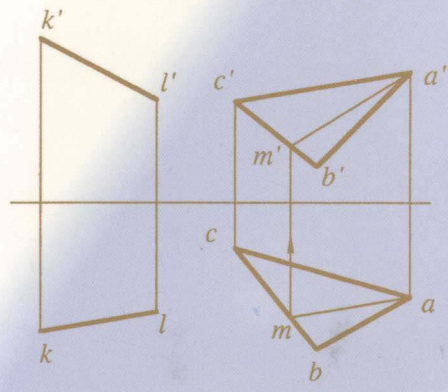
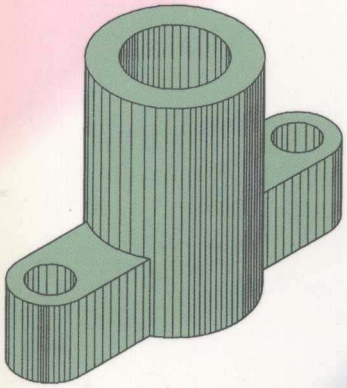
Descriptive Geometry and Mechanical Drawing

Edited By Wang Yuehui





Dalian Maritime University Press

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Comments and suggestions are welcome and appreciated.

Wang Yuehui
王跃辉

July 2001

Preface

Descriptive Geometry and Mechanical Drawing responds to a demand for a short, concise, English text and workbook that can be used in an introductory course in engineering drawing. It covers the theories of both descriptive geometry and mechanical drawing. Descriptive Geometry introduces the theory and practice required for the solution of problems involving space relationships and techniques of constructing representations of space geometric shapes on a plane. Mechanical drawing introduces the principles of mechanical drawing and provides the means how to make mechanical drawings.

Descriptive Geometry and Mechanical Drawing is organized such that students acquire understandings of the theories of descriptive geometry, the functions of mechanical drawings within the mechanical design process, the types of drawings that are produced, and the methods by which they are made. With this as background, the theory of multiview drawing and size description is presented along with mechanical fundamentals. Lastly, specific applications of mechanical drawing such as auxiliaries, sections, details, and assemblies are introduced.

The theories and principles provided in this book are precursors to the courses such as Mechanical Design and Computer-aided Design and Drafting.

Contents

Chapter 1 The Fundamentals of Projections

1.1 Method of Projections

A shadow is formed on the ground when an object is in the sun. After a scientific abstraction this natural phenomenon is called projection in descriptive geometry, and the method with which an object is represented, in plane-geometry drawing, on the plane is called method of projection. In the method of projection, the light are called projecting line or projector, the ground is called plane of projection, the shadow is called projection.

In descriptive geometry the construction of plane-geometry drawing, representing three dimensional designs of object, is based on the method of projection.

1.1.1 Types of Projections

There are two types of projections in descriptive geometry. One is called **central projection**, and the other is called **parallel projection.**

1) Central Projection

In Fig. 1-1 triangle *ABC* and point *S* are shown situated in space in front of plane *P*. Straight lines originating at point *S* and projecting the triangle *ABC* on the plane *P* in points *a*, *b*, and *c*. The triangle *abc* is called the central projection of the triangle *ABC*. Point *S* is termed the center of projection. The plane *P* is the plane of projection or projection plane, and the straight lines *SAa, SBb, SCc* are the projecting line or projector. The method in which projecting lines pass through a center of projection is call central projection.

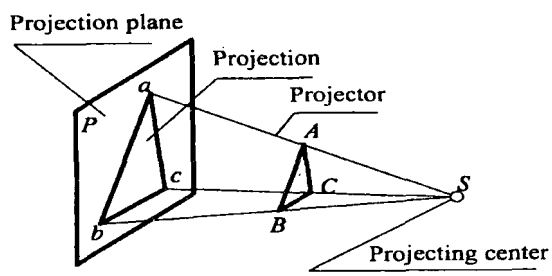


Fig. 1-1 Central projection

2) Parallel Projection

If the center of projection *S* is considered to lie at infinity, it follows that all the projecting lines are parallel. In order to draw these lines, it is necessary to know the direction of projection. The representations thus obtained are called parallel projection.

