CHAPTER 9. DIMENSIONING

When a drawing is made, dimensioning is of vital importance since one can determine the size of an object represented only by its dimensioning, whatever the scale is and however accurately the drawing is completed. When dimensioning a drawing, it is very important to specify the dimensions correctly in accordance with an object's application and the conditions of its manufacture. This chapter deals with the principal rules of dimensioning.

Dimension and Extension Lines. Dimension Figures

Dimensioning of a drawing is completed with *dimension figures* (numerical values of certain dimensions) and *dimension lines,* showing the directions and boundaries of measurements. Dimension lines should be parallel to the line-segments dimensions which they show (Fig.9.1 and 9.2).

The dimension line terminates with arrowheads which must touch the boundaries of measurements. The following lines may serve as the boundaries of measurements: *extension lines,* level lines, axis or centre lines.

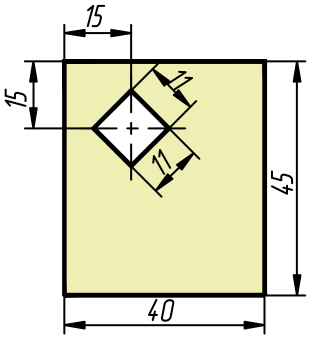


Fig.9.1

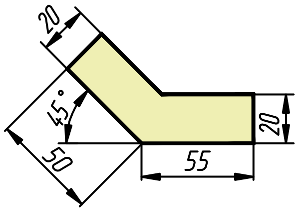


Fig.9.2

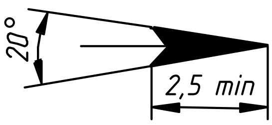
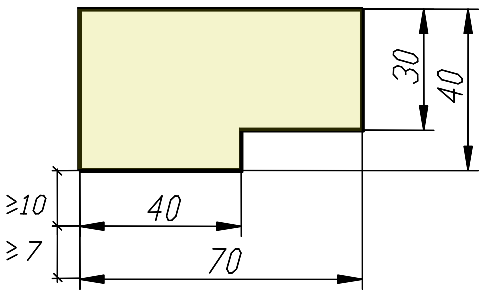


Fig.9.3

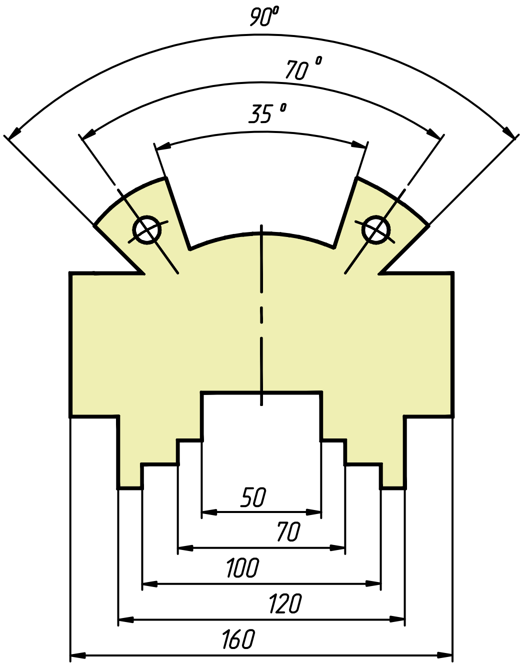
Extension lines, as well as axis or centre lines, should extend to 2…3 mm past the arrowheads of dimension lines.

The length of arrowheads depends on the thickness *s* of the base-line of a given drawing. The recommended arrowhead's length is (4-5) *s*, Fig.9.3. The length of arrowheads should be approximately equal for all dimensions of a given drawing.

The distance between the parallel dimension lines should be not less than 7 mm. The distance between a dimension line and parallel to it contour (axis or centre) line – not less than 10 mm, depending on the size of a representation and free space on a drawing.



a



b

Fig.9.4

Contour (axis, centre, extension) lines must never be used as dimension lines. Dimension lines must never be used as a continuation of contour (axis, centre, extension) lines. Dimension lines should be drawn outside the outline, whenever possible, and should be kept well clear of the intersection points of lines, the conjugate points of arcs, and arcs and lines on a drawing.

To avoid misunderstanding, if there is not enough space for an arrowhead because of the close positioning of a contour or extension line, the latter may be broken (Fig.9.5).

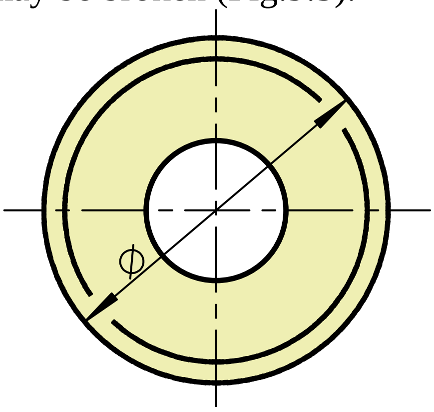


Fig.9.5

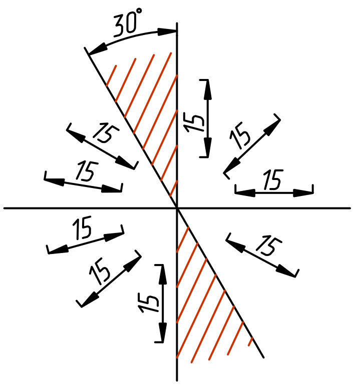


Fig.9.6

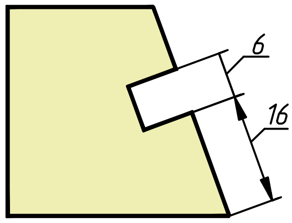


Fig.9.7

Engineering drawings are usually dimensioned in millimetres, and it is not necessary to put on the abbreviation for the units used (mm). If, to some reasons, the linear dimensions are specified in other units, the abbreviation for the units used must be printed at the dimension figure (e.g. 20 cm; 3 mm) or in the corresponding notes of a drawing (technical requirements).

A dimension figure is placed on top of the dimension line, parallel to it and, as a rule, closer to its centre.

If parallel dimensions are to be shown, it avoids confusion if the smallest dimension is put closest to the outline, and the others arranged in ascending order. If several parallel dimension lines, symmetric to the common axis, are to be drawn, it is easier to read the drawing if they are arranged chequer-wise (Fig.9.4, b).

The distance between a dimension line and a dimension figure is about 1-1.5 mm. If the lines are vertical or inclined, dimension figures are printed in the way shown in Fig.9.6. If a dimension line is in a hatched area (Fig.9.6), the corresponding dimension figure is placed on the shelf of an extension line (Fig.9.7).

