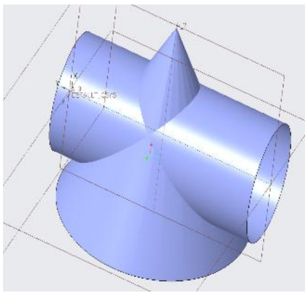
UNIVERSITY OF MISKOLCI

FACULTY OF MECHANICAL ENGINEERING

INSTITUTE OF MATHEMATICS

DESCRIPTIVE GEOMETRY

EXERCISES



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University of Miskolc

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Institute of Mathematics

Department of Descriptive Geometry

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Academic reviewer

Dr. József Túri

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INTRODUCTION

Descriptive geometry is known to be of decisive importance in two areas.

The first is that after the spatial objects have been clearly mapped onto the plane one by one, constructions can be made for the spatial objects in the plane of the drawing.

Another key importance of descriptive geometry is the development of a mathematical visual perception of objects in three-dimensional space.

The main goal of the course is for the practitioner of descriptive geometry to develop a practical view of space through the visual geometric perception of space, which already takes into account the possibilities and limitations of model making during planning and leads to a solution that can be created, which the mechanical engineer can also communicate by developing editing skills.

In the course material, the basic geometrical knowledge essential for design engineering practice and the comprehensive principles, the discussion of which aims to develop the ability to apply independently, have been systematized.

The negotiation method is adapted to the needs of construction subjects so that the student, design engineer candidate can successfully recognize the geometrical content of the engineering tasks, deal effectively with the strict geometric formulation of the question, and come to a constructive solution independently. The careful study of the theoretical curriculum and the independent solution of the practical tasks in close unity develop the skills for the bijective representation of spatial objects and the constructive solution of spatial geometry tasks in the plane of the drawing.

The examples of the practice worksheets for students of the Industrial Product and Design Engineering BSC program at the Faculty of Mechanical Engineering and Information Technology of the University of Miskolc are related to the subject areas to be learned within the framework of the Descriptive Geometry course, but at the same time, they are also useful for mechanical engineering students and students of other faculties.

The diagrams of the practice worksheets were created with AutoCAD2021 designer and CREO Parametric 3D modelling software.

Miskolc, 2025.

Author

CONTENT

LIST OF NOTATIONS

P	point (capital Latin letter)
e	straight (line) (Latin lowercase)
$\underline{S}$	plane (Latin capital letter underlined)
$\ominus$	lying on it
$\underline{\circ}$	not lying on it
$\parallel$	parallel
$\times$	intersect
$\not\times$	skew, bypasse
$\perp$	perpendicula
$\underline{K}_1$	first plane of projection (horizontal)
$\underline{K}_2$	second plane of projection (frontal)
$\{\underline{K}_1, \underline{K}_2\}$	system of projection planes
$\underline{K}_3$	the plane of the third projection, perpendicular to the planes of the first and second projections
x_{12}	the intersection line of the planes of the first and second projections (axis)
v_1	the first projector line, perpendicular to the first plane of projection
v_2	the second projector line, perpendicular to the second plane of projection
f_i	the i^{th} principal line parallel to the i^{th} plane of projection
h	the first principal line parallel to the first plane of projection, horizontal line
f	the second principal line parallel to the second plane of projection, frontal line
p	the profile line perpendicular to the intersection line of the first and second planes of projections, the third main line parallel to the third plane of projection
e_1	the first grade line on the plane, perpendicular to the first principal line

e_2	the second grade line on the plane, perpendicular to the second principal line
$\underline{V}_1$	the first projector plane, perpendicular to the first plane of projection
$\underline{V}_2$	the second projector plane, perpendicular to the second plane of projection
$\underline{P}$	the profile plane, perpendicular to the first and second planes of projections
α_1	the first inclination angle, angle with the plane of the first projection
α_2	the second inclination angle, angle with the plane of the second projection
N_1	the first trace point of the straight line
N_2	the second trace point of the straight line
n_1	the first trace line of the plane
n_2	the second trace line of the plane
n	the normal
$\underline{E}_s$	the tangent plane
e_i	thetangent line of the spiral at the point A_i
n_f	the principal normal line
b_i	the principal binormal line of the spiral at the point A_i

GLOSSARY

Space: The space is a concept created through abstraction from experience to describe the shape of material objects and their location in relation to each other. Space is boundless in all directions.

Geometric body: The part of space occupied by material objects.

Boundary: The boundary is the end of something.

Point: The point is that which has no part, i.e. the spatial element without extension. Lines of finite extent are bounded by points.

Line: A line has only length, neither thickness nor width.

Straight line: A straight line is a line that lies equally with respect to the points on it.

Surface: The surface has only length and width, no thickness.

Plane: A plane is a surface that lies evenly in relation to the lines on it.

Geometry: Geometry deals with shapes made up of points in space.

Half-line: A point splits the line it fits into two half-lines.

Half-plane: A straight line divides the plane adjacent to it into two half-planes.

Half space: A plane divides the space into two halves.

Segment: Any two points of a straight line divide it into two half-lines and a segment. The two points are the two endpoints of the section.

Length: If a section is chosen as the unit of length, the sections can be measured with positive real numbers relative to it.

Distance: The length of the segment connecting two points is the distance between the two points.

Angle: A pair of intersecting lines divides the plane into two congruent parts, these plane parts are the angles.

Right angle: If the pair of intersecting lines divides the plane into four congruent parts, then these plane parts are right angles.

Acute angle: An angle smaller than a right angle.

Obtuse angle: An angle larger than a right angle.

Right angle: The legs of a right angle form a straight line.

Unit angle: 180th part of a right angle, 1°.

Directed segment: The segment is directed if the order of its endpoints is specified.

Direction of rotation: The direction of rotation is given by the size of the angle and the order of the legs of the angle.

Movement: When a shape moves, its points move to a new position, but its shape does not change.

Offset: Moving the points of the square by a directed segment.

Rotation: Moving the points on the plane around a point in a given direction of rotation.

Pair of intersecting lines: Two lines intersect if they have a common plane and a common point.

Parallel lines: Two lines are parallel if they have a common plane and no common point.

Skew line pair: Two lines skew if they have no common plane and no common point.

Broken line: Sections connected to each other form a broken line.

Directed fracture line: If the sections of the fracture line are directed in a way that connects to each other, we get a directed fracture line.

Closed fractional line: If the start and end points of finitely many fractional lines are the same, then it is called a closed fractional line.

Polygon: If the segments of the closed broken line have no points in common apart from the prescribed connection points, then it is called a polygon. The sections are the sides of the polygon, the connection points are the vertices of the polygon.

n-angle shape on the plane: An n-angle has n angles and n sides.

Polyhedron: A part of space that is bounded by a finite number of polygonal regions and does not contain a complete straight line is called a polyhedron. The bounding polygon domains together form a polyhedral surface.

Geometric locales: A set of points with a property.

Circle: The geometric location of points on the plane that are at a given distance from a specified point on the plane, different from zero. The specified point is called the center of the circle.

Chord: The section connecting two points of the circle is called a chord.

Diameter: The chord passing through the center of the circle is called the diameter.

Sphere: The geometric location of points in the space that are at a given distance from a specified point of the space, different from zero. The specified point is called the center of the sphere.

Tangent: A straight line that has one and only one point in common with a line or surface is called a tangent, and the common point is called a point of contact.

Tangent plane: The plane that has one and only one point in common with a surface is called a tangent plane, and the common point is called a point of contact.

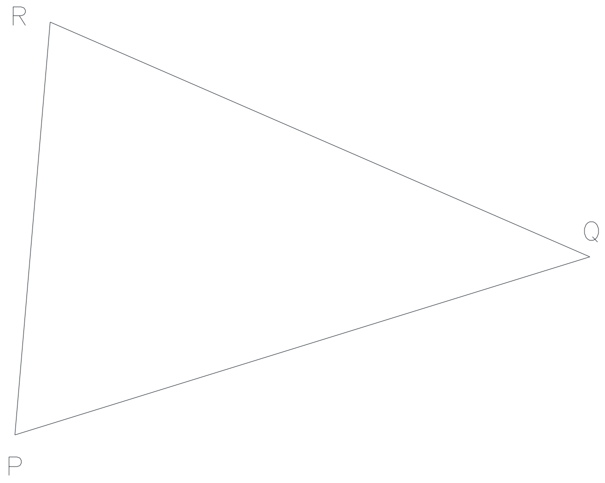
Ellipse: The ellipse is the geometric location of the points on the plane whose sum of distances from two given points on the plane is a constant greater than the distance between the two given points.

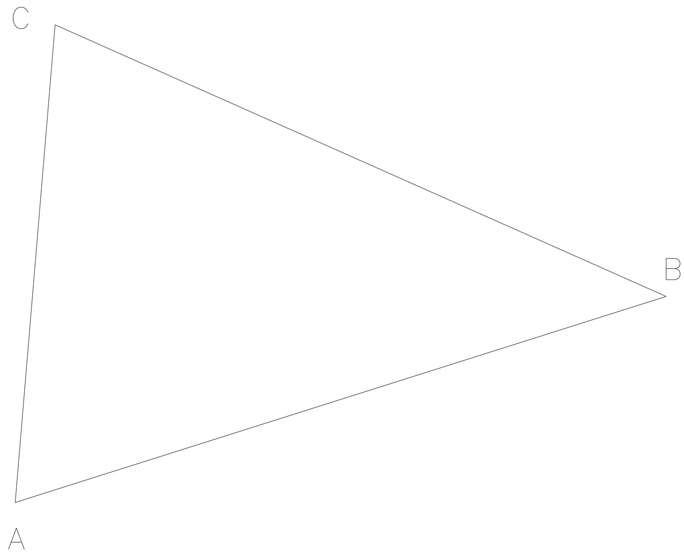
Parabola: A parabola is the locus of points on the plane that are equidistant from a given point and a straight line in the plane.

Hyperbola: The hyperbola is the geometric location of those points on the plane whose absolute value of the difference in distance from two given points on the plane is a constant smaller than the distance between the two given points.

1.1 OVERVIEW SOME PLANAR GEOMETRY CONSTRUCTIONS

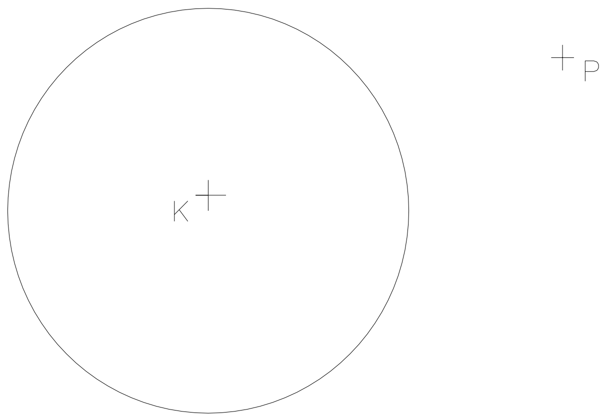
Construct the center **K** of the circle, which lies on the vertices of the triangle **PQR**!





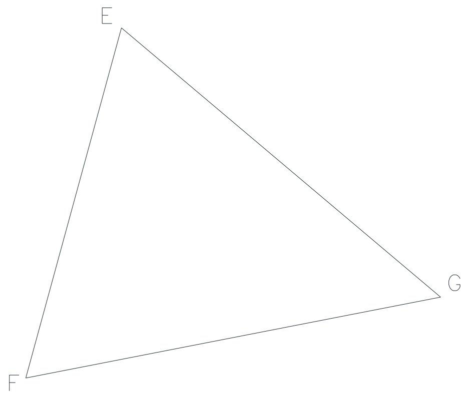
Construct the center **O** of the circle, which tangents the sides of the triangle **ABC** from the inside!

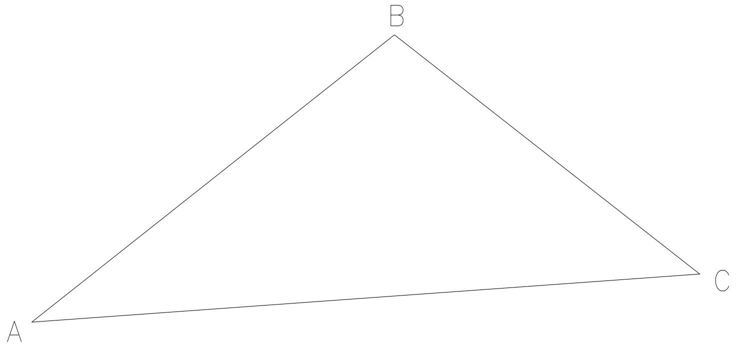
Construct the tangent straight lines to the given circle with center point **K** from the also given point **P**!



Construct the length part 2/5 of the segment **AB**!

Construct the centroid **S** of the triangle **EFG**!

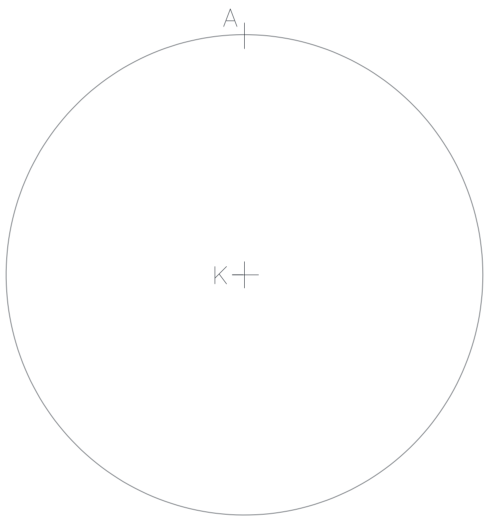




Construct the altitude point **M** of the obtuse triangle **ABC**!

Construct the square **ABCD** whose diagonal section **AC** is the given!

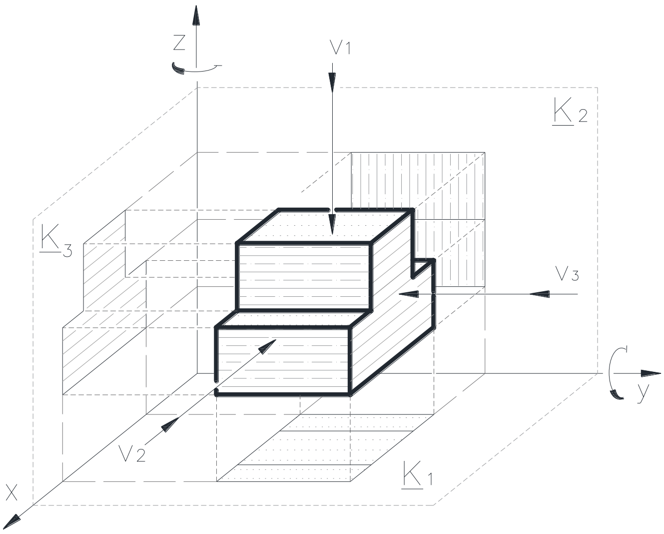
Construct the regular triangle **ABC**,
whose side is the segment **AB**
and the vertex **C** is above the segment **AB**!

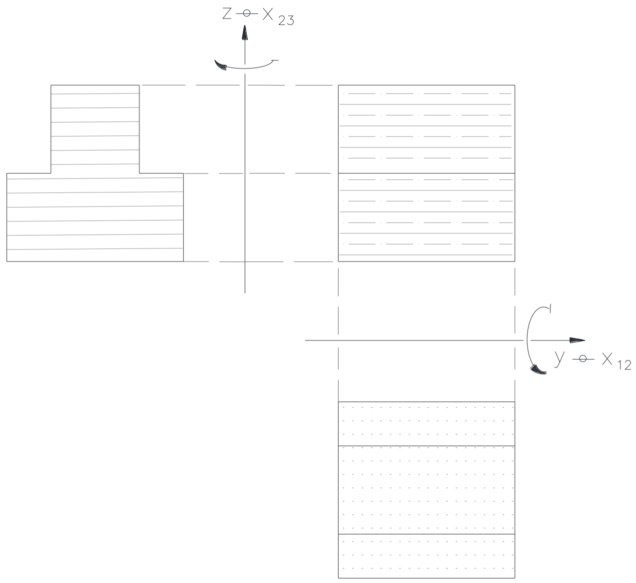


Construct a *regular hexagon* inscribed
in the given circle with center **K**,
one of whose vertices is the point **A**
given on the arc of the circle!

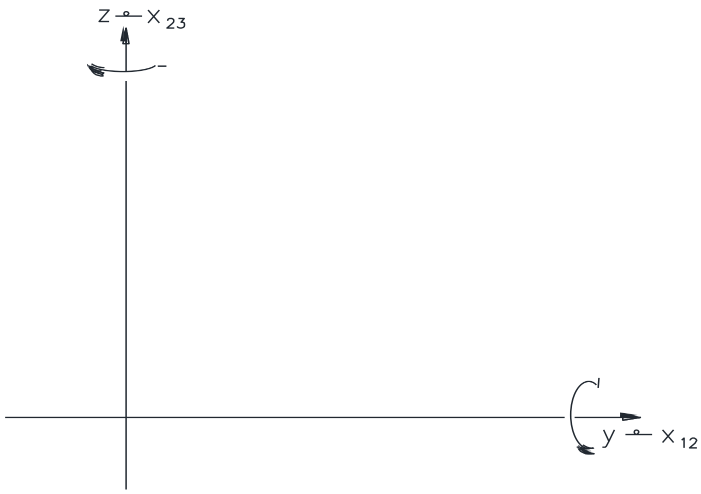
1.2. CREATION OF THE REGULARIZED PROJECTIONS

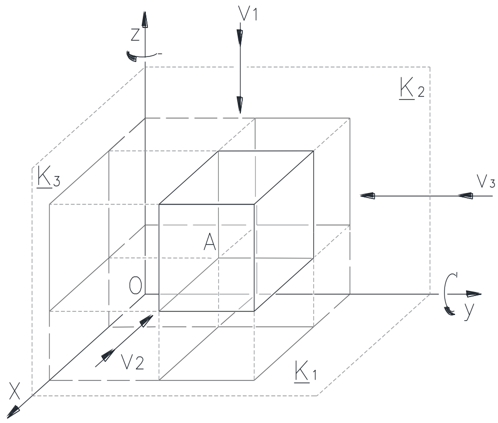
Mark the distance of the truncated cube on the axonometric image and then on the regularized projections: *z* from projection plane $\underline{K}_1$, *x* from projection plane $\underline{K}_2$ and *y* from projection plane $\underline{K}_3$!



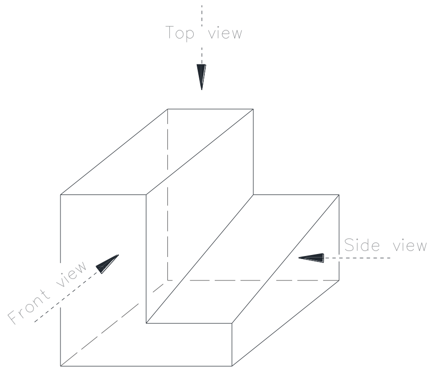


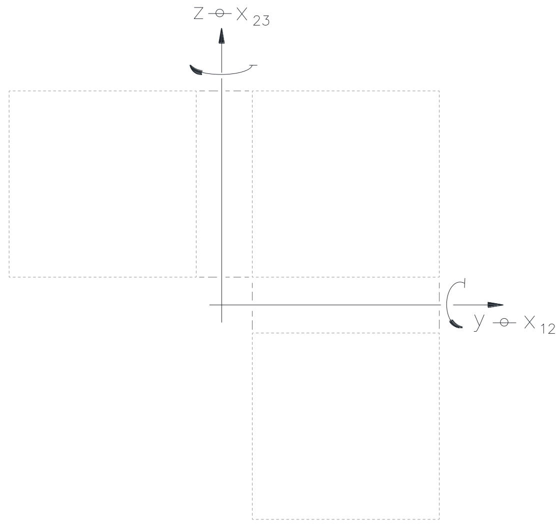
Draw the front, top and side views of the cube with edge length ***a***=30*mm* so that it is located at 5*mm* above the projection plane $\underline{K}_1$, at 10*mm* in front of the projection plane $\underline{K}_2$, and at 15*mm* away from the projection plane $\underline{K}_3$!

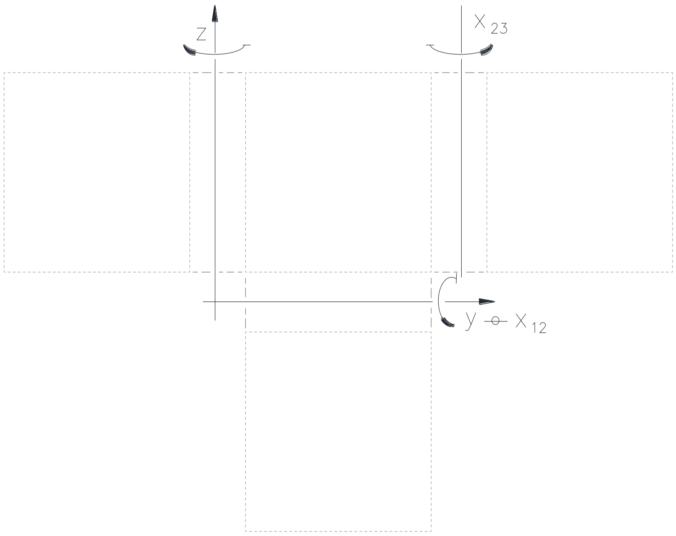




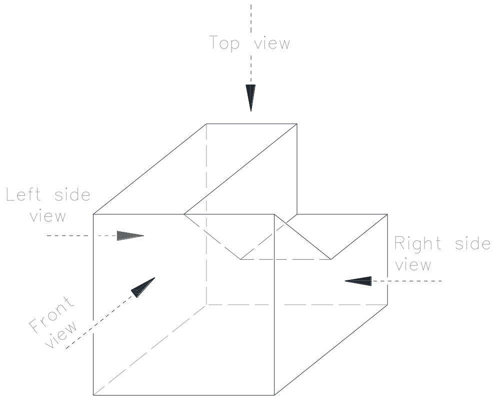
Draw the regularized projections of the truncated cube!



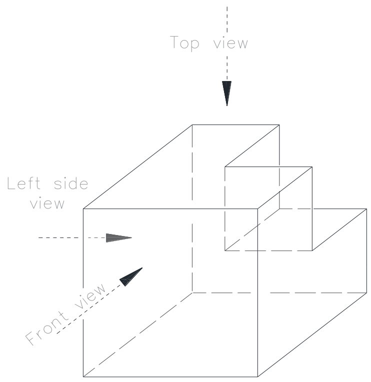


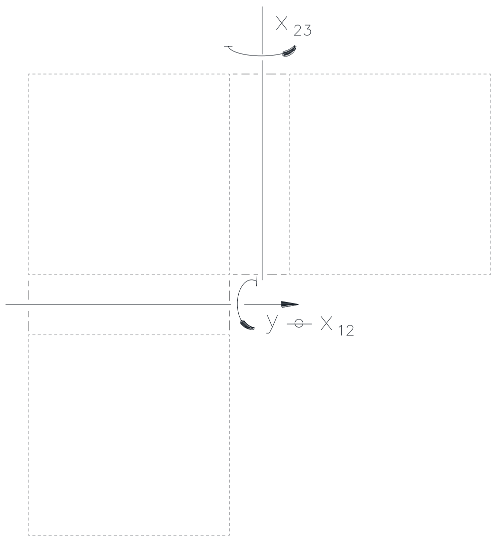


Place the **K**$_3$ image plane parallel to the [*zx*] coordinate plane, on the opposite side of the truncated cube, and draw the regularized projections with both side views!



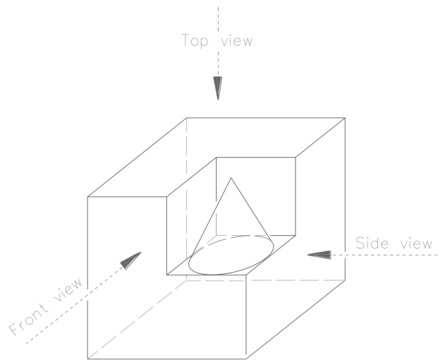
Draw the regularized projections of the truncated cube using its left side view!

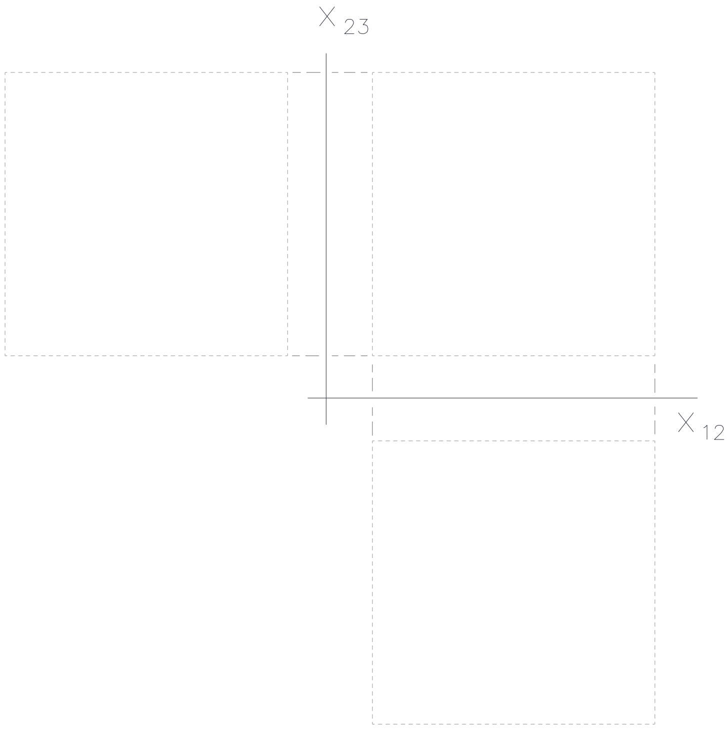




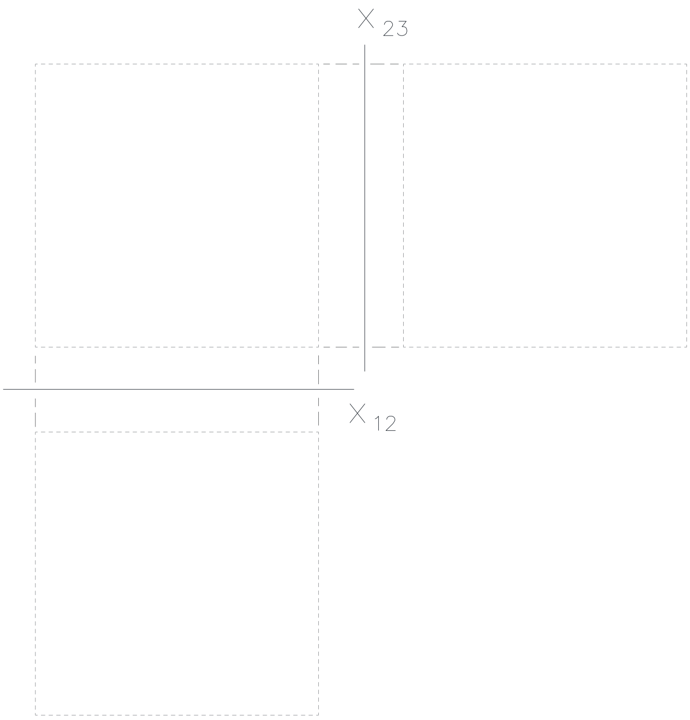
1.3. REGULARIZED PROJECTIONS AND RECONSTRUCTION OF SHAPES

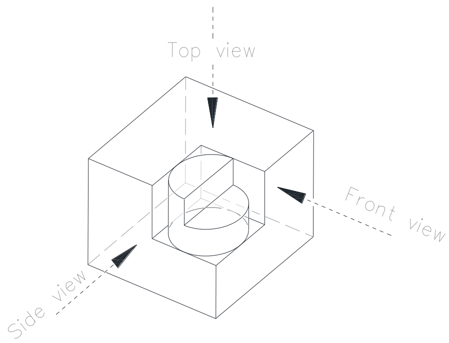
Create three views of the truncated cube and the cone!



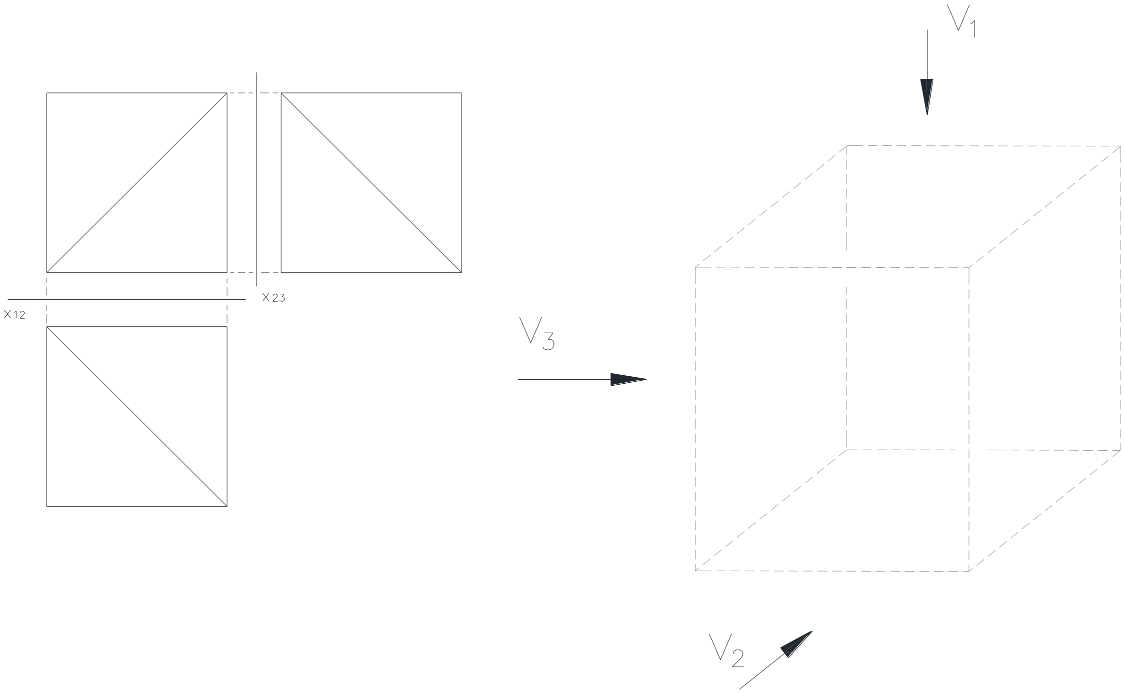


Create three regulated views of the truncated cube and cylinder!

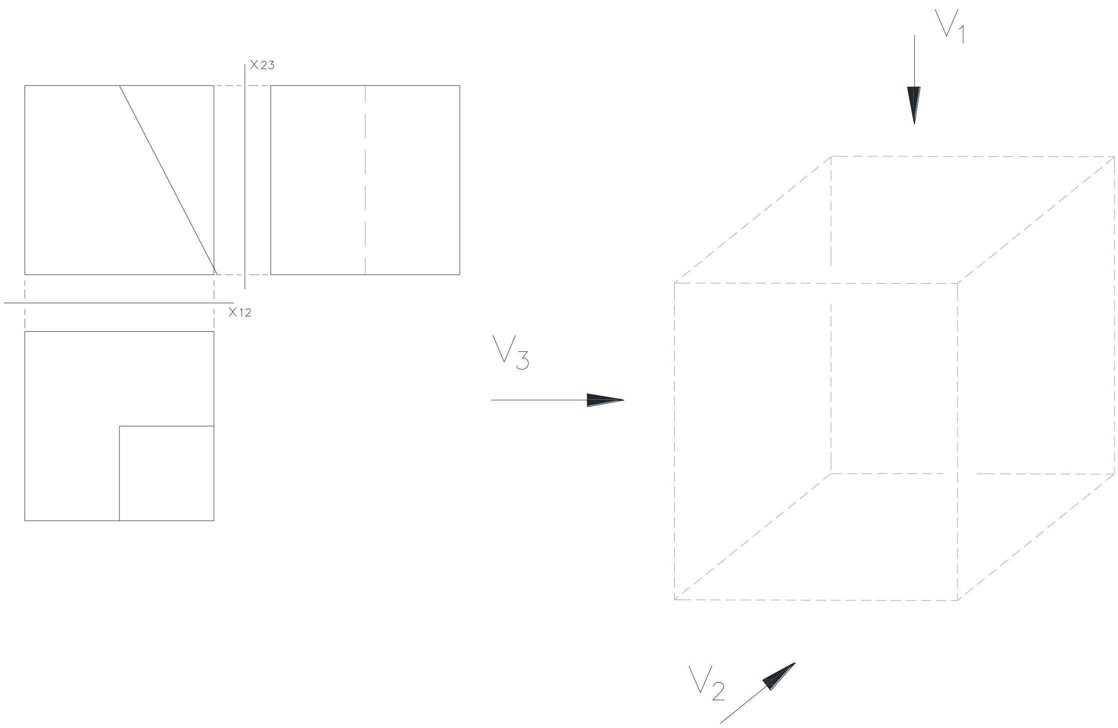




Draw the axonometric representation of the truncated cube from its three regularized projections. Show visibility too!

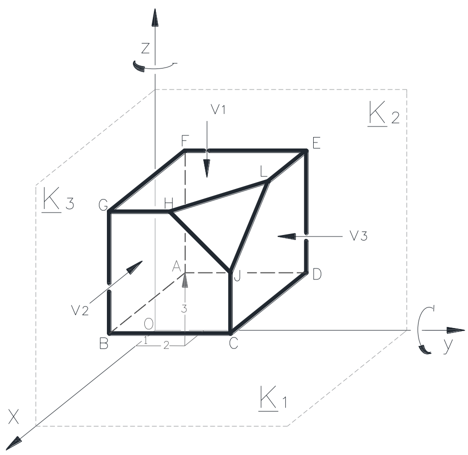


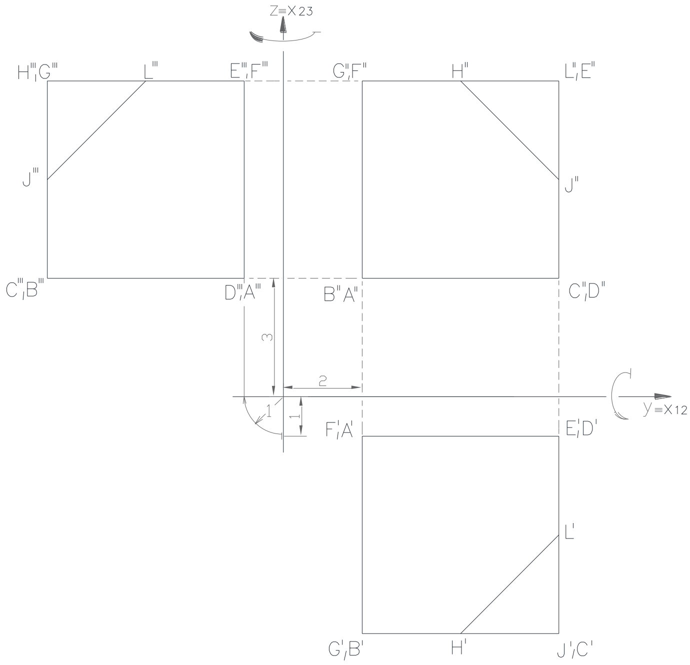
Draw the axonometric representation of the truncated cube from its three regularized projections, indicating visibility!



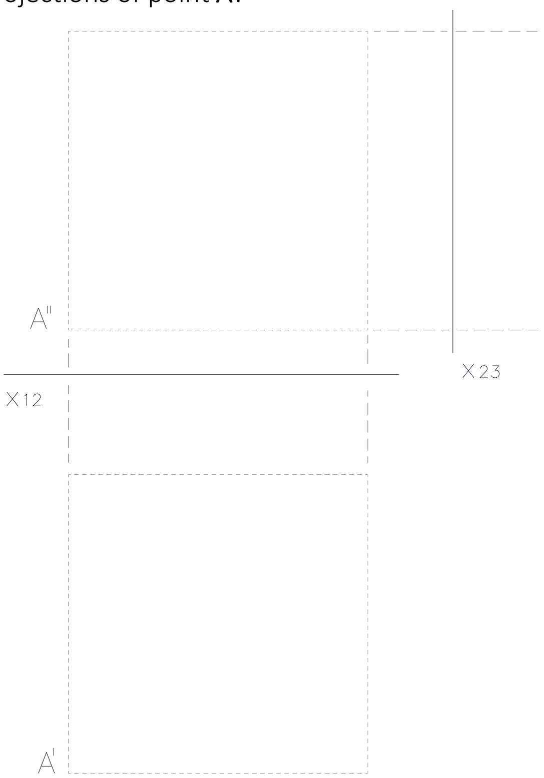
1.4. REGULARIZED PROJECTIONS OF POINTS

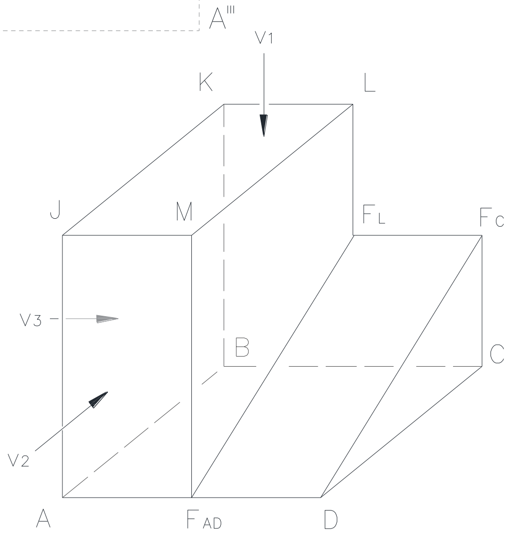
Study the regularized projections of the vertices of a truncated cube placed at **3** units above the projection plane **K**$_1$, at **1** unit in front of the projection plane **K**$_2$, and at **2** units away from the projection plane **K**$_3$.



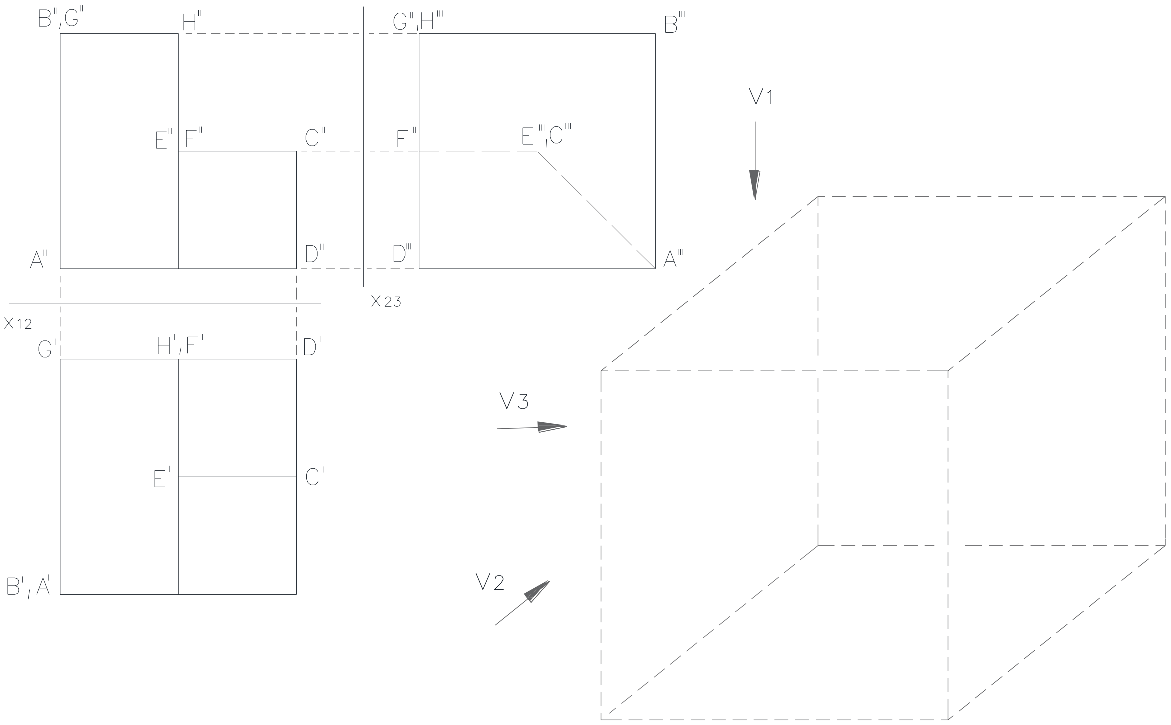


Determine the regularized projections of the vertices of the truncated cube. Let the projected point created by projection straight line **v**$_1$ be marked **I**, the projection point formed by projection straight line **v**$_2$ be marked **II**, and the projection point formed by projection straight line **v**$_3$ marked **III** according to the projections of point **A**!

