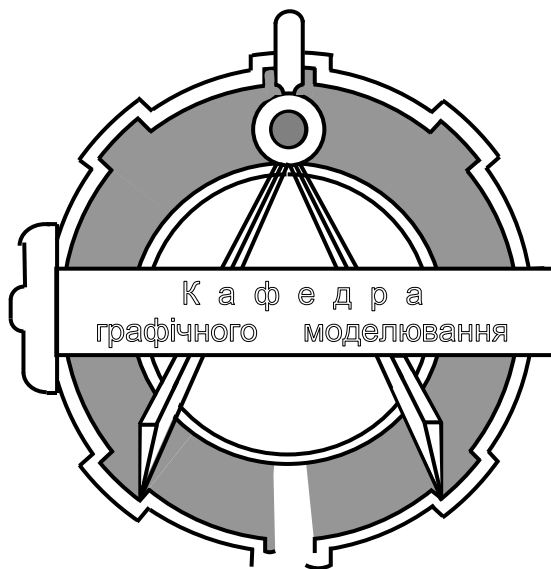
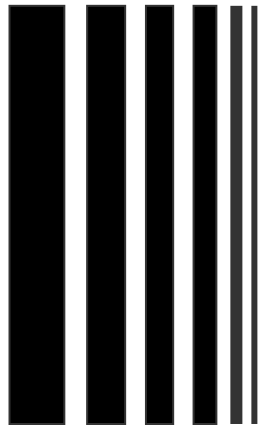


МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

**ТЕРНОПІЛЬСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ
УНІВЕРСИТЕТ ІМЕНІ ІВАНА ПУЛЮЯ**



**ГЕОМЕТРИЧНІ
ПОБУДОВИ**



**МЕТОДИЧНІ ВКАЗІВКИ
ТА ЗАВДАННЯ ДО ВИКОНАННЯ
ГРАФІЧНОЇ І САМОСТІЙНОЇ
РОБОТИ
ДЛЯ ІНОЗЕМНИХ СТУДЕНТІВ
З КУРСУ «ІНЖЕНЕРНА ГРАФІКА»**

Тернопіль
2016

УДК 744(07)
ББК 30.11
Г36

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Методичні вказівки розглянуто й затверджено на засіданні
кафедри графічного моделювання
Тернопільського національного технічного університету імені Івана Пулюя
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Г36 Геометричні побудови : методичні вказівки та завдання до виконання
графічної і самостійної роботи для іноземних студентів з курсу
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Навчально-методичний посібник з курсу “Інженерна графіка” містить матеріали з
геометричного креслення. Наведено основні правила оформлення креслень згідно єдиної
системи конструкторської документації. Подано необхідні відомості для виконання
геометричних побудов. Викладено правила проставлення розмірів.

Призначено для студентів університетів, коледжів і технікумів стаціонарної заочної
форм навчання спеціальностей, які згідно з навчальними планами вивчають дисципліну
“Інженерна графіка”.

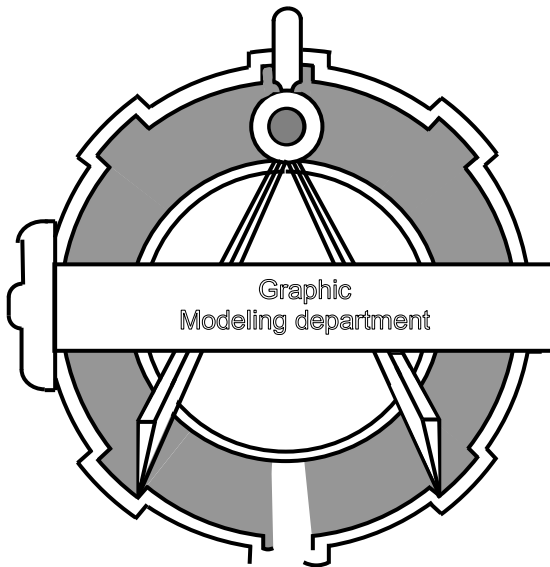
Об’єм навчально-методичного посібника – 79 сторінки, 81 рисунок.

Використано 8 літературних джерел.

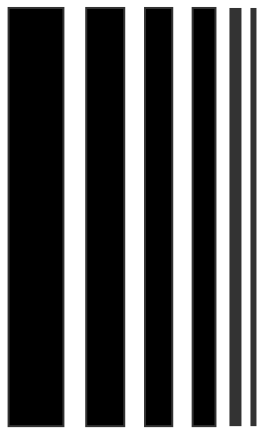
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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

**TERNOPIL IVAN PUL'UJ NATIONAL TECHNICAL
UNIVERSITY**



GEOMETRIC CONSTRUCTION



**STUDYGUIDE
AND TASKS TO EXECUTE
GRAPHIC AND INDEPENDENT WORK
FOR FOREIGN STUDENTS
«ENGINEERING GRAPHICS» COURSE**

**Ternopil
2016**

UDK 744(07)
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Г36

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G36 Geometrical Construction: the study guide and tasks for students of all
forms of training to perform graphic and independent work in "Engineering graphics"
course / Authors: *Pik A.I.*, *Skyba O.P.*, *Kovbashyn V.I.*, *Denysiuk N.R.* – Ternopil:
TNTU Publishing, 2016 – 80 p.

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The study guide "Engineering Graphics" contains materials on geometric drawings. The basic
rules of designing drawings under a unified system of design documentation are proposed. The
necessary information to perform geometric constructions is provided. The rule of dimensioning are
proposed as well.

Intended for students of universities, colleges and secondary technical schools with full-time
and distance learning, where the discipline "Engineering Graphics" are studied according to the
curriculum.

Volume of the study guide– 79 pages, 81 pictures.
8 references.

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1. GENERAL INSTRUCTIONS

1.1. The objectives of the course "Engineering Graphics"

Creation of new machines and devices, efficient and qualitative use of modern technology requires deep knowledge of proper making and understanding the drawings, diagrams and other design documents.

Modern technical drawing is a major engineering and design document that is used by designers, engineers, technologists, controllers and workers in their daily activities.

The course "Engineering Graphics" includes the basic sections of descriptive geometry and drawing, which provide the graphical training of future specialists in higher technical institutions.

The purpose and objectives of the course is to teach students to understand, read, and execute drawings in a proper way.

The "Geometric Drawing" is a preparatory section. It describes: a) basic rules, norms and conventions of making and designing drawings in accordance with the basic requirements of state standards; b) various geometric constructions that occur during the construction of technical forms (tilt, obliquity, interface, building a compass and drawing curves etc.).

1.2. General guidelines for executing the drawings

1. All drawings must be made clearly and neatly in accordance with national standards of Ukraine GOST 3321-96 and currently existing standards of Class 2 of the previously active single system of design documentation (SSDD) YESKD that complete the complex of standards - SDD. This is a complex of state standards, which set the rules and regulations on the procedure for the development, registration and circulation of design documentation.

2. Rules for handling the tools are explained in details in the literature recommended below.

3. At the opening stage, the drawings are made by thin lines using the pencil **2T** or **T**, the thickness of lines should be 0.2 ... 0.3 mm; and at the second stage (the stage of tracing) – the thickness of visible contour lines should be 0.8 ... 1.0 mm made by the pencil **TM** or **M**. The tracing should be done clearly, slightly pressed in paper. The pencil should be thinned at the length 20 ... 25 mm. The graphite should be thinned conically or in the shape of "scoop". The T-square is used for horizontal and vertical parallel lines drawn from left to right. The try-square is used for vertical and inclined lines drawn from the bottom to the up. The drawing board is placed with the inclination from 15° to 20° so that the light falls from the left. Before you start, you need to prepare the workplace, arrange at your disposal all the necessary drawing instruments and tools, literature and other appliances and aids.

4. Drawings should be performed in the following order:

- draw the axial and centerlines of thickness 0.2 mm;
- execute the drawings by thin lines using the pencil 2T or T;
- apply the extension and dimension lines;
- apply dimensions and perform explanatory inscriptions;
- check carefully the drawing, and then apply dash lines;
- fill in the main inscription.

5. Drawings should be executed on the sheets of drawing paper, the format of which is specified in the subject of the assignment.

6. The order of tracing the drawings:

- put all the axial and centerlines by the pencil **T** or **TM**. The centers of all arcs should be determined by crossing the dashes. All dash-dotted lines must cross the contour line by the dashes and run out no more than 1 to 5 mm.

- circle all circles and arcs, starting with the circles and arcs of smaller radii. To use the compass, the pencils graphite should be well thinned and placed on the same level with the needle of the compass.

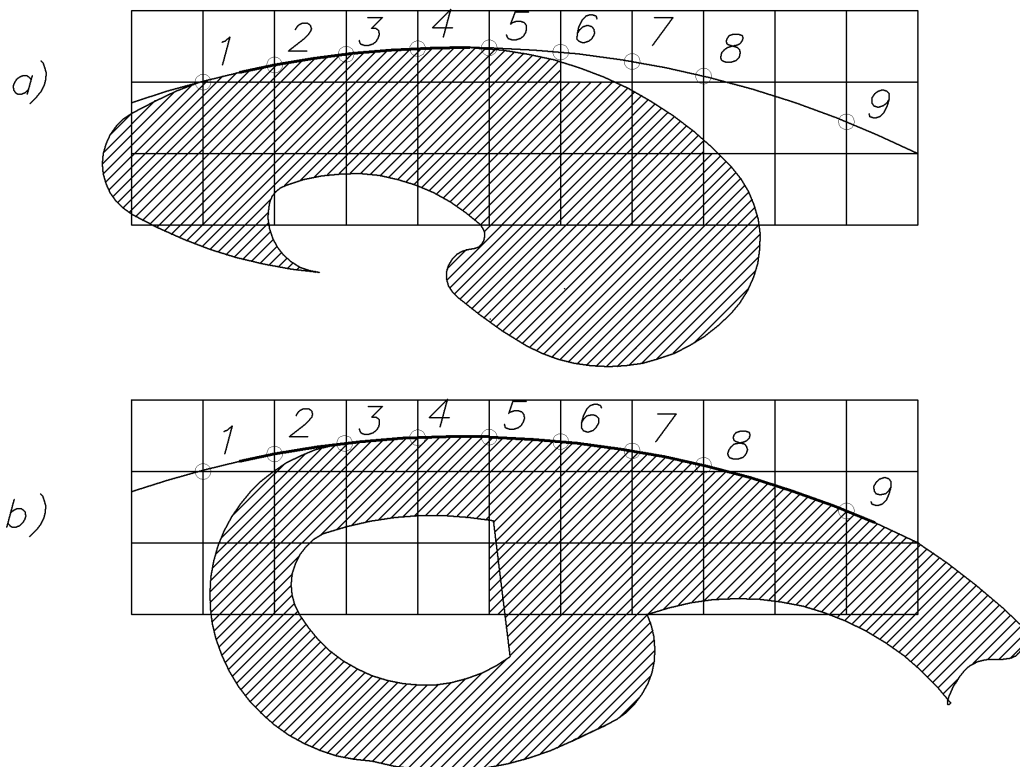


Fig. 1

The compass pencil should be less rigid than the working one to ensure the equal contrast of lines. For example, to trace the lines by pencils **M** or **TM**, the graphite of pencil **2M** or **M** should be insert in compass. Firstly, all horizontal lines of contour image should be traced, starting from the top of the sheet. Then, all

vertical lines of contour image should be traced, starting from the left side of the paper. In the same sequence, the inclined and curved lines are traced using a ruler and a template. The edge of the template should coincide with no less than four or five points of the curve (points **1, 2, 3, 4, 5**) (Fig. 1). The line connecting these points does not reach the extreme points (**1** and **5**). The next templates should coincide with at least four or five points, beginning with the fourth one (points **4, 5, 6, 7, 8**) (Fig. 1). The line should be continued up to the point **8**. Next imposition of the template must overlap the previously drawn part of the curve, ensuring the smoothness in all its areas. Tracing the construction lines is the next stage. The dimension and extension lines should be applied as well as all the numbers of dimensional letters and inscription numbers. The final stage is to apply arrows that limit the dimension lines as well as to put letters and numbers of main inscription.

1.3. Basic requirements for executing the drawings

To execute drawings one should obey the rules and conventions, and the established state standards of Ukraine - complex SDD (system of design documentation) standards.

1.3.1. FORMATS (GOST 2.301-68)

Drawings and other design documents are performed on the formats specified by GOST 2.301-68. Formats of drawing sheets determine the dimensions of the outer frame, which is drawn by a thin solid line (Fig. 2).

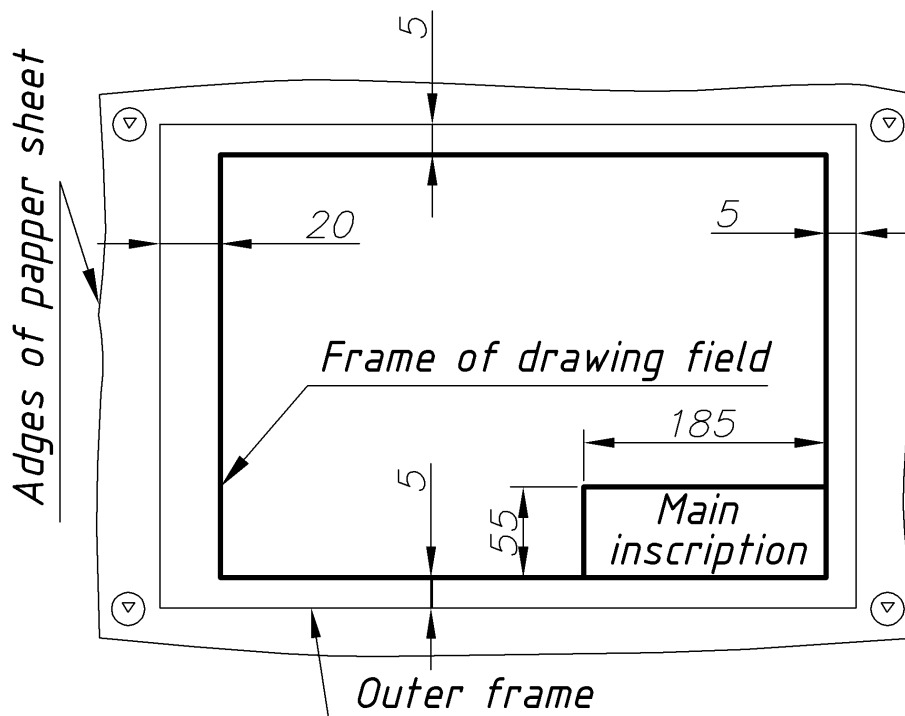


Fig. 2

Main formats and their designations are listed in Table 1.

Table 1

Dimensions of the main formats

Designations of formats	A0	A1	A2	A3	A4
Dimensions of format sides, mm	841×1189	594×841	420×594	297×420	210×297

In case of necessity, the format A5 with the sides **148×210** mm can be used.

The square of format A0 is 1m² and the sides relate as $1/\sqrt{2}$. Solving these two equations, the dimensions of format sides can be determined. Each subsequent format of smaller size is obtained by dividing the previous format into two equal parts along its short side.

Additional formats that are formed by increasing the smaller sides of the main formats on the value multiple of their sizes can be used. For example, the format A0×2 has sizes 1189×1682, format A3×3 - 420×891 etc. Dimensions of additional formats should be chosen from Table 2.

Table 2

Dimensions of additional formats

Multiplicity	Format				
	A0	A1	A2	A3	A4
2	1189×1682	-	-	-	-
3	1189×2523	841×1783	594×1261	420×891	297×630
4	-	841×2378	594×1682	420×1189	297×841
5	-	-	594×2102	420×1486	297×1051
6	-	-	-	420×1783	297×1261
7	-	-	-	420×2080	297×1471
8	-	-	-	-	297×1682
9	-	-	-	-	297×1892

Dimensions of the main inscription (55×185), which is always placed at the right bottom corner of the format, right up to the frame, are represented in Fig. 2. GOST 2.104 - 68 regulate the shape and content of the format (Fig. 3). One should remember that on the format A4, the frame of the main inscription should be drawn only along the short side of format. On the other formats, the frame can be drawn

along any side. Thick solid lines of minimum thickness 0.7 mm should draw the frame of a drawing field.

The main inscription on the formats of geometric drawings should be done according to the pattern, which is shown in Fig. 3.

The columns of main inscription (Fig. 3) must be filled in as follows:

in column 1 – the name of products, starting with a noun; and the document title if it was coded. For example, the working drawing details – "gear wheel"; the design of the electric schematic diagram – "Module A4. Electric schematic diagram";

in column 2 – the indexing of a document in accordance with GOST 2.202-80;

in column 3 – the designation of a part material (column should be filled in only in the drawings of parts);

in column 4 – the letter, which is given to this document in accordance with GOST 2.103-68;

in column 5 – the mass of products according to GOST 2.109-73 (except the training drawings);

in column 6 – the scale (put down in accordance with GOST 2.302-68);

in column 7 – the serial number of the sheet (except the documents that consist of a single sheet);

in column 8 – the total number of document sheets (on the first page only).

The example of filling in the column 2 of the main inscription in the training drawing is shown in Fig. 3:

TNTU. 010211.005 – the structure of indexing the drawings;

TNTU – Ternopil National Technical University

01 – the number of an assignment;

02 – the number of a theme;

11 – the number of a variant;

005 – the number of a figure.

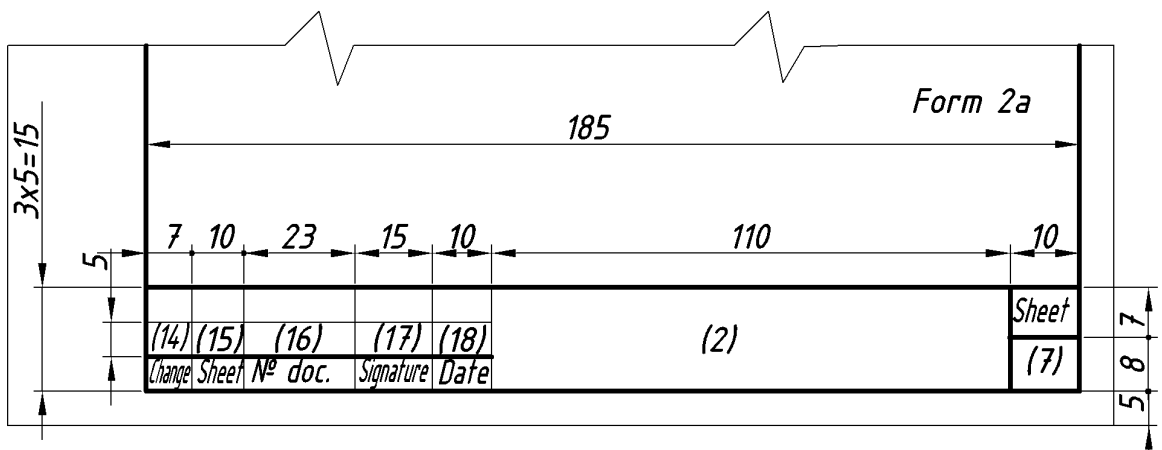
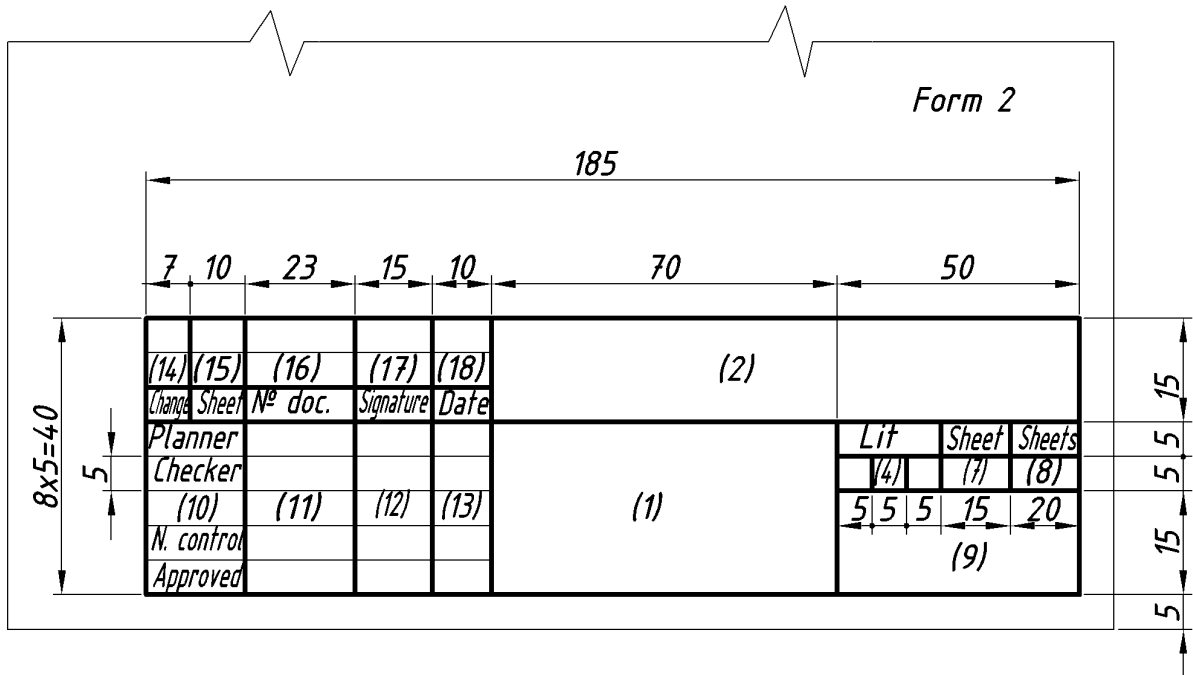
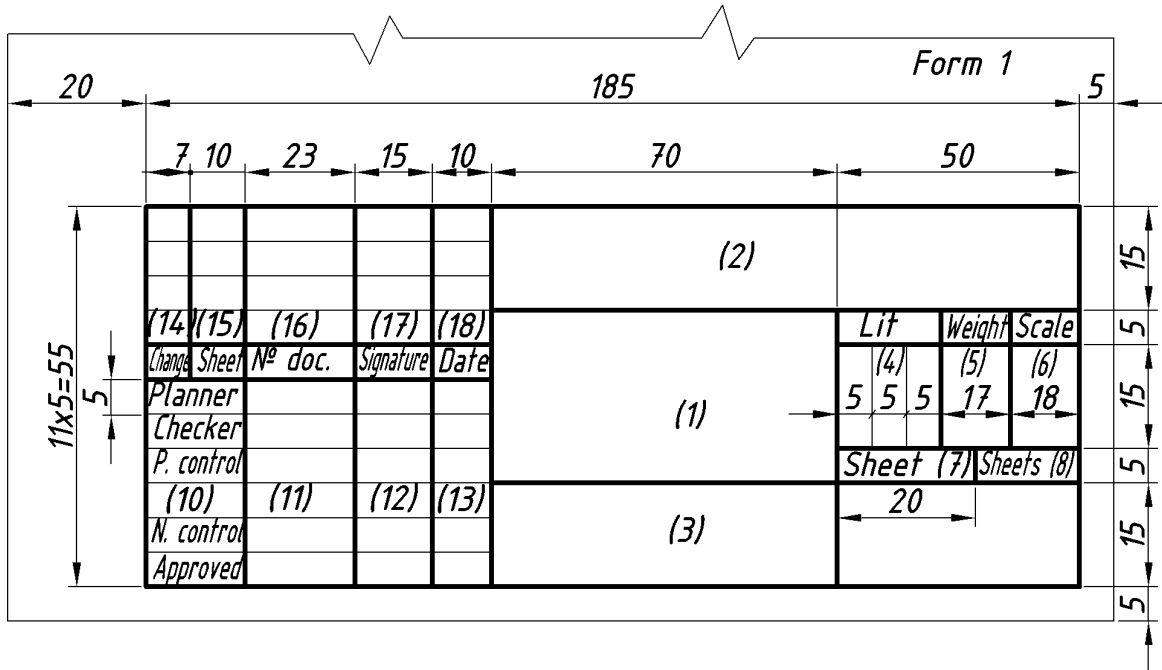


Fig. 3

1.3.2. SCALES (GOST 2.302 – 68)

The scale is the ratio of linear dimensions of the image in the drawing to its true size.

Preferably, the drawings are performed so that the dimensions of the image and the subject itself were the same, ie in a scale 1: 1. However, depending on the sizes and complexity of the subject, as well as on the appearance of the drawing, the sizes of the image must be often increased or decreased as compared with the real ones. In these cases, the images will be presented in scale.

Depending on the complexity and sizes of depicted products, and in accordance with GOST 2,302 – 68, the scales are selected from the ranges:

Reduction scale – 1:2; 1:2.5; 1:4; 1:5; 1:10; 1:15; 1:20; 1:25; 1:40; 1:50; 1:75; 1:100; 1:200; 1:400; 1:500; 1:800; 1:1000.

Real size – 1:1.

Scale of magnification– 2:1; 2.5:1; 4:1; 5:1; 10:1; 20:1; 40:1; 50:1; 100:1.

When designing the general layout drawings of large projects, the scales 1: 2000; 1: 5000; 1: 10000; 1: 20,000; 1: 25000; 1: 50000 can be used.

If necessary, the scales of magnification (**100n**): **1** can be used, where **n** is integer.

When choosing the scale, the usability of drawing should be taken into account first. The scale pointed in the column "Scale" (in main inscription in the tables) is indicated: 1: 1; 1: 2; 2: 1, and so on. In the field of drawing, the scale is indicated in brackets next to the conventional notations of the image. Example: AA (2: 1); B1 (5: 1); B (1: 4).

1.3.3. LINES (GOST 2.303 – 68)

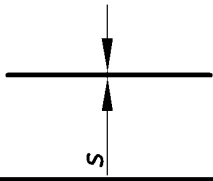


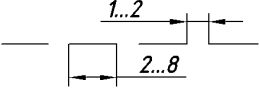
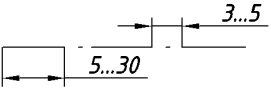


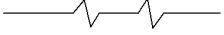
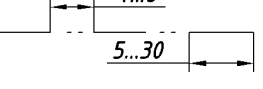
GOST 2.303-68 establish nine types of lines depending on the thickness of the image and the main purpose (Table 3).

The thickness of lines in the drawing must be a multiple of selected thickness of main solid line, and this thickness can vary from 0.5 to 1.4 mm. The thickness of lines should be the same for all the images in this drawing that are drawn at the same scale.

The length of dashes in the dash and dash-dotted lines is selected depending on the sizes of the image. Dashes in the line and the intervals between them should be the same length.

Table 3

Line types, basic parameters and their usage

№ з/п	Line	Line thickness relatively the thickness of the main line	General application
1	<p>Continuous thick (main)</p> 	s (0,5...1,4)MM	<ol style="list-style-type: none"> 1. Visible outlines 2. Visible edges
2	<p>Continuous thin (straight or curved)</p> 	$\frac{s}{3} \dots \frac{s}{2}$	<ol style="list-style-type: none"> 1. Imaginary lines of intersection 2. Dimension lines 3. Projection lines 4. Leader lines 5. Hatching lines 6. Outlines of revolved section in place 7. Short centre lines
3	<p>Continion thin freehand</p> 	$\frac{s}{3} \dots \frac{s}{2}$	<ol style="list-style-type: none"> 1. Limits of partial or interrupted views and sections. If the limit is not a chain thin
4	<p>Dashed</p> 	$\frac{s}{3} \dots \frac{s}{2}$	<ol style="list-style-type: none"> 1. Hidden outlines 1. Hidden edges
5	<p>Chain thin</p> 	$\frac{s}{3} \dots \frac{s}{2}$	<ol style="list-style-type: none"> 1. Center lines. 2. Lines of symmetry. 3. Trajectories.
6	<p>Chain thick</p> 	$\frac{s}{2} \dots \frac{2}{3} s$	<ol style="list-style-type: none"> 1. Indication of lines or surfaces to which a special requirement applies
7	<p>Cutting plane</p> 	$s \dots 1 \frac{1}{2} s$	<ol style="list-style-type: none"> 1. Cutting plane
8	<p>Continious thin (straight) with zigzags</p> 	$\frac{s}{2} \dots \frac{2}{3} s$	<ol style="list-style-type: none"> 1. Long break line
9	<p>Phanton line</p> 	$\frac{s}{3} \dots \frac{s}{2}$	<ol style="list-style-type: none"> 1. Outlines of adjacent part 2. Alternative or extreme position of movable part 3. Centroidal lines

Dash-dotted lines should begin, intersect and end by dashes. Thin solid lines replace dash-dotted lines used as the center ones, where the circle diameter or

dimensions of other geometric figures in the image are smaller than 12 mm. Circle center in all cases is determined by crossing the dashes.

In complex cross-sections, the dash-dotted thin lines can connect the ends of open-ended lines. The length of the ends of open-ended lines is selected within 8 - 20 mm depending on the image sizes.

Main lines (visible contour lines) should be drawn with thickness from 0.8 to 1.0 mm, dashed lines (invisible path lines) – from 0.4 to 0.5 mm, and others – from 0.25 to 0.3 mm.

1.3.4. DRAWING FONTS (GOST 2.304 – 81)

According to GOST 2,304 – 81, the inscriptions in drawings and other technical documents of all industries and construction are performed by means of the font with the slope 75° to the base of a line, or without inclination. The font thickness is 1:14 (type A) or 1:10 (type B) from the size (height) of the font. The standard regulates such font sizes (**1.8**); **2.5**; **3.5**; **5**; **7**; **10**; **14**; **20**; **28**; **40**. The height of capital letters in millimeters determines the font size. The sizes of letters and numbers, thickness of lines, distance between letters, words and lines should be selected based on the size or thickness of font lines.

For the convenient writing, the font of type B is recommended for the inscriptions in drawings and other design documents. To write the font it is necessary to draw a grid by thin lines, depending on the height of letters and numbers. A pencil at the angle 75° should draw the grid for all font sizes. The students should fill in each letter and number in the grid to master their skills to write letters and numbers without using the grid.

The writing and tracing rectilinear elements of letters is mainly performed from the top to the bottom and from the left to the right; and for the curved parts of letters – from the top to the bottom clockwise or counterclockwise. To execute the drawings, the font sizes **3.5** and **5** are used, in particular, to apply sizes, as well as to perform text inscriptions and to fill in columns of specifications. Font sizes **5** and **7** are used primarily for names of details and for indexing the documents in the correspondent column of the main inscription of drawing; and the size **10** – for general headings.

1.3.5. GRAPHICAL DESIGNATION OF MATERIALS IN DRAWINGS (GOST 2.306 – 68)

The product is made of material, which is indicated in the frame of the main inscription of drawings (Column 3, Fig. 3). For convenient use of drawing in

sections, the graphical designations of materials are applied; these designations characterize the material only in general terms. Some of them, which are the most often used in engineering drawings, are shown in Table 5. Parallel lines of dashes are applied at the angle 45° to the line of drawing frame (Fig. 4) or to the axis of remote or consignment sections. The distance between the lines is from 1 to 10 mm depending on the section area (for educational drawings from 2 to 3 mm are recommended). It should be the same in all sections relating to the given part.

