UNIT 8

ISOMETRIC DRAWINGS

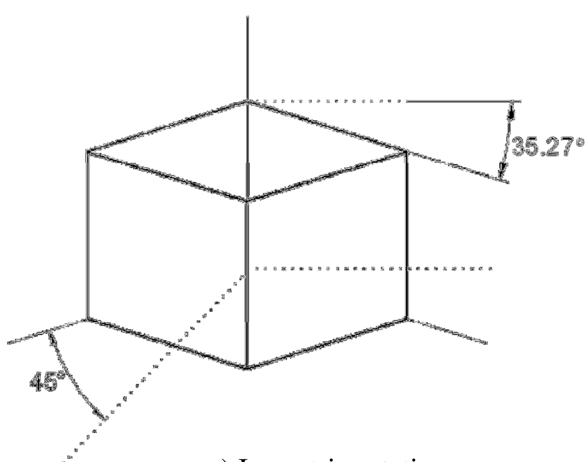
9.1 Introduction

Isometric drawings are a type of pictorial drawings that show the three principal dimensions of an object in a single view. The principal dimensions are the overall sizes for the object along the three principal directions. Pictorial drawings consist of visible object faces and the features lying on the faces. The internal features of the object are largely hidden from view. They tend to present images of objects in a form that mimics what the human eye would see naturally. Pictorial drawings show images that bear physical resemblance to the real or imagined object. Non-technical personnel can interpret them because they are generally easy to understand. Pictorial drawings are excellent starting point in visualization and design and are often used to supplement multiview drawings. Hidden lines are usually omitted in pictorial drawings, except where they aid clarity.

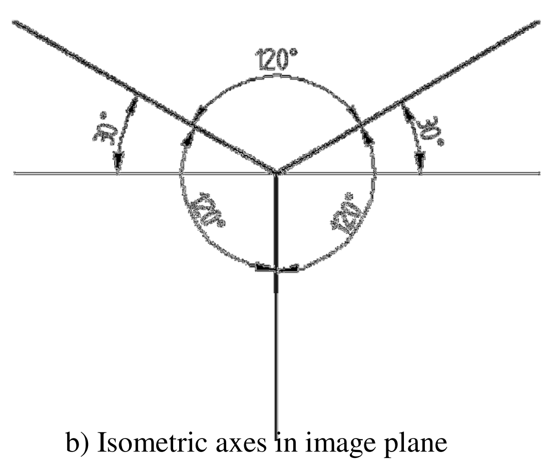
An isometric drawing is one of three types of axonometric drawings. It is created on the basis of parallel projection technique. The other two types of axonometric drawings are dimetric and trimetric drawings. In isometric drawings, the three principal axes make equal angles with the image plane. In dimetric drawing, two of the three principal axes make equal angles with the image plane while in trimetric drawing; the three principal axes make different angles with the image plane. Isometric drawings are the most popular and are easier to construct than the others.

9.2 Isometric Projection and Scale

An isometric projection is a representation of a view of an object at 35^o 16' elevation and 45^o azimuth. The principal axes of projection are obtained by rotating a cube through 45^o about a vertical axis, then tilting it downward at 35^o 16' (35.27^o) as shown in Fig. 9.1a. A downward tilt of the cube shows the top face while an upward tilt shows the bottom face. The 45^o rotation is measured on a horizontal plane while the 35^o 16' angle is measured on a vertical plane. The combined rotations make the top diagonal of the cube to appear as a point in the front view. The nearest edge of the cube to the viewer appears vertical in the isometric view. The two receding axes project from the vertical at 120^o on the left and right sides of the vertical line as shown in Fig. 9.1b. The three principal axes are therefore inclined at 120^o and are parallel to the cube edges in the isometric view. These three principal axes are known as isometric axes. The two receding axes are inclined at 30^o to the horizontal line while the vertical axis is at 90^o to the horizontal line. The three visible faces of the cube are on three planes called isometric planes or isoplanes. These isoplanes are called left, right, and top isoplanes. The front view of objects is commonly associated with the left isoplanes, the right view with the right isoplanes, and the top view with the top isoplanes. The lines an object parallel to the isometric axes are referred to as isometric lines while lines not parallel to them are known as non-isometric lines as shown in Fig. 9.2a. Isometric projection is not the most pleasant to the human eye but it is easy to draw and dimension.



a) Isometric rotations



b) Isometric axes in image plane

Fig. 9.1: Isometric projection

Now the regular axis is usually inclined at 45^o but the receding axes in an isometric projection are inclined at 30^o to the horizontal. Hence there is a difference in orientation between the receding isometric axis and the regular axis. These orientations of axes are shown in Fig. 9.2b, where a measurement of 10 units along the regular axis projects to 8.16 units on the isometric axis. Thus one unit of measurement on the regular axis is equal to 0.816 on the isometric scale. This means that a regular length of one unit must be scaled to 0.816 units in an isometric projection.

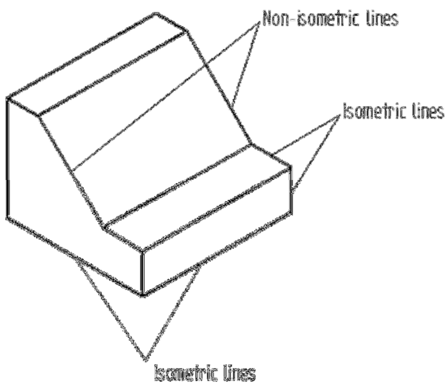


Fig. 9.2a: Types of isometric lines

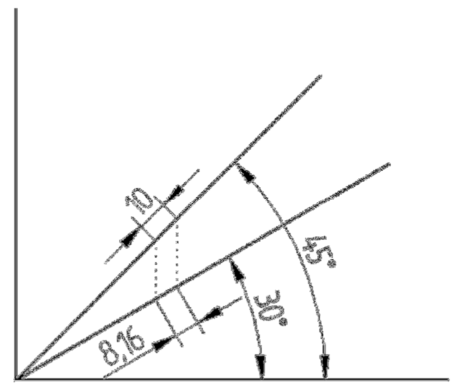
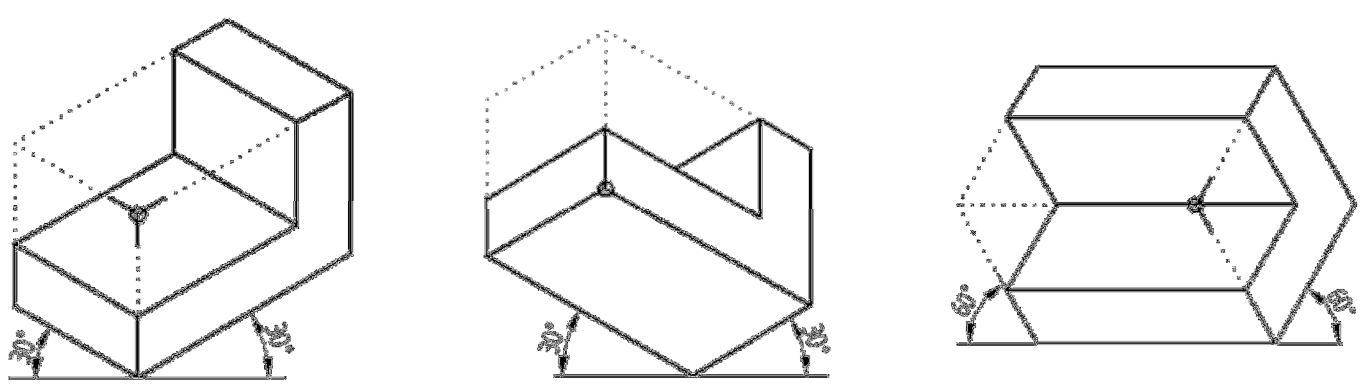