Dimension figures must never be crossed or separated by any lines of a drawing. Dimension figures must never touch any line. If it is necessary to print a dimension figure on an axis line or in a hatched section, the axis/hatching line may be broken (Fig.9.8). No other lines may be broken in such a case. No breaks are permitted in the point of intersection of the centre or axis lines (Fig.9.9, a).

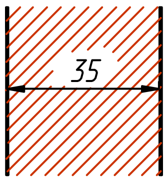
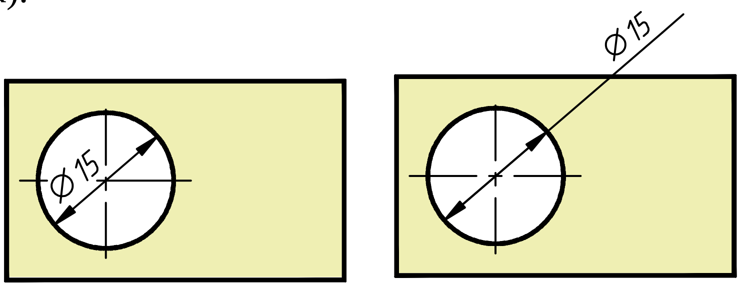


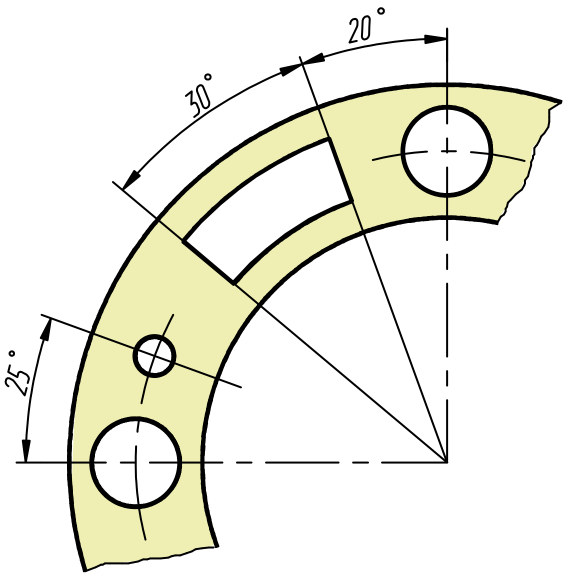
Fig.9.8



a b

Fig.9.9

When dimensioning angles, draw the dimension lines with a compass; the point of the compass should be on the point of the angle (Fig.9.10). The angles are dimensioned in degrees, minutes and seconds, the units should be designated (Fig.9.10 and 9.11). In the area above the horizontal axis line dimension figures are placed on top of dimension lines from the side of convexity, in the area below the horizontal axis line dimension figures are placed from the side of concavity. If a dimension is to be placed in a hatched area (Fig.9.11), it is printed on the shelf of an extension line. Likewise dimension the small angles, if there is not enough space, in whatever area they are situated (Fig.9.11, angle 5°).



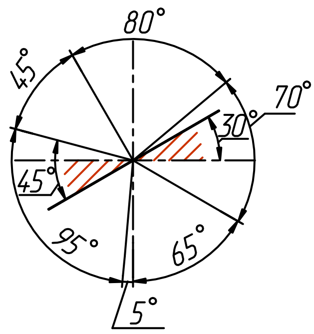
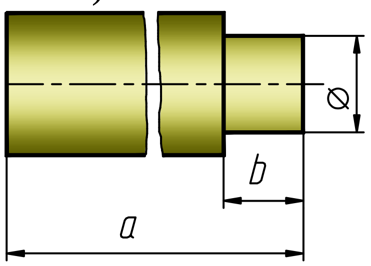
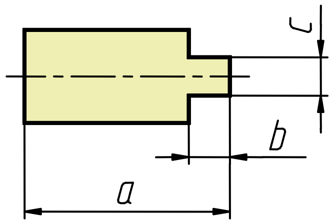


Fig.9.10 Fig.9.11

When the outline is broken, the dimension line is full (Fig.9.12, dimension a).





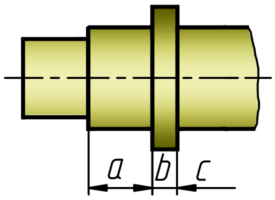
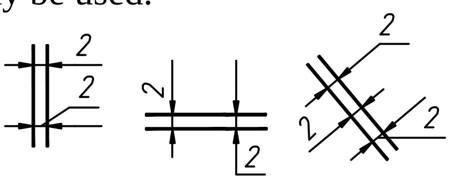


Fig.9.12 Fig.9.13 Fig.9.14

When the distance between the boundaries of measurements is less than the length of three arrowheads, counter-arrowheads are used (Fig.9.13, dimensions 5 and 10). The arrowheads of adjacent dimension lines may be taken for the counter-arrowheads (Fig.9.14, dimension b). The lines between the counter-arrowheads are never broken. If there is too little space and it is impossible to place any dimension figure, the variants shown in Fig.9.15 and 9.16 may be used.



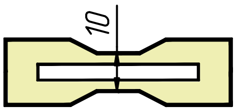


Fig.9.15 Fig.9.16

When printing a group of adjacent small dimensions, replace the arrowheads by clearly printed dots or hatching lines on the extension lines (Fig.9.17). The hatching lines are drawn at 45° to the dimension lines. The dots and hatching lines must never be placed on the contour lines; in this case, dimensioning is produced as shown in Fig.9.18.

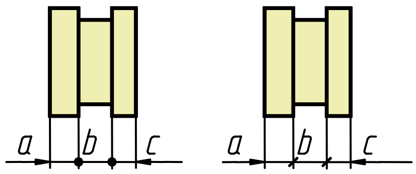


Fig.9.17

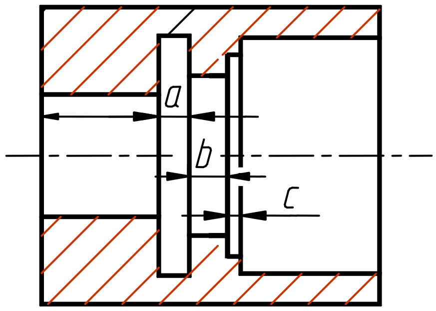
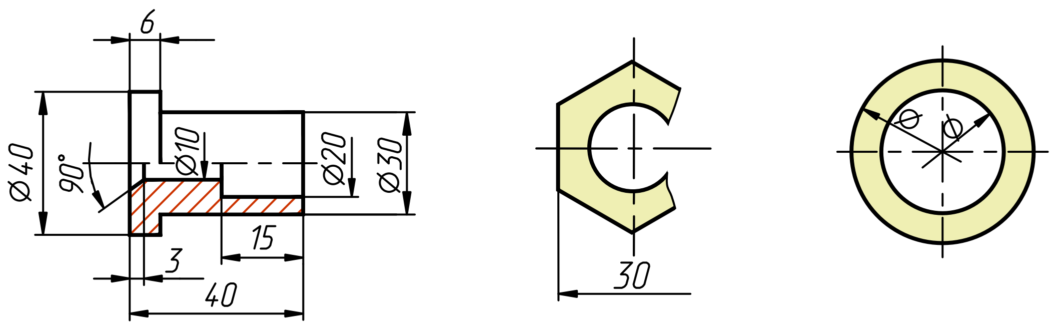