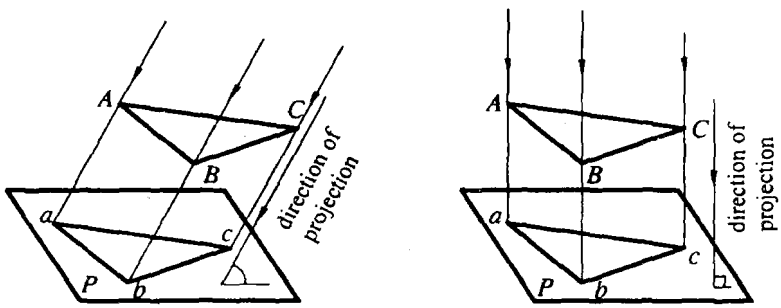
Fig. 1-2 shows the construction of the parallel projection *abc* of triangle *ABC* on the plane of projection *P*. The line to which the projecting lines *Aa, Bb, Cc* is parallel gives the direction of projection.

(1) Oblique Projection

If the given direction of projection forms an oblique angle with the plane of projection, the parallel projection in this case is called an oblique projection (Fig. 1-2 (a)).

(2) Right-angle Projection

If the given direction of projection is perpendicular to the plane of projection, the parallel projection in this case is called a right-angle projection (Fig. 1-2 (b)).



(a)Oblique projection (b)Right-angle projection

Fig.1-2 Parallel projection

Generally the right-angle projection is used in mechanical drawing, and it is also called orthographic projection.

1.1.2 The Characteristics of Orthographic Projection

In order to present an object in orthographic projection, we need to know the characteristics of projection of geometric elements. That is, how the points, lines, and planes will show in orthographic projection. The characteristics of orthographic projection are as follows:

1) True Length or Shape Projection

When a straight line or a plane is parallel to the plane of projection, its projection shows as in its true length or shape (Fig. 1-3 (a), (b)).

2) Collective Projection

When a straight line or a plane is perpendicular to the plane of projection, its projection shows as a point or a straight line (Fig. 1-3 (c)).

3) Foreshorten Projection

When a straight line or a plane is oblique to the plane of projection, its projection is foreshortened (Fig. 1-3 (d), (e)).

4) Proportional Division of Projection

If a line in space is divided by a point in the ratio $m : n$, the projection of this line is also

divided by the corresponding projection of point in the same ratio $m : n$ (Fig. 1-3 (d)).

5) The Projection of a Point on a Line

If a point lies on a line in space, the projection of that point also lies on the corresponding projection of the line (Fig. 1-3 (d)).

6) The projections of parallel lines

If the lines are parallel to each other, their projections on the same plane of projection are also parallel to each other(Fig.1-3(f)).