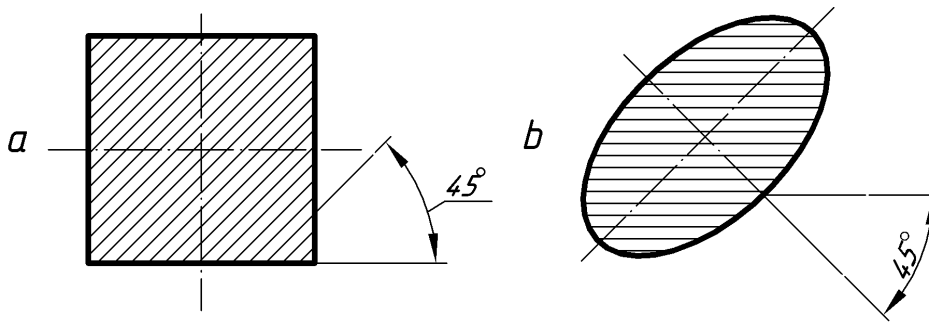


Fig. 4

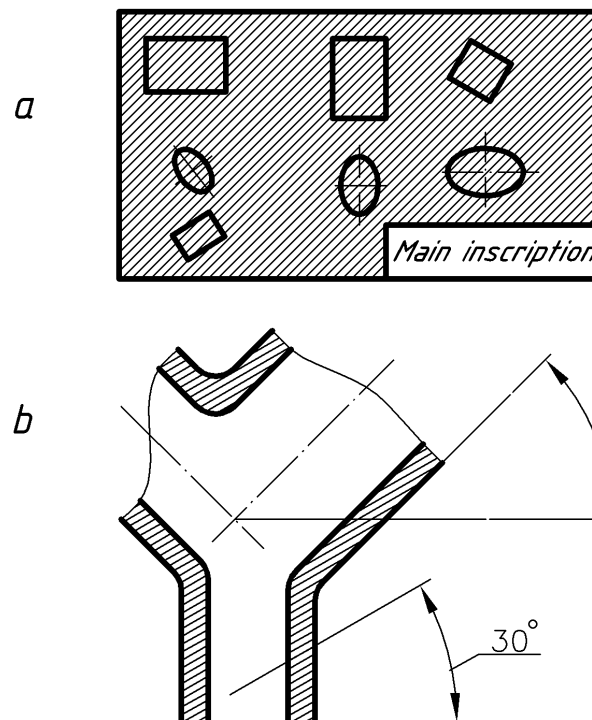
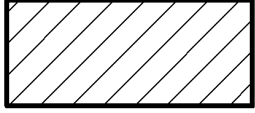
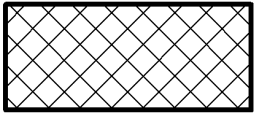
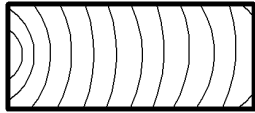
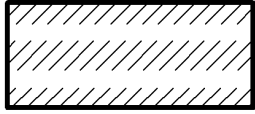
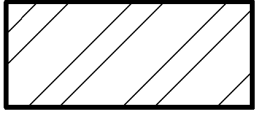
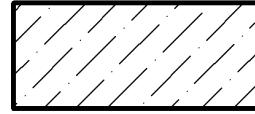
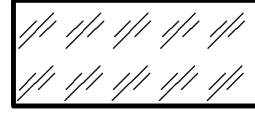




Fig. 5

Table 5

Graphical notation materials in sections

<i>Material</i>	<i>Graphical notation</i>
1. <i>Cast or malleable iron and general use for all materials</i>	
2. <i>White metal, zink lead, babbitt and alloys</i>	
3. <i>Wood</i>	
4. <i>Natural stone</i>	
5. <i>Ceramics and silicate materials</i>	
6. <i>Concrete</i>	
7. <i>Glass</i>	
8. <i>Water and other liquids</i>	
9. <i>Natural soil</i>	

When the direction of dash lines coincides with the contour or axial lines, the angle 30° or 60° is used instead of inclination angle 45° (Fig. 5).

Dash lines of adjacent sections are applied to one section to the right, and to another – to the left, or the pitch of dash lines is changed. Displacement of dash lines is used as well.

Narrow planes of sections with the width less than 2 mm can be coloured in black.

1.3.6. DIMENSIONING (GOST 2.307 – 68)

Dimensioning is one of the most important and crucial stages of executing drawings. It is carried out in accordance with the basic requirements of GOST - 2.307-68:

1. Each size is applied in the drawing only once. Repetition of sizes on the images or during writing the inscription is not allowed.
2. Total amount of sizes should be minimal but sufficient to manufacturing the product and to controlling its quality when using this drawing.
3. Regardless of the scale in the drawing, the actual size in millimeters without marking the measure unit is applied.
4. Arrows that reach by their ends the correspondent line, which is the limit of measurement (remote, axial, contour), restrict dimension lines on both ends (Fig. 6). They are mainly put out of the image outline. The arrows sizes of dimensional lines depend on the thickness of visible contour lines (Fig. 7). In the training drawings, the dimension arrows should be put at the length from 5 to 7 mm.
5. The minimal distance between parallel lines is 7 mm, and between the size and contour lines – 10 mm (Fig. 6).
6. Remote lines are complementary. They are drawn from the limit of measurement perpendicular to the rectilinear segment of the detail element, which size is applied. Remote lines should continue from 1 to 5 mm beyond the ends of the arrows or serifs (Fig. 6).
7. Contour, axial, center and extension lines cannot be used as dimensional lines. Axial and center lines can be used as remote ones. Therefore, they must be continued (Fig. 6). However, the section of remote and extension lines cannot be applied.
8. The numbers of linear dimensions at different inclination of dimensional lines are put as shown in Fig. 8. If you need to specify the size in the shaded area, the dimensional number is put on the shelf – the footnote (Fig. 8).

9. Arrows on the diameter of a circle or arc radius must be turned to the line of the circle or arc. Dimension lines of diameters and radii applied to circles should not take horizontal and vertical positions or match the center lines.

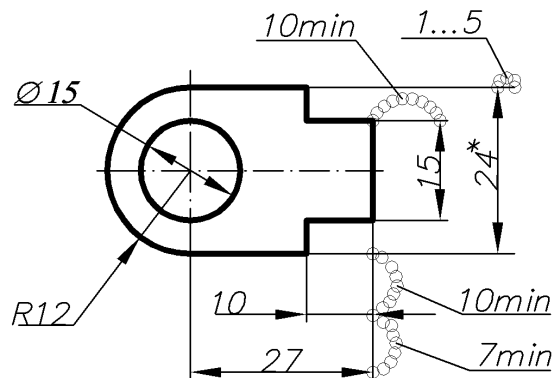


Fig. 6

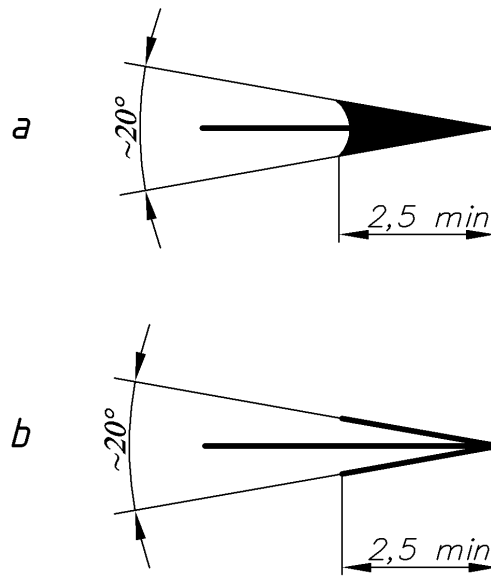


Fig. 7

10. Dimension numbers of radii should be completed with designation for the samples R10, R25, where the letter height equals the number height. Dimension numbers of diameters are completed with conventional sign \varnothing , which is put before dimensional number on the sample $\varnothing 15$ (Fig. 6).

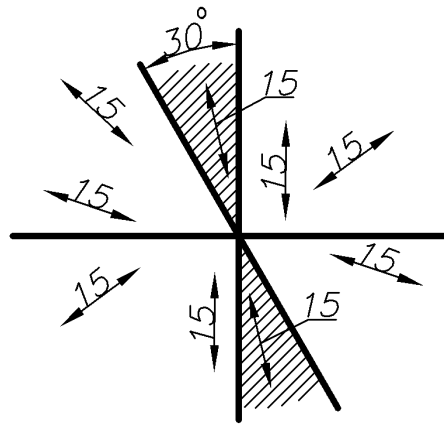


Fig. 8

11. In case of space shortage between dimensional arrows, the dimension number is put as shown in Fig. 9, placing the number to the right if possible.

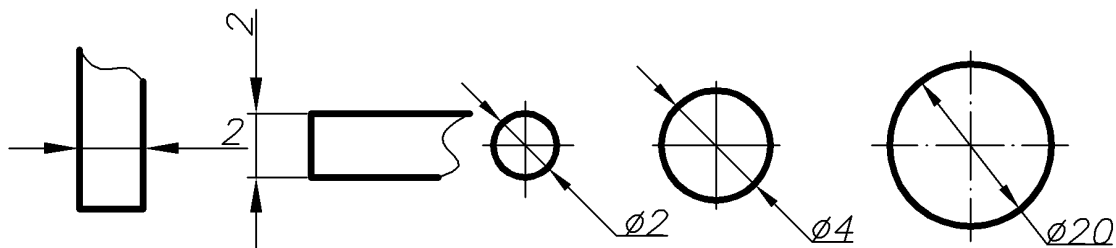


Fig. 9

12. If there is not enough space for dimensional arrows during the application of dimension number, they may be put on the outside or can be replaced by serifs that are applied at the angle 45° to the dimension line along the inscription or clearly plotted points (Fig. 10).

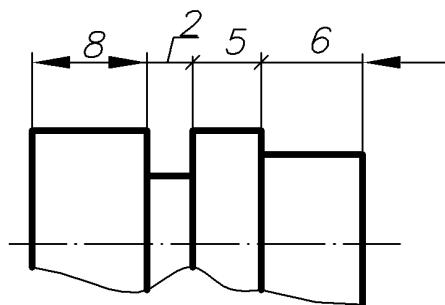


Fig. 10

13. Tapered chamfers, made at the ends of cylindrical parts at the angle 45° , are referred to as the product of cathetus value at its angle: $2 \times 45^\circ$. If in the drawing of given parts there are some several identical tapered chamfers, they are referred to as 2 chamfers $2 \times 45^\circ$ (Fig. 11). When other angles are used to execute the chamfer, it is

marked as shown in Fig. 11b, ie the cathetus value and angle size is separately indicated.

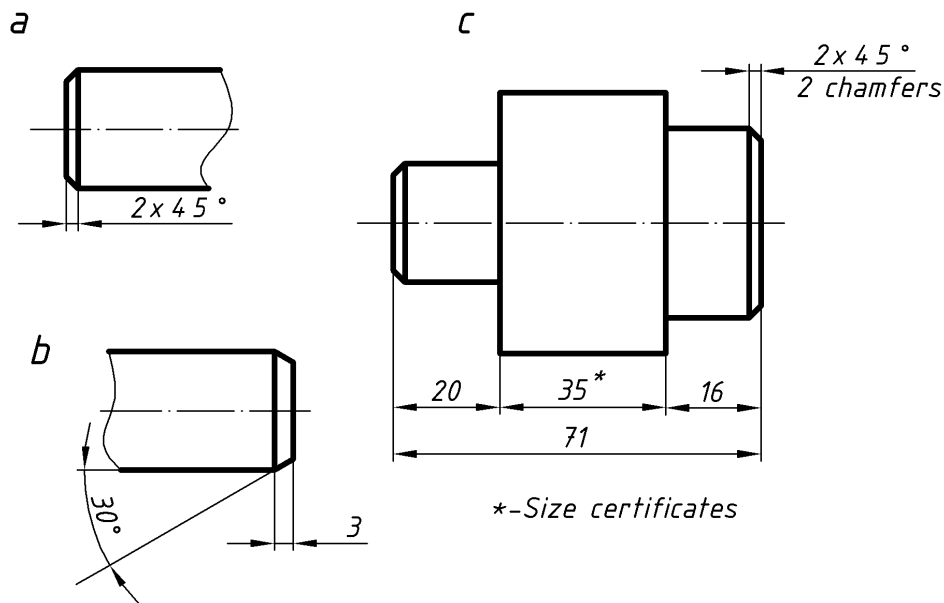


Fig. 11

14. The dimensioning of other signs and conventions are applied, which can reduce the number of images and sizes.

15. Dimensioning is performed using the "nonclosed circuit" principle except construction drawings. The closed circuit is allowed if one of the sizes is indicated as a reference. This size is denoted with an asterisk (*), and the technical requirements record: "Size certificates" (Fig. 11c).

16. Over parallel or concentric dimension lines, the dimensional numbers are put in a checkerboard pattern (Fig. 12).

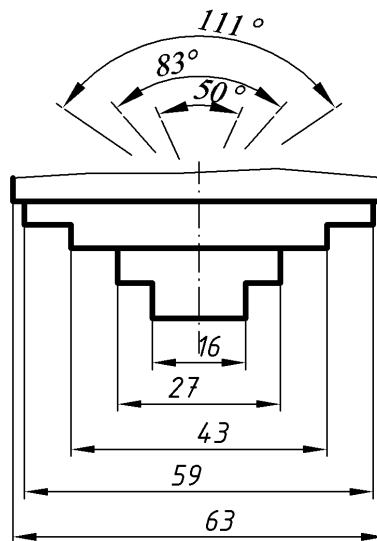


Fig. 12

17. When there is not enough space for the arrow because of close contour line, the former can be broken (Fig. 13).

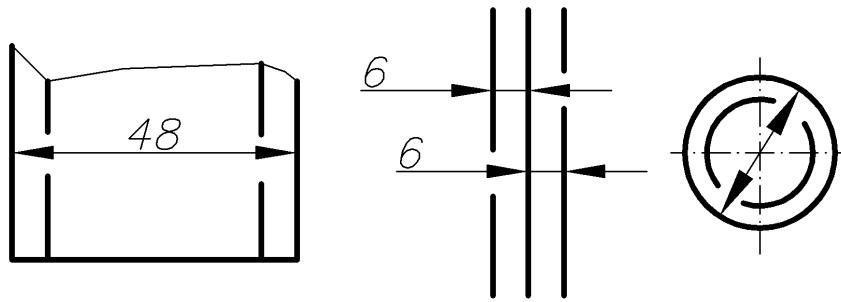


Fig. 13

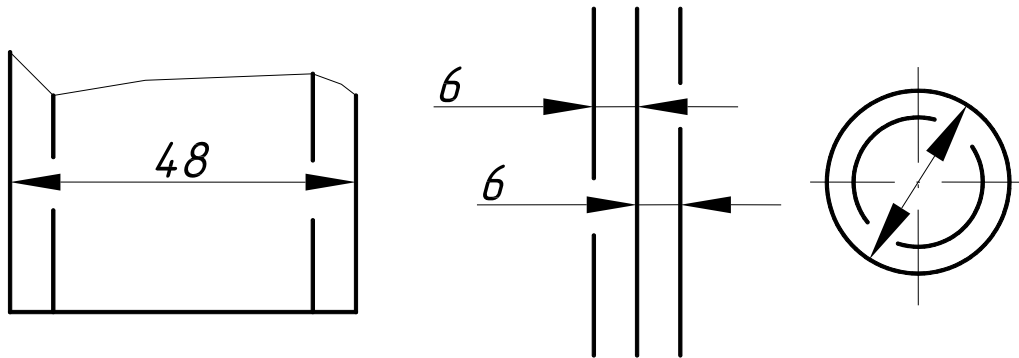


Рис. 13

18. Sizes of angle, circle arcs and chords are applied as shown in Fig.14. Over dimensional number the sign “ \cap ” is applied. Angular size is applied as shown in Fig.15. For the small size angles, the dimensional numbers are placed on the shelves of callouts lines in any area.

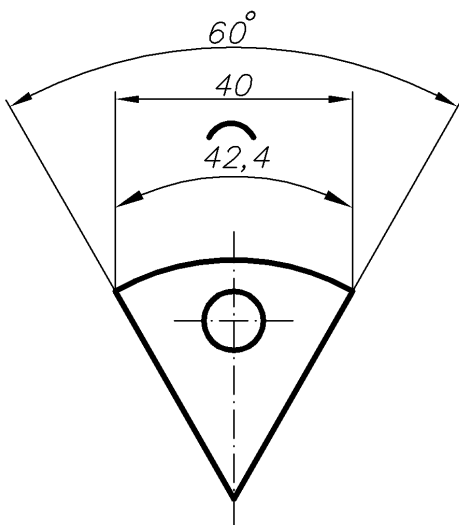


Fig. 14

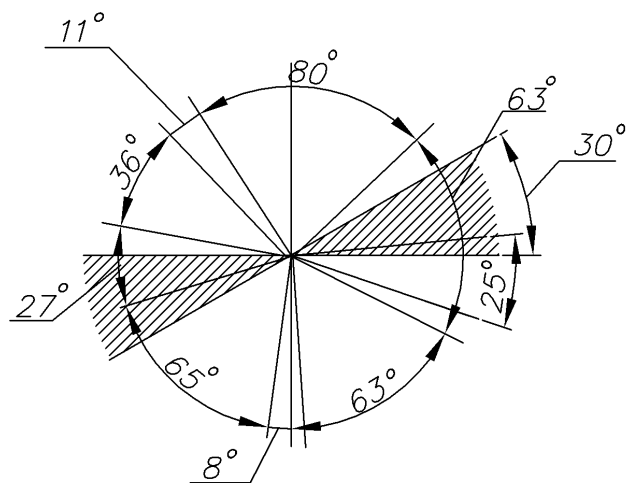


Fig. 15

19. If you need to put the top oblique angle coordinates or the center of curvature arc, the remote lines are applied from the point of intersection of the oblique angle parties or from the center of curvature arc (Fig. 16).

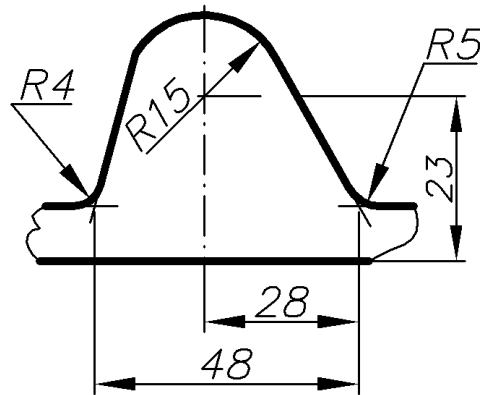


Fig. 16

20. The appearance and section of a symmetrical object or some other symmetrically placed elements are represented only to the symmetry axis or with breakage. The dimension lines relating to these items are drawn with a break. The break of dimension line is performed outside the axis or the object breakage line (Fig. 17a).

Dimension lines can be drawn with a breakage, representing the size of a circle diameter regardless of the circle is depicted entirely or partially. Besides, the dimension line breakage is performed on the center of a circle (Fig. 17b).

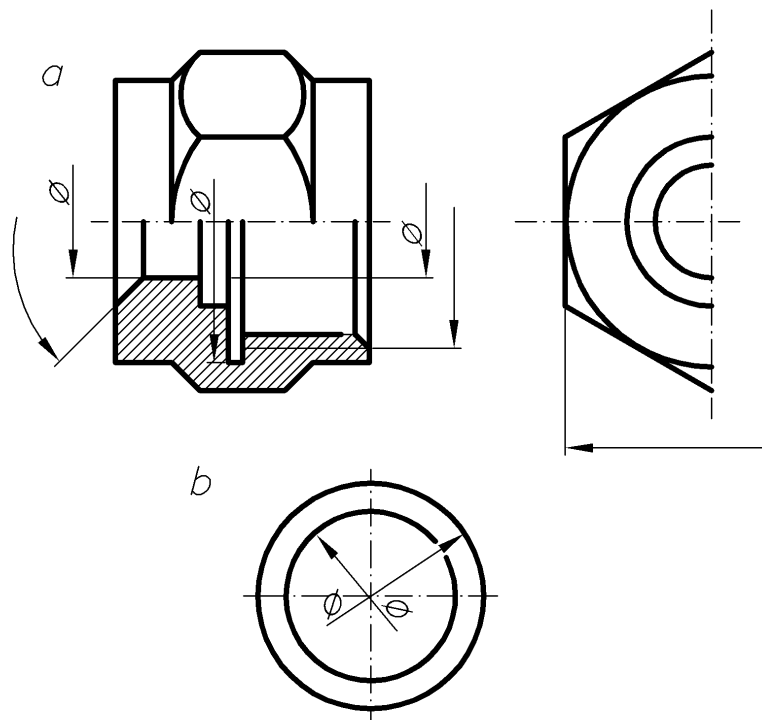


Fig. 17

21. When representing the product with a breakage, the dimension line is not broken (Fig.18).

22. Any lines of the drawings cannot separate or cross the dimension numbers. The contour line cannot be broken during the application of dimension number. The dimension numbers cannot be applied at the intersection of dimensional, axial or center lines. Axial, center lines and dash lines can be broken (Fig.19).

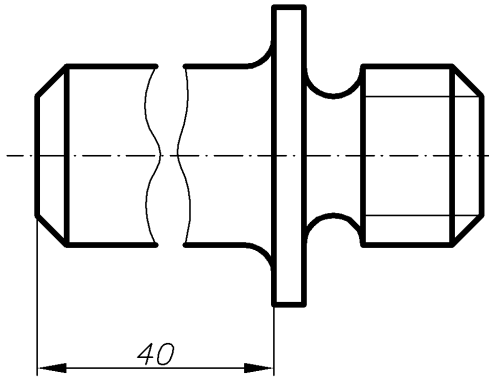


Fig. 18

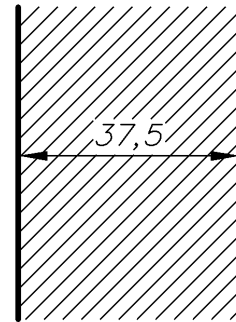


Fig. 19

23. To dimension the arc radius, it is necessary to put the size that determines the position of its center. In this case, it is presented as a section of the center and extension lines. If the radius value is great, the center can be extended to the arc. In this case, the dimensional line of the radius is presented with fracture at the angle 90° (Fig.20).

24. If the centers of some radii coincide, their dimension lines cannot be extended to the center, except the outer ones (Fig.21).

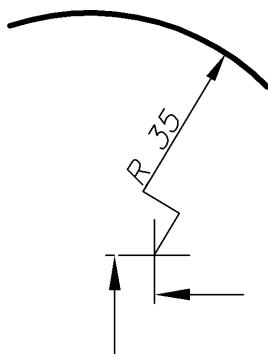


Fig. 20

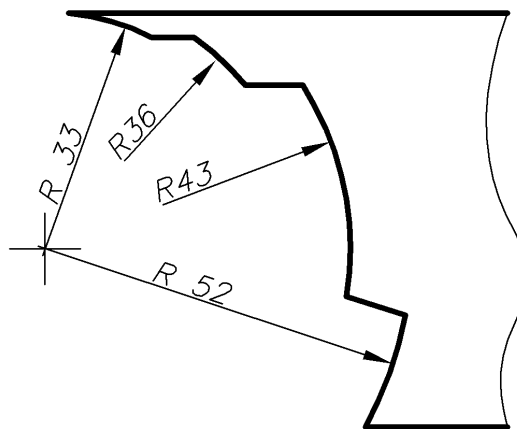


Fig. 21

25. Dimensions of product diameters of complex configuration can be applied as shown in Fig. 22. If it is difficult to distinguish the sphere from other surfaces, the word "Sphere" is put as well as the sign as shown in Fig. 23. The size of sphere sign diameter equals the size of the dimensional numbers in the drawing.

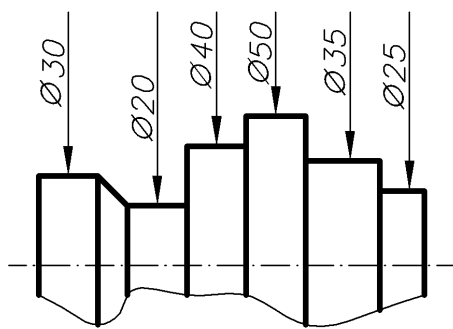


Fig. 22

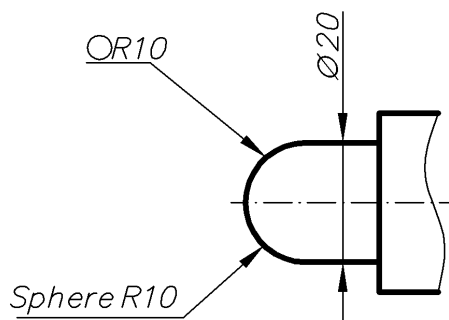


Fig. 23

26. The size of a square is applied as shown in Fig. 24. The height of the sign "square" equals the height of digits of dimensional numbers in the drawing.

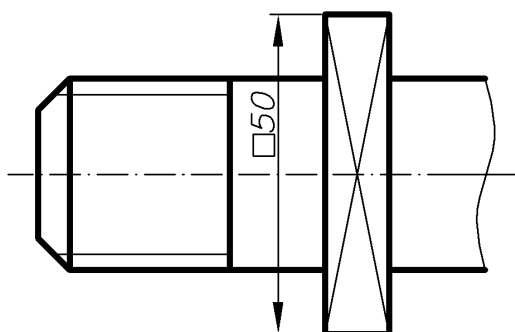


Fig. 24

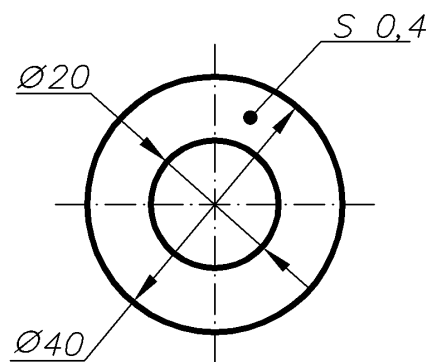


Fig. 25

27. If the drawing contains one image of a detail, the size of its thickness or length is applied as shown in Fig. 25 and Fig. 26.

28. Product dimensions are always applied nominal, regardless of image scale. If the item is shown with a deflection on the scale, the dimensional number is underlined (Fig. 27). This rule cannot be applied to some image elements that are hard to erase or desirable to increase their visual perception, as well as to the thin plates, gaskets, and washers represented on scale 1:1.

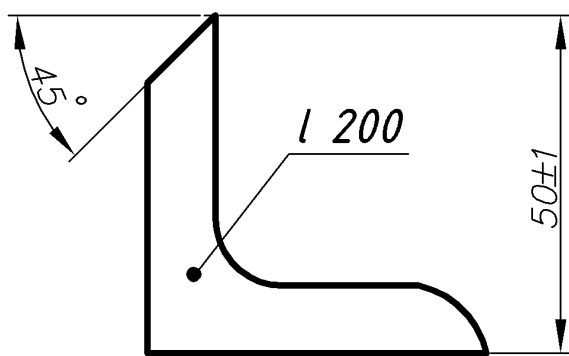


Fig. 26

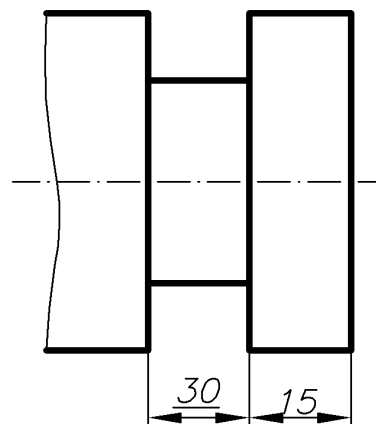


Fig. 27

29. Dimension line is preferred to be drawn out the contour of the image. The internal and external dimensions of the workpiece should be placed at various sides of the image (Fig. 28). However, dimensions can be put in the middle of the image contour providing of the drawing does not lose clarity.

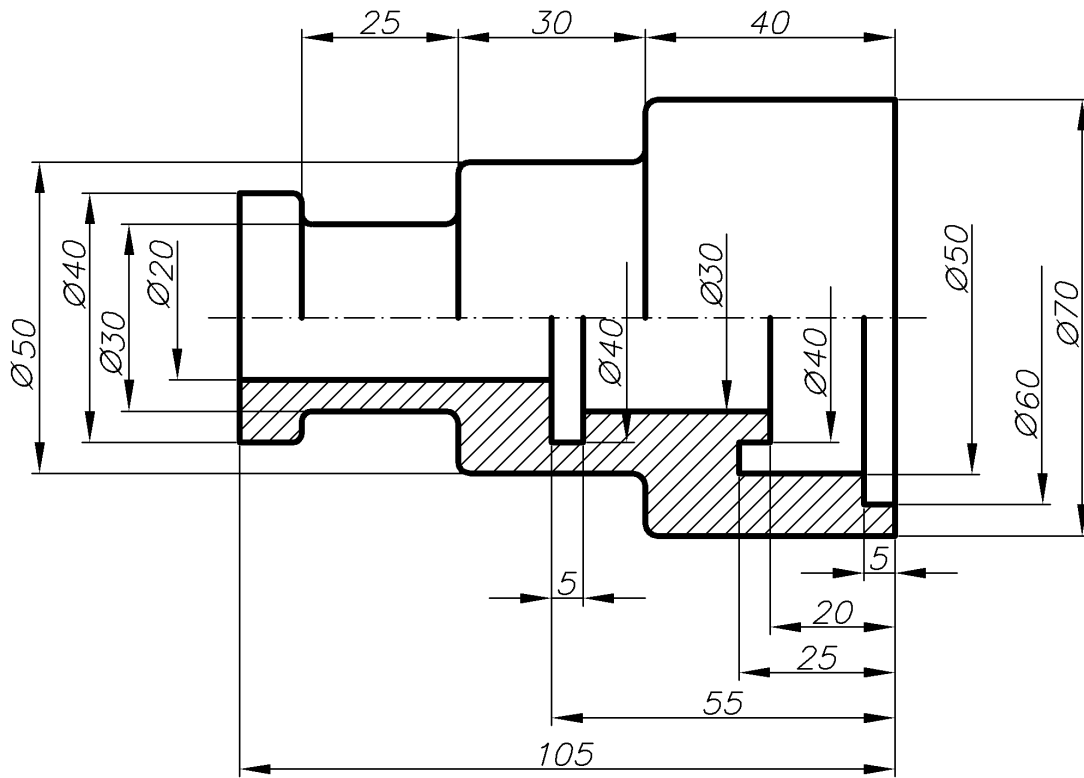


Fig. 28

30. Dimensioning the invisible contour is applied in cases where the drawing of extra image is not obvious (Fig. 29).

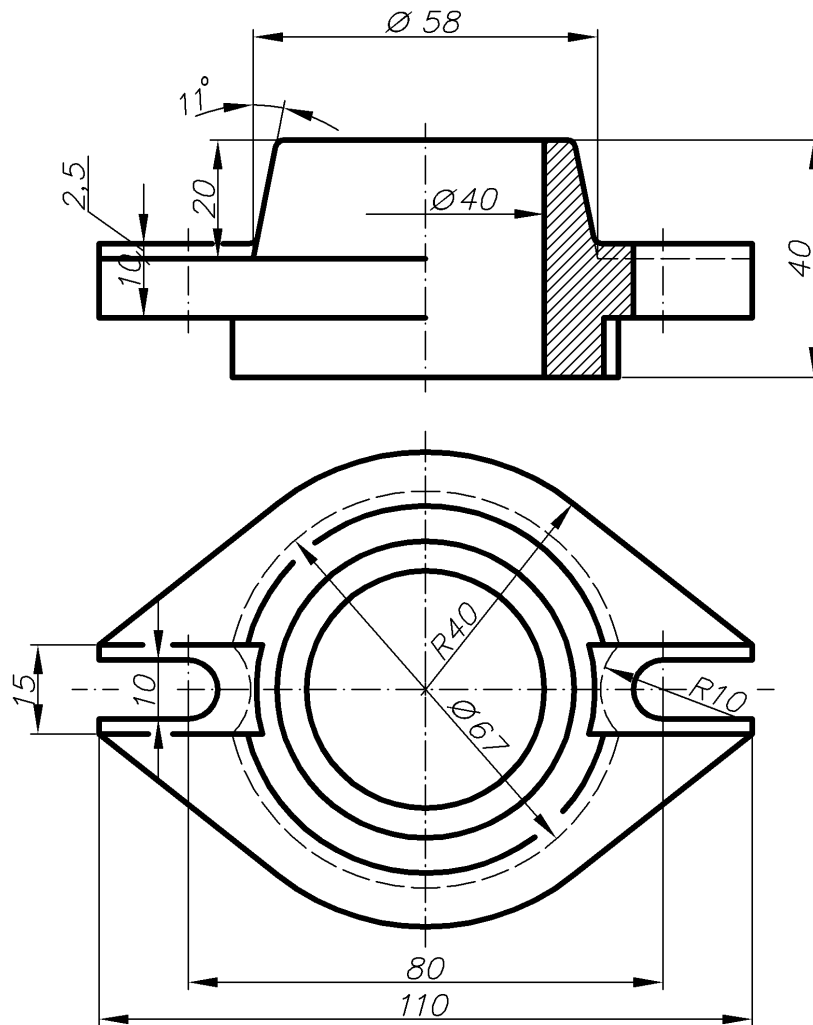


Fig. 29

31. In order to put the correct dimensions, you must choose a base for their reference.

Dimension framework is a supporting treated surface of parts or geometrical axis of its main elements, which determine the position relatively to other surfaces, lines or points. At the same time, the appointment of the detail in the car or the site is taken into account. According to GOST 21495-76, frameworks are divided into the design (main and auxiliary) ones, and measuring and technological ones. Design framework is the coordinate plane, which allows pinpointing the position of any assembly unit or part in the product.

