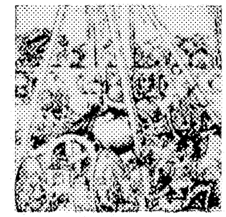
SPRINGS

Chapter 18



LEARNING OBJECTIVES

Upon completion of this chapter you will be able to:

1. Understand the purposes and uses of springs in mechanical assemblies.
2. Identify the various types of springs used in mechanical assemblies.
3. Differentiate between left-hand and right-hand springs.
4. Produce drawings of basic spring types.
5. Select the proper spring type and design requirements for a given engineering application.

18.1 INTRODUCTION

A **mechanical spring** is an elastic body whose mechanical function is to store energy when deflected by a force and to return the equivalent amount of energy on being released. In machines, mechanical springs exert a particular force, provide a means of flexibility, or store or absorb energy. Springs come in a variety of styles and sizes as off-the-shelf standard parts (Fig. 18.1), and can be designed for specific engineering applications in an infinite number of nonstandard configurations. In general, springs are classified as wire springs, flat springs, or specialty springs. Helical springs (Fig. 18.2) are similar to threads in that they are spiral shaped and made from round or square wire. They are designed to resist tensile, compressive, or torsional loads.

You can probably think of a number of engineering applications where springs are important mechanical components—the suspension system of an automobile, for example. Constant-force springs are found in many door openers. Springs are used in valves to position various components or to return components to a particular location after the force has been removed. Automation assemblies employ springs to absorb and store energy. Of course, most mechanical methods of keeping time have some kind of spring assembly. Fixturing in manufacturing and machining applications depends heavily on springs to absorb and release energy.

Most springs are represented by their centerline and the phantom lines defining their outside diameter when drawn in 2D, and as circles connected by crossing lines (from end to end) when represented in 3D (see "Focus On . . ." and "Applying Parametric Design" boxes). Seldom are springs drawn or modeled pictorially (coils drawn or modeled). However, at the end of the chapter, a step-by-step procedure for drawing spring coils is provided. Some CAD systems have macros programmed to generate 3D solid or surface models of springs automatically. This capability is seldom exercised unless the spring is nonstandard and must be represented accurately in order to be manufactured correctly.

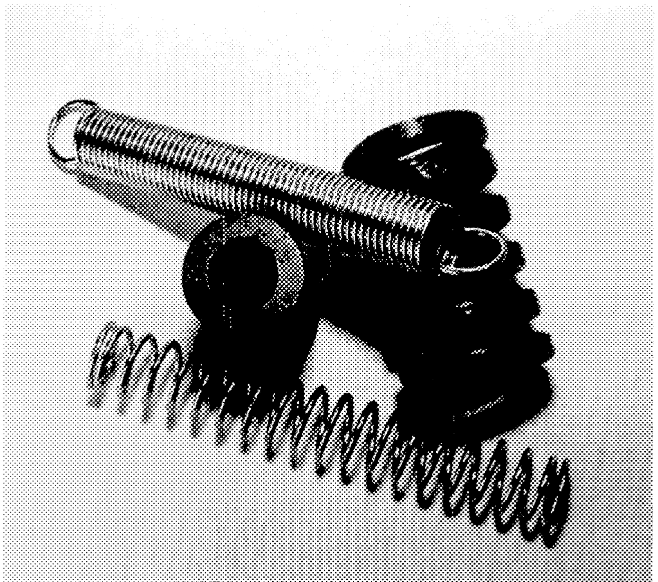


FIGURE 18.1 Industrial Springs

A number of requirements are applicable to all spring drawings, including material specifications and inspection notes. Since most springs are standard configurations and sizes, specifications and notes are more important than the drawing itself. Material specifications are designated in a general note on the drawing.

Springs are produced according to specific standards and specifications. ANSI recognizes six types of springs:

- **Compression**—helical, cylindrical, volute, coned disk (Belleville)
- **Extension**—helical
- **Garter**—helical
- **Torsion**—helical, torsion bar, spiral
- **Flat**—cantilever
- **Constant-force**—flat

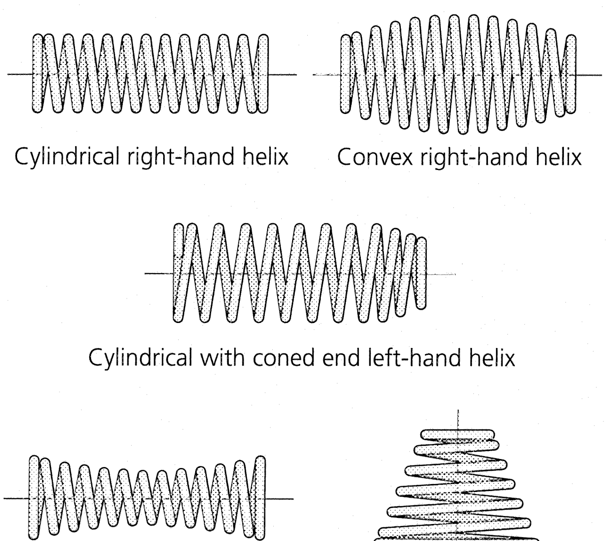


FIGURE 18.2 Helical Compression Spring Forms

18.1.1 Spring Terms

The following terms are used throughout this chapter and on drawings of mechanical springs.

Coils, active The number of coils used in computing the total deflection of a spring; those coils that are free to deflect under load

Deflection, total The movement of a spring from its free position to maximum operating position; in a compression spring, the deflection from the free length to the solid (compressed) length

Force The force exerted on a spring to reproduce or modify motion, or to maintain a force system in equilibrium

Helix The spiral form (open or closed) of compression, extension, and torsion springs

Length, free The overall length of a spring in the unloaded position

Length, solid The overall length of a compression spring when all coils are fully compressed

Load The force applied to a spring that causes deflection

Pitch The distance from center to center of the wire in adjacent active coils (recommended practice is to specify number of active coils rather than pitch)

Set The permanent distortion of the spring when stressed beyond its elastic limits

Total number of coils The number of active coils n plus the coils forming the ends

18.2 RIGHT-HAND AND LEFT-HAND SPRINGS

If dictated by design requirements, the direction of helix is specified as LEFT-HAND (LH) or RIGHT-HAND (RH). Otherwise, the direction of helix is specified as OPTIONAL. Usually, the direction is not important, except when a plug is screwed into the end or when one spring fits inside another. In the latter case, one spring is designated left-hand and the other spring right-hand. Figure 18.3 shows how the coils look for right-hand and left-hand springs: When you look at the back of your hands, the spring will be coiling either to the left or to the right.

Focus On . . .

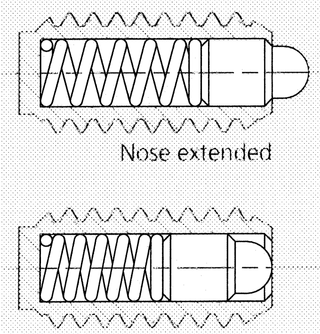
SPRING DESIGNS DRAWN FROM TOOLING LIBRARIES

Springs are found on a wide variety of designs throughout industry. Many standard off-the-shelf mechanical fasteners use springs. The choice of spring depends on the function of the spring. The size and force requirements are determined by the required application. Here, we see compression springs in the stainless spring plunger and the spring hook clamp. Both of these mechanical components are taken from Carr Lane's tooling library, which contains more than 6,000 3D modeled parts. The library is available for industry and schools and comes in a wide variety of CAD/CAM formats and for most CAD systems.

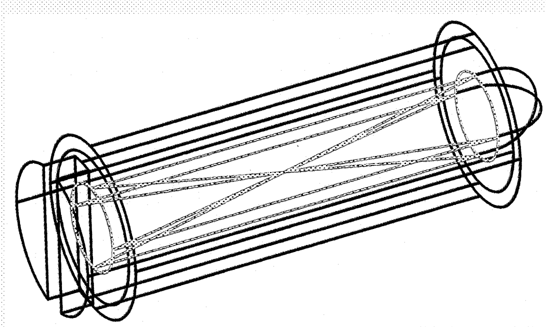
The spring plunger employs a spring to keep a required force on the nosepiece of the unit. The drawing of the plunger shows the nose in the extended and the retracted (compressed) positions. This mechanical device can quickly locate a part being positioned on a jig or fixture, or lift the part after it is machined. The spring must be strong enough to overcome the weight of the part in this latter application.

The hook clamp uses a spring to keep pressure on the body and arm of the clamp. This design is extremely compact and well suited for tight spaces and where high clamping forces are required.