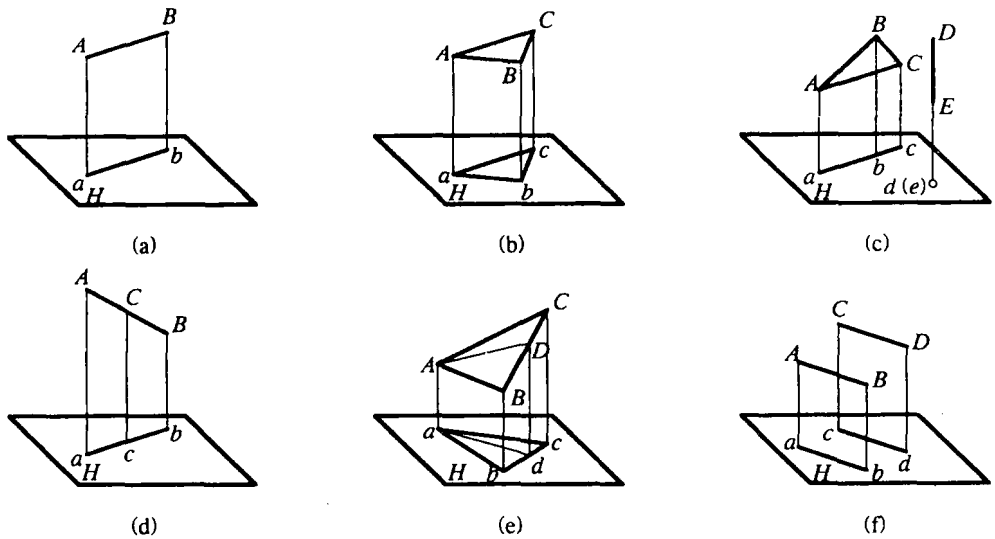


Fig. 1-3 The characteristics of right-angle projection

1.2 The Projections of Points

1.2.1 The Projections of a Point on Two Projection Planes

1) The Formation of Two Projection Planes

The following important facts regarding the projections of a point should be carefully noted:

One projection alone does not define the position of a point in space. This can readily be understood from Fig. 1-4 in which the point A and its orthographic projection a on plane H are shown. On the projector from point A_1 perpendicular to plane H, any number of points A_2, A_3 and so on may be taken, and all of which will be projected onto the plane H as one and the same point. If the projection a is given on the plane H, it is impossible to determine from this projection the altitude of point A in space in relation to plane H.

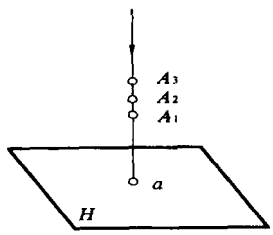


Fig. 1-4 One projection alone does not define the position of a point in space

The position of a point in space may be determined if, instead of a single projection, both projections of a point on two planes which intersect at right angle are constructed. Two such projection planes *H* (called horizontal plane) and *V* (called frontal plane) are shown in Fig. 1-5. The line of intersection of the horizontal plane *H* and the frontal plane *V*, i.e. *OX*, is called the projection axis or ground line. The projection axis *OX* divides each of the projection planes into two parts, or semi-planes. The horizontal plane *H* is divided into the front and rear parts and the frontal plane *V* into the top and bottom parts.

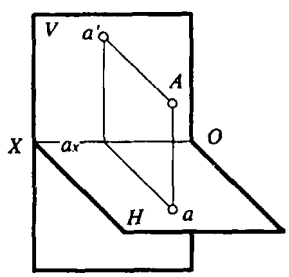


Fig. 1-5 Two projection planes intersect at right angle

The projection planes *H* and *V* divided space into four quarters or quadrants. The first quadrant is limited by the front part of projection plane *H* and the top part of projection plane *V*. See Fig. 1-5. The other three quadrants are not dealt with in this book.

In the pictorial drawing Fig. 1-5, point *A* in space (designated by a capital letter) is projected onto two projection planes. Where its projector intersects the frontal plane it is identified as a' (a lowercase letter with one prime), and where its projector intersects the horizontal plane it is identified as *a* (the same lowercase letter without prime). a' and *a* are referred to as the frontal and horizontal projections of point *A*, or simply *V*-, *H*-projections of point *A*.

In order to construct the projections of point *A* in the plane of paper, two projection planes

need to be opened. It is assumed that the *V*-plane is stationary and *H*-plane is hinged to it. Then revolve the *H*-plane downward until it is in the same plane as the *V*-plane. Thus a two-projection drawing results. See Fig. 1-6 (a). To simplify the drawing, the boundaries of two projection planes are usually not shown, Fig. 1-6 (b).

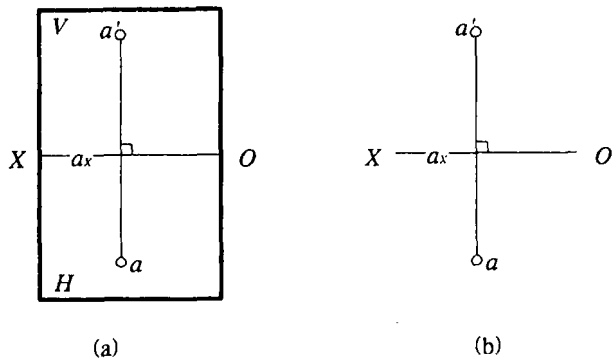


Fig. 1-6 A two-projection drawing of a point

2) The Rules of Projections of Points on Two Projection Planes

As shown in Fig. 1-5, the plane determined by the projectors *A a* and *A a'* is perpendicular both to *H*-plane and *V*-plane. Therefore it is also perpendicular to the axis *OX*, the intersection line of *H*- and *V*-plane. The intersection point of the plane with the axis *OX* is identified as a_x.