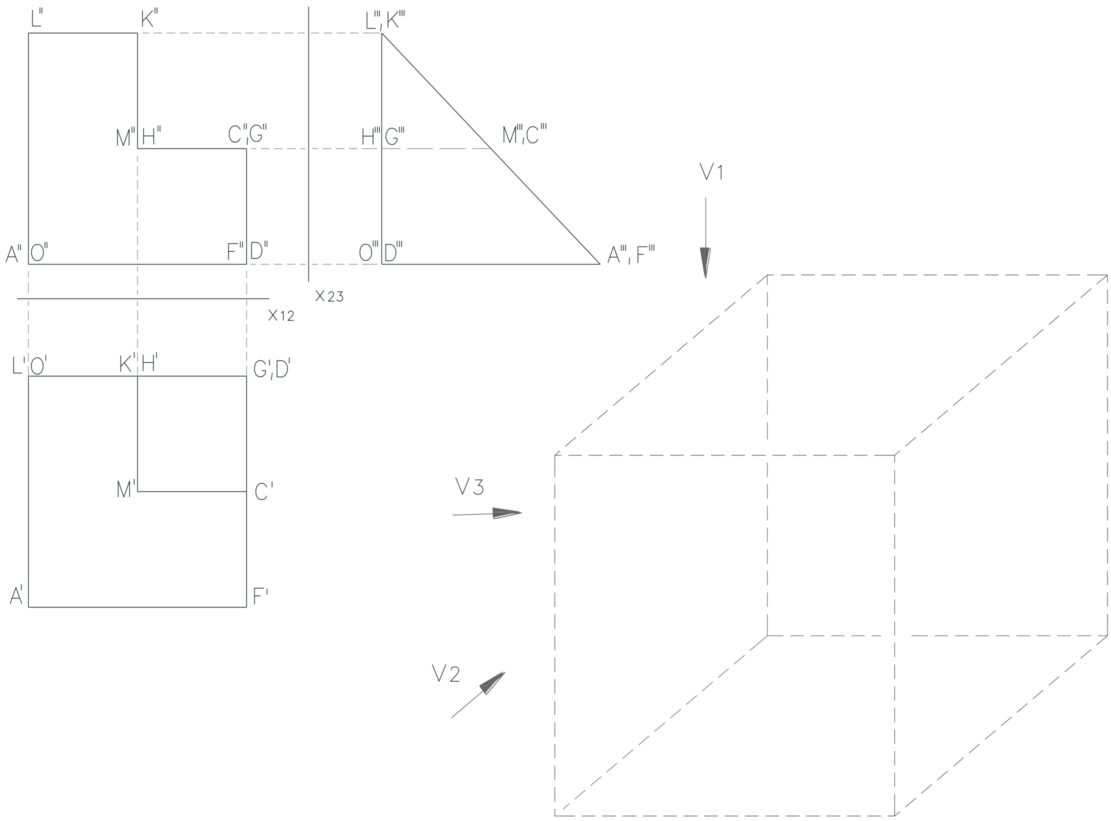




Draw the axonometric representation of the truncated cube from its three regularized projections! Show visibility too!

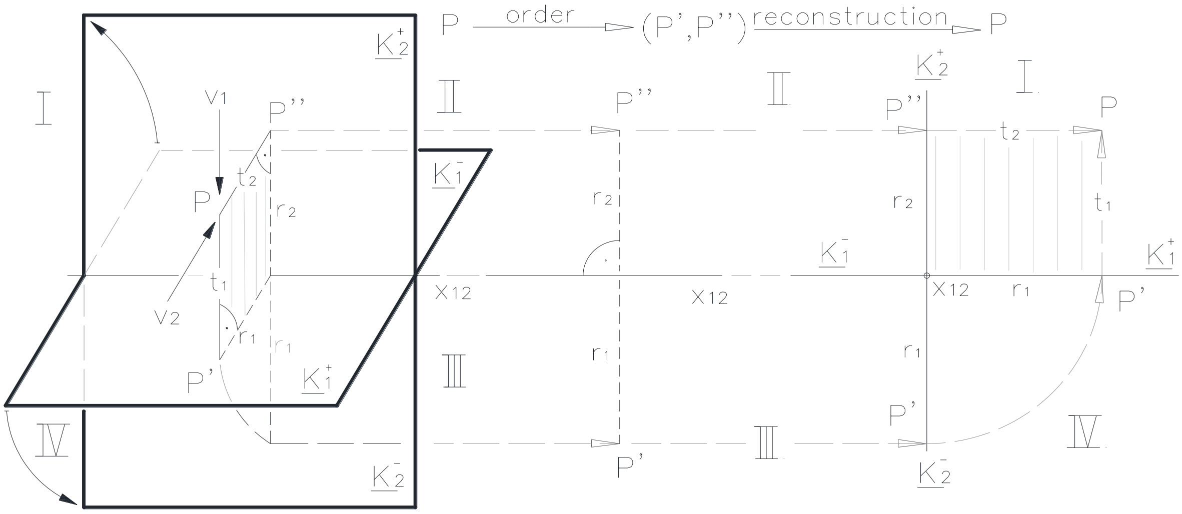


Draw the axonometric representation of the truncated cube indicating visibility from its three regularized projections!

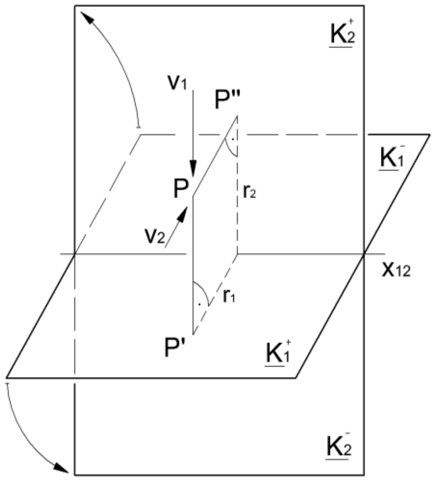


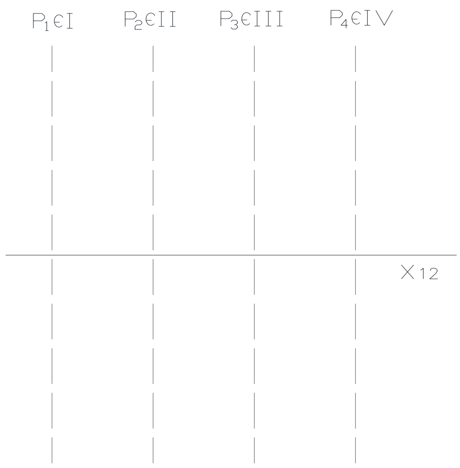
2.1. THE MONGE REPRESENTATION OF THE POINT

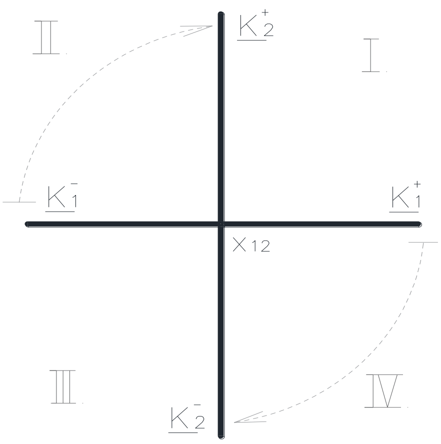
Monge: "... Descriptive Geometry is the reconstructable representation of three-dimensional objects on the two-dimensional plane ..."



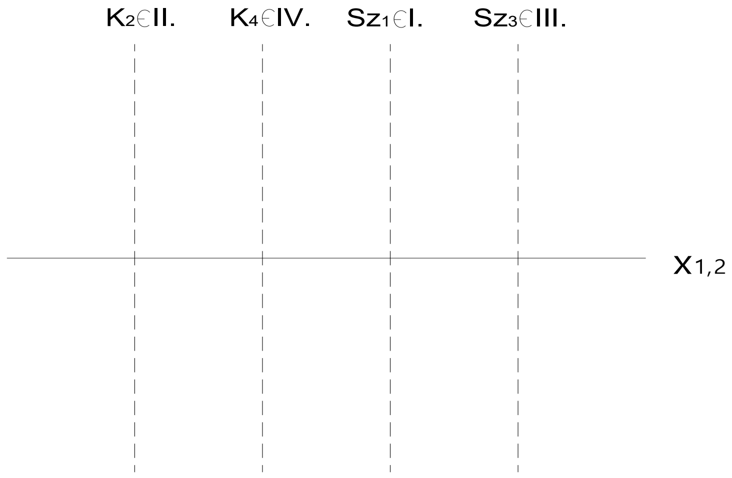
Describe the points P_1, P_2, P_3 and P_4 on the given regular lines in the I., II., III. and IV. quarter of the space, which are ±20*mm* from $\underline{K}_1$, and ±10*mm* from $\underline{K}_2$!

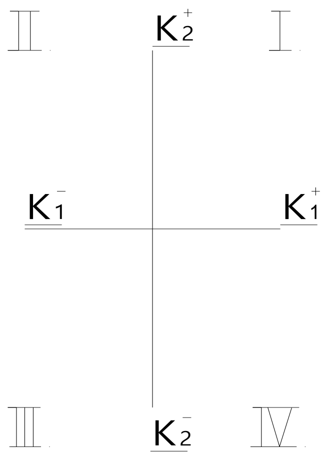




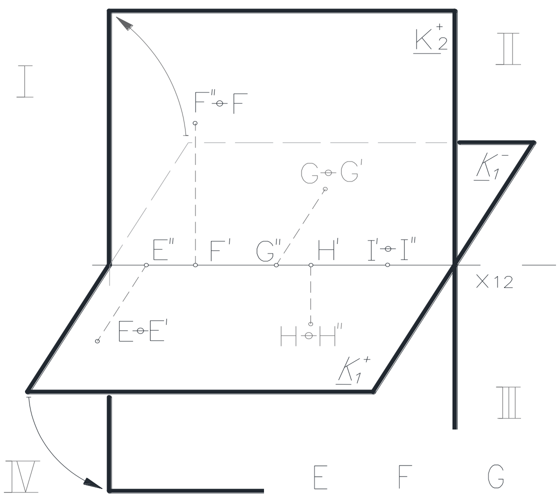


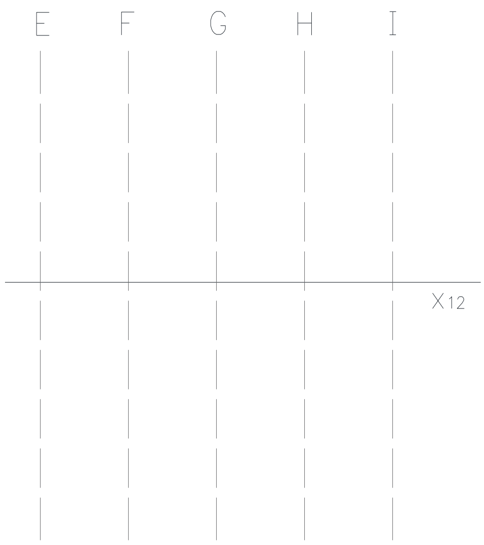
Describe the points on the coincidence plane K and the plane of symmetry S_z, which are **15***mm* from the planes of projections according to their location in the quarters, on the given regular lines!

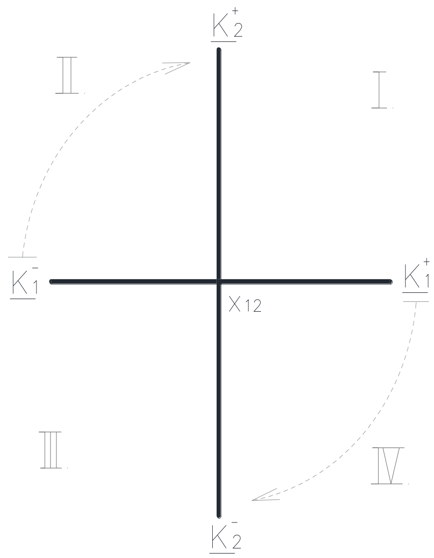




As shown in the axonometric representation, determine the points lying on the planes of projections so that the distances between the plane K_2 and points **E**, **G** are ±15*mm*, the heights between the plane K_1 and points **F**, **H** are ±22mm, and point **I** lies on the **x**12 axis!

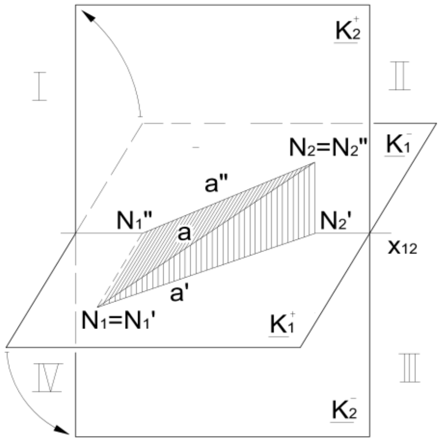






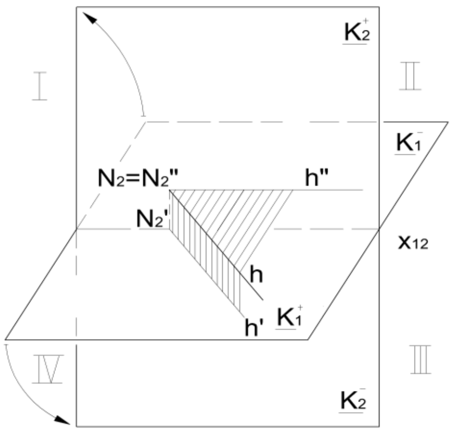
2.2. REPRESENTATION OF THE STRAIGHT LINES

Draw a straight line in a general position such that the distance of the first trace point **N_1** from the plane $\underline{K}_2$ is **35***mm*, the height of the second trace point **N_2** relative to the plane $\underline{K}_1$ is **20***mm*, and the difference between the deviation of the trace points **N_1** and **N_2** relative to the plane $\underline{K}_3$ is **55***mm*! Desribe the bisecting point **F** of the finite part of the line **a**, falling between its traces!



$x_{1,2}$

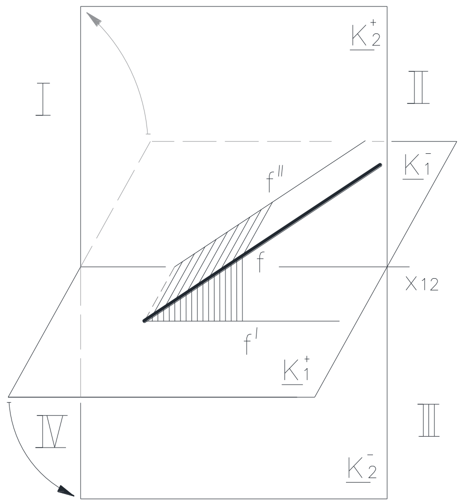
Describe a horizontal line **h**, which is **8***mm* above plane $\underline{K}_1$ and it forms angle **45°** with $\underline{K}_2$! Determine the trace point of the horizontal line, than the point **A** on the **h**, which creates **30***mm* from the trace point, if the point **A** muts be in the **I**. quarter of the space!



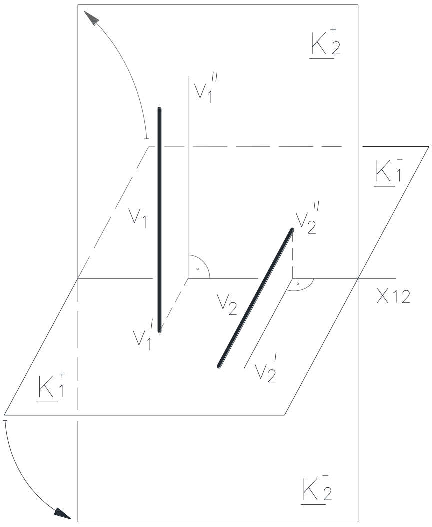
$x_{1,2}$

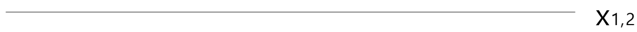
Determine a frontal line **f**, which is **10***mm* before $\underline{K}_2$ and it forms angle **30°** with plane $\underline{K}_1$! Determine the trace point of the frontal line, than the point **A** on it, which is **35***mm* from the trace point in the **I**. quarter of the space!

$x_{1,2}$

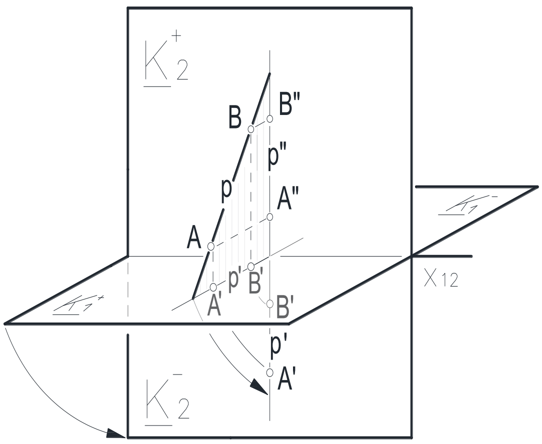


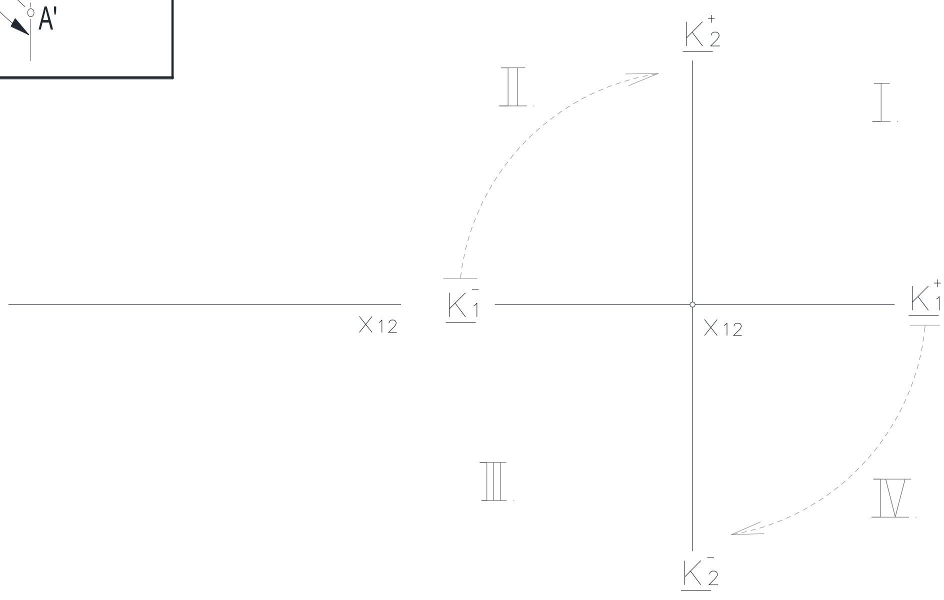
Describe the projection line **v**$_1$, which are **10***mm* from the plane <u>K</u>$_2$, and **v**$_2$, which are **20***mm* from the <u>K</u>$_1$, then lay sections of **15***mm* in length on each of them, indicating the visibility!





Determine a **profil** line with its points **A** and **B**! The **A** is **20***mm* from plane <u>K</u>$_1$ and **10***mm* from plane <u>K</u>$_2$, and **B** is **10***mm* from plane <u>K</u>$_1$ and **25***mm* from plane <u>K</u>$_2$. Determine the trace points of the profile line, and lay on it a point **C** at **12***mm* from plane <u>K</u>$_1$!





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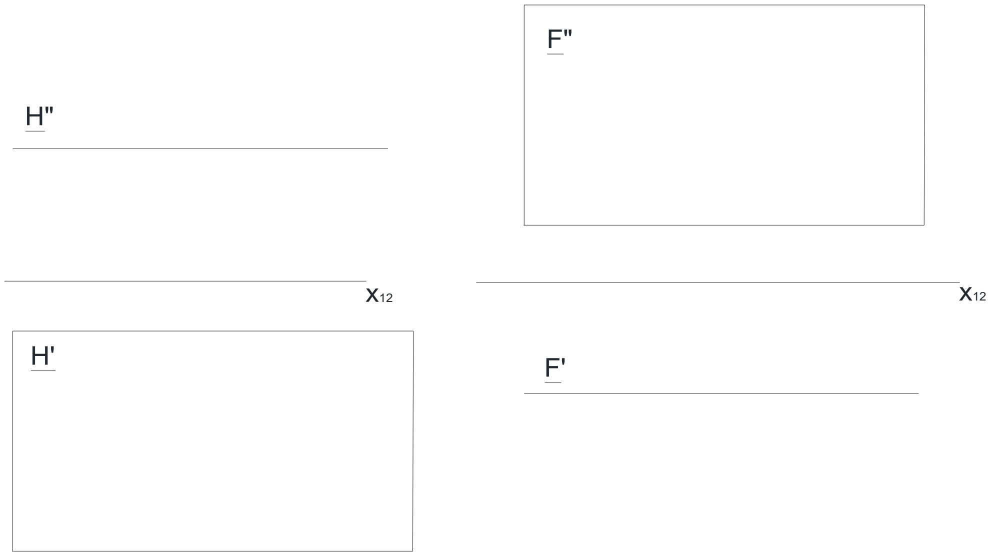
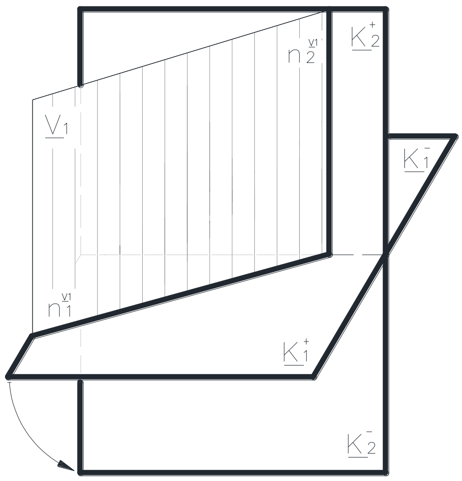
2.3. REPRESENTATION OF THE PLANE

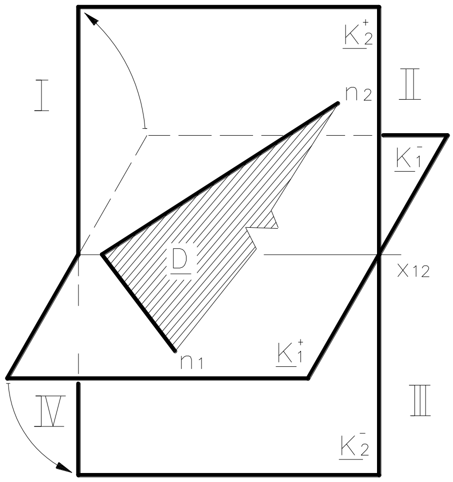
Draw a regular triangle on the given horizontal plane $\underline{H}$ and square on the given frontal plane $\underline{F}$!



Represent a first projector plane $\underline{V}_1$ determined by its trace lines if the angle between it and the projection plane $\underline{K}_2$ is 30^o! Place any triangle on it!



Draw a second projector plane $\underline{V}_2$, which is determined by its trace lines, if the angle between it and the projection plane $\underline{K}_2$ is 45^o! Place any triangle on it!

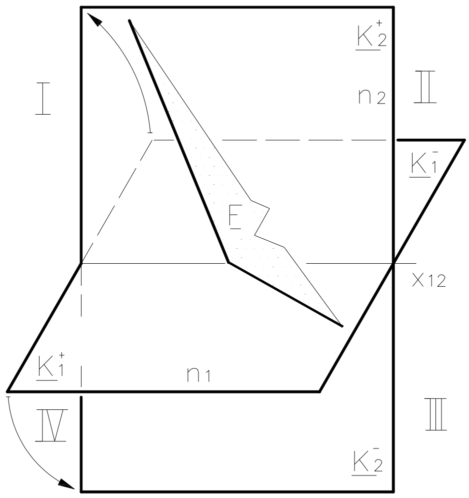


Describe an inclined (slanted) plane with its traces, then place a straight line **t** on it!

x1,2

Describe a strained plane with its traces, then place a straight line **t** on it!

x1,2

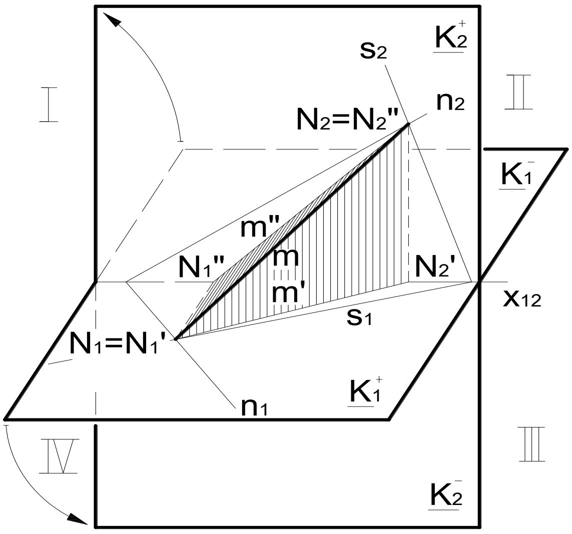


Describe a plane by trace lines, which is parallel with axis $\mathbf{x}_{12}$ and forms the angle 30° with plane $\underline{K}_1$, than place a triangle on it, whose vertices **A** and **B** lies each a point on the first trace line $\mathbf{n}_1$, and the vertex **C** lies on the second trace line $\mathbf{n}_2$!

x23

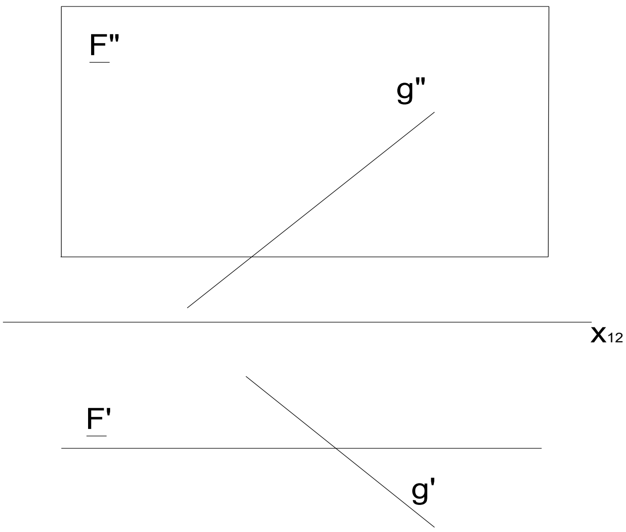
x12

3.1. INTERSECTIONS OF THE GEOMETRIC BASIC ELEMENTS

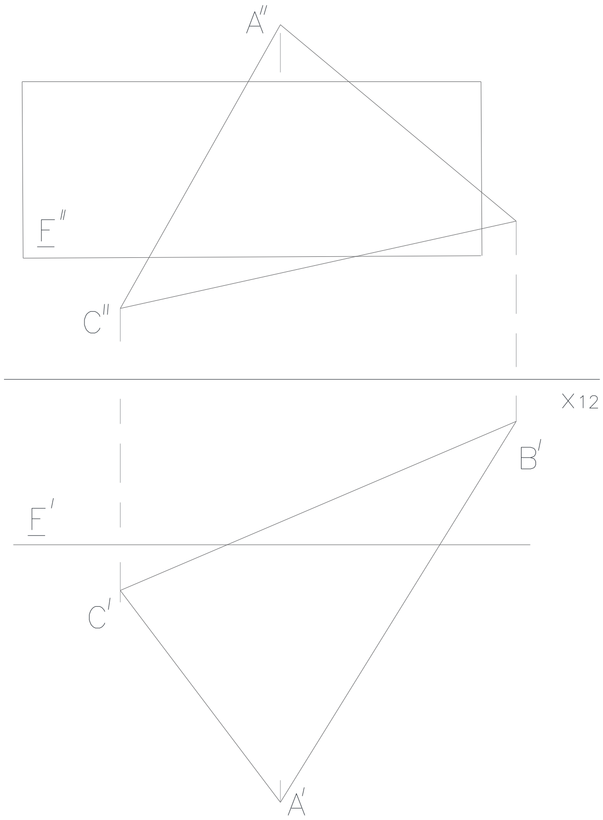


Let draw the planes N[n_1, n_2] and S[s_1, s_2] with their trace lines on the planes of projections! Construct the intersection line **m** of the given planes!

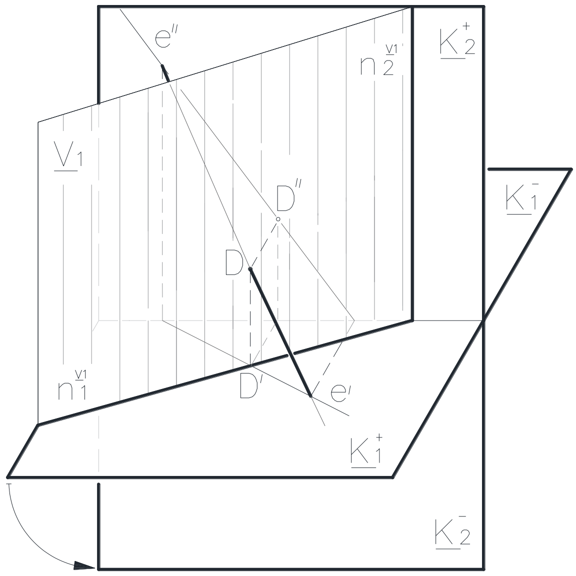
$x_{1,2}$



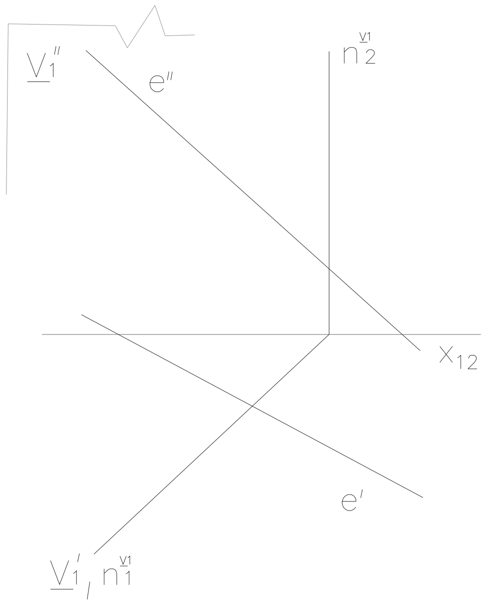
Determine the intersection point **D** between the given straight-line **g** in general position and the frontal plane F, then show the visibility!

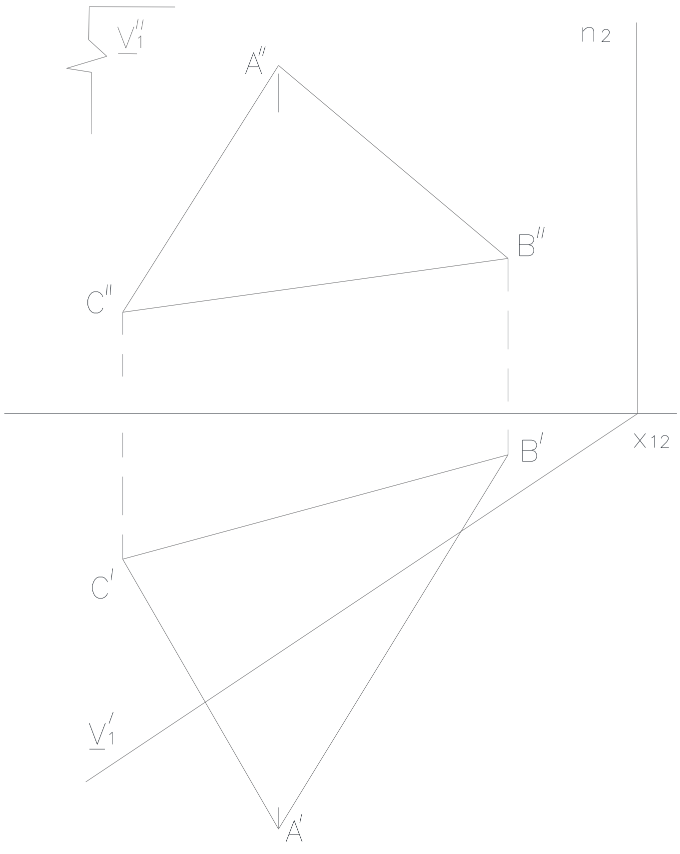


Determine the intersection line **f** between the given plane S(A,B,C) in general position and the frontal plane F, then show the visibility!



Determine the intersect point **D** between the projector plane $\underline{V}_1$ and line **e**, then show the visibility!

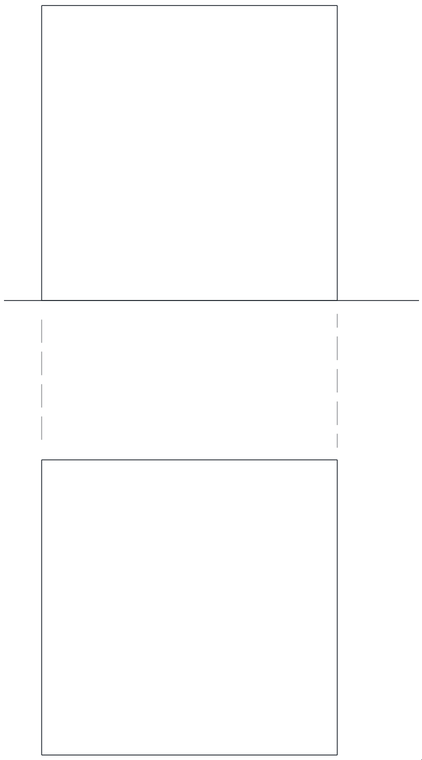


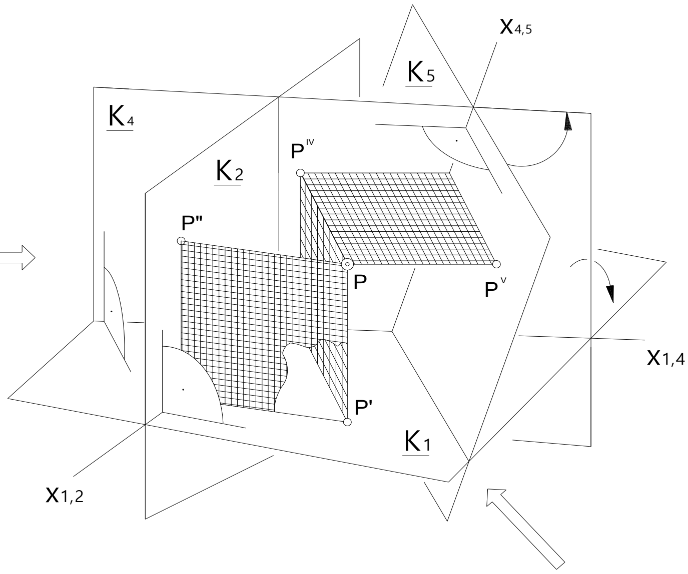


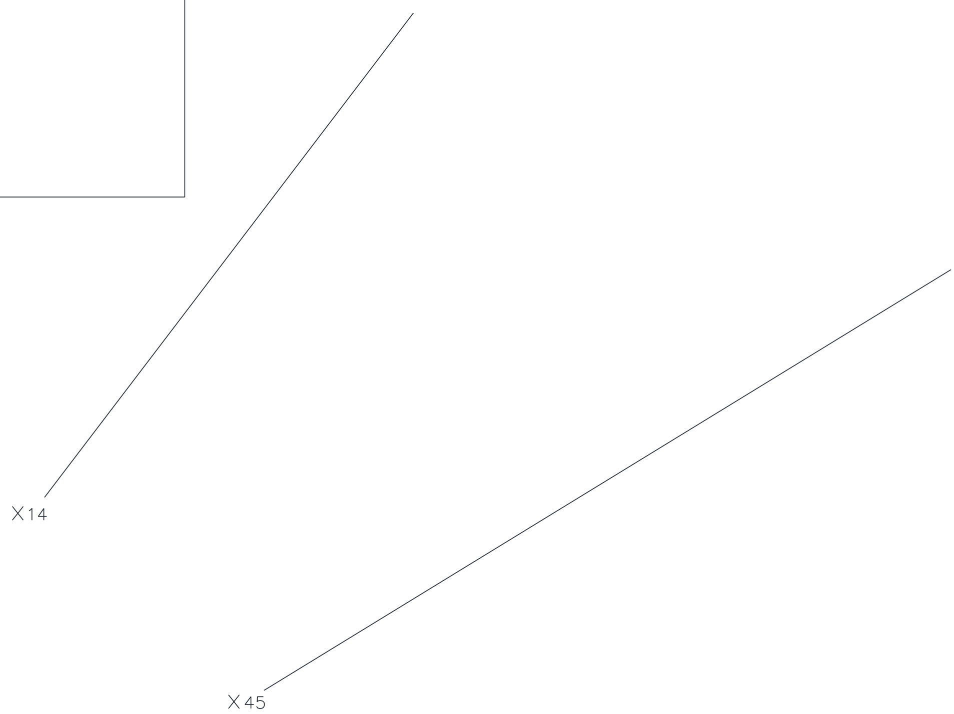
Determine the intersect straight line **m** between the projector plane $\underline{V}_1$ and the plane $\underline{S}$[ABC] in general position, then show the visibility!

3.2. THE NEW PLANES OF PROJECTIONS

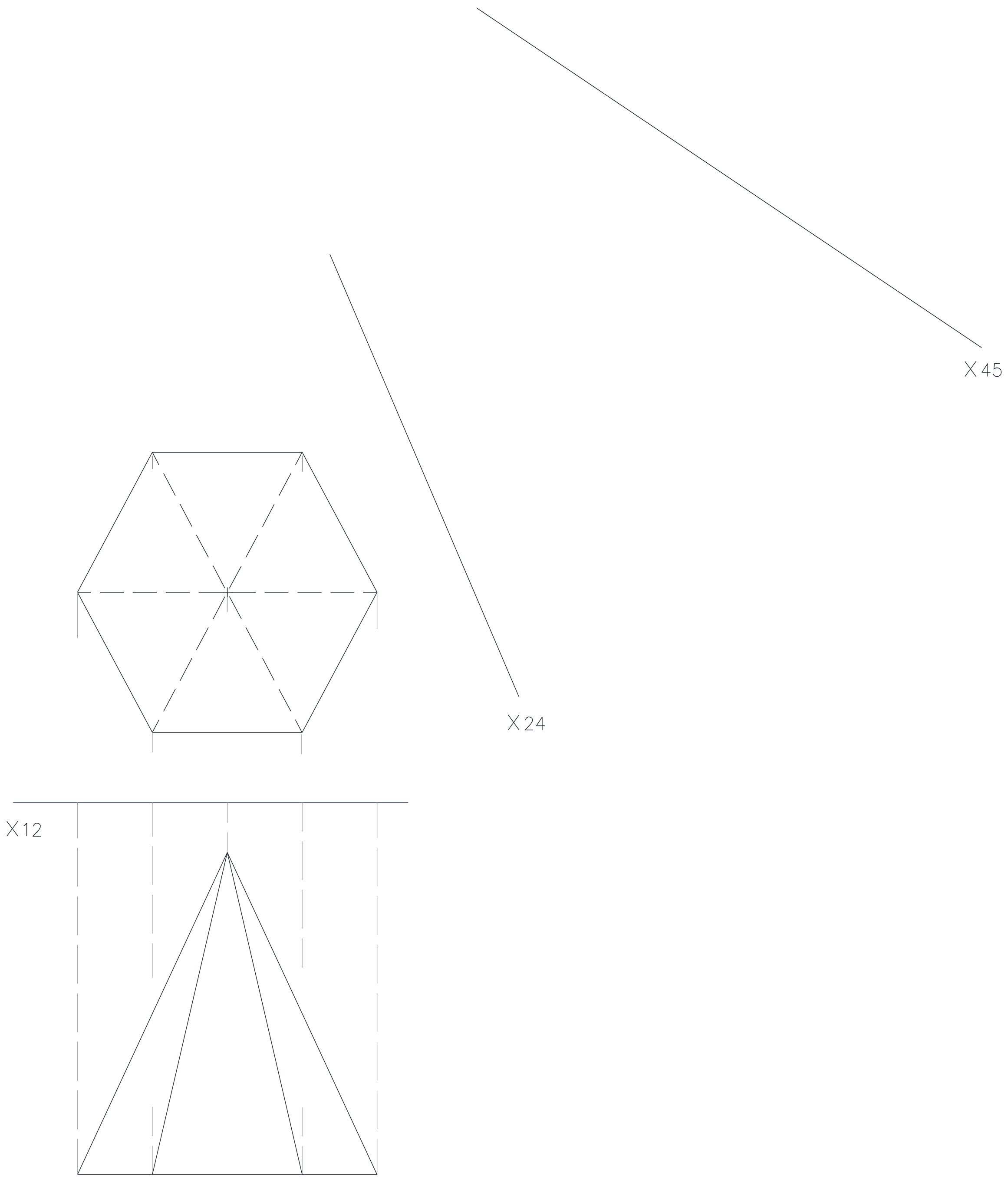
Mark the vertices of the cube lying on the plane of projection $\underline{K}_1$, then create the visual projection of the cube by transforming to the plane of projection $\underline{K}_4$ connected to the plane of projection $\underline{K}_1$, and then to the plane of projection $\underline{K}_5$ connected to the plane of projection $\underline{K}_4$!







