

MASTERING SOLIDWORKS®

The Design Approach

THIRD EDITION



IBRAHIM ZEID
NATHAN BROWN

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Mastering SolidWorks®

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The Design Approach

Third Edition

***Ibrahim Zeid
Nathan Brown***

Mastering SolidWorks

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Features of Mastering SolidWorks®: The Design Approach

Tutorial 4-6: Create Features

This tutorial covers the creation of these features: chamfer, fillet, slot, shell, draft, and rib. All dimensions are inches. Here are useful observations:

1. Make sure to pay attention to the visual clues shown in the left pane while creating these features.
2. For example, the box symbol under **Chamfer parameters** indicates that you can chamfer a face, an edge, or a vertex (corner point). As expected, chamfering a face chamfers all its edges. Chamfering a corner chamfers the three edges that meet there.
3. A rib requires a profile sketch (e.g., a line or stepwise line) and a thickness.

Tutorials

Step 1: Create *Sketch1* and *Block* feature: **File** > **New** > **Part** > **OK** > **Top Plane** > **Extruded Boss/Base** on **Features** tab > **Center Rectangle** on **Sketch** tab > click origin and sketch and dimension as shown > exit sketch > reverse extrusion direction > enter 0.5 for thickness **D1** > **✓** > **File** > **Save As** > *tutorial4.6* > **Save**.

Step 2: Chamfer an edge of *Block* feature: **Fillet** dropdown on **Features** tab > **Chamfer** > select *Block* edge > shown

Step 5: Shell *Block* feature: **Shell** on **Features** tab > select top face of *Block* > enter 0.1 for wall thickness **D1** > **✓**.

Step 6: Draft *Block* feature: Delete the chamfer, fillet, and shell features > **Draft** on **Features** tab > enter 10 degrees for **Draft Angle** > select top face of *Block* as **Neutral Plane** > select *Block* four side faces to draft > **✓**.

Step-by-Step Instructions

HANDS-ON FOR TUTORIAL 12-1. Edit the title block to add a tolerance general note in the **Comments** box of the title block. The note should read:

GENERAL TOLERANCE
 .X ± .030
 .XX ± .010
 .XXX ± .005
 .XXXX ± .0005

Hands-on for Tutorials

Example 12.1 Calculate the limits and tolerance zones for the following three fits: clearance of RC3, transition of LT4, and interference of FN2. Use a basic size of 5.0000 in.

Solution Following the above four steps, Table 12.2 shows the results.

Fit	d_{\min}	d_{\max}	d_{\min}	d_{\max}	h	s	A
RC3 (H7/f6)	5.0000	5.0016	4.9974	4.9984	0.0016	0.0010	0.0016
LT4 (H8/k7)	5.0000	5.0025	5.0001	5.0017	0.0025	0.0016	-0.0017
FN2 (H7/s6)	5.0000	5.0016	5.0035	5.0045	0.0016	0.0010	-0.0045

Examples and Solutions

problems

1. List the sources of variability in manufacturing.
2. Why do we need tolerances?
3. List the two types of tolerances. What does each type control?
4. Inspection gauges are used to check whether a part is within its tolerance limits. Perform an in-depth research study on inspection gauges including their types, their design, and how they are used during part inspection.
5. What is the difference between a nominal and a basic size? Give an example.
6. Three types of tolerances exist: unilateral, bilateral, and symmetric. Describe each type. Give a numerical example for each type.

Problems

The target audience for this book is college students in courses that use SolidWorks to learn and master CAD/CAM for design, visualization, prototyping, and manufacturing. The book's primary market is four-year colleges and two-year community colleges. Freshman Engineering Design courses should find this book useful, refreshing, and interesting. Other important markets include high schools, professionals, and training courses. We have written the book with the target audience in mind. Page iii highlights some of the book's features.

The book includes relevant math in Chapter 8 (Curves), Chapter 9 (Surfaces), and Chapter 13 (Analysis Tools). The math is concentrated in one or two sections in each of these three chapters. We include the math for two reasons. First, it shows students who are curious how CAD/CAM systems work "under the hood." Second, it broadens the book's appeal to many students, professors, and readers. This math may be ignored without affecting the continuity of the coverage of the material in any of these three chapters.

The philosophy behind the book is original, unique, and effective. We cover and present SolidWorks as a design system rather than a software program. Thus, instead of focusing on describing SolidWorks menus and syntax, we describe design approaches, methodologies, and techniques to help CAD designers/engineers and draftspersons achieve engineering tasks in the fastest, easiest, and most effective way.

Based on this philosophy, the book focuses on design, modeling, and drafting concepts instead of menus and commands. Thus, we present command sequences to achieve CAD and modeling tasks. Of course, we provide SolidWorks syntax and details, but do so in accordance with the proposed philosophy of the book. We start with a CAD task to accomplish (what to do) and then go about accomplishing it (showing how to use SolidWorks to do it). This philosophy is more motivating to student learning than simply going through layers of menus and commands.

The book approach is designed to showcase SolidWorks as a powerful modeling and design system instead of only a software program. We include challenging modeling and design examples and problems in the book. As part of the book's unique approach, we cover the theoretical concepts behind the various functions of SolidWorks. This should provide information to curious minds about why things work the way they do, as well as explain their limitations and use.

The book provides abundant illustrations, step-by-step instructions, and rich and challenging end-of-chapter problems. The book is suitable for use at various levels, from freshman to senior to graduate courses. Instructors can choose the chapters and topics that suit their teaching needs and courses. They can also choose the level of depth. The book includes both examples and tutorials. An example covers one concept whereas a tutorial is more comprehensive by covering a full design task. Most examples and tutorials have a hands-on exercise at the end that serves two purposes. First, it ensures that the student has completed the example or tutorial, because it builds on it. Second, it both challenges and extends the student's understanding.

The book is organized into parts and chapters. Instructors may cover the chapters in any order to fit their course and student needs. However, we recommend covering Chapters 1 and 2 first to build a sound foundation in 3D CAD/CAM modeling concepts. Chapter 1 is designed to provide a quick grasp of basic functionalities: create parts, create assemblies, and create drawings. These three functionalities correspond to the three modes of SolidWorks: part, assembly, and drawing. Therefore, students can start designing basic and simple products after using only one chapter of the book; they do not have to wait until later chapters to learn how to design and document simple parts and assemblies. Later chapters provide further details. Thus, Chapter 1 provides breadth and the remainder of the book provides depth. Chapter 2 covers essential concepts required for a sound understanding of 3D modeling and efficient use of today's parametric features-based solid modeling CAD/CAM systems such as SolidWorks.

Acknowledgments from Second Edition

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—Abe Zeid

Contents at a Glance

Preface	vi
Part I Computer Aided Design (CAD) Basics	1
Chapter 1 Getting Started	3
Chapter 2 Modeling Management	37
Chapter 3 Design Intent	81
Part II Basic Part Modeling	97
Chapter 4 Features and Macros	99
Chapter 5 Drawings	135
Chapter 6 Assemblies	157
Chapter 7 Rendering and Animation	195
Part III Advanced Part Modeling	215
Chapter 8 Curves	217
Chapter 9 Surfaces	249
Chapter 10 Sheet Metal and Weldments	289
Chapter 11 Sustainable Design	319
Part IV Part Development and Analysis	337
Chapter 12 Tolerances	339
Chapter 13 Analysis Tools	377
Part V Part Manufacturing	409
Chapter 14 Rapid Prototyping	411
Chapter 15 Numerical Control Machining	427
Chapter 16 Injection Molding	463
Appendix A ANSI and ISO Tolerance Tables	491
Appendix B SolidWorks Certification	505
Index	517

Contents

Part I Computer-Aided Design (CAD) Basics

Chapter 1 Getting Started

1.1 Introduction	3
1.2 Engineering Design Process	4
1.3 CAD Process	4
1.4 Manufacturing Process	5
1.5 CAM Process	6
1.6 SolidWorks Installation and Resources	6
1.7 SolidWorks Overview	8
1.8 Customize SolidWorks	11
1.9 Modeling Plan	12
1.10 Part Creation	14
1.11 Examples	15
1.12 Tutorials	22
Tutorial 1–1 Create a Flap	22
Tutorial 1–2 Create a Pin and Bushing Bearing	24
Tutorial 1–3 Create a Pillow Block	25
Tutorial 1–4 Create Drawings	28
Tutorial 1–5 Create an Assembly	29

Problems	32
----------	----

Chapter 2 Modeling Management

2.1 Overview	37
2.2 Types of CAD Models	37
2.3 Planning Part Creation	39
2.4 Part Topology	40
2.5 Parametric Modeling	40
2.6 Customizing SolidWorks	42
2.7 Productivity Tools	43
2.8 Coordinate Systems	43
2.9 Sketch Planes	44
2.10 Sketch Status	46
2.11 Part Feature Tree	47
2.12 Construction Geometry	48
2.13 Reference Geometry	48
2.14 Sketch Entities	50
2.15 Sketch Relations	51
2.16 Equations and Link Values	51
2.17 Geometric Modifiers	53

2.18 Grids	54
2.19 Patterns	54
2.20 Selecting, Editing, and Measuring Entities	58
2.21 Boolean Operations	59
2.22 Templates	61
2.23 Viewing	61
2.24 Model Communication	62
2.25 Tutorials	63
Tutorial 2–1 Create a Coil Spring	63
Tutorial 2–2 Create a Mount Plate	65
Tutorial 2–3 Create a Bracket	66
Tutorial 2–4 Create a Wheel	67
Tutorial 2–5 Create a Tire and a Pin	69
Tutorial 2–6 Create a Caster Assembly	70

Problems	73
----------	----

Chapter 3 Design Intent

3.1 Introduction	81
3.2 Capturing Design Intent	82
3.3 Documenting Design Intent	83
3.4 Comments	83
3.5 Design Binder	84
3.6 Equations	85
3.7 Design Tables and Configurations	85
3.8 Dimension Names	85
3.9 Feature Names	85
3.10 Folders	86
3.11 Tutorials	86
Tutorial 3–1 Design Intent via Two Modeling Plans	86
Tutorial 3–2 Design Intent via Three Modeling Plans	89
Tutorial 3–3 Design Intent via Design Specifications	91
Tutorial 3–4 Design Intent via Mating Conditions	93

Problems	95
----------	----

Part II Basic Part Modeling

Chapter 4 Features and Macros

4.1 Introduction	99
4.2 Features	100
4.3 Spur Gears	103
4.4 Design Library and Library Features	109
4.5 Configurations and Design Tables	110

4.6 Macros	111	6.7 Assembly Exploded Views and Animations	164
4.7 Tutorials	114	6.8 Assembly Motion Study	165
Tutorial 4–1 Create Sweep Features	114	6.9 Interference and Collision Detections	166
Tutorial 4–2 Create Loft Features	116	6.10 Assembly Design Tables	166
Tutorial 4–3 Use the Hole Wizard	118	6.11 Tutorials	166
Tutorial 4–4 Create Compression Spring	119	Tutorial 6–1 Create a Cam and a Follower	
Tutorial 4–5 Create Spiral	120	Assembly	167
Tutorial 4–6 Create Features	121	Tutorial 6–2 Create a Working Hinge Assembly	168
Tutorial 4–7 Use the Smart Fasteners Wizard	122	Tutorial 6–3 Mate Two Gears with a Gear Mate	169
Tutorial 4–8 Create a Bolt	123	Tutorial 6–4 Create a Functional Rack and Pinion	171
Problems	126	Tutorial 6–5 Create a Functional Ball Screw	173
Chapter 5 Drawings	135	Tutorial 6–6 Study Universal Joint Motion	174
5.1 Introduction	135	Tutorial 6–7 Create a Motion Study	176
5.2 Engineering Drafting and Graphics Communication	136	Tutorial 6–8 Detect Collision and Interference	178
5.3 ASME Abbreviation Rules	137	Tutorial 6–9 Create a Design Table	179
5.4 ASME Drafting Rules	138	Tutorial 6–10 Create a Part in the Context of	
5.5 ASME Dimensioning Rules	139	an Assembly	180
5.6 Dimensions	142	Problems	183
5.7 Drawing Content and Layout	144	Chapter 7 Rendering and Animation	195
5.8 Angles of Projection	145	7.1 Introduction	195
5.9 Views	146	7.2 Scenes and Lighting	196
5.10 Sheets	148	7.3 Rendering Models	197
5.11 Title Blocks	149	7.4 Decals	198
5.12 Drafting Control	150	7.5 Textures	199
5.13 Tolerances	150	7.6 Materials	199
5.14 Bills of Materials	151	7.7 Appearance and Transparency	201
5.15 Model and Drawing Associativity	151	7.8 Background and Scenes	201
5.16 Design Checker	151	7.9 Cameras and Camera Sleds	201
5.17 Tutorials	152	7.10 Animation	201
Tutorial 5–1 Create Drawing Views	152	7.11 Tutorials	202
Tutorial 5–2 Insert Annotations	153	Tutorial 7–1 Apply Colors to Objects	202
Tutorial 5–3 Fill Title Block	153	Tutorial 7–2 Apply a Background and a Scene	203
Tutorial 5–4 Create Assembly Drawing with		Tutorial 7–3 Apply Lights to a Scene	204
Bill of Materials	154	Tutorial 7–4 Add Material and Transparency	205
Tutorial 5–5 Use Model-Drawing Associativity	155	Tutorial 7–5 Add a Camera to a Scene	206
Problems	156	Tutorial 7–6 Create a Motion Study	207
Chapter 6 Assemblies	157	Tutorial 7–7 Create a Camera-Sled Based	
6.1 Introduction	157	Animation	210
6.2 Assembly Mates	158	Problems	213
6.3 Bottom-Up Assembly Modeling	159	Part III Advanced Part Modeling	215
6.4 Top-Down Assembly Modeling	159	Chapter 8 Curves	217
6.5 The Assembly Tree	164	8.1 Introduction	217
6.6 Assembly Drawings	164	8.2 Curve Representation	218
		8.3 Line Parametric Equation	219

8.4 Circle Parametric Equation	220	Chapter 10 Sheet Metal and Weldments	289
8.5 Spline Parametric Equation	221	10.1 Introduction	289
8.6 Two-Dimensional Curves	222	10.2 Sheet Metal	289
8.7 Three-Dimensional Curves	223	10.3 Sheet Metal Features	291
8.8 Curve Management	224	10.4 Sheet Metal FeatureManager Design Tree	296
8.9 Tutorials	224	10.5 Sheet Metal Methods	297
Tutorial 8–1 Create a 2D Curve by Using an Explicit Equation	224	10.6 Weldments	299
Tutorial 8–2 Create a 2D Curve by Using a Parametric Equation	225	10.7 Weldment Features	301
Tutorial 8–3 Create a 3D Curve by Using a Parametric Equation	225	10.8 Weld Symbols	305
Tutorial 8–4 Create a 3D Curve by Using 3D Points	227	10.9 Tutorials	306
Tutorial 8–5 Create a 3D Curve by Using 3D Sketching	228	Tutorial 10–1 Create Sheet Metal	306
Tutorial 8–6 Create a 3D Curve by Using Composite Curves	229	Tutorial 10–2 Create a Sheet Metal Drawing	308
Tutorial 8–7 Create a 3D Curve by Projecting a Sketch onto a Curved Face	231	Tutorial 10–3 Create a Sheet Metal Part from a Solid Body	309
Tutorial 8–8 Create a 3D Curve Using Projected Curves	232	Tutorial 10–4 Create a Sheet Metal Part from a Flattened State	310
Tutorial 8–9 Create a Stethoscope Model	241	Tutorial 10–5 Create a Weldment	311
Problems	244	Tutorial 10–6 Create a Weldment Drawing	313
Chapter 9 Surfaces	249	Problems	316
9.1 Introduction	249	Chapter 11 Sustainable Design	319
9.2 Surfaces	249	11.1 Introduction	319
9.3 Using Surfaces in Solid Modeling	252	11.2 Design and Society	321
9.4 Surface Representation	254	11.3 Guidelines and Principles	321
9.5 Plane Parametric Equation	255	11.4 Life Cycle Assessment	323
9.6 Ruled Surface Parametric Equation	257	11.5 Impact Metric	325
9.7 Surface Visualization	260	11.6 Implementation	327
9.8 Surface Management	260	11.7 Design Activities	327
9.9 Tutorials	261	11.8 Sustainable Design Tools	328
Tutorial 9–1 Create Basic Surfaces: Extrude, Revolve, Loft, Sweep, Knit, and Radiate	261	11.9 SolidWorks Sustainability	329
Tutorial 9–2 Create Basic Surfaces: Planar, Filled, Boundary, and Offset	263	11.10 Tutorials	332
Tutorial 9–3 Visualize Surfaces	264	Tutorial 11–1 Redesign a Steel Washer	332
Tutorial 9–4 Create an Artistic Bowl	265	Problems	335
Tutorial 9–5 Use Surface Intersections	268	Part IV Part Development and Analysis	337
Tutorial 9–6 Create a Tablespoon	269	Chapter 12 Tolerances	339
Tutorial 9–7 Create a Computer Mouse	271	12.1 Introduction	339
Tutorial 9–8 Create a Baseball Hat	273	12.2 Tolerance Types	340
Tutorial 9–9 Create a Hair Dryer	277	12.3 Tolerance Concepts	340
Tutorial 9–10 Create an Oil Container	279	12.4 ASME Tolerance Rules	343
Problems	282	12.5 Tolerancing Tapers	347
		12.6 Limits of Dimensions	348
		12.7 Tolerance Accumulation	353
		12.8 Statistical Tolerancing	354

12.9 True Position	356	14.5 SolidWorks Triangulation	417
12.10 Geometric Tolerances	357	14.6 RP Steps	418
12.11 Datum Target Symbols	359	14.7 RP Building Techniques	419
12.12 Tolerance Interpretation	360	14.8 Bottle Prototype	420
12.13 Tolerance Analysis	362	14.9 Tutorials	421
12.14 SolidWorks Tolerance Analysis	364	Tutorial 14–1 Generate Part Prototype File	421
12.15 Tutorials	367	Tutorial 14–2 Generate Assembly Prototype File	422
Tutorial 12–1 Create Conventional Tolerances	367	Tutorial 14–3 Read Back an STL File	423
Tutorial 12–2 Create Geometric Tolerances	369	Problems	425
Tutorial 12–3 Define Datum Targets	370	Chapter 15 Numerical Control Machining	427
Tutorial 12–4 Tolerance a Taper	371	15.1 Introduction	427
Tutorial 12–5 Perform Tolerance Stack-up Analysis	372	15.2 Basics of Machine Tools	428
Problems	374	15.3 Basics of Machining	430
Chapter 13 Analysis Tools	377	15.4 Turning	438
13.1 Introduction	377	15.5 Drilling	438
13.2 Data Exchange	378	15.6 Milling	439
13.3 Mass Properties	381	15.7 Electrical Discharge Machining	439
13.4 Animation and Motion Analysis	385	15.8 Manufacturing of Design	441
13.5 Flow Simulation	386	15.9 SolidWorks DFMXpress	442
13.6 Finite Element Method	386	15.10 Basics of NC Machining	445
13.7 Finite Element Analysis	389	15.11 G-Code and M-Code Programming	447
13.8 SolidWorks Simulation	391	15.12 CAM Add-In Software	449
13.9 Von Mises Stress	391	15.13 Tutorials	449
13.10 Tutorials	396	Tutorial 15–1 Drill Holes	450
Tutorial 13–1 Export Native SolidWorks Files	396	Tutorial 15–2 Mill Faces	452
Tutorial 13–2 Import IGES and STEP Files into SolidWorks	396	Tutorial 15–3 Mill Pockets	455
Tutorial 13–3 Calculate Mass Properties of a Solid	397	Tutorial 15–4 Mill Slots	457
Tutorial 13–4 Perform Motion Analysis Using a Motor	398	Problems	460
Tutorial 13–5 Perform Static Linear FEA on a Part	403	Chapter 16 Injection Molding	463
Tutorial 13–6 Perform Thermal FEA on a Part	405	16.1 Introduction	463
Tutorial 13–7 Perform Flow Analysis on a Hose	406	16.2 Basics of Injection Molding Machines	464
Problems	408	16.3 Basics of Injection Molding	465
Part V Part Manufacturing	409	16.4 Basics of Mold Design	467
Chapter 14 Rapid Prototyping	411	16.5 Basics of Part Design	470
14.1 Introduction	411	16.6 Phases of Mold Design	471
14.2 RP Applications	412	16.7 SolidWorks Mold Design	472
14.3 RP Overview	414	16.8 Tutorials	473
14.4 RP Concepts	414	Tutorial 16–1 Create a Block Mold	473
		Tutorial 16–2 Create a Sandbox Mold	477
		Tutorial 16–3 Create a Hemisphere Mold	481
		Tutorial 16–4 Create an Easter Egg Mold	484
		Tutorial 16–5 Generate a Mold Drawing	487
		Problems	488

Appendix A	ANSI and ISO Tolerance Tables	491		
Appendix B	SolidWorks Certification	505		
	B.1 Certified SolidWorks Associate (CSWA)	505	B.6 CSWP–Simulation	507
	B.2 Certified SolidWorks Professional (CSWP)	506	B.7 CSWP–Mold Making	508
	B.3 CSWP–Surfacing	506	B.8 Testing Resources	508
	B.4 CSWP–Sheet Metal	507	B.9 Sample Test Questions	509
	B.5 CSWP–Weldments	507		
			Index	517

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Chapter	Figure	Credit
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6	FIG06–07_Step-02	Screenshot © 2020 Altra Industrial Motion Corp
6	FIG06–08_Step-01	Screenshot © 2020 Altra Industrial Motion Corp

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Part II

Basic Part Modeling

The primary goal of this part is to explore and cover the details of engineering drawings, assemblies, and rendering. We have covered these topics briefly in Part I. Each topic has its own chapter in Part II to understand it in depth. Part II also covers the full set of features that can be used in CAD modeling. In Part I, we purposely limited our models to the basic features of extrusions and revolves.

Chapter 4, “Features and Macros,” is all about when and how to use the full set of features available to design advanced parts with complex geometry. Chapter 5, “Drawings,” covers the details of drawings, including the creation and control of the title block. Chapter 6, “Assemblies,” covers assembly details, including the bottom-up and top-down approaches. Chapter 7, “Rendering and Animation,” closes Part II by showing how to create realistic renderings of parts and assemblies that show material and texture. CAD visualization is important to convey and present designs efficiently.

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4

chapterfour

Features and Macros

4.1 Introduction

We have been using a limited set of features thus far in the book. We have used extrusions and revolves. We have used the SolidWorks features **Extruded Boss/Base** and **Revolved Boss/Base** and their subtracting counterparts, **Extruded Cut** and **Revolved Cut**. These four features create one class of parts: those with constant cross sections. We use the extruded boss or cut to create uniform thickness parts. We use the revolved boss or cut to create axisymmetric parts. Amazingly, these four features can create 80% or more of the mechanical parts you are likely to need.

These four features cannot create some classes of parts: They cannot create parts whose cross sections are variable or parts that have nonplanar faces or other geometric shapes. The features that allow us to create these types of parts are **Lofted Boss/Base**, **Swept Boss/Base**, **Lofted Cut**, **Swept Cut**, **Hole Wizard**, **Rib**, **Draft**, **Shell**, and **Dome**, as shown in Figure 4.1. We cover all these features in this chapter. You can also access more features by clicking this sequence: **Insert** (menu) > **Features**.



Figure 4.1
Available features

A **feature** is defined as a solid that, when combined with other features (solids), creates parts. A CAD part consists of a set of features created in a certain sequence stored in its feature tree. Some features, such as bosses and cuts, originate as sketches, while others, such as shells and fillets, modify other features. Features are always listed in the feature tree (which SolidWorks calls the **FeatureManager Design Tree**) of the part.

Today's modeling is referred to as feature-based modeling, and the resulting models are known as feature-based models. The first feature you create in a part is known as the base feature. You use the base feature as the basis to create other features. A base feature obviously cannot be negative (i.e., a cut), and SolidWorks does not allow it. When you begin creating a feature, **Extruded Boss/Base** and **Revolved Boss/Base** are the only selectable feature types. You might also expect **Swept Boss/Base** and **Lofted Boss/Base** to be selectable when you begin creating a feature, but they are not. **Lofted Boss/Base** becomes selectable only after you create a sketch (profile), and **Swept Boss/Base** becomes selectable after you create a cross section and a path (sweep direction).

