Chapter Objectives

- Explain how pattern development is used in the packaging industry.
- Identify the methods for processing sheet-metal patterns.
- Describe the general principles of pattern development.
- Discuss the three main types of pattern development.
- Prepare patterns using the three main types of pattern development.
- Prepare patterns for intersecting prisms and cylinders.

Pack it Up  The use of yellow and gray is important to these packaging designs. How do these colors complement the packaged items? Would you use these colors? Why or why not?
Philippe Starck is a French designer who created a line of everyday items for Target. Design Guys, a Minneapolis-based firm, was asked to create the packaging for the Starck product line. The team at Design Guys wanted to showcase Starck’s work using an understated look that could still grab the customer’s attention. They wanted their packaging to reflect Starck’s elegance and artistry, and his belief that joy can be found in simple things.

The team at Design Guys invented unique fold-up forms using plastic shrink-wrap. They chose a joyful yellow color set off by a neutral gray. They included Philippe Starck’s face and commentary about his design on the packaging. Their packaging is powerful because it says something about the joy of using the item inside, about the artistry of Philippe Starck, and about Target, the store that makes high quality and great design available to a mass audience.

**Academic Skills and Abilities**
- Graphic design
- Engineering technology
- Marketing
- Problem solving
- Sketching and visualizing

**Career Pathways**
Designers are both creative and practical. A bachelor’s degree is required for most entry-level positions. Helpful high school courses include English, mathematics, business, family and consumer sciences, computer-aided design (CAD), and art.

Go to glencoe.com for this book’s OLC to learn more about Design Guys.
14.1 Principles of Pattern Development

**Preview** Patterns are essential in making industrial products and those we use at home. Look at the packages the products you buy every day. Did you ever think these were made from patterns?

**Content Vocabulary**
- pattern development
- stretchout
- development pattern
- parallel-line development
- stretchout line
- measuring line
- radial-line development
- triangulation
- transition piece

**Academic Vocabulary**
Learning these words while you read this section will also help you in your other subjects and tests.
- diverse
- approximate

**Graphic Organizer**
Use a table like the one below to organize notes about pattern development.

<table>
<thead>
<tr>
<th>Type of pattern development:</th>
<th>Application:</th>
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Go to glencoe.com for this book’s OLC for a downloadable version of this graphic organizer.

**Academic Standards**

**English Language Arts**
Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge (NCTE)

**Mathematics**
Solve problems that arise in mathematics and in other contexts (NCTM)

**Industry Standards**

**ADDA Section 14**
Standards and Practices Listing (ASME Y14.24)
Understanding Pattern Development

How are patterns used in designing products for industry?

Making patterns or pattern developments is an important part of industrial drafting. Many different industries use them. Familiar items such as pipes, ducts for hot- or cold-air systems, parts of buildings, aircraft, automobiles, storage tanks, cabinets, boxes and cartons, frozen food packages, and countless other items are designed using pattern developments.

To make such items, a drafter must first draw them as a pattern or pattern development. A pattern development, also called a stretchout or simply a development, is a full-size layout of an object made on a single flat plane. A development that is not full size is not a pattern; it is simply a drawing or representation of the pattern. Therefore, outlines for very large objects drawn at a reduced scale are not pattern developments.

The pattern is the original part of the pattern development from which flat patterns can then be cut from flat sheets of material that are folded, rolled, or otherwise formed into the required shape (see Figure 14-1). Materials used include paper; wood; fiberboard; fabrics; various cardboards, plastics, and films; metals such as steel, tin, copper, brass, and aluminum; and so on.

The cover on this book is an example of a pattern development. It was initially flat, then was wrapped around the book to make a protective covering. Notice that it fits neatly around all surfaces. It does so because each part has been carefully measured and laid out in relation to other parts.

Describe How are pattern developments different from other technical drawings?

The Packaging Industry

What are some materials used for pattern developments?

Packaging is a very large industry that uses pattern developments. Creating packages takes both engineering and artistic skill because each package design must meet specific requirements. They must be cost-effective for mass production, and at the same time resilient and durable enough to protect what they contain. Some packages must look attractive for sales appeal.

To meet these requirements, designers use many diverse materials in various thicknesses, that can be folded easily into the desired shape or form.

Packages made of cardboard, corrugated board, and other materials require an allowance...
for thickness. Examples are boxes made up of a separate container and cover (see Figure 14-2) and a slide-in box (see Figure 14-3).

**Sheet-Metal Pattern Drafting**

What processes are used to form metal objects made from patterns?

Metal that has been formed into very thin, flat sheets is called sheet metal. It is available in many different thicknesses, or gauges. For steel, gauges are based on a weight of 41.82 pounds per square foot per inch of thickness. Gauges for other metals like aluminum or copper are calculated differently. Standard gauges for sheet metals are available from ASTM.

Sheet metal is used to make patterns for many objects. The metal is shaped by bending (see Figure 14-4), folding, or rolling and fastened by riveting, seaming, soldering, or welding. For each sheet-metal object, two drawings are usually made. One is a pictorial drawing of the finished product, and the other is a development, or pattern, that shows the shape of the flat sheet that, when rolled or folded or fastened, will form the finished object (see Figure 14-5).