Fig.9.18

If there is only one boundary of measurements (for example, when a view is connected to a sectional view (Fig.9.19, a), or when a view with a break takes place (Fig.9.19, b), the dimension lines are broken (Fig.9.19, a, dimensions ∅10, ∅20 and 90°; Fig.9.19, b, dimension 20). Note: the dimension line is broken behind the symmetry axis of the representation, at a distance of 6-10 mm from the axis. The dimension figure is put as close as possible to the symmetry axis and, preferably, between the axis and the contour or extension line. In the given examples, dimensions ∅10, ∅20, 90° and 20 specify the distance between two symmetrically positioned elements, and not the distance from the elements to the symmetry axis of the representation.

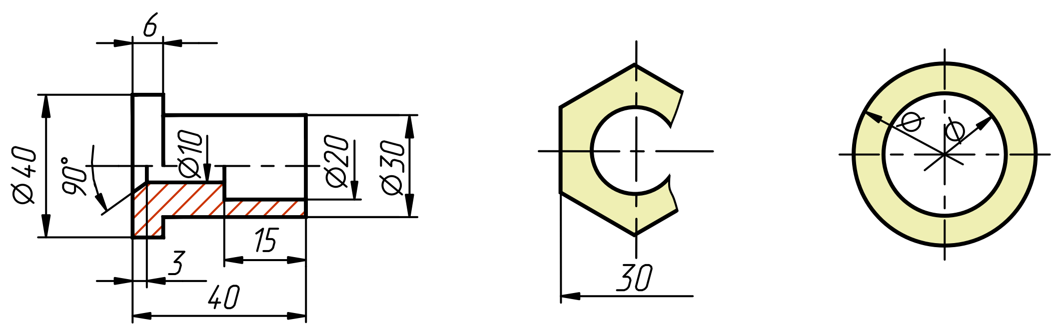


a b c

Fig.9.19

It is also permitted to break the dimension line when a circle diameter is dimensioned, even if the circle is not fully represented (Fig.9.19, c). *Note: the dimension line should be broken outside the circle centre.*

The extension and dimension lines should be mutually perpendicular. However, if the angle contained by the extension and contour lines is very small (Fig.9.20, dimensions ∅25 and ∅28), the extension line is passed to the dimension line at an angle different from a right one. In this case, as usually, the dimension line is parallel to the dimensioned segment.



a b

Fig.9.20

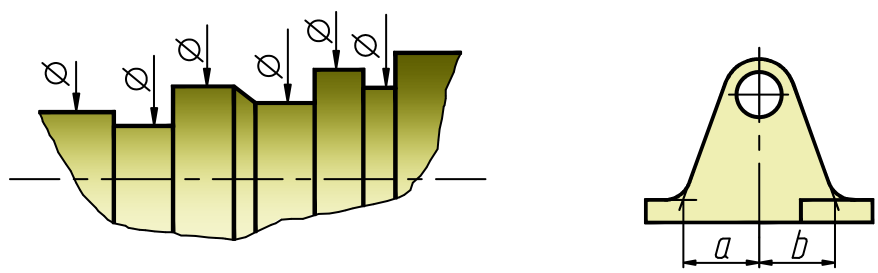
To simplify a drawing, dimensioning of cylindrical surfaces of a complex configuration is produced as shown in Fig.9.21, a. If it is necessary to specify the co-ordinates of vertices of a rounded-off angle (Fig.9.21, b), the angle vertex is drawn with continuous thin lines.

The arcs of circles may be used as the extension lines (Fig.9.10, a). In this case, the dimension line must coincide with the direction of the arcs' radius.

Conventional Symbols

A list of the most frequently used conventional symbols is shown below:

∅	-	diameter
R	-	radius
⌒	-	arc of a circle
□	-	square
∠	-	slope
▷	-	taper



a) b)

Fig.9.21

Diameter. Diameter is denoted by the symbol ∅ placed in front of the dimension, e.g. ∅50. There are no other symbols or signs between the symbol ∅ and a dimension. Neither are there any spaces. Diameter may be dimensioned either on a representation where a circle or its part is projected in true size (Fig.9.22, ∅40), or on a representation where it is projected as a straight line (Fig.9.22, ∅20).

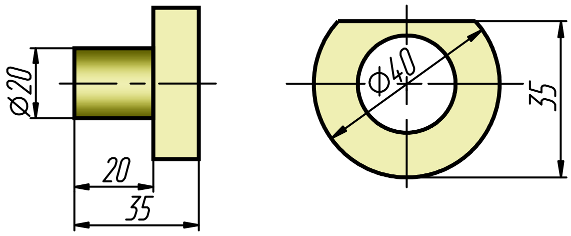


Fig.9.22

Fig.9.23 presents several examples of diameter dimensioning. Some of the dimensions are placed on the shelves of the extension lines. The shelves are passed horizontally and are produced by means of a break of the dimension line proper. *Note: The break should be located at a distance from an arrowhead.*

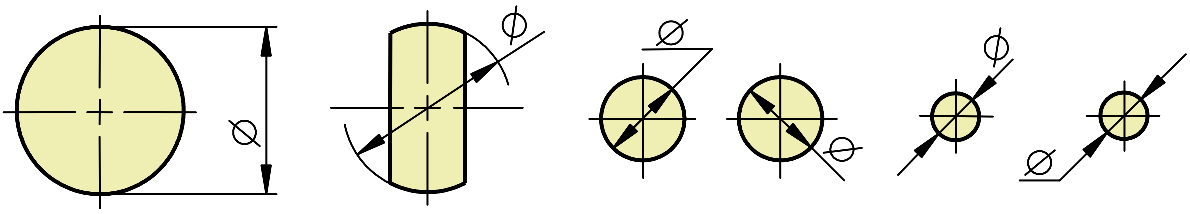
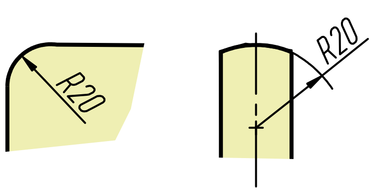