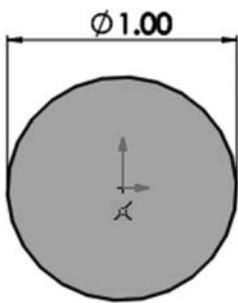
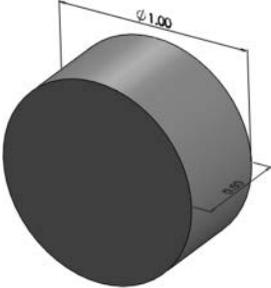
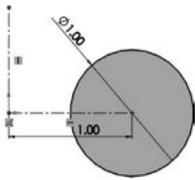
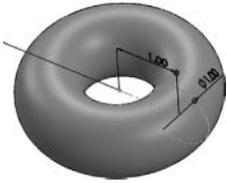
4.2 Features

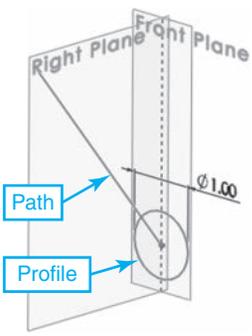
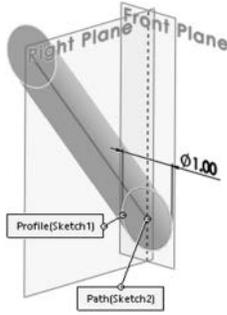
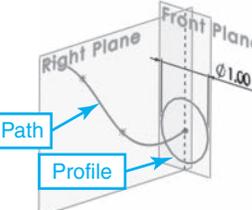
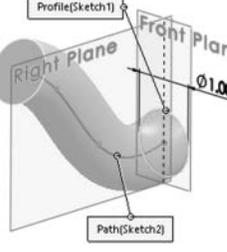
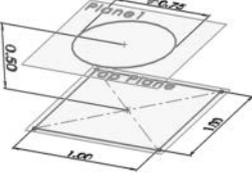
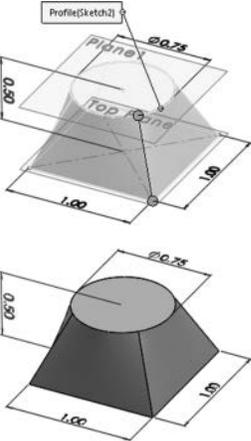
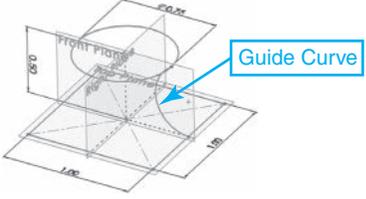
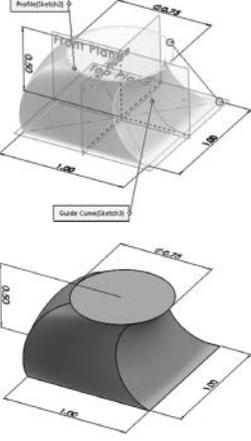
To master feature-based modeling, you should be able to answer three fundamental questions:

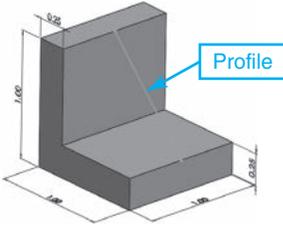
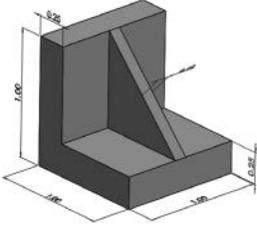
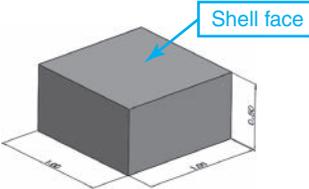
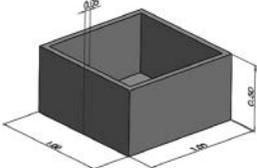
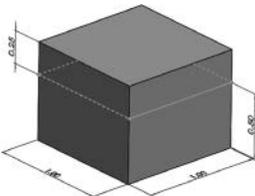
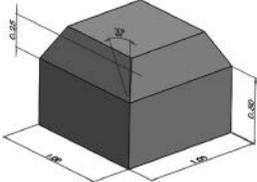
- 1 What are the available features that a CAD/CAM system offers for modeling parts?
- 2 What is the input required to create each feature?
- 3 Which feature should you use for a given modeling problem?

Section 4.1 and Figure 4.1 provide the answer to the first question. Table 4.1 answers the other two questions. It shows a simple basic example of each feature. Keep in mind that the third question may have multiple answers; one of them is always the best answer. For example, you may use a loft or a sweep. However, if a part has a constant cross section along a curve, sweep is better to use because it requires fewer steps to create the part. If the part has a variable cross section, a loft is better to use. The tutorials in this chapter provide some modeling examples.

Table 4.1
Available Features

No.	Feature	Input (sketch)	Resulting Feature	When to Use in Modeling?
1	Extrusion	Cross section and a thickness 		<ul style="list-style-type: none"> • Use for parts with constant cross section (CS) and uniform thickness (UT). • If needed, break part into subparts, each with a constant CS and UT.
2	Revolve	Cross section, an axis of revolution, and an angle of revolution 		<ul style="list-style-type: none"> • Use for parts that are axisymmetric. • If needed, break part into subparts, each of which is axisymmetric.

No.	Feature	Input (sketch)	Resulting Feature	When to Use in Modeling?
3	Sweep	<p>Linear sweep: cross section and a line as a path</p> 		<ul style="list-style-type: none"> Use for parts with constant cross section (CS) along a linear direction (path) that may or may not be perpendicular to the cross section. If the path is perpendicular to the cross section, the linear sweep becomes an extrusion.
		<p>Nonlinear sweep: cross section and a curve as a path</p> 		<ul style="list-style-type: none"> Use for parts with constant cross section (CS) along a nonlinear direction that may or may not be perpendicular to the cross section.
4	Loft	<p>Linear loft: at least two cross sections (profiles)</p> 		<ul style="list-style-type: none"> Use for parts with variable cross section along a given direction. The cross sections are blended linearly from one section to the other.
		<p>Nonlinear loft: at least two cross sections (profiles), and a curve as a guide curve</p> 		<ul style="list-style-type: none"> Use for parts with variable cross section along a given direction. The cross sections are blended nonlinearly from one section to the other, along the guide curve.

No.	Feature	Input (sketch)	Resulting Feature	When to Use in Modeling?
5	Rib	Rib profile (e.g., line or stepwise line) 		<ul style="list-style-type: none"> Use when a stiffener between angled walls (faces) of a part is required to increase part structural strength.
6	Shell	Shell face and shell wall thickness 		<ul style="list-style-type: none"> Use when you need to remove material from an existing part. The material removal (shelling) occurs in a direction perpendicular to the selected shelling face. While you can achieve the same result using an extrude cut for simple shells, a shell operation is faster to use.
7	Draft	Direction of pull, parting lines, and a draft angle. The direction of pull must be perpendicular to the parting lines. 		<ul style="list-style-type: none"> Use when you need to draft faces at an angle; usually used for injection molding to allow pulling the molded part from the mold cavity.

The other features shown in Figure 4.1 and not covered in Table 4.1 are covered in the tutorials in this chapter.

Example 4.1 Create the free-form torus shown in Figure 4.2.

Solution The torus shown in Figure 4.2 is a variation of the torus (donut shape) feature (No. 2) shown in Table 4.1. While that feature of Table 4.1 is a revolve, the free-form torus shown in Figure 4.2 can only be created as a sweep. The key modeling concept here is to use pierce relations to force the torus cross section (small circle) to conform to the sweep path (large circle) and the guide curve (closed spline), as shown in Figure 4.2. You pierce the small circle to the spline and pierce the center of the small circle to the large circle. These two pierce conditions force the small circle to become “elastic”; that is, it expands and shrinks, as it must always touch the spline and the big circle. Pierce condition is only available to pierce a point to a curve. You cannot pierce two curves. SolidWorks enables the pierce condition in the right context.

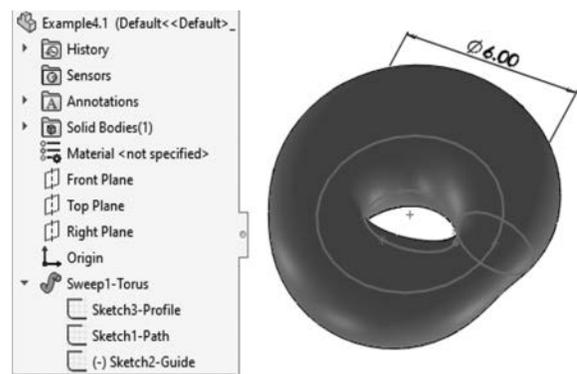
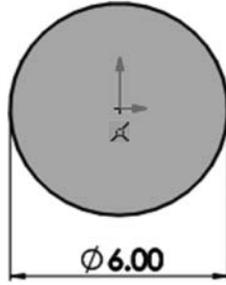
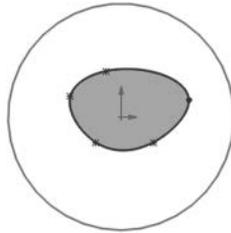


Figure 4.2
Free-form torus

Step 1: Create *Sketch1-Path* (sweep path): **File** > **New** > **Part** > **OK** > **Top Plane** > **Sketch** tab > **Circle** on **Sketch** tab > click origin to sketch and dimension as shown > exit sketch > **File** > **Save As** > *example4.1* > **Save**.

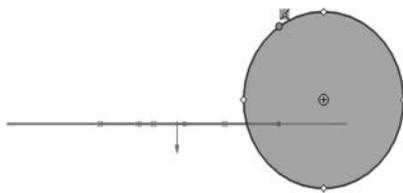


Step 2: Create *Sketch2-Guide* (sweep guide curve): **Top Plane** > **Sketch** tab > **Spline** on **Sketch** tab > sketch free spline as shown > exit sketch.



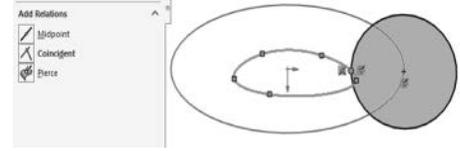
Note: *Sketch1-Path* and *Sketch2-Guide* are two separate sketches, and they both use **Top Plane**.

Step 3: Create *Sketch3-Profile* (sweep profile): **Front Plane** > **Sketch** tab > **Circle** on **Sketch** tab > sketch a circle anywhere > **Point** on **Sketch** tab > click circle anywhere.

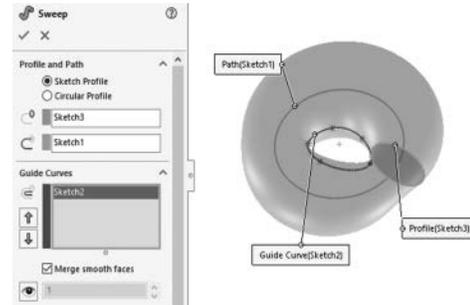


Note: Do not dimension the circle as doing so over-constrains it when you apply the pierce relation.

Step 4: Create pierce relations: While *Sketch3-Profile* is still open from Step 3, click small circle center + **Ctrl** + select large circle > **Pierce** relation > ✓ > select point created on circle + **Ctrl** + spline > **Pierce** relation > ✓ > exit sketch.



Step 5: Create *Sweep-Torus* feature: **Features** tab > **Swept Boss/Base** > select *Sketch3-Profile* as **Profile** > select *Sketch1-Path* as **Path** > select *Sketch2-Guide* as **Guide Curve** > ✓.



HANDS-ON FOR EXAMPLE 4.1

Re-create the free-form torus by replacing the spline by a circle that is not centric with the large circle.

4.3 Spur Gears

Gears are an important and essential mechanical element in mechanical design. A wide range of products and applications use gears. There are various types of gears: spur, helical, bevel, spiral, worm, planetary, and rack and pinion, to name a few. A spur gear is the simplest type of gear and the type we cover here. Typical mechanical design courses in colleges cover the principles and design of gears. In this section, we cover spur gears from a CAD point of view (i.e., how we construct a gear once it is designed). While gears are standard elements that can be purchased off the shelf (they can also be inserted from the SolidWorks Toolbox into a part or assembly file), it is important to learn how to create a gear feature in a CAD/CAM system.

A gear tooth is the intricate part of a gear. Figure 4.3 shows two meshing gears. Figure 4.4A shows the conjugate line and pressure angle. Figure 4.4B shows the involute profile. Gearing and gear meshing ensure that two disks (the two gears) in contact roll against one another without slipping.

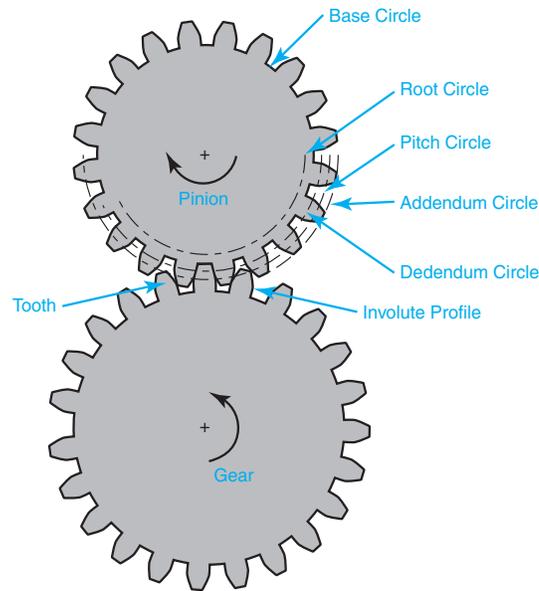


Figure 4.3
Meshing gears

Moreover, the gear teeth should not interfere with the uniform rotation that one gear would induce in the other—a requirement known as the conjugate action. The conjugate action also ensures that the perpendicular line to a tooth profile at its point of contact with a tooth from the other gear always passes through a fixed point on the centerline connecting the centers of the two meshing gears. Figure 4.4A shows the conjugate line. The conjugate line is also known as the line of force because the driving force from the driving gear (driver) is transmitted in the direction of this line to the other gear (driven). The angle between the perpendicular radius to the conjugate line and the centerline is always constant for two meshing gears. This angle is known as the *pressure angle* and is shown as the angle \emptyset in Figure 4.4A.

The key to successful functional gears is the conjugate action. While various profiles can produce conjugate action, the involute profile is the best because it allows for imperfections in gear manufacturing and yet maintains the conjugate action. The imperfection may produce a slightly different distance between the two shafts of the gears from the designed value. Figure 4.4B shows how the shape of the involute profile is generated. An **involute** is defined as the path of the endpoint of a cord when it is pulled straight (held taut) and unwrapped from a circular disk, as shown in Figure 4.4B. The involute geometry ensures that a constant rotational speed of the driving gear produces a constant rotational speed in the driven gear. For spur gears, the teeth are cut perpendicular to the plane of the gear, where the involute profile resides.

The creation of a gear CAD model requires two basic concepts: knowledge of the gear geometry and the involute equation. The geometry is shown in Figure 4.3. The **base circle** is the circle where the involute profile begins. The **pitch circle** defines the contact (pitch) point between the two gears (see Figure 4.4A). The **dedendum circle** is usually the same as the base circle, as can be concluded from Figure 4.4A (dedendum $d = r_p - r_b$). The **addendum circle** is the circle that defines the top of the tooth as shown in Figure 4.4C (addendum $a = r_a - r_p$, where r_a is the addendum circle radius). Typically, the addendum and the dedendum are equal. In such case, the pitch and base circle sizes determine the values for both. The **root circle** is

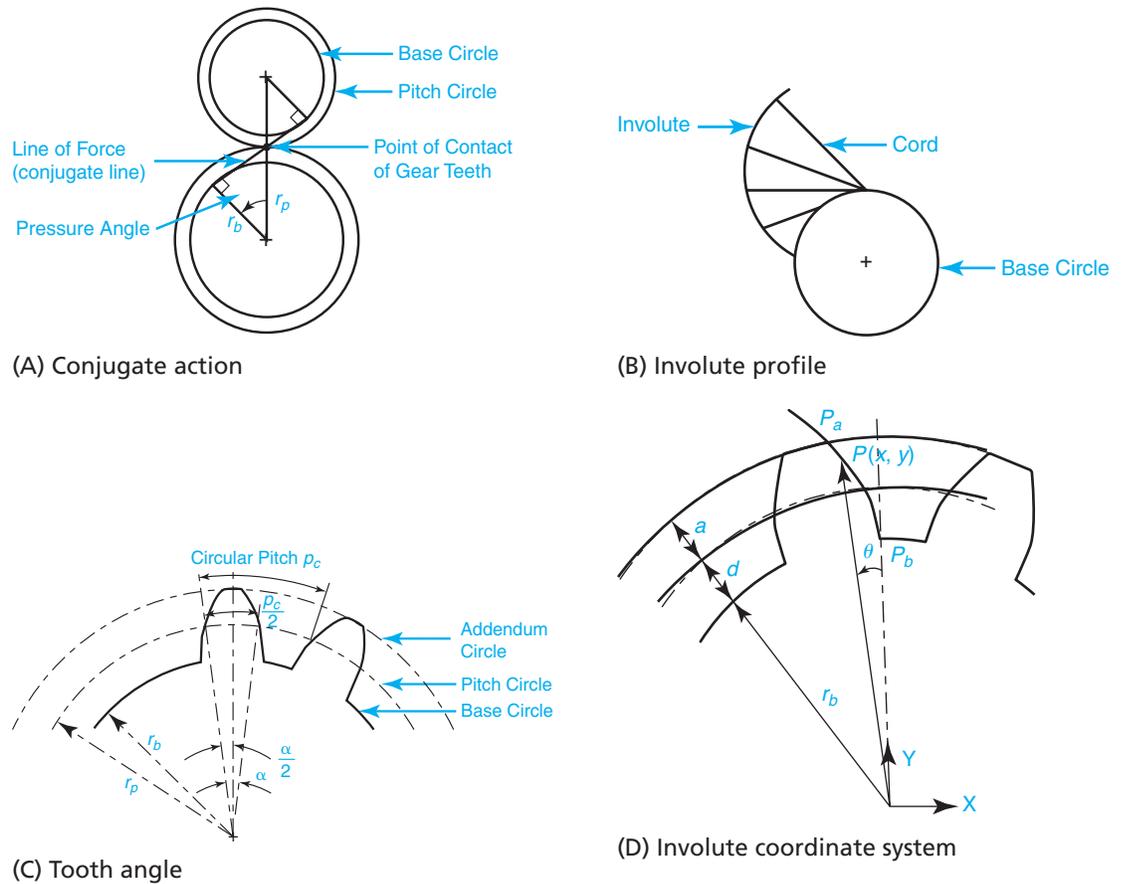


Figure 4.4
Details of a gear tooth

smaller than the base circle to allow cutting the tooth during manufacturing. The tooth profile between the base and root circles is not an involute. It could be any geometry, such as line.

The creation of a gear CAD model requires two steps: Calculate the tooth angle α and the tooth involute profile. While many books on mechanical engineering design offer extensive in-depth coverage of gear analysis, we offer a simplified but accurate version that enables us to create a CAD model of the gear. We begin with the definition of circular pitch. As shown in Figure 4.4C, the **circular pitch, p_c** , is defined as the distance along the pitch circle between corresponding points on adjacent teeth. As shown in Figure 4.4C, we use p_c as the circular pitch of the gear, r_p as the pitch circle radius, and α as the tooth angle. Using these variables, we can write:

$$p_c = \frac{\pi d_p}{N} \quad (4.1)$$

where $d_p = 2r_p$ is the pitch circle diameter and N is the number of gear teeth. From the tooth geometry shown in Figure 4.4C, we can write:

$$\frac{p_c}{2} = r_p \alpha \quad (4.2)$$

Substituting p_c from Eq. (4.2) into Eq. (4.1) and reducing gives:

$$\alpha = \frac{\pi}{N} \text{ radius or } \alpha = \frac{180}{N} \text{ degrees} \quad (4.3)$$

The derivation of the involute equation is more complex and is not covered here. We align the involute of one tooth with the XY coordinate system as shown in Figure 4.4D, where the lowest point P_b on the involute lies on the Y axis. This orientation does not represent a limitation but rather simplifies the form of the involute equation, which is therefore given by:

$$\begin{aligned}x &= -r_b(\sin \theta - \theta \cos \theta) & \theta \leq \theta \leq \theta_{\max} \\y &= r_b(\cos \theta + \theta \sin \theta)\end{aligned}\tag{4.4}$$

where r_b (the base circle radius) is given by (see Figure 4.4A):

$$r_b = r_p \cos \phi\tag{4.5}$$

and (x, y) are the coordinates of any point P on the involute at an angle θ , as shown in Figure 4.4D. The lowest point P_b on the involute corresponds to the value of $\theta = 0$ and lies on the base circle. Point P_a lies on the addendum circle and does not necessarily correspond to the value of $\theta = \theta_{\max}$. We can arbitrarily select a large enough value for θ_{\max} so that the involute crosses the addendum circle and then trim it to that circle. Therefore, we create the involute profile by generating points on it using Eq. (4.4) and connecting them with a spline curve, or we input Eq. (4.4) into a CAD/CAM system.

The root circle is always less than the base circle. For simplicity, we have the root circle radius, r_r , be 0.98 of the base circle radius. (There are other formulas that do not give consistent results.) Thus, we write:

$$r_r = 0.98r_b\tag{4.6}$$

The following steps summarize the calculations we need to create a gear CAD model:

- 1 The input parameters we need are the pitch circle radius r_p , the pressure angle ϕ , and the gear number of teeth N .
- 2 Calculate r_b using Eq. (4.5).
- 3 Calculate r_r using Eq. (4.6).
- 4 Calculate the gear dedendum $d = r_p - r_b$.
- 5 Assuming that the addendum and dedendum are equal, calculate the addendum circle radius as $r_a = r_p + a = r_p + d$ (see Figures 4.4C and 4.4D).
- 6 Use Eq. (4.3) to calculate the tooth angle α .
- 7 Enter the involute parametric equation given by Eq. (4.4) into a CAD/CAM system to sketch the involute curve as a spline.
- 8 Create one gear tooth and use a sketch circular pattern to pattern it to create all gear teeth.

Example 4.2 Create the CAD model of a spur gear with $r_p = 60$ mm, $\phi = 20^\circ$, and $N = 20$.

Solution Using the above calculation steps, you get $r_b = 56.382$ mm, $d = a = 3.618$ mm, $r_a = 63.618$ mm, $r_r = 55.254$ mm, and $\alpha = 9^\circ$. There are two methods to create the tooth involute curve.

In the first method, you use Eq. (4.4) with $\Delta\theta = 5^\circ$. You generate 11 points on the involute, for $\theta_{\max} = 50^\circ$. You generate the points on the involute curve. You then use **Insert** > **Curve** > **Curve Through XYZ Points**. A better method is to input Eq. (4.4) into SolidWorks and let SolidWorks generate the curve. You need to use radians for the angle θ . You use 1 radian for θ_{\max} . This value is arbitrary to ensure that the involute curve intersects and crosses the addendum circle to be able to trim it to the intersection point. Also, SolidWorks uses the parameter t , requiring us to replace θ with t when you input the equation. Figure 4.5 shows the spur gear. You create half a tooth, mirror it to create a full tooth, and use a circular pattern for the full tooth to create all teeth of the gear. Here are the detailed steps.

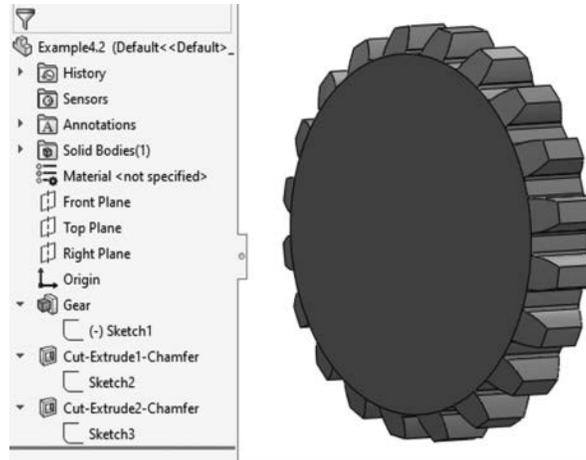
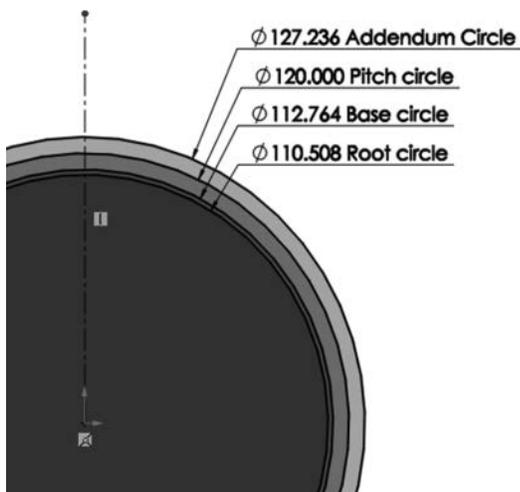


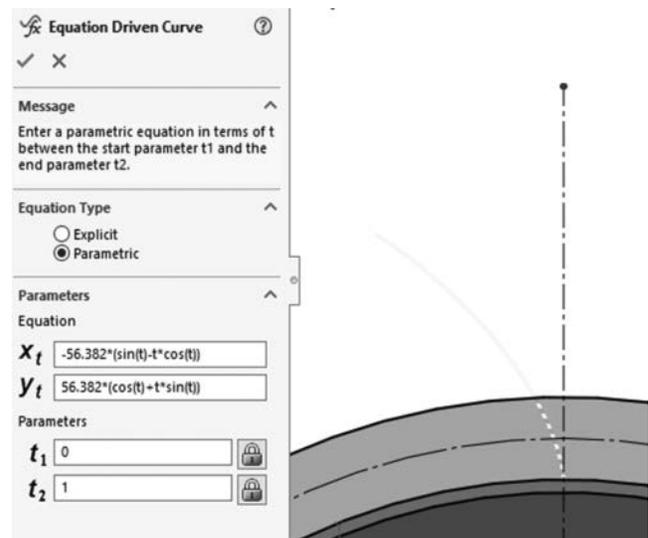
Figure 4.5
Spur gear

Step 1: Create *Sketch1* circles and axes: **File** > **New** > **Part** > **OK** > **Front Plane** > **Circle** on **Sketch** tab > sketch four circles and dimension as shown > **Centerline** on **Sketch** tab > sketch vertical line > **File** > **Save As** > *example4.2* > **Save**.