Some metal objects without seams are formed by die stamping, or pressing a flat sheet into shape under heavy pressure (see Figure 14-6A). Others are made by spinning (see Figure 14-6B). Die stamping and spinning stretch the metal out of its original shape and into a new one.
Calculating Volume

Familiar items such as pipes, storage tanks, cabinets, and boxes are designed and patterns are prepared using pattern development. When these items are meant to hold a specific quantity or amount of fluid, solid, or gaseous material, the designer must calculate the volume of the items to make sure they will hold the specified amount of material. For some shapes, calculating the volume is easy. For example, to find the volume of a cube, simply multiply the length times the width times the height. Calculating the volumes of other shapes requires the use of other mathematical formulas.

The volume of a right cylinder is determined using the formula:

$$\text{Volume} = \pi r^2 \times \text{height}$$

For example, the calculations to find the volume of the cylinder shown here are:

Area of base = \(\pi r^2\)

= \((3.1416) (2^2)\)

= \((3.1416) (4)\)

= 12.57 square inches

Volume = \((12.57) (4)\)

= 50.28 cubic inches

The volume of a right circular cone is determined using the formula:

$$\text{Volume} = \frac{1}{3} \pi r^2 \times \text{height}$$

For example, the calculations to find the volume of the cone shown here are:

Area of base = \(\pi r^2\)

= \((3.1416) (2^2)\)

= \((3.1416) (4)\)

= 12.57 square inches

Volume = \(\frac{1}{3} (12.57)(6)\)

= 25.14 cubic inches

For help with this math activity, go to the Math Appendix located at the back of this book.

**Academic Standards**

**Mathematics**

**Geometry** Use visualization, spatial reasoning, and geometric modeling to solve problems.
Surface Geometry

Sheet-metal patterns, like all other patterns, are developed using principles of surface geometry. Two general classes of surfaces are plane (flat) and curved. The six faces of a cube are plane surfaces. The top and bottom of a cylinder are also plane surfaces. However, the side surface of the cylinder is curved (see Figure 14-7).

Curved surfaces that can be rolled in contact with a plane surface, such as cylinders and cones, are called single-curved surfaces. Exact pattern developments can be made for them. The other curved surface is called double curved and is found on spheres and spheroids. Because exact pattern developments cannot be made for objects with double-curved surfaces, drafters approximate.

Figure 14-8 shows the pattern for a cube. Refer to Figure 14-9 for the patterns for four other regular solids. To understand pattern development better, lay these patterns out on paper. Then cut them out and fold them to make the solids. Secure the joints with tape. Any solid that has plane surfaces can be made in the same way.

Finishing a Pattern

In dealing with sheet-metal patterns, drafters must also know about the processes of wiring, hemming, and seaming and the material quantity required for each process. Wiring is one method to reinforce open ends of an item by enclosing a wire in its edge (see Figure 14-10A). To allow for wiring, a drafter must add a band of material to the pattern equal to 2.5 times the wire’s diameter.

Hemming is another way to stiffen edges of a sheet-metal product by folding the edges. Single- and double-hemmed edges are shown in Figures 14-10B and C. Edges can also be fastened by soldering on lap seams (see Figure 14-10D), flat lock seams Figure 14-10E, or grooved seams Figure 14-10F. See Figure 14-10G and H for other types of seams and laps. The material required for each process depends on the thickness, the fastening method, and the application. In most cases, the corners of the lap are notched to make a neater joint.

Differentiate  What are the three methods used to finish the edge of a sheet metal part?

Types of Developments

What specific shapes can be formed using pattern development?

The type of development needed for an individual object depends on the object’s shape. The three basic types are parallel-line development, radial-line development, and triangulation.
Parallel-Line Development

Making a pattern by drawing the edges of an object as parallel lines is known as parallel-line development. The patterns in Figures 14-8 and 14-11 are made in this way. In the patterns for prisms and cylinders, the stretchout line, which shows the full length of the pattern when it is completely unfolded, is straight, and the measuring lines, or vertical construction lines, are perpendicular to it and parallel to each other.

Radial-Line Development

The edges on cones and pyramids are not parallel. Therefore, the stretchout line is not a continuous straight line. Also, instead of being parallel to each other, measuring lines radiate from a single point. This type of development is called radial-line development.

Imagine the curved surface of a cone as being made up of an infinite number of triangles, each running the height of the cone. To understand the development of the pattern, imagine rolling out each of these triangles, one after another, on a plane (flat surface). The resulting pattern would look like a sector of a circle. Its radius would be equal to an element of the cone, that is, a line from the cone's tip to the rim of its base. Its arc would be the length of the rim of the cone's base. See Figure 14-12 for the developed pattern of a cone.