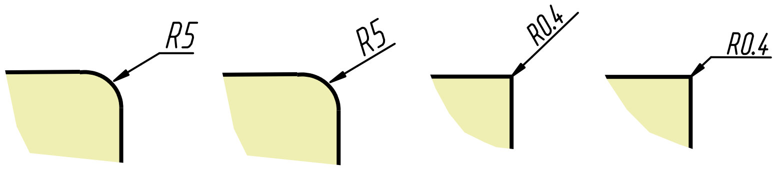
Fig.9.23

Radius. Radius is denoted by the letter R placed in front of the dimension, e.g. R25. There are no other symbols or signs between the letter R and a dimension. The radius dimension line is placed on that representation where the arc is projected in true shape. The dimension line should follow the direction of the true radius and terminate with one arrowhead touching the outline (Fig.9.24, a), or the corresponding extension line (Fig.9.24, b). If a radius is less than 6 mm (*on a drawing)*, the arrowhead should be placed from the external side of the arc (Fig.9.25, a, b).



a b

Fig.9.24



a b c d

Fig.9.25

The arcs of radius 1 mm and less are not drawn but the dimensions are shown (Fig.9.25, c).

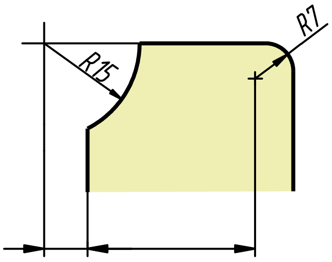


Fig.9.26

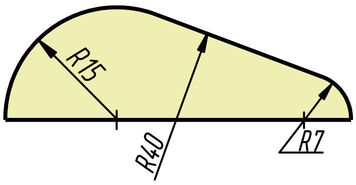


Fig.9.27

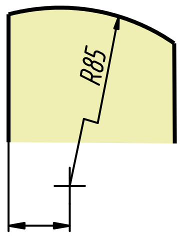
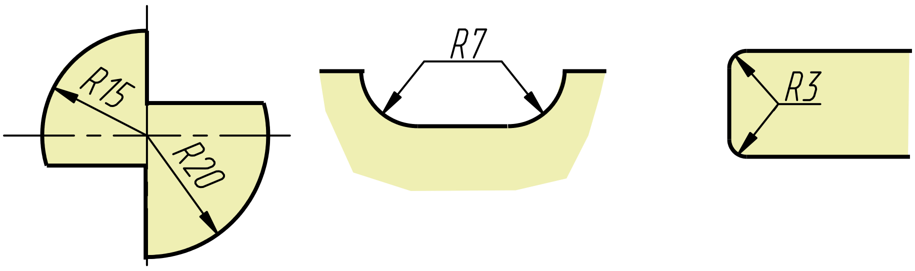


Fig.9.28

If it is necessary to specify the centre of an arc, it is usually marked by the centre lines crossing (Fig.9.24, b) or by the intersection of the extension lines (Fig.9.26). When drawing an arc of a large radius (no need to mark its centre), the dimension line may be broken (Fig.9.27, R40).

If the centre of an arc of a large radius must be marked, it may be drawn nearer to the outline and the dimension line is broken (Fig.9.28). In this case, both parts of the broken dimension line should be parallel to each other, the line of the break - at 90° to them. If several dimension lines of radii are passed from one centre, they are not placed on one straight line (Fig.9.29, a). If the values of several radii are equal, they may be shown on one shelf (Fig.9.29, b, c).



a b c

Fig.9.29

Note: Radii specify the arcs which round-off the outline, and also most of the arcs are of 180° and less. Full circles and arcs of more than 180° are specified only by diameters, even though they may have breaks (Fig.9.30).

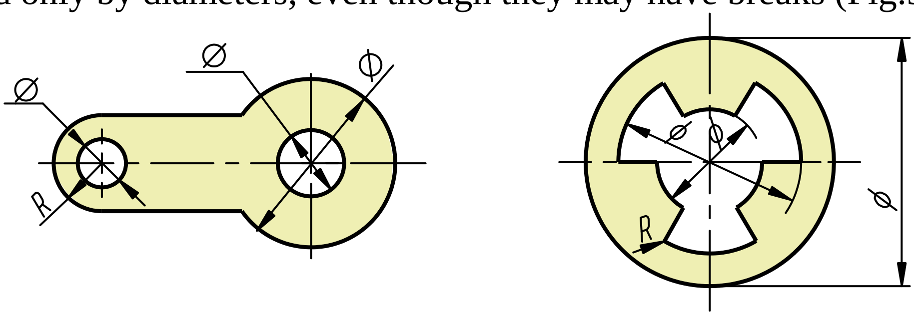


Fig.9.30

If the symbol of a diameter or radius is applied to dimension a sphere and it is hard to distinguish the sphere from other surfaces, the word “Sphere” or the sign ◯ may precede the symbol, e.g. ◯ R12, “Sphere ∅20”, “Sphere R12”.

An arc of a circle. The relative position of two points on an arc of a given radius (Fig.9.31) may be determined by the length of the chord *a*, the angle α or by the arc length *l*.

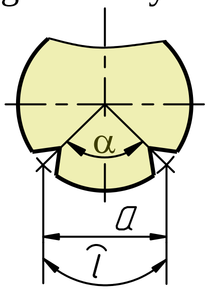


Fig.9.31

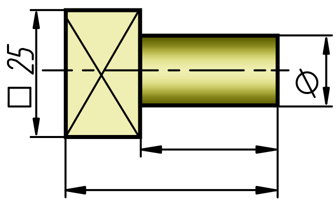


Fig.9.32

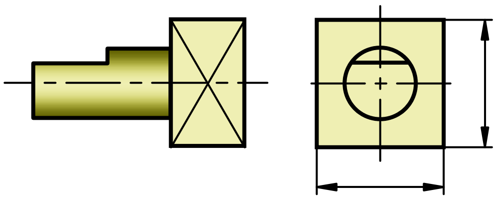


Fig.9.33

The dimension line specifying the arc length is passed concentrically to the arc, the extension lines - parallel to the angle bisectrix. The symbol ⌒ is placed above the dimension figure (Fig.9.31). The length of an arc is specified in metric units, and the dimension figure is printed in the usual way, along the dimension line.

Square. Squares are denoted by the symbol □ placed on the view where the square is projected as a line (Fig.9.32). If a square is dimensioned on a view of its natural shape, dimensions should be shown as in Fig.9.33.