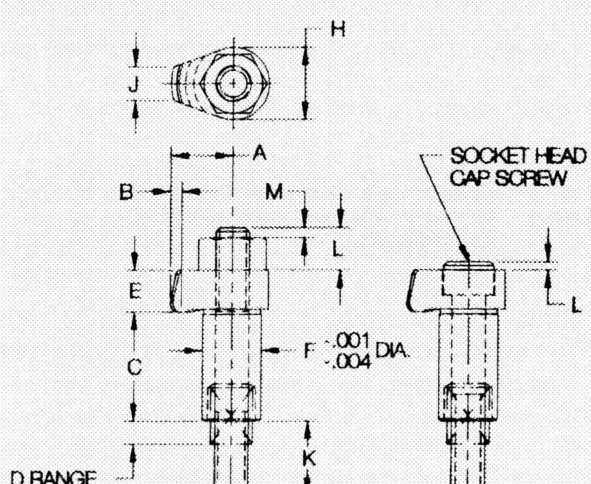
In the 2D views of the plunger device, the spring is represented pictorially. The 3D wireframe model of the plunger and the clamp use a simplified version of representation—showing the spring's end circles (diameters) connected by a crossing pair of lines. Seldom are springs modeled with 3D surface modeling or created as solid models.



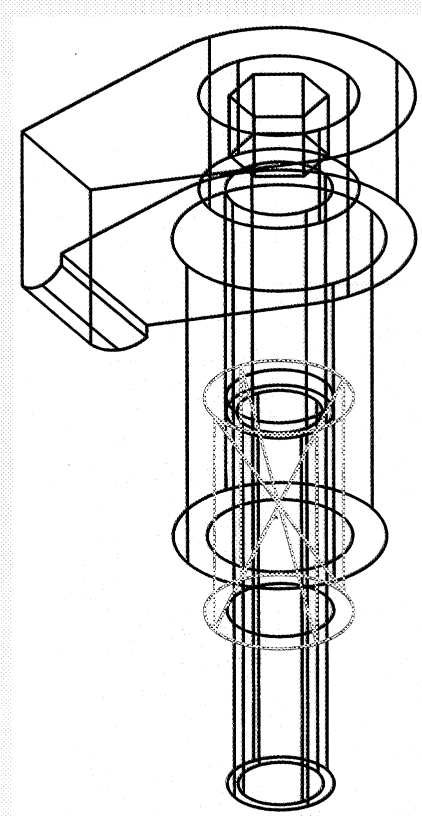
Stainless short spring plunger.



Wireframe model of spring plunger.



Hook clamp.



Wireframe model of hook clamp.

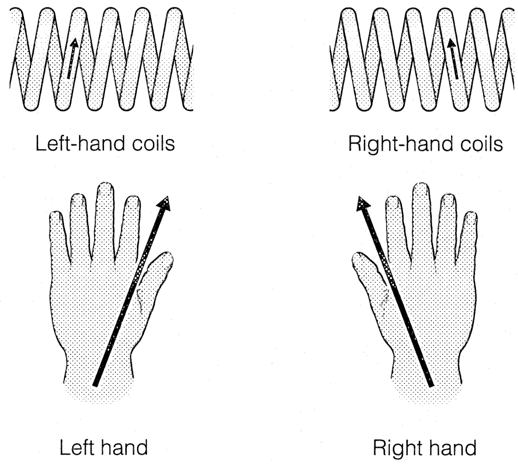


FIGURE 18.3 Left-Hand and Right-Hand Springs

18.3 COMPRESSION SPRINGS

A **compression spring** is an open-coil helical spring that resists a compressive force applied along the axis. Compression springs are coiled as a constant-diameter cylinder. Figure 18.4 shows an industrial application of a compression spring. Here, a large safety valve at a power plant has a compression spring incorporated into its design. Other common forms of compression springs, such as conical, tapered, concave, convex, and various combinations of these, are utilized as required by the application. While square, rectangular, or special-section wire may have to be

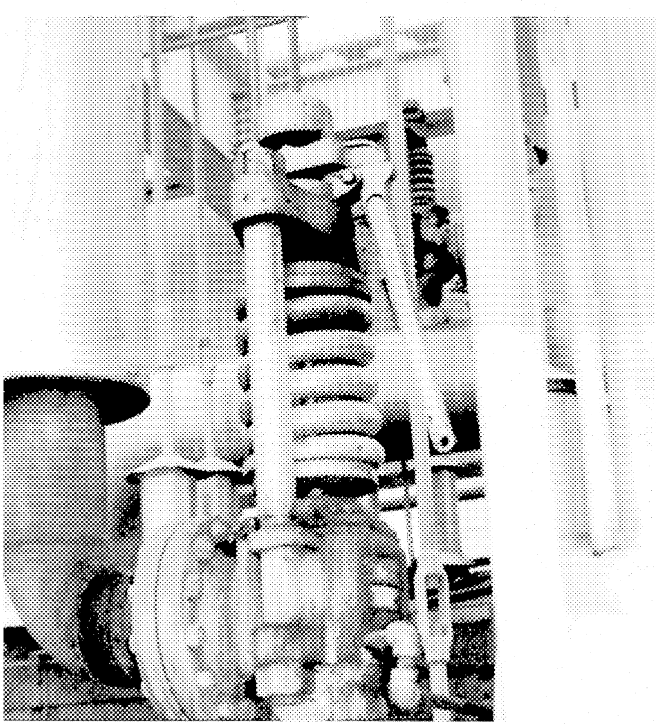
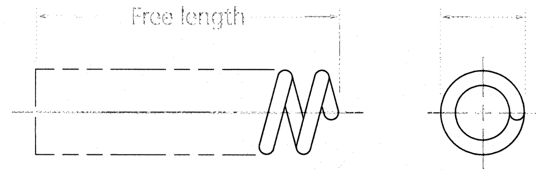


FIGURE 18.4 Compression Spring on a Safety Valve



Spring Data

Material specification . . . .
Wire diameter. . . . .
Direction of helix. . . . .
Total coils . . . .

FIGURE 18.5 Drawing Requirements for Helical Compression Springs

specified, round wire is predominant in compression springs. Figure 18.5 shows the recommended way to specify compression springs.

There are four basic types of compression spring ends, as shown in Figure 18.6. The particular type of ends specified affect the pitch, solid height, number of active and total coils, free length, and seating characteristics of the spring. The type of ends is specified on the drawing and dimensioned as required. Depending on the application of the compression spring, the following requirements are specified:

TO WORK OVER _____ MAX. DIAMETER ROD
TO WORK IN _____ MIN. DIAMETER BORE
ID (with tolerance) __________________________
OD (with tolerance) __________________________

18.4 EXTENSION SPRINGS

Extension springs (Fig. 18.7) absorb and store energy by resisting a pulling force. Various types of ends attach the extension spring to the source of the force. Most extension springs are wound with an initial tension, which holds the coils tightly together. The load necessary to overcome the internal force and just start coil separation is the same as the initial tension.

18.5 HELICAL EXTENSION SPRINGS

A **helical extension spring** is a close-wound spring, with or without initial tension, or an open-wound spring that resists an axial force trying to elongate the spring. Extension springs are formed or fitted with ends for attaching the spring to an assembly. Guidelines for specifying dimensional and force data on engineering drawings showing helical extension springs (Fig. 18.8) are similar to those established for helical compression springs. Usually, all coils in an

