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ALMATY UNIVERSITY OF POWER ENGINEERING AND TELECOMMUNICATIO

Department of Control Systems of Aerospace Equipment

FUNDAMENTALS OF COMPUTER DRAFTING AND OF 3D MODELING

Lecture notes for students of all specialties

Almaty 2014

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Volume of the course “Fundamentals of computer drafting and of 3D modeling” is 90 hours (2 credits), including 8 hours of lectures (theory of the construction drawings and the introduction of 3D modeling), 16 hours of practical training (practice on constructing drawings), 16 hours of laboratory exercises (study of the elements in the AutoCAD computer graphics system).

Lecture notes are briefly provide the major provisions, set out in a lecture course “Fundamentals of computer drafting and of 3D modeling”. The lectures 1-3 outline fundamentals of the theory of drawing: projection methods, a complex drawing of the point, the line and the plane, ways of replacing the projection planes and the method of rotation around the projecting line, solving graphically some geometric tasks. Lecture 4 provides general concepts of surfaces and describes the basics of the 3D modeling in the AutoCAD computer graphics system.

Illustr. – 51, Ref. – 11 items.

Reviewer: cand. of philol. scn., docent Kozlov V.S.

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Contents

1 Lecture №1. Projection methods. Projections of a point and a straight line

Content of lecture: goals, objectives and structure of the discipline, the method of orthogonal projection, and the projection of a point and a straight line**.**

Objectives of the lecture: to explore the method of orthogonal projection onto two and three mutually perpendicular planes, consider the projection of a straight line.

The aim of the lecture course is to give the theoretical basis of imaging in the drawings. Basis for the ability to perform and read blueprints, as it is necessary in the design of products and during their manufacturing, maintenance and repairing, is the theory of constructing the drawings (TCD). Studying the TCD is the best way to develop spatial imagination, without which engineering creativity is impossible. Spatial imagination allows visualizing the shape and the sizes of objects, their relative positions in space by means of the drawing, and gives an opportunity to present products, which do not exist yet. The basic method of TCD is the graphical method. The study of theory must be accompanied by the contracting the drawings.

1.1 Central, parallel and orthogonal projection

Suppose are given (see Figure 1.1) a plane π (projections plane) and outside of it a point S_1 (center of projection). To project a point A on the plane π, through the point S_1 we draw a straight line S_1A until its intersect with the plane π at point A_1. Point A_1 is the central projection of the point A, straight line S_1A_1 is projecting ray. Projection of any figure is the set of projections of all its points.

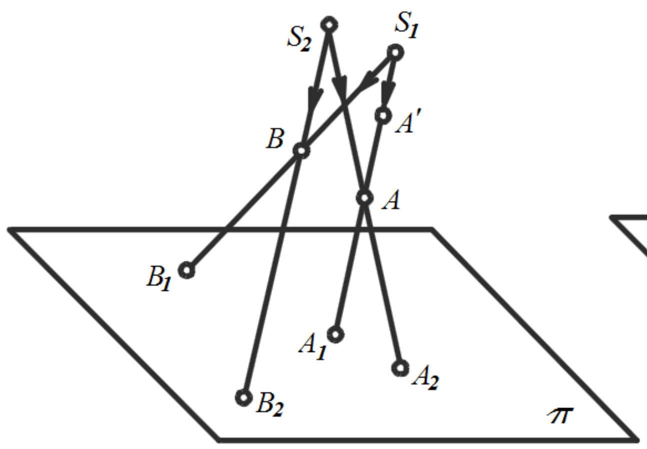


Figure 1.1

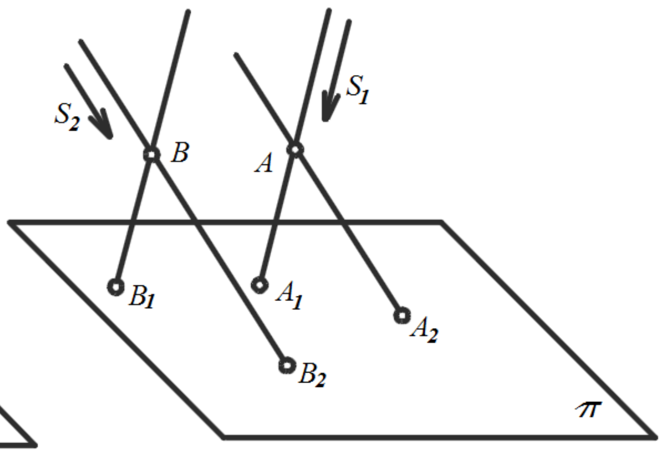


Figure 1.2

Simple shapes are points, lines and planes, and complex shapes consist of set of points, lines and planes.

Without altering the position of π and taking a new center S_2, we get a new projection of point A – point A_2. Thus, given π and S it is easy to obtain projection of a point. However, with one projection (e.g. A_1), the position of the point in space cannot be determined; because any point on S_1A_1 is projected into the same point A_1. For solutions two projections are needed (e.g. A_1 and A_2).

Parallel projection is a special case of the central projection, when $S=S_\infty$ (infinitely removed from π). In this case, projected lines are parallel to each other (see Figure 1.2). Parallel projection is completely determined by the position of the plane (π) and the direction of the projection (S). To determine the position of a point in space it is also necessary to have two projections obtained by two different directions of projecting; position of the point is determined by the intersection of lines drawn through A_1 and A_2 parallel to directions S_1 and S_2.

Properties of *parallel* and *central* projections:

a) each point and line in space have a single projection on the given plane;

b) projection of a point is a point;

c) a line in the general case is projected on a plane as a straight line;

d) to construct the projection of a line it is enough to project two of its points and draw a straight line through the obtained projection points ;

e) if the point belongs to the line, then the projection of this point belongs to the projection of this line.

For *parallel* projections, other than the above, it is true:

f) if the line is parallel to the direction of projection, then the projection of this line is a point;

g) segment of a line, parallel to the plane of projection, is projected onto this plane in full size.

Orthogonal (rectangular) projection is a special case of parallel projection in which the projection direction S is perpendicular to the plane of projection (see Figure 1.3)

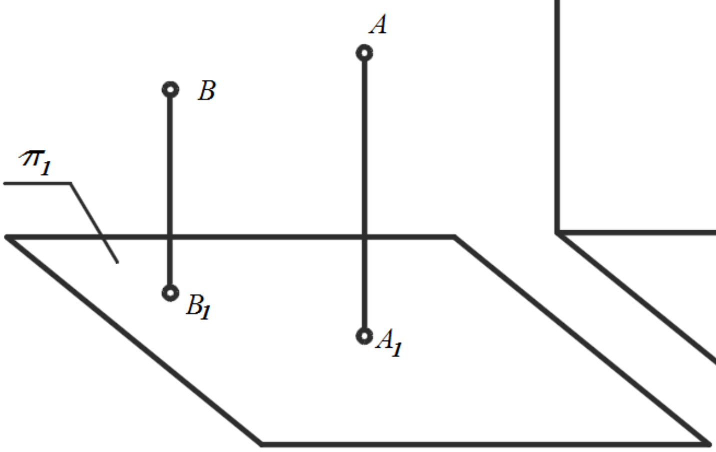


Figure 1.3

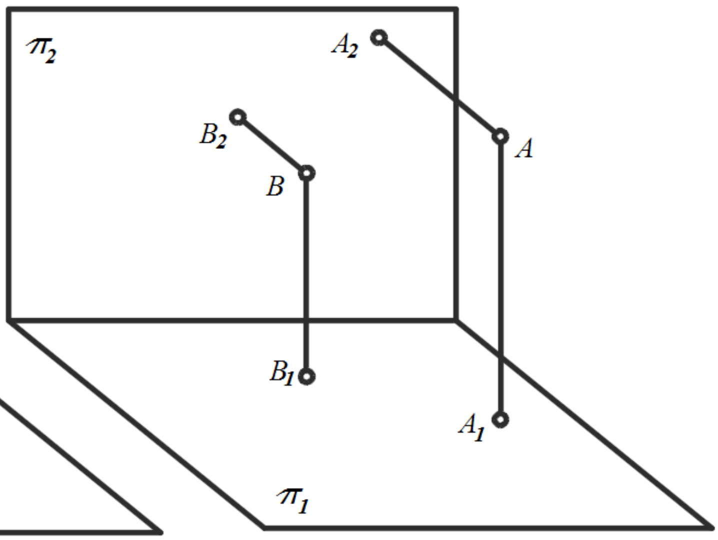


Figure 1.4

Here, to determine the position of a point in space it is also necessary to have two parallel projections obtained from the two directions of projection. In orthogonal projecting they are projections in two mutually perpendicular planes π_1 and π_2 (see Figure 1.4). In technical drawing parallel rectangular projection is mainly applied for 2 or 3 mutually perpendicular planes.

Position of a point in the space of two mutually perpendicular planes, horizontal π_1 and frontal π_2, is determined by its projections A_1 and A_2 (see Figure 1.5). Planes π_1 and π_2 divide the space into quadrants. The line of intersection of planes is called the axis of the projection *X*.

Rotating the plane π_1 around the axis of projection by 90 º, we get one plane of the drawing. Projections A_1 and A_2 will be located on the same perpendicular to the axis of projection – link lines. As a result of combining π_1 and π_2, we obtain epure of Monge or complex drawing (see Figure 1.6).

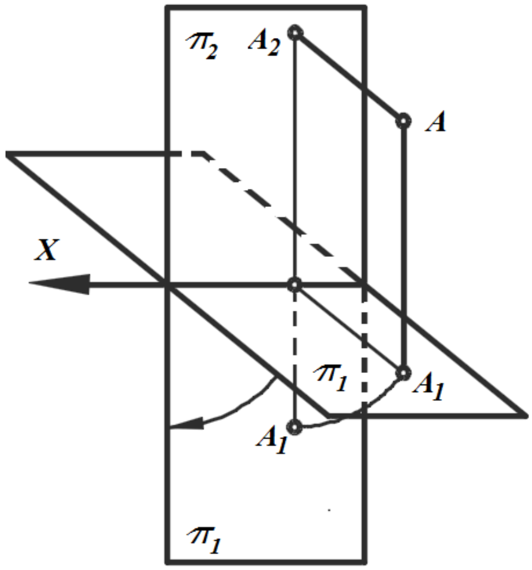


Figure 1 .5

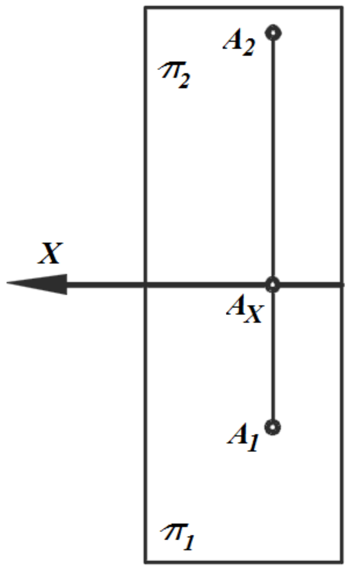


Figure 1.6

The third plane of projection π_3, perpendicular to π_1 and π_2, is called the profile plane (see Figure 1.7). In addition to the *X*-axis axis of projections *Y* and *Z* appear. Letter *O* denotes the intersection point of planes π_1, π_2, π_3.

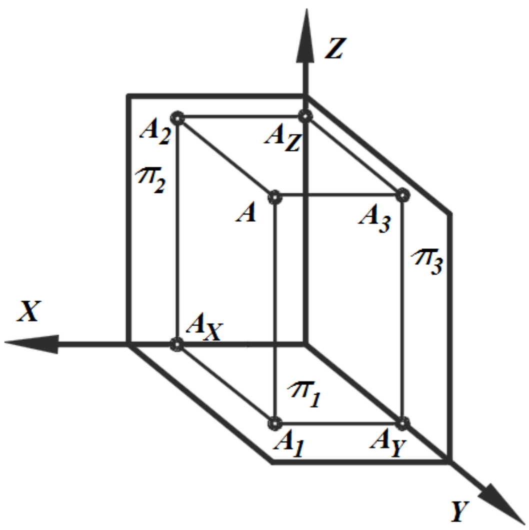


Figure 1.7

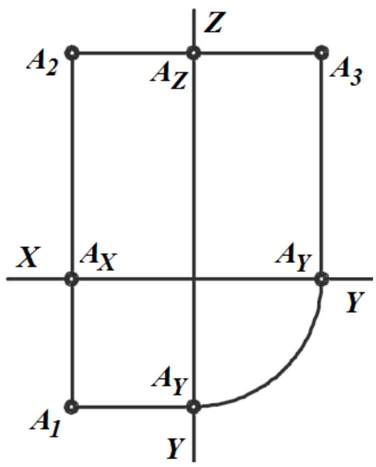


Figure 1.8

If we imagine cutting the planes along the Y axis and rotating π_1 around the X axis by 90º, and π_3 - around the Z axis by 90º, then all three planes align in one plane of the drawing (see Figure 1.8). The lines connecting the projection points between each other are called linking lines.

Descartes introduced a system of rectangular coordinates, where the planes π_1, π_2 and π_3 - planes of coordinates, straight lines, which they intersect - the axes of coordinates X, Y, Z, and the point of intersection of the axes - the origin of coordinates O. Coordinate planes divide space for 8 octants. Taking the projection axes as the coordinate axes, we can find the coordinates of the point according to its projections. Coordinates of the point are called distances, cut off by link lines on the coordinate axes. Distances OA_x (see Figure 1.7) - the abscissa X, OA_y – ordinate Y, OA_z - applicate Z.

1.2 Projections of a straight line segment

Suppose the projections of points A and B are given (see Figure 1.9). After drawing straight lines though same named projections of these points we obtain the projection of a segment AB - frontal (A_2B_2) and horizontal (A_1B_1).