Slope. A slope of a line toward the principal direction is measured in an angle tangent or the angle itself. For example, a slope of the line AB to the line AC is *tan*α (Fig.9.34).

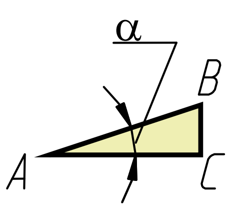


Fig.9.34

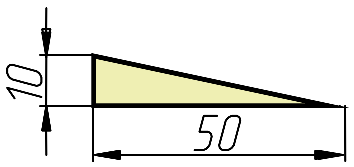


Fig.9.35

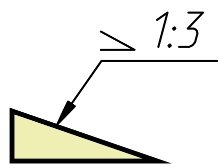


Fig.9.36

Hence, to construct a given slope, say 1:5, draw a right triangle with the legs 10 and 50 mm, or with the legs 11 and 55 mm, etc. The hypotenuse of the triangle yields the desired slope (Fig.9.35).

Slope is denoted by the symbol ∠, the acute angle of which points in the direction of the slope. The symbol and the dimensions are placed on the shelf of an extension line with the arrowhead (Fig.9.36). A slope may also be specified in %, e.g. ∠5%.

Taper. Taper is a ratio of algebraic difference of the diameters of a truncated cone bases to its height: $K = (D_1 - D_2)/H$; or the ratio of diameter of a full cone base to its height. 'Taper' is denoted by the symbol ▷, the vertex of which points in the direction of the cone vertex (Fig.9.37). The symbol and the dimensions are placed on the shelf of an extension line or above the cone axis. Taper may also be specified in %, e.g. ▷10%.

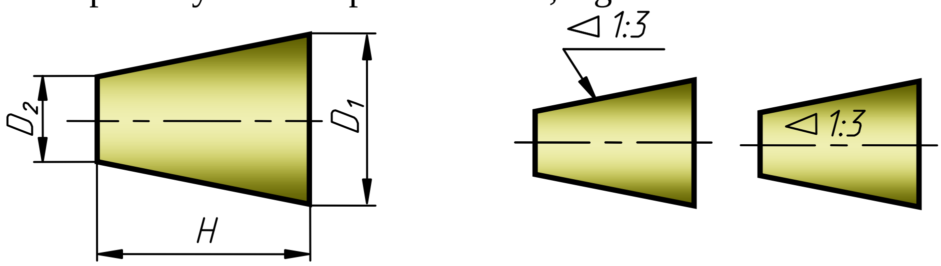


Fig.9.37

Chamfers dimensioning. When dimensioning cone chamfers (Fig.9.38), the *dimension line is passed parallel to the cone axis*. The first figure shows the truncated cone height, the second - the inclination angle of the cone generatrix. *This simplification is permitted only if the inclination angle of the cone generatrix is 45°; at any other value of the angle two dimensions are printed - a linear one and an angle ones* (Fig.9.39).

If the chamfer height (height of a truncated cone) on a drawing is 1 mm or less, the chamfer is not drawn but is dimensioned (Fig.9.40).

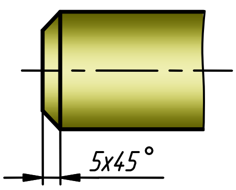


Fig.9.38

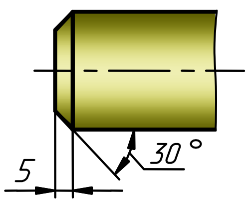


Fig.9.39

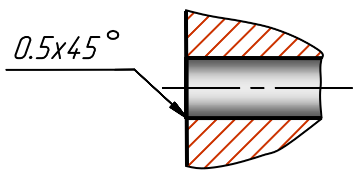


Fig.9.40

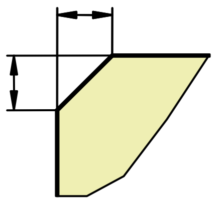


Fig.9.41

Dimensioning an engineering drawing of parts is closely connected to the parts' operational usage in an assembly and with their manufacture.

All dimensions may be divided in two groups:

Forming. Dimensions determining the form of any element of a detail;

Coordinating. Dimensions of the arrangement of a detail's elements (distance between holes centres; from edges and frames to holes centres; distances to walls of slots, grooves, flanges and other elements).

It is recommended to group the dimensions of one constructive element in one drawing space of the element view on which this element is represented most completely (Fig.9.42-9.43).

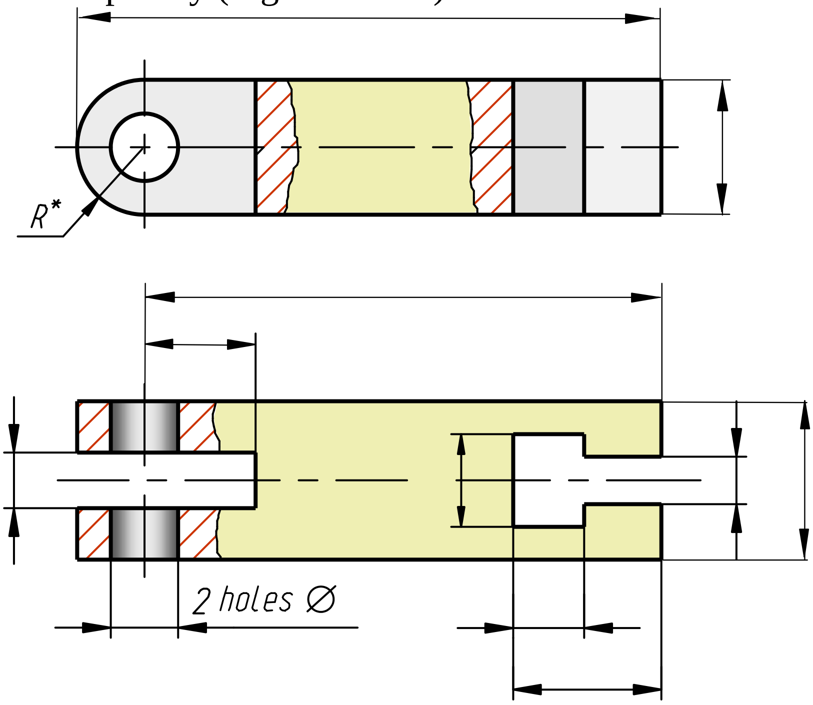


Fig.9.42

When dimensioning a step-type hole (Fig.9.43, a), its diameter is shown together with its depth. The number of the holes is printed once at the smallest diameter.