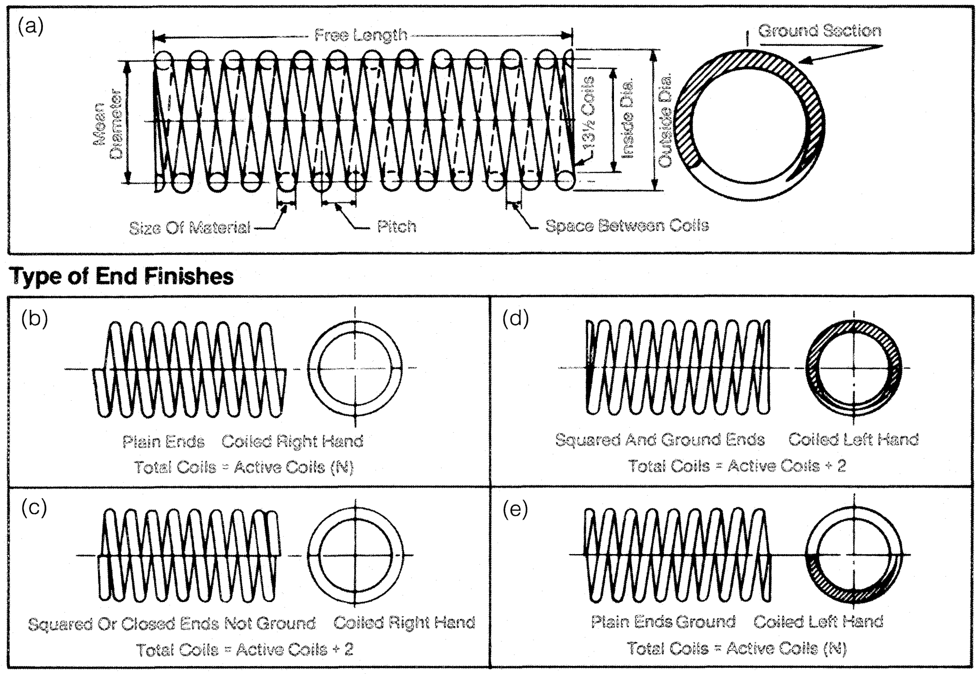


FIGURE 18.6 End Finishes for Compression Springs

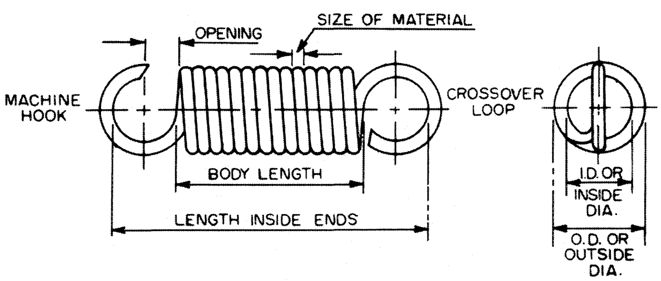
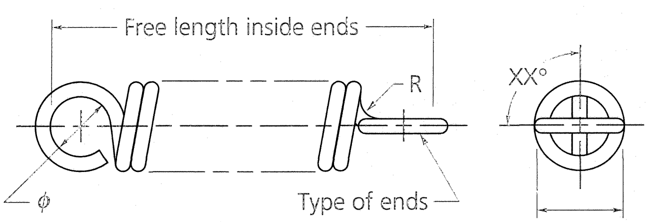


FIGURE 18.7 Extension Springs



Spring Data

Material specification . . . .
Wire diameter. . . . .
Direction of helix. . . . .
Total coils . . . .
Extended length without permanent set . . . .
Relative position of ends . . . .
Initial tension . . . .
Force at operating length of ______

FIGURE 18.8 Drawing Requirements for Helical Extension Springs

extension spring are active. Exceptions are those with plug ends and those with end coils coned over swivel hooks. The total number of coils required is specified.

18.6 GARTER EXTENSION SPRINGS

A **garter spring** (Fig. 18.9) is a long, close-coiled extension spring with its ends joined to form a ring. Garter springs are used in mechanical seals on shafting, to hold round segments together, as a belt, and as a holding device. The diameter over which the spring is to function is specified.

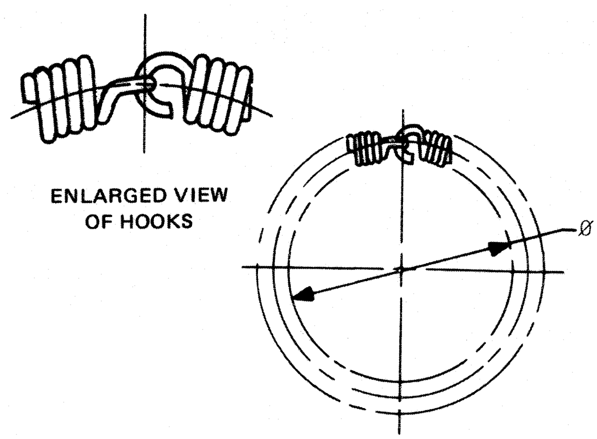
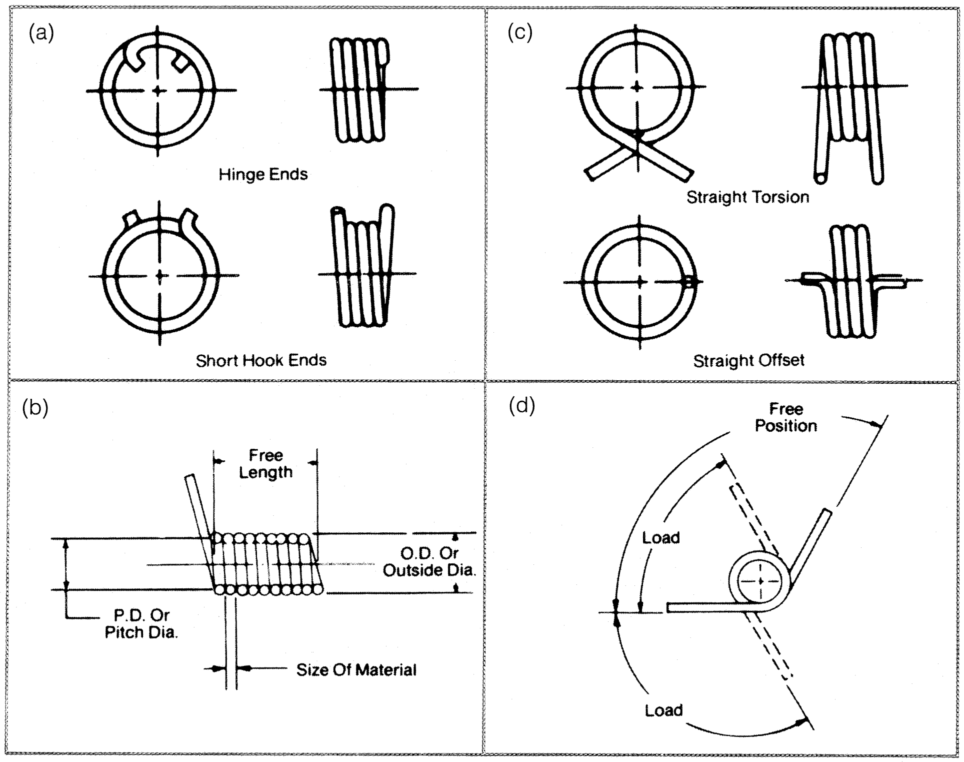


FIGURE 18.9 Drawing Requirements for Garter Springs



:IGURE 18.10 Drawing Requirements for Helical Torsion Springs

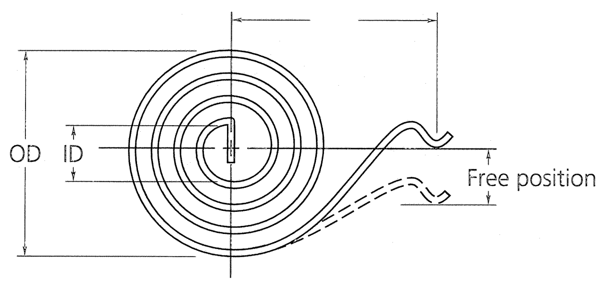
ʼor example, a shaft diameter may be given, although other han an actual shaft may be involved.

18.7 HELICAL TORSION SPRINGS

Ielical torsion springs (Fig. 18.10) are springs that resist a orce or exert a turning force in a plane at right angles to the xis of the coil. The wire itself is subjected to bending tresses rather than torsional stresses. Usually, all coils in a orsion spring are active. The total number of coils required nd the length in the free position are specified. The helix of torsion spring is important. Either **LEFT-HAND** or **RIGHT-IAND** is specified.

18.8 SPIRAL TORSION SPRINGS

piral torsion springs (Fig. 18.11), made of rectangular ection material, are wound flat, with an increasing space etween the coils. A spiral torsion spring is made by inding flat spring material on itself in the form of a spiral. is designed to wind up and exert a force in a rotating irection around the spring axis. This force may be delivered torque, or it may be converted into a push or pull force.



Spring Data

Material specification . . . .
Material size . . . .
Outside diameter. . . . .
Inside diameter . . . .
Developed length of material . . . .
Active length of material. . . . .
Number of coils in free position. . . . .
Torque at final position . . . .
Maximum deflection beyond final position without set . . . .
Type of ends. . . . .