The technological base determines the position of the workpiece or product in their manufacture or repair.

Measuring base determines the relative position of the workpiece or product and measuring tools.

32. Measuring references can be:

- The planes, from which the treatment begins, such as the joint face, terminal face and others. In Fig. 30, the detail is shown, which main (design) frameworks are a

joint face **A** and geometrical axis of the detail. The sizes **a**, **b**, **c**, **d**, the diameters **1**, **2**, and so on are counted from them.

- Straight lines, such as the axis of symmetry, any mutually perpendicular edges of details and more.

The dimensions that refer to the same item (grooves, performances and so on) are recommended to concentrate in one place, placing them on the picture, which depicts this item sharpest (Fig. 31).

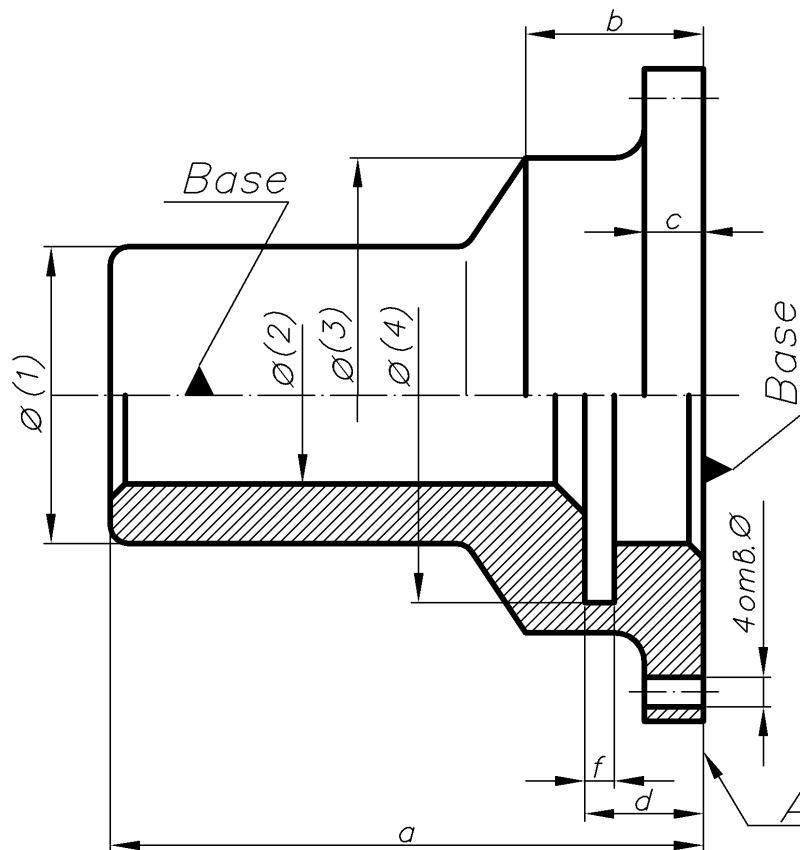


Fig. 30

- Point. Fig. 32 shows a cam mechanism of a machine. This framework is the point O (the pole of polar coordinate system). The straight line OX (polar axis) is a base for reference of angles.

When dimensioning, the technology of manufacturing the details must also be taken into account.

In designs of machines, the shafts and other round parts can often be found, which are treated using the turning or revolving machines (Fig. 33).

Fig. 33b illustrates an example of incorrect dimensioning and ineffectual option of handling the roller, as in this case it is impossible to process the part using one installation (besides, in turning the cylinder of small diameter, the large axial runout occurs).

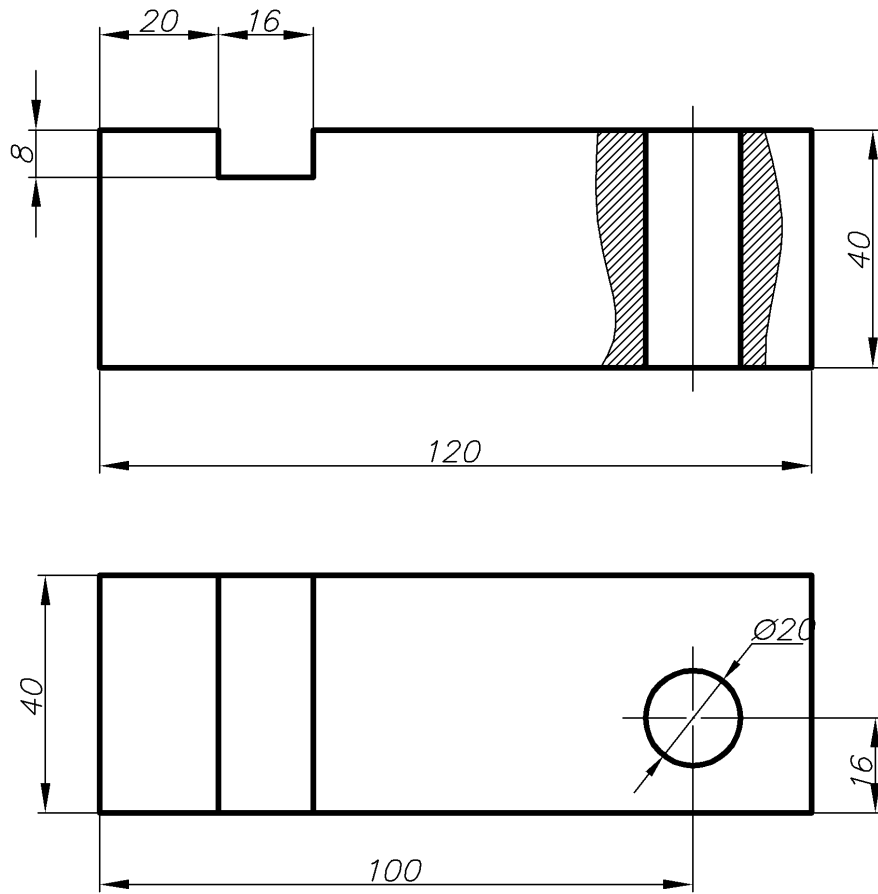


Fig. 31

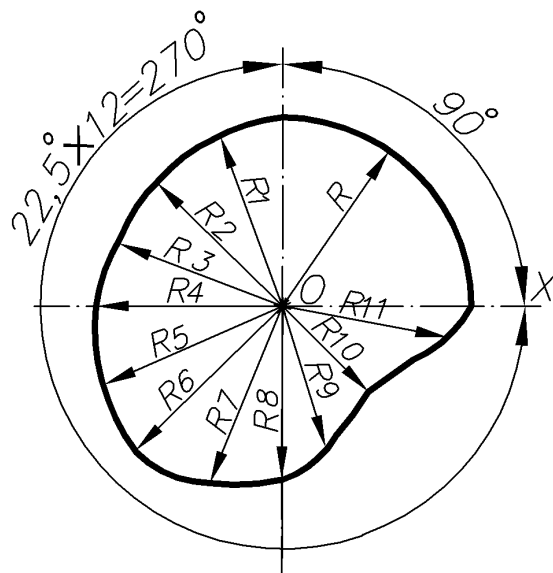


Fig. 32

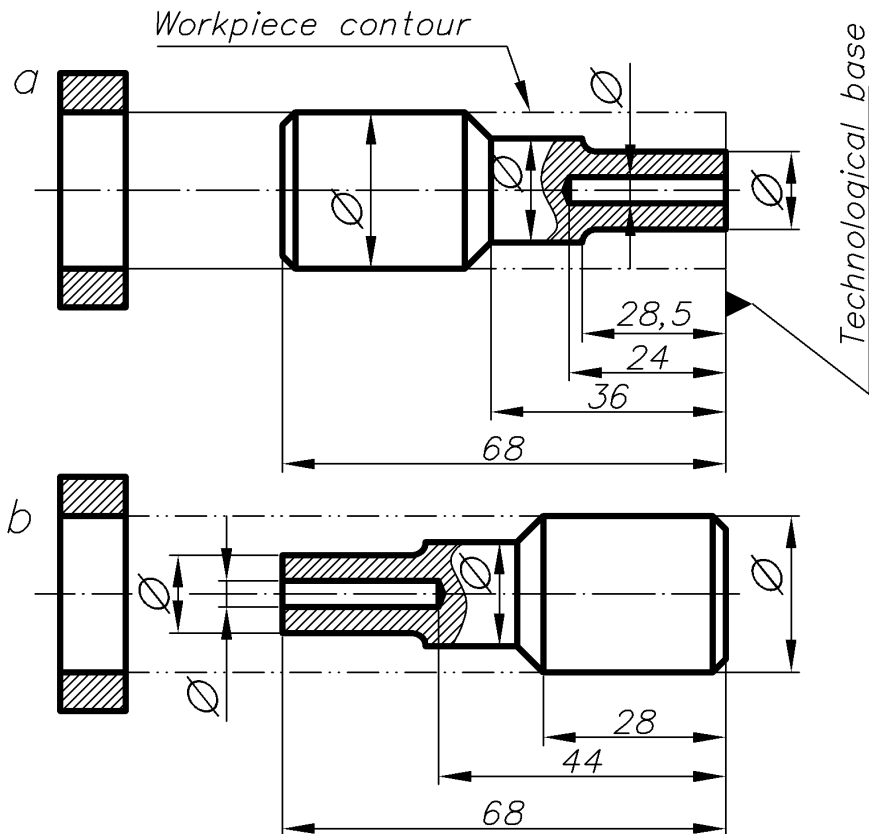


Fig. 33

34. When dimensioning, the priority should be given to series of numbers, taking into account the requirements of relevant standards. **Normal obliquity and angle of taper** (GOST 8593-81) is presented in Table 6, **normal linear dimensions** – in Table 7, **normal curvature radii and chamfer** – in Table 8 (GOST 10948-64). When using the tables, the preference should be given to the first row, then to the second, next to the third and so on.

Table 6

Normal obliquity

Obliquity c	Angle of taper α	Obliquity c	Angle of taper α
1:500	6'52.5"	1:6	9°31'38.2"
1:200	17'11.3"	1:5	11°25'16.3"
1:100	34'22.6"	1:4	14°15'0.1"
1:50	1°8'45.2"	1:3	18°55'28.7"
1:30	1°54'34.9"	1:1.866025	30°
1:20	2°51'51.1"	1:1.207107	45°
1:15	3°49'5.9"	1:0.866025	60°
1:12	4°46'18.8"	1:0.651613	75°
1:10	5°43'29.3"	1:0.500000	90°
1:8	7°9'9.6"	1:0.288675	120°
1:7	8°10'16.4"		

Table 7

Normal linear dimensions

1st line	10; 11; 12; 14; 16; 18; 20; 22; 25; 28; 32; 36; 40; 45; 50; 56; 63; 71; 80; 90
2nd line	10; 10.5; 11; 12; 13; 14; 16; 17; 18; 20; 21; 22; 24; 25; 26; 28; 30; 32; 34; 36; 38; 40; 42; 45; 48; 50; 53; 56; 60; 63; 67; 71; 75; 80; 85; 90; 95

Note: Other normal dimensions are obtained by dividing and multiplying the numbers in the range from 10 to 95 by 10^n .

Table 8

Normal curvature radii and chamfers

1st line	... 1.0; 1.6; 2.5; 4.0; 6.0; 10; 16; 25; 40...
2nd line	...1.0; 1.2; 1.6; 2.0; 2.5; 3.0; 4.0; 5.0; 6.0; 8.0; 10; 12; 16; 20; 25; 32; 40; 50...

1.4. Geometric constructions

Geometric construction is a graphical method of solving geometrical problems on the plane using the drawing tools.

To study the "Geometric drawing", the students must possess the skills of using drawing tools. They must be able to execute the basic constructions using the gon, ruler, and compass.

1.4.1. INCLINATION. To draw many technical details, geometric inclinations should be performed. For example, inclinations are widely used for manufacturing the structural sections, such as channel bars, double-T iron, which number indicates their height in inches.

The inclination of the straight line **BC** relatively to the horizontal line **AB** is the ratio $i=h/l=tg \varphi$, where φ is the inclination angle.

Fig. 34 shows the construction of inner faces of channel bars, where the inclination is 10%.

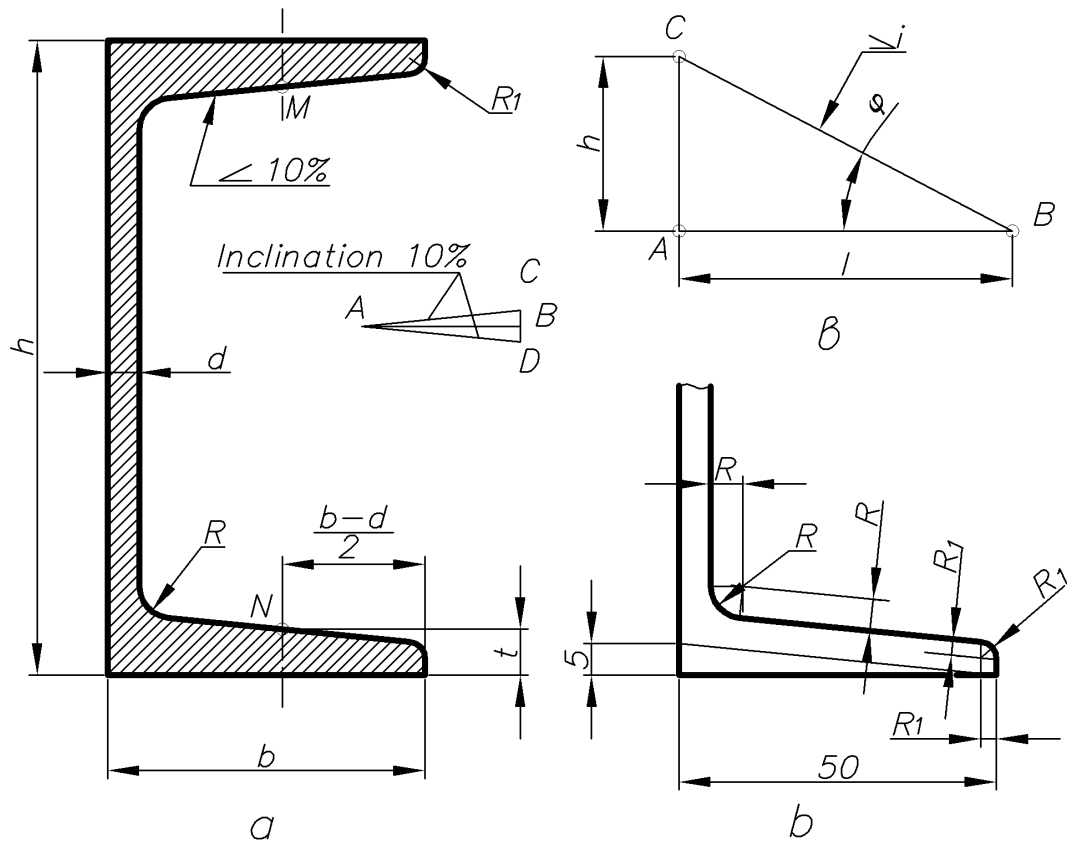


Fig. 34

The construction of inner faces of channel bars is performed in the following order:

- Along with the profile on the horizontal line **AB**, 10 random segments of equal length are laid. On the perpendicular line at the point **A**, the mentioned above segment is laid on both sides. Hypotenuses **AC** and **AB** have inclination of 10%.

- Through the points **M** and **N**, which are at the distance $(b-d)/2$ from the end of faces and at the height **t** from external horizontal (lower and upper) edges of faces, the inclination lines parallel to **AC** and **AD** are laid. Then the oblique angles with radii **R** and **R₁** are rounded (Fig. 34). Similarly the inclination of faces for double-T iron is performed.

Sign of inclination \angle , the top of which should be directed towards the inclination, is put before the dimensional number. It is placed directly next to the image of inclination surface (Fig. 34). A small inclination in the drawing may be increased to portray.

1.4.2. OBLIQUITY. Obliquity is the ratio of the diameters difference of right circular cone bases to its height $K=(D-d)/l$. At the same angle, the obliquity is **2h** times greater than the inclination (Fig. 35).

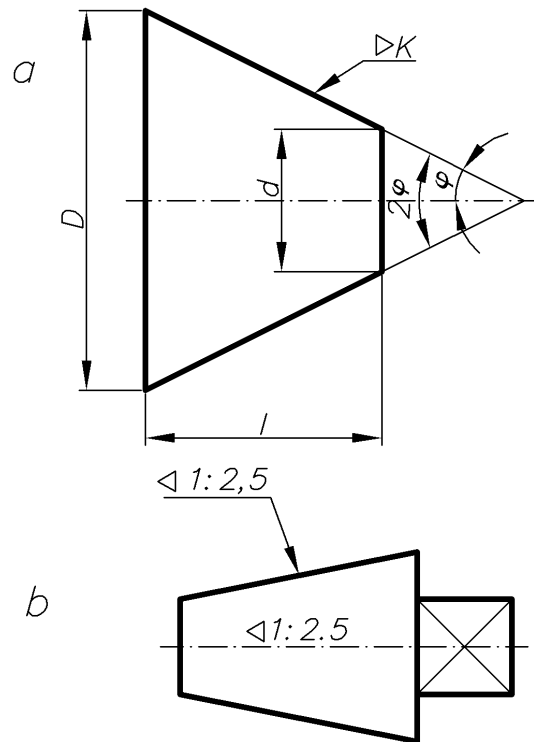


Fig. 35

Before the dimensional number of obliquity, the conventional sign is applied, the top of which is directed towards the top of the cone (Fig. 35).

1.4.3. DIVISION OF A SEGMENT INTO TWO EQUAL PARTS. This structure can be performed using the triangle and compass. With the triangle through the ends of the **A** and **B** segments (Fig. 36) the straight lines at the direct angles equal to the segment **AB** to their mutual intersection at the point **C** are drawn. Then, from the point **C**, the perpendicular line is put down to **AB**, which will divide the segment into two equal parts.

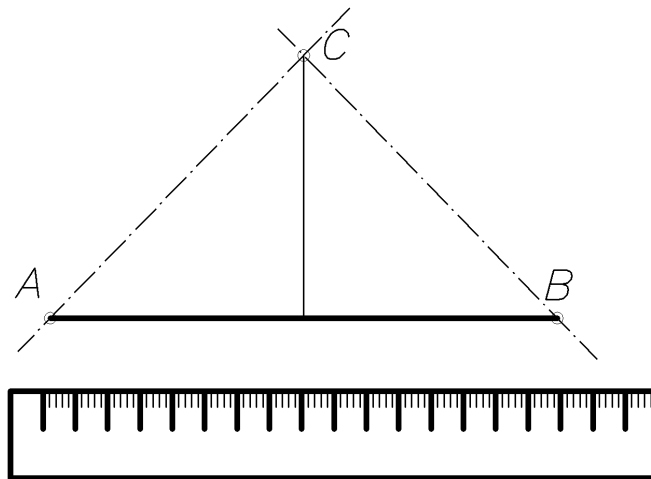
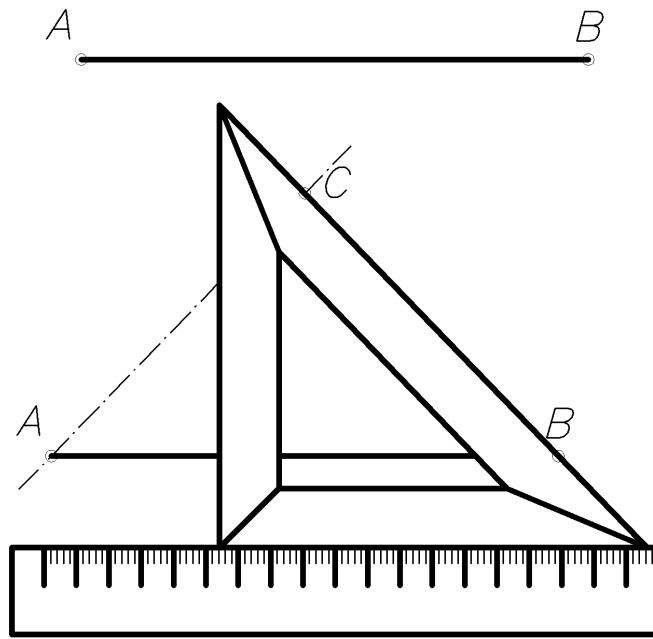


Fig. 36

To divide the segment into two equal parts using compass (Fig. 37), the arcs are drawn to the mutual intersection of points **C** and **D** from the ends of the **A** and **B** segments and from the center of radius **R**, which is larger than half of the segment. Having connected these points, the segment **AB** is divided by the point **E** into two equal parts. This method is also a way of drawing the perpendicular line through the middle of the segment.

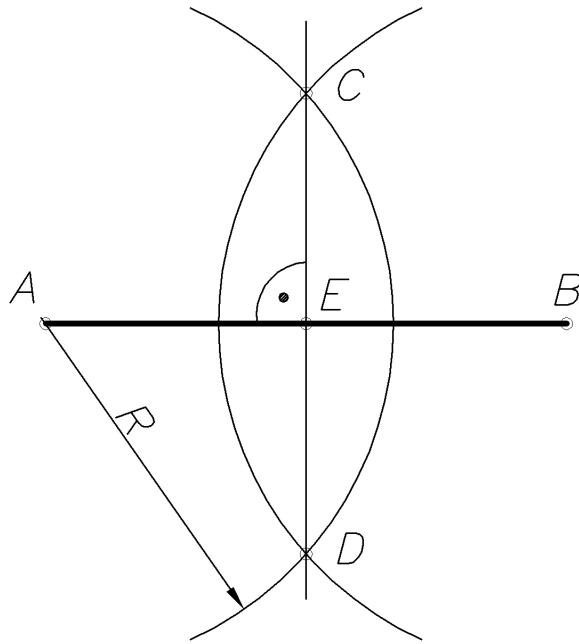


Fig. 37

1.4.4. DIVISION OF A SEGMENT INTO n EQUAL PARTS. To divide the segment **AB**, for example, into five equal parts (Fig. 38), the straight line at an arbitrary angle is drawn from the end **A** of the segment **AB**. Five equal segments are put on this line. The end of the fifth segment (point 5) connects with the point **B**. The straight lines parallel to the line **AB** are drawn through the points 1, 2, 3 and 4, deviding the segment **AB** into five equal parts.

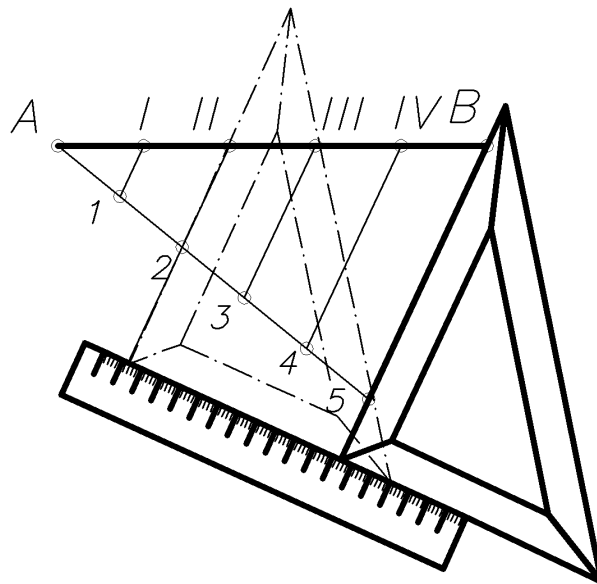


Fig. 38

1.4.5. DIVISION OF AN ANGLE INTO TWO EQUAL PARTS. From the top of the angle α , the arc is drawn by arbitrary radius **R**. The arc intersects with the angle parties in the points **1** and **2** (Fig. 39). From the points **1** and **2** as from the

centers, the circular arc is drawn by arbitrary radius R_1 to the mutual intersection. The line connecting the obtained point with the angle top will divide the angle α in half.

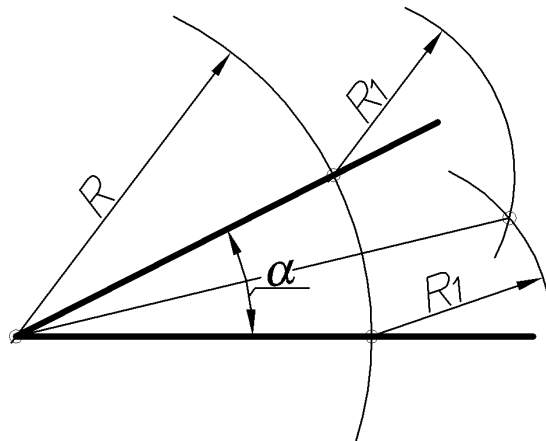


Fig. 39

1.4.6. DIVISION OF THE RIGHT ANGLE INTO THREE EQUAL PARTS. From the top of the right angle (Fig. 40), the arc of random radius R is drawn to the intersection with the angle parties. From the intersection points **1** and **2** as from the centers, the same radius on the previously obtained arc marks the points **3** and **4**. Straight lines connecting these points with the top of right angle, divide it into three equal parts.

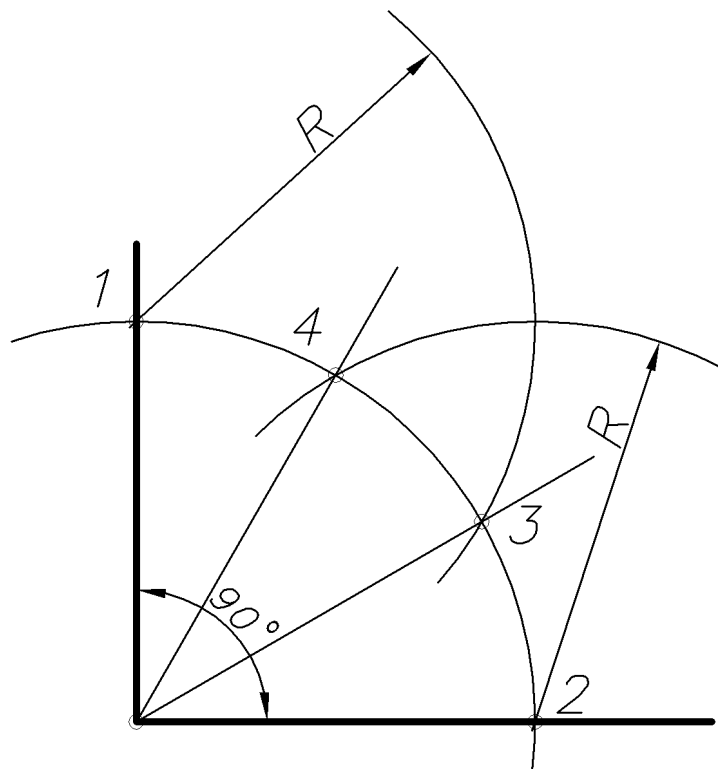


Fig. 40

1.4.7. DRAWING THE PERPENDICULAR LINE TO THE STRAIGHT LINE FROM THE POINT THAT IS OUTSIDE THE STRAIGHT LINE. From the point **C** (Fig. 41) as from the center, the circle arc of arbitrary radius R , which intersects the straight line **a** in the points **1** and **2**, is drawn. From these points as from the centers, the circle arcs of arbitrary radius R_1 are drawn to the mutual intersection at the point **D**. Straight line drawn through the points **C** and **D** is perpendicular to the given line.

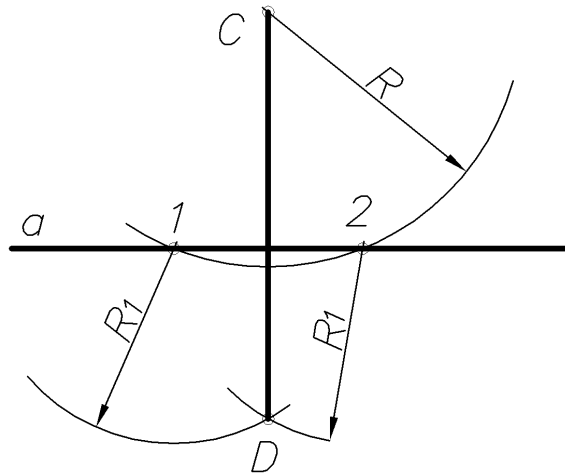


Fig. 41

1.4.8. DRAWING THE PERPENDICULAR LINE TO THE STRAIGHT LINE FROM THE POINT THAT IS ON THE STRAIGHT LINE. From the given point **C** (Fig. 42) as from the centers, the circle arc of arbitrary radius, which intersects the straight line **a** at the points **1** and **2** is drawn. From these points as from the centers, the circle arcs of arbitrary radius R_1 are drawn to the mutual intersection at the point **D**. Straight line drawn through the points **C** and **D** is perpendicular to the given straight line.

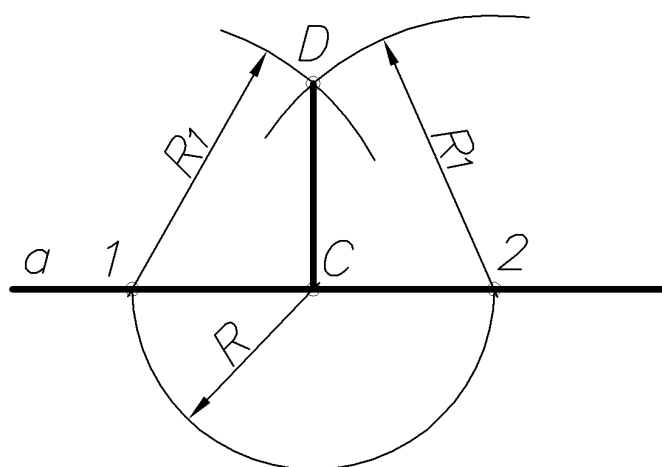


Fig. 42

1.4.9. DRAWING THE PERPENDICULAR LINE FROM THE END OF A SPECIFIED SEGMENT. From the arbitrary point **O** outside the segment (Fig. 43) as from the centers, the circle is drawn with a radius equal to the distance from the point **O** to the point **C**. From the point **D** of intersection of the circle with the segment **DC**, the circle diameter is drawn. The straight line drawn through the points **A** and **C** is perpendicular to the given segment.