Fig. 9.2b: Isometric scale

Now isometric projection is a true or accurate representation of an object on the isometric scale, that is, when measurement is made along the isometric axes. This is about 18% short of the actual dimensions of the object. In practice, a regular length of one unit is drawn as one unit on the isometric axis, thus introducing some error to the projection. Hence, the actual images of object shown in isometric views are called isometric drawings and not isometric projections. The main difference between an isometric projection and an isometric drawing is size. The drawing is slightly larger than the projection because it is full scale. Features in isometric drawings may be created on isometric planes or non-isometric planes. For features on non-isometric planes, it will be helpful to first create them on isometric planes and then project them to non-isometric planes during construction of isometric drawings.

9.3 Types of Isometric Drawings

Isometric axes can be positioned in different ways to obtain different isometric views of an object. Three basic views are in general use and they are regular isometric, reverse isometric and long-axis isometric as shown in Fig. 9.3. In regular isometric, the viewer looks down on the object so the top of the object is revealed. The receding axes are drawn upward to the left and right at 30^o from the horizontal. The nearest end of the object is at the lower base of the B-box as shown in Fig. 9.3a. This is the most common type of isometric drawing. The viewer in reverse isometric is looking



a) Regular b) Reverse c) Long-axis

Fig. 9.3: Types of isometric drawings

up at the bottom of the object so this view reveals the bottom of the object. The receding axes are drawn downward from the horizontal at 30° with the back lower end at the base of the B-box, see Fig. 9.3b. The long-axis isometric keeps the largest principal dimension of the object horizontal as one principal axis. This is normally used for objects with length considerably larger than the width or depth. The viewpoint could be from the left or right side of the object but the long axis is drawn horizontal and the others are drawn at 60° as indicated in Fig. 9.3c. The long-axis isometric is the least used.

9.4 Constructing Isometric Arcs and Circles

Arcs and circles are common features on objects, especially in mechanical design and drafting. Isometric arcs are portions of isometric circles which are ellipses on isometric planes. Fig. 9.4 shows a component with isometric arcs on the right face or right isoplane. Since the arcs are portions of isometric circles, the technique for creating isocircles will be discussed. It is worth noting that an isometric arc can be constructed without creating a full isometric circle. One important rule to remember when creating curves in isometric projection is that the isometric face or plane the curves lie on should be created first using guide or construction lines. Then the curves can be created using projection of key points and intersection of projection lines from the key points. A second rule is that true dimensions are transferred to non-isoplanes. Hence where there are inclined and oblique faces, the true sizes of features on the auxiliary views should be used during construction. As mentioned earlier, isometric circles are ellipses and commonly called isocircles. There are several techniques available for creating isocircles, but an easy and more popular one is the four-center ellipse. This technique will be used here to create the three basic isometric circles: top isocircle, left (front) circle, and right circle. The four-center ellipse is an approximate ellipse but it is usually good enough for most drafting applications. Fig. 9.5 shows in five steps, the creation of the top isocircle.

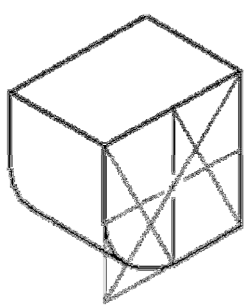


Fig. 9. 4 Isometric arcs

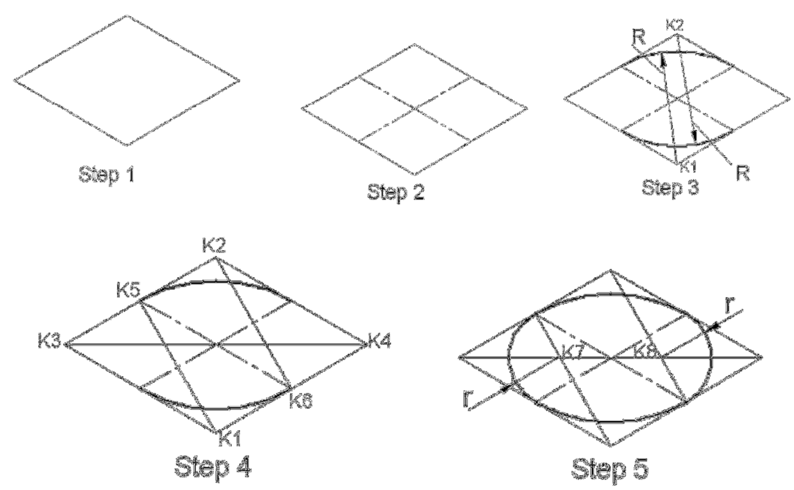


Fig. 9.5: Constructing top isocircle

Step 1: **Draw a square using the circle diameter as size**

For the top isocircle, the top isoplane is the right surface to draw the square. The top isoplane is horizontal as can be seen in step 1 of Fig. 9.5. Draw the isometric square.

Step 2: **Draw the center lines of the square**

Draw the two center lines of the square as shown in Step 2 of Fig. 9.5.

Step 3: **Draw the big arcs of the isocircle**

Identify the key points K1 and K2. These are two centers of the four center ellipse technique. Notice that these centers are located at the obtuse angle corners of the isometric square. Using the radius R, with centers at K1 and K2 draw the two big arcs for the isocircle as shown in Step 3 of Fig. 9.5.

Step 4: **Locate the centers of the small arcs of the isocircle**

Draw the diagonal K3-K4 between the acute angle corners of the square in Fig. 9. 5. Then draw lines K1-K5 and K2-K6. The intersection (K7) of the lines K3-K4 and K1-K5 in Step 5 locates one center for a small arc. The other small arc center is located at K8, the intersection of lines K3-K4 and K2-K6.

Step 5: **Draw the small arcs of the isocircle**

Using the centers of the small arcs K7 and K8, draw the two small arcs of radius r, as shown in Step 5 of Fig. 9.5. Verify that the big and small arcs are tangent to the isometric square. If a CAD package is used, circles could be drawn instead of arcs. The circles must then be trimmed to obtain the arcs required in the isocircle.