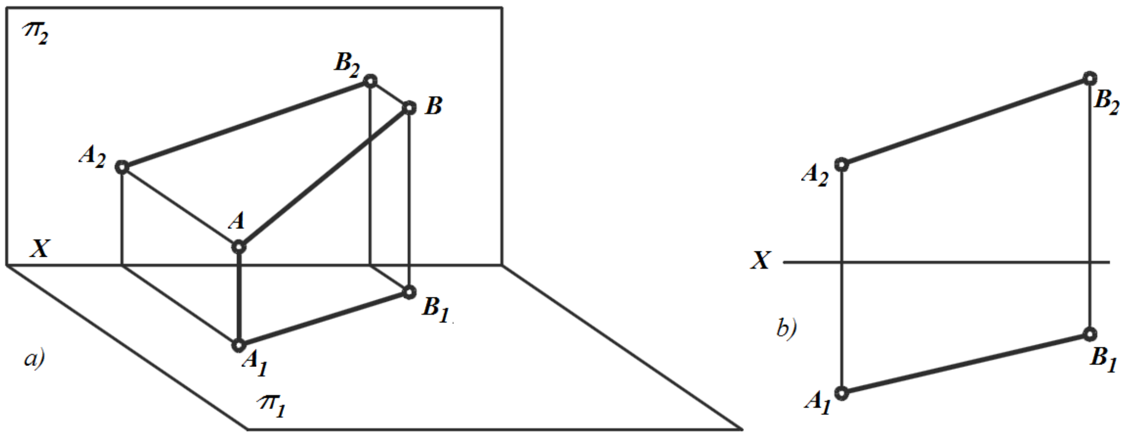


Figure 1.9

In the case of general position points A and B are situated at different distances from each of the planes π_1, π_2, π_3, i.e. line AB is not parallel to any of them, and not perpendicular to them. Here, each of the projections is less than the segment itself $A_1B_1<AB$, $A_2B_2<AB$, $A_3B_3<AB$.

Straight line can take special (particular) positions regarding the planes of projections. A line, parallel to one of the planes of projections and not perpendicular to the other two, is called a line of level. A line, perpendicular to one of the planes of projections, respectively , parallel to the other two, is called projecting line.

Let's consider the properties of projections of horizontal line of level (denoted by the letter h); it is a line parallel to the plane π_1 (see Figure 1.10). Here, the front projection of the line is parallel to the coordinate axis X, and the horizontal projection is equal to the segment itself ($A_2B_2 \parallel OX$, $A_1B_1 = |AB|$).

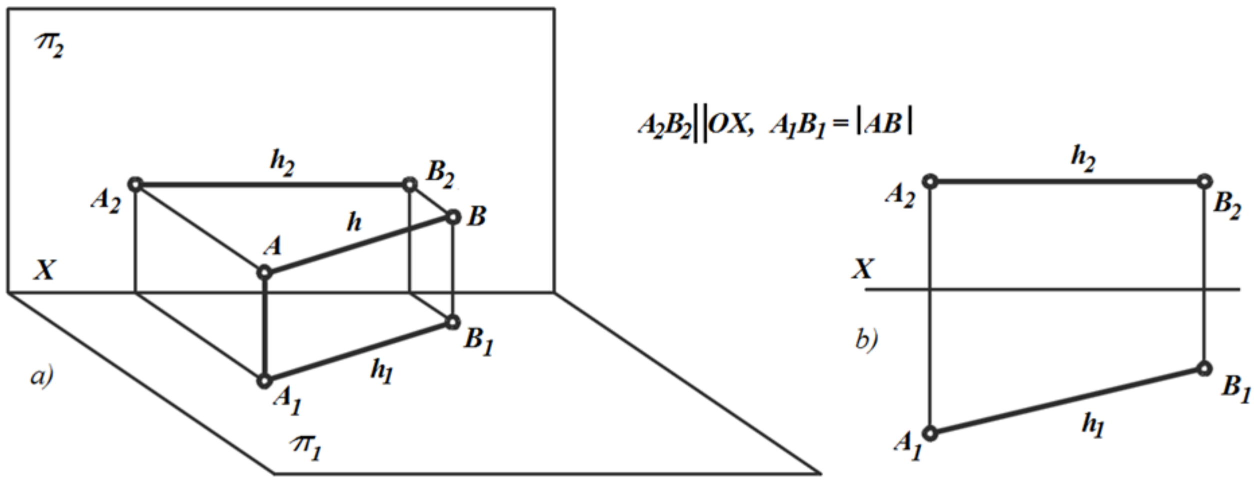


Figure 1.10

Figures 1.11 and 1.12 show the projections of frontal $f \parallel \pi_2$ and profiled $p \parallel \pi_3$ lines of level respectively.

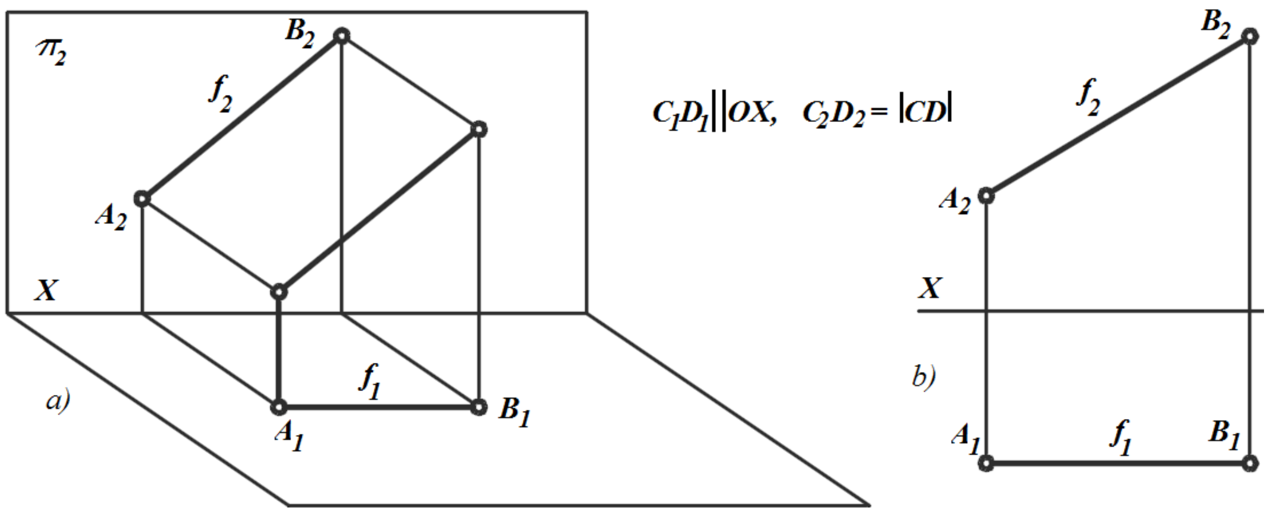


Figure 1.11

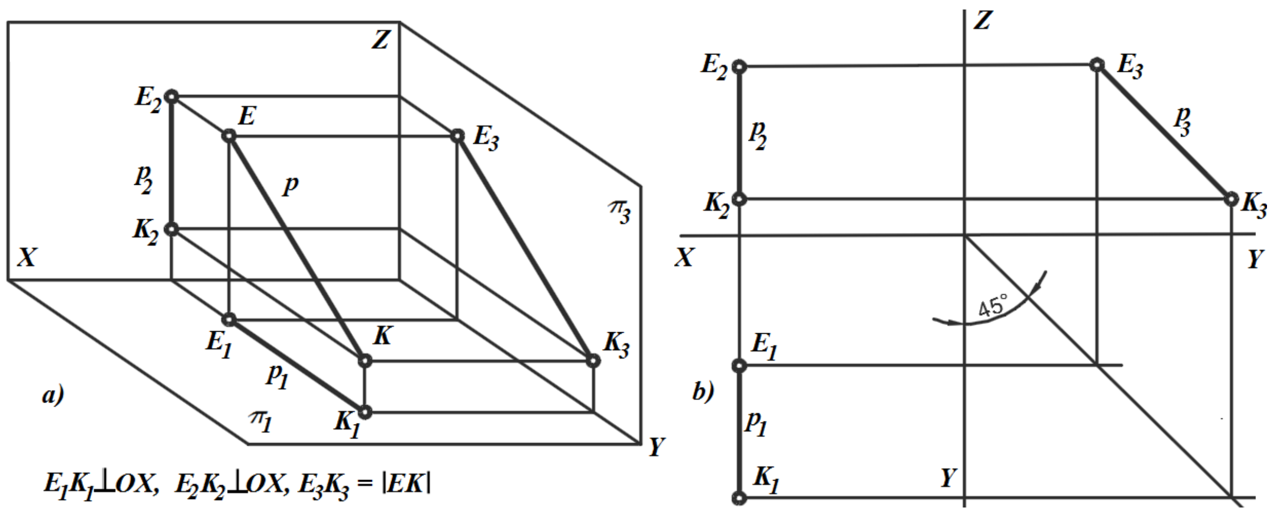


Figure 1.12

Let's consider the properties of projections of horizontal projecting line (see Figure 1.13). Here $EK \perp \pi_1$, $EK \parallel \pi_1$ and $EK \parallel \pi_3$, projection of the line onto the plane π_1 constitutes a point ($E_1 \equiv K_1$), and the projection on a plane π_2 and π_3 perpendicular to axes OX and OY respectively ($E_2K_2 \perp OX$, $E_3K_3 \perp OY$).

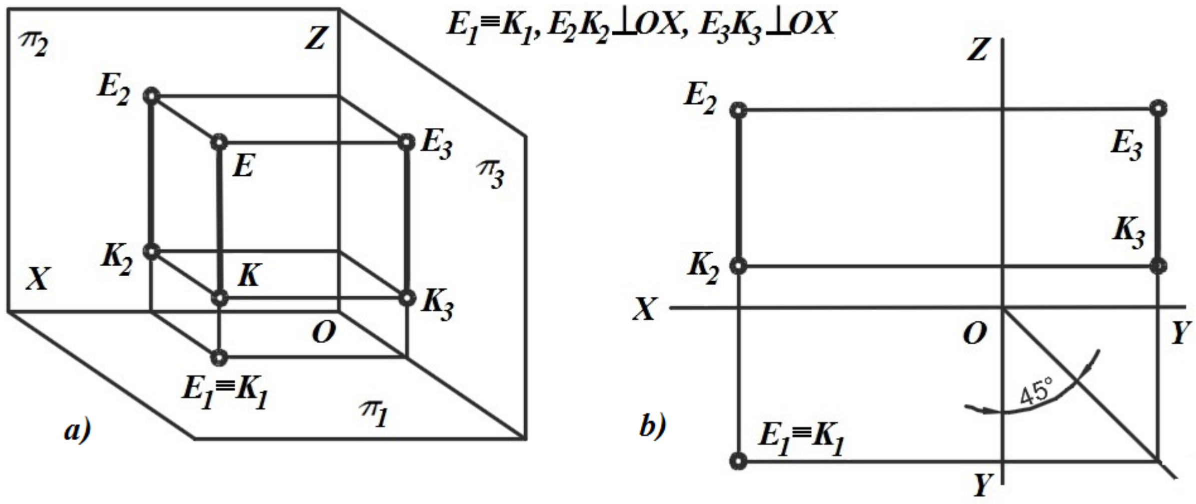


Figure 1.13

Figures 1.14 and 1.15 show the projections of frontal-projecting ($CD \perp \pi_2$) and profiled-projecting ($AB \perp \pi_3$) lines, respectively.

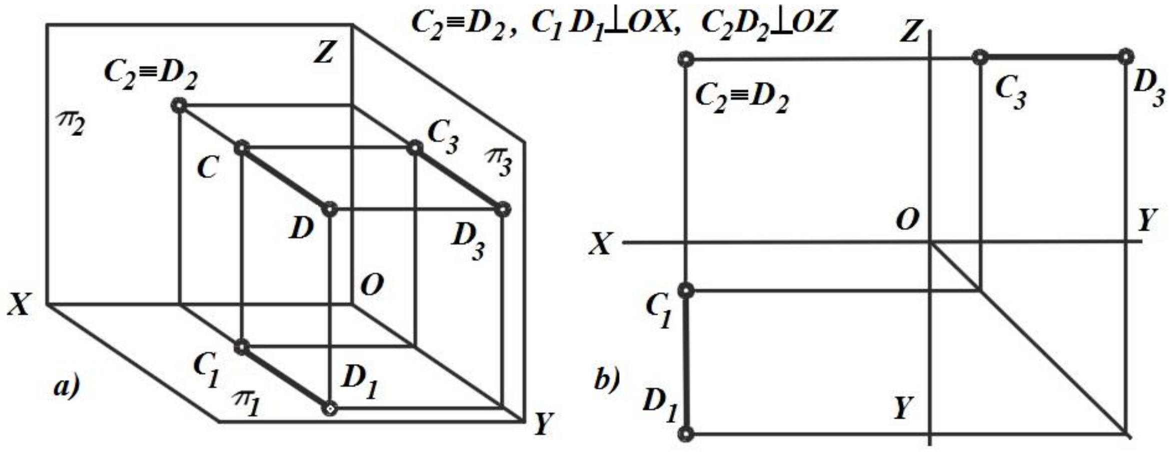


Figure 1.14

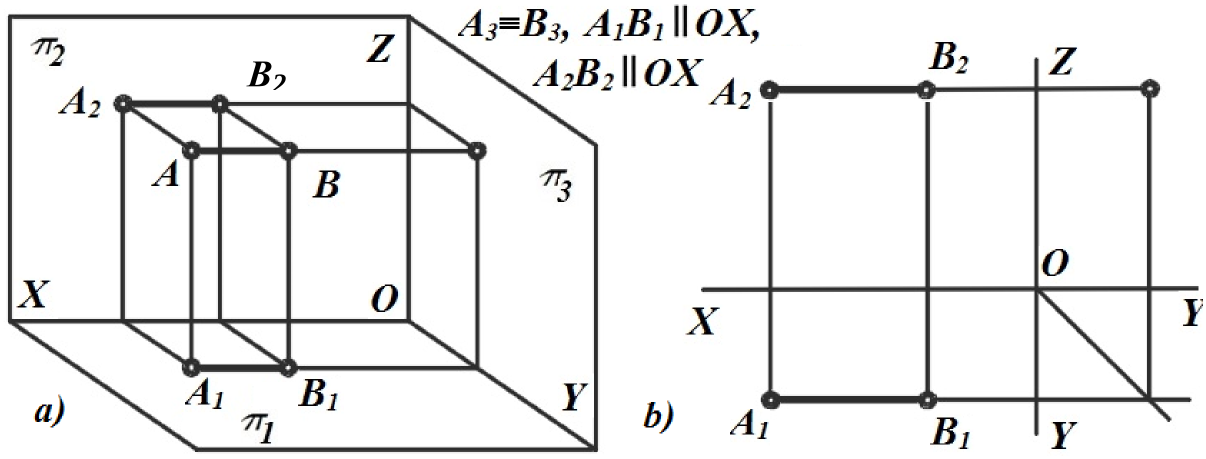


Figure 1.15

1.3 Point on a line

If a point belongs to the line, the projections of this point lie on the corresponding projections of the line. In a parallel projection ratio of segments of straight line is equal to the ratio of their projections (see Figure 1.16). Since the lines AA_0, CC_0, BB_0 are parallel to each other, according to Thales' theorem, $\frac{AC}{CB} = \frac{A_0C_0}{C_0B_0}$.