Triangulation

Some surfaces, such as double-curved surfaces, cannot be developed exactly. The method used to make approximate developments of these surfaces is known as triangulation. It involves dividing the surface into triangles, finding the true lengths of the sides, and then constructing the triangles in regular order on a plane. Because the triangles have one short side, on the plane they approximate the curved surface.

Transition Pieces

A piece that is used to connect pipes, such as hot- and cold-air ducts, and openings of different shapes, sizes, or positions is known as a transition piece. Transition pieces have a surface that is a combination of different forms, including planes, curves, or both, and are usually developed by triangulation. Refer to Figure 14-13 for a few examples of transition pieces that require triangulation.
**Figure 14-11**
A pattern for a prism, showing stretchout line and lap

**Figure 14-12**
Developed surface of a cone

**Figure 14-13**
Examples of transition pieces

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**Section 14.1 Assessment**

After You Read

**Self-Check**

1. Explain why pattern development is important to packaging industry.
2. List methods for processing sheet-metal patterns.
3. Differentiate between pattern drafting and other kinds of technical drafting.
4. Identify the three main types of pattern developments and the purpose for each.

**Academic Integration**

**English Language Arts**

5. Using research resources such as the library, the Internet, or a business periodical, find two articles about an event or trend in the packaging industry. In a one-page essay, tell how the event or trend discussed could affect pattern drafting. Identify the source for each article and tell how you found it. Indicate whether or not you feel the information is valid and reliable, and why you feel that way.

**Drafting Practice**

6. Referring to Figure 14-2, draft a full-size pattern development for a box which, when assembled, will measure 6" wide, 4" long, and 2.5" tall. Draft another pattern development for a suitable cover for the box. Assemble the box and cover. Material: card stock or cardboard.

Go to glencoe.com for this book's OLC for help with this drafting practice.
Connect  Sometimes you can solve problems by using board drafting techniques and Auto-
CAD commands to develop CAD pattern developments on your own. What types of patterns do
you think you might create this way?

Content Vocabulary
• elbow

Academic Vocabulary
Learning these words while you read this section will also help you in your other subjects and tests.
• convenient

Graphic Organizer
Use a table like the one below to organize notes about pattern development using board
drafting and CAD techniques. Add rows as needed.

<table>
<thead>
<tr>
<th>Parallel line</th>
<th>Steps in drawing patterns</th>
<th>Triangulation</th>
<th>Intersections</th>
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Academic Standards

Mathematics
Organize and consolidate mathematical thinking through communication (NCTM)

Science
Structure and properties of matter (NSES)

Industry Standards
ADDA Section 14
Standards and Practices Listing (ASME Y14.24)
Parallel-Line Developments

Why is accuracy so important when drawing pattern developments?

Pattern development drawings are often prepared in board drafting on buff, light green, or light brown paper rather than on tracing materials such as vellum or film, and nearly always in pencil. Remember that pattern developments are prepared at full size and that accuracy in layout and measurements is of key importance.

Because accuracy is crucial, lines are often drawn somewhat thinner than they are for other types of drawings, but they still need to be sharp and black, and of good quality.

The easiest type of development to create is the parallel-line development. It is used to develop patterns for prisms, cylinders, and elbows.

Prisms

See Figure 14-14 for a pictorial view of a rectangular prism. To draw this pattern, proceed as follows:

1. Draw the front and top views full size. Label the points as in Figure 14-15A.

2. Draw the stretchout line (SL). Find the lengths of sides 1-2, 2-3, 3-4, and 4-1 in the top view. Mark off these lengths on the SL (see Figure 14-15B).

3. At points 1, 2, 3, 4, and 1 on the SL, draw vertical crease (fold or bend) lines. Make them equal in length to the height of the prism (see Figure 14-15C).

4. Project the top line of the pattern from the top of the front view. Make it parallel to the SL. Darken all outlines until they are sharp and black (see Figure 14-15D). Use a small circle or X to identify a fold line.

5. Add the top and bottom to the pattern by transferring distances 1-4 and 2-3 from the top view, as shown in Figure 14-15E.

6. Add laps or tabs as necessary for the assembly of the prism. The size of the laps will vary depending on how they are to be fastened and the type of material used.
A slight variation is the pattern for a truncated prism (see Figure 14-16). To draw it, first make the front, top, and auxiliary views at full size. Label points as shown. The next two steps are the same as steps 2 and 3. Then project horizontal lines from points A-B and C-D on the front view to locate points on the pattern. Connect the points to complete the top line of the pattern. Add the top and bottom as shown. Tabs may be added.

**Cylinders**

Figure 14-17A shows a pattern development for a cylinder. It is made by rolling the cylinder out on a plane surface. In the pattern for cylinders, the stretchout line is straight and equal in length to the circumference of the cylinder (see Figure 14-17B). If the base of the cylinder is perpendicular to the axis, its rim will roll out to form the straight line.