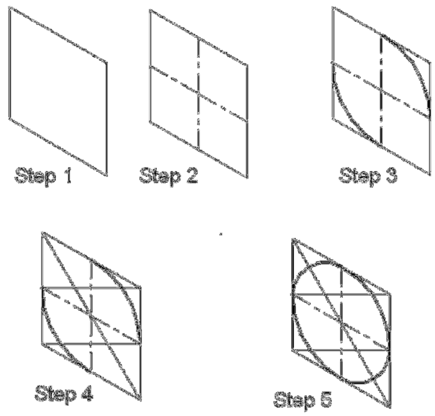


Fig. 9.6: Constructing left isocircle

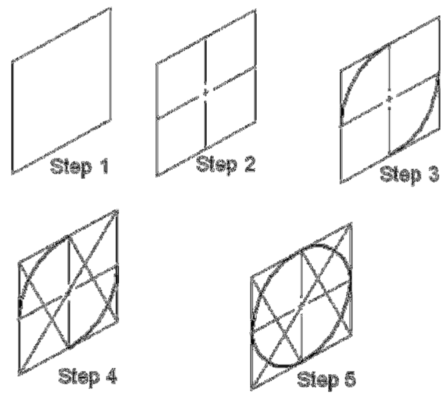


Fig. 9.7: Constructing right isocircle

Fig. 9.6 and Fig. 9.7 show, respectively, in five steps how the left and right isocircles can be created. These steps are the same as described above in Fig. 9.5 for the top isocircle, except that the isoplanes are respectively the left and right ones.

The construction of isometric arcs follows the same steps as isocircles. However, a quick visual inspection of the arc in a problem will reveal which quadrant(s) the arc is located in. Quarter arcs and half circle arcs are quite common in mechanical drafting. For example, Fig. 9.4 has a quarter arc on one of the acute angle corners, requiring the construction one of the small radius arcs in an isocircle.

The five steps described above for creating isocircles could be reduced to three as shown in Fig. 9.8 by combining steps 1 and 2 as Step 1; and combining steps 3 (without drawing the large arcs) and 5 as Step 3.

This leaves Step 4 above as the new Step 2 in which all the key points K1 to K8 are created. The centers of the four arcs can then be identified as K1, K2, K7, and K8. In the last step (new Step 3), the four arcs are created as shown in Fig. 9.8.

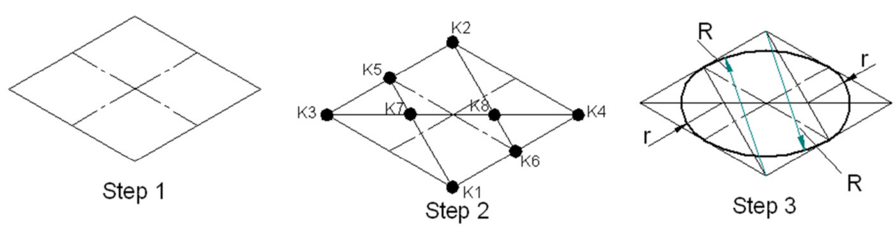


Fig. 9.8: Constructing top isocircle

9.5 Construction Techniques for Isometric Drawing

It is quite easy creating isometric lines on isometric planes. This is done by drawing the lines parallel to isometric axes. However, creating non-isometric lines and angles must be done with care. In general, angles of non-isometric lines are drawn by creating line segments between the end points of the locations that form the angle. On isometric planes, circles in principal orthographic views turn to isometric ellipses and arcs appear as partial isometric ellipses as discussed in the previous section. Irregular curves are created from intersections of projection lines from isometric planes.

There are two common techniques generally used for isometric drawings. These are the box and the centerline layout techniques, but the box technique is the most common construction technique. The box technique is also known as the coordinate technique. In the approach, a bounding (B-) box is first made with guide lines using the principal dimensions object. The principal dimensions may be designated as W for width, H for height, and D for depth. It may be necessary to add up dimensions along the principal axes to get the principal dimensions of an object. The faces on the objects are then created after the B-box is ready. Each feature on the object is properly located and created within the B-box. This technique is good for drawing objects with angular and radial features or objects that have irregular shapes or form. The general steps in the box technique are:

1. Define the origin of and create the isometric axes.
2. Create the bounding box using the principal dimensions.
3a. Use dimensions from top and front view to mark out faces.
3b. Or use dimensions from top and side views to mark out faces.
4. Locate and create all features on the faces.
5. Finish and check the drawing.

9.5.1 Applications of the Box Techniques

In this section, the box technique will be used to create isometric views of different typical objects as illustrations. These include objects with normal faces, inclined faces, oblique faces, and irregular curves. As pointed above for isocircles, the number steps used here could be reduced as one develops proficiency in the technique. The activities could be done using freehand sketching or with CAD software on a computer.

Object with Normal Faces Fig. 9.9 shows the construction of the isometric drawing of an object with normal faces. The multiview drawing of the object is shown in Fig. 9.9a. Note that Step 4 in the general procedure is not needed for this object.

Steps 1 and 2 of the general procedure can be combined into one by drawing the B-box directly keeping the isometric axes direction in mind.