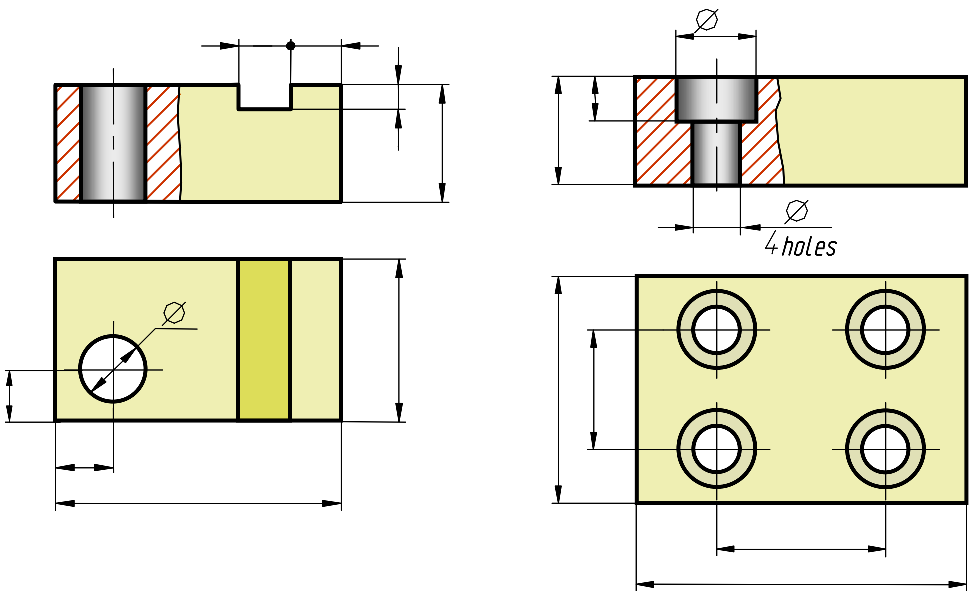


Fig.9.43

There are some more rules about how to dimension a drawing properly:

- dimension lines should be drawn outside the outline, whenever possible;
- unless unavoidable, do not dimension hidden details. It is usually possible to dimension the same detail on another view.
- avoid intersection of the dimension and extension lines, and the crossing of the latter with the outline;
- external dimensions should be placed on other side of a representation than internal dimensions (internal ones - near the sections, external- near the views)

The total number of dimensions on a drawing should be minimal but sufficient for manufacturing and monitoring a part. Dimensions should not be repeated. It is necessary to put a dimension on only once, however many views are drawn.

Dimensioning According to The Base

Dimensioning an engineering drawing is subject to a number of factors: the geometric form of a part, the peculiarities of its construction and the destination, technology and manufacturing accuracy. To make a part perfect for operation in an assembly unit, it is necessary to adjust the dimensions of the elements and related surfaces. Co-ordination is achieved by putting on dimensions from a certain place taken for the base.

Surfaces, lines or points co-ordinating the position of a part in an assembly unit or in the process of its manufacturing are referred to as *the Base*. There are four types of dimension base: constructional, technological, measuring and assembling, each having its own assignment.

A Constructional base is a surface, line or point determining the position of a part in an assembly unit. Other elements of the part or other parts of the assembly unit are oriented relative to this base. All adjacent dimensions are specified in accordance with it. Dimensioning according to the constructional base is not connected with the process of manufacturing a part.

A Technological base is a surface, line or point relative to which each of the surfaces processed during a part manufacturing are oriented. They are selected subject to the sequence of the mechanical processing of the parts. All free dimensions are usually specified according to this base.

A Measuring base is a surface, line or point from which the dimensions are indicated during the measurement of ready-to-use parts.

An Assembling base is a set of surfaces, lines or points relative to which the parts are oriented during their assembly.

Each base type may be set along three principal directions (a part’s length, width and height), sometimes along oblique surfaces.

A part may have several bases, one taken as the principal base, others as auxiliary. Every auxiliary base is oriented according to the principal one.

Dimensioning according to the base should be applied, if possible, to one view (to avoid mistakes).

The technological base is usually used in training drawing, as it is impossible to determine the position of a certain part in an assembly unit.

The following elements may be taken for a dimension base: processed ends; shoulders of work-pieces; edges; bearing, supporting and other surfaces; axes of symmetry; centre and other lines; points from which it is convenient to produce dimensioning. Methods of dimensioning depend on the selection of the dimension base.

There are three methods of dimensioning most frequently applied in practice: *chaining, from a base and combinatorial* (Fig.9.44).

The chaining method consists of sequential printing of dimensions pretending to make a chain to determine the sequence of the processing of different elements of a part (Fig.9.44, a). In this case, each dimension is specified by a new base. This method is applied to show inter-centre distances, dimensions of step-type parts, etc.

The from a base consists of dimensioning according to one base (Fig.9.44, b). It is very convenient for production engineering. Dimensions, specified according to one base, are the co-ordinates showing the distance from this base to the planes, lines and points of the part. Accuracy here depends only on the technology of the part’s manufacturing and does not depend on the accuracy of the other dimensions.

