Chapter Objectives

- **Identify** and describe various types of pictorial drawings.
- **Explain** the differences in the three types of axonometric projection.
- **Make** cavalier, normal, and cabinet oblique drawings.
- **Create** one-point and two-point perspective drawings.
- **Select** appropriate isometric sections.
- **Manipulate** 3D models in AutoCAD to achieve isometric, oblique, and perspective views.

**Discuss the Photo**

**Fashion and Function**  In this store design, Koolhaas has completely opened the storefront to passersby on Rodeo Drive. What else in this photo seems unusual for a store display?
One remarkable feature of the Prada store in Beverly Hills is the absence of a façade. There is neither door nor display window—the entire width of the building is open to Rodeo Drive. Look down as you cross the “air curtain” and you see merchandise in large display cones embedded in the ground. Walk ahead and you climb a large wooden stair first up and then down the far side like a hill. Rem Koolhaas, architect, wants to transform the shopping experience.

Every aspect of shopping here is a new experience for the novice. Dressing rooms have “magic mirrors” that allow you to see front and back at the same time. A touch screen lists your possibilities as you try them on and allows you to browse for alternatives. Later, at home, you can rethink your selections and make final choices by logging on to your virtual garment closet. Everything you tried on is right there for you.

**Academic Skills and Abilities**

- Academic skills and abilities
- Math and science
- Visual orientation
- Spatial reasoning
- Computer applications
- Drafting and drawing

**Career Pathways**

Bachelor’s degree programs in architecture often require five years to complete. Helpful high school courses include advanced mathematics, science, and computer-aided design (CAD). All states require architects to be licensed.
12.1 Types of Pictorial Drawing

Connect  Scan for this section’s content vocabulary terms and try to define them using what you already know about them, as well as contextual clues, decoding, or dictionary look-up.

Content Vocabulary
• isometric drawing
• isometric axes
• axonometric projection
• dimetric projection
• trimetric projection
• picture plane
• cavalier oblique
• normal oblique
• cabinet oblique
• perspective drawing
• vanishing point
• technical illustration

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

Graphic Organizer
Use a chart like the one below to organize notes about pictorial drawings.

Academic Standards

English Language Arts
Apply strategies to interpret and evaluate texts (NCTE)

Mathematics
Representation  Select, apply, and translate among mathematical representations to solve problems (NCTM)

Science
Structure and properties of matter (NSES)

Go to glencoe.com for this book’s OLC for a downloadable version of this graphic organizer.
Pictorial Drawings

What are the three main types of pictorial drawings?

Pictorial drawing is an essential part of graphic language. It is often used to show exploded views on production and assembly drawings (see Figure 12-1). These views are made to explain the operation of machines and equipment, to illustrate parts lists, and so on. See Figure 12-2.

The three distinct categories of pictorial drawings are:
- isometric
- oblique
- perspective

Each category has variations, but the three fundamental ones are based on how the drawings are constructed and how they appear. Each has its own specific use and is constructed in its own unique way. See Figure 12-3 for a single object drawn using various pictorial techniques.

Isometric Drawing

In an isometric drawing, the object is aligned with isometric axes, three axes spaced at equal angles of 120° (see Figure 12-4A). Several vertical and horizontal positions of the isometric axes are identified in Figure 12-4B.
Nonisometric lines are not parallel to any of the isometric axes.

Two-point perspective isometric is a type of isometric projection that uses three axes at angles to show three sides of an object. Isometric projection is one form of axonometric projection. The other forms are dimetric and trimetric projection. All three projections are made according to the same process; the difference is in the angle of projection (see Figure 12-6). In isometric projection, the axes form three equal angles of 120° on the plane of projection. Only one scale is needed for measurements along each axis. Isometric projections are the easiest type of axonometric projection to make. In dimetric projection, only two of the angles are equal.

Nonisometric lines do not appear in their true length, so they cannot be measured.

Axonometric Projection

Axonometric projection is projection that uses three axes at angles to show three sides of an object. Isometric projection is one form of axonometric projection. The other forms are dimetric and trimetric projection.

Measurements can be made only along isometric lines.
and two special foreshortened scales are needed to make measurements. In **trimetric projection**, all three angles are different, and three special foreshortened scales are needed.

**Reading Check**

What does the term *isometric projection* mean?

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**Oblique Drawing**

**What is an advantage of oblique drawings over isometric drawings?**

Oblique drawings are plotted in the same way as isometric drawings; that is, on three axes. However, in oblique drawing, two axes are parallel to the **picture plane** (the plane...)

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**Area of a Triangle**

The triangle is one of the most common geometric figures used in drafting and throughout industry. Finding the area of any triangle is simple, because the formula is the same in every case.

The formula for finding the area of a triangle is:

\[ A = \frac{bh}{2} \]

It can also be stated as: The area of any triangle equals the product of the base and the altitude to that base, divided by 2.

**Example 1:**

\[
\begin{align*}
\text{AREA } & = \frac{bh}{2} \\
& = \frac{6 \times 10}{2} \\
& = 30 \text{ in.}^2
\end{align*}
\]

**Example 2:**

**Right Triangle**

\[
\begin{align*}
\text{AREA } & = \frac{bh}{2} \\
& = \frac{6 \times 5}{2} \\
& = \frac{30}{2} \\
& = 15 \text{ in.}^2
\end{align*}
\]

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**Academic Standards**

**Mathematics**

**Problem Solving** Select, apply, and translate among mathematical representations to solve problems (NCTM)
on which the view is drawn) rather than just one, as in isometric drawing. These two axes on which drawings are always plotted always make right angles with each other (see **Figure 12-7**). As a result, oblique drawings show an object as if viewed face on. That is, one side of the object is seen squarely, with no distortion, because it is parallel to the picture plane.

The methods and rules of isometric drawing apply to oblique drawing. However, oblique drawing also has some special rules:

- **Place the object so that the irregular outline or contour faces the front.** See **Figure 12-8A**.
- **Place the object so that the longest dimension is parallel to the picture plane** (see **Figure 12-8B**).

**Oblique Projection**

Oblique projection, like isometric projection, is used to show depth (see **Figure 12-9**). Depth is shown by projectors, or lines, to represent the object’s receding edges. These lines are drawn at an angle other than 90° from the picture plane, to make the receding planes visible in the front view. As in isometric drawing, lines on these receding planes, that are actually parallel to each other are shown as parallel. Figure 12-9 shows how an oblique projection is developed. You probably will never have to develop an oblique projection in this way, but, as with isometric projection, it is a good idea to understand the theory behind it.

Because oblique drawing can show one face of an object without distortion, it has a distinct advantage over isometric drawing. It is especially useful for showing objects with irregular outlines. Refer again to **Figure 12-8A**. **Figure 12-10** shows several positions for oblique axes. In all cases, two of the axes, AO and OB, are drawn at right angles. The oblique axis OC can be at any angle to the right, left, up, or down. The best way to draw an object
is usually at the angle from which it would normally be viewed.

**Types of Oblique Drawings**

Oblique drawings are classified according to the length of the receding lines of an object along the oblique axis. Drawings in which the receding lines are drawn full length are known as **cavalier oblique**. Some drafters use three-quarter size receding length. This is sometimes called **normal oblique** or **general oblique**. If the receding lines are drawn one-half size, the drawing is **cabinet oblique**. See Figure 12-11 for a bookcase in cavalier, normal, and cabinet drawings. Cabinet drawings are so named because they are often used in the furniture industry.