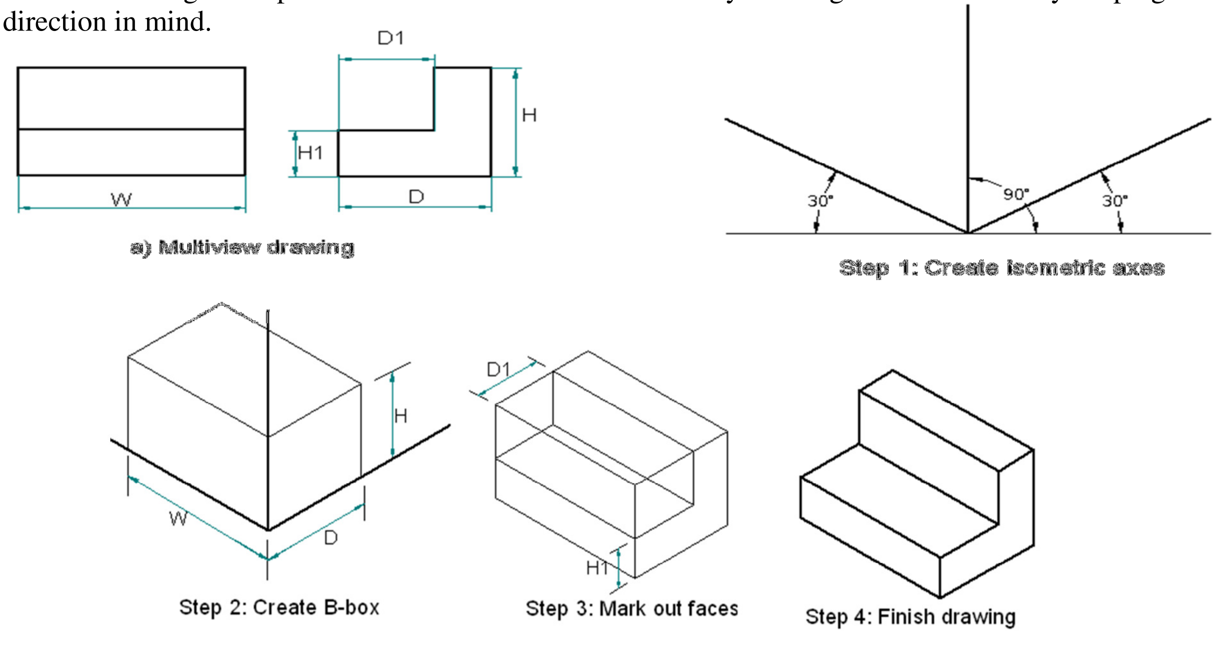


Fig. 9.9: Box method for normal faces

Object with Inclined Faces Fig. 9.10 shows the construction of the isometric drawing of an object with inclined face. The multiview drawing of the object is shown in Fig. 9.10a. Note that Step 4 in the general procedure requires the creation of an isometric circle on the inclined face.

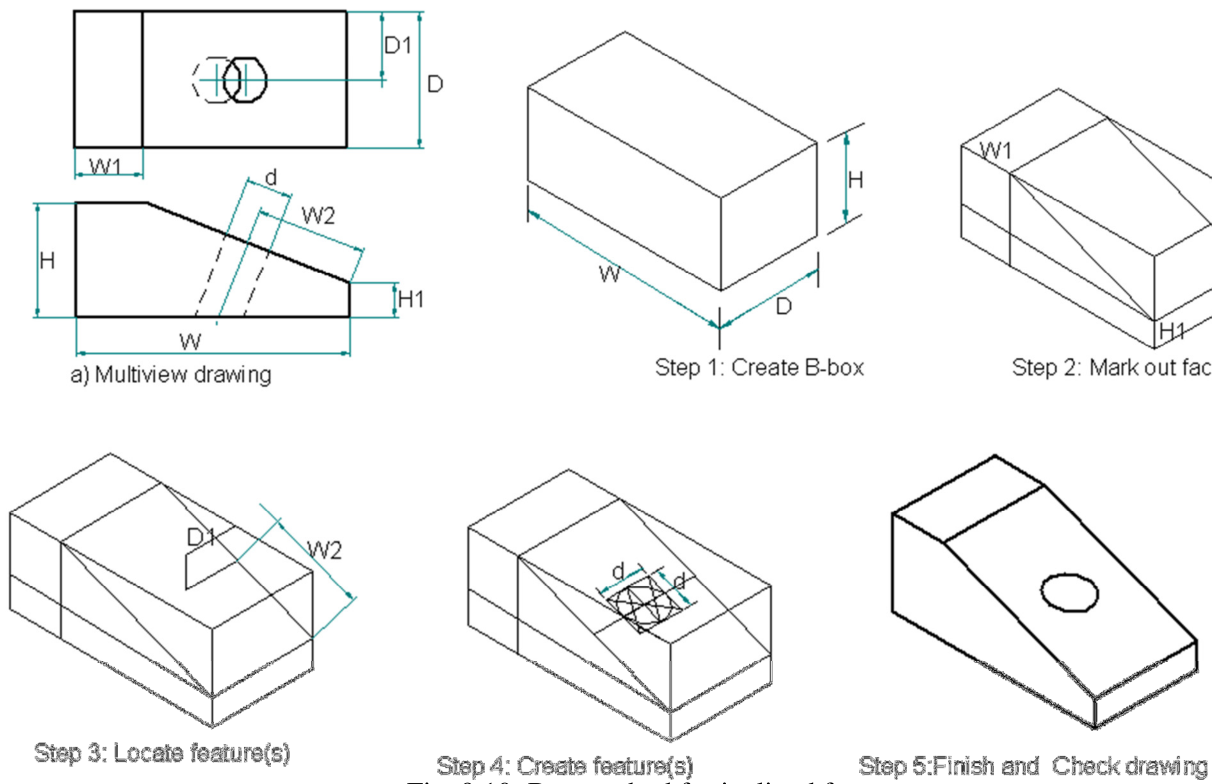


Fig. 9.10: Box method for inclined face

Object with Oblique Faces Fig. 9.11 shows the construction of the isometric drawing of an object with oblique face. The multiview drawing of the object is shown in Fig. 9.11a. Step 4 in the general procedure is not required in this object.

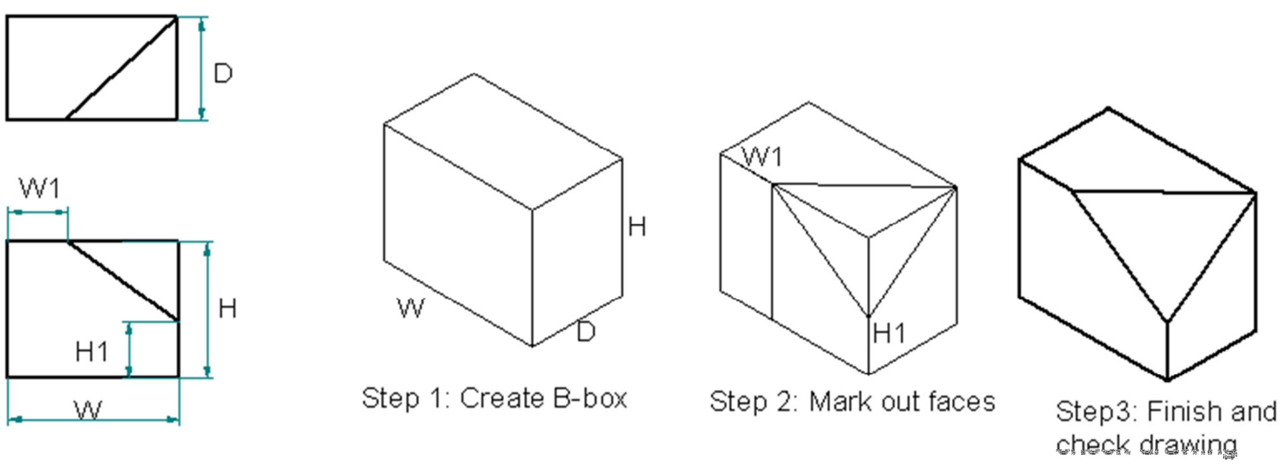


Fig. 9.11: Box method for oblique face

Object with Angled Faces Fig. 9.12 shows the construction of the isometric drawing of an object with angled faces. The multiview drawing of the object is shown in Fig. 9.12a. By inspection of the multiview drawing, it is clear that the right vertex on the top view is at the midpoint of the depth dimension D. This helps in locating the vertex on the B-box without using trigonometry. Observe that with the front angle of 30^o and the dimensions W and W1 given, the dimension H1 would not be shown. So H1 must then be calculated using trigonometry. It can be shown that: $H1 = H - (W - W1)\times\tan30^o$. Thus the lines defining the angles on the object can be created on the B-box without actually measuring the angles 60^o and 30^o. Always remember that angles on an object are not directly measured in isometric construction. They are used to calculate the end points of lines defining the angles. Finally, note that Step 4 in the general procedure is not required in this object.

