimeter Circle, 54–56
- Projected View, 249–250
- Rectangle, 15–17
- Sketching, 4, 110–111
 - 3 Point Arc Slot, 64
 - Centerline, 110–111
 - Centerpoint Arc, 67–68
 - Centerpoint Arc Slot, 65–66
 - Centerpoint Straight Slot, 63
 - Chamfer, 82–83
 - Circle, 52–54
 - Circular Sketch Pattern, 97–99
 - Copy Entities, 102
 - Ellipse, 73
 - Extend Entities, 89–90
 - Fillet, 81
 - Jog Line, 110
 - Line, 5, 22, 28
 - Linear Sketch Pattern, 95–97
 - Mirror Entities, 92–94
 - Move Entities, 100
 - Offset Entities, 90–92
 - Parabola, 76–77
 - Parallelogram, 59
 - Partial Ellipse, 75–76
 - Perimeter Circle, 66–67
 - Point, 87
 - Polygon, 71–72
 - Rotate Entities, 103
 - Scale Entities, 103–104
 - Spline, 73

- Split Entities, 106–109
- Straight slot, 61–62
- Stretch Entities, 104–106
- Tangent Arc, 68–69
- Text, 84–87
- Trim Entities, 88
- Smart Dimension, 6, 8, 11–12, 17, 23, 387, 451, 455–457
- Smart Fasteners, 398–400
- Standard 3 View, 249
- Top View, 20
- Undo, 23
- View Orientation, 19–20, 33
- Top sketch plane, 3, 4
- Top View tool, 20
- torsional springs, drawing, 184–187
- transition fit, 539
- trimming, entities, 88

U

- Undo tool, 23
- unidirectional dimensioning, 462
- unilateral tolerance, 519–520
- units, 14–15, 461–462. *See also* English units; metric units

V

- vertex chamfer, 155–156
- View Orientation tool, 19–20, 33
- View Selector cube, 19–20
- views
 - auxiliary, drawing, 262–266
 - broken, 259–261

- detail, drawing, 261–262
- orthographic, 229
 - ANSI standards, 229
 - compound lines, 237
 - first-angle projection, 229–230, 243, 266–268
 - hidden lines, 234–235
 - moving, 249
 - normal surfaces, 233–234
 - oblique surfaces, 238
 - precedence of lines, 235–236
 - side view orientations, 231–232
 - slanted surfaces, 236–237
 - third-angle projection, 229–230, 231, 243
- section, 250–251
 - aligned, 258–259
 - changing the style, 257
 - drawing, 252–257
- virtual condition, 556, 578–579
 - calculating for the hole, 579
 - calculating for the shaft, 579

W

- washers, 393–394
- whole depth, 655
- working depth, 655
- Wrap tool, 191–194
- wrapping text, 87

X-Y-Z

- zero limit, 521
- zooming, rectangles, 19