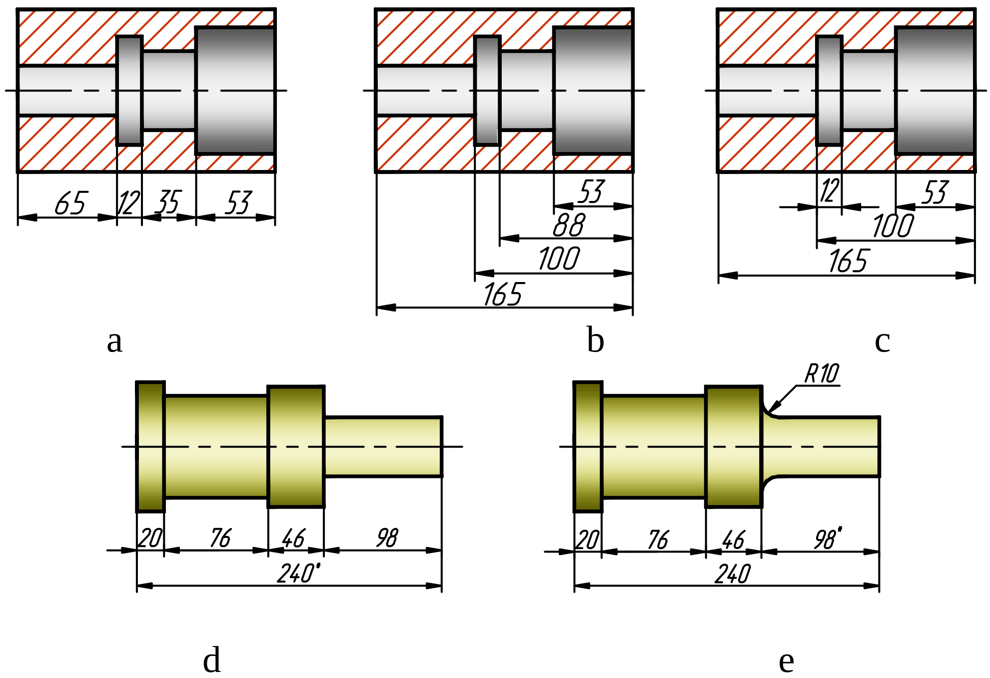


Fig.9.44

The combinatorial method consists of a combination of the chaining and the from a base (Fig.9.44, c). In this case, not only the principal dimension base, but also the auxiliary ones are used. This method is widely applied, especially in complex drawings. Whatever the method, the chain of dimensions must never be closed, as it may prevent the accurate manufacturing of a detail. For example, when an overall dimension is to be shown on a drawing and becides it is obtained by means of the chaining method, one of the intermediate dimensions should be omitted.

Referential and Other Dimensions

Referential dimensions are the dimensions which cannot be completed on a given drawing. But they should be shown to make the drawing easier to use.

They are usually denoted by the symbol * and the following note printed in the technical requirements: "*Referential Dimensions".

Among the referential dimensions you may find one of the dimensions of a closed dimensional chain, dimensions from the drawings of blanks, etc.

If one of the dimensions of a dimension chain is marked as referential, the chain may be closed (Fig.9.44, d, e).

Overall dimensions are the dimensions of the external (or internal) limits of an item outline. The overall dimensions are primarily placed on drawings of original parts. Drawings of standard parts do not usually have overall dimensions.

Simplifications in Dimensioning

There are some simplifications allowing us to reduce the number of dimensions on a drawing (sometimes the number of representations also). For example, dimensions of two symmetrically positioned elements (except holes) are put on only once (no numbering shown), grouped in one place (Fig.9.45). Dimensions of chamfers and grooves are not included in a dimension chain.

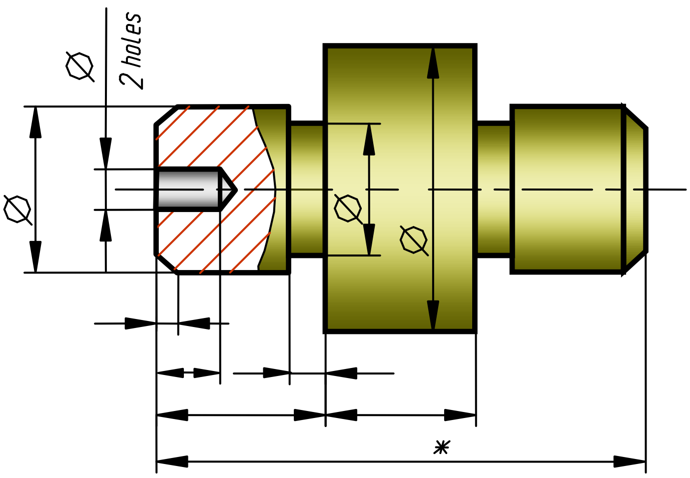
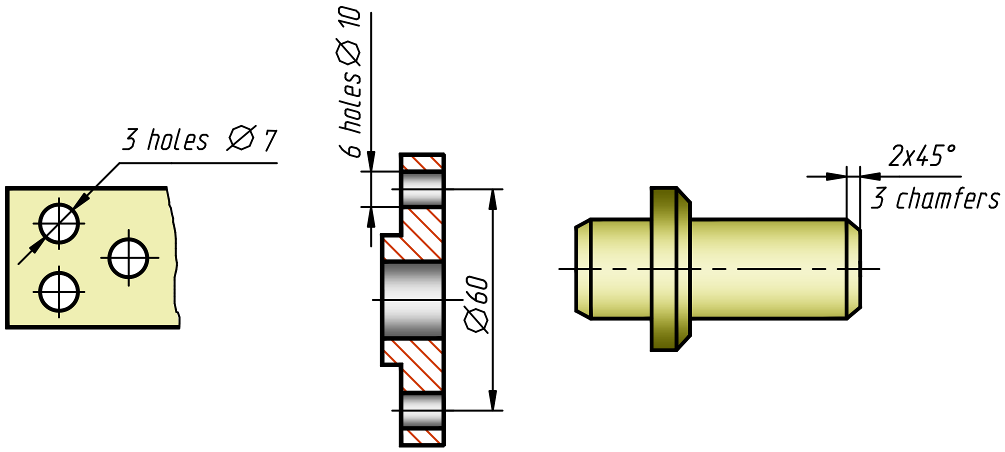


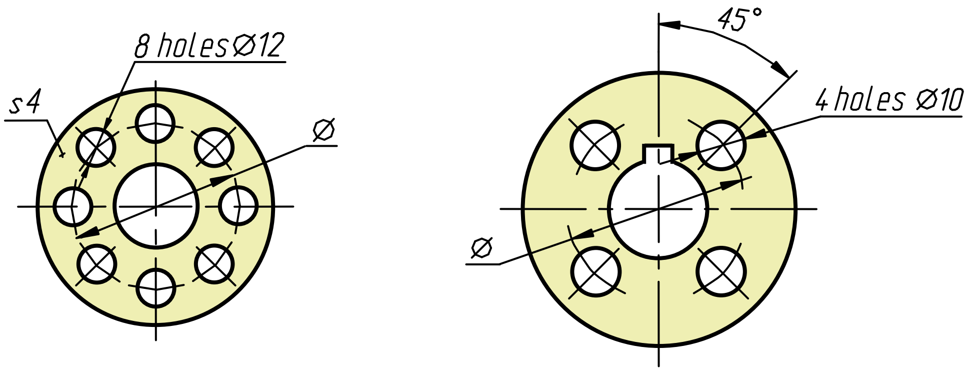
Fig.9.45

When several elements, similar in the form and size, are dimensioned, the dimensions of only one of them is shown and the number of the elements. This technique may be used provided the elements lie in one plane (Fig.9.46, a) or are located on a common axis (Fig.9.46, d, e). The number of the elements is placed on the shelf of an extension line (Fig.9.46, a, b, d, e) in front of the dimensional figure. It may also be placed under the shelf (Fig.9.46, c).