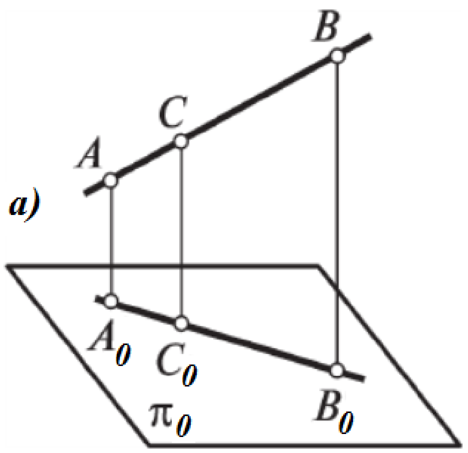


Figure 1.16

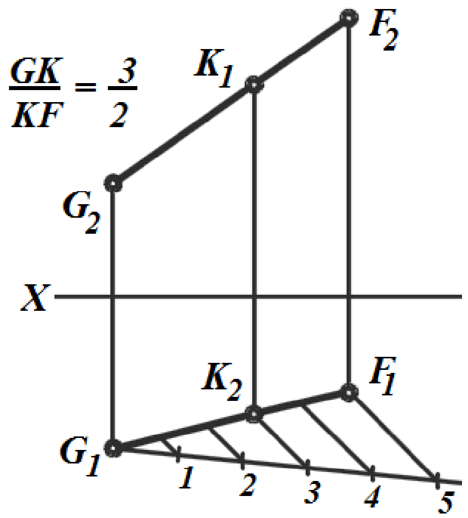


Figure 1.17

This property can be used to divide a line segment at a predetermined ratio (see Figure 1.17).

1.4 Line traces

Point of intersection of a line with the plane of projection is called the trace of the line (see Figure 1.18). Horizontal projection of horizontal trace (point M_1)

coincides with the trace itself, and frontal projection of this track M_2 lies on the axis X. Frontal projection of front track N_2 coincides with the trace of N, and the

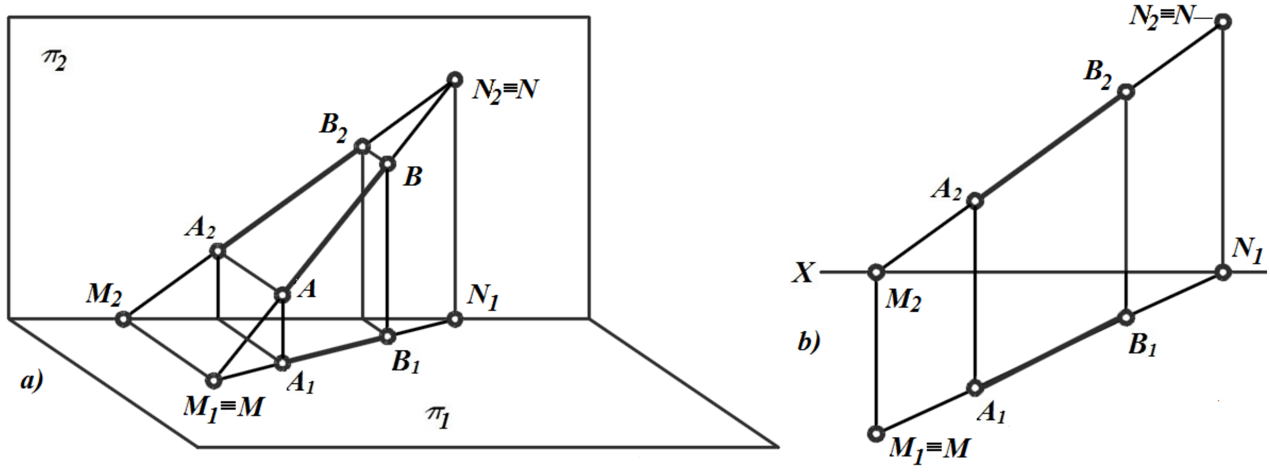


Figure 1.18

horizontal projection of N_1 lies on the same projection axis X.

Therefore, in order to find the horizontal trace, we must continue frontal projection A_2B_2 to the intersection with the X-axis and through the point M_2 draw a perpendicular to the axis X to the intersection with the extension of the horizontal projection A_1B_1. Point $M \equiv M_1$ is horizontal trace of the line AB. Similarly, we find the frontal trace $N \equiv N_2$.

1.5 Mutual arrangement of two lines

Two lines in space may be parallel, intersecting or crossing.

If two lines in space parallel to each other, then their projections on the plane are also parallel to each other (see Figure 1.19). The converse statement is not always true (compare the lines C_0D_0 and CD in the figure).

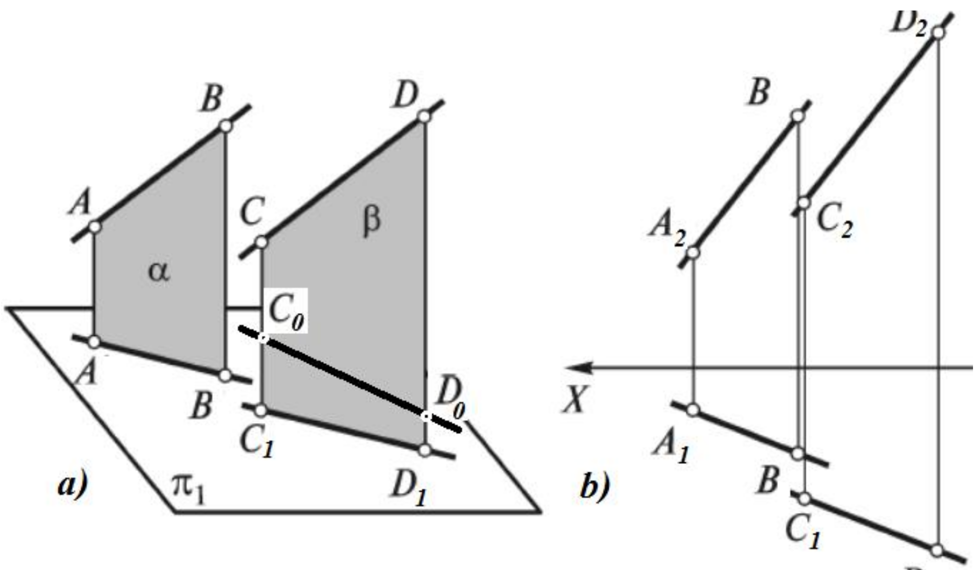


Figure 1.19

If lines intersect, then their same named projections intersect with each other at a point, which is the projection of the point of intersection of these lines (see Figure 1.20).

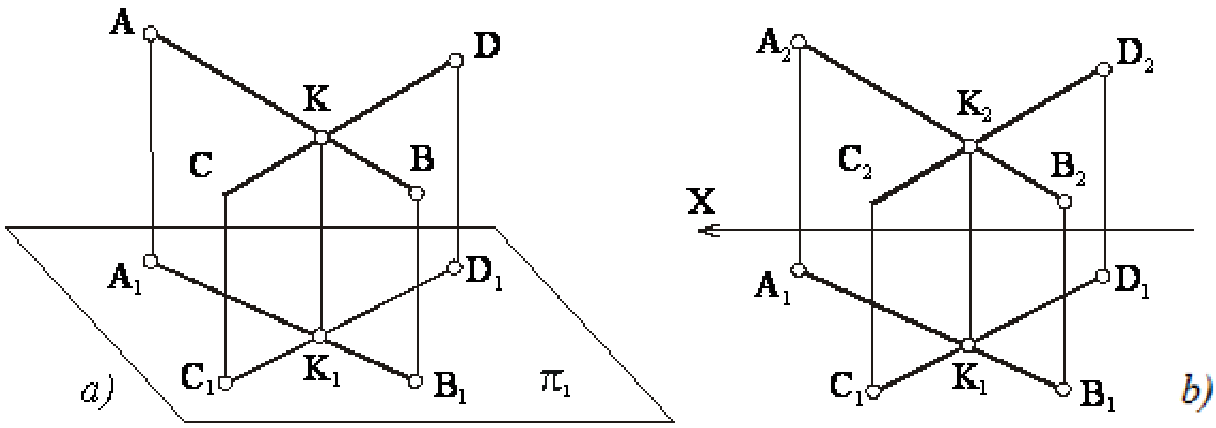


Figure 1.20

Crossing lines do not intersect and are not parallel with each other the (see Figure 1.21). As shown in the figure, the point with projections K_2 and K_1 belong to *AB*, while the point with projections L_2 and L_1 belongs *CD*. These points are equidistant from π_2, but their distances from π_1 are different: point *L* is located higher than point *K*. Points *L* and *K* are competing points.

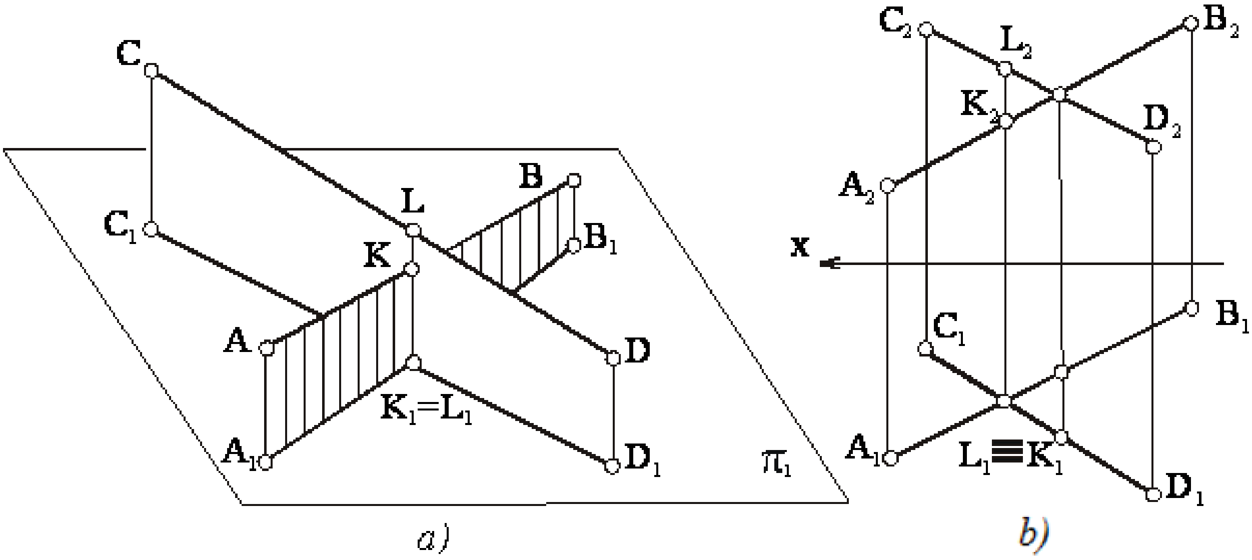


Figure 1.21

2 Lecture №2. Projections of a plane on the drawing

Content of lecture: ways to specify projection of the plane on the drawing; plane in general and special positions; projections of flat angles; projection of parallel and intersecting planes**.**

Objectives of the lecture: to explore the ways of planes projections construction in the drawing and mutual positioning of planes.

2.1 Methods of setting the plane on the drawing

The plane on the drawing can be given:

a) with projections of 3 points, which do not lie on the one line (see fig 2.1,*a*);

b) with projections of the line and point taken out of the line (see fig 2.1,*b*);

c) with projections of two intersecting lines (see fig. 2.1,*c*);

d) with projections of two parallel lines (see fig 2.1,*d*);

e) with projections of any flat shapes - triangle, polygon, circle, etc. (see fig 2.1,*e*);

f) with line traces, which are defined as the intersection lines of considered plane with the planes of projections (see fig. 2.1,*f*).