Thus, the general rules of projections of points can be stated as follows:

The line connecting projections *a* and *a'* is perpendicular to axis *OX* , i.e., *a a'* $\perp OX$. The line is called projection line.

The distance from *a'* to the axis *OX* is equal to the distance from space point *A* to the horizontal plane *H*, and the distance from *a* to the axis *OX* is equal to the distance from space point *A* to the frontal plane *V*. See Fig. 1-5 and Fig. 1-6.

1.2.2 The Projections of a Point on Three Projection Planes

1) The Formation of Three Projection Planes

The position of a point in space can be defined with two projection planes. However, if an object in space needs to be represented clearly, three projection planes have to be used.

On the basis of two projection planes *H* and *V*, the third projection plane *W* is introduced. The *W*-plane, called the profile projection plane, is perpendicular to and intersects with both *H*-plane and *V*-plane. The intersections of three projection planes form the projection axes *OX*, *OY*, *OZ* with the origin at *O*. See Fig. 1-7.

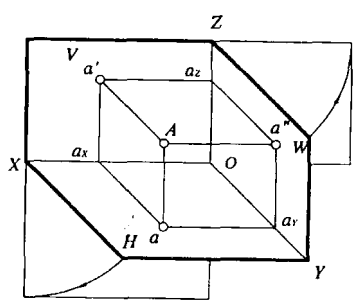


Fig. 1-7 A point in three-projection planes

The *H*-, *V*-, *W*-planes divided space into eight parts called octants. Only the first octant as shown in Fig. 1-7 is used in this book.

In the pictorial drawing Fig. 1-7, point *A* in space (designated by a capital letter) is projected onto three projection planes. Where, as you know, its frontal projection is identified as a' and horizontal projection is identified as *a*, and where its projector intersects the profile plane it is identified as a'' (a lowercase letter with double primes). a'' is referred to as the profile projection of point *A*, or simply *W*-projection of point *A*.

Following the opening of two projection planes, the *W*-plane is revolved to the right until it becomes in the same plane as the *V*-plane. Thus, a three-projection drawing forms, Fig. 1-8 (a). To simplify the drawing, the boundaries of the three projection planes are usually not shown, Fig. 1-8 (b).

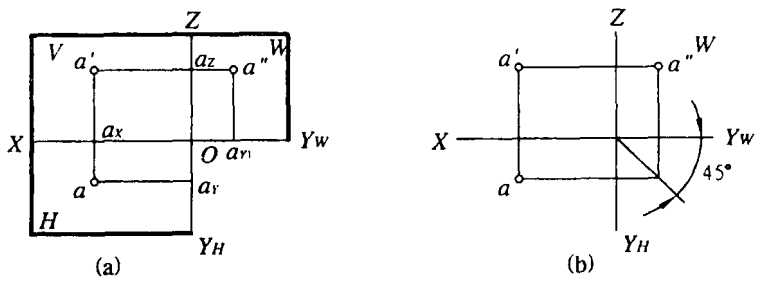


Fig. 1-8 A three-projection drawing of a point

2) The Rules of Projections of Points on Three Projection Planes

Based on the general rules of projections of points on two projection planes, the rules of projections of points on three projection planes can be stated as follows:

The line connecting projections *a* and a' is perpendicular to axis *OX*, i.e., $a\,a' \perp OX$.

The line connecting projections *a* and a'' is perpendicular to axis *OZ*, i.e., $a\,a'' \perp OZ$.

The distance from *a* to the axis *OX* is equal to the distance from a'' to axis *OZ*, and equal to the distance from space point *A* to the frontal plane *V*. See Fig. 1-7 and Fig. 1-8.

【Example 1-1】In Fig. 1-9, the projection a' on *V*-plane and projection *a* on *H*-plane of point *A* are given. Construct the projection a'' on *W*-plane.