If the elements on a drawing are evenly positioned on a circle (holes, recesses and the like), the angle dimensions specifying their mutual location are not printed, only the number of the elements is shown. But it is necessary to denote the angle of 45° (Fig.9.46, e), as it specifies the positioning of four holes ∅10 relative to the slot.



a b c



d e

Fig.9.46

When dimensioning the distances between similar evenly positioned elements of an object (Fig.9.47 - distances btw 15 holes of diameter 8), instead of the chaining method it is recommended to do as follows. Print the dimension between two neighbouring elements (Fig.9.47, dimension 11) and the product of the distance size by the number of distances, as the dimension between the utmost elements (Fig.9.47, dimension 14x11=154).

If a large number of dimensions is placed according to one common line (base) as shown in Fig.9.48, it is permitted to replace independent dimension lines by one common line passed from the mark 0: for linear dimensions (Fig.9.49, a), for angle dimensions (Fig.9.49, b).

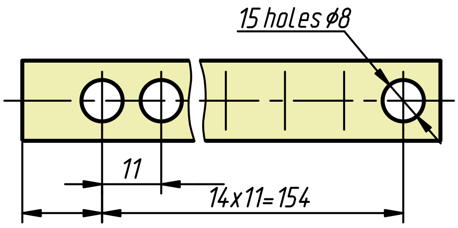


Fig.9.47

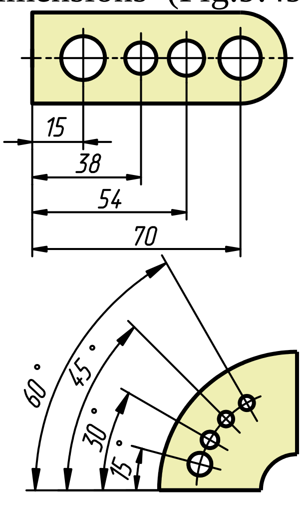


Fig.9.48

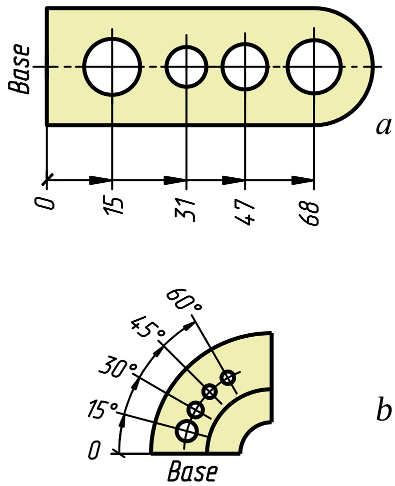
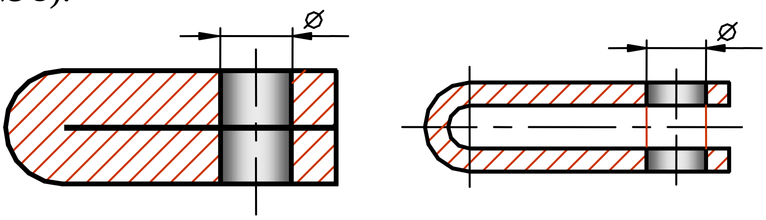


Fig.9.49

Similar elements located in different parts of an object (for example, holes) are considered as one element provided there is no space between them (Fig.9.50, a) or they are connected by continuous thin lines (Fig.9.50, b). If there are not the above conditions, the total number of the elements must be shown (Fig.9.51, two holes ∅10 and Fig.9.52, six holes ∅8).



a b

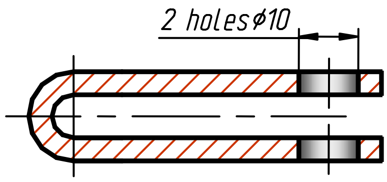


Fig.9.50 Fig.9.51

If similar elements are situated on different surfaces of an object and are shown on different representations, the number of these elements is printed separately for each surface. For example, in Fig.9.52 ten holes ∅8 are divided into two groups: 6 and 4.

Dimensions of similar elements or their groups lying on one surface may be repeated only if they are located at a significant distance from each other and are not correlated with each other by dimensions (Fig.9.53).

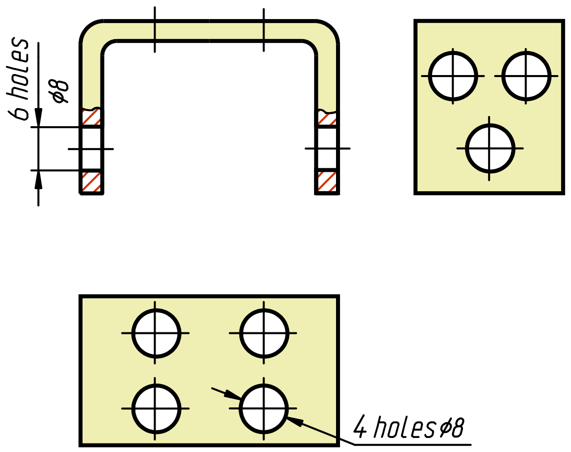


Fig.9.52

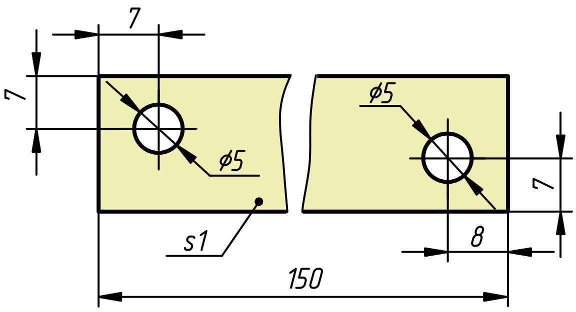


Fig.9.53

If the radii of rounding-offs, bends and the like on a drawing are similar or if one of them is predominant, they are not dimensioned on a representation. Their dimensions are noted in the technical requirements on a drawing margin by the following signs: “Radii of rounding-offs 4 mm”, “Internal radii of bends 10 mm”, “Non-mentioned radii 8 mm”.

Questions to Chapter 9

Is the scale taken into account when the dimension figures are put on a drawing?

How many millimetres past should an extension line extend from the arrowheads of a dimension line?

What are the limits of the distance between parallel dimension lines?
How is a dimension line of an angle passed?
In what cases are the counter-arrowheads of dimension lines applied?
How is a slope denoted on a drawing?
What is taper and how is it denoted on a drawing?
What does the sign “2.5 x 45°” mean?
How should the dimension figures be arranged when several parallel dimension lines are drawn symmetrically relative to the common axis?
When are dimensions of several similar, in form and size, elements of an object denoted only once (no numbering)?
What are the rules of printing of linear dimensions?
What are the recommendations of dimensioning between evenly positioned similar elements of an object?
What are the methods of dimensioning?
Discuss dimensioning of one constructional element.