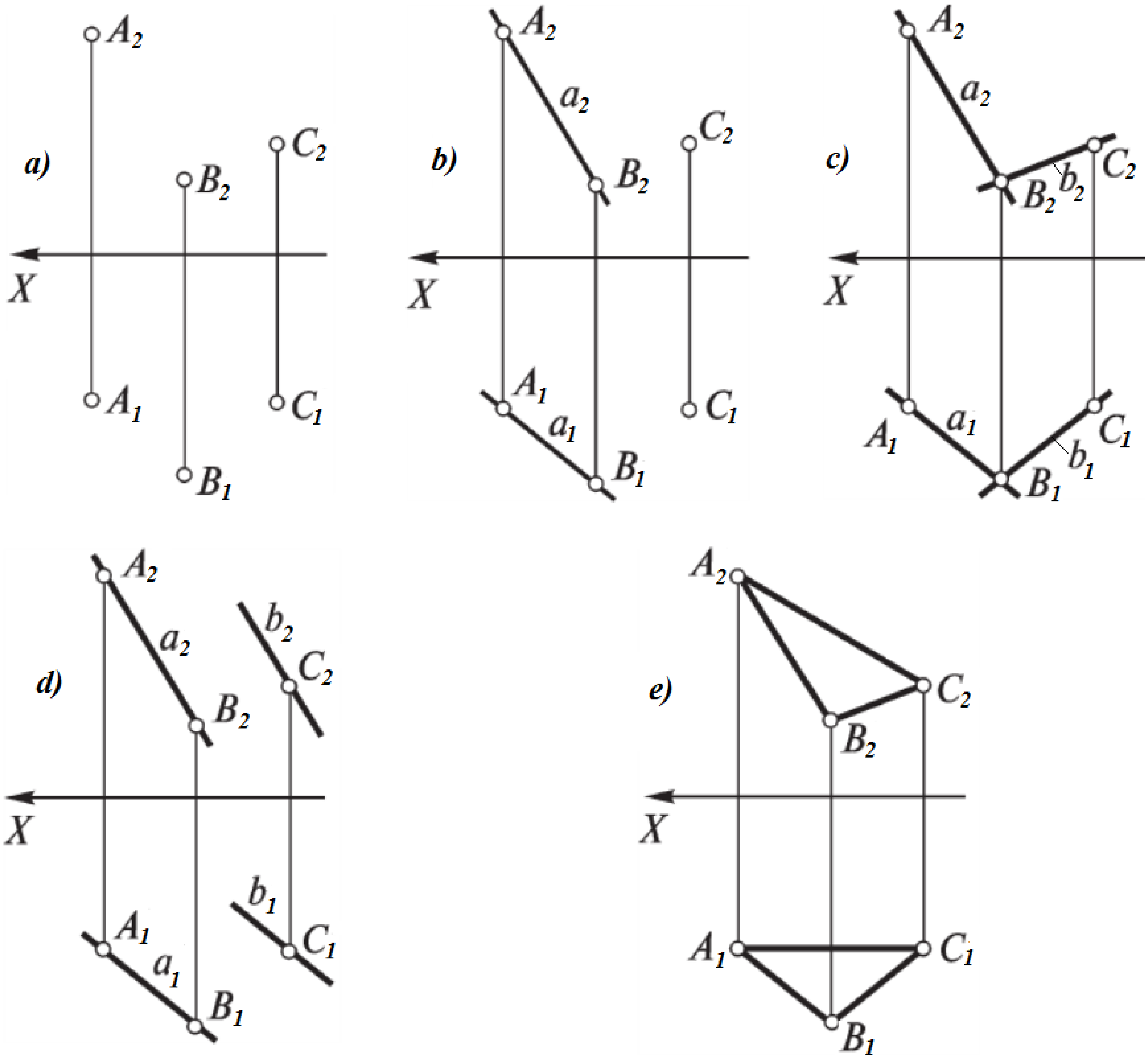
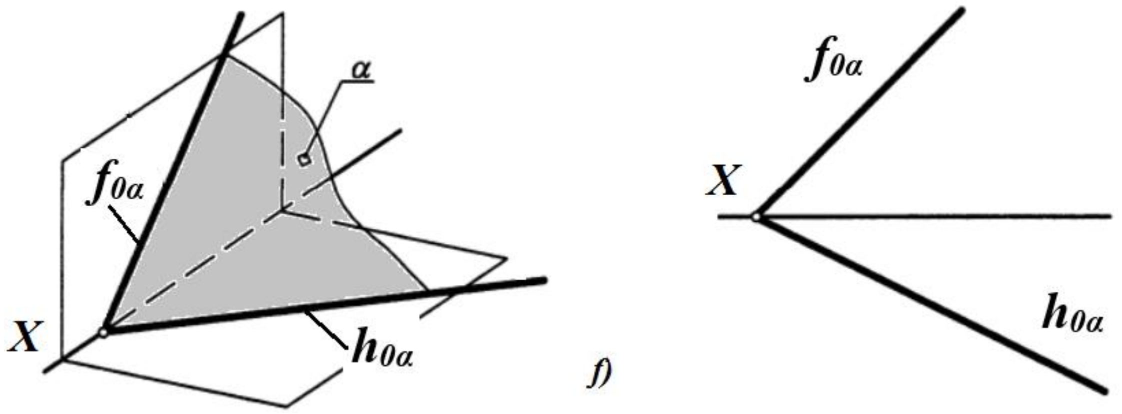


Figure 2.1

Continuation of Figure 2.1



2.2 Projections of planes of special position

If the plane is not parallel or perpendicular to any of the planes of projection, it is called the plane of general position.

A plane parallel to the plane π_1 is called the horizontal plane. Such plane γ *(ABC)* is shown at Figure 2.2. Front projection of this figure is a line parallel to the *X*-axis and coinciding with the front trace $f_0\gamma$ of plane and the horizontal projection of $\gamma_1 (A_1B_1C_1)$ is equal to the figure itself.

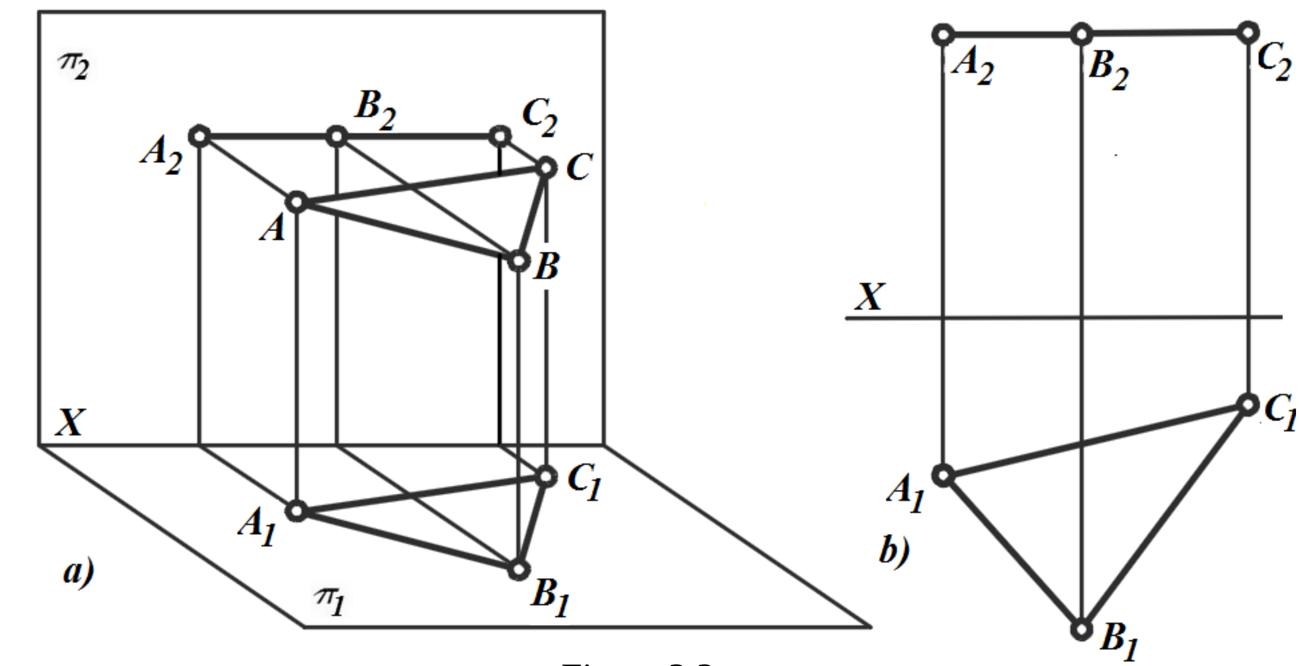


Figure 2.2

A plane parallel to the plane π_2 is called the frontal plane (see figure below 2.3). Its horizontal projection is a straight line parallel to the axis *X*, and its front projection is equal to the figure itself.

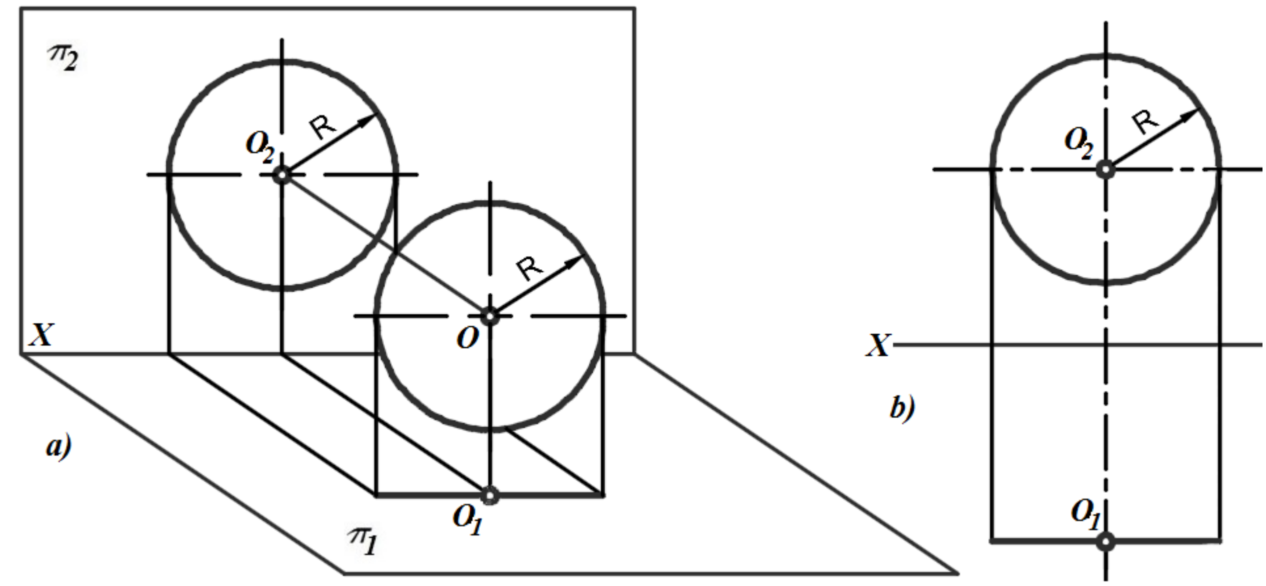


Figure 2.3

A plane parallel to the plane π_3 is called the profile plane (see Fig.2.4).

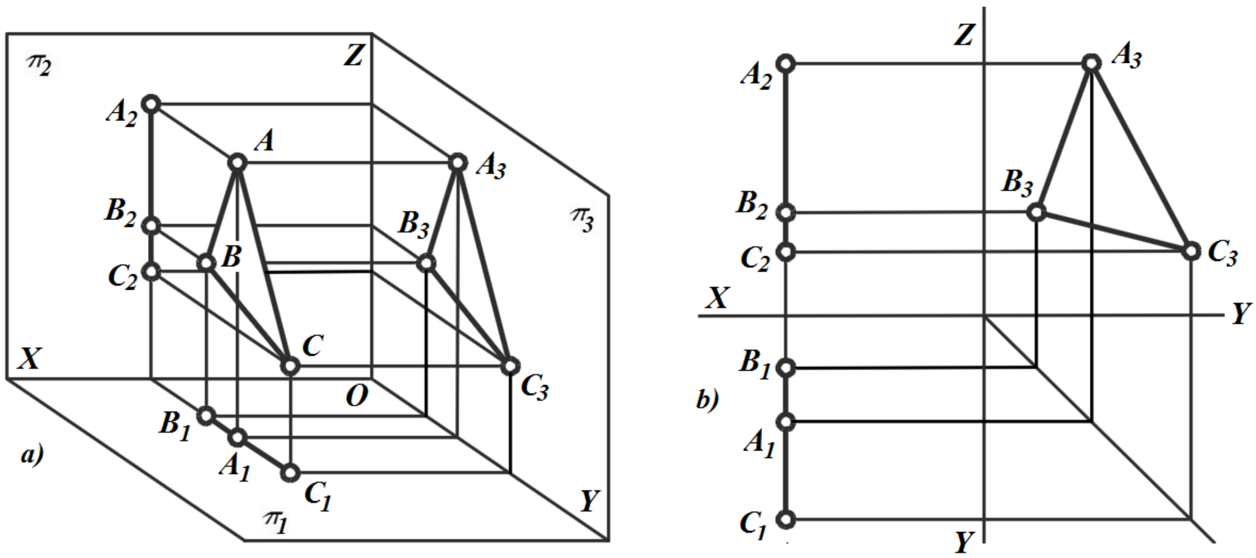


Figure 2.4

A plane perpendicular to π_1 (but not parallel to π_2 or π_2) is called the horizontal projecting plane. In Figure 2.5 a horizontal projecting plane β is set by traces. Front trace of such $f_{o\beta}$ plane is perpendicular to the X -axis and the horizontal trace $h_{o\beta}$ has a collective property: the horizontal projection of any point, line or plane figure, belonged to the plane β, coincides with the trace $h_{o\beta}$.

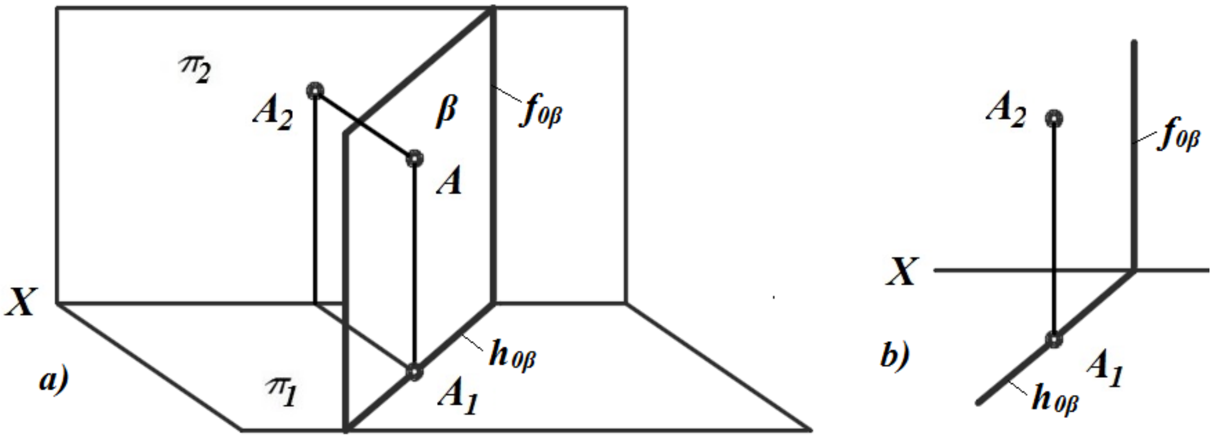


Figure 2.5

A plane perpendicular to the plane π_2 (but not parallel to the plane π_1 or π_3), is called frontally projecting plane (see Figure 2.6).