In developing a cylinder, imagine that it is actually a many-sided prism. Each side forms an edge called an *element*. Because there are so many elements, however, they seem to form a smooth curve on the surface of the cylinder. Imagining the cylinder in this way will help you find the length of the stretchout line. This length will equal the total of the distances between all of the elements. Technically, of course, the elements are infinite in number. For your purposes, however, you need to mark off elements at convenient equal spaces only around the circumference of the cylinder. (Refer to Figure 14-18 for various methods of dividing a circle.) Then add up these spaces to make the stretchout line. This must equal the circumference of the cylinder.

Figure 14-19 is a pictorial view of a truncated right cylinder, showing the imaginary elements.
Figure 14-20 shows how to develop a pattern for this cylinder. To draw this pattern, proceed as follows:

1. Draw the front and top views at full size. Divide the top view into a convenient number of equal parts (12 in this case) to locate a set of equally spaced points in the top view.

2. Transfer the points in the top view to the front view to locate points at intervals on the inclined surface.

3. Begin the stretchout line. You will determine its actual length later when you mark off the elements. Again, the stretchout line must equal the circumference of the cylinder.

4. Using dividers, find the distance between any two consecutive elements in the top view. Then mark off this distance along the stretchout line as many times as there are parts in the top view. Label the points thus found (see Figure 14-20). Then draw a vertical construction line upward from each point. Note: In this and subsequent steps, the colored arrows on the figure show the direction in which the various lines are projected.

5. From these intersection points on the front view, project horizontal construction lines toward the development.

6. Locate the points where the horizontal construction lines intersect the measuring lines (vertical lines) from the stretchout line. Connect these points in a smooth curve.

7. Darken outlines and add laps as necessary.

Because the surface of a cylinder is a smooth curve, your pattern will not be entirely accurate. This happens because it was made by measuring distances on a straight line (chord) rather than on a curve. Figure 14-21 represents part of the top view of the cylinder just discussed. The drawing shows that the distance from point to point is slightly shorter along the chord than along the arc. The difference can be found by calculating the actual length of the arc using the following formula in which \( d \) stands for diameter:

\[
\text{Circumference} = \pi d
\]

Figure 14-21: The chords used to approximate a cylinder are slightly shorter than the radial distance they represent because a straight line is the shortest distance between two points.
As long as you include enough elements to represent the cylinder adequately, however, the difference is negligible.

Another method for developing a cylinder is shown in Figure 14-22. In this case, the views of the front and half-bottom are used. Attaching the two views saves time and increases accuracy.

Elbows

An elbow is a joint, a place in a pipe or duct where two pieces meet at an angle other than 180°. The simplest type of elbow is a square or is composed of two pieces. More complex elbows provide smoother curves.

Square Elbows

A square elbow consists of two cylinders cut off at 45°. Therefore, only one pattern is needed (see Figure 14-22). Allow a lap for the type of seam to be made if required.

If a lap is not needed on the curved edges, both parts can be developed on one stretchout (see Figure 14-23). Notice that the seam in Figure 14-23A is on the short side and in Figure 14-23B it is on the long side. In Figure 14-22, the seam on both pieces is on the short side. In most cases, this placement is not critical.

Radial-Line Developments

When might a pattern for a cone-shaped object be needed?

Objects that have conical or pyramidal shapes cannot be developed using parallel-line development because the stretchout line is not a straight line. If a conical or pyramidal object has an axis at 90° to its base, it can be developed using radial-line development. The procedures in this section show how to develop a pattern for right (90°) cones and pyramids.

Right Circular Cone

A right circular cone is one in which the base is a true circle and the tip is directly over the center of the base (see Figure 14-24A). The pattern for a cone is shown in Figure 14-24B. To draw the pattern, proceed as follows:

1. Draw front and half-bottom views to the desired size.
2. Divide the half-bottom view into several equal parts. Label the division points as shown.
3. On the front view, measure the cone’s slant height, which is the true distance from the apex to the rim of the base (line A1). Using this length as a radius, draw an arc of indefinite length as a measuring arc. Draw a line from apex A to the arc at any point a short distance from the front view.
4. Using dividers, find the straight-line distance between any two division points on the half-bottom view. Then use...
this length to mark off spaces 1-2, 2-3, 3-4, and so forth, along the arc. Label the points to be sure none have been missed. Complete the development by drawing line A1 at the far end.

5. Add laps for the seam as required. How much to allow for the seam depends on the size of the development and the type of joint to be made.

Truncated Circular Cone

A circular cone that has been cut along a plane that is not parallel to the base is known as a truncated circular cone (see Figure 14-25A). The pattern for such a cone is shown in Figure 14-25B. To draw it, proceed as follows:

1. Draw the front, top, and bottom (or half-bottom) views.
2. Proceed as in Figure 14-24 to develop the overall layout for the pattern.
3. Project points 1 through 6 from the bottom view to the front view and then to the apex. Label the points where they intersect the miter (cut) line to avoid mistakes. These lines, representing elements of the cone, do not show in true length in the front view. Their true length shows only when they are projected horizontally to the points on the arc.
4. Project the elements of the cone from the apex to the points on the arc.