FIGURE 18.11 Drawing Requirements for Spiral Torsion Springs

18.9 SPRING WASHERS

Because of trends toward miniaturization and greater compactness of design, **spring washers** are widely employed in industrial designs. They have space and weight advantages

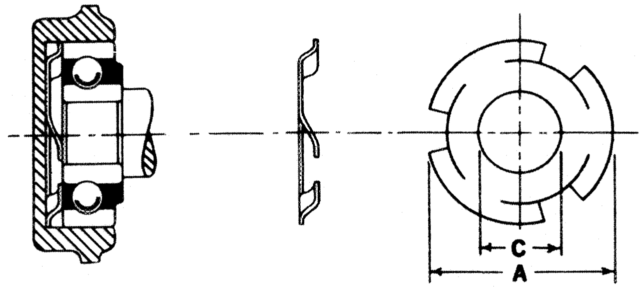
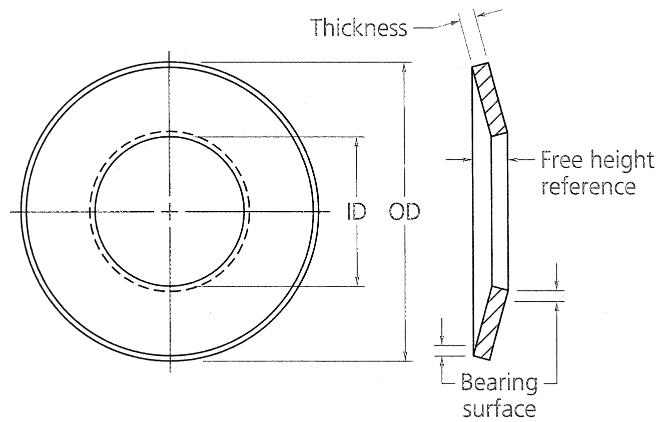


FIGURE 18.12 **Finger Spring Washer Installed in a Bearing Housing**



Spring Data

Material specification . . . .
Thickness of material. . . . .
Free height . . . .
Force at compressed height of ______
(Special data) . . . .

FIGURE 18.13 **Drawing Requirements for Coned Disk (Belleville) Springs**

over conventional wire springs and are often more economical. Their applications include keeping fasteners secure, distributing loads, absorbing vibrations, compensating for temperature changes, eliminating side and end play, and controlling end pressure. Figure 18.12 shows a finger spring washer used for preloading ball bearings.

A **coned disk (Belleville) spring** (Fig. 18.13) is a spring washer in the form of the frustum of a cone. It has constant material thickness and functions as a compression spring.

18.10 FLAT SPRINGS

The term **flat springs** covers a wide range of springs or stampings fabricated from flat strip material, which, when deflected by an external load, releases stored energy. Only a small portion of a complex-shaped stamping may actually be functioning as a spring. Leaf springs on the rear of cars and vans are examples of flat springs.

Flat springs include all springs made of flat strip or bar stock that deflects as a cantilever or as a simple beam. Figure 18.14 is an example of a detail drawing of a flat spring. A pictorial view shows the part in its finished state and gives the bending angle in degrees. The dimensioned view is of the flat (developed) part.

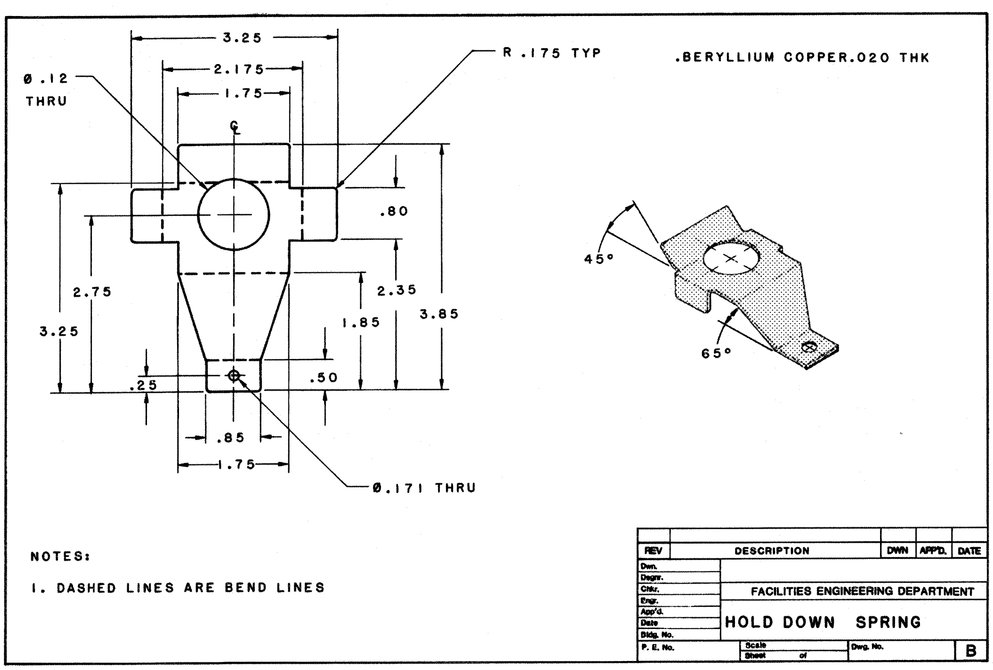


FIGURE 18.14
Hold-Down Spring

Applying Parametric Design . . .

SPRINGS CREATED WITH SWEEPS AND BLENDS

Springs and other helical features can be created with the sweep or blend commands. **Sweeps** (see Fig. A) are established along a three-dimensional path by creating a three-dimensional (3D) spline for the sweep trajectory. You can modify the Z coordinates of spline points (all other sketcher entities must lie on a 2D sketching plane) in order to establish points in space. In all other respects, 3D sweeps are created in the same way as are 2D sweeps. Sweeps are created by sketching a trajectory and then sketching a section to follow along it (Fig. B).

To Create a 3D Spline:

1. Create a 2D spline and dimension it to a coordinate system.
2. Modify the X, Y, and Z coordinates for one or more spline points. You can modify the spline coordinates manually or by using a spline definition file.

A **rotational blend** (Fig. C) is created by rotating sections about the Y axis. Angular dimensions are entered to control section orientation, and sections can be dimensioned from their Sketcher coordinate system to control radial placement.

If you define a rotational blend as being closed, the first section will be used automatically as the last section and a closed solid feature will be created; there is no need to sketch the last section.

Another method for creating springs (Figs. D–G) uses an advanced curve command called a **helical sweep**. A helical sweep is created by sweeping a section along a trajectory that lies in the *surface of revolution*. The trajectory is defined by both the profile of the surface of revolution and the distance between coils.

Helical Sweep

1. **Part**—part name: **spring**—**Feature**—**Create**—**Datum**—**Plane**—**Default**—**Create**—**Datum**—**Coord System**—**Default**—**Done**
2. **Create**—**Protrusion**—**Advanced**—**Done**—**Helical Sweep**—**Done**—**Constant**—**Thru Axis**—**Right Handed**—**Done**—**Plane** (pick DTM3) —**Okay**—**Top** (pick DTM2) — (sketch a line as shown in Fig. D) —**Alignment** (align the end of the line to DTM2) —**Regenerate**—**Dimension** (add dimensions as shown) —**Regenerate**—**Axis** (add an axis line along DTM3) —**Sketch**—**Line**—**Centerline**—**Vertical**—**Alignment** (align the axis line to DTM3) —**Regenerate**—**Done**