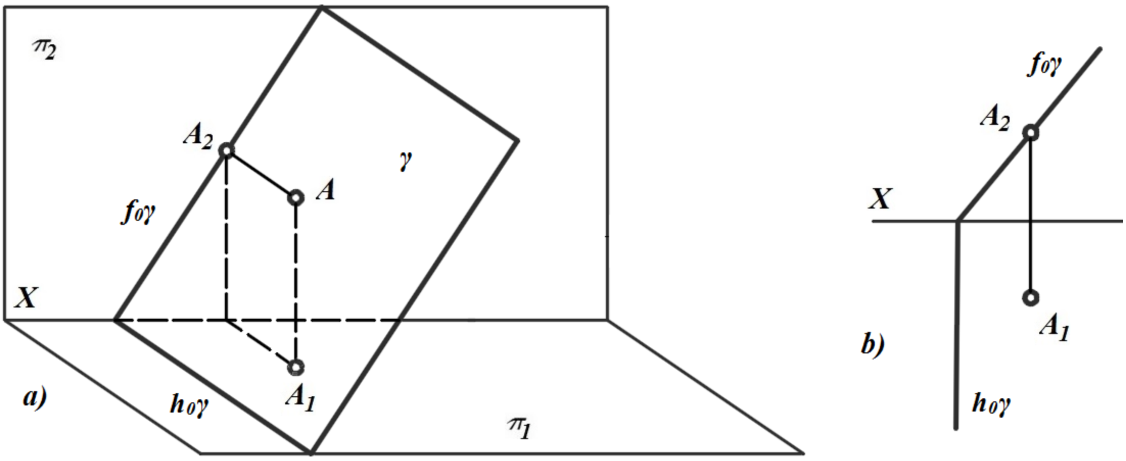


Figure 2.6

A plane perpendicular to the plane π_3 (but not parallel to the plane π_1 and π_2) is called profile-projecting plane (see Figure 2.7).

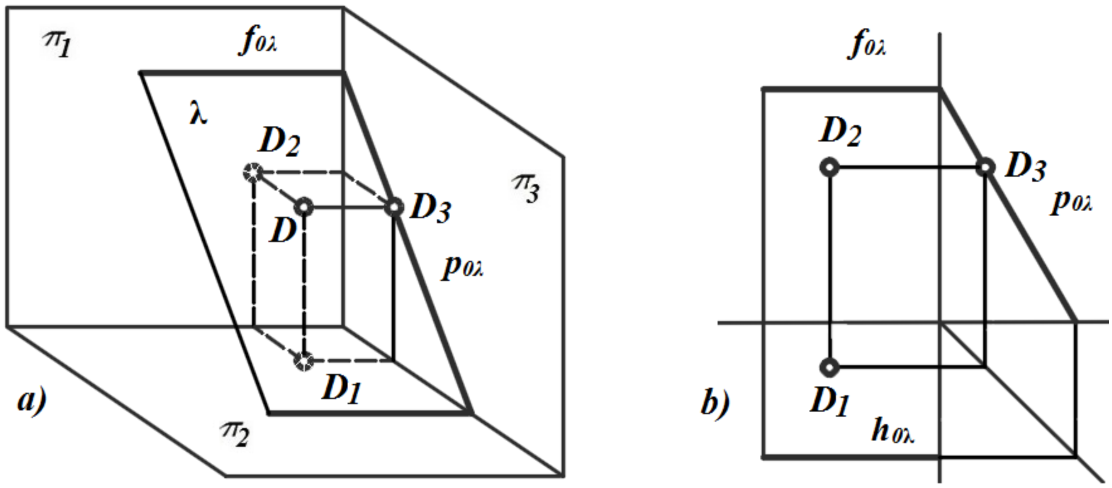


Figure 2.7

2.3 Projections of plane angles

If the plane γ, which contains some angle ABC, is perpendicular to the projection plane, the angle is projected to this plane as a straight line (see Figure 2.8).

If the plane of a *right* angle is not perpendicular to projection plane of and at least one of its sides is parallel to it, then the right angle is projected onto this projection plane as a right angle (see Figure 2.9).

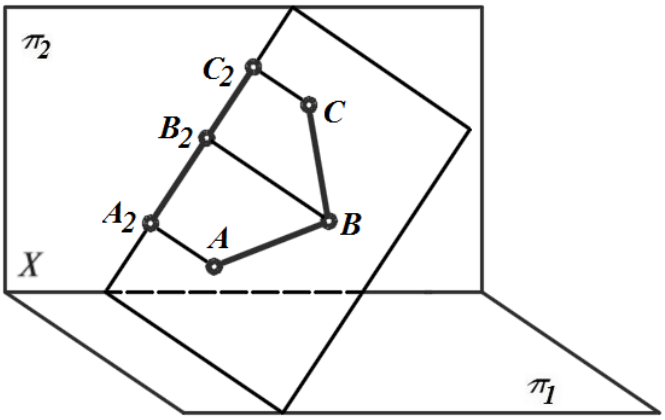


Figure 2.8

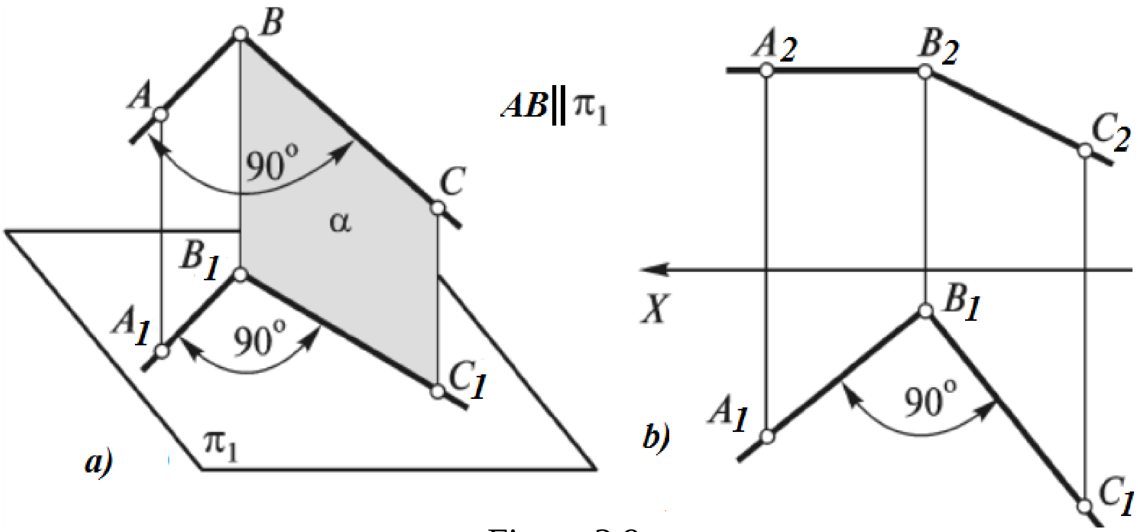


Figure 2.9

The considered features of projecting of a right angle are widely used in problems solving. For example, two intersecting horizontal h and frontal f will make the plane γ. If to draw from any point a line l, perpendicular to h and f (see Figure 2.10), then this line will be perpendicular to the plane γ.

2.4 Mutual position of two planes

Two planes can be parallel or intersecting.

If the planes are parallel, then in each of them one can construct two intersecting straight lines so that the lines are respectively parallel to two lines of the other plane.

In Figure 2.11 the plane β is given as triangle ABC, and the plane γ is given with two intersecting lines m and n. In order to plane β and γ be parallel to each other, it is sufficient that m and n are parallel, for example, to the sides of the triangle ABC: $m \| AB$, $n \| AC$. Lines can be parallel to any other line lying in the plane $\beta(ABC)$.

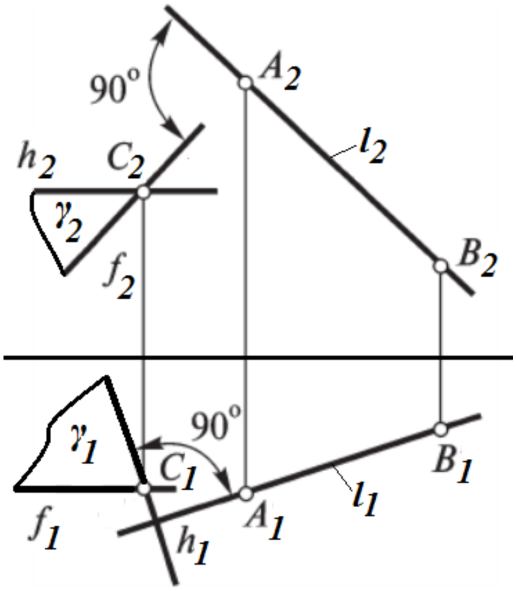


Figure 2.10

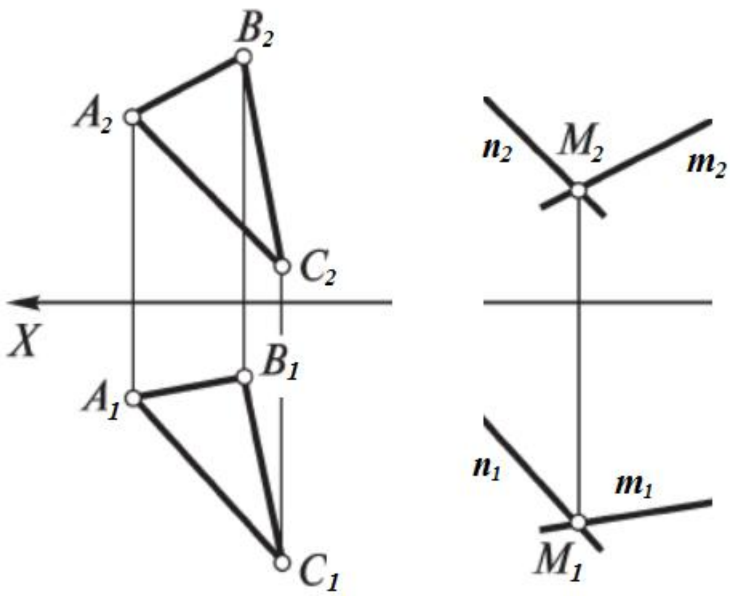


Figure 2.11

If the planes are given by their traces, then for parallelism of the planes is needed their traces to be parallel to each other (see Figure 2.12), i.e. $f_{0\gamma} \| f_{0\beta}$, $h_{0\gamma} \| h_{0\beta}$.

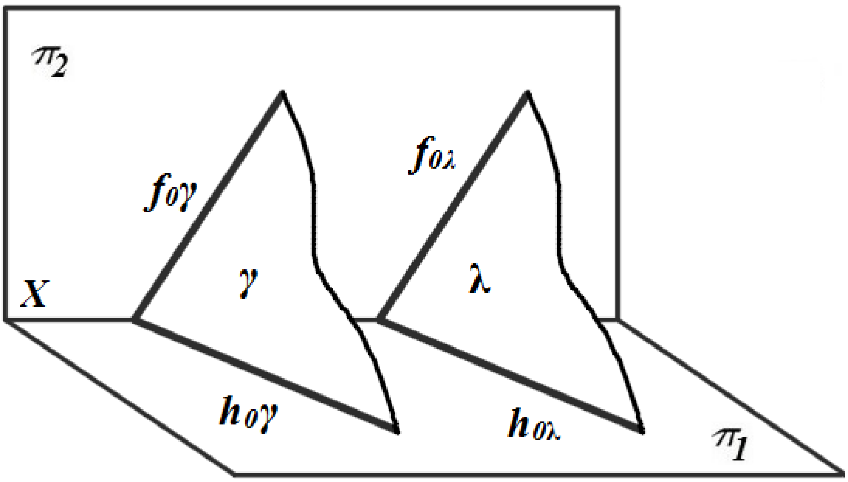


Figure 2.12

If traces of planes are parallel to the *X*-axis, these planes can be parallel or intersecting. For an unambiguous answer is needed to build a third, profile, traces.

In the lecture the issues related to the definition of the relative position of the plane and the line, plane and the point are considered.

3 Lecture №3. Methods of transformation of the orthogonal projections. Solution of metric and positional tasks

Contents of lecture: method of replacing projections planes and the method of rotation around the projecting lines; notions of metric and positional tasks and workarounds.

Objectives of the lecture: to consider the concepts on methods to transform the orthogonal projections, to classify geometric tasks and consider the solution of some of them.

Transformation of the orthogonal projections is using to bring the given geometric elements on the epure to a new position relative to the plane of projection, more convenient to solve a particular task.

3.1 Method of replacing the projection planes

The method consists in that the additional projection plane is inserted and there occur transition to another system of the projection planes, wherein geometrical images in the space retain their position. While replacing, the mutual perpendicularity of two projection planes surely remains.

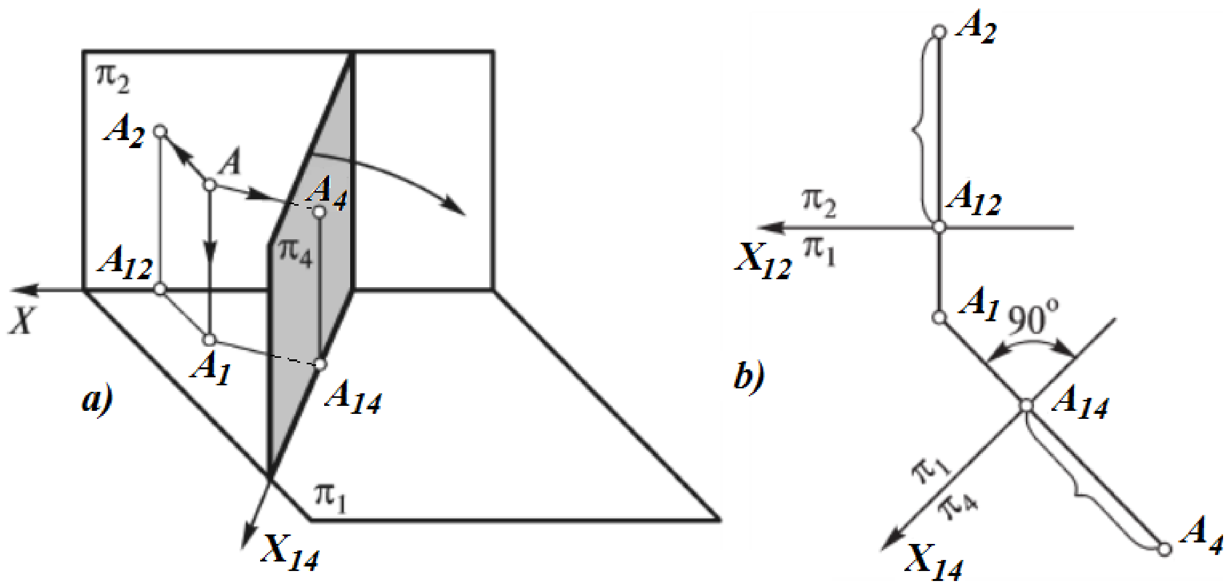


Figure 3.1

Let's a point A and a system of two projection planes π_1 and π_2 are given (see Figure 3.1,*a*). We insert the plane $\pi_4 \perp \pi_1$ and not perpendicular to π_2. Point A_4 is the projection of the point A on the π_4. We get two systems of projection planes: main π_1-π_2 and additional π_1-π_4. Upon the transition from one system of projection planes to the other, applicate Z_1 of the point A and its horizontal projection A_1 remain unchanged (invariant) for the two systems. Figure 3.1,*b* demonstrates the operation of transition from one system of planes to the other in the orthographic drawing (on epure). For plot projection A_4 of the point A on the plane π_4 based on given projections A_1, A_2 on epure and a new axis of projection x_{14}, it is necessary:

1) from the horizontal projections of the point A_1 to drop a perpendicular to the new axis of projection x_{14};

2) from the point A_{14} on this perpendicular to measure the Z_A coordinate of the point A, i.e, $A_{14}\,A_4 = A_{12}A_2 = Z_A$.