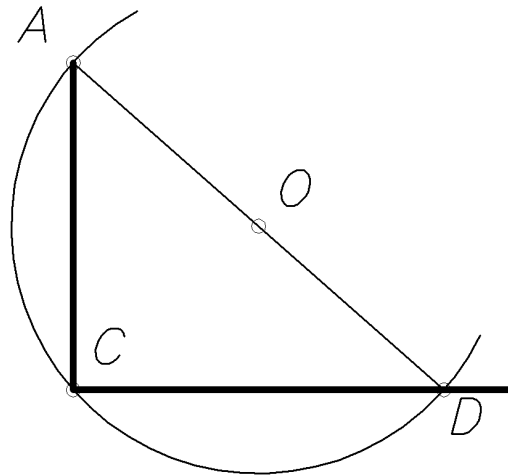


Fig. 43

1.4.10. DIVISION OF A CIRCLE INTO THREE EQUAL PARTS. From the point **C** of the circle (Fig. 44) with radius R , the points **1** and **2** are marked on it. The arc **1-2** is the third part of the circumference. Point **3** is marked on the circle from the point **1** by the radius equal to **1-2** chord. The circle is divided into three equal parts from the points **1**, **2** and **3**. **1-2-3** equilateral triangle is inscribed in a circle.

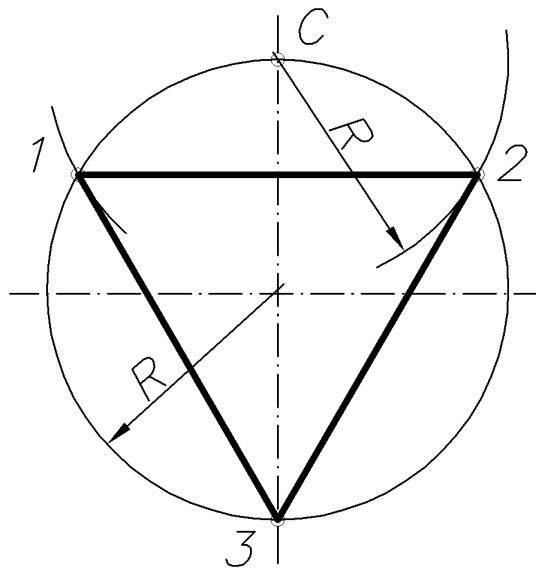


Fig. 44

1.4.11. DIVISION OF A CIRCLE INTO FIVE EQUAL PARTS. From the middle of radius-point **C** (Fig. 45) as from the centers, the point **M** is marked on the diameter of the arc with **CD** radius. The segment **DM** determines the length of the sides of an inscribed pentagon. The executing of pentagon tops is explained in the drawing.

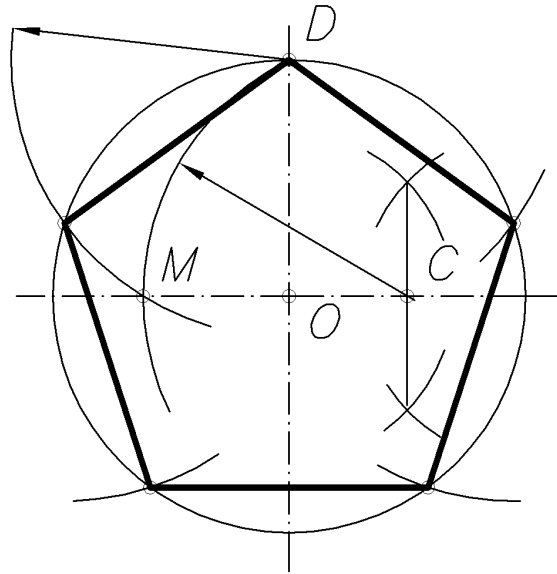


Fig. 45

1.4.12. DIVISION OF A CIRCLE INTO SIX EQUAL PARTS. The side of a regular **hexagon**, which is inscribed in a circle, equals to the radius of the circle. All constructions are shown in Fig. 46.

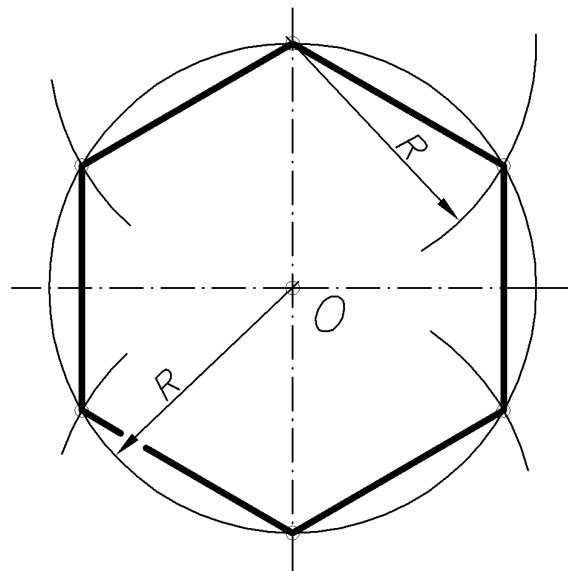


Fig. 46

1.4.13. DIVISION OF A CIRCLE INTO n EQUAL PARTS. Let us divide the circle, for example, into $n=7$ equal parts (Fig. 47). From the point **C** as from the center with the radius **R**, which is equal to the diameter of the circle, the points **A** and

B are marked on the horizontal axis. From the points **A** and **B** the rays are drawn through paired (or unpaired) graduations of the diameter **CD**. The resulting points of intersection with the circle divide it into seven equal parts. To get the regular heptagon, one should connect these points.

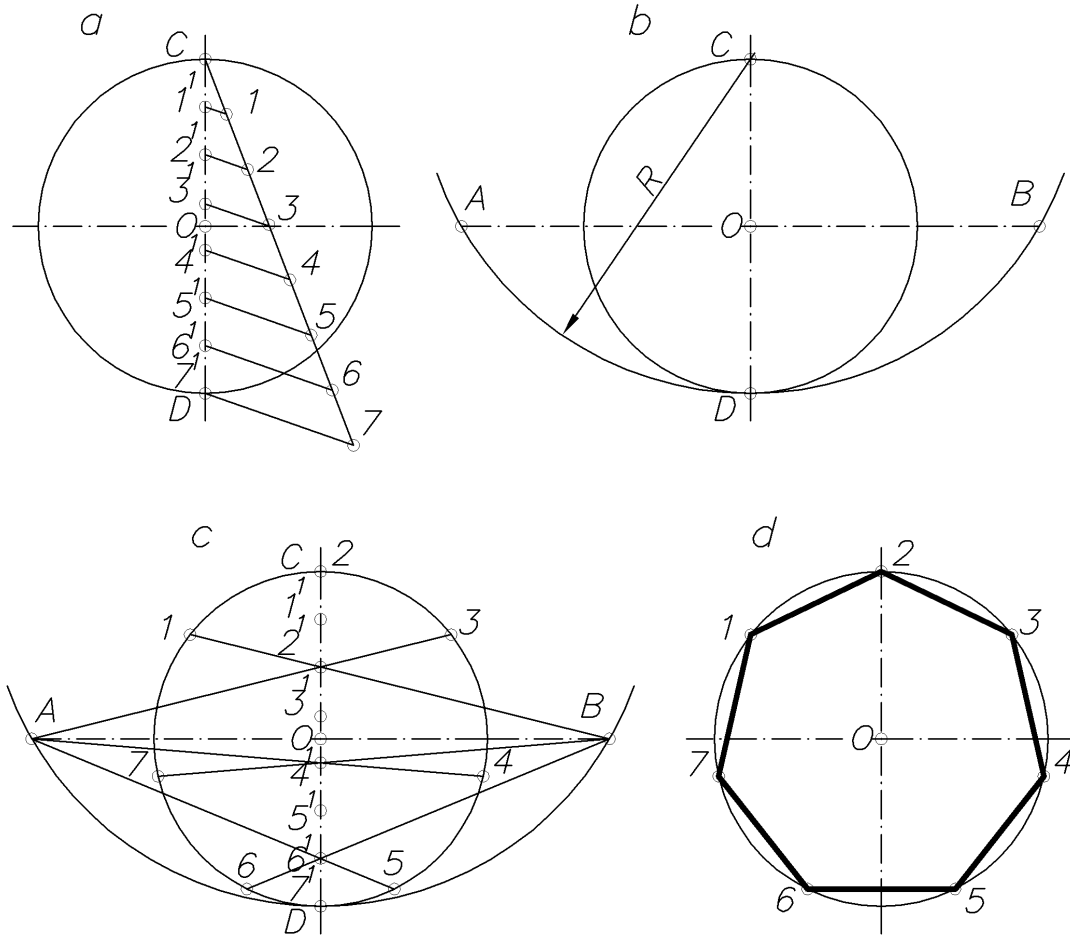


Fig. 47

1.4.14. DRAWING THE REGULAR n -GON USING THE GIVEN

SIDE a. Let the segment **AB** be the side of regular n -gon (Fig. 48). From the ends of the segment **AB**, the circle arcs of radius $R = AB$ are drawn to the mutual crossing at the points **O** and **O₆** (a). The straight line that passes through the points **O** and **O₆** is the set of centers of all n -gons with a given side.

To construct a square for the given side, the perpendicular lines are drawn from the points **A** and **B** to the intersection with arcs of circles (b). The intersection of the diagonal **AC** (or **BD**) with vertical axis determines the center **O₄** square, which is inscribed in the circle of radius **O₄A** (c, d).

To construct the center of a regular pentagon, the segment **O₄O₆** is divided in half (e). The point **O₅** will be the center of the regular pentagon, which is inscribed in a circle of radius **O₅A** (f). Drawing the **O₅O₆** segment on the vertical axis from the point **O₆** to the up, the points **O₇**, **O₈**, **O₉**, ..., **O_n** are marked as the centers of regular seven-, eight-, nine -, ..., n -gons, inscribed in a circle of radius **O₇A** (g), **O₈A**; **O₉A**,

..., O_nA .. The point O_6 is the center of a regular hexagon inscribed in a circle of radius O_6A (h).

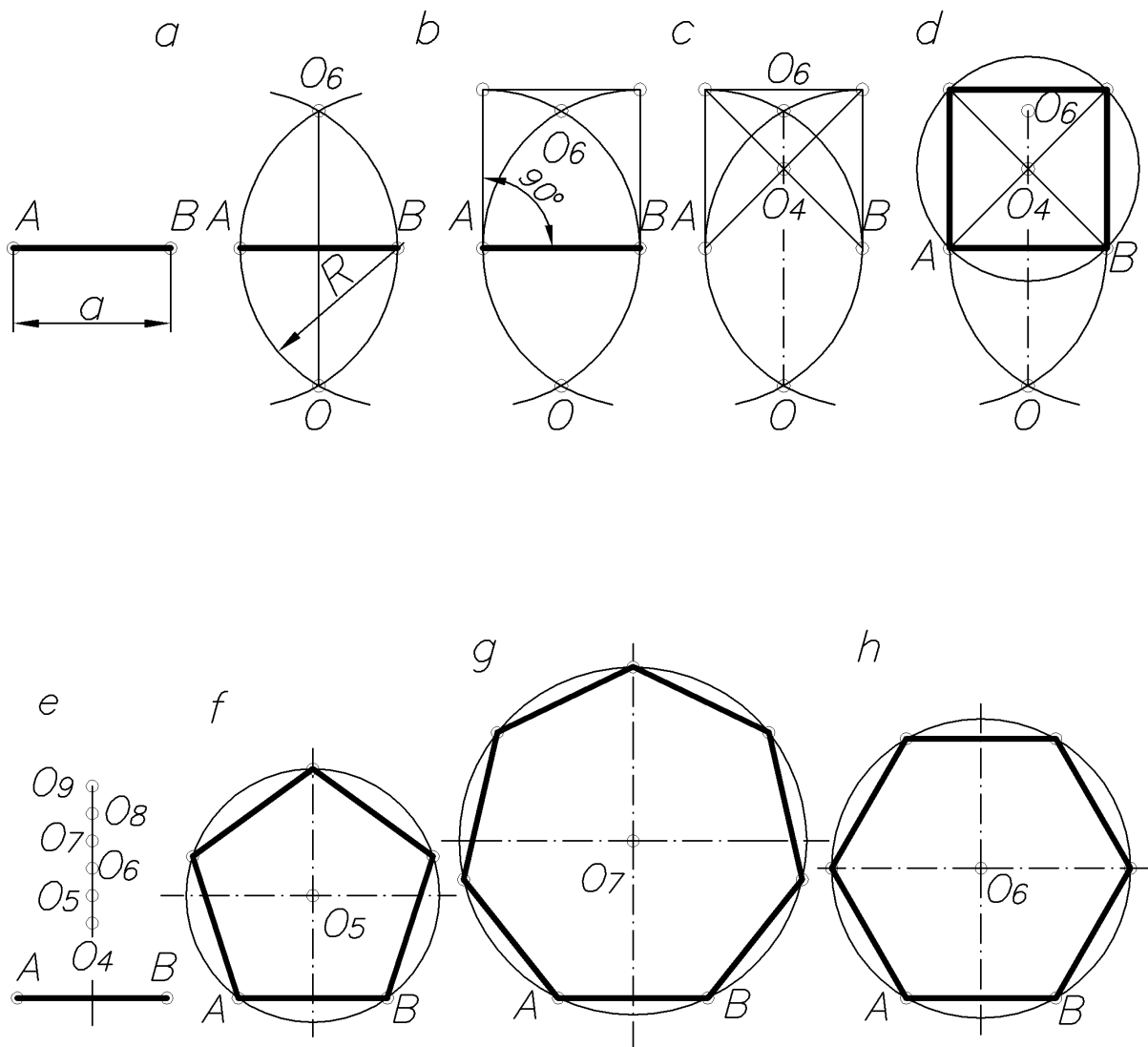


Fig. 48

1.4.15. DETERMINATION OF THE RADIUS AND CENTER OF THE ARC. The perpendicular line (b) is drawn to the mid of arbitrarily drawn chord **AB** (Fig. 49) in the way shown in Fig. 41.

A similar operation is repeated for the chord **BC** (c). Perpendicular intersection defines the arc center **O**. The segment **OC** is the radius of the arc.

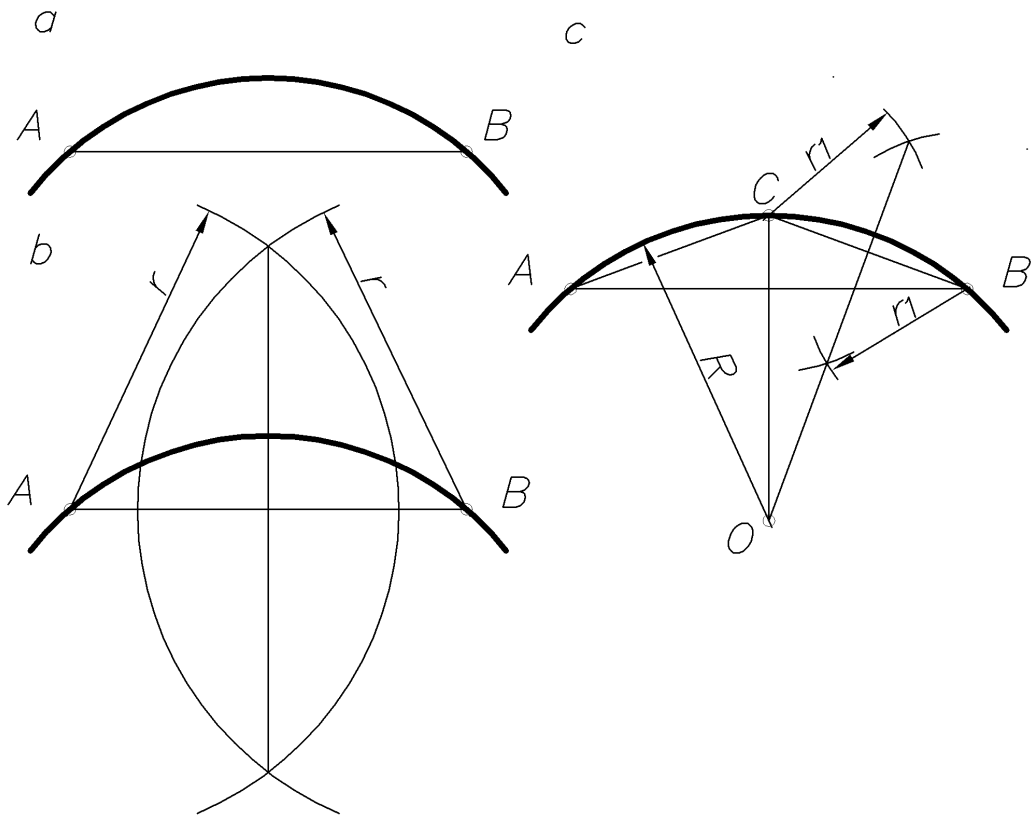


Fig. 49

1.4.16. CONJUGATION. The outlines of many technical forms consist of the lines that smoothly pass into one another. Smooth transition of one line into another is called conjugation. There are some basic types of various lines' conjugations: conjugation of a straight line with a circle arc, conjugation of two differently placed straight lines by means of a circle arc, conjugation of arcs of two circles using a straight line, and conjugation of the arcs of two circles by means of the third one.

Circle arcs that help perform conjugation are called conjugation arcs. To construct the conjugation, it is necessary to find in the drawing its center, radius and conjugation points, in which the conjugation arc transforms into conjugated lines. Taking into account one of these settings the others can be determined graphically.

When conjugating the straight line with the circle arc, the letter serves as a tangent to the circle. In this case, the center of the circle arc **O** and the conjugation points **K** lie on the perpendicular line to the conjugated straight line (Fig. 50). When conjugating the arcs of two circles, the conjugation point **K** must lie on the line connecting the centers of conjugated arcs (Fig. 51).

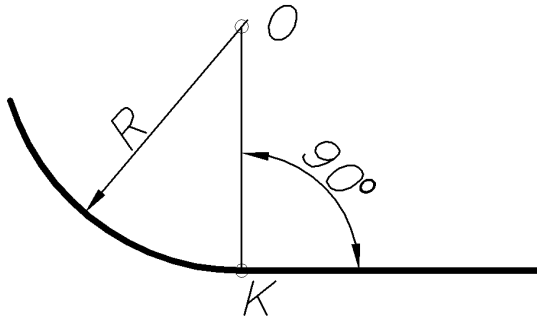


Fig. 50

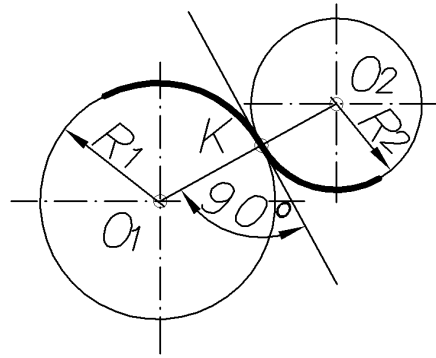


Fig. 51

1.4.16.1. Conjugation of straight lines that intersect one another using the arc. To construct the conjugation of two perpendicular lines **a** and **b** by means of the circle arc with a given radius **R** (Fig. 52), from the point of intersection of the lines as from the centers, one should execute the following tasks:

- draw the circle arc with the radius **R** to the intersection with the straight lines at the points **A** and **B** (a);
 - draw the circle arcs by the same radius to mutual intersection at the point **E** (b) from the obtained points as from the centers;
 - draw the conjugation arc (c) from the point **O** using the radius **R**.
- Points **A** and **B** in this case are the conjugation points.

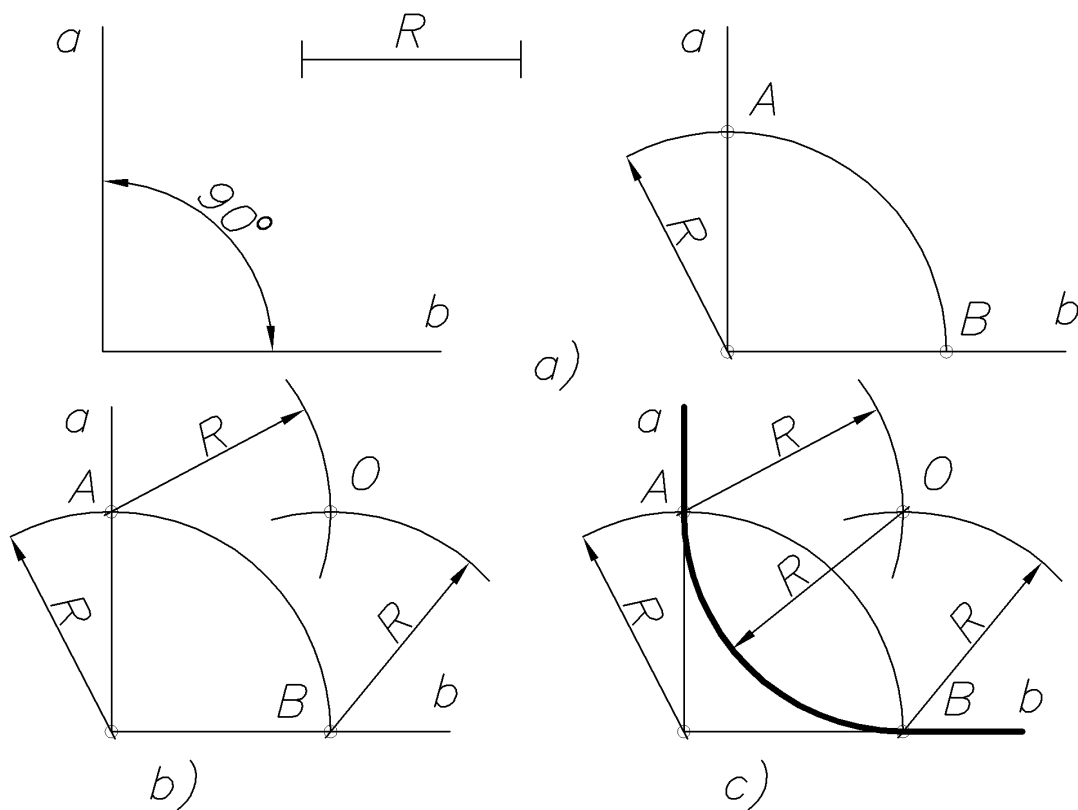


Fig. 52

To construct the conjugation of two lines **a** and **b** that intersect one another at an acute angle by the arc of a given radius **R** (Fig. 53), it is necessary to define the set of circle centres, which occur from the straight lines at the distance **R**. For this purpose at the distance **R** the straight lines that are parallel to the given ones are drawn to the intersection at the point **O** (a). The arc with radius **R** drawn from the point **O** as from the center is considered the conjugated arc (b). Fundamentals of a perpendicular line, dropped from the point **O** on the straight lines **a** and **b**, are considered the conjugation points.

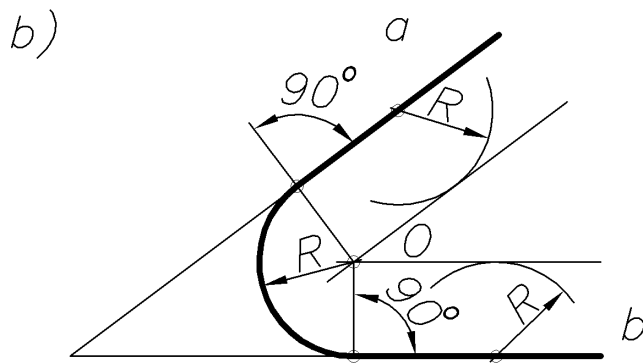
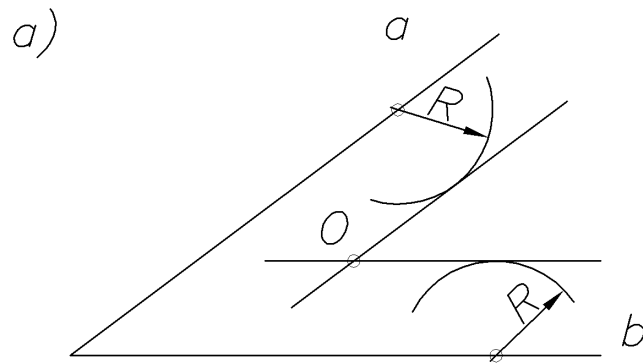


Fig. 53

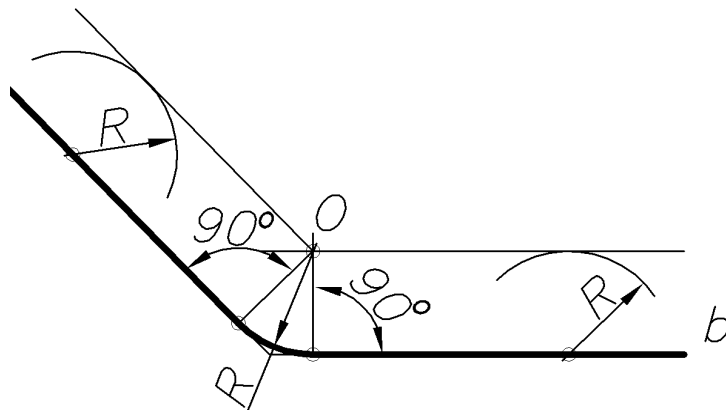


Fig. 54

1.4.16.2. Conjugation of parallel lines by a circle arc. If the conjugation point **A** is given on one of the lines **a** and **b** (Fig. 55), the conjugation is performed as follows: from the point **A** the perpendicular line is drawn directly onto the straight line **b** (a). The segment **AB** is divided in half (b) and from the point **O** as from the center, the conjugation arc of radius **OA** (c) is drawn.

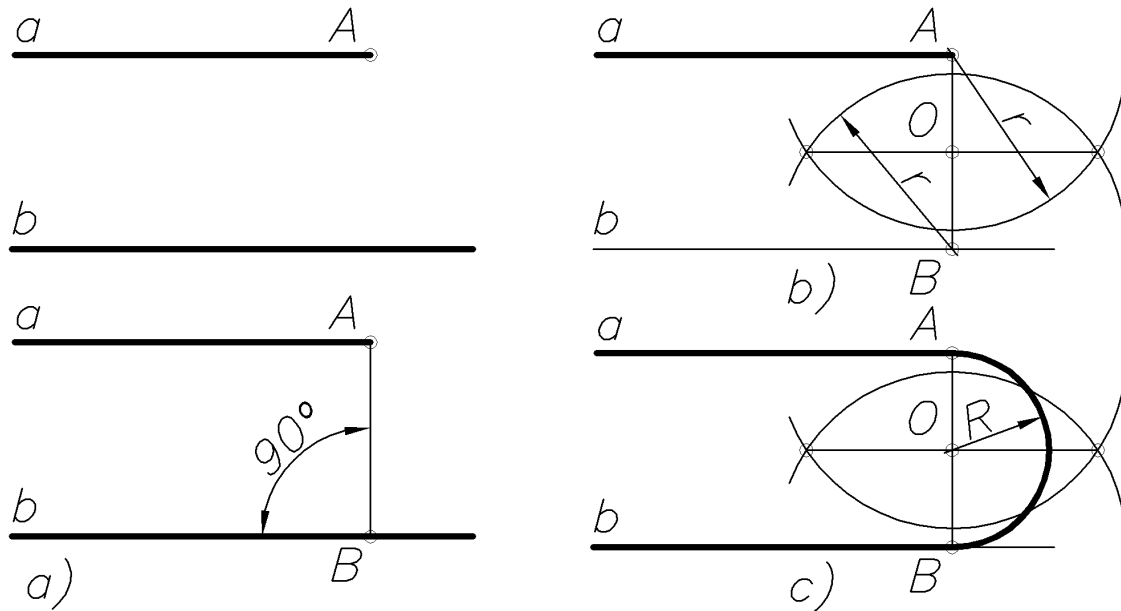


Fig. 55

1.4.16.3. Conjugation of a circle arc of radius R and the straight line a by the arc of a given radius R_1 . For this conjugation (Fig. 56), the plural number of the arc centers of radius R_1 is defined. At the distance R_1 from the straight line **a**, the line **m** parallel to it is drawn. From the center **O** of the radius $(R+R_1)$, the arc of a concentric circle is drawn. The point **O₁** is the center point of the conjugation arc. The conjugation point **C** is obtained on the perpendicular line dropped from the point **O₁** on the straight line **a**; and the point **B** is obtained on the line connecting the points **O** and **O₁**.

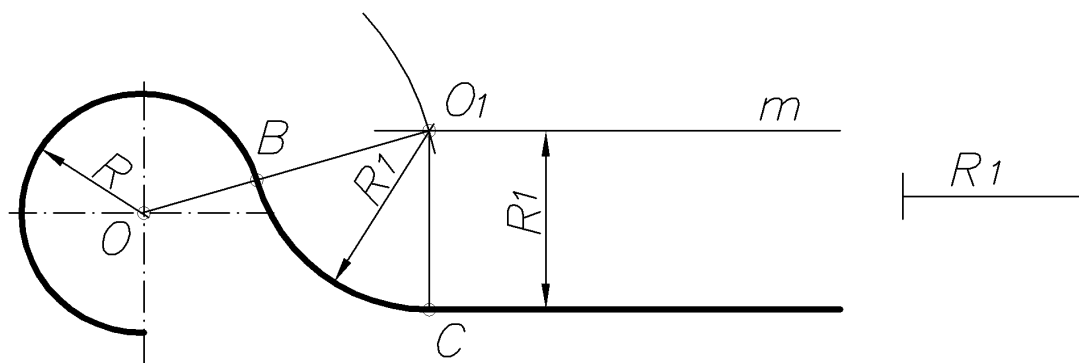


Fig. 56

1.4.16.4. Conjugation of the arcs of two circles using a straight line. This conjugation is just the construction of external or internal tangents to these circles (Fig. 57).

For the external tangent conjugating of two circles of radius R and R_1 (a), it is necessary to connect the centers of circles, then to divide the segment OO_1 by the point O_2 in half, then from the point O to draw a circle of radius $(R-R_1)$, which is the difference of the given circles radii (b). The points E and D (c) are marked on this circle of radius O_2O . The segments OE and OD are lengthened to the intersection with the circle of radius R , the conjugation points C and B are obtained (d). The points E and D are connected with the center O_1 . From the points C and B , in a parallel way to the segments O_1E and O_1D , the segments conjugating two circles are drawn. Conjugation points on a circle of radius R_1 can be obtained by drawing the perpendiculars from the point O_1 to the segments O_1E and O_1D .