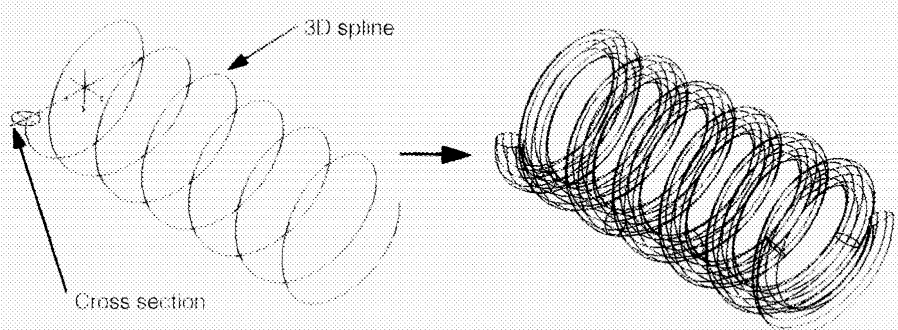


FIGURE A **A Spring Created from a 3D Spline**

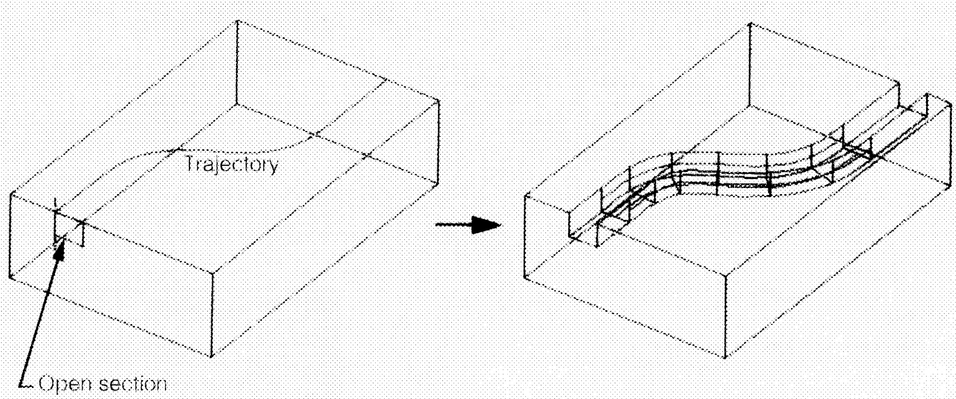


FIGURE B **A Swept Cut**

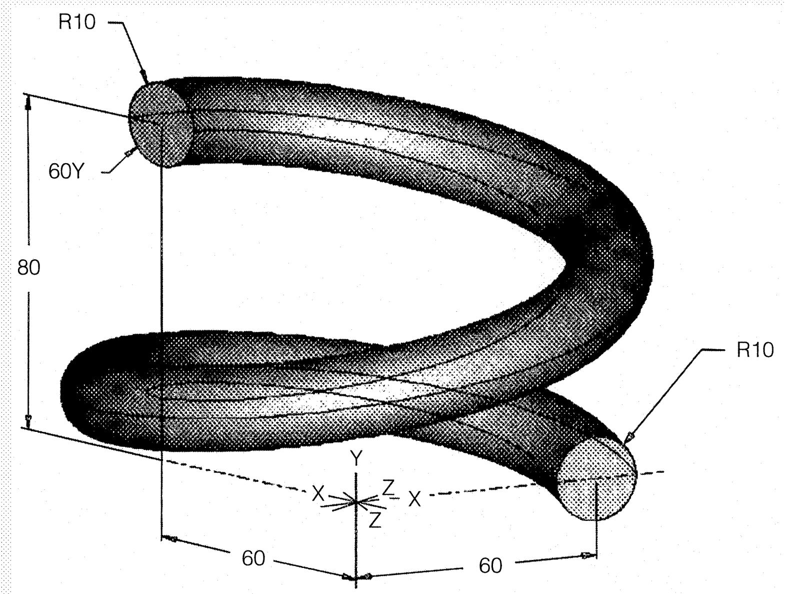


FIGURE C **A Sketched Rotational Blend with the First and Last Sections Displayed**

3. **Enter Pitch Value [40]** — (Now sketch the cross section, here a ∅15 circle) —**Sketch**—**Circle**—**Ctr/Point**—**Dimension** (add diameter dimension) —**Modify** (make dimension 15) —**Alignment** (align center of circle) —**Regenerate**—**Done**
4. [Spring is done (see Fig. E). Add the cut line as shown. This will create a ground end] **Create**—**Cut**—**Extrude**—**Solid**—**Done**—**Both side**—**Thru All**—**Done**—**Plane** (pick DTM3) —**Okay**—**Bottom** (pick DTM3) — **Sketch**—**Line**—**Horizontal**—**Alignment** (align the line to DTM1) —**Dimension** (dimension the line as in Fig. F) —**Regenerate**—**Modify** (modify dimensions to 200 and 240 as shown) —**Done**—**Okay** (see Figs. G–J)

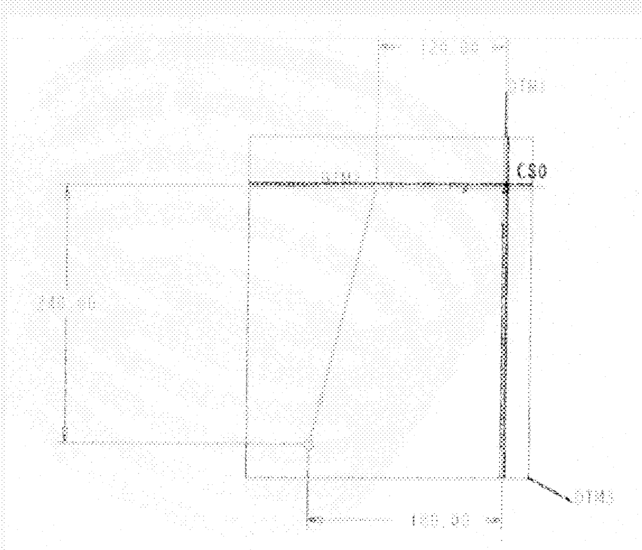


FIGURE D **Sketch of Spring Trajectory**

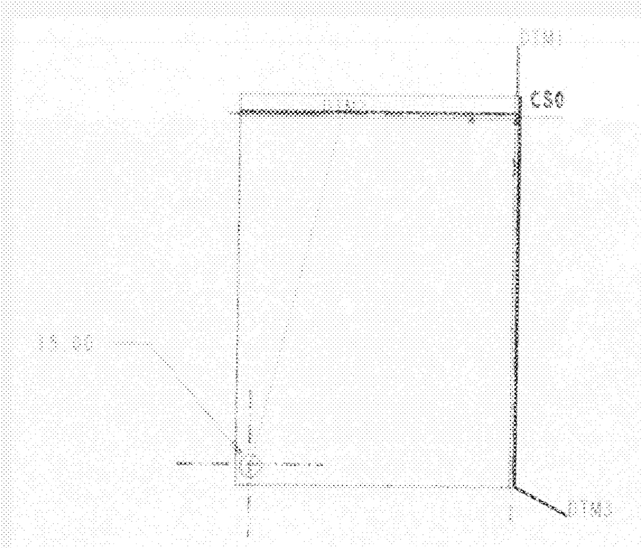
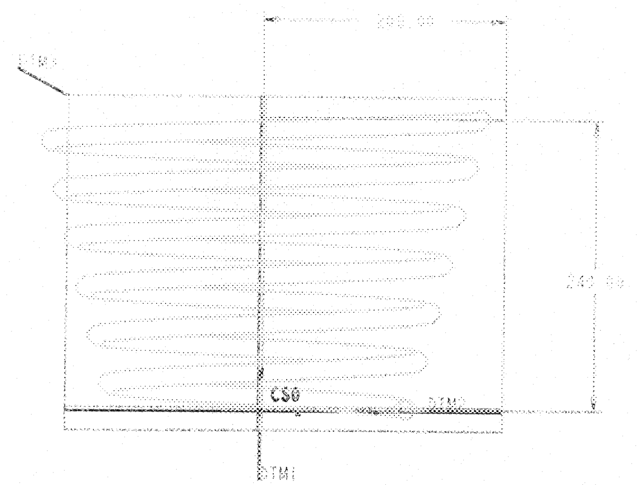