Note that you cannot change the two projection planes at once. The new projection plane must remain perpendicularity to the remainder plane. Therefore, replacement of the planes can be made only in sequential order: first replace one plane, then the other. The operation can be repeated many times, if it is required for solving the task.

Example 3.1 - In Figure 3.2 it is shown the determination of the length of a line segment *AB* in general position.

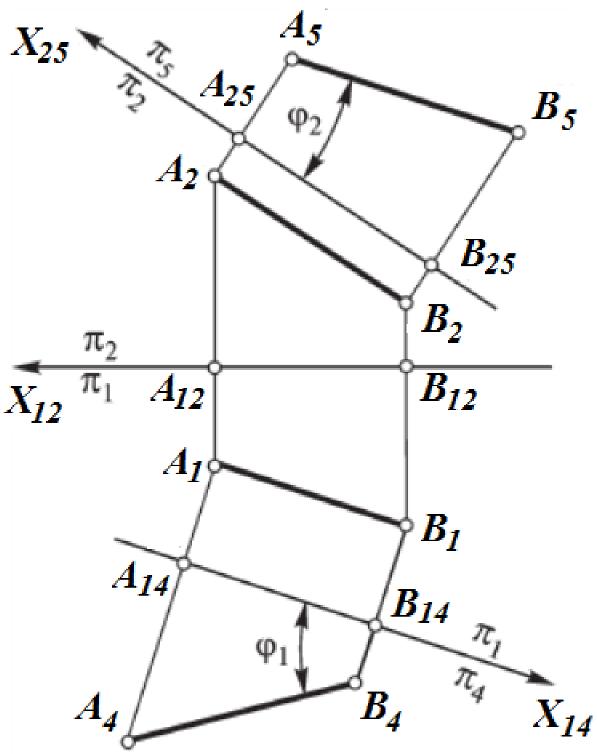


Figure 3.2

In order the line *AB* in general position become the line of the level, we introduce a new plane π_4 (or π_5), which would be parallel to it. In the drawing, an additional plane π_4 is perpendicular to the plane π_1 and parallel to the line *AB* (the axis X_{14} of π_1/π_4 is parallel to projection A_1B_1) , and then the line *AB* is a frontal in the system π_1-π_4. Through the points A_1 and B_1 we conduct new connection lines, perpendicular to the axis X_{14}. Distance from the axis X_{14} to the A_4 and B_4 is equal to the distance from the A_2 and B_2 to the axis X_{12}. The resulting system of projection planes π_1/π_4 the line *AB* (A_4B_4) is a level line, i.e. the true size of the segment *AB* .

Similarly, you can convert the line *AB* to the horizontal. To do this, we leave π_2 in its and replace π_1 to π_5, parallel to *AB* and perpendicular to the π_2. Now, the line *AB* is a level in the system π_2/π_5, and A_5B_5 is the true size of *AB*.

3.2 Method of rotation around an axis, perpendicular to the plane of projection

The method consists in that the given figure is rotated around an axis, perpendicular to the plane of projection, in order to bring it into particular position with respect to the original unchangeable position of projection planes.

Let us see how the position of point *A* changes as it rotates around the axis *i*, perpendicular to π_1 (see Figure 3.3). Point

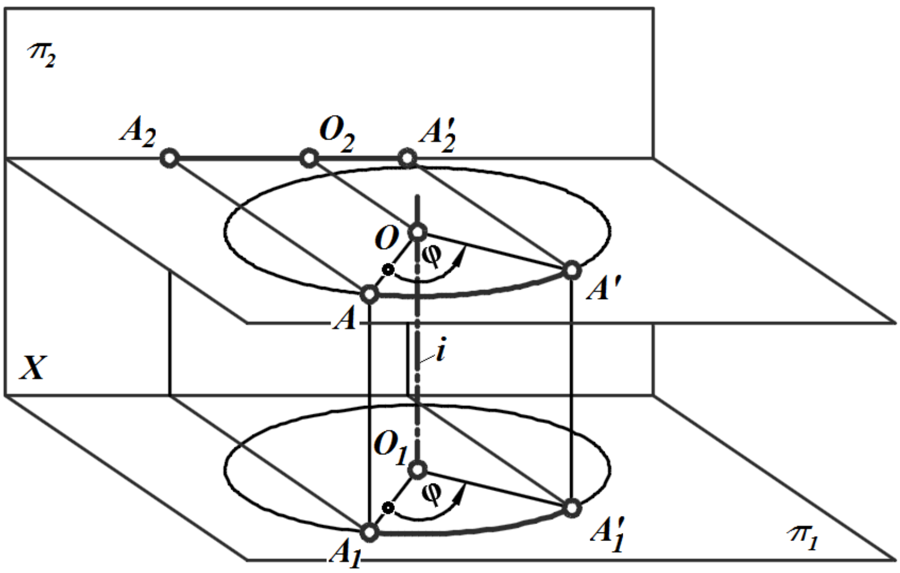


Figure 3.3

A moves along a circular arc in the plane α ($\alpha \perp i$, and hence, $\alpha \parallel \pi_1$), so this circle is projected onto a plane π_1 without distortion, while on the plane π_2 - a segment of straight line, parallel to the axis X. Thus, if point A moves around the axis i along the arc of radius R at an angle φ, then it takes the position A'. The horizontal projection A_1 turns around the center O_1 by the same angle φ and takes the position A_1'. Front projection of the point A_2 will move along the straight line, parallel to the axis X, and takes the position A_2'. On the epure that will look as shown in Figure 3.4.

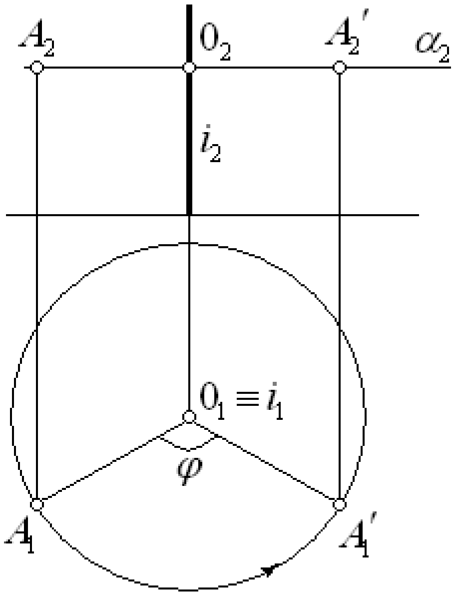


Figure 3.4

Similarly, we can perform a rotation around an axis, perpendicular to the frontal plane π_2. Here, a frontal projection of the point moves along a circular arc, and the horizontal projection – along the line, parallel to the axis X. A method of rotation of geometric shapes around the axes perpendicular to the plane of projection is widely used in solving geometrical problems.

Example 3.2 - Figure 3.5 shows the determining the length of the line segment AB using the method of rotation around a horizontal- projecting axis i, passing through point B. While the rotation the point B remains stationary, because it lies on the axis of rotation, wherein a horizontal projection of the point A describes the circle of radius A_1B_1, and its front projection shifts parallel to the axis X. Thus, we rotate the projection A_1B_1 around the point B_1 as long as it will be parallel to the axis X (B_1A_1'), wherein the point A_2 comes to the position A_2', and then segment B_2A_2' represents the natural interval value of segment AB, and the angle α - angle of slope of the line AB to the plane of projection π_1.

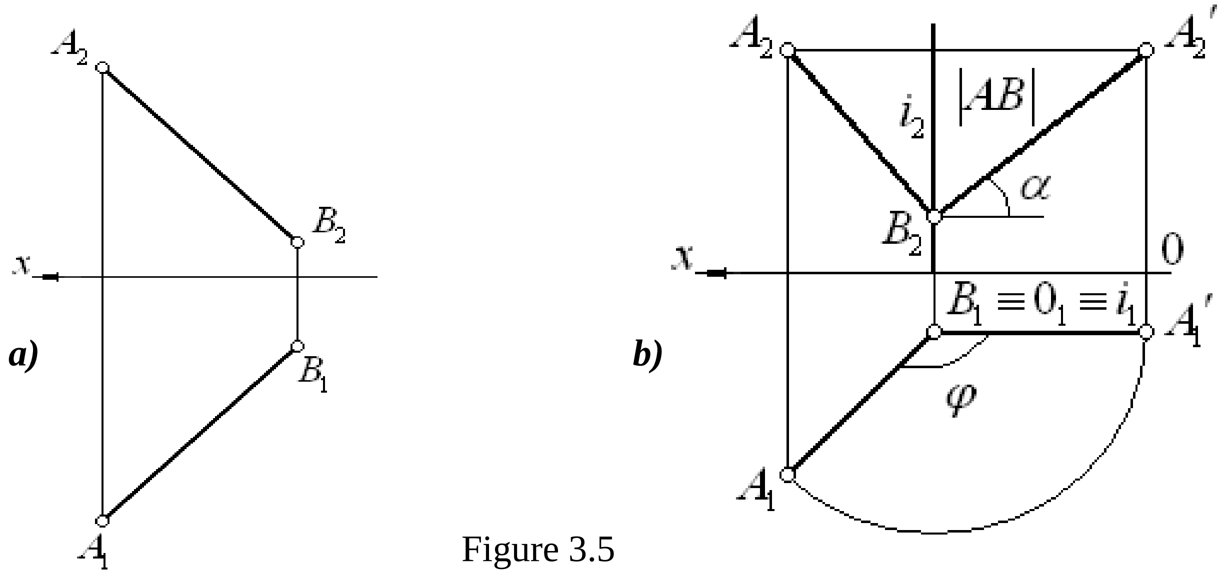


Figure 3.5

3.3 Classification of geometric tasks

All tasks of TCD (theory of constructing the drawings) can be divided into positional and metric.

Positional tasks consist in determining the belonging and constructing mutual intersections of geometric shapes.

Tasks on determining the belonging of one geometric shape to another one can be divided into three types:

a) belonging of a point to a line ($A \in l$);

b) belonging of a point to a surface ($A \in \alpha$);

c) belonging of a line to a surface ($l \in \alpha$).

Problems on construction of intersections of geometric shapes fall into two groups:

a) crossing of the line with the surface ($l \cap \alpha$);

b) mutual intersection of surfaces ($\alpha \cap \beta$);

Metric tasks are tasks, the solutions of which are related to determining any metric properties of figures (lengths of lines, angles, areas, volumes, etc.) in the drawing.

The most difficult tasks, the solution of which use metric and as well as positional properties of figures, are complex.

In the parallel (orthogonal) projection geometric images, randomly arranged in space, project onto the plane of projection with distortion. In this case, the projections of values of their linear and angular characteristics are distorted .

Determining undistorted values of the linear and angular characteristics of the figures, arbitrarily arranged in space, from their projections represent a class of metrical problems.

Many metric and complex problems, which meet in practice, can be solved using standard techniques. Algorithms for solving all metric problems are based on two invariants of orthogonal projection:

a) theorem about projecting the right angle ;

b) property of any plane figure to be projected without distortion (in congruent figures) on a projection plane, which is parallel to this figure, i.e. $(\Phi \subset \beta) \wedge (\beta \,||\, \pi_1) \Rightarrow \Phi_1 \cong \Phi$.

All metric tasks can be assigned to one of three groups:

a) tasks on the determination of distances from a point to another point, to a line, to a plane, to the surface, and from a line to a plane;

b) tasks on the determination of the angles between :

- intersecting or crossing straight lines;
- lines and planes;
- planes (the determination of the dihedral angle);

c) tasks on the determining the values of plane figures.

3.4 Solution of some geometric tasks

Example 3.3 – Determine the distance from point *D* to the plane of the triangle *ABC* (see Figure 3.6).

Solution. Using the method of replacing the projection planes, transfer the given plane in general position into the projecting position, by adding a horizontal into the plane and entering the plane of the projections π_4, perpendicular to the horizontal ($X_{14} \perp h_1$).