![Figure 12-10](image1.png)

**Read Check**

In an oblique drawing, what relationship do two axes have to the picture plane?

**Perspective Drawing**

When creating pictorial drawings, what factors that affect appearance do you need to consider?

A **perspective drawing** is a three-dimensional representation of an object as it looks to the eye from a particular point (see Figure 12-12). Of all pictorial drawings, perspective drawings look the most like photographs. The distinctive feature of these drawings is that in perspective, lines on the receding planes that are actually parallel are not drawn parallel, as they are in isometric and oblique drawing. Instead, they are drawn as if they were converging, or coming together.

![Figure 12-11](image2.png)

**Section 12.1 Types of Pictorial Drawing**
Definition of Terms

Figure 12-13 illustrates terms used in perspective drawing. The following definitions refer to the card that appears on the picture plane.

- **visual rays** The sight lines from points on the card that converge at the observer's eye.
- **picture plane (PP)** The plane on which the object (a card in this case) is drawn.
- **line of sight (LS)** The visual ray from the eye perpendicular to the picture plane.
- **station point (SP)** The point from which the observer is looking at the card.
- **horizon line (HL)** The line formed where a horizontal plane that passes through the observer's eye meets the picture plane.
- **ground plane** The plane on which which the observer stands.
- **ground line (GL)** The line formed where the ground plane meets the picture plane.
- **center of vision (CV)** The point at which the line of sight pierces the picture plane.

Figure 12-14 shows how the projectors, or receding axes, converge in perspective drawing. The point at which they meet is the **vanishing point**. Figure 12-14 also shows how the observer's eye level affects the perspective view. This eye level can be anywhere on, above, or below the ground. If the object is seen from above, the view is an **aerial**, or bird's-eye, view. If the object is seen from underneath, the view is a **ground**, or worm's-eye, view. If the object is seen face on, so that the line of sight is directly on it rather than above or below it, the view is a **normal view**. The view in Figure 12-13 is a normal view.

Types of Perspective Drawings

Perspective views can have one, two, or even more vanishing points. **One-point perspective**, also called parallel perspective, is a perspective view...
that has one vanishing point (see Figure 12-15). Notice that if the lines of the building in Figure 12-15 were extended, they would converge at a single point.

Two-point perspective drawings have two vanishing points. This view is also called angular perspective, because none of the faces is drawn parallel to the picture plane. The photograph in Figure 12-16 shows a typical two-point perspective.

**Factors That Affect Appearance**

Two factors affect how an object looks in perspective. The first is its distance from the viewer, and the second is its position, or angle, in relation to the viewer.

**The Effect of Distance**

The size of an object seems to change as you move toward or away from it. The farther from the object you go, the smaller it looks. As you come closer, it seems to become larger. Figure 12-17 shows a graphic explanation of this distance effect. An object is placed against a scale at a normal reading distance from the viewer. In that position, the object appears to be the size indicated by the scale. However, if the object is moved back from the scale to a point twice as far away from the viewer, it looks only half as large. Notice that each time the distance is doubled, the object looks only half as large as before.
The Effect of Position

An object’s shape also seems to change when it is viewed from different angles. This is illustrated in Figure 12-18. If you look at a square from directly in front, the top and bottom edges are parallel. If the square is rotated so that you see it at an angle, these edges seem to converge. The square also appears to grow narrower. This foreshortening occurs because one side of the square is now farther from you.

Technical Illustration

What techniques are used to manipulate the appearance of technical drawings for aesthetic or other reasons?

Generally, technical illustration is defined as a pictorial drawing that provides technical information using visual methods. Technical illustrations are used to present complex parts and assemblies graphically, in a way that both professionals and the general public can read and understand. They help people understand both the form (shape) and function of parts in an assembly. Technical illustrations must show shapes and relative positions in a clear and accurate way. Shading may be used to bring out the shape. It serves a practical purpose, not an artistic one.

Technical illustrations range from sketches to rather detailed shaded drawings and may be prepared using board drafting techniques or sophisticated CAD or modeling software. They may be based on any of the pictorial methods: isometric, perspective, or oblique. The complete project, parts, or groups of parts may be shown. The views may be exterior, interior, sectional, cutaway, or phantom. The purpose in all cases is to provide a clear and easily understood description.

In addition to pictorials, technical illustrations include graphs, charts, schematics, flowcharts, diagrams, and sometimes circuit layouts. Dimensions are not generally a part of technical illustrations, because they are not working drawings. However, dimensions are occasionally added to show the relative position of parts or to show the adjustment of parts in an assembly.

Uses of Technical Illustration

Technical illustration has an important place in all areas of engineering and science. Technical illustrations form a necessary part
of the technical and service manuals for machine tools, automobiles, machines, and appliances. In technical illustration, pictorial drawings describe parts in terms of both their form and their function. They can also show the steps that need to be followed to complete a product on the assembly line or even to set up an assembly line.

Technical illustrations have been used for many years in illustrated parts lists, operation and service manuals, and process manuals (see Figure 12-19). The aircraft and automotive industries in particular have found production illustrations especially valuable. In many industries, these technical illustrations are used from the time an item is designed, through the many production phases, to completion. The technical illustrations included in the service, repair, and operation manuals delivered with the product show the customer how to assemble and operate the product.

**Reading Check**

**List** What are the uses of technical illustrations?

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<th>PART NAME</th>
<th>NO. REQ’D</th>
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</tr>
<tr>
<td>10</td>
<td>CAP SCREW</td>
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**Choice of Drawing Type**

Most technical illustrations are pictorial line drawings. Therefore, you should have a complete understanding of the various types of pictorial line drawings and their uses. Usually, any type of pictorial drawing can be used as the basis for a technical illustration. However, some types are more suitable than others. This is especially true if the illustration is to be rendered (shaded).

Figure 12-20 is a V-block shown in several types of pictorial drawing. Notice the difference in the appearance of each. Isometric is the least natural in appearance. Perspective is the most natural. This might suggest that all technical illustrations should be drawn in perspective. This is not necessarily true. While perspective is more natural than isometric in appearance, it takes more time to produce, and it is also more difficult to draw. Thus, it is often a more costly method to use.

The shape of the object also helps to determine the type of pictorial drawing to use. Figure 12-21 shows a pipe bracket drawn
in isometric and oblique. This object can be
drawn easily and quickly in oblique. Also, in
many cases, oblique looks more natural than
isometric for objects of this shape.

If a pictorial drawing is to be used only in
a plant, the illustrator usually makes it isome-
tric or oblique. These are the quickest and least
costly pictorials to make. If the illustration is
to be used in a publication such as a journal,
operator’s manual, or technical publication,
dimetric, trimetric, or perspective may be used.

Exploded Views
Perhaps the easiest way to understand an
exploded view is to separate an object into
its individual parts. In Figure 12-22, three
views are shown in part A, and a pictorial
view is shown in part B. In part C, an “explo-
sion” has projected the various parts away
from each other. This illustrates the principle
of exploded views.

All exploded views are based on the same
process: projecting the parts from the posi-
tions they occupy when put together. Simply
put, the parts are just pulled apart. Refer to
Figure 12-23A for the presentation drawing of
a fishing reel. An exploded illustration of the
reel is shown in Figure 12-23B. Note that all
parts are easily identifiable in the exploded
view. Flow lines are generally used to show
exactly where each part fits into the assembly.