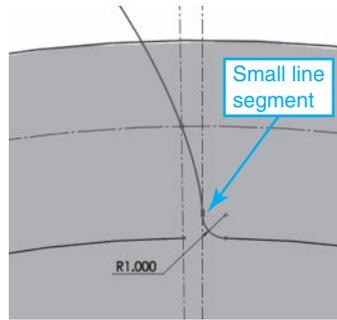
Note: Set the part units to mm before you start. The vertical centerline serves as a validation that the involute bottom endpoint passes through it when you create it in Step 2. Also, you will not close the sketch until you finish Step 5.



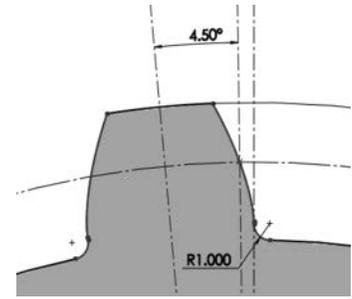
Step 2: Create *Sketch1* tooth involute: **Front Plane** > **Sketch** tab > **Spline** dropdown on **Sketch** tab > **Equation Driven Curve** > **Parametric** > enter x and y equations and limits as shown > ✓.



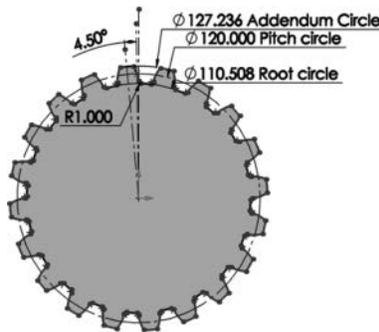
Step 3: Create *Sketch1* tooth bottom: **Line** on **Sketch** tab > sketch a line passing through bottom end of involute curve and crossing the root circle > **Esc** on keyboard > select the line + **Ctrl** on keyboard + involute curve > **Tangent** from **Add Relations** options on left pane > ✓ > **Point** on **Sketch** tab > create a point at intersection of involute and pitch circle (turn relations on: **View** > **Sketch Relations** to see all) > **Centerline** on **Sketch** tab > sketch a line passing through origin and crossing involute at any point > **Esc** key > select centerline just created + **Ctrl** + point > **Coincident** from **Add Relations** options on left pane > ✓ > **Trim Entities** on **Sketch** tab > **Trim to closest** > select line below root circle and select root circle between two centerlines > ✓ > **Fillet** on **Sketch** tab > enter 1 mm for radius > select line and root circle > **Yes** to continue > ✓ > select base circle > **Delete** key on keyboard.



Step 4: Create *Sketch1* tooth other half: **Trim Entities** on **Sketch** tab > **Trim to closest** > select involute top part > **Centerline** on **Sketch** tab > sketch a line passing through origin and to left of involute > **Smart Dimension** on **Sketch** tab > select the centerline just created and the other centerline to the right of it > enter 4.5 > ✓ > **Mirror Entities** on **Sketch** tab > select involute + **Ctrl** key + line segment connected to involute + fillet created in Step 3 > click **Mirror about** box on left of screen > select the far left centerline > ✓ > **Trim Entities** on **Sketch** tab > **Trim to closest** > click addendum circle outside tooth > click root circle inside tooth twice to delete its two segments inside the tooth > ✓.

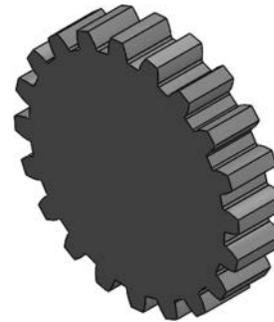


Step 5: Create *Sketch1* all gear teeth: **Linear Sketch Pattern** dropdown on **Sketch** tab > **Circular Sketch Pattern** > click first box under **Parameters** on left pane > select origin to define axis of pattern > click **Entities to Pattern** box > select the tooth profile 7 entities

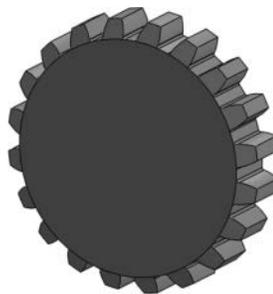


> enter 20 for the number of instances to create > ✓ > the sketch becomes over defined when you pattern the tooth because of the profile mirror of first tooth. Click this sequence to resolve it: **Over Defined** (shown red in status bar) > **Diagnose** > **Accept** > **Trim Entities** > **Trim to closest** > trim all excess from root circle (segments inside teeth) > ✓ > exit sketch.

Step 6: Create *Gear* feature: Select *Sketch1* > **Features** tab > **Extruded Boss/Base** > Enter 25 for **D1** > reverse extrusion direction > ✓.



Step 7: Create *Sketch2* and *Cut-Extrude1-Chamfer*: Select *Gear* front face > **Features** tab > **Extruded Cut** > **Circle** on **Sketch** tab > click origin and draw circle > select root circle and sketched circle and add **Conradial** relationship > exit sketch > enter 10 for **D1** > check **Flip side cut** > click **Draft** icon > enter 60 for **Draft Angle** > ✓.



Step 8: Create *Sketch3* and *Cut-Extrude2-Chamfer*: Repeat Step 7 but use the back face of *Gear*.

HANDS-ON FOR EXAMPLE 4.2

Add a hole and a keyway to the gear blank. Use a diameter of 50 mm for the hole and 10 × 10 mm keyway.

4.4 Design Library and Library Features

Design reuse and using off-the-shelf standard components are important concepts that speed up design and thus make it less expensive. The field of mechanical design has many standard parts that designers use every day in their designs (e.g., fasteners [nuts and bolts], gears, bearings). While these parts are universally standard, a company may have some parts that are unique and reusable only in that company's designs. SolidWorks provides the concepts of design library and library features to enable designers to reuse off-the-shelf components.

A **library feature** is a part that you create once and save in a library for reuse in the future. This library is known as the **design library**. You may save a library feature with the *.sldprt* or *.sldlfp* extension. Most of the time library features are inserted into assemblies as components or inserted into new empty (blank) parts. Commonly used library features include holes and slots. Using several library features to construct a single part saves time and also ensures consistency in your CAD models.

Using library features is easy: You drag a library feature from the design library and drop it onto the open part or assembly. SolidWorks asks you if you want to insert a copy or instance (**derived part**) of the part, as shown in Figure 4.6. If you select **Yes**, it inserts the copy in the open part. If you select **No**, it opens a blank part and inserts it there.

You save library features in a design library, which you can organize into folders. The path to the SolidWorks design library folder is *C:\Program Data\SolidWorks\SolidWorks version\design library*. (Make sure that hidden files are visible in Windows to see the *Program Data* folder.) Click the **Design Library** tab in the SolidWorks Task Pane (on the right of the screen), as shown in Figure 4.7A, to open the design library.

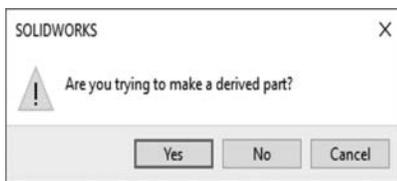
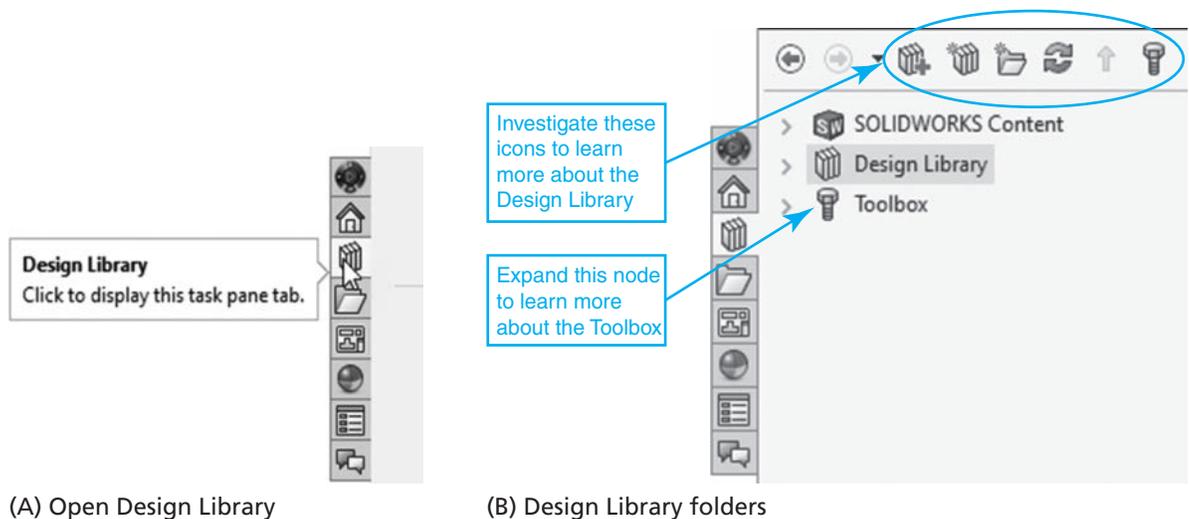


Figure 4.6
Using a library feature



(A) Open Design Library

(B) Design Library folders

Figure 4.7
SolidWorks Design Library

The library is organized into folders, and you can add new custom folders to the library. You should save your library features into the SolidWorks design library to have them accessible. If you do not, you have to navigate to the folder where you saved the features. The most commonly used SolidWorks library is **Toolbox**, shown in Figure 4.7B. Expand the Toolbox node and investigate its contents.

4.5 Configurations and Design Tables

A family of parts is a natural outcome from the concept of parametric solid modeling. Defining a solid (part) in a sketch by parameters (dimensions are values for the parameters) enables us to modify the dimensions and create a similar but different-size replica of the part with a click of a button. We refer to these replicas as a family of parts. SolidWorks calls them *configurations*. You can also create configurations of assemblies. The configurations are created by changing the dimensions of some key parameters of the part or assembly. The configurations have the same topology as the original but different geometry. For example, consider a two-feature part: a base block and a shaft boss. You configure the part into a square block and a skinny long boss or a rectangle block and short fat boss.

You use design tables to help create and control configurations in three ways: change sizes, change configurations of components, and/or suppress/unsuppress features. SolidWorks uses a Microsoft Excel sheet as its design table. You can insert a design table into an open part or assembly by clicking this sequence: **Insert** (menu) > **Tables** > **Design Table**. This opens the **Design Table** under the **PropertyManager** tab on the left pane, as shown in Figure 4.8. You can specify one of the three sources shown to create the design table. When you click the green checkmark to finish, SolidWorks acts accordingly. For example, if you select the **Auto-create** (default) option, SolidWorks displays a list of the open part dimensions and asks you to select some to include in the design table. The table is created with the current values of the part dimensions as the default configuration. The configuration appears as a row in the table. You can add other rows with different values for dimensions. Each row is a different configuration. The **Design Table** is saved under the **ConfigurationManager** tab.

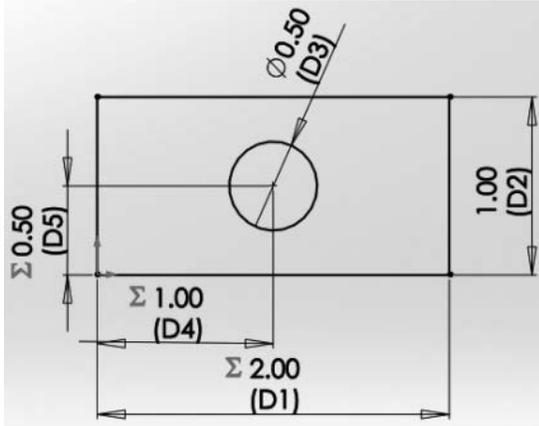


Figure 4.8
Design table

Example 4.3 Create design tables.

Solution This example builds on Example 2.4. It shows how to create a design table where you change the value of parameter (dimension name) *D2* to create four configurations of the sketch. The steps are as follows.

Step 1: Open *example2.4* part: **File > Open >** locate and select the file > **Open**.

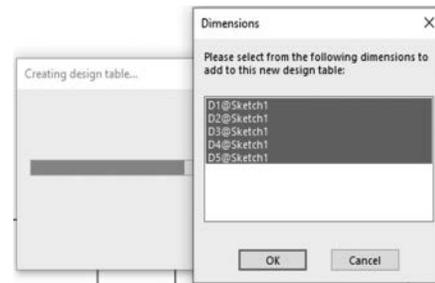


Step 3: Create three other configurations: Step 2 opens the Excel sheet shown > copy the *Default* config row and paste three times > edit the name cell and change configuration names as shown > edit the *D2* column and change as shown > click anywhere on screen away from Excel sheet to make it disappear > **OK** to accept the popup window indicating that new configurations were created.

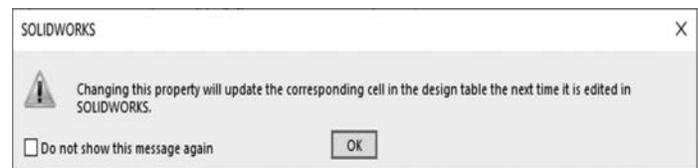
	A	B	C	D	E	F
1	Design table for: Example2.4					
2		D1@Sketch1	D2@Sketch1	D3@Sketch1	D4@Sketch1	D5@Sketch1
3	Default	=2 * "D2@Sketch1"	1	0.55	=.5 * "D2@Sketch1"	=.5 * "D2@Sketch1"
4	Config1	=2 * "D2@Sketch1"	2	0.55	=.5 * "D2@Sketch1"	=.5 * "D2@Sketch1"
5	Config2	=2 * "D2@Sketch1"	3	0.55	=.5 * "D2@Sketch1"	=.5 * "D2@Sketch1"
6	Config3	=2 * "D2@Sketch1"	4	0.55	=.5 * "D2@Sketch1"	=.5 * "D2@Sketch1"

Step 5: Investigate effect of design table on sketch parameters: Click feature tree > select *Sketch1* > observe that dimensions are displayed in a pink color and each time you click or move one, you get a window (shown to the right) warning you.

Step 2: Create design table with *Default* config: **Insert > Tables > Design Table > ✓ >** click *D1* (shown here) + **Shift** key on keyboard + *D5* (shown here) to select all dimensions > **OK**.



Step 4: Review the design configurations: Step 3 creates a tree with four nodes, as shown, under the **ConfigurationManager** tab > double-click any configuration to display the corresponding sketch > the current configuration is displayed in dark black in the tree.



HANDS-ON FOR EXAMPLE 4.3

Edit the sketch and change the value of *D2* to 6. What happens to the design table? Explain the result.

4.6 Macros

Design automation offers two benefits. First, it enhances productivity. Second, it helps with repetitive tasks that are mundane. For example, if you follow the same design process over and over, automating it would be the logical thing to do.

Macros aid in design automation. Macros are also viewed as a way to customize your CAD/CAM system. A **macro** is a short computer program

that is used to repeat commonly performed operations. That computer program is generated automatically by a CAD/CAM system in the background during use of the system, from the time you turn on the macro until you turn it off. You can use the macro after creation over and over, with different input values (e.g., new dimensions). After you create a macro, you can use it for recording, edit it, run it, pause it, stop it, and assign it to a shortcut key (hotkey) or to a menu item. When you assign a macro to a shortcut key or to a menu item, you can specify which method (function) of the macro to run. Click **Tools > Macro** to access the macro menu. SolidWorks saves the macro file in the same part folder and uses *.swp* as the file extension, with the default names *Macro1.swp*, *Macro2.swp*, and so on, unless you change them.

A higher level of automation than using macros is to use Visual Basic (VB) or another programming language to perform full automation and have better control of the automation. As a matter of fact, VB is the programming engine behind macros. Instead of writing the macro VB code, the SolidWorks macro interface enables us to generate the code automatically while you perform the design tasks as usual. It is this VB code that you save in a file when you save the macro. You can use the VB editor to edit and tweak the VB code.

Macro VB code uses the SolidWorks API (application programming interface). The code makes calls to API functions. Think of the API as a gateway between the application you want to write and SolidWorks code that has been already written. In other words, the API provides access to the SolidWorks geometric engine.

You can learn VB programming by creating multiple macros, studying their generated VB code, and expanding on it. VB is an object-oriented programming (OOP) language that requires knowledge and understanding of object-oriented design and how objects are defined and implemented.

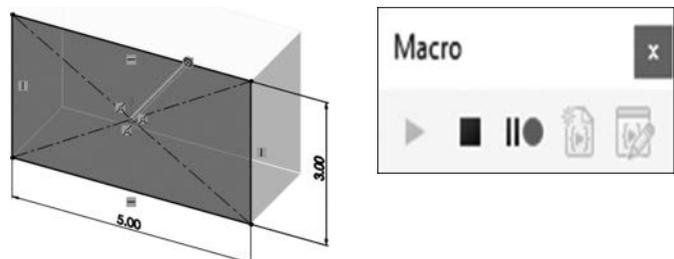
The programming approach could be useful for creating an entire assembly from a few parameters. You can write a program to define some variables and store them in a row in a design table. Each row represents a new version of the assembly. You delete all rows from the table and keep the last row, which is the new assembly.

Example 4.4 Develop a macro to create an extrusion.

Solution This example illustrates the creation and use of macros. It shows how to create a block extrusion and record the steps of creating it in a macro.

Step 1: Turn on macro and create *Sketch1* and *Boss-Extrude1* feature:
File > New > Part > OK > Tools > Macro > Record > Front Plane > Extruded Boss/Base on **Features** tab > **Sketch** tab > **Center Rectangle** on **Sketch** tab > sketch a rectangle and dimension as shown > exit sketch > enter 2 for **D1** > reverse extrusion direction > ✓ > **File > Save As > example4.4 > Save.**

Note: **Macro > Record** opens the **Macro** recording window shown. Hover over its buttons to read them.



Step 2: Stop and save macro: **Tools > Macro > Stop** (or click black square on **Macro** window shown in Step 1) > type *BlockShaft* for macro name in the **Save As** window that opens > **Save**.

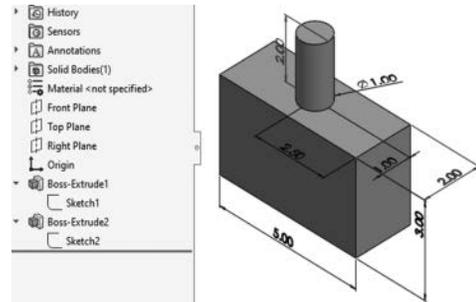
Note: The full macro file name is *BlockShaft.swp*. The default folder for the file is the part file folder from Step 1.

Step 3: View the macro VB code: **Tools > Macro > Edit** > select *BlockShaft.swp* > **Open**. The editor displays all the lines of code associated with the macro. Figure 4.9 shows the first lines of the macro VB code. Explore the code and try to understand which sections pertain to which steps performed in SolidWorks.

Step 4: Run the macro: Open a new part or delete the feature from the current part > **Tools > Macro > Run** > select *BlockShaft.swp* > **Open** > enter 8 for rectangle width when dimension box appears > ✓ > enter 6 for rectangle height when dimension box appears > ✓.

HANDS-ON FOR EXAMPLE 4.4

Modify the part as shown to the right and re-create the macro. Rerun the macro twice to investigate locating the shaft to the left or to the right side from the center. This simulates the idea of using a macro to investigate “what if” design scenarios such as sizes or feature locations.



```

Microsoft Visual Basic for Applications - BlockShaft - [BlockShaft1 (Code)]
File Edit View Insert Format Debug Run Tools Add-Ins Window Help
Ln 15, Col 17
Project - BlockShaft
BlockShaft
SOLIDWORKS OI
Modules
BlockShaft1
Properties - BlockShaft
BlockShaft Module
Alphabetic Categorized
(Name) BlockShaft1
(General) main
C:\Users\npbrow02\AppData\Local\Temp\swx13880\Macro1.swb - macro recorded on 07/26/20 by npbrow02
Dim swApp As Object
Dim Part As Object
Dim boolstatus As Boolean
Dim longstatus As Long, longwarnings As Long

Sub main()

Set swApp = Application.SldWorks

Set Part = swApp.ActiveDoc
Dim myModelView As Object
Set myModelView = Part.ActiveView
myModelView.FrameState = swWindowState_e.swWindowMaximized
boolstatus = Part.Extension.SelectByID2("Front Plane", "PLANE", 0, 0, 0, False, 0, Nothing, 0)
Part.SketchManager.InsertSketch True
Part.ClearSelection2 True
boolstatus = Part.Extension.SetUserPreferenceToggle(swUserPreferenceToggle_e.swSketchAddConstToRectEntity, swUserPref
boolstatus = Part.Extension.SetUserPreferenceToggle(swUserPreferenceToggle_e.swSketchAddConstLineDiagonalType, swUser
Dim vSkLines As Variant
vSkLines = Part.SketchManager.CreateCenterRectangle(0, 0, 0, 4.85360263446762E-02, 4.02982604054422E-02, 0)
Part.SetPickMode
Part.ClearSelection2 True
boolstatus = Part.Extension.SelectByID2("Line1", "SKETCHSEGMENT", 0.012913254715556, -3.98529757600781E-02, 0, False,
Dim myDisplayDim As Object
Set myDisplayDim = Part.AddDimension2(-4.45284645363975E-04, -6.92417623541022E-02, 0)
Part.ClearSelection2 True
Dim myDimension As Object
Set myDimension = Part.Parameter("D1@Sketch1")
myDimension.SystemValue = 0.127
boolstatus = Part.Extension.SelectByID2("Line4", "SKETCHSEGMENT", 6.23348623853211E-02, 2.76720183486239E-02, 0, False,
Set myDisplayDim = Part.AddDimension2(0.103697247706422, 2.62155963302754E-03, 0)
boolstatus = Part.Extension.SelectByID2("D1@Sketch1@example4.4.SLDPRT", "DIMENSION", 0, 0, 0, False, 0, Nothing, 0)
Part.ClearSelection2 True
Set myDimension = Part.Parameter("D2@Sketch1")
myDimension.SystemValue = 0.0762
Part.ClearSelection2 True
Part.SketchManager.InsertSketch True

```

Figure 4.9
VB editor window

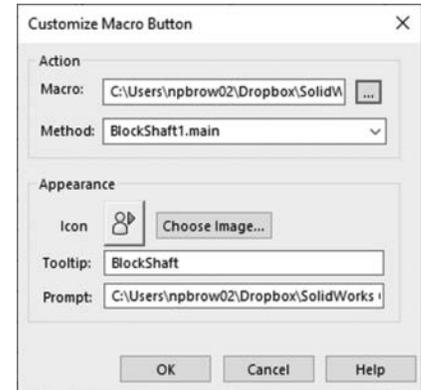
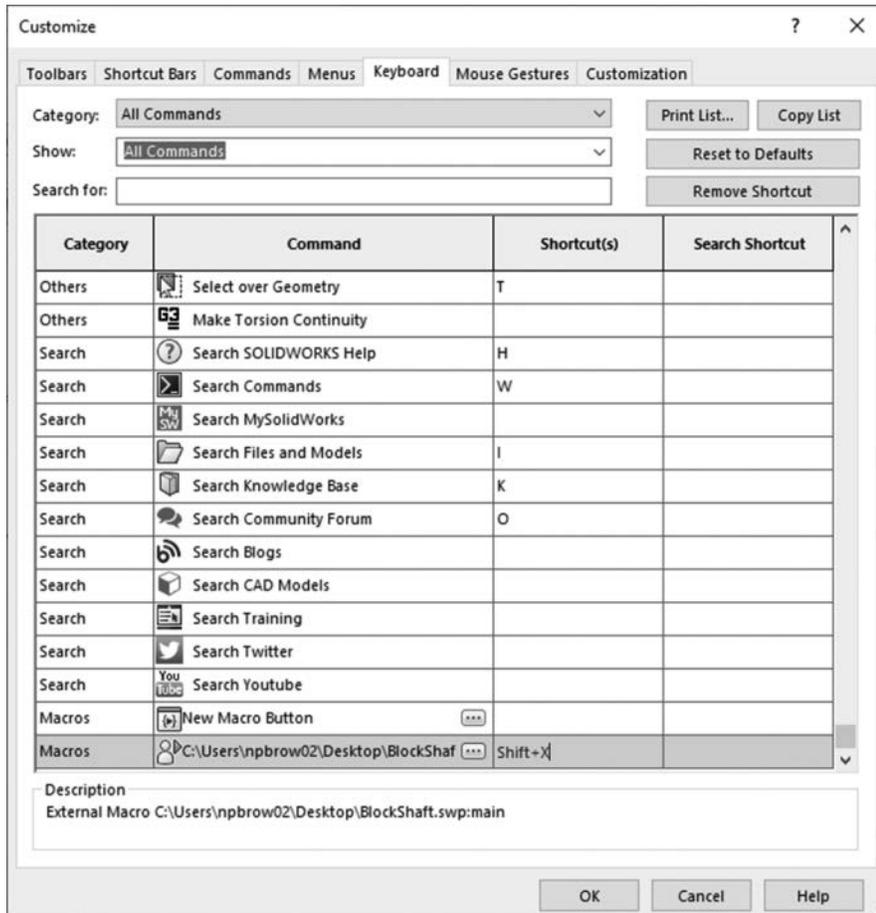
Example 4.5 Create a hotkey for a macro.