FIGURE E **Section of Spring Geometry**



IGURE F Adding a Cut to Create Ground End

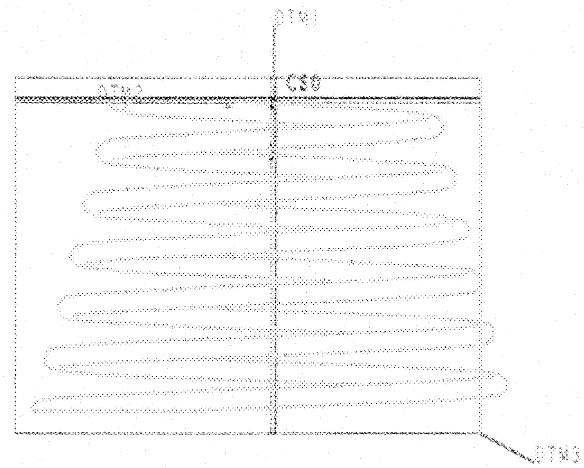


FIGURE G Completed Spring

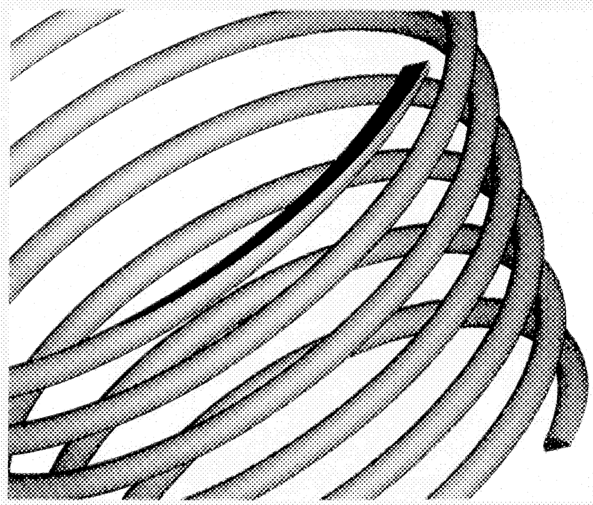
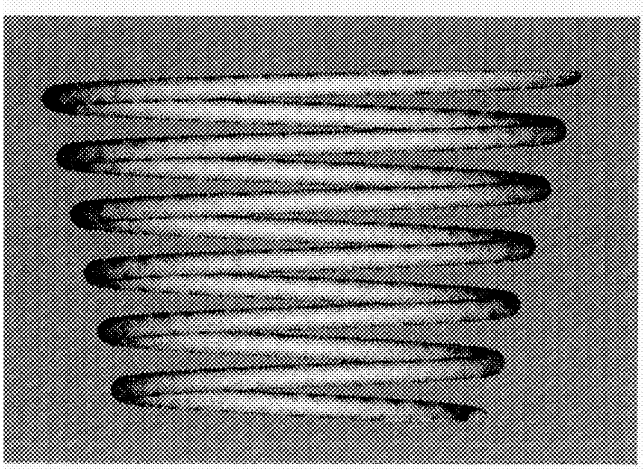


FIGURE H Close-Up of Ground Edge



GURE I Shaded Image of Spring

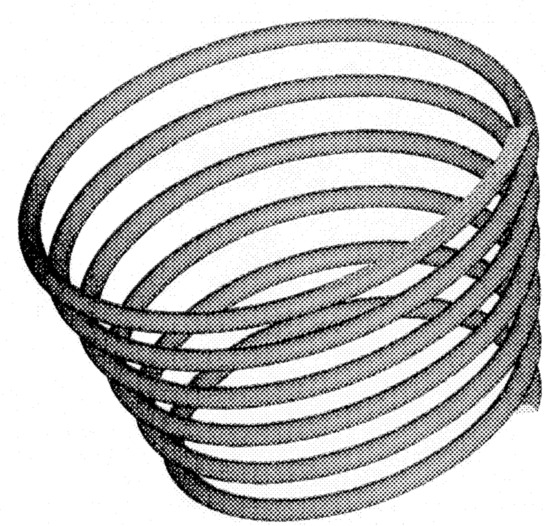
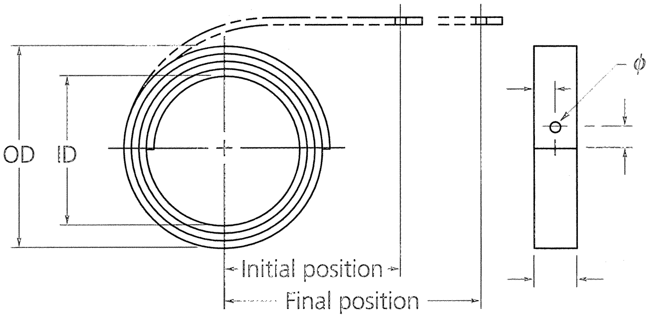


FIGURE J Shaded Image Showing Ground End



Spring Data

Material specification . . . .
Material size . . . .
Active length. . . . .
Number of coils. . . . .
Force. . . . .
Fits over. . . . .

FIGURE 18.15 Drawing Requirements for Constant-Force Springs

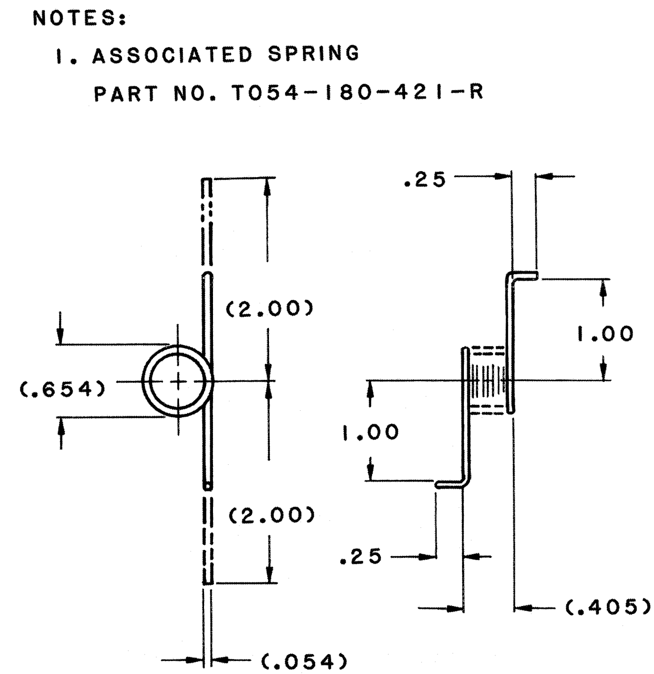


FIGURE 18.16 Torsion Spring Detail

18.11 CONSTANT-FORCE SPRINGS

A **constant-force spring** (Fig. 18.15) is a strip of flat spring material that has been wound to a given curvature so that, in its relaxed condition, it is in the form of a tightly wound coil or spiral. A constant force is obtained when the outer end of the spring is extended tangent to the coiled body of the spring. A constant torque is obtained when the outer end of the spring is attached to another spool and wound in either the reverse or the same direction as originally wound. Because the material for this type of spring is thin and the number of coils would be difficult to show in actual form, it is acceptable to exaggerate the thickness of the material and to show only enough coils to depict a coiled constant-force spring.

18.12 DRAWING SPRINGS

Springs are drawn using simplified methods, except when the spring must be pictorially correct for dimensioning. Even when these situations occur, it is normal practice to show only a limited number of coils and to use the simplified method for the remaining coils. The simplified method of representing springs employs phantom lines to establish the spring's outside diameter, and a centerline to locate its axis. Figure 18.16 shows an industrial detail of a torsion spring. The ends are drawn true, and the coils are shown with phantom lines. In Figure 18.17, six active coils were required, along with plain open ends.

To Draw the Coils of a Compression Spring:

1. Lay out the free length (overall length), the coil centerline, and the outside diameter of the spring. These dimensions are blocked in with construction lines. The *mean diameter* is drawn as shown in the side view (end view) of the spring. The mean diameter equals the outside diameter of the coil minus the wire diameter.

   One coil diameter (wire diameter) is drawn in the side view (Fig. 18.17). The inside diameter and the outside diameter of the coil are drawn in the side view (end view).

   The front view of the spring is divided into even spaces based on the total number of coils. Each of the coil cross-section diameters is drawn lightly along the top and bottom of the coil length, at the appropriate divisions.
2. Lightly draw the coil winding (left- or right-hand) as shown. The appropriate end style is then constructed. (The plain open end is used in this example.)
3. Darken the coil, using appropriate line weights, and dimension accordingly. (Dimensions are not shown in this example; refer to previous examples throughout the chapter.)

Drawing an *extension spring* is similar to constructing a compression spring except that the coils are solid in the relaxed (unloaded) position; in other words, the coils touch.

To draw a Full-Loop-over-Center Extension Spring (Fig. 18.18):

1. Draw centerlines and the outside and inside diameters. Then draw the end loops (they will be the same as the end view) at the required length, and complete the construction.