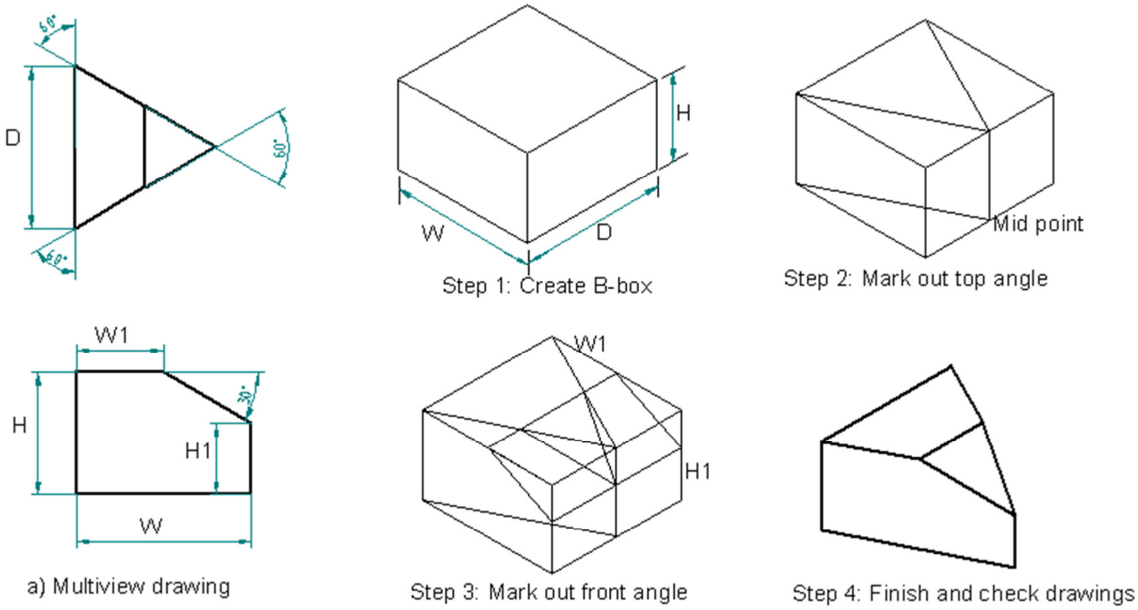


Fig. 9.12: Box method for angles

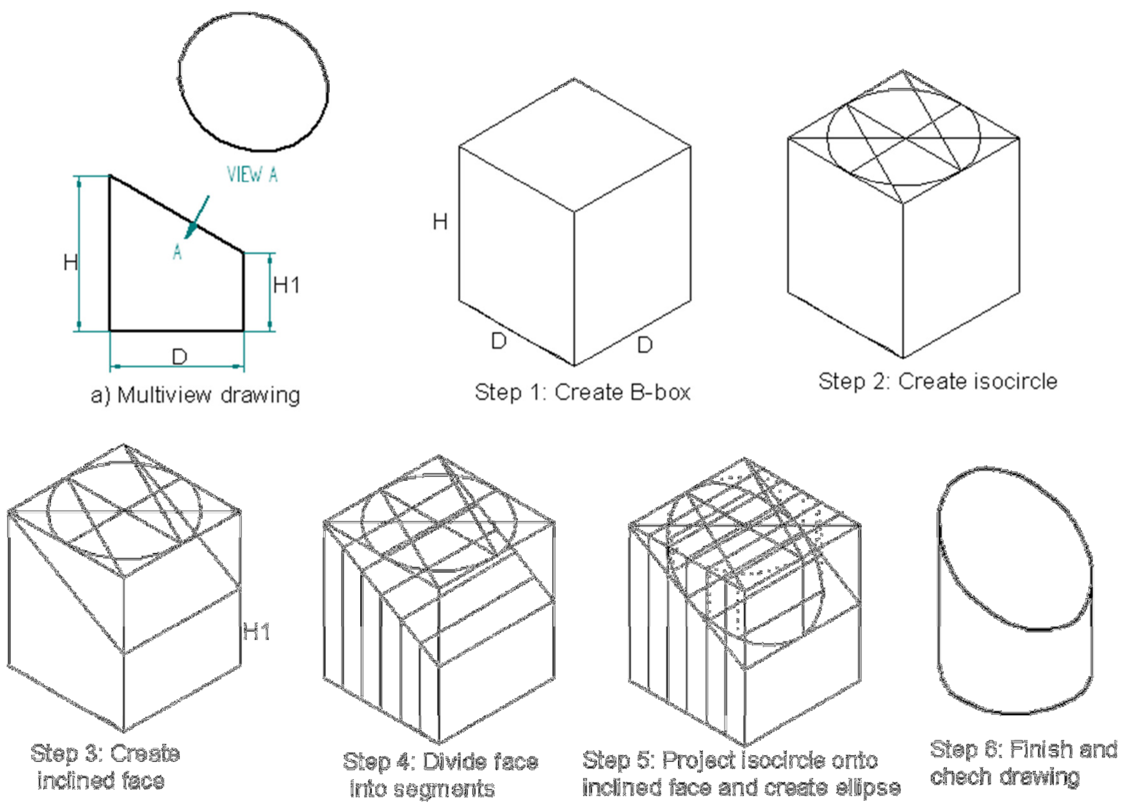


Fig. 9.13: Box method for ellipse on inclined face

Object with Ellipse on Inclined Faces Fig. 9.13 shows the construction of the isometric drawing of an object with angled faces. The multiview drawing of the object is shown in Fig. 9.13a. Step 1 follows the general procedure and Step 2 creates the isocircle for the cylinder. In Step 4, the inclined face is divided into segments that are used to project the isocircle onto the inclined face in Step 5. These two steps are perhaps the most challenging in this problem. Care is needed to first transfer the segments to the isocircle so as to define the key points on the isocircle that will be projected onto the inclined face. Then the key points so established are transferred to the inclined face and the ellipse is created. Again, note that Step 4 in the general procedure is not required in this object.

5.1.6 Object with Irregular Curves

Fig. 9.14 shows the construction of the isometric drawing of an object with irregular curve. The multiview drawing of the object is shown in Fig. 9.14a. Step 1 follows the general procedure and Step 2 creates the isocircle for the cylinder. In Step 2, the dimensions shown on the top view of Fig. 9.14a are used to mark out the key points on the curve. It is like dividing the curve into segments so that enough key points can be generated to be used to approximate the curve. Step 3 shows the creation of the irregular curve. Again, note that Step 4 in the general procedure is not required in this object.