Solution This example assigns the macro from Example 4.4 to the **Shift+X** hotkey on the keyboard. When the user presses this combination on the keyboard, the macro runs.

Step 1: Create macro hotkey: **File > Open > locate example4.4 > Open.**

Step 3: Create hotkey: Click **Shortcut(s)** column in **Macros** row as shown > **Shift+X** to add shortcut as shown below > **OK.**

Step 2: Locate macro file: **Tools > Customize > Keyboard** tab > scroll to bottom and locate **Macros** row > click ellipsis button (...) in this row to open window shown > click the browse button (...) > locate macro file (.swp extension) > **Open > OK.**



Step 4: Use hotkey to run macro: Press **Shift+X** in an open part.

4.7 Tutorials

Tutorial 4-1 Create Sweep Features

A sweep feature requires, at minimum, a profile (cross section) to sweep and a path (curve) to sweep along. You can use a guide curve to control the sweep further. If you do not use a guide curve, the sweep cross section stays constant.

Sweep operations may fail for different reasons. Figure 4.10 shows three error messages. As a general rule, the sweep path and guide must intersect the cross-section plane, and the cross section must not intersect itself as it traverses the path and/or the guide curve.

Rebuild Errors

Cannot get a point on the path to start with. For an open path, the path must intersect with the section plane.

(A) Path does not intersect cross-section plane

Rebuild Errors

Guide curve # 1 is invalid. It does not intersect the section plane.

(B) Guide curve does not intersect cross-section plane

Rebuild Errors

The sweep could not be completed because it intersected itself when passing through the first segment of the path. Check to make sure the path does not pass too close to itself.

(C) Cross section intersects itself

Figure 4.10

Some possible sweep operation errors

Create the sweep features shown in Figure 4.11. All dimensions are in inches.

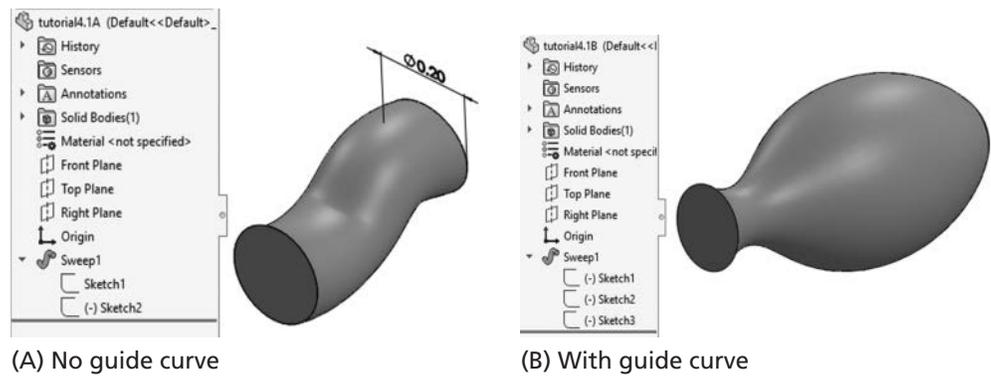


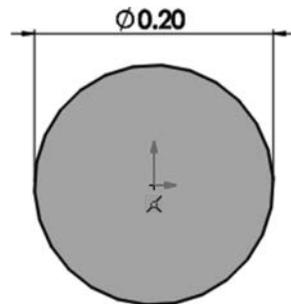
Figure 4.11

Sweep features

No-guide-curve sweep (Figure 4.11A) modeling steps:

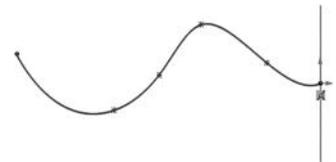
Step 1: Create *Sketch1-Profile*:

File > New > Part > OK > Front Plane > Circle on Sketch tab > click origin and sketch circle and dimension as shown > exit sketch > File > Save As > tutorial4.1A > Save.

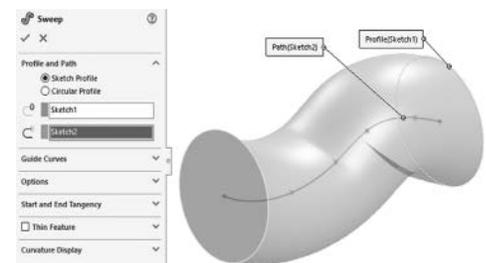


Step 2: Create *Sketch2-Path*:

Right Plane > Spline on Sketch tab > sketch spline as shown (press **Esc after last point is clicked to exit **Spline**); make sure spline snaps to origin > exit sketch.**

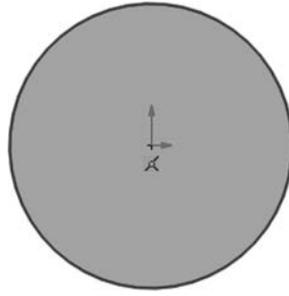


Step 3: Create *Sweep1* feature: **Sweep Boss/Base on Features tab > select circle sketch as **Profile**, as shown to the right > select spline sketch as **Path**, as shown to the right > ✓.**



With-guide-curve sweep (Figure 4.11B) modeling steps:

Step 1: Create *Sketch1-Profile*:
File > New > Part > OK > Front Plane > Circle on Sketch tab > click origin and sketch circle as shown > exit sketch > File > Save As > tutorial4.1B > Save.

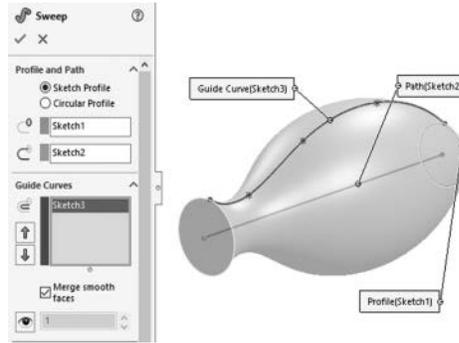
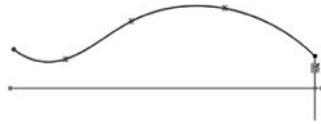


Step 2: Create *Sketch2-Path*: **Top Plane > Line on Sketch tab > sketch line as shown (to the right) from origin > exit sketch.**



Step 4: Create *Sweep* feature: **Sweep Boss/Base on Features tab > select circle sketch as Profile, as shown > select Step 2 spline sketch as Path > select Step 3 spline sketch as Guide > ✓.**

Step 3: Create *Sketch3-Guide*:
Right Plane > Spline on Sketch tab > sketch spline as shown (press Esc after last point is clicked to exit Spline); select spline endpoint near circle sketch > Ctrl + select circle sketch > Make Pierce > exit sketch.



HANDS-ON FOR TUTORIAL 4-1

Change the cross sections of both sweeps to a 2 × 2-inch square. What happens? Resolve the error(s) and explain your solution.

Tutorial 4-2 Create Loft Features

Create the wine glass shown in Figure 4.12. All dimensions are in inches. We introduce the concept of **Convert Entities** on the **Sketch** tab in this tutorial. You copy one circle in one sketch to another sketch. This concept enables you to copy entities from one sketch to another. While you could easily create a new circle and dimension it, using the **Convert Entities** method is faster (as there is no need to sketch a circle and dimension it). SolidWorks creates an **On Edge** relation between the two circles and shows a small green cube on the copied entity to indicate the relation. When you click the copied circle while editing the sketch, SolidWorks displays the **On Edge** relation in the relations pane to the left of the screen.

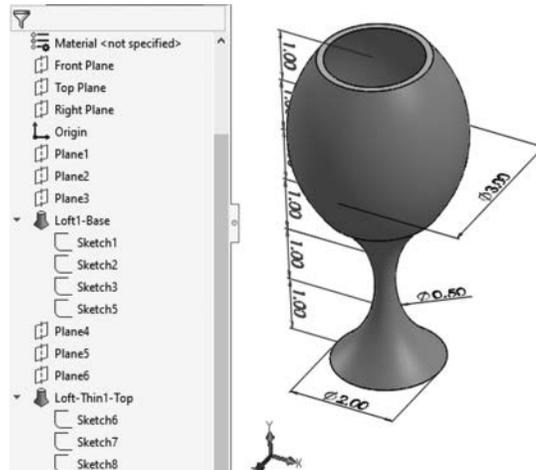
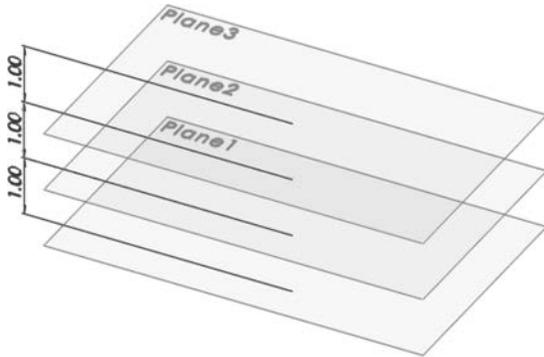
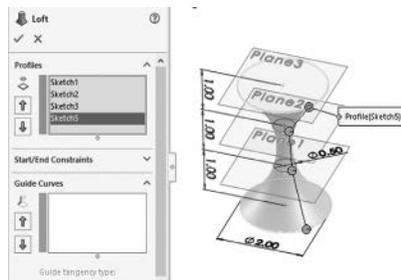


Figure 4.12
Loft feature

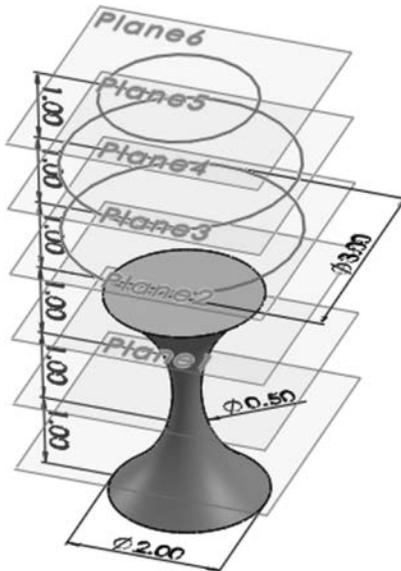
Step 1: Create *Plane1–Plane3*: **File** > **New** > **Part** > **OK** > **Reference Geometry** on **Features** tab > **Plane** > expand feature tree and select **Top Plane** > enter 1.0 for **Offset Distance** > ✓ > repeat for *Plane2* and *Plane3* but select the previously created plane > **File** > **Save As** > *tutorial4.2* > **Save**.



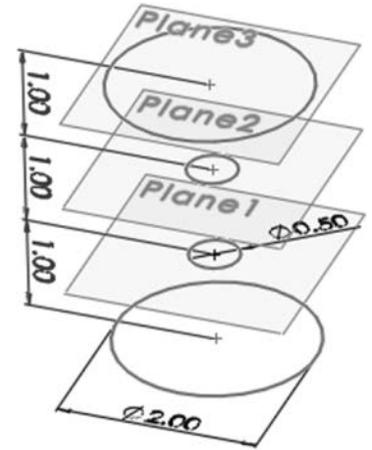
Step 3: Create *Loft-Base* feature: **Lofted Boss/Base** on **Features** tab > select *Sketch1–Sketch4* > ✓.



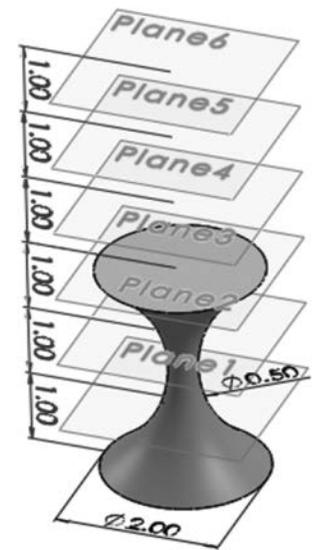
Step 5: Create *Sketch5–Sketch7*: Select *Plane4* as **Sketch Plane** > **Circle** on **Sketch** tab > click origin and drag to sketch and dimension a 3.0-inch diameter circle > exit sketch > select *Plane5* as **Sketch Plane** > **Sketch** on **Sketch** tab > **Convert Entities** on **Sketch** tab > click *Sketch5* (just created) > ✓ > ✓ > exit sketch > select *Plane6* as sketch plane > **Sketch** on **Sketch** tab > **Convert Entities** on **Sketch** tab > click circle on *Plane3* > ✓ > ✓ > exit sketch.



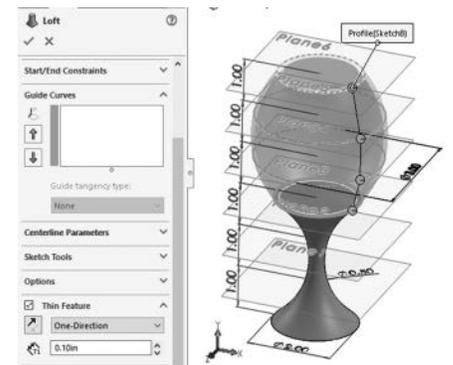
Step 2: Create *Sketch1–Sketch4*: **Top Plane** > **Circle** on **Sketch** tab > click origin and drag to sketch and dimension a 2.0-inch diameter circle > exit sketch > select *Plane1* as sketch plane and create a 0.5-inch diameter circle > exit sketch > select *Plane2* as sketch plane > **Sketch** on **Sketch** tab > **Convert Entities** on **Sketch** tab > click circle on *Plane1* > ✓ > ✓ > exit sketch > select *Plane3* as sketch plane > **Sketch** on **Sketch** tab > **Convert Entities** on **Sketch** tab > click circle on **Top Plane** > ✓ > ✓ > exit sketch.



Step 4: Create *Plane4–Plane6*: **Reference Geometry** on **Features** tab > **Plane** > expand feature tree and select *Plane3* > enter 1.0 for distance > ✓ > repeat for *Plane5* and *Plane6* but select the previously created plane.



Step 6: Create *Loft-Thin1-Top* feature: **Lofted Boss/Base** on **Features** tab > select the circle of *Sketch4* and then select *Sketch5–Sketch7* > check **Thin Feature** box > enter 0.1 for thickness (**T1**) > if needed, click direction box to toggle direction of thickness to the inside > ✓.

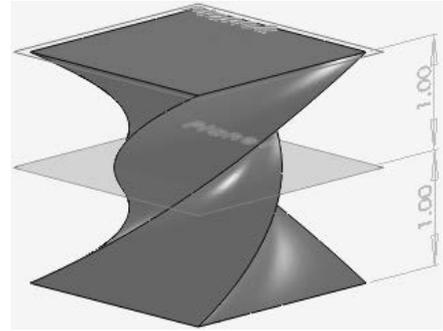


Note: Make sure you select the circle and sketches in a way so that the interpolation points (green circles shown here) line up; otherwise, you twist the loof.

Note: The thickness of the thin feature has a direction: inside or outside the profile. Reverse the direction of the double arrows shown to toggle.

HANDS-ON FOR TUTORIAL 4-2

Create a loft using three squares of different sizes as cross sections separated by 1 inch. The square sizes are 2×2 , 1×1 , and 2×2 , respectively. Create the loft connecting the three sections such that the loft is twisted as shown.



Tutorial 4-3 Use the Hole Wizard

The hole wizard provides two advantages. First, it helps create standard hole sizes and types so that off-the-shelf bolts will fit perfectly in the holes. Second, it greatly speeds up the process of creating these holes. This tutorial shows how to create sample holes: counterbore, countersink, and tapped holes. Figure 4.13 shows these holes. You create an extrusion and add holes to it. You also create *Sketch2* on the top face of the *Block* feature with a center rectangle (construction rectangle) that you use to place holes at its corners.

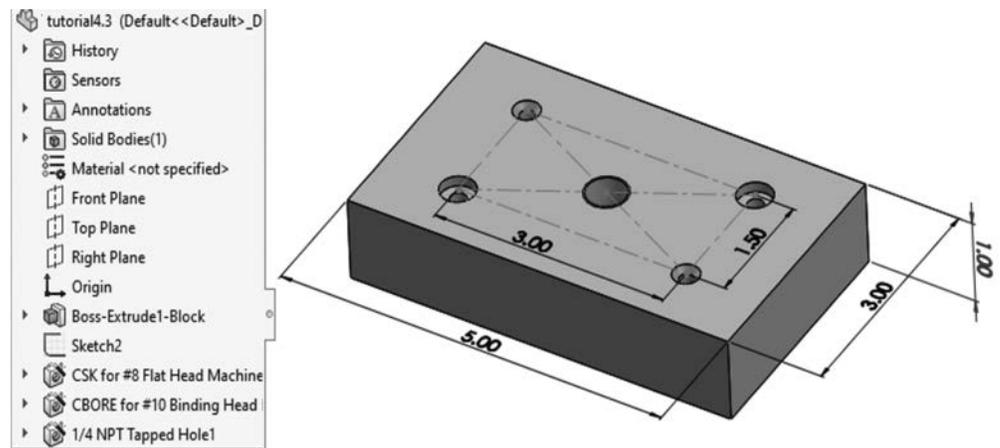
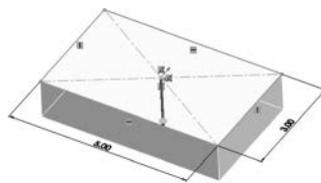


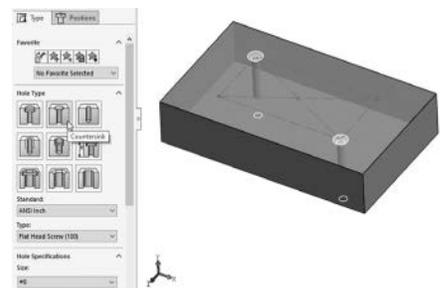
Figure 4.13
Wizard holes

Step 1: Create *Sketch1* and *Block* feature: **File > New > Part > OK > Top Plane > Extruded Boss/Base** on **Features** tab > **Center Rectangle** on **Sketch** tab > click origin and sketch and dimension rectangle as shown > exit sketch > enter 1 for **D1** > reverse extrusion direction > **File > Save As > tutorial4.3 > Save**.

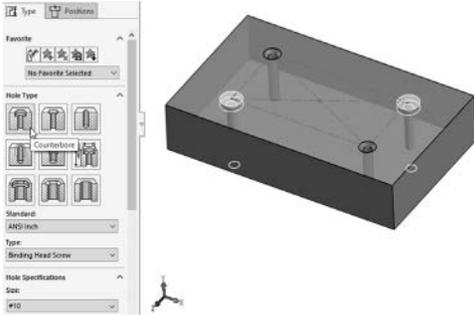


Step 2: Create *Sketch2*: Top face of *Block* > **Center Rectangle** on **Sketch** tab > click origin and sketch a 3.0×1.5 rectangle, as shown in Figure 4.13 > click **For Construction** box > exit sketch.

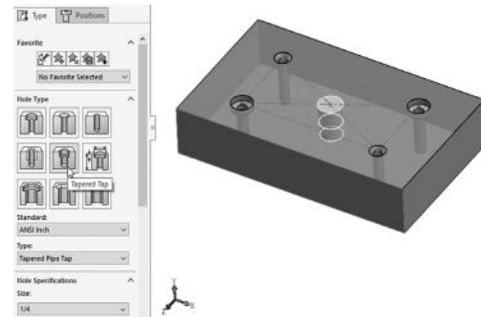
Step 3: Create two diagonal countersink hole features (**CSK...** node in feature tree): **Hole Wizard** on **Features** tab > select **Countersink** under **Hole Type** (hover over types until you read it) > select **#8** for **Size** under **Hole Specifications > Positions** tab > click top face of *Block* and then click two corners of construction rectangles as shown > ✓.



Step 4: Create two diagonal counterbore hole features (*CBORE...* node in feature tree): **Hole Wizard** on **Features** tab > select **Counterbore** under **Hole Type** (hover over types until you read it) > select #10 for **Size** under **Hole Specifications** > **Positions** tab > click top face of *Block* and then click two other corners of construction rectangles as shown > ✓.



Step 5: Create *Tapped Hole1* feature: **Hole Wizard** on **Features** tab > select **Tapered Tap** (hover over types until you read it) > select 1/4 for **Size** under **Hole Specifications** > **Positions** tab > click top face of *Block* and then click rectangle center as shown > ✓.



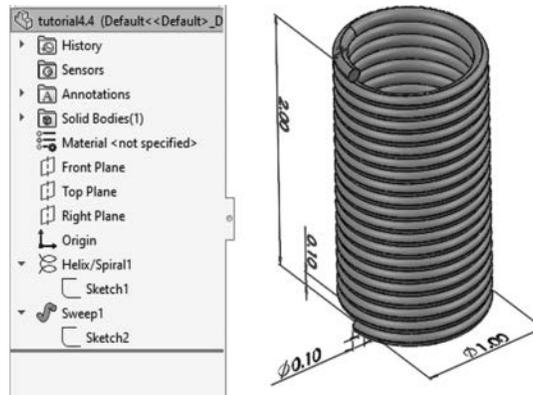
HANDS-ON FOR TUTORIAL 4-3

Create a 1/16 tapered pipe tap through all holes, located 0.5 from the top edge and 1.5 from the left edge of the block.

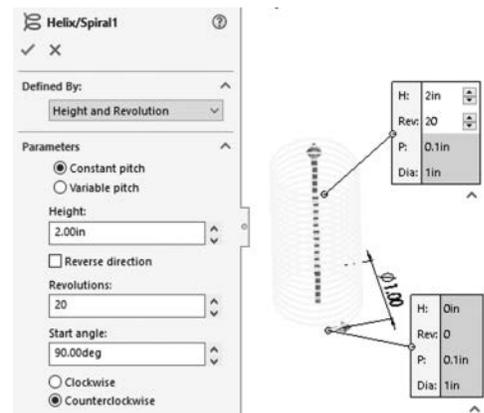
Tutorial 4-4 Create Compression Spring

Figure 4.14 shows the constant length compression spring you create in this tutorial.

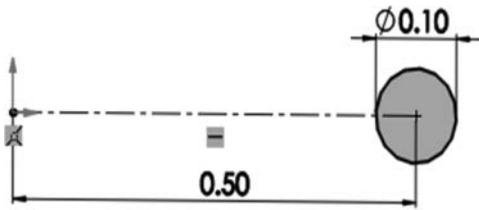
Figure 4.14
Compression spring



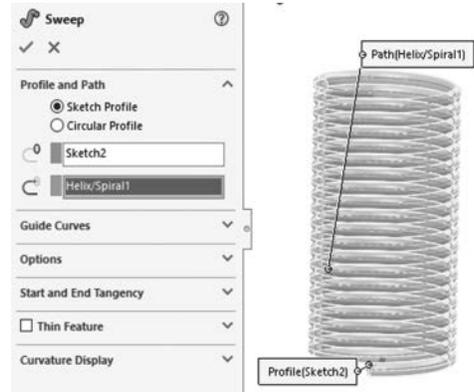
Step 1: Create *Sketch1* and *Helix/Spiral1* curve: **File** > **New** > **Part** > **OK** > **Top Plane** > **Circle** on **Sketch** tab > click origin and sketch and dimension circle with 1.0-inch diameter > exit sketch > **Insert** (menu) > **Curve** > **Helix/Spiral** > select the circle just sketched > **Height and Revolution** from **Defined By** dropdown shown > **Constant Pitch** > enter 2.0 for **Height**, 20 for **Revolutions**, and 90 for **Start Angle**, as shown > ✓ > **File** > **Save As** > *tutorial4.4* > **Save**.