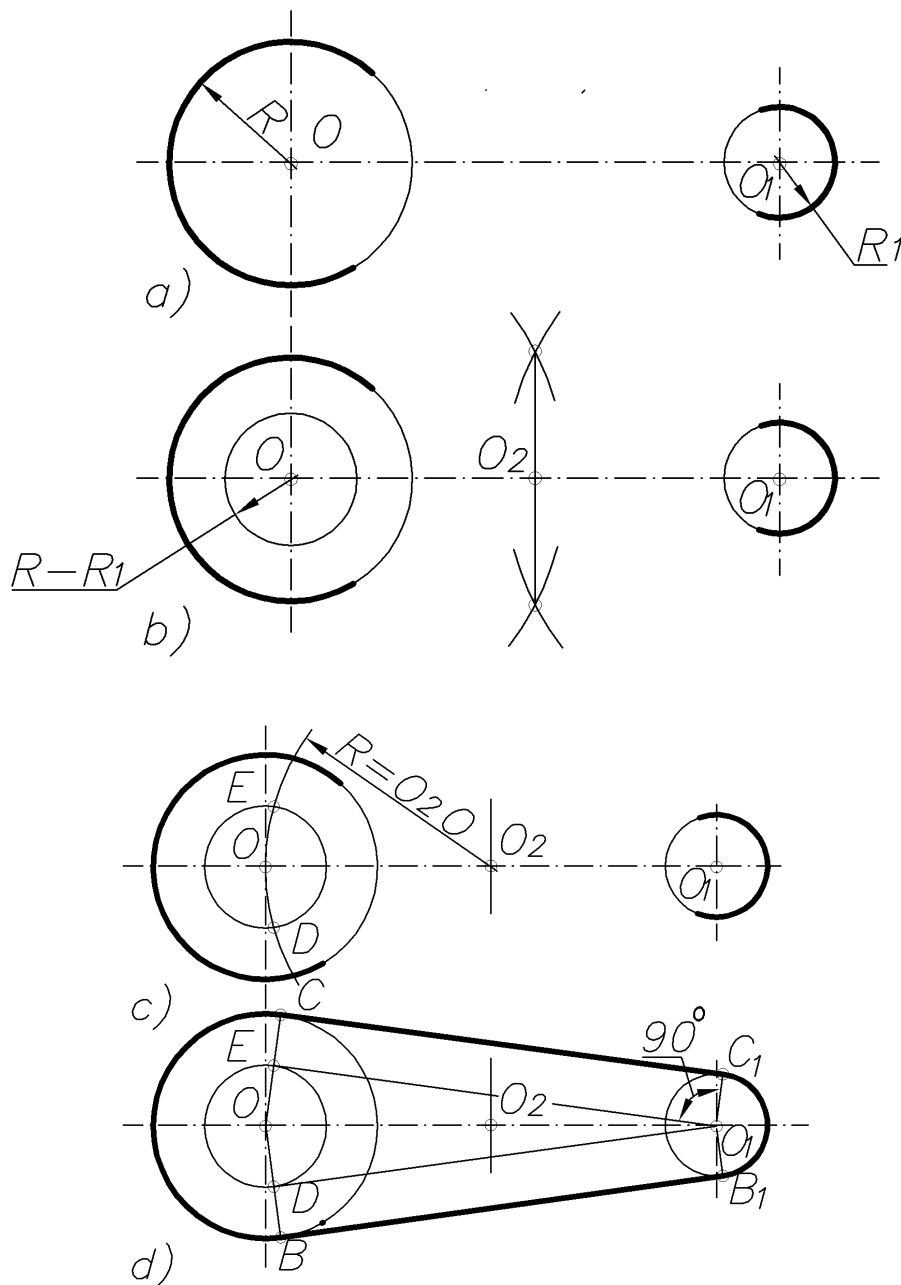


Fig. 57

To build the internal tangents conjugating two circles of radius R and R_1 (Fig. 58), the arc of the radius OO_2 is drawn from the middle of the segment OO_1 of the point O_2 ; and from the center O the arc of radius $(R + R_1)$ is drawn, which is the sum of the radii of the given circles (b). At the intersection of these circles the points E and D are marked, which connect with the point O_1 . The tangents that conjugate two circles are parallel to the EO_1 and DO_1 segments (c). Construction of conjugation points is clear from the drawing.

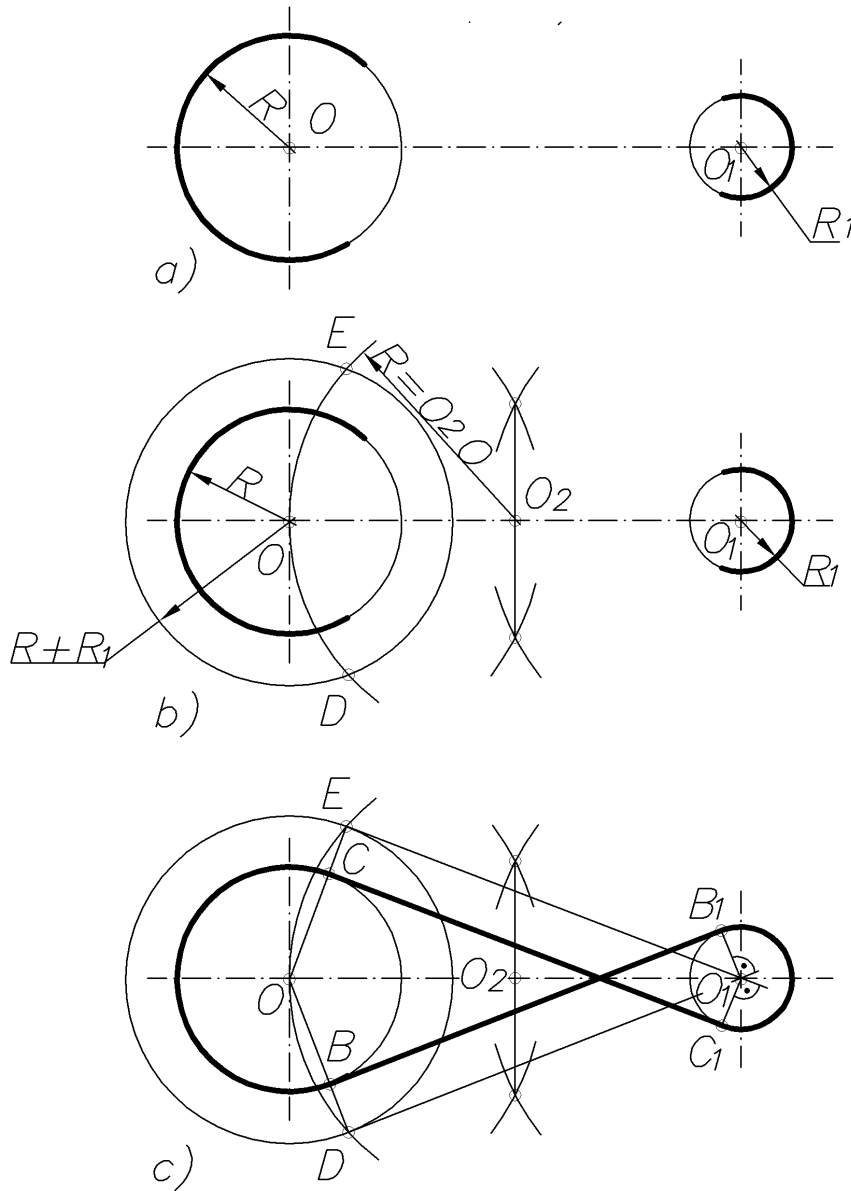


Fig. 58

1.4.16.5. Construction of conjugation of two circle arcs. Conjugation of two arcs of circles may be external and internal.

Fig. 59a shows the external conjugation of two arcs of circles, and in Fig. 59b – the internal one. Conjugation point lies on a line connecting the centers of circles. The distance between the centers in the first case shall be the sum of the radius of

circles $(R+R_1)$, and in the second - the difference of these radii $(R-R_1)$. At the conjugation point **A** the circles have a common tangent **t**.

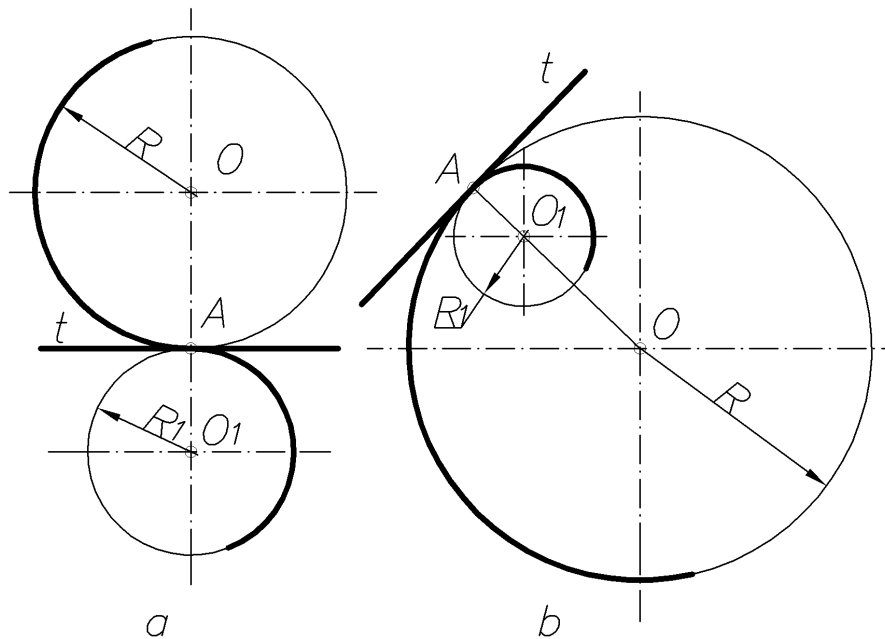


Fig. 59

1.4.16.6. Construction of conjugation of two circle arcs by the arc of a given radius. This type of conjugation can be external, internal and mixed. In the external conjugation the arcs are outside the conjugation arc, ie the conjugation points are the points of inflection.

Fig. 60 shows an example of construction of the external conjugation of two circle arcs of radii R and R_1 using the arc of radius R_2 . From the center O of radius $(R+R_2)$, and from the center O_1 of radius (R_1+R_2) the arcs are drawn to the intersection point O_2 (a). Conjugation points **B** and **C** lie on the lines connecting the point O_2 with arc centers O and O_1 . From the point O_2 as from the center the conjugation arc of radius R_2 (b) is drawn.

Internal conjugation of circle arcs using the third one is characterized by the fact that the conjugated arcs lie in the middle of the conjugation arc, ie the conjugation arc and the conjugated arcs lie on the same side of tangents drawn through the conjugation points. The conjugation points in this case are the self-contact points. Fig. 61 shows the internal conjugation. The conjugated arcs of radii R and R_1 and the radius of conjugated arc R_2 are specified. From the center O , the arc of radius (R_2-R) is drawn, and from the center O_1 - the arc of radius that equals the radius (R_2-R_1) . At the intersection point of these arcs, the point O_2 with the centers of the given circles O and O_1 is obtained.

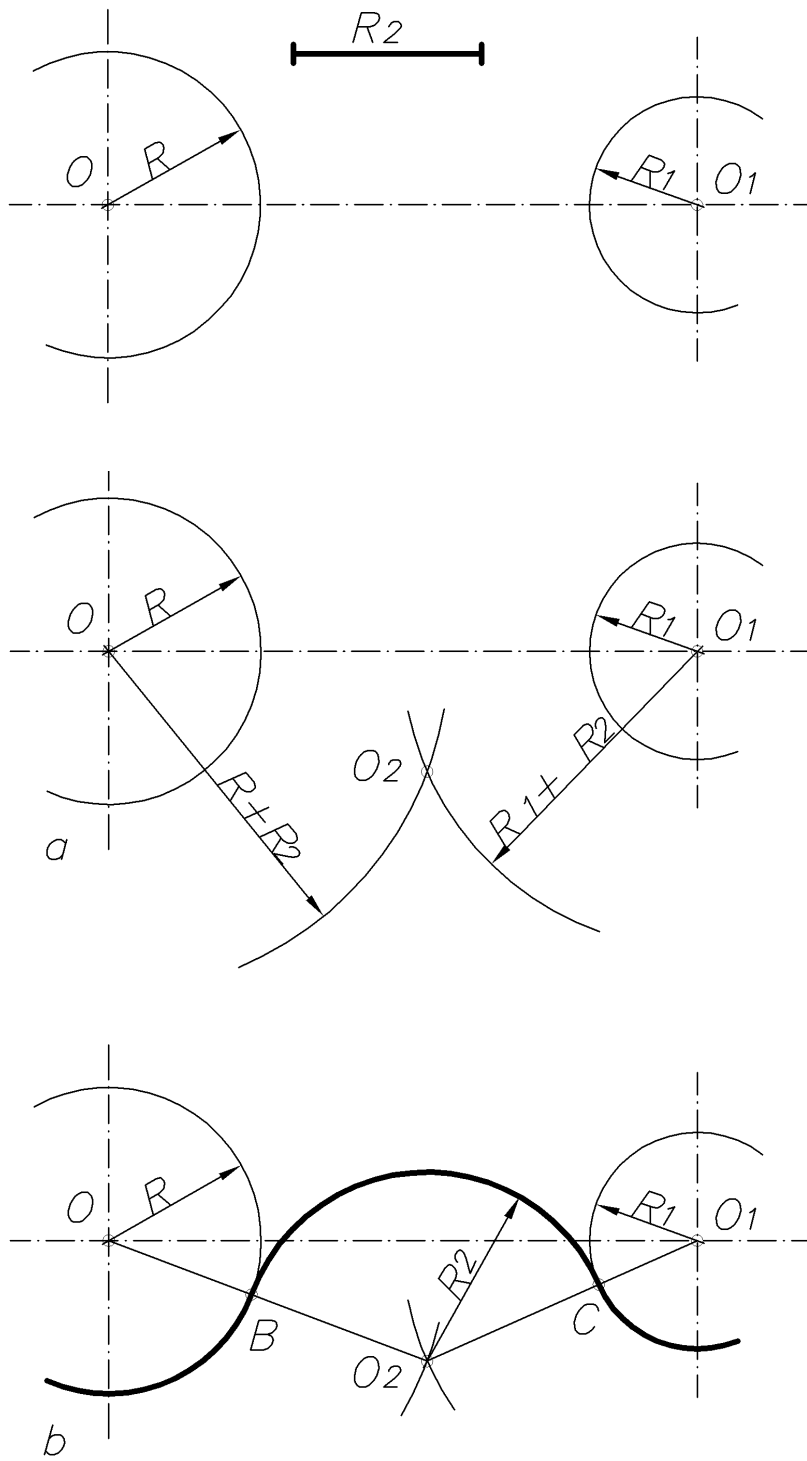


Fig. 60

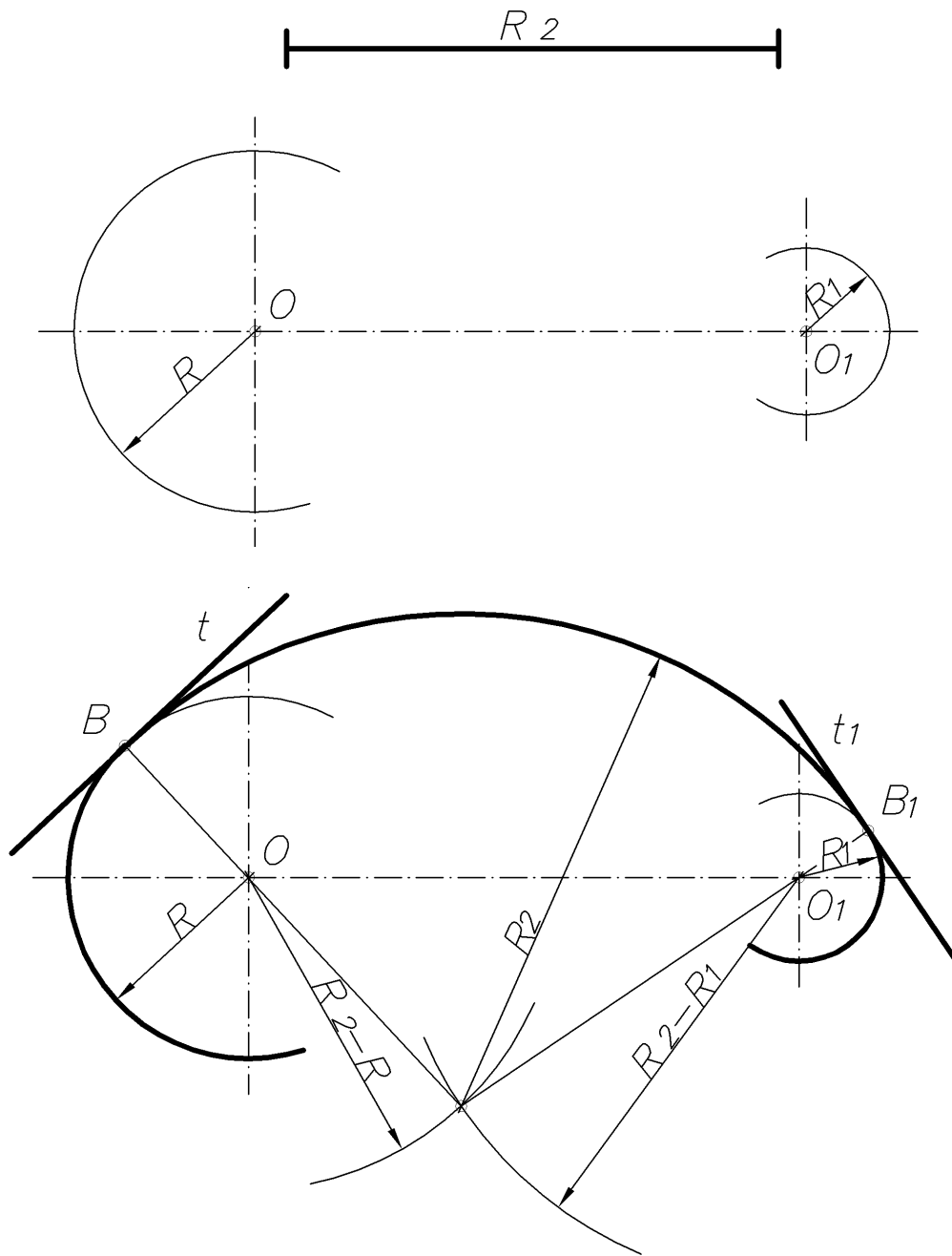


Fig. 61

Mixed conjugation of two given arcs of circles by the third arc is characterized by the fact that one conjugated arc is in the middle of conjugation arc, and another – outside it, that is one point of conjugation is a point of self-contact, and another – a point of inflection.

Fig. 62 shows an example of mixed conjugation of two arcs of circles by the third arc of radius R_2 . From the center O (a) the arc of radius $(R_2 - R)$ is drawn, and from the center O_1 – of radius $(R_2 + R_1)$. The intersection of the drawn arcs defines the center of conjugation arc. The conjugation arc with the arc of radius R has an internal conjugation, and the arc of radius R_1 - external. The point B is a point of self-contact, and point B_1 - a point of inflection.

The mixed conjugation of the same arcs are shown in Fig. 62b. Now the conjugation arc with the arc of radius R conjugates externally, and with the arc of radius R_1 - internally. The point B is the inflection point, and the point B_1 - the self-contact point.

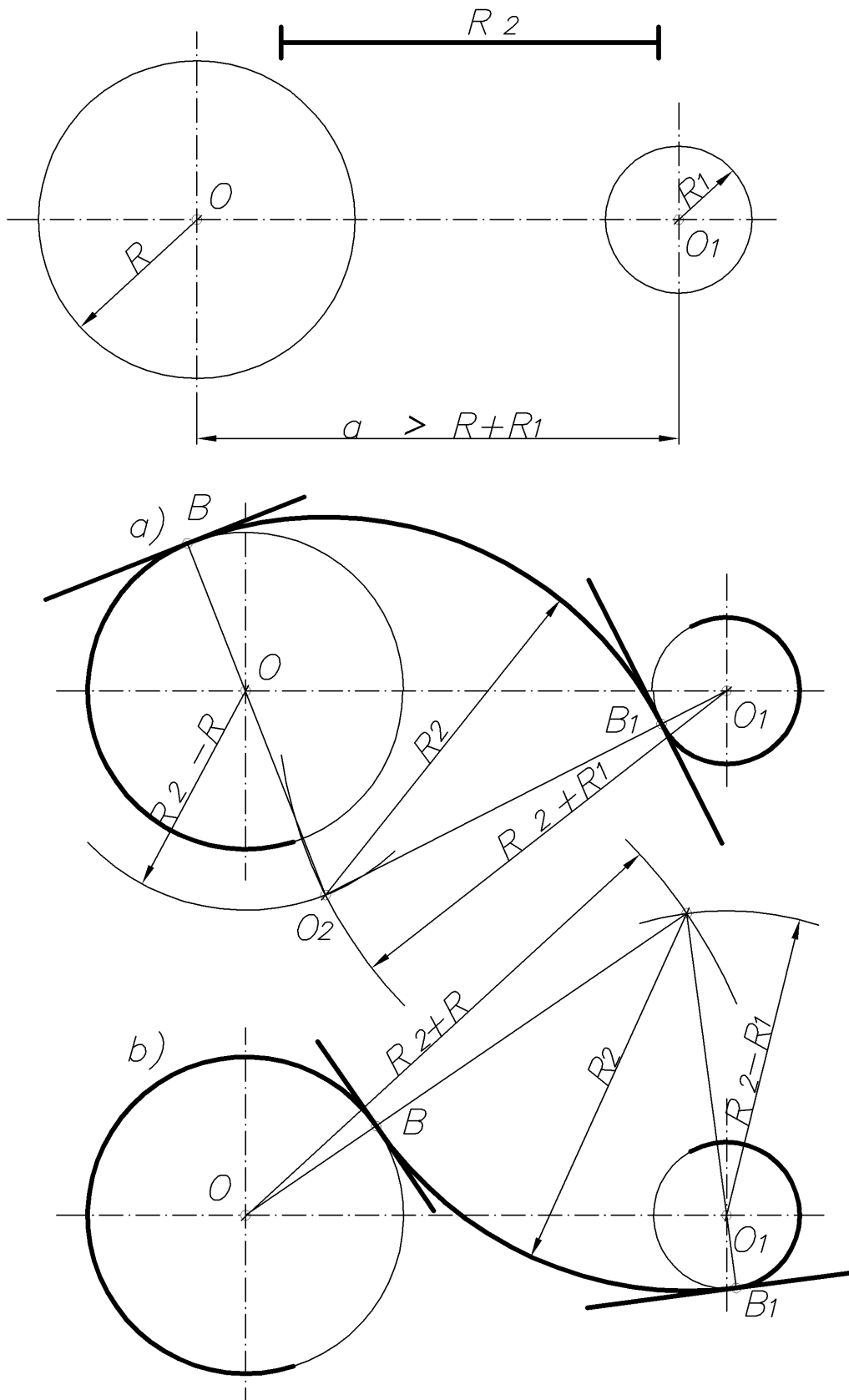


Fig. 62

Fig. 63 shows the mixed conjugation of two circle arcs by the third arc of the given radius R_2 , the distance a between the centers of arcs is smaller than the amounts of their radius ($R+R_1$). The construction is shown in the drawing.

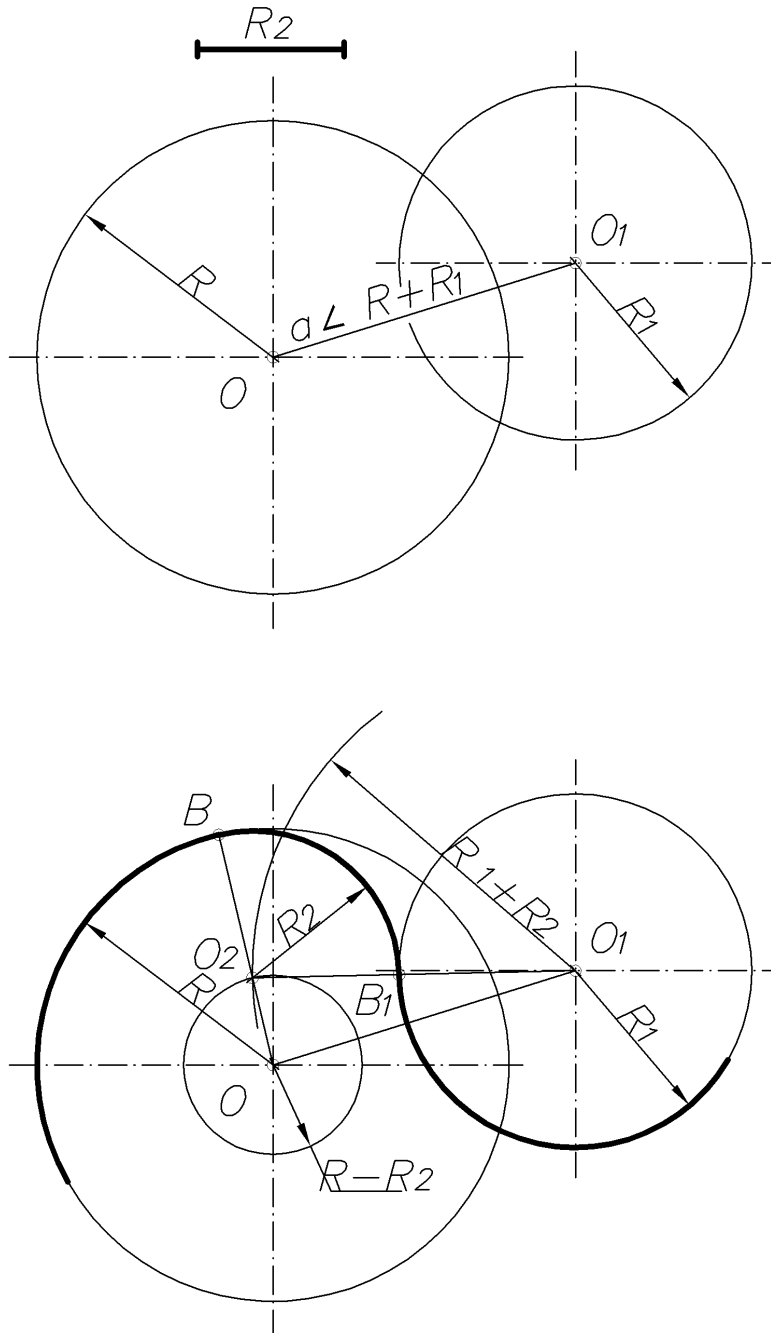


Fig. 63

1.4.17. CONSTRUCTION OF OVALS. Ovals relate to compound curves. They are widely used in technology when designing the outlines of engineering parts as well as in construction - in the design of arches, door and window openings, etc.

Oval is a figure consisting of two reference circles, internally conjugated by the arcs.

1.4.17.1. Construction of an oval with adjacent reference circles (the problem has multiple solutions) (Fig. 64). From the centers of reference circles O and

O_1 of the radius that equals to, for example, the distance between their centers, the circle arcs are drawn to the intersection at the points O_2 and O_3 .

If the straight lines through the centers O and O_1 are drawn, in the intersection of reference circles, the conjugation points C, C_1, D and D_1 can be obtained. From the points O_2 and O_3 as from the center of radius R_2 , the conjugation arc is drawn.

1.4.17.2. Construction of an oval with reference circles that intersect one another. (the problem has multiple solutions as well) (Fig. 65). From the intersection points of reference circles C_2 and O_3 , the straight lines are drawn, for example, through the centers O and O_1 to the intersection with reference circles at the conjugation points C, C_1, D and D_1 , and the radius R_2 , which equals to the diameter of the reference circle and conjugation arc.

1.4.17.3. Construction of an oval using two given axes AB i CD (Fig. 66).

One of the options of setting the solutions are proposed below. The OE segment, which equals the half of the greater axis AB , is laid on the vertical axis. From the point C as from the center, the arc of radius CE is drawn to the intersection with the segment AC at the point E_1 . To the middle of segment AE_1 , the perpendicular line is drawn; and the points of its intersection with the axes of the oval O_1 and O_2 are marked. The points O_3 and O_4 that are symmetrical to the points O_1 and O_2 axes relatively to axes CD and AB are laid. Points O_1 and O_3 are the centers of reference circles of radius R_1 , which equals the O_1A segments; and the points O_2 and O_4 are the centers of conjugation arcs of radius R_2 , which equals the segment O_2C . The straight lines connecting the centers O_1 and O_3 with O_2 and O_4 in the intersection point with the oval determine the conjugation points.

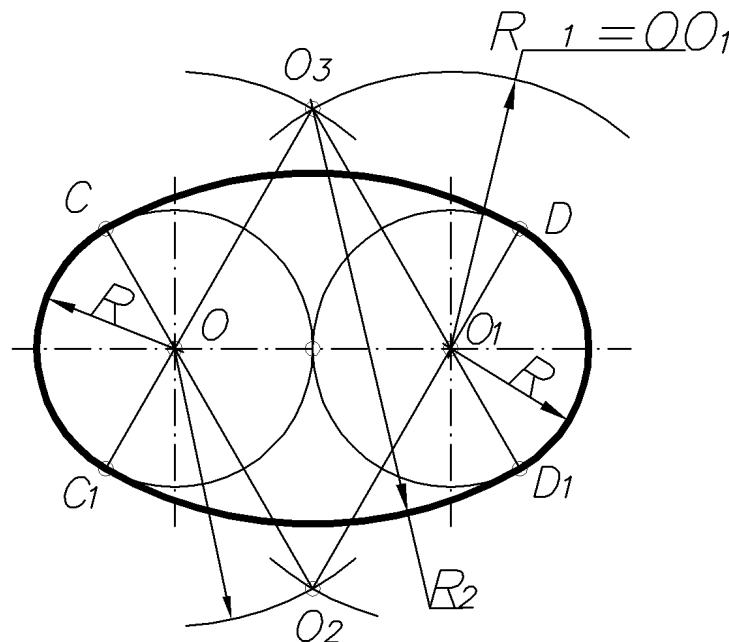


Fig. 64

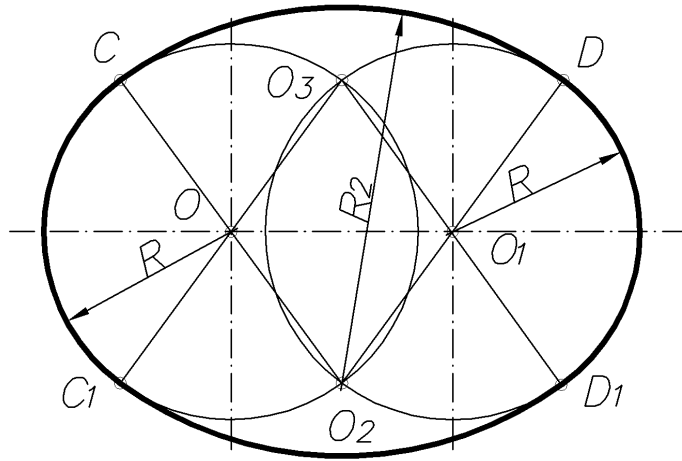


Fig. 65

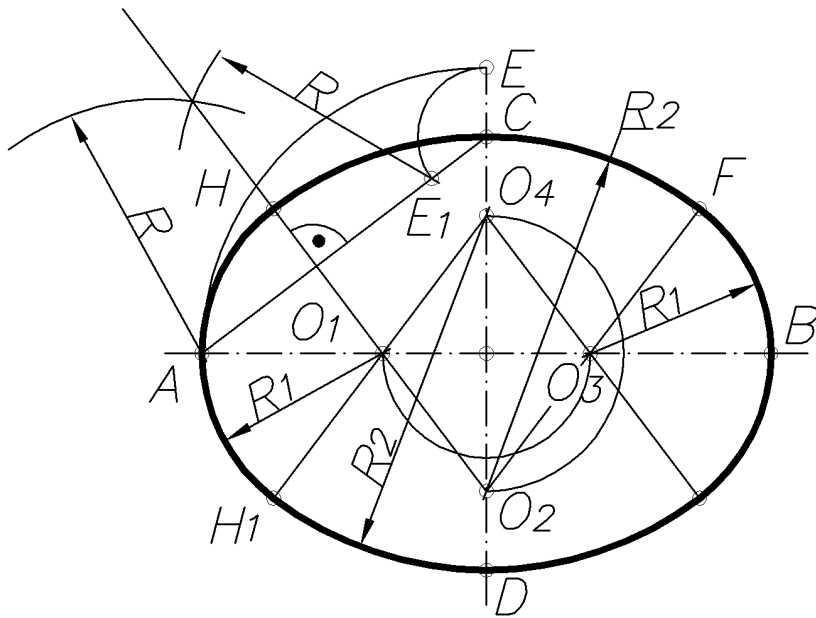


Fig. 66

1.4.17.4. Construction of an oval with reference circles of different diameters, which intersect one another. Fig. 67 shows the construction of an oval, using the given reference oval of larger radius R . From the points A and B as from the centers, the conjugation arcs of radius R_1 , which equals to a given reference circle diameter, are drawn to its intersection with straight lines that connect the points A and B with the end of vertical diameter – the point O_1 . The segment O_1E is a radius of the second reference circle. From the point O_1 as from the center of the radius $R_2=O_1E$ the arc of the second reference circle is drawn. Points A , B , E and E_1 are the points of conjugation.