Pyramids

Before you can begin to develop a pattern for a pyramid, you must find the true length of its edges. For example, in the pyramid in Figure 14-26A, you need to find the true length of OA. Figure 14-26B shows the top and front views of the pyramid. In neither view does the edge OA show in true length. However, if the pyramid were in the position shown in Figure 14-26C, the front view would show OA in true length. In this figure, the pyramid has been revolved about a vertical axis until OA is parallel to the vertical plane. In Figure 14-26D, line OA is shown before and after revolving (OA').

The construction in Figure 14-26D is a simple way to find the true length of the edge line OA. Revolve this view to make the horizontal line OA'. Project A' down to meet a base line projected from the original front view. Draw a line from this intersection point to a new front view of O. This line will show the true length of OA.
Figure 14-27 shows the pattern for a right rectangular pyramid. To draw it, proceed as follows:

1. Find the true length of one of the edges (O1 in this case) by revolving it until it is parallel to the vertical plane (O1’).
2. With the true length as a radius, draw an arc of indefinite length to use as a measuring arc.
3. On the top view, measure the lengths of the four base lines (1-2, 2-3, 3-4, 4-1). Mark these lengths off as the straight-line distances along the arc.
4. Connect the points and draw crease lines. Mark the crease lines.
5. Add base 1-2-3-4 as shown.

Oblique Pyramids

See Figure 14-28 for the development of an oblique pyramid. To draw it, proceed as follows:

1. Find the true lengths of the lateral edges. Do this by revolving them parallel to the vertical plane as shown for edges O2 and O1. These edges are both revolved in the top view, and then projected to locate 2’ and 1’. Lines O2’ and O1’ in the front view are the true lengths of edges O2 and O1. Edge O2 = edge O3. Edge O1 = edge O4.
2. Start the development by laying off 2-3. Because edge O2 = edge O3, you can locate point O by plotting arcs centered on 2 and 3 and with radii the true length of O2 (O2’). Point O is where the arcs intersect.
3. Construct triangles O-3-4, O-4-1, and O-1-2 with the true lengths of the sides to complete the development of the pyramid as shown.

Explain How do you find the true length of the lateral edges of an oblique pyramid?
**Triangulation**

**What is another word for “triangulation”?**

Refer to Figure 14-29 for the use of triangulation in developing an oblique cone. To draw this pattern development, proceed as follows:

1. **Draw elements on the top- and front-view surfaces to create a series of triangles, as shown in Figure 14-29A and B. Number the elements 1, 2, and so forth. For a better approximation of the curve, use more triangles than shown in Figure 14-29.**

2. **Find the true lengths of the elements by revolving them in the top view until each is horizontal. From the tip of each, project down to the front-view base line to get a new set of points 1, 2, and so forth. Connect these with the front view of point O to make a true-length diagram (see Figure 14-29C).**

3. **To plot the development in Figure 14-29D, construct the triangles in the order in which they occur. Take the distances 1-2, 2-3, etc., from the top view. Take the distances O1, O2, etc., from the true-length diagram. Connect the curve and add tabs if needed.**

**CAD Pattern Developments**

**Why is it important to learn to draw pattern developments in CAD?**

In industry, special third-party softwares are often used for pattern developments. This software may be a stand-alone product or an add-on to a basic drafting program such as AutoCAD. This type of software is *parametric*, that is, it builds the shapes you select according to the parameters you set.

For example, in Figure 14-30, the user has specified a truncated circular cone with an upper diameter of 24”, a lower diameter of 36”, and a height of 18”. The software uses those parameters to automatically create a full-size pattern for the cone.

It is important, however, to know how to draw developments in CAD independent of automated software. The procedures parallel those for board drafting.
**CAD Parallel-Line Development**

*Figure 14-31* is a pictorial view of a rectangular prism. A pattern for this prism is made by parallel-line development (see *Figure 14-32*). To draw this pattern, proceed as follows:

1. Use the PLINE command to draw the front and top views at full size.
2. Select the top view and then enter the LIST command. A text window appears listing information about the rectangle. The perimeter equals the length of the stretchout line you need. Draw the stretchout line.
3. At the beginning of the stretchout line, create a 2" vertical line to represent the beginning of the pattern. Offset this line to the right by 1.5", .5", 1.5", and .5" (the dimensions of the top view) to create the crease lines and the right end of the development. The last vertical line should lie exactly at the end of the stretchout line. Add the top horizontal across the entire development.
4. Add small circles as shown in *Figure 14-32* to identify the crease lines.
5. Add the top and bottom to the pattern by copying the top view and placing it as shown on the development. Use the COPY command to create both the top and the bottom.
6. Add laps or tabs as necessary for the assembly of the prism. The size of the laps will vary depending on how they are to be fastened and the type of material used. Here you should use the OFFSET command to create .1" tabs and chamfer the corners of the tabs at 45°.

**CAD Radial-Line Development**

AutoCAD provides tools to make radial-line development a fast, accurate process. See *Figure 14-33* for a pictorial of a frustum of a right circular cone. The top radius is .75", the bottom radius is 1.25", and the height is 1.12". Develop the cone as shown in *Figure 14-34*.

