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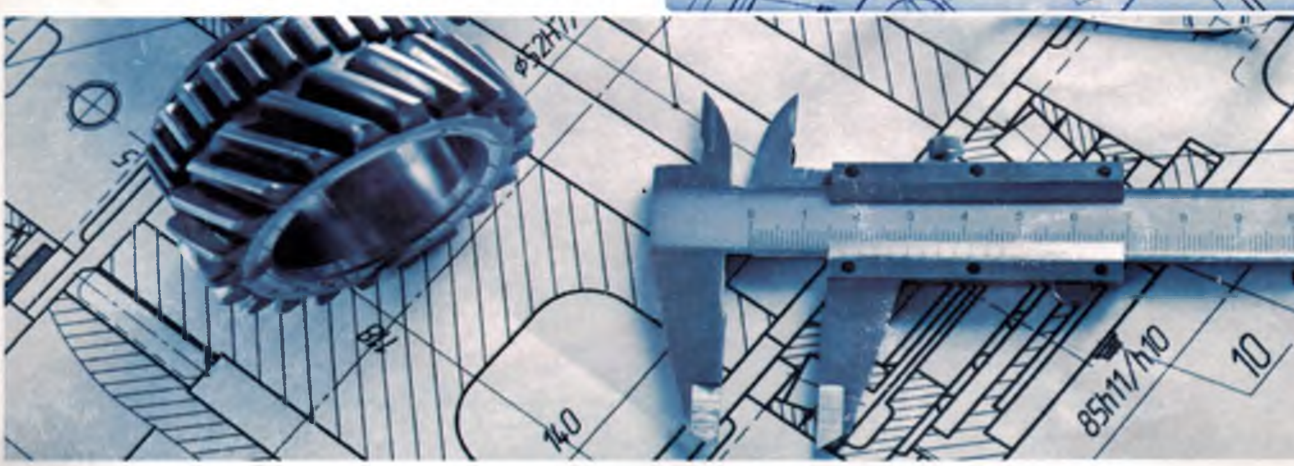
ENGINEERING DRAWING



Ministry of Education of the Azerbaijan Republic
Azerbaijan State Oil and Industry University

ENGINEERING DRAWING

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Engineering drawing is one of the main courses taught at the first-year level in all disciplines of engineering. This book is mainly designed for students of all the technical universities and other basic courses of professional technical institutions. As it is essentially intended to be a classroom textbook, it contains a large number of tasks covering every stage of subject in a simple and understandable form. The presentation of the subject matter and illustrations is simplified so as to enable the reader understand the basic concepts of the subject easily.

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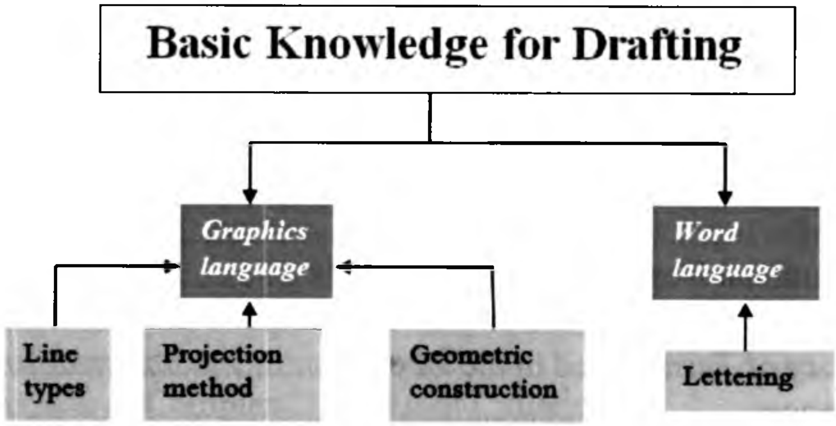
PREFACE

Dear Students!

"Engineering drawing" is a unique graphical language of human culture. Being one of the oldest languages in the world, it is remarkable for its brevity, precision and clarity. Alphabet of this language contains only two signs - a point and a line.



Any area of human activity is connected with transfer of graphical information, i.e. data on objects or the phenomena of the world surrounding us. The graphics was always the faithful assistant in people's life. Graphic literacy is necessary for everybody as well as speaking and writing abilities. Training in fundamental "Engineering drawing" science is one of the technical and educational components. The means of implementation, namely, manual, mechanized or automated drawing is the knowledge of engineering drawing based on engineering education, engineering creativity and system of technical documentation foundation. Now in higher educational institutions of Azerbaijan where engineering majors are studied, one of the main technical courses is "Engineering drawing". It is presented in the form of synthesis of three independent subjects: Descriptive Geometry, Drawing and Computer Graphics.

You will find all necessary knowledge of these subjects in this book. We wish you success in it.

Authors of the book

INTRODUCTION

Our world has become the one where computers are used to solve many problems quickly and accurately. We use calculators to solve arithmetical problems, word processors to check spelling and grammar in texts and computer-aided design (C.A.D.) programs to do much of our drawing for us. However, in the same way that we need to know what [+, - , * and ÷] mean when we press that symbol on a calculator, and we need to be able to write a text before we can ask a word processor to check it, in the same way we need knowledge and understanding of geometric and engineering drawing before we can use computers to help us with design. These understandings can come through studying and using this book.

This book deals with the material which is covered in two semester courses at Azerbaijan State Oil and Industry University.

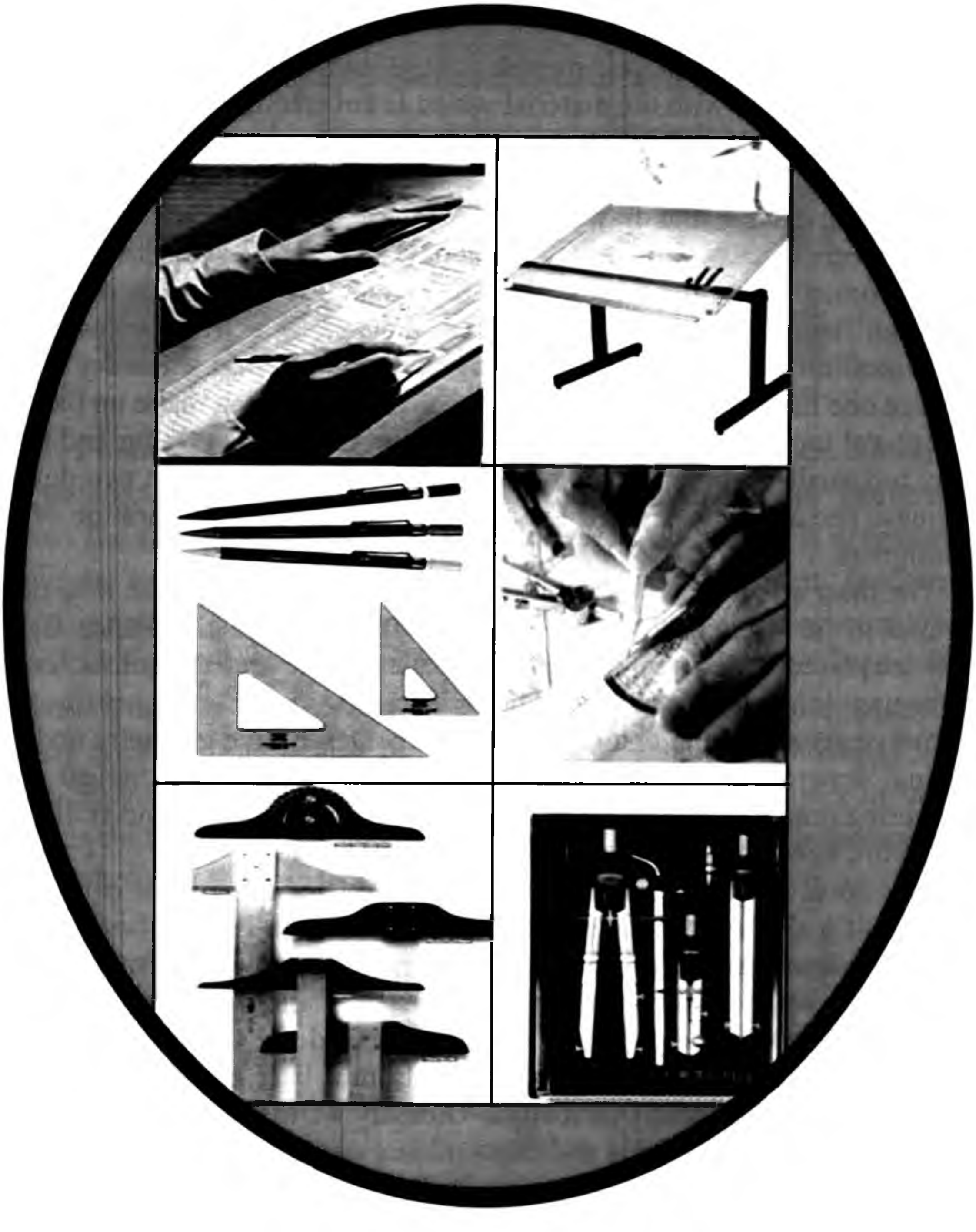
The purpose of this book is to give students a good basis for understanding and mastering engineering drawing.

Engineering drawing is purely a practical subject, the subject which has to be known thoroughly by all engineers and technicians. Engineers express their ideas in design using engineering drawing language which provides means of communication no matter where an engineer comes from. In order to use this language one has to know principles and conventions which make up the grammar of graphical language. But there is even one more important thing and that is the ability to visualize a complicated object in three dimensions from two dimensional drawings. The ability to visualize is important for accurate preparation of drawing by designers.

The most effective way of improving your ability to visualize is to do graded exercises in the visualization of the space in which points, lines, planes, figures and solids are placed in different relation to one another. A whole set of such exercises, introducing you step by step to proficiency in visualization, is provided by descriptive geometry and engineering drawing. Descriptive geometry and machine building drawing are therefore something more than a theoretical basis for engineering drawing. It is a key for making your mind flexible and skillful in your future work as creative designers.

This book covers a range of topics directly related to the most commonly used branches of a shortened course of engineering drawing. It includes the following parts: the rules of making drawings, descriptive geometry and machine-biulding drawing. The book consists of ten chapters. Each chapter has several questions and assignments at the end of it. They are arranged so that they might require knowledge from an earlier chapter but not from a later one. In Appendix **1** it is given the English-Russian-Azerbaijani Glossary of the terms used in the book. Appendix **2** contains symbols and conventional designations of the basic concepts in engineering drawing.

PART I
THE RULES OF MAKING DRAWINGS



CHAPTER I

PREPARATION OF DRAWINGS

1.1. Lettering

Most notes on drawings are done in capital letters although this is not always so. Two identical alphabets and numbers printed differently are shown below. Most draftspersons develop great skills in printing by hand. If you need to print, try both standard and italic, and develop a style that suits you.

Standard lettering:

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0

Italic lettering:

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0

1.2. Drawing Sheet

Sizes of drawings typically comply with either of two different standards, ISO (World Standard) or ANSY/ASME14 (American), according to the following table:

Table 1.1

ISO a drawing size(mm)		ANSY/ASME14(American)	
A4	210x297	A	8.5"x11"
A3	297x420	B	11"x17"
A2	420x594	C	17"x22"
A1	594x841	D	22"x34"
A0	841x1189	E	34"x44"

The metric drawing sizes correspond to the international paper sizes. A full set of pencils would have the following nib sizes: 0.13, 0.18, 0.25, 0.35, 0.5, 0.7, 1.0, 1.5, and 2.0 mm. However, the International Standardization Organization (ISO) calls for four pencil widths and sets a color code for each: 0.25 (white), 0.35

(yellow), 0.5 (brown), 0.7 (blue); these nibs produce lines related to various text character heights and the ISO paper sizes.

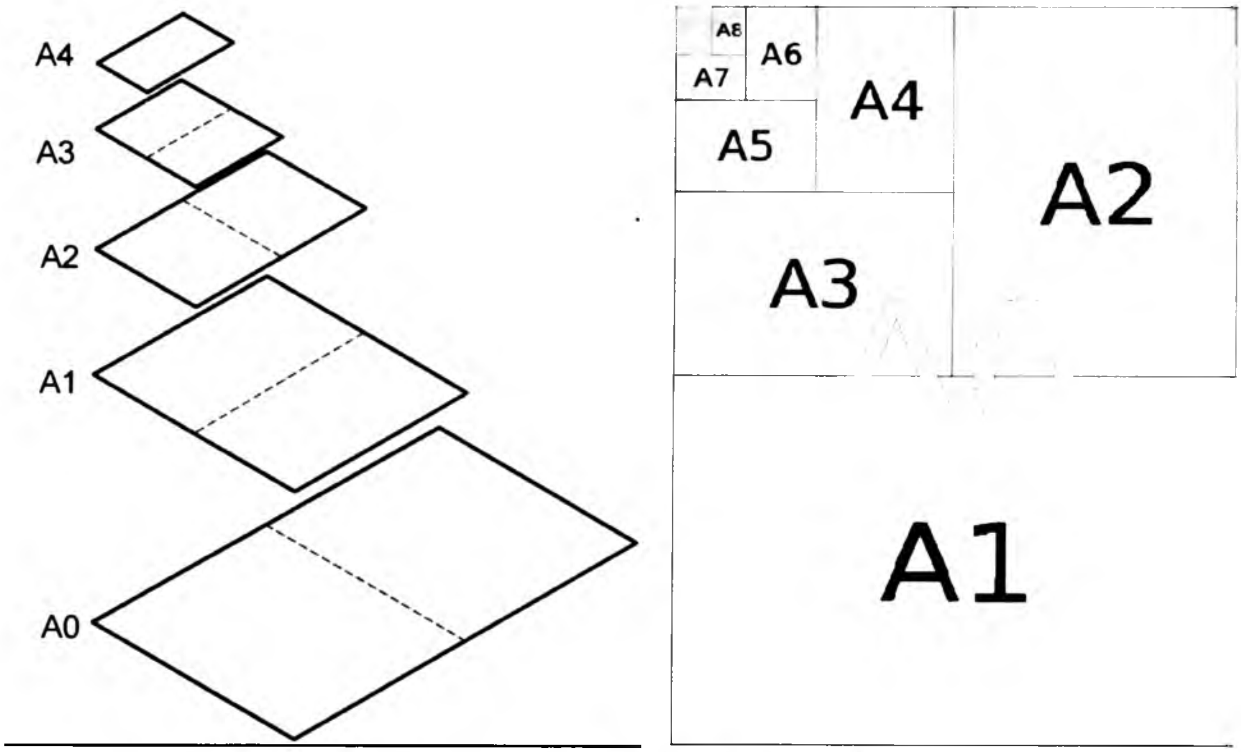


Fig. 1.1

Most paper comes in standard sizes. The largest sheet you are likely to use is A0 and the smallest A4. If your drawing paper has no frame, then draw one. A minimum of 20 mm from the left side and 5 mm from the other sides are used on A0 and A1 from the edge of the paper to the frame line. A minimum of 10 mm from the left side and 3 mm from the other sides are used on A2, A3 and A4.

All ISO paper sizes have the same ratio aspect; one to the square root of 2, meaning that a document designed for any given size can be enlarged or reduced to any other. Given this ease of changing sizes, it is common to copy or print a given document on different paper sizes, especially within a series, e.g. a drawing on A3 may be enlarged to A2 or reduced to A4.

The U.S. customary "A-size" corresponds to "letter" size, and "B-size" corresponds to "ledger" or "tabloid" size. There were also once British paper sizes, which went by names rather than alphanumeric designations.

American Society of Mechanical Engineers (ASME) Y14.2, Y14.3, and Y14.5 are commonly referenced standards in the U.S.

1.3. Scales

The objects we encounter in our day-to-day life are usually either too large or too small to be drawn to their true size. For instance, a car or a building can be drawn to its true size if, and only if, we use a piece of paper that is large enough to accommodate the true dimensions of that car or building. But as we have noted above, the largest size of paper (under ISO standard) is A0 (841-mm X 1189-mm), which is much smaller than these objects. The discrepancy between the actual sizes of objects and the size of the papers we use for drawing necessitates us to prepare drawings that are either smaller or bigger in size than the actual objects. This is only possible through the use of scales.

Scale is the ratio of the linear dimension of an object shown in the drawing to the real linear dimension of the same element of the object (Fig. 1.2).

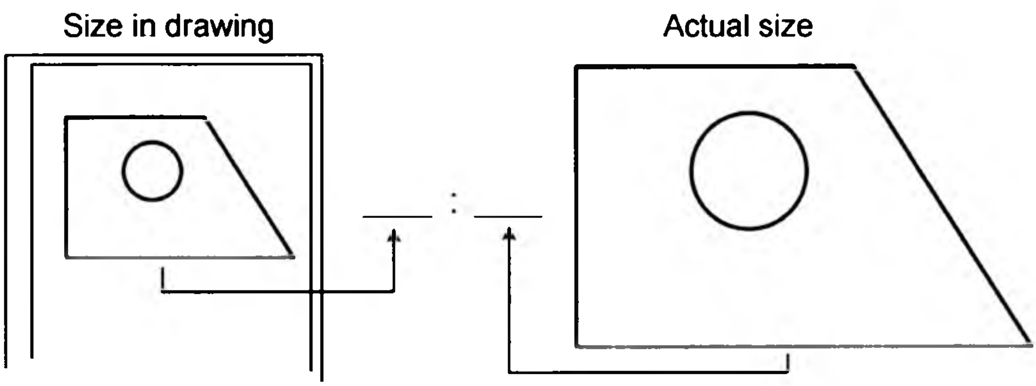


Fig. 1.2

The scale must depend on the size of the object; a miniature electronic component may be drawn 100 times larger than it really is, whilst some maps have natural dimensions divided by millions.

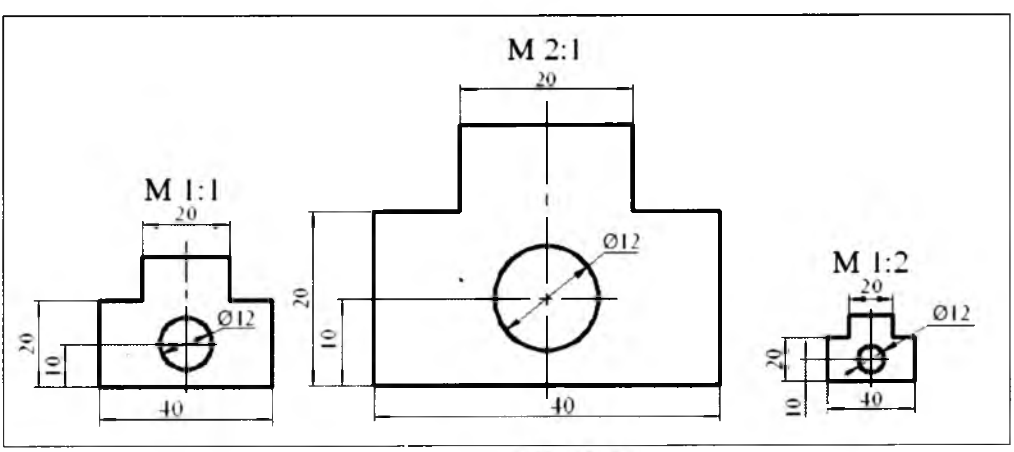


Fig.1.3

The scale of 1:1 (read as one-to-one) implies that the object has been drawn to its true size (Fig. 1.3).

A scale of 2:1 (read as two-to-one) implies that the object has been enlarged twice of its true size. A scale of 1:2 (read as one-to-two) implies that the object has been reduced to its half size, etc.

The recommended scales in Engineering Drawing are:

True size scale	1:1		
Reduction scales	1:2 1:20 1:200	1:5 1:50 1:500	1:10 1:100 1:1000
Magnification (enlargement) scales	2:1 20:1 200:1	5:1 50:1 500:1	10:1 100:1 1000:1

As compared with the actual sizes, the views are reduced or magnified to definite number of times. This number is called the numerical scale.

The State Standard establishes the following scales:

a) reduction scales

1:2- drawings made to one half of the actual size;
1:2,5- drawings made to one to two and a half of the actual size;
1:4- drawings made to one fourth of the actual size;
1:5; 1:10; 1:15; 1:20; 1:40; 1:50; 1:75; 1:100; 1:200; 1:400; 1:500 ; 1:800; 1:1000.

b) Magnification (enlargement) scales.

2:1- drawings made to twice of the actual size;
2,5:1- drawings made to two and a half of the actual size;
4:1- drawings made to four times of the actual size;
5:1 ; 10:1 ; 20:1 ; 40:1 ; 50:1 ; 100:.

It must be remembered that whatever the drawing scale (reduction or magnification scales) are used, we should always indicate the actual dimensions of the object on the drawing, regardless of their reduced or magnified dimensions.

1.4. Framing and Title Block (Main Inscription) on Drawing

Working drawings of machine details show not only the shape of these parts and all the dimensions, but also contain definite technical instructions. You may well have to add information to your finished drawing and this should be shown in blocks. This information could include:

a) Title;
b) Your name;
c) Your location (college or company);
d) The scale of the drawing;
e) The system of projection used

f) Date;

g) Instructions regarding the finish of the surface of the detail;

h) The name of the material the given detail is made of;

i) The designation (number) of the detail, its name and other information.

This information is given in a special box in the lower right corner of the drawing, called the ***main inscription or title block*** (Fig. 1.4).

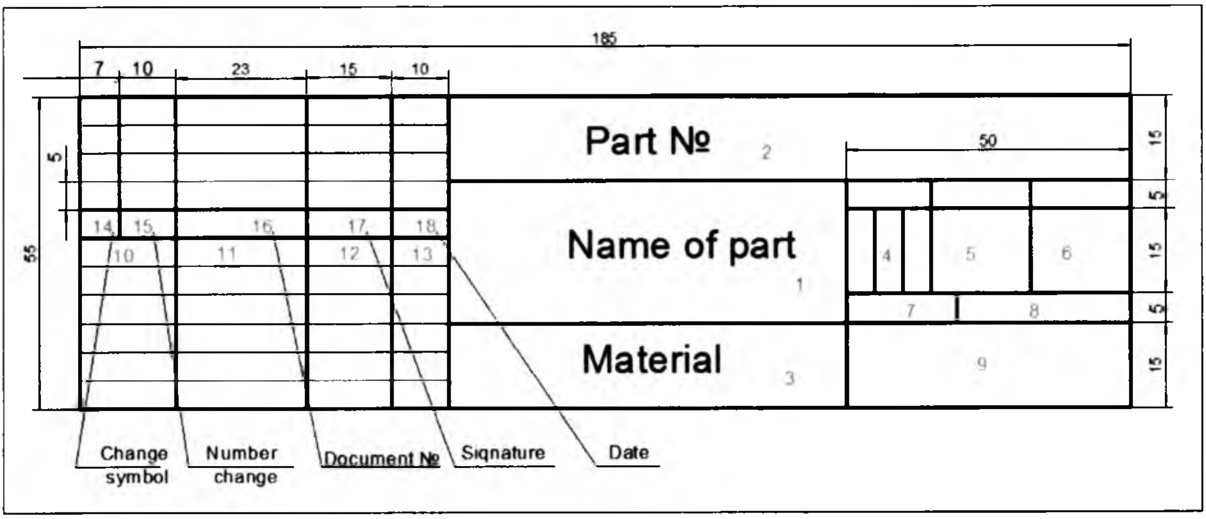


Fig.1.4

From the first position **(1)** of the main inception we learn the name of the part represented in drawings.

The drawing symbol is indicated in the second position **(2)**.

The name and grade of the material from which the detail is made, as well as the standard number for this material, are indicated in the third position **(3)**.

The drawing symbol, which indicates the category of the drawing, is written in the fourth position **(4)**. Drawings designed for trial series are marked with letter A, written in the first square. Mass production drawings are marked by letter B, written in the second square.

In the fifth position **(5)** we write the net weight of the detail in kilograms.

The scale of the drawing is indicated in the sixth position **(6)**, the number of the sheet in the seventh position **(7)**, and the total number of sheets we write in the eighth position **(8)**.

The name of the factory and department is given in the ninth position **(9)**.

Their posts are written in the tenth position **(10)**, and their full names in the eleventh position **(11)**.

The twelfth position **(12)** is reserved for their signatures, and the date, on which the drawing is signed, is written in the thirteenth position **(13)**.

Perfectly rectangular working space is determined by drawing the ***border lines***. They may be drawn at equal distances of about 20 mm from the left-side hand edges of the paper, 5 mms from the other sides (right-hand edges, top and bottom). More space on the left-hand side is provided to facilitate binding of the drawing sheets in a book form, if it is desired (Fig. 1.5).

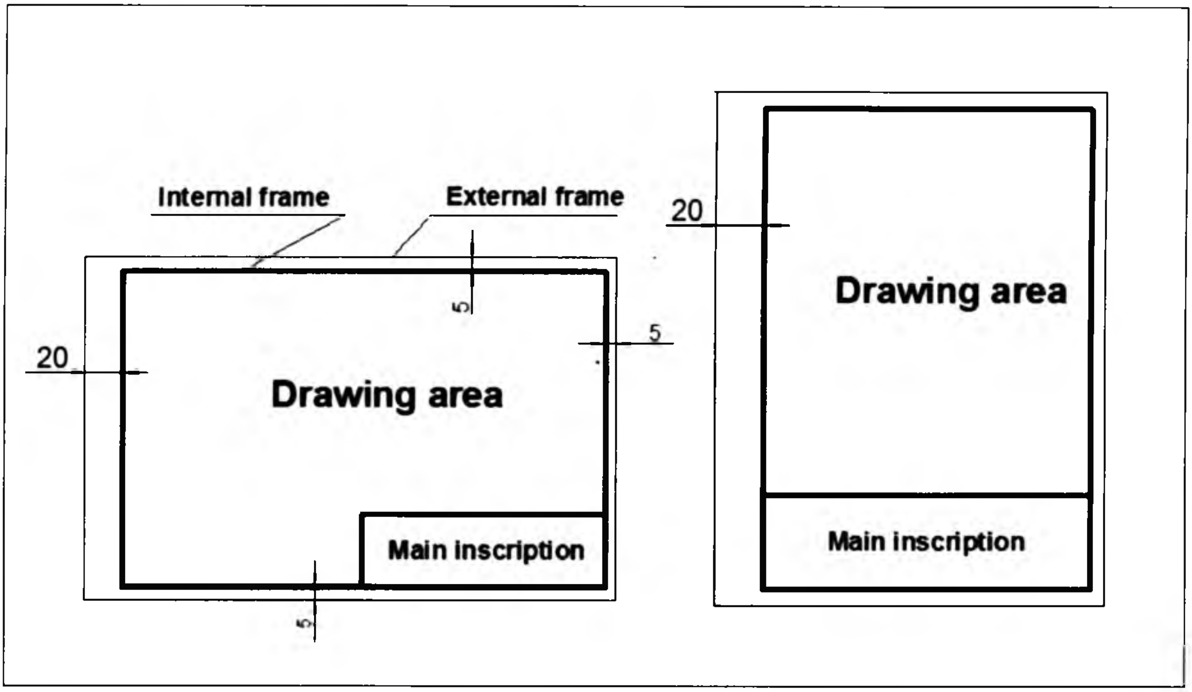


Fig. 1.5

To draw the borderlines we have to mark points along the left-hand edge of the paper at the required distance from the top and bottom edges and through them. Then we should draw horizontal lines with the T-square. Along the upper horizontal line, mark two points at required distance from the left-hand and right-hand edges, and draw vertical lines through them with the aid of T-square and a set-square. Erase the extra lengths of lines beyond the points of intersection.

1.5. Line Styles

Technical drawing lines are used for different purposes to provide specific information for designers, manufacturers and others. Looking at the drawings the person who will read drawings has to learn what they mean. Line types are also a means of communication between draftspersons.

Continuous thick line is used to depict visible outlines of object.

Continuous thin line is used to depict dimension lines, backside section lines, implied axis lines and to state the code of the planes, at diagonal lines which are used to show plane surface, intersection, leader, hatching.

Dashed thin lines is used do depict invisible/hidden lines representing invisible edges on the objects.

Dashed thick line with dots is used to state the special places/surfaces which will be processed additionally similar to coat, to harden etc.

Dashed thin lines with dots is used to depict axis lines of symmetrical drawings, in front of section planes.

Chain thin line with thick ends is used to depict cutting plane and to draw the trace at section planes.

Continuous thin zigzag line is used when free hand lines are drawn by tools.

Free hand line is used to depict limits of partial and interrupted views and sections.

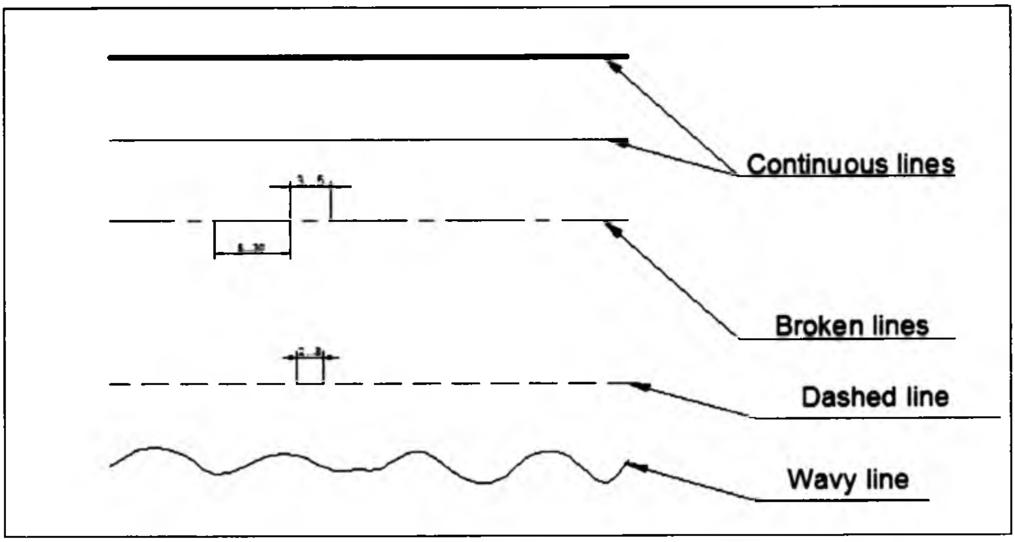


Fig. 1.6

The lines used for drawings are classified into several groups depending on their designation. The most common types of lines are the following:

a) Visible outlines;
b) Hidden outlines;
c) Center lines;
d) Dimension and extension lines.

The lines showing the visible outline of the objects and their components are the heaviest ones (Fig.1.7), their thickness varies from 0.6 to 1.5 mm. The greater thickness of these lines as compared to other lines makes the drawing of the object more legible.

To distinguish the visible outlines from the hidden ones, the latter is drawn in broken lines.

In the top and left- hand views (Fig.1.7) broken lines indicate the cylindrical bore in the front and rear walls of the detail. In the main view, the same type of lines indicates the thickness of the right-hand wall and base.

Broken lines are drawn according to the following rules:

a) Dashes must be one half or one.
b) Each dash must not be longer than 2…8 mm.
c) All dashes must be of equal length.
d) The space between the dashes must be about a fourth of their length.

Any object, which can be divided into two equal and absolutely identically shaped sections, is said to be symmetrical in shape. The line, dividing the drawing of a symmetrically shaped object into two identical halves, is called the **axis of symmetry.**

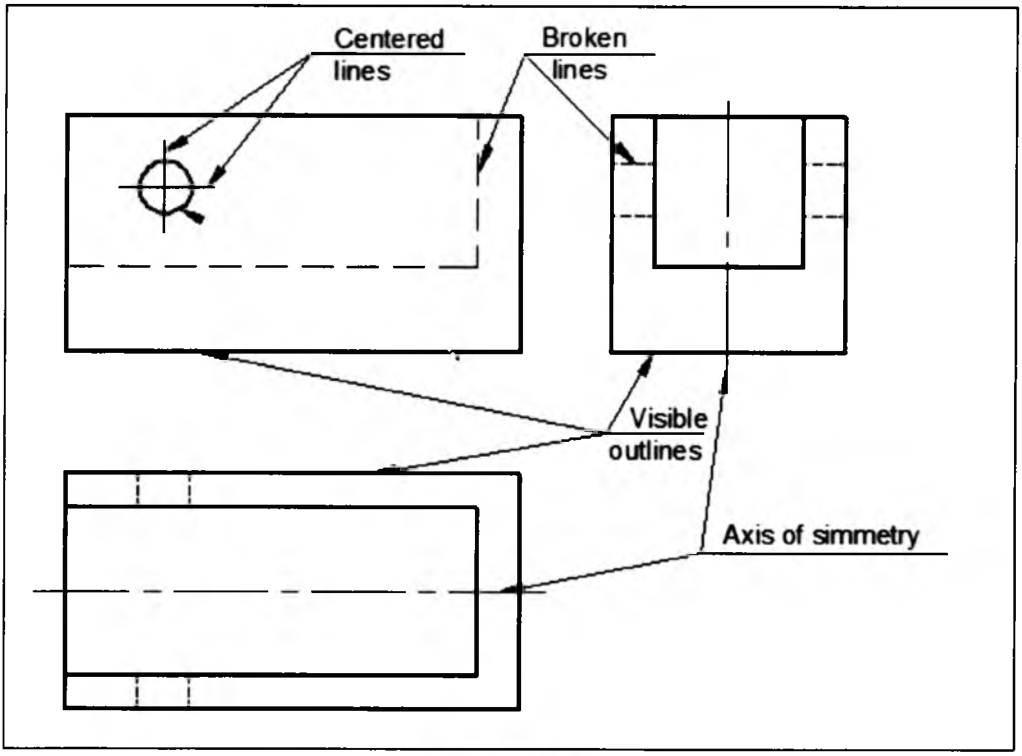


Fig 1.7

In Figure 1.6, we can see two symmetrical representations of a detail-its left-hand view and its top view. The first view is symmetrical about its vertical axis, while the second view is symmetrical about horizontal axis.

In the drawing of a detail, if it is a circle, we usually draw two axes of symmetry intersecting each other at the right angles through its center. The axis of symmetry drawn in circles is called **center line.** Center and axial lines are drawn in dots and dashes according to the following rules:

a) The thickness of dot and dash lines must be one half or one third that of the visible outline in the given drawing.

b) Each dash must be approximately 5...30 mm long.

c) There must be equal (approximately 3...5) spaces between each dash with a dot in the center of each space.

Center lines should intersect each other in the center of their dashes, the point of intersection indicating the position of the circle center.

Dimension lines indicate the detail of the object to which the dimension figures refer (Fig. 1.8). They must be drawn in parallel to the section, dimensions of which they indicate. They may also be drawn within the outline of the drawing of the detail (dimensions 18 and 40), but it is preferable for them to be outside the outline (dimensions 8, 18, 36, 54 and 80 in the same figure).

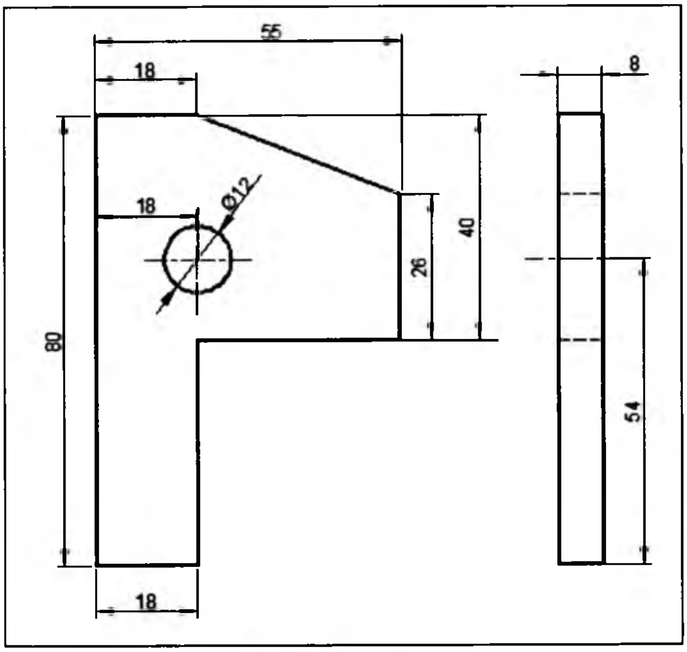


Fig.1.8

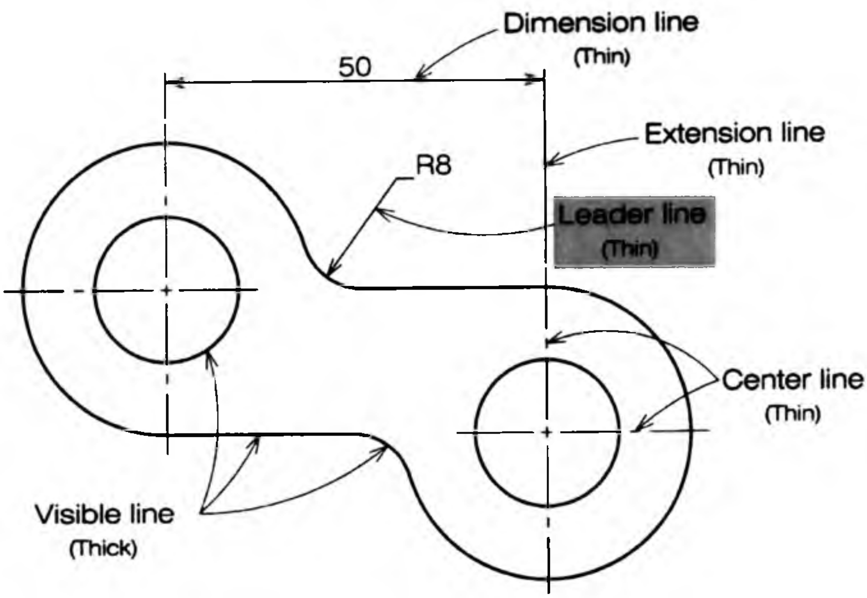


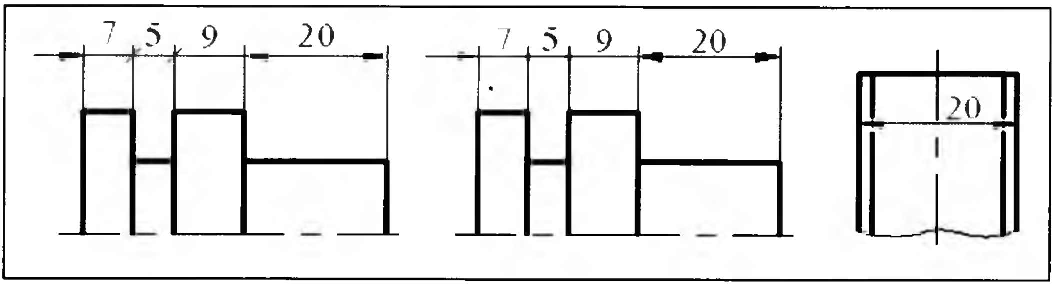
Fig. 1.9

Figure 1.9 shows the other example of line conventions in engineering drawing.

1.6. Dimensioning

When an engineering drawing is made, dimensioning is of vital importance. All the dimensions, necessary to make the articles drawn must be on the drawing and they must be presented so that they can be easily read, easily found and not open to misinterpretation. A neat drawing can be spoilt by bad dimensioning.

If the dimensions between adjacent elements are assigned by a chain and distance between these elements, arrows are not required, then in this case, it is allowed to replace arrows with the notches, drawn on at an angle of 45^0 to dimensional lines(Fig. 1.10, c).



a) b) c)

Fig. 1.10

Dimension figure, indicating diameter lengths, is always preceded by the standard symbol Ø (Fig. 1.11). This symbol allows us to reduce the number of views in the drawings of "arcular" parts : cylinders, cones and so on.

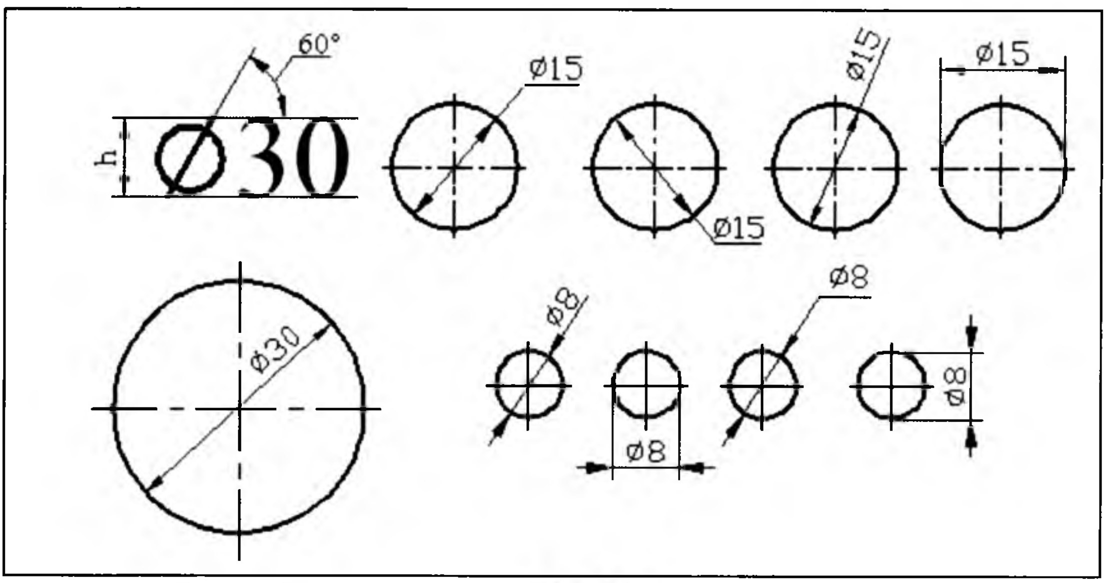


Fig. 1.11

As shown in Figure 1.12 the letter **R**, is a conventional symbol used for the word "radius", must always precede the figures indicating the length of the radius.

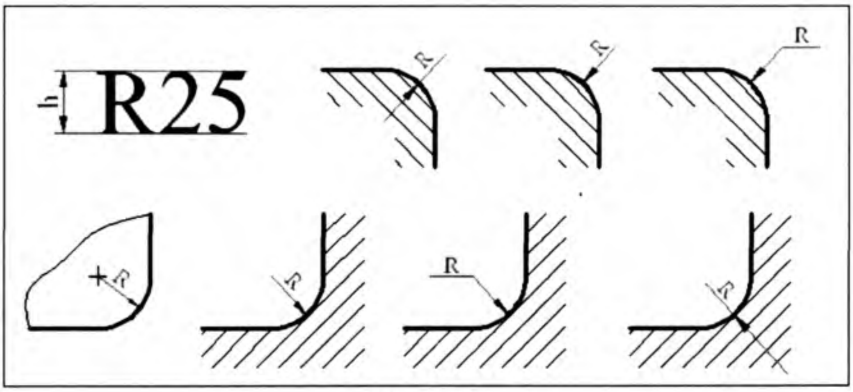


Fig.1.12

One end of the radius dimension line always terminates in an arrowhead, touching the line of the arc of the circle; the other end indicates the center of the arc. Located on a center or axial line it should be marked with a dash.

Many parts of machines have several conical surfaces called **tapered chamfers or bevels.** They are often made at an angle of 45° ; in such cases the dimensions consist of inceptions, the first figure of which indicates the height of the truncated cone and the second one indicates the magnitude of the angle. For example 1,5x45^0 (Fig. 1.13).

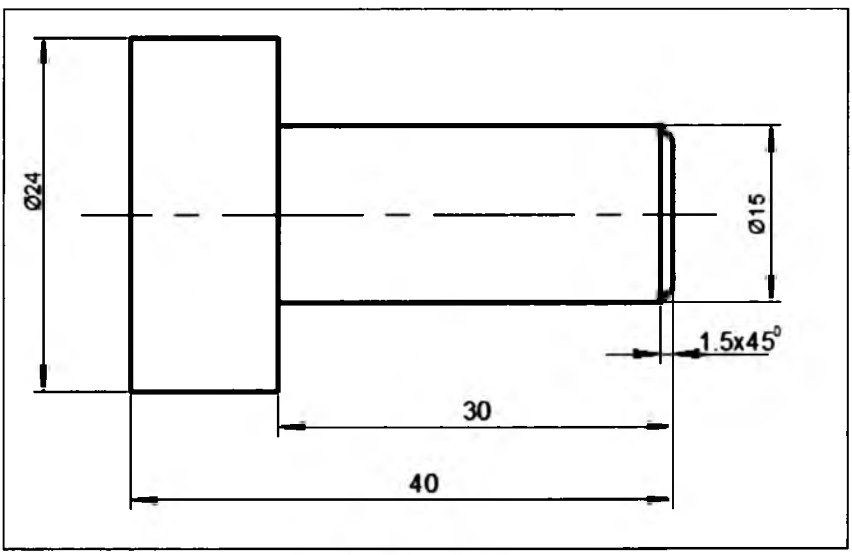


Fig. 1.13

In current productions, the accuracy of the dimensions of details may vary, i.e., it may deviate from the **nominal** specified size.

Engineering drawings are usually dimensioned in millimeters. There are many rules about how to dimension a drawing properly, but it is unlikely, that two people will dimension the same drawing in exactly the same way. However, take into account, that when dimensioning you must be particularly neat and concise, thorough and consistent. The following rules must be adhered to when dimensioning:

1. Projection lines should be thin ones and should extend about 1 mm from the outline to 3 -6 mm past the dimension line (Fig. 1.14).

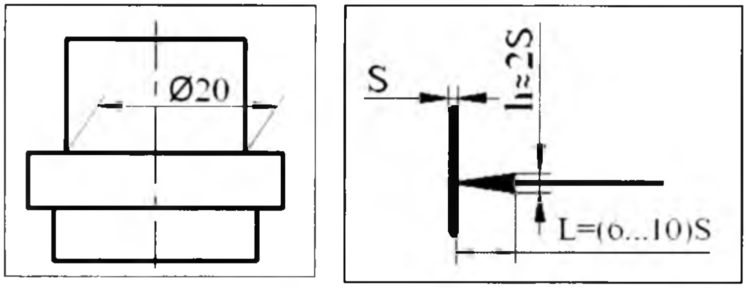


Fig.1.14

2. The dimension line should be a thin line that terminates with arrowheads at least 3 mm long and these arrowheads must touch the projection lines.