Mark the vertices of the regular hexagon-based straight pyramid lying on the frontal plane F, then create the visual projection of the regular hexagon-based straight pyramid by transforming to the plane of projection K_4 connected to the plane of projection K_2, and then to the plane of projection K_5 connected to the plane of projection K_4!

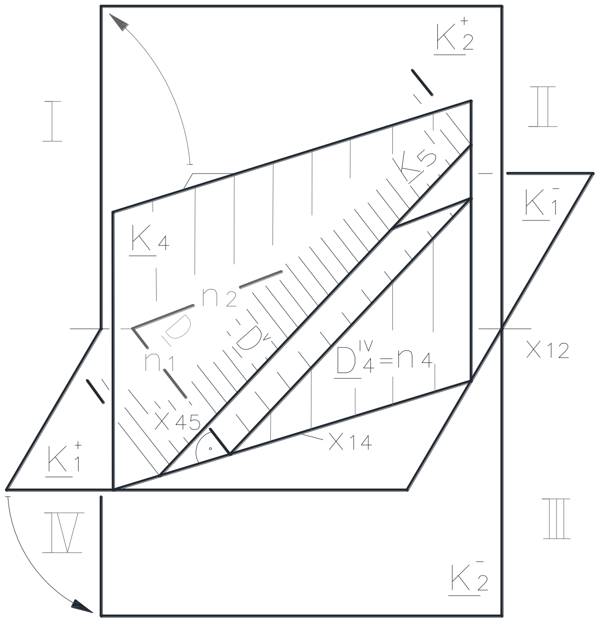


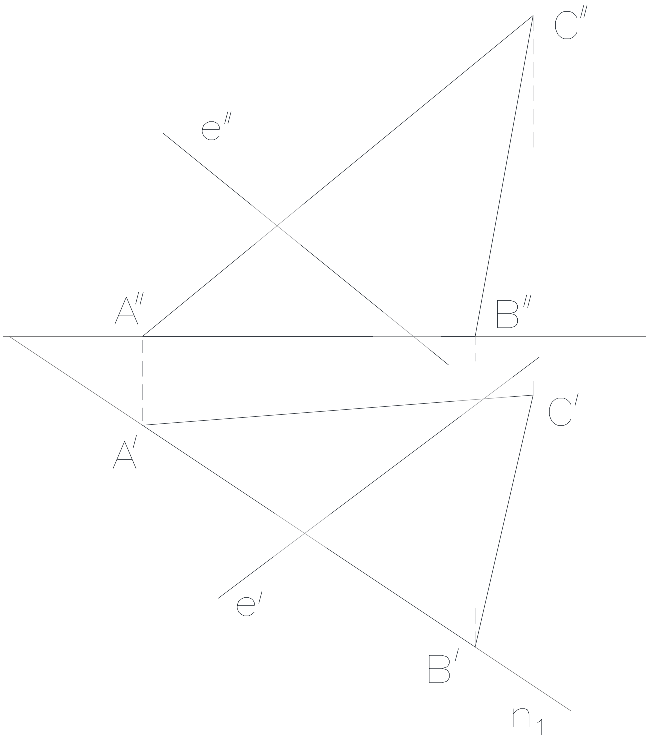
3.3. TRANSFORMATIONS OF THE PLANE INTO SPECIAL POSITION

The triangle **ABC** in general position is given so, that the side **AB** is lying on the plane of projection $\underline{K}_1$. Furthermore, the line **e** is given in general position.

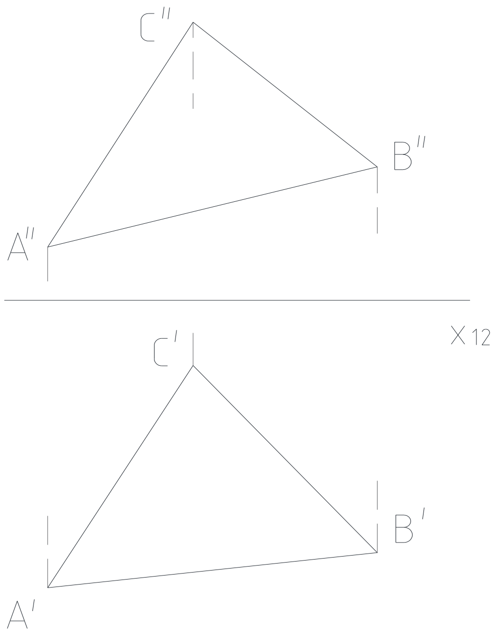
Determine the intersection point **D** between the line **e** and the triangle **ABC** using a new plane of projection $\underline{K}_4$, in which the plane of the triangle is a projector plane!

Demonstrate the visualisation!





Let the triangle **ABC** in general position is given. Determine the true dimension of the triangle **ABC**! Construct the altitude point **M** of the triangle!

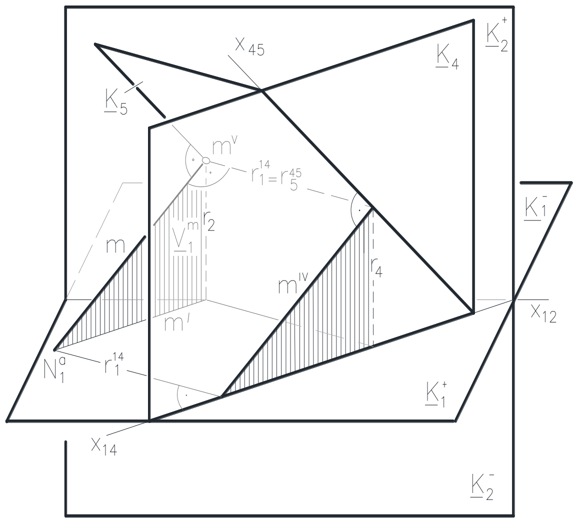


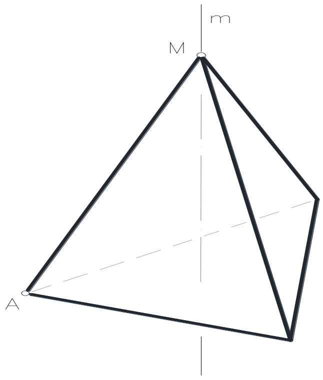
3.4. TRANSFORMATION OF THE STRAIGHT LINE INTO SPECIAL POSITION

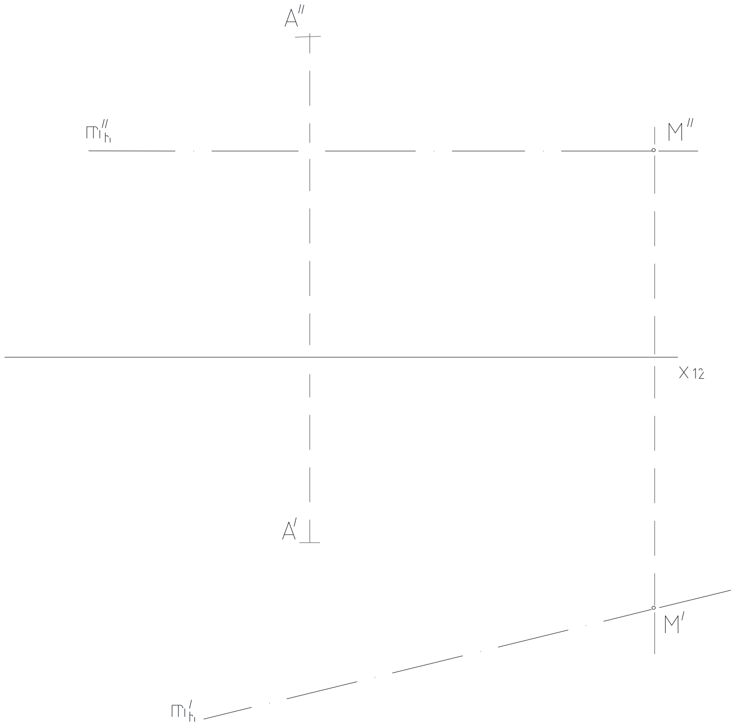
The vertex **A** of the base right triangle and the middle straight line $\mathbf{m}_h$ in the horizontal position are given. The vertex **M** of the right pyramid also are given lying on the $\mathbf{m}_h$.

In the first step use a new plane of projection connected to the **K**$_1$ to construct the two regulated projection of the pyramid!

Show the visibility too!

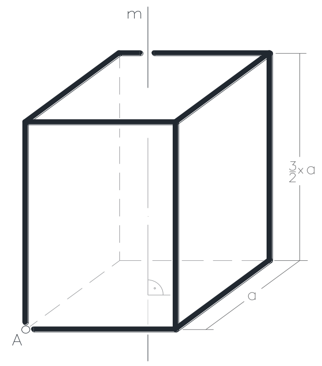


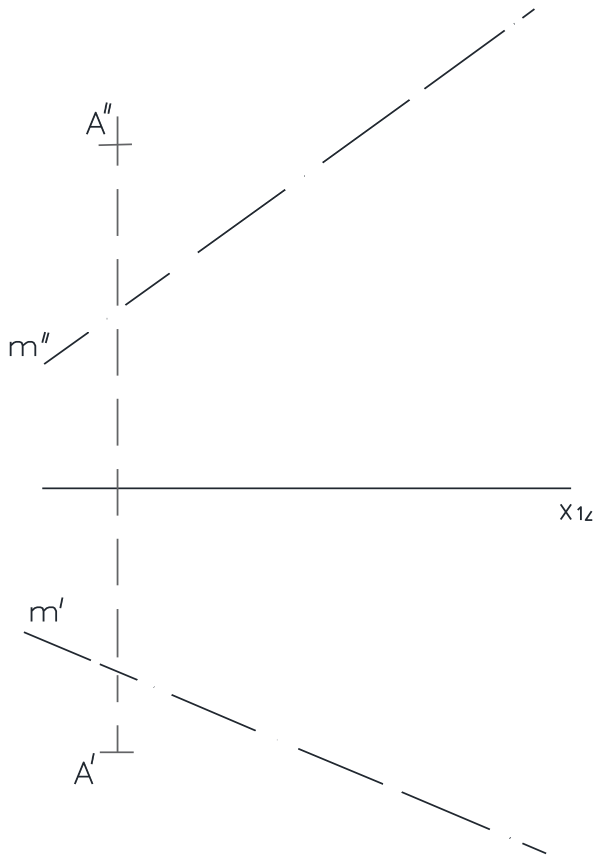




The vertex A of the base square and the middle straight line m of the right prism are given. The length of the height of the prism is one and half times of the side length of the base square.

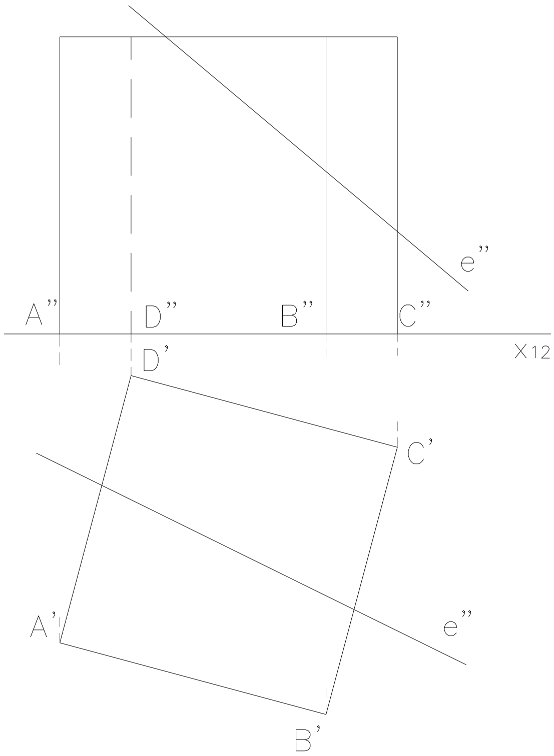
In the first step use a new plane of projection connected to the $\underline{K}_1$ to determine the prism! Show the visibility too!



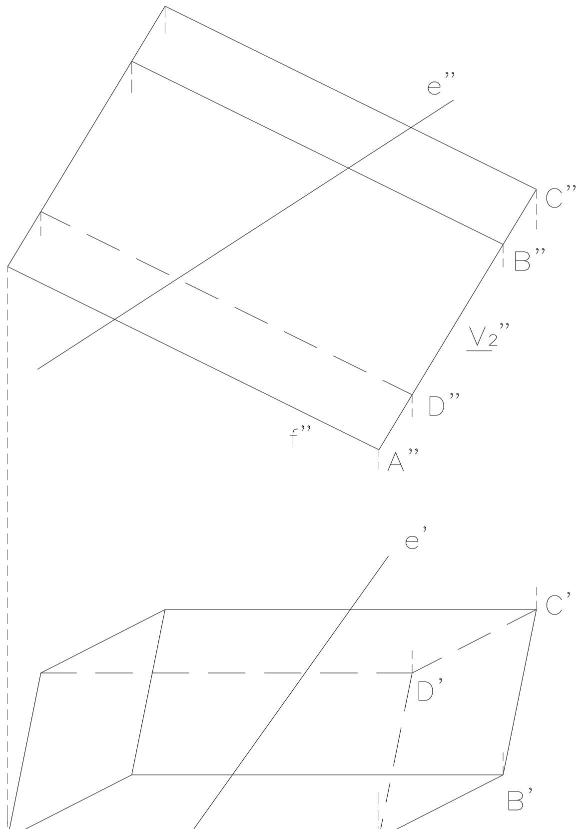


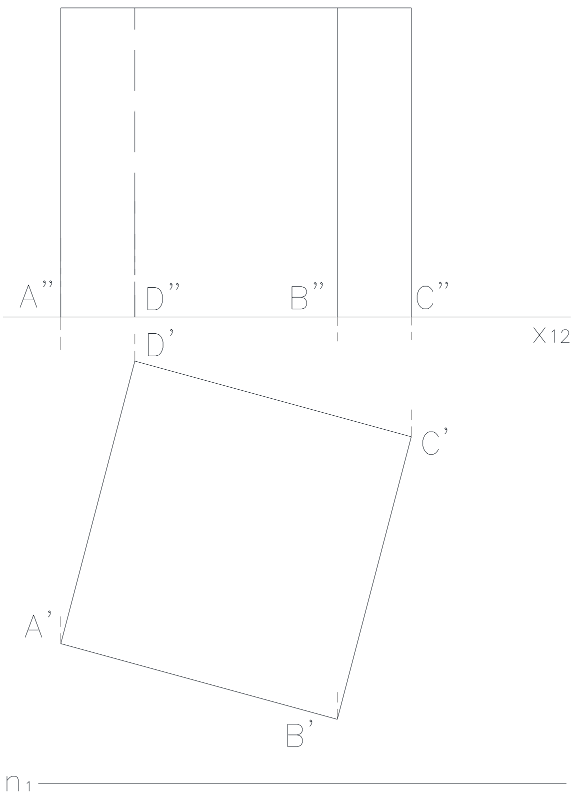
4.1. INTERSECTION BETWEEN A PRISM AND BASE ELEMENTS

Determine the intersection points of the given prism placed on the plane $\underline{K}_1$ and the line **e**! Demonstrate the visibility!



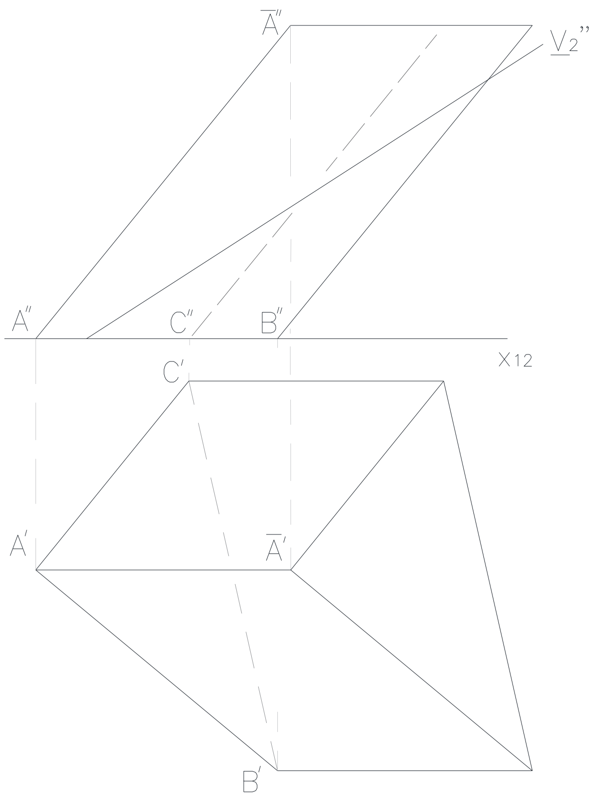
Construct the intersection points of the prism placed on a projector plane $\underline{V}_2$ and the line **e**, then demonstrate the visibility!





Given the square-based straight prism placed on the plane of projection $\underline{K}_1$ and an the first trace line $\mathbf{n}_1$ parallel to $\mathbf{x}_{12}$. Create the third plane of projection $\underline{V}_3$, which lies on the trace line $\mathbf{n}_1$, if the angle between it and the first plane of projection $\underline{K}_1$ is $\alpha_1 =$ 30°! Determine the intersection poligon between the prism and the plane $\underline{V}_3$! Indicate the visibility of the side surface part between the base plane and the intersecting plane!

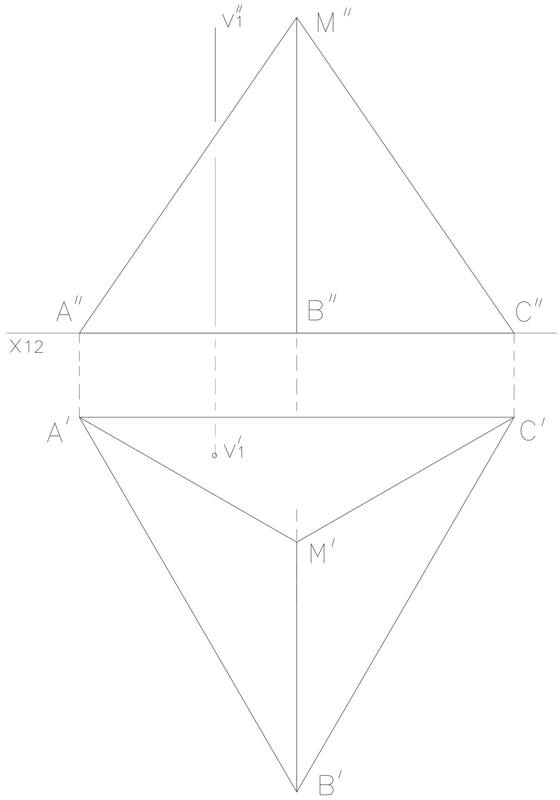
The skewed prism placed on the plane $\underline{K}_1$ is given. Determine the intersection polygon between the given prism and the plane $\underline{V}_2$! Describe the side surface between the base plane and the intersecting plane. Show the visibility! Construct the real size of the intersected polygon by rotating around first trace line $\mathbf{n}_1$ into the plane of projection $\underline{K}_1$!

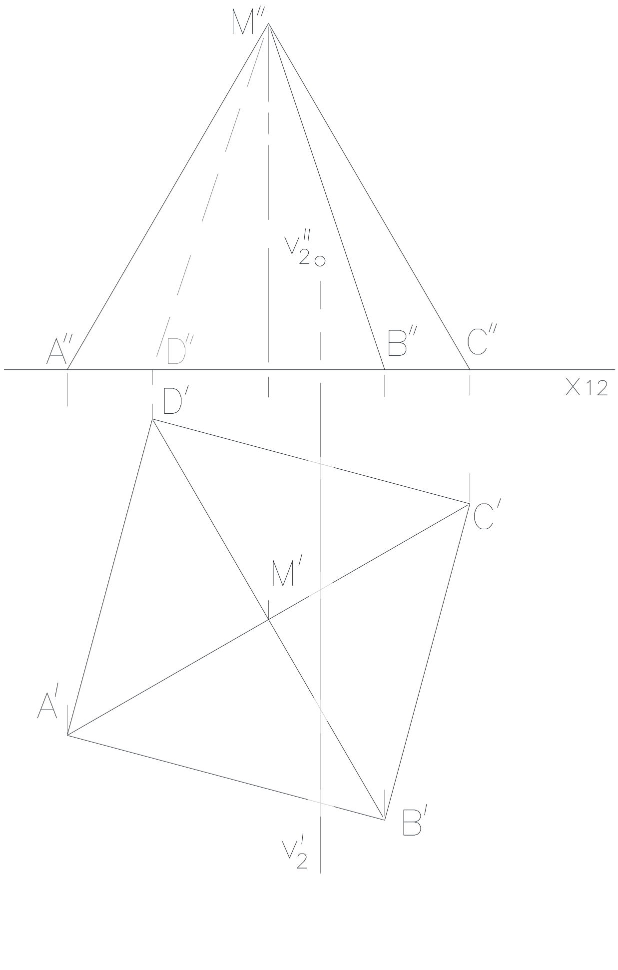


4.2. INTERSECTION BETWEEN A PYRAMID AND A STRAIGHT LINE

Determine the points of intersection of the square-based straight pyramid on the image plane <u>**K**</u>$_1$ and the horizontal line **h**.

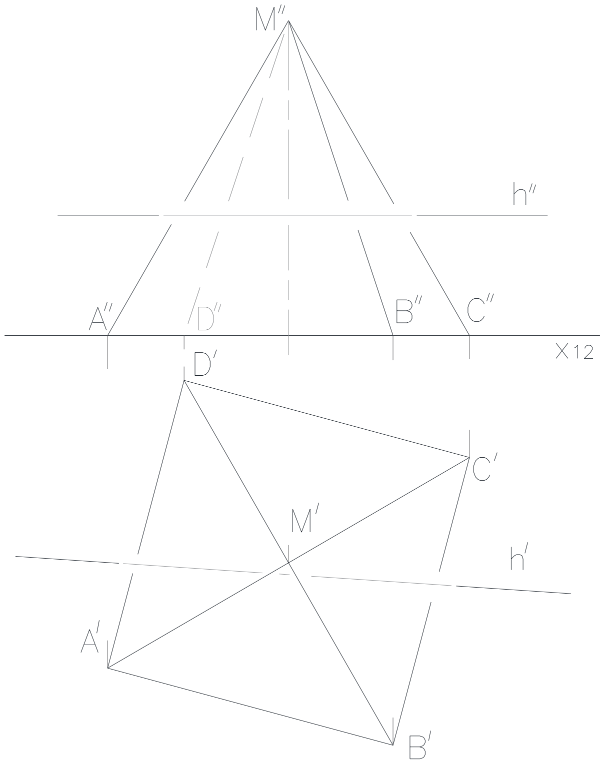
Indicate their visibility.





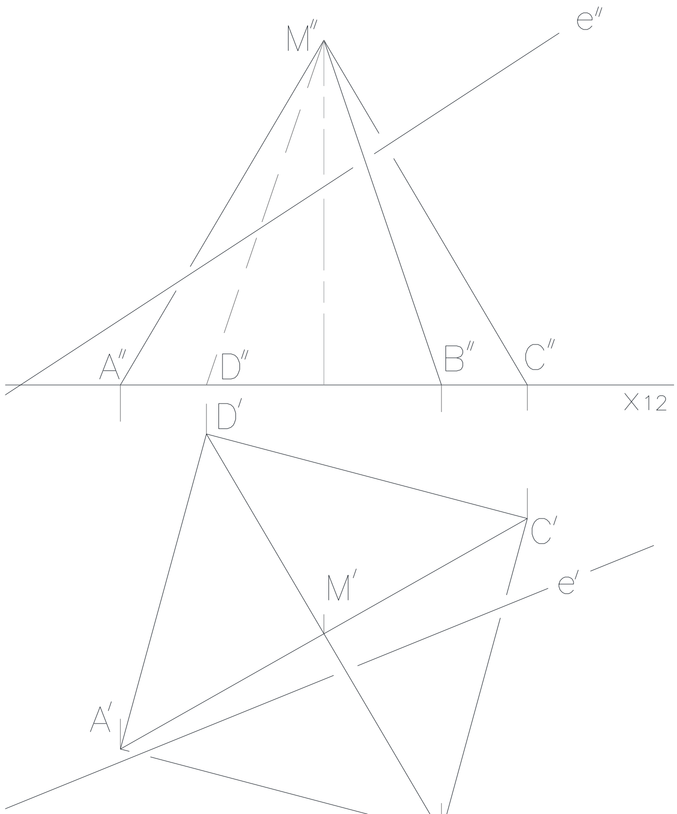
Determine the points of intersection of the square-based straight pyramid on the plane of projection <u>**K**</u>$_1$ and the straight line **v**$_2$ in second projector position.

Indicate their visibility.



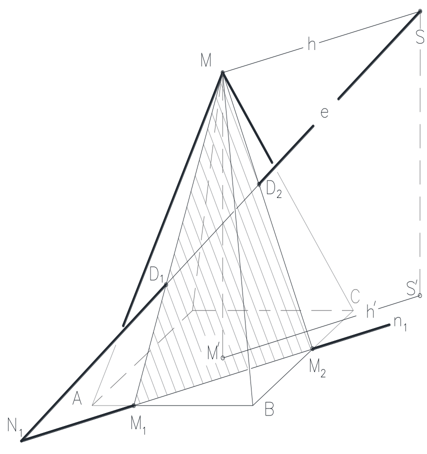
Determine the points of intersection of the square-based straight pyramid on the image plane **K**$_1$ and the horizontal line **h**.

Indicate their visibility.

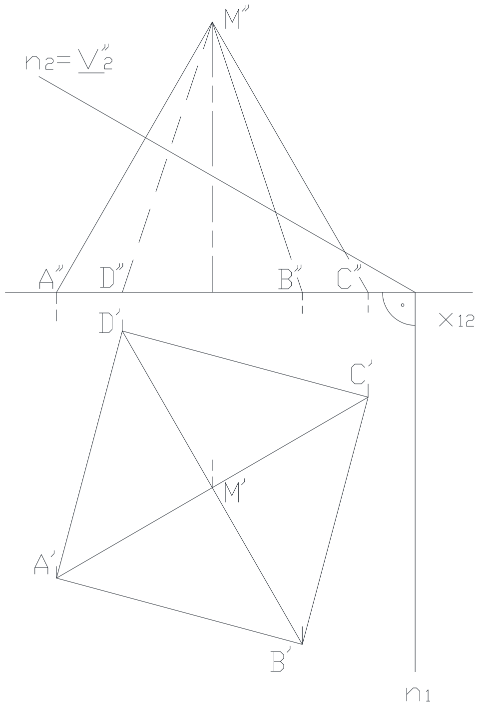


Construct the intersection points between the given pyramid placed on the plane **K**$_1$ and the line **e** using the plane [**Me**], then show the visibility!

The axonometric sketch for the solution is given below.



4.3. INTERSECTION BETWEEN A PYRAMID AND A PLANE

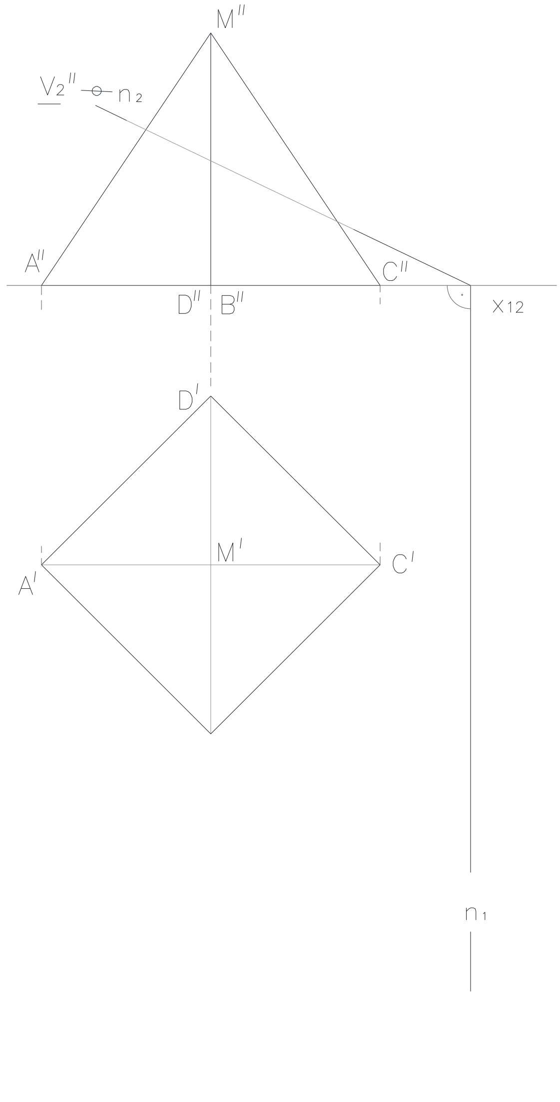


Determine the intersection of the given square-based right pyramid and the second projection plane V2! Show the visibility of the solid between the plane of projection K1 and the V2 intersecting plane! Construct the true size of the plane section by rotating the intersecting plane V2 into the plane of projection K1!

The square-based right pyramid is given in such a way that two of its lateral edges are in profile position. Furthermore, the second projection plane V2 is given too.

Determine the intersection between the pyramid and the second projection plane V2 using the central collineation connection between the base plane and the intersecting plane!

Show the visibility of the solid between the plane of projection K1 and the V2 intersecting plane!



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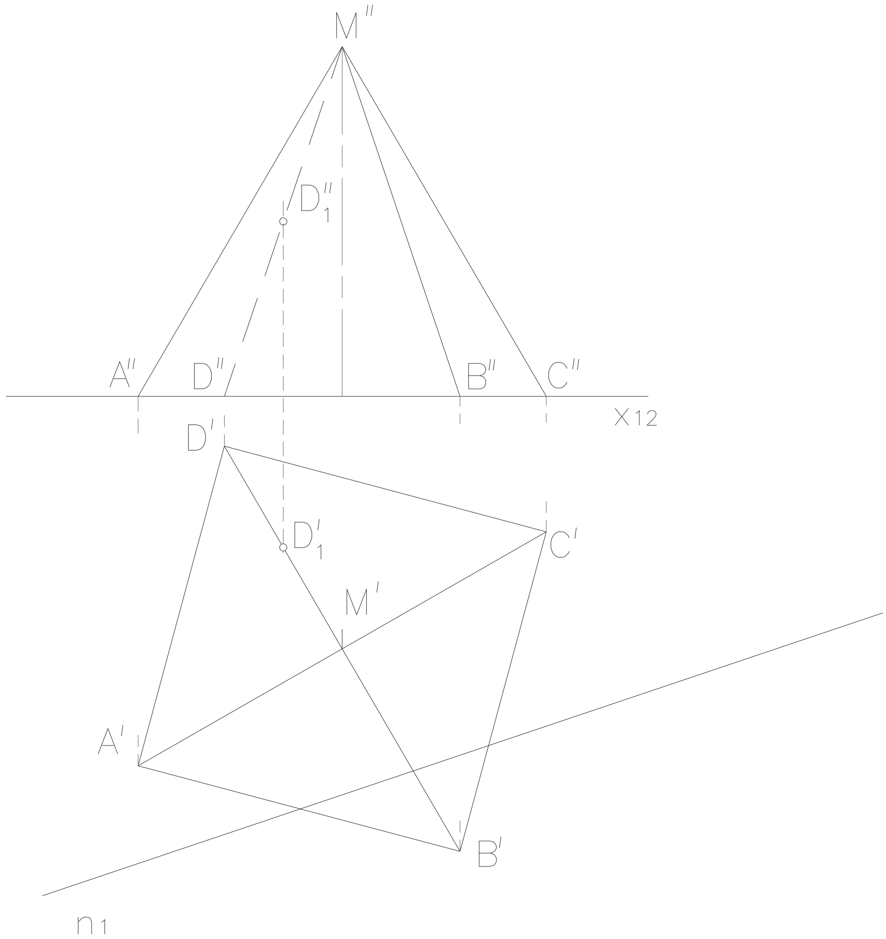
The square-based right pyramid on the plane of projection $\underline{K}_1$ is given. Furthermore, the $\underline{S}$ intersecting plane is given by its first trace line n_1 and point D_1 lying on the lateral edge DM of the pyramid.

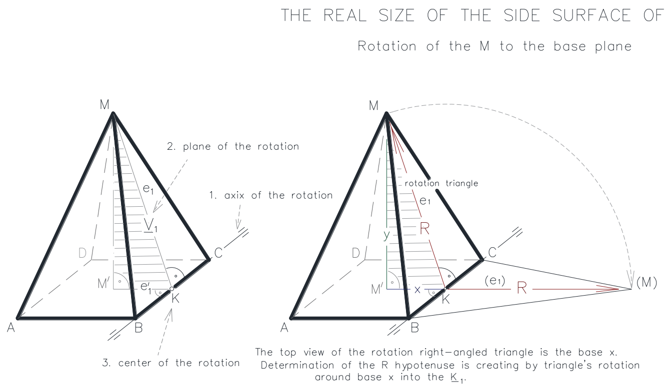
Determine the intersection between the pyramid and the intersecting plane $\underline{S}$ [n_1, D_1]!

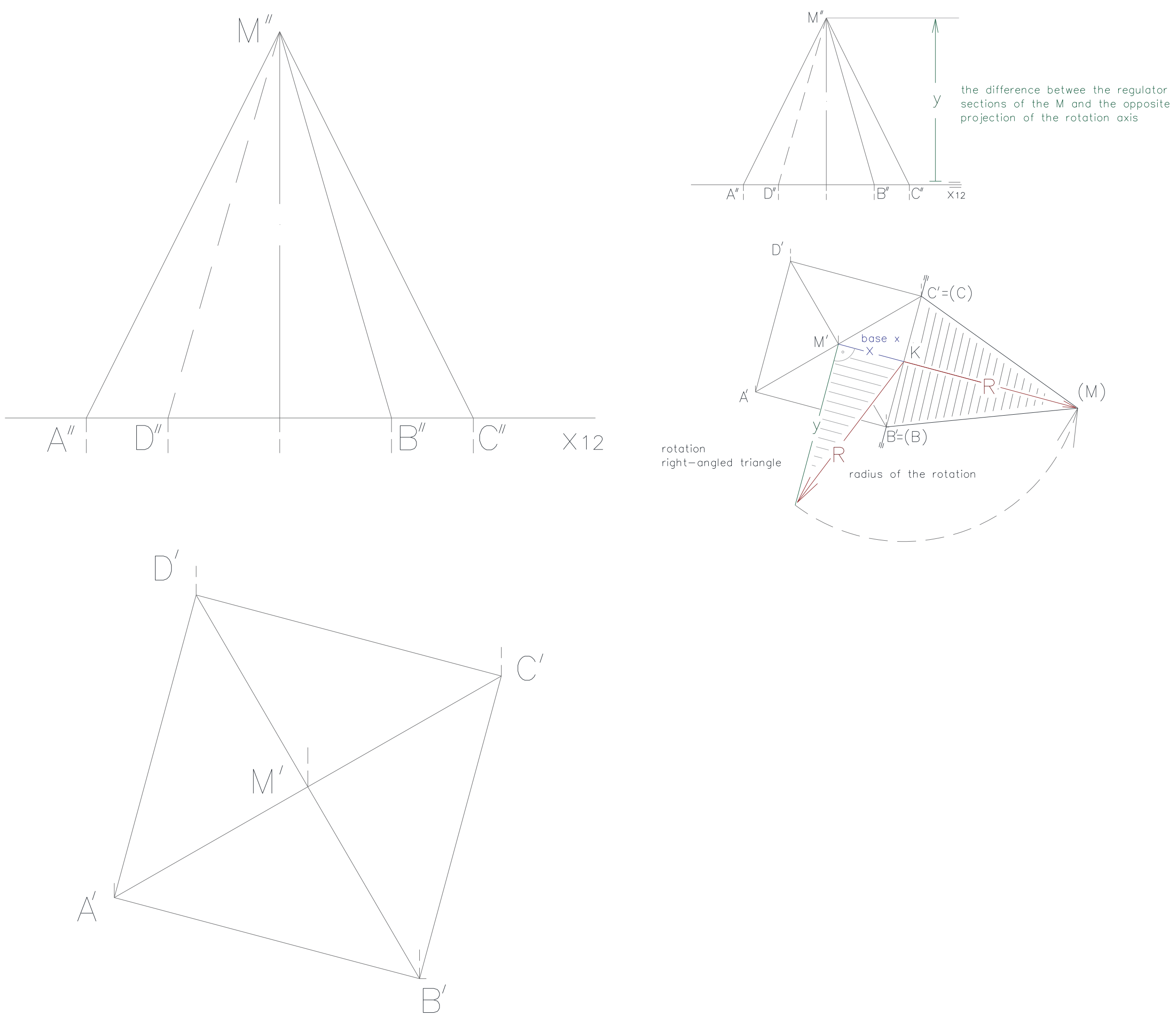
Show the visibility of the solid between the plane of projection $\underline{K}_1$ and the $\underline{S}$ [n_1, D_1] intersecting plane!



4.4. ROTATION OF THE PYRAMID SIDE-SURFACE INTO THE BASE PLANE

Construct the true size of one side surface of a regular square-based straight pyramid standing on the plane of projection K̲$_1$! The steps of the spatial construction and its creation on the two ordered perpendicular projections:

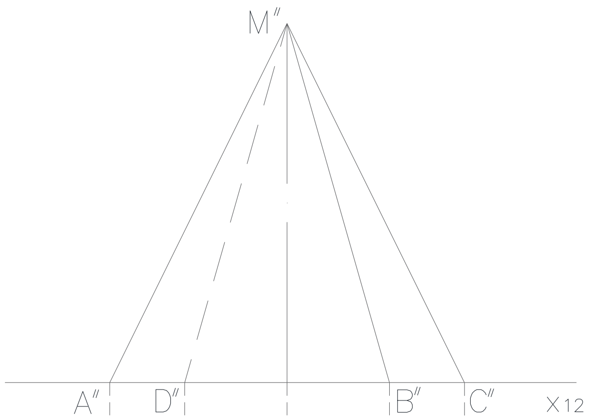


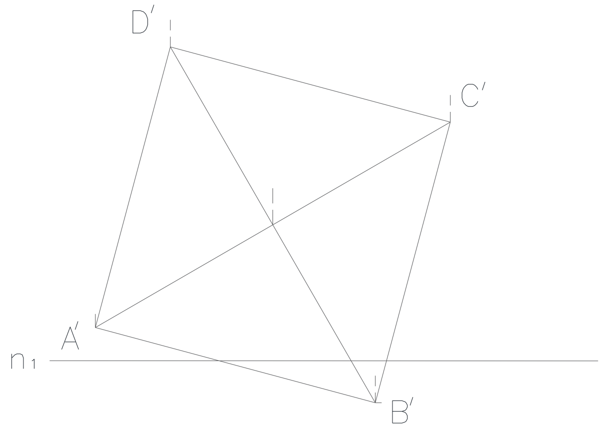


Given is the square-based straight pyramid standing on the first plane of projection and the first trace **n**$_1$ parallel to the axis **x**$_{12}$. Intersect the pyramid with the third projection plane V̲$_3$, which lies on the first trace n1 and forms an angle of **α**$_1$=**45**° with the first plane of projection K̲$_1$!

Describe the visualisation of the side surfaces between the base plane and the cutting plane!

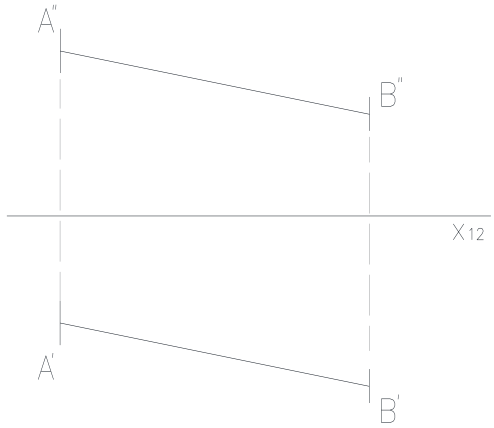
Construct the true size of the truncated cone side surfaces and section by rotating to the first projection plane K̲$_1$!

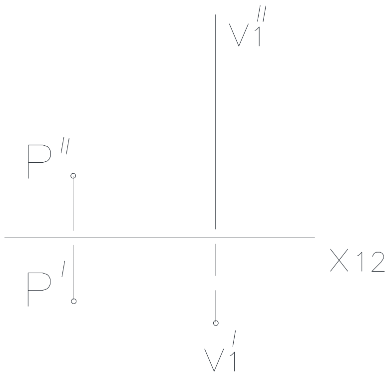




5.1. TRUE SIZE OF DISTANCES

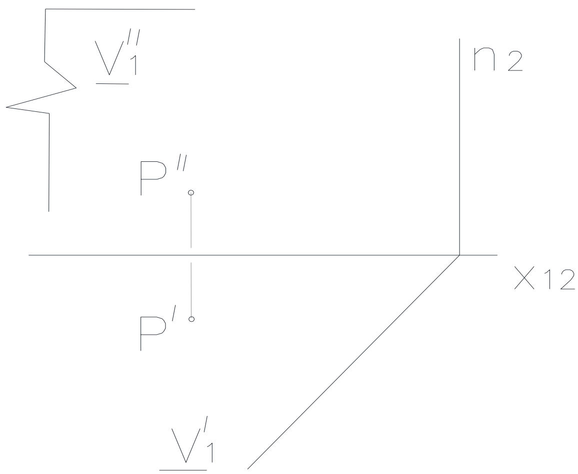
Construct the true length ***l*** of section **AB**!