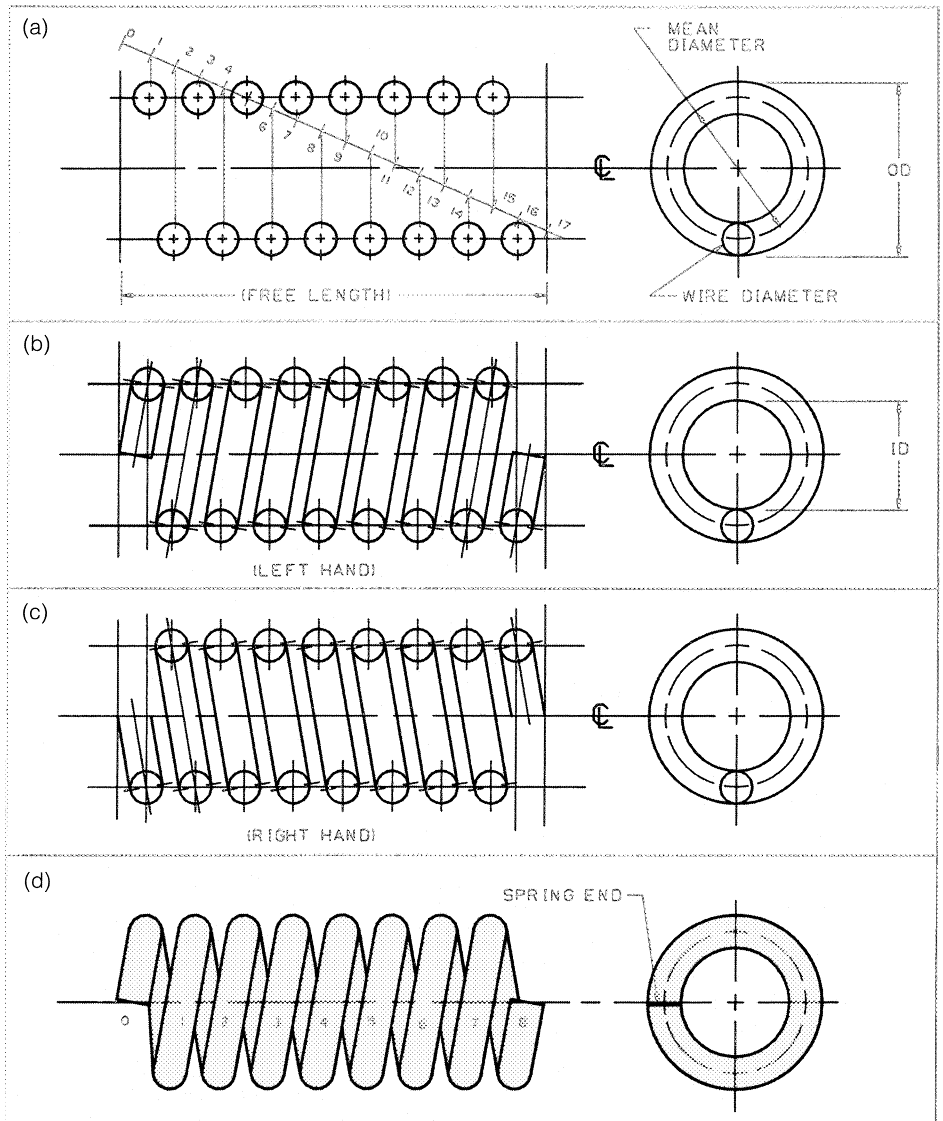


FIGURE 18.17 Drawing a Compression Spring

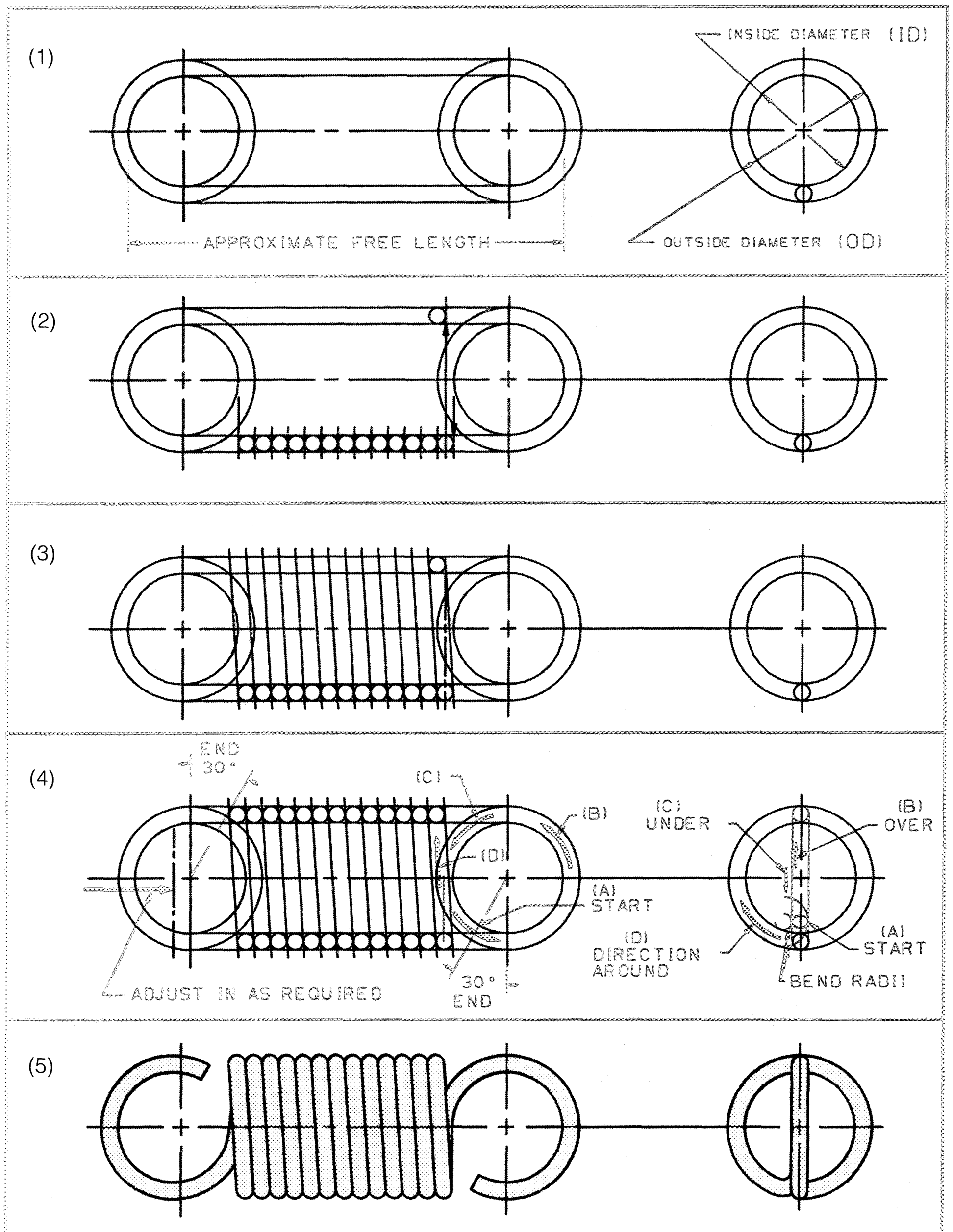
- Using a circle template and the appropriate diameter (wire size), draw the wire diameters on the top and the bottom.
- Extend a construction line from the end of the edge of the wire diameter on the lower left to the edge of the upper left diameter. Draw lines parallel to the first construction line along the total length of the spring coils.
- Draw circles that represent the wire diameters along the upper portion of the coil length, as shown. Then adjust the spring end as shown. The spring ends are established by a 30° construction line extended from the coil end diameter.
- Complete the coil and end visibility carefully. Use appropriate line weights to darken and complete the drawing. Add dimensions as required to manufacture the spring.

QUIZ

True or False

1. Spring washers should not be used in applications where weight and space are the prime considerations.
2. The solid length of a spring is its overall length in the unloaded position.
3. Usually, all coils in a torsion spring are active.
4. A Belleville spring is a coned disk spring.
5. *Set* is the permanent distortion of the spring when stressed beyond its elastic limits.
6. A garter spring may not be used to hold round segments together.
7. There is really only one basic type of compression spring end.
8. The force that is applied to a spring that causes deflection is known as load.

FIGURE 18.18 Drawing an Extension Spring



Fill in the Blanks

9. __________, __________, and __________ are three types of end configurations used on extension springs.
10. A __________ is a spring washer in the form of the frustum of a cone.
11. A __________ is the spiral form of compression, extension, and torsion springs.
12. A __________ is an open-coil helical spring that resists a compressive force along the axis.
13. The __________ is the movement of a spring from its free position to maximum operating position.
14. __________ absorb and store energy by resisting a pulling force.
15. A __________ spring is made by winding flat spring material on itself in the form of a spiral.
16. A __________ spring is a strip of flat spring material that has been wound to a given curvature so it is in the form of a tightly wound coil.