3. The dimension may be inserted within a break in the dimension line or be placed on top of the dimension line (Fig.1.10, c).

4. The dimensions should be placed so that they are read from the bottom of the paper or from the right-hand side of the paper.

5. Dimension lines should be drawn ***outside*** the outline, whenever possible, and should be kept well clear of the outline.

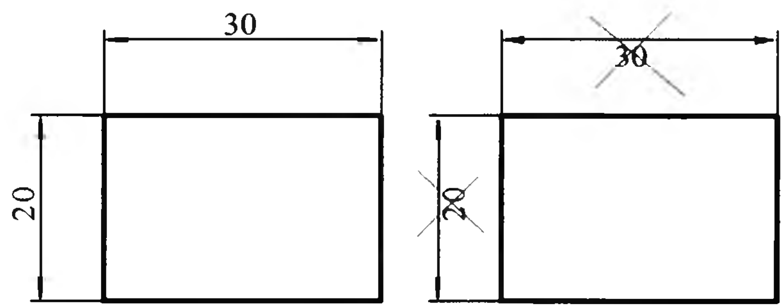


Fig.1.15

6. Overall dimensions should be placed outside the intermediate dimensions.

7. Center lines must *never* be used as dimension lines. They may be used as projection lines.

8. Diameters may be dimensioned in one of two ways. Either dimension directly across the circle (*not* on a center line), or project the diameter to outside the outline. "Diameter" is denoted by the symbol φ placed in front of the dimension (Fig.1.11).

9. When dimensioning a radius, you must, if possible, show the center of the radius. The actual dimension for the radius may be shown on either side of the outline but should, of course, be kept outside if possible. The word radius must be abbreviated to *R* and placed in front of the dimension (Fig.1.12).

10. When a diameter or a radius is too small to be dimensioned by any of the above methods, a leader line may be used. The leader line should be a thin line and should terminate on the detail that it is pointing to with an arrowhead or, within an outline, with a dot. Long leader lines should be avoided even if it means inserting another dimension. The leader line should always meet another line at an acute angle.

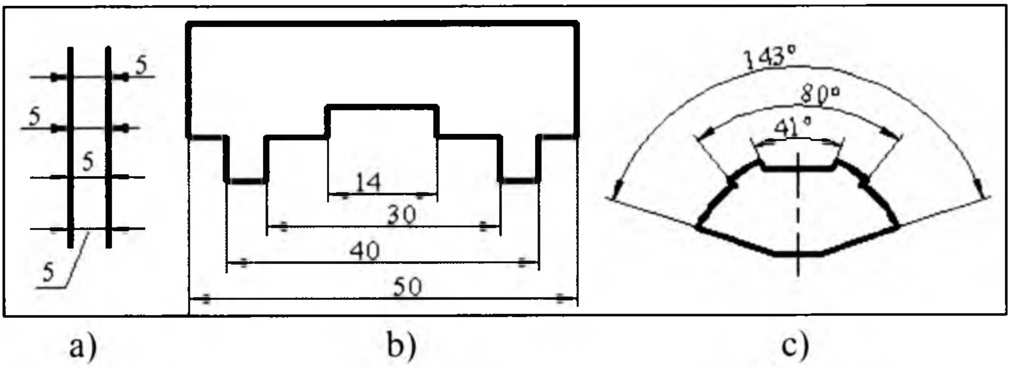


Fig. 1.16

11. Dimensions should *not* be repeated on a drawing. It is necessary to put on a dimension only once, however many views are drawn. There is one exception to this rule. If, by inserting one dimension, it saves adding up lots of small dimensions then this is allowed. These types of dimensions are called "auxiliary dimensions" and are shown to be so either by underlining the dimensions or putting them in brackets.

12. Unless unavoidable, do *not* dimension hidden detail. It is usually possible to dimension the same detail on another view.

13. When dimensioning angles, draw the dimension lines with a compass; the point of the compass should be on the point of the angle (Fig.1.16, c). The arrowheads may be drawn on either side of the dimension lines, and the dimension may be inserted between the dimension lines or outside them. Whatever the angle is, the dimension must be placed so that it can be read either from the bottom of the paper or from the right-hand side (Fig.1.17).

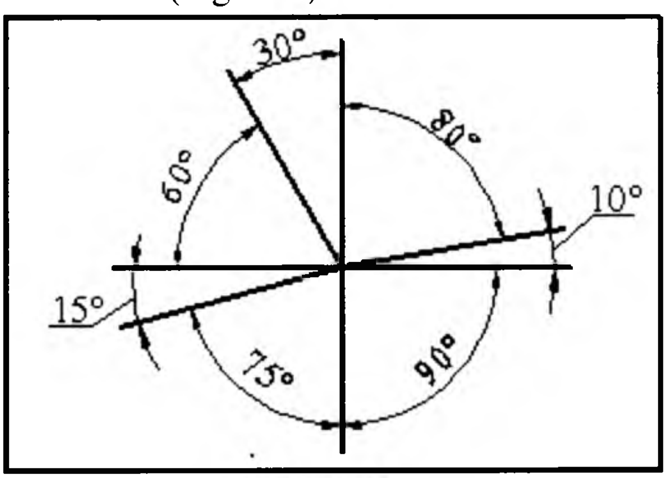


Fig.1.17

14. If a lot of parallel dimensions are given, it avoids confusion as the dimensions are arranged so that they are all easier to read (Fig.1.20).

15. If a lot of dimensions are to be shown from one projection line (often referred to as a *datum line*), either of the methods shown in Figures 1. 16,a and b may be used. Note that in both methods, the actual dimension is close to the arrowhead and is not in the center of the dimension line.

16. If the majority of dimensions on a drawing are in one unit, it is not necessary to put on the abbreviation for the units used, i.e. cm or mm. In this case, the following note must be printed on your drawing.

Unless otherwise stated, dimensions are in millimeters!

17. If a very large radius is drawn, whose center is off the drawing, the dimension line is drawn with a single zig-zag in it (Fig.1.18).

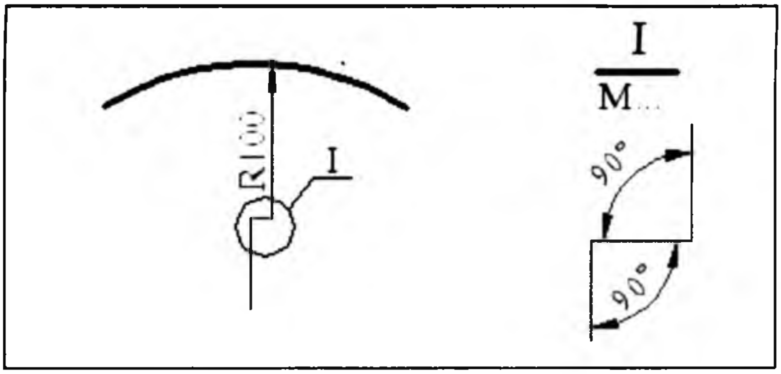


Fig.1.18

18. Dimensioning small spaces raises its own problems and solutions. There is one or two more rules that do not require illustrating.

19. If the drawing is to scale, the dimensions put on the drawing are the actual dimensions of the component and not the size of the line on your drawing.

20. Square is denoted by the symbol "□" placed in front of the dimension. It applies only in cases where the image does not give a complete picture of the square shape. In those cases where the square shape is clearly visible on the drawing, indicate the lengths of two sides of the square (Fig. 1.19).

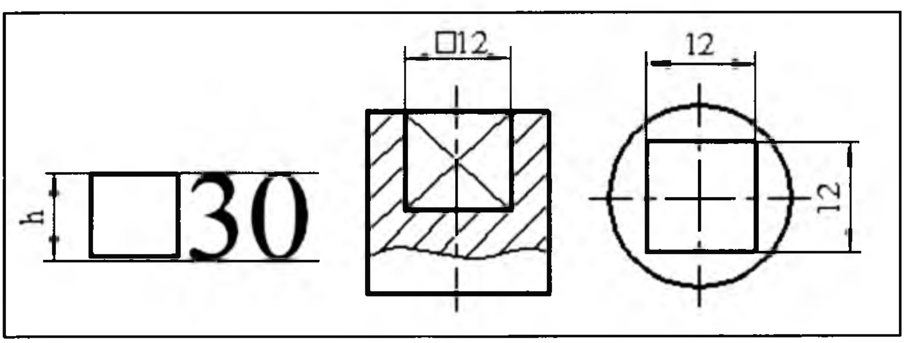


Fig.1.19

21. Taper is denoted by the symbol "◁", "Diameter" is placed in front of the dimension (Fig. 1.20, a). Skew is denoted by the symbol "∠" placed in front of the dimension too (Fig. 1.20, b).

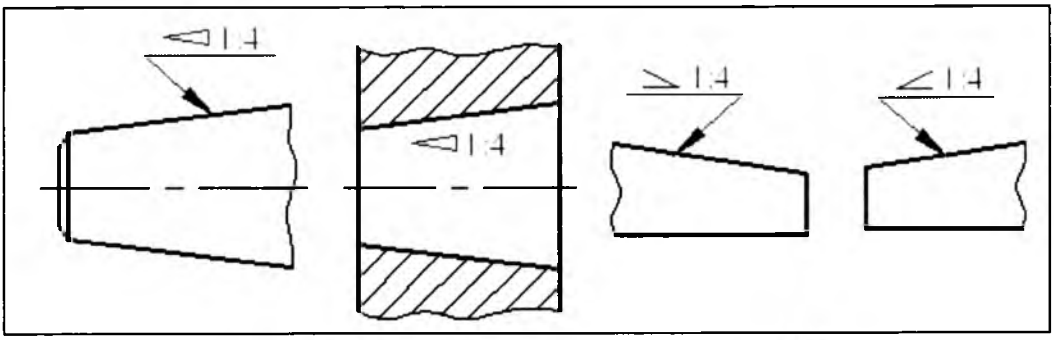


Fig. 1.20

The above 21 rules do not cover all aspects of dimensioning (there is a new set on tolerance dimensions alone) but they should cover all that if necessary.

Dimensioning properly is a matter of applying common sense to the rules because no two different drawings can ever raise exactly the same problems. Each drawing needs to be studied very carefully before you begin to dimension it.

Examination questions often ask for only five or six "important" dimensions to be inserted on the finished drawing. The overall dimensions, namely, length, breadth and width are obviously important but the remaining two or three are not so important.

QUESTIONS AND ASSIGNMENTS TO CHAPTER I

1. How many types of letters are used in engineering drawing?
2. What is the difference between standard lettering and italic lettering?
3. How many types of scales are used in engineering drawing?
4. How many types of drawing lines do you know and what is the purpose of each type?
5. What are the rules of writing dimension indicated in vertical dimension lines?
6. What are the rules of writing dimension indicated in parallel dimension lines?
7. What common types of lines do you know?
8. When do we use visible and hidden outlines?
9. What are the rules of drawing broken lines?
10. What space must be between the dashes?
11. What space must be between dot and dashes?
12. What must be the thickness of broken lines?
13. What line is called the axis of symmetry?
14. What lines are called the center lines?
15. What rules do you know to draw the center lines?
16. List out and draw the standard thickness of lines that are used in engineering drawing.
17. Enumerate the rules of dimensioning.

18. Give the shape identification symbols for diameter.
19. Give the shape identification symbols for radius.
20. Give the shape identification symbols for square.
21. What is the meaning of the symbol before the dimension figure?
22. What does letter R in front of the dimension figure signify?
23. Why do we write figure with plus and minus sign, as, for example 250 ...? When do we indicate dimensions?
24. How can you calculate upper and lower tolerance?
25. Are zero tolerances indicated in drawings?
26. What do you know about nominal size?
27. What does the symbol 1:2 mean in a drawing?
28. What types of the scales do you know?
29. In what cases do you use scales reduction?
30. In what cases do you use scales magnification?
31 What is the procedure of preparing a scale?
32. In which part of the drawing do we write the information about the material the object is made of; its name, symbol and other data?
33. How is the main inscription or the title block called?
34. Why are the dimensions indicated in the drawing?
35. Why is dimensioning of an object important?
36. How do we add letters and symbols in dimensioning?
37. Where should the dimension figures be written in the drawing?
38. What must the distance between parallel dimension lines, and the distance between dimension and contour lines be?
39. How must the dimension lines be located in the drawings?
40. In what cases must the arrows of the dimension lines be drawn from outside the extension lines?
41. Can contour or axial lines be used as dimension lines?
42. In what case should the incline be in the drawing?
43. What is the meaning of the symbol "$\lhd$" before the division figure?
44. What is the meaning of the symbol "$\angle$" before the division figure?
45 Explain chain dimensioning and parallel dimensioning with the help of simple sketches.
46. Describe the drawing sheet designation and its sizes as per 1SO-A series.

CHAPTER II
GEOMETRIC CONSTRUCTIONS

This chapter is concerned with the construction of plane geometrical figures. Plane geometry is the geometry of figures consisting of two-dimensional figures, that have only length and breadth. Solid geometry is the geometry of three-dimensional figures.

If we examine the pictures of the object given in the drawings, we can see that they consist of different types of lines.

Let's look at these drawings (Fig. 2.1). In the first drawing we can see straight lines only, in the second one - circles and straight lines, in the third one - straight lines, circles and arcs of circles.

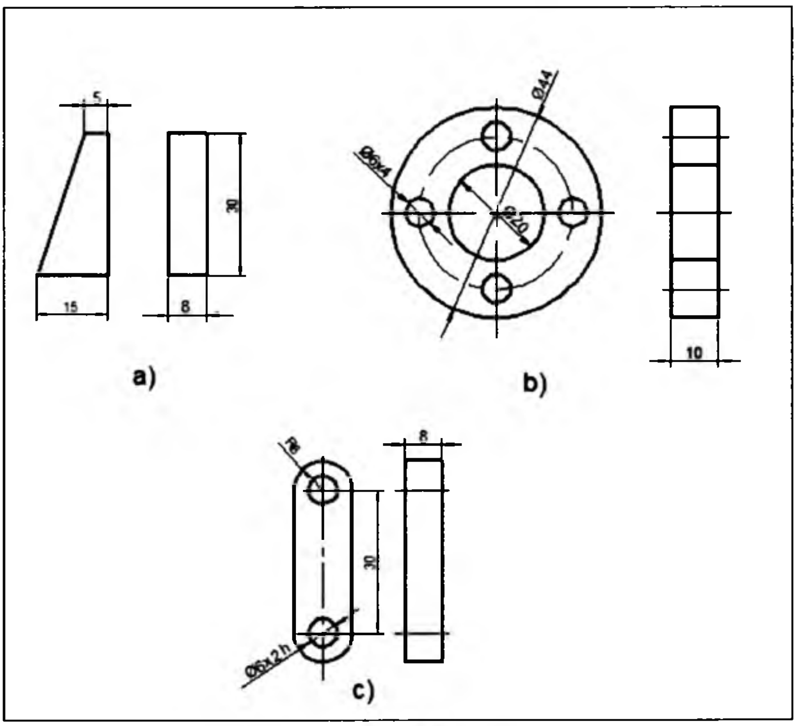


Fig.2.1

These examples show that in order to make drawings on paper or metal we must learn how to draw various geometrical figures. There are an endless number of plane figures but we will concern ourselves only with more common ones – the triangle, the quadrilateral and well known polygons.

This can only be attained after a study of the methods of geometrical constructions which we are going to discuss in this chapter.

2.1. Dividing and Constructing Lines and Angles

Let's practise several problem solutions.

Task 1. Divide straight line AB into two equal parts (Fig. 2.2).

The solution is as follows:

1. Set the supporting leg of your compass at point A of line AB.
2. Set the legs of your compass over at any distance slightly greater than half of the length of line AB.
3. Draw an arc from A as the center.
4. Transfer the supporting leg of the compass to the opposite point B of line AB, without changing the distance between the legs.
5. Draw an arc intersecting the first arc at points C and D with the same radius, from point B,.
6. Draw a straight line through points C and D, where the two arcs intersect.

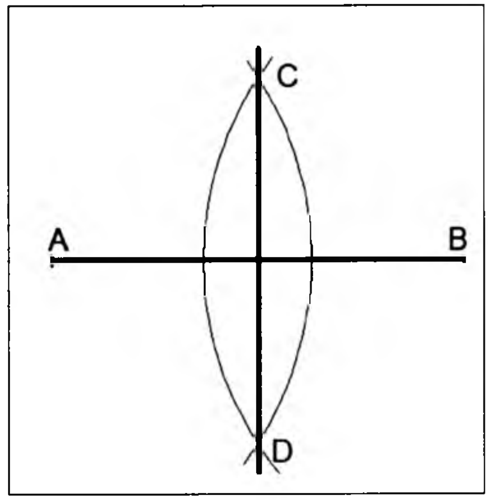


Fig.2.2

This line divides line AB into two equal parts. It is important to note that line CD which divides AB into two equal parts intersects AB at the right angles.

Task 2. Draw a line perpendicular to the given straight line AB from point C on that line (Fig.2.3).

Solution.

1. Set the supporting leg of your compass on the given point C.

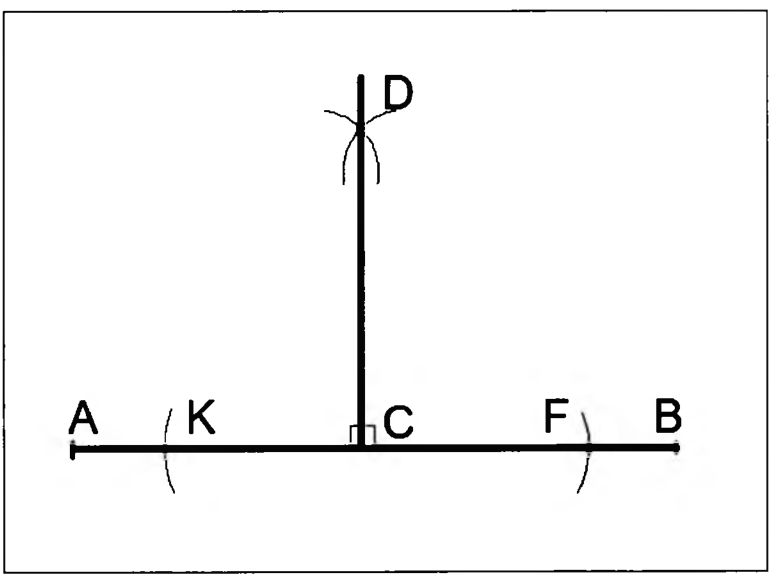


Fig. 2.3

2. Draw the compass legs apart from any distance that will be less than the distance between point C and the nearest end of straight line AB.

3. Draw two short arcs cutting line AB at K and F with this radius and from center C.

4. Set the supporting leg of the compass on the point of intersection of one of the arcs and line AB.

5. Double the distance between the compass legs.

6. Draw a short arc from K above point C.

7. Set the supporting leg of the compass on the intersection of the second arc and line AB (point F).

8. Draw a short arc above C, intersecting the first arc at point D with the same radius.

9. Join the point of intersection D with point C by a straight line.

Straight line CD will be the required perpendicular.

Task 3. Divide an angle in two equal parts (Fig.2.4).

Solution.

1. Set legs of your compass at any length of R shorter than the length of the side of the given angle.

2. Set the supporting leg of the compass at point O, which is the apex of the angle.

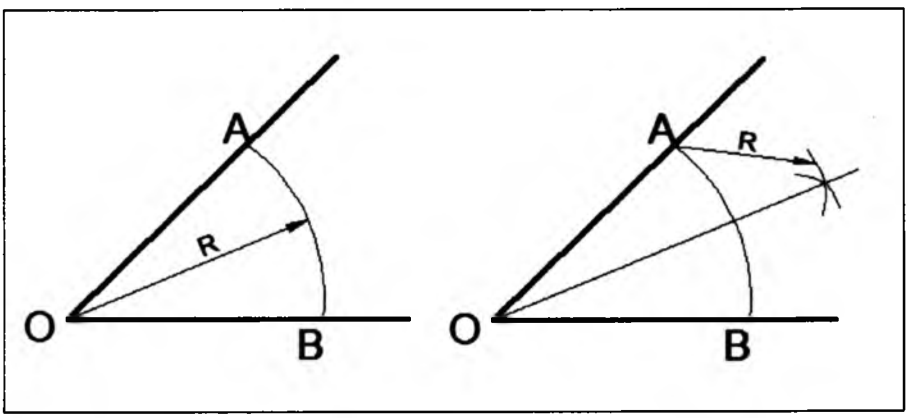


Fig.2.4

3. Draw an arc cutting both sides of the angle at points A and B with radius R.

4. Set the supporting leg of the compass at point A, where the arc intersects the side of the angle.

5. Set the legs of the compass at a somewhat greater length than half of arc AB.

6. Describe a short arc beyond arc AB with this radius R.

7.Transfer the supporting leg of the compass to the other point of intersection of the arc and the side of the angle (point B).

Task 4. Divide right angle into three equal parts (Fig. 2.5).

Solution.

1. Set legs of your compass with the same radius R, shorter than the length of the side of the given angle.

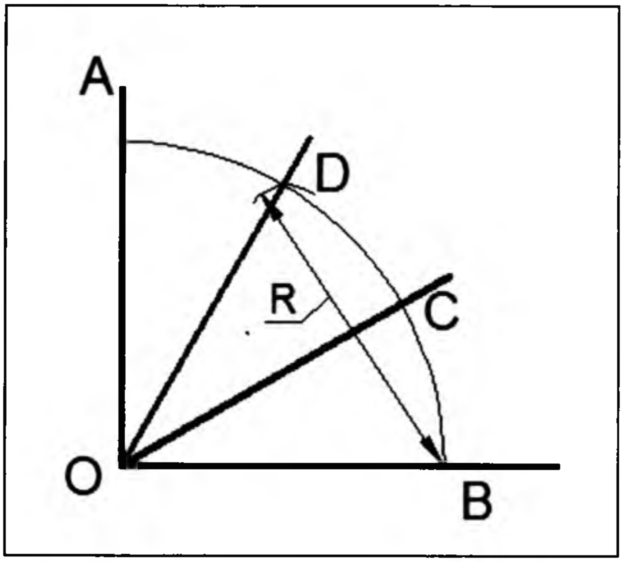


Fig.2.5

2. Set the supporting leg of the compass on the apex of angle O.

3. Draw an arc, cutting both sides of the angle at points A and B, with radius R, from point O,

4. Set the supporting leg of your compass at one of the points (A), where the arc intersects the side of the angle.

5. Draw an arc intersecting first arc at point C with the same radius R.

6. Transfer the supporting leg of your compass to the second point B, where the arc intersects the side of the angle.

7. Draw the second arc to intersect the first arc at point D with the same radius R.

8. Draw straight lines to the apex of angle O from the points of intersection D and C. The lines OD and OC will divide the right angle into three equal parts.

Only the right angles can be divided into three equal parts by the method described in this task.

Task 5. Construct an equilateral triangle with the given length of one side of AB (Fig. 2.6).

Solution

1. Draw a straight line somewhat longer than line AB.

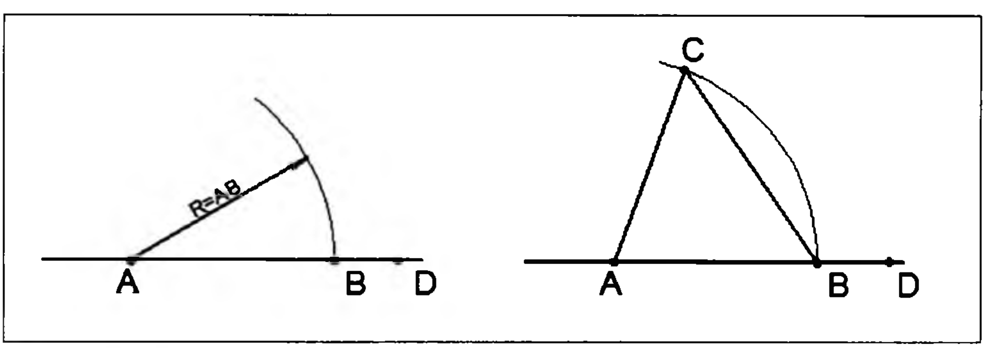


Fig.2.6

2. Set your compass at a length equal to that of line AB.

3. Set the supporting leg of your compass at point C and draw an arc, which cuts the line D at point B.

4. Draw a small arc to intersect the first arc at point A with the same radius R.

5. Join points A, B, and C, with straight lines.

The obtained triangle is an equal triangle constructed from the given length of one of its sides.

Task 6. Divide a line into a number of equal (i.e. seven) parts (Fig.2.7).

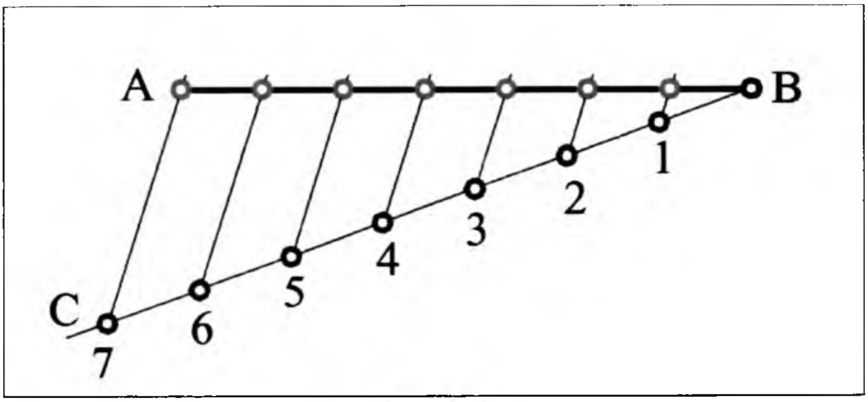


Fig. 2.7

2.2. Tangency Lines

A tangent to a circle is a straight line that touches the circle at one point. Every curve ever drawn could have tangents drawn on it, but this chapter is concerned only with tangents to circles. They have wide applications in engineering drawing since the outlines of most engineering details are made up of straight lines and arcs. Wherever a straight line meets an arc, a tangent meets a circle.

It is important to point out that arcs merge into each other so gradually that when we look at the drawing it is impossible to say where one arc ends and the other begins.

This gradual transition of a straight line into a curved line, or of one curve into another is called ***tangency***.

The point at which one line merges into another is called **the point of tangency.**

Let's consider a simple case, where it is necessary to draw an arc tangent to a straight line at point A. For this purpose, we first join the point A with the center of the arc and then, from point A, we draw a straight line perpendicular to the radius of the arc (Fig. 2.8).

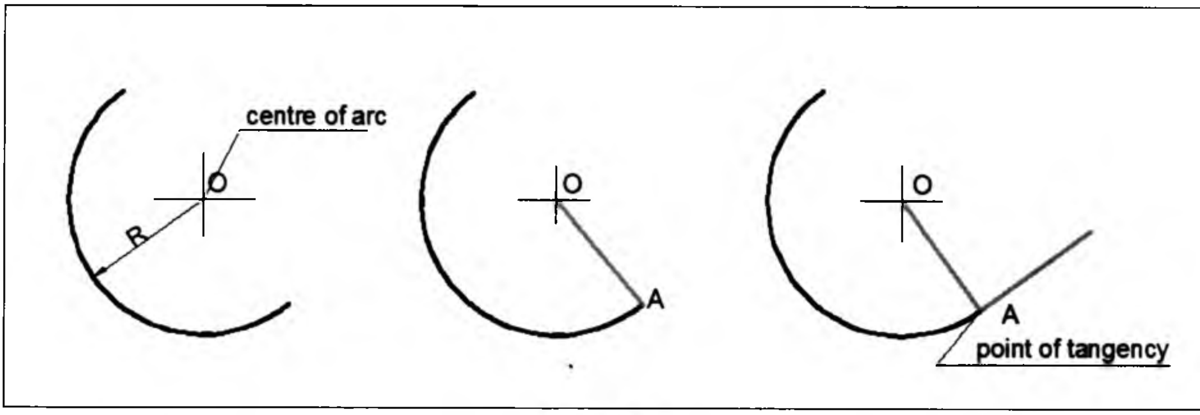


Fig. 2.8

Let's take another example to draw the arc tangent to the other arc.

Two arcs can only be drawn tangent to each other if their point of tangency lies on the straight line joining the center of these two arcs (Fig 2.10).

The solution is as follows:

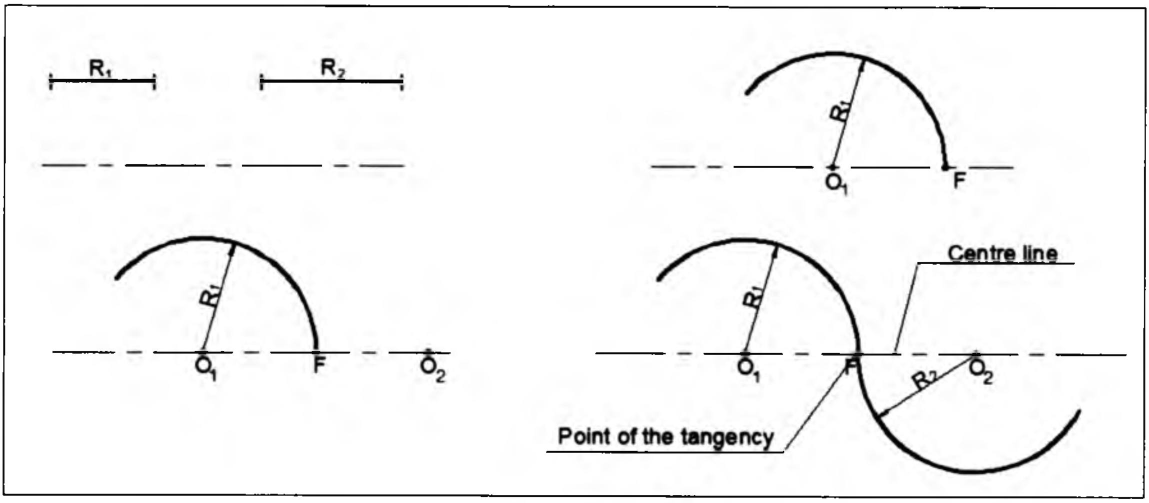


Fig.2.9

1. The supporting leg of a compass is set on the given center O.
2. With the compass set a leg at a length with radius R_1 an arc is drawn to intersect the straight line.
3. From the point where this arc intersects the straight line, draw a distance equal to the second given radius R_2 marked off on the line.

Thus obtained point O_2 will be the center of the second arc, while the point where the first arc intersects the straight line will be the point of tangency.

4. From the point O_2 as center, another arc is drawn after the compass is set at the length equal to R_2.

Let's consider another example, where two arcs are tangent to the third arc.

Usually when such contours are drawn or marked out the radii of all three arcs are given as well as the location of centers O_1 and O_2 of the two tangential arcs. Then the problem becomes tangential arc. This center is found as follows:

1. The compass is set at the length equal to the sum of the radii of the first arc R_1 and the tangential arc R_2.

2. The supporting leg of the compass is set in the center O_1 of the first arc.

3. With this radius, equal to R_1+R_2 and from the center O_1 a small area is drawn.

4. From point O_2, as the center, with a radius equal to the sum of the radii R_1+R_2, draw the second arc intersecting the first arc at point O_3.

5. The points of tangency, A_1 and A_2 according to the above rule, will be on the lines joining the centers of the tangent arcs.

6. The construction is completed by drawing an arc from the center O_3 with radius R_2.

Task. Construct an oval if its length and width are known (Fig.2.10).

The solution is as follows:

1. Draw two axes of symmetry intersecting each other at right angles, at point O.

2. On the vertical axis of symmetry arrange out given width of the oval; half of this width must be above O, and the other, below O. In the same way, arrange out the length of the oval on the horizontal axis.

3. Join the two short arcs of intersection; describe when the dimensions of the oval are arranged out on the vertical and horizontal axes at points C and B with a straight line.

4. With a radius equal to half of the length of the oval (OB), and from the center O, draw an arc between the horizontal and vertical axes, cutting the vertical axis at point E.

5. From the center C, with radius CE draw an arc intersecting the straight line CB at point F.

6. Bisect the straight line FB. The line passing through the center of FB will intersect the lower part of the vertical axis at point R and the horizontal axis at L.

7. From center O, and with the radius equal to OL, draw a short arc cutting the left half of the horizontal axis at point M.

8. From the center O and with the radius equal to OR, draw an arc intersecting the vertical axis at point N.

9. Draw a straight line from R through point M; from point N, draw straight lines through points M and L.

10. From center R and with the radius of RC draw an arc between the extensions of RM and RL. With the same radius and from center N describe an arc between the extensions of NL and NM.

11. From centers M and L, with a radius equal to MA or MB, draw arcs to join the previously described arcs.

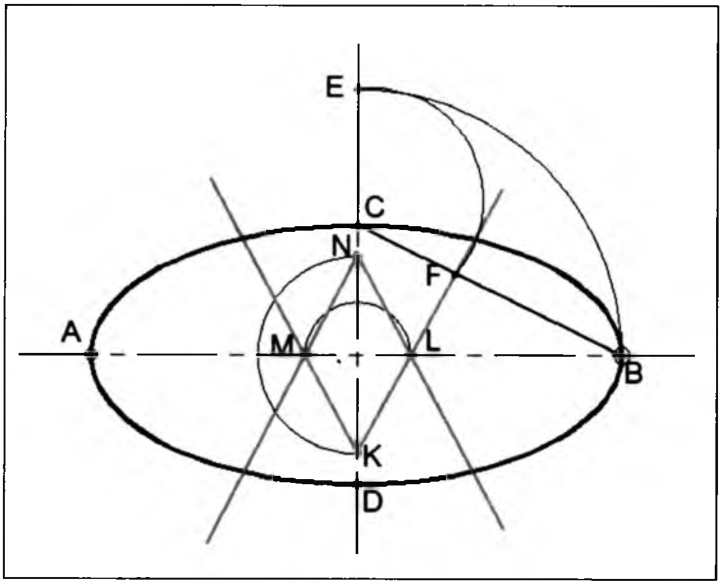


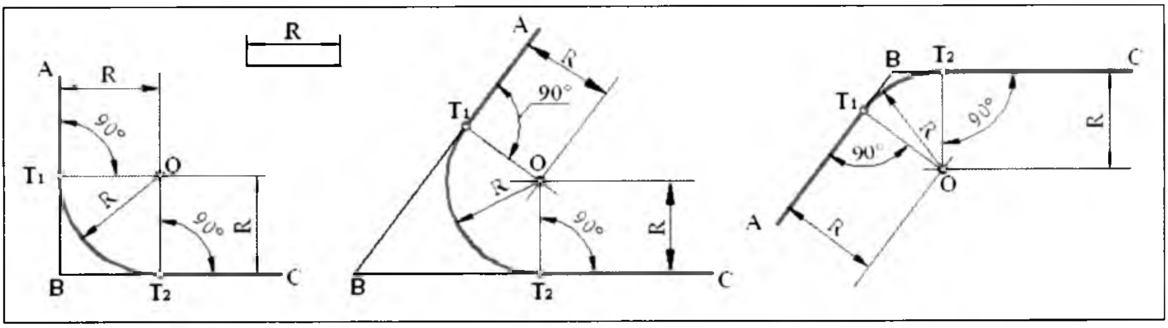
Fig.2.10

2.3. Blending of Lines and Curves

It is usually only very simple type of engineering detail that has an outline composed entirely of straight lines. The inclusion of curves within the outline of a component may occur for several reasons: to eliminate sharp edges, thereby making it safer to handle; to eliminate a stress center, thereby making it stronger; to avoid extra machining, thereby making it cheaper; and last, but by no means least, to improve its appearance. This last reason applies particularly to those industries that manufacture articles to sell to the general public. Nowadays it is not enough to produce vacuum cleaners, food mixers or ball-point pens functional and reliable. It is equally important to make them attractive so that they, and not the competitors' products, are the ones that catch the shopper's eye. The designer uses circles and curves to smooth out and soften an outline. Modern machine-shop processes like cold metal forming, and the increasing use of plastics and laminates, allow complex outlines to be manufactured as cheaply as simple ones, and the blending of lines and curves plays an increasingly important role in the draftsperson's world.

Blending is a topic that students often have difficulty in understanding and yet there are only a few ways in which lines and curves can blend. When constructing an outline that contains curves blending, do not worry about the point of contact of the curves; rather, be concerned with the positions of the centers of the curves. A curve will not blend properly with another curve or line unless the center of the curve is correctly found. If the center is found exactly, the curve is bound to blend exactly too.

To find the center of an arc, with radius R, which blends with two straight lines meeting at right angles (Fig. 2.11, a):



a) b) c)

Fig.2.11

Construct lines, parallel with lines AB and BC, and distance R away, to intersect at O.

O is the required center.

Find points T_1 and T_2.

Draw an arc with center O through points T_1 and T_2.

This construction applies only if the angle is a right angle. If the lines meet at any angle other than 90°, use the construction shown in Fig. 2.12, b and c.

To find the center of an arc, with radius R, which blends with two straight lines meeting at any angle (Fig. 2.11, b and c):

Construct lines, parallel to lines of the angle and with distance *R*, to intersect at O.

O is the required center.

Draw lines, perpendicular to lines AB and BC, find points T_1 and T_2.

Draw an arc with center O through points T_1 and T_2.

To find the center of an arc, with radius R, which blends with a line and a circle, center O_1, radius R (Fig. 2.12):

Construct a line, parallel to the given line, with distance *R*. The center must lie somewhere along this line.

Draw an arc to intersect the parallel line in O_1 with center B, with radius R $+R_1$.

O_1 is the required center.

Join points O_1 and O, to find point N_1.

Draw perpendicular line to AB, to find point N_2.

Draw an arc with center O through points N_1 and N_2.

To find the center of an arc, with radius R, which blends with two circles, centers O_1 and O_2, radii R_1 and R_2, respectively:

There are two possible blending - shown in Figs. 2.13 and 2.14.

If an arc, with radius *R* is blended with a circle, with radius R_1, the center of the arc must be at distance *R* from the circumference and hence $R + R_1$ (Fig. 2.14) from the center of the circle.

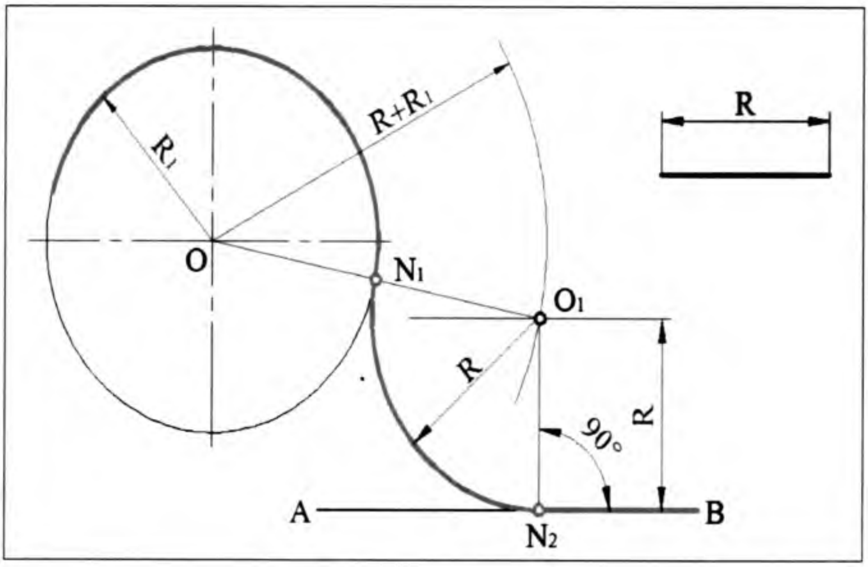


Fig. 2.12

Draw an arc with center O_1, with radius R+R_1.
Draw an arc to intersect the first arc in O with center O_2, radius R + R_2.
O is the required center.
Join points O and O_1, to find point N_1. Then join points O and O_2, to find point N_2.
Draw an arc with center O through points N_1 and N_2.
This blending is referred to as ***external blending.***

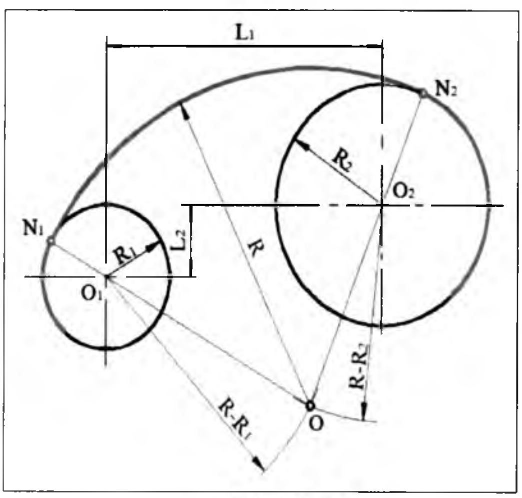


Fig.2.13

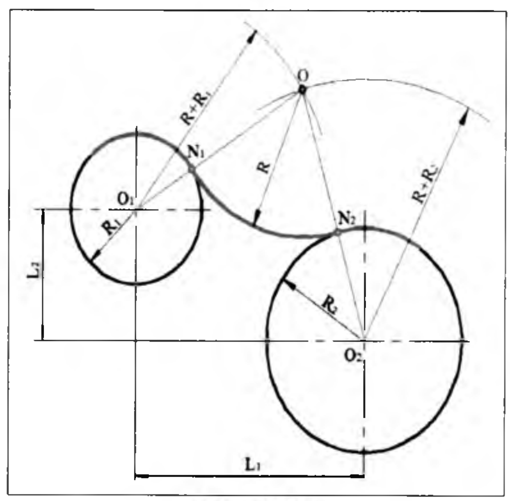


Fig.2.14

The example of an external blending is shown in Figure 2.14.
If an arc, with radius *R*, is to blend with a circle, radius R_1, the center of the arc must be at distance *R* from the circumference and hence R - R_1 (Fig. 2.13) from the center of the circle.
Draw an arc with center O_1, radius R - R_1.
Draw an arc to intersect the first arc in O with center O_2, with radius R - R_2.
O is the required center.

Join points O and O_1, to find point N_1. Then join points O and O_2, to find point N_2.

Draw an arc with center O through points N_1 and N_2.

This blending is referred to as ***internal blending.***

To join two parallel lines with two equal radii, the sum of which equals to the distance between the lines (Fig. 2.15):

Draw the center line between the parallel lines.

Drop a perpendicular to meet the center line in O_1 from a point A.

Draw an arc to connect the center line in B with center O_1 and radius O_1A.

Produce AB to meet the other parallel line in C.

Erect a perpendicular from point C to connect the center line in O_2.

Draw arc BC with center O_2, radius O_2C.

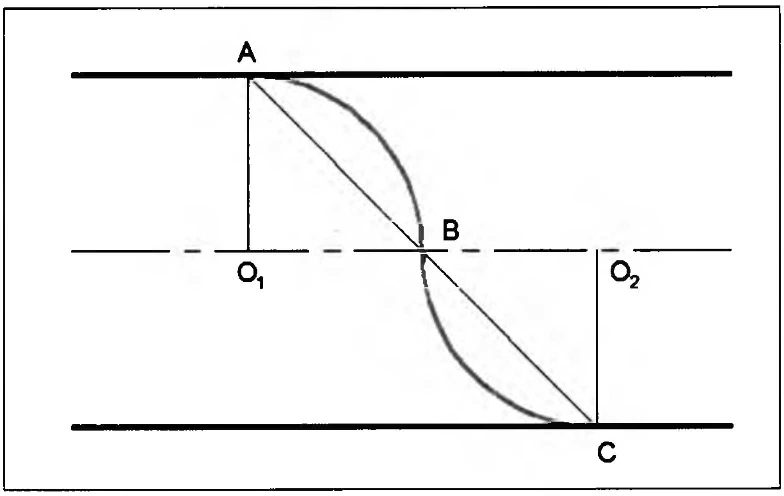


Fig. 2.15

To join two parallel lines with two equal radii, R, the sum of which is more than the distance between the lines (Fig. 2.16):

Draw the center line between the parallel lines.

Drop a perpendicular from point A, and mark $AO_1 = R$ on it.

Draw the center line between the parallel lines.

Drop a perpendicular from point A, and mark off $AO_1 = R$ on it.

Draw an arc with center O_1, with radius R to connect the center line in B.

Produce AB to connect the other parallel line in C.

Erect perpendicular $CO_2 = R$ from C.

Draw arc BC with center O_2, with radius R.

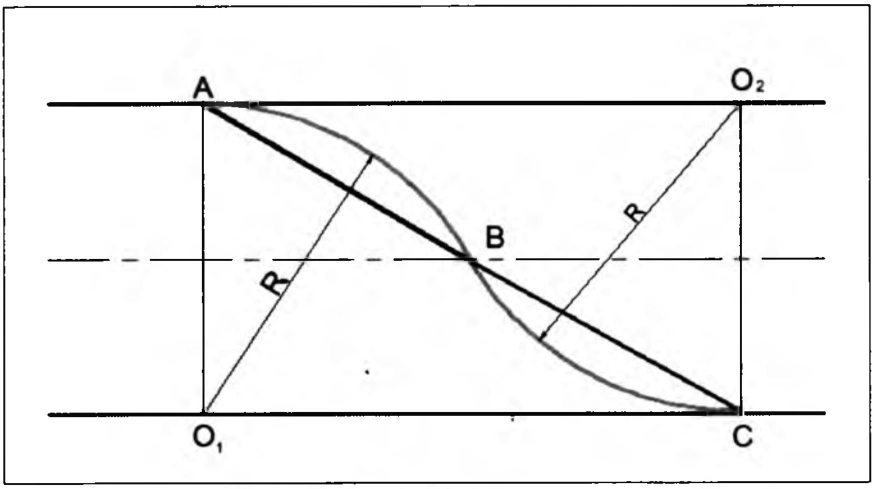


Fig. 2.16

In practice very often we have to construct curves. Ellipse, parabola and hyperbola are called conic sections because these curves appear on the surface of a cone when cutting they become typical cutting plane.