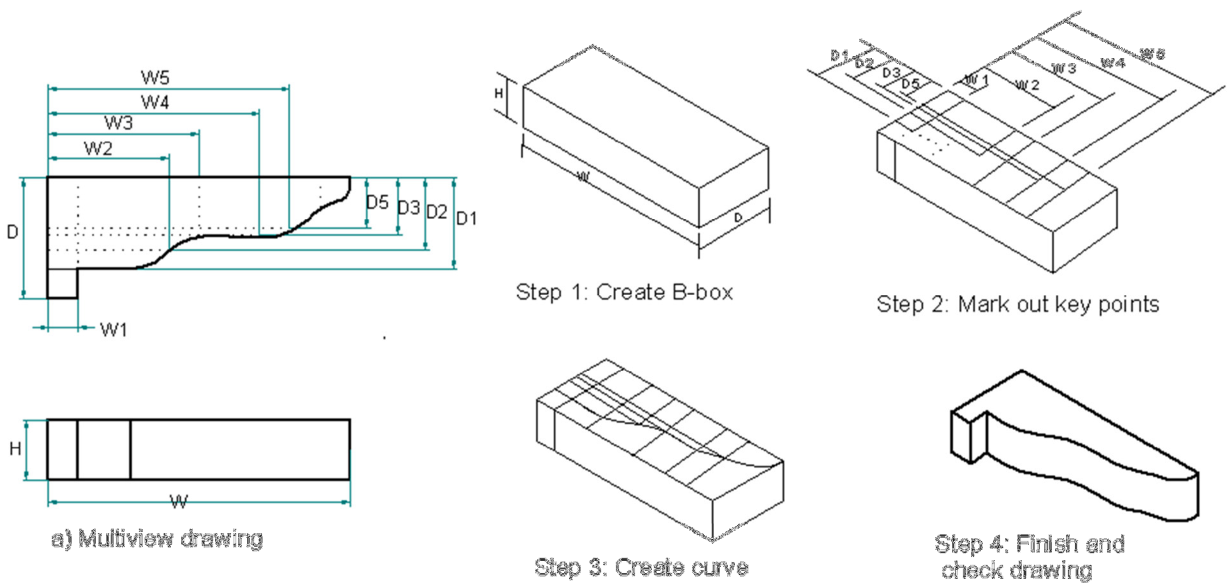


Fig. 9.14: Box method for irregular curve

9.5.2 Centerline Technique for Isometric Drawings

The centerline technique is better for objects with many circular and arc features. This method begins with a construction of all the centerlines in the object using the top or bottom face as reference. The center points of all the circles and arcs are located and the circles and arcs are created. Other features are added to complete the drawing. Fig. 9.15 shows the use of the center line method in the construction of an object. In it, the following steps are outlined:

Step 1: Create the center lines

All centerlines in the object are created aligned with isometric axes. The size of the object will determine the length of the center lines. Either the top or bottom face of the object can be used as reference. The bottom face was used as reference in Fig. 9.15.

Step 2: Create Isocircle Squares

On the center lines drawn in Step 1, locate the centers of the isocircles. Using the dimensions available; draw the squares for the isocircles on one face as shown in Step 2 of Fig. 9.15.

Step 3: Create Arc Centers for Isocircle on One Face

Using the four-center ellipse technique create the centers of the arcs for the isocircles on one face.

Step 4: Create the Isocircles on One Face

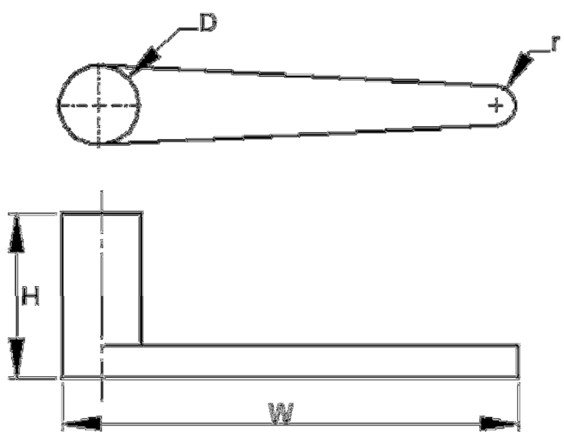
Once the centers of the arcs for the isocircles are finalized in Step 3, create the arcs for each isocircle.

Step 5: Create Isocircles on the Other Faces

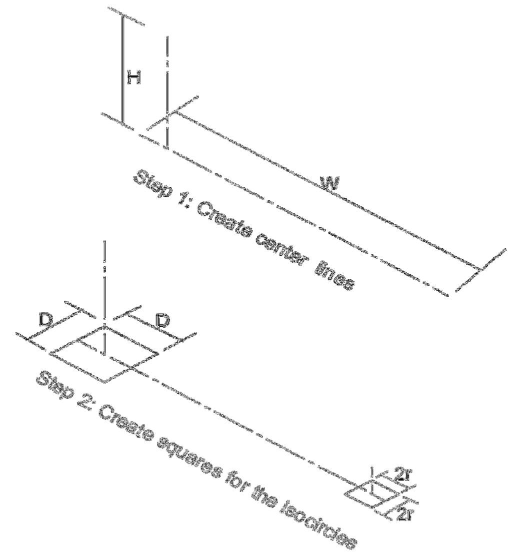
Repeat Steps 2 to 4 for other faces.

Step 6: Finish and Check the Drawing

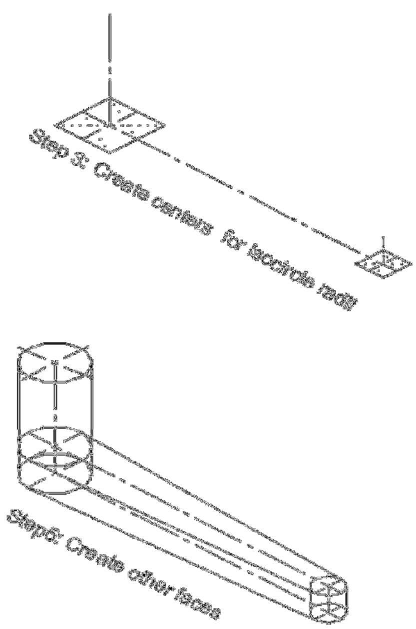
Complete the drawing by creating connecting features to the isocircles and removing lines and arcs that are hidden. Check that the drawing is correct.