Identification Illustrations
Pictorial drawings are very useful for identi-
fying parts. They save time when the parts are
manufactured or assembled in place. They are
also useful for illustrating operating instruc-
tion manuals and spare-parts catalogs.

Evaluate What type of pictorial drawing is
the most natural, and why do all drawings
not use this type?

Identification illustrations are usually pre-
sented in exploded views. If the object contains
several parts, number them as in Figure 12-23B.
In this example, the names of the numbered
parts are given in a parts list, a portion of which
is shown in Figure 12-23C. If an object consists
of only a few parts, identify them by their names
as in Figure 12-24.
Figure 12-23
A fishing reel (A) with an exploded assembly drawing (B) and partial parts list (C)

Figure 12-24
An identification illustration with parts labeled

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Rendering

Rendering, or surface shading, is a method of enhancing a solid model so that it looks almost lifelike. It may be used when shapes are difficult to read or for aesthetic reasons. For most industrial illustrations, accurate descriptions of shapes and positions are more important than fine artistic effects. You can often achieve satisfactory results without any rendering. In general, you should limit rendering when possible. Render the least amount necessary to define the shapes that are being illustrated. Rendering takes time and is expensive.

In board drafting, materials used to render technical illustrations include screen tints, pen and ink, wash, stipple, felt-tip pen and ink with smudge and edge emphasis.

Rendering is done in a very different way in CAD drawings. Items to be rendered are created as solid models using 3D drawing techniques. These models can then be rendered using the rendering function of the CAD software. However, many top companies now import the models into high-end, dedicated rendering software. Figure 12-25 shows an example of a part that has been modeled and rendered using a CAD program.

When viewing the rendered object in Figure 12-25, can you answer the following questions?

- Is the part opaque or transparent?
- Can you tell from which direction the light source is hitting the object?

Given the reflections that appear on inside surfaces, does the object have a bright or dull finish?

Consider these definitions as you attempt to answer the questions:

- **Reflectivity** the ability for an object’s surface to bounce light back to the viewer.
- **Opacity** not letting light pass through; not transparent or translucent.
- **Light source** direction from which light is directed onto an object.
- **Material finish** the quality of the surface of an object that renders it bright or dull.

Outline Shading

Outline shading is a convention, or standard method, used by board drafters. It may be done mechanically or freehand. Sometimes a combination of both methods is used. The light is generally considered to come from behind and above the observer’s left shoulder and across the object’s diagonal (see Figure 12-26A). In Figure 12-26B, the upper left and top edges are in the light, so they are drawn with thin lines. The lower right and bottom edges are in the shadow. They should be drawn with thick lines. In Figure 12-26C, the edges meeting in...
the center are made with thick lines to accent the shape. In Figure 12-26D, the edges meeting at the center are made with thin lines. Thick lines are used on the other edges to bring out the shape. See Figure 12-27 for an example of the use of a small amount of line shading. In this case, the shading is used to outline important parts of the drawing.

**Surface Shading**

Shading of the surface, or surface shading or rendering, can be done using board drafting techniques or computer software. In either method, the theory of shading is the same. With the light rays coming from the conventional direction (Figure 12-28A), the top and front surfaces of a cube should be lighted. Therefore, the right-hand surface should be shaded. In Figure 12-28B, the front surface is unshaded and the right surface is lightly shaded using vertical lines. If the front surface has light shading, then the right side should have heavier shading (Figure 12-28C). Solid shading may sometimes be required to avoid confusion. If the front is shaded, then a darker shade may be used on the right-hand side (Figure 12-28D).

Figure 12-28E was shaded in AutoCAD using the SHADE command. Notice that all three visible sides are shaded differently to define the 3D shape.
Wash Rendering

A wash rendering, or wash drawing, is a form of watercolor rendering that has traditionally been done with watercolor and watercolor brushes. CAD drawings can be imported to an illustration program and “painted” to achieve the same effect. Wash rendering is commonly used to render architectural drawings and for advertising furniture and similar products in newspapers (see Figure 12-29). Wash rendering is highly specialized and is usually done by a commercial artist. However, some technical illustrators and drafters are occasionally required to do this type of illustrating.

Photo Retouching

Photo retouching is the process used to change details in a photograph. Retouching can be done by hand or with computer software such as Adobe Photoshop®. Details may be added, removed, or simply repaired. This process is often needed in preparing photographs for use in publications. It can be used to change the appearance of specific details or the entire photograph.

Section 12.1 Assessment
After You Read

Self-Check

1. Identify and describe the different types of pictorial drawing types.
2. Explain the differences in the three types of axonometric projection.
3. Explain how to make cavalier, normal, and cabinet oblique drawings.

Academic Integration

English Language Arts

4. The English language has many words whose meanings vary, depending on the use of the word in a particular context. Section 12.1 introduced the content vocabulary terms, cabinet oblique and cavalier oblique, which have specific drawing-related meanings in mechanical drawing. How else can the words cabinet and cavalier be defined?

Drafting Practice

5. In Figure 12-30 below, identify the following pictorial drawings as two-point perspective, one-point perspective, oblique cabinet, isometric, or oblique cavalier.
To develop a pictorial drawing, you must understand the concepts involved and then apply them to a drawing using either board drafting or CAD techniques. What do you think are the differences and similarities of those techniques?

**Content Vocabulary**
- box method
- isoplane

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

**Graphic Organizer**
Use a table like the one below to organize notes about pictorial drawing techniques.

<table>
<thead>
<tr>
<th>Drawing Techniques</th>
<th>Board Drafting</th>
<th>CAD</th>
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<tr>
<td>Oblique drawing</td>
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<td></td>
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<tr>
<td>Perspective drawing</td>
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</tbody>
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Go to glencoe.com for this book’s OLC for a downloadable version of this graphic organizer.
Isometric Drawing Techniques

How do you draw circles, nonisometric lines, and reversed axes in isometric construction?

Section 12.1 discussed the various types of pictorial drawings and their applications. This section describes how to apply the principles of pictorial drawing using board drafting and CAD techniques. In isometric drawing, order is important. For example, in board drafting, you must create the isometric lines—those that are parallel to the isometric axes—before you can begin to draw nonisometric lines. This section explains construction techniques and then takes you step by step through practice exercises for isometric drawing.

Isometric Constructions

Before you attempt to create an isometric drawing using drafting instruments, you should understand the techniques used to create various geometric shapes accurately. The following pages describe several procedures. Practice these techniques before you attempt to create an isometric drawing.

Drawing Isometric Circles

In isometric drawing, circles appear as ellipses. Because it takes a long time to plot a true ellipse, a four-centered approximation is generally drawn, especially for large isometric circles. Isometric circle templates may be used for small ellipses. Figure 12-31 describes how to create a four-centered approximation of an ellipse. Figure 12-32 shows isometric circles drawn on three surfaces of a cube.

Figure 12-33 shows how to make an isometric drawing of the cylinder shown as a multiview drawing in Figure 12-33A. Follow these steps:

1. Draw an ellipse of the 3.00" circle following the procedure shown in Figure 12-32.
2. Drop centers A, C, and D a distance equal to the height of the cylinder (in this case, 4.00") as in Figure 12-33B.
3. Draw lines A'C' and A'D'.
4. Complete the ellipses as in Figure 12-33C. Construct a line through C'D' to locate the points of tangency. Draw the arcs using the same radii as in the ellipse at the top.
5. Draw the vertical lines to complete the cylinder. Notice that the radii for the arcs at the bottom match those at the top.