Figure 2.18 shows construction of sinusoid. We have to divide given circle with radius R into 12 equal parts. From the point O_1 draw a horizontal line O_1A, the length of which is equal to the circumference ($L = 2\pi R$). This line is also divided into 12 equal parts. From these points draw horizontal lines, and from points on line AB - vertical lines, then find the intersection of the corresponding straight lines. The resulting points are sinusoid points. Connecting them smoothly, we get a sinusoid.

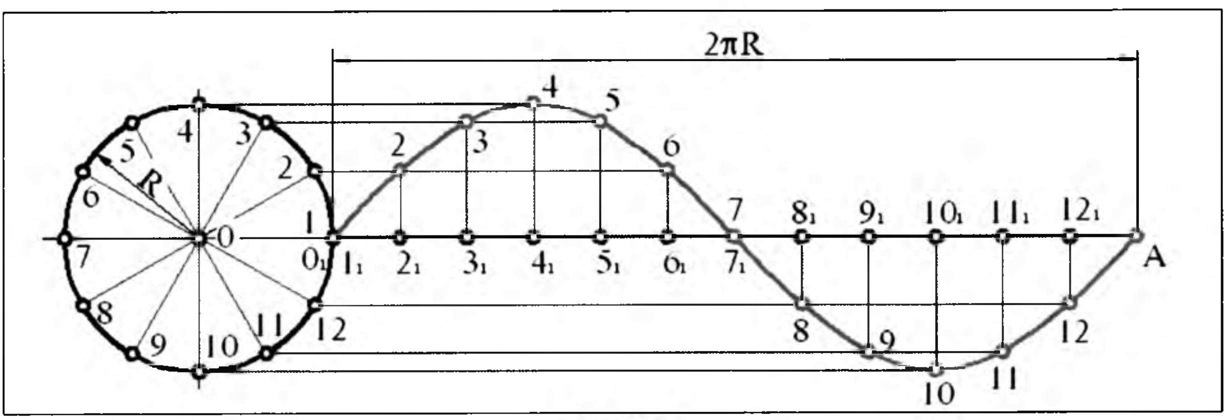


Fig. 2.17

2.4. Dividing of Circle into a Number of Equal Parts

In practice, we often face with the necessity of dividing the circle into equal parts. For example, in manufacturing gears, flanges with holes are made in the construction of regular polygons. Let’s pay attention to the example of dividing a circle with radius R into three equal parts (Fig. 2.18). We deviate from the circle of arbitrary point A and from that point a radius equal to the radius of the circle that holds the arc. This arc intersects the circle at points 1 and 2. The intersection point of circle with center line is the third point. These points divide the circle into three equal parts.

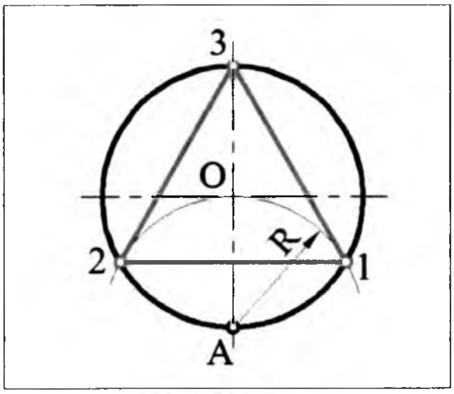


Fig. 2.18

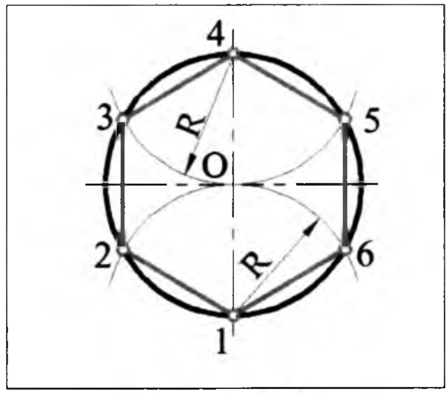
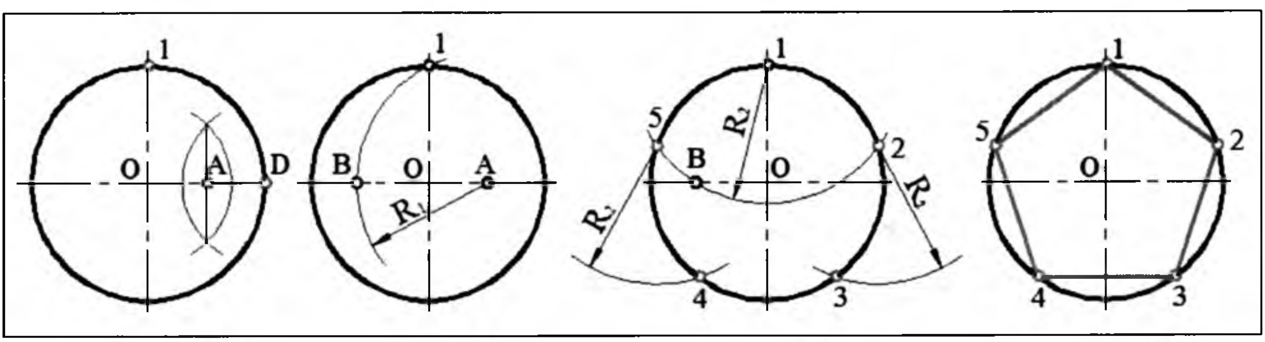


Fig.2.19

The dividing of the circle into six equal parts is drawn in the same way (Fig. 2.19).

Now let's consider the dividing of the circle into five equal parts (Fig. 2.20). One of the five division points is 1. Divide the segment OD in two equal parts (Fig.2.20, a). In order to do this, we use the rule of division line segment into two equal parts. This point will be point A. Then from point A with radius R_1 = 1A draw arc which intersects the horizontal axis at circumferential point B (Fig.2.20, b).



a) b) c) d)

Fig. 1.20

From point 1 we draw an arc with radius R_2 = 1B, which intersects the circle at points 2 and 5. Taking these points for the centers, we draw the same arc with radius R_2, crossing the circle at points 3 and 4 (Fig.2.20, c).

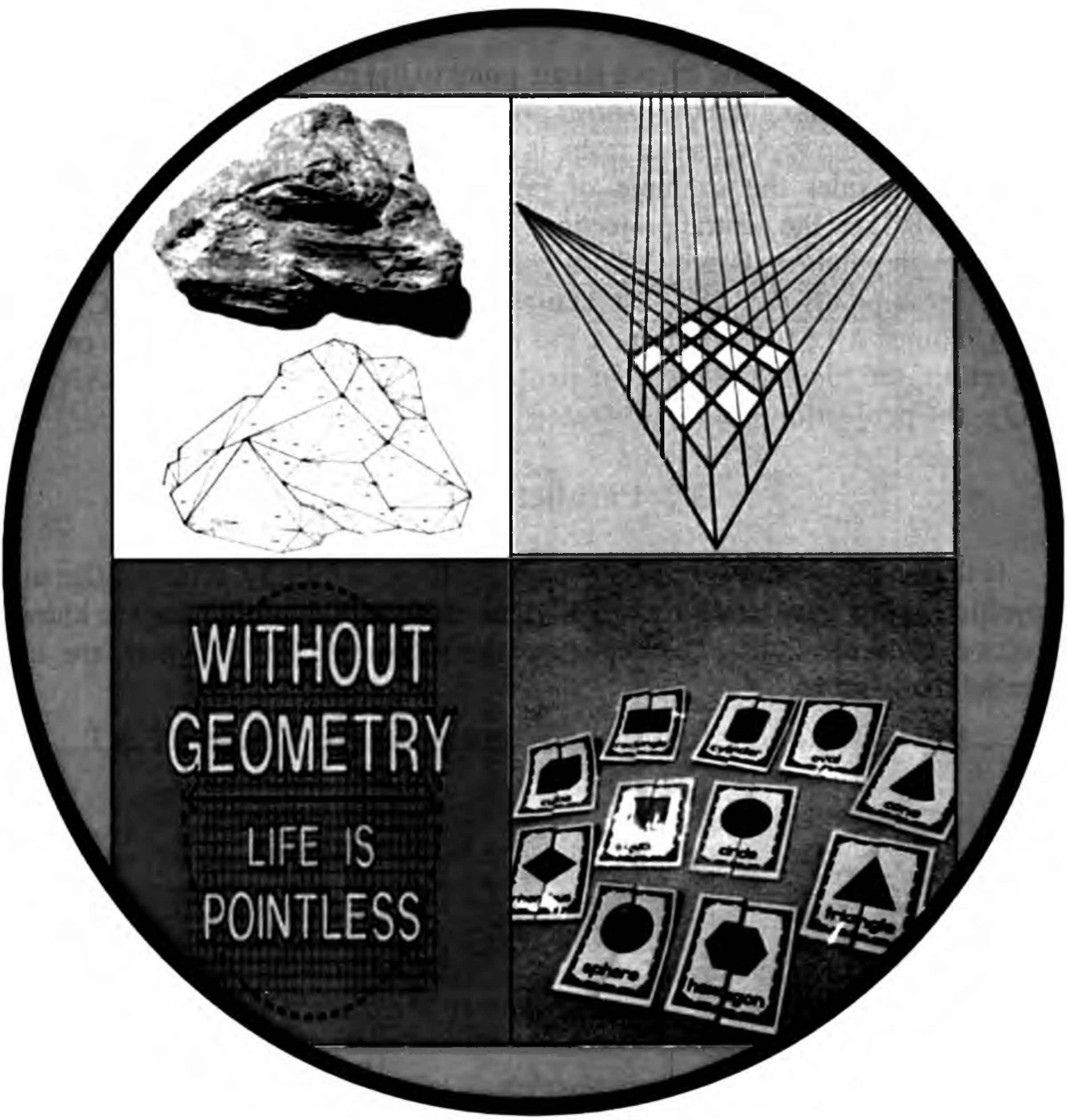
Thus, the circle is divided into five equal parts. We connect these points by straight lines, as shown in Figure 2.20, d, we shall get a regular pentagon inscribed in a circle.

QUESTIONS AND ASSIGNMENTS TO CHAPTER II

1. What are the rules of dividing the straight line into two equal parts?
2. What are the rules of drawing a line perpendicular to the given straight line from a given point on that line?
3. What are the rules of dividing an angle into two equal parts?
4. What are the rules of dividing a right angle into three equal parts?
5. What are the rules of drawing a perpendicular to the straight line?
6. What distance must be between the legs of the compass if you want to divide the straight line into two equal parts?
7. What are the rules of drawing a right angle with the help of the compass and the ruler?
8. What are the rules of drawing a parallel line to the given line?
9. What are the rules of constructing 60° angle?
10. What are the rules of constructing 90° angle?
11. What are the rules of constructing 45° angle?
12. What are the rules of constructing 30° angle?
13. What are the rules of dividing a line into a number of equal parts?
14. What are the rules of constructing tangency line to the circle?
15. What are the rules of constructing an oval according to its length and width?
16. Find the center of an arc, with radius R, which blends with two straight lines meeting at right angles.
17. Find the center of an arc, with radius R, which blends with two straight lines meeting at any angle.
18. Find the center of an arc, with radius R, which blends with a line and a circle, center O_1, radius R.
19. Find the center of an arc, radius R, which blends with two circles, centers O_1 and O_2, radii R_1 and R_2, respectively?
20. Define an internal blending.
21. Define an external blending.
22. Join two parallel lines with two equal radii, the sum of which equals to the distance between the lines.
23. Join two parallel lines with two equal radii, R, the sum of which is greater than the distance between the lines.
24. What are conic sections and why are they called so?
25. What are sinusoids and what are the rules of their constructions?
26. Explain the rules of dividing the circle into three equal parts.
27. Explain the rules of dividing the circle into six equal parts.
28. Explain the rules of dividing the circle into five equal parts.

PART II
DESCRIPTIVE GEOMETRY

Gaspard Monge (1746 — 1818) was sworn not to divulge the above method and for 15 years it was a jealously guarded military secret. Only in 1794, he was allowed to teach it in public at the Ecole Normale, Paris where Lagrange was among the auditors. "With his application of analysis to geometry, this devil of a man will make himself immortal", exclaimed Lagrange.



CHAPTER III

METHODS OF PROJECTIONS. ORTHOGONAL PROJECTIONS. PLANES OF PROJECTIONS. GASPARD MONGE'S METHOD. POİNT.

3.1. Central Projections

In descriptive geometry the construction of plane geometry drawings, representing three dimensional designs of objects, is based on the **method of projections** (The word "projection" comes from the Latin projicere – to hurl or throw).

If all the rays emanate from a single point to the plane of projection, a projection method is called the ***central projection***.

The point, the rays emanate from, is called the ***center of projection***.

Let's consider the example of production of projection points A, B, C (triangle ABC) by the central projection (Fig. 3.1).

Through points A, B and C a straight line passes to pierce plane α at points A', B', C'. These points are called the **central projection** of points A, B, C (triangle ABC). Points A, B, C are termed the original points, point **S - the center of projection**, the plane α – **plane of projection**, and the straight line SAA', SBB' SCC' – **the projection line or projector**.

3.2. Parallel Projections

If the center of projection S is considered to lie at infinity, it means that all the projecting rays are parallel. In order to draw these rays it is necessary to know the direction of projections. The representations obtained in this way are called **parallel projections.**

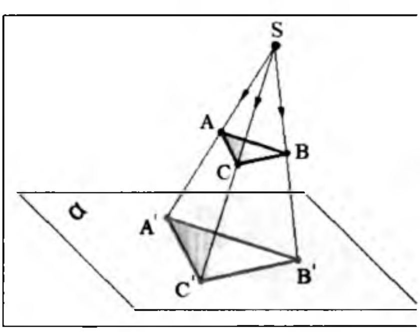


Fig. 3.1

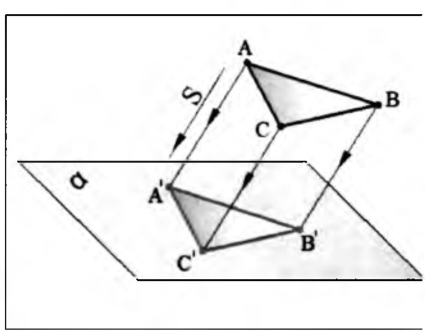


Fig. 3.2

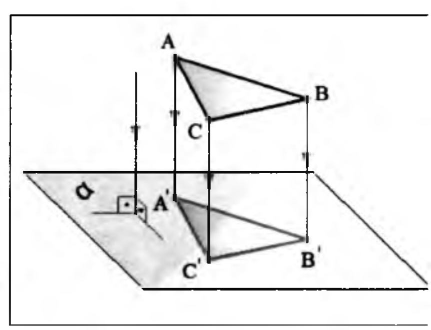


Fig. 3.3

This method does not apply in technical drawing, but at the same time is quite widely used in architecture and the design of various engineering structures.

Figure 3.2 shows the construction of the parallel projection of triangle ABC on the plane of projection α. The lines, to which the projection rays AA', BB', CC' are parallel, show the **direction of projection.**

3.3. Orthogonal Projections

A special case of the parallel projection is right-angle projection.

In engineering practice right-angle projection is the most widely used because of its comparative simplicity, the precision of construction it allows, and possibility of obtaining dimensions without distortion. Right-angle projection is usually termed **orthographic or orthogonal projection**.

Figure 3.3 shows the construction of the orthogonal projection of triangle ABC on the plane of projection α.

The method of orthogonal projection consists of projecting an object on three mutually perpendicular planes by ray's orthogonal (perpendicular) to these planes (Fig. 3.4).

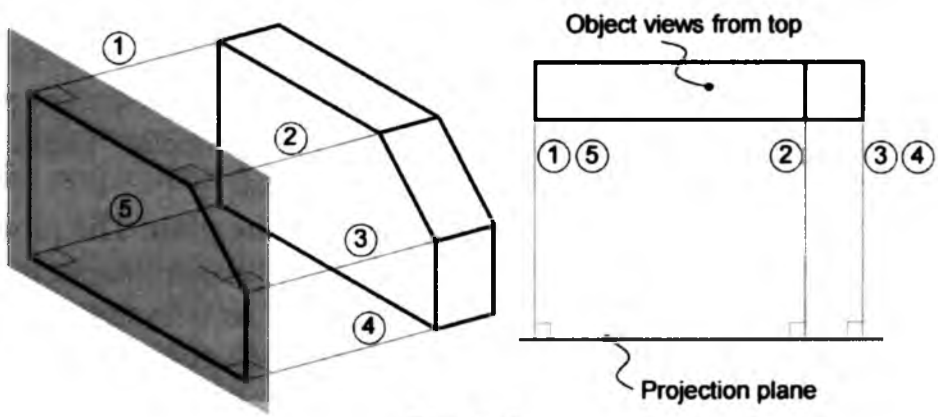


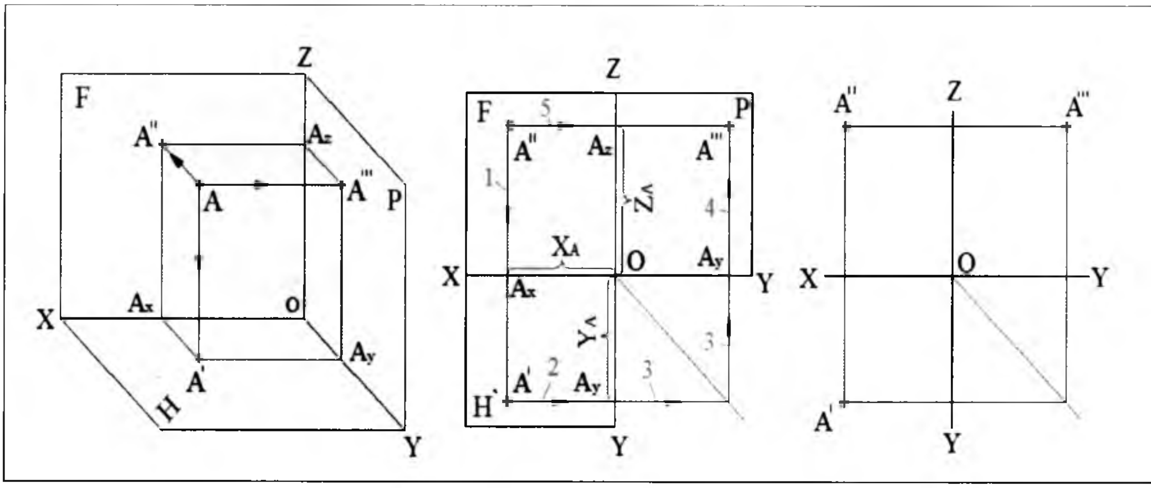
Fig. 3.4

3.4. Three Coordinates and Three Projections of Point

The three planes employed for the purpose of orthogonal projections are called **planes of projection.** They intersect each other at the right angles (Fig. 3.5, a).

One of the planes of an orthogonal projection is horizontal and is called **the horizontal plane of projection**; the other is **the frontal plane of projection** (in front of viewer). The third plane is called **the profile plane of projection** (in profile of viewer).

A horizontal plane is parallel to leveled ground and it is denoted by H. The top view (Plan) is drawn on it.



a) b) c)

Fig. 3.5

The plane, which is parallel to a frontal wall is called frontal plane and is denoted by F. The front view is drawn on it.

The plane, which is parallel to a profile wall is called profile plane and is denoted by P. The side view is drawn on it.

Planes employed for projections of front view, top view and side view are called ***principle planes of projections.*** They are also known as ***reference planes***. These planes intersect at right angles to each other. These are frontal plane, horizontal plane and profile plane. They are assumed to be transparent planes.

Planes H, F and P are infinite, opaque and perpendicular. The projection on **F** is called **the front view or the elevation** of the object.

The projection on **H** is called **the top view or the plan**. The projection on **P** is called **the left view** of the object. The projection planes intersect in pairs and define three axes: x-, y-, z, which may be regarded as a system of rectangular. Cartesian coordinates in space with the origin at O. Each coordinate axis is divided into half-lines by point O.

The line of intersection of the H and F planes of the projections is called **the coordinate axis**, designated **ox**,where **x** is absiss. The line of intersection of the H and P planes of the projections is called **the coordinate axis**, designated **oy**, where **y**- is ordinate. The line of intersection of the P and F planes of the projections is called **z coordinate axis**, designated **oz**, where **z**- is applicate.

Suppose that at a certain distance from these projection planes is point A. We find the projections of point A on the projection planes. For this purpose from this point we draw perpendiculars to plane H, F and P. Point A' is the horizontal projection of point A, A'' is the frontal projection of point A, and point A''' is the profile of point A.

The projecting of details in space is a difficult process, so very often we use their **complex drawing**. Complex drawing is called the drawing, in which the same plane projection parts produced in different planes of projections are combined.

This method was first proposed by French scientist Gaspard Monge and is known as the **Gaspard Monge's method** (Figs. 3.5, b).

In this method of bringing planes H and F into coincidence, the projections **A''** and **A'** will be located on a single perpendicular to the **x**-axis, and the distance **A_xA'**- from the horizontal projection of **A** to the **X**-axis – will be equal to the distance from point **A** itself to the F plane, while distance **A_xA''**–from the frontal projection of point **A** to the **x-** axis –to the distance from point **A** itself to the H plane. To obtain a complex drawing, consisting of the above-indicated projections, planes H and F are rotated to coincide about the **x**-axis as shown by the arrows (2) and (3).

On complex drawings the point and its projections are not depicted. The straight line, connecting different projections of a point is called **communication line**.

Figure 3.5, c shows the final version of complex drawing where we can see that all projection planes are coincident. In this figure, the x-and z- axes, which lie in the stationary planes F are depicted only once, while the y-axis is indicated twice. This is due to the fact that as the y-axis rotates together with plane H, it coincides (ortographically) with the z-axis,but the same axis coincides with the x-axis when rotating together with plane F.

Each of the orthogonal projections of **A** is defined by only two coordinates, since it is located on the plane.

In an orthographic representation (Fig. 3.5, c) where all projection planes are coincident, the projections A' and A'' will be on a single perpendicular to the **x**-axis, and the projections A'' and A''' will be situated on a single perpendicular to the **z**-axis.

As for the projections A' and A''', we see that they are joined by the line – segments A'A_y and A'''A_y which are perpendicular to the y- axis. However, since this axis occupies two positions in the orthographic representation, the line segment A'A_y cannot be an extension of A'''A_y.

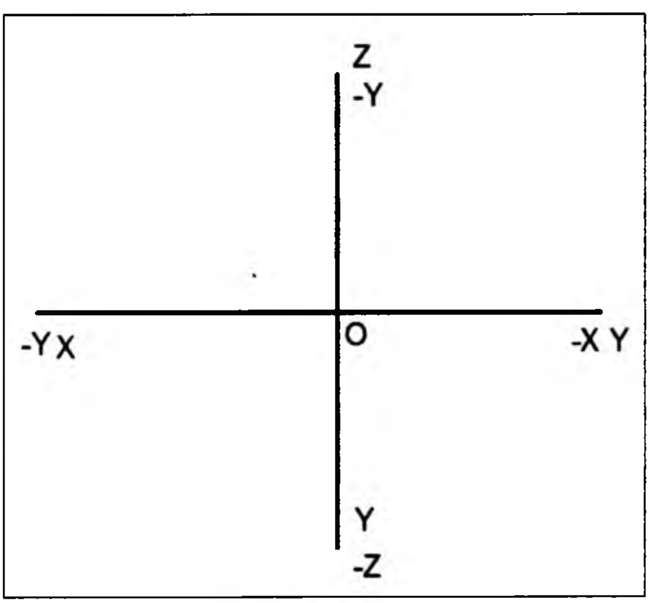


Fig. 3.6

In Figure 3.6, the x-and z- axes, which lie in the stationary planes F, are depicted only once, while the y-axis is indicated twice. This is due to the fact that as the y-axis rotates together with the plane H, it coincides (ortographically) with the z-axis,but the same axis coincides with the x-axis when rotating together with plane P.

Table 3.1

Octant	Signs of coordinates		
	x	y	z
I	+	+	+
II	+	-	+
III	+	-	-
IV	+	+	-
V	-	+	+
VI	-	-	+
VII	-	-	-
VIII	-	+	-

Distance **y** from the horizontal projection of a point to the coordinate axis is equal to the distance from the point to the frontal plane of projection.

Distance **z** from the vertical projection of a point to the coordinate is equal to the distance from the point to the horizontal plane of projection.

Coordinate **z** is positive for points located above the horizontal plane of projection and negative for those situated below that plane.

Coordinate **y** is positive for points located in front of the vertical plane of projection and negative for those situated behind that plane.

3.5. Four Quadrants. Projections of Different Points to Planes of Projection

When the planes of projection are extended beyond the line of intersection they divide the space into four dihedral angles or four quadrants, which are usually numbered as shown in Figure 3.7. The detail may be situated in any of the quadrants, its position relative to the planes is described above, below H and in front or behind the F. The projections are obtained by drawing perpendiculars from the detail to the planes, i.e. by looking from the front and from above. Then they are shown on a flat surface by rotating one of the planes as it has already been explained. It should be remembered that the first and the third quadrants are always open out to the planes while rotating. The positions of the views with respect to the reference line will change according to the quadrant in which the object may be situated.

When considering orthogonal, projectionist assumes that object is located in the first quadrant at an infinite distance from the planes of projection. Since these planes are opaque, the viewer can see only those points, lines and figures situated within the confines of the first quadrants.

The point is the most simple of geometric elements, which does not have the size. It is used in solving of many geometric problems.

A point may be situated in space in any of the four quadrants formed by the two principal planes of projection or may lie in one or both of them.

When constructing projections, bear in mind that the orthogonal projection of a point on a plane is the foot of the perpendicular dropped from the point to the plane.

Let's denote points in space by capital letters A, B, C,etc.

Now we will consider the position of points in the fourth space and construct their complex drawings (Figs. 3.7 and 3.8).

1. The point is located in the I quarter.

If a point is located in the first quarter t (point A), after the planes coincide, its frontal projection will be above the **x**-axis, horizontal projection will be under the **x**-axis.

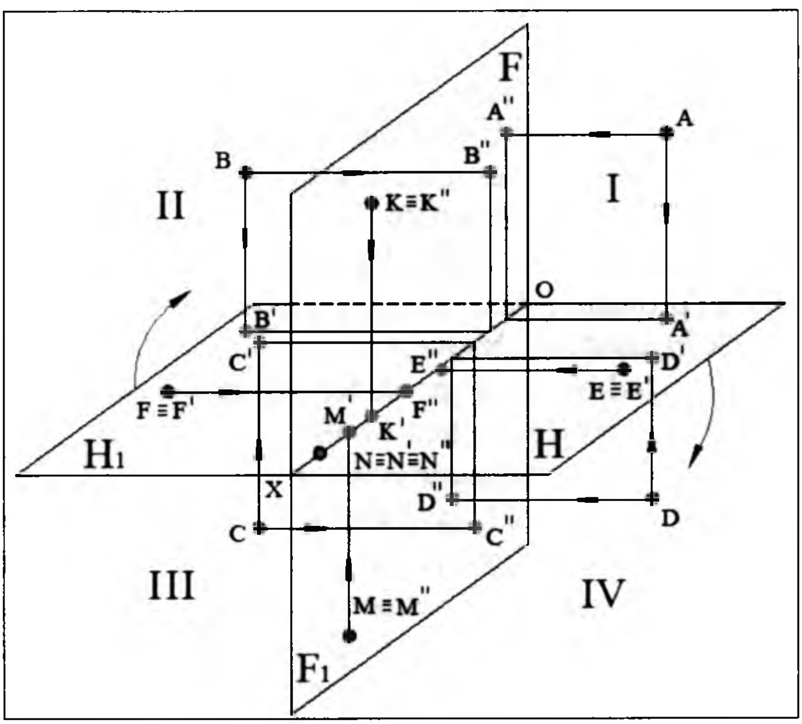


Fig. 3.7

2. The point is located in the II quarter.

If a point is located in the second quarter (point B), after the planes coincide, both projections will be above the **x**-axis.

3. The point is located in the III quarter.

If a point is located in the third quarter (point C), its horizontal projection after the planes coincide, is above the **x**-axis,and its frontal projection is below the **x**-axis.

4. The point is located in the IV quarter.

If a point is situated in the fourth quarter (point D), then its both projections will be below the x- axis.

Points M, K, F, and E are located on the projecting planes.

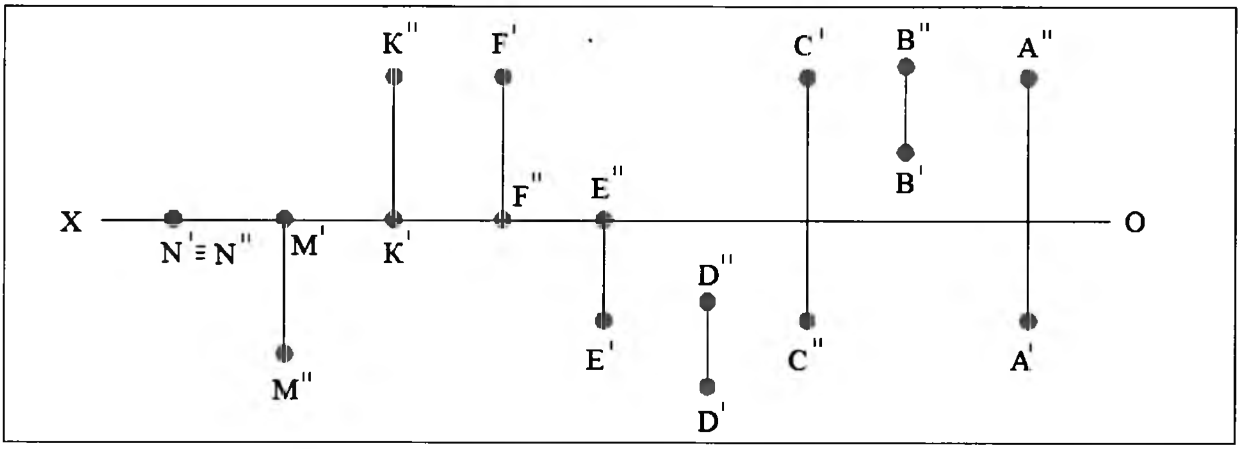


Fig. 3.8

5. The point is located on plane H.

If a point is located on the H(point E), the point coincides with its horizontal projection **E'**, frontal projection lies on the **x**-axis.

6. The point is located on plane H_1.

If a point is located on H_1 (point F), the point coincides with its horizontal projection **F'**, frontal projection lies on the **x**-axis.

7. The point is located on plane F.

If a point is located on the F(point K), the point coincides with its frontal projection **K''**, horizontal projection lies on the **x**-axis.

8. The point is located on plane F_1.

If a point is located on the F_1 (point M), the point coincides with its frontal projection **F''**, horizontal projection lies on the **x**-axis.

9. ***The point is located on the x-axis.***

If a point is located on the x-axis, its horizontal and frontal projections coincide with each other and are located on the **x**-axis.

OUTCOMES

- If the point is in one of the quarters of the space, then none of its projection lies on the x-axis.

-If the point is located on the plane of projection, one of the projections of this point lies on the x-axis;

- If the point is located on the x-axis, the two projections of this point also lie on the x-axis.

QUESTIONS AND ASSIGNMENTS TO CHAPTER III

1. What are the methods of projections?
2. What is the central projection?
3. What is the center of projection?
4. What is the plane of projection?
5. What is the parallel projection?
6. What is the difference between central and parallel projections?
7. Describe the method of orthogonal projection.
8. What is an orthographic projection of an object?
9. How are reference planes denoted?
10. What different types of planes do you know?
11. What is the principle plane of projection?
12. What is the horizontal plane of projection?
13. What is the frontal plane of projection?
14. What is the profile plane of projection?
15. What is the coordinate axis (the axis of projection)?
16. What is a plan?
17. What is the communication line?
18. What are four quadrants?
19. How many quadrants are planes H and F divided into?
20. What serves as a boundary between the following pairs of quadrants: II, III and IV, I and IV, II, III and I?
21. What quadrants are situated above the horizontal plane of projection, below the horizontal plane of projection, in front of the frontal plane of projection, behind the frontal plane of projection?
22. Does one projection of a point determine the position of that point in space?
23. How are the points of space usually denoted?
24. What is the position in space, in rotation to plane H of a point, the frontal projection of which is a) above the reference line Ox, and b) below it?
25. Does an orthographic drawing make any sense if the perpendiculars dropped from the projections of a point on the coordinate axis do not meet?
26. What is the meaning of the expression "Given: a point in space"?
27. How can the position of a point in space be found from its projections?
28. How do we designate the distance from a point of space to the horizontal plane of projection, to the frontal plane of projection?
29. What coordinate is determined on an orthographic representation by the horizontal projection of a point, by the frontal projection of a point?
30. What is the sequence of finding the profile projection of a point with its given horizontal and frontal projections?
31. How is the distance between a point and the planes of projection determined (if the orthographic projections of this point are given)?
32. How are the following projection planes: horizontal, frontal, profile designated?

33. What coordinates define the horizontal projection of a point, the frontal projection of a point, the profile projection of a point?
34. What determines the distance from a point in space to the profile plane on an orthographic drawing?
35. What is the position of a point if any of its two coordinates is equal to zero? (For instance, $x=0$, $z=0$)
36. What is the position of a point if any of its coordinates is equal to zero?
37. In which case is the point located in the I quarter?
38. In which case is the point located in the II quarter?
39. In which case is the point located in the III quarter?
40. In which case is the point located in the IV quarter?
41. In which case is the point located on plane H?
42. In which case is the point located on plane H_1?
43. In which case is the point located on plane F?
44. In which case is the point located on plane F_1?
45. In which case is the point located on the x-axis?
46. What is the Gaspard Monge's method?
47. What is the complex drawing?

CHAPTER IV
STRAIGHT LINE

4.1. Positions of Straight Lines Relative to Projection Planes

A straight line is the shortest distance between two points. A straight line is infinite; it may be defined by two points, or by a point and angles of inclination to the projection planes. In most cases, it is defined by a line segment, i.e. part of the line between two given points. In order to construct the projection line, we need to find the projection of its endpoints and connect them. The length of the projection of the line cannot be more than its true value. A straight line is read as it is indicated in space, for example **AB** is indicated on the complex drawing as **(A' B', A'' B'', A'''B''')**.

With regard to the plane of projection, a straight line can take an oblique position (general position) and special positions (be perpendicular and parallel to the planes of the projections). Let's consider these positions.

1. **An oblique line** is inclined to all three planes of projection, or this line is not parallel to any of the planes of projection. (Fig.4.1)

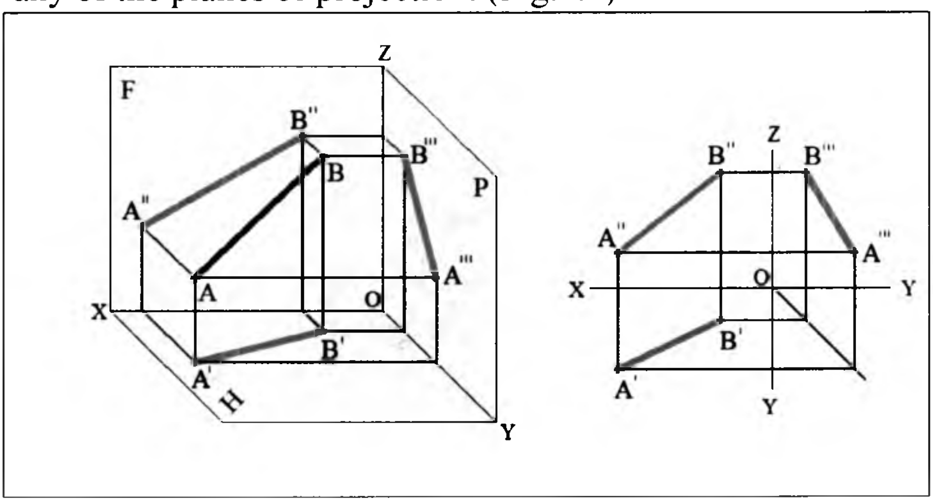


Fig. 4.1

Figure 4.1 shows line AB represented orthographically. It is specified orthographically by the projections of two points: A and B. By connecting line projections of these points with straight lines, we get the projections of the line-segment.

It is seen that all three projections of the line are inclined to the reference lines, i.e. to the x, y and z axes. Each of the projections - **A' B', A'' B'', A''' B'''** - is shorter than AB itself in space.

2. A horizontal line.

A straight line parallel to the horizontal plane of projection H is called ***a horizontal line*** or simply ***a horizontal*** (Fig. 4.2). All points of a horizontal is at the same distance from plane H, the frontal projection of a horizontal is parallel to the reference line x-axis. The profile projection is parallel to the y-axis.

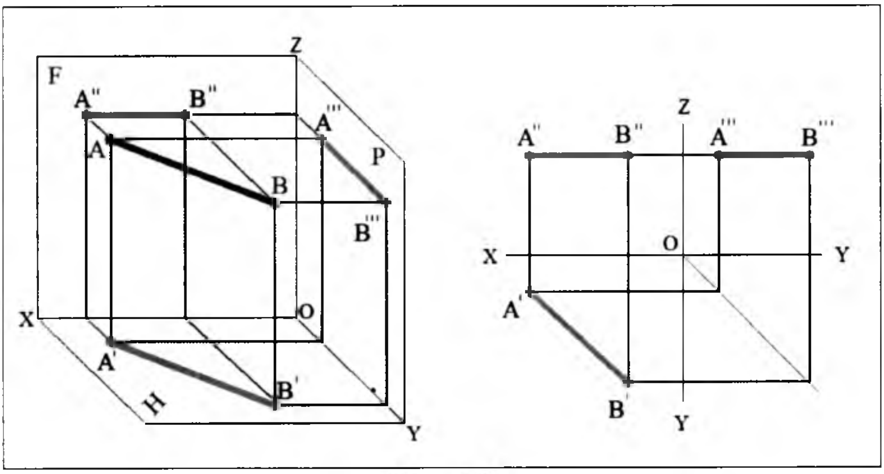


Fig. 4.2

The horizontal projection of the horizontal line gives its true length, i.e. | A' B' | = | AB | .

3. A frontal line.

A line parallel to the frontal plane of projection F is called ***a frontal line*** or simply ***a frontal*** (Fig. 4.3). All points of a frontal at at the same distance from plane F. The horizontal projection of the frontal is parallel to the x-axis.

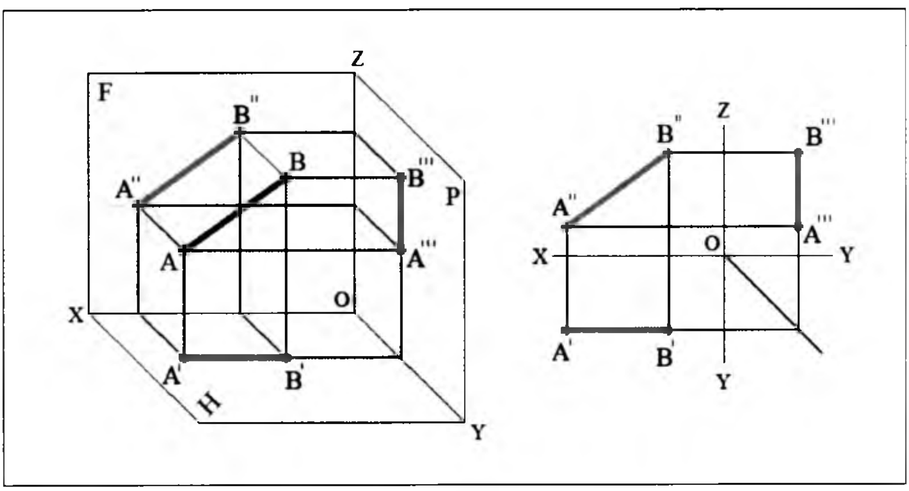


Fig. 4.3

The profile projection is parallel to the z-axis, and the frontal projection is equal in length to the projected frontal | A'' B'' | = | AB | .

4. A profile line.

A line parallel to the profile plane of projection P is called ***a profile line*** or simple ***a profile*** (Fig. 4.4).

All points of a profile line are at the same distance from plane P. The horizontal and the frontal projections of the profile line are perpendicular to the x-axis, and the length of the profile projection is the true length of the line in space: | A''' B''' | = | AB |

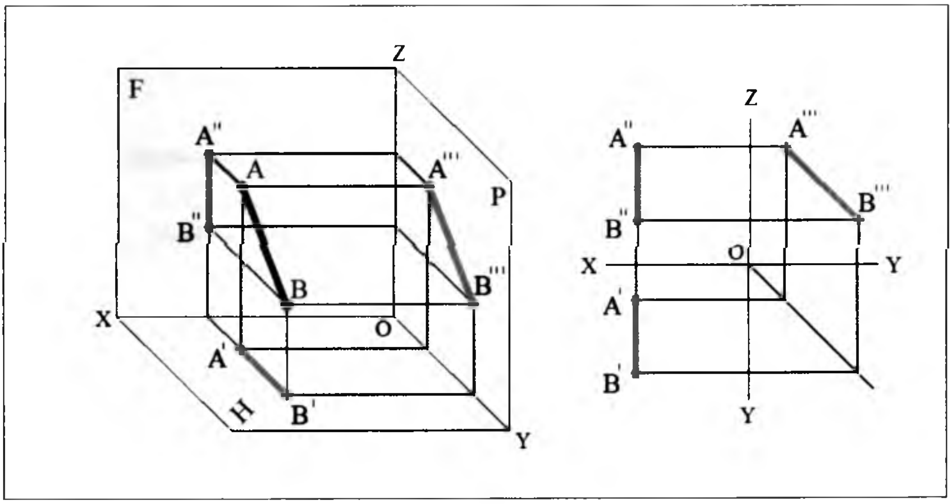


Fig. 4.4

In a complex drawing, frontal and horizontal projections of the profile line are perpendicular to the x-axis.

5. A horizontal-projecting straight line

When a line is perpendicular to one reference plane, it will be parallel to the other one. A straight line perpendicular to the horizontal plane of projection is called horizontal-projecting straight line.

The horizontal projection AB coincides in the point A' ≡ B' (Fig. 4.5).

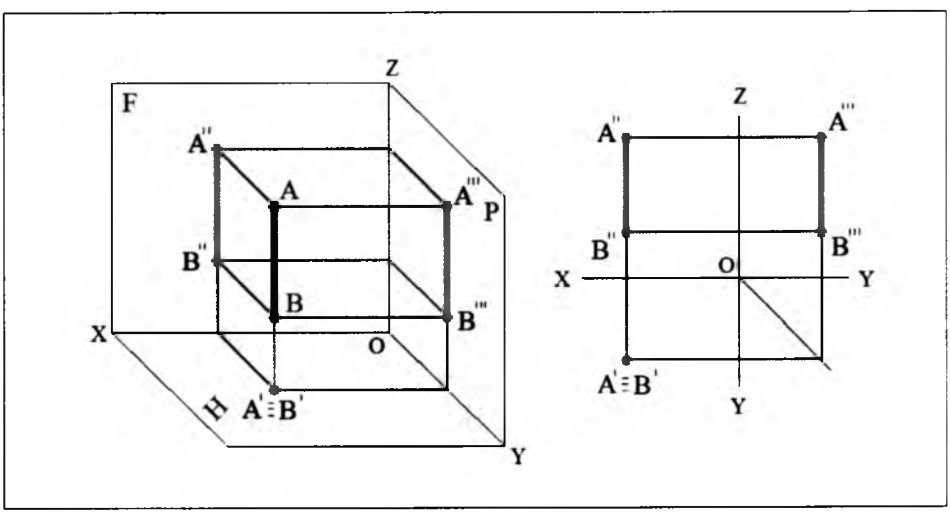


Fig. 4.5

Its frontal projection A" B" is equal to AB and perpendicular to the x-axis, the profile projection A'"B'" is equal to AB and perpendicular to the y-axis.

6. A frontal-projecting straight line

A straight line perpendicular to the frontal plane of projection is called frontal-projecting straight line. The frontal projection AB coincides at point A" = B"(Fig. 4.6).

Its horizontal projection A' B' is equal to AB and perpendicular to the x-axis, the profile projection A'"B'" is equal to AB and perpendicular to the z-axis.

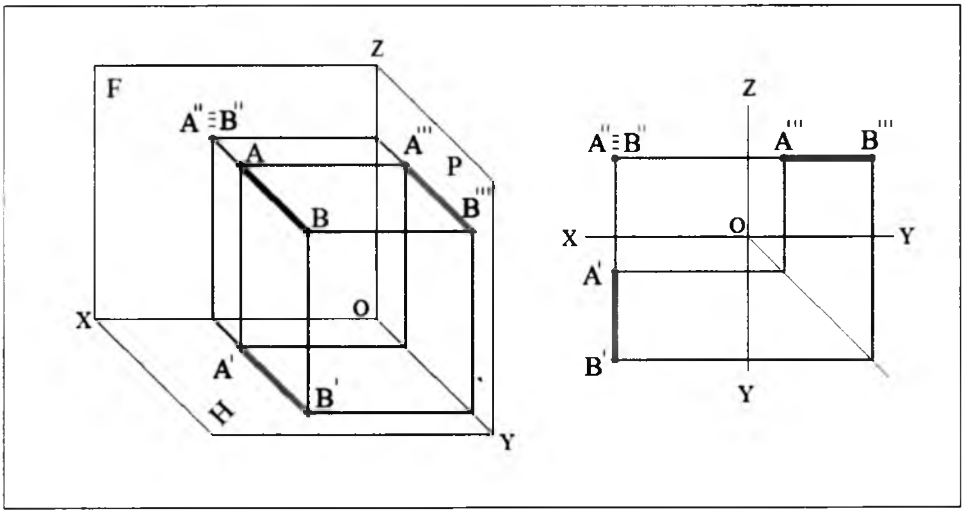


Fig.4.6

7. A profile-projecting straight line

A straight line perpendicular to the profile plane of projection is called profile-projecting straight line. The profile projection AB coincides at point A" B" (Fig. 4.7).