Step 2: Create *Sketch2*: **Front Plane** > **Circle** on **Sketch** tab > sketch and dimension circle as shown (align center with X-axis as shown) > exit sketch.



Step 3: Create *Sweep1* feature (spring): **Swept Boss/Base** on **Features** tab > select *Sketch2* as **Profile** > select *Helix/Spiral1* as **Path** > ✓.



HANDS-ON FOR TUTORIAL 4-4

Edit the spring helix to have a variable pitch. Use a pitch of 0.2 at midheight point.

Tutorial 4-5 Create Spiral

Figure 4.15 shows the spiral spring you create in this tutorial.

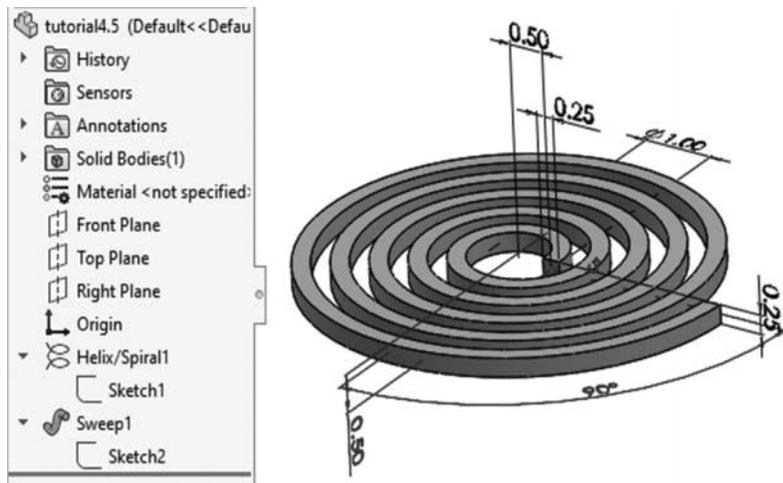
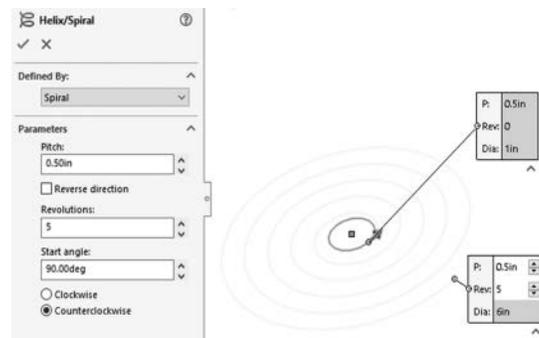
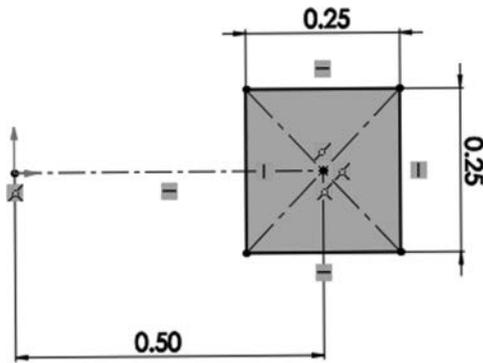


Figure 4.15
Spiral spring

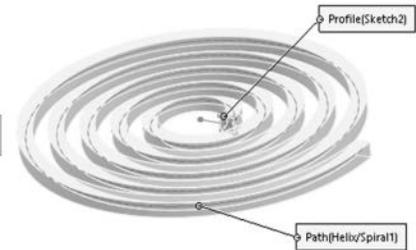
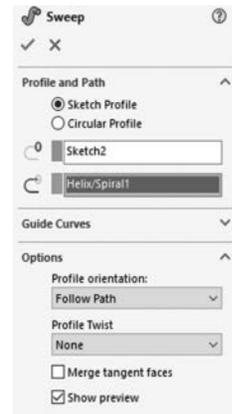
Step 1: Create *Sketch1* and *Helix/Spiral* curve: **File** > **New** > **Part** > **OK** > **Top Plane** > **Circle** on **Sketch** tab > click origin and sketch and dimension circle with 1.0-inch diameter > exit sketch > **Insert** (menu) > **Curve** > **Helix/Spiral** > select the circle just created > **Spiral** from **Defined By** dropdown shown > enter 0.5 for **Pitch** and 5 for **Revolutions**, as shown > **Start Angle** of 90 and select **Counterclockwise** > ✓ > **File** > **Save As** > *tutorial4.5* > **Save**.



Step 2: Create *Sketch2: Front Plane > Center Rectangle* on **Sketch** tab > sketch and dimension rectangle as shown (align center with X-axis as shown) > exit sketch.



Step 3: Create *Sweep* feature (spiral): **Swept Boss/Base** on **Features** tab > select *Sketch2* as **Profile** > select *Helix/Spiral* as **Path** > select **Show Preview** under **Options** > ✓.



HANDS-ON FOR TUTORIAL 4-5

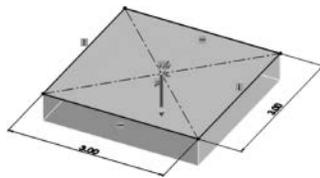
Change the spiral cross section to a circle with 2.0-inch diameter. Can you generate the spiral? Why or why not? Explain.

Tutorial 4-6 Create Features

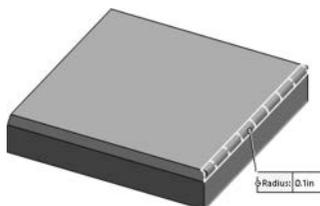
This tutorial covers the creation of these features: chamfer, fillet, slot, shell, draft, and rib. All dimensions are in inches. Consider these useful observations:

- 1 Make sure to pay attention to the visual clues shown in the left pane while creating these features.
- 2 For example, the box symbol under **Chamfer parameters** indicates that you can chamfer a face, an edge, or a vertex (corner point). As you would expect, chamfering a face chamfers all its edges. Chamfering a corner chamfers the three edges that meet there.
- 3 A rib requires a profile sketch (e.g., a line or stepwise line) and a thickness.

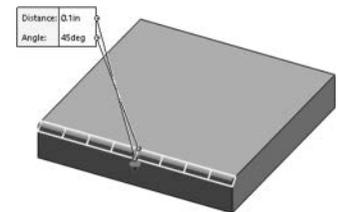
Step 1: Create *Sketch1* and *Block* feature: **File > New > Part > OK > Top Plane > Extruded Boss/Base** on **Features** tab > **Center Rectangle** on **Sketch** tab > click origin and sketch and dimension as shown > exit sketch > reverse extrusion direction > enter 0.5 for **D1** > ✓ > **File > Save As > tutorial4.6 > Save**.



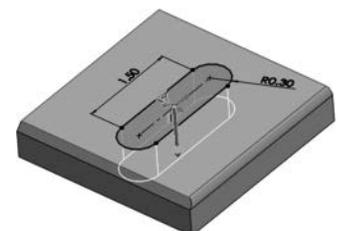
Step 3: Fillet an edge of *Block* feature: **Fillet** on **Features** tab > select **Constant Size Fillet** > select *Block* edge shown > use 0.1 for **Radius** > ✓.



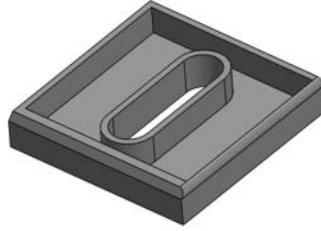
Step 2: Chamfer an edge of *Block* feature: **Fillet** dropdown on **Features** tab > **Chamfer** > select **Angle Distance** chamfer > select *Block* edge shown > use 0.1 for **Distance** and 45 degrees for **Angle** > ✓.



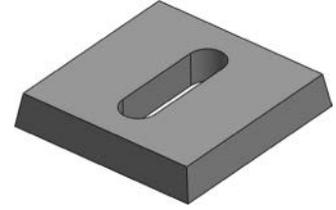
Step 4: Create a straight slot in *Block* feature: Select *Block* top face as a sketch plane > **Extruded Cut** on **Features** tab > **Straight Slot** on **Sketch** tab > sketch and dimension slot as shown > make origin and slot midpoint **Coincident** > exit sketch > **Through All** > ✓.



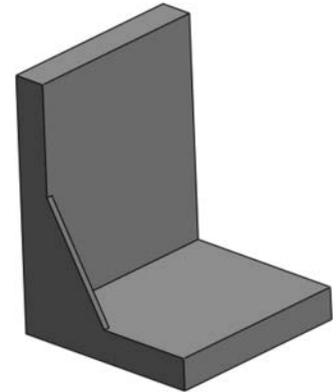
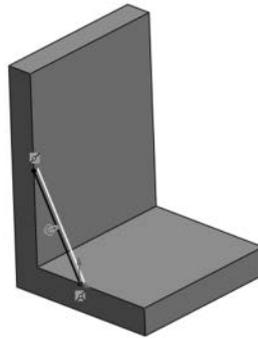
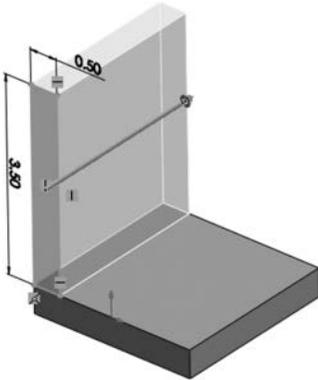
Step 5: Shell *Block* feature:
Shell on **Features** tab > select
top face of *Block* > enter 0.1 for
D1 > ✓.



Step 6: Draft *Block* feature:
Suppress the chamfer, fillet, and
shell features > **Draft** on
Features tab > enter 10 degrees
for **Draft Angle** > select top
face of *Block* as **Neutral Plane**
> select *Block* four side faces to
draft > ✓.



Step 7: Create a rib feature: Suppress the slot and draft features > select front face of *Block* > **Extruded Boss/Base** on **Features** tab > **Rectangle** on **Sketch** tab > sketch and dimension rectangle as shown below > exit sketch > reverse extrusion direction > enter 3.0 for **D1** > ✓ > **Front Plane** > **Rib** on **Features** tab > **Line** on **Sketch** tab > sketch a line using the midpoints of the two edges as shown below > exit sketch > enter 0.5 for rib thickness (**T1**) > select **Second Side** for **Thickness** > **Parallel to Sketch** for **Extrusion Direction** > ✓.



HANDS-ON FOR TUTORIAL 4-6

Create the following features:

- Distance-distance chamfer
- Vertex chamfer
- Variable-size fillet
- Face fillet
- Full round fillet
- 3-point arc slot
- Three-stepped rib using three-stepped line as the rib profile

Tutorial 4-7 Use the Smart Fasteners Wizard

You use the Smart Fasteners wizard to insert the correct fastener based on the hole you select. It is a form of automation using off-the-shelf components. SolidWorks has its own standard library of fasteners. You can only use the wizard at the assembly level. You need to activate the wizard in order for the **Smart Fasteners** icon on the **Assembly** tab to work. If you click the icon before activation, you get this error: **Smart Fasteners requires SolidWorks Toolbox, which is not present.**

In this tutorial, you create an assembly of a block and plate. You create a counterbore hole in the plate and a blind hole in the block, assemble them, and fasten them together with a smart fastener. Figure 4.16 shows the assembly and its tree. All dimensions are in inches.

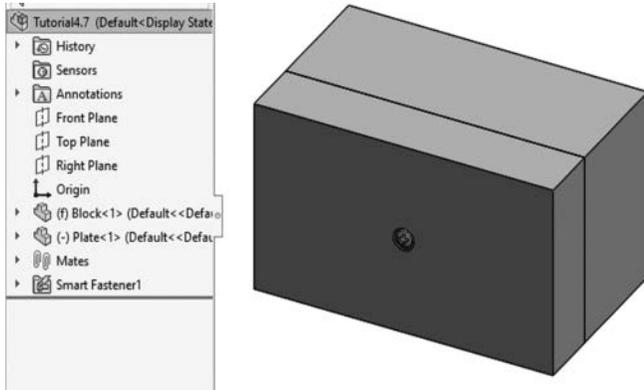
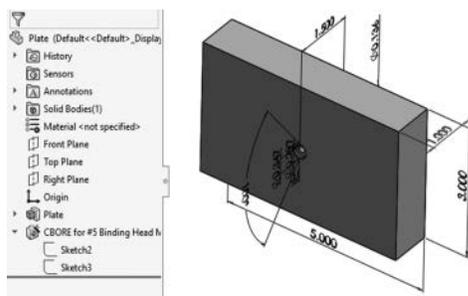


Figure 4.16

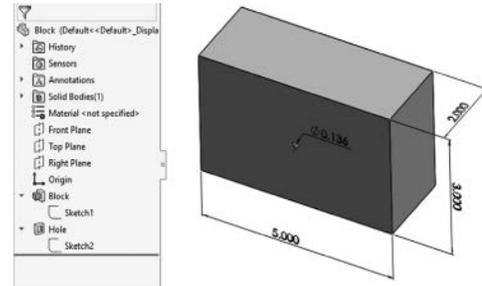
Assembly using smart fastener

Step 1: Create *Plate* feature: **File** > **New** > **Part** > **OK** > **Front Plane** > **Extruded Boss/Base** on **Features** tab > **Center Rectangle** on **Sketch** tab > click origin and sketch and dimension rectangle as shown > exit sketch > enter 1 for **D1** > reverse extrusion direction > **✓** > **Hole Wizard** on **Features** tab > select **Counterbore** under **Hole Type** (hover over each hole type until you read the correct type) > **ANSI inch** for **Standard** > binding head screw for **Type** > select **#5** for **Size** under **Hole Specifications** > **Positions** tab > click front face of *Plate* and then click origin > **✓** > **File** > **Save As** > *Plate* > **Save**.

Note: The diameter of the counterbore hole shown below corresponds to #5 size. You need it to create the corresponding hole in the block in Step 2.



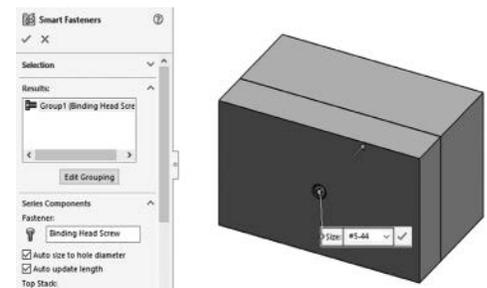
Step 2: Create *Block* feature: **File** > **New** > **Part** > **OK** > **Front Plane** > **Extruded Boss/Base** on **Features** tab > **Center Rectangle** on **Sketch** tab > click origin and sketch and dimension rectangle as shown > exit sketch > enter 2 for **D1** > reverse extrusion direction > **✓** > front face of *Block* > **Extruded Cut** on **Features** tab > **Circle** on **Sketch** tab > click origin and sketch and dimension as shown > exit sketch > enter 1 for **D1** > **✓** > **File** > **Save As** > *Block* > **Save**.



Step 3: Create assembly: **File** > **New** > **Assembly** > **OK** > **Browse** > locate *Block* and *Plate* parts > select **Block** + **Ctrl** + **Plate** > **Open** > click **✓** to place *Block* instance in assembly origin > click anywhere in graphics pane to place *Plate* instance > **Mate** on **Assembly** tab > **Coincident** > select the corresponding top edges of *Block* and *Plate* > **✓** > select the corresponding right edges of *Block* and *Plate* > **✓** > **✓**.

Step 4: Activate Smart Fasteners wizard: **Tools** > **Add-Ins** > **SolidWorks Toolbox Library** > **OK**. This adds the **Toolbox** menu to the menu bar to the right of the **Tools** menu. You may deactivate the **Toolbox** by using the same sequence but unchecking the **Toolbox Browser** from the **Add-Ins** window.

Step 5: Add a fastener: **Smart Fasteners** on **Assembly** tab > **OK** (to accept that it may take extra time) > expand feature tree > expand *Plate* instance tree node > select **CBORE for #5** node > **Add** > **✓** > **File** > **Save As** > *Tutorial4.7* > **Save**.



HANDS-ON FOR TUTORIAL 4-7

Modify *Block* and *Plate* parts to create four corner countersink holes. Re-create the assembly and use four smart fasteners.

Tutorial 4-8 Create a Bolt

Bolts, like gears, are important and essential mechanical elements. While bolts are standard off-the-shelf components, this tutorial shows how to create the CAD model of one due to its learning value. Figure 4.17 shows the bolt and its feature tree. All dimensions are in inches.

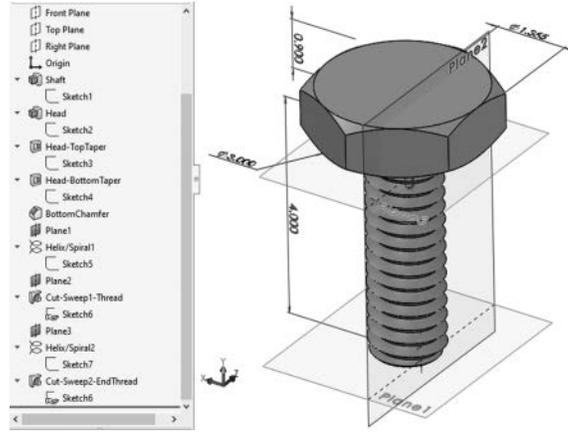
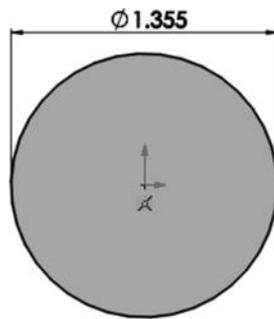


Figure 4.17
A bolt

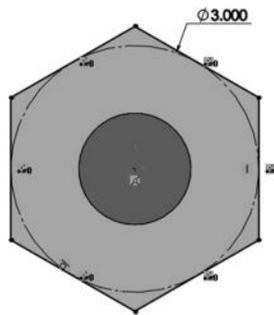
Step 1: Create *Sketch1* and *Shaft* feature: **File > New > Part > OK > Top Plane > Extruded Boss/Base** on **Features** tab > **Circle** on **Sketch** tab > click origin and sketch and dimension as shown > exit sketch > enter 4 for **D1** > reverse extrusion direction > ✓ > **File > Save As > Bolt > Save.**



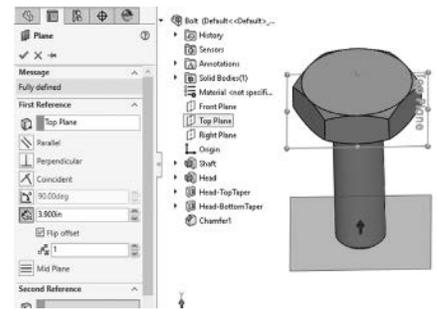
Step 4: Create *BottomChamfer* feature: **Fillet** dropdown on **Features** tab > **Chamfer** > select bottom edge of *Shaft* feature > enter 0.1 for **D** > enter 45 for **A** > ✓.



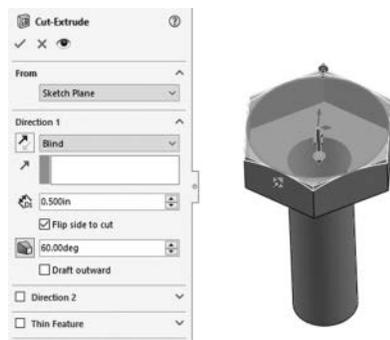
Step 2: Create *Sketch2* and *Head* feature: Select top face of *Shaft* feature > **Extruded Boss/Base** on **Features** tab > **Polygon** (hexagon icon) on **Sketch** tab > click origin and sketch and dimension as shown > apply vertical relation to one edge > exit sketch > enter 0.9 for **D1** > ✓.



Step 5: Create *Plane1*: **Reference Geometry** on **Features** tab > **Plane** > expand feature tree > select **Top Plane** > enter 3.9 for **D1** > click **Flip offset** checkbox > ✓.

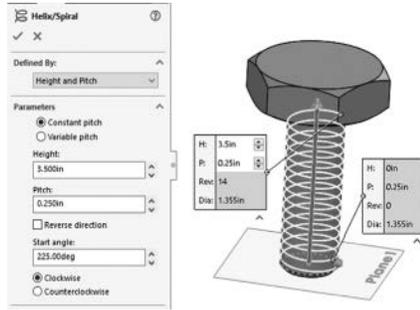


Step 3: Create *Sketch3* and *Head-TopTaper* feature: Select top face of *Head* feature > **Extruded Cut** > **Circle** on **Sketch** tab > click origin and sketch (make circle tangent to hexagon sides) > exit sketch > enter 0.5 for **D1** > click checkbox as shown > enter 60 for draft angle > ✓ > repeat to create *Head-BottomTaper* to chamfer the bottom of the head.



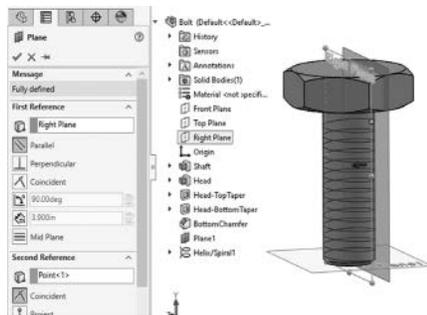
Note: You use a distance of 3.9 for *Plane1*, not 4.0, because the chamfer is 0.1 high.

Step 6: Create *Sketch5* and *Helix/Spiral1*: Select *Plane1* > select **Sketch** on **Sketch** tab > **Convert Entities** on **Sketch** tab > expand feature tree > select *Sketch1* > ✓ > exit Sketch > select *Sketch5* > **Insert** > **Curve** > **Helix/Spiral** > select **Height and Pitch** > enter 3.5 for **Height**, 0.25 for **Pitch**, and 225 for **Start angle** > ✓.

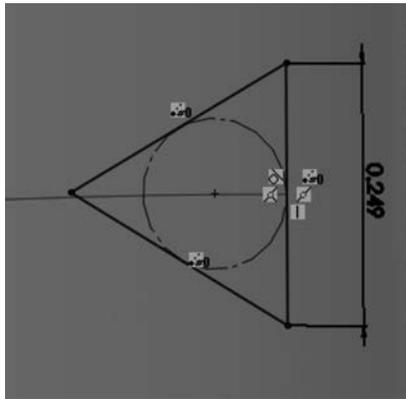


Note: The helix 3.5 height is arbitrary. That leaves 0.4 (out of 3.9). You use 0.25 for the other end thread helix and 0.15 underneath the bottom of bolt head as a length with no threads.

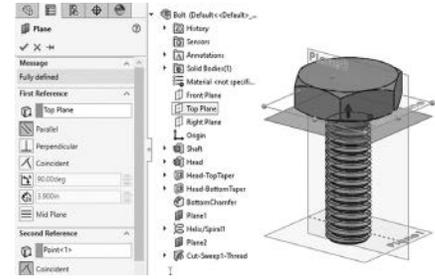
Step 7: Create *Plane2*: **Reference Geometry** on **Features** tab > **Plane** > expand feature tree > select **Right Plane** > select **Parallel** > click **Second Reference** box > select top endpoint of *Helix/Spiral1* > ✓.



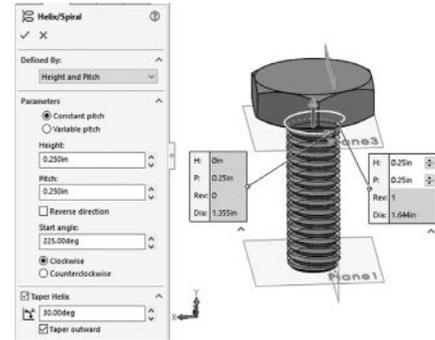
Step 8: Create *Sketch6* and *Cut-Sweep1-Thread* feature: Select *Plane2* > select **Sketch Swept Cut** on **Features** tab > **Polygon** (hexagon icon) on **Sketch** tab > 3 for **Number of Sides** > click near end of helix and sketch and dimension as shown with right side vertical and *Helix/Spiral1* endpoint and right triangle edge midpoint coincident > exit sketch > **Swept Cut** on **Features** tab > select *Sketch6* as **Profile** > select *Helix/Spiral1* as **Path** > ✓.



Step 9: Create *Plane3*: **Reference Geometry** on **Features** tab > **Plane** > expand feature tree > select **Top Plane** > select **Parallel** > click **Second Reference** box > select top endpoint of *Helix/Spiral1* > ✓.