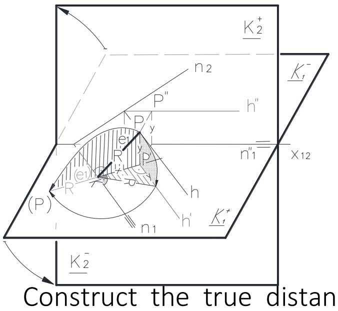


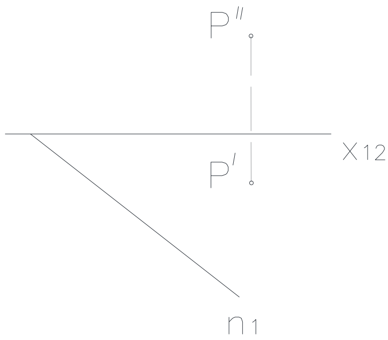
Determine the true distance ***d*** between the point **P** and first projection line $\mathbf{v_1}$!

Construct the true distance ***d*** between the point **P** and the first projection plane $\underline{\mathbf{V}}_1$!

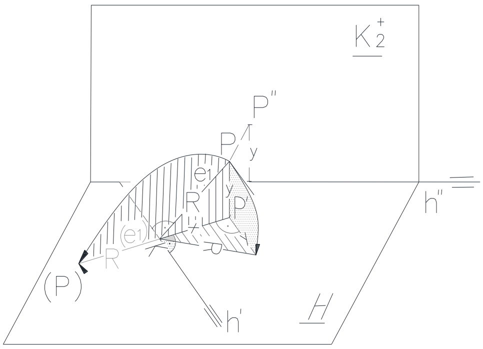


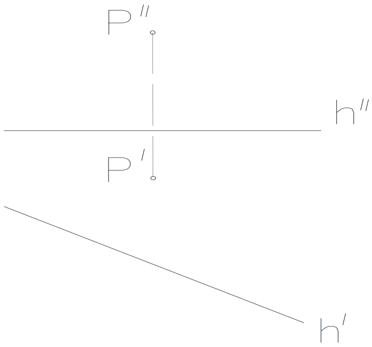
Construct the true distance ***d*** between the point **P** and the first trace line $\mathbf{n}_1$ using rotation!

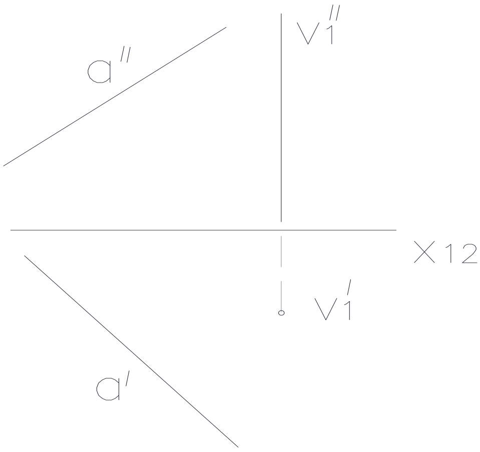




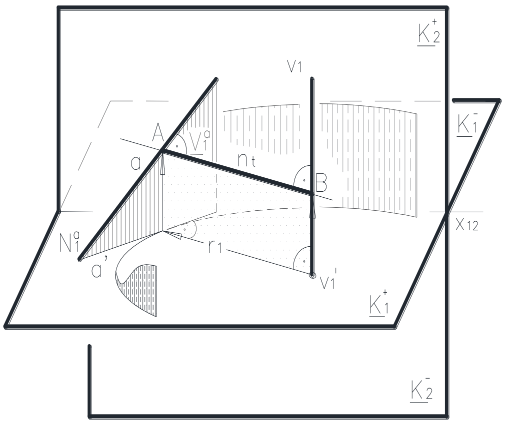
Construct the true distance ***d*** between the point **P** and the first main line **h** using rotation!





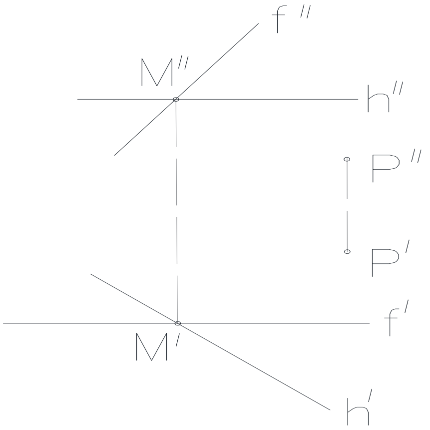


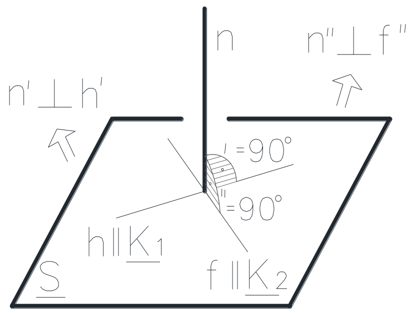
Construct the $|\mathbf{n}_t|$ true distance between the line **a** and the first projection straight line $\mathbf{v}_1$, and determine the position of the normal transverse $\mathbf{n}_t$!



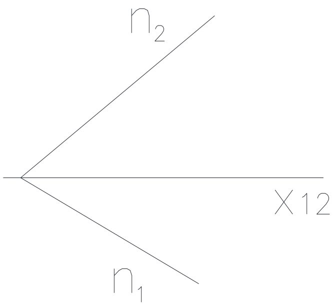
5.2. TRUE ANGULAR DIMENSIONS

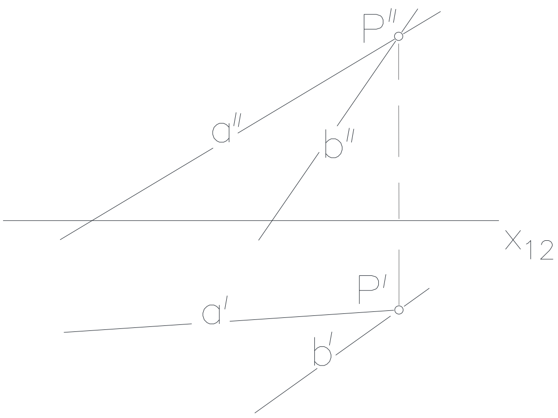
Construct the normal **n** to the plane given by its main lines **h** and **f**, fitting to the point **P**!





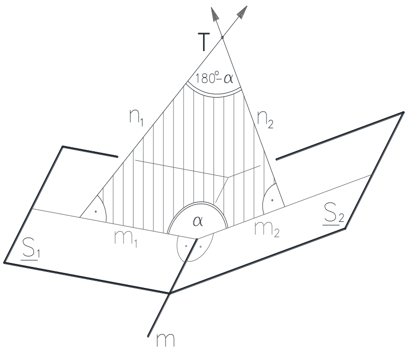
Determine the size of angles $\boldsymbol{\alpha_1}$ and $\boldsymbol{\alpha_2}$ between the given plane by traces and planes of projections <u>K</u>$_1$ and <u>K</u>$_2$!

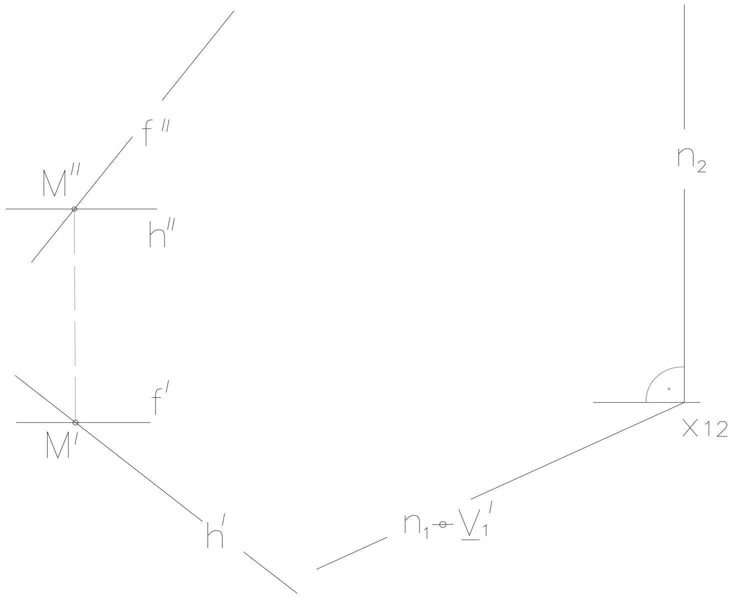




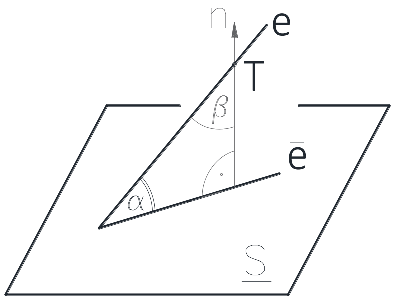
Construct the true size angle $\boldsymbol{\alpha}$ between the intersecting lines **a** and **b**!

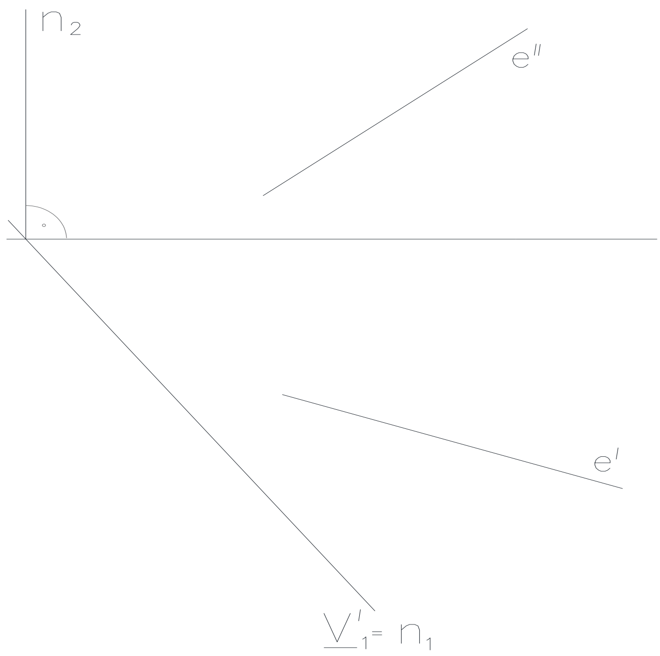
Construct the true size angle ***α*** between the plane given by it's main lines and the first projection plane given by it's trase lines!





Construct the true angle ***α*** between the given straight-line **e** and the first projection plane **V**$_1$!



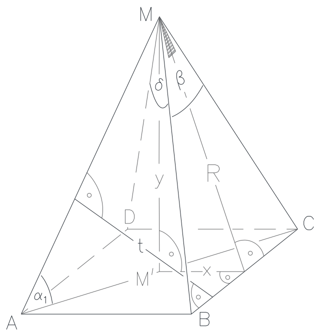


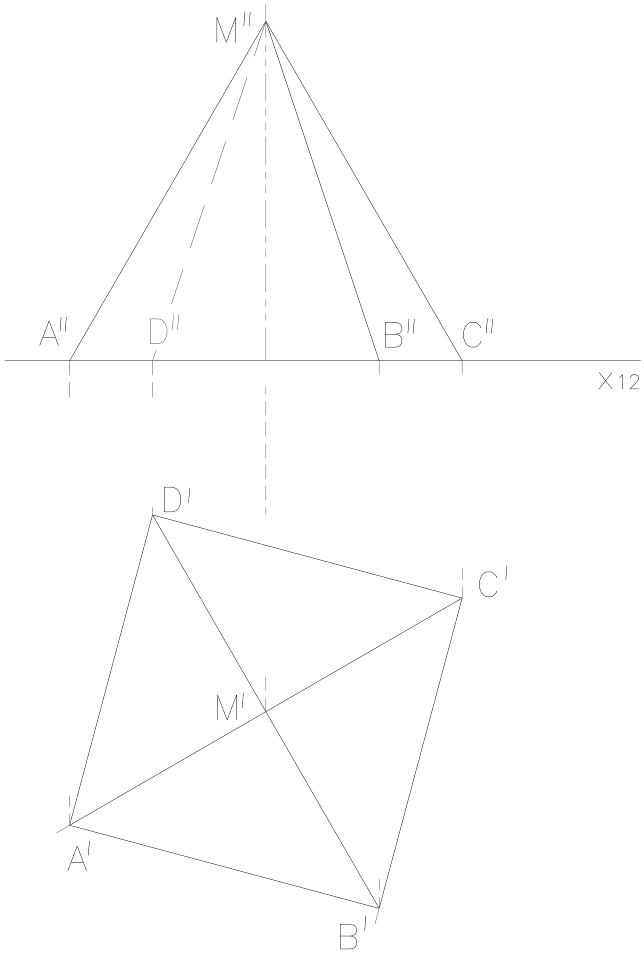
5.3. DIMENSIONS ON THE PYRAMID

Given the square-based orthogonal prism on the plane of projection $\underline{K}_1$ such that any side is not parallel to the plane of projection $\underline{K}_2$!

Construct:

- the distance t between the lateral edge I**AM**I and the base edge I**BC**I,
- the angle α_1 between the first plane of projection $\underline{K}_1$ and the lateral edge I**AM**I,
- the angle β between the lateral edges I**BM**I and I**CM**I,
- the angle δ between the lateral edges I**BM**I and I**DM**I!





Given **triangle-based right prism** on the plane of projection $\underline{K}_1$ such that the base edge I**AC**I is parallel to the plane of projection $\underline{K}_2$!

Construct:

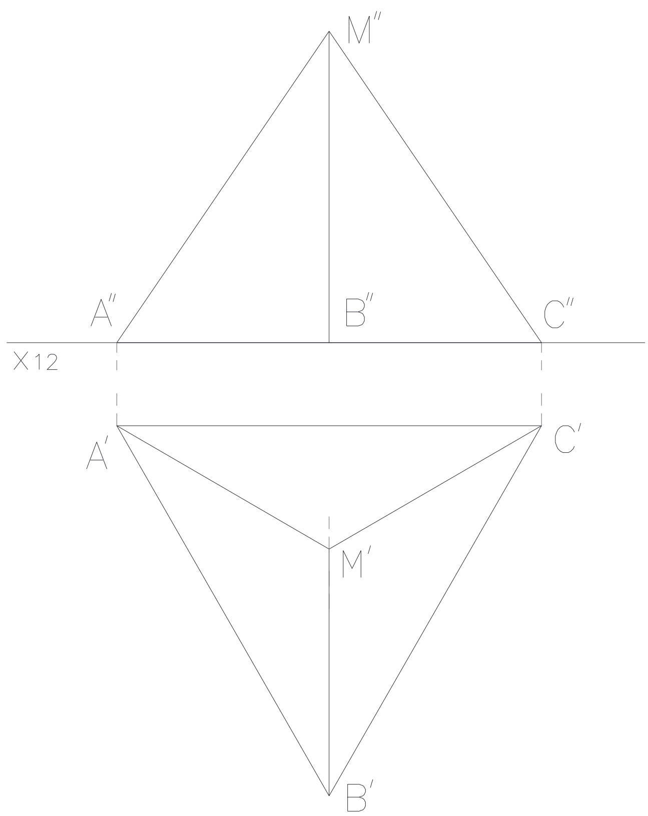
- the distance $\boldsymbol{t}$ between the point **B** and lateral plane [**ACM**],

- the distance $\boldsymbol{n}_t$ between the base edge I**AC**I and lateral edge I**BM**I,

- the angle $\boldsymbol{\alpha}$ between the first plane of projection $\underline{K}_1$ and the lateral plane [**ACM**],

- the angle $\boldsymbol{\beta}$ between the first plane of projection $\underline{K}_1$ and lateral edge I**BM**I,

- the angle $\boldsymbol{\gamma}$ between the lateral edges I**AM**I and I**BM**I!



6.1. REPRESENTATION OF THE CIRCLE

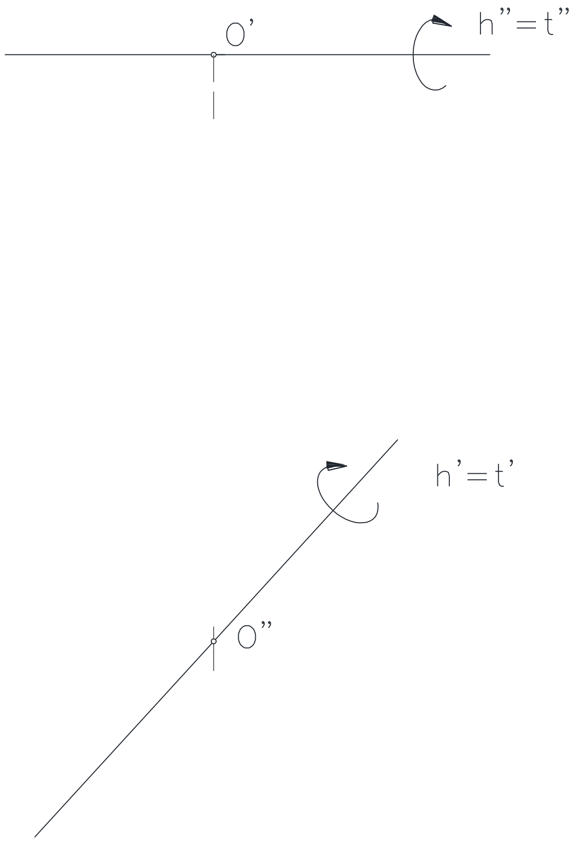
Represent the circular disc with the axis **t** in horizontal position, the center point **O** and the radius **r=**25mm.

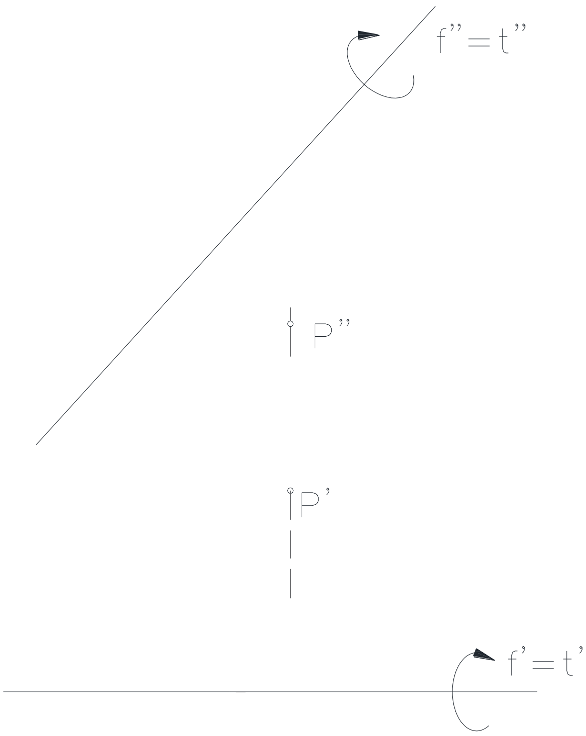
Construct the major axis **AB** and the minor axis **CD** of the second projection ellipse of the circle.

Determine the tangents and hyperosculating circles at the axis endpoints.

Draw the second projection ellipse!

Show the visibility of the axis **t** and the circular disc with continues and dashed lines!





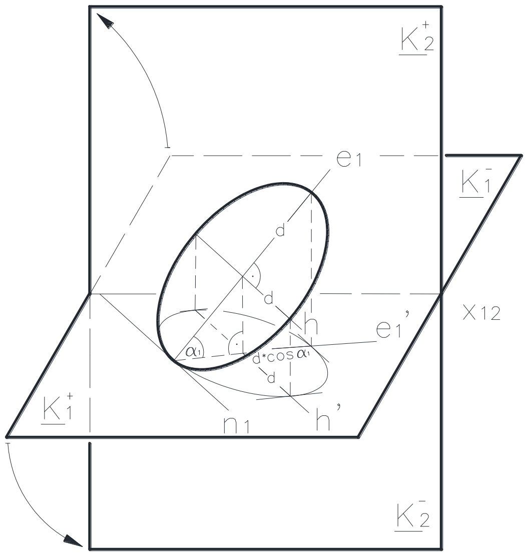
Represent the circular disc with the axis **t** in frontal position and the point **P** on the perimeter line!

Construct the major axis **AB** and the minor axis **CD** of the first projection ellipse.

Determine the tangents and hyperosculating circles at the axis endpoints, furthermore the tangent **e** at the point **P**!

Draw the first projection ellipse!

Show the visibility of the axis **t** and the circular disc with continues and dashed lines!



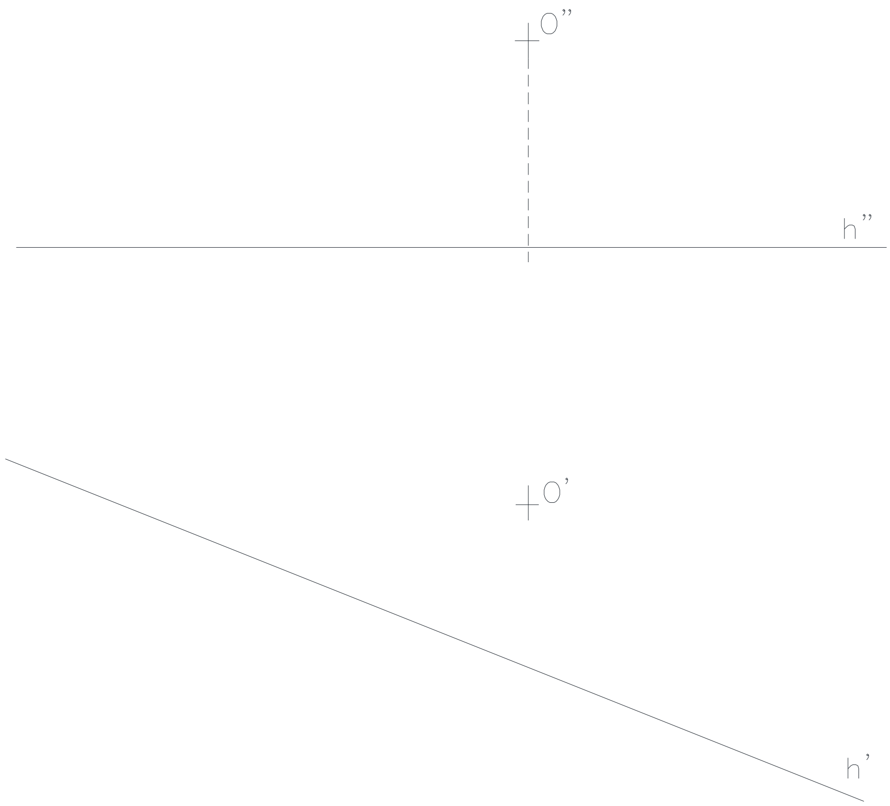
Represent the circle lying on the plane S[Oh], of which the center point is **O**, and the **h** horizontal line is its tangent!

Construct:

- the real size of the circle,
- both projections of the major axis **AB** and the minor axis **CD** of the first projection ellipse, and the tangents at endpoints of axes,
- both projection of the major axis **PQ** and the minor axis **RS** of the second projection ellipse, and the tangents at endpoints of axes,
- the tangents $\mathbf{e}_{1,2}$ in profile direction with its circle points P_1, P_2!

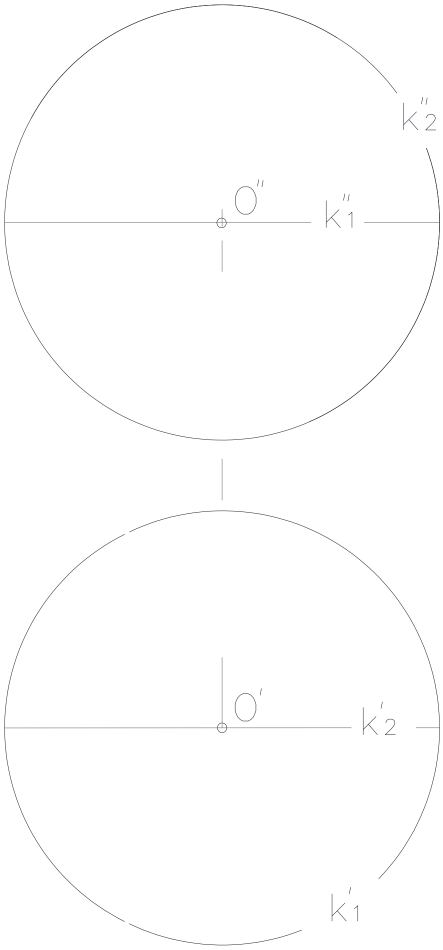
Draw both projections of the circle!

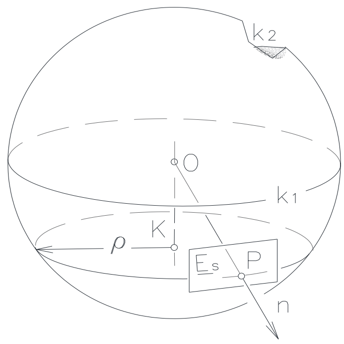
Show the visibility of the disc and its axis **t**!



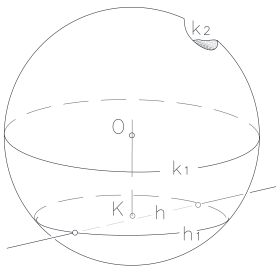
7.1. THE SPHERE

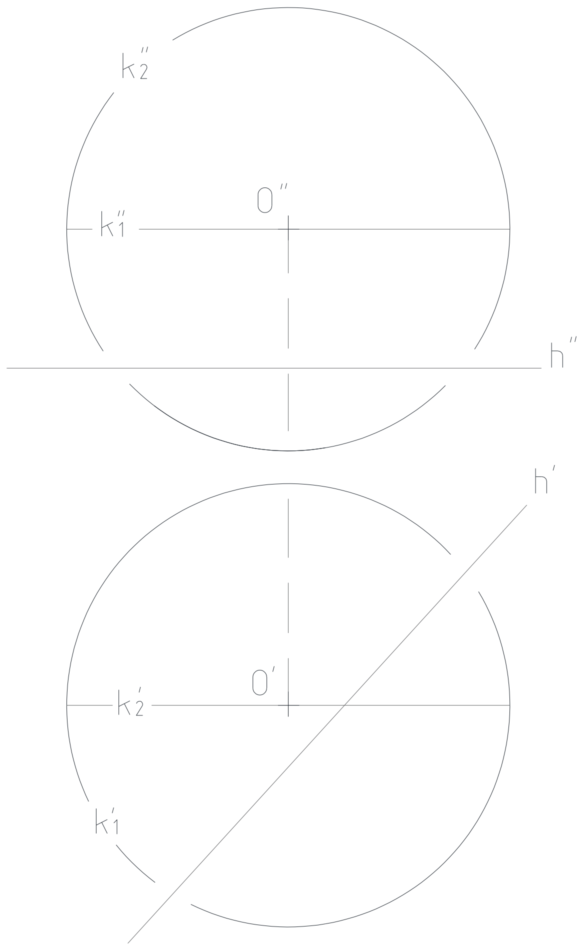
Describe a point **P** with normal **n** and tangential plane E̲s[**h**, **f**] on the given sphere!



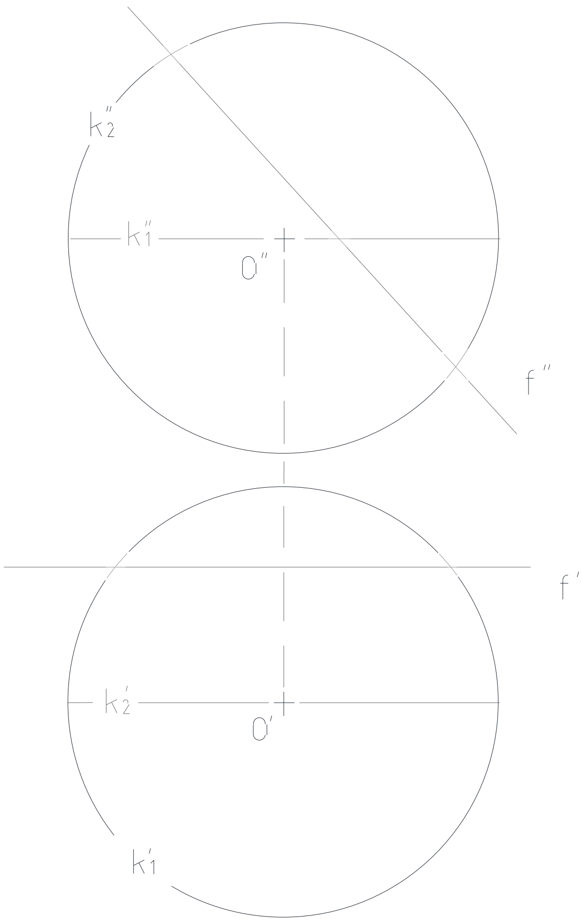


Construct the intersection points D_1 and D_2 of the given sphere and horizontal line **h**! Show the visibility!

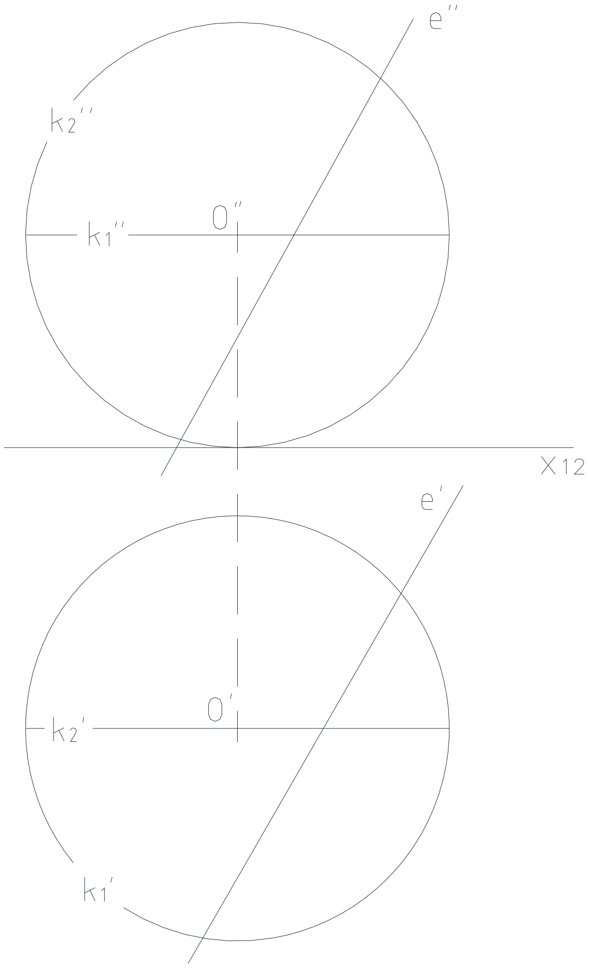




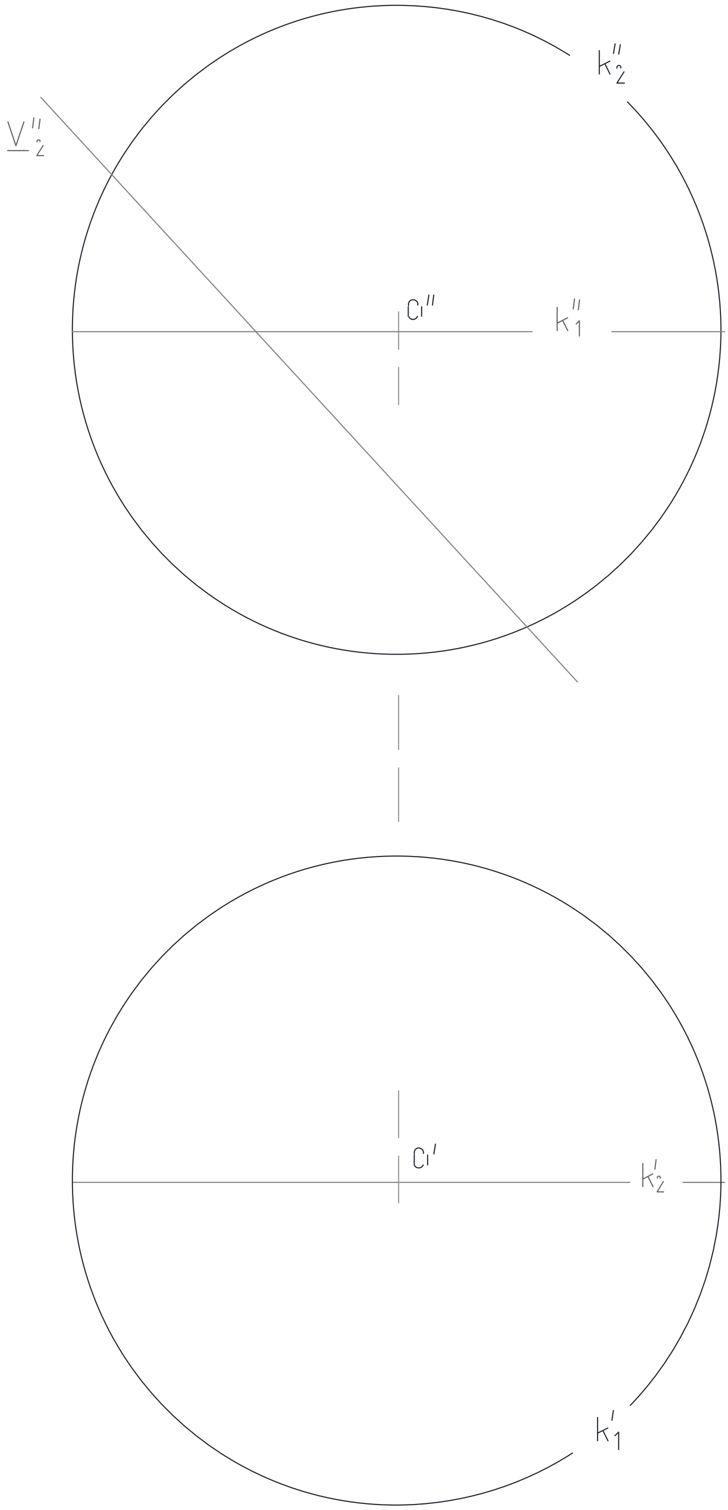
Construct the intersection points **D**$_1$ and **D**$_2$ of the given sphere and frontal line **f**!
Show the visibility!



Construct the intersection points **D$_1$** and **D$_2$** of the given sphere and straight-line **e**!
Show the visibility!

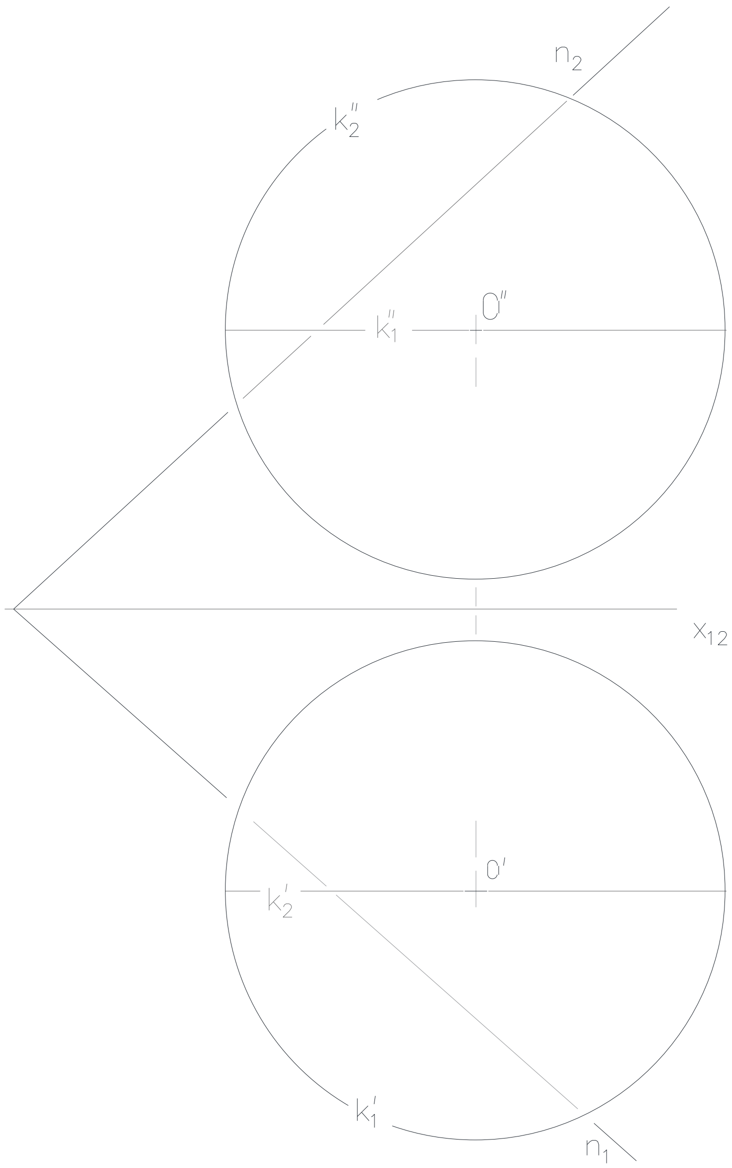


7.2. INTERSECTION OF A SPHERE AND A PLANE



Construct the intersection between the given sphere and the given plane **$\underline{V}_2$**!

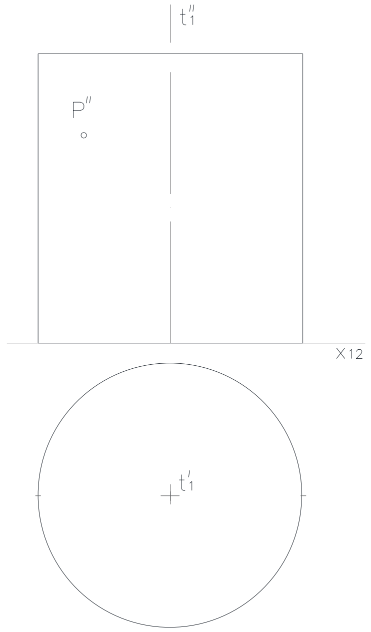
Determine the center point the intersected circle, the axes of first projected ellipse, the points $K_{1,2}$ with tangents $\mathbf{e_{1,2}}$ on the first contour circle $\mathbf{k_1}$! Represent the spherical cap above the second projection plane $\underline{V}_2$, indicating the visibility!

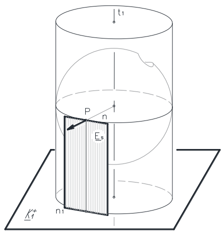


Construct the intersection between
the given sphere
and the given plane **S**[**n**$_1$,**n**$_2$]
using the new plans of projections!
Determine
- the center point **K** of the intersected circle,
- the axes on both projections of the circle,
- the points with tangents on the first and second contour circle!

Show the visibility!

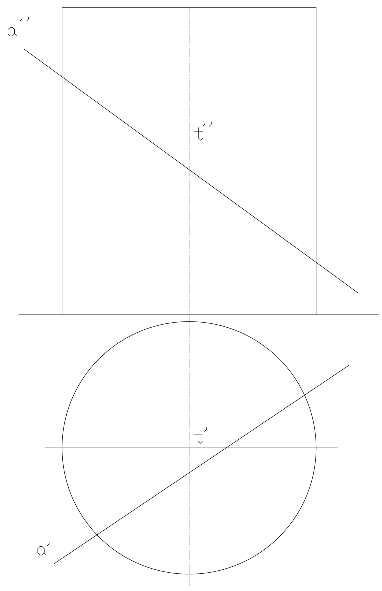
8.1. THE CYLINDER

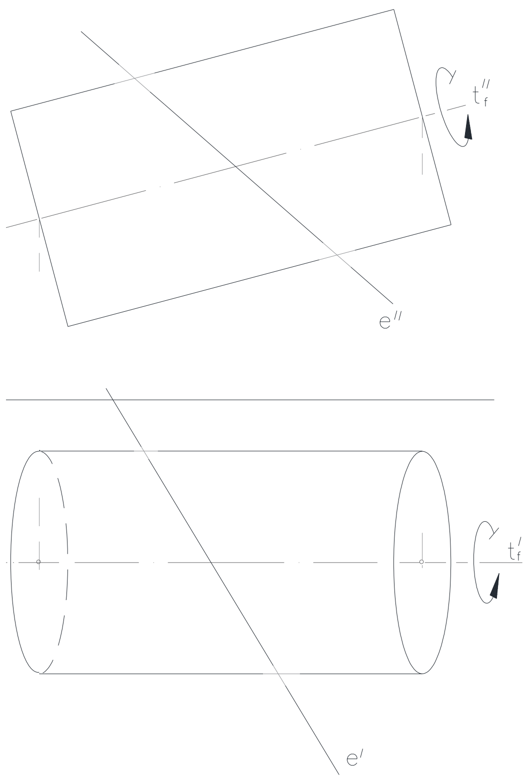




The cylinder with the first projection line axis $\mathbf{t}_1$ and the second projection of the point **P** are given. Determine the first projection of the point **P** lying on the cylinder surface, the tangent plane $\underline{E}$s and the surface normal **n** at the point **P** lying on the cylinder!