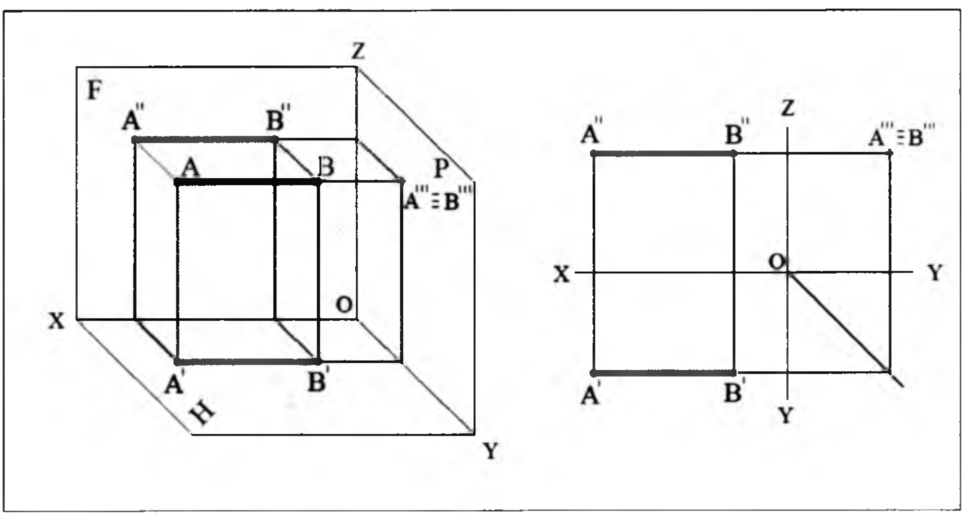


Fig. 4.7

Its horizontal A' B' and frontal A"B" projections are equal to AB and parallel to the x-axis. The profile projection AB coincides at point A''' = B''' (Fig. 4.7).

4.2. Relative Position of Points and Lines

If a point in space lies on a straight line, the projections of that point also lie on the corresponding projections of the straight line.

To illustrate it let the line given there be line m, its projections m' and m"; and point A is on line m (Fig.4.8).

Figure 4.8 shows that a horizontal projection of point (A') is located on the horizontal projection of line m', a frontal projection of point (A") is located on the horizontal projection of line m".

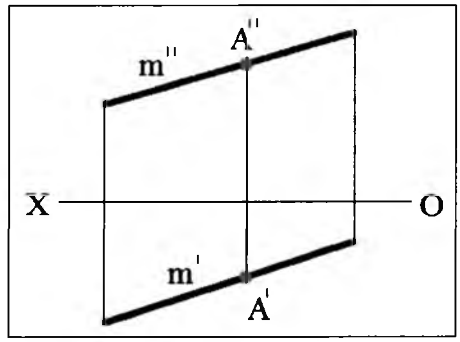


Fig. 4.8

4.3. True Length of Straight Line Segment. Method of Right Triangle

Method of right triangle is used to determine the true length of straight line segment.

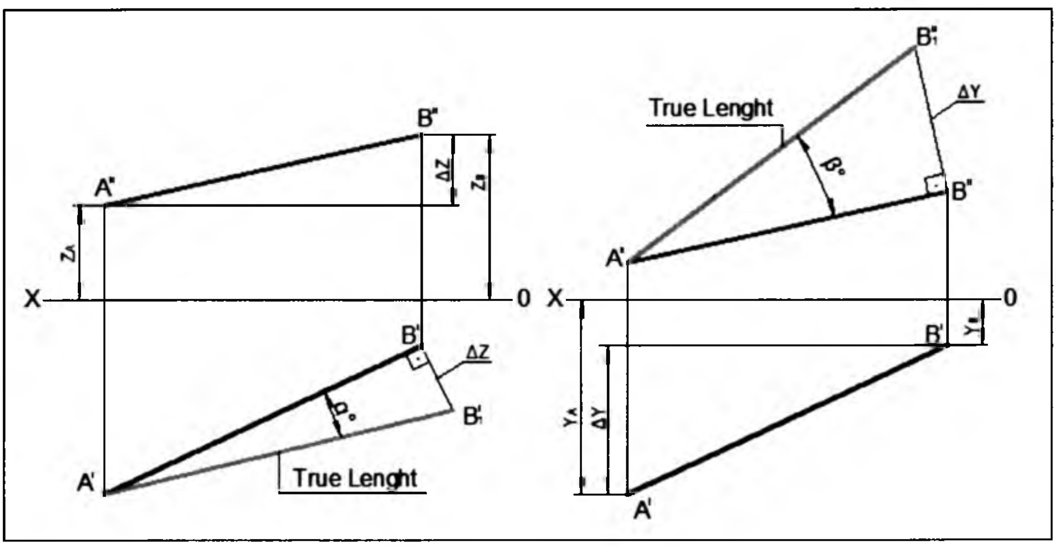


Fig. 4.9

Let's determine the true length of straight line segment AB (Fig. 4.9). We find the length of the remote end of this line segment from plane H - Z_A and Z_B segments. After that, we find the difference between these segments: $\Delta Z = Z_B - Z_A$. From point B' we draw the perpendicular to line A' B', and here postpone segment ΔZ. Points B_1 we connect to point A'.

Straight line segment $A'B_1'$ is the hypotenuse of the triangle $A'B'B_1'$. Its length is equal to the length of the line segment AB, and the angle α is the angle between line AB and plane F.

Thus the true length of line in the orthographic drawing is constructed as the hypotenuse of right triangle, one side of which is equal in length to one of the projections of the line and the second side of which is equal to the difference between the distance of the extreme points of the line from the plane of projection.

4.4. Traces of Line

The trace of line is the point in which the line intersects a projection plane. In the general case the line may intersect all three planes of projection and have three traces: the horizontal trace - H (H', H", H'"), the point of intersection of the line with the H plane, the frontal trace -F (F', F", F'"), the point of intersection of the line with the F plane, and the profile trace - P (P', P", P'"), which is the intersection with the P plane.

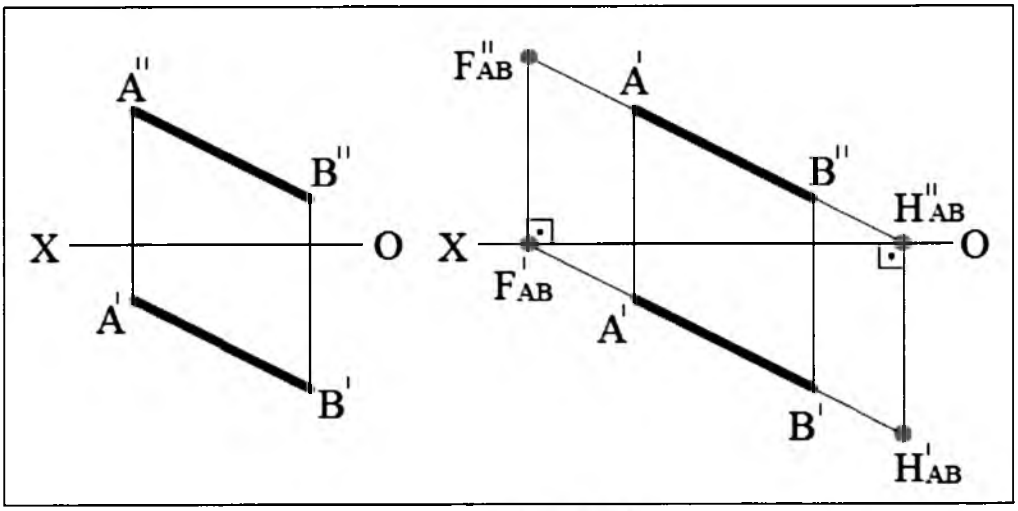


Fig. 4.10

In Figure 4.10, an oblique line segment AB is shown in a system of two planes of projection and let us find its horizontal and frontal traces. These traces are defined as points in which a line intersects its projections.

The foregoing peculiarities in the positions of projections of traces permit to formulate the following rules for an orthographic construction of traces:

1. To construct the horizontal trace H of a line, prolong the frontal projection A"B" to intersection with the x-axis. The obtained point H''_{AB} is the frontal projection of the required trace H. Through point H''_{AB} erect a perpendicular to the x-axis. Prolong the horizontal projection A'B' of the line segment AB to intersect the perpendicular from point H'_{AB}.

2. To construct the frontal trace F of a line, prolong its horizontal projection to intersection with the x-axis. The obtained point F'_{AB} is the horizontal projection of the required trace F. Through point F' erect a perpendicular to the x-axis. Prolong the frontal projection A"B" of the line segment AB to intersect the perpendicular from point F''_{AB}.

The horizontal and vertical traces of a line in a system of three planes of projection will be determined by the same rules as those given above. The only added requirement will indicate the profile projections of these points.

4.5. Relative Positions of Two Straight Lines

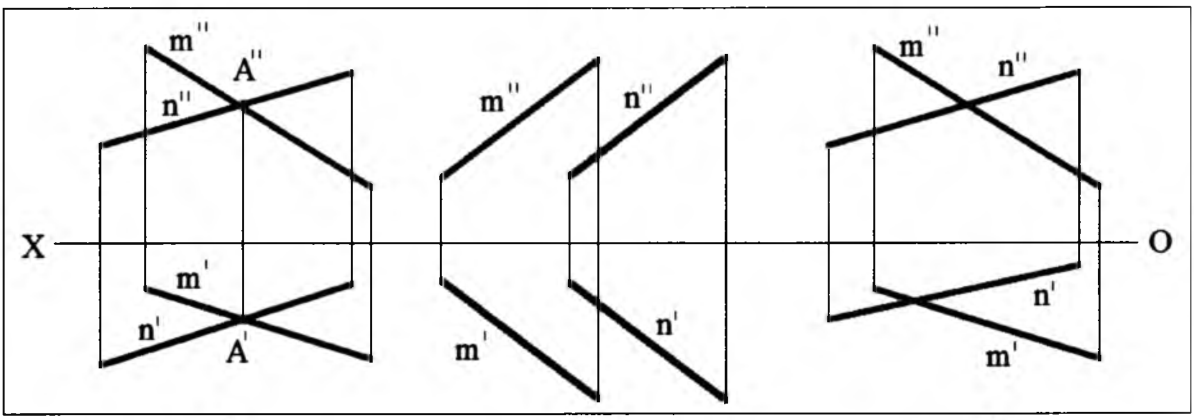
Two straight lines may occupy the following relative positions in space:

1) They may be in parallel;
2) They may intersect;
3) Non intersect (skew lines).

1. Parallel straight lines

The corresponding projections of parallel lines are in parallel to each other (Fig. 4.11, b).

If through the given parallel lines m and n projecting planes pass, they are in parallel and their intersections with the planes of projection give two parallel lines.



a) b) c)

Fig 4.11

2. Intersecting straight lines

In this case the lines have a common point, the projections of which are A' and A" lying on a single perpendicular to the x-axis (Fig.4.11, a). Thus, if lines intersect, the points of intersection of their line projections must lie on a single perpendicular to the coordinate axis.

3. Non-intersecting or skew straight lines

If the lines do not intersect and are not parallel to each other, then the points of intersection of their similar projections do not lie on a single perpendicular to the axis (Fig. 4.11, c).

QUESTIONS AND ASSIGNMENTS TO CHAPTER IV

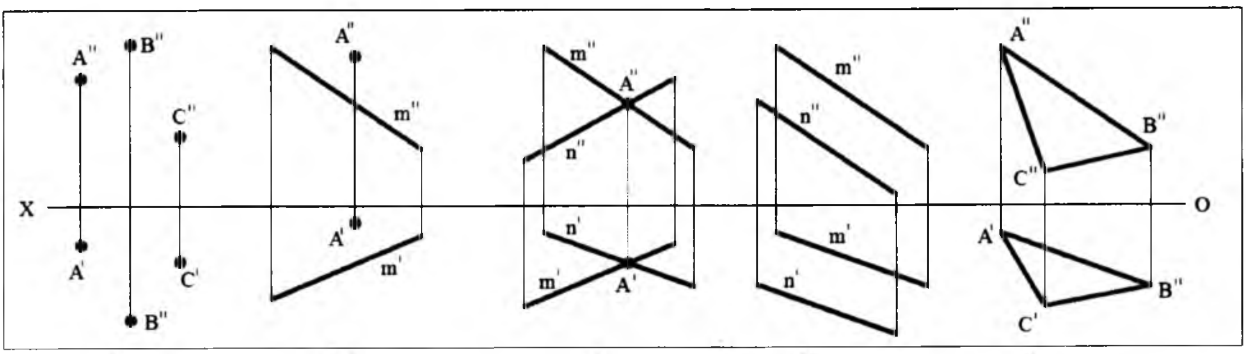
1. What is a straight line?
2. What is an oblique line?
3. What is a horizontal line?
4. What is a frontal line?
5. What is a profile line?
6. What is a horizontal-projecting straight line?

7. What is a frontal-projecting straight line?
8. What is a profile-projecting straight line?
9. When is the projection of a straight line equal to its true length?
10. When does a straight line become a point?
11. How many projections of a line are required to determine its position in space? Why is one projection insufficient for this purpose?
12. How are the projections of a horizontal line located?
13. How are the projections of a frontal located? How are the projections of a profile located?
14. The straight line is on the frontal plane of a projection. How are its frontal, horizontal and profile projections located?
15. The straight line is on the horizontal plane of a projection. How are its frontal, horizontal and profile projections located?
16. The straight line is on the profile plane of a projection. How are its frontal, horizontal and profile projections located?
17. What is the position of a line if its two principal projections are located on the reference axis?
18. How is the true length of a line determined by means of the right triangle method?
19. How can a line given on the orthographic drawing by two projections be divided in the ratio m:n?
20. In which case does a point in space lie on a straight line? Show it on complex drawing.
21. Define method of right triangle.
22. What is a trace of a straight line and how are projections of traces constructed on an orthographic drawing with the projections of a given straight line?
23. How are the horizontal and frontal traces of a line constructed?
24. Give the definitions of parallel, intersecting and skew lines.
25. How are two parallel lines shown on the orthographic drawing?
26. How are two intersecting lines shown on the orthographic drawing?
27. How are two non-intersecting (or skew) lines shown on the orthographic drawing?
28. Draw 45^0 inclined lines, show its true length.
29. Draw 60^0 inclined lines, show its true length.
30 Draw 30^0 inclined lines, show its true length.

CHAPTER V
PLANE

5.1. Ways of Plane Representation on Drawing

The position of a plane in space may be determined by:
1) Three points not lying on a straight line (Fig. 5.1, a);
2) A straight line and a point not lying on the line (Fig. 5.1, b);
3) Two intersecting lines (Fig. 5.1, c);
4) Two parallel lines (Fig. 5.1, d);
5) A triangle or any other plane geometrical figure (Fig. 5.1, e);
6) Traces (Fig. 5.2).



a) b) c) d) e)

Fig. 5.1

5.2. Traces of Plane

The traces of a plane are lines along which the given plane intersects the planes of projection. An oblique plane (not perpendicular to any of the projection planes) has three traces: horizontal, frontal and profile.

When solving problems of descriptive geometry it is often convenient to judge the position of plane relative to the projection planes from its traces.

The planes in space are designated by the letters α, β, γ.., and the traces, by the same letters with the subscript H for the horizontal trace α_H , β_H , γ_H ..., the subscript F for the frontal trace α_f , β_f , γ_f ..., and the subscript P for the profile trace α_P , β_P , γ_P.

The oblique plane P is shown in Figure 5.2.

The traces α_H α_f α_P intersect in pairs on the axis at points α_x α_y and α_z, which are called vanishing points(or the points of convergence of the traces)

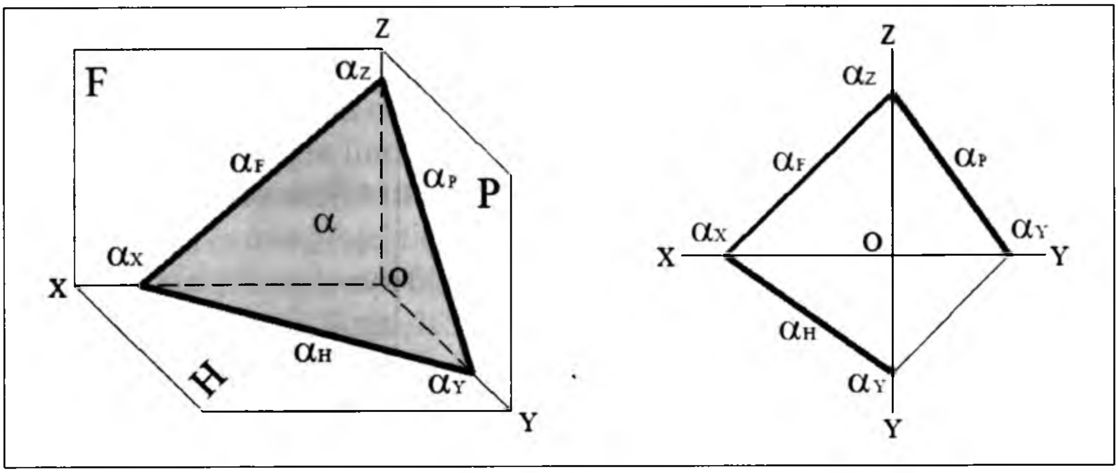


Fig. 5.2

Each of the traces of the plane coincides with its similar projection, and the other two (different projections) lie on the axis. For example, a horizontal trace of the plane coincides with its horizontal projection, but its frontal projection lies on the x-axis and its profile projection lies on the y-axis.

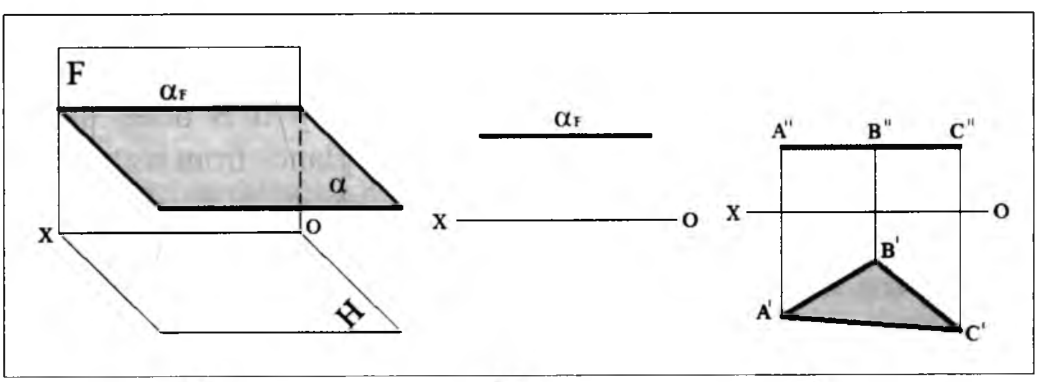
5.3. Various Plane Positions Relative to Projection Planes

With regard to the plane of projection, plane can be parallel (level plane), perpendicular (projecting plane), and at an angle (plane of general position).

1. A horizontal plane

The plane, which is parallel to the horizontal plane of projection H is called a horizontal plane (Fig. 5.3).

The horizontal plane is perpendicular to the frontal and the profile planes of projection.



a) b) c)

Fig. 5.3

Figure 5.3, b shows a complex drawing of a horizontal plane in traces. As it is seen from the drawing, a frontal trace of horizontal plane is parallel to the x-axis and this plane has no horizontal trace.

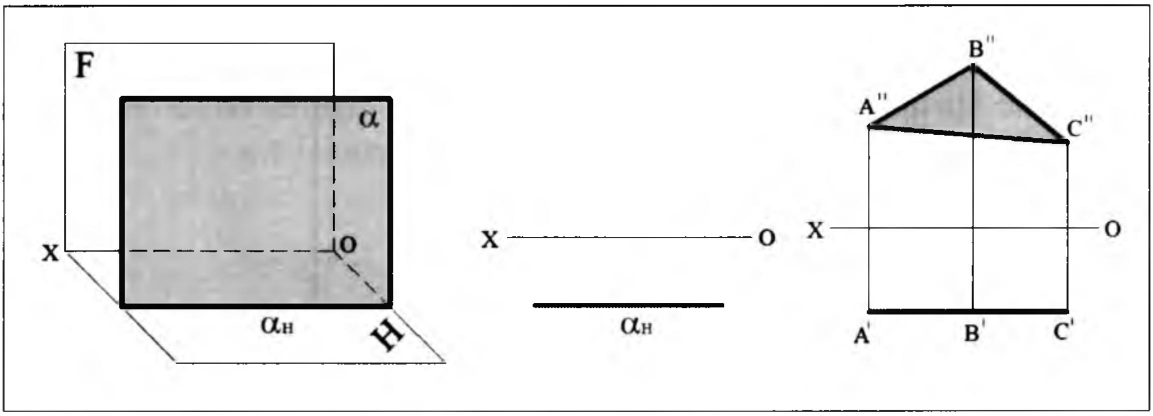
Figure 5.3, c shows a horizontal plane in a triangle ABC. This triangle which is projected on plane F, will be in its true size, but its frontal projection is a straight line, parallel to the x-axis.

Frontal trace of the horizontal plane possesses collecting properties.

2. *A frontal plane*

The plane, which is parallel to the horizontal plane of projection F is called a horizontal plane (Fig. 5.4).

The frontal plane is perpendicular to the horizontal and the profile planes of projection.



a) b) c)

Fig. 5.4

Figure 5.4, b shows a complex drawing of a frontal plane in traces. As it is seen from the drawing, a horizontal trace of frontal plane is parallel to the x-axis and this plane has no frontal trace.

Figure 5.3, c shows a frontal plane in a triangle ABC. This triangle is projected on plane F in its true length, and its horizontal projection is the straight line parallel to the x-axis.

Horizontal trace of the frontal plane possesses collecting properties.

3. A profile plane

The plane, which is parallel to the profile plane of projection P is called a profile plane (Fig. 5.5).

The horizontal and frontal traces of profile plane are perpendicular to the x-axis.

This plane has no profile trace. Its both traces possess collecting properties. The profile projection of this figure will be of true size.

4. A horizontal projecting plane

The plane, which is perpendicular to the horizontal plane of projection H is called a horizontal projecting plane (Fig. 5.6).

The distinguishing feature of this plane in an orthographic representation is the perpendicularity of the frontal trace α_f to the x-axis .The angle between α_f and x-axis will be a right angle, because α_f is a line of intersection of two planes that are perpendicular to H.

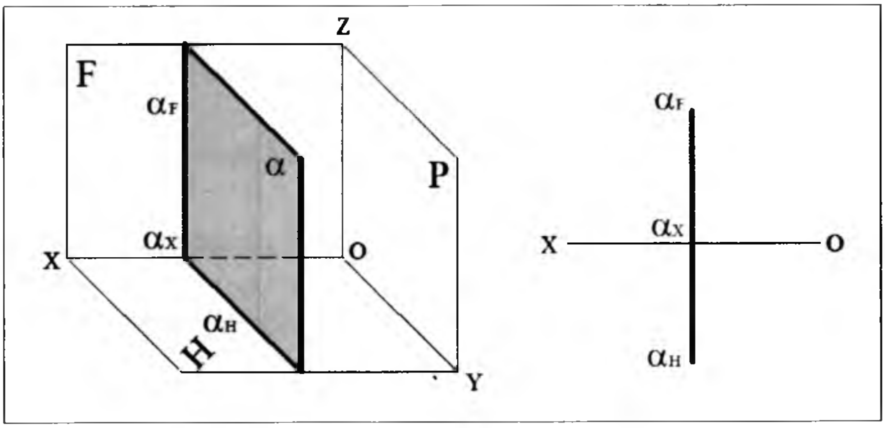


Fig. 5.5

The horizontal projections of all points and figures lying on this plane will coincide with the horizontal trace α_H . Its horizontal trace possesses collecting properties.

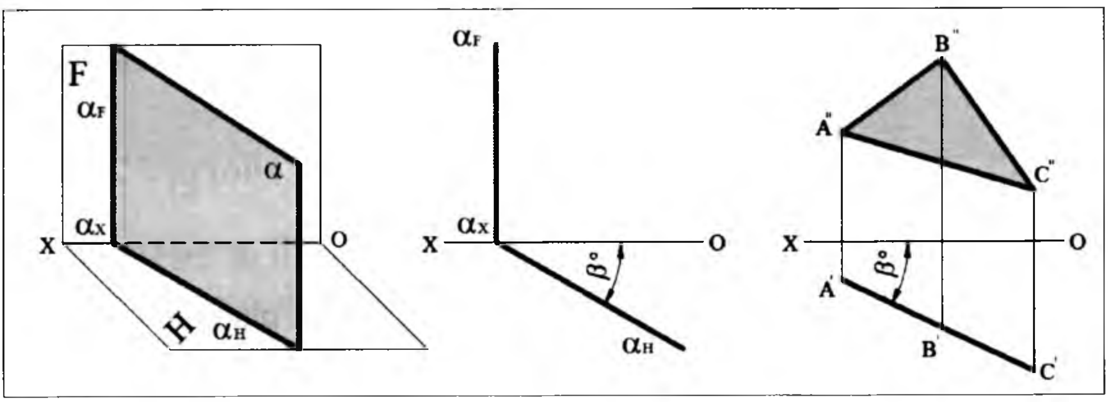


Fig. 5.6

5. A frontal projecting plane

The plane, which is perpendicular to the frontal plane of projection F is called a frontal projecting plane (Fig. 5.7).

The distinguishing feature of this plane in an orthographic representation is the perpendicularity of the horizontal trace α_H to the x-axis .The angle between α_H and x-axis will be a right angle, because α_H is a line of intersection of two planes perpendicular to F.

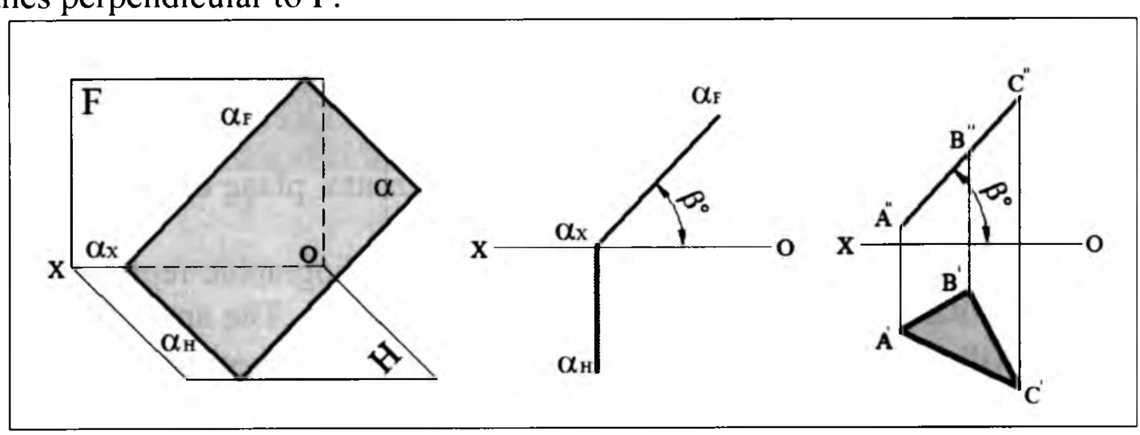


Fig. 5.7

The frontal projections of all points and figures lying on this plane will coincide with the horizontal trace α_F . Its frontal trace possesses collecting properties.

6. A profile projecting plane

The plane, which is perpendicular to the profile plane of projection P is called a profile projecting plane (Fig. 5.8).

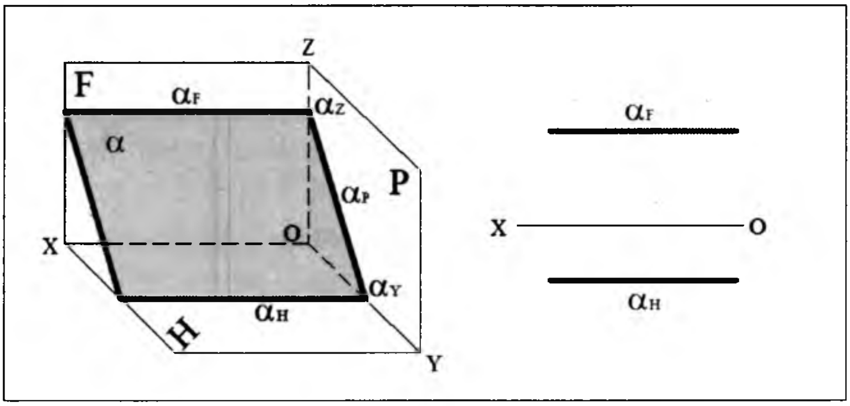


Fig. 5.8

Its profile trace α_P possesses collecting properties, horizontal and frontal traces are parallel to the x-axis.

7. An oblique plane

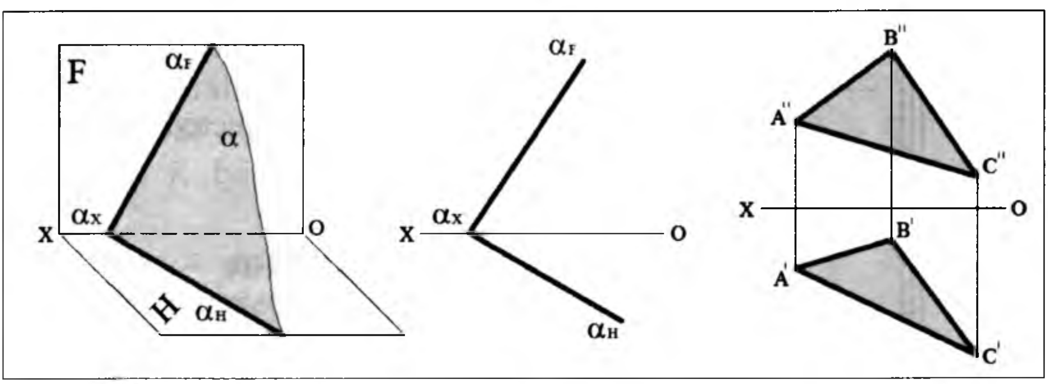


Fig. 5.9

An oblique plane is inclined to all three planes of projection; this plane is not parallel to any of the planes of projection (Fig. 5.9).

5.4. Principal Lines of Plane.

The straight lines lying on a given plane and parallel to the planes of projections are called the principal lines of that plane.

1. The horizontal of a plane

A straight line lying in a given plane and parallel to the horizontal plane of projection H is called the horizontal of that plane (Fig.5.10).

A horizontal of a plane, as any horizontal in space, is projected on the frontal plane of projection F as a line parallel to the x-axis.

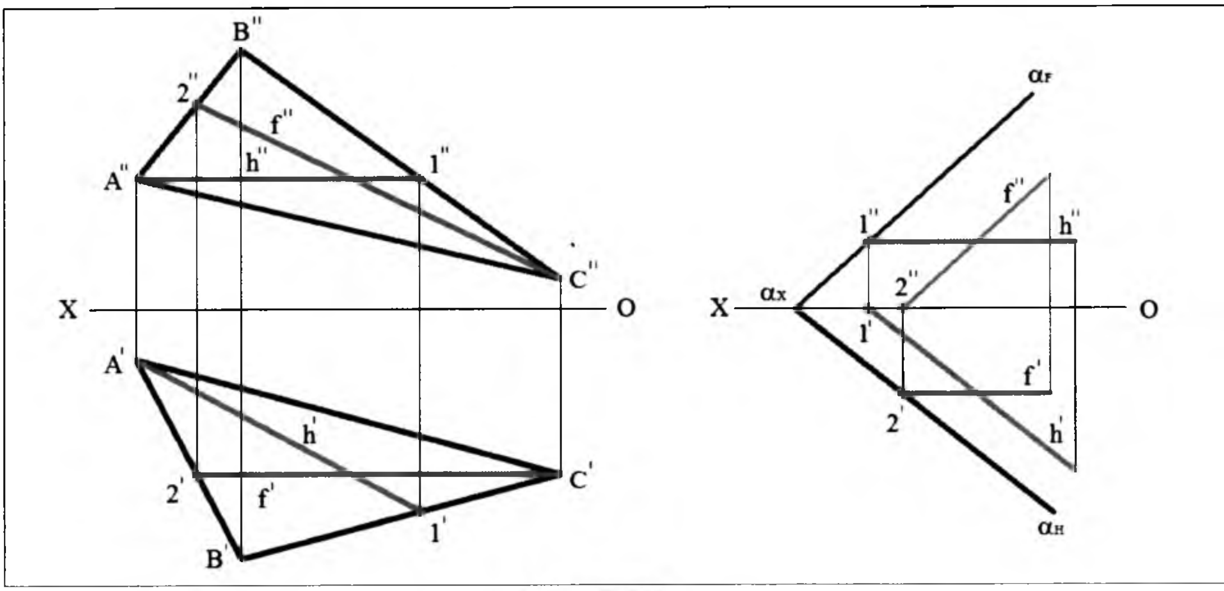


Fig. 5.10

If the plane is given by its traces (Fig. 5.10, b), the construction of a horizontal lying in it may also start with drawing of the horizontal projection of the horizontal. Since the horizontal projection of the horizontal of a plane is parallel to the horizontal trace of that plane.

2. The frontal of a plane

A straight line, lying on a given plane and parallel to the frontal plane of projection F is called the frontal of that plane (Fig. 5.10).

A frontal of a plane as any frontal in space is projected onto the horizontal plane of projection H as a line parallel to the x-axis.

5.5. Lines on the Given Plane

The elements determining a plane are sufficient to allow straight lines and point contained on the plane to be constructed.

As it is known from geometry, a straight line is contained on plane if two points of the line lie on that plane.

A point lying on the plane is located on the straight line contained on that plane. Hence, to construct the projections of the point, first it is necessary to construct the projections of the straight line and then, on its projections to mark the projections of the point. The projections of the point must lie on the line projections of the straight line.

For instance, if the plane is given on the orthographic drawing by triangle ABC (Fig. 5.11), it is possible to construct the projections of any line, such as m, lying on the given plane. Take two points 1 and 2 on the sides AB and BC of the triangle. Each projection of the points 1 and 2 must belong to the corresponding projections of the lines AB and CD. Joining the similar projections of these points (1 and 2), we have the projections 1'2' and 1"2" of line 12. The constructed line belongs to the given plane since they have two points in common.

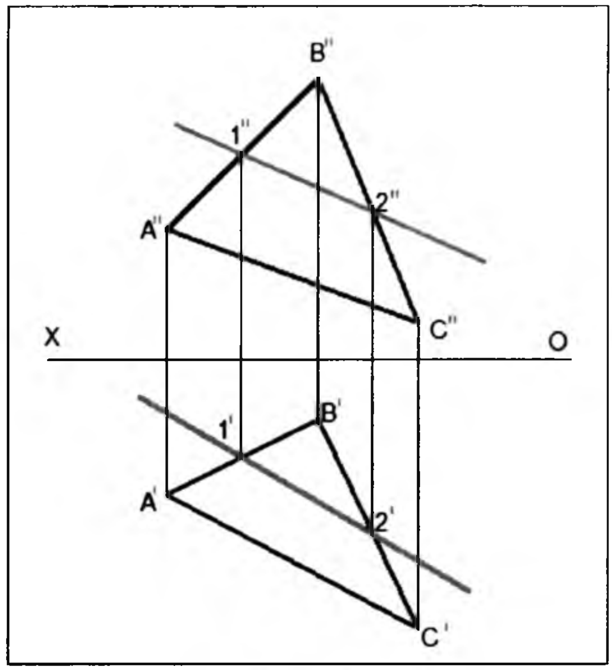


Fig. 5.11

5.6. Points on the Given Plane

The construction of points contained on the given plane may be reduced in general to drawing an auxiliary line passing through a point and lying on a plane.

For instance, if the plane is determined by the parallel lines AB and CD (Fig. 5.12) in order to construct a point K lying on the given plane.

First, we draw a straight line through point K intersecting the straight lines AB and CD. This line must be parallel to the x-axis. Next, with the help of projecting lines passing through points 1" and 2" the points 1and 2 are determined as shown by arrows.

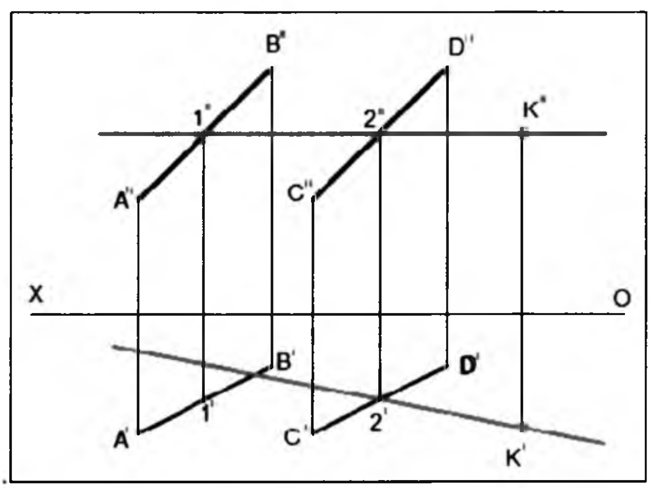


Fig. 5.12

Through points **e** and **f** the horizontal projection 1'2' of the auxiliary line 12 is drawn. Line 12 lies on the given plane since they have two points in common.

Taking an arbitrary point K on line 12, we determine its projections on the similar projections of that line.

Point K lies on the given plane since the point is situated on the straight line contained on that plane.

QUESTIONS AND ASSIGNMENTS TO CHAPTER V

1. How many positions of plane in space do you know? List them.
2. How can a plane in space be determined?
3. Name the methods of specifying a plane on a drawing.
4. What is a trace of a plane?
5. What is meant by the term "an oblique plane"?
6. How many traces does an oblique plane have on three plane systems of projection? List these traces.
7. What is meant by the term "a projecting plane"?
8. What is meant by the term "a horizontal projecting plane"?
9. What is meant by the term "a frontal projecting plane"?
10. What is meant by the term "a profile projecting plane"?
11. What is meant by the term "principal lines of plane"?
12. Define the position of the projections of the horizontal line lying on the given plane.
13. Define the position of the projections of the frontal and profile line lying on the given plane.
14. Define the position of the projections of profile line lying on the given plane.
15. What is the necessary condition for locating of straight line on the given plane?
16. What is the necessary condition for locating of point on the given plane?
17. How is the point lying on the plane constructed?
18. How can it be checked whether a point is contained on plane?
19. What is the necessary condition for line given by its traces to be located on the plane given by the traces of that plane?
20. How are the traces of the plane constructed when it is given by two intersecting lines?
21. How are the traces of the plane constructed when it is given by two intersecting lines in case one of two lines is parallel to the x-axis?

CHAPTER VI
TWO PLANES. LINE AND PLANE

6.1. Relative Positions of Two Planes

Two planes in space may be either mutually parallel or intersecting.

1. Parallel planes

Two planes are parallel, if two intersecting lines of one plane are parallel to two intersecting lines of the other (Fig. 6.1). We know that two parallel planes intersect a third one along parallel lines. Thus, similar traces of parallel planes are parallel.

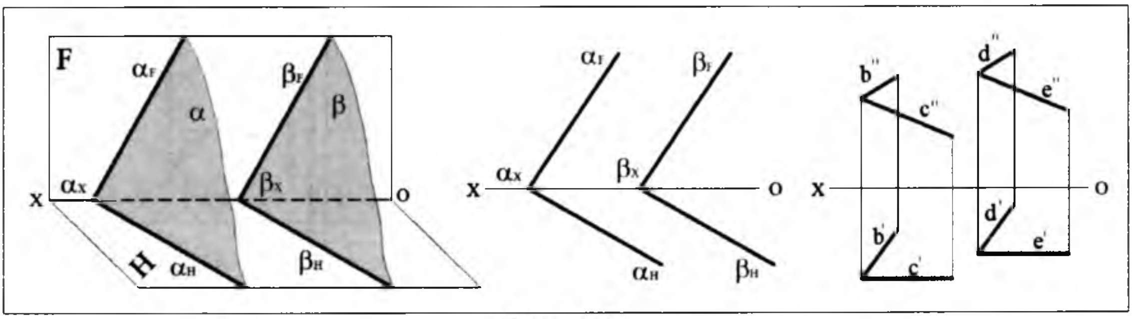


Fig. 6.1

2. Intersecting planes

The line of intersection of two planes is a straight line. To find the line of intersecting of two planes, two points or a point and the direction have to be known.

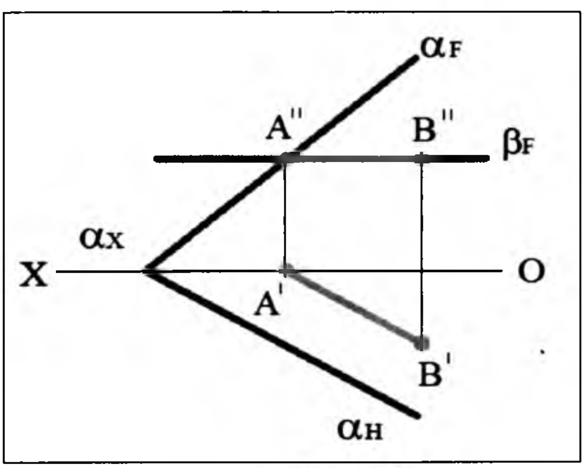


Fig. 6.2

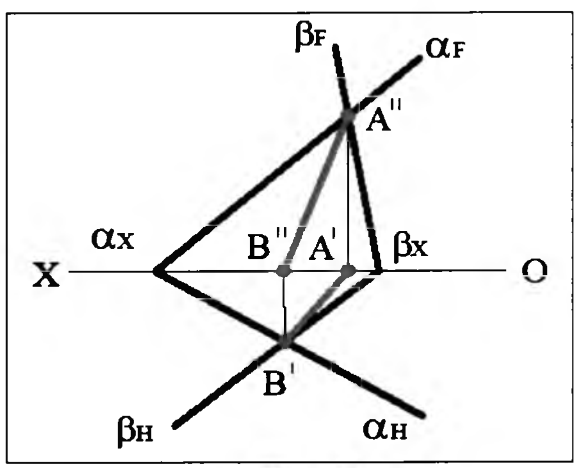


Fig. 6.3

Let's first consider a particular case of intersecting planes when one of them is parallel to the plane of projection. Figure 6.2 shows how to find intersecting line of oblique and frontal planes (Fig.6.2).

By intersecting two oblique planes, we find the points of intersection of the same mentioned traces (Fig.6.3).

By joining these points, we obtain the projections of intersection line of the given planes.

Attention should be paid to a particular case of intersection of two oblique planes when two corresponding traces of the planes are parallel.

The intersection line of planes α and β - AB is parallel to the horizontal traces of the given planes (Fig. 6.4).

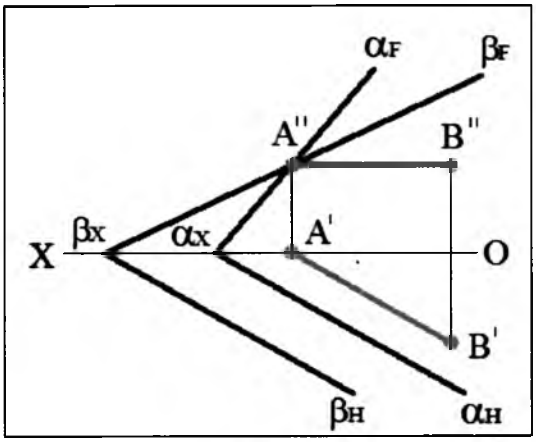


Fig.6.4

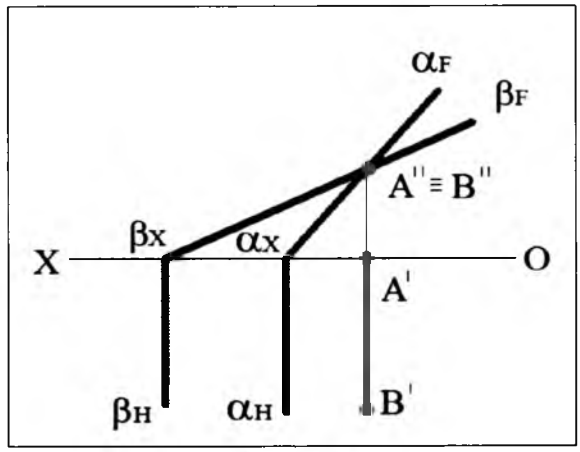


Fig.6.5

Similarly, if the frontal traces of two intersecting planes are parallel, the line of intersection is the frontal common to both planes and if the profile traces of the planes are parallel, the line of intersection is profile line common to the planes.

Another particular case is intersection of two horizontal (or frontal) projecting planes when two corresponding traces of the plane are parallel (Fig. 6.5).

α and β – are two frontal projecting intersecting planes. Front traces of these planes α_F and β_F intersect at point A'. Horizontal traces α_H and β_H are parallel to each other, so the horizontal projection of the line of intersection of the planes will be parallel to these traces. Thus, the line of intersection of the planes will be frontal projecting straight line AB.

6.2. Method of Auxiliary Section Planes

In some cases, the definition of projection line of intersection of two planes by conventional methods is not possible. In this case we can use the auxiliary planes. Figure 6.6,a shows two oblique planes, given by their traces. Let's define the line of intersection of these planes, using the method of auxiliary section planes.