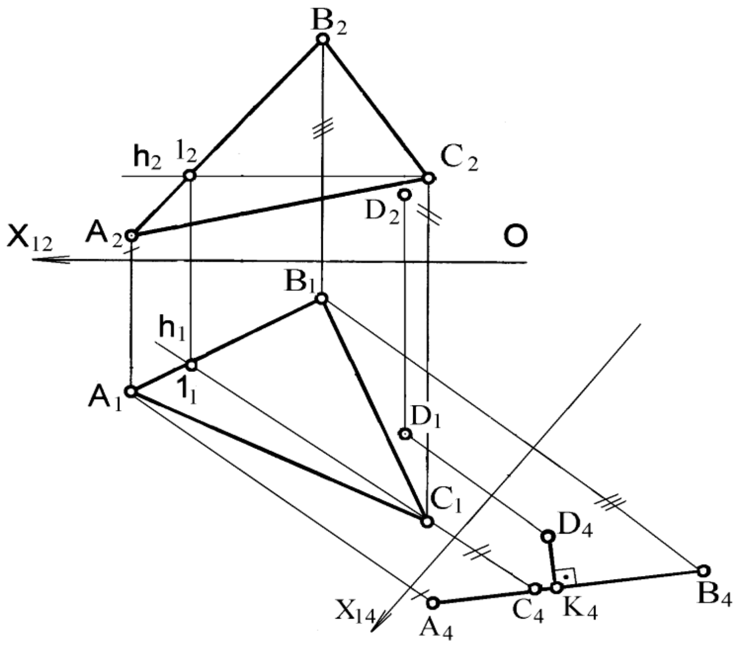


Figure 3.6

Given: $\alpha(ABC)$, ***D*.** **Required to determine:** $[D \cdot \alpha\ (ABC)]$.	**Algorithm of solving the task (AST):** **1)** $h \subset \alpha\ (ABC)$]; **2)** $\pi_4 \perp h \rightarrow X_{14} \perp h_1$; **3)** D_4, A_4, B_4, C_4; **4)** $D_4K_4 \perp A_4B_4$; **5)** $D_4K_4 = [D \cdot \alpha]$.

Example 3.4 – Determine the shortest distance between the crossing straight lines (see Figure 3.7).

Solution. Transfer one of the lines in general position in the projecting position, using two replacements of projection planes, the first replacement is used to transfer the line *DE* in the position of the level straight, and the second replacement is used to transfer it into a projecting position.

Given: ***AB*, *DE*.** **Required to determine:** $[(AB) \bullet (DE)]$, $\{(AB)\text{-}DE)\}$.	**AST:** **1)** $\pi_4 \| DE \rightarrow x_{14} \| D_1E_1$; **2)** A_4B_4, D_4E_4; **3)** $\pi_5 \perp DE \rightarrow x_{45} \perp D_4E_4$; **4)** D_5E_5, A_5B_5; **5)** $D_5C_5 \perp A_5B_5$; **6)** $D_5C_5 = [(AB) \bullet (DE)]$.

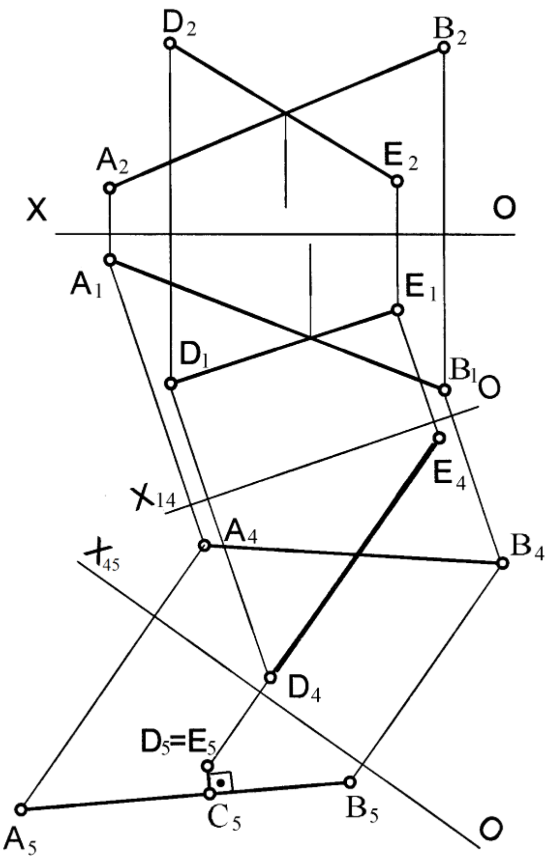


Figure 3.7

Example 3.5 –Determine the point of intersection of a straight line with the plane (see Figure 3.8,*a*), and considering that the plane is nontransparent, to determine the visibility of the line.

Given: b, γ **(*ABC*).** **Required to determine:** $b \cap \gamma$ **(*ABC*).**	**AST:** **1)** $\alpha \supset b, \alpha \perp \pi_2 \rightarrow \alpha_2 \equiv b_2$; **2)** $m = \alpha \cap \gamma, m_2 \equiv \alpha_2 \equiv b_2$; **3)** $1_2 = m_2 \cap A_2C_2 \wedge 2_2 = m_2 \cap B_2C_2$; **4)** $\updownarrow 1_1 \subset A_1C_1 \wedge 2_1 \subset B_1C_1$; **5)** $m_1 = 1_1 \cup 2_1$; **6)** $K_1 = b_1 \cap m_1$; **7)** $K_2 \subset b_2$; **8)** $K = b \cap \gamma$ **(*ABC*).**

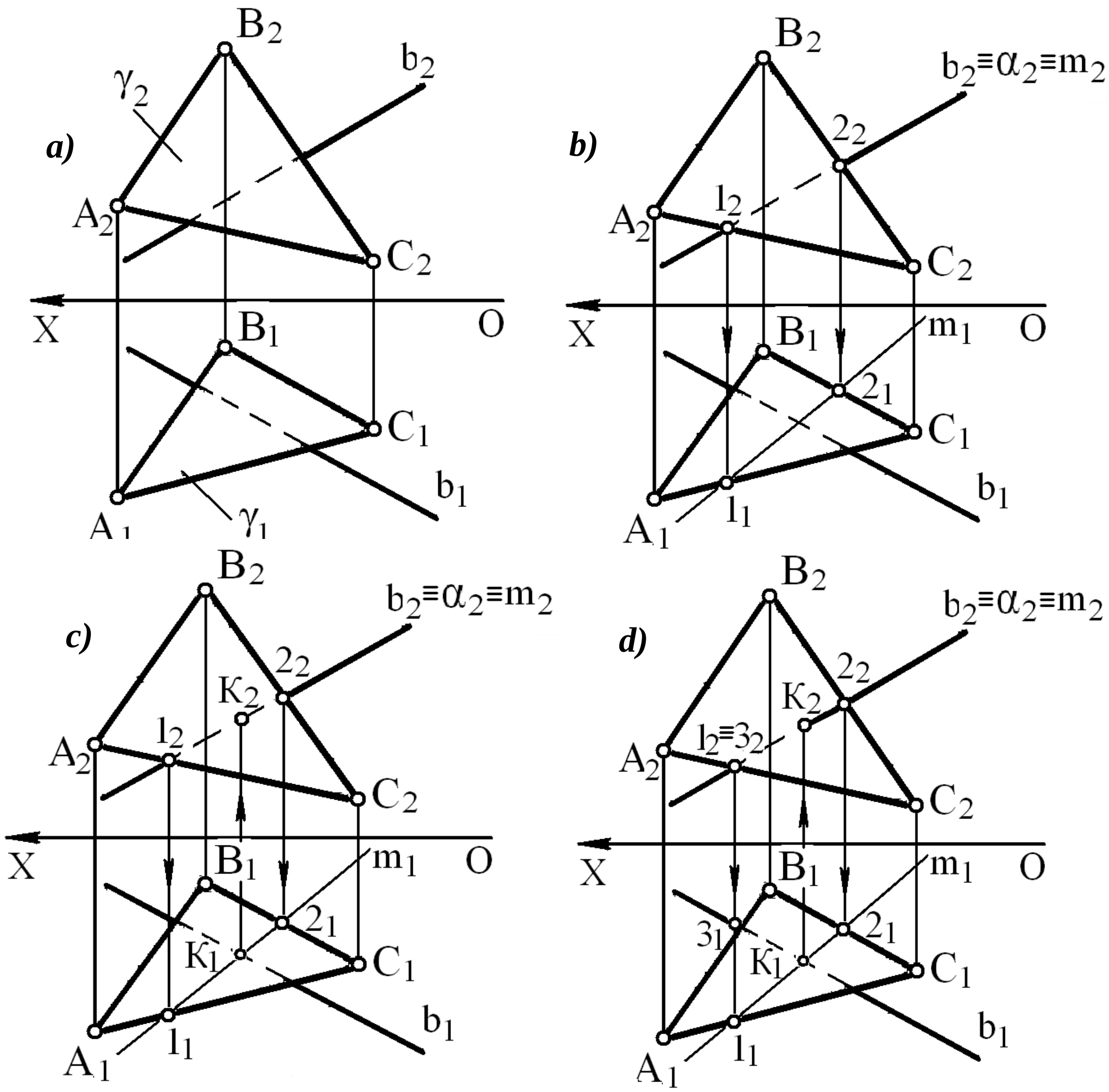


Figure 3.8

4 Lecture №4. General concepts of surfaces. Elements of the 3D modeling in AutoCAD

Content of lecture: surfaces and their formation. Formation of three-dimensional objects in AutoCAD. Construction of bodies models.

Objectives of the lecture: to give general concepts about surfaces and their formation, to consider the basics of working with three-dimensional objects in the AutoCAD system.

4.1 Some information about surfaces

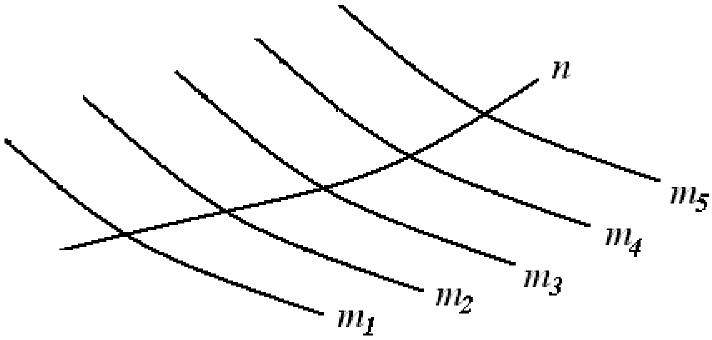


Figure 4.1

In TCD surface (see Figure 4.1) is considered as a sequence of successive positions of the moving line (a generator) or other surface in space. Generators can be straight and crooked, the lasts can be constant and variable. The same surface can often be created with the movements of various generators. One shows only some positions of generator on the drawing. Line, intersection with which is a necessary condition of movement of generator when forming surface, is called guiding (sometimes is used the line on which is moving the point not belonging to the generator). Of the various forms of generators, guiding lines, as well as rules of formation of surfaces, the most simple and convenient are chosen for the imaging surface and solving problems associated with it.

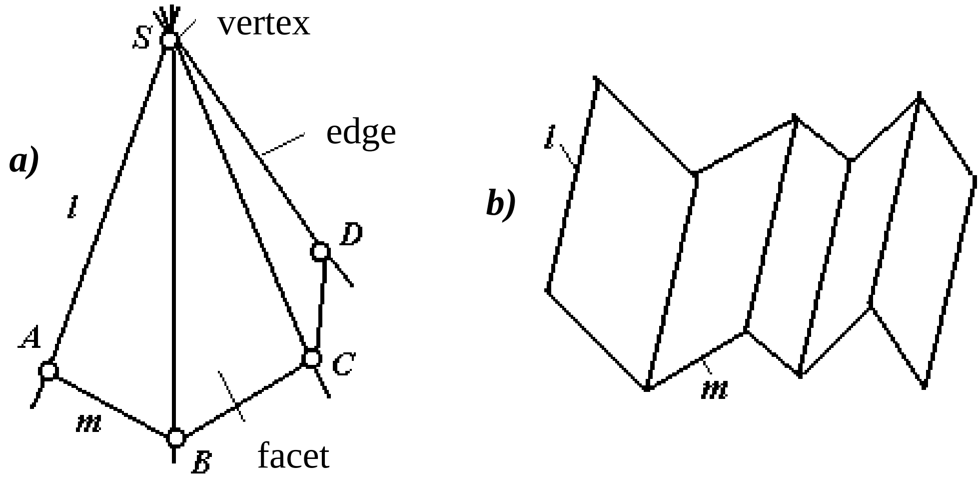


Figure 4.2

Let us consider the classification of surfaces, adopted in TCD.

Surface, which can be formed by the movement of a straight line, is called a ruled surface (RS). RS, which can be deployed so that it is aligned with the plane without breaks and folds with all its points, is called deployable. To deployable surfaces we include RS, in which adjacent rectilinear generators are parallel or intersect with each other, or the tangent to a space curve. The rest of the RS and all non-ruled surfaces are non-deployable. Deployable surfaces - multifaceted, cylindrical, conical and surface with the edge of regression (torso).

Multifaceted (or polyhedral) surfaces are formed by moving a straight generator on sloping guiding line (see Figure 4.2). If one point of generator is fixed, we will get pyramidal surface, if generator is parallel to the given direction - prismatic. Closed face surfaces form polyhedron. Facets - flat polygons, edges - the line of intersection of faces, vertexes - ends of edges (point of intersection). Pyramid - polygon at the base and other faces - triangles with a common vertex. Straight pyramid - if the vertex is projected into the center of the base. Correct - if the base is a regular polygon. Prism - two identical faces in parallel planes, and the rest - parallelograms. A parallelepiped - if the bases are parallelograms. In drawing polyhedron are shown as projections of vertexes, edges and faces. In constructing the images, visibility edges and faces are necessary.

Generators of cylindrical surfaces are always parallel, the guiding line is a curve. Particular cases - a right circular cylinder, an oblique circular cylinder. In conical surfaces all rectilinear generators have a common fixed point - vertex, guiding - anyone curve. Particular cases - a right circular cone, oblique circular cone. In surfaces with edges of return straight generators are tangent to a curvilinear guiding.

Among non-ruled surfaces, we distinguish surface with constant and variable generator. Firsts divide into surface of rotation with a curvilinear generator (sphere, torus, ellipsoid of rotation, etc.) and cyclic surface (surfaces of curved pipes, of springs).

A set of lines or points of a surface define wire-frame surface. Usually these lines are plane curves, which planes are parallel to each other. Two intersecting families of carcass' lines form a mesh frame of surface. Points of intersection of the lines (can be specified by coordinates) form a punctual carcass of the surface. Wire-frame surfaces are used at constructing turbine casings, balloons of cathode-ray tubes and so on (see figure 4.3).