Determine the common points between the cylinder and the line ***a***. Indicate the visibility!





A cylinder is given, with the axis $\mathbf{t}_f$ in frontal position, and a straight line **e** in general position.

Construct the intersection points!

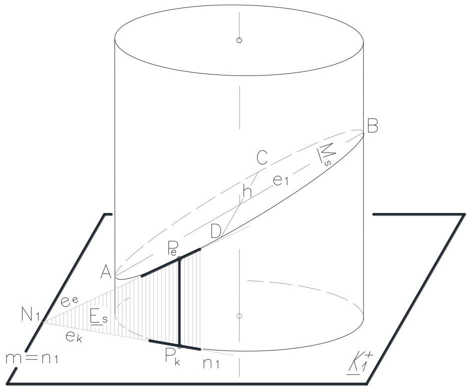
Indicate the visibility!

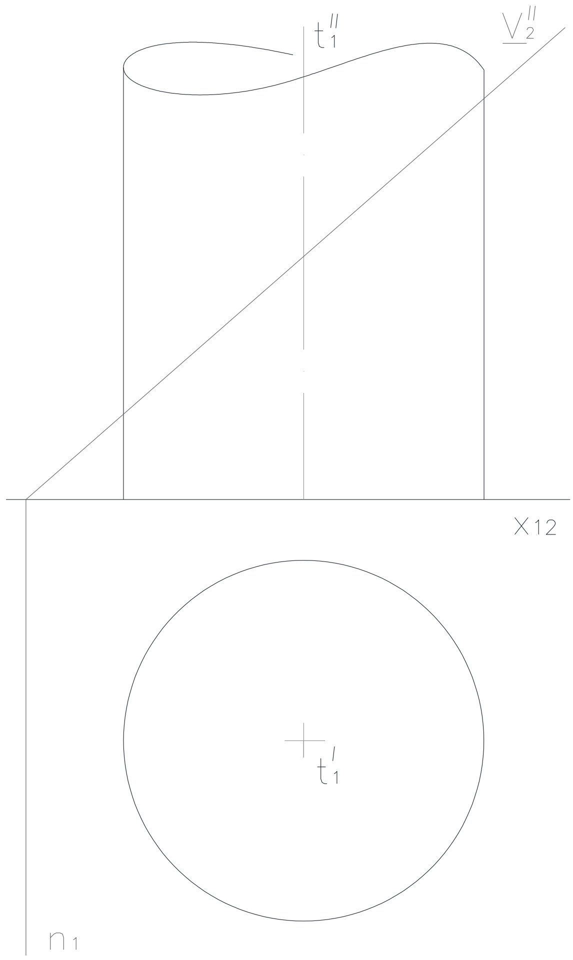
A cylinder is given, with the axis **t**$_1$ in first projection line position, and a plane **V**$_2$ in second projection position. straight line **e** in general position.

Determine both projections of their section!

Construct the axes of the section, a point **P**$_e$ in a general position with the tangent **e**$_e$, and then the true size of the section!

Indicate the part of the body between the base plane and the intersecting plane!

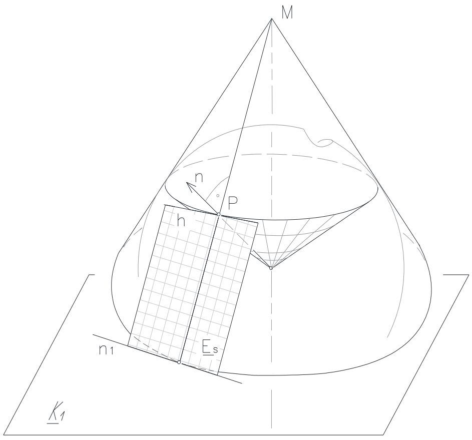


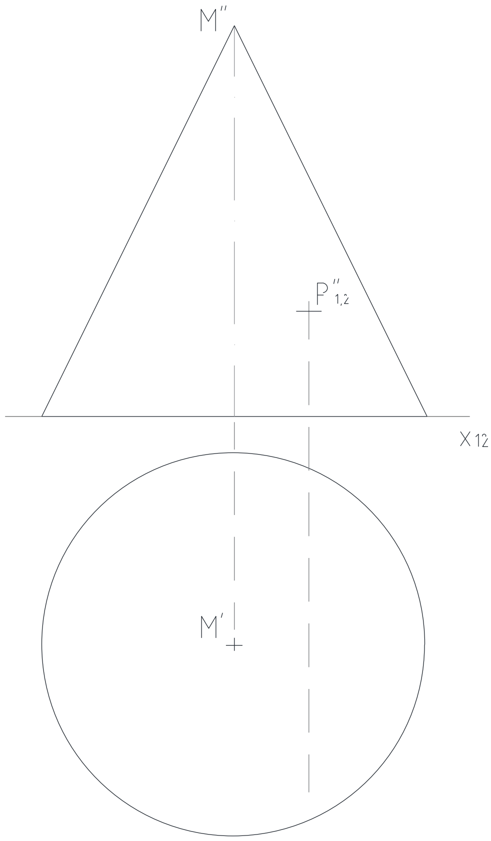


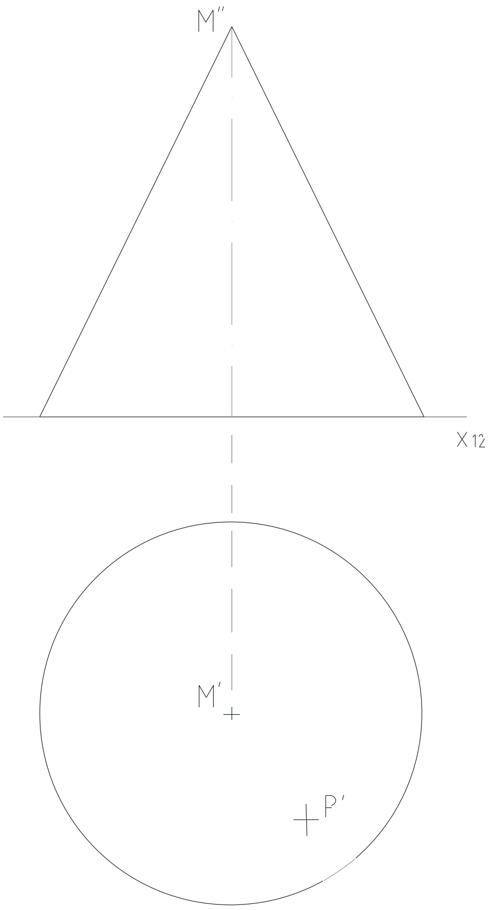
University of Miskolc Óváriné Dr. Blajati, Zsuzsanna
Faculty of Mechanical Engineering and Informatics Department of Descriptive Geometry in Institute of Mathematics

9.1. THE CONE

The cone of rotation with the axis in the first projection position and the second projection of the point **P**$_{1,2}$ are given. Construct the first projection of **P**$_{1,2}$ lying to the cone's surface, the tangent plane **E**$_s$ lying to it at the front point, and the surface normal of **n**!



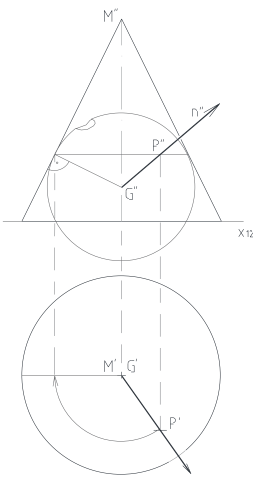


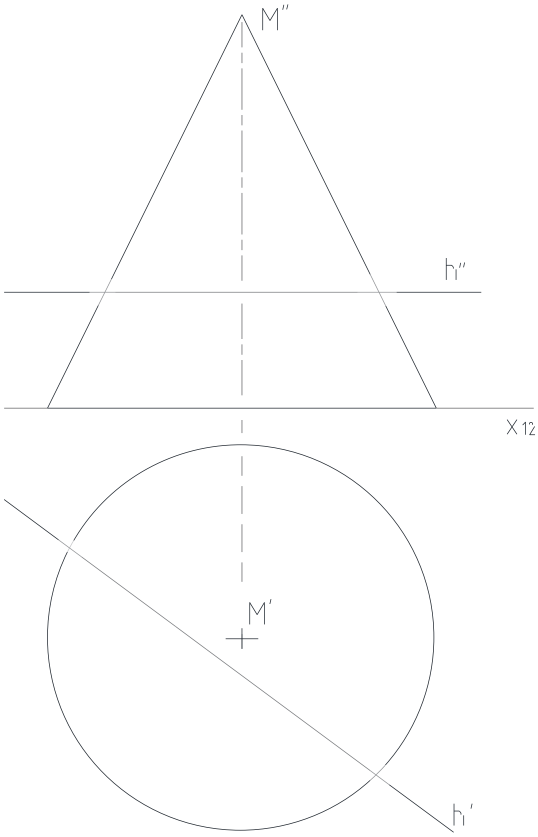


The cone of rotation with its axis in the first projection line position and the first projection of a point **P'** is given.

Determine the second projection of point **P** so that point **P** lies on the cone's surface using the circle parallel to the base circle containing the point!

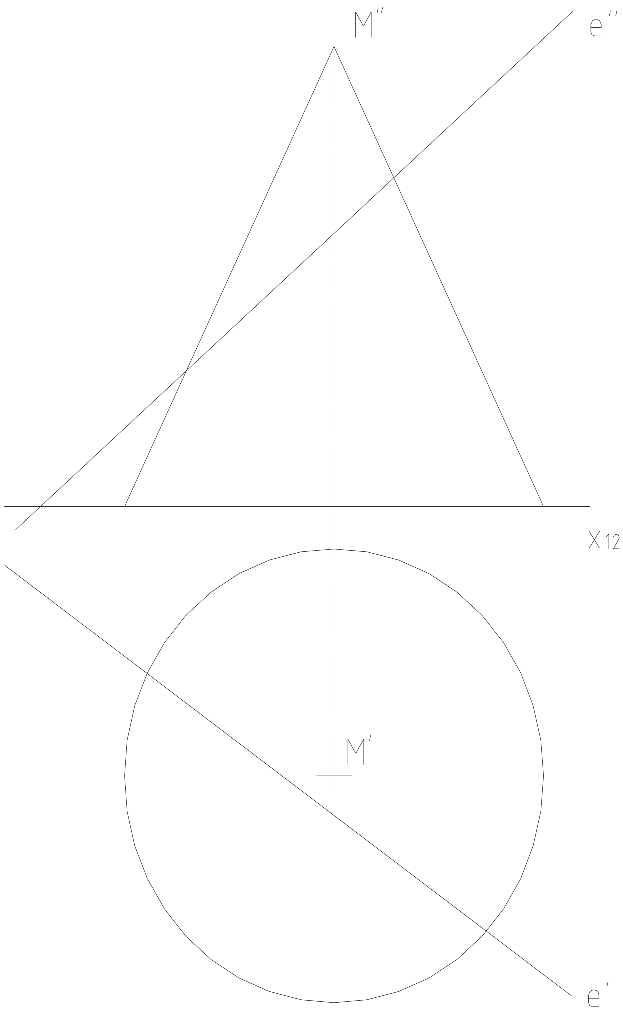
Using the cone-tangent sphere containing the point **P**, construct the surface normal at the point **P** and the normal **n**!



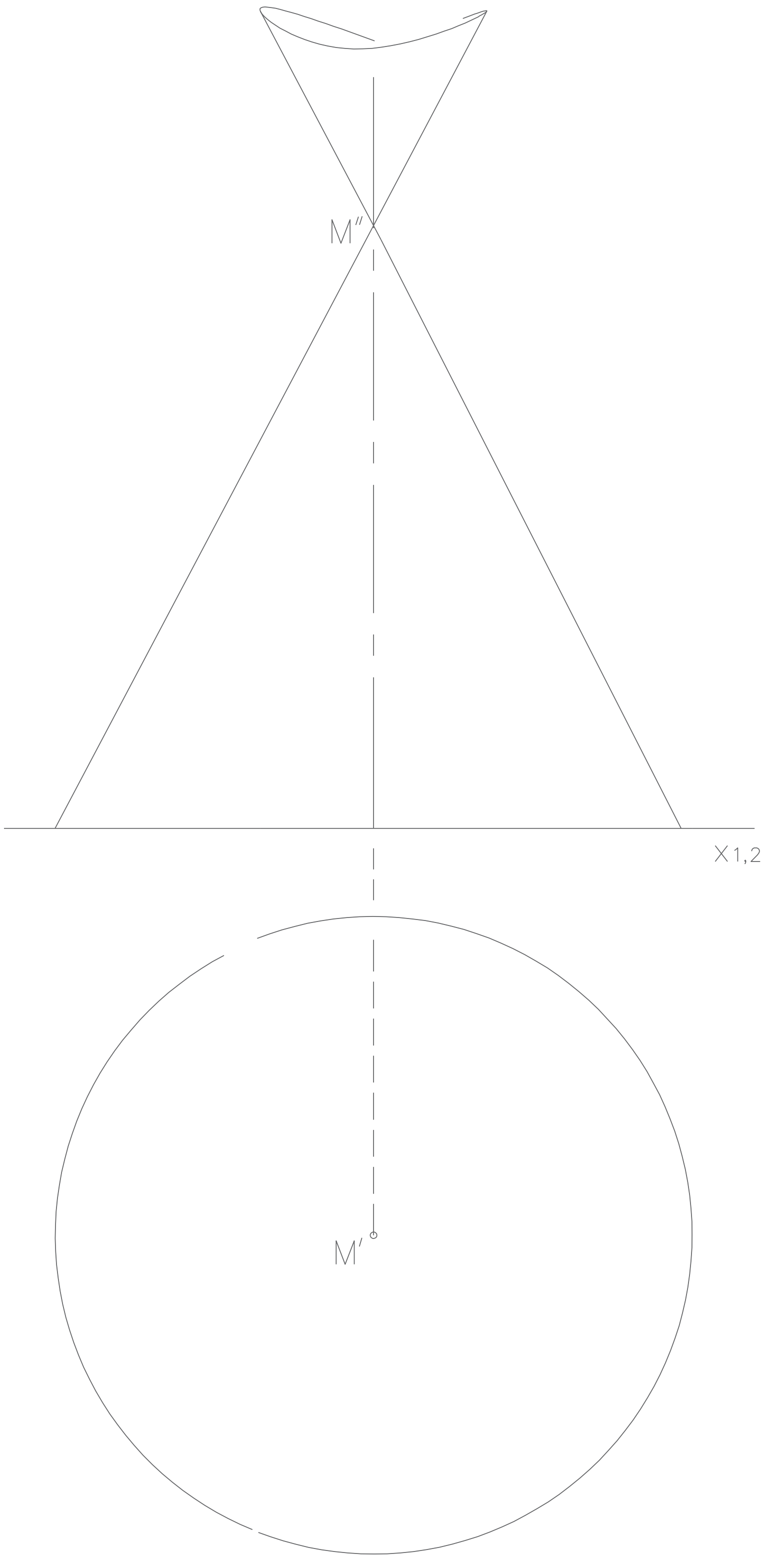


Determine the points of intersection of the cone on the plane **K**$_1$ and the horizontal line **h**. Indicate their visibility.

Construct the intersection points between the given cone on the plane **K**$_1$ and the line **e** using the plane [**Me**], then show the visibility!



9.2. ELLIPTIC SECTION OF THE CONE OF ROTATION

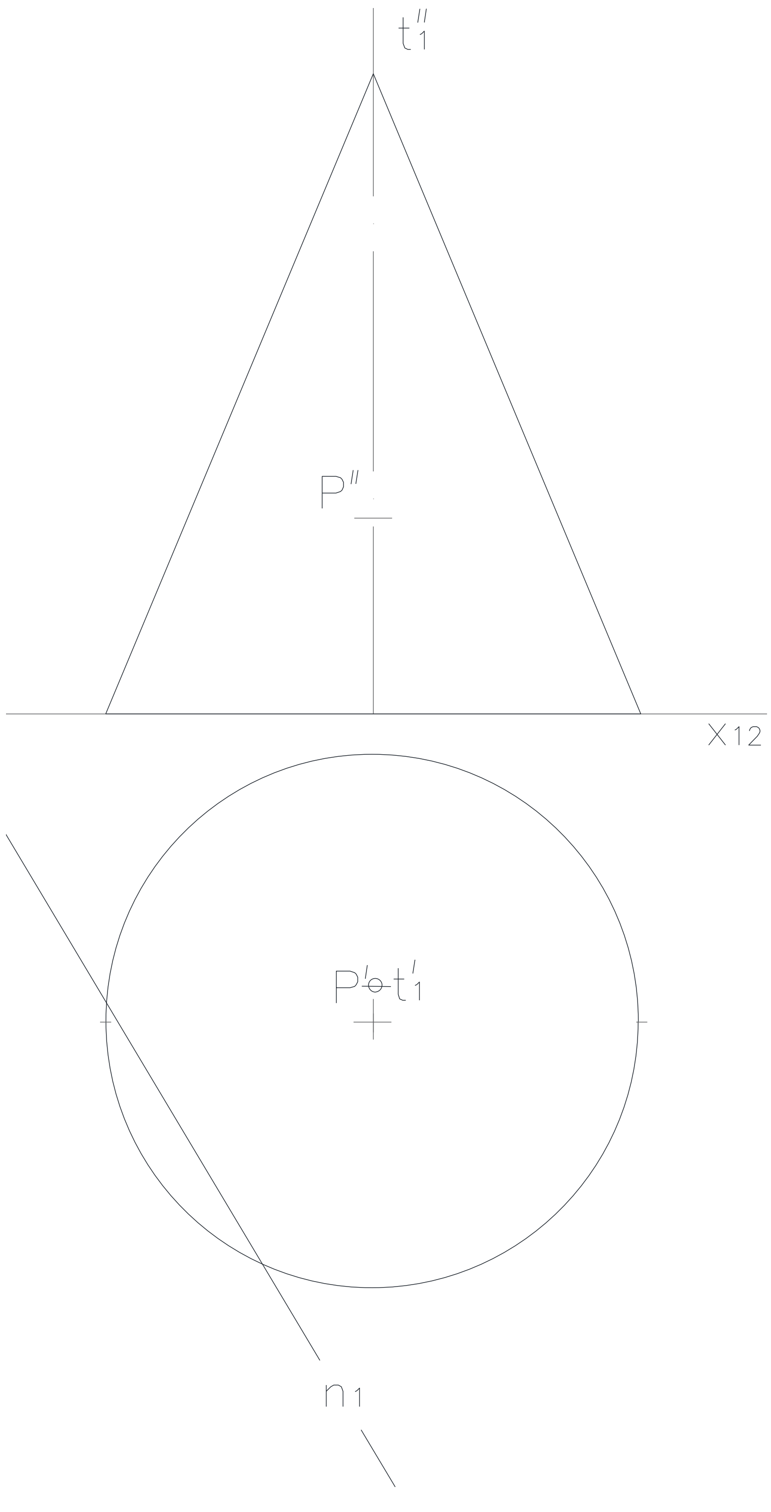


The rotation cone on the plane of projection $\underline{K}_1$ is given. Determine a second projector plane $\underline{V}_2$ that intersects the cone in an ellipse!

Construct the first projection of the ellipse intersection ***e***! Determine the major axis AB and the minor axis **CD** of the ellipse, then its focus points F_1 and F_2, and a general point with its tangent!

Draw the first projection of the section using the hyper osculating circles!

Visually describe the conic section between the base plane and the section plane.



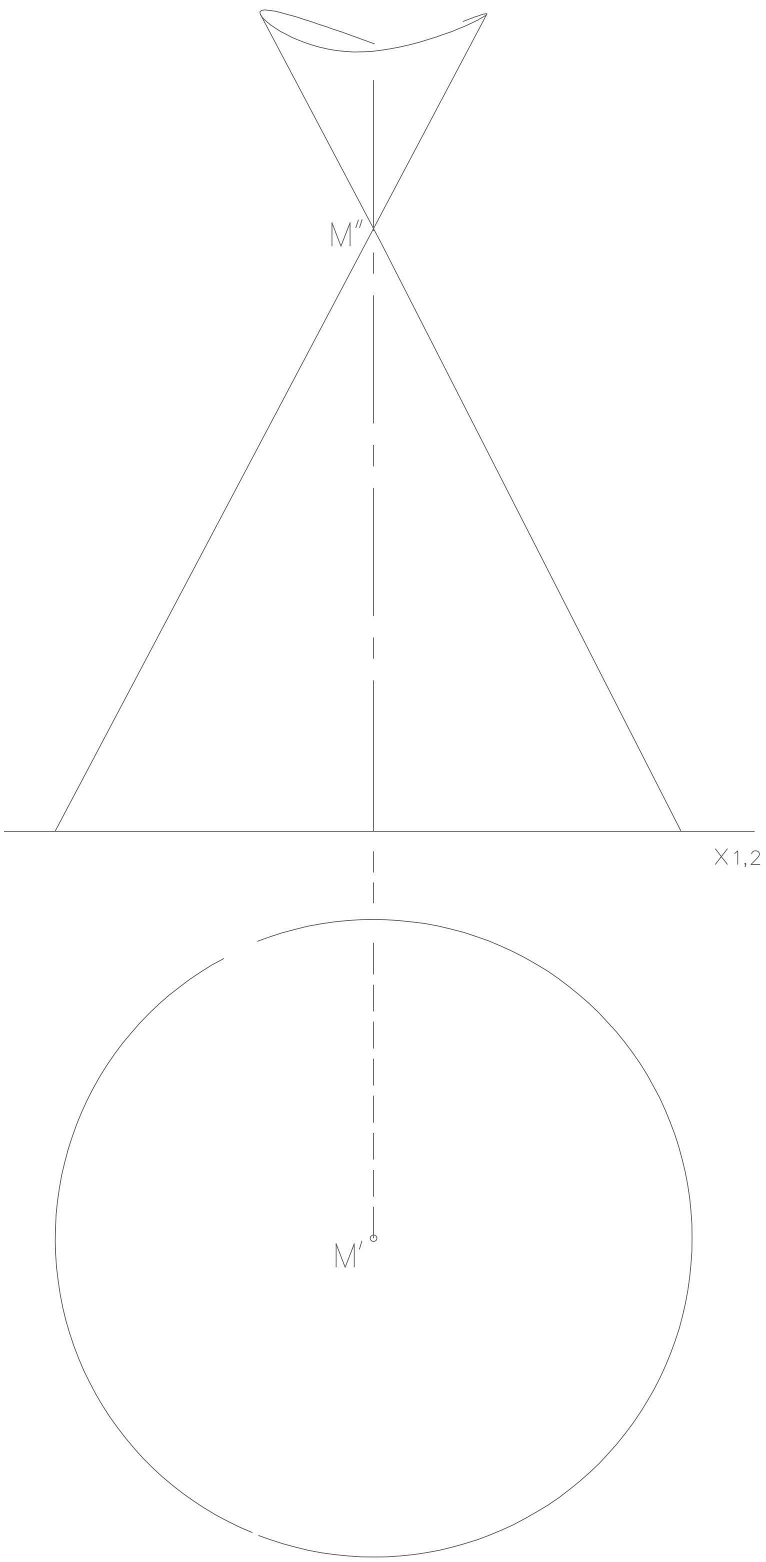
Describe the intersection between the given cone lying on the **K**$_1$ and the plane determined the trace line **n**$_1$ and the point **P**, using the introduction a new plane of projection!!

Construct the axes of the first and second images of the section, some of its generally located points, and the tangent in one of them!

Draw the first and second projection of the section using the hyper osculating circles!

Visually describe the conic section between the base plane and the section plane.

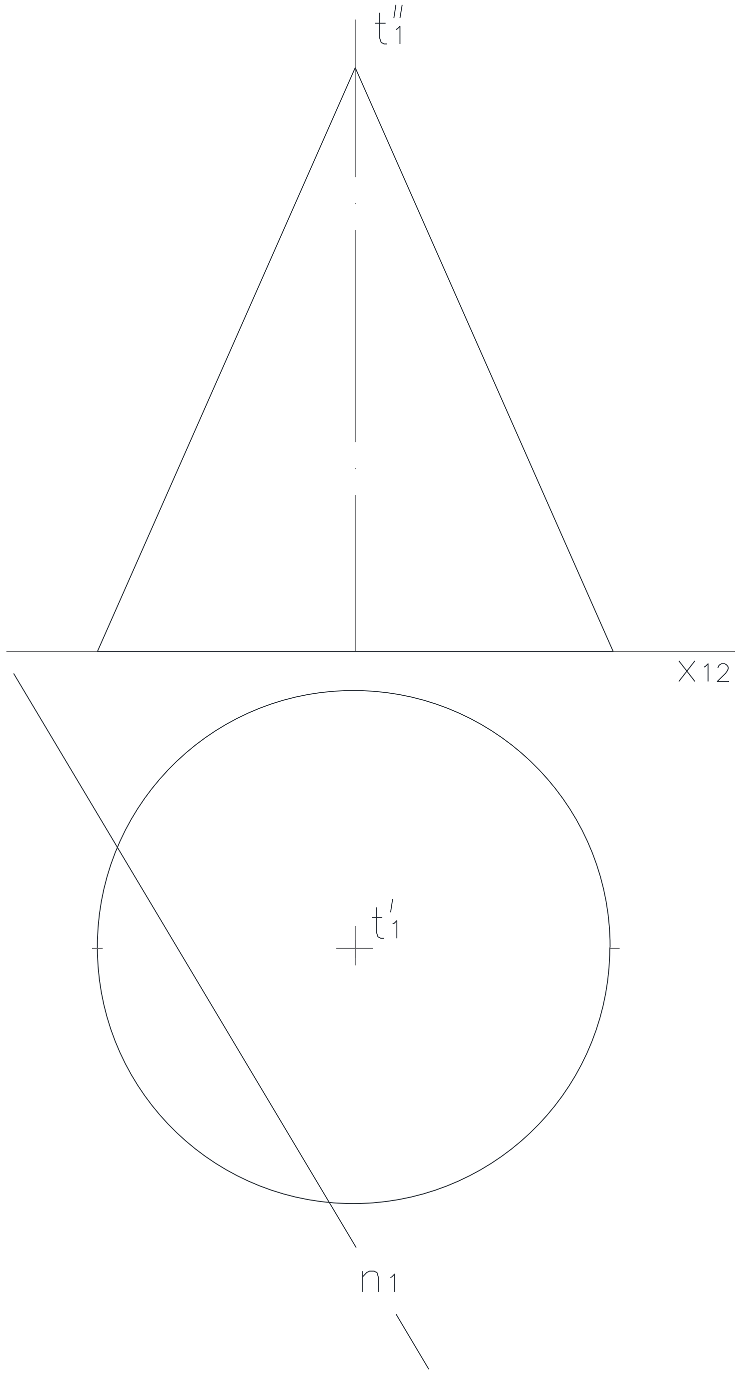
9.3. PARABOLA SECTION OF THE CONE OF ROTATION



The rotation cone on the plane of projection $\underline{K}_1$ is given. Determine a second projector plane $\underline{V}_2$ that intersects the cone in parabola!

Construct the first projection of the parabola section **p**, its **T** axis point and **t** axis, furthermore, draw the directrix **d**, as well as some general points, and the tangent at one of them!!
Draw the first projection of the section using the hyper osculating circles!

Visually describe the conic section between the base plane and the section plane.



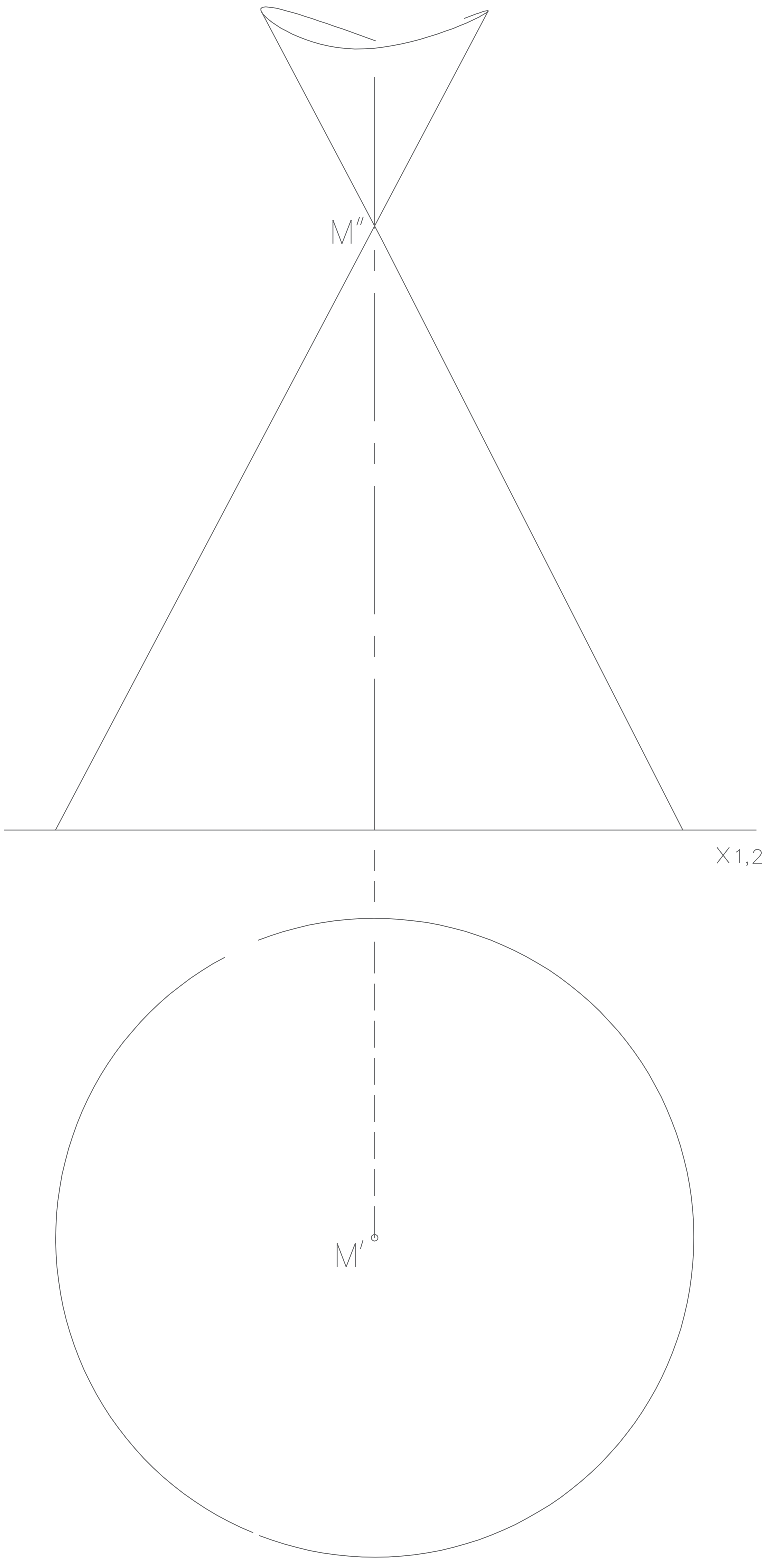
Given the cone lying on the $\underline{K}_1$ and the plane determined the trace line **n**$_1$. Determine an inclined plane, that intersect the cone in parabola, using the introduction a new plane of projection!!

Construct the axes of the first and second projections of the section, some of its generally located points, and the tangent in one of them!

Draw the first and second projection of the section using the hyper osculating circles!

Visually describe the conic section between the base plane and the section plane.

9.4. HYPERBOLIC SECTION OF THE CONE OF ROTATION

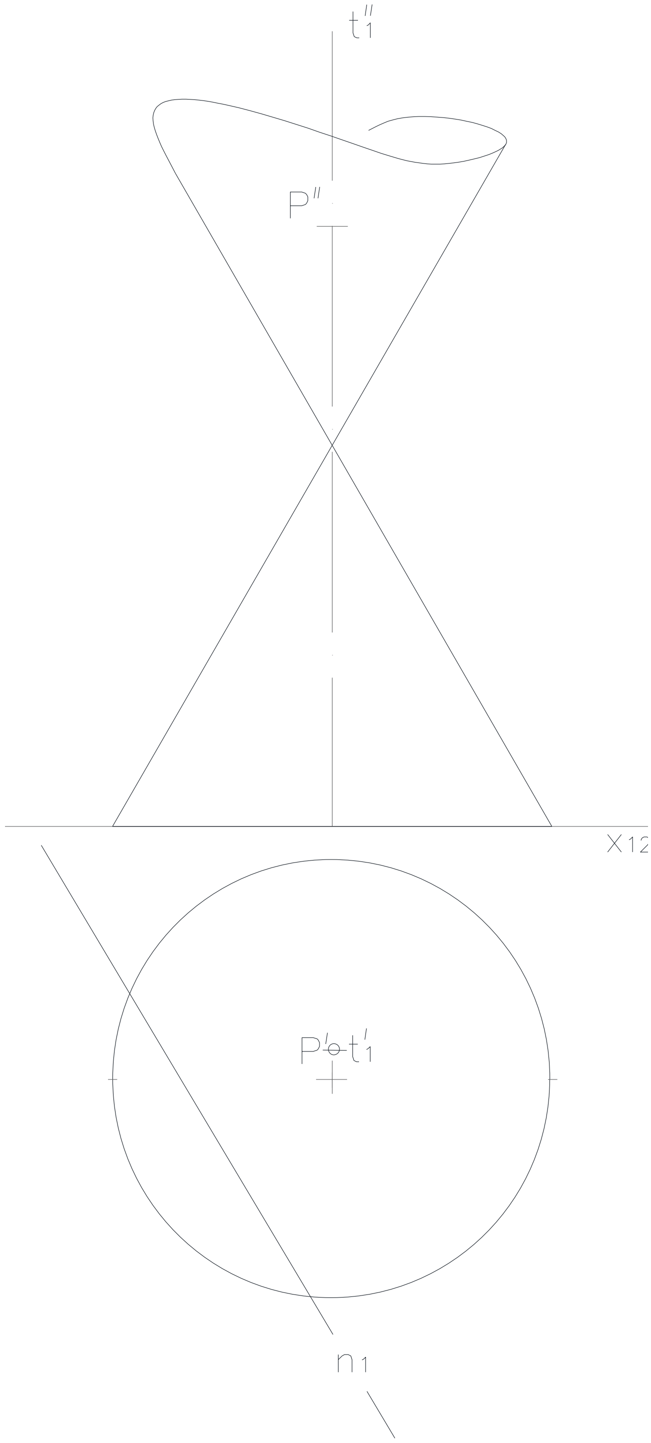


Determine the intersection of a hyperbola of the conic of revolution with a second projection plane, $\underline{V}_2$!

Construct the real and imaginary axes **AB** and **CD**, the asymptotes **u** and **v**, the focal points **F**$_1$ and **F**$_2$, some general points, and the tangent in one of the first projection of the hyperbola section ***h***.

Draw the first projection of the section using the hyper osculating circles!

Visually describe the conic section between the base plane and the section plane.



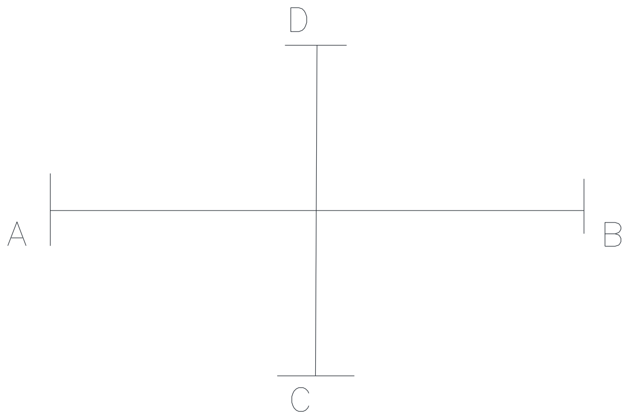
Determine the plane of the hyperbolic section of the cone of rotation with the first projector line axis, which lies on the given first trace **n**$_1$, by introducing a new image plane!

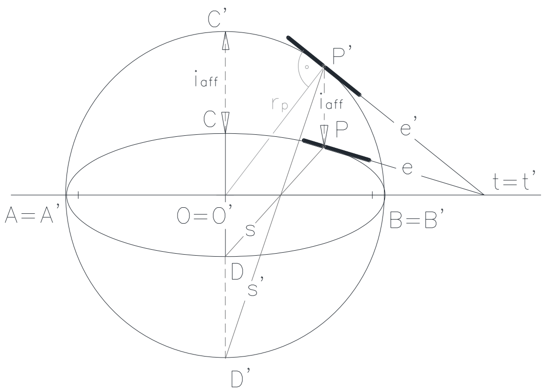
Construct the axes of the first and second images of the section, some general points, and the tangent in one of them!

Draw the first and second projections of the section! Show the conic body between the base plane and the intersecting!

9.5. THE SECTION CURVES OF THE CONE

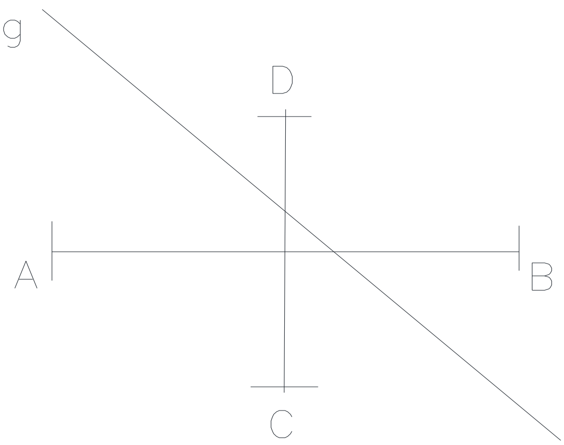
The major axis **AB** and the minor axis **CD** of the ellipse are given. Construct a general point with its tangent of the ellipse! Draw the ellipse!

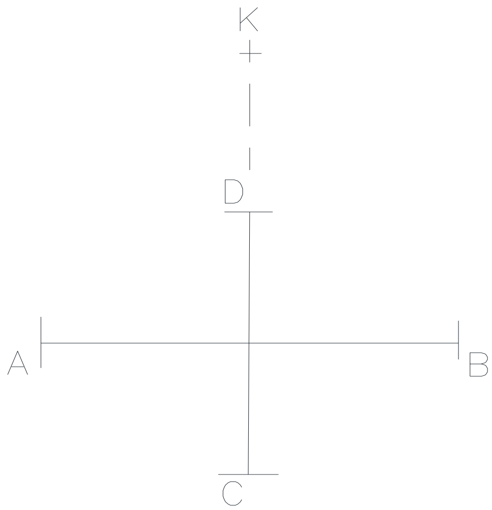




The major axis **AB**, the minor axis **CD** of the ellipse and the line **e** are given. Construct the intersect points of the line **e** and the the ellipse!

Draw the ellipse!





The major axis **AB**, the minor axis **CD** of the ellipse and the external point K lying on the line of the minor axis are given. Construct the tangents $\mathbf{e}_{1,2}$ from the external point **K** together with the tangency points $\mathbf{E}_{1,2}$! Draw the ellipse!!

Draw the ellipse!

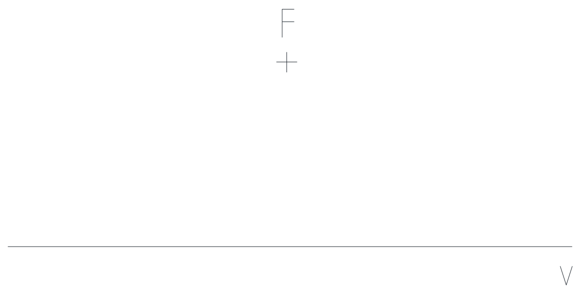
The parabola is given by the focus **F** and the directrix **v**.

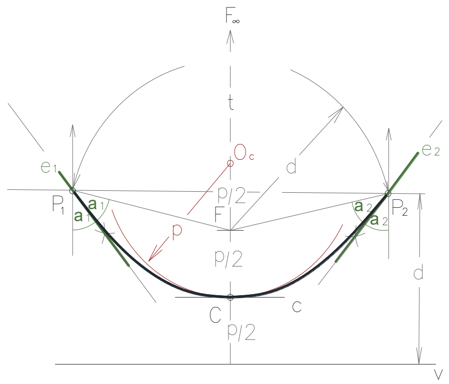
Construct

- its axis **t**,
- its vertex **C** with the vertex tangent **c**,
- - the center of its hyper osculating circle **O**$_c$ and
- - some arbitrary point with its tangent!

Draw an arc of the parabola using its hyper osculating circle!

Draw an arc of the parabola!