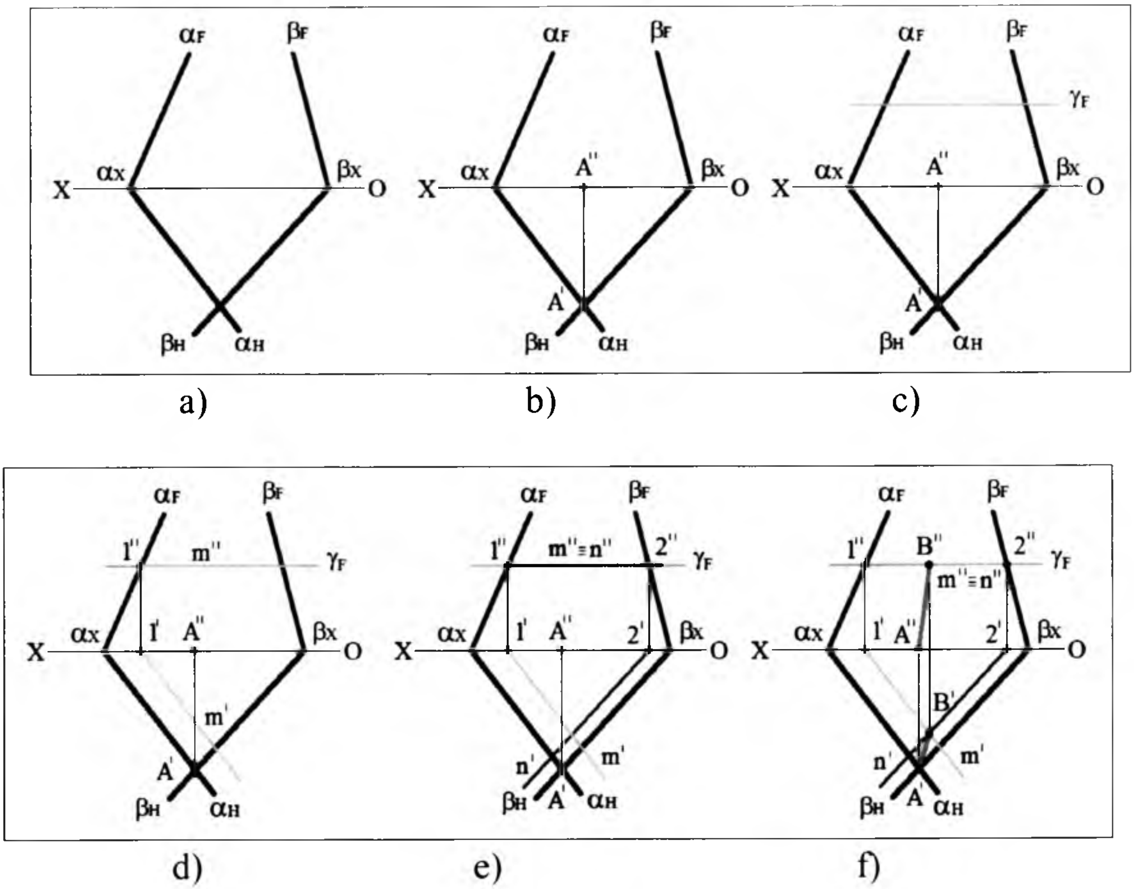


Fig. 6.6

Horizontal traces of planes α and β intersect at point A' (Fig. 6.6, b). Frontal traces don't intersect in this size of drawing. So we draw auxiliary horizontal section plane γ (Fig. 6.6, c). Then we draw a consistent projection of the intersection lines of planes α and γ (Fig. 6.6, d) and β and γ (Fig. 6.6, e); lines m (m', m'') and n (n', n''). We find the points of intersection of these lines - points B' and B'' (Fig. 6.6, f).

AB is the intersection line of planes α and β.

6.3. Line cutting Plane.

The problem of this section is one of the basic problems of descriptive geometry.

A line cutting a plane gives a point. Projecting planes are used as auxiliary planes because of the simplicity with which these planes, passing through straight line may be shown on the drawing, due to the collecting properties of the traces of such planes.

The solution of problems on the intersection of line and plane involves three stages:

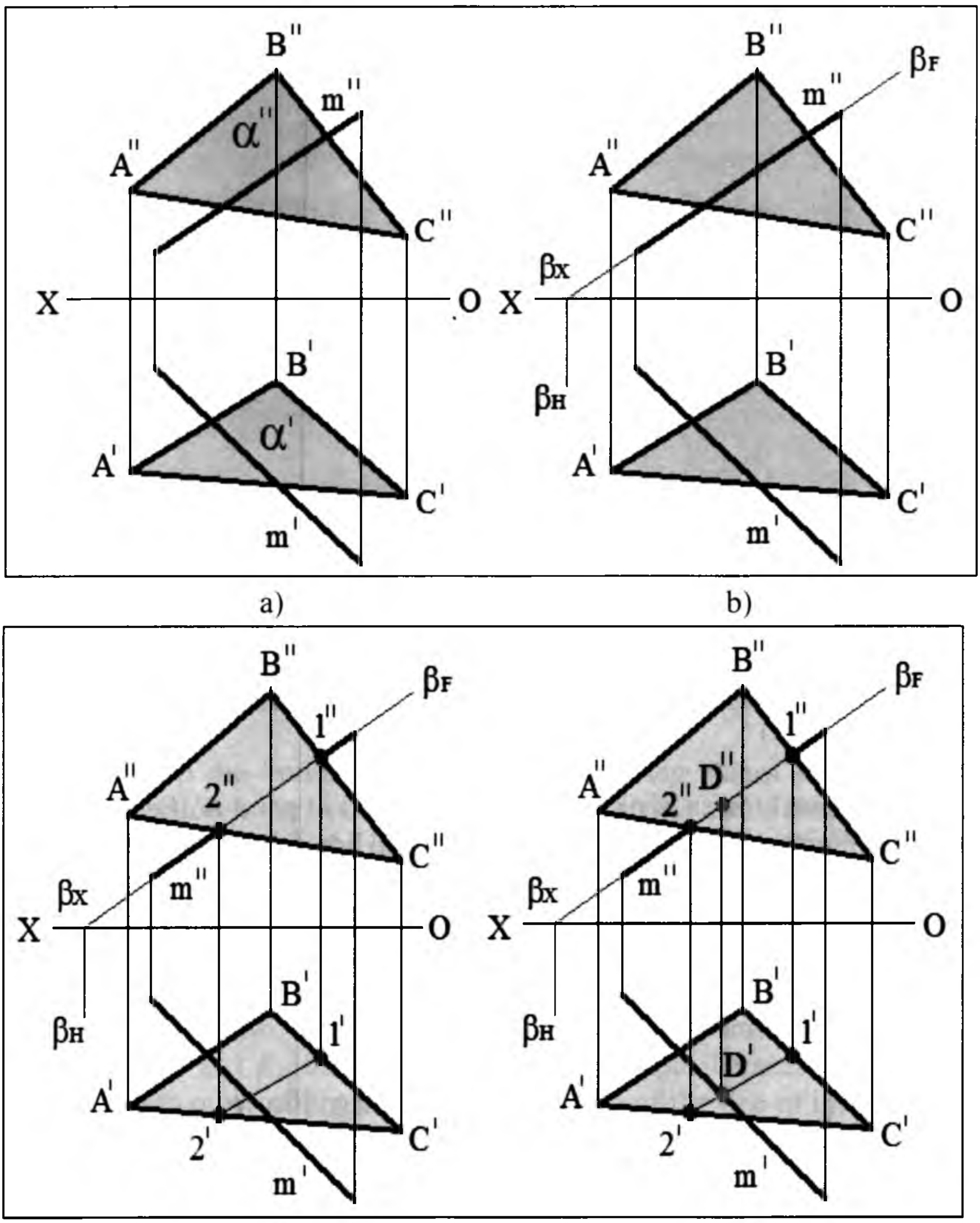


Fig. 6.7

1. We draw the auxiliary projecting plane (in certain cases the level plane) through the given straight line m. (Fig. 6.7, b).

2. We find the intersecting line12 of two planes - α and β (Fig. 6.7, c).

3. Finally, point D will be the point of intersection of the given line m with the constructed line 12 (Fig. 6.7, d).

Figure 6.8 shows how to construct intersection line of oblique plane given by traces with the straight line. The auxiliary plane β passing through line m is horizontal projecting plane (Fig.6.8, b).

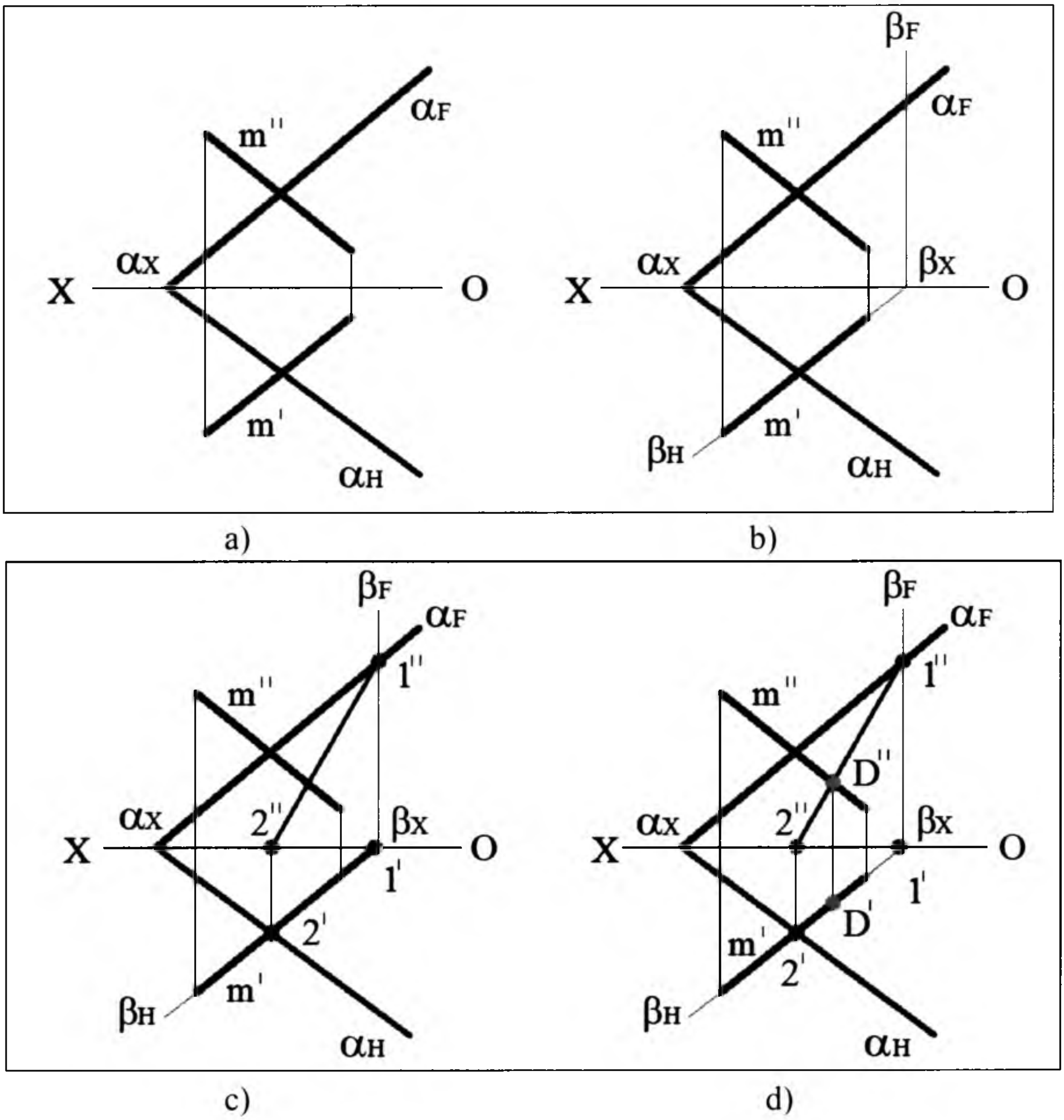


Fig. 6.8

Trace α_H coincides with projection m (Fig.6.8, c). The line 12 is the line of intersection of planes α and β. The intersection of projections m" and 1"2" determines the frontal projection D" of point D, which is the point of intersection of line m on plane.

The horizontal projection D' of point D is found by drawing through D' a line of recall to intersecting line m' (Fig.6.8, d).

QUESTIONS AND ASSIGNMENTS TO CHAPTER VI

1. When are two planes parallel?
2. What gives the intersection of two planes?
3. How can a line of intersection of two oblique planes be constructed?

4. How can a line of intersection of two oblique planes be constructed, if their corresponding traces are parallel?
5. Construct the intersection line of two horizontal (or frontal) projecting planes, if their corresponding traces are parallel.
6. What is the method of auxiliary section planes?
7. What are auxiliary planes used for when constructing the line of intersection of two planes?
8. How is it possible to determine whether the given line and plane are parallel?
9. How can a straight line be drawn through the given point parallel to the given plane?
10. Draw the plane, parallel to the given plane.
11. Draw the straight line, parallel to the given plane.
12. Which planes are most frequently used as auxiliary planes?
13. Which planes are generally used as auxiliary ones for determining the plane of intersection of a given line in a plane?
14. What constructions are required to determine the point of intersection of line on plane?
15. When is the intersection point of line with plane without auxiliary constructions determined? How is this done?
16. What is the necessary condition for perpendicularity of straight line to plane?
17. What are the positions on an orthographic drawing of the projections of straight line, which is perpendicular to plane given by its traces?
18. What is the necessary condition for perpendicularity of two planes?
19. Are two planes mutually perpendicular, if their similar traces are perpendicular?
20. Which lines of the plane are the most frequently used for drawing of the two mutually perpendicular planes?

CHAPTER VII
SOLIDS

A solid has three dimensions, length, breadth and thickness. To represent a solid on a flat surface having only length and breadth, at least two orthographic views are necessary. Sometimes additional views projected on auxiliary planes become necessary to make the description of a solid complete.

Solids may be divided into two main groups: polyhedra and solids of revolution.

7.1 Polyhedra

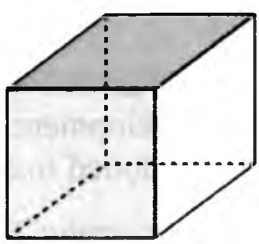
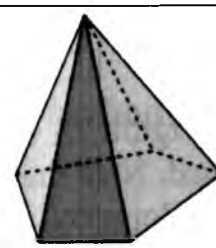
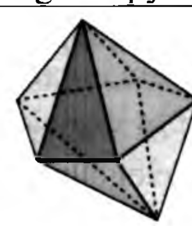
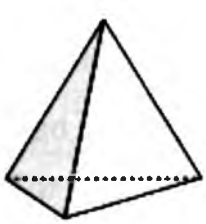
A variety of spatial figures is common in engineering, construction and architecture. Closed spatial figure bounded by plane polygons is called a polyhedron. A polyhedron, defined as a solid bounded by planes is called ***faces***.

The lines of intersection of two adjacent faces of a polyhedron are called ***edges.***

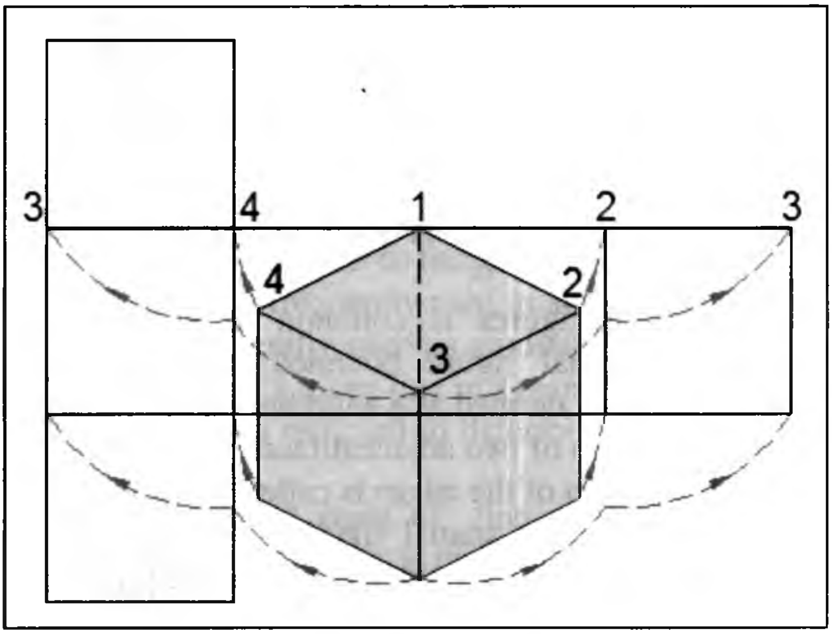
The point of intersection of the edges is called the ***apex*** of the polyhedron.

Polyhedra are the simplest spatial figures. The most common polyhedra are cube, prism and pyramid. Table 7.1 shows some of the types of polyhedra.

Table 7.1

		
Cube	Square pyramid	Pentagonal pyramid
		
Triangular prism	Hexagonal prism	Pentagonal prism
		
Tetrahedron	Octahedron	Dodecahedron

A prism is polyhedron with an n-side polygon base, another congruent parallel base (with the same rotational orientation), and *n* other faces (necessarily all parallelograms) joining corresponding sides of the two bases. All cross-sections, parallel to the base faces are congruent to the bases. Prisms are named for their base, so a prism with a pentagonal base is called a pentagonal prism. The distance between the bases of the prism is called the ***height of the prism.***



Fig, 7.1

Figure 7.1 shows how a square prism is unfolded and its development obtained. Note that corners in the undeveloped solid are shown as dotted lines in the development.

A **right prism** is a prism in which the joining edges and faces are perpendicular to the base faces. This applies if the joining faces are rectangular. If the joining edges and faces of a prism are not perpendicular to the base faces, such prism is called an **oblique prism**.

For example, **a parallelepiped** is an oblique prism the base of which is a parallelogram, or equivalently a polyhedron with six faces are all parallelograms. A **truncated prism** is a prism with nonparallel top and bottom faces.

A **pyramid** is a polyhedron formed by connecting a polygonal base and a point, called the apex. The distance from the apex of the pyramid to its base is called the ***height of the pyramid***.

A right pyramid has its apex directly above the centroid of its base. Non-right pyramids are called ***oblique pyramids***.

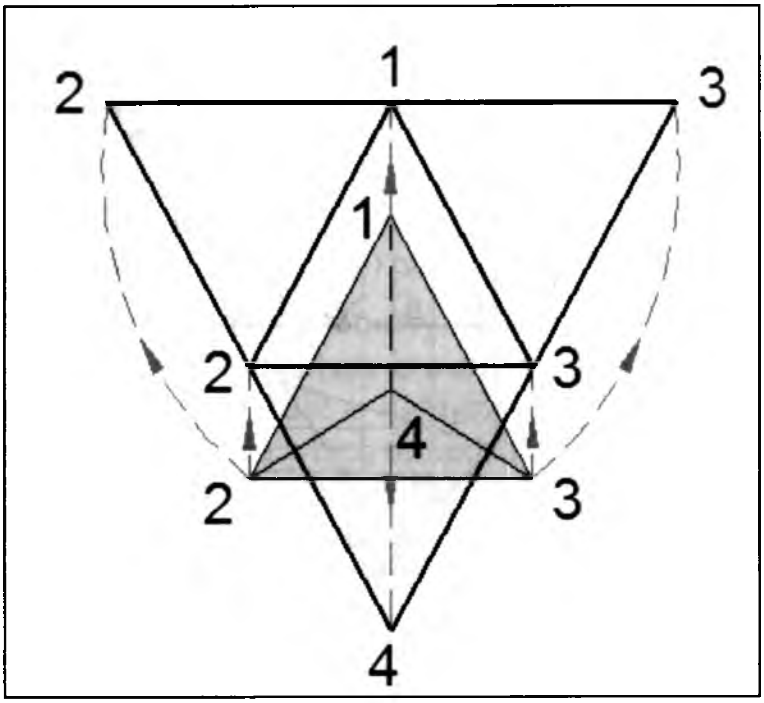


Fig. 7.2

A triangle-based piramid is more often called ***a tetrahedron***.

Figure 7.2 shows how a tetrahedron (triangle pyramid) is unfolded and how its development is obtained.

7.2 Construction of Complex Drawing of Polyhedra

Construction of the complex drawing of polyhedron begins with the construction of the projection of its base. As an example, let's consider the construction of a complex drawing of a regular triangular prism whose base lies in the horizontal plane of projection (Fig. 7.3). First, let's construct the projection of the bottom base of the prism. As for the condition of the problem it is located on the plane H, the horizontal projection A'B'C' is equal to the true length of the base and is located below the x-axis and a frontal projection A"B"C" lies on the x-axis.

Next we construct the projection of the upper base of the prism. The horizontal projection of the upper base $A'_1B'_1C'_1$ prism coincides with the horizontal projection of the bottom base and a frontal projection of the upper base $A''_1B''_1C''_1$ is parallel to the frontal projection of the lower base at a distance equal to the height of the prism. We join the similar points of the bases and get the projection of the prism edges. Then we construct a profile projection of the prism.

For a more accurate image of polyhedron projection it is necessary to show its visible and invisible elements. Visible element is the element, which is closer to the observer. Invisible elements on the complex drawing are shown in dashed lines and visible elements – in continuous thick line.

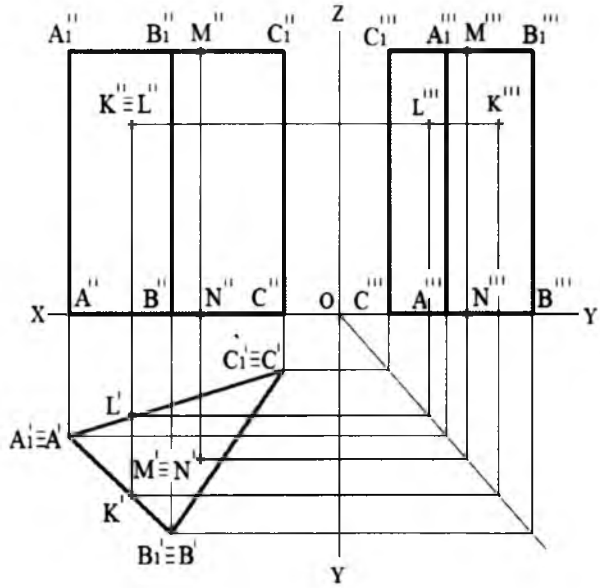


Fig. 7.3

7.3. Solids of Revolution. Cylinder and Cone

In mathematics, engineering, and manufacturing a **solid of revolution** is a solid figure obtained by rotating a plane curve around some straight line (the axis) that lies on the same plane.

In its simplest form, a ***cylinder*** (from Greek κύλινδρος – *kulindros*, "roller, tumbler") is the surface formed by the points at a fixed distance from a given straight line called the ***axis*** of the cylinder. The solid enclosed by this surface and by two planes perpendicular to the axis is also called a cylinder. It is one of the most basic curvilinear geometric shapes.

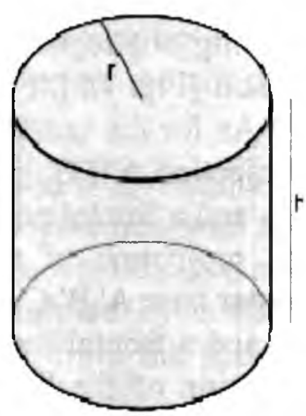


Fig .7.4

In common use a *cylinder* is taken to mean a finite section of a ***right circular cylinder***, i.e., the cylinder with the generating lines perpendicular to the bases, with its ends closed to form two circular surfaces, as in the figure (right). Figure 7.4 shows a right circular cylinder with radius *r* and height *h*.

A **cone** is a three-dimensional geometric shape that tapers smoothly from a flat base (frequently, though not necessarily, circular) to a point called the apex or vertex.

The term "cone" sometimes refers just to the surface of this solid figure, or just to the lateral surface.

The axis of a cone is the straight line (if any), passing through the apex, around which, the base (and the whole cone) has a circular symmetry.

In common usage in elementary geometry, cones are assumed to be **right circular**, where *circular* means that the base is a circle and *right* means that the axis passes through the center of the base at right angles to its plane. Contrasted with right cones are oblique cones, in which the axis does not pass perpendicularly through the center of the base. In general, however, the base may be of any shape and the apex may lie anywhere (though it is usually assumed that the base is bounded and therefore has finite area, and that the apex lies outside the plane of the base).

A cone with a polygonal base is called ***a pyramid***.

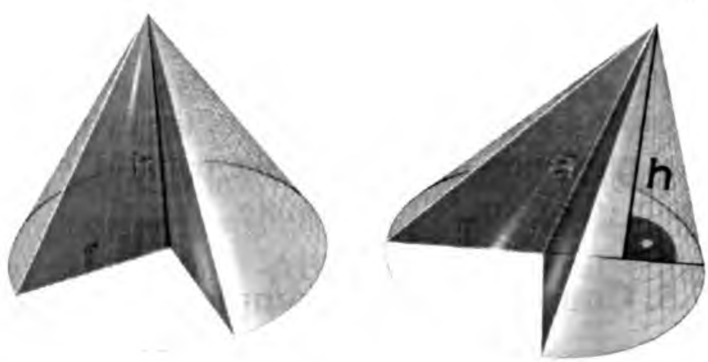


Fig. 7.5

Figure 7.5 shows a right circular cone and an oblique circular cone.

7.4. Construction of the Complex Drawing of Cylinder

Construction of the complex drawing of a right circular cylinder begins with the construction of projection of the center of cylinder base (Fig. 7.6). In our example, the lower base is located on the horizontal plane of projection. The upper base of the cylinder is parallel to the lower base, so the horizontal projections of the two bases are the same circles and they are in the equal magnitude of their true size. The frontal projection of lower base is straight line located on the x-axis.

Frontal projection of the upper base is equal and parallel to that line. The distance between these projections is the height of the cylinder. Profile projections of bases are also equal in length and parallel to each other by line segments. Connecting the endpoints of these lines, we find the frontal and horizontal projection of the cylinder. As it can be seen from the figure, these projections are rectangles.

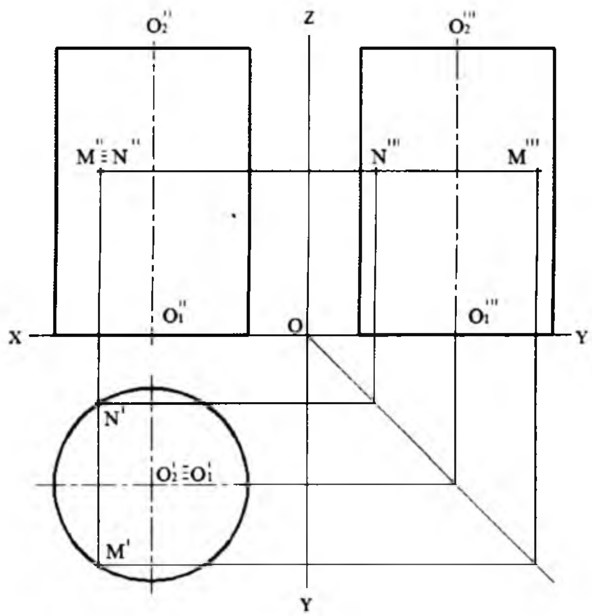


Fig. 7.6

Let's consider a point on the surface of the cylinder M and N, as shown in Fig. 7.6. Frontal projection of point M (the point M") is visible, and the frontal projection of point (the point N") is invisible.

7.5. Construction of Complex Drawing of Cone

Construction of the complex drawing of a right circular cone begins with the construction of horizontal projection of the cone base – the point O' (Fig. 7.7). From this point we draw a circle, a radius equal to the radius of the base - R_1

This circle is a horizontal projection of the base of the cone and is equal to the true size of the base. In our example, the base is located on the horizontal plane of projection. Therefore, a frontal projection of the base will lie on the x-axis and the profile projection on the y-axis. Their lengths are equal to the diameter of the base. The horizontal projection of the cone apex coincides with the center of the base (S' ≡ O'). We draw the line in the height of the cone and perpendicular to the x-axis and y-axis through the frontal and profile projections of base. We obtain frontal and profile projections of the apex (S" and S'"). Connecting obtained projection of cone apex with the end of the line segment projections of base; we obtain frontal and profile projections of cone.

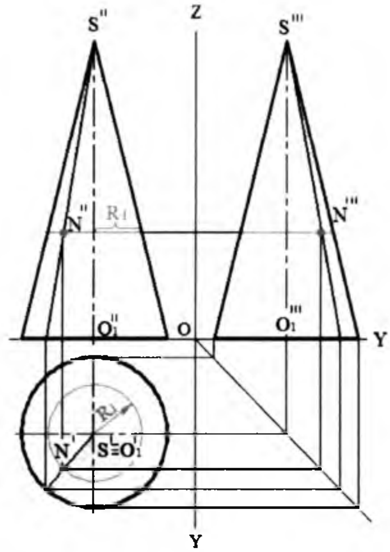


Fig.7.7

Let's determine visible and invisible elements of the cone. The base of the cone in horizontal projection is invisible. Therefore, all points of the base, except for the points located on the perimeter, are invisible dots.

7.6. Intersection of Polyhedron with Plane

When we intersect polyhedron with the plane we get the geometrical figure, its shape depends on position and type of polyhedron and the cutting plane. Let's construct a section of the pyramid ABCDS with frontal projecting plane α (Fig.7.8).

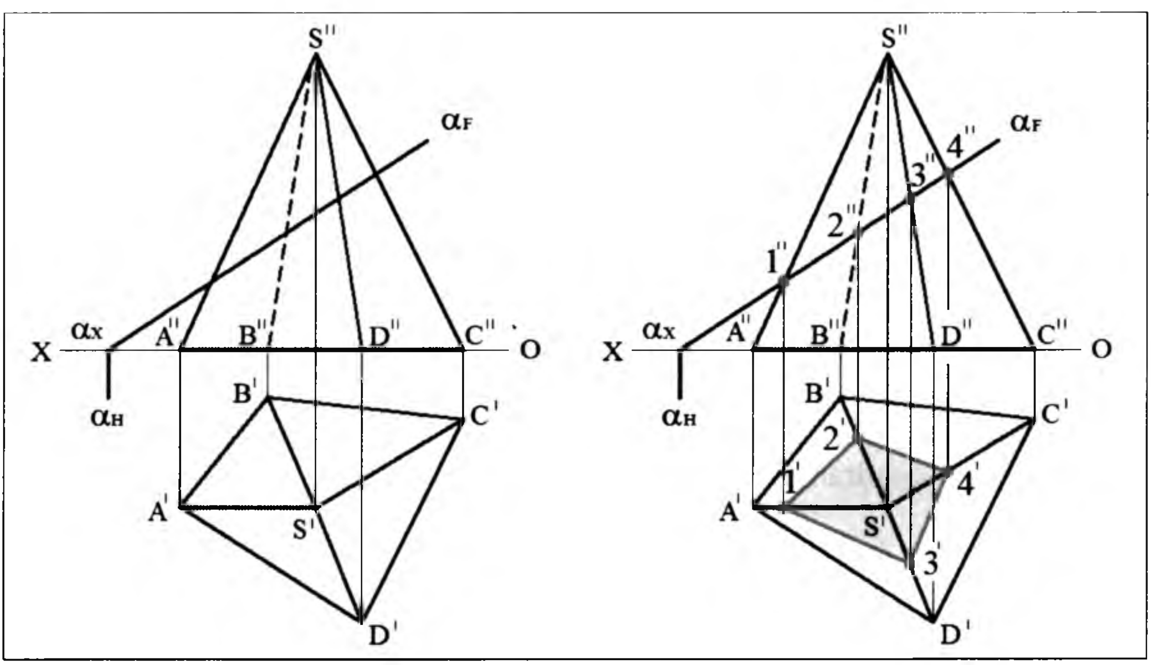


Fig. 7.8

We find the points of intersection of the frontal trace of plane α_H with edges A'S', B'S', D'S' and C'S' – these are 1", 2", 3", 4". Then we find the horizontal projections of these points - 1', 2', 3' and 4' and connect the horizontal and frontal projections of points 1, 2, 3 and 4.

The quadrilateral 1'2'3'4 ' is horizontal projection of section of the pyramid with frontal projecting plane. Its frontal projection is located on the frontal trace of the plane α.

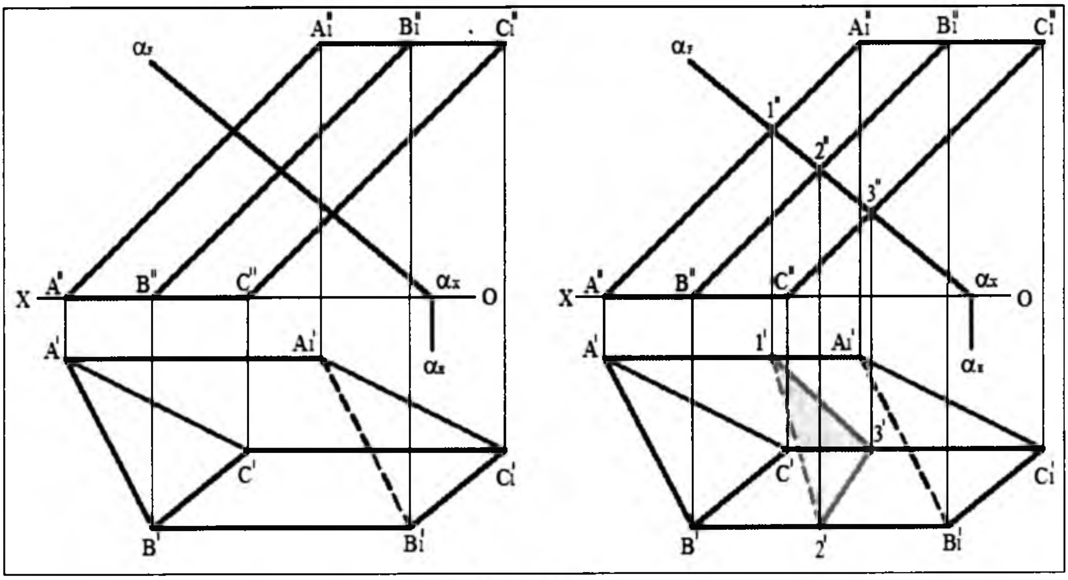


Fig. 7.9

Figure 7.9 shows the construction of the section of the prism by frontal projecting plane.

7.7. Intersection of Polyhedron with Straight Line

When we intersect a straight line with the plane we get two points which are called entry point and exit point.

1. We carry out the projecting plane through the given straight line.
2. We build intersection of polyhedron with this plane.
3. We define required points of this section with a straight line.

In Figure 7.10 is shown the determination of points of intersection of pyramid ABCDS with a straight line m. Through a straight line the frontal projecting plane α is carried out. After that we build intersection of pyramid with this plane – a quadrangle 1' 2 '3' 4'.

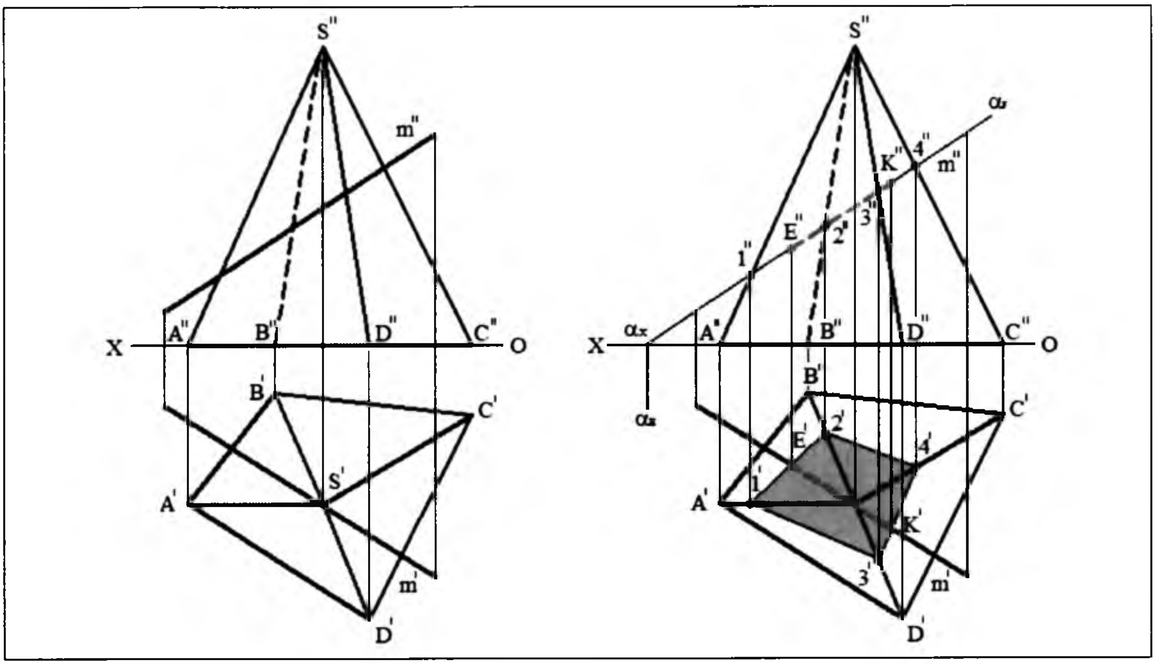


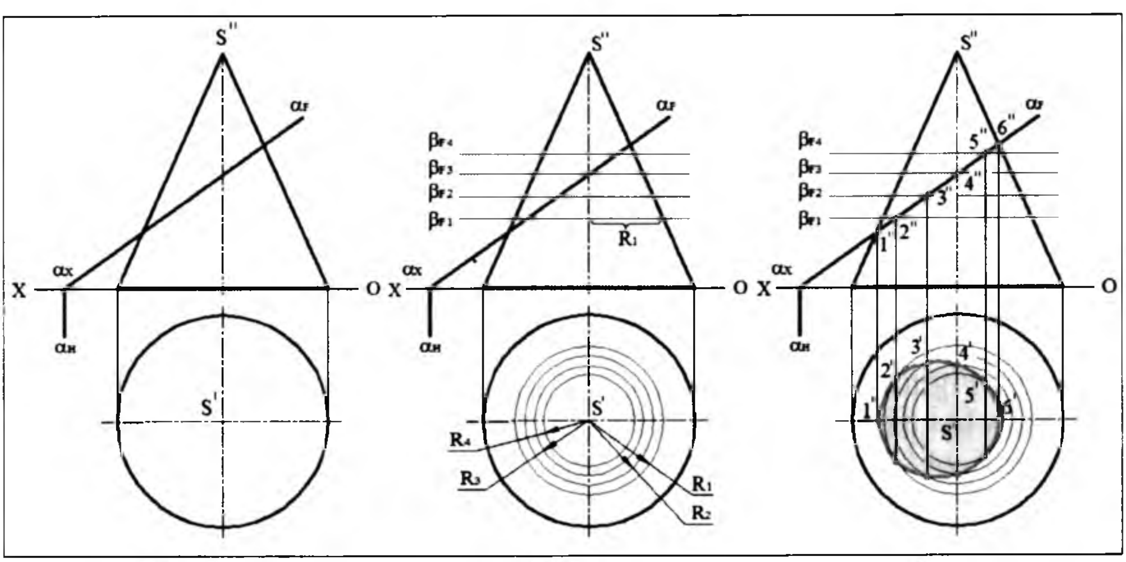
Fig. 7.10

This quadrangle intersects with straight line m' at points E' and K' which are horizontal projections of intersection points of straight line with polyhedron. We find frontal projections of these points – points E" and K".

7.8. Intersection of Solid of Revolution with Plane

By intersecting a solid of revolution with the plane, we get the figure the form of which depends on type of this solid of revolution, and also depends on the position of a cutting plane.

As an example we determine the section of a cone by the frontal projecting plane α (Fig. 7.11, a).



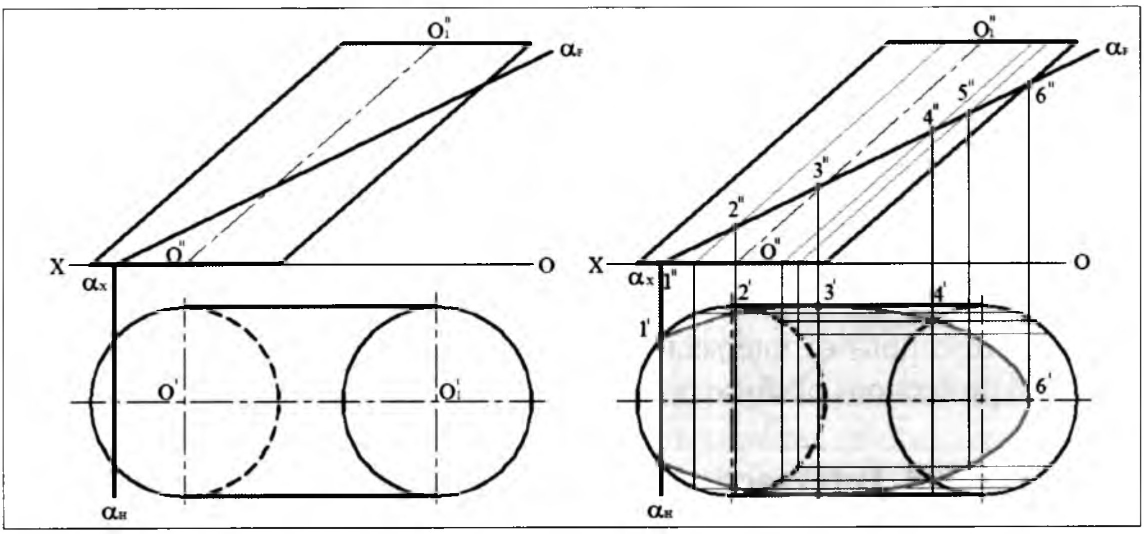
a) b) c)

Fig. 7.11

On the complex drawing the frontal trace of the plane α intersects with a cone at points 1" and 6" (Fig. 7. 11, c). These points are characteristic points.

To determine additional points we use a method of cutting planes.

We draw the additional horizontal planes β_1, β_2, β_3 and β_4 (Fig. 7.11, b). The plane β_1 intersects cone on circle with radius R_1. We show this section on horizontal projection (we draw a circle with radius R_1). The frontal trace of the plane β_1 intersects with frontal trace of the plane α at point 2". The horizontal projection of this point is on the constructed circle – point 2'. Similarly we build points 3", 4", 5" and 3', 4', 5'. We connect consistently constructed horizontal projections of points and receive cone section of the plane α.



a) b)

Fig. 7.12

Let's determine the figure which we get when intersecting of the inclined cylinder with the frontal projecting plane (Fig. 7.12, a). We find characteristic points – points 1", 3" and 6". To determine additional points we draw the element of cylinder and find frontal projections of intersection points of this element of cylinder with frontal trace of the plane – points 2", 4" and 5". We mark respectively horizontal projections of these points and consistently we connect them.

This figure is the section of cylinder with the plane (Fig. 7.12, b).

7.9. Intersection of Two Cylinders

In Figure 7.13 is shown construction of intersecting of projections of two cylinders by using the method of auxiliary planes.

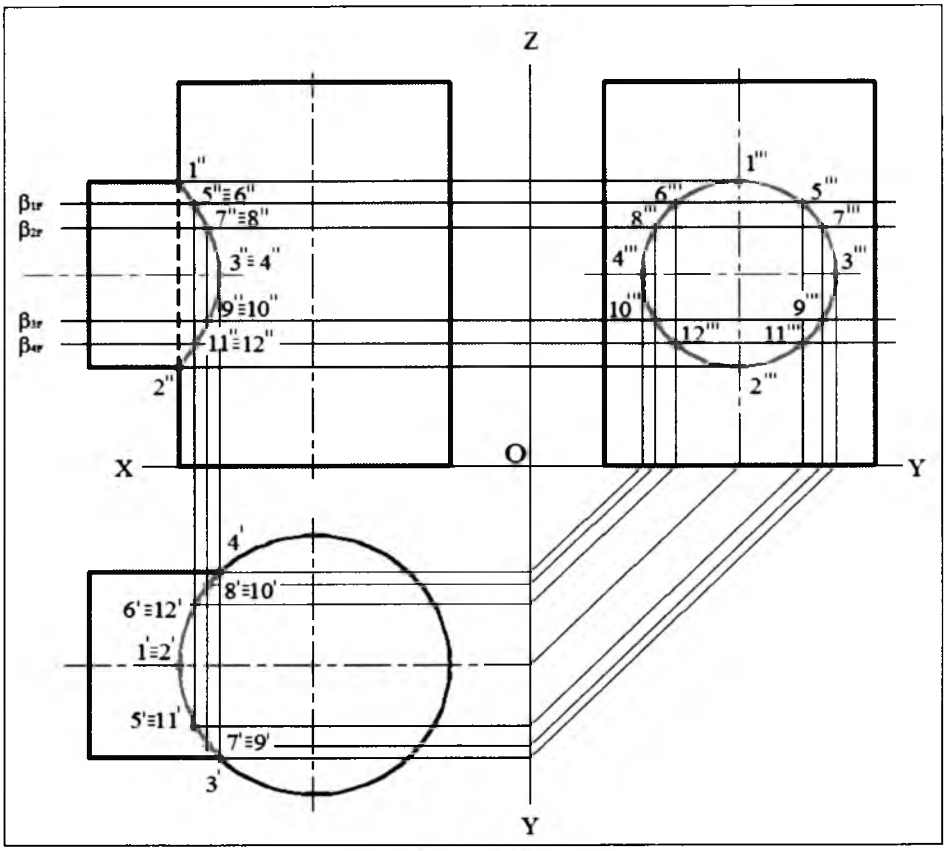


Fig. 7.13

We begin construction with the image of projections of those points positions of which can be defined directly from drawing – projection of points 1, 2, 3 and 4. Auxiliary horizontal planes β_1, β_2, β_3 and β_4 are drawn for the determining of additional points.

These planes intersect the vertical cylinder on a circle, equal to diameter of this cylinder, and the horizontal cylinder on the rectangles parallel to the horizontal plane of projections.