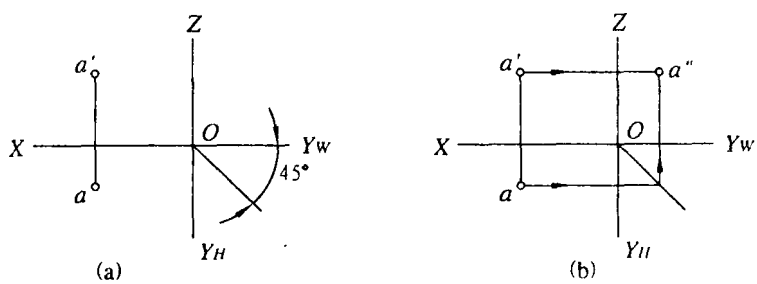


Fig. 1-9 Construct the third projection based on two given projections

Analysis:

According to the rules of projections of points on three projection planes, a 45° miter line can be used to construct the profile projection or horizontal projection when the other two projections are given. In this case, the projection lines used to connect horizontal projection and profile projection intersect at a point lying on the miter line.

Construction:

(1) Draw a 45° miter line from origin O to bisect $\angle Y_H O Y_W$;

(2) Draw a projection line perpendicular to axis OY_H from projection a to intersect the miter line, and then draw a projection line perpendicular to axis OY_W from the intersection point;

(3) From projection a' draw a projection line perpendicular to axis OZ to intersect projection line which is perpendicular to axis OY_W at a''. The profile projection a'' is constructed, Fig. 1-9.

1.2.3 The Relation Between Three Projection Planes and the System of Three Coordinate Planes

It is often convenient to establish the position of points by giving their coordinates relative to the system of three coordinate lanes. If the point A is assigned by rectangular coordinates, three projection planes serve as the planes of the system of coordinates. The point O of intersection of axes X, Y, and Z is then the origin of coordinate. The coordinates of point A, denoted by x_A, y_A, and z_A, are respectively equal to the distances from point A to W-, V-, and H-planes, shown in Fig. 1- 10.

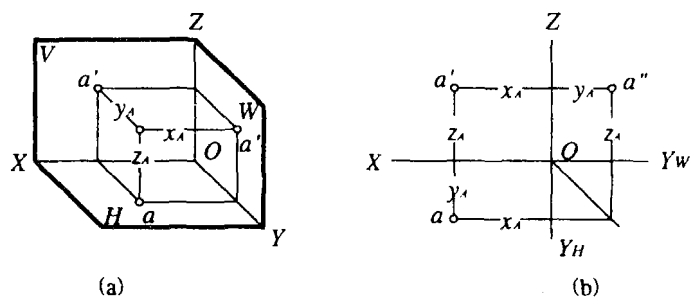


Fig. 1- 10 Coordinates of a point

Knowing the coordinates of a point it is possible to construct the projections of point and, conversely, by means of three-projection drawing the coordinates of point may also be determined.

Note that the coordinates may be given in specific units of measurements.

【Example 1-2】 In Fig. 1-11, the coordinates of point A are (20, 10, 15). Construct three projections of the point.

Construction:

(1) From origin O lay off the coordinate $x_A = Oa_x = 20$ on the axis X;

(2) Through point a_x draw a projection line parallel to axes OY_H and OZ, and then lay off $y_A = a_x a = 10$, $z_A = a_x a' = 15$. The projections a and a' are constructed;

(3) Construct projection a'' by means of projections a and a', as shown in Fig. 1-11.

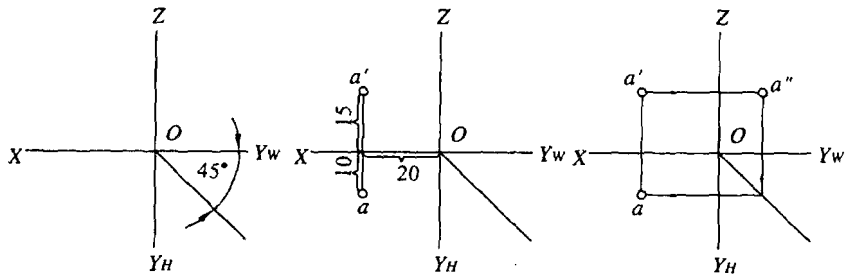


Fig. 1-11 Construct the projections of point by means of coordinates

1.2.4 The Relative Position of Two Points

The relative position of two points is determined by coordinate differences of two points. If $x_A - x_B > 0$, it means that point A lies to the left of point B. Conversely, point A lies to the right of point B. If $y_A - y_B > 0$, it means that point A lies in front of point B. Conversely, point A lies at the back of point B. If $z_A - z_B > 0$, it means that point A lies above point B. Conversely, point A lies below point B.