1. Draw front and half-bottom views. Extend a line through the center of the
front view to about 1.5” above the top of the front view. Use the EXTEND command to extend the sides of the front view to find the virtual apex of the cone (see Figure 14-34A).

2. Enter PDMODE and 3 to change the point display to an X that is easily visible. Enter the REGEN command to see the points. Then use the DIVIDE command to divide the half-bottom view into 6 equal parts (see Figure 14-34B).

3. Enter the DIST command and select points A and B to find the true distance from the apex to the rim of the base. Using this length as a radius, create a circle with its center at the apex. Draw line AC from apex A to the circle at point C (any point a short distance from the front view). See Figure 14-34B. Trim away the part of the circle between the front view and line AC to form arc BC.

4. Use the DIST command again to find the straight-line distance between any two division points on the half-bottom view. (Use the Node object snap to snap to two of the division points.) Enter the MEASURE command and pick arc BC near line AC. For the segment length, enter the straight-line distance that you found using the DIST command. AutoCAD marks points along the arc at the interval you entered.

5. For the development, you need only the first 12 of these intervals. Create a line from the twelfth division mark to the apex (point A). This determines the other end of the development. Trim away the rest of arc BC, and delete the rest of the points (see Figure 14-34C).

6. Enter the DIST command and find the distance from the apex to point D. With this distance as a radius, create another circle with its center at the apex. Trim the circle to the lines that represent the...
beginning and end of the development (see Figure 14-34D).

7. Clean up the drawing by trimming away unneeded lines. Enter PDMODE and enter a new value of 0 to hide the division points, using REGEN to change the points on-screen. To finish the drawing, add .1” tabs with 45° chamfers (see Figure 14-34E).

**Intersections**

What is the first step in developing a pattern for intersecting objects?

As you may recall from Chapter 10, a line intersects a plane at the piercing point, or point of intersection (see Figure 14-35). When two plane surfaces meet, the line where one passes through the other is called the line of intersection (see Figure 14-36). When a plane surface meets a curved surface, or where two curved surfaces meet, the line of intersection may be either a straight line or a curved line, depending on the surfaces and their relative positions.

Package designers, sheet-metal workers, and machine designers must be able to find the point at which a line pierces a surface and the line where two surfaces intersect to find the true length of each side. Figure 14-37 shows some ways in which different surfaces intersect.

**Drawing Intersections**

The intersection of two 3D objects requires special attention. The exact location of the line of intersection must be determined before a pattern can be developed.

**Intersecting Prisms**

See Figure 14-38 for a drawing of the intersection of two prisms. To draw the complete front and top views of the intersecting prisms, proceed as follows:

1. Draw the hexagon shape in the top view at 2.00” across the flats.
2. Project downward from the corners of the hexagon to establish the vertical lines for the front view.

3. Measure the 3.50" vertical distance to establish the top and bottom of the front view.

4. Locate the exact center of the front view. You can do this easily and quickly by striking diagonals from corner A to corner C and from corner B to corner D.

5. Draw a light construction line through the center point X at 60° to the horizontal (120° to the vertical).

6. Measure 2.00" along the inclined line in both directions from point X to establish the ends of the square prism.

7. In any convenient location to the right or left, construct an auxiliary view of the square prism. In Figure 14-38, it is to the right of the front view.

8. Project back to the front view to establish the top and bottom edges of the square prism. The lines of intersection on the front view will be added later.

9. Project lines upward from G, F-F', and G' on the right side to establish horizontal distances on the diamond shape in the top view. Do likewise on the left side.

10. Draw a horizontal layout line through the center of the top view (G-G').

11. Establish points F and F' in the top view by projecting both points F-F' from the front view to the top view. This completes the top view.

12. Add the lines of intersection on the front view by projecting points H-H' down from the top view to the front view. Connect points I and I' with points H-H' to complete the drawing.

Define Why does the intersection of two 3D objects require special attention?

**Intersecting Cylinders**

See Figure 14-39A for a drawing of the line of intersection of two cylinders. Because cylinders have no edges, you must assume positions for the cutting planes. Draw plane AA to contain the front line (element) of the vertical cylinder. This plane will also cut a line, or element, on the horizontal cylinder. The intersection of these two lines in the front view identifies a point on the required curve. Similarly, planes BB, CC, and DD cut lines on both cylinders that intersect at points common to both cylinders. See Figure 14-39B for a drawing indicating the development of the vertical cylinder.
In Figure 14-40, the line of intersection of two cylinders joined at an angle is shown. In this drawing, cutting planes are located by an auxiliary view. To make the development of the inclined cylinder, take the length of the stretchout line from the circumference of the auxiliary view. Choose a cutting plane that divides this circumference into equal parts so that the measuring lines are equally spaced along the stretchout line. Project the lengths of the measuring lines from the front view. Join their ends into a smooth curve.