Let's consider the plane β_1. It intersects the vertical cylinder on a rectangle, element of this cylinder on a profile projection we designate with points 5''' and 6'''. Horizontal projections of these points lie on element of the horizontal cylinder – points 5' and 6'. From these points we draw vertical straight lines and find their frontal projections – points 5'' and 6''.

Similarly we construct projections of points 7, 8, 9, 10, 11 and 12. Having connected these points, we receive projections of cylinder section.

7.10. The Intersection of Cone with Cylinder

Let's construct intersection of the cone with cylinder (Fig. 7.14). We show projections of points 1 and 2 – points of intersection of top and low element of cylinder with left element of the cone.

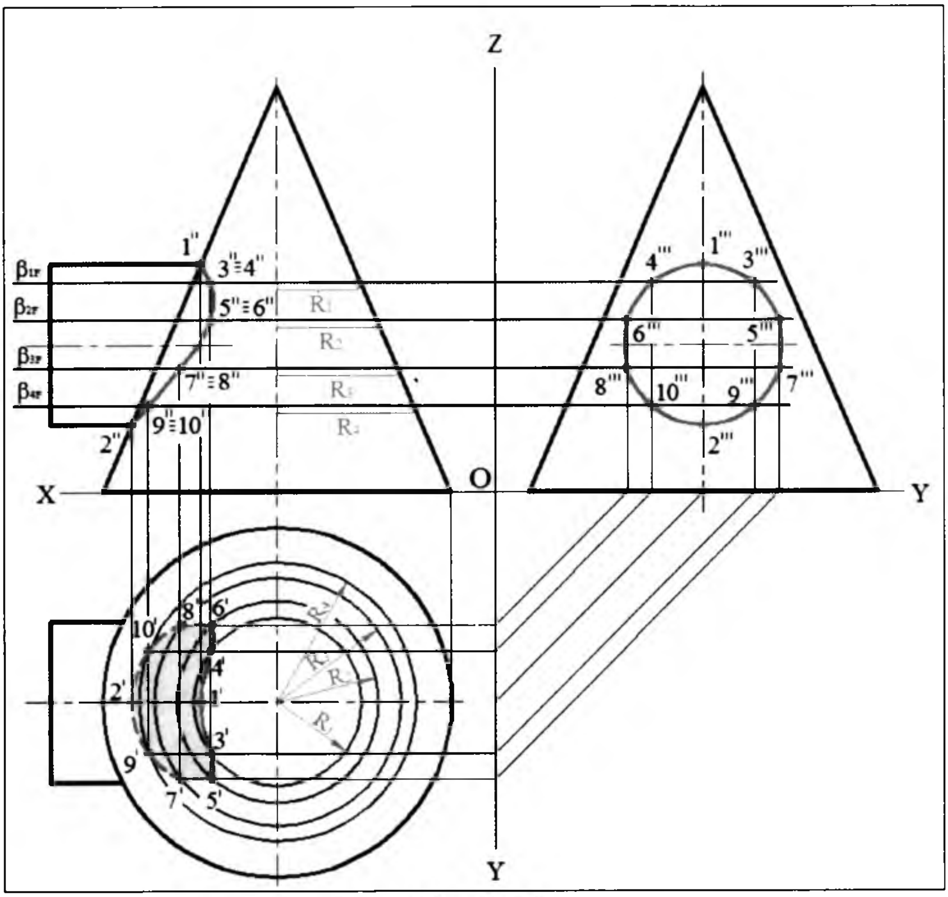


Fig. 7.14

To determine additional points, we use a method of the auxiliary planes. We draw the auxiliary horizontal planes β_1, β_2, β_3 and β_4. The plane β_1 intersects a cone on the circles with radius R_1, and the cylinder on a rectangle element of the cone on a profile projection we designate with points 3''' and 4'''. Horizontal projections of these points are 3' and 4' on circle with R_1 radius. From these points we draw frontal straight line and find frontal projections – points 3'' and 4''.

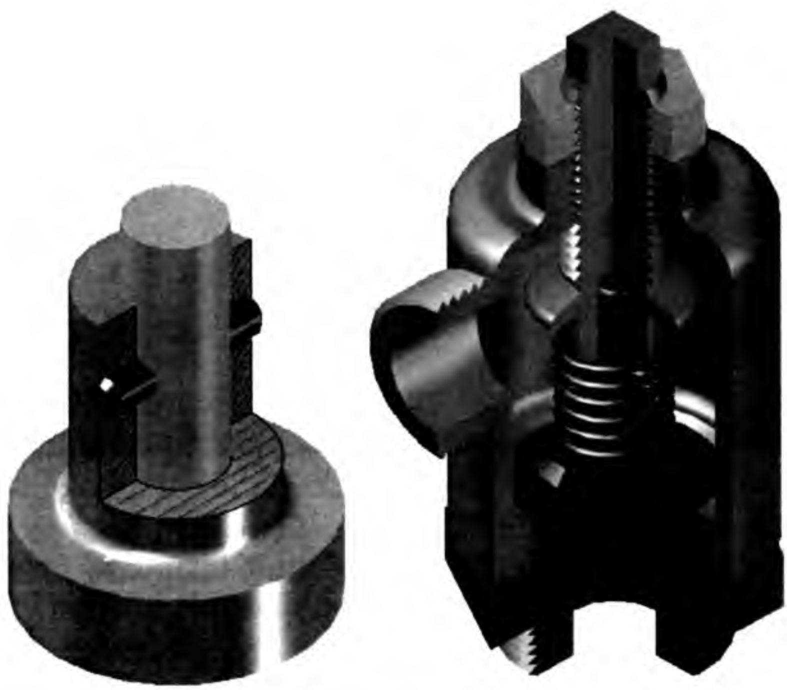
Similarly we construct projections of points 5, 6, 7, 8, 9 and 10. Having connected these points, we receive projections of section of cylinders. Then on a horizontal projection we show visible and invisible parts of section.

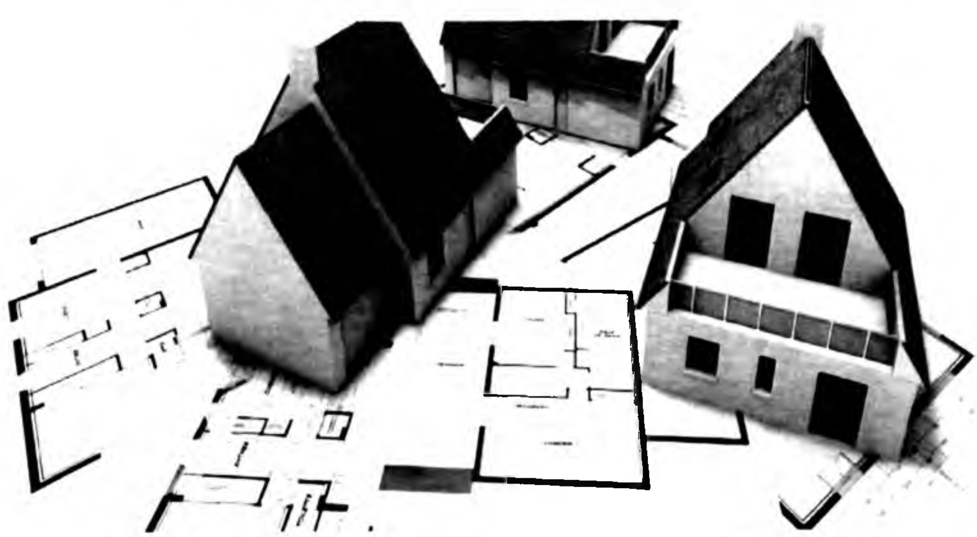
QUESTIONS AND ASSIGNMENTS TO CHAPTER VII

1. Which dimensions do solids have?
2. What is polyhedron?
3. What are the faces of polyhedron?
4. What are the edges of polyhedron?
5. What is the apex of polyhedron?
6. What types of polyhedra do you know?
7. What is the pyramid?
8. What is the prism?

9. What is the height of the prism?
10. Show the development of a square prism.
11. What is the right prism?
12. What is the oblique prism?
13. What is the parallelepiped? Is parallelepiped a right prism or an oblique one?
14. What is the truncated prism?
15. What is the height of the pyramid?
16. What is the right pyramid?
17. What is the oblique pyramid?
18. What is the tetrahedron?
19. Show the development of tetrahedron.
20. What is the right cylinder?
21. What is the axis of the cylinder?
22. What is the cone?
23. Construct the complex drawing of prism.
24. Construct the complex drawing of cylinder.
25. Construct the complex drawing of cone.
26. What do we get when the plane intersects polyhedron?
27. What are the rule of intersecting of polyhedron with a plane?
28. What are the rules of intersecting of polyhedron with straight line?
29. What are the rules of intersecting of solids of revolution with plane?
30. What are the rules of intersecting of two cylinders?
31. What are the rules of intersecting of cylinder with cone?

PART III
MASHINE BIULDING DRAWING





CHAPTER VIII
PROJECTION DRAWING

8.1. Views

People learned to draw pictures of the objects around them long before they learned to write. Drawings carved by primitive people on rocks, the walls of caves and so forth have survived to our days.

Many drawings of human being, animals, fish and other objects, made by our forefathers thousands years ago, have been found on the eastern shore of lake Onega and on the shores of the White sea. These drawings were carved on granite rocks with stone tools.

In Russia rock drawings are found along the Yenisei River, in the Altai Mountains, in Kazakhstan and other places.

The ability to make simple drawings helped man to develop his first written language. There were no words or characters in ancient writing. The ideas of objects were conveyed by pictures of these objects. Stories of military campaigns, battles and hunting were recorded in these "picture" languages.

The ancient people drew on the bark of trees, stone, bone, leather and other materials. Meanwhile, they learned to make a material called papyrus used especially for writing and drawing.

Alongside with the rise of a bulding technique, people began to use pictures for building houses, palaces, temples and fortresses.

At first, these drawings consisted only of a single picture showing what the object would look like in view from above. This picture was called **a plan.** Later, people began to add a front view of the object to this plan. The drawings were improved by the addition of other "views" of the object represented in them.

Let's consider these "views" more carefully.

Parts are made in factories and they are assembled into machines or other articles according to drawings.

A drawing is the representation on a plane surface of an object that precisely and fully gives its shape and contains all the information needed for its manufacture and inspection.

A drawing tells the draftsperson what the shape and size of the part must be, what material it is to be made of, how its surface must be completed and a great deal of other information of readable part is to be made.

On receiving a drawing for a job, the worker must read it, after close studying the drawing, he must understand all the information contained in it.

In order to be able to read drawings, first of all we must have a clear idea of how to depict machine parts in them.

Let's now discuss the question of what side of an object we must look at in order to represent a given view. As an example let's take a simple object, a part.

Every representation contained in drawings is the view of the part from one of six sides: **front, left, right, top, bottom and rear (back)** (Fig. 8.1).

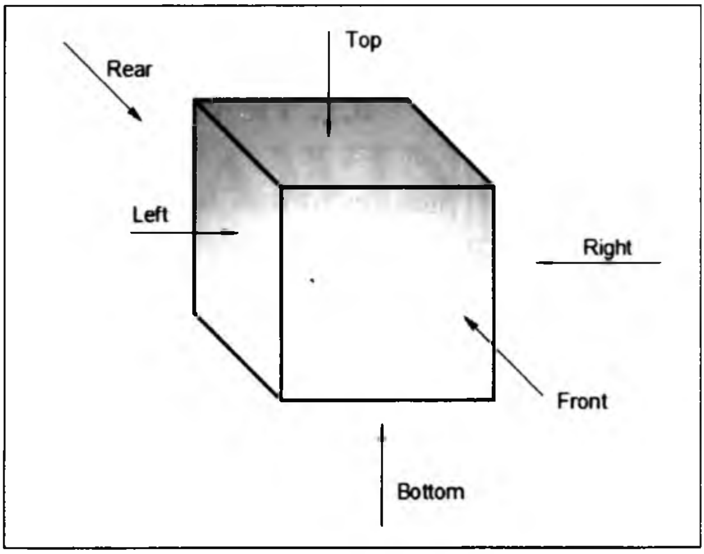
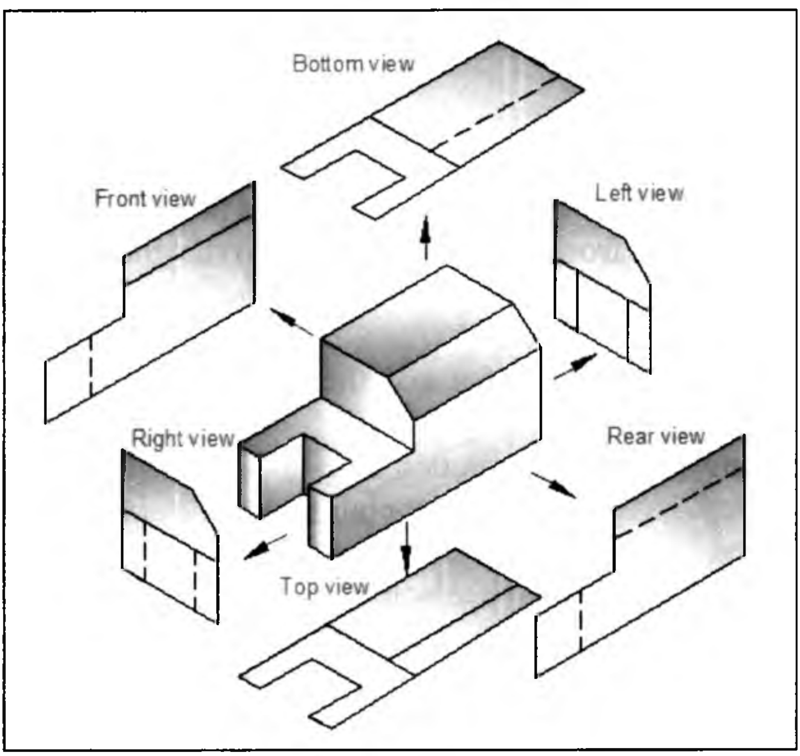


Fig.8.1

When drawing each view, the object must be looked at directly, as shown by the arrows in Figure 8.1. Here it is important to note that all the arrows indicating the direction of the object look at right angles to each other (Fig. 8.2).



The main view, which is obligatory for every drawing, is the front view as it is the shape of the part, and is described as the main view for that reason. Other views are: **left-side view, right hand view, top view, front view, bottom view and back (or rear) view** (Fig. 8.3).

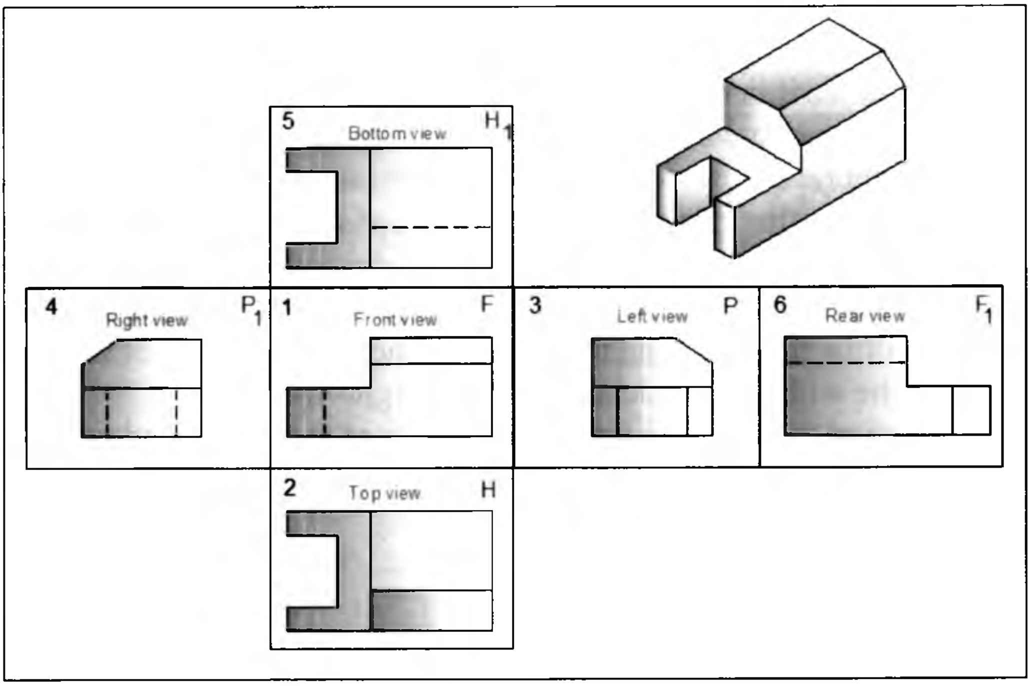


Fig. 8.2

Most objects in the world today are created in 3 dimensions, they display height, width, and length hence the term 3D (Three dimensional). Most orthographic drawings are drawn showing these three dimensions (Fig. 8.3).

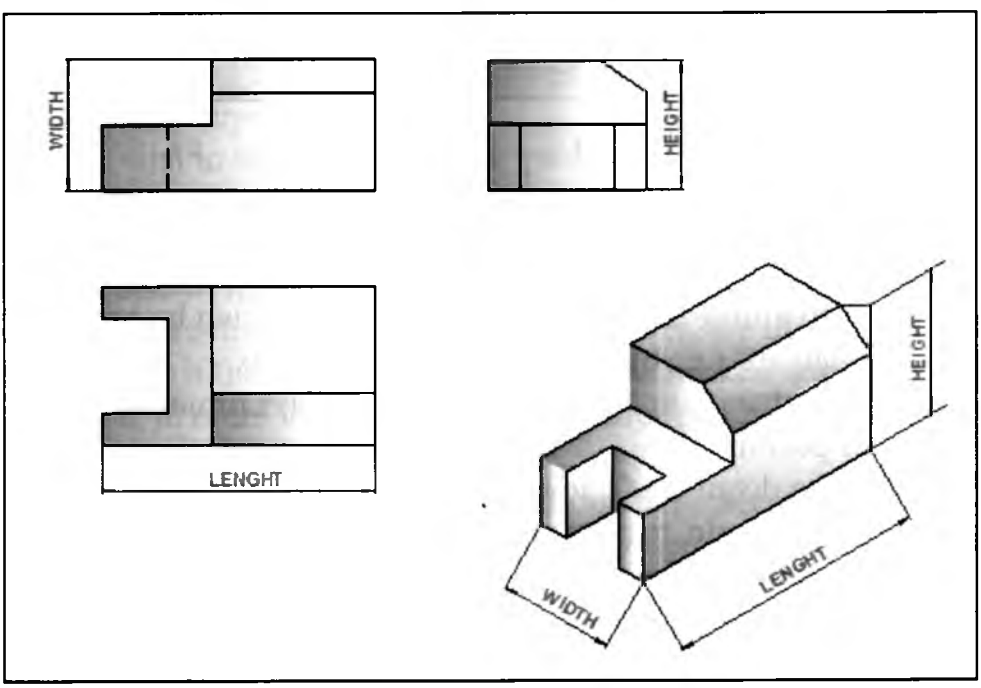


Fig. 8.3

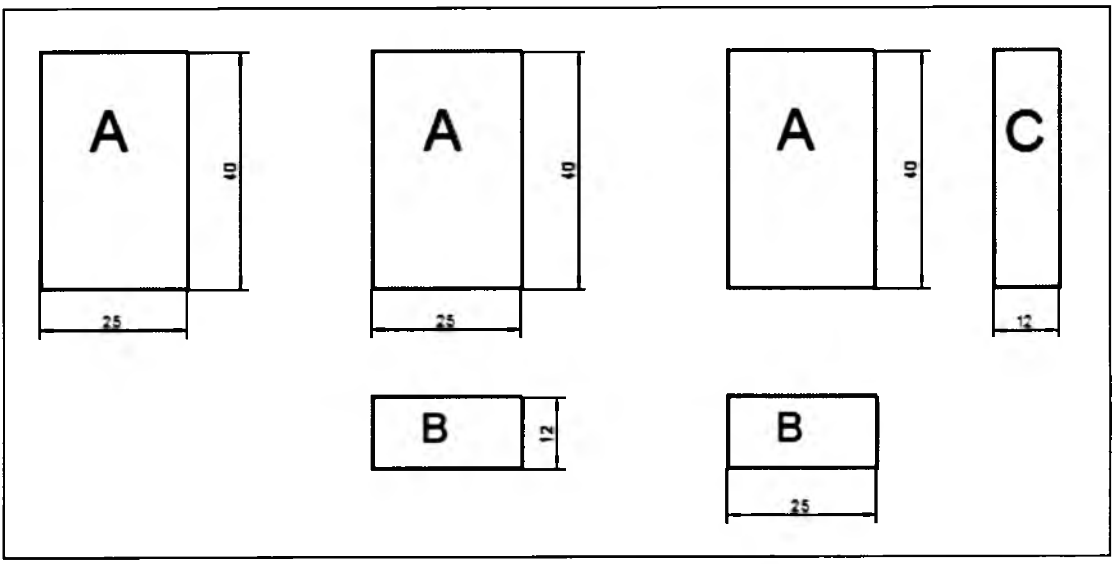
All six views are given in drawings only in very rare cases, when the depicted part has a very complicated shape. Usually, two or three views are quite sufficient.

The three most common views drawn on technical drawing are: main view, right- hand view and top view. The person creating the part may need other views to better visualize it in order to properly manufacture it.

Let's first study how object is drawn in three views. A drawing of an object starts with a representation of the main (front) view. To draw this view we must look at the part so that our eyes are exactly opposite its center. In this position, only its wide front face A will be visible. We cannot see its top and bottom faces, as the former is located above the top edge and the latter-below its bottom edge.

Let's draw the rectangular contour of the part: the base of this rectangle will be equal to the width of the detail, and the height- to its length.

Let's then measure the length and width of the detail, and write its dimensions (in millimeters) on the drawing (40 and 20 mm in Fig 8.3).



a) b) c)

Fig. 8.3

To draw the top view we must look at the part so that our eyes or "line of sight" is directed downwards. But we can see the same thing by turning the object to ourselves through 90° i.e., by turning its top towards us.

It's very important to note that an object is always turned to describe a right angle to its initial position.

By turning the detail to 90° towards us we can see its upper face B, which has the shape of a rectangle, the base of which is equal to the width, and the height- to the thickness of the part (Fig. 8.3, b).

The plan must be located strictly under the main view, as shown in the drawing (Fig. 8.3, b). After you have drawn the plan indicate the thickness of the part -12mm.

Now, let's put the part in the third position, so that its left –hand side faces us. First return it to its initial position and then turn it through an angle of 90° to the right position (Fig. 8.3, c). In this position, we can see its left-hand side "c" which, like the first two sides, is rectangular in shape. The left- hand view is drawn to the right of the main view and on the same level.

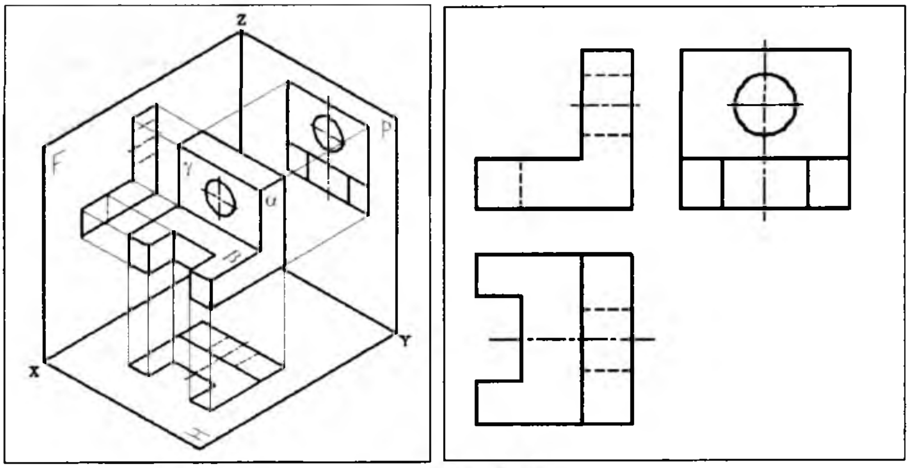


Fig. 8.4

Figure 8.4 shows the projection of parts in space and on the complex drawing. The lines of recall and axis on complex drawings are not shown.

8.2. Sectioning

Suppose that you make a drawing of a box. You draw the box in orthographic projection and are pleased with the result. But someone comes along and says, quite reasonably, “It is a good drawing, but, after all, a box is only a container and you haven’t shown what is inside the box; surely it is that what is important”. And of course, he is right.

It is often vital to show both what is inside an object and outside it. In orthographic projection, this is shown in section.

Drawings should give a clear and precise picture not only of the appearance of an object but also of its interior construction. As we know, invisible or hidden outlines of objects are drawn in broken lines. However, the drawings will be clear and comprehensible if the projections contain as few broken lines as possible.

In this case, in order to make a drawing clearer and more comprehensible, we usually use a sectional view or section.

A sectional view or section is a conventional representation in which a part of an object or machine is imagined to be cut or broken away so as to expose the interior.

Figure 8.5 shows the process of obtaining images of the subject on horizontal and frontal planes of projections.

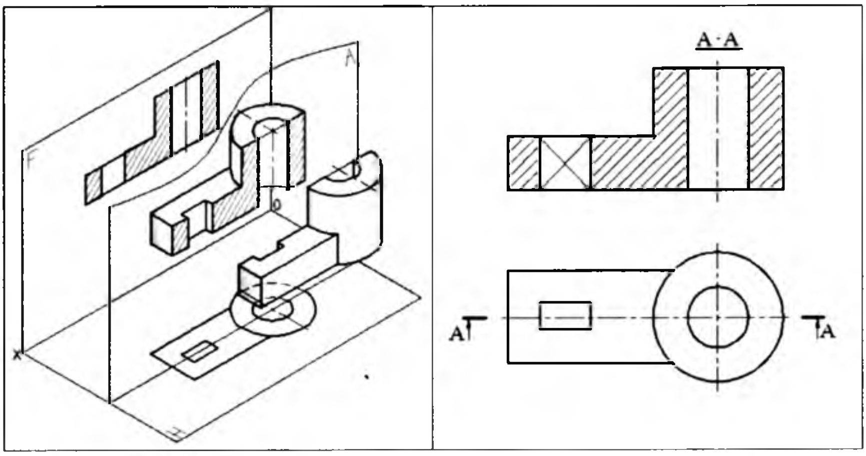


Fig. 8.5

Note carefully the following rules:

1. The point where the section is made is denoted by a cutting plane. This is drawn with a thin chain dot line which is thickened where it changes direction. The arrows point in what direction the section is projected.

2. Where the cutting plane cuts through solid material, the material is hatched at 45 °.

3. When a section is projected, the remaining visible features which can be seen on the other side of the cutting plane are also drawn on the section.

4. It is not common to draw hidden detail on a section.

There are several types of sections: simple section; full section; broken out section; offset or complicated section, revolved section and so on. Let's consider some of them.

To show the cross-section of the shaft and the depth of a key-way, we have conventionally to cut the shaft by a plane running perpendicular to its axis and passing through the key-way. This plane is called the **cutting plane** (Fig. 8.5). On the drawing the direction of the cutting plane is indicated by a line with arrowheads. This line is called the section line or the trace of cutting plane.

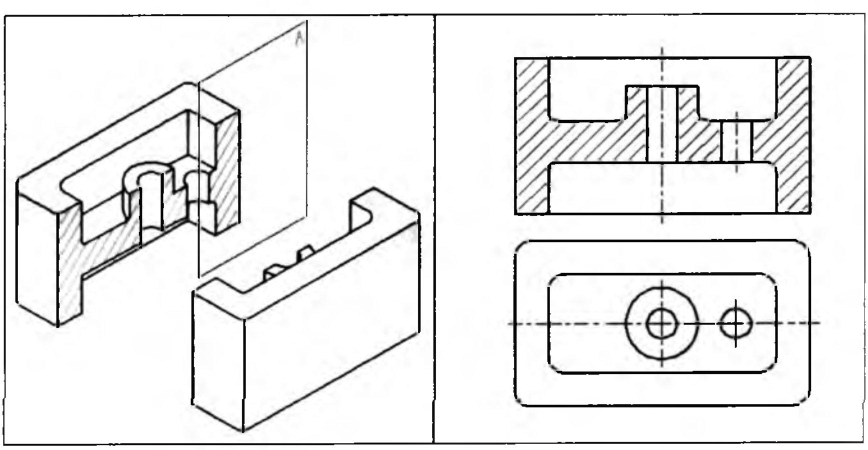


Fig. 8.6

The arrows indicate the direction in which the figure of the section must rotate to bring it on plane of the drawing.

Depending on the direction of the cutting plane, sections are classified as ***frontal sections*** (when the cutting plane is parallel to the frontal plane of projection), ***horizontal sections*** (when the cutting plane is parallel to the horizontal plane of projection) and ***profile sections*** (when the cutting plane is parallel to the profile plane of projection).

Figure 8.6 shows construction of frontal section of detail.

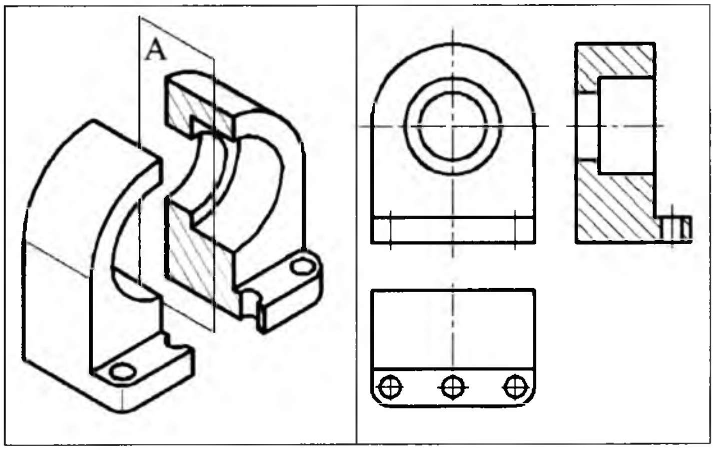


Fig. 8.7

Figure 8.7 shows construction of profile section of detail.

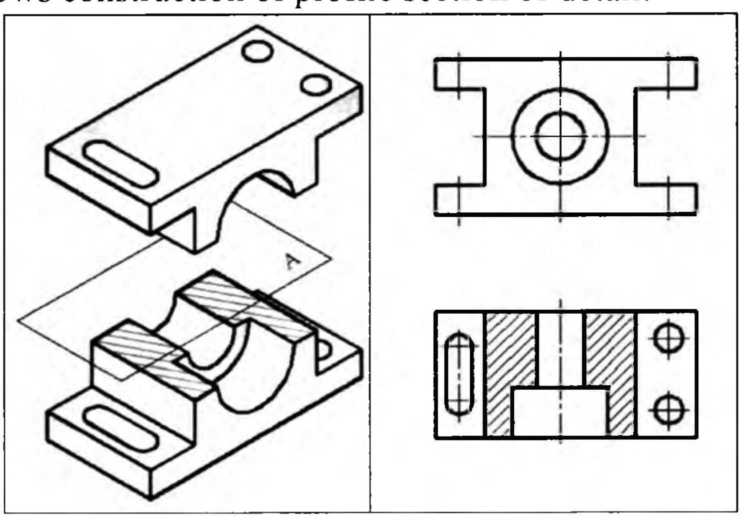


Fig. 8.8

Figure 8.8 shows construction of horizontal section of detail.

If the sectional views are made by a single cutting plane, such sections are called ***simple sections.***

Sectional views, in which the cutting plane cuts across the whole object, showing the entire view in section, are called ***full sections.***

Therefore the view and the corresponding section from a symmetrical figure drawings may be simplified to one representation instead of two separate representations (view and section) by joining half of the view with half of the corresponding section. In these cases it is always preferable to locate the section to the right of the vertical axis or below the horizontal axis.

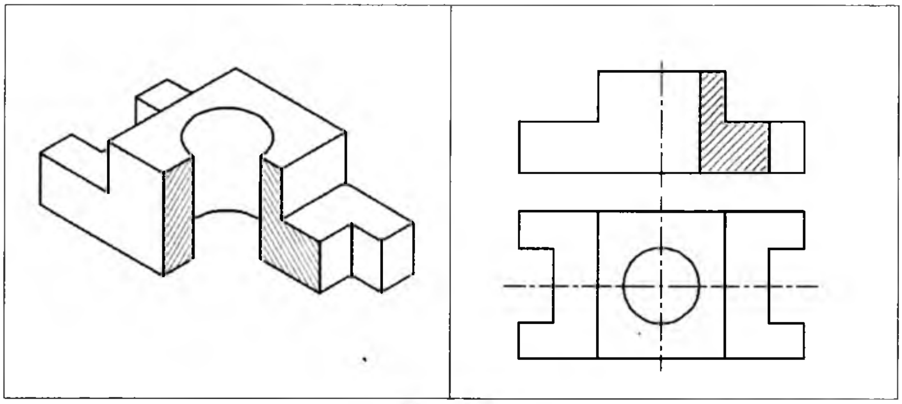


Fig. 8.9

Figure 8.9 shows half of the main view combined with half of the corresponding vertical section. Such combinations of half of view and half of section help to give a picture of an object's exterior and its internal construction with a single representation.

If the cutting plane is at an angle to the horizontal plane projection, this section is called the ***inclined section***. Figure 8.10 shows construction of profile section of detail.

The section is made along the plane **A-A**. The arrows indicate the direction of view of the observer. The section is projected on plane, parallel to the cutting plane, and then it is combined with the frontal plane of projection.

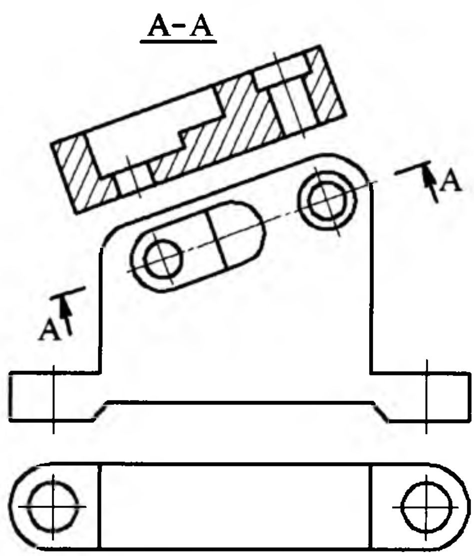


Fig. 8.10

If an object has a hole or recess, partial sections are drawn i.e. only a portion of the object is given in section. The section, that is used to determine the detail only in limited place is called ***a local section*** (Fig. 8.11).

The local section is always shown as a wavy line drawn by hand. This line should not coincide with any other lines of the image. A local section gives a complete representation about sizes and shape of the hole.

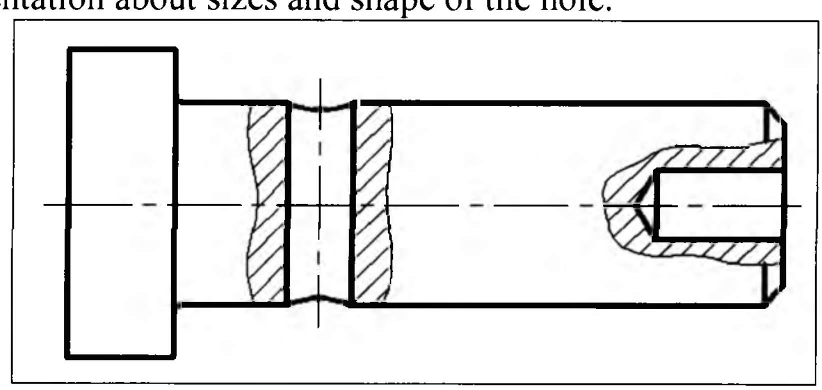
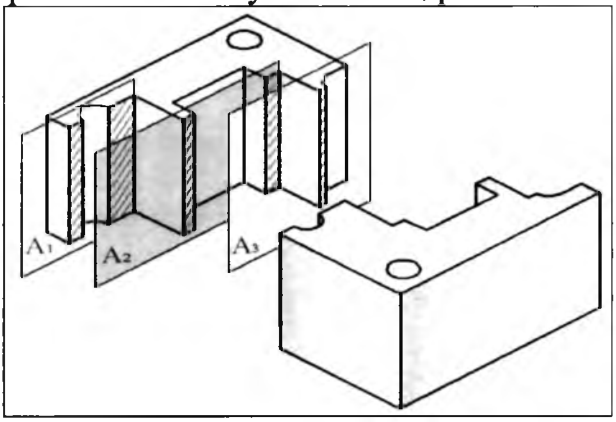


Fig. 8.11

Sections, made with two or more cutting planes are called ***complicated sections.***

Complicated sections, made with parallel planes are called ***stepped sections.*** Stepped sections may be frontal, profile and horizontal.



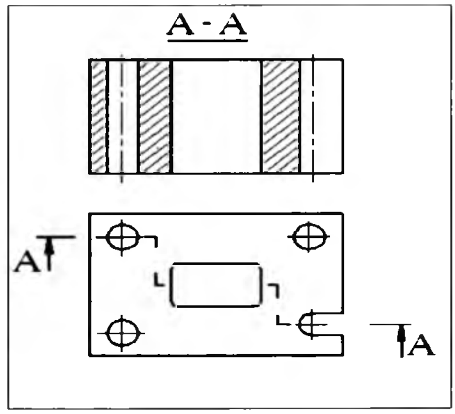


Fig. 8.12

Figure 8.12 shows a stepped section produced by three frontal parallel intersecting planes.

Complicated sections, formed by two or more intersecting planes are called ***broken sections***.

Figure 8.13 shows a broken section of detail by two intersecting planes.

When dimensions are written on sections we must do the following:

- the dimension line must be drawn above of the axis of symmetry;

-the dimension line extends slightly beyond the axis of symmetry;

-the arrow is drawn only on one side of the dimension line.

Position of the cutting plane is indicated in the drawing by cutting line. The initial and final dashes must not cross the contours of the corresponding image(Fig.8.14).

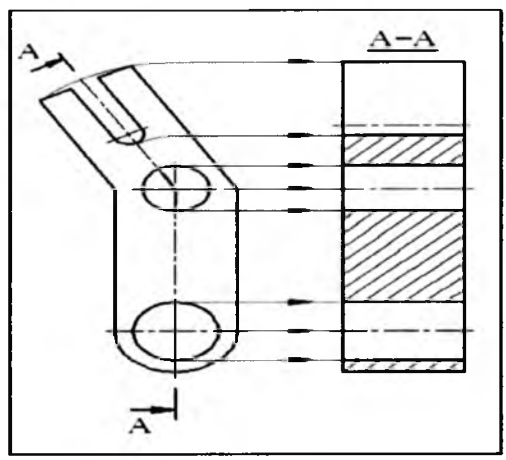


Fig. 8.13

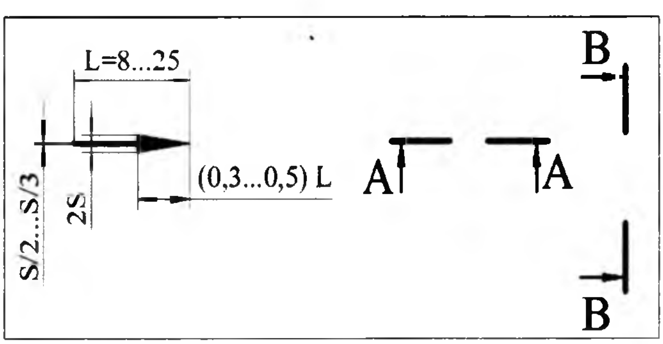


Fig. 8.14

The thickness of the dashed lines is 1.5 smaller than the thickness of the continuous thick line. In the initial and final dashes the arrows, indicating the direction of gaze should be put. Arrows should be applied at a distance of 2 ... 3 mm from the end of the dash. Letters are applied about arrow. The section should be noted as "A-A".

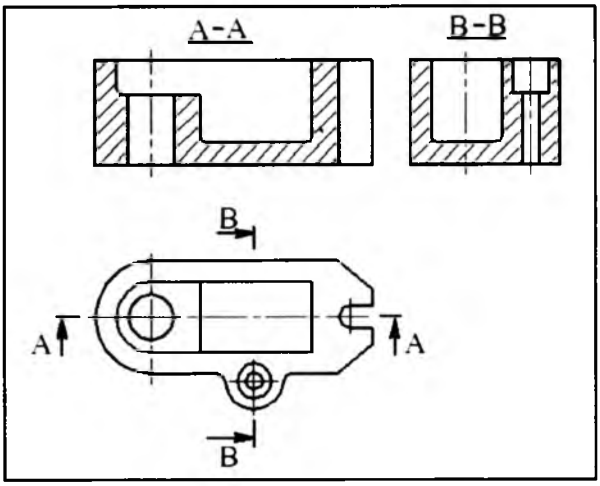


Fig. 8.15

Figure 8.15 shows the section of asymmetrical detail. The cutting frontal and profile planes are designated with A-A and B-B.

8.3. Construction of the Third Projection of Detail on Two Given Projections

Construction of the third projection of detail on two given projections is of training character. It allows you to develop the capacity for spatial thinking; it helps to better understand the details of the construction.

Usually, in the educational process are given front (main) view and a top (plan) view, and you have to construct a profile(left-side) view, or frontal and profile views are given, and you have to construct a horizontal(top) view.

Figure 8.16 shows the main view and top view of detail, and is required to construct the left, i.e., profile projection. To do this, we first need to get acquainted with the construction of details, to create a complete picture of its geometric forms.

This detail can be broken down into two mutually perpendicular prisms.

Lower prism has a length of 50 mm, a width of 40 mm and a height of 15 mm. The upper prism has a prismatic groove with

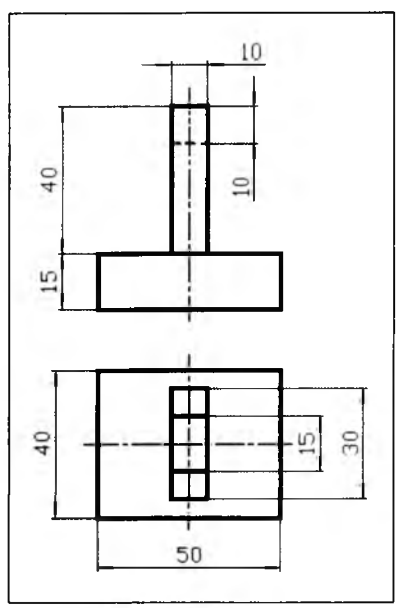
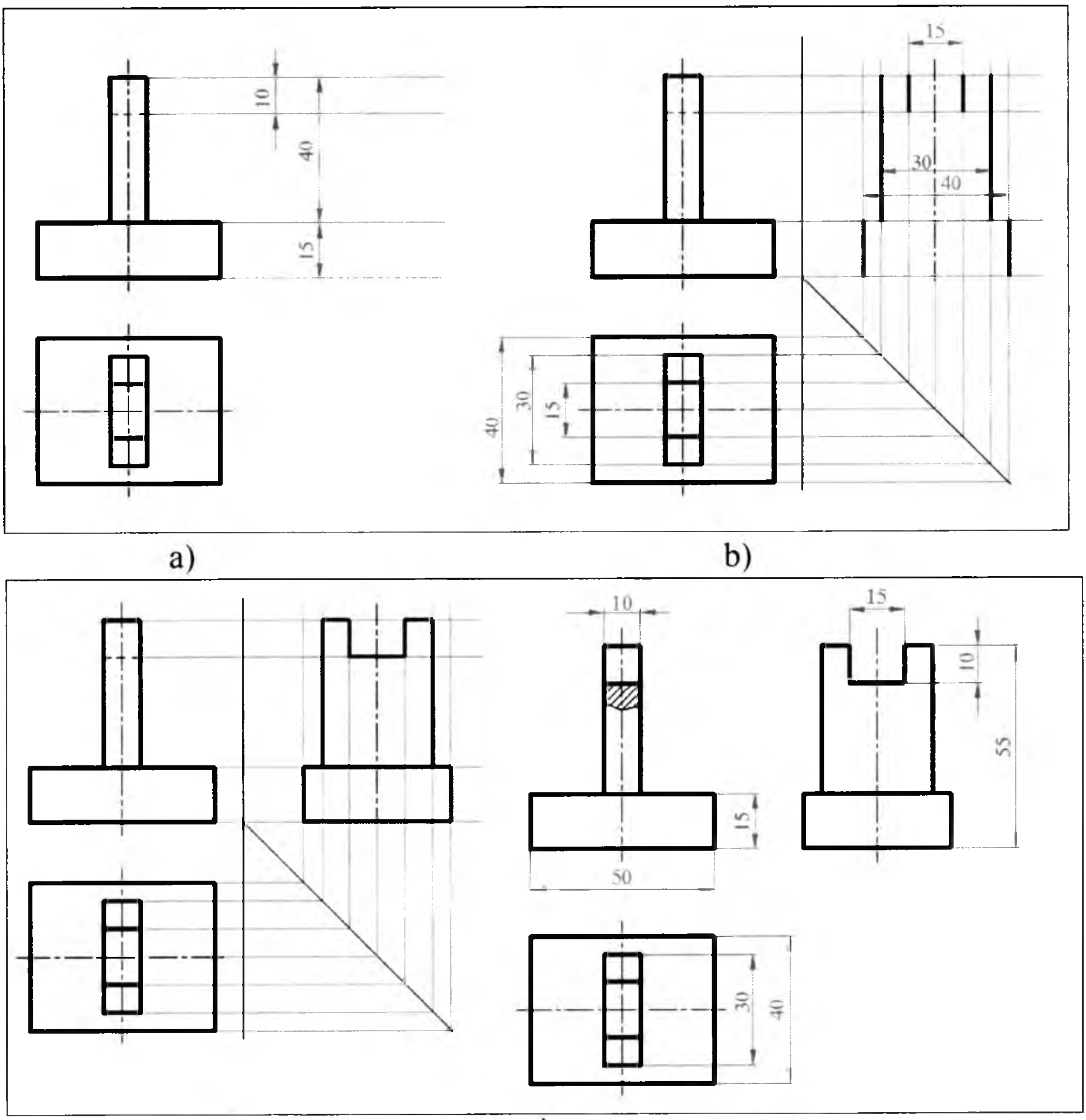


Fig. 8.16

dimensions 10x15 mm. Sizes of the upper prism are: length 30 mm , width 10 mm, height 40 mm.