Fig. 1-12 shows the relative position of point A and B. Point A lies to the left of, in front of and below of point B.

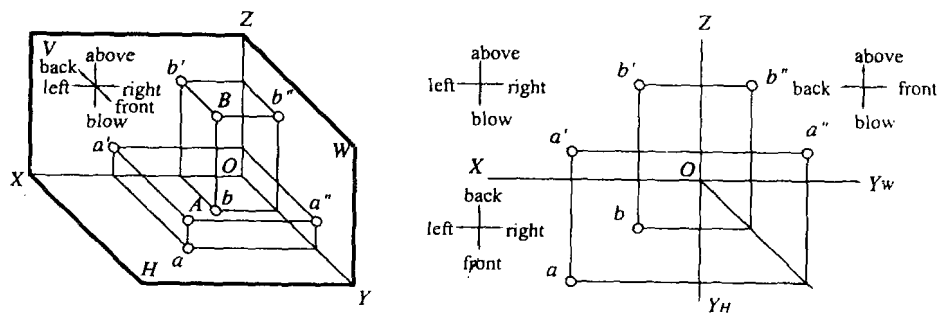


Fig. 1-12 The relative position of two points

1.2.5 The Coincidence of Points

When two points lie on a projector, their projections certainly coincide at one projection on the projection plane to which the projector is perpendicular, and these two points are called the coincidence of points to the projection plane.

The projection of coincidence of points is of coincidence projections, so it needs to distinguish the visibility of the projection.

The method of distinguishing the visibility is to compare the coordinate values of two points, and the larger one is visible. As shown in Fig. 1-13, for the point A and B, $z_A > z_B$, horizontal projection of point *A* is visible and *B* is invisible, and for points C and D, $y_C > y_D$, frontal projection of point *C* is visible and *D* is invisible. For the invisible projection, the letter, which denotes the projection, needs to be bracketed.

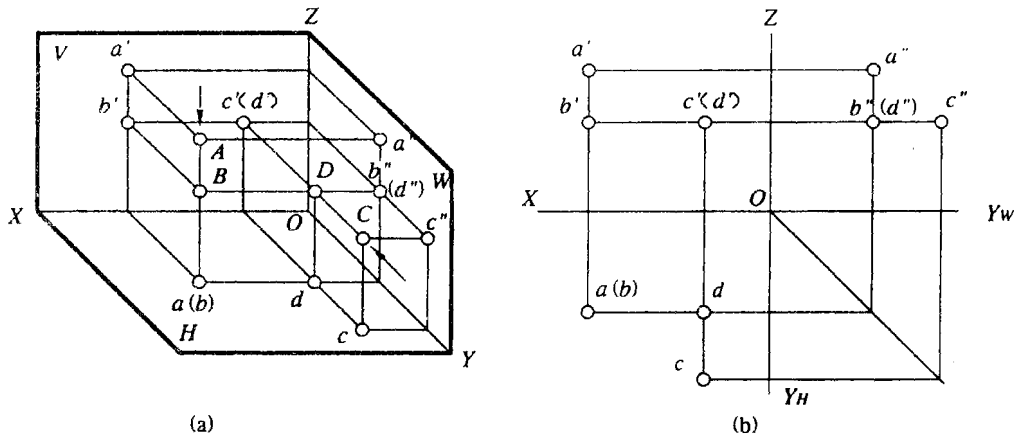


Fig. 1-13 The coincidence of points

1.3 The Projections of Straight Lines

The projection of a straight line on a projection plane is still a straight line except when this line is perpendicular to the projection plane. Because of two point define a straight line, the projections of straight line on three projection planes are indeed the projections of two points which are connected with straight lines.