Step 10: Create *Sketch7* and *Helix/Spiral2*: Select *Plane3* > select **Sketch** on **Sketch** tab > **Convert Entities** on **Sketch** tab > expand feature tree > select *Sketch1* > ✓ > exit sketch > select *Sketch7* > **Insert** >

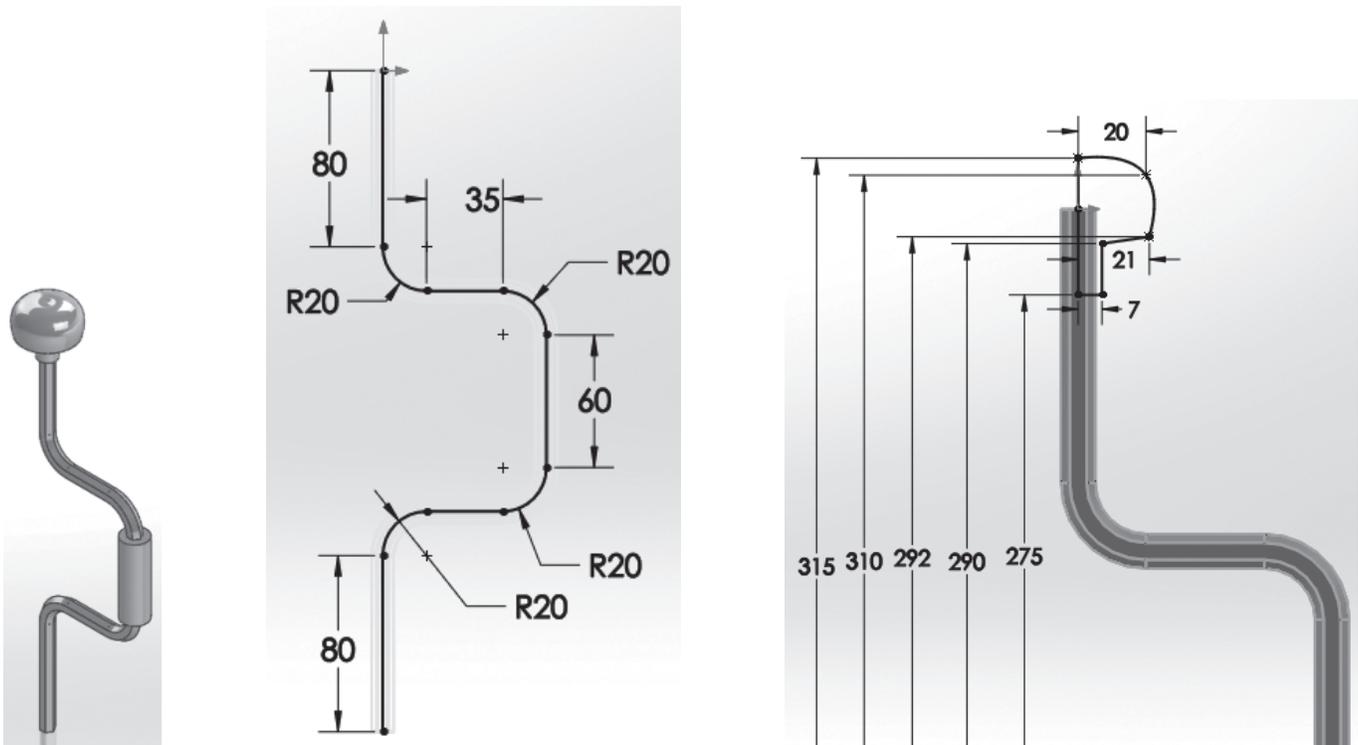


Curve > **Helix/Spiral** > select **Height and Pitch** > enter 0.25 for **Height** > click **Taper Helix** checkbox > enter 30 for taper angle (A) > click **Taper outward** checkbox > ✓.

Step 11: Create *Cut-Sweep2-EndThread* feature: **Swept Cut** on **Features** tab > select *Sketch6* as **Profile** > select *Helix/Spiral2* as **Path** > ✓.

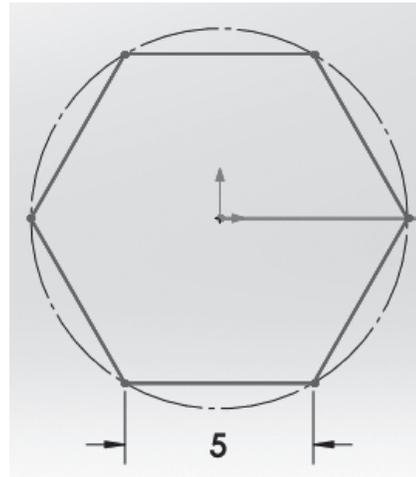
Problems

- 1 What is a feature? Give two examples of features.
- 2 Why can an extruded cut or a revolved cut *not* be a base feature?
- 3 What is the required input needed to create a sweep? What is the optional input?
- 4 What is the required input needed to create a loft? What is the optional input?
- 5 Table 4.1 shows a rib feature. Which is the better way to create it: by using a rib or by using an extrusion? Explain your answer.
- 6 Table 4.1 shows a block that is shelled. Which is the better way to create it: by using shelling or by using extrusion cut? Explain your answer.
- 7 A spur gear has a pitch circle radius of 3 inches, a pressure angle of 14.5 degrees, and 20 teeth. Calculate all the parameters required to create the gear CAD model. Create the CAD model.
- 8 Same as Problem 7, but for a pitch circle radius of 100 mm, pressure angle of 14.5 degrees, and 30 teeth.
- 9 Create a macro to automate the creation of a donut revolve.
- 10 Create the brace drill handle shown in Figure 4.18. All dimensions are in millimeters.

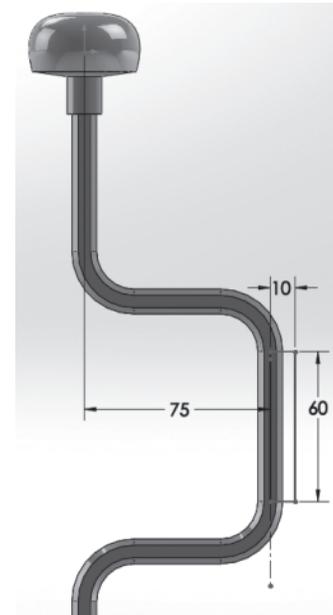


All vertical dimensions are measured from the bottom end of the drill handle. The top curve is a spline connecting three points.

Figure 4.18
Brace drill handle



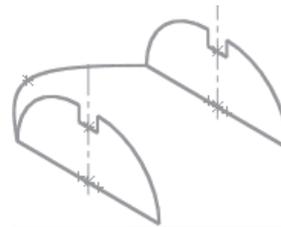
Drill handle cross section



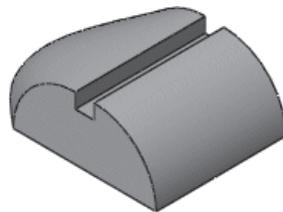
Cross section of middle handle

Figure 4.18
(continued)

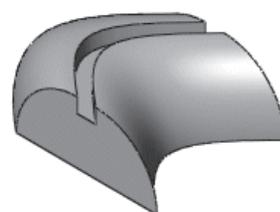
- 11** Create the loft feature shown in Figure 4.19. Assume dimensions.
Hint #1: This loft shows you the local and global influence of the guide curve.
Hint #2: Use **Guide curves influence types** under the **Guide Curves** section shown on the left pane of the screen.



Two profiles and guide curve



Local influence of guide curve



Global influence of guide curve

Figure 4.19
Influence of guide curve

- 12** Create the CAD model of the helical spring shown in Figure 4.20. All dimensions are in centimeters.

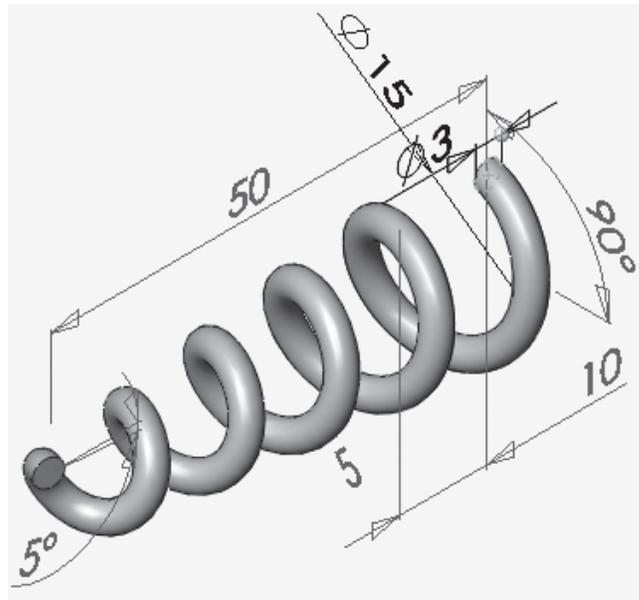


Figure 4.20
Helical spring

- 13** Create the CAD model of the 3D probe shown in Figure 4.21. All dimensions are in millimeters.

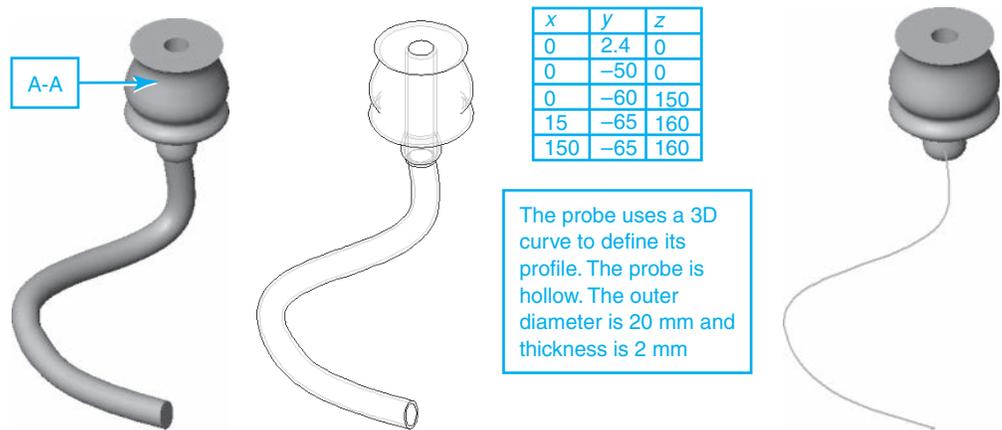


Figure 4.21
3D probe

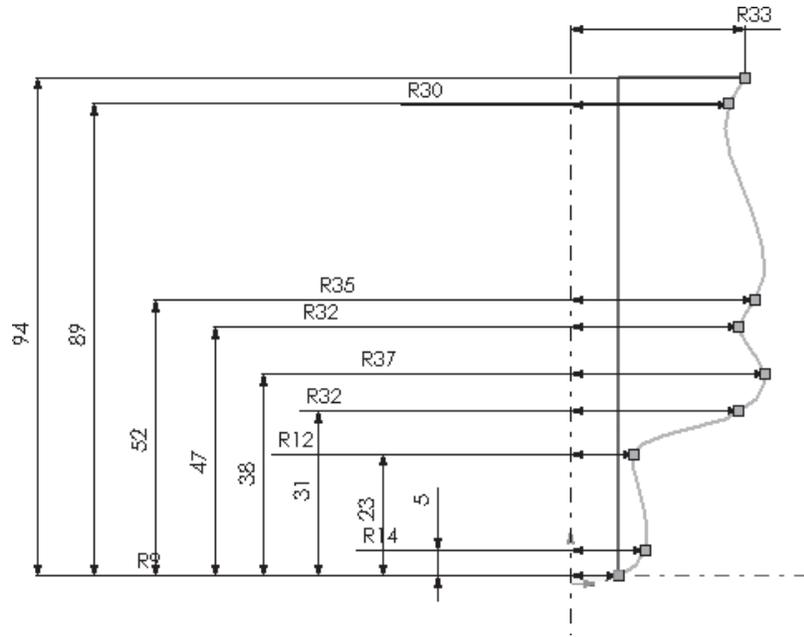


Figure 4.21
(continued)

- 14 Create the CAD model of the football goal post shown in Figure 4.22. All dimensions are in inches. *Hint:* The dimensions of the post are per NFL specs: The post is 10 feet (120 in.) high, the crossbar is 18.5 feet (222 in.) wide from the inner edges of the uprights, and the uprights are 20 feet (240 in.) high. The diameter of the post tubes is arbitrary, so use 8 in. here.

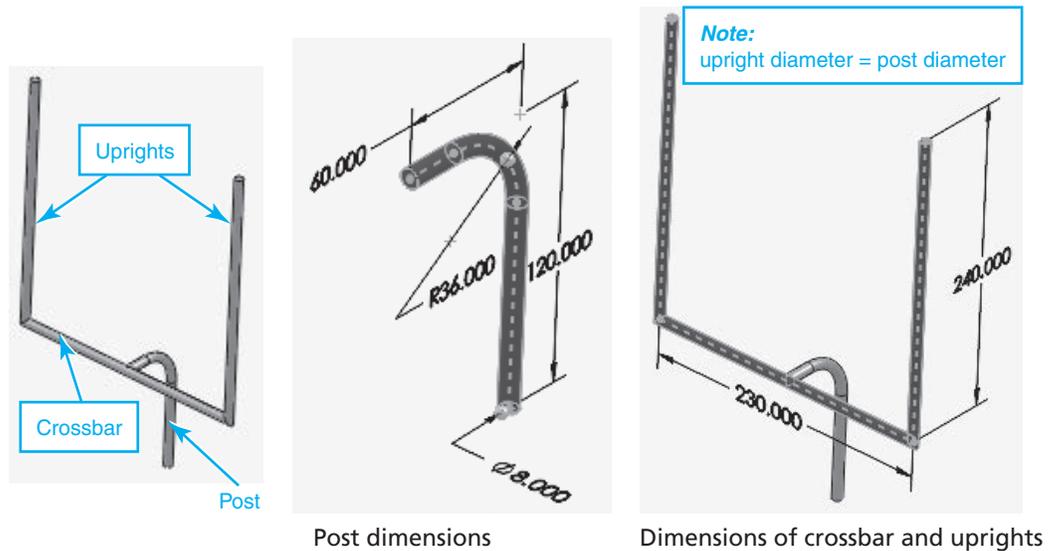
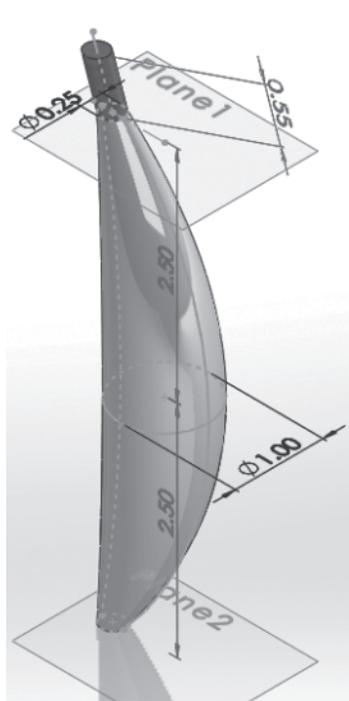
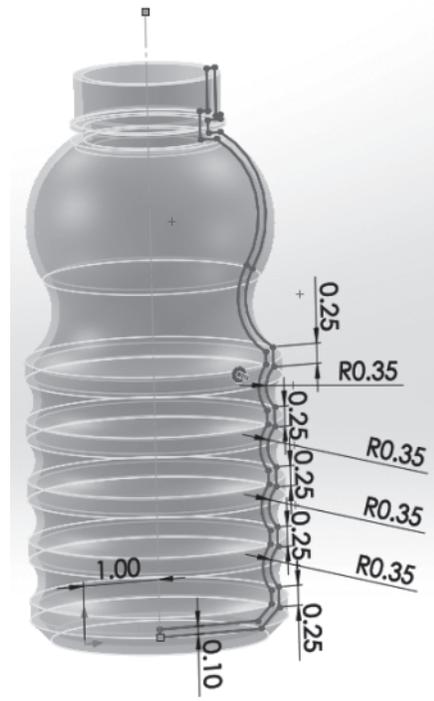


Figure 4.22
Football goal post

- 15 Create the CAD models shown in Figure 4.23. All dimensions are in inches.



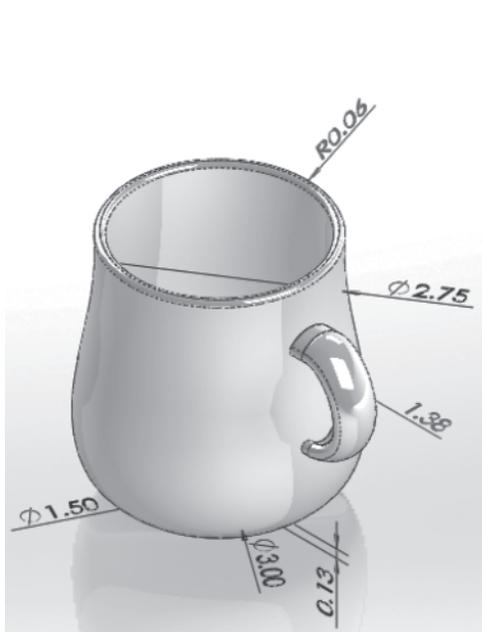
(A) Banana



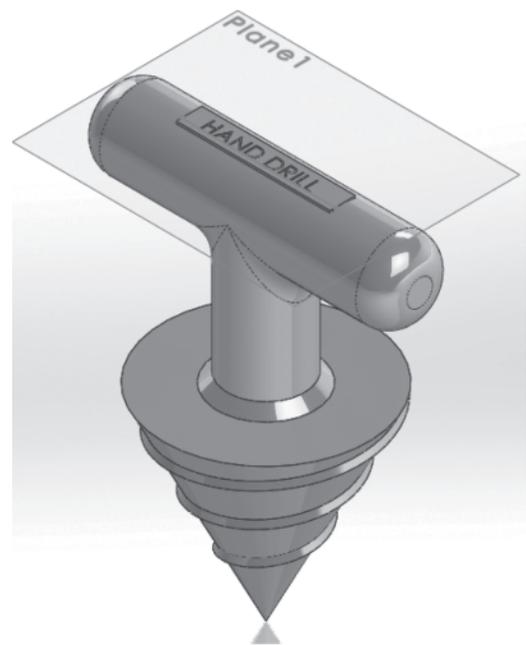
(B) Water bottle

Figure 4.23
CAD models

- 16 Create the CAD models shown in Figure 4.24. All dimensions are in inches.



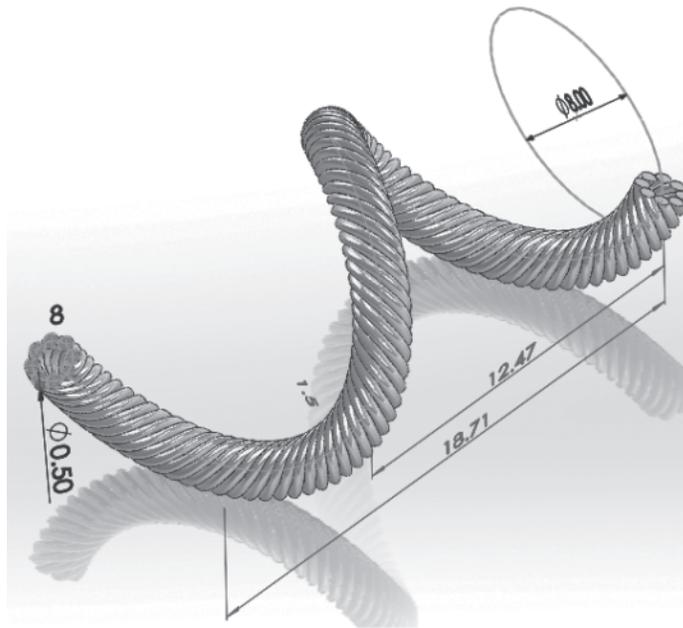
(A) Coffee mug



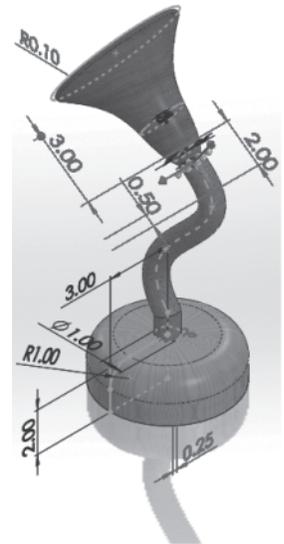
(B) Hand drill

Figure 4.24
CAD models

19 Create the CAD models shown in Figure 4.27. All dimensions are in inches.



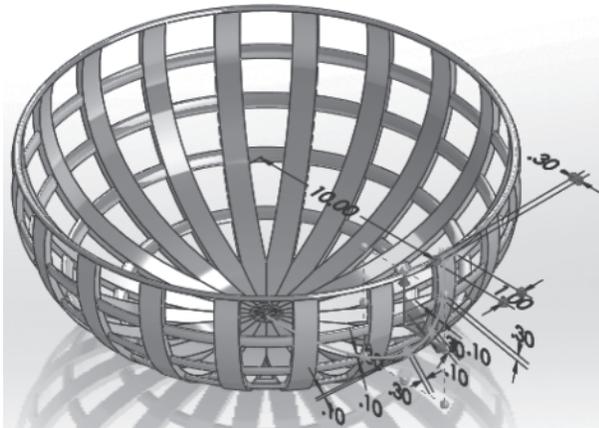
(A) Fiber optic wire



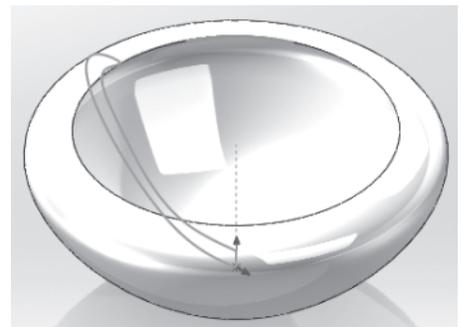
(B) Desk lamp

Figure 4.27
CAD models

20 Create the CAD models shown in Figure 4.28. All dimensions are in inches.



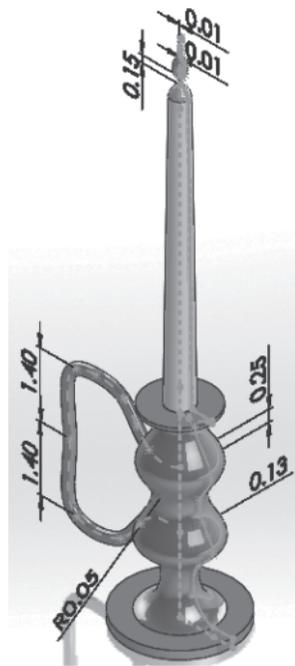
(A) Fruit basket



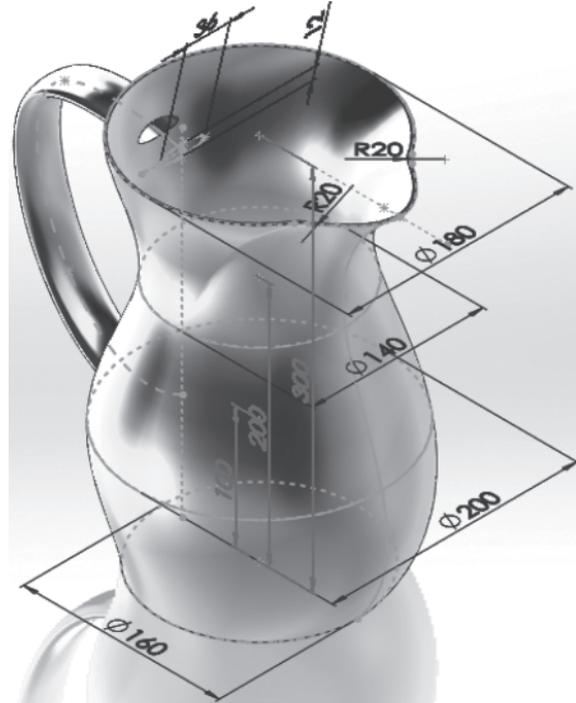
(B) Bowl

Figure 4.28
CAD models

E1 Create the CAD models shown in Figure 4.29.



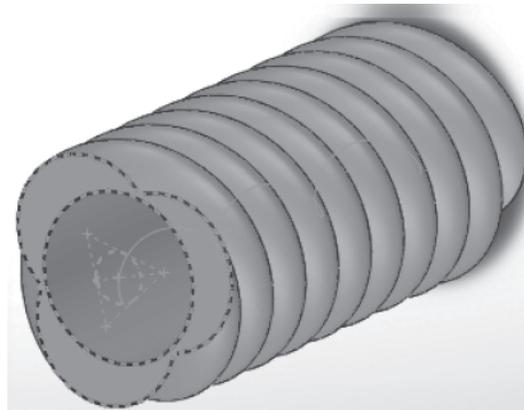
(A) Candle and holder
(dimensions in inches)



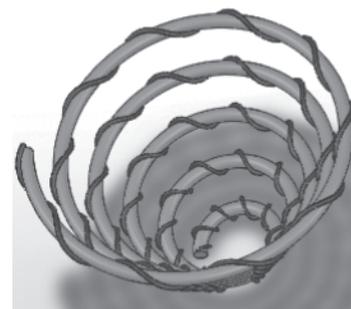
(B) Pitcher (dimensions in millimeters)

Figure 4.29
CAD models

E2 Create the CAD models shown in Figure 4.30.