Fig. 8.16 shows the sequence of the construction of the missing third – profile projection.

1. The profile projection is always situated on the same level with the frontal projection, so we draw horizontal lines of recall (Fig. 8.17, a).



a) b)

d) c)

Fig. 8.17

2. This detail is symmetrical, so we draw a symmetry axis of the profile projection. Then we mark dimensions on the profile projection characterizing the width of the detail (Fig. 8.17, b).

3. We define corresponding points of intersection of horizontal and frontal lines on the profile projection and join them (Fig.8.17, c).

4. We remove the unnecessary lines and show the necessary sections and dimensions (Fig. 8.17, d).

Thus, we obtain the missing profile projection of detail.

8.4. Sketch and Working Drawing

The rules of drawings, we are now acquainted with, must be remembered.

Very often before making a drawing, sketches are made.

What is a sketch? What is the difference between a working drawing and a sketch?

Drawings made by hand and containing all the information necessary for making the detail represented in them are called **sketches.** When machine parts are designed, sketches are sometimes made and used for the manufacture of experimental models. Sketches are drawn in approximate scales. Most of details can be seen on an orthographic drawing than on an isometric one, mainly because more than one view is drawn. For this reason it is often advantageous for a draftsperson to make an orthographic sketch.

What is a working drawing?

Technical drawings, according to which machine parts are manufactured and assembled at factories, as well as repaired are called **working drawings.**

In working drawings, machine parts are represented in their finished form, i.e. the form into which they have to be assembled.

Let's consider the sequence of sketch detail construction(Fig. 8.18):

1.We draw on a sheet of the outer frame and the frame that limits the drawing. We show border of the title block. Then we draw rectangles with thin lines, within which views of detail and center lines will be located (Fig. 8.18, a).

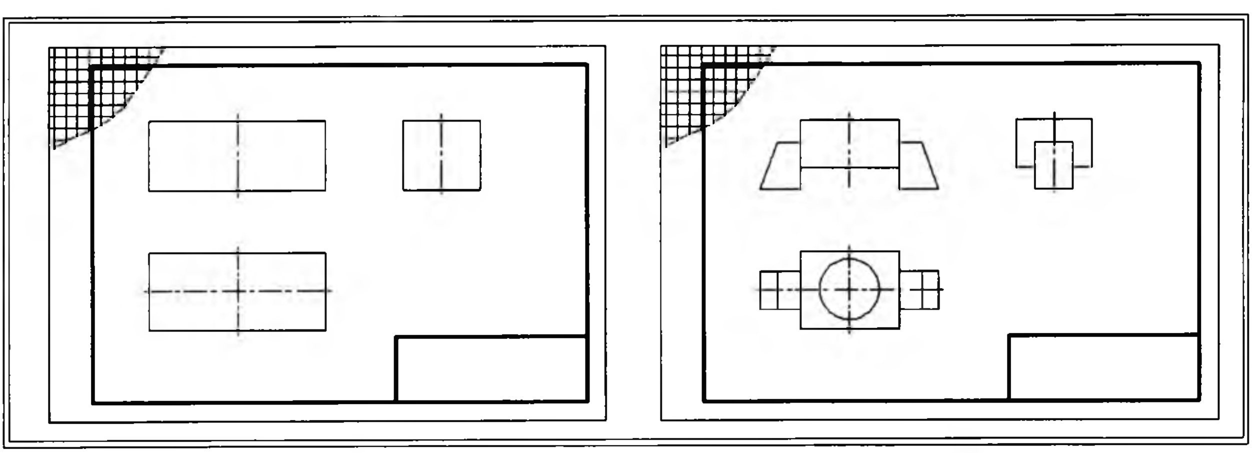
2. Draw the visible elements of detail with contour lines (Fig. 9.18, b).

3. Draw the invisible elements of details with dashed lines (Fig. 9.18, c).

4. Show necessary sections (Fig.8.19, d).

5. Draw dimension lines and extension lines (Fig 9.19, e).

6. Show dimensions and fill the title block (Fig. 9.19, f).



a) b)

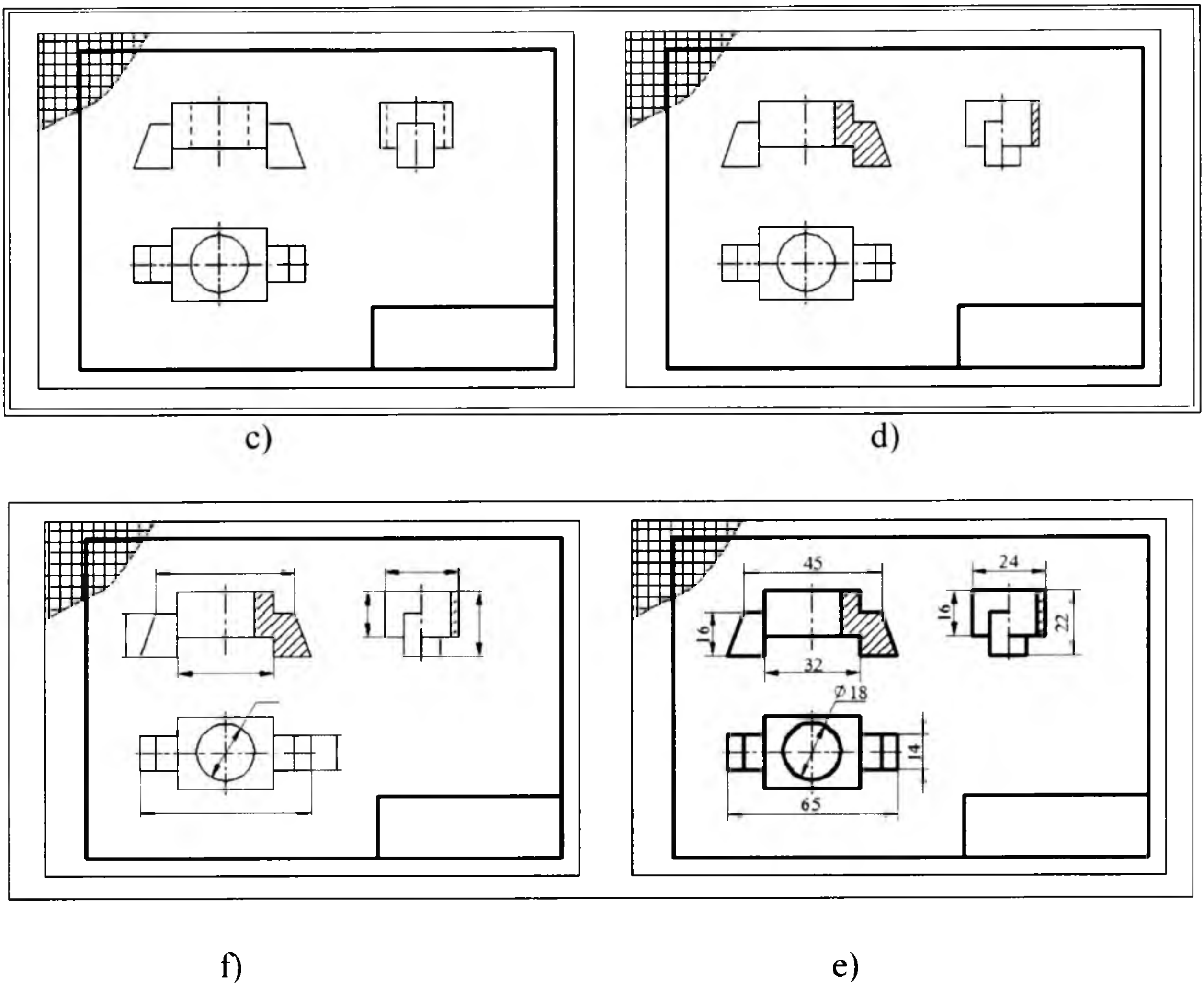


Fig. 8.18

In practice, based on the finished sketch engineers create working drawing of detail.

QUESTIONS AND ASSIGNMENTS TO CHAPTER VIII

1. What is the plan?
2. How many views does every representation contain in a drawing?
3. What is the main view?
4. How many dimensions do objects create in the world today? What are they?
5. What is the left-hand side view?
6. What parts are not sectioned?
7. When is sectioning of an object important?
8. What angle are inclined section lines at?
9. What is the frontal section?
10. What is the horizontal section?
11. What is the profile section?

12. What is the cutting plane?
13. What is the simple section?
14. What is the half – section?
15. What is the full section?
16. What is the inclined section?
17. What is the local section?
18. What is the complicated section?
19. What is the stepped section?
20. What is the broken section?
21. What is the difference between full section and half section?
22. What angle must the hatch be done at?
23. Describe the different types of sectional views with suitable examples.
24. What are the rules of construction of the third projection of detail on two given projections?
25. What is a sketch?
26. What is a working drawing?
27. What is the difference between a working drawing and a sketch?
28. Write brief notes on the preparation of working drawings.

CHAPTER IX
AXONOMETRIC DRAWING

Drafted by an orthographic projection details give providing information about their shape and size, but these projections don't give a spatial representation of the detail. In order to get a better understanding of the detail, there is a need to construct its spatial image. For the presentation of detailed drawings, this system has been found to be far superior to all others. The system has, however, the disadvantage of being very difficult to understand by people not trained in its usage. It is always essential that an engineer is able to communicate his ideas to anybody, particularly to people who are not engineers, and it is therefore an advantage to be able to draw using a system of projection that is more easily understood. The method of full representation of the object (detail) on the drawing is called ***axonometry***.

In ***an axonometric drawing***, the projection rays are drawn parallel to each other and perpendicular to the plane of projection.

An axonometric drawing which has all three axes divided by equal angles is ***isometric drawing***.

An axonometric drawing which has two axes divided by equal angles is ***dimetric drawing***.

On ***a trimetric drawing***, the relationship of the angle between axes to each other is none of the above.

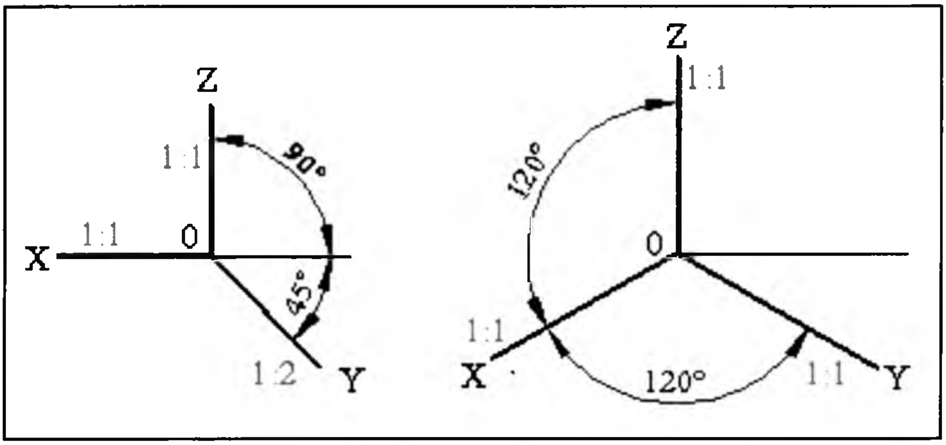
We shall study two methods of making pictorial views of objects according to the rules of axonometric drawing: isometric and dimetric projections. Isometric and oblique projections present the more pictorial view of an object.

Axonometric projection, in which the projecting rays are perpendicular to the plane of projection, is called ***rectangular***.

If projecting rays are inclined to the plane of projection, the projection is called ***oblique***.

9.1. The Main Parameters of Axonometric Projections

The main parameters of the axonometric projection are axonometric axes directions and the ***distortion coefficient***. The axis-x is a horizontal axis, the axis z – the frontal axis and the y – axis has an angle of inclination of 45° in the ***oblique frontal dimetric projection***. The coefficients of the axes distortion are as follows: $R_x = K_s = 1$, $K_y = 0.5$ (Fig. 10.1, a). So, dimensions along the y – axis must be reduced in half. It is convenient to use the triangular rulers with angles 45°, 45° and 90° for construction of oblique frontal dimetric projection.



a) b)

Fig. 9.1

In rectangular isometric projection angles between the axes of the projections are 120°, distortion coefficients are $K_x = K_y = K_z = 0.82$. To simplify the process of constructing axonometry The State Standard proposed distortion coefficients to be 1:1 (Fig. 9.1, b).

9.2. The Rectangular Isometric Projection

If you were to make a freehand drawing of a row of houses, the house furthest away from you would be the smallest house on your drawing. This is called the "perspective" of the drawing and, in a perspective drawing none of the lines are parallel. Isometric drawing ignores perspective altogether. Lines are drawn parallel to each other and drawings can be made with T-square and set square. This is much simpler than perspective drawing.

Figure 9.2 shows a shaped block drawn in rectangular isometric projection. You will notice that there are three isometric axes. They are inclined at 120° to each other. One axis is vertical and the other two axes are at 30° angle to it. Dimensions measured along these axes, or parallel to them, are true lengths.

In isometric drawing true measurement can be made only along or parallel to the isometric axes.

The faces of the shaped block shown in Fig. 9.2 are all at 90 ° to each other. The result of this is that all of the lines in the isometric drawing are parallel to the isometric axes. If the lines are not parallel to any of the isometric axes, they are no longer true lengths.

Figure 9.3 illustrates the construction of an isometric projection of a rectangle, whose sides are parallel to the axes of the projections.

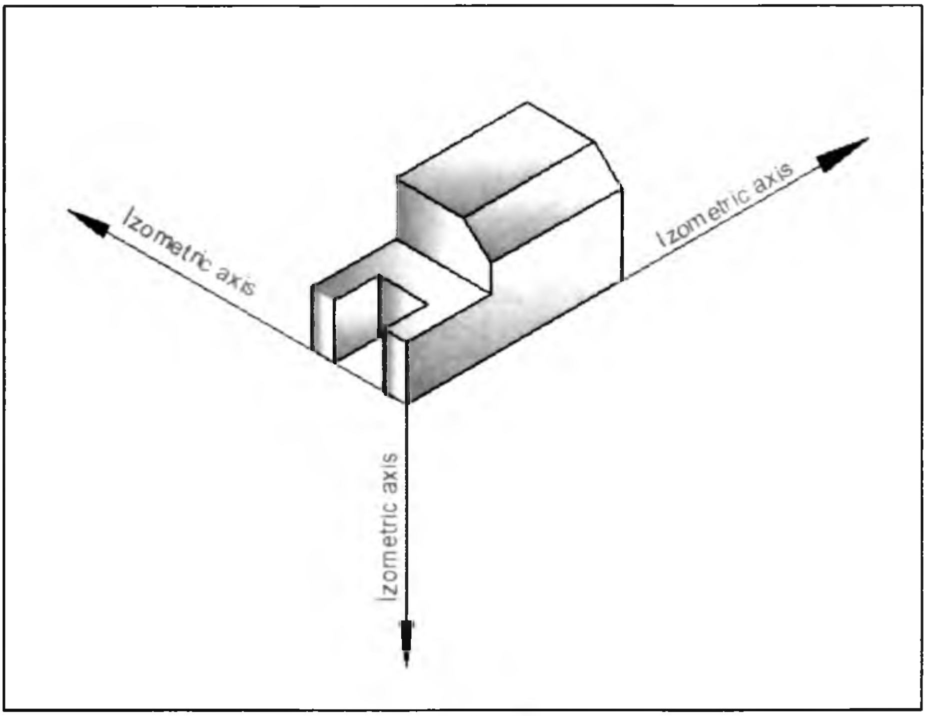


Fig. 9.2

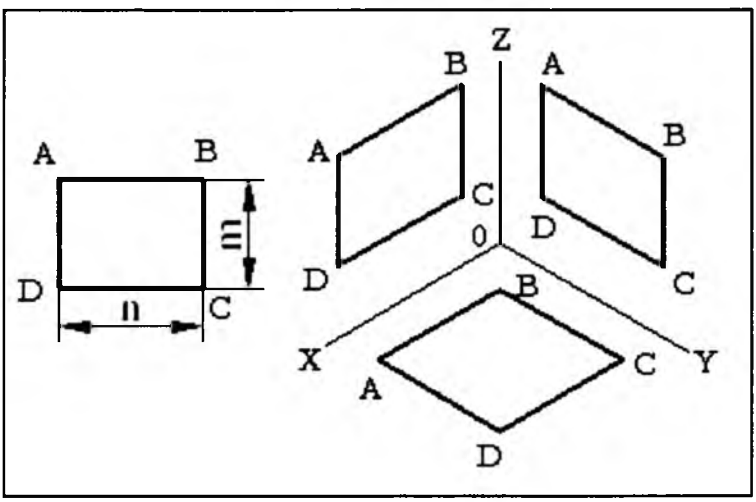


Fig.9.3

An example of this is given in Fig. 9.4 which shows an isometric drawing of a regular hexagonal prism. The hexagon is first drawn as a plane figure and a simple shape, in this case a rectangle is drawn around the hexagon. The rectangle is easily drawn in isometric projection and the positions of the corners of the hexagon can be transferred from the plane figure to the isometric drawing with a pair of dividers.

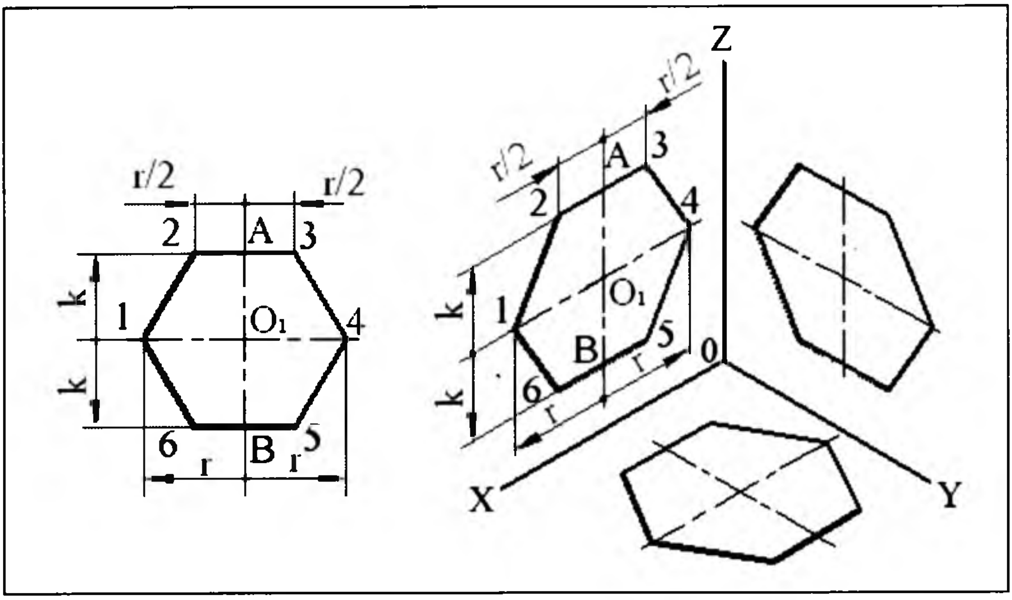


Fig. 9.4

The dimensions of the hexagon should all be 25 mm and you can see from Fig. 9.4 the lines which are not parallel to the isometric axes do not have true lengths.

9.3. The Circles Drawn in Isometric Projection

Isometric projections of the circle on the projection plane are ***ellipses***. When constructing an isometric projection of the circle, axes of the ellipse are drawn perpendicular to each other. Construction of the ellipse is a difficult process, so it is replaced by ***oval.***

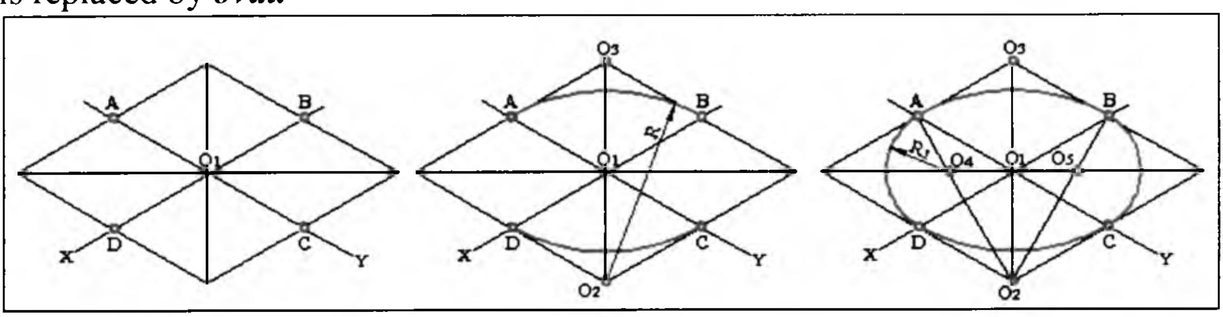


Fig. 9.5

All of the faces of a cube are square. If a cube is drawn in isometric projection, each square side becomes a rhombus. If a circle is drawn on the face of a cube, the circle will change its shape when the cube is drawn in isometric projection. Figure 9.5 shows how to plot the new shape of the circle.

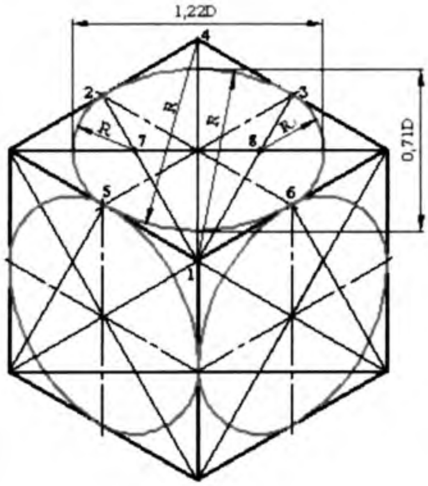


Fig. 9.5

The circle is first drawn as a plane figure, and is then divided into an even number of equal lines. The face of the cube is then divided into the same number of equal lines. Center lines are added and the measurement from the center line of the circle to the point where line 1 crosses the circle is transferred from the plane drawing to the isometric drawing with a pair of dividers. This measurement is applied above and below the center line. This process is repeated for lines 2, 3, etc. The points that have been plotted should then be carefully joined together with a neat freehand curve.

Since a circle can be divided into four symmetrical quadrants, it is really necessary to draw only a quarter of a circle instead of a whole plane circle. The dimensions which are transferred from the plane circle to the isometric view are called "ordinates" and the system of transferring ordinates from plane figures to isometric views is not confined to circles. It may be used for any regular or irregular shape.

Non- isometric lines are located by determining the endpoints of the non-isometric line.

9.4. The Frontal Diametric Projection of Rectangle

Figure 9.8 illustrates constructing of the front dimetric projections of a circle inscribed in a square. First, we draw the axis of oblique frontal dimetric projection.

If a plane figure is parallel to the frontal plane of projection, its dimetric projection on this plane repeats itself without any changes of the shape. So, dimetric projection of a plane figure, parallel to the frontal plane of projection, is the same figure.

As an example, Figure 9.9 shows the construction of dimetric projection of cube inscribed in the side faces of the circles.

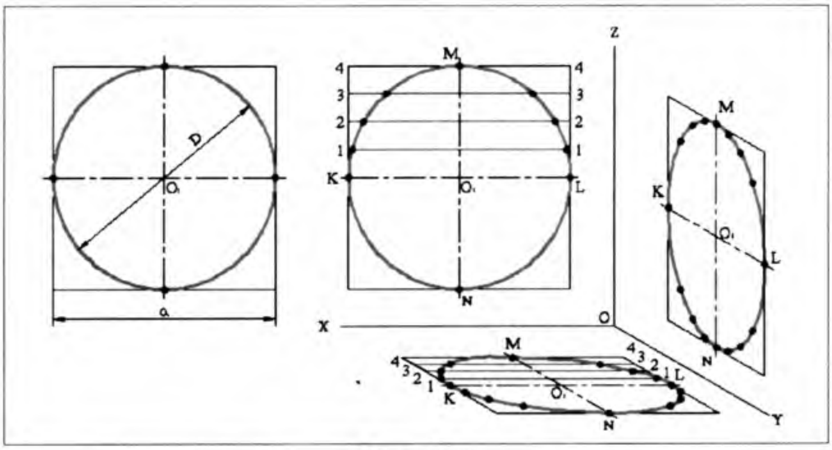


Fig. 9.8

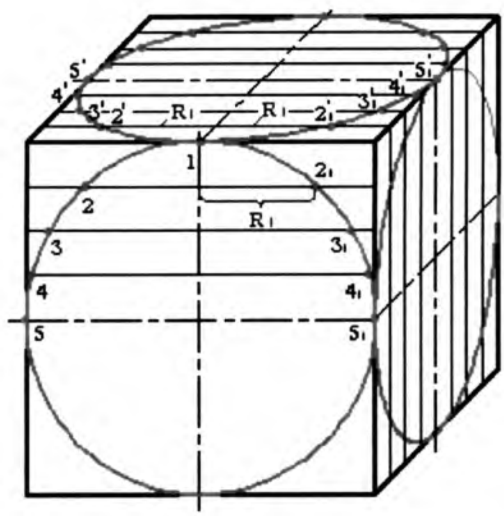


Fig. 9.9

9.5. Axonometric Projections of Detail

Figure 9.10 shows three views of detail, having prism shape. There are two rectangular passes and one blind square hole in detail.

Detail is symmetric with respect to two mutually perpendicular axes. Drawn details are given with sections. Let's construct an axonometric projection of this detail. More convenient and easy is the choice of an isometric projection. The sequence of isometric projection construction of the details is shown in figure 9.1.

The sequence of dimetric projection construction of the details is shown in Figure 9.12.

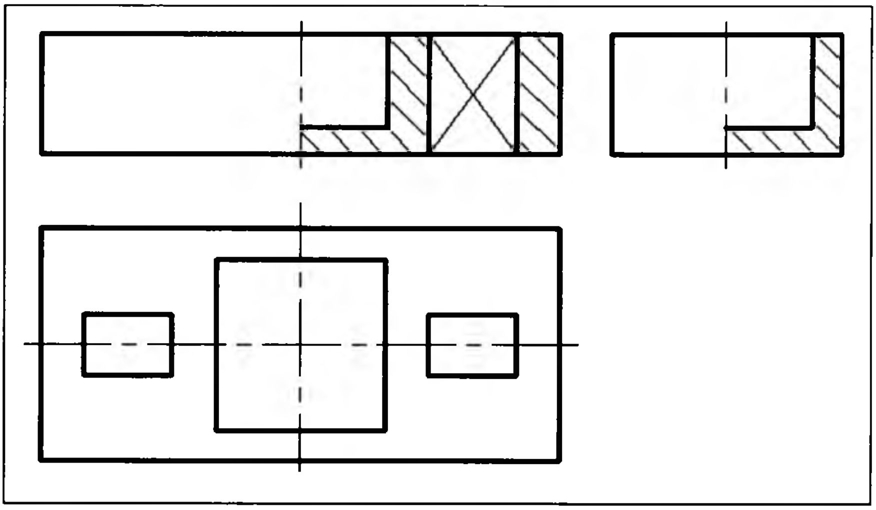


Fig. 9.10

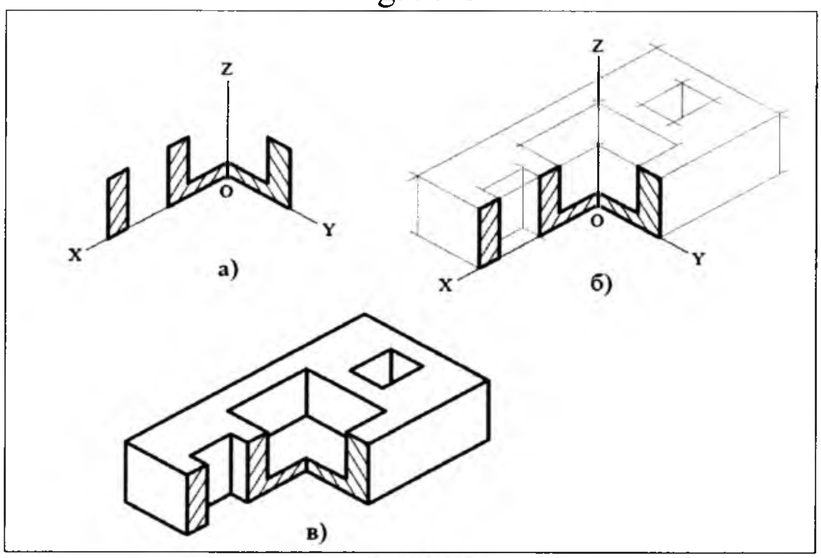


Fig. 9.11

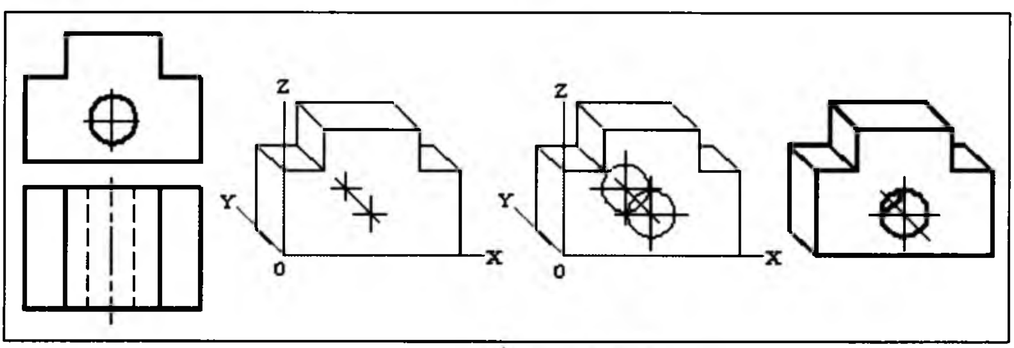
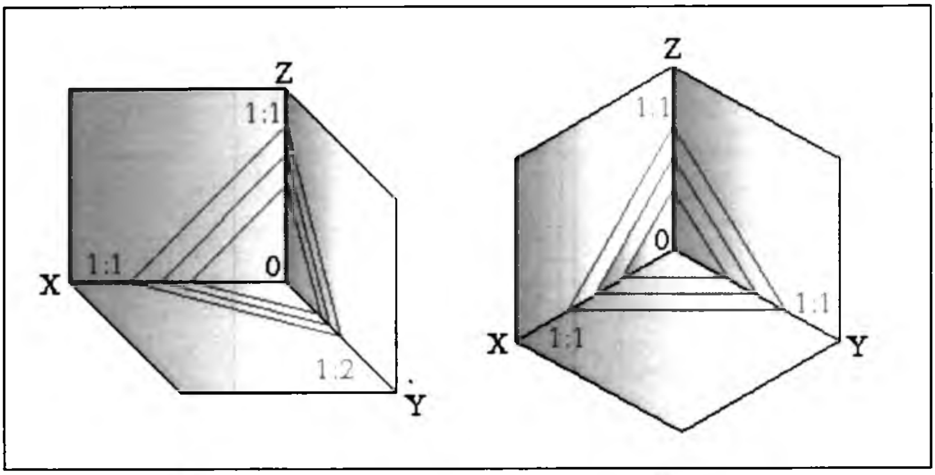


Fig. 10.12

9.6. Construction of Sections in Axonometric Projections

If it is necessary to get more information about the details we have to give the section in the axonometric projection. At the sectional part of axonometric view, only that part of the detail is hatched, which is directly in contact with the cutting plane.



a) b)

Fig. 9.13

Unlike an orthographic projection, in axonometric projections hatching angle is not 45°. Hatch direction depends on the type of axonometric projection and the position of the truncated portion.

Figure 9.13 shows the direction of hatching, depending on the axonometric projections. As it is noted above, in dimetric projecting the axis Y dimensions are reduced in half. Accordingly, we have to mark an equal length of line segments on X and Z axes, but by half of this line segment on Y axis. By joining the ends of lines, we get a triangle, the sides of which show the direction of the hatch on the dimetric projections (Fig.9.13, a).

The directions of the axes dimensions don't change. In isometric projecting, we have to mark an equal length segments on the axes X, Y and Z. Joining the ends of lines, as in the first case, we get a triangle, the sides of which show the direction of the hatch on the isometric projections(Fig. 9.13, b).

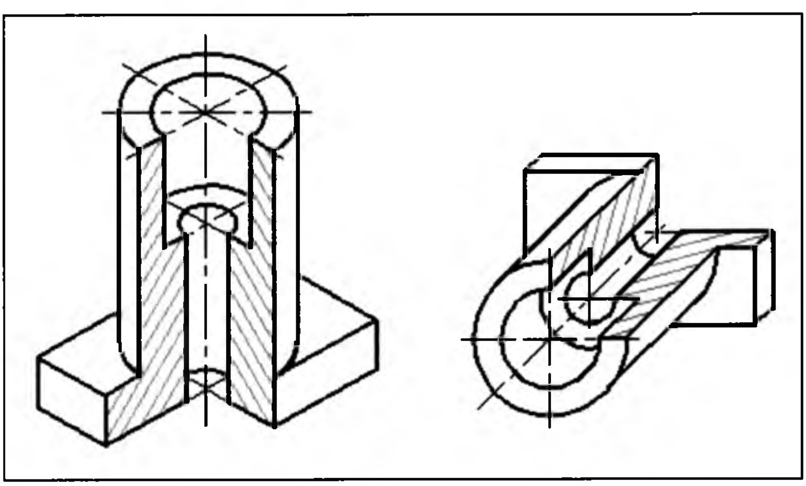


Fig.9.14

Figure 9.14 shows examples of hatching on axonometric projections of detail.

QUESTIONS AND ASSIGNMENTS TO CHAPTER IX

1. What method is called the axonometry?
2. How are the projection rays drawn on axonometric drawing?
3. If a client of yours is having difficulty on visualizing a design, what type of drawing would be the easiest to understand?
4. What is the isometric projection referred to as?
5. What is the dimetric projection referred to as?
6. What is the trimetric projection referred to as?
7. What is the rectangular isometric projection referred to as?
8. In what type of projection does each of the axes have different ratios of foreshortening?
9. What type of axonometric drawing has equal foreshortening along two axis directions and a different amount on the third axis?
10. How are lines of an isometric drawing that are not parallel to the isometric axes called?
11. What angles must the edges of the cube be to each other in isometric projection at?
12. What is the oblique projection referred to as?
13. What is the oblique frontal dimetric projection referred to as?
14. What are the main parameters of axonometric projections?
15. What is the difference between isometric and diametric projections?
16. Why is rectangular isometric drawing much simpler than perspective drawing?
17. What is the isometric view of a circle?
18. Draw an isometric square.
19. Draw a frontal dimetric projection of rectangle.
20. What are the rules of constructing of sections in axonometric projection of detail?

CHAPTER X
JOINTS

10.1. Threads

The thread is probably the most important single component in engineering. The application of the thread to nuts, bolts, studs, screws, etc., provides us with the ability to join two or more pieces of material together securely, easily and, most importantly of all, not permanently. There are other methods of joining materials together, but the most widely used ones – riveting, welding. It is true that these methods are cheaper, but when we know that we might have to take the thing apart again we use the screw thread. Since the thread is so important it is well worthwhile looking at the whole subject more closely.

The standard thread was introduced by Sir Joseph Whitworth in the 1840s. It was the first standard thread; previously nut and bolt were made together and would fit another nut or bolt only by coincidence. Meanwhile, it was a revolutionary step forward.

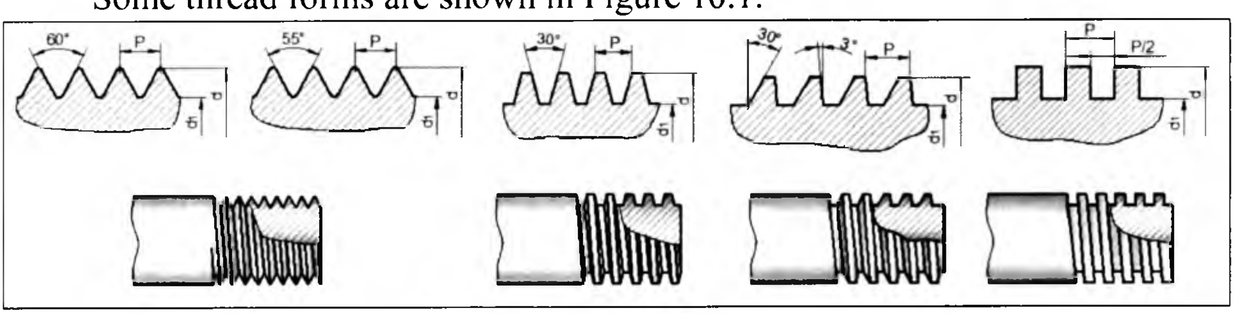
The BSW (British Standard Whitworth) thread and its counterpart the BSF (British Standard Fine) thread were the thread standards in Britain until metrication; and will probably be in use for many years.

However, the United States of America developed and adopted the unified thread as their standard and countries using the metric system of measurement had their own metric thread forms. It became increasingly obvious that an international screw thread standard was needed.

The breakthrough came when it was decided that British Industry should adopt the metric system of weights and measures. The International Standards Organization (ISO) has formulated a complex set of standards to cover the whole range of engineering components.

Their thread standard, the ISO, is now the international thread standard. The ISO and unified thread profiles are identical. The unified thread standard is the International Standard for countries which are still using imperial units.

Some thread forms are shown in Figure 10.1.



a) b) c) d)

Fig. 10.1

The ***triangular thread*** (Basic form of ISO thread) is shown in Figure 10.1, a. You will note that the thread is thicker at the root than at the crest. This is because the stresses on the thread are greater at the root and the thread needs to be thicker there if it is to be stronger. In practice, since there is nothing gained by having the root and crest of a nut and bolt in contact, and because "square" corners are difficult to manufacture, the ISO thread form is usually modified to that shown in Fig. 10.1,a. We can see that the contact will be only on the flanks.

The ***acme thread*** (Fig. 10.1, b) is extensively used for transmitting power. The thread form is easier to cut than the square thread because of its taper and, for the same reason; it is used on the lead screw of lathes where the half-nut engages easily on the tapered teeth.

Fastening threads are usually ***vee threads.*** Vee threads result in higher friction, which lessens the possibility of loosening. Vee threads are more convenient to manufacture.

The ***square thread*** (Fig. 10.1, d) is now rarely used because the acme thread has superseded it. Its main application is for transmitting power since there is less friction than with a vee thread.

The ***Buttress thread*** (Fig. 10.1, c), combines the vee thread and the square thread without retaining any of their disadvantages. It is a strong thread and has less friction than a vee thread.

10.2. Drawing Threads

A thread drawn in full, would take too long a time on a drawing that has several threads on it, and would be physically impossible on a small thread.

There are conventions for drawing threads which make life very much easier. Let's learn the methods of representing threads, shown in Figure 10.2 and in Figure 10.3.

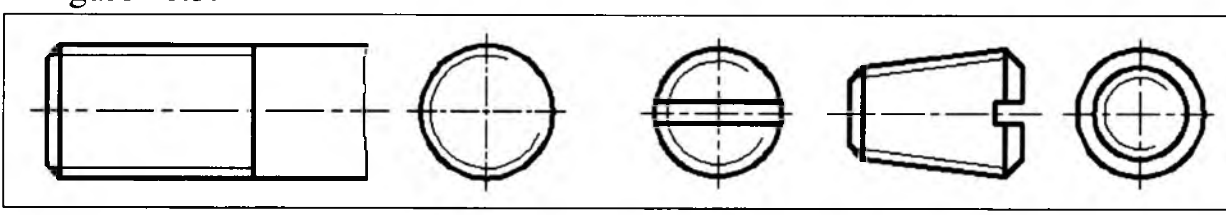


Fig. 10.2

The only conventional symbol, which shows whether the thread is right- or left-handed is the second one. This is not much of an advantage because the thread has to be dimensioned and it is a simple matter to state whether a thread is right- or left-handed.

Left-hand threads are rarely met, and unless specifically stated, a thread is assumed to be ***right-handed*** (table 10.1).

Figure 10.2 shows the convention for ***external threads***. Figure 10.2 shows the convention for ***internal threads***.

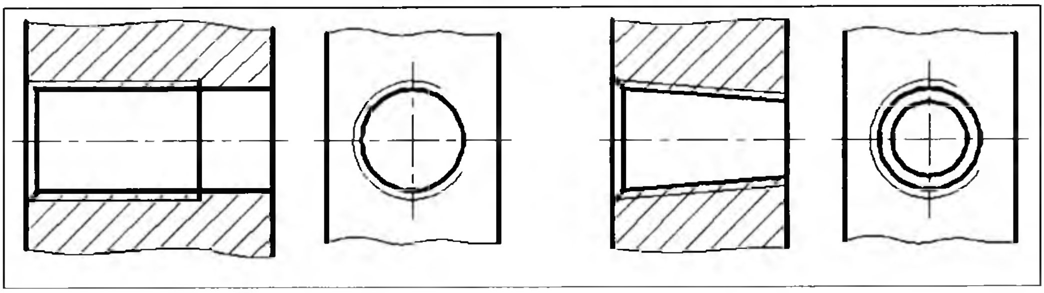


Fig. 10.3

It should be explained that, on the drawings for internal threads, the thread does not reach the bottom of the hole. When an internal thread is cut, the material is first drilled a little deeper than is actually required. The diameter of the hole is the same as the root diameter of the thread and is called the tapping diameter. The cutting angle of the drill, for normal purposes, is 118° – almost 120°.

Thus, a 60 ° set square is used to draw the interior end of an internal screw thread.

In the threaded connection sections in the images on the plane parallel to its axis, it is shown only in the opening part of the thread, threaded rod of which is not locked (Fig. 11.4).

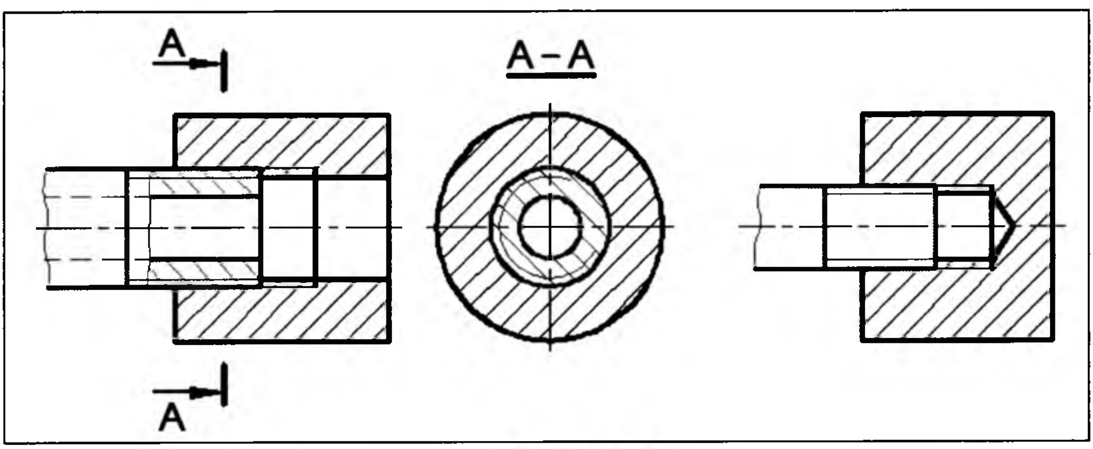


Fig. 10.4

Hatches in the sections and the cuts are performed along the line of the external diameter of the thread to the internal diameter of the hole.

There are three characteristic diameters of threads: *major diameter*, *minor diameter*, and *pitch diameter*: industry standards specify minimum (min) and maximum (max) limits for each of these, for all recognized thread sizes. The min limits for *external* (or *bolt*, in ISO terminology), and the max limits for *internal* (*nut*), thread sizes are there to ensure that threads do not strip at the tensile strength limits for the parent material. The min limits for internal and max limits for external threads are there to ensure that the threads fit together.

10.3. Designation of ISO Threads

The coarse series ISO thread is only one of 12 different threads in the ISO series. This thread, like the fine thread series, has a pitch which varies with the diameter of the bolt. The remaining 10 thread series have constant pitches, whatever the diameter of the thread is.

All the series except the coarse thread series are used in special circumstances. The vast majority of threads used come from the coarse thread series.

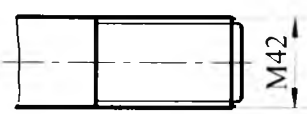
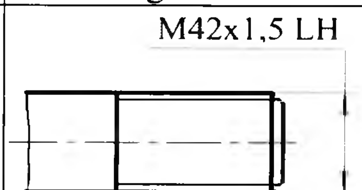
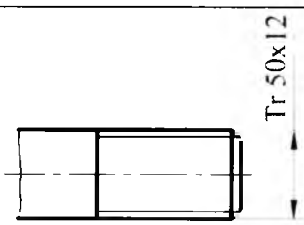
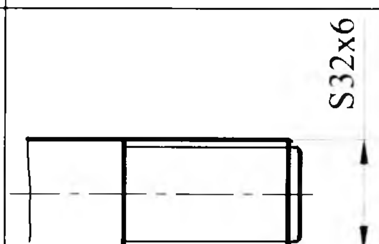
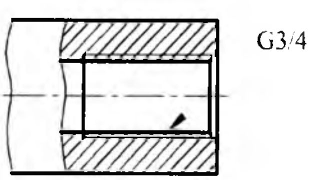
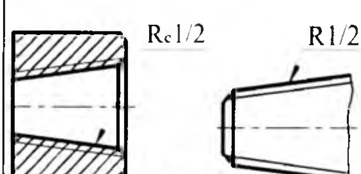
The method used on drawings for stating an ISO thread is quite simple. For the metric thread forms and series you have to use letter “M”. The diameter of the thread is stated immediately after “M”. Thus M12 is ISO thread form, 12 mm diameter thread and M20 is ISO thread form, 20 mm diameter thread. In many countries the designation shown above is used to denote coarse thread series. If a thread is used from a constant pitch series, it is added after, so that M14X1.5 is a 14 mm diameter with a constant pitch of 1.5 mm.