To draw quarter rounds, use the method in Figure 12-34 or an ellipse template. In each case, measure the radius along the tangent lines from the corner. Then draw the actual perpendiculars to locate the centers for the isometric arcs. Observe that the method for finding \( R_1 \) and \( R_2 \) is the same as that for finding the radii of an isometric circle. When an arc is more or less than a quarter circle, you can sometimes plot it by drawing all or part of a complete isometric circle and using as much of the circle as needed.

Figure 12-35 shows how to draw outside and inside corner arcs. Note the tangent points \( T \) and the centers 1, 1', 2, and 2.

**Drawing Irregular Curves**

Irregular curves in isometric drawings cannot be drawn using the four-center method. To draw irregular curves, you must first plot points and then connect them using a French curve. See Figure 12-36.

**Using Isometric Templates**

Isometric templates are made in a variety of forms. They are convenient and can save time when you have to make many isometric
drawings. Many of them have openings for drawing ellipses, as well as 60° and 90° guiding edges. Simple homemade guides like those in Figure 12-37A are convenient for straight-line work in isometric. These templates can be made to any convenient size. Figure 12-37B shows various ways to position the templates for making an isometric drawing. Ellipse templates such as those in Figure 12-38 are very convenient for drawing true ellipses. If you use these templates, your drawings will look better and you will not have to spend time plotting approximate ellipses. See Chapters 3 and 4 for information on templates and how to use them.

Describe What is the drawing order in isometric drawing?

Isometric Drawing Creation

Figure 12-39A shows a multiview drawing of a filler block. To make an isometric drawing of the block, begin by drawing the isometric axes in the first position (Figure 12-39B). They represent three edges of the block. Draw them to form three equal angles. Draw axis line OA vertically. Then draw axes OB and OC using the 30°-60° triangle. The point at which the three lines meet represents the upper front corner O of the block (Figure 12-39C).

Measure off the width W, the depth D, and the height H of the block on the three axes. Then draw lines parallel to the axes to make the isometric drawing of each block. To locate the rectangular hole in Figure 12-39D, lay off 1.00" along OC to c. Then from c, lay off 2.00" to c'. Through c and c', draw lines parallel to OB. In like manner, locate b and b' on axis OB and draw lines parallel to OC. Draw a vertical
Pictorial drawings, in general, are made to show how something looks. Because hidden edges are not “part of the picture,” they are normally left out. However, you might need to include them in special cases, to show a certain feature.

Figure 12-40 shows how to make an isometric drawing of a guide. The guide is shown in a multiview drawing in Figure 12-40A. This drawing is more complex because it includes a circular hole and several rounded surfaces. Study the size, shape, and relationship of the views in Figure 12-40A before you proceed. Then follow these steps:

1. Draw the axes AB, AC, and AD in the second position (see Figure 12-40B).
2. Lay off the length, width, and thickness measurements given in Figure 12-40A. That is, starting at point A, measure the length (3.00″) on AB; the width (2.00″) on AC; and the thickness (.62″) on AD.
3. Through the points found, draw isometric lines parallel to the axes. This “blocking in” produces an isometric view of the base.
4. Block in the upright part in the same way, using the measurement given in the top view of Figure 12-40A.
5. Find the center of the hole and draw centerlines as in Figure 12-40B.
6. Block in a .75″ isometric square and draw the hole as an approximate ellipse or use an ellipse template.
7. To make the two quarter rounds, measure the .50″ radius along the tangent lines from both upper corners as in Figure 12-40C. Draw real perpendiculars to find the centers of the quarter circles. Refer again to Figure 12-34 for information about drawing isometric quarter rounds. An ellipse circle template can also be used for this purpose.
8. Darken all necessary lines. Erase all construction lines to complete the isometric drawing. See Figure 12-40D.

Nonisometric Lines

To draw a nonisometric line, first locate its two ends, and then connect the points. Angles on isometric drawings do not show in
their true size. Therefore, you cannot measure them in degrees.

**Figure 12-41** shows how to locate and draw nonisometric lines in an isometric drawing using the **box method**. The box method involves the development of a framework, or box, that provides surfaces on which to locate points. The nonisometric lines are the slanted sides of the packing block shown in the multiview drawing in **Figure 12-41A**. To make an isometric drawing of the block, use the following procedure.

1. Block in the overall sizes of the packing block to make the isometric box figure as in **Figure 12-41B**.
2. Use dividers or a scale to transfer distances AG and HB from the multiview drawing to the isometric figure. Lay these distances off along line AB to locate points G and H. Then draw the lines connecting point D with point G and point C with point H. This is shown in Figure 12-41C.

3. Complete the layout by drawing GJ and HI and by connecting points E and J to form a third isometric line, as in Figure 12-41D.

4. Erase the construction lines to complete the drawing (see Figure 12-41E).

**Angles**

To draw the 40° angle in Figure 12-42A, use the following procedure.

1. Make AO and AB any convenient length. Draw AB perpendicular to AO at any convenient place (see Figure 12-42A).

2. Transfer AO and AB to the isometric cube in Figure 12-42B. Lay off AO along the base of the cube. Draw AB parallel to the vertical axis.

3. Connect points O and B to complete the isometric angle.

Follow the same steps to construct the angle on the top of the isometric cube. This method can be used to lay out any angle on any isometric plane.

**Figure 12-42**

Constructing angles in isometric drawings

**Figure 12-43**

Drawing oblique surfaces in isometric drawings

**Reversed Axes**

Sometimes you will need to draw an object as if it were being viewed from below. To do so in isometric drawing, reverse the position of the axes. Refer again to Figure 12-4. To draw an object using reversed axes, follow the example in Figure 12-44. Consider how an object appears in a multiview drawing (see Figure 12-44A). Then begin the isometric view by drawing the axes in reversed position.
(see Figure 12-44B). Complete the view with dimensions taken from the multiview drawing (see Figure 12-44C). Darken the lines to finish the drawing.

**Long Axis Horizontal**

When long pieces are drawn in isometric, make the long axis horizontal as in Figure 12-45 or at 30°. For example, a long object is shown in a multiview drawing in Figure 12-45A. See Figure 12-45B for the beginning of an isometric drawing with the axes shown by thick black lines. In Figure 12-45C, the same object is drawn with the long axis at 30° to the horizontal. The overall size and shape of the object, along with the intended use of the object, determines which method should be used. Remember that in isometric drawing, you must draw circles first as isometric squares; then complete them by the four-center method or by using an ellipse template.

**Dimensions of Isometric Drawings**

You can place dimensions on isometric drawings in two general ways. The older method is to place them in the isometric planes and adjust the letters, numerals, and arrowheads to isometric shapes (see Figure 12-46A). The newer unidirectional system (see Figure 12-46B) is simpler. In this system, numerals and lettering are read from the bottom of the sheet. However, because isometric drawings are not usually used as working drawings, they are seldom dimensioned at all. Refer to Chapter 7 for more information about the aligned and unidirectional methods of dimensioning.
Isometric Sections

Isometric drawings are generally “outside” views of an object. Sometimes, however, a sectional view is needed. To create a sectional view, take a section on an isometric plane—a plane that is parallel to one of the faces of the isometric cube. See Figure 12-47 for isometric full sections taken on a different plane for each of three objects. Note the construction lines showing the parts that have been cut away.