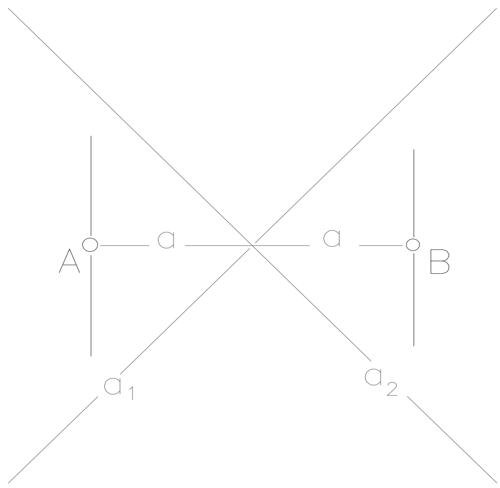


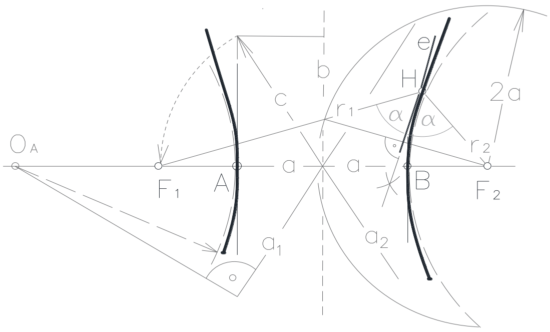
-

Given the real axis **AB** and the pair of asymptotes a_1, a_2, the hyperbola is given.

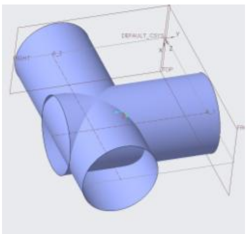
Construct

- its imaginary axis,
- its focal points **F**$_1$ and **F**$_2$,
- its hyperosculating circles at the real axis endpoints,
- its tangent at any arbitrary point!



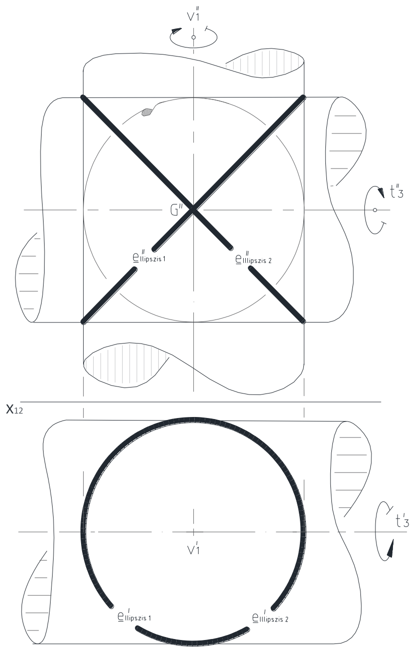


10.1. THE INTERSECTIONS BETWEEN THE CYLINDER AND THE CONE



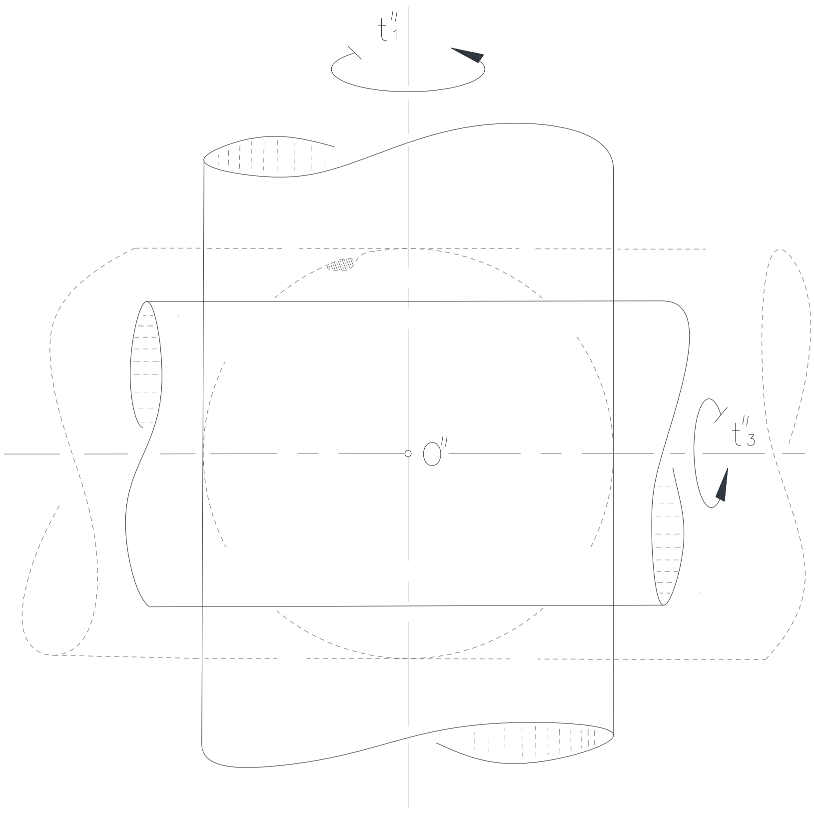
The intersection curve of two second-order surfaces is a fourth-order spatial curve, which, in the case of two cylinders of rotation with **equal radius and intersecting axes**, disintegrates into two second-order curves. These plane curves are $\underline{e}_{llipse1}$ and $\underline{e}_{llipse2}$, for cylinders of equal radius with perpendicular and non-perpendicular intersecting axes. By changing the radius of any rotation cylinder, the double projection of the intersection disintegrates into **two sectors of a hyperbola**.

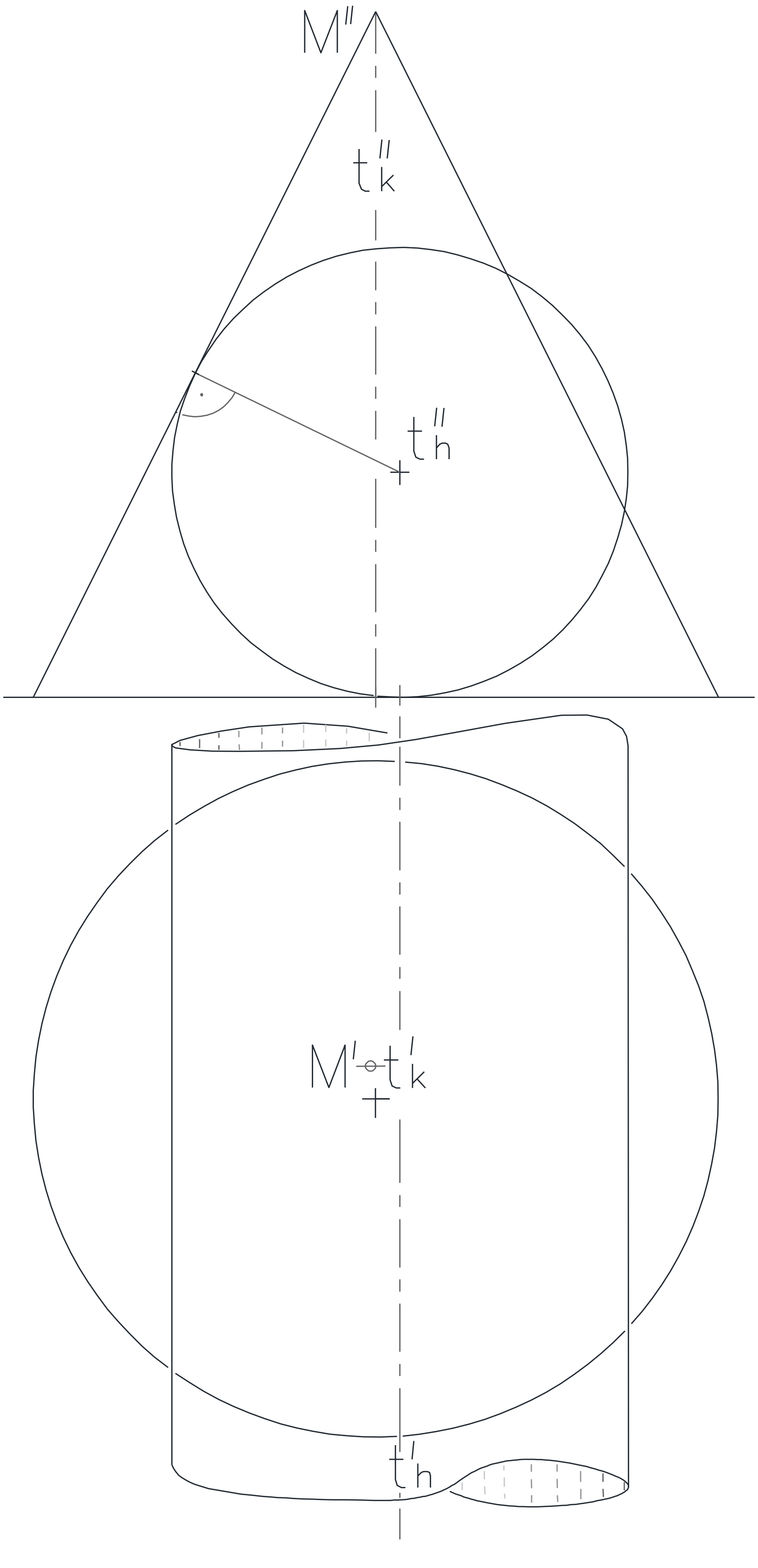
The endpoints of the hyperbola's sectors extending to infinity, the lines of the asymptotes, which can be regarded as the extreme position before the radius change, result from the lines of the $\underline{e}_{llipse1}$ and $\underline{e}_{llipse2}$ curves that appear at the edges when passing through rotation cylinders, in case of the intersecting axes and equal radius.



Determine the intersection of the given rotational cylinders!
Construct
- the points on the second contours of the cylinders, mark them by **1, 2, 3, 4,** then the tangent in one of them,
- the points ***35 mm*** from the intersection of the axes, mark them by **5, 6, 7, 8,** and then the tangent in one of them,
- the asymptotes of $a_{1,2}$ defining the double projection!

Draw the double projection of the intersection curve!





Given the right cone with the first projection position axis standing on the plane $\underline{K}_1$, and the right cylinder of rotation with the second projection position axis, which tangents both the cone and the plane $\underline{K}_1$. Construct

- the self-intersection point O,
- points 1, 2 which lie on the first contour line of the cylinder, indicating their tangents,
- the points 3, 4 with the tangent, at which the cylinder creator line is the tangent of the intersection curve,
- - the lowest points 5, 6 and the highest points 7, 8,
- - the points 8 mm above the base plane of the cone, and the tangent of the curve in one of them!

Draw the second and first projections of the intersection curve!

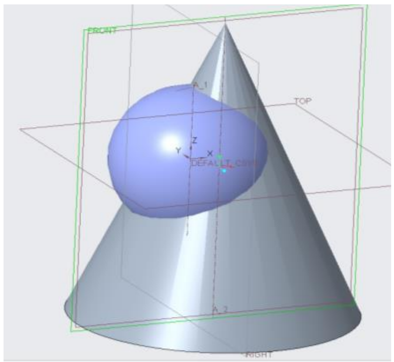
Represent the cone surface outside the cylinder according to visibility!

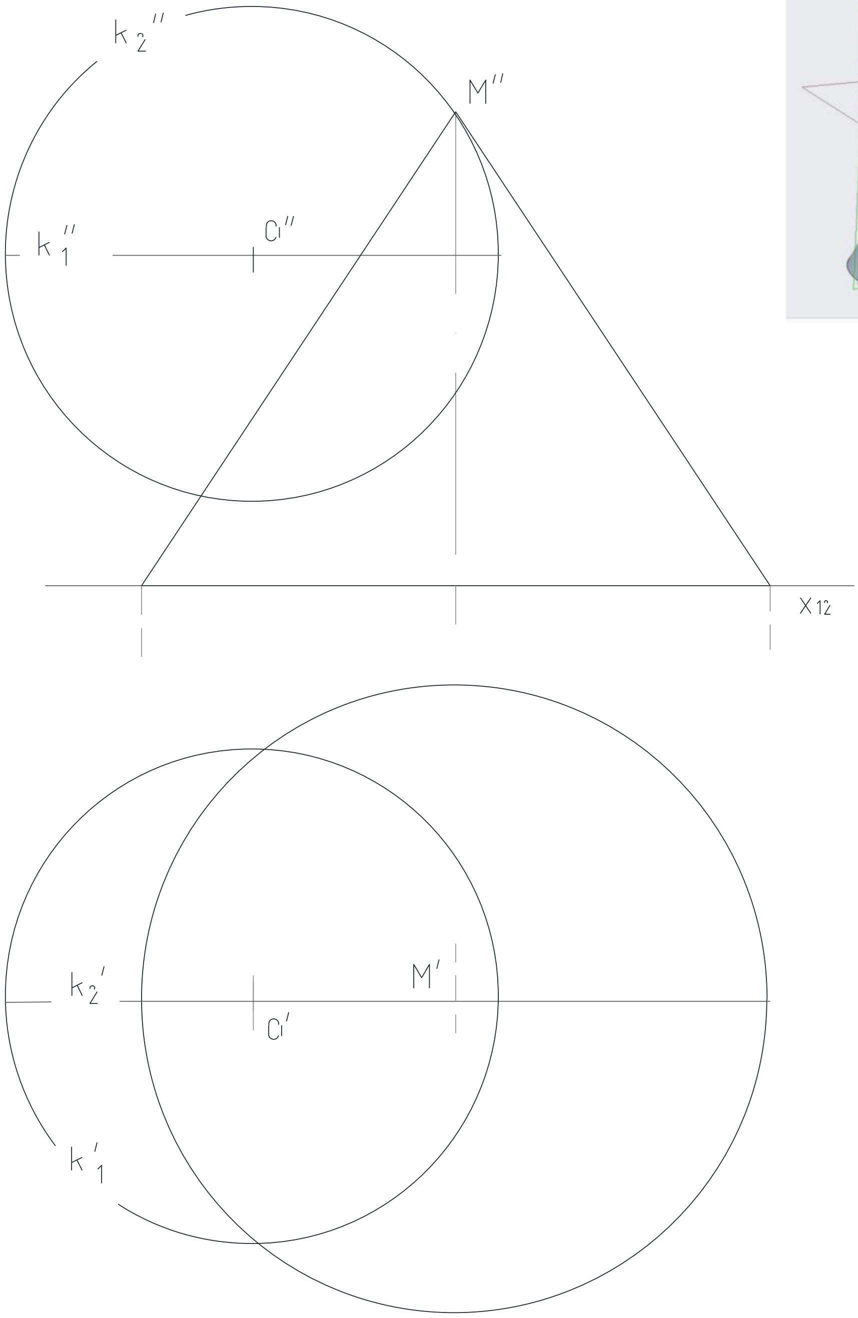
10.2. CONSTRUCTION OF INTERSECTIONS WITH SLICING

Given a cone of rotation lying on a horizontal plane and a sphere tangent to the cone at the vertex M.
Construct their intersection curve

- the contour points,
- some general points, and in one of them, the tangent
- the singular point!

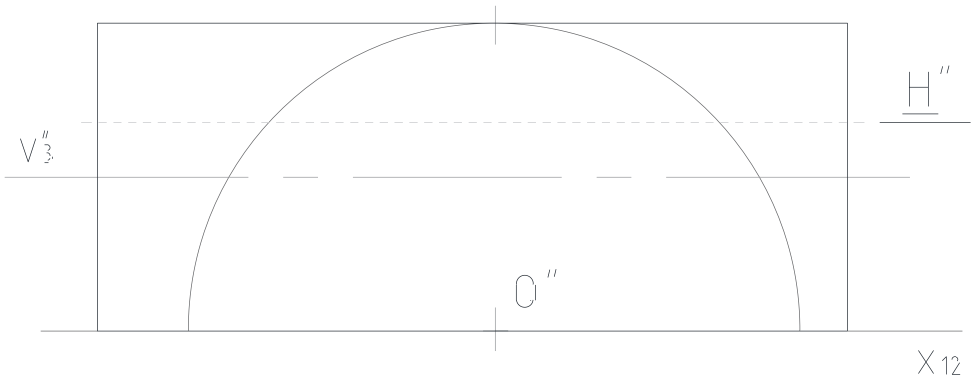
Draw the projections of the intersection curve, then describe the part of the cone's surface outside the sphere, indicating the visibility!

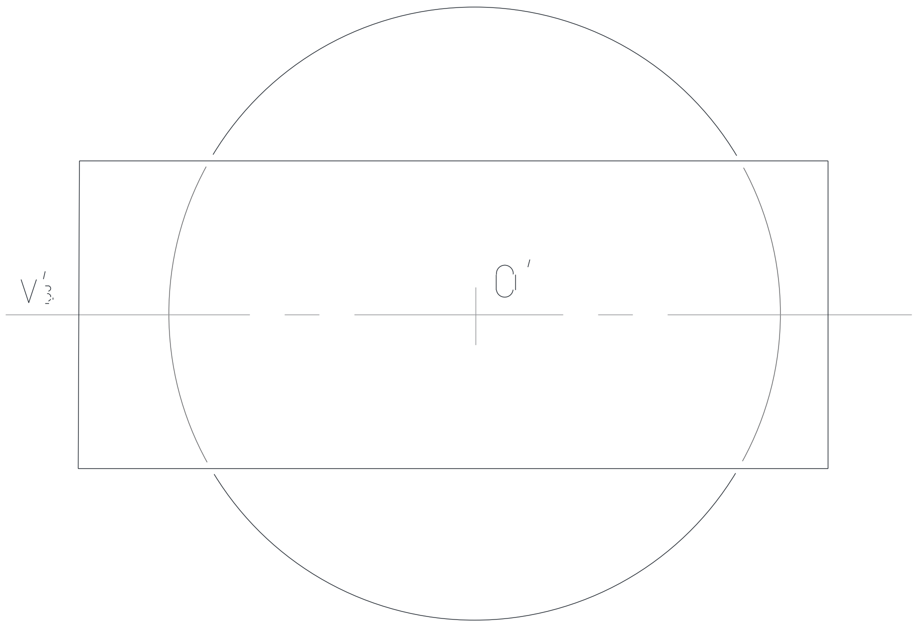


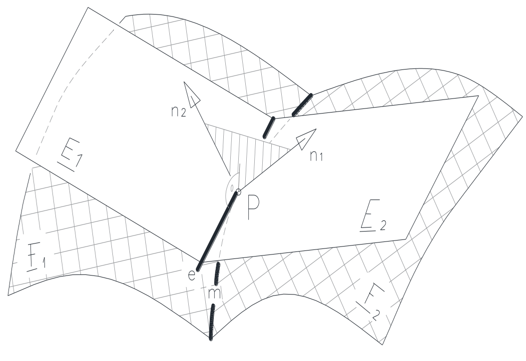


Given a half-sphere placed on the plane <u>K</u>$_1$ and a cylinder of rotation with a third projector line axis v3, the diameter of which is equal to the radius of the half-sphere.
Construct their intersection curve
- the contour points,
- some general position points, and in one of them the tangent
- the singular point!

Draw the projections of the intersection curve, then describe the part of the cylinder surface outside the sphere, indicating the visibility!!



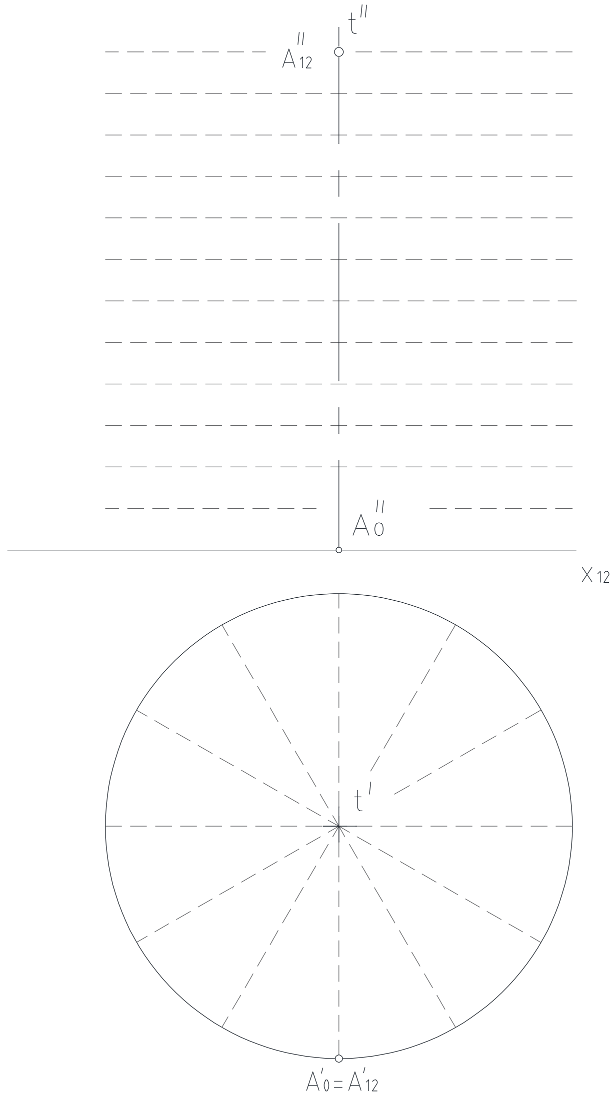




11.1. THE HELIX AND ITS DEVELOPABLE SURFACE

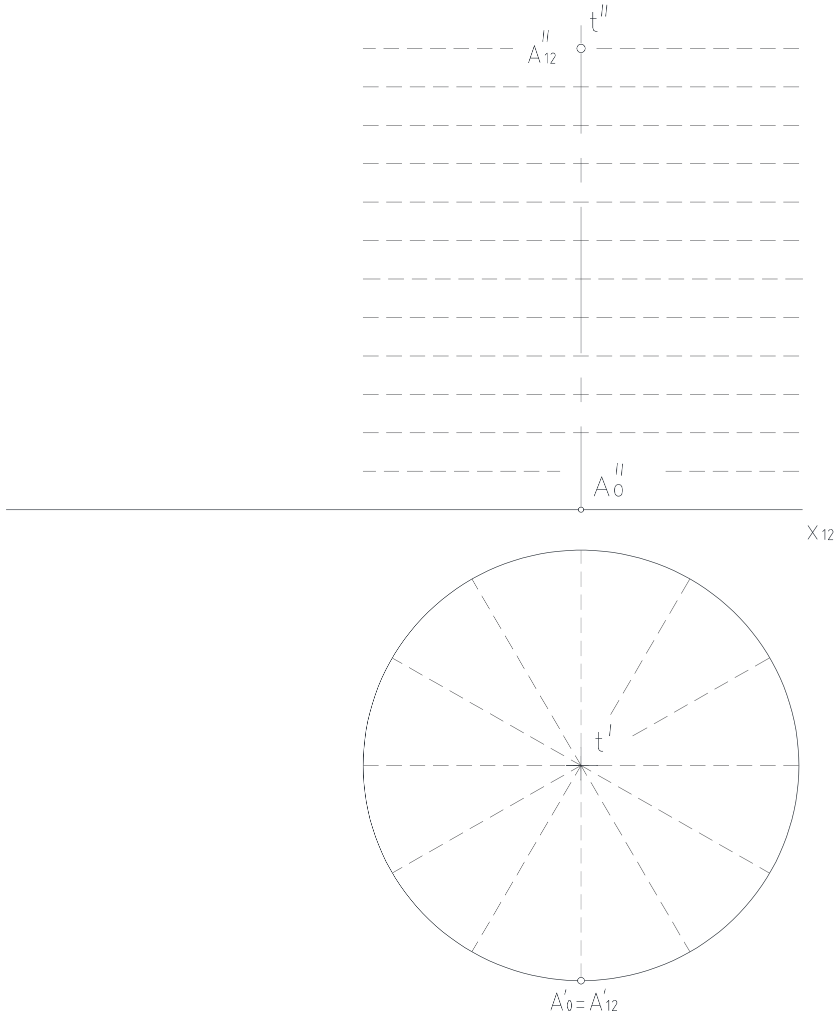
Given the axis **t** at the first projector line position of a **right-handed** helix, the base circle lying on the $\underline{K}_1$, and the points A_0 and A_{12} of one complete thread.

Draw
- the thread between the A_0 and A_{12},
- the approximate expansion of its base circle,,
- the vertex **M** of the cone of the tangents,
- the leading trihedron at point A_{10}!



Given the axis **t** at the first projector line position of a **left-handed** helix, the base circle lying on the $\underline{K}_1$, and the points A_0 and A_{12} of one complete thread.

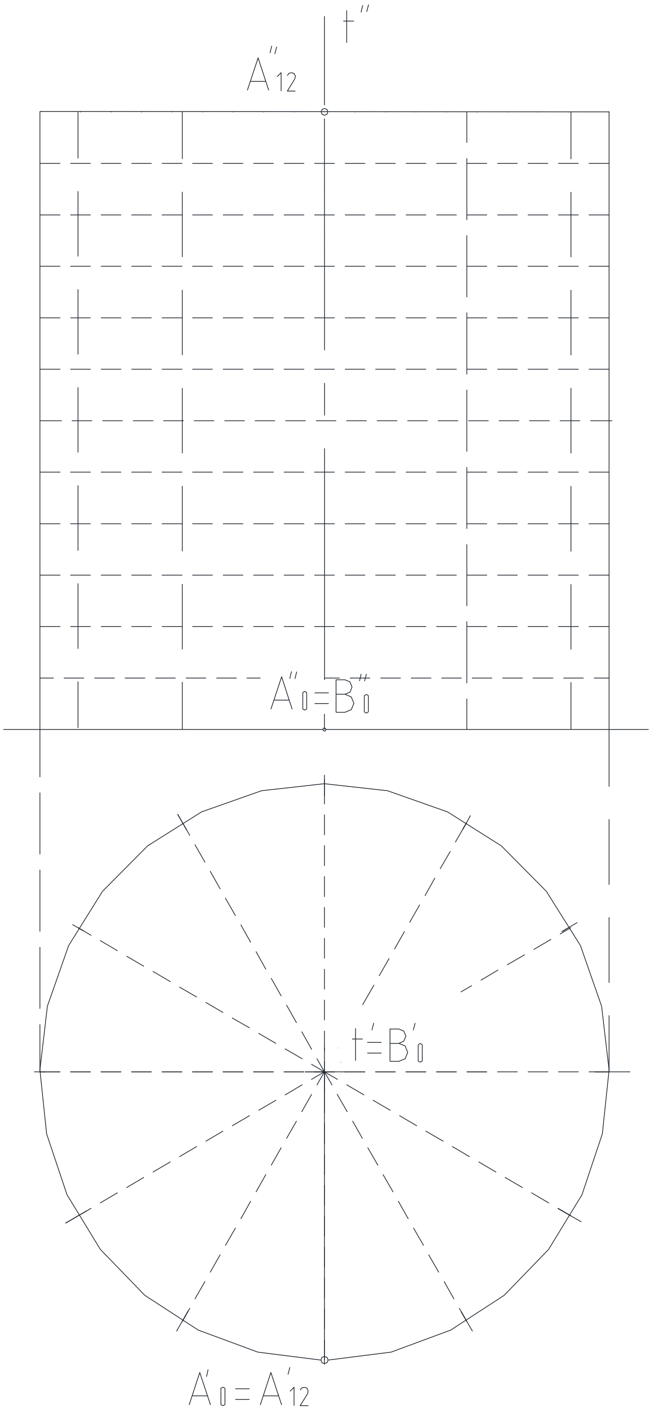
Draw
- the thread between the A_0 and A_{12},
- the approximate expansion of its base circle,,
- the vertex **M** of the cone of the tangents,
- the leading trihedron at point A_{10},
- the developable surface of the half thread ended at palne $\underline{K}_1$ with it's face section!



11.2. THE CLOSED HELICOID SURFACES

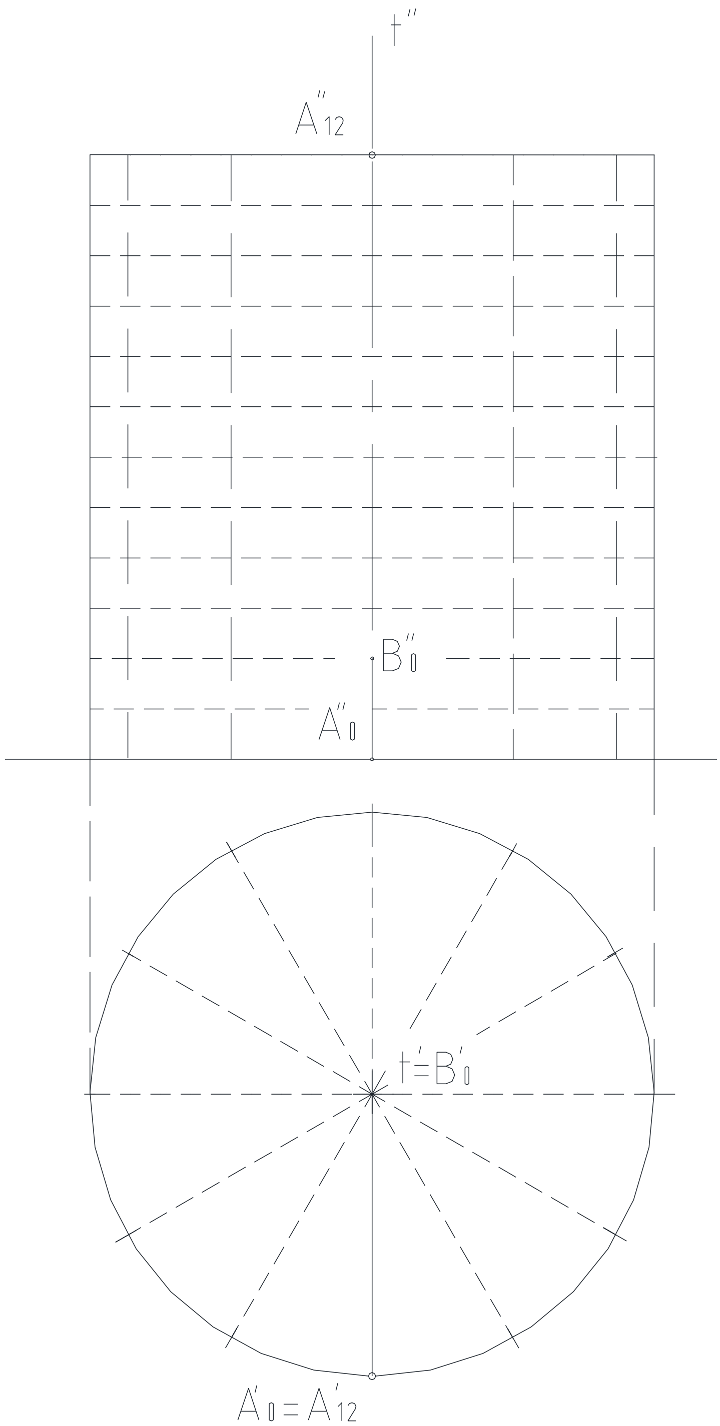
The axis **t** in first projector line position and the radius **r** with the base circle on the plane $\underline{K}_1$, and the end points $\mathbf{A}_0$ and $\mathbf{A}_{12}$ of a thread are given.

Draw a complete thread of the **left-hand** helix, next a complete thread of the closed flat helicoid surface with the given section $\mathbf{A}_0\mathbf{B}_0$!



The axis **t** in first projector line position and the radius **r** with the base circle on the plane $\underline{K}_1$, and the end points **A**$_0$ and **A**$_{12}$ of a thread are given.

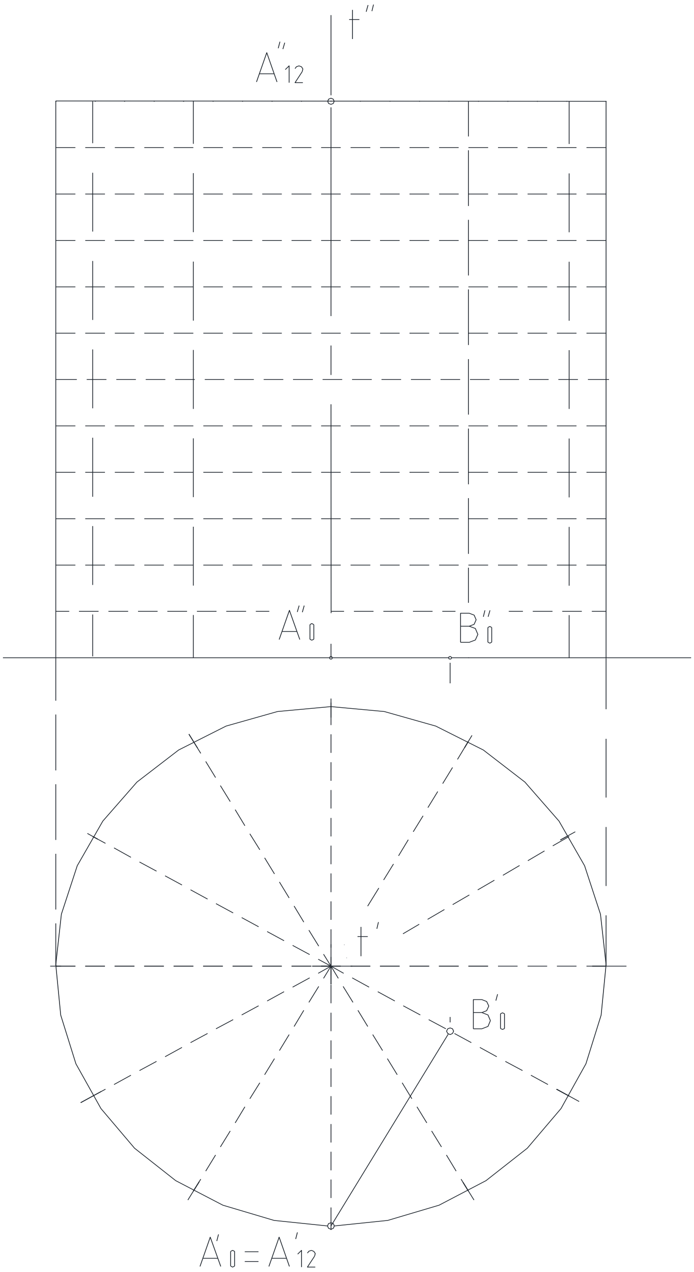
Draw a complete thread of the **left-hand** helix, next a complete thread of the **closed angled** helicoid surface with the given section **A**$_0$**B**$_0$!



11.3. THE OPENED HELICOID SURFACES

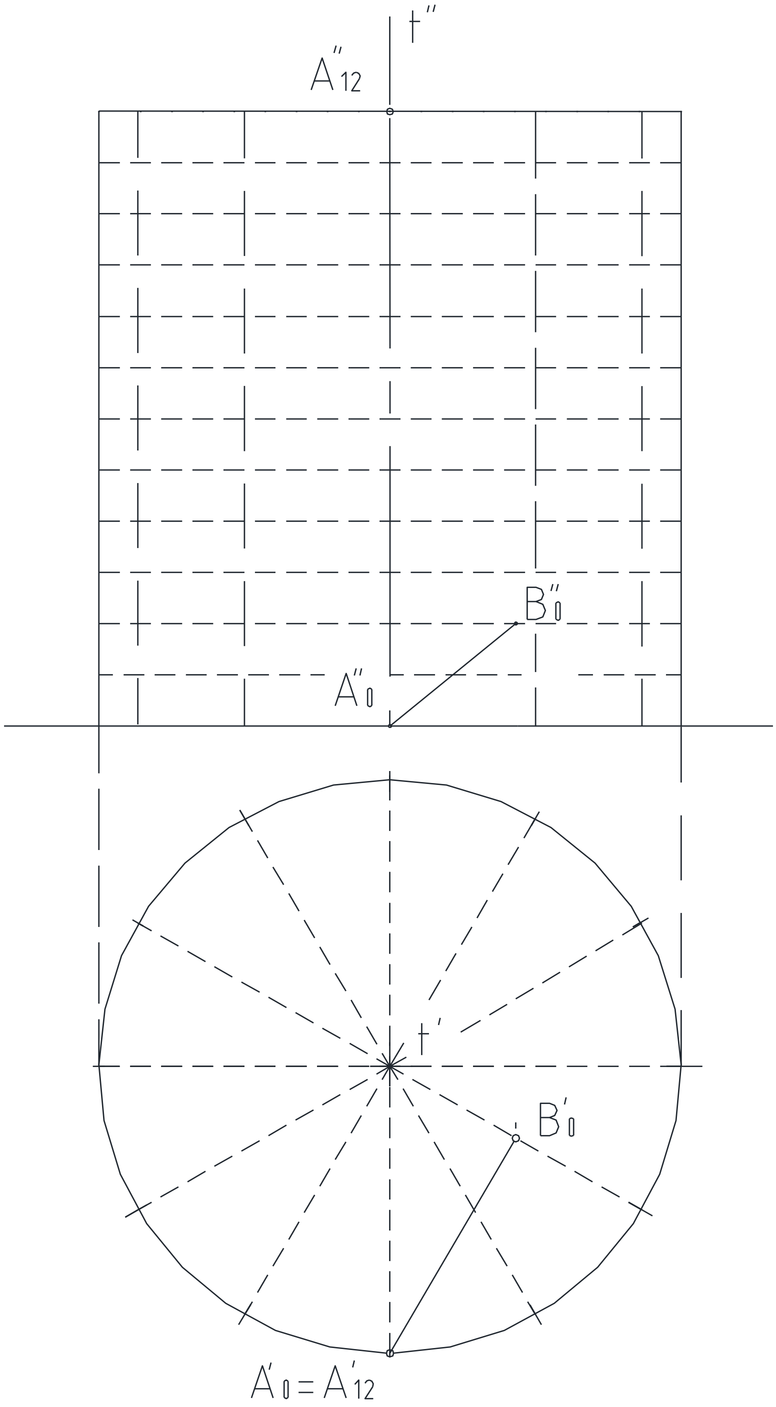
The axis **t** in first projector line position and the radius **r** with the base circle on the plane $\underline{K}_1$, and the end points A_0 and A_{12} of a thread are given.

Draw a complete thread of the **left-hand** helix, next a complete thread of the opened flat helicoid surface with the given section A_0B_0!



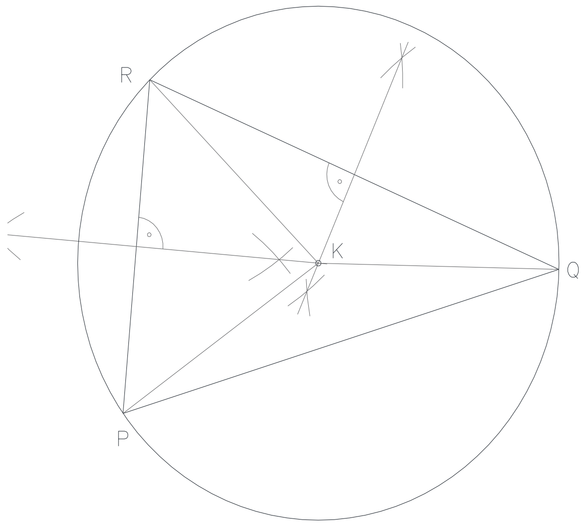
The axis **t** in first projector line position and the radius **r** with the base circle on the lane $\underline{K}_1$, and the end points A_0 and A_{12} of a thread are given.

Draw a complete thread of the **left-hand** helix, next a complete thread of the opened angled helicoid surface with the given section A_0B_0!

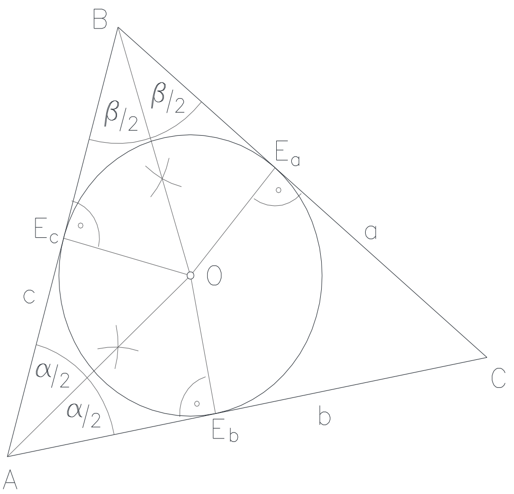


1.1. SOLUTION

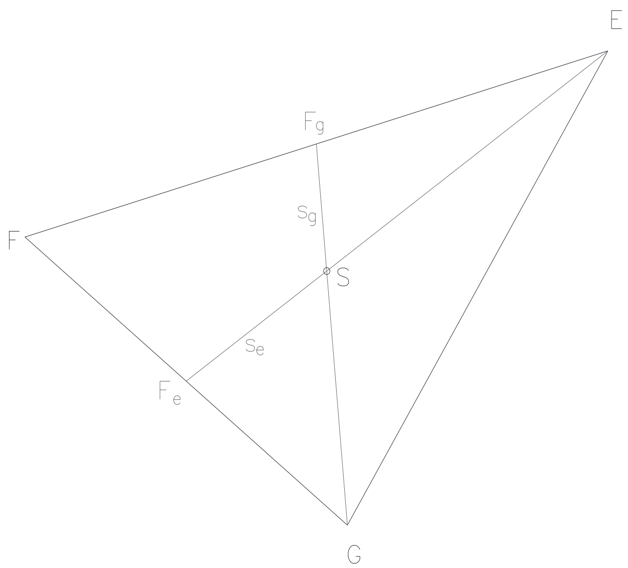
Construct the center **K** of the circle, which lies on the vertices of the triangle **PQR**!