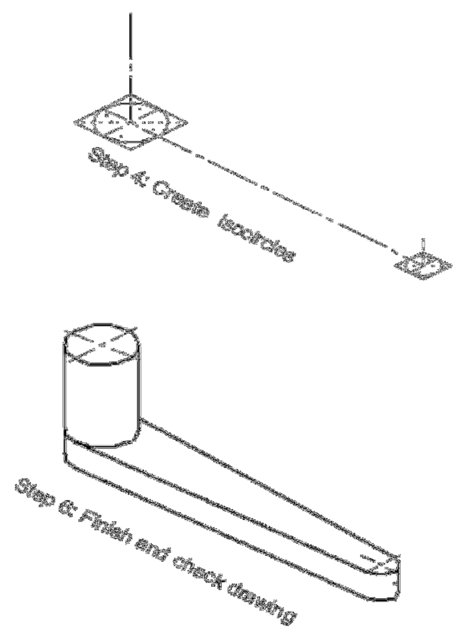
a) Multiview sketch



b) Layout construction



c) Create centers for features

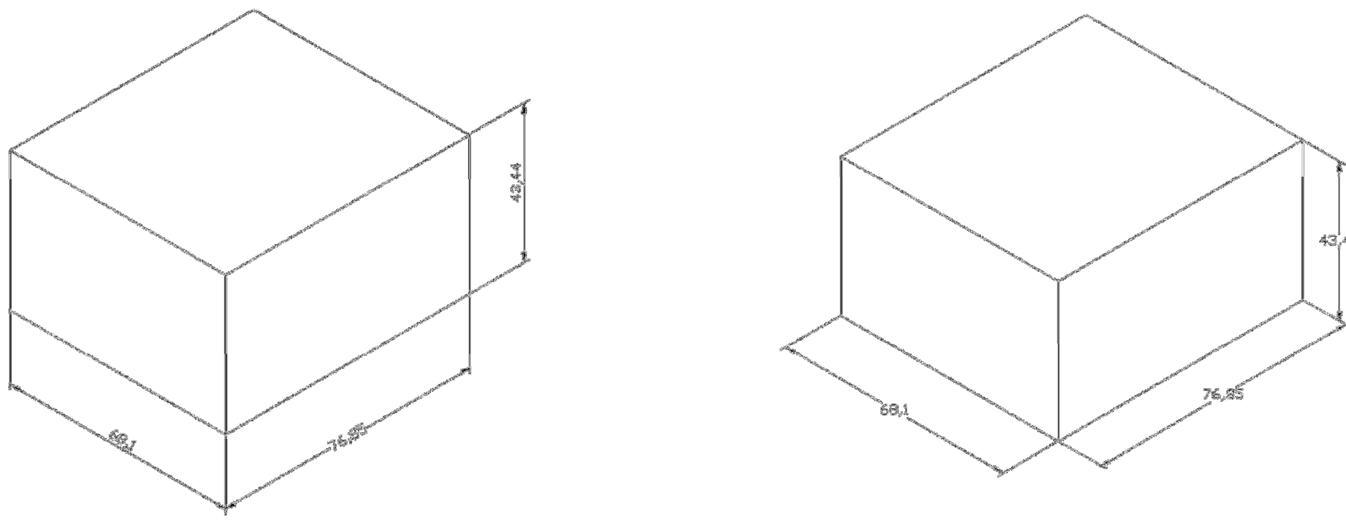


d) Finish sketch

Fig. 9.15: Center line method for isometric drawing

9.6 Isometric Annotations

Isometric annotations consist of textual information added to isometric views for complete documentation. These include dimensions, notes, tables, etc. Annotations should be placed on isoplanes and dimension lines should be parallel to isometric axes. As much as is possible, keep all dimensions outside of view and show dimensions between points on the same plane only. Arrowhead heel should be parallel to the extension lines and dimension value should be parallel with extension lines. The front (for width dimensions) and right (for depth dimensions) isoplanes are preferred for annotations. Fig. 9.16a shows a box dimension with the preferred format, however, Fig. 9.16b, shows the same box dimension with the width and depth sizes on the top isoplane. This is also a common format for isometric dimensioning. The height dimensions are placed vertical and could be on the front or right isoplane. The dimension value can be placed aligned with the dimension line or placed horizontally. Though the aligned placement is recommended by ANSI, the horizontal placement is common, perhaps due to relative easy when drawing manually or sketching freehand.



a) Aligned dimension placement b) Horizontal dimension placement

Fig. 9.16: Isometric annotations

9.7 Applications of Isometric Views

Isometric views are used in component and assembly drawings. Isometric component pictorials may be presented in two formats: isometric detail drawing or isometric insert view. Isometric detail drawing is a single view with proper annotations. Isometric insert view is an isometric view of a component that is added to necessary orthographic views principally to aid visualization and sometimes for completeness of documentation. In assembly drawings, isometric views provide general graphic description of each component in outline, exploded and section views. Section pictorial views show all internal components in mating position at a plane defined by the cutting plane line. Broken section isometric views are used in assembly and detail drawings.

9.7.1 Iso-detail Drawings

Annotated isometric view of a component may be referred to as *iso-detail* drawing. This is a single isometric view drawing of a component with all specifications and dimensional information necessary for the manufacture and inspection of the component. This is done mostly for components with relatively simple form. Fig. 9.18 shows two examples of isometric principal drawings. However, sketched isometric views may be dimensioned during design development. Because these sketches are not drawn to scale, they are not iso-detail drawings but may be called iso-detail diagrams.

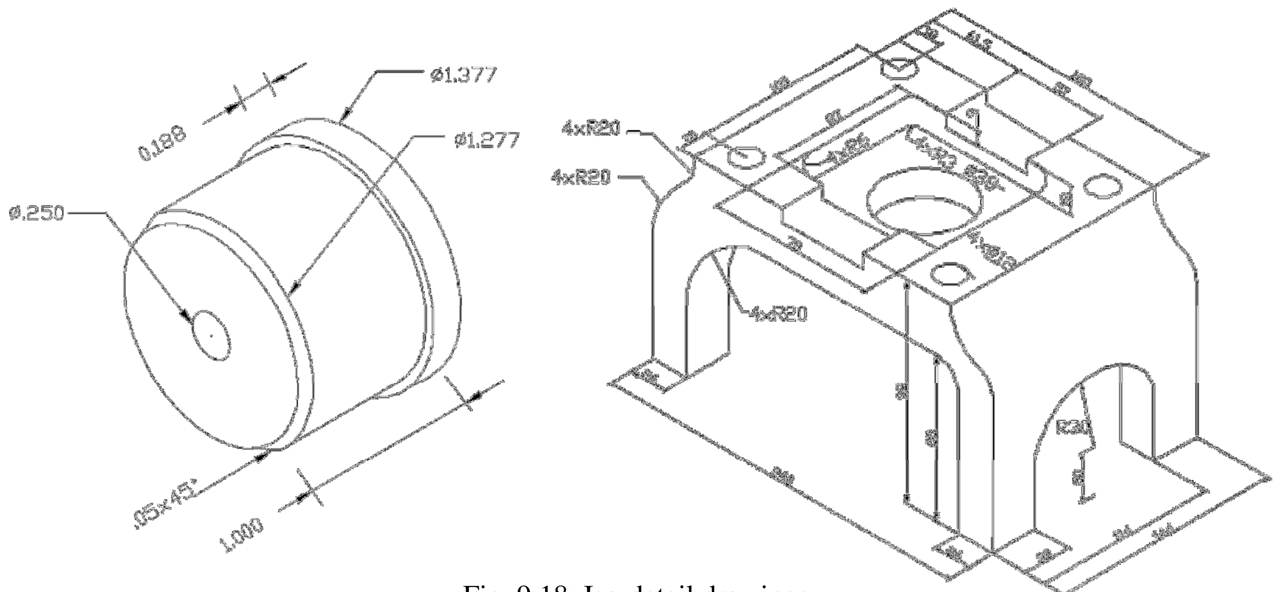
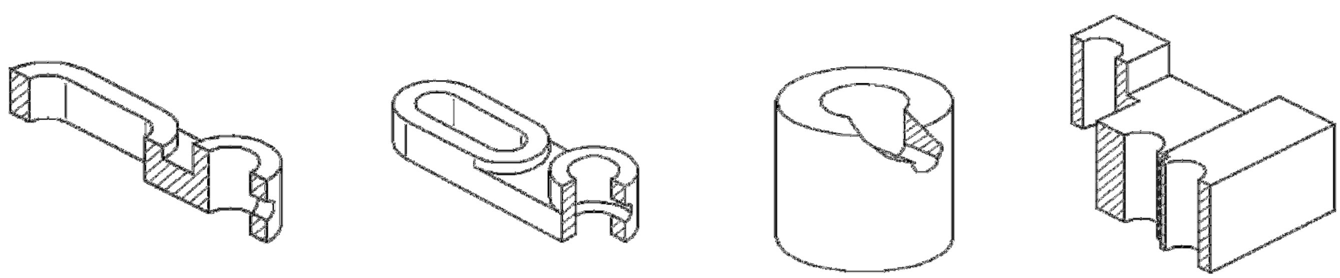