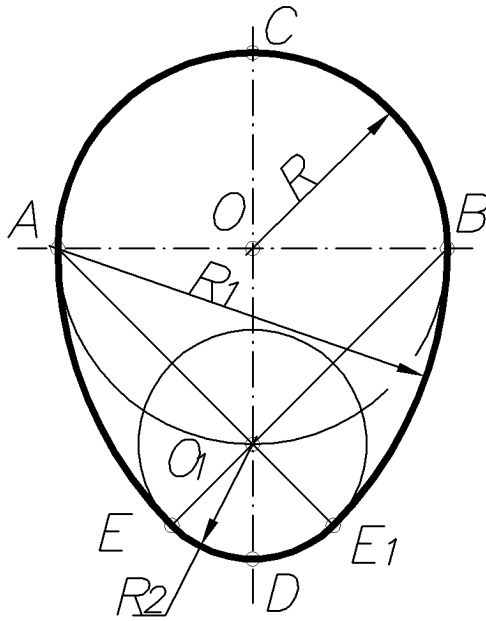


Fig. 67

1.4.17.5. Construction of an elongated oval with supporting wheels of different diameters, which do not intersect one another (Fig. 68). From the point **O** of radius **R₃**, which is greater than the radius of the reference circle **R**, the arc of a circle is drawn and the points **O₁**, **O₂** and **O³** are marked. The next constructions are similar to the previous ones.

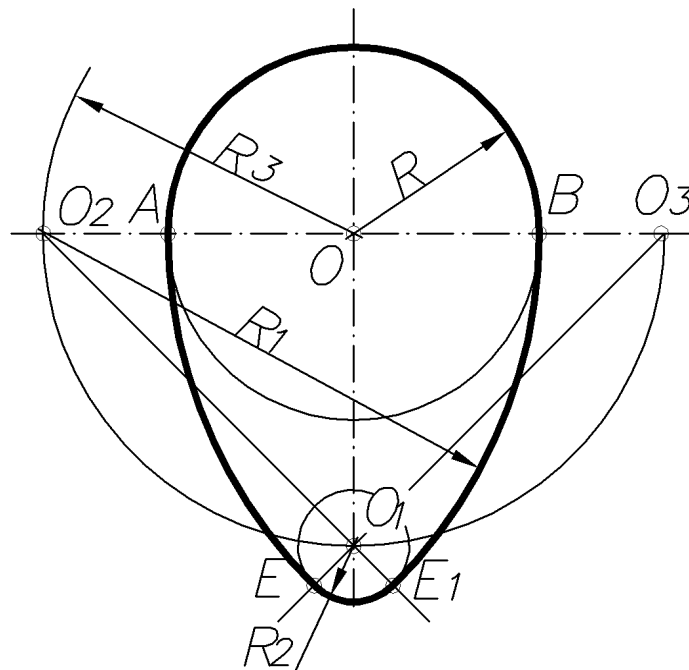


Fig. 68

1.4.17.6. Construction of an oval of the reduced form with reference circles of various diameters (Fig. 69). From the point **O** of radius **R₃**, the arc of a circle is drawn and the point **O₁** is marked. The explanation is presented in the drawing.

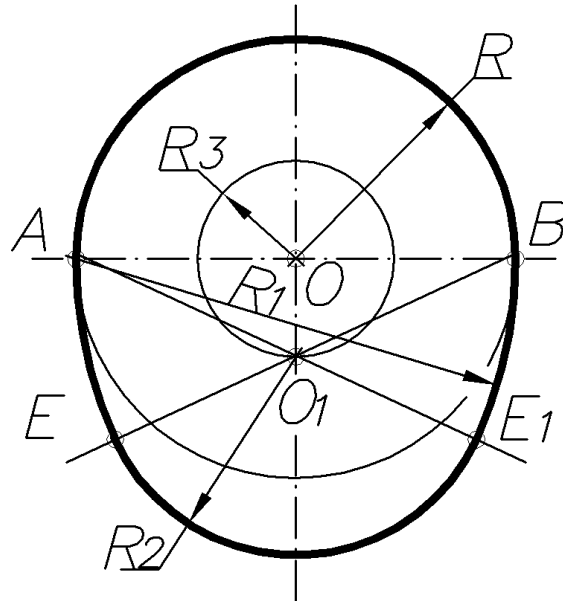


Fig. 69

1.4.18. CONSTRUCTION OF AN ELLIPSE, PARABOLA, AND HYPERBOLE. Ellipse, parabola and hyperbole belong to the curves of the second order, ie the curves, which are described by equations of the second degree in the Cartesian coordinate system. The feature of a curve of the second order is the fact that the straight line crosses it at two points. Second-order curves can be obtained when the plane crosses the right cone of rotation. Therefore, they are often called the conic sections. If the plane does not pass through the top and crosses all generatings of the cone, the ellipse is obtained in section, in a separate case – the circle. If the cutting plane is parallel to one of the generatings of the cone, it crosses the cone along its parabola. In parallelity to both generatings in section, the hyperbole is obtained.

Ellipse is called the set of points in the plane, the sum of the distances from each of two given points **F** and **F₁** (foci) of this plane is constant, greater than the distance between the foci, and equals to **2a** (Fig. 70), ie **FE+E₁=2a**. **2c** distance between foci **F** and **F₁** is called the focal ellipse. The point of intersection of the ellipse axes is called its center, the points of intersection of the axes with the ellipse - its vertices. The segments that connect opposite vertices of an ellipse and equal respectively **2a** and **2c**, are called its large and small axes. The segments that connect foci of the ellipse with the points of the curve are called the radius vectors. Ellipse equation is as follows:

$$x^2/a^2+y^2/b^2=1,$$

where **b²= a²-c²**.

The tangent **t** to an ellipse has the same angles **α** with radius vectors of the contact point **E**, and the normal **n** divides the angle between the radius vectors in half.

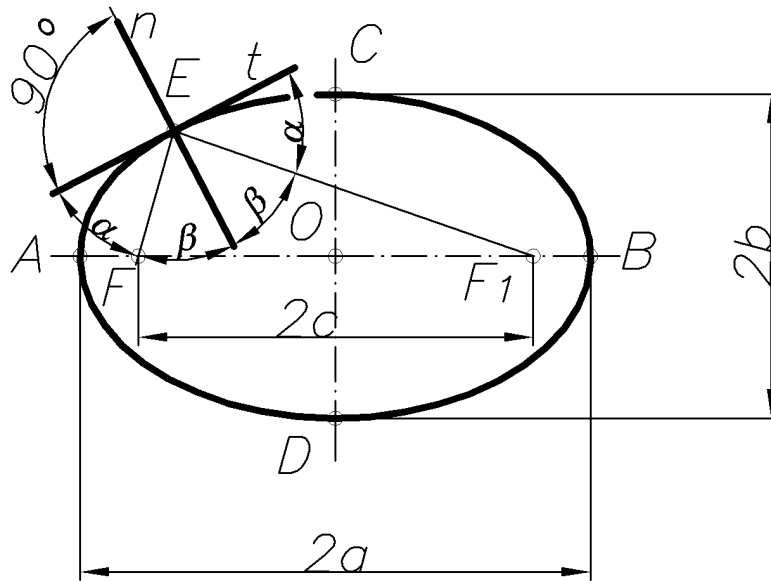


Fig. 70

Parabola is a set of plane points that are equidistant from a given point (the focus) and the straight line (headmistress), and lie in the same plane. Fig. 71 shows the arbitrary point C of the parabola, which is remote from the focus F at a distance FC that equals the distance CD to the headmistress l . Since the vertex of the parabola O is also equidistant from the focus and the headmistress, so the $FO=OA=p/2$, where p is the distance from the focus to the headmistress. The simplest equation of the parabola in rectangular Cartesian coordinates $y^2=2px$, and its headmistress - $x=-p/2$.

The tangent t to a parabola, for example, at the point C is a bisector of the angle between the radius vector and FC and the segment CD or, that is the same, perpendicular to the tangent t .

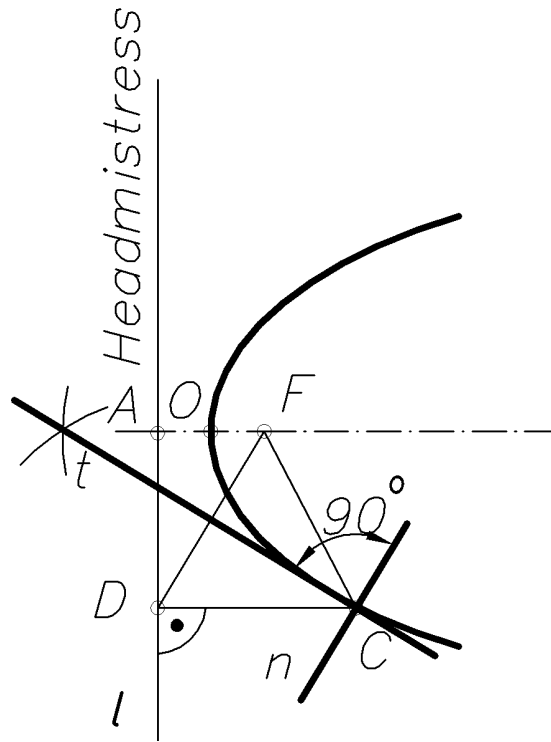


Fig. 71

Hyperbole is a set of points in the plane, the difference of distances to two given points (foci) of this plane is constant and equals to the $2a$ (Fig. 72).

The distance between the tops of legs of the hyperbole A and A_1 is also equal to $2a$. If any arbitrary point E is taken on the hyperbole, so the $F_1E - FE = 2a$. Hyperbole has two axes (x - real, y - imaginary) and two asymptomies m – the straight lines that intersect with hyperbole legs in improper points. The distance between foci FF_1 is called the focal length. It is equal to $2c$. Hyperbole equation:

$$x^2/a^2 - y^2/b^2 = 1,$$

if $b = \sqrt{c^2 - a^2}$.

The tangent t and normal n of the hyperbole at the point E is a bisector relatively to the internal and external angles between the radius vector FE and F_1E .

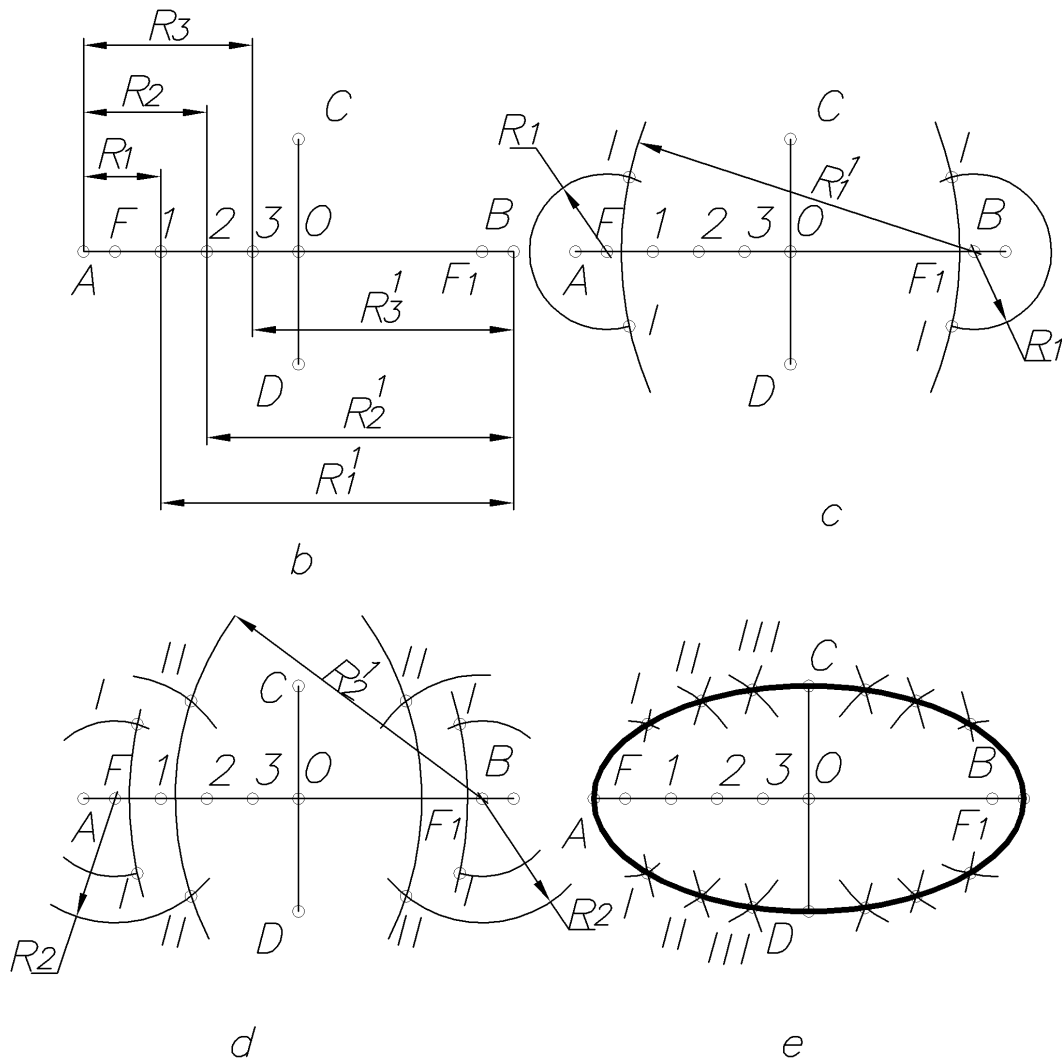


Fig. 73

Method 2: To solve this problem, the properties of the ellipse are used as projections of the circle. From the center of the ellipse, two circles are drawn. Their diameters equal the minor and major axes of the ellipse (Fig. 74a). From the center of the ellipse the beam of rays are drawn to the intersection with the circles at points **1**, **2**, **3**, **4**, ... and **1'**, **2'**, **3'**, **4'**, From the points **1**, **2**, **3**, **4**, ... the straight lines parallel to the minor axis of the ellipse (b) are drawn, and from the points with **1'**, **2'**, **3'**, **4'**, ... - parallel to the major axis (a) (Fig. 74b). Intersection of the correspondent pairs of rays defines a number of points (Fig. 74c). Having connected these points by smooth curve, the ellipse can be obtained (Fig. 74d).

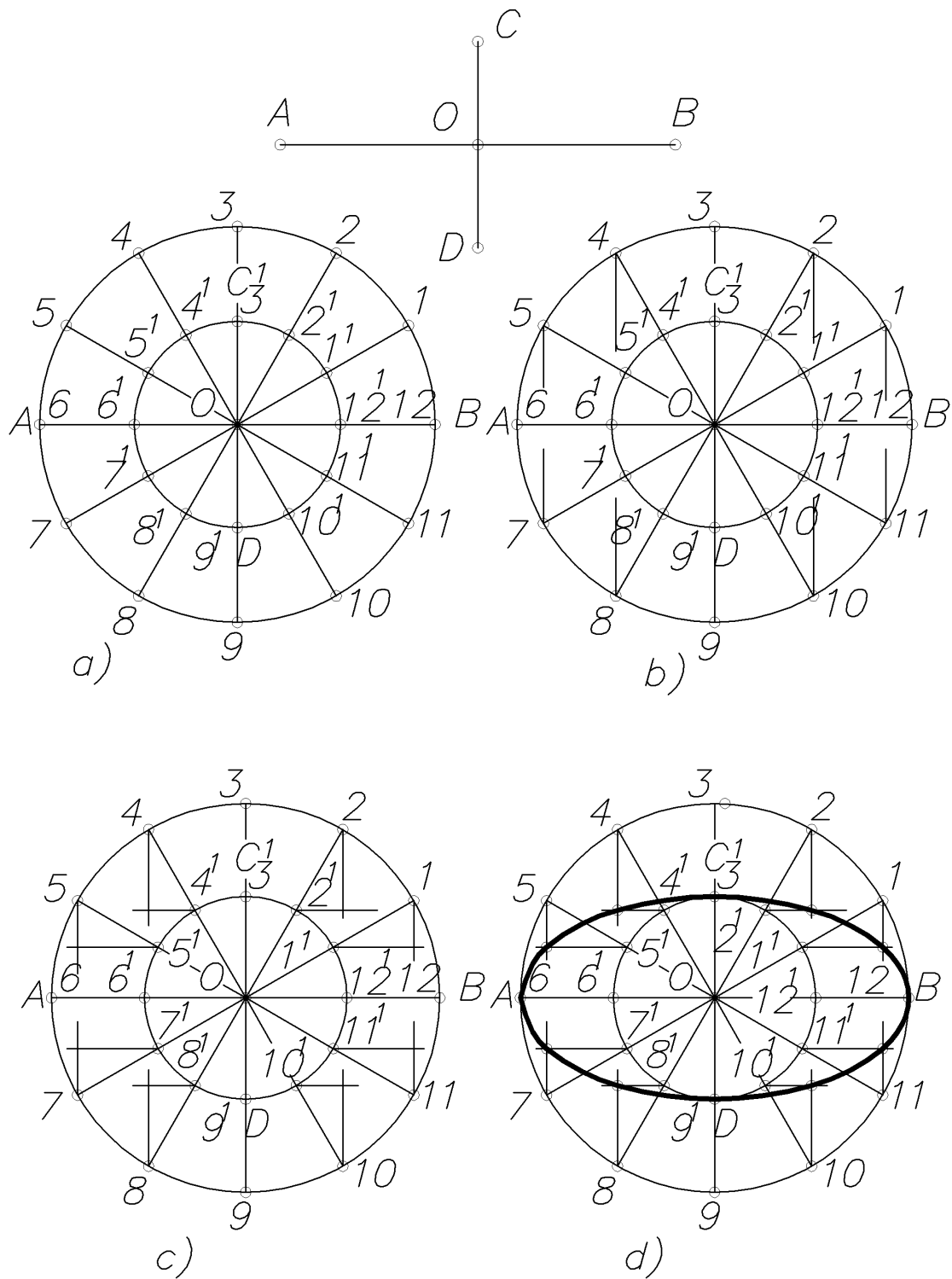


Fig. 74

1.4.18.2. Construction of an ellipse using the conjugated diameters. Two diameters, each of which bisects in half the ellipse chords, which are parallel to another diameter, are called conjugated diameters of the ellipse. They can be considered the projections of mutually perpendicular diameters of the circle.

Method 1 (Fig. 75). The circle diameters A^1B^1 and S^1D^1 relate the conjugated diameters of the ellipse AB and CD . The point C^1 should be connected to the point C . From random circle points **1** and **2**, the straight lines parallel to this segment are

drawn, and from the bases of perpendicular lines from the points on the diameter A^1B^1 - straight lines parallel to the OC . At the intersection, the points are obtained that belong to the ellipse.

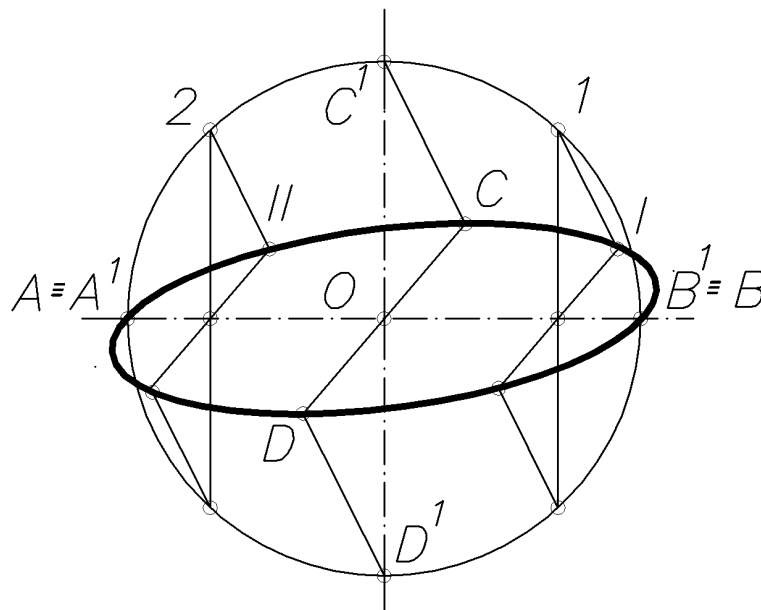


Fig. 75

Method 2 (Fig. 76). Through the ends of conjugate diameters the straight lines parallel to them are drawn. Therefore, the parallelogram $KLMN$ is obtained. Conjugated diameter DC and the side of the parallelogram KL are divided into an arbitrary, but the same number equal parts. From points A and B the rays are drawn correspondently through the points of division of conjugated diameter, and the points of division of parallelogram sides. The intersection of rays determines the points of the ellipse. Construction of the bottom part of the ellipse is similar.

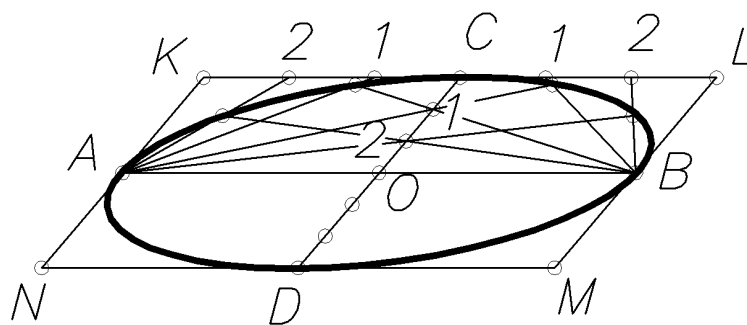


Fig. 76

1.4.18.3. Construction of a parabola using the given focus and headmistress.

Through the focus F of the parabola (Fig. 77a) its axis is drawn perpendicular to the headmistress. Having divided the segment FA in half, the peak of the parabola O is determined. On the axis from the point O towards the focus, the number of arbitrary points with the increasing distance between them are put. Through these points, the straight lines parallel to the headmistress are drawn (Fig. 77 b). From the focus as

from the center, the circle arcs of radii, which are equal to the distance between the correspondent vertical straight lines and headmistress, are drawn. At the intersection of circle arcs with relevant vertical straight lines, the points that belong to parabola are obtained (Fig. 77 c).

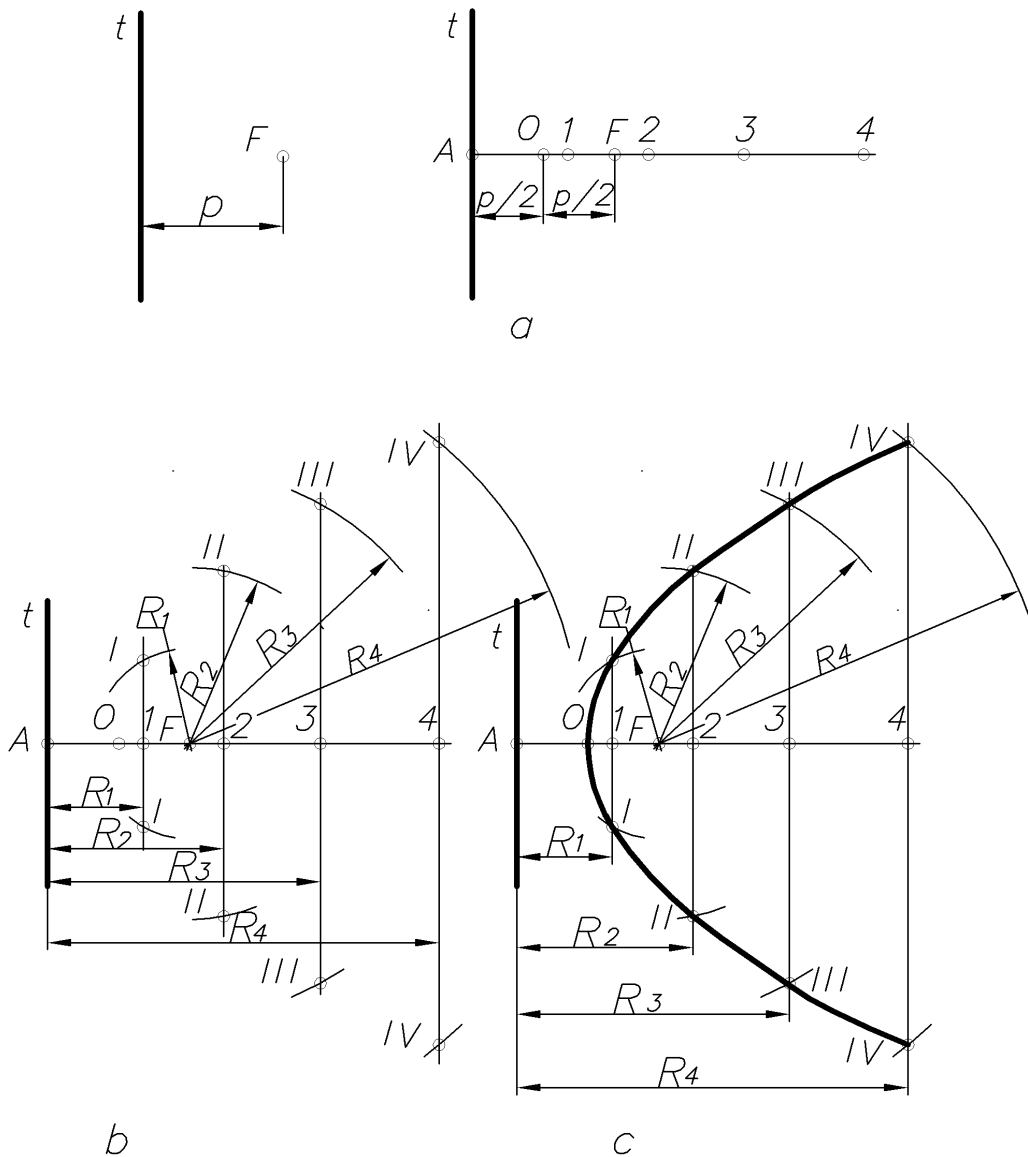


Fig. 77

1.4.18.4. Construction of a parabola using the vertex O, the axis and the chord BC.

Method 1. The segment **OD** on the axis of parabola is divided into arbitrary number of equal parts. From the points of separation, the straight lines (Fig. 78a), parallel to the segments **OC** and **OB** and to the intersection with the chord **BC** are drawn (**DC** and **DB** segments are divided into the appropriate number of equal parts). From the chords points **1¹**, **2¹**, **3¹**, **4¹** the straight lines parallel to the axis of the parabola are drawn (Fig. 78 b). From the ends of the chord (points **B** and **C**) the rays are drawn through the points on the axis **1**, **2**, **3**, **4** to the intersection with the

correspondent straight lines parallel to the axis of the parabola. Connecting the point **B**, **IV**, **III** and using a template, the parabola is obtained (Fig. 78, c).

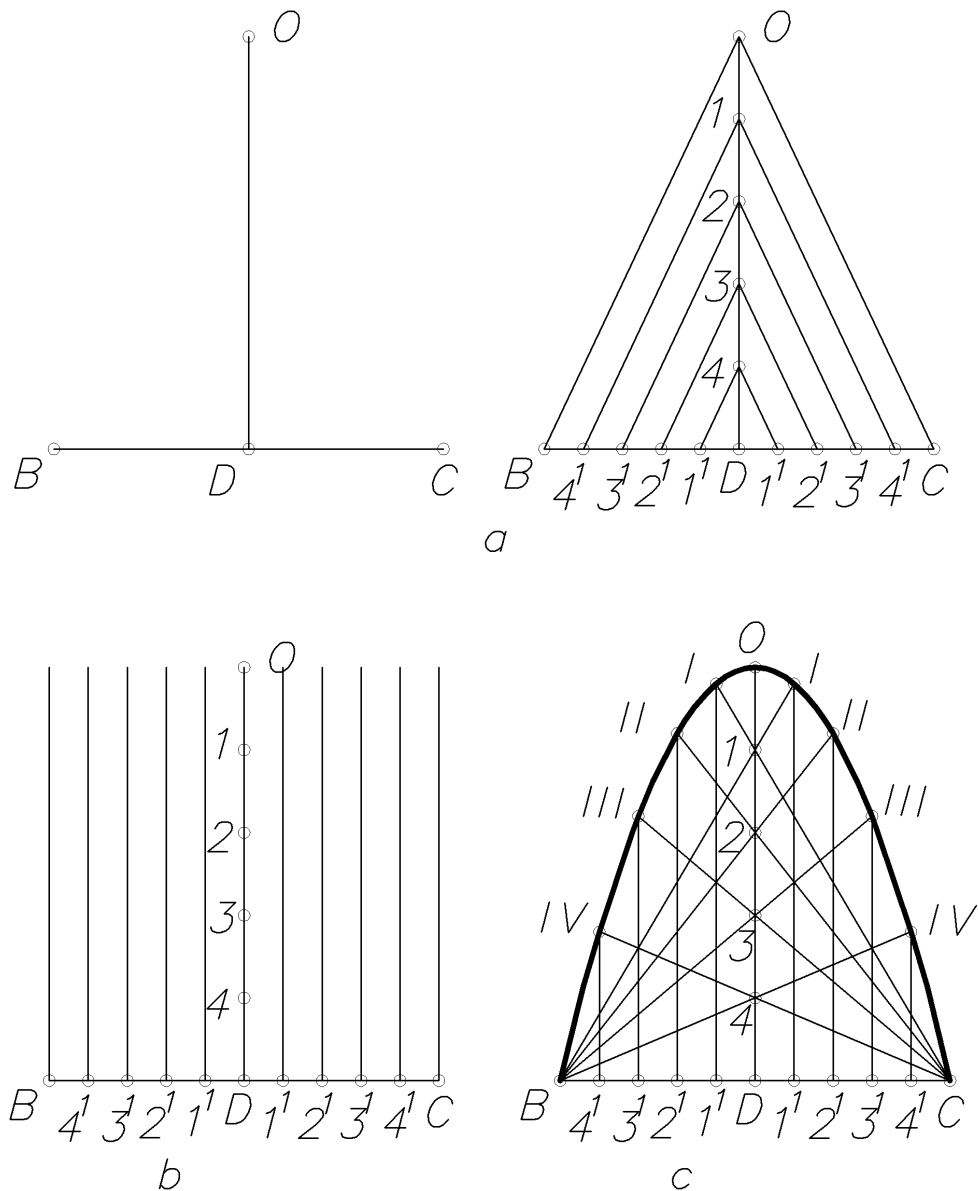


Fig. 78

Method 2. From the points **O** and **B** (Fig. 79), the mutually perpendicular straight lines to the intersection at the point **K** are drawn (Fig. 79a).

The segments **OK** and **BK** are divided into the same number of equal parts. From the point **O**, the rays to the points of division on the segment **BK** are drawn (Fig. 79 b), and from the point of separation on the segment **OK** - straight lines parallel to the axis of the parabola. At the intersection of corresponding straight lines, the points of the parabola are obtained (Fig. 79 c).