Construct the center **O** of the circle, which tangents the sides of the triangle **ABC** from the inside!

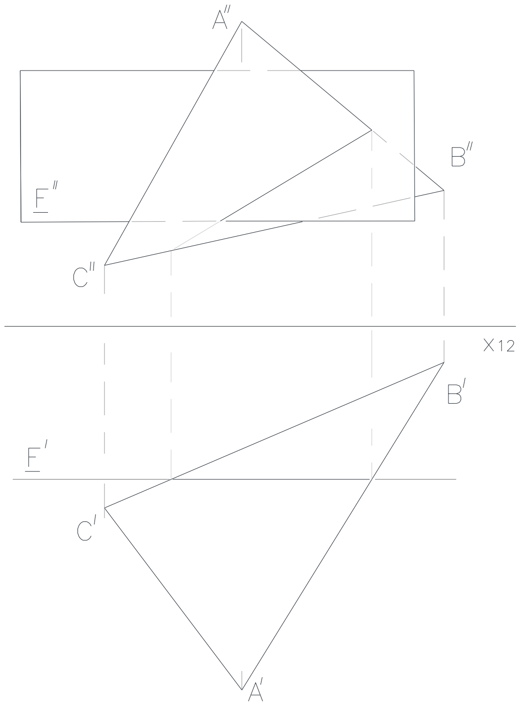


Construct the centroid **S** of the triangle **EFG**!

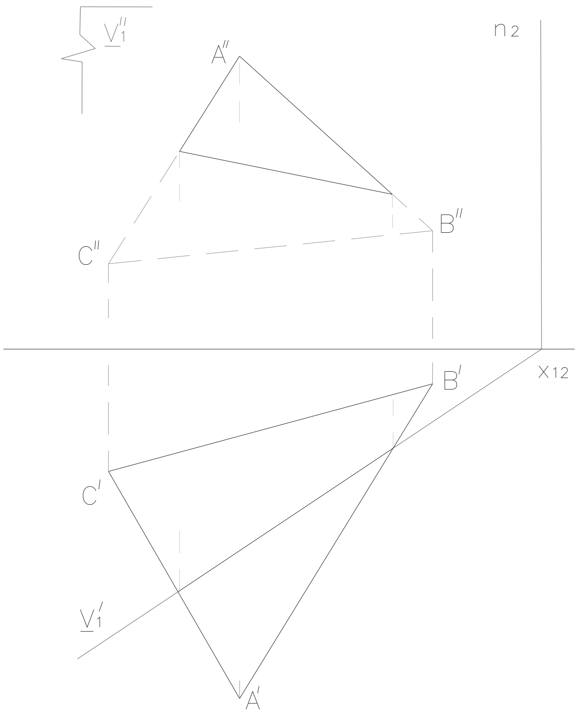


3.1. SOLUTION

Determine the intersection line **f** between the given plane S(A,B,C) in general position and the frontal plane F, then show the visibility!



Determine the intersect straight line **m** between the projector plane $\underline{V}_1$ and the plane S[ABC] in general position, then show the visibility!



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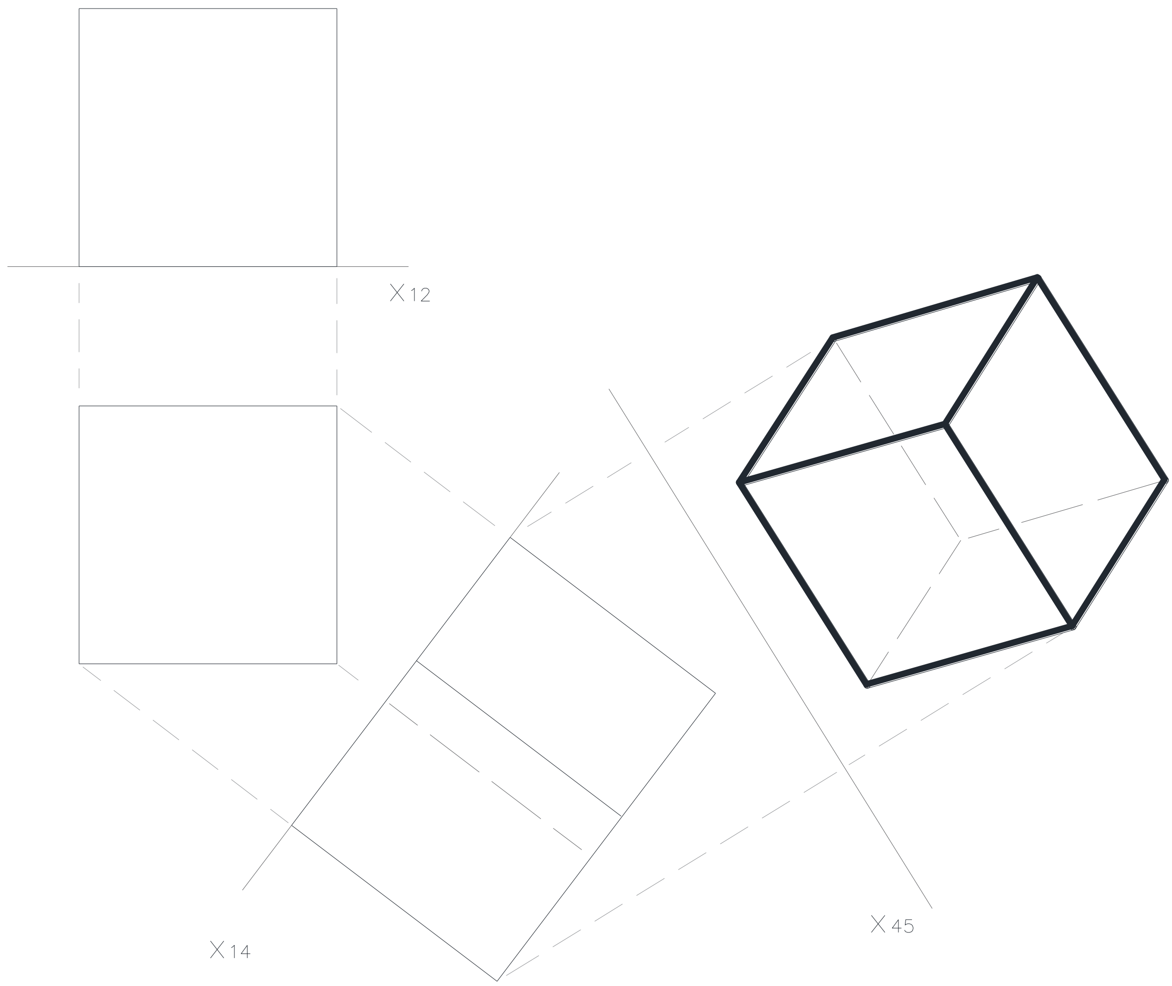
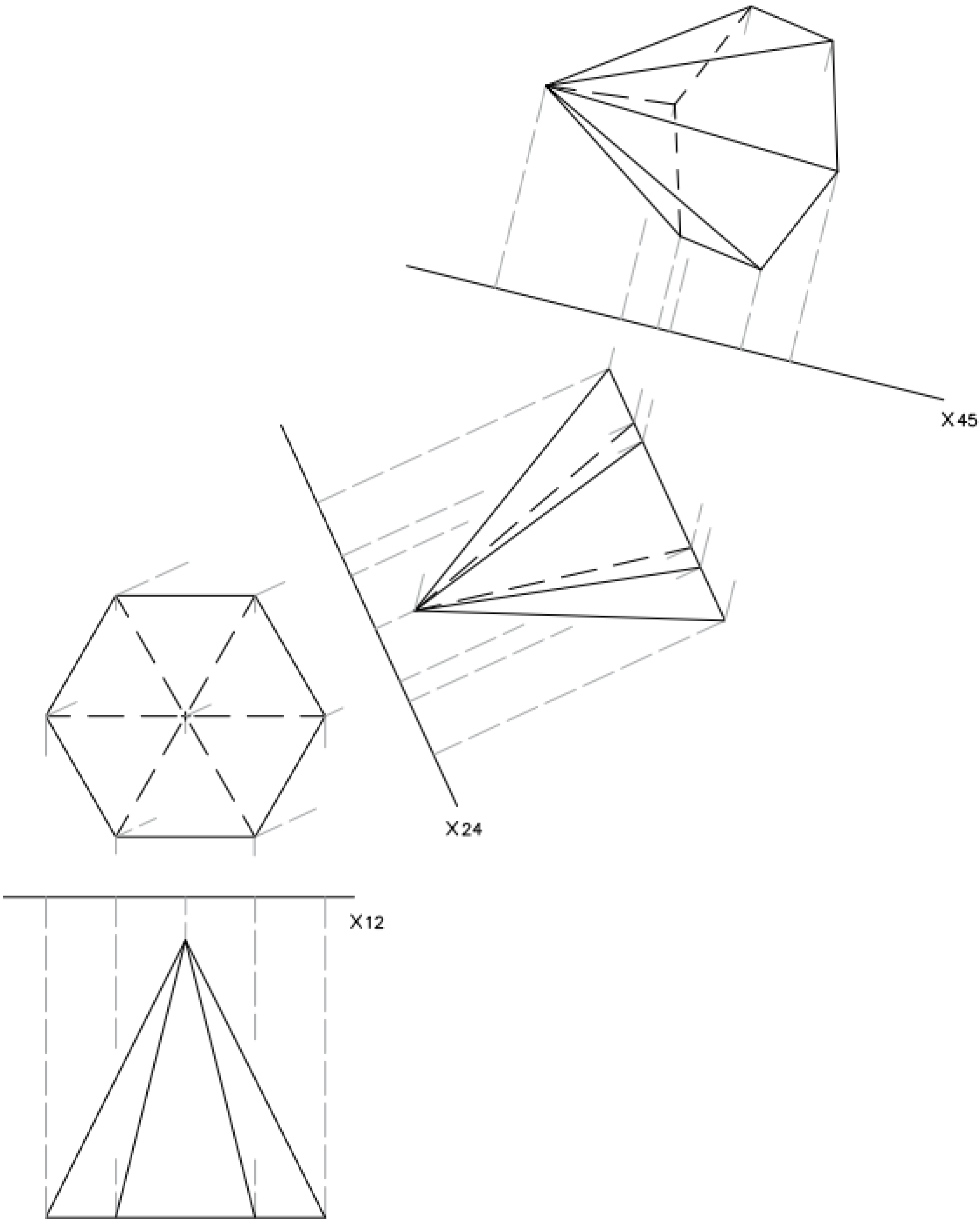
Department of Descriptive Geometry in Institute of Mathematics

3.2. SOLUTION

Mark the vertices of the cube lying on the plane of projection $\underline{K}_1$, then create the visual projection of the cube by transforming to the plane of projection $\underline{K}_4$ connected to the plane of projection $\underline{K}_1$, and then to the plane of projection $\underline{K}_5$ connected to the plane of projection $\underline{K}_4$!

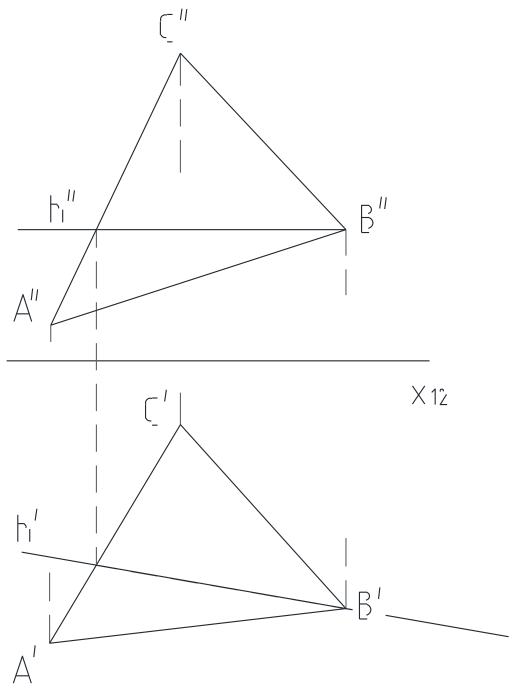


Mark the vertices of the regular hexagon-based straight pyramid lying on the frontal plane F, then create the visual projection of the regular hexagon-based straight pyramid by transforming to the plane of projection K_4 connected to the plane of projection K_2, and then to the plane of projection K_5 connected to the plane of projection K_4!

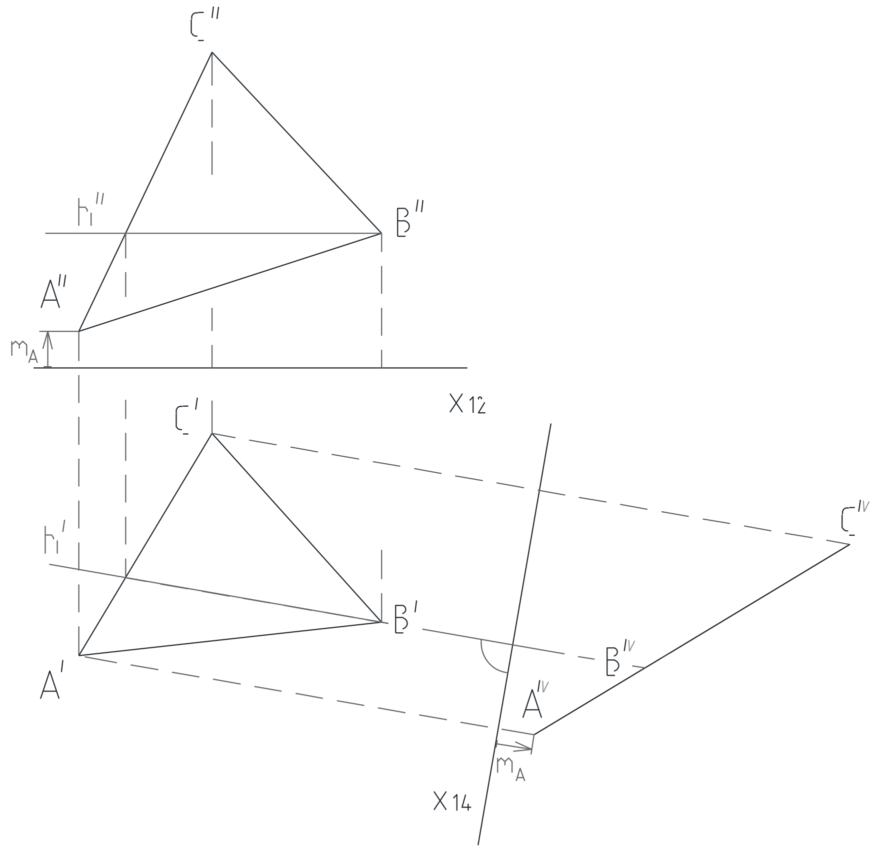


3.3. SOLUTION

Let the triangle **ABC** in general position is given. Determine the true dimension of the triangle **ABC**! Construct the altitude point **M** of the triangle!

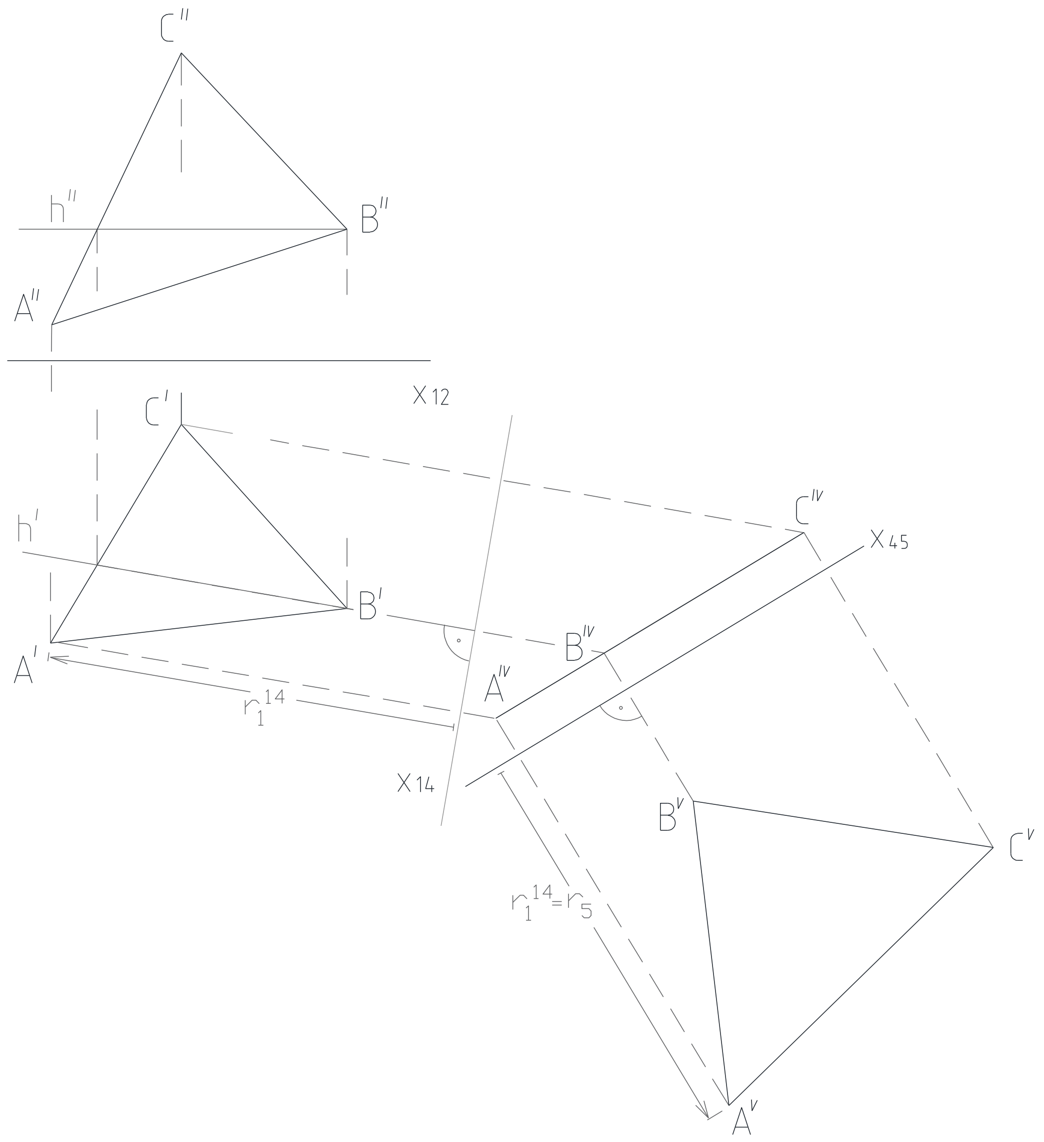


Step 1.:

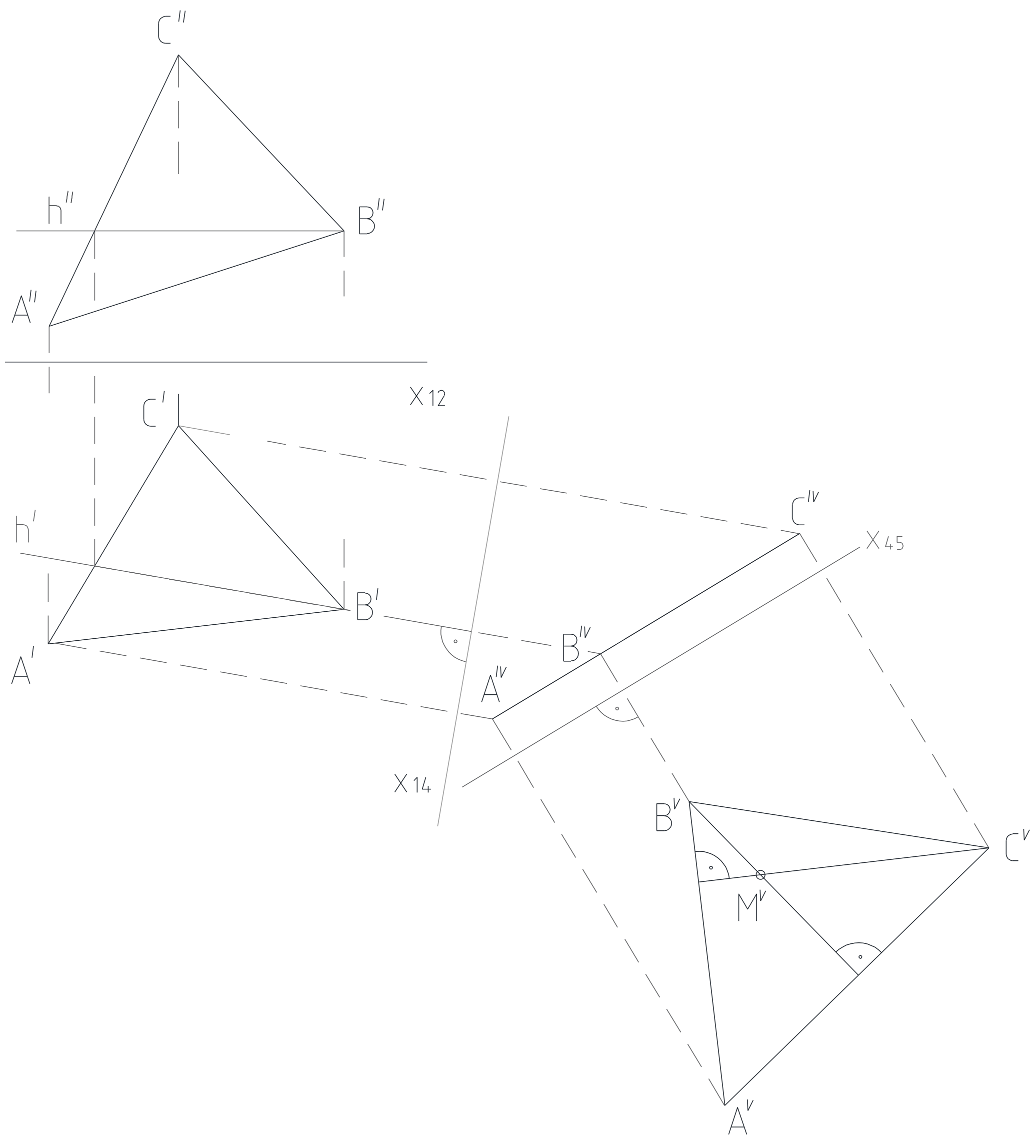


Step 2.:

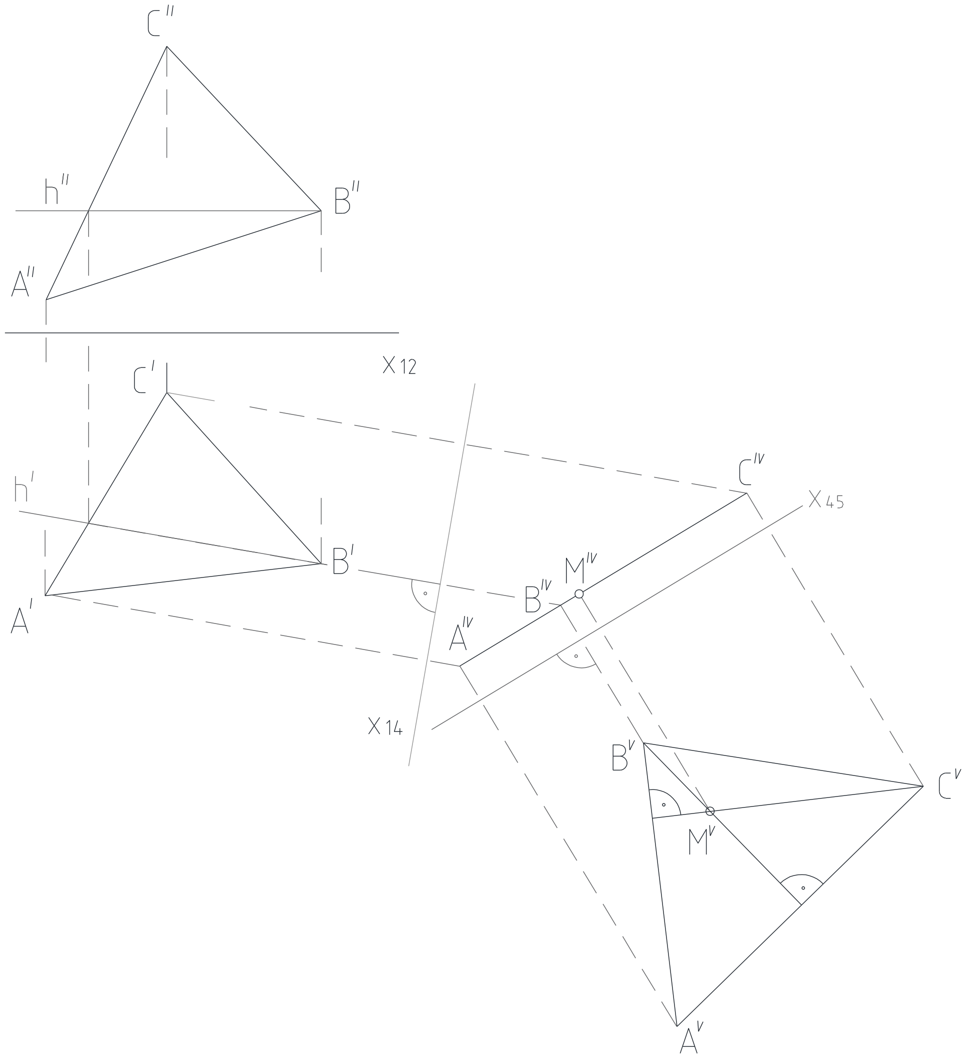
Step 3.:



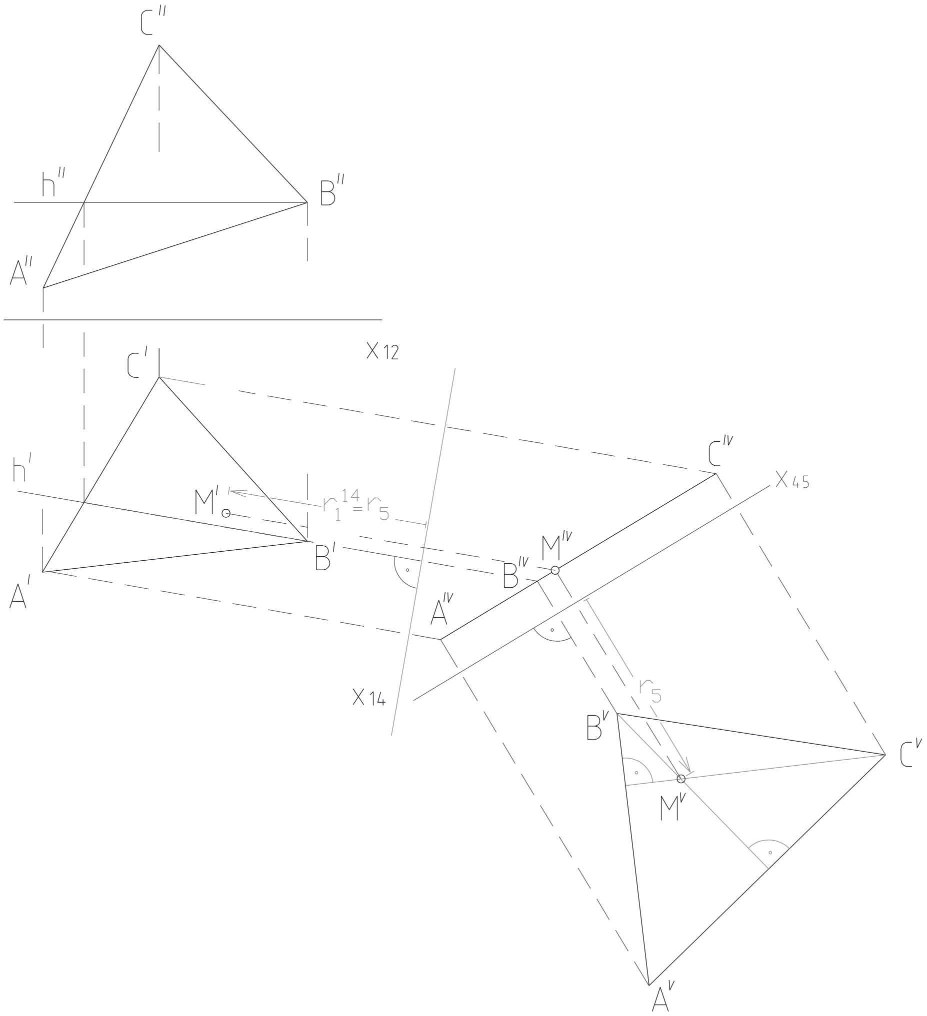
Step 4.:



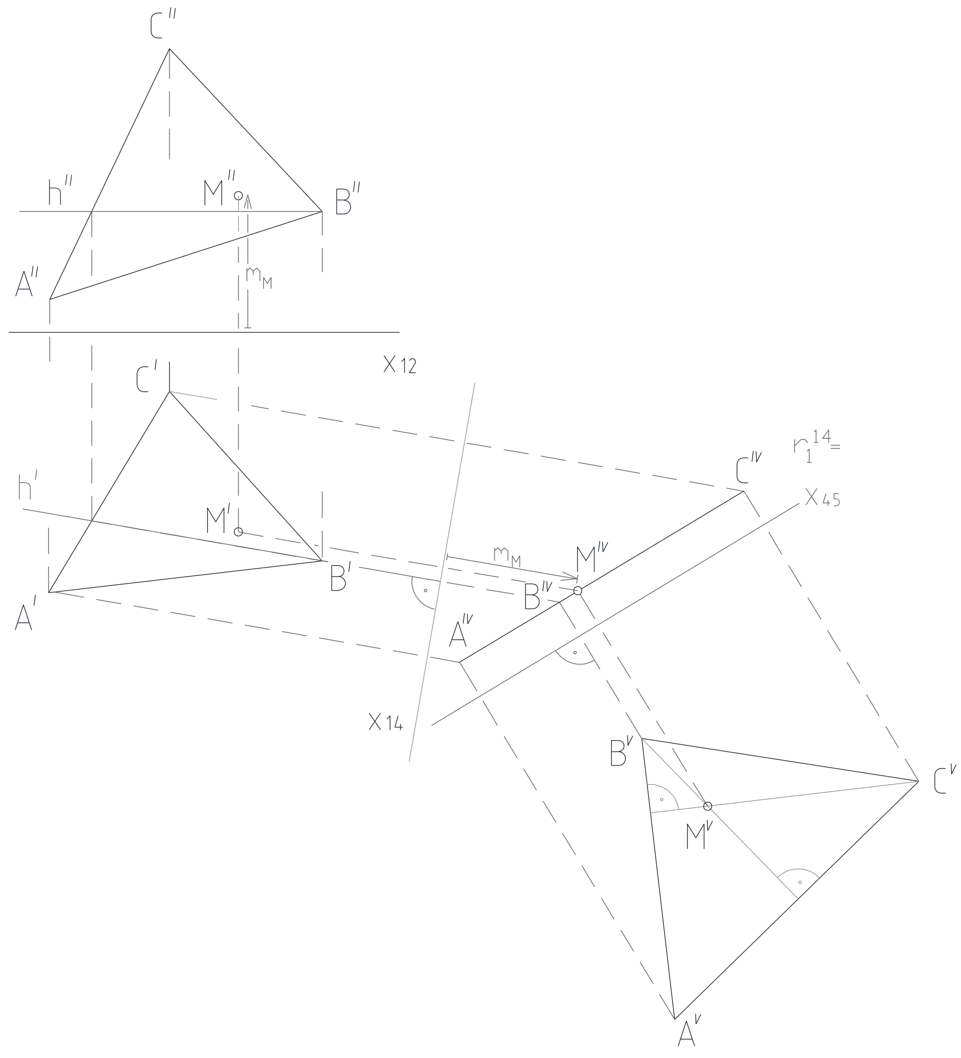
Step 5.:



Step 6.:



Step 7.:

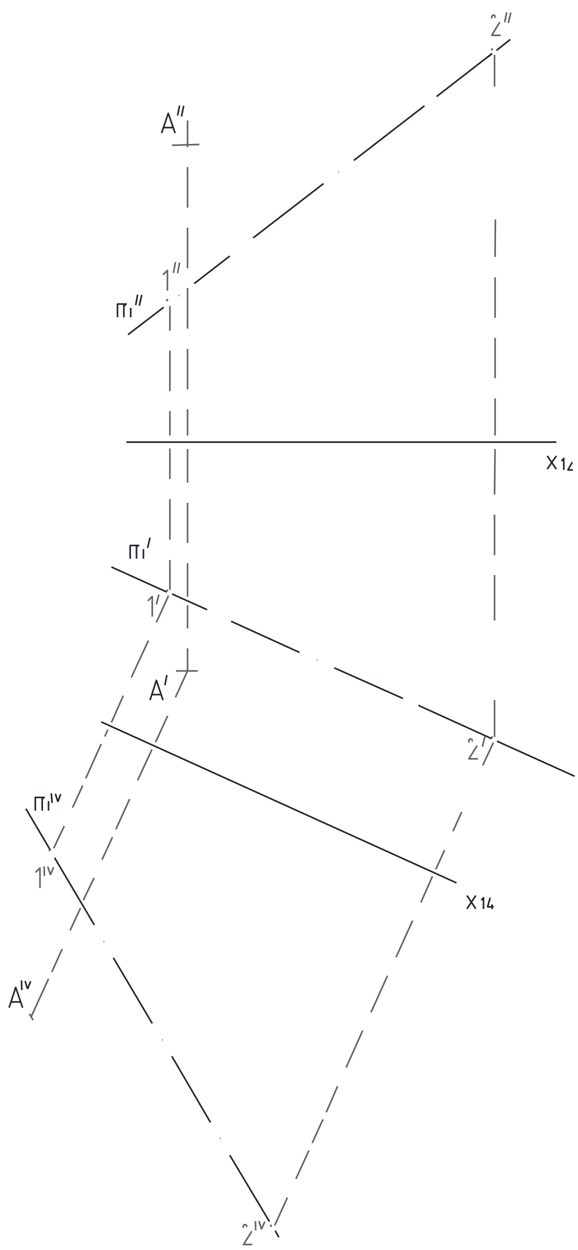


3.4. SOLUTION

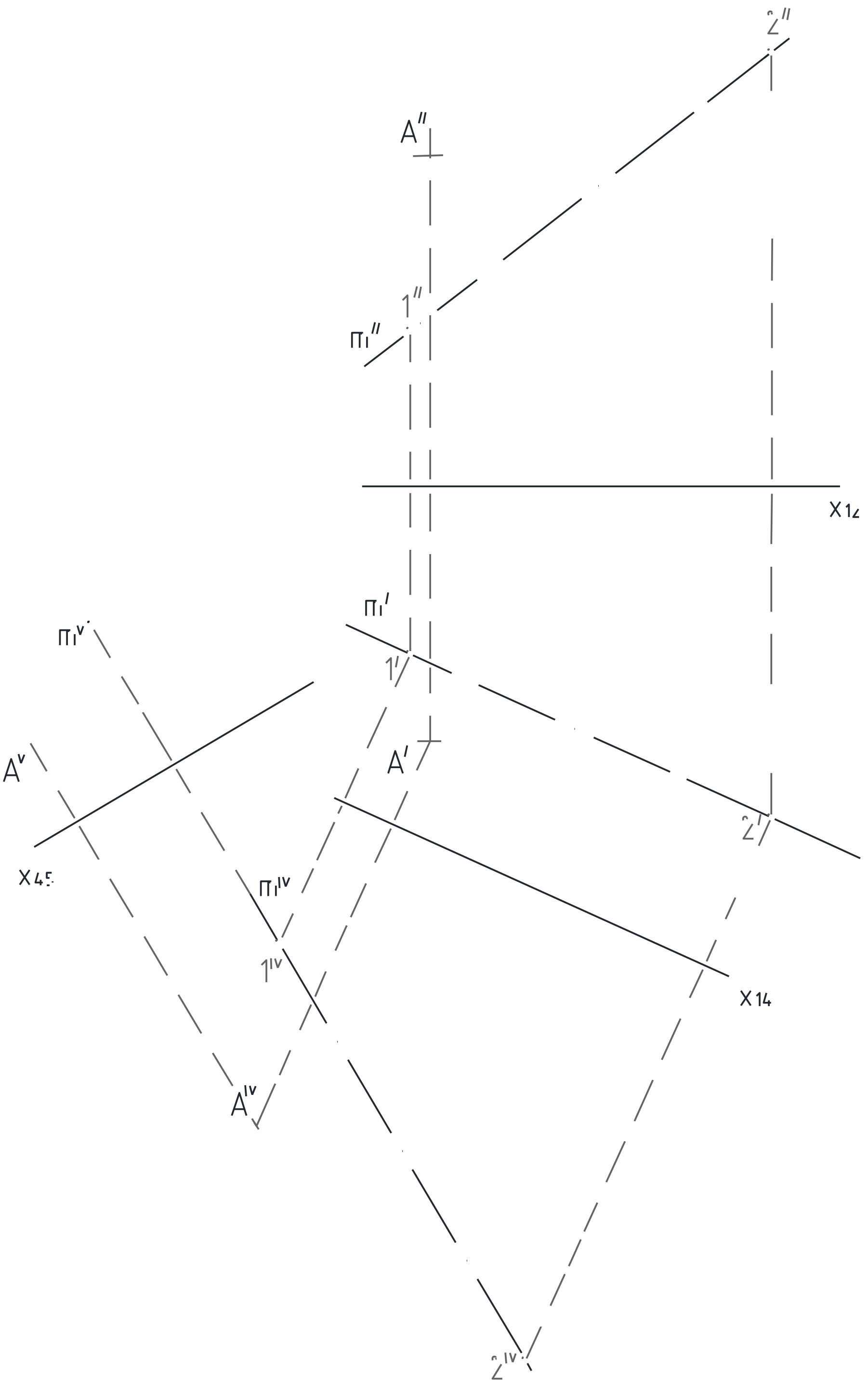
The vertex **A** of the base square and the middle straight line **m** of the right prism are given. The length of the height of the prism is one and half times of the side length of the base square.

In the first step use a new plane of projection connected to the $\underline{K}_1$ to determine the prism! Show the visibility too!

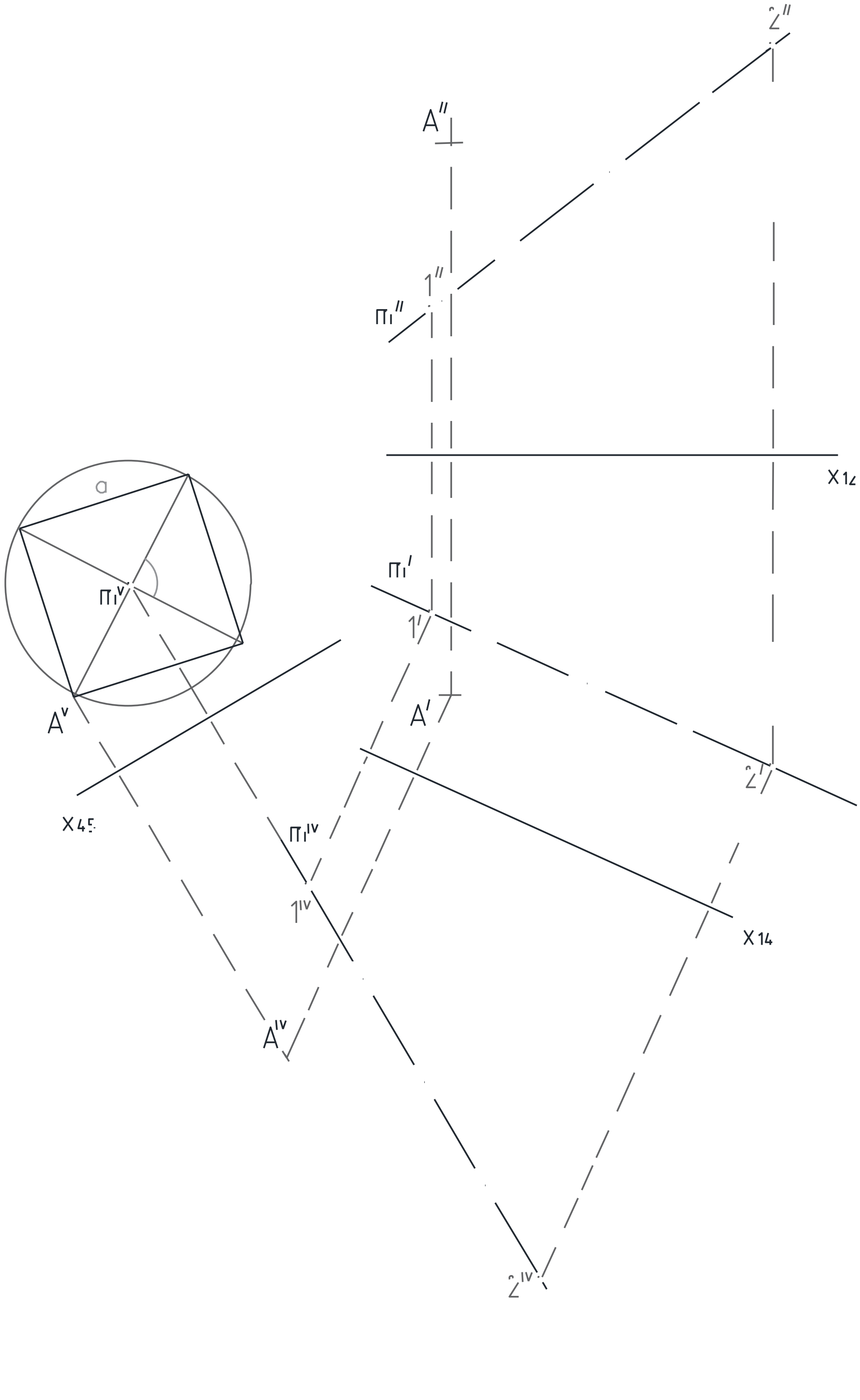
1. Step: The x_{14} || m'.