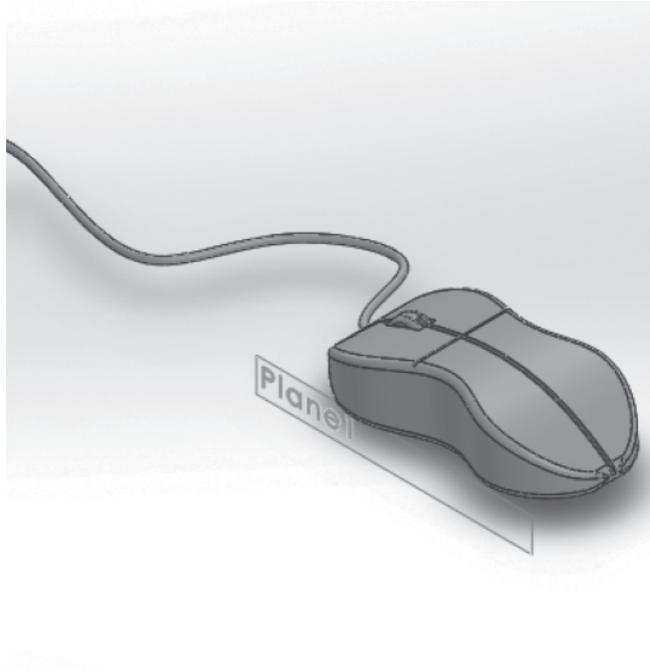
(A) A flex



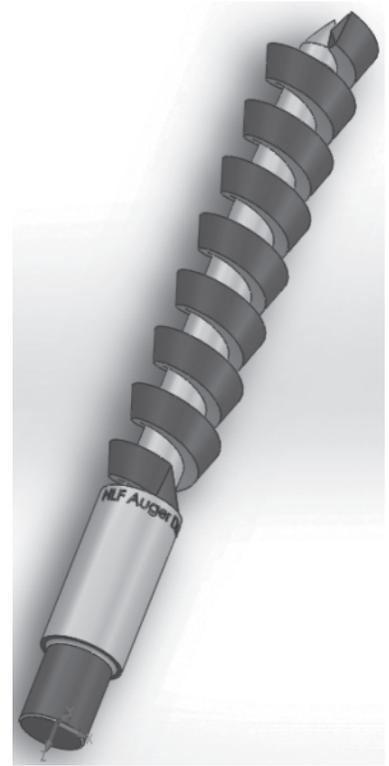
(B) Steel cone

Figure 4.30
CAD models

 Create the CAD models shown in Figure 4.31.



(A) Computer mouse



(B) Auger drill

Figure 4.31
CAD models

Index

NUMBERS

2D curves, 222

- tutorials
 - explicit equations, 224
 - parametric equations, 225
 - stethoscope model creation, 241–243

3D curves, 223

- tutorials
 - 3D points, 227–228
 - 3D sketches, 228–229
 - composite curves, 229–230
 - parametric equations, 225–226
 - projected curves, 232–241
 - projected sketches on curved faces, 231–232
 - stethoscope model creation, 241–243

3D points, 227–228

3D printing, 419. *See also* rapid prototyping (RP)

3D Sketch feature, 303

3D sketches, 228–229

.3dxml file format, 379

A

abbreviation rules (ASME), 137–138

abort symbol, 9

actual size, 340–341

addendum circle (gears), 104

additive manufacturing, 412

additive modeling plan in drain plug tutorial, 90

.ai file format, 380

air acidification, 326

aliasing, 195

ambient light, 196

analysis tools. *See also* tolerance analysis

- animation and motion analysis, 385–386
- finite element analysis, 389–390
- finite element method, 386–389
- flow simulation, 386
- mass properties calculations, 381–385
- purpose of, 377–378
- SolidWorks Simulation/SimulationXpress, 391
- tutorials
 - flow simulation, 406–407
 - mass properties calculations, 397–398
 - motion analysis, 398–403
 - static linear analysis, 403–404
 - thermal analysis, 405

types of, 377–378

Von Mises stress, 391–396

analytic curves, 217, 218

analytic surfaces, 249

angle dimension tolerances, 346

angle tolerance (STL files), 418

angles of projection, 145–146

angular dimensions, 139

animations

- analysis tools for, 385–386
- of assembly models, 164–165
- tutorials, 210–212
- types of, 201–202

annotations, inserting, 153

ANSI (American National Standards Institute), 137, 491

ANSI fits, 348–349

ANSI weld symbols, 305–306

anti-aliasing, 195

API (application programming interface), 112

appearance

- of models, 201
- tutorials, 205–206

applications of rapid prototyping, 412–413

arithmetic tolerancing, 355

artistic bowl creation tutorial, 265–267

ASME (American Society of Mechanical Engineers), 137

- abbreviation rules, 137–138
- dimensioning rules, 139–144
- drafting rules, 138
- tolerance rules, 343–346

assemblies. *See* assembly models

assembly drawings, 164

- creating with bill of materials, 154–155

Assembly mode (SolidWorks), 8

assembly models, 157–158

- applying colors, 202–203
- configurations, 165
- creating
 - bottom-up modeling, 159
 - example, 20–22
 - top-down modeling, 159–163
 - tutorial, 29–31
- defined, 157

design tables, 166

exploded views and animations, 164–165

interference and collision detection, 166

mates, 158

motion study, 165–166, 385–386

parts versus, 157
planning, 157
saving as images, 62
tutorials
 ball screw creation, 173–174
 cam and follower creation, 167–168
 design table creation, 179–180
 gear mates, 169–171
 interference and collision detection, 178
 motion analysis, 398–403
 motion study creation, 176–177
 part creation in context, 180–182
 rack and pinion creation, 171–173
 universal joint motion, 174–176
 working hinge creation, 168–169
viewing, 62

assembly prototype file creation tutorial, 422–423

assembly trees, 157, 164

associativity of parts and engineering drawings, 151, 155

attachments in design binders, 85

auxiliary views, 146

B

BA (bend allowance), 290–291

background

 of models, 201
 tutorials, 203–204

ball screw assembly creation tutorial, 173–174

base circle (gears), 104

base features, 99

base flanges, 292

base plate creation example, 17–18

base support structure for rapid prototyping, 416–417

baseball hat creation tutorial, 273–277

baseline dimensions, 139, 354

basic size, 340–341

BD (bend deduction), 291

bend allowance (BA), 290–291

bending sheet metal, 290–291, 298–299, 310–311

bends, 292, 293

bicycle handlebar model tutorial, 228–229

bilateral tolerances, 342

bill of materials (BOM), 144, 151

 assembly drawings with, 154–155

Bill of Rights for the Planet, 322–323

block mold creation tutorial, 473–477

blocks in top-down assembly modeling, 160

bolt creation example, 123–125

Boolean operations, 59–61

BootCamp, 6

bosses, 471

bottle prototype, 420–421

bottom-up assembly modeling, 159

boundaries as surfaces, 251, 263–264

bracket creation tutorial, 66–67

broken views, 147

broken-out sections, 147

Brundtland Report, 320

B-splines. See splines

bubbles, 466

build orientation, 415

burn marks, 467

burrs, 436

bushing bearing creation tutorial, 24

C

CAD (computer-aided design) process, 4–5

CAD models. See parts

CAD/CAM systems

 analysis tools

 animation and motion analysis, 385–386

 finite element analysis, 389–390

 finite element method, 386–389

 flow simulation, 386

 mass properties calculations, 381–385

 purpose of, 377–378

 SolidWorks Simulation/SimulationXpress, 391

 tutorials, 396–407

 types of, 377–378

 Von Mises stress, 391–396

 data exchange, 378–381

 SolidWorks supported file formats, 379–380

 standard/de facto file formats, 378

 validating file translation, 380–381

CAM (computer-aided manufacturing) process, 6. See also manufacturing process

CAM add-in software, 449–450

cam and follower assembly creation tutorial, 167–168

camera sleds, 201, 202, 210–212

camera-based animation, 202, 210–212

cameras, 201, 206–207

canned cycles, 447

capturing design intent, 82–83

carbon footprint, 321–322, 325

Cartesian dimensions, 139

caster assembly creation tutorial, 70–72

caustic effects, 198

cavity (of molds), 468

center modifiers, 53–54

center planes for features, 38

.cgr file format, 380

chain dimensioning, 354

Chamfer feature, 304
chamfers, creating, 121–122
changing font size of dimensions, 9
circle parametric equation, 220–221
circular patterns, 54–55
circular pitch, 105
CL (cutter location) data, 447
coil spring creation tutorial, 63–65
collision detection in assembly models, 166, 178
colors, applying to objects, 202–203
comments, 83–84
communication
 guidelines for, 137
 abbreviation rules, 137–138
 dimensioning rules, 139–144
 drafting rules, 138
 SolidWorks tools for, 62
components. See parts
composite curves, 229–230
composites
 defined, 37
 images of, 38
 in part creation, 38
compression spring creation example, 119–120
computer mouse creation tutorial, 271–273
concurrent engineering, 442
configurations
 in assembly models, 165
 in design intent, 85
 design tables and, 112–114
conical tapers, 347
conics. See analytic curves
conjugate action (gears), 103–104
construction geometry, 48
continuous machining, 437–438
contours (loops), 217
conventional tolerances, 340, 367–368
converting
 shelled solids to sheet metal, 298
 solids into sheet metal, 297, 309–310
 surfaces into solids, 253
cooling time, 468
coordinate systems, 43–44, 437–438
copying
 entities, 58, 116–118
 features, 58–59
cores (of molds), 468
corners, 292, 294
crop views, 147
cross-section modeling approach, 12–14
 in drain plug tutorial, 90
 in slider block tutorial, 87
curve-driven patterns, 54–55

curves
 2D curves, 222
 3D curves, 223
 analytic curves, 217, 218
 equations
 circle parametric equation, 220–221
 line parametric equation, 219–220
 parametric versus explicit, 218–219
 spline parametric equation, 221–222
 in sketches, 217
 splitting, 224
 surfaces and, 249
 synthetic curves, 218
 tutorials
 2D curve creation with explicit equation, 224
 2D curve creation with parametric equation, 225
 3D curve creation with 3D points, 227–228
 3D curve creation with 3D sketches, 228–229
 3D curve creation with composite curves, 229–230
 3D curve creation with parametric equation, 225–226
 3D curve creation with projected curves, 232–241
 3D curve creation with projected sketches on curved faces, 231–232
 stethoscope model creation, 241–243
customizing SolidWorks, 11–13, 42
cutter location (CL) data, 447
cutting solids with surfaces, 253
cutting tools, 431–433

D

data exchange between CAD/CAM systems, 378–381
 SolidWorks supported file formats, 379–380
 standard/de facto file formats, 378
 tutorials
 exporting SolidWorks files, 396
 importing IGES and STEP files, 396–397
 validating file translation, 380–381
datum targets, 343, 359–360, 370–371
datums, 343, 359
de facto file formats, 378
decals, 198–199
Declaration of Interdependence for a Sustainable Future, 323
dedendum circle (gears), 104
defects
 in injection molding, 466–467
 in weldments, 300
degrees of freedom (DOF), 158, 431

deleting

- entities, 9, 349
- features, 9

depth of cut, 433–436

derived parts, 109

design, sustainable. See sustainable design

design binders, 84–85

design checkers, 151–152

design for anything (DFX), 442

design for assembly (DFA), 442

design for manufacturing (DFM), 442–445

design intent

- capturing, 82–83
- defined, 81
- documenting, 83
 - comments, 83–84
 - design binders, 84–85
 - design tables and configurations, 85
 - dimension names, 85
 - equations, 85
 - feature names, 85–86
 - folders in feature tree, 86
- geometric modeling versus, 81
- manufacturing process and, 441–442
- tutorials
 - design specifications, 91–93
 - mating conditions, 93–94
 - three modeling plans, 89–91
 - two modeling plans, 86–89

design intent systems, 81

design library, 110–112

design specifications in design intent, 91–93

design tables

- in assembly models, 166, 179–180
- configurations and, 112–114
- in design intent, 85
- examples, 110–114

designated points in part creation, 38

detail views, 146–147

deviation tolerance (STL files), 418

DFA (design for assembly), 442

DFM (design for manufacturing), 442–445

DFMExpress, 442–445

DFX (design for anything), 442

diameter/radius display, toggling, 10

dimensioning engineering drawings, 135–136

dimensioning rules (ASME), 139–144

dimensions. See also tolerances

- changing font size, 9
- in configurations, 112–114
- defined, 40–41
- in engineering drawings, examples, 143–144
- limits of, 348–353
- naming, 85

radius/diameter display, 10

in SolidWorks, 142–144

types of, 139, 155

DimXpert module, 364–365

direct dimensioning, 354

directional light, 196

disabling snap to endpoint/midpoint, 9, 54

documenting design intent, 83

- comments, 83–84
- design binders, 84–85
- design tables and configurations, 85
- dimension names, 85
- equations, 85
- feature names, 85–86
- folders in feature tree, 86

drafting rules (ASME), 138

drafts, 102, 470

- creating, 121–122

drain plug tutorial

- additive modeling plan, 90
- cross-section modeling approach, 90
- subtractive modeling plan, 91

Drawing mode (SolidWorks), 8

drawing templates, 148

drawings. See engineering drawings

drilling, 438–439, 442–443

drilling holes tutorial, 450–452

drills, 431

driving tools in NC machining, 446

dry machining, 430

ductile material, 391–392

.dwg file format, 380

.dxf file format, 380

E

Easter egg mold creation tutorial, 484–486

edge flanges, 293

edges, 40

editing

- entities, 58–59
- sketch planes, 45–46
- templates, 12–13

EDM (electrical discharge machining), 439–441

EDP (engineering design process), 4. See also sustainable design

eDrawings, 7, 62

ejection, 468

ejector marks, 467

enabling snap to endpoint/midpoint, 9, 54

enclosure, sheet metal as, 290

End Cap feature, 302–303, 304

end modifiers, 53–54

energy

- measuring consumption, 326

minimizing consumption, 321
renewable versus nonrenewable, 320

engineering design process (EDP), 4. See also sustainable design

engineering drawings

assembly drawings, 164
associativity with parts, 151, 155
communication guidelines for, 137
 abbreviation rules, 137–138
 dimensioning rules, 139–144
 drafting rules, 138
content and layout, 144–145
 angles of projection, 145–146
 bill of materials (BOM), 151
 control options in SolidWorks, 150
 sheets, 148–149
 title blocks, 149
 tolerances, 150, 343–346
 view types, 146–148
creating, 148
 example, 18–20
 tutorial, 28–29
design checkers, 151–152
dimensioning, 135–136
examples, dimensions in engineering
 drawings, 143–144
purpose of, 135
saving as images, 62
tutorials
 annotation insertion, 153
 assembly drawing creation with bill of
 materials, 154–155
 model-drawing associativity, 155
 mold drawing creation, 487
 sheet metal drawing creation, 308–309
 title block filling, 153–154
 view creation, 152–153
 weldment drawing creation, 313–315
viewing, 62

engraving parts tutorial, 231–232

entities

copying, 116–118
deleting, 9, 349
editing, 58–59
enabling/disabling snap to
 endpoint/midpoint, 9
geometric modifiers, 53–54
measuring, 59
offsetting, 58
in part creation, 50
patterns, 54–57
selecting multiple, 9, 58
transforming, 58
trimming, 58
viewing/hiding, 9

environmental sustainability. See sustainable design

.eprt file format, 379

equations

for curves
 2D curve creation with explicit equation
 tutorial, 224
 2D curve creation with parametric
 equation tutorial, 225
 3D curve creation with parametric
 equation tutorial, 225–226
 circle parametric equation, 220–221
 line parametric equation, 219–220
 parametric versus explicit, 218–219
 spline parametric equation, 221–222
in design intent, 85
in part creation, 38, 51–53
for surfaces
 parametric equations, 254–255
 plane parametric equation, 255–256
 ruled surface parametric equation,
 257–260

event-based motion studies, 385–386

examples

assembly model creation, 20–22
base plate creation, 17–18
Boolean operations, 59–61
circle parametric equation, 221
decal creation, 198–199
design table creation, 110–114
dimensions in engineering drawings,
 143–144
engineering drawings creation, 18–20
equations and link values, 51–53
feature-based pattern creation, 56–57
fit limits and tolerance zone calculations,
 352–353
free-form torus creation, 102–103
Gauss quadrature, 384
line parametric equation, 220
macro creation, 113–115
macro hotkey creation, 114
mass properties calculations, 384–385
material and texture additions, 200
modeling plan approaches, 39–45
parametric modeling, 41–42
part creation, 49–50
pin creation, 16–17
plane parametric equation, 256
plate creation, 15–16
ruled surface parametric equation, 257–258
sketch-based pattern creation, 55–56
SolidWorks DFMXpress, 445
SolidWorks TolAnalyst, 365–367
spline parametric equation, 222
spur gear CAD model creation, 107–109
stress testing, 393–396
surface-to-surface intersection curve
 creation, 258–260

- tolerance analysis, 364
- top-down assembly modeling, 161–163
- exiting current mode, 9**
- explicit equations for curves, 218–219, 224**
- exploded views of assembly models, 164–165**
- exporting SolidWorks files, 396**
- extension lines, 140**
- extrusions, 15, 100**
 - creating with macro, 113–115
 - defined, 37
 - images of, 38
 - in part creation, 38
 - as surfaces, 250, 261–263

F

- fabrication with rapid prototyping, 413**
- faces**

- milling tutorial, 452–455
 - part topology, 40

- facets (STL files), 418**

- FDM (fused deposition modeling), 419**

- FEA (finite element analysis), 389–390**

- static linear analysis tutorial, 403–404
 - thermal analysis tutorial, 405

- feature tree, 9**

- assembly trees versus, 164
 - folders in, 86
 - in part creation, 14, 47–48
 - for sheet metal, 296–297
 - for weldments, 301–302

- feature-based pattern creation example, 56–57**

- FeatureManager Design Tree. See feature tree**

- features, 15. See also parts; names of specific features**

- base features, 99
 - Boolean operations, 59–61
 - center planes, 38
 - creating, 15, 121–122
 - defined, 100
 - deleting, 9
 - design intent. *See* design intent
 - examples
 - bolt creation, 123–125
 - feature creation, 121–122
 - free-form torus creation, 102–103
 - hole wizard usage, 118–119
 - loft feature creation, 116–118
 - Smart Fasteners wizard usage, 122–123
 - sweep feature creation, 114–116
 - library features, 110–112
 - measuring, 59
 - naming, 85–86

- patterns, 54–57
 - reference geometry, 48–49
 - sheet metal, 291–296
 - transforming, 58–59
 - types of, 99, 100–102
 - weldments, 301–304

- features modeling approach, 12–14**

- base features, 99
 - questions in, 100
 - in slider block tutorial, 88–89

- feedrate, 433–436**

- FEM/FEA (finite element modeling/finite element analysis), 386–390, 393–396**

- file data exchange between CAD/CAM systems, 378–381**

- SolidWorks supported file formats, 379–380

- standard/de facto file formats, 378
 - tutorials

- exporting SolidWorks files, 396

- importing IGES and STEP files, 396–397

- validating file translation, 380–381

- file formats**

- SolidWorks supported, 379–380
 - standard/de facto, 378

- filled surfaces, 252, 263–264**

- fillets, creating, 121–122**

- filling title blocks, 153–154**

- finite element analysis (FEA), 389–390**

- static linear analysis tutorial, 403–404
 - thermal analysis tutorial, 405

- finite element method, 386–389, 393–396**

- fits, types of, 348–353**

- flanges, 291–293**

- flap creation tutorial, 22–23**

- flashing, 467**

- flat tapers, 347**

- flattening sheet metal, 292, 296**

- flow marks, 467**

- flow simulation, 386, 406–407**

- FloXpress, 406–407**

- flutes, 431**

- fog light, 196**

- folders in feature tree, 86**

- folding sheet metal, 295**

- font size of dimensions, changing, 9**

- free forms**

- defined, 37
 - images of, 38
 - in part creation, 38
 - surfaces as, 249

- free-form torus creation example, 102–103**

- fully defined sketches, 46**

- fused deposition modeling (FDM), 419**

G

GaBi, 328

gate and runner system, 469–470

gauges of sheet metal, 290

Gauss quadrature, 382–385

G-code programming, 447–449

GD&T (geometric dimensioning and tolerancing). See tolerances

gear teeth, 103

gears

conjugate action, 103–104

examples, 107–109

geometry of, 104–105

modeling, 105–106

spur gears, 103–109

tutorials

gear mates, 169–171

rack and pinion creation, 171–173

types of, 103

genera (genus), 40

geometric arrays. See patterns

geometric dimensioning and tolerancing (GD&T). See tolerances

geometric modeling

capturing design intent, 82

curves

2D curves, 222

3D curves, 223

analytic curves, 217, 218

circle parametric equation, 220–221

line parametric equation, 219–220

parametric versus explicit equations,
218–219

in sketches, 217

spline parametric equation, 221–222

splitting, 224

synthetic curves, 218

tutorials, 224–243

design intent versus, 81

surfaces

curves and, 249

as free forms, 249

manipulation, 260

parametric equations, 254–255

plane parametric equation, 255–256

purpose of, 249–250

ruled surface parametric equation,
257–260

in solid modeling, 252–253

tutorials, 261–281

types of, 250–252

visualization, 260

geometric modifiers, 53–54

geometric relation symbols, 10

geometric tolerances, 340

assigning and interpreting, 357–359

creation tutorial, 369–370

symbols, 357

true position, 356–357

green design. See sustainable design

grids, 54

Gusset feature, 302–303, 304

H

hair dryer creation tutorial, 277–279

Hannover Principles, 322–323

.hcg file format, 380

healthy buildings, 322

Help menu (SolidWorks), 11–12

**hemisphere mold creation tutorial,
481–484**

hems, 292, 294

hiding

sketch relations, 38

sketches, 9

Task Pane (SolidWorks), 9

hinge assembly tutorial, 168–169

hole wizard, 118–119

hole-based systems, 341

holes

drilling tutorial, 450–452

tolerances, 341

home position, 436

hose flow analysis tutorial, 406–407

hotkeys, 43, 114

housing (of molds), 468

.hsf file format, 380

IGES files, importing, 396–397

.igs file format, 379

images, saving as, 62

**impact metric of sustainable design,
325–326**

importing IGES and STEP files, 396–397

inch tolerances, 345–346

**in-context assembly modeling,
159–163**

injection molding

benefits and drawbacks, 464

defects in, 466–467

machines for, 464–465

materials, 464

mold design

overview, 467–470

phases of, 471–472

in SolidWorks, 472–473

part design, 470–471

purpose of, 463–464

steps in, 464, 465–466

tutorials

- block mold creation, 473–477
- Easter egg mold creation, 484–486
- hemisphere mold creation, 481–484
- mold drawing creation, 487
- sandbox mold creation, 477–480