Figure 12-48 is an illustration of an isometric half section. The construction lines in Figure 12-48A are for the complete outside view of the original object. Notice the outlines of the cut surfaces. Figure 12-48B shows how to create the section. Draw the complete outside view as well as the isometric cutting plane. Then erase the part of the view that the cutting plane has cut away.

Explain Why do you not dimension isometric drawings?
Oblique Drawing Techniques

How is perspective drawing more complex than isometric and oblique drawing?

In oblique drawing, the front of the object is easy to draw, because it is parallel to the picture plane. The rest of the drawing follows rules similar to those for isometric drawings. Lines that are parallel to the axes are drawn first. This section explains construction techniques and then steps you through practice exercises for oblique pictorial drawing.

Oblique Constructions

As with isometric drawing, you should understand how to draw the geometry in an oblique drawing before you begin a complete drawing. The techniques used in oblique drawing are described below.

Obliques

On the front face, circles and curves show in their true shape. On other faces, they show as ellipses. Draw the ellipses using the four-center method or an ellipse template. See Figure 12-49A for a circle as it would be drawn on a front plane, a side plane, and a top plane. Figure 12-49B and C show an oblique drawing with arcs in a horizontal plane and in a profile plane, respectively.

When you draw oblique circles using the four-center method, the results will be satisfactory for some purposes, but they will not be pleasing. Ellipse templates give much better results. If you use a template, first block in the oblique circle as an oblique square. This shows where to place the ellipse. Blocking in the circle first also helps you choose the proper size and shape of the ellipse. If you do not have a template, plot the ellipse as shown in Figure 12-50.

Explain What is the four-center method?

Oblique Drawing Creation

The procedure for making an oblique drawing is much the same as that for creating an isometric drawing. Notice that the oblique
drawing in Figure 12-51 can show everything but the two small holes in true shape. Follow these steps:

1. Draw or review the multiview drawing of the object to be drawn in oblique. See Figure 12-51A.
2. Draw the axes AB, AC, and AD for the base in second position and lay off the length, width, and thickness of the base on the axes (see Figure 12-51B).
3. Draw the base and block in the upright, omitting the projecting boss (cylinder) (see Figure 12-51B).
4. Block in the boss and find the centers of all circles and arcs. Draw the circles and arcs (see Figure 12-51C).
5. Darken all necessary lines and erase construction lines to complete the drawing (see Figure 12-51D).

Angles and Inclined Surfaces

Angles that are parallel to the picture plane show in their true size. For all other angles, lay the angle off by locating both ends of the slanting line.

Figure 12-52A is a multiview drawing of a plate with the corners cut off at angles. The rest of the figure shows the plate in oblique drawings. In Figure 12-52B, the angles are parallel to the vertical plane. In Figure 12-52C, they are parallel to the profile plane, and in Figure 12-52D, they are parallel to the horizontal plane. In each case, the angle is laid off.
by measurements parallel to one of the axes. These measurements are shown by the construction lines.

**Oblique Sections**

Like isometric drawings, oblique drawings are generally “outside” views. Sometimes, however, you need to draw a sectional view. To do so, take a section of a plane parallel to one of the faces of an oblique cube. See Figure 12-53 for an oblique full section and an oblique half section. Note the construction lines indicating the parts that have been cut away.

**Perspective Drawing Techniques**

What techniques for drawing inclined surfaces, circles, and arcs used?

Perspective drawing involves techniques similar to those used for isometric and oblique drawings. However, perspective drawing is more complex, because you must consider line of sight, vanishing points, and other features. This section explains construction techniques and then takes you step by step through practice exercises for one- and two-point perspective drawing.

**Perspective Constructions**

As with isometric and oblique drawing, you should understand how to draw the geometry in a perspective drawing before you begin to draw one. The techniques for inclined surfaces, circles, and arcs are described in the following paragraphs.

**Inclined Surfaces**

Plot inclined surfaces in perspective by finding the ends of inclined lines and connecting them. This drawing method is shown in Figure 12-54.

**Circles and Arcs**

See Figure 12-55 for a two-point perspective of an object with a cylindrical surface. Points on the front and top views are located first and then are projected to the perspective view. A path is formed where the projection lines meet. The perspective arc is drawn along
the path using a French curve or an ellipse template.

**One-Point Perspective Creation**

Refer to **Figure 12-56**, which shows an object in multiview and isometric drawings. **Figure 12-57** shows how to draw the same object in a one-point, bird’s-eye perspective view. Follow these steps:

1. Decide on the scale to be used and draw the top view near the top of the drawing sheet as in **Figure 12-57A**. A more interesting view is obtained if the top view is drawn slightly to the right or left of center.

2. Draw an edge (top) view of the picture plane (PP) through the front edge of the top view.

3. Draw the horizon line (HL). The location depends on whether you want the object to be viewed from above, at, or below eye level. Draw the ground line. Its location in relation to the horizon line determines how far above or below eye level the object will be viewed. See Figure 12-57A.

4. To locate the station point (SP), draw a vertical line (line of sight) from the picture plane toward the bottom of the sheet. Draw the line slightly to the right or left of the top view. Set your dividers at a distance equal to the width of the top view. Begin at the center of vision of the picture plan and step off 2 to 3 times the width of the top view along the line of sight, to locate the station point. See **Figure 12-57B**.
5. Project downward from the top view to establish the width of the front view on the ground line. Complete the front view.

6. The vanishing point is the intersection of the line of sight and the horizon line. Project lines from the points on the front view to the vanishing point (see Figure 12-57C). Establish depth dimensions in the following way: Project a line from the back corner of the top view to the station point. At point A on PP, drop a vertical line to the perspective view to establish the back edge. Draw a horizontal line through point B to establish the back top edge.

7. Proceed as in the previous step to lay out the slot detail (see Figure 12-57D).

8. Darken all necessary lines and erase construction lines to complete the drawing.

In Figures 12-58 and 12-59, the object is drawn in one-point perspective in the other two positions. Notice that in all three cases, one face of the object is placed on the picture plane (thus the name parallel perspective). Therefore, this face appears in true size and shape. True-scale measurements can be made on it.

**Reading Check** How does the creation of one-point and two-point perspective differ?
Two-Point Perspective Creation

Refer to Figure 12-60 for an object shown in multiview and isometric drawings. See Figure 12-61 for the method to draw this same object with a two-point bird’s-eye perspective view.

1. Draw an edge view of the picture plane (PP). See Figure 12-61A. Allow enough space at the top of the sheet for the top view. Draw the top view with one corner touching the PP. In this case, the front and side of the top view form angles of 30° and 60°, respectively. Other angles may be used, but 30° and 60° seem to give the best appearance on the finished drawing. The side with the most detail is usually placed along the smaller angle for a better view.

2. Draw the horizon line (HL) and the ground line (GL).

3. Draw a vertical line (line of sight) from the center of vision (CV) toward the bottom of the sheet to locate the station point.

4. Draw line SP-B parallel to the end of the top view and line SP-C parallel to the front of the top view (see Figure 12-61B). Use a 30°-60° triangle.