Answer the Following

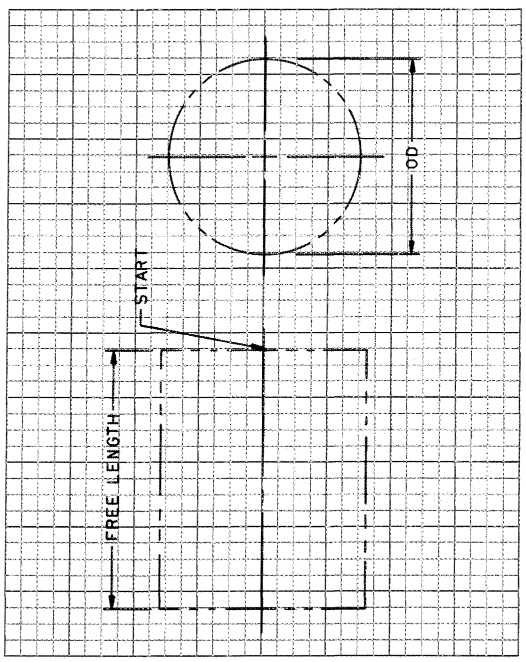
17. What is the difference between the free length and the solid length of a spring?
18. What is the difference between the terms *active number of coils* and *total number of coils?*
19. Describe the difference between a left-hand spring and a right-hand spring.
20. What is a compression spring?
21. Describe how *pitch* is defined for springs.
22. What is the difference between a helical extension spring and a garter extension spring?
23. Describe the basic function of an extension spring.
24. What is a spring washer?

EXERCISES

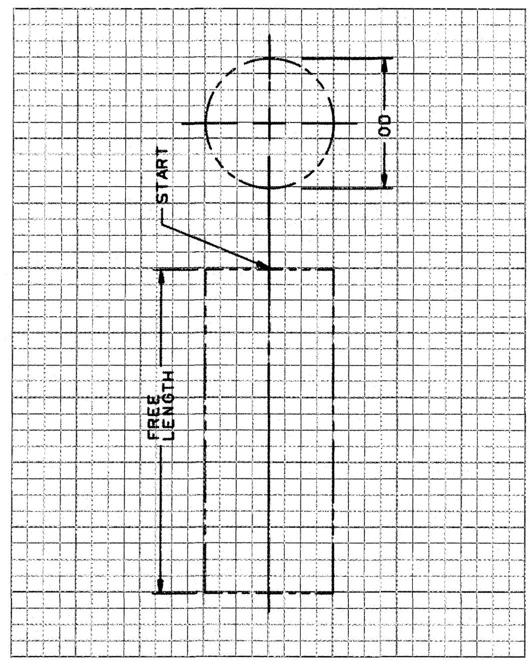
Exercises may be assigned as sketching or instrument projects. Transfer the given information to an "A"-size sheet of .25 in. grid paper. Complete all views, and solve for proper visibility, including centerlines, object lines, and hidden lines. Exercises that are not assigned by the instructor can be sketched in the text to provide practice and to enhance understanding of the preceding instructional material. Dimensions for fasteners used in these exercises can be located in figures throughout the chapter and in Appendix C.

Exercise 18.1 Using detailed representation, draw the compression spring as shown. List all pertinent specifications on the drawing. The spring is steel, has a wire diameter of .250 in., is left-hand wound, with square ends, and has eight active coils and ten total coils.

Exercise 18.2 Draw all coils for the compression spring. The spring is right-hand wound, has a wire diameter of .187 in., with plain ends, and has a total of eighteen active coils (also eighteen total coils). List all controlling specifications.



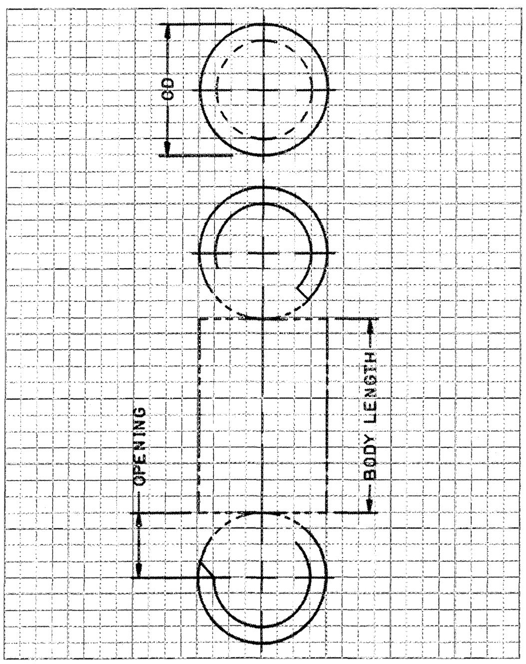
EXERCISE 18.1



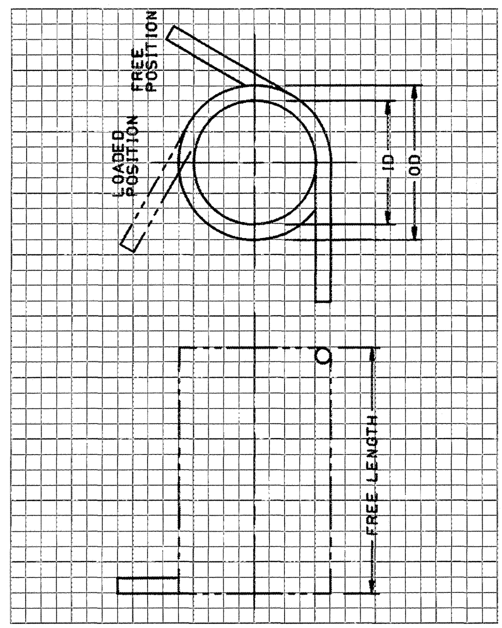
EXERCISE 18.2

Exercise 18.3 Complete the helical extension spring. The spring is to be right-hand wound, has a .250 in. wire diameter, and comes with round ends, as shown. Draw all coils. List all specifications.

Exercise 18.4 Complete the helical torsion spring using a wire diameter of .200 in. and seventeen coils. The spring is left-hand wound. Draw all coils. List all specifications.



EXERCISE 18.3



EXERCISE 18.4

PROBLEMS

Problem 18.1 Draw a detailed representation of a compression spring. List all specifications on the drawing. The spring is steel, has a wire diameter of .200 in., is right-hand wound, with square ends, and has ten active coils and twelve total coils. Use the same OD.

Problem 18.2 Draw a compression spring showing five coils at each end and the remainder with phantom lines. The spring is left-hand wound, has a wire diameter of .125 in., comes with plain ends, and has a total of twenty active coils (also twenty total coils). List all controlling specifications. Use the same OD.

Problem 18.3 Draw a helical extension spring. The spring is to be left-hand wound, has a .200 in. wire diameter, and comes with round ends. Draw all coils, list the specifications, and use the same OD.

Problem 18.4 Construct a helical torsion spring with a wire diameter of .187 in. and fifteen coils. The spring is right-hand wound. Draw all coils. List all specifications. Use the same OD.

Problem 18.5 Design and detail an extension spring with a full loop over center on the right end and a long hook over center on the left end. The spring is right-hand wound and has a free length of 180 mm with a 6 mm wire size. There are fourteen total coils. The coil length is 80 mm with an OD of 50 mm. Show all dimensions.

Problem 18.6 Design and detail an extension spring with the following specifications:

Approximate free length = 1700 mm
Winding = left-hand (spiral)
Wire size = 5 mm
OD = 50 mm
Ends = full loop over center for both

Problem 18.7 Draw and dimension a compression spring with plain closed ends and a wire diameter of 10 mm. The spring will be left-hand wound, with an OD of 48 mm. The free length is 160 mm. Calculate the solid length. There are ten total coils (eight are active).

Problem 18.8 Design and detail a compression spring with the following specifications:

Free length = 4.00 in.
Coils = 6 total; 3 active
Wire size = .50 in.
Ends = closed ground
OD = 3.75 in.
Winding = left-hand
Solid length = (calculate)

Problem 18.9 Design and detail a compression spring with the following specifications:

Free length = 190 mm
Coils = 18 total; 12 active
Wire size = 6 mm
Ends = plain open
OD = 60 mm
Winding = right-hand
Solid length = (calculate)

Problem 18.10 Design and detail a compression spring with the following specifications:

Free length = 5.00 in.
Coils = 7 total; 5 active
Wire size = .375 in.
Ends = ground open
OD = 3.00 in.
Winding = left-hand
Solid length = (calculate)

Problem 18.11 Design and detail (draw 2× size) a torsion spring with the following specifications:

Free length = .875 in.
Coils = 5
Wire size = .125 in.
Ends = straight and turned to follow radial lines to center of spring and to extend .375 in. from OD of spring
OD = 1.375 in.
Winding = left-hand

Problem 18.12 Design and detail a torsion spring with the following specifications:

Free length = 50 mm
Coils = 10
Wire size = 6 mm
Ends = as assigned by instructor
OD = 70 mm
Winding = right-hand