1.3.1 The Projections and Positions of Straight Lines Relative to the Projection Planes

The positions of straight lines relative to the projection planes are classified in three types: a line parallel to one of three projection planes, a line perpendicular to one of three projection planes and a line inclined to all three projection planes.

The letters α , β and γ represent respectively the angles of a straight line with *H*-, *V*- and *W*-planes in space.

1) A Line Inclined to Three Projection Planes

A line inclined to all three projection planes is called an oblique line. In Fig. 1-14(a) a pictorial drawing shows an oblique line in space, and in Fig. 1-14(b) a three-projection drawing shows its projections.

In the three-projection drawing it is seen that all three projections of the oblique line are inclined to the axes *X*, *Y* and *Z*.

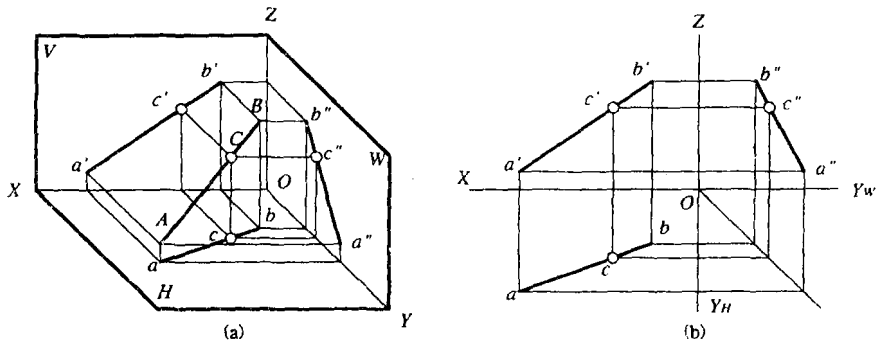


Fig. 1-14 An oblique line in space and its projections

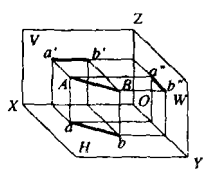
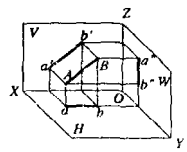
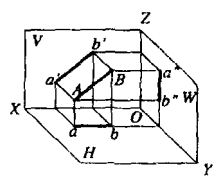
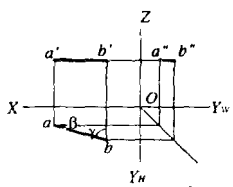
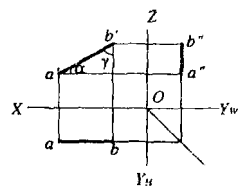
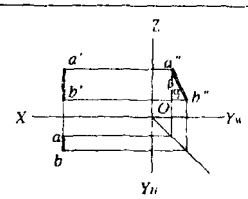
In Fig. 1-14 it is easy to understand that each of the projections *ab*, *a' b'* and *a" b"* of the oblique line *AB* on three projection planes is shorter than *AB* itself. The angles formed by the projections of *AB* with axes *X*, *Y* and *Z* are not equal to the angles of inclination of *AB* itself to the projection planes *H*, *V* and *W*.

2) A Line Parallel to One of Three Projection Planes

A straight line parallel to *H*-plane is called a horizontal line or simply a horizontal; one parallel to *V*-plane is called a frontal line or simply a frontal; and one parallel to *W*-plane is called a profile line.

The characteristics of lines parallel to the projection planes are shown in Tab. 1-1.

Tab. 1-1 The characteristics of lines parallel to the projection planes

Name	Horizontal Line	Frontal Line	Profile Line
Visual fig.			
Projection			
Characteristics	(1)*ab*=*AB* (2)Give the value of *β* and *γ* (3)*a' b'* //*OX* *a" b"* //OY_1	(1)*a' b'* =*AB* (2)Give the value of *α* and *γ* (3) *ab*//*OX*, *a" b"* //*OZ*	(1)*a" b"* =*AB* (2)Give the value of *α* and *β* (3) *a' b'* //*OZ*, *ab*//*OY*