5. Drop vertical lines from the picture plane to the horizon line to locate vanishing point left (VPL) and vanishing point right (VPR). Draw the front or side view of the object on the ground line as shown in Figure 12-61B.

6. Begin to block in the perspective view by projecting vertical dimensions from the front view to the line of sight (also called the measuring line) and then to the vanishing points. See Figure 12-61C.

7. Finish blocking in the view by projecting lines from points 1 and 2 on the top view to the station point. Where these lines cross the picture plane, drop vertical lines to the perspective view to establish the length and width dimensions. Project point 1’ to VPL and point 2’ to VPR.

8. Add detail by following the procedure described in steps 6 and 7. See Figure 12-61D.

9. Darken all necessary lines and erase construction lines to finish the drawing.

Figures 12-62 and 12-63 show the same object drawn in the other positions. Notice that none of the faces appear in true size and shape because none of them are on the picture plane.

Perspective Grids

Perspective drawing can take a lot of time. This is because so much layout work is needed before you can start the actual perspective view. Also, a large drawing surface is often needed in order to locate distant points. However, you can offset these disadvantages by using perspective grids. Examples are shown in Figure 12-64. There are many advantages in using grids. But there is one major disadvantage: a grid cannot show a variety of views. It is limited to one type of view based on one set of points and one view location. However, for the work done in some industrial drafting rooms, only one view may be needed.

You can buy perspective grids, or you can make your own. Creating your own grids is only practical, however, if you have a number of perspective drawings to make in a special style.

Evaluate What are the advantages and disadvantages of perspective grids?
Figure 12-61

Procedure for making a two-point perspective drawing (bird's-eye view)
CAD Techniques

Why would you choose to create a CAD drawing in 2D rather than in 3D?

In many ways, making a 2D pictorial drawing is a simpler process if you use a CAD system. For example, you do not have to construct ellipses to represent circles or holes on isometric planes. AutoCAD creates “isocircles” on all three planes. For rendering, however, the CAD work becomes somewhat more complex because all rendering is done on 3D models. The following sections discuss using AutoCAD to create various types of pictorial drawings.
2D Isometric Drawing Techniques

You can create isometric drawings in either two or three dimensions. If the drawing is to be used as an isolated illustration or for a single purpose, a 2D isometric is often sufficient. Drawings created in an engineering environment are often created in three dimensions, because 3D models can be used for many different purposes.

To create a 2D drawing of the block in Figure 12-65A, begin by setting up the grid and snap spacing for an isometric drawing. The rest of the steps are then fairly easy. As in board drafting, you should draw the isometric lines first. Follow these steps:

1. Press the F7 key to turn on the grid, and enter ZOOM All.
2. Enter the SNAP command at the keyboard. Notice the options that appear on the Command line. Enter S (Style), and then enter I (Isometric). Enter a vertical spacing of .25 to finish setting the snap. Notice that the grid and crosshairs (cursor) change to an isometric orientation. In Auto CAD, isoplane is one of the three isometric plane orientations available for the cursor to choose in automatic drawing. By default, the crosshairs are parallel to the left isometric plane, or isoplane. You can change them to the top and right planes using the ISOPLANE command. However, it is faster and more convenient to use one of the shortcut methods. You can toggle through the left, top, and right isoplanes by pressing CTRL+E or simply by pressing the F5 key. Both of these methods work while other commands are active, which can simplify drawing tasks. Figure 12-66 shows the crosshairs in each isometric orientation.
3. Change the crosshairs to the right isoplane.
4. Draw the baseline of the block up and to the right, as shown in Figure 12-65B. Reenter the LINE command and use the Midpoint object snap to snap a second line to the midpoint of the base. Extend the second line vertically up from the midpoint of the base, and make its length equal to the height of the block (1.50”). This temporary vertical line will form the basis for the top line and the isometric circle.
5. At any location on the screen, draw a 2.50” line parallel to the isometric baseline. This will become the top line of the isometric block. After creating the line, move it into position by selecting the midpoint of the 2.50” line as the base point for the move and snapping it to the upper end of the temporary vertical line. Refer again to Figure 12-65B.
6. Use the LINE command to connect the ends of the top and bottom lines of the block.

Figure 12-65
Development of a 2D isometric drawing in AutoCAD

Figure 12-66
Positions of the isometric crosshairs
7. Switch the crosshairs to the left isoplane, and draw the .50" lines at the top and bottom front corner and the top back corner to show the depth of the block. Then connect the .50" lines to complete the basic shape of the block (see Figure 12-65C).
8. Isometric circles, or isocircles, are created using the ELLIPSE command. When the snap is set to Isometric mode, an additional option called Isocircle appears when you enter the ELLIPSE command. To create the hole in the block, first make sure the crosshairs are set to the right isoplane. Then enter the ELLIPSE command and select the Isocircle option. Use the Midpoint object snap to snap the center of the isocircle to the midpoint of the temporary vertical line you created in step 4. The command acts exactly like the CIRCLE command. Enter a diameter of .50" to complete the isocircle. Erase the temporary vertical line. The completed block should look like the isometric drawing in Figure 12-65A.

**The Ortho Mode**

Like the snap and grid, the Ortho mode is affected by the isometric orientation. You can therefore use Ortho to keep lines aligned perfectly with the isometric axes. Use Ortho for all isometric lines.

**3D Isometric Drawings**

As you may recall from previous chapters, AutoCAD provides standard, predefined isometric views for 3D objects and assemblies. Therefore, to create a 3D isometric, you simply build the objects in three dimensions, and then change to an isometric view. The following steps use the EXTRUDE command to create a simple exploded assembly model of the base block from Figure 12-67 and the dowel that fits into the hole. Note: Display the View toolbar to save time. Picking the view buttons is faster than using the View pull-down menu.

1. Use the PLINE command to create the front view of the block just as you would for a 2D orthographic drawing (see Figure 12-67A).
2. Enter the ISOLINES command and set a new density of 10. This is not critical, but it will show the isocircle in better detail in the finished drawing.
3. Enter the EXTRUDE command and select the entire front view. Specify a height equal to the thickness of the block (.50'). Press Enter to specify a taper angle of 0 (no taper).
4. Display the model from the SW Isometric viewpoint to verify that the base is now a 3D model. Then return to the previous view by picking the Undo button on the Standard or Standard Annotation toolbar. Although this looks like a correct isometric representation of the block, it has one major fault as a solid model. The circle is not truly a hole. It is a solid cylinder in the middle of a solid block. You must subtract the extruded circle from the block to create a real hole.
5. Enter the SUBTRACT command, and pick anywhere on the outside of the base block as the solid from which to subtract. Press Enter and then select the cylinder to subtract. Remove hidden lines, and notice the difference in the model (see Figure 12-67B). The hole now passes all the way through the block. Now you can create the dowel that fits into the hole in the base. To create an exploded assembly, you must show the dowel above the base and in line with the hole.
6. Enter the PLAN command and select the World option to return to the plan view of the model.
7. Enter the CIRCLE command. Use the Center object snap to center the new circle on the hole in the base. Create the circle with a diameter of .235.
8. Enter the EXTRUDE command, select the new circle, and extrude it to a height of 3.00 to create the dowel. The dowel now exists and is in line with the base block, but the base of the dowel is...
aligned with the top of the block (see Figure 12-67C). To explode the assembly, you must move the dowel up while keeping it in proper alignment.