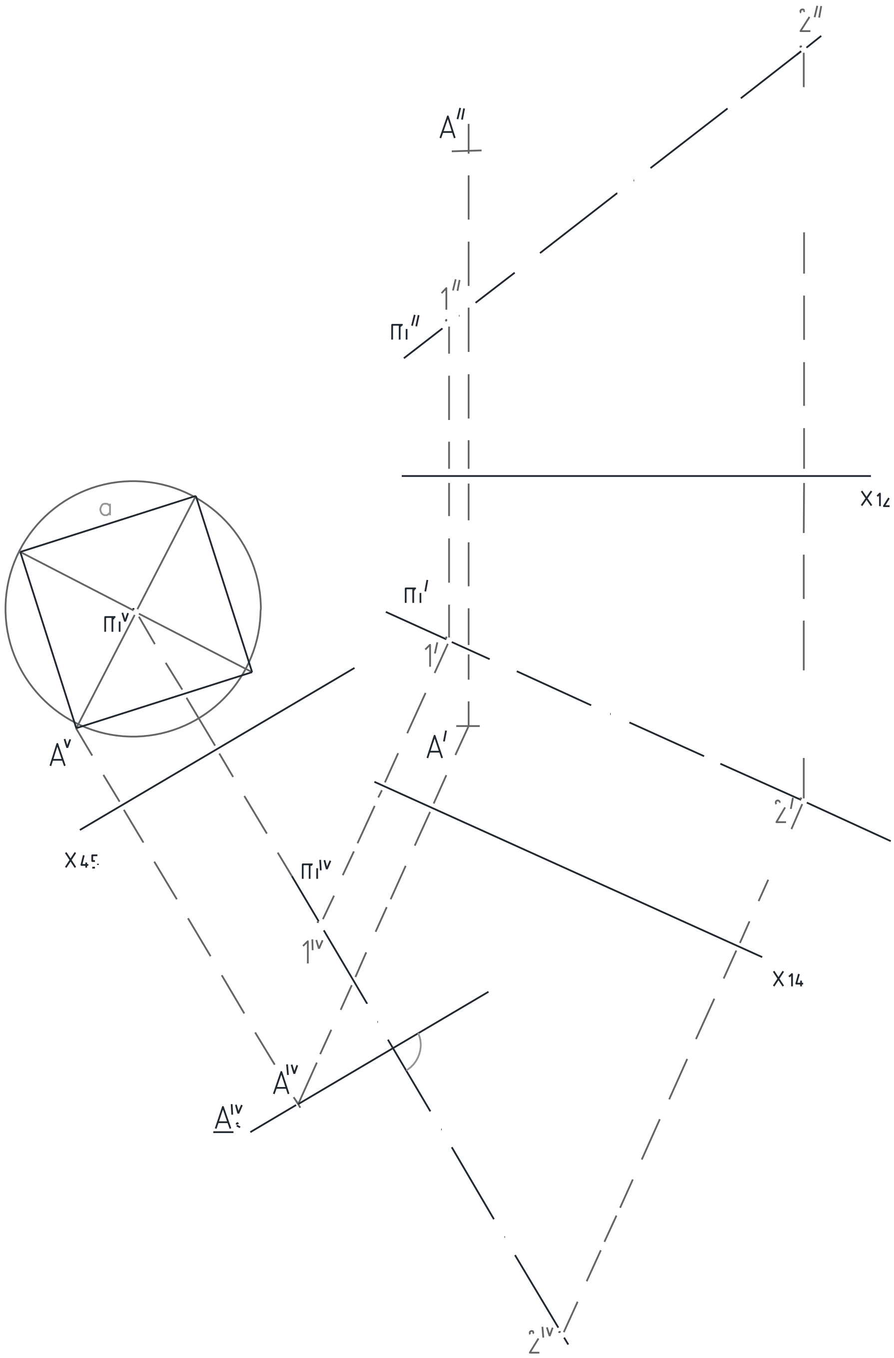
2. Step: The $x_{45} \perp m^{IV}$.



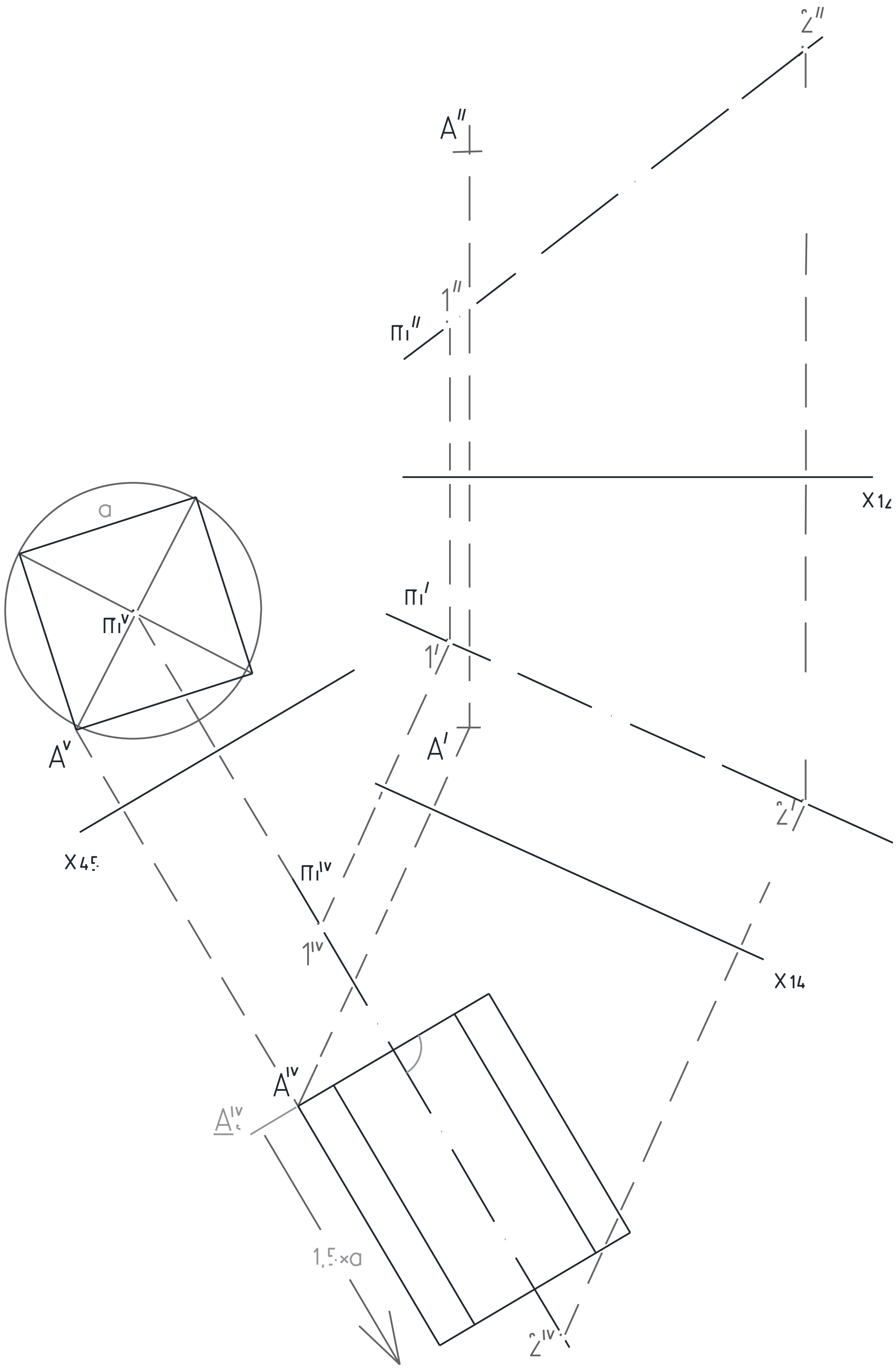
3. Step: The m^V and A^V determine the fifth projection of the base square.



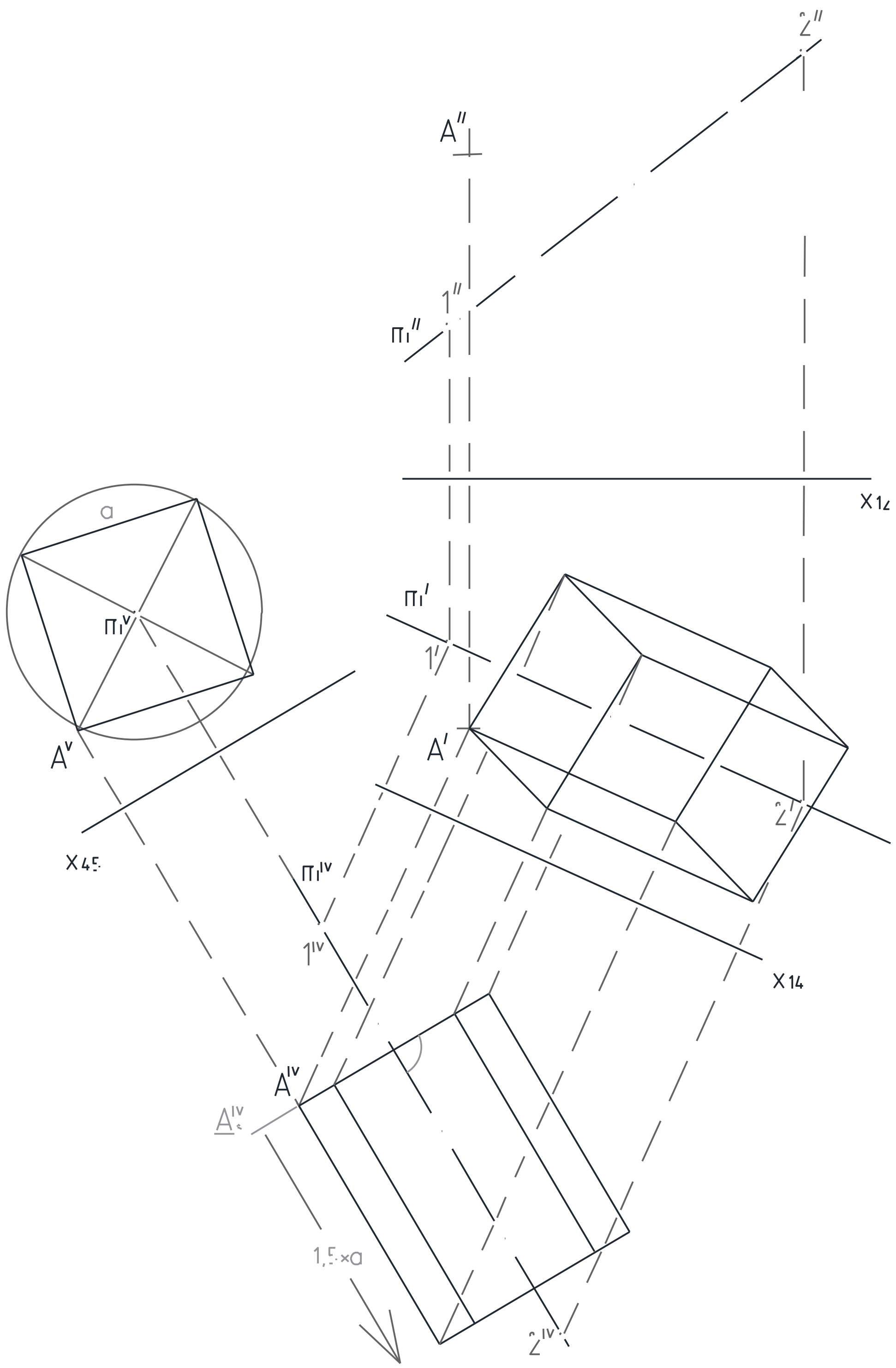
4. Step: The fourth projection of the base square is lying on the fourth projection plane. The base plane is lying on the A^{IV} and perpendicular to the m^{IV}.



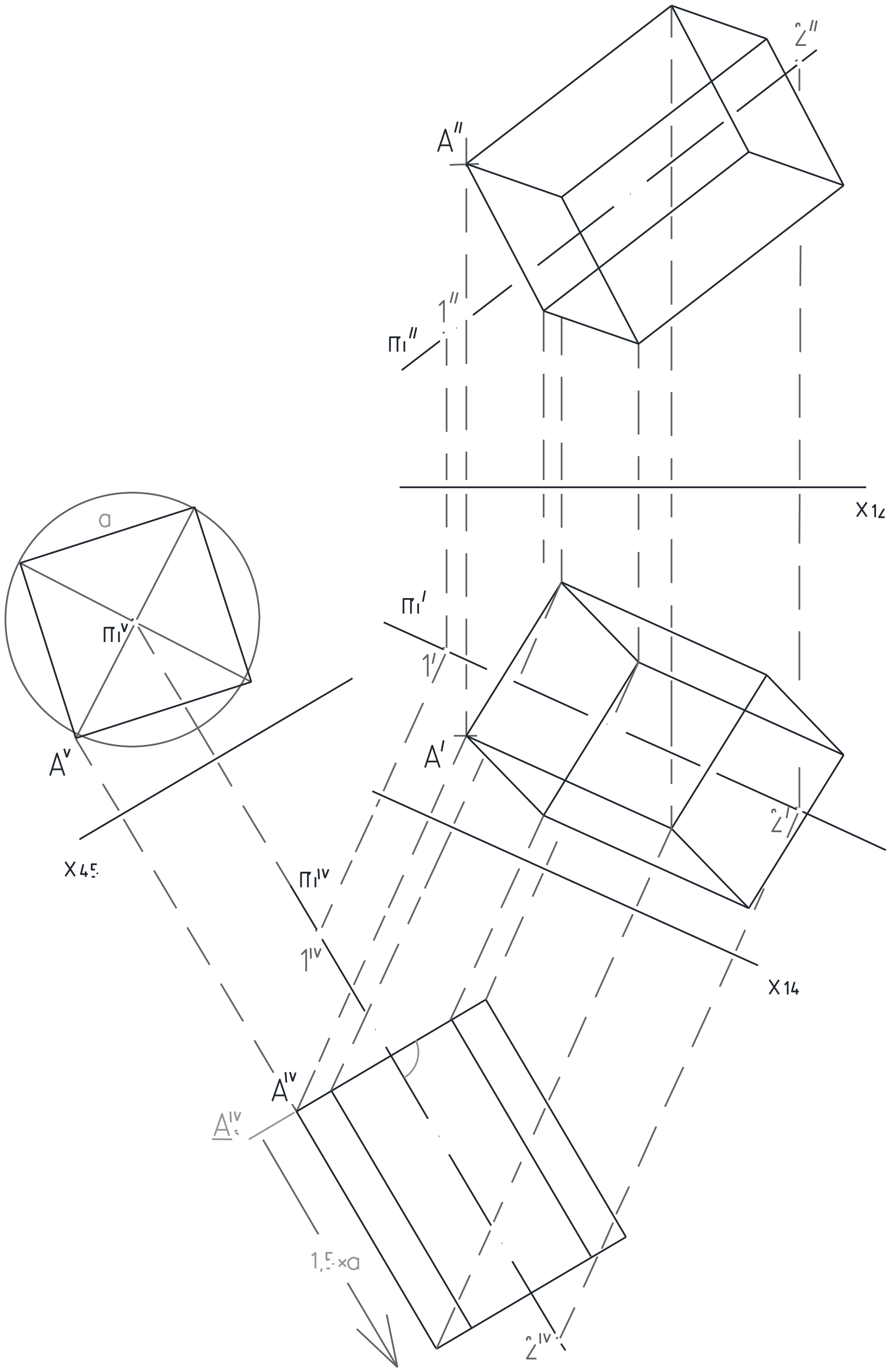
5. Step: The height of the fourth projection of the prism is shown in real size.



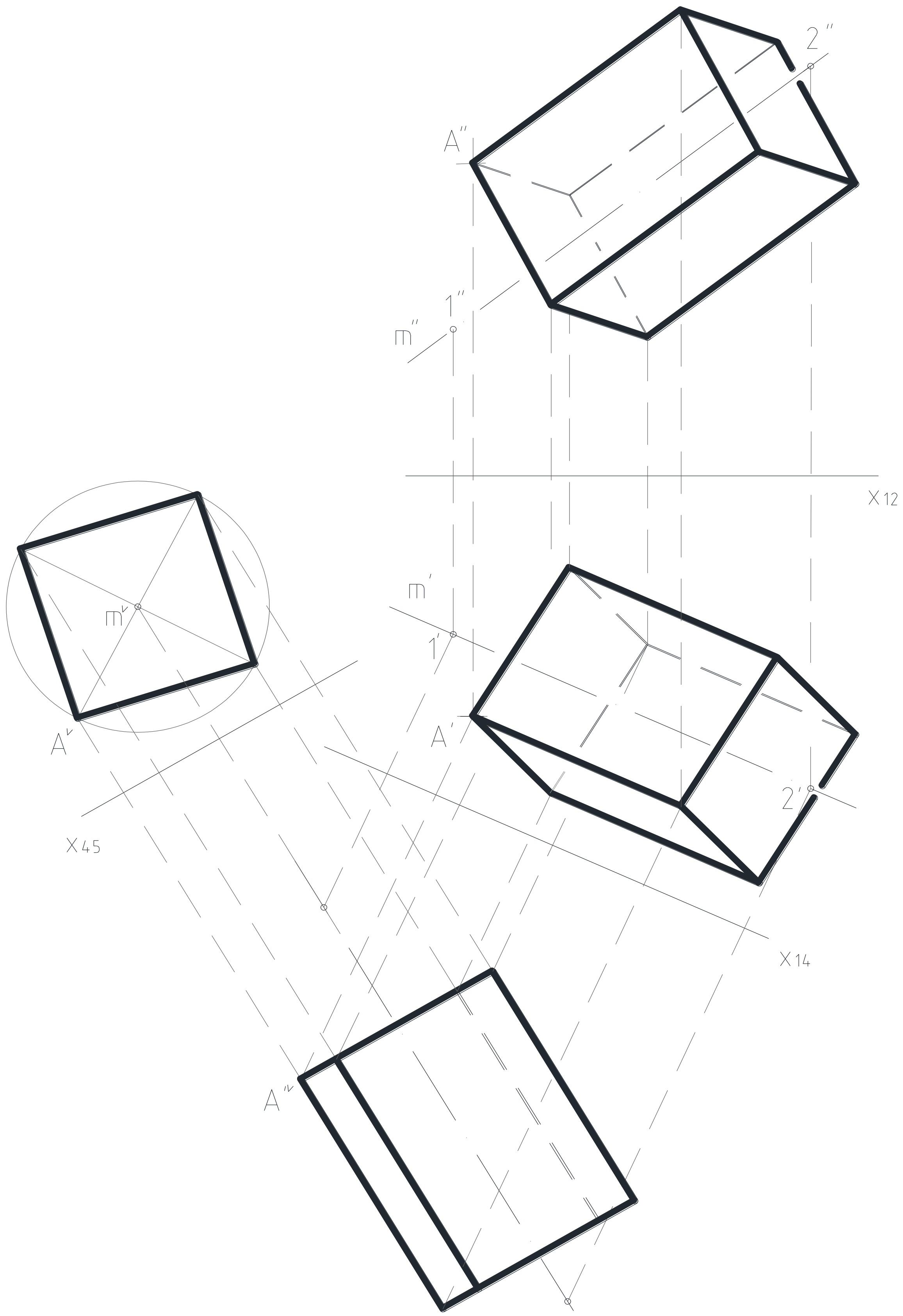
6. Step: Determining the first projection of the prism by omitting the fifth projection.



7. Step: Determining the second projection of the prism by omitting the fourth projection.



8. Step: Determining the visibility of the prism using the method of covering lines.

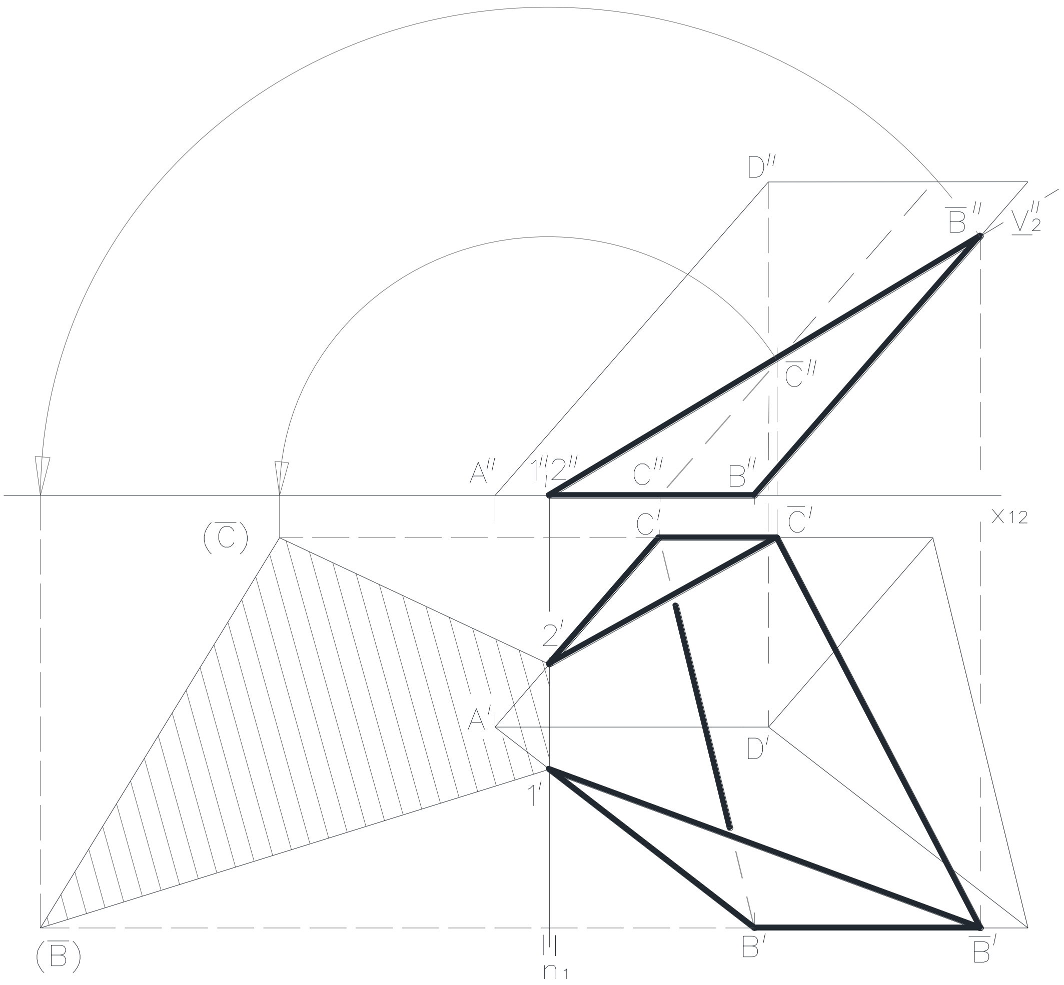


4.1. SOLUTION

Determine the intersection polygon between the given skewed prism placed on the plane <u>K</u>₁ and the plane <u>V</u>₂!

Describe the side surface between the base plane and the intersecting plane, then show the visibility!

Construct the real size of the intersected polygon!

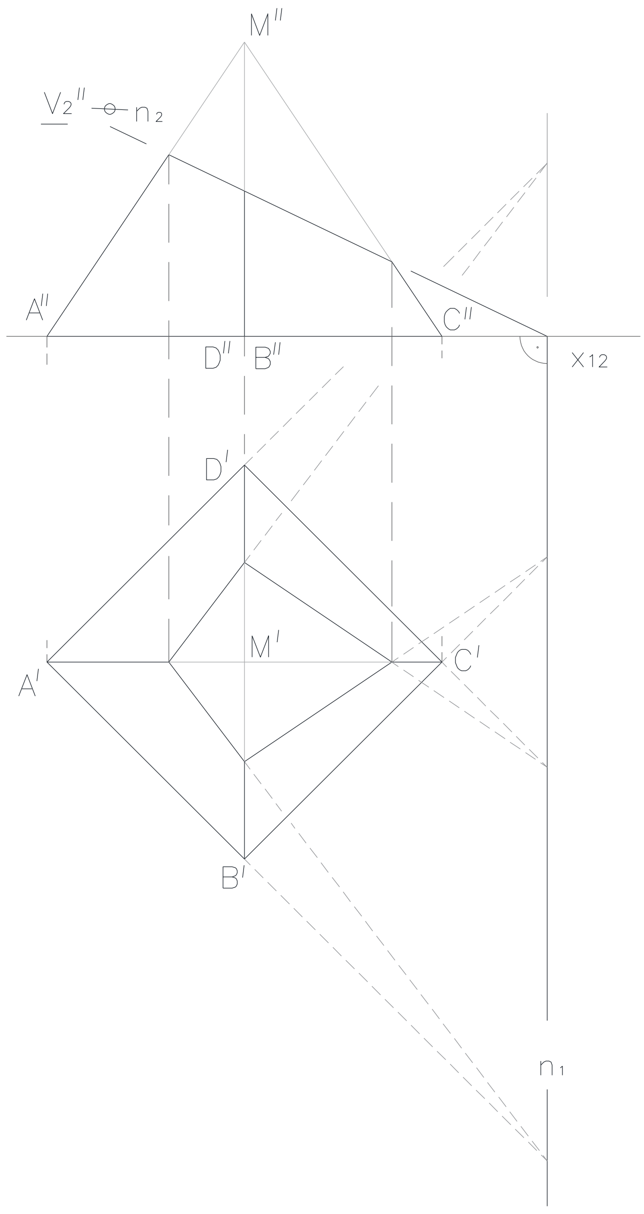


4.3. SOLUTION

The square-based right pyramid is given in such a way that two of its lateral edges are in profile position. Furthermore, the second projection plane V₂ is given too.

Determine the intersection between the pyramid and the second projection plane V₂ using the central collineation connection between the base plane and the intersecting plane!

Show the visibility of the solid between the plane of projection K₁ and the V₂ intersecting plane!



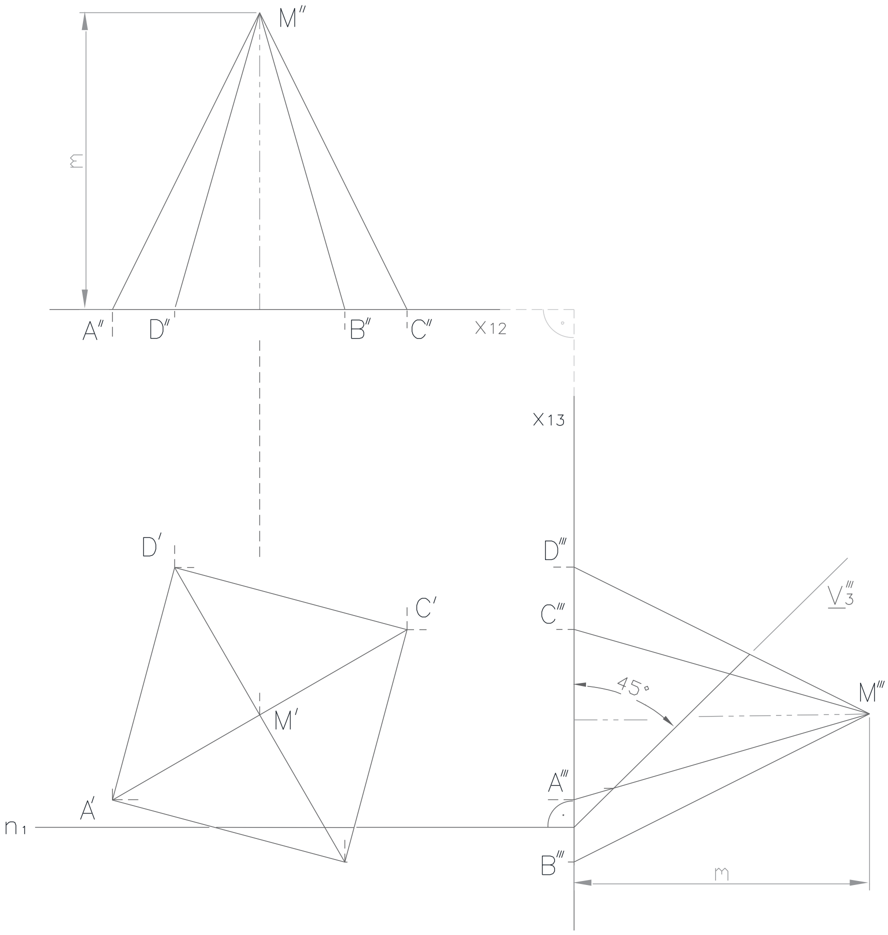
4.4. SOLUTION

Given is the square-based straight pyramid standing on the first plane of projection and the first trace $\mathbf{n}_1$ parallel to the axis $\mathbf{x}_{12}$. Intersect the pyramid with the third projection plane $\underline{V}_3$, which lies on the first trace n1 and forms an angle of $\boldsymbol{\alpha}_1$=**45**° with the first plane of projection $\underline{K}_1$!

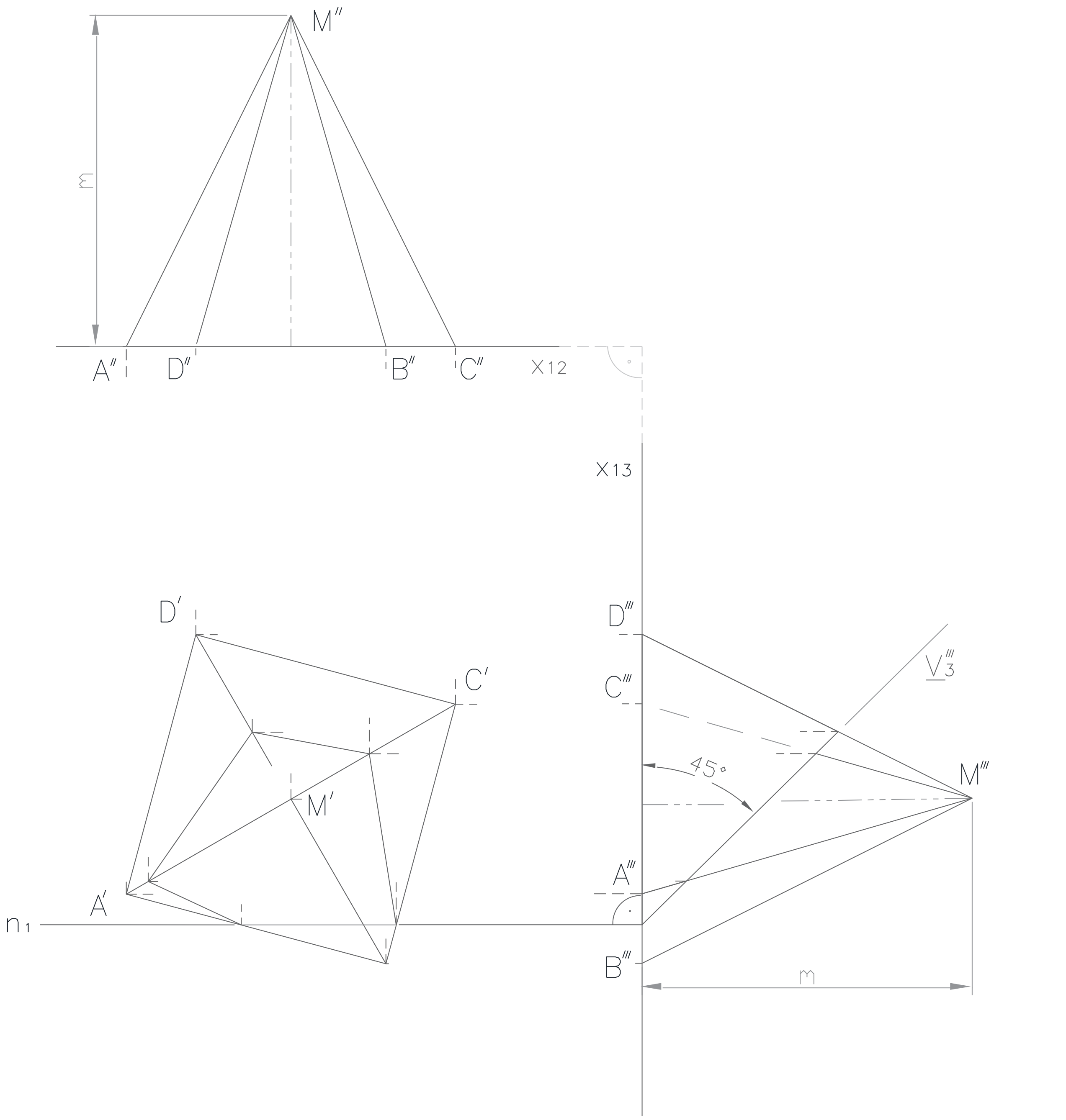
Describe the visualisation of the side surfaces between the base plane and the cutting plane!

Construct the true size of the truncated cone side surfaces and section by rotating to the first projection plane $\underline{K}_1$!

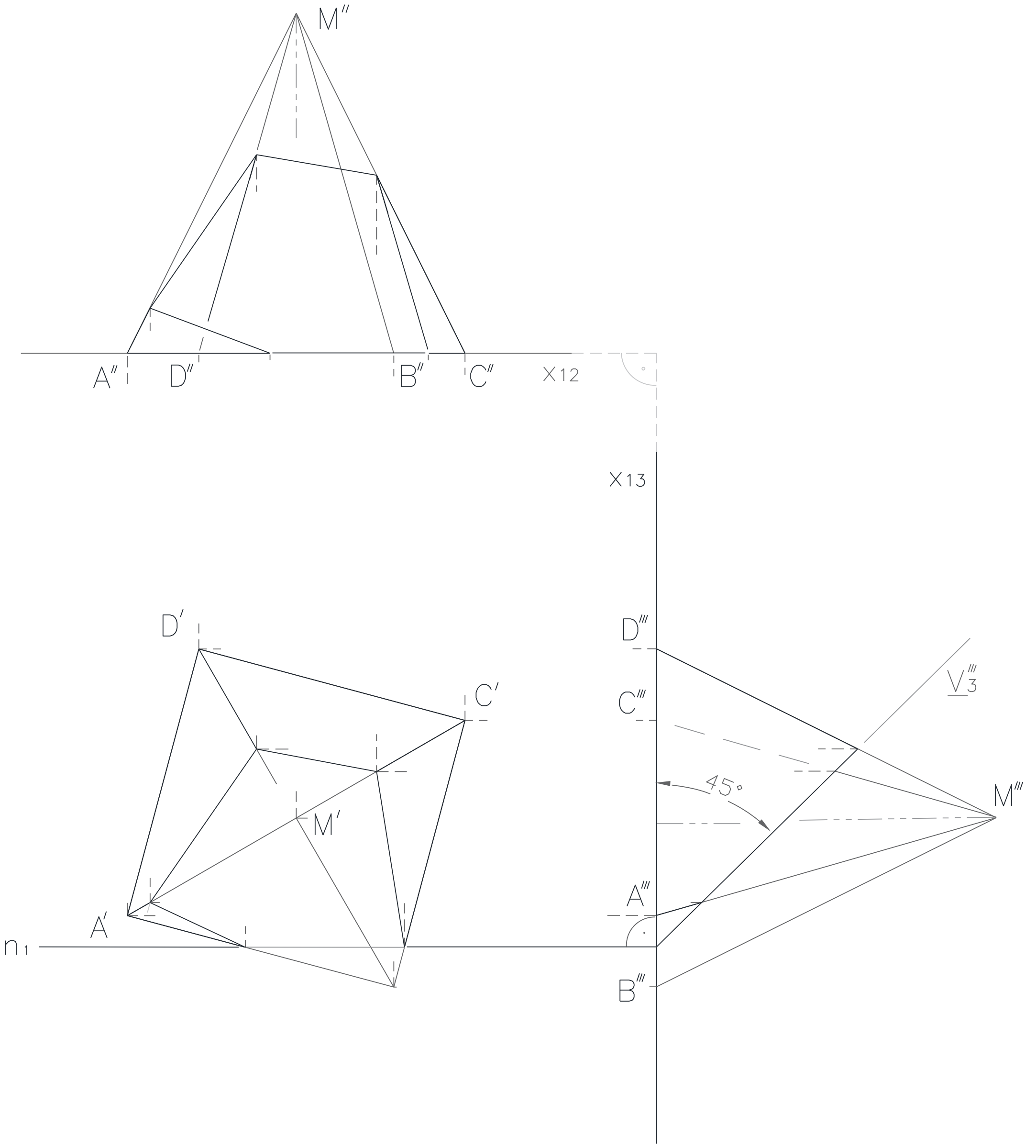
Step 1.



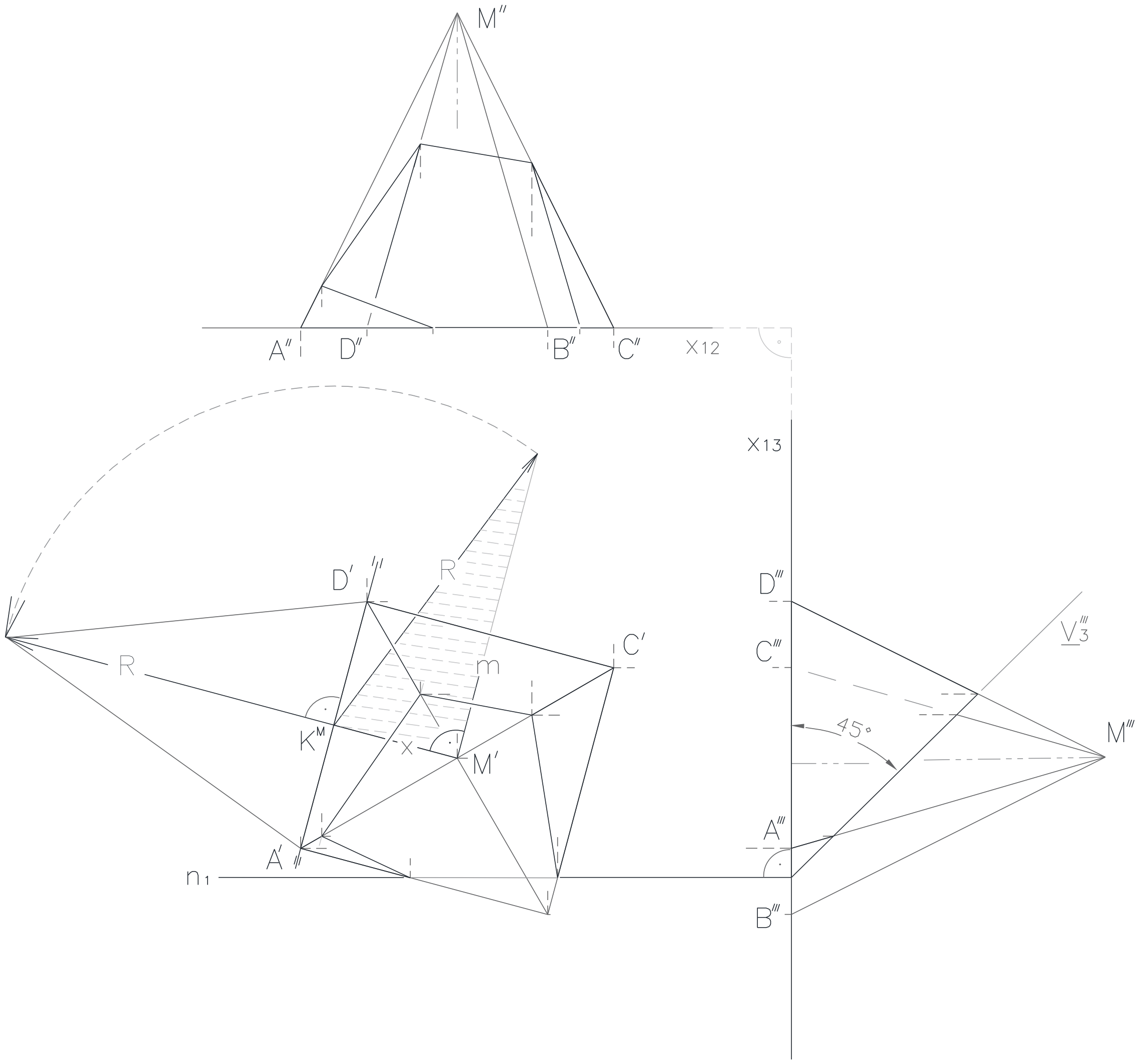
Step 2.