However, the British Standard requires that the pitch will be included in the coarse thread series. Thus, a thread with the designation M30X3.5 is coarse series ISO thread with a pitch of 3.5 mm.

A thread with the designation M16X2 is a coarse series ISO thread with a pitch of 2 mm.

Table 10.1 shows examples of thread designations.

Table 10.1

Designation	Transcript	Designation	Transcript
	Metric thread, diameter-42 mm, right – handed.		Metric thread, diameter-42 mm, left–handed.
	Acme thread diameter-50 mm, right – handed, pitch-12 mm.		Buttress thread, diameter-32mm, pitch-6mm.
	Pipe cylindrical thread, diameter - ¾ inch.		Tapered internal and external threads, diameter – ½ inch.

There are further designations concerned with the tolerances, or accuracy of manufacture, but these are beyond the scope of this book.

10.4. Assembly Drawings

There are not many engineering items that are completely functional by themselves. There are some of them, a spanner or a rule for instance, but even a simple object like a wood chisel has three components and a good pair of compasses may have 12 component parts. Each part should be drawn and dimensioned separately and then a drawing made of all the component parts are put together. This is called an "assembly drawing". The student at school or college is often instructed to draw the assembled components only and is shown the dimensioned details in no particular order. If the assembly is particularly difficult, the parts are often shown in an exploded view and the assembly presents no difficulty. The assembled parts may form an object, which is easily recognizable, but the real problem occurs when there seems to be no possible connection between any of the component parts. In an examination, when loss of time must be avoided at all costs, the order of assembly needs to be worked out quickly. The only approach is to view the assembly somewhat like a jigsaw puzzle. The parts must fit together and be held together, either because they interlock or there is something holding them together. Try to look for similar details on separate components. If there is an internal square thread on one component and an external thread of the same diameter on another component, the odds are that one screws inside the other. If two different components have two or more holes with the same pitch, it is likely that they are joined at those two holes. A screw with an M10 thread must fit an M10 threaded hole. A tapered component must fit another tapered component. The important thing, particularly in examinations, is to start drawing. Never spend too long trying to puzzle out an assembly. There is always an obvious component to start drawing, and, while you are drawing it, the rest of the assembly will become apparent as you become more familiar with the details.

10.5 Nut, Bolt and Stud

We will see how to draw a standard nut and bolt with their principal dimensions. There are, however, many other types of fastenings in everyday use in industry, and some of them are shown later.

A **nut** is a type of fastener with a threaded hole (Fig. 10.5). Nuts are almost always used opposite a mating bolt to fasten a stack of parts together.

The two parts are kept together by a combination of their threads' friction, a slight stretch of the bolt, and compression of the parts. In applications where vibration or rotation may work a nut loose, various locking mechanisms may be employed: adhesives, safety pins or lock wire, nylon inserts, or slightly oval-shaped threads. The most common shape is hexagonal, for similar reasons as the bolt head – 6 sides give a good granularity of angles for a tool to approach from (good in tight spots), but more (and smaller) corners would be vulnerable to being rounded off. It takes only 1/6 of a rotation to obtain the next side of the hexagon and grip is optimal. However polygons with more than 6 sides do not give the requisite grip and polygons with less than 6 sides take more time to be given a complete rotation. Other specialized shapes exist for certain needs, such as wing nuts for finger adjustment and captive nuts for inaccessible areas.

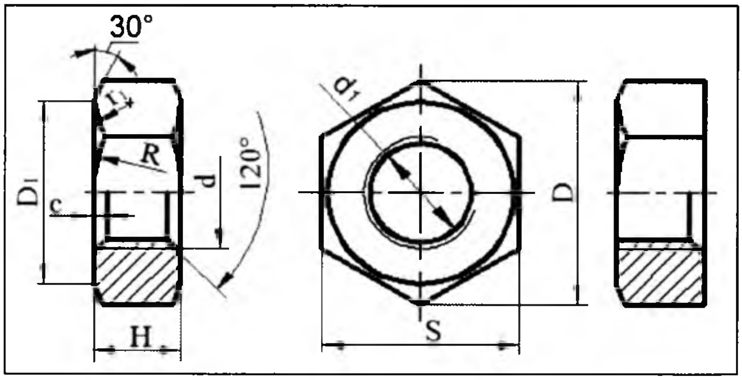


Fig. 10. 5

A **bolt** is a form of threaded fastener with an external male thread (Fig.10.6, a). Bolts use a wide variety of head designs, so do screws. These are designed to engage with the tool used to tighten them. Some bolt heads instead lock the bolt in place, so that it does not move and a tool is only needed for the nut end.

a) b)

Fig. 10.6

A **threaded rod**, also known as a **stud,** is a relatively long rod that is threaded on both ends; the thread may extend along the complete length of the rod (Fig. 10.6, b)

Bolts are thus closely related to, and often confused with screws. Figure 10.7 shows complex drawing of bolt in two projections. When we draw the bolt, its axis has to be parallel to the title block (main inscription).

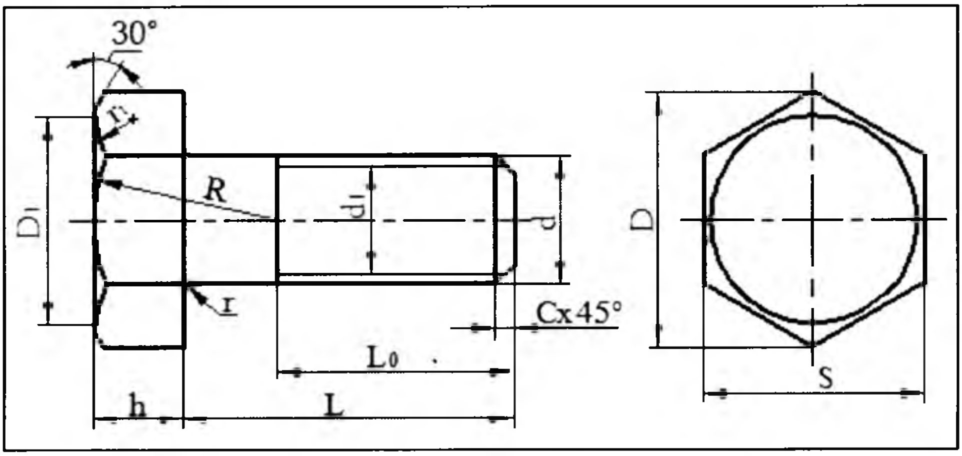


Fig.10.7

The stud and set bolt (sometimes called a tap bolt or cap screw) are used when it is impossible or impractical to use a nut and a bolt. Figure 10.8 and 10.9 show both in their final positions.

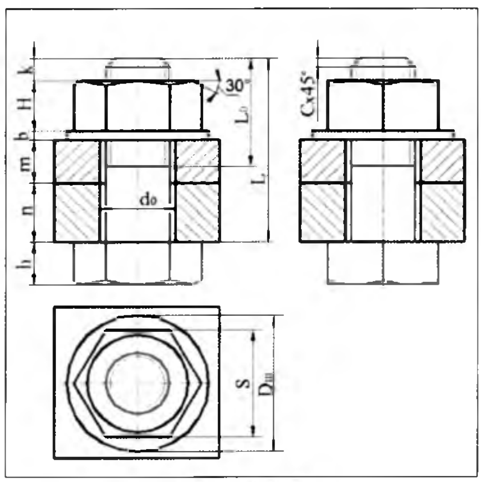


Fig. 10.8

They are both screwed into a tapped hole in the bottom piece of material. The top piece of material is drilled slightly larger than the stud or screw and is held in position by a nut and a washer in the case of the stud, and by the head of the set bolt and washer in the case of the set bolt. The stud would be used when the two pieces of material were to be taken apart quite frequently; the set bolt would be used if the fixing was expected to be more permanent.

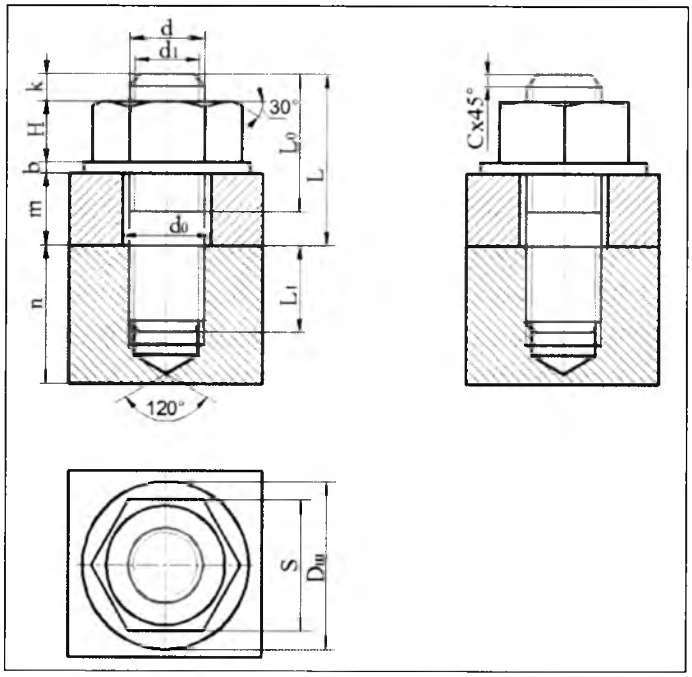


Fig. 10.9

10.6. Flange joints

A flange is an external or internal ridge, or rim (lip), for strength, as the flange of an iron beam such as an I-beam or a T-beam; or for attachment to another object, as the flange at the end of a pipe, steam cylinder, etc.

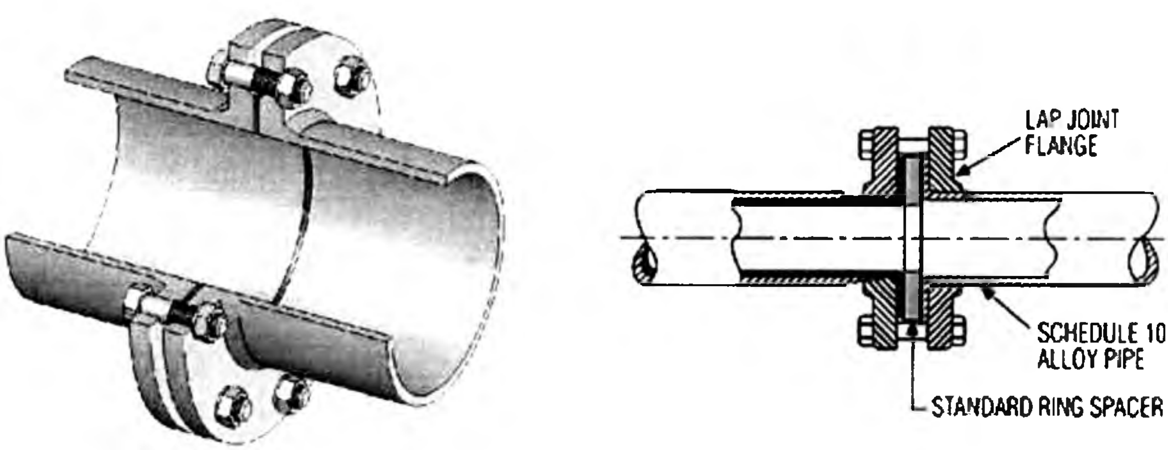


Fig. 10.10

Thus flanged wheels are wheels with a flange on one side to keep the wheels from running off the rails. The term "flange" is also used for a kind of tool used to form flanges. Pipes with flanges can be assembled and disassembled easily.

10.7. Pipe Joints. Fittings

A fitting is used in pipe systems to connect straight pipe or tubing sections, to adapt to different sizes or shapes, and for other purposes, such as regulating or measuring fluid flow. The term *plumbing* is generally used to describe conveyance of water, gas, or liquid waste in ordinary domestic or commercial environments, whereas *piping* is often used to describe high-performance (e.g. high pressure, high flow, high temperature, hazardous materials) conveyance of fluids in specialized applications. The term *tubing* is sometimes used for lighter-weight piping, especially types that are flexible enough to be supplied in coiled form.

a) b) c) d) e)

Fig. 10.11

While there are hundreds of specialized fittings manufactured, some common types of fittings are used widely in piping and plumbing systems. They are: coupling (Fig. 10.11, a), reducers (Fig. 10.11, b), elbows (Fig. 10.11, c), tees (Fig. 10.11, d) and crosses (Fig. 10.11, e).

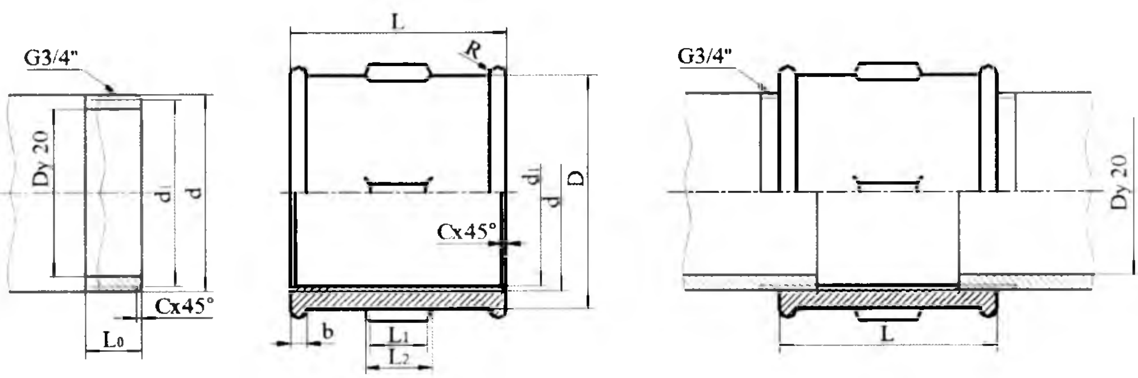
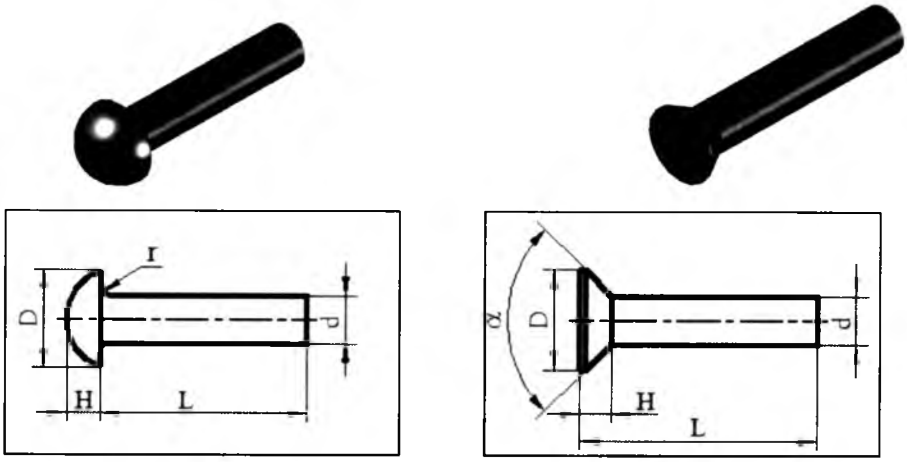


Fig. 10.12

Figure 10.12 shows complex drawing of coupling joints.

10.8. Rivets and Riveted Joints

A rivet is a permanent mechanical fastener (Fig. 10.23). Before installing, a rivet consists of a smooth cylindrical shaft with a head on one end. A rivet is used to join two or more pieces of material together permanently. The enormous advances in welding and brazing techniques, and the rapidly increasing use of bonding materials have led to a slight decline in the use of rivets. However, they remain an effective method of joining materials together, and, unlike welding and bonding, require very little special equipment or expensive tools when used on a small scale.



a) b)

Fig. 10.13

The most widely used rivets are ***round head rivets*** (Fig. 10.13, a) and ***blind head rivets*** (Fig. 10.13, b). The rivet is usually supplied with one end formed to one of these shapes. The other end is hammered over and shaped with a tool called a “dolly”.

When rivets are used they must be arranged in patterns. The materials to be joined must have holes drilled in them to take the rivets and these holes weaken the material, particularly if they are too close together. If the rivets are placed too close to the edge of the material, the joint will be weakened. The two basic joints are called “lap and butt joints” (Figs. 10.14 and 10.15).

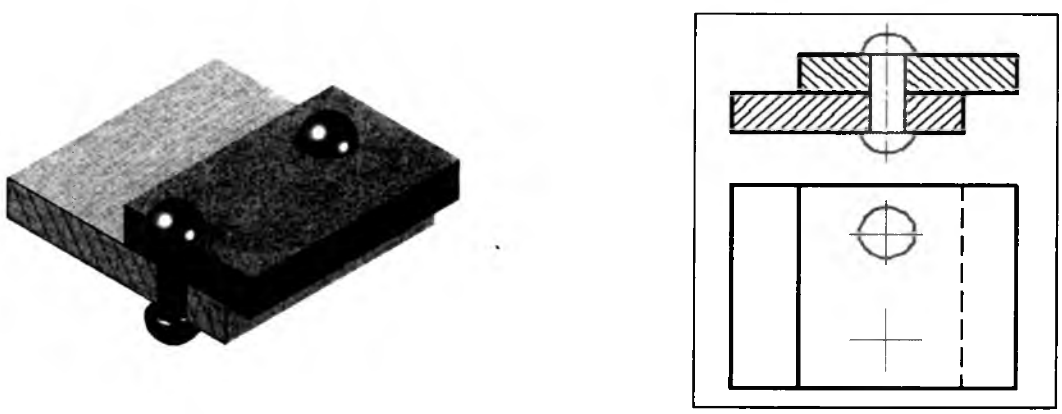


Fig. 10.14

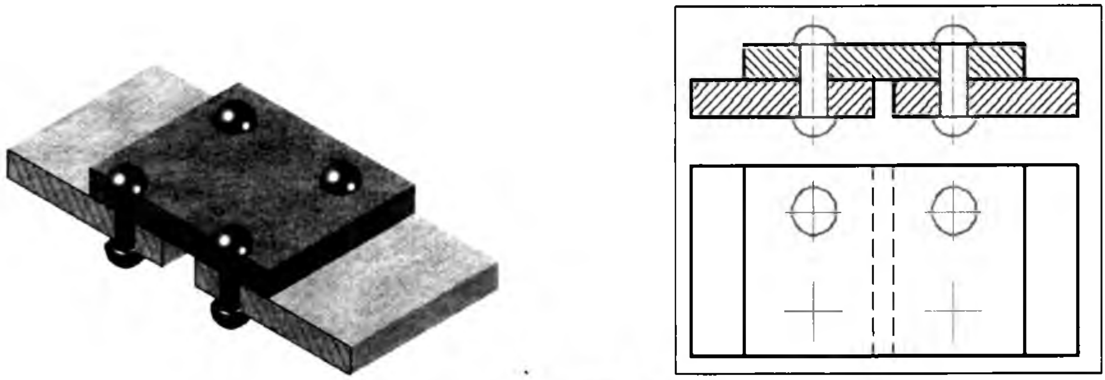


Fig. 10.15

There is no limit to the number of rows of rivets, nor to the number in each row, but the spacing, or pitch of the rivets, must be as it is shown in Fig. 10.15. The most used types of rivets are: single row lap, double row lap, double row zig-zag lap and double cover plate butt lap rivets.

10.9. Keys. Keyways

A key is a piece of metal inserted between the joint of shaft or hub to prevent relative rotation between the shaft and the hub. One of the most common applications is between shafts and pulleys.

There is a wide variety of keys, designed for light and heavy duties, for tapered and parallel shafts and to allow or prevent movement of the hub along the shaft.

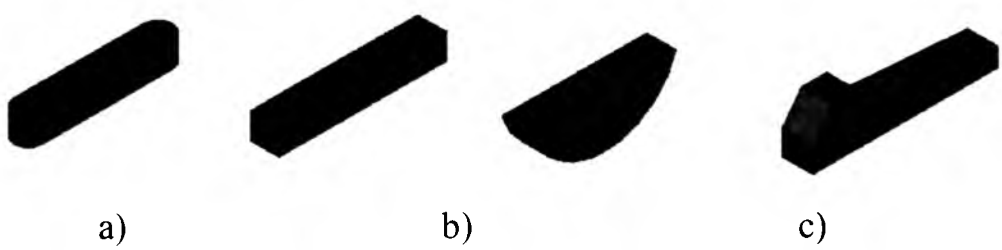


Fig. 10.16

Feather keys and ***parallel keys*** (Fig. 10.16, a) are used when it is desired that the hub should slide along the shaft, yet not allowing the rotation around the shaft.

Woodruff keys (Fig. 10.16, b) are used on tapered shafts. They adjust easily to the taper when assembling the shaft and the hub.

Taper keys (Fig. 10.16, c), are used to prevent sliding, and the ***gib head*** allows the key to be extracted easily.

Saddle keys are suitable for light duty only since they rely on friction alone.

Round keys are easy to install because the shaft and the hub can be drilled together but they are suitable for light duty only.

a) b)

Fig. 10.17

Figure 10.17 shows the sequence of key joints detail with the shaft via the Feather keys (Fig.10.17, a) and Gib head (Fig. 10.17, b) keys.

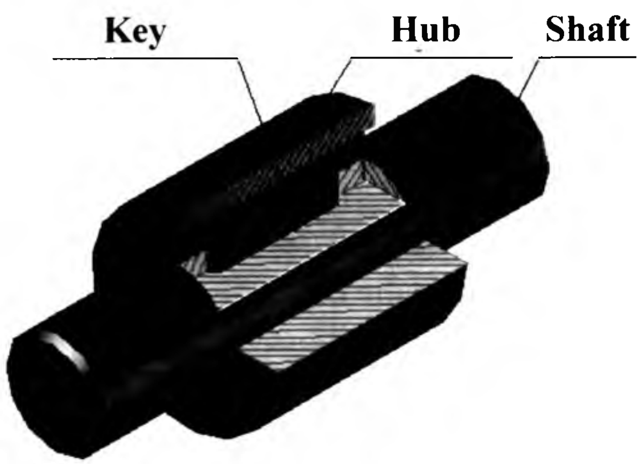
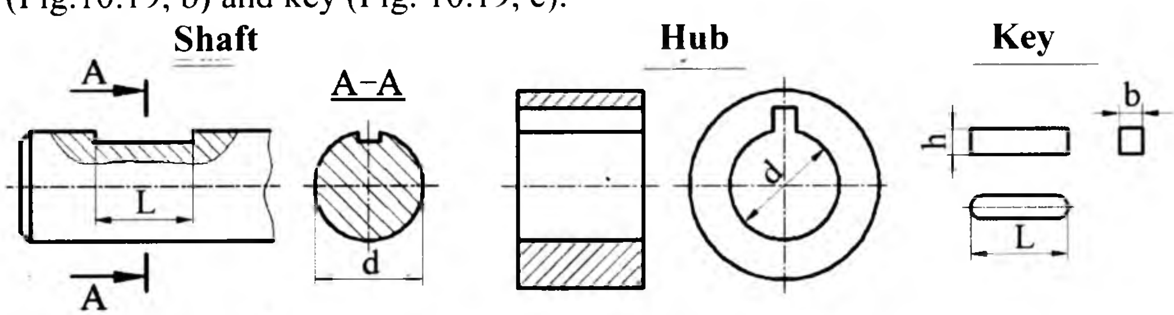


Fig. 10.18

Figure 10.19 shows the joints of the shaft to the hub via the feather key. For a clearer picture of the shaft and the hub they are given in section. Figure 10.18 shows complex drawing of elements of this joints – shaft (Fig.10.19, a), hub (Fig.10.19, b) and key (Fig. 10.19, c).



a) b) c)

Fig. 10.19

Assembly drawing of feather (parallel) key joint is shown in Figure 10.20.

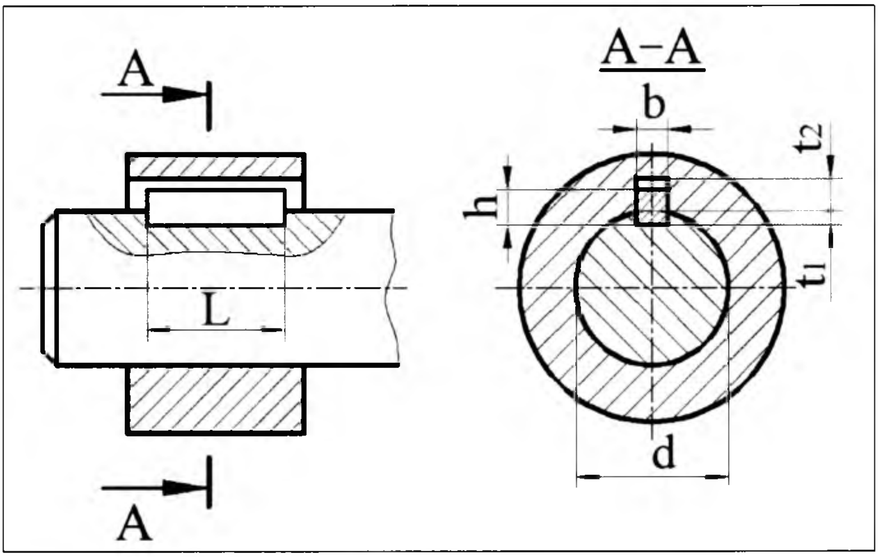


Fig. 10.20

Dimensions of keys are selected depending on the shaft diameter. In order to show the key assembly, we have to give local section. The key is not hatched in the longitudinal section.

In the section perpendicular to the axis of the shaft (section A-A), key is hatched.

D – diameter of the shaft , b – width of the key, h – height of key, t1 and t2 – the depth of the slot, under the key on the shaft and in the wheel , L – the length of the key.

The length of the key depends on the operating conditions and should be 4-5 mm smaller than the length of the wheel hub.

10.10. Welding joints

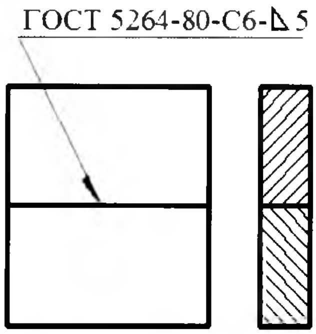
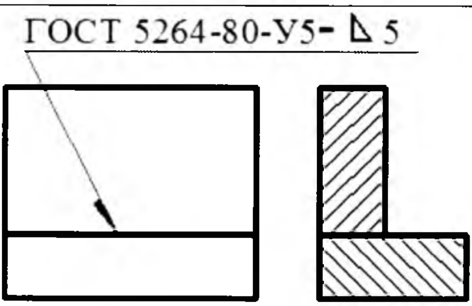
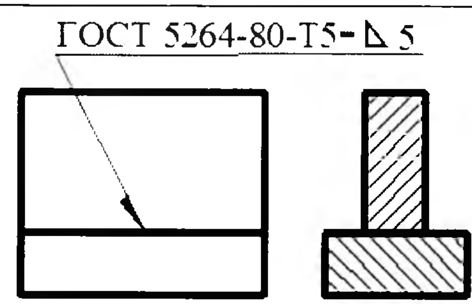
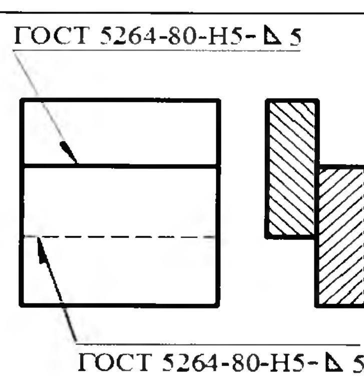
Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing fusion, which is distinct from lower temperature metal-joining techniques such as brazing and soldering, which do not melt the base metal. In addition to melting the base metal, a filler material is often added to the joint to form a pool of molten material (the weld pool) that cools to form a joint that can be as strong as the base material. Pressure may also be used in conjunction with heat, or by itself, to produce a weld.

Although less common, there are also solid state welding processes such as friction welding or shielded active gas welding in which metal does not melt.

The four basic types of weld joints are the butt joint, lap joint, corner joint, and T-joint (a variant of this last is the cruciform joint). Other variations exist as well—for example, double-V preparation joints are characterized by the two pieces of material each tapering to a single center point at one-half of their height.

Welds can be geometrically prepared in many different ways (Table 10. 2).

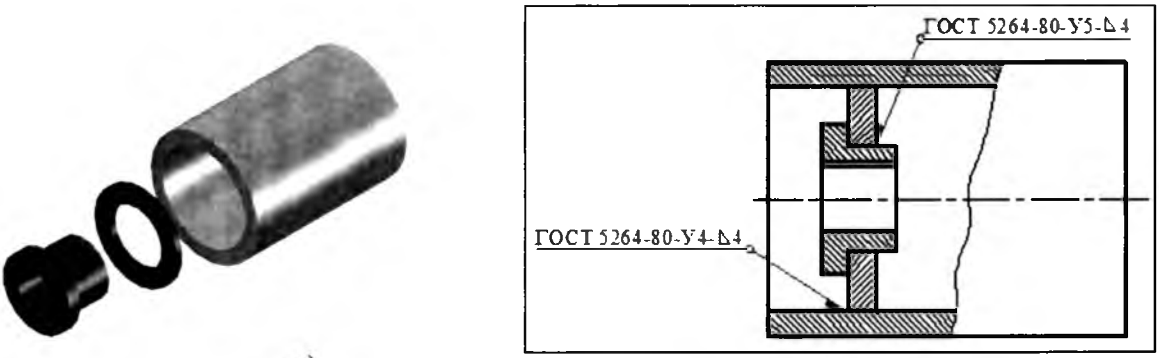
Table 10.2

Kinds of welds	A visual image of the weld seam	The image and the symbol of the weld seam on the complex drawing
Butt joint		
Corner joint		
T-joint		
Lap joint		

Single-U and double-U preparation joints are also fairly common—instead of having straight edges like the single-V and double-V preparation joints, they are curved, forming the shape of a U. Lap joints are also commonly more than two pieces thick—depending on the process used and the thickness of the material, many pieces can be welded together in a lap joint geometry.

In the drawing, all kinds of welds represent the continuous thick line (visible seam) and the dashed line (invisible seam).

Figure 10.21,a shows visual image details of the welding joint, and Figure 10.21, b - the complex drawing of welding joint with symbols of weld seams.



a) b)

Fig.10.21

QUESTIONS AND ASSIGNMENTS TO CHAPTER X

1. What types of joints do you know?
2. Which applications provide us with the ability to join two or more pieces of material together securely?
3. What is the triangular tread?
4. What is the acme thread?
5. What is the square thread?
6. What is the buttress thread?
7. What is the left-hand thread?
8. What is the right-handed thread?
9. How is the conventional symbol for external threads drawn?
10. How is the conventional symbol for internal threads drawn?
11. What is the cutting angle of the drill for normal purposes?
12. How many characteristic diameters do threads have?
13. How is the metrical thread form signed?
14. How is the right handed metric thread with diameter 42 designated? Draw this thread.
15. How is the right- handed acme thread with diameter 50 designated?

16. How is the pipe cylindrical thread with diameter 3/4 inch designated?
17. How is the left–handed metric thread with diameter 42 designated?
18. How is the buttress thread with diameter 32 designated?
19. How are the tapered internal and external threads with diameter 1/2 inch designated?
20. What is nut and how is it drawn?
21. What type of thread bolt belongs to external and internal one?
22. What is the thread rod?
23. How is the stud and the set bolt drawn?
24. What are the flange joints and where are they used?
25. What do fittings mean?
26. What type of fittings do you know?
27. When is the coupling used?
28. When are the reducers used?
29. When are the elbows used?
30. When are the tees used?
31. What is welding?
32. When are the feather keys and parallel keys used?
33. Where are woodruff keys used?
34. What are the taper keys used for?
35. What are the saddle keys?
36. What are the round keys?
37. What kinds of welds do you know?
38. What is the butt joint? Show its complex drawing and symbols
39. What is the corner joint? Show its complex drawing and symbols
40. What is the T-joint? Show its complex drawing and symbols
41. What is the lap joint? Show its complex drawing and symbols

APPENDIX 1

CONVENTIONAL DESIGNATIONS AND SYMBOLS

a) Convensional designations of geometric elements and their projections:

1. A, B, C, D...- points in space;
2. a, b, c, d...- straight lines in space;
3. Principal lines:

   h – horizontal;
   f –frontal;
   p –profile;
4. (AB) – straight line passing through points A and B;
5. $[AB)$ – ray beginning at point A;
6. $[AB]$ – straight line segment, which is limited to points A and B;
7. $\alpha, \beta, \gamma, \delta$, ... – planes;
8. $\llcorner$ - right angle;
9. $|\quad|$ - distance between the geometric elements;
10. $|AB|$-distance between point A;
11. $|Aa|$ - distance between point A and the straight line a;
12. $|A\alpha|$ - distance between point A and the plane α;
13. $|ab|$ - distance between straight lines a and b;
14. $|\alpha\beta|$ - $|A\alpha|$ - distance between planes α and β;
15. $(a \wedge b)$ – angle between straight lines a and b;
16. $(a \wedge \alpha)$ – angle between the straight line a and the plane α;
17. $(\alpha, \wedge \beta)$ – angle between planes α and β;
18. Planes of projection:

   H – horizontal plane of projection;
   F - frontal plane of projection;
   P - profile plane of projection;
19. x, y, z - coordinate axis
20. O – the point of intersection of the axes of the projections;
21. $A', A'', A''', B', B'', B''', C', C'', C'''$ - respectively horizontal, frontal and profile projections of points A, B, C;

22. $a', a'', a''', b', b'', b''', c', c'', c'''$ - respectively horizontal, frontal and profile projections of straight lines *a, b, c;*

23. $\alpha, \alpha'' \alpha''', \beta', \beta'', \beta''', \gamma', \gamma'', \gamma'''$ - respectively horizontal, frontal and profile projections of planes α, β, γ;

24. α_H, α_F, α_P – respectively horizontal, frontal and profile traces of planes α
A_0, B_0, C_0, D_0 ... – auxiliary projection of points *A, B, C, D* (used when the true lengh is determined).

b). Symbols forming connection between geometric elements:

1. $=$ - equals;
2. $\equiv$ - coincides;
3. $\|$ - parallel;
4. $\perp$ - perpendicular;
5. $\supset$ - passes;
6. / - oblique.

c) Symbols indicating the end of operation:

1. $\wedge$ - conjunction *"and"*;
2. V - conjuction *"or"*;
3. $\Rightarrow$ - conjuction *"then"* $((a \| b \wedge b \| c) \Rightarrow a \| c)$;
4. $\Leftrightarrow$ - equivalent.

APPENDIX 2
GLOSSARY OF TERMS USED IN THE BOOK

ENGLISH	AZERBAIJAN	RUSSIAN
Letters	Şriftlər	Шрифты
Sizes of drawing	Formatlar	Форматы
Scale	Miqyas	Масштаб
Reduction scale	Kiçiltmə miqyası	Масштаб уменьшения
Magnification scale	Böyütmə miqyası	Масштаб увеличения
Natural scale	Həqiqi ölçü miqyası	Масштаб натуральной величины
Frame	Çərçivə	Рамка
Title block	Künc ştampı	Угловой штамп
Main inscription of drawing	Çertyojun əsas yazısı	Основная надпись чертежа
Line styles	Xəttin növləri	Типы линий
Continuous thick line	Bütöv qalın xətt	Сплошная толстая линия
Continuous thin line	Bütöv nazik xətt	Сплошная тонкая линия
Dashed line	Ştrix xətt	Штриховая линия
Dashed thin lines with dots	Ştrix nöqtəli xətt	Штрих-пунктирная линия
Wavy line	Dalğavari xətt	Волнистая линия
Continuous thin zigzag line	Əsas bütöv nazik ziqzaq xətt	Сплошная тонкая зигзаговая линия
Axis of symmetry	Simmetriya oxu	Ось симметрии
Hidden outlines	Görünməyən xətlər	Невидимые линии
Center lines	Mərkəz xəttləri	Центровые линии
Dimension lines	Ölçü xətləri	Размерные линии
Tapered chamfer	Konik faska	Коническая фаска
Parallel	Paralel	Параллель
Perpendicular	Perpendikulyar	Перпендикуляр
Bisector	Bisektrisa	Биссектриса
Blending	Qovuşma	Сопряжение
Internal blending	Daxili qovuşma	Внутреннее сопряжение
External blending	Xarici qovuşma	Внешнее сопряжение
Curve	Əyri	Кривая
Arc	Qövs	Дуга
Circle	Çevrə	Окружность
Radius	Radius	Радиус
Diameter	Diametr	Диаметр
Angle	Bucaq	Угол
Descriptive	Tərsimi	Начертательная

Projection	Proyeksiya	Проекция
Plane	Müstəvi	Плоскость
Methods of projections	Proyeksiyalama metodları	Методы проецирования
Central projection	Mərkəzi proyeksiyalama	Центральное проецирование
Center of projection	Proyeksiyalama mərkəzi	Центр проецирования
Parallel projection	Paralel proyeksiyalama	Параллельное проецирование
Direction of projection	Proyeksiyanın istiqaməti	Направление проекции
Projection line (or projector)	Proyeksiyalayıcı xətt	Проецирующая прямая
Orthogonal projection	Ortoqonal proyeksiyalama	Ортогональное проецирование
Plane of projection	Proyeksiya müstəvisi	Плоскость проекции
Plane geometrical figure	Yastı həndəsi fiqur	Плоская геометрическая фигура
Space	Fəza	Пространство
Ray	Şüa	Луч
Surface	Səth	Поверхность
Point	Nöqtə	Точка
Coincide	Üst-üstə düşür	Совпадают
Frontal	Frontal	Фронталь
Horizontal	Horizontal	Горизонталь
Profile	Profil	Профиль
Infinite	Sonsuz	Бесконечная
Axis	Ox	Ось
Complex drawing	Kompleks çertyoj	Комплексный чертеж
Communication line	Rabitə xətti	Линия связи
Sketch	Esgiz	Эскиз
Principal planes of projection	Əsas proyeksiya müstəviləri	Основные плоскости проекций
Quadrant	Kvadrant	Квадрант
Quarter	Rüb	Четверть
Straight line	Düz xətt	Прямая
Straight line segment	Düz xətt parçası	Отрезок прямой
Special position of straight line	Düz xəttin xüsusi vəziyyəti	Прямая особого положения
General position of straight line	Düz xəttin ümumi vəziyyəti	Прямая общего положения
Horizontal-projecting straight line	Horizontal-proyektləndirici düz xətt	Горизонтально-проецирующая прямая
Frontal-projecting straight	Frontal-proyektləndirici	Фронтально-

line	düz xətt	проецирующая прямая
Profile-projecting straight line	Profil- proyektləndirici düz xətt	Профильно-проецирующая прямая
Intersecting straight lines	Kəsişən düz xətlər	Пересекающиеся прямые
Non-intersecting (or skew) straight lines	Kəsişməyən (və ya çarpaz) düz xətlər	Непересекающиеся (или скрещивающиеся) прямые
True length(actual size)	Əsil boy(həqiqi ölçü)	Истинная величина
Trace of straight line	Düz xəttin izi	След прямой
Plan	Üst görünüş	Вид сверху
Elevation	Baş görünüş	Главный вид
Trace of plane	Müstəvinin izi	След плоскости
Intersecting planes	Kəsişən müstəvilər	Пересекающиеся плоскости
Auxiliary	Köməkçi	Вспомогательная
Mutually	Qarşılıqlı	Взаимно
Method of auxiliary section planes	Köməkçi müstəvilər üsulu	Метод вспомогательных плоскостей
Solids	Fəza figurları	Пространственные фигуры
Polyhedra	Çoxüzlülər	Многогранники
Polyhedron	Çoxüzlü	Многогранник
Edge	Til	Ребро
Apex	Təpə	Вершина
Prism	Prizma	Призма
Base	Oturacaq	Основание
Right prism	Düz prizma	Правильная призма
Oblique prism	Maili prizma	Наклонная призма
Truncated prism	Kəsik prizma	Усеченная призма
Tetrahedron	Üçbucaqlı piramida(tetraedr)	Треугольная пирамида (тетраэдр)
Development of polyhedra	Çoxüzlülərin açılışı	Раскрытие многогранников
Visible and invisible elements of polyhedron	Çoxüzlünün görünən və görünməyən elementləri	Видимые и невидимые элементы многогранника
Element of cylinder	Silindrin doğuranı	Образующая цилиндра
Element of cone	Konusun doğuram	Образующая конуса
Curvilinear	Əyrixətli	Криволинейная
Lateral surface	Yan səthi	Боковая поверхность
Cutting plane	Kəsici müstəvi	Секущая плоскость
Technical drawings	Texniki rəsm	Технический рисунок
Working drawing	Işçi çertyoj	Рабочий чертеж
Detail	Detal	Деталь

View	Görünüş	Вид
Part	Hissə	Часть
Section	Kəsim	Разрез
Frontal section	Frontal kəsim	Фронтальный разрез
Horizontal section	Horizontal kəsim	Горизонтальный разрез
Profile section	Profil kəsim	Профильный разрез
Inclined section	Maili kəsim	Наклонный разрез
Simple section	Sadə kəsim	Простой разрез
Full section	Tam kəsim(1/2 kəsim)	Полный разрез(1/2)
Local section	Yerli kəsim	Местный разрез
Complicated section	Mürəkkəb kəsim	Сложный разрез
Stepped section	Pilləli kəsim	Ступенчатый разрез
Broken section	Sınıq kəsim	Ломаный разрез
Axonometry	Aksonometriya	Аксонометрия
Isometric projection	İzometrik proyeksiya	Изометрическая проекция
Rectangular isometric projection	Düzbucaqlı izometrik proyeksiya	Прямоугольная изометрическая проекция
Oblique projection	Çəpbucaqlı proyeksiya	Косоугольная проекция
Perspective drawing	Perspektiv rəsm	Перспективное изображение
The oblique frontal dimetric projection	Çəpbucaqlı frontal dimetrik proyeksiya	Косоугольная фронтальная диметрическая проекция
Distortion coefficient	Təhrif əmsalı	Коэффициент искажения
Assembly	Yığım	Сборка
Thread	Yiv	Резьба
Triangular thread	Üçbucaq yiv	Треугольная резьба
Acme thread	Trapesvari yiv	Трапециевидная резьба
Buttress thread	Dayaq yivi	Упорная резьба
Major diameter	Xarici (böyük) diametr	Внешний диаметр
Minor diameter	Daxili (kiçik) diametr	Внутренний диаметр
Pitch	Yivin addımı	Шаг резьбы
Crest	Təpə	Вершина
Root	Əsas oturacaq	Основа
Nut	Qayka	Гайка
Bolt	Bolt	Болт
Screw	Vint	Винт
Tapped hole	Ikitərəfli dəlik	Сквозное отверстие
Cap screw	Bərkidici vint	Крепежный винт
Stud	Sancaq	Шпилька
Self-locking nut	Sıxıcı qayka	Нажимная гайка
Spring washer	Kətan kəndir	Проволочная губка
Rivets	Ştift	Заклепки

Riveted Joints	Stift birləşməsi	Заклепочные соединения
Round head rivets	Yarımdairəvi başlıqlı ştiftlər	Заклёпки с полукруглой головкой
Single row lap	Bircərgəli tikiş	Однорядный шов
Double row lap	Ikicərgəli tikiş	Двухрядный шов
Tolerances	Sadələşdirmələr	Допуски
Left-hand thread	Sol yiv	Левая резьба
Right-hand thread	Sağ yiv	Правая резьба
Inch	Düymə	Дюйм
Tapered thread	Konusvari	Коническая резьба
Pipe thread	Boru yivi	Трубная резьба
Rod	Çubuq	Стержень
Threaded rod	Yivli çubuq	Стержень с резьбой
Shaft	Val	Вал
Key	İşgil	Шпонка
Keyway	İşgil üçün dəlik yeri	Отверстие для шпонки
Pulley	Qasnaq(blok)	Шкив
Gib head key	Konik işgil	Коническая шпонка
Feather keys(parallel keys)	Prizmatik işgil	Призматическая шпонка
Woodruff key	Seqmentvari işgil	Сегментная шпонка
Hub	Oymaq	Втулка
Weld	qaynaq	Сварка
Weld seam	Qaynaq tikişi	Сварной шов
Butt joint	Uc-uca qaynaq birləşməsi	Стыковое соединение
Lap joint	Üst-üstə qaynaq birləşmə	Нахлесточное соединение
T-joint	Tavrşəkilli qaynaq birləşməsi	Тавровое соединение
Corner joint	Dirsək qaynaq birləşməsi	Угловое соединение
Visible seam	Görünən tikiş	Видимый шов
Invisible seam	Görünməyən tikiş	Невидимый шов
Coupling	Mufta	Муфта
Reducer	Ötürücü	Переходник
Elbow	Bucaqlıq	Угольник
Tee	Üçboğaz	Тройник
Cross	Dördboğaz	Крестовина

REFERENCES

1. И.А. Габибов. Инженерная графика. Учебник для студентов технических вузов. Баку: изд. АГНА, 2011.
2. И.А. Габибов. История науки: Инженерная графика. Баку: изд. АГНА, 2010.
3. İ.Ə. Həbibov, C.X.İsmayılov və b. Maşınqayırma rəsmxətti. Ali texniki məktəblər üçün dərslik. Bakı:ADNA-nın mətbəəsi, 2004.
4. Bağırova G.S. Tərsimi həndəsə: Mühazirələrin konspekti. Dərs vəsaiti, Bakı: ADNA-nın mətbəəsi, 2014.
5. Bağırova G.S. AutoCADda ikiölçülü kompüter qrafikası. Dərs vəsaiti, Bakı: ADNA-nın mətbəəsi, 2014.
6. N.D. Batt. Elementary Engineering Drawing. India: Charotar publishing house, 1993.
7. K. Morling. Engineering and Geometric. London: Elsevier Ltd, Third edition, 2010.