**Intersection of Cylinders and Cones**

To find the line of intersection of a cylinder and a cone, use horizontal cutting planes (see Figure 14-41). Each plane cuts a circle on the cone and two straight lines on the cylinder. Points of intersection occur where the straight lines of the cylinder cross the circles of the cone in the top view. Project these points onto the front view to get the intersection line. Figure 14-42 shows this construction for a single plane. Use as many planes as needed to make a smooth curve.

**Intersection of Planes and Curved Surfaces**

Refer to Figure 14-43 for a drawing of the intersection of a plane MM and the curved surface of a cone. To find the line of intersection, use horizontal cutting planes A, B, C, and D. Each plane cuts a circle from plane MM. Thus, you can locate points common to MM and the cone as in the top view. Project these points onto the front view to get the curve of intersection.

**CAD Intersections**

Some companies that use CAD systems create complex solid models of intersecting objects. The pattern development is then created directly from the solid model using third-party software. However, you can develop an intersection in CAD using a technique similar to that used in board drafting.

See Figure 14-38 for drawing of two intersecting prisms. Note: Construction lines are in color in the illustration for clarity only. It is not
necessary or desirable to use a different color for these lines because parts of them are incorporated into the final drawing. Create the intersection shown in Figure 14-44 by following these steps.

1. Draw the hexagon shape in the top view at 2.00" across the flats.
2. Use the XLINE command to place construction lines downward from the corners to establish the vertical lines for the hexagon in the front view.
3. Place line AB horizontally across the construction lines as shown in Figure 14-44A. Offset the line downward by 3.50" to create the bottom line of the front view. Trim the construction lines to the boundaries of the front view.
4. Locate the exact center of the front view. You can do this easily and quickly by striking a diagonal from corner A to corner C. Start a new line at the midpoint of line AC (the center of the front view), and use polar coordinates to extend it 2.00" at 30°. Copy the new line using its right endpoint as the base point. Place the copy so that the right endpoint is at the intersection of the diagonals. Enter the PEDIT command and use the Join option to change the two lines into a single polyline, a line of any length as defined in Chapter 4, that defines the length and location of the rectangular prism.
5. To the right of the front view, construct an auxiliary view of the square prism.
6. Enter the OFFSET command. Instead of selecting the line to offset, enter T to activate the Through option. Select the polyline you created in step 4 as the line to offset. For the through point, choose point D in Figure 14-44B, at the top of the auxiliary view. This creates the top edge of the rectangular prism. Then repeat this operation, choosing point D’ at the bottom of the auxiliary as the through point to establish the lower edge of the rectangular prism. Connect the ends to complete the front view of the rectangular prism. Erase the diagonal line AC.

7. Use XLINE to draw horizontal construction line DD’ through the center of the top view.

8. In the auxiliary view of the rectangular prism, draw both diagonals. Use the DIST command to find the actual distance from the intersection of the diagonals to any corner of the square. Then offset line DD’ by this amount above and below to establish the edges of the rectangular prism in the top view.

9. Establish the right and left ends of the rectangular prism in the top view by creating vertical construction lines from key points on the front view (see Figure 14-44C). Finish the top view by drawing the connecting lines on both sides and trimming the horizontal construction lines. Notice that two of the lines are hidden on the left side of the prism. Clean up the drawing by deleting the vertical construction lines.

10. Add the lines of intersection on the front view by creating vertical construction lines through points E. Connect points F and F’ with points E in the front view and trim away the unneeded portions of the lines (see Figure 14-44D). Delete the two remaining vertical construction lines to complete the drawing.

Section 14.2 Assessment
After You Read

Self-Check

1. Explain how a pattern is developed using parallel-line development, radial-line development, and triangulation.

2. Identify the steps for developing patterns for intersecting prisms and cylinders.

Academic Integration

Mathematics

3. Calculate Costs Miller Box and Packaging Supply manufactures a one-size-fits-all packing box. It plans to manufacture 750,000 boxes to be sold at $0.44 each. The fixed costs to make them are $142,570. The variable costs to make them are $0.19 each. How many boxes must Miller sell to break even?

Math Concept Number and Operations

To find the break-even point in units, use the following formula: Total Fixed Costs ÷ (Selling Price per Unit – Variable Costs per Unit)

Drafting Practice

4. Draw the front and top views of each object shown in Figure 14-45, and then develop the pattern. Add the top in the position it would be drawn for fabrication.

Go to glencoe.com for this book’s OLC for help with this drafting practice.
Pattern development is used extensively in the packaging industry for many products. Pattern development involves drafting a usually full-size drawing for an item that is either folded, rolled, or stamped into its shape using different methods. The three main types of pattern development are parallel-line, radial-line, and triangulation.

On parallel-line developments, the stretchout line is always straight, while on radial-line development, it is curved. Triangulation developments involve approximating the surface geometry for objects that cannot be precisely patterned. Patterns can also be developed for intersections, or combined shapes, such as prisms and cylinders.