9. Switch back to the SW Isometric viewpoint to see the dowel and base block. Also, if Ortho mode is not on, turn it on now by pressing the F8 key. This will keep the dowel in proper alignment.

10. Enter the MOVE command and select the dowel. Move it straight up to clear the base block, as shown in Figure 12-67D.

11. To complete the exploded assembly, you need to create a trail to show how the two parts fit together. In this case, the trail will be a centerline that extends through the center of the dowel and the center of the hole in the base block. Enter the LAYER command and create a new layer called Center. Specify the Center linetype, and make this the current layer.

12. Enter the LINE command and use the Center object snap to select the center of the top of the dowel as the starting point for the line.

13. With Ortho still on, move the crosshairs straight down and select a point below the base block for the other endpoint of the line. The centerline should now run through the center of the dowel and through the center of the hole in the base block.

14. Pick the grip at the top of the centerline and move it up so that it extends beyond the top of the dowel.

15. Enter the HIDE command to see the exploded assembly. It should look similar to the one in Figure 12-67E.

Figure 12-67
Steps to develop a 3D exploded assembly model in AutoCAD

Oblique Drawing Techniques—CAD

What is the advantage of using 3D Orbit in creating oblique drawings?

The procedures for creating an oblique drawing using a CAD system are much like those for creating an isometric drawing. You can create oblique drawings in either two or three dimensions.

2D Oblique Drawings

Because the front view of an oblique drawing is at true size and shape, you can draw the front view as you normally would an orthographic. Then you can change the snap to make the top and side views easier to create. Follow these steps:

1. Create the front view of the pole support as in Figure 12-68A.

2. Be sure the grid is on, and enter the SNAP command at the keyboard. Enter R (for Rotate) and pick the lower right corner of the front view as the base point. Enter a rotation angle of 30. The grid and
crosshairs rotate counterclockwise 30°. Set the snap to .25.

3. Starting at the lower right corner of the base, create the .75" line that represents the depth of the pole support. Then copy this line to the other key points as in Figure 12-68B to define the depth. Use the Endpoint object snap to ensure accuracy.

4. Copy the right upright, hole, and arched top of the front view to the back of the object (see Figure 12-68C).

5. Draw a line tangent to the front and back arcs to connect them, and add the lines to complete the right side of the object (see Figure 12-68D).

6. To complete the oblique drawing, trim away the unwanted lines from construction, as shown in Figure 12-68E.

The procedure given here is for a cavalier oblique drawn at 30°. The same procedure can be used to create an oblique at any angle simply by changing the angle of the snap rotation. To create a cabinet oblique, divide the depth dimensions by 2 before adding the dimensions to the drawing.

**3D Oblique Drawings**

Like 3D isometric drawings, 3D oblique drawings are created as normal 3D models. The viewpoint is then changed to create the oblique. Follow these steps to create a model of the pole support:

1. Use the PLINE command to draw the front view of the pole support shown in Figure 12-69A.

2. Set ISOLINES to 10. Then enter FACETRES and enter a new value of 1. FACETRES
A B

is a command variable that controls the appearance of curved objects in 3D views.

3. Use the EXTRUDE command to extrude the object by the depth dimension, .75".

4. To create the hole, use the SUBTRACT command to subtract the hole from the pole support (if your version of AutoCAD supports this feature).

5. For convenience, select the SW Isometric viewpoint from the View menu. As with the 3D isometric, the drawing is lying on its side (see Figure 12-69A). Use the ROTATE3D command to rotate it into position. Use the Xaxis option and select the lower front corner as the base point. Rotate it 90° to achieve the position in Figure 12-69B.

AutoCAD includes a free-rotation feature known as 3D Orbit. This feature allows you to rotate a model in 3D space interactively using a spherical orbit algorithm. The advantage of using 3D Orbit is that you can actually see the object as you rotate the view. See Figure 12-70. Activate this feature using the 3DORBIT command. Move the viewpoint by dragging the mouse. Note: In some versions of AutoCAD, the spherical orbit does not appear. The command works exactly the same in these versions, however.

Recall What does extrude mean?

Perspective Drawing Techniques—CAD

How are the commands 3DORBIT, PLINE, and EXTRUDE used in perspective drawing?

Perspective drawing in AutoCAD is done entirely in 3D. Therefore, the first step in drawing any perspective view is to create a normal model of the object. Then you can view the model either in parallel projection (normal) or perspective views. The 3DORBIT command provides an easy method of adding perspective to a model. Follow these steps:

1. Create the box shown in Figure 12-71A using the PLINE and EXTRUDE commands. Extrude it to a height of .50 inch.

2. For convenience, switch to AutoCAD’s preset SW Isometric view.

3. Enter the 3DORBIT command and right-click to present a shortcut menu. From this menu, pick Projection and then Perspective. This places the model into the perspective mode.

4. Use the cursor to move the object in the perspective view. Create a view similar to the one in Figure 12-72. Press Enter to end the 3DORBIT command.
Use DVIEW to create a 3D perspective view.

The 3DORBIT command offers better control for creating 3D perspective views.

5. Enter the HIDE command to remove hidden lines. As you can see, the object retains the perspective view even after you end the 3DORBIT command.

6. To remove the perspective view, reenter the 3DORBIT command, right-click, and choose Projection and Parallel.

**Self-Check**

1. Select and draw appropriate isometric sections.
2. Manipulate 3D models in AutoCAD to achieve isometric, oblique, and perspective views.

**Academic Integration**

**Mathematics**

3. Imagine you are applying for a loan to start your freelance drafting business. The lender tells you that you will get a better rate if your debt payments-to-income ratio is low. Your debt payments would be for any credit card balances or loans that you are paying. If your monthly income is $1,200 and your monthly debt payments total $180, what is your debt-payments-to-income ratio?

**Number and Operations**

To figure out a ratio, you need to use a fraction. To calculate the DPR ratio, divide the total debts by the total income. Convert the decimal outcome to a percentage by moving the decimal point two places to the right and adding a percent sign (%).
Chapter Summary

**Section 12.1**
- An isometric drawing is a drawing in which the object is aligned with the three axes equally spaced at 120° angles. An oblique drawing is one in which two axes of the object are parallel to the projection plane. A perspective drawing is a three-dimensional representation of an object as it appears to the eye from a particular point.
- Axonometric projection has three types: diametric in which only two angles are equal; trimetric in which all three angles are different; and isometric in which the axes form three equal angles of 120° on the plane of projection.

**Section 12.2**
- Oblique drawings are classified according to the length of an object’s receding lines along the oblique axis: cavalier (full length), normal (three-fourths size), and cabinet (one-half size).
- One-point perspective is a view that has one vanishing point in comparison to a two-point perspective that has two vanishing points.
- At times, it is necessary to show a sectional (full or half) view of an isometric drawing. The process involves drawing the object’s complete view and then erasing the part that has been cut away.
- AutoCAD provides predefined, standard views for 3D objects. The first step is to build the object in three dimensions and then change to an isometric, oblique, or perspective view as your need dictates.