Bodies with surfaces of rotation (SR) are used in many areas of technology: cathode-ray tube, a Dewar flask, etc. Depending on the type of generator, SR can be ruled or non-ruled or consist of the parts of these surfaces. SR is a surface that can be obtained by rotation of a generator around a fixed straight line of the axis (see Figure 4.3), axis is shown as a dash-and-dot line. The concepts of parallels and meridians are introduced for SR. Some SR are particular cases of other surfaces. So, we can talk about the cylinder and cone of rotation. For them, the meridians are straight. For cylinder meridians are parallel to the axis and equidistant from it. For cone meridians intersect the axis in the same point under the same angle to the axis. The surface of rotation and the planes, perpendicular to the axis, limit right circular cylinder and a right circular cone. Meridian of the cylinder is a rectangle, of the cone - triangle. Sphere is a limited surface and can be completely displayed on the drawing. Equator and meridians of a sphere are equal among themselves circles. Torus is obtained by rotating the circle (or arc) about an axis, lying in the plane of the circle, but not passing through its center (distinguish open, closed and self-intersecting torus).

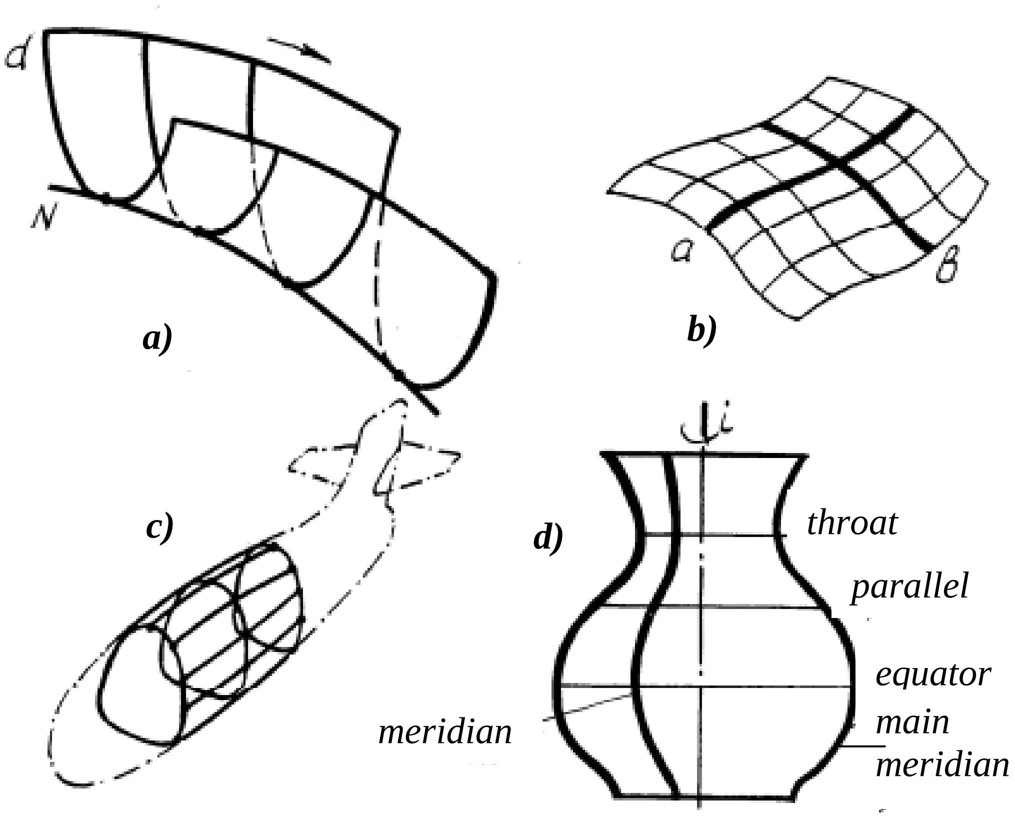


Figure 4.3

In the lecture the solutions of the tasks on determining the position of a point, lying on the surface of a right circular cylinder, right circular cone and a sphere are considered. In addition, the solutions of tasks on intersecting of a plane and of a straight line with these surfaces are considered.

4.2 General concepts of 3D-modeling in AutoCAD

To create 3D objects in CAD systems wire-frame, surface and solid modeling are used. In wire-frame model only object edges are presented, verges are not defined, the model is transparent, and the concept of volume is missing. In surface model, edges and verges are defined. Model is not transparent; it has volume, but has no mass (takes into account the wall thickness). Solid model (SM) allows describing the object more realistic. SM gives full information about the outer edges and the verges of the object, and describes its internal structure; model has volume and mass. SM provides: view from anywhere in the space, performance of the sectioning of the model, automated construction of two-dimensional drawings, obtaining realistic images, addition of material characteristics and external lighting, the solution of physical problems .

4.3 Solid Modeling

Algorithms for creating solid models in AutoCAD are based on the using of three-dimensional primitives or two-dimensional shapes with their subsequent transformation into a three-dimensional model and the transformation of three-dimensional (3D) models using the commands of bodies editing.

There are the following primitives: *Polysolid*, *Box*, *Wedge*, *Cone*, *Sphere*, *Cylinder*, *Pyramid* , *Torus*.

Figures 4.4 - 4.7 show the results of using the methods of creating solid models based on two-dimensional shapes using commands of conversion.

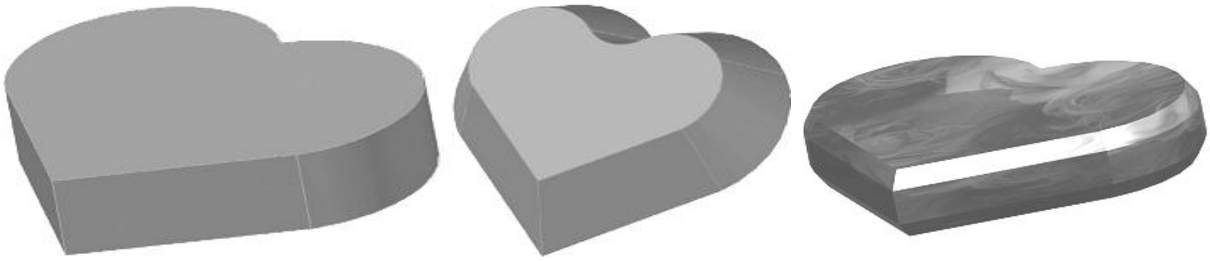


Figure 4.4 – Results of using the command *Extrude*

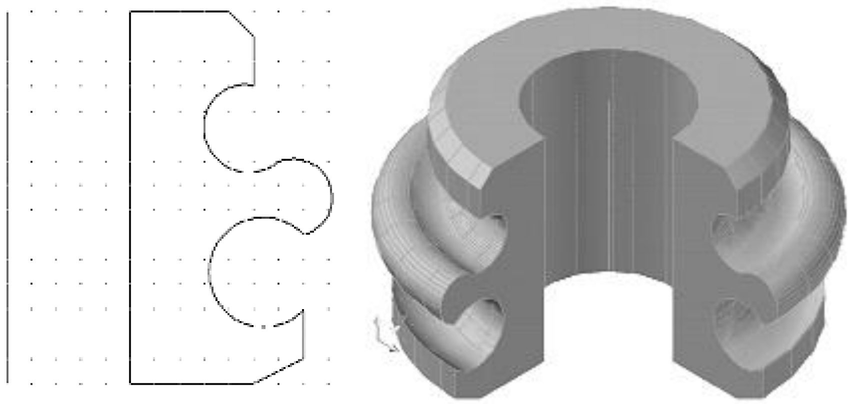


Figure 4.5 – Results of using the command *Revolve*

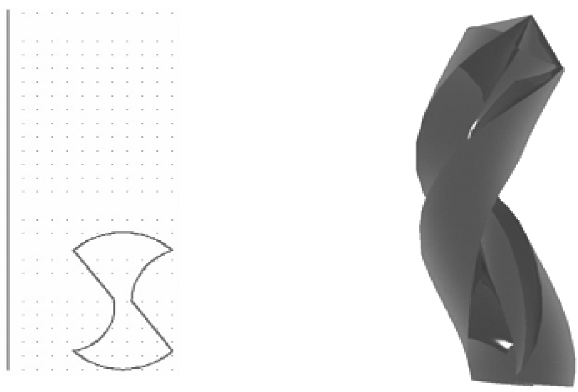


Figure 4.6 – Results of using the command *Sweep*

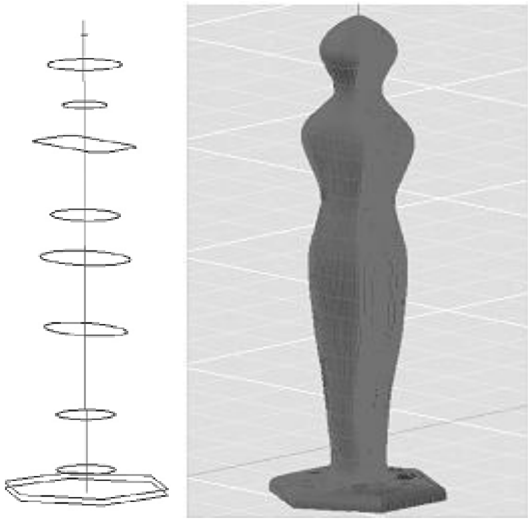


Figure 4.7 – Results of using the command *Loft*

In AutoCAD, there is a possibility to construct a solid model of a composite body with the use of set theory operations, represented by commands *Union, Subtract* and *Intersect.*

Figures 4.8 - 4.10 show the construction of the plate's model using the method of extrusion with the set theory operations. First, two-dimensional contours are created for this (see Figure 4.8). Then, these contours are extruded to the desired height (see Figure 4.9).

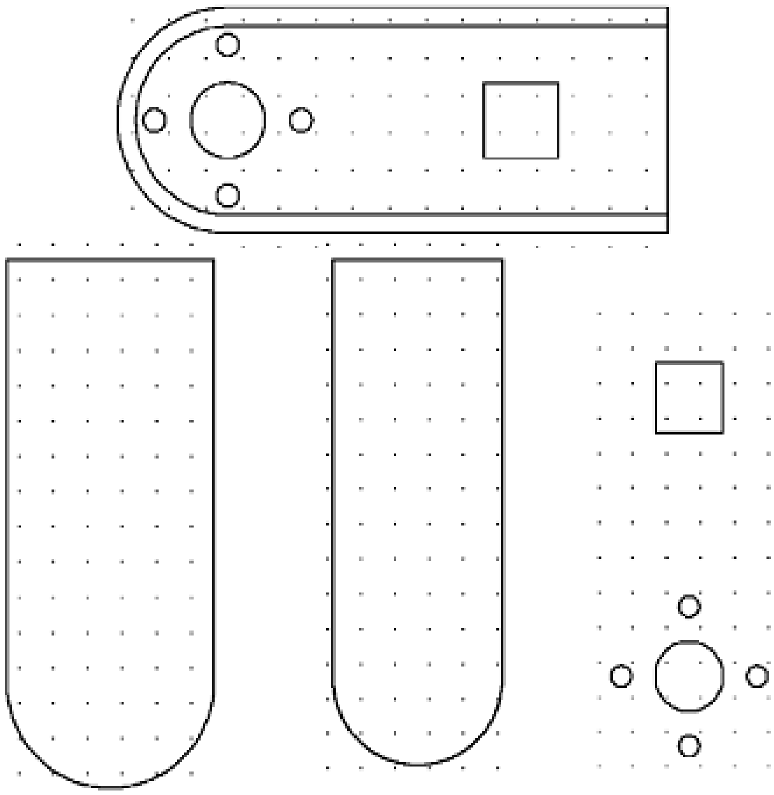


Figure 4.8 – Plane contours of the plate for the extrusion

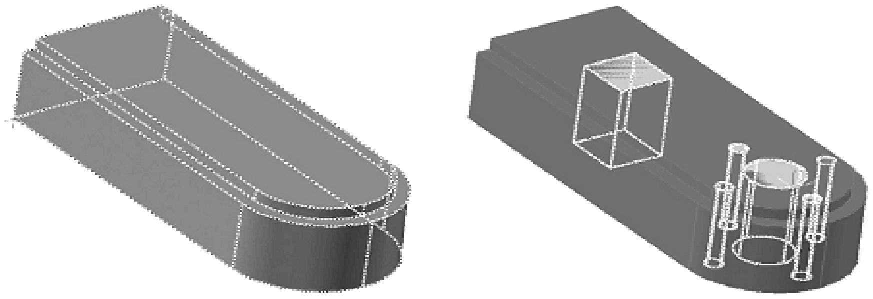


Figure 4.9 – Extruding the bases of the plate and the holes

Next, association of two bodies is carried out and holes are subtracted from the resulting body. The result of constructions in the form of a tinted solid model of the plate is shown in Figure 4.10.

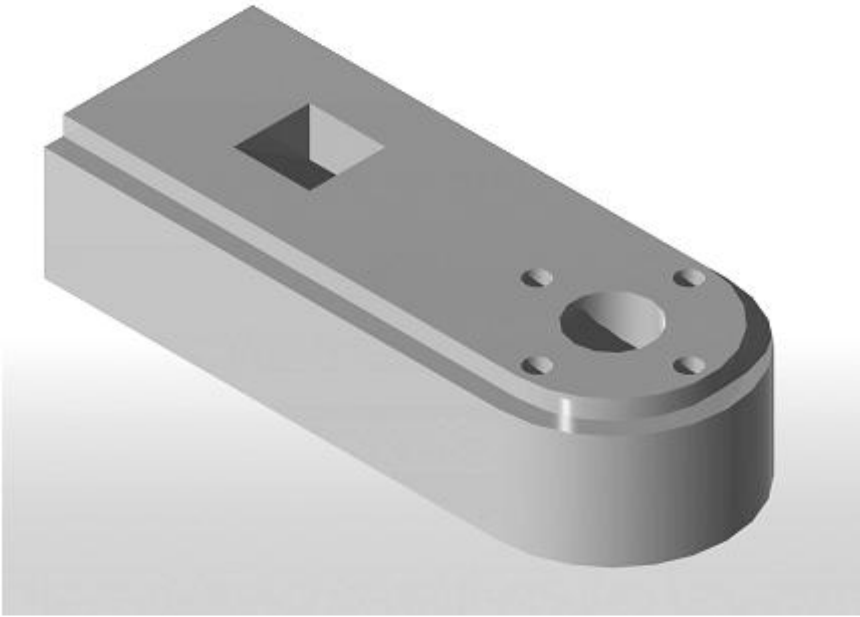


Figure 4.10 – Solid model of the plate

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