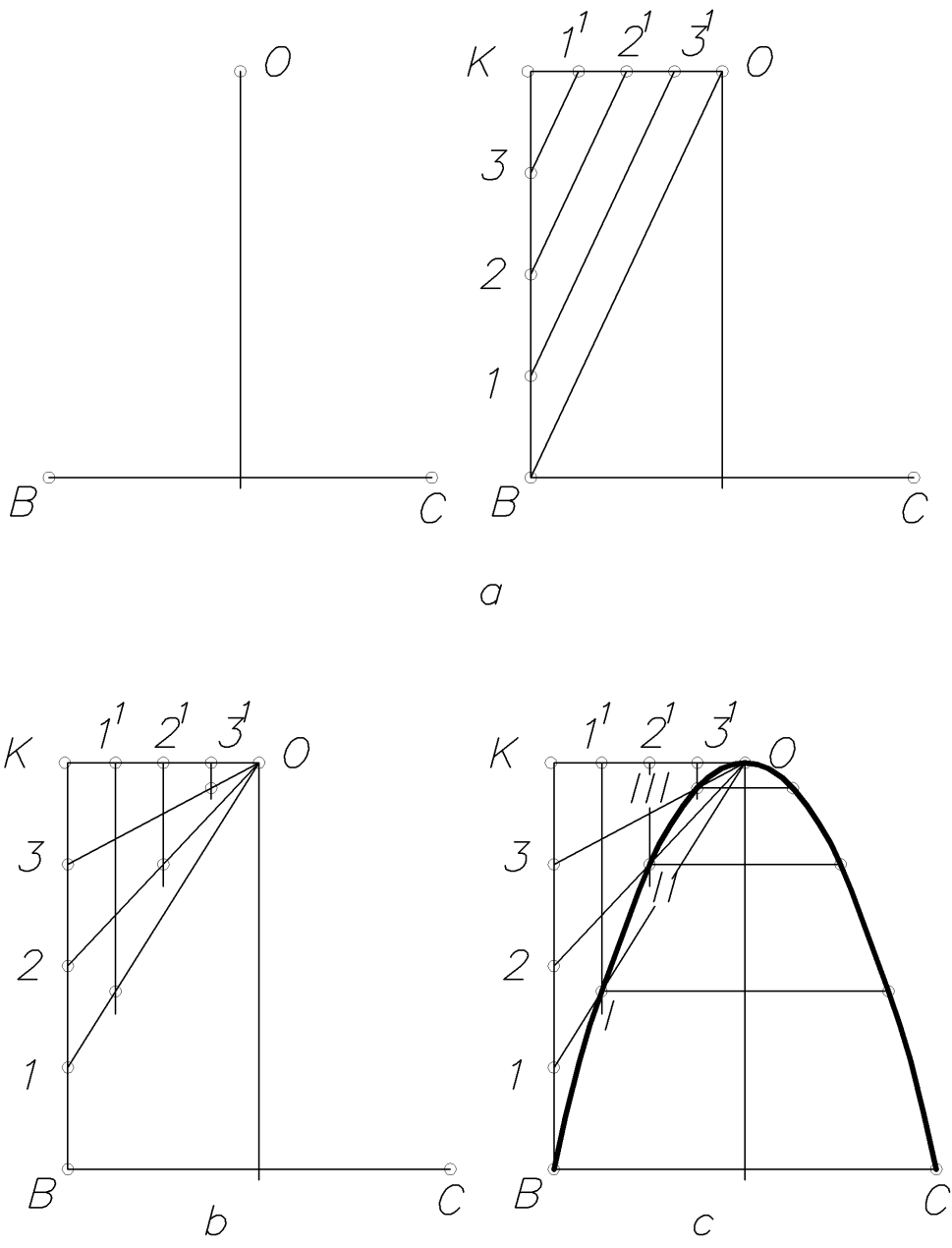


Fig. 79

1.4.18.5. Construction of a parabola that touches at points A and C to two straight lines at the point B (Fig. 80). The drawing shows straight lines, which intersect one another at an obtuse and acute angles. The segments AB and BC are divided into the same number of equal parts (Fig. 80a).

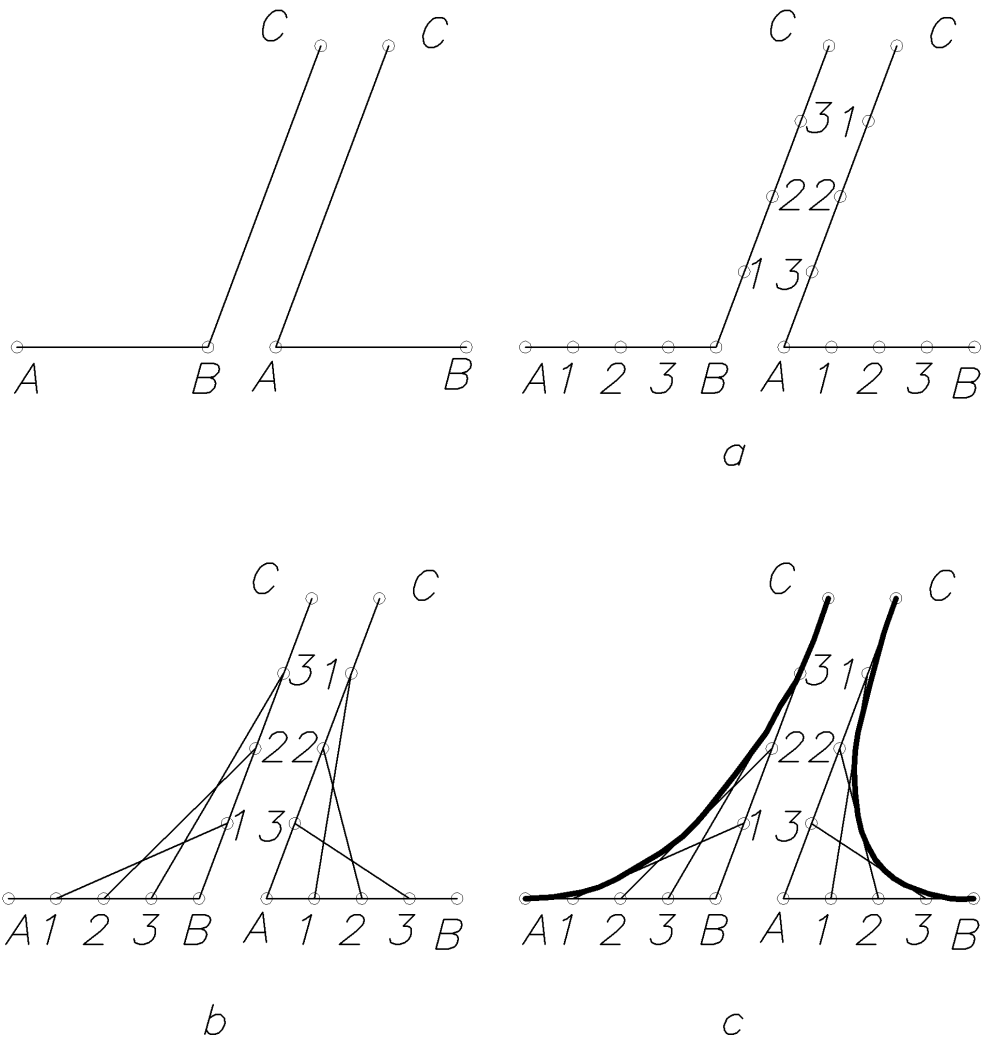


Fig. 80

The straight lines (Fig. 80 b) connect the same points. Using templates, the curve is drawn - a parabola, which is tangent to the conducted segments (Fig. 80 c).

1.4.18.6. Construction of a hyperbole, using the focus F and F_1 (Fig. 81). From the middle of a focal length FF_1 (point O) into both directions, the arbitrarily equal segments that define the vertex of the hyperbole A and A_1 are drawn (Fig. 81a). On the left from the point F on the real axis, the arbitrary points $1, 2, 3 \dots$ are marked, that is the distance between them increases with estrangement from the focus (Fig. 81 b). The distance from the points A and A_1 to the points $1, 2, 3, \dots$ is determined (Fig. 81 c). Since the foci F and F_1 of radii $R_1=A_1$ and $R_1^1=A_1$, the arcs are drawn to the mutual intersection; and four points on the two branches of the hyperbole are obtained (Fig. 81 d). Similarly, from the foci, the arcs of radii, which are equal to A_2 and A_12 ; A_3 and $A_13 \dots$ are drawn, and the number of points of the hyperbole is obtained (Fig. 81, e).

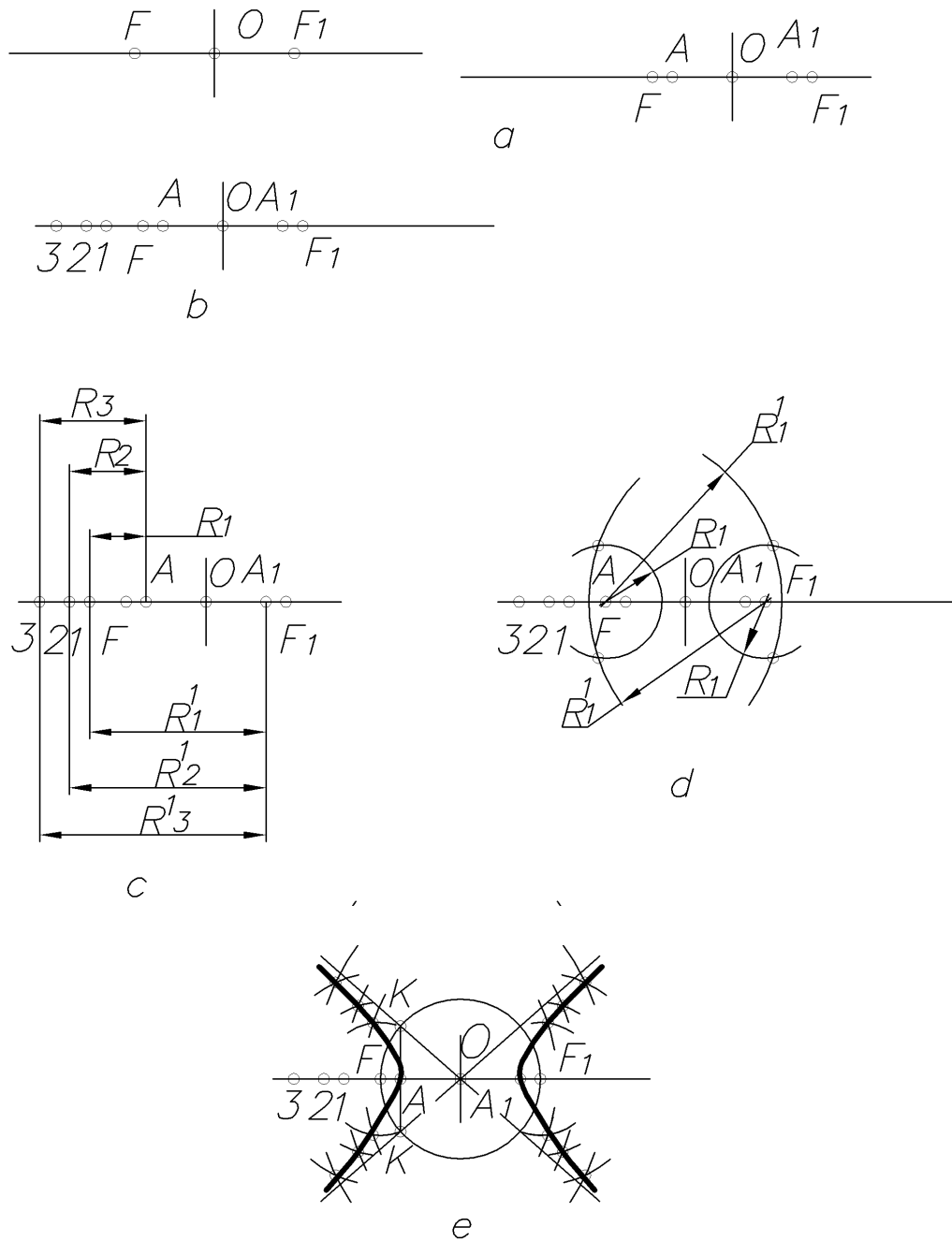


Fig. 81

The construction of hyperbola asymptotes is as follows: from the centers of the hyperbole \mathbf{O} , the circle of \mathbf{OF} radius is drawn, and through the vertex \mathbf{A} – the straight line perpendicular to the real axis of hyperbole and to the intersection with the circle at the points \mathbf{K} . The straight lines that pass through these points and the point \mathbf{O} are the asymptotes of hyperbole.

2. GUIDANCE FOR EXECUTING THE TASK 1

”GEOMETRIC DRAWING”

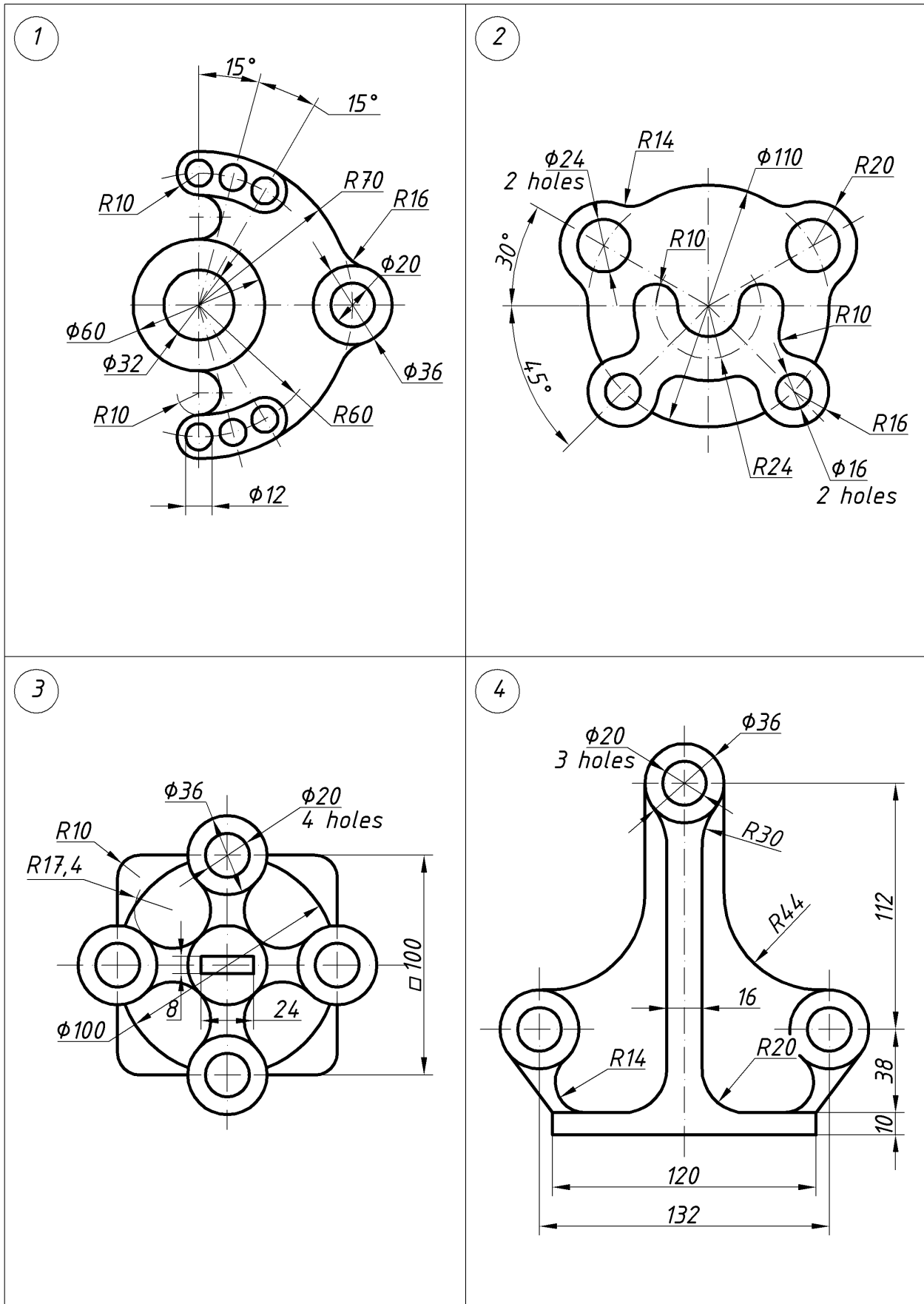
2.1. The purpose of the task 1 "Geometric Drawing" is the acquisition of knowledge and skills during the executing and designing the drawings in accordance with the requirements of state standards of Ukraine. General recommendations, the requirements for executing and designing the drawings are listed in sections 1.2, 1.3, 1.4 of these guidelines.

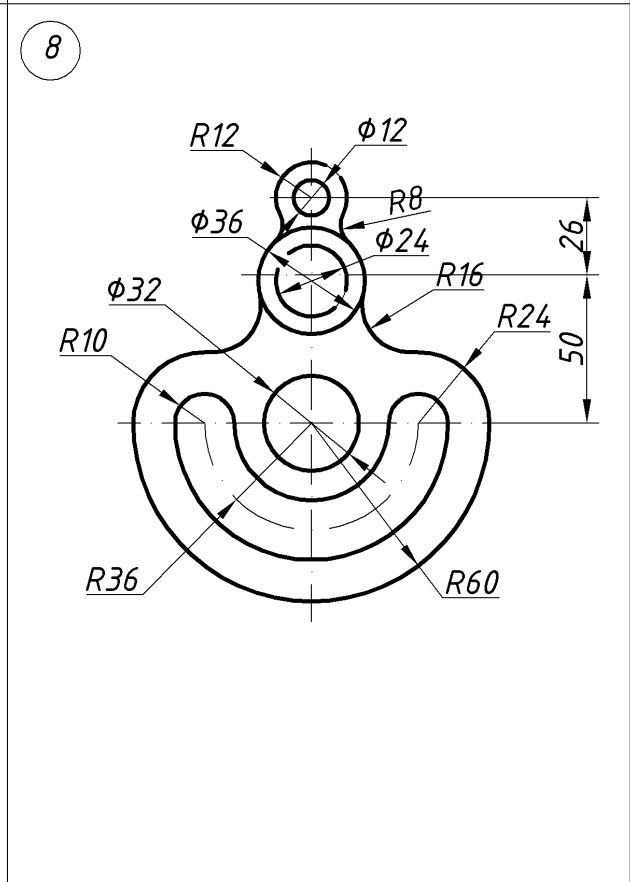
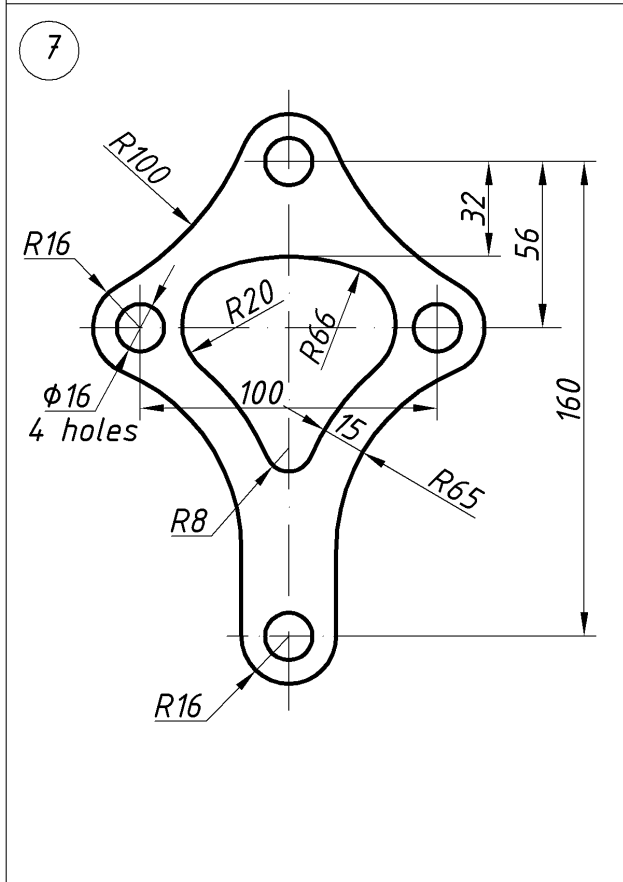
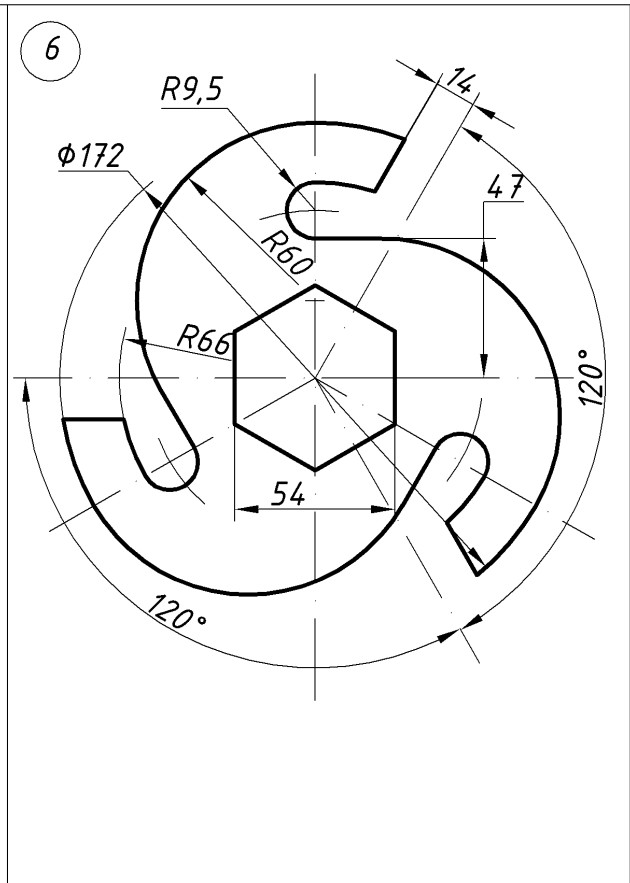
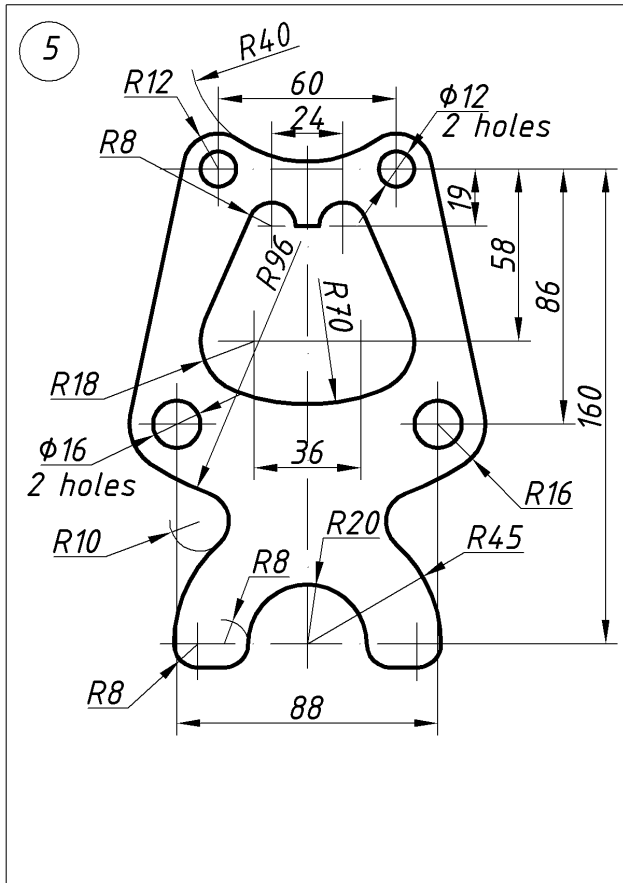
2.2. Variants of tasks are shown in appendix A. The relevant serial number of student's enrollment in the register journal of a group defines the variant.

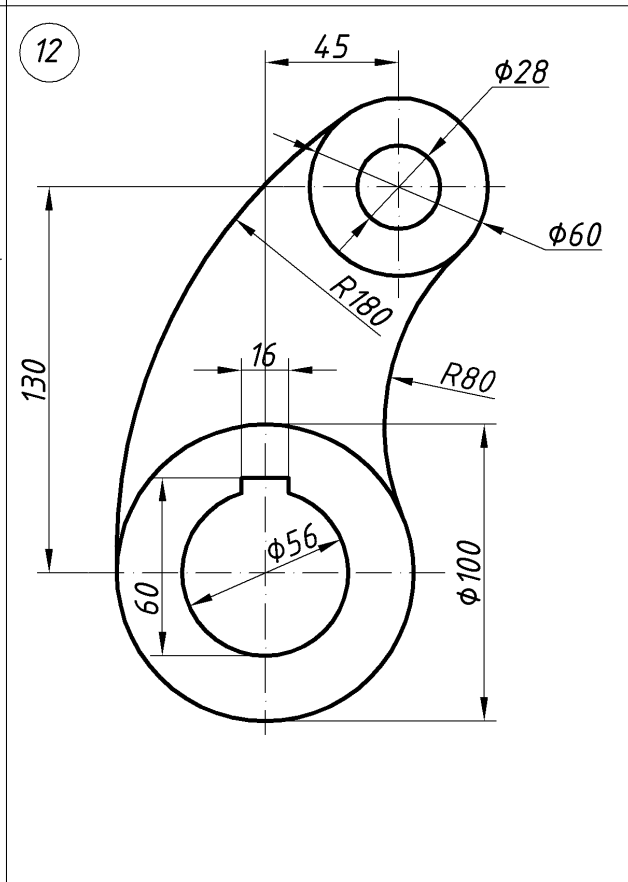
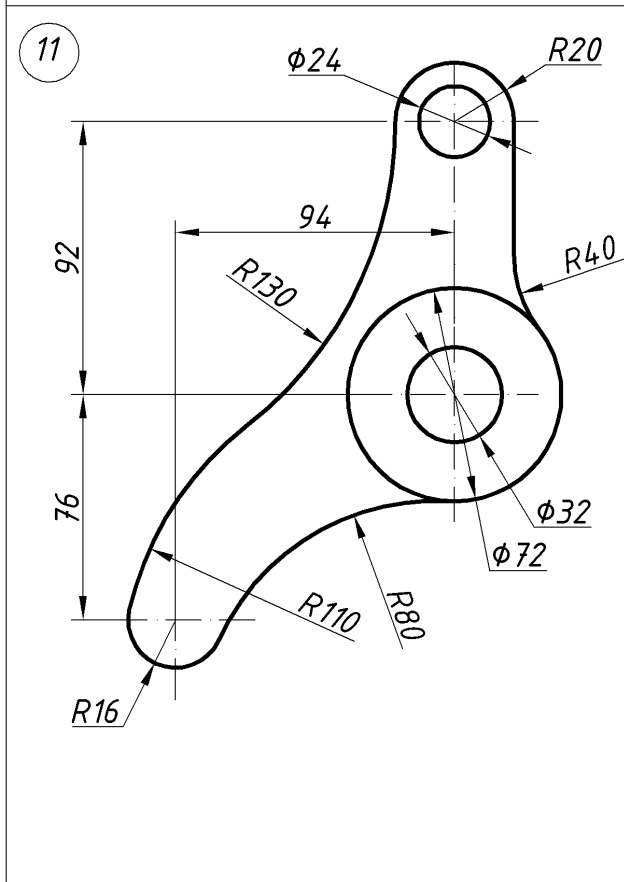
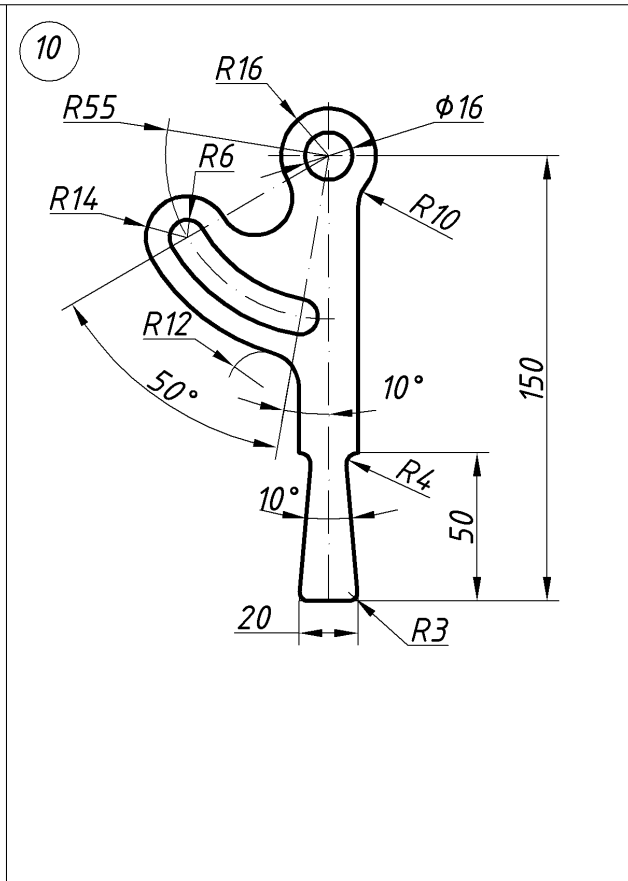
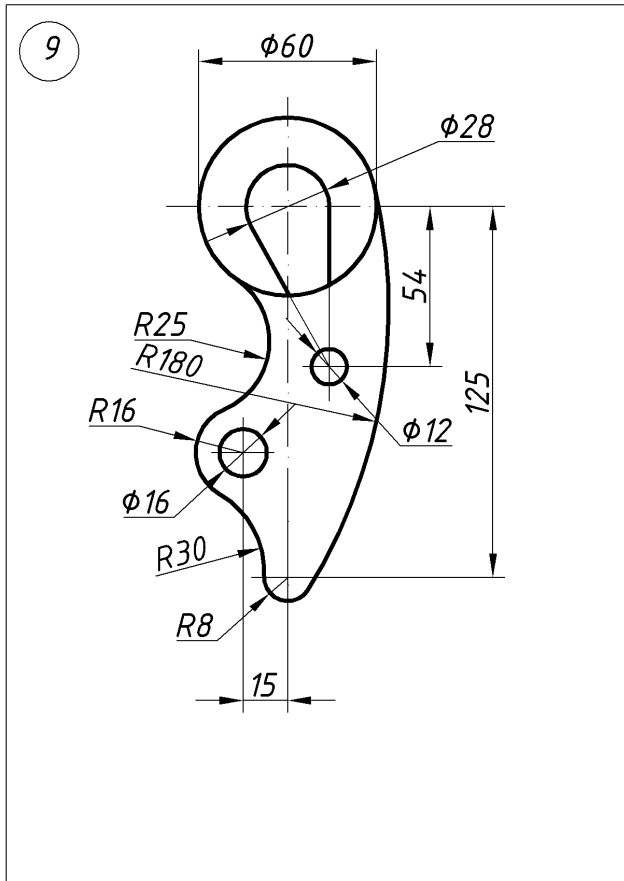
2.3. The task must be performed on a sheet of paper of format A4.. The required sizes should be applied independently according to GOST 2.307-68. Recommendations to the implementation are given in section 1.3 of this guideline.