**Review Content Vocabulary and Academic Vocabulary**

1. Use each of these Content and Academic Vocabulary words in a sentence or drawing.

**Content Vocabulary**
- isometric drawing (p. 407)
- isometric axes (p. 407)
- axonometric projection (p. 408)
- dimetric projection (p. 408)
- trimetric projection (p. 409)
- picture plane (p. 409)
- cavalier oblique (p. 411)
- normal oblique (p. 411)
- cabinet oblique (p. 411)
- perspective drawing (p. 411)
- vanishing point (p. 412)
- technical illustration (p. 414)

**Academic Vocabulary**
- fundamental (p. 407)
- specific (p. 407)
- principles (p. 422)
- box method (p. 426)
- isoplane (p. 438)
- establish (p. 434)

**Review Key Concepts**

2. Identify various pictorial drawing types.
3. Explain the differences between the three types of axonometric projection.
4. Make cavalier, normal, and cabinet oblique drawings.
5. Create one-point and two-point perspective drawings.
6. Select appropriate isometric sections.
7. Manipulate 3D models in AutoCAD to achieve isometric, oblique, and perspective views.
**Technology**

8. The Information Age

Many historical eras have been given names that in some way describe the particular generation. Examples include the Age of Reason, the Gilded Age, and the Age of Discovery. We currently live in the Information Age. Why do you think our era has been given this name? In a one-page paper, define the Information Age and the emphasis it places on the processing and exchange of information.

9. Information Literacy

You hear the word economy at least daily. How would you define the word? Research the major economic systems used worldwide today. Go to libraries, databases, and computer networks to find your sources. Be sure to keep bibliographical information on those sources. When you have enough information, write a five-page paper explaining the two most commonly used economic systems. Be sure to use proper grammar, spelling, and organizational rules. Devote one page to critiquing the quality of the individual sources you found.

**Mathematics**

10. Recording Finances

Ahra set up a spreadsheet for her company’s finances. For each month, she has information about earnings and expenditures. Create a monthly spreadsheet to display this data that includes an equation for total cash flow.

Spreadsheets

Spreadsheets are basically tables, with rows and columns, use to display information. Computer spreadsheet programs can perform operations automatically when you input an equation into the row or column in question.

Step 1: Consider which data categories should go in the columns and rows.

Step 2: Create an equation for total cash flow using earnings and expenditures. Create another line for this data as well.

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**Multiple Choice Question**

11. You have a design problem for which you need a solution that is easy to draw, can be drawn without projecting from other views, and whose measurements can be made with a regular scale. Which of these drawings would meet your needs?

a. oblique
b. axonometric
c. 3D oblique
d. isometric

**TEST-TAKING TIP**

When you take a test, read the instructions before you begin. Failing to read directions could cause you to completely misinterpret what the test is asking you to do.

12. Architectural Drafting

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**

Work with a partner to brainstorm ways research and development can be used as a tool to troubleshoot, or solve problems. For example, what kind of research might be needed to solve technological problems? What is the difference between technological and non-technological problems?

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.

For problems 1 through 15, determine an appropriate scale and create isometric drawings according to the instructions for each problem. Do not dimension.

1. Determine an appropriate scale, and create an isometric drawing of the object(s) assigned from Figure 12-74. Note: These objects may also be used for oblique and perspective drawing practice.
2. Make an isometric drawing of the stirrup shown in Figure 12-75. Start the drawing at the lower left. Note the thick starting lines.

3. Make an isometric drawing of the brace shown in Figure 12-76. Start the drawing at the lower right. Note the thick starting lines.

4. Make an isometric drawing of the ratchet shown in Figure 12-77.
5. Make an isometric drawing of the object(s) assigned from Figure 12-78. Note: These objects may also be used for oblique and perspective drawing practice.

6. Make an isometric full or half section of the object(s) assigned from Figure 12-78.
7. Make an isometric drawing of the hung bearing shown in Figure 12-79. Most of the construction is shown on the layout. Make the drawing as though all corners were square, and then construct the curves.

8. Make an isometric drawing of the bracket shown in Figure 12-80. Some of the construction is shown on the layout. Make the drawing as though all corners were square, and then construct the curves.
9. Make an isometric drawing of the tablet shown in Figure 12-81. Use reversed axes. Refer to the layout on the right.

10. Make an oblique drawing of the angle support shown in Figure 12-82.
11. Make an oblique half or full section of the object(s) assigned from Figure 12-83. Note: These objects may also be used for isometric and perspective drawing practice.

Figure 12-83
12. Make a one-point perspective or two-point perspective drawing of each object assigned. Use any suitable scale.
For problems 13 and 14, determine an appropriate scale and create a pictorial drawing according to the instructions for each problem. Do not dimension unless instructed to do so.

13. To develop a good understanding of the relationship of the various types of pictorial drawings, make an isometric, oblique cavalier, oblique cabinet, one-point perspective, and two-point perspective sketch of the tool support shown in Figure 12-84D.

14. Make instrument or CAD drawings of the same tool support (Figure 12-84D) in isometric, oblique cavalier, oblique cabinet, one-point perspective, and two-point perspective. Compare the sketches you made in Problem 13 with the instrument or CAD drawings. Are they similar? Which type of pictorial drawing gives the most natural appearance?

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.

Challenge Your Creativity

1. Design an educational toy or game for children ages three to five. Material optional. Carefully consider safety issues. Include overall dimensions only.

2. Design a portable tool holder to accommodate a cordless electric drill with accessories. The design should also incorporate a means for attaching the tool holder to a tool panel. The accessories include at least a set of drill bits and screwdriver bits. Prepare a list of all items before proceeding with the design. Material optional. Develop design sketches and pictorial drawings with dimensions.

3. Design a device that can be used to convert a portable electric router into a bench-type router. It can be designed as a floor model or a bench-top model. Make it easy and quick to install and remove the router. Material optional. Each team member should develop design sketches of his or her design. Select the best ideas from each to finalize the team design. Prepare a final set of pictorial drawings with dimensions.

4. Design a park bench to be made from at least two different materials. Develop design sketches and pictorial drawings with dimensions.

5. In this chapter, you used AutoCAD's SUBTRACT command to create a hole in a solid model. SUBTRACT is one of several commands that allow you to perform Boolean operations (operations based on Boolean mathematics) on 3D models. The other two common Boolean commands are UNION, which allows you to combine simpler models to create a single, more complex model, and INTERSECTION, which creates a new model from the intersecting portion of two existing models. Investigate these commands and then use them to create a solid model of the bracket shown in Figure 12-80. Challenge: It is possible to build this model using more than one construction method. Try at least two different methods and determine which variation results in the smallest database (file) size.

Teamwork

3. Design a device that can be used to convert a portable electric router into a bench-type router. It can be designed as a floor model or a bench-top model. Make it easy and quick to install and remove the router. Material optional. Each team member should develop design sketches of his or her design. Select the best ideas from each to finalize the team design. Prepare a final set of pictorial drawings with dimensions.

4. Design a park bench to be made from at least two different materials. Develop design sketches and pictorial drawings with dimensions.

5. In this chapter, you used AutoCAD’s SUBTRACT command to create a hole in a solid model. SUBTRACT is one of several commands that allow you to perform Boolean operations (operations based on Boolean mathematics) on 3D models. The other two common Boolean commands are UNION, which allows you to combine simpler models to create a single, more complex model, and INTERSECTION, which creates a new model from the intersecting portion of two existing models. Investigate these commands and then use them to create a solid model of the bracket shown in Figure 12-80. Challenge: It is possible to build this model using more than one construction method. Try at least two different methods and determine which variation results in the smallest database (file) size.