Fig. 9.18: Iso-detail drawings

In orthographic detail drawings, it is common in practice to have an isometric view included, though annotations are not added to the isometric view.

9.7.2 Isometric Section and Exploded Views

Different types of sections in isometric views can be created but the common ones are the regular (full), half, broken, and offset sections. Objects of irregular interiors are good candidates for isometric sections. Hatch line inclination should be chosen with care to ensure that they are not parallel to isometric lines or feature lines. A 60^{o} inclination for hatch patterns is common practice. Other angles should be used where this is not appropriate. Fig. 9.20a and Fig. 9.20b show examples of isometric full section and half section respectively. Fig. 9.20c and Fig. 9.20d show examples of isometric broken and offset sections



a) Straight section   b) Half section   c) Broken section   d) Offset section

Fig. 9.20: Isometric section views

9.7.3 Isometric Outline and Exploded Views

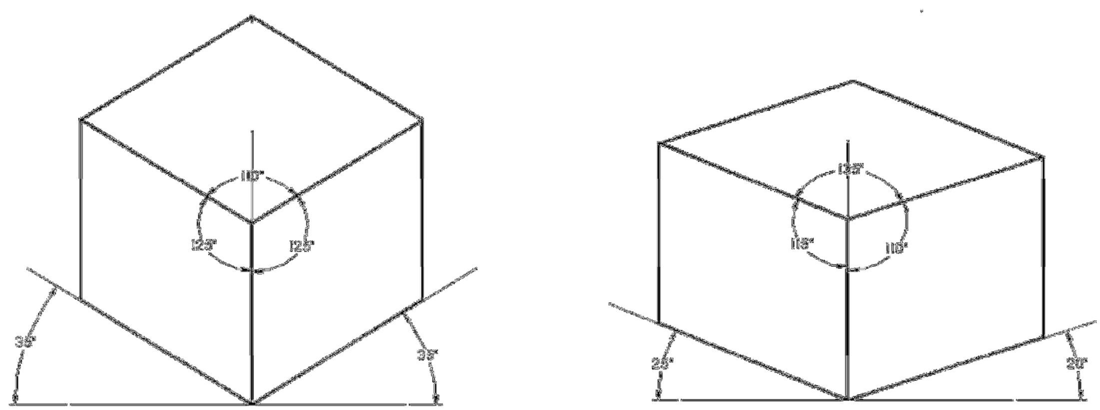
Outline pictorial views show all external components in mating positions as the example in Fig. 9.21a. Exploded pictorial views show all components in relative position at some distance apart; but aligned to adjacent components. Exploded assembly drawings are great aids in assembling, installations, and maintenance of products. They are popular in catalogues, maintenance manuals and guides, technical illustrations, etc. They are normally arranged along isometric axes with cases of several offsets if assembly is of a complex product. Fig. 9.21b shows the exploded isometric view of Fig. 9.21a.

a) Outline b) Exploded

Fig. 9.21: Assembly Isometric views

9.8 Dimetric and Trimetric Projections

Dimetric and trimetric projections are similar to isometric projection but differ in the angles between the reference axes on the image plane. Fig. 9.22 shows examples of isoplanes on cubes for dimetric and trimetric projections. In diametric projection, two of the angles between the principal axes are equal as shown in Fig. 9.22a. These angles are normally greater than 90^o but less than 180^o. The angle 120^o produces an isometric projection, so it is not acceptable in dimetric projection. The third angle is chosen to be less or greater than the value of the equal angles. Common values for angles in dimetric projection are 15^o, 20^o, 25^o, 35^o, and 40^o with the horizontal line at the base of the cube. It is much easier constructing isometric drawing than dimetric drawings. In trimetric projection, the angles between the principal axes are different from each other as indicated for the example in Fig. 9.22b. Though this gives greater flexibility in the drawings that may be created, the construction process is more tedious than even that for diametric drawings. Thus, it is rear to find trimetric drawings. Some CAD packages allow dimetric and trimetric views to be generated from solid models. However, isometric drawings are the favorites.



a) Dimetric b) Trimetric

Fig. 9.22: Examples of isoplanes in other axonometric projections

9.9 Summary

Pictorial drawings are created by means of axonometric, oblique, and perspective projections. Axonometric projections have three variants of isometric, dimetric, and trimetric projections. Perspective projection is used to generate one-point, two-point, and three-point perspective drawings. Pictorial drawings show all three principal dimensions of an object in one view. They are easy to interpret and non-technical personnel can understand them but do not reveal much of hidden details. Hence, when objects have hidden features or are relatively complex in form and shape, a single view is usually not able to describe it adequately, especially for manufacturing and inspection purposes.

The three basic isometric views in general use are regular isometric, reverse isometric and long-axis isometric views. The most common is the regular isometric view. Isometric views are most often constructed with the box-technique, but round objects like cylinders, and cones can be constructed using the centerline technique. Isometric views can be presented in outline, section and exploded formats. Annotated isometric view of a component may be referred to as *iso-detail* drawing. Iso-insert views are found in ortho-detail drawings. This is a single isometric view drawing of a component with all specifications and dimensional information necessary for the manufacture and inspection of the component. Isometric views can be generated from solid models.