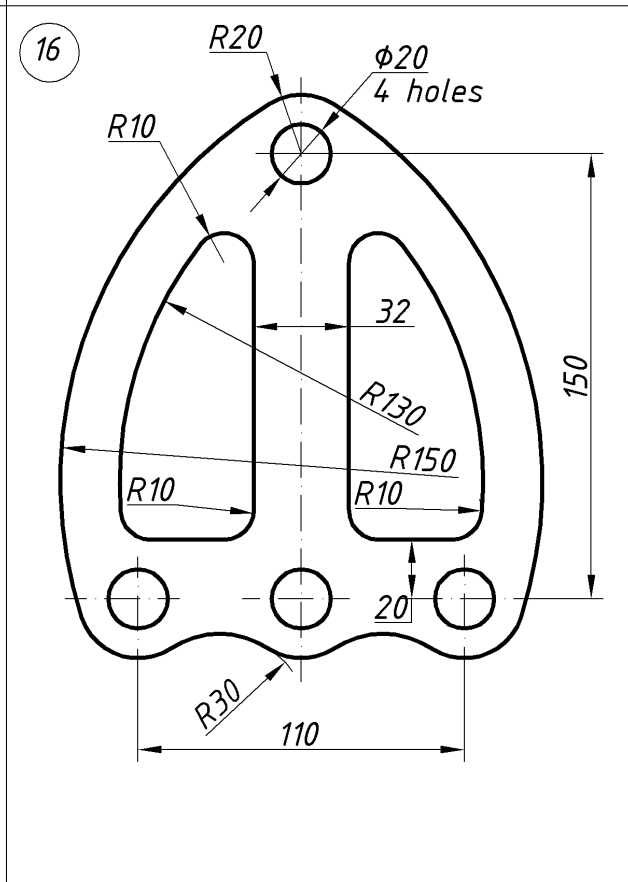
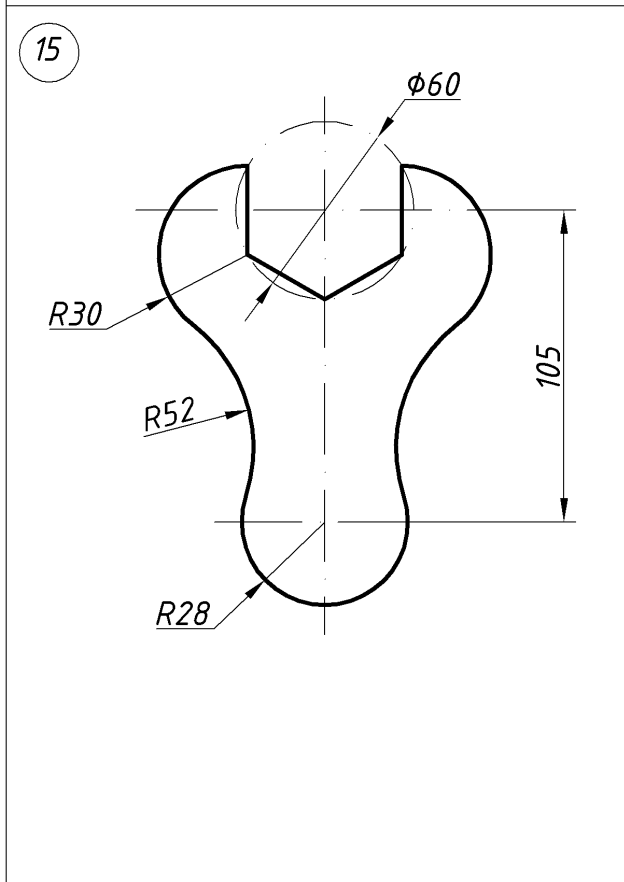
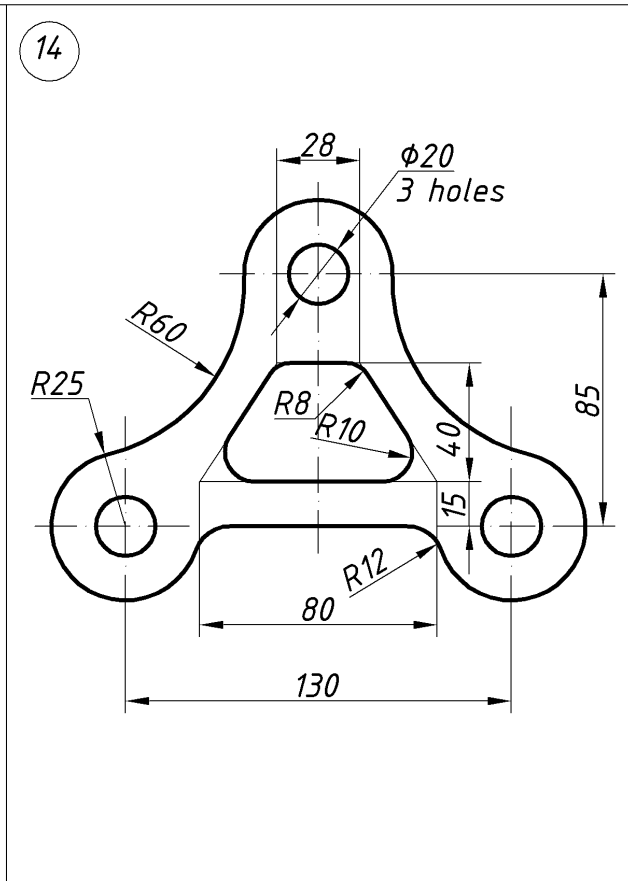
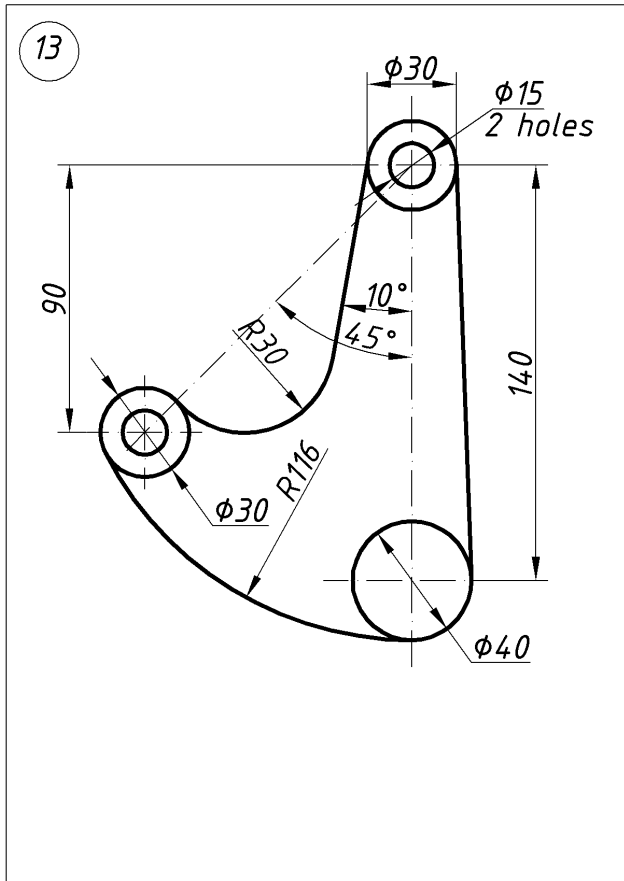
Appendix B shows a sample of executing the drawings and dimensioning on similar details.

Variants of tasks

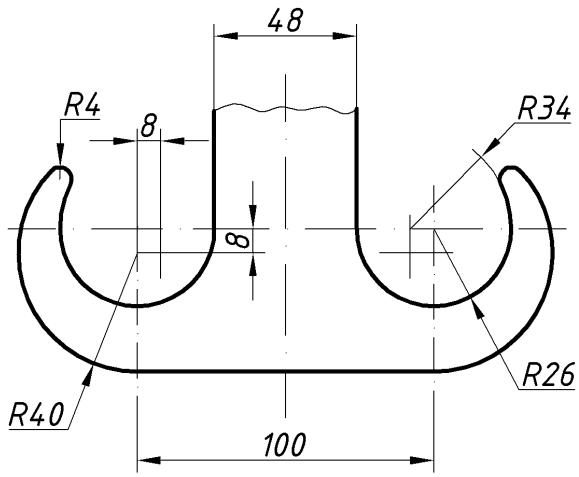




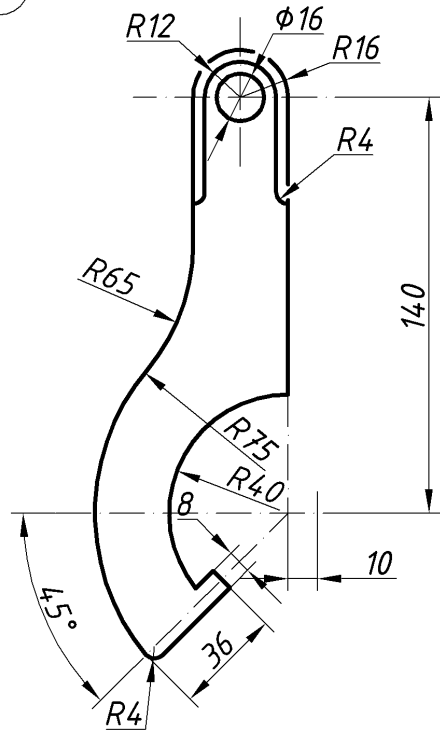




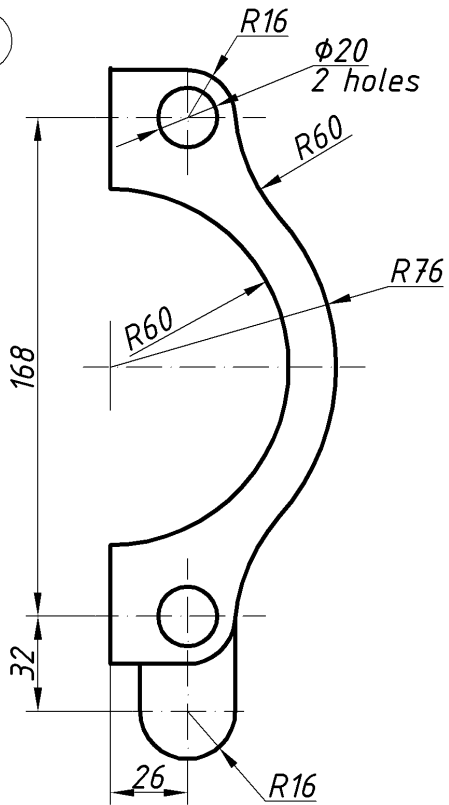
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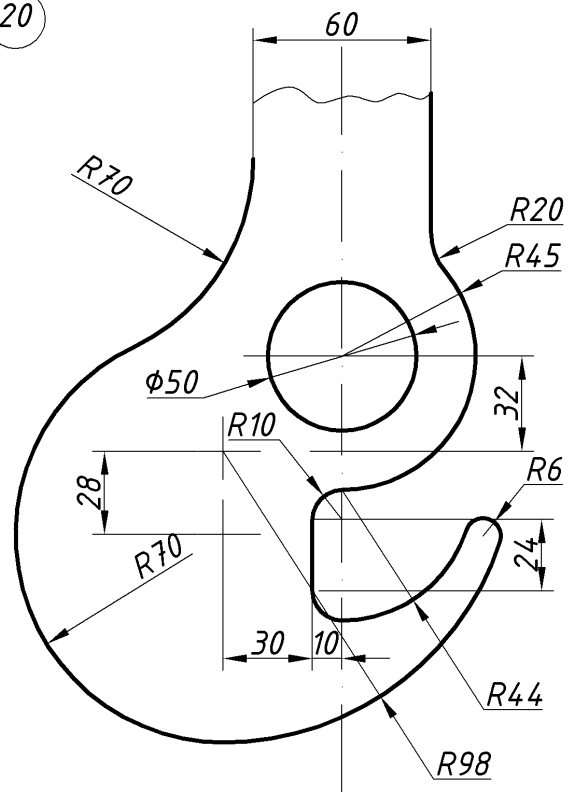
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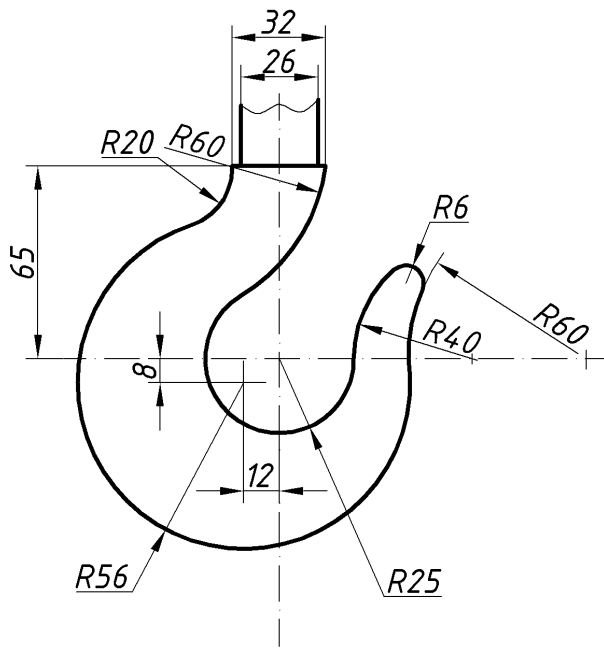
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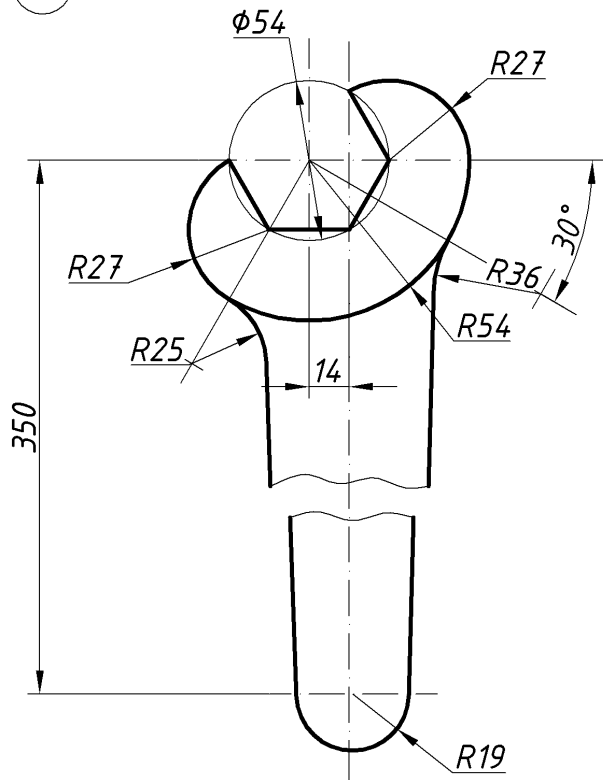
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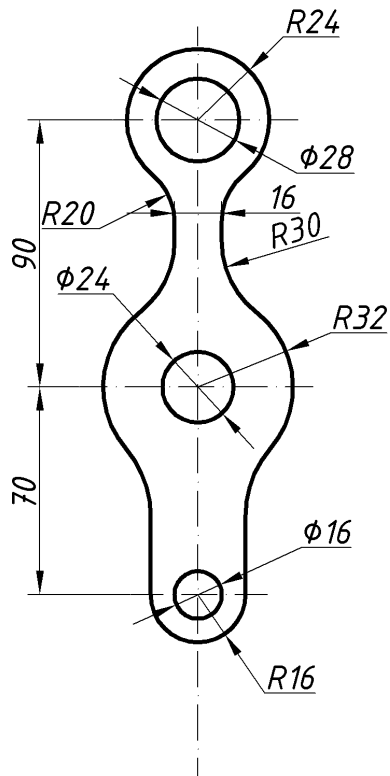
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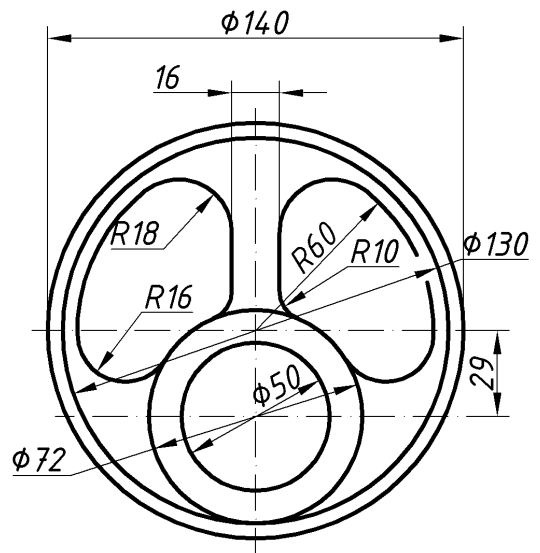
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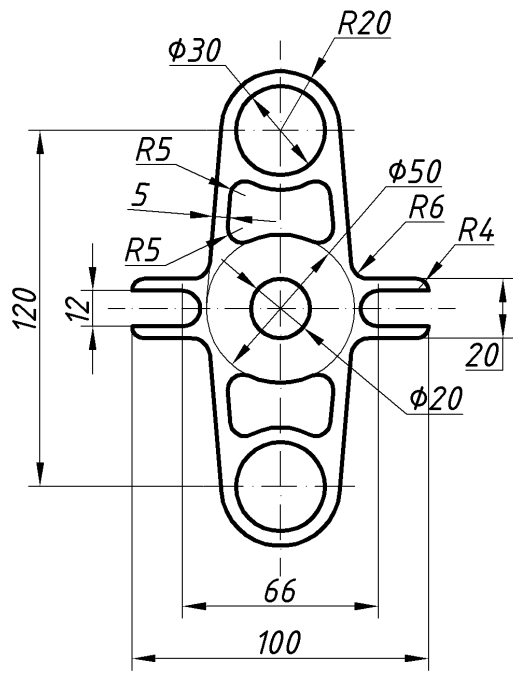
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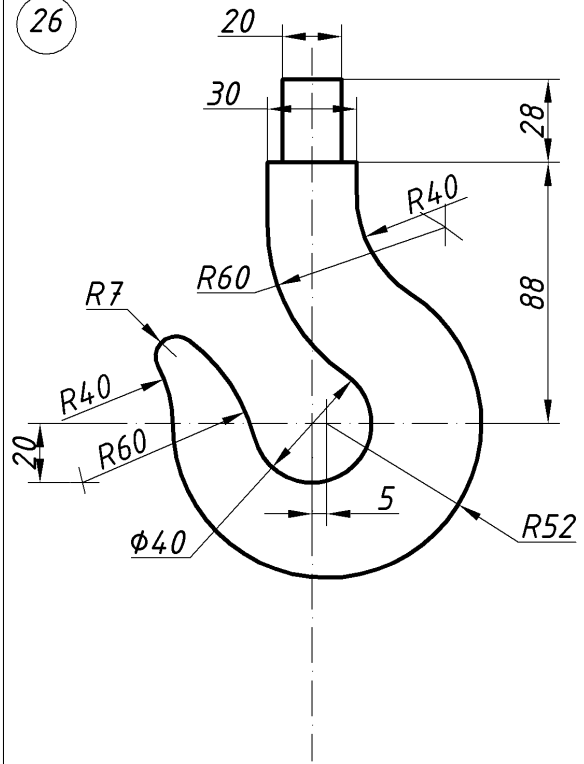
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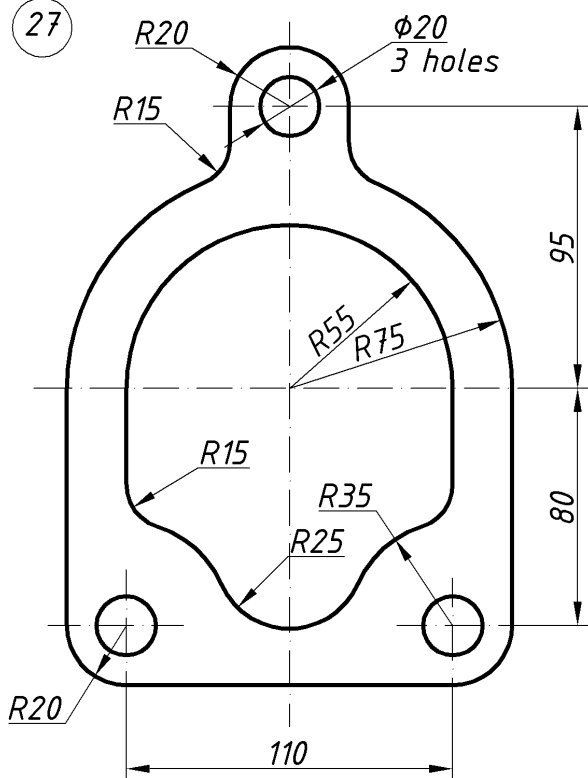
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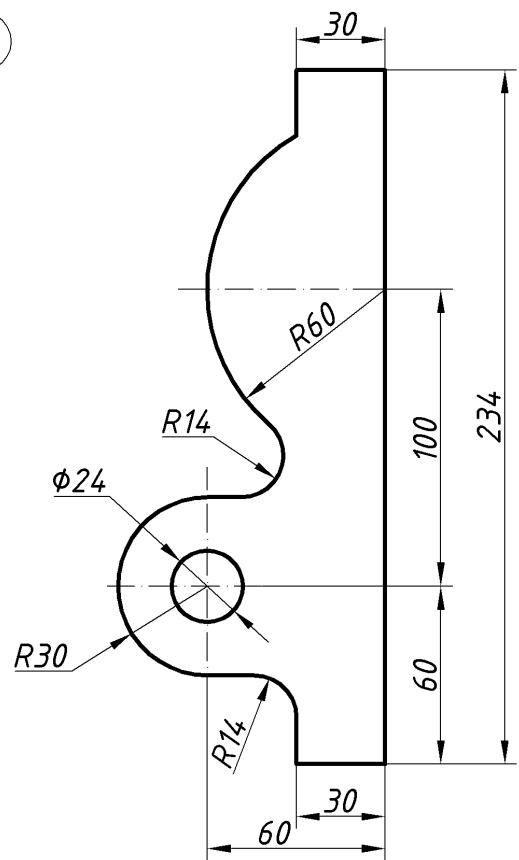
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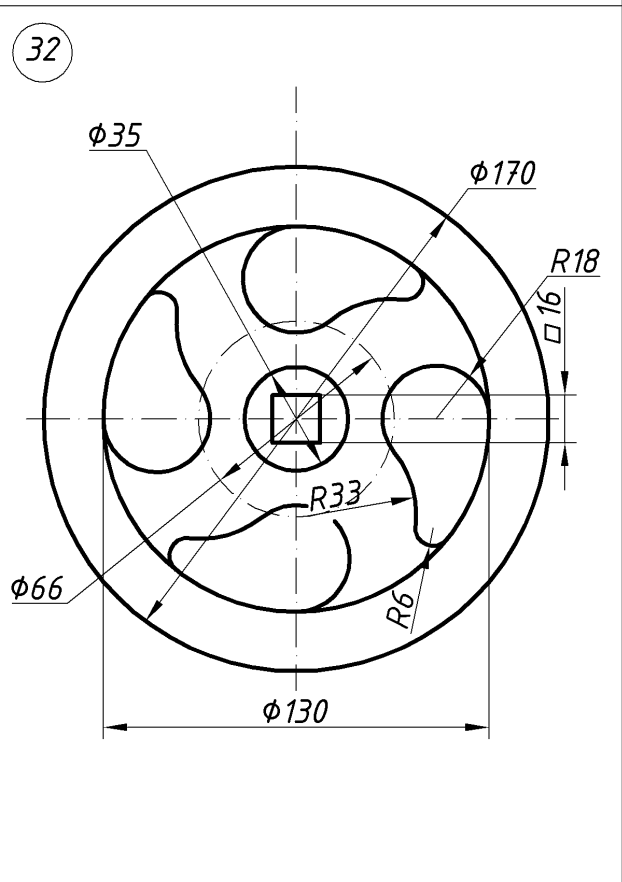
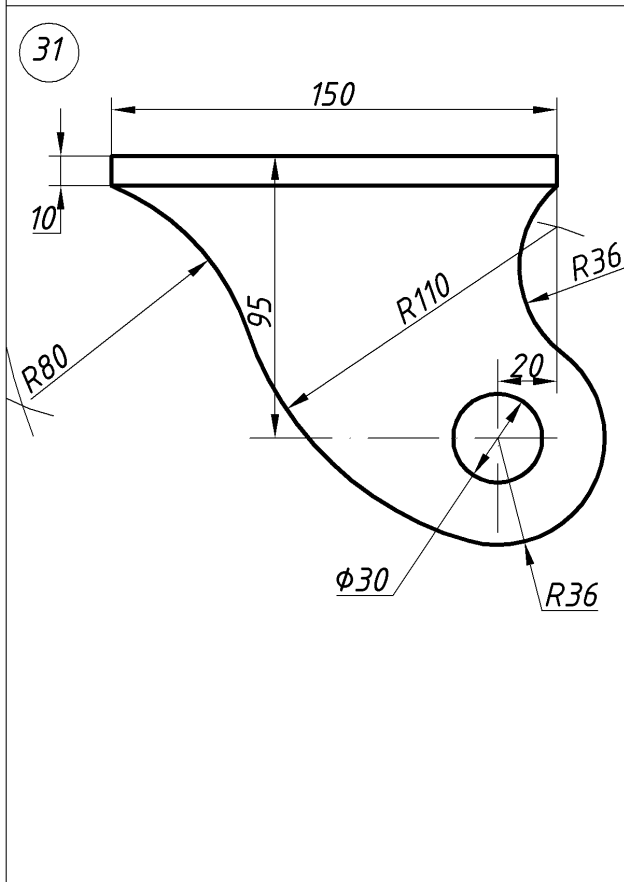
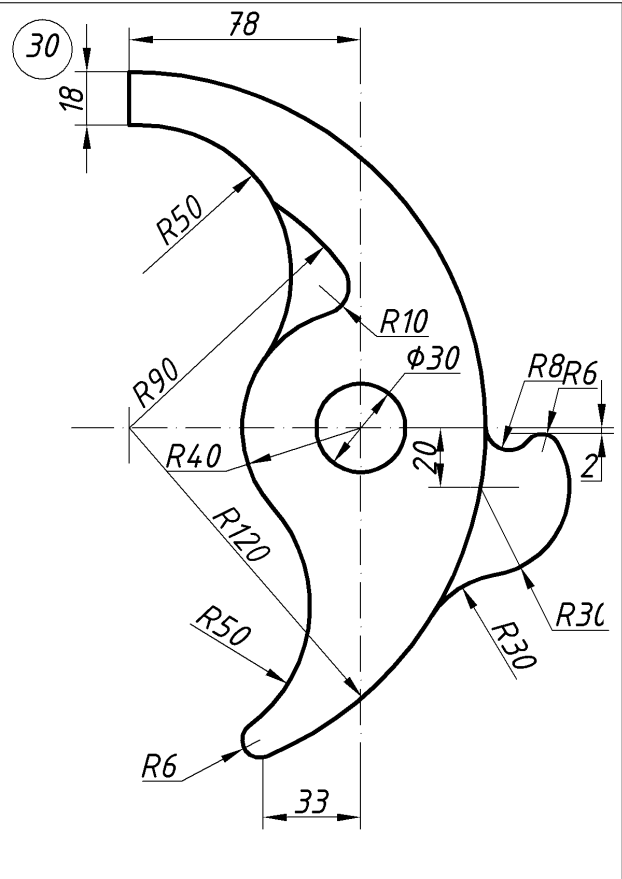
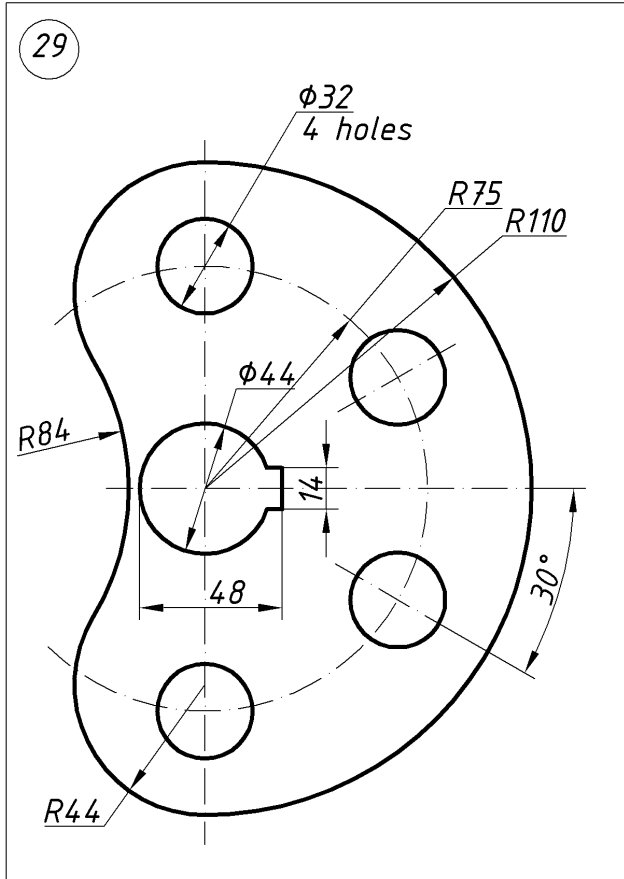


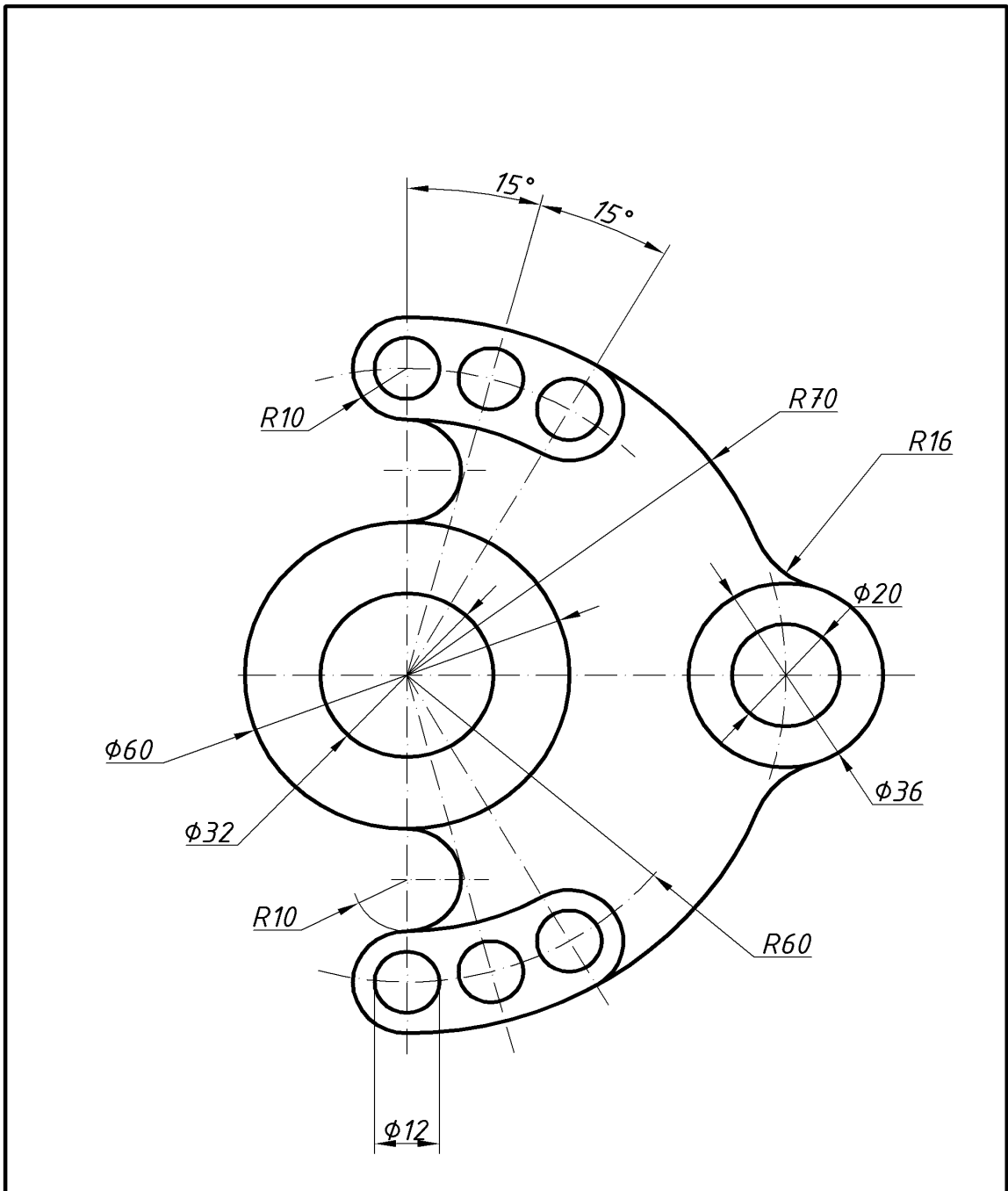
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Навчально-методична література

Пік А.І., Скиба О.П., Ковбашин В.І., Денисюк Н.Р.

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ГРАФІЧНОЇ І САМОСТІЙНОЇ РОБОТИ
ДЛЯ ІНОЗЕМНИХ СТУДЕНТІВ
З КУРСУ «ІНЖЕНЕРНА ГРАФІКА»**

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