1. Use each of these content and academic vocabulary words in a sentence or drawing.

Content Vocabulary
- pattern development (p. 497)
- stretchout (p. 497)
- development (p. 497)
- pattern (p. 497)
- parallel-line development (p. 501)

Academic Vocabulary
- diverse (p. 497)
- approximate (p. 500)
- convenient (p. 506)

Review Key Concepts
2. List uses for pattern development in the packaging industry.
3. Describe how sheet metal is used in pattern development.
4. Describe the general principles of pattern development.
5. Identify the three main types of pattern development.
6. Explain when parallel-line, radial-line, and triangulation developments are used.
7. Explain how patterns are developed for intersecting prisms and cylinders.
8. History of Technology

There have been many technological events in history that have powerfully changed the world. Brainstorm three major technology-related events in history. For example, you might choose the invention or the automobile, or the first successful heart transplant. Research these events and in a two-page report, tell how each has shaped history in terms of culture, politics, the economy, and the way in which people relate to each other. Also, tell how one or more event has helped advance the field of science or mathematics.

9. Problem-Solving Tools

Because of a recent fire in your area, you want to become more aware of practices that would help prevent fires at your school. Use the library, the Internet, and any safety rules posted in your classrooms to research fire prevention. Then create a poster to encourage safety awareness at school. In your poster, explain fire prevention, safety precautions, and practices for extinguishing fires. Also outline the different types of fires that can start in a school environment.

10. Calculate Dimensions

Determine the length of side $c$ in the triangle below.

$$c^2 = a^2 + b^2$$

11. Multiple Choice Question

In pattern development, a method that is used for making approximate developments of surfaces that cannot be developed exactly is

a. parallel-line development
b. triangulation
c. radial-line development
d. approximation

12. Time Management Skills

Organizations such as SkillsUSA offer a variety of architectural, career, and drafting competitions. Completing activities such as the one below will help you prepare for these events.

Activity Time management involves five basic steps: list all tasks, break big tasks into small steps, prioritize all tasks, estimate the time to complete each, and schedule each. With a partner, follow these steps for two weeks. Analyze the ones each of you found challenging. Write a brief paper identifying ways the two of you will work to improve those steps that challenged you.

Go to glencoe.com for this book’s OLC for more information about competitive events.
Drafting Problems

The drafting problems in this chapter are designed to be completed using board drafting techniques or CAD.

Problems 1 through 9 are planned to fit on an 11.00" × 17.00" or 12.00" × 18.00" drawing sheet. Draw the front and top views of each problem. Develop the patterns as shown in the example in Figure 14-46. Include dimensions and numbers as required by your instructor. Patterns may be cut out and assembled.

1. Draw the front and top views of each object shown in Figure 14-47, and then develop the pattern. Add the top in the position it would be drawn for fabrication.
2. Draw the front and top views of each object shown in Figure 14-48, and then develop the pattern.

3. Draw the front and top views of each object shown in Figure 14-49, and then develop the pattern.

4. Draw the front and top views and then develop the pattern for each object shown in Figure 14-50.
5. Draw two views of each pair of objects shown in Figure 14-51. Develop the line of intersection, and complete the top views. Develop patterns for both parts of each pair.

Figure 14-51

For problems 10 and 11, follow the directions to create patterns and drawings of the objects as assigned.

6. Make a pattern drawing for the tool tray shown in Figure 14-52. No other views are necessary.

Figure 14-52

7. Make a pattern drawing of the cookie sheet shown in Figure 14-53. No other views are necessary.

Figure 14-53
8. Make a complete set of working drawings for the model racer shown in Figure 14-54, including all necessary views and patterns. Take dimensions from the printed scale.

**Figure 14-54**

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### Design Problems

Design problems have been prepared to challenge individual students or teams of students. In these problems, you are to apply skills learned mainly in this chapter but also in other chapters throughout the text. They are designed to be completed using board drafting, CAD, or a combination of the two. Be creative and have fun!

1. Design a carton to be used in shipping the model racer shown in Figure 14-58. The overall dimensions of the racer are $4.50" \times 5.00" \times 11.00"$. The carton should be designed as a one-piece development, easily assembled. Design it in a way that will require no adhesive for assembly. Use a computer paint program to design the outside surface of the carton. Use various colors. Trace the pattern onto stiff cardboard, cut it out, and assemble it.

2. Work as a team to design a CO₂ racecar. Be creative and make it an ultramodern concept car. Each team member should develop design sketches for the team to review. As a team, select the final design choice. Prepare a drawing at full size. Each team member should then be assigned the development of one part of the car.

Remember, all patterns must be full size. A paper model can then be constructed by cutting out the individual patterns, forming them, and assembling them into the finished model.

**Teamwork**

3. Design a porch lamp to be installed against an outside wall. The top is to be either a right rectangular pyramid or a right circular cone. The mounting base is to include a right circular cone, a frustum of a cone, or a frustum of a right rectangular pyramid. Material: sheet brass or copper with decorative glass inserts. Prepare a working drawing and all patterns needed for the manufacture of the lamp.

4. Design a carton for the porch lamp designed in design problem 3. Transfer the pattern to stiff cardboard. Cut it out and assemble it.