inserting annotations, 153

inserts, 470

inspecting

- parts, 340
- weld joints, 300

instances, 158

interference detection in assembly

- models, 166, 178

interpolations, 447

interpreting tolerances, 360–362

intersection (Boolean operation), 59

intersection modifiers, 53–54

intersections (surfaces) tutorial, 268–269

involute profile, 104

ISO (International Organization for Standardization), 137, 327, 491

ISO fits, 348–349

ISO weld symbols, 305

J

job shop production, 428

jogs, 292, 294

.jpg file format, 380

K

K-Factor, 290

knit surfaces, 252, 261–263

L

laminated object manufacturing (LOM), 419

lathes, 428–430, 438

layering (slicing), 415–416

layout sketches, 159–160

LCA (life cycle assessment), 322, 323–327

leaders, 140

least material condition (LMC), 342–343

library features, 110–112

life cycle assessment (LCA), 322, 323–327

lighting

- in rendering, 196–198
- tutorials, 204–205
- types of, 196

limit dimensions, 341, 343

limits of dimensions, 348–353

line parametric equation, 219–220

linear patterns. See rectangular patterns

link values, 51–53

linking parameters, 51

LMC (least material condition), 342–343

lofted bends, 292, 295

lofts, 101

- creating, 116–118
- as surfaces, 251, 252, 261–263

LOM (laminated object manufacturing), 419

loops, 40, 217

M

machine tools, 428–430

machining

- cutting tools, 431–433

- drilling, 438–439

- EDM (electrical discharge machining), 439–441

- home position, 436

- machine tools, 428–430

- machining parameters, 433–436

- machining quality, 436

- milling, 439

- motion axes, 431

- NC machining

 - G-code and M-code programming, 447–449

 - programming concepts, 445–447

- process types, 428

- rapid positioning, 438

- SolidWorks DFMXpress, 442–445

- squaring stock, 436

- stock, 433

- toolpaths, 436–438

- turning, 438

- tutorials

 - drilling holes, 450–452

 - face milling, 452–455

 - pocket milling, 455–457

 - slot milling, 457–459

machining parameters, 433–436

machining quality, 436

MacOS, SolidWorks on, 6

macros, 111–114

- defined, 111

- examples

 - extrusion creation, 113–115

 - hotkey creation, 114

manufacturing engineers, 5

manufacturing process, 5

- CAM add-in software, 449–450

- design and, 441–442

- dimensioning for, 136

- injection molding

 - benefits and drawbacks, 464

 - defects in, 466–467

 - machines for, 464–465

 - materials, 464

- mold design overview, 467–470
 - mold design phases, 471–472
 - part design, 470–471
 - purpose of, 463–464
 - SolidWorks mold design, 472–473
 - steps in, 464, 465–466
 - tutorials, 473–487
- machining
 - cutting tools, 431–433
 - drilling, 438–439
 - EDM (electrical discharge machining), 439–441
 - home position, 436
 - machine tools, 428–430
 - machining parameters, 433–436
 - machining quality, 436
 - milling, 439
 - motion axes, 431
 - process types, 428
 - rapid positioning, 438
 - SolidWorks DFMXpress, 442–445
 - squaring stock, 436
 - stock, 433
 - toolpaths, 436–438
 - turning, 438
- NC machining
 - G-code and M-code programming, 447–449
 - programming concepts, 445–447
- prototyping
 - purpose of, 411
 - visualization with, 412–413
- rapid prototyping (RP)
 - applications, 412–413
 - benefits of, 411–412
 - bottle prototype, 420–421
 - build orientation, 415
 - layering (slicing), 415–416
 - steps in, 414, 418–419
 - STL files, 417–418
 - support structure, 416–417
 - techniques, 419
 - triangulation (tessellation), 414–415
 - tutorials, 421–424
- tolerances
 - datum targets, 359–360
 - geometric tolerances, 357–359
 - interpreting, 360–362
 - purpose of, 339–340
 - standardizing, 348–353
 - statistical tolerancing, 354–355
 - terminology, 340–343
 - true position, 356–357
 - types of, 340
- tutorials
 - drilling holes, 450–452
 - face milling, 452–455
 - pocket milling, 455–457
 - slot milling, 457–459
 - types of, 427–428
- mass customization, 428**
- mass production, 428**
- mass properties calculations, 381–385, 397–398**
- master parts. See templates**
- material conditions, 342–343**
- materials**
 - in injection molding, 464
 - properties, 392
 - rendering, 199–200
 - sheet metal, 289–290
 - in sustainable design, 325–326
 - transparency, 205–206
 - Von Mises stress, 391–396
- mates, 20**
 - applying, 158
 - defined, 157
 - tutorials
 - ball screw creation, 173–174
 - gear mates, 169–171
 - rack and pinion creation, 171–173
- mating conditions in design intent, 93–94**
- maximum material condition (MMC), 342–343**
- M-code programming, 447–449**
- MCS (model coordinate system), 43–44, 437–438**
- measuring entities/features, 59**
- meshing gears, 103–104**
- millimeter tolerances, 344–345**
- milling, 439, 443**
 - faces, 452–455
 - pockets, 455–457
 - slots, 457–459
- milling machines, 428–430**
- mills, 431**
- mirroring**
 - entities, 58
 - features, 59
- miter flanges, 293**
- MMC (maximum material condition), 342–343**
- model coordinate system (MCS), 43–44, 437–438**
- model items (dimensions), 155**
- modeling plan approaches**
 - design intent tutorials
 - three modeling plans, 89–91
 - two modeling plans, 86–89
 - example, 39–45
 - explained, 12–14
- models. See parts**
- modes (SolidWorks)**

- exiting, 9
- list of, 8
- mold base, 469**
- mold design**
 - overview, 467–470
 - phases of, 471–472
 - in SolidWorks, 472–473
- molds. See injection molding**
- motion axes, 431**
- motion study**
 - of assembly models, 165–166, 176–177
 - tutorials, 207–210, 398–403
 - types of, 385–386
- mount plate creation tutorial, 65–66**
- mouse button usage, 9**
- mouse wheel usage, 9**
- moving**
 - entities, 58
 - features, 58–59
 - Task Pane (SolidWorks), 10
- multiaxial loading, 393**
- multiple entities, selecting, 9, 58**
- multiple open windows, 9**
- multiple parts, viewing, 10**

N

- NA (neutral axis), 290**
- named (orthographic) views, 146**
- naming**
 - dimensions, 85
 - features, 85–86
- NC (numerical control) machining**
 - G-code and M-code programming, 447–449
 - programming concepts, 445–447
- neutral axis (NA), 290**
- nominal size, 340–341**
- nonrenewable energy, 320**
- normal vectors, 255**
- numerical control machining. See NC (numerical control) machining**

O

- offsetting**
 - entities, 58
 - surfaces, 263–264
- oil container creation tutorial, 279–281**
- opening**
 - parts, 8
 - STL files, 423–424
- optimization with rapid prototyping, 413**
- ordinate dimensions, 139**
- orthographic (named) views, 146**
- Our Common Future (Oxford University Press), 320**
- over defined sketches, 46**

P

- panning parts, 10**
- parameters, 40–41**
 - in configurations, 112–114
 - in equations, 51
 - linking, 51
- parametric equations**
 - for circles, 220–221
 - for curves, 218–219
 - 2D curve creation tutorial, 225
 - 3D curve creation tutorial, 225–226
 - for lines, 219–220
 - for planes, 255–256
 - for ruled surfaces, 257–260
 - for splines, 221–222
 - for surfaces, 254–255
- parametric modeling, 40–42**
- part history tree. See feature tree**
- Part mode (SolidWorks), 8**
- part prototype file creation tutorial, 421–422**
- partial filling (short shot), 466**
- parting axes, 469**
- parting lines, 468**
- parting surfaces, 469**
- parts. See also features**
 - applying colors, 202–203
 - assembly models versus, 157
 - associativity with engineering drawings, 151, 155
 - configurations. *See* configurations
 - creating, 14–15. *See also* sketches
 - in assembly context, 180–182
 - Boolean operations, 59–61
 - coordinate systems, 43–44
 - equations and link values, 51–53
 - example, 49–50
 - feature tree, 47–48
 - grids, 54
 - modeling plan approaches, 12–14
 - parametric modeling, 40–42
 - patterns, 54–57
 - planning, 38–39
 - sketch entities, 50
 - sketch planes, 43–46
 - templates, 61
 - curves. *See* curves
 - data exchange between CAD/CAM systems, 378–381
 - derived parts, 109
 - design intent. *See* design intent
 - designing for injection molding, 470–471
 - engraving tutorial, 231–232
 - examples
 - assembly model creation, 20–22
 - base plate creation, 17–18

- engineering drawings creation, 18–20
- part creation, 49–50
- pin creation, 16–17
- plate creation, 15–16
- inspecting, 340
- model communication tools in
 - SolidWorks, 62
- opening, 8
- reusing, 110–112
- saving as images, 62
- sheet metal. *See* sheet metal
- surfaces. *See* surfaces
- tolerancing, 136, 150. *See also* tolerances
- topology, 40
- types of, 37–38
- viewing, 10, 61, 62
- viewing multiple, 10
- visualization. *See* visualization
- welded. *See* weldments
- zooming/panning/rotating, 10
- patterns, 38, 54–57**
- .pdf file format, 379**
- PDM (product data management), 442**
- picture frame model tutorial, 229–230**
- pillow block creation tutorial, 25–27**
- pin and bushing bearing creation tutorial, 24**
- pin creation example, 16–17**
- pitch circle (gears), 104**
- placing toolbars, 10**
- planar surfaces, 252, 263–264**
- plane parametric equation, 255–256**
- planning**
 - assembly models, 157
 - part creation, 38–39
- plate creation example, 15–16**
- playback animation, 201–202**
- PLM (product life cycle management), 442**
- plus and minus tolerancing, 343**
- pocket milling tutorial, 455–457**
- point light, 196**
- point-to-point (PTP) machining, 437–438**
- pressure angle, 103**
- process planners, 5**
- product data management (PDM), 442**
- product life cycle management (PLM), 442**
- productivity tools, 43**
- programmable mice, 43**
- programming. *See* NC (numerical control) machining**
- projected curves, 232–241**
- projected views, 146**
- projection, angles of, 145–146**
- prototyping. *See also* rapid prototyping (RP)**
 - purpose of, 411
 - visualization with, 412–413

- .prt file format, 380**
- .prtdot file format, 379**
- .psd file format, 379**
- PTP (point-to-point) machining, 437–438**

R

- rack and pinion assembly creation tutorial, 171–173**
- radial dimensions, 139**
- radiate surfaces, 261–263**
- radius/diameter display, toggling, 10**
- rapid positioning, 438**
- rapid prototyping (RP)**
 - applications, 412–413
 - benefits of, 411–412
 - bottle prototype, 420–421
 - build orientation, 415
 - layering (slicing), 415–416
 - steps in, 414, 418–419
 - STL files, 417–418
 - support structure, 416–417
 - techniques, 419
 - triangulation (tessellation), 414–415
 - tutorials
 - assembly prototype file creation, 422–423
 - opening STL files, 423–424
 - part prototype file creation, 421–422
- real-time animation, 201**
- rectangular patterns, 54–55**
- recycling, 320, 322**
- reference dimensions, 155**
- reference geometry, 48–49**
- reflection in rendering, 197–198**
- regardless of feature size material condition (RFS), 342–343**
- relations, 51**
- relative-to-model views, 148**
- rendering**
 - appearance and transparency, 201
 - background, 201
 - cameras, 201
 - complexity of, 195–196
 - decals, 198–199
 - lighting, 196–198
 - materials, 199–200
 - models, 197–198
 - purpose of, 195
 - resolution, 195
 - scenes, 196
 - textures, 199
- renewable energy, 320**
- resolution**
 - in rendering, 195
 - of STL files, 417–418
- resources for SolidWorks, 11–12**
- reusing parts, 110–112**

revolves, 15, 100
defined, 37
images of, 38
in part creation, 38
as surfaces, 250, 261–263
RFS (regardless of feature size material condition), 342–343
ribs, 102, 471
creating, 121–122
rips, 292, 294
root circle (gears), 104
rotating
entities, 58
features, 58–59
parts, 10
rotation speed, 433–436
ruled surface parametric equation, 257–260
runners, 469–470

S

sandbox mold creation tutorial, 477–480
.sat file format, 379
save symbol, 9
saving
as images, 62
STL files, 417–418
scaling
entities, 58
features, 59
scenes
accessing library, 201
cameras in, 201, 206–207
in rendering, 196
tutorials
applying, 203–204
lighting, 204–205
screen capture, 9, 62
section views, 146
selecting multiple entities, 9, 58
selective laser sintering (SLS), 419
SGC (solid ground curing), 419
shaft-based systems, 341
shafts, 341
sheet metal
bending, 290–291, 298–299
creating, 297–299
as enclosure, 290
feature tree, 296–297
features, 291–296
gauges, 290
materials, 289–290
purpose of, 289
rules in DFMXpress, 443
tutorials
part creation via bending, 310–311
sheet metal creation, 306–307
sheet metal creation from solid body, 309–310
sheet metal drawing creation, 308–309
types of, 289
sheets in engineering drawings, 148–149
shelled solids, converting to sheet metal, 298
shells, 102, 121–122
short shot (partial filling), 466
shots, 468
shrinkage, 468
shut-off surfaces, 472
simple tensile tests, 392–393
Simulation, 391
SimulationXpress, 391
single limits in tolerances, 346
sink marks, 466
sinker EDM, 439–441
sizes, types of, 340–341
sketch entities. See entities
sketch planes, 15, 43–46
sketch relations, viewing/hiding, 38
sketch symbols, 9
sketch-based pattern creation example, 55–56
sketches
construction geometry, 48
creating features, 15
curves in, 217
entities, copying, 116–118
parametric modeling, 40–42
relations, 51
status, 46–47
tutorials
3D curve creation with 3D sketches, 228–229
3D curve creation with projected sketches on curved faces, 231–232
viewing/hiding, 9
SLA (stereolithography apparatus), 419
.sldftp file format, 379
.sldlfp file format, 379
.sldprt file format, 379
slicing (layering), 415–416
slider block tutorial
cross-section modeling approach, 87
features modeling approach, 88–89
slots
creating, 121–122
milling, 457–459
SLS (selective laser sintering), 419
Smart Fasteners wizard, 122–123
snap to endpoint/midpoint, enabling/disabling, 9, 54
society, design and, 321
solid ground curing (SGC), 419

solid models, 40
 converting to sheet metal, 297, 309–310
 mass properties calculation tutorial, 397–398
 surfaces in, 252–253

SolidWorks
 API (application programming interface), 112
 CAM add-in software, 449–450
 certification, 505–516
 communication tools, 62
 customizing, 11–13, 42
 dimensions in, 142–144
 drafting control options, 150
 exporting files, 396
 FEM/FEA modules, 391
 FloXpress, 406–407
 importing IGES and STEP files, 396–397
 machining, 442–445
 on MacOS, 6
 modes
 exiting, 9
 list of, 8
 mold design, 472–473
 operational overview, 8–12
 productivity tools, 43
 resources, 11–12
 starting, 8
 STL files, 417–418
 sustainable design tools, 328–332
 system requirements, 6
 tolerance analysis, 364–367, 372–373
 viewer version, 62

Sphera, 328

spindle speed, 433–436

spiral spring creation example, 120–121

spline parametric equation, 221–222

splines, 50

splitting curves, 224

spot light, 196

springs
 compression spring creation example, 119–120
 spiral spring creation example, 120–121

spur gears, 103–109

squaring stock, 436

standard file formats, 378

standardizing tolerances, 348–353

start parts. See templates

starting SolidWorks, 8

static linear analysis, 389, 403–404

statistical tolerance analysis, 363–364

statistical tolerancing, 354–355

steel washer redesign tutorial, 332–334

.step file format, 379

STEP files, importing, 396–397

stereolithography apparatus (SLA), 419

stethoscope model creation tutorial, 241–243

.stl file format, 379

STL files
 opening, 423–424
 saving, 417–418
 tutorials
 assembly prototype file creation, 422–423
 part prototype file creation, 421–422

stock
 defined, 433
 squaring, 436

stress testing, 391–396

stress-strain curve, 391–392

stretching entities, 58

Structural Member feature, 302, 303

subtraction (Boolean operation), 59

subtractive manufacturing, 412

subtractive modeling plan in drain plug tutorial, 91

support structure for rapid prototyping, 416–417

surface finish, 199

surface intersections tutorial, 268–269

surfaces
 curves and, 249
 equations
 parametric equations, 254–255
 plane parametric equation, 255–256
 ruled surface parametric equation, 257–260
 as free forms, 249
 manipulation, 260
 purpose of, 249–250
 in solid modeling, 252–253
 tutorials
 artistic bowl creation, 265–267
 baseball hat creation, 273–277
 basic surface creation, 261–264
 computer mouse creation, 271–273
 hair dryer creation, 277–279
 oil container creation, 279–281
 surface intersections, 268–269
 tablespoon creation, 269–271
 visualization, 264–265
 types of, 250–252
 visualization, 260

surface-to-surface intersection curve creation example, 258–260

Sustainability, 328–332

SustainabilityXpress, 328

sustainable design
 Declaration of Interdependence for a Sustainable Future, 323
 defined, 320
 guidelines for, 321–322
 Hannover Principles, 322–323

impact metric, 325–326
LCA (life cycle assessment), 323–327
manufacturing process and, 441–442
purpose of, 319–320
society and, 321
SolidWorks Sustainability, 328–332
steel washer redesign tutorial, 332–334
steps in, 327–328
tools, 328

sustainable manufacturing, 319–320

sustainable waste, 319–320

sweeps, 101

creating, 114–116
as surfaces, 251, 261–263

symmetric tolerances, 342

symmetry of parts, 38

synthetic curves, 218

synthetic surfaces, 249

system requirements for SolidWorks, 6

T

tablespoon creation tutorial, 269–271

tabs, 292, 293

tangent vectors, 219, 254

tapers, tolerancing, 347–348, 371–372

tapping tools, 431

targets in Boolean subtraction, 59

Task Pane (SolidWorks)

moving, 10
viewing/hiding, 9

templates

creating, 61
drawing templates, 148
editing, 12–13

tessellation (triangulation)

defined, 414–415
STL files, 417–418

testing with rapid prototyping, 413

textures, 199, 200

thermal analysis tutorial, 405

thickening surfaces, 253

thread types, 431

threads, 471

.tif file format, 380

time-based motion studies, 385

tire and pin creation tutorial, 69–70

title blocks

in engineering drawings, 149
filling, 153–154
tolerances in, 343

toggle radius/diameter display, 10

TolAnalyst module, 364–367, 372–373

tolerance accumulation, 353–354

tolerance analysis, 362–367

example, 364
methods of, 362

purpose of, 362

in SolidWorks, 364–367

tutorial, 372–373

tolerance notes, 343

tolerance synthesis, 362

tolerance zone, 341

tolerances. See also dimensions

ASME tolerance rules, 343–346

datum targets, 359–360

geometric tolerances, 357–359

interpreting, 360–362

purpose of, 339–340

standardizing, 348–353

statistical tolerancing, 354–355

of STL files, 418

terminology, 340–343

true position, 356–357

tutorials

conventional tolerance creation, 367–368

datum target definition, 370–371

geometric tolerance creation, 369–370

taper tolerances, 371–372

tolerance analysis, 372–373

types of, 340

tolerancing

parts, 136, 150

tapers, 347–348, 371–372

tool offset, 447

tool splitting, 468

toolbars, placing, 10

tooling, 468

tooling cost, 470

tooling split, 472

toolpaths, 436–438, 449–450

tools

in Boolean subtraction, 59

driving in NC machining, 446

injection molding machines, 464–465

machine tools, 428–430

for sustainable design, 328

top-down assembly modeling, 159–163

topology of parts, 40

torus creation example, 102–103

transforming

entities, 58

features, 58–59

translating

entities, 58

features, 58–59

files, 380–381

transparency

of models, 201

tutorials, 205–206

triangulation (tessellation)

defined, 414–415

STL files, 417–418

Trim/Extend feature, 302–303

- trimming entities, 58**
- true length dimensions, 139**
- true position, 356–357**
- turning, 438, 442**
- tutorials**
 - for analysis tools
 - flow simulation, 406–407
 - mass properties calculations, 397–398
 - motion analysis, 398–403
 - static linear analysis, 403–404
 - thermal analysis, 405
 - assembly models
 - ball screw creation, 173–174
 - cam and follower creation, 167–168
 - creating, 29–31
 - design table creation, 179–180
 - gear mates, 169–171
 - interference and collision detection, 178
 - motion study creation, 176–177
 - part creation in context, 180–182
 - rack and pinion creation, 171–173
 - universal joint motion, 174–176
 - working hinge creation, 168–169
 - background and scene application, 203–204
 - bolt creation, 123–125
 - bracket creation, 66–67
 - camera-based animation creation, 210–212
 - cameras in scenes, 206–207
 - caster assembly creation, 70–72
 - coil spring creation, 63–65
 - compression spring creation, 119–120
 - for curves
 - 2D curve creation with explicit equation, 224
 - 2D curve creation with parametric equation, 225
 - 3D curve creation with 3D points, 227–228
 - 3D curve creation with 3D sketches, 228–229
 - 3D curve creation with composite curves, 229–230
 - 3D curve creation with parametric equation, 225–226
 - 3D curve creation with projected curves, 232–241
 - 3D curve creation with projected sketches on curved faces, 231–232
 - stethoscope model creation, 241–243
 - data exchange
 - exporting SolidWorks files, 396
 - importing IGES and STEP files, 396–397
 - design intent
 - design specifications, 91–93
 - mating conditions, 93–94
 - three modeling plans, 89–91
 - two modeling plans, 86–89
 - engineering drawings
 - annotation insertion, 153
 - assembly drawing creation with bill of materials, 154–155
 - creating, 28–29
 - model-drawing associativity, 155
 - title block filling, 153–154
 - view creation, 152–153
 - feature creation, 121–122
 - flap creation, 22–23
 - hole wizard usage, 118–119
 - for injection molding
 - block mold creation, 473–477
 - Easter egg mold creation, 484–486
 - hemisphere mold creation, 481–484
 - mold drawing creation, 487
 - sandbox mold creation, 477–480
 - lighting in scenes, 204–205
 - loft feature creation, 116–118
 - for machining
 - drilling holes, 450–452
 - face milling, 452–455
 - pocket milling, 455–457
 - slot milling, 457–459
 - materials and transparency, 205–206
 - motion study creation, 207–210
 - mount plate creation, 65–66
 - object color application, 202–203
 - pillow block creation, 25–27
 - pin and bushing bearing creation, 24
 - for rapid prototyping (RP)
 - assembly prototype file creation, 422–423
 - opening STL files, 423–424
 - part prototype file creation, 421–422
 - for sheet metal
 - part creation via bending, 310–311
 - sheet metal creation, 306–307
 - sheet metal creation from solid body, 309–310
 - sheet metal drawing creation, 308–309
 - Smart Fasteners wizard usage, 122–123
 - spiral spring creation, 120–121
 - steel washer redesign, 332–334
 - for surfaces
 - artistic bowl creation, 265–267
 - baseball hat creation, 273–277
 - basic surface creation, 261–264
 - computer mouse creation, 271–273
 - hair dryer creation, 277–279
 - oil container creation, 279–281
 - surface intersections, 268–269
 - tablespoon creation, 269–271
 - visualization, 264–265
 - sweep feature creation, 114–116
 - tire and pin creation, 69–70

- for tolerances
 - conventional tolerance creation, 367–368
 - datum target definition, 370–371
 - geometric tolerance creation, 369–370
 - taper tolerances, 371–372
 - tolerance analysis, 372–373
- for weldments
 - weldment creation, 311–313
 - weldment drawing creation, 313–315
- wheel creation, 67–68

twist vectors, 254

U

- under defined sketches, 46**
- undercuts, 470, 471**
- undo symbol, 9**
- unfolding sheet metal, 295**
- uniaxial stress tests, 392–393**
- unilateral tolerances, 341–342**
- union (Boolean operation), 59**
- universal joint motion assembly tutorial, 174–176**

V

- validating file translation, 380–381**
- VB (Visual Basic), 112**
- .vda file format, 379**
- venting, 470**
- verification with rapid prototyping, 413**
- vertices (vertex), 40**
- viewing**
 - multiple parts, 10
 - parts, 10, 61
 - sketch relations, 38
 - sketches, 9
 - Task Pane (SolidWorks), 9
 - without SolidWorks software, 62
- views**
 - creating, 152–153
 - exploded, 164–165
 - types of, 146–148
- virtualization software on MacOS, 6**
- Visual Basic (VB), 112**
- visualization**
 - animations, types of, 201–202
 - with prototyping, 412–413
 - purpose of, 195
 - rendering
 - appearance and transparency, 201
 - background, 201
 - cameras, 201
 - complexity of, 195–196
 - decals, 198–199
 - lighting, 196–198

- materials, 199–200
- models, 197–198
- purpose of, 195
- resolution, 195
- scenes, 196
- textures, 199
- of surfaces, 260, 264–265

voids, 467

Von Mises stress, 391–396

W

- warping, 467**
- water eutrophication, 326**
- water footprint, 326**
- WCS (working coordinate system), 43–44**
- Weld Bead feature, 302–303, 304**
- weld joints**
 - inspecting, 300
 - types of, 301
- weld lines, 467**
- weld symbols, 305–306**
- welding**
 - equipment, 300
 - processes, 299–300
 - purpose of, 299
- weldments**
 - creating, 299–301
 - defects in, 300
 - feature tree, 301–302
 - features, 301–304
 - tutorials
 - weldment creation, 311–313
 - weldment drawing creation, 313–315
 - weld symbols, 305–306
- wet machining, 430**
- wheel creation tutorial, 67–68**
- wire EDM, 439–441**
- working coordinate system (WCS), 43–44**
- working hinge assembly creation tutorial, 168–169**
- worst-case tolerance analysis, 362–363**
- .wrl file format, 379**

X

- .x_b file format, 379**
- .x_t file format, 379**
- .xaml file format, 380**

Z

- zero-radius programming, 446**
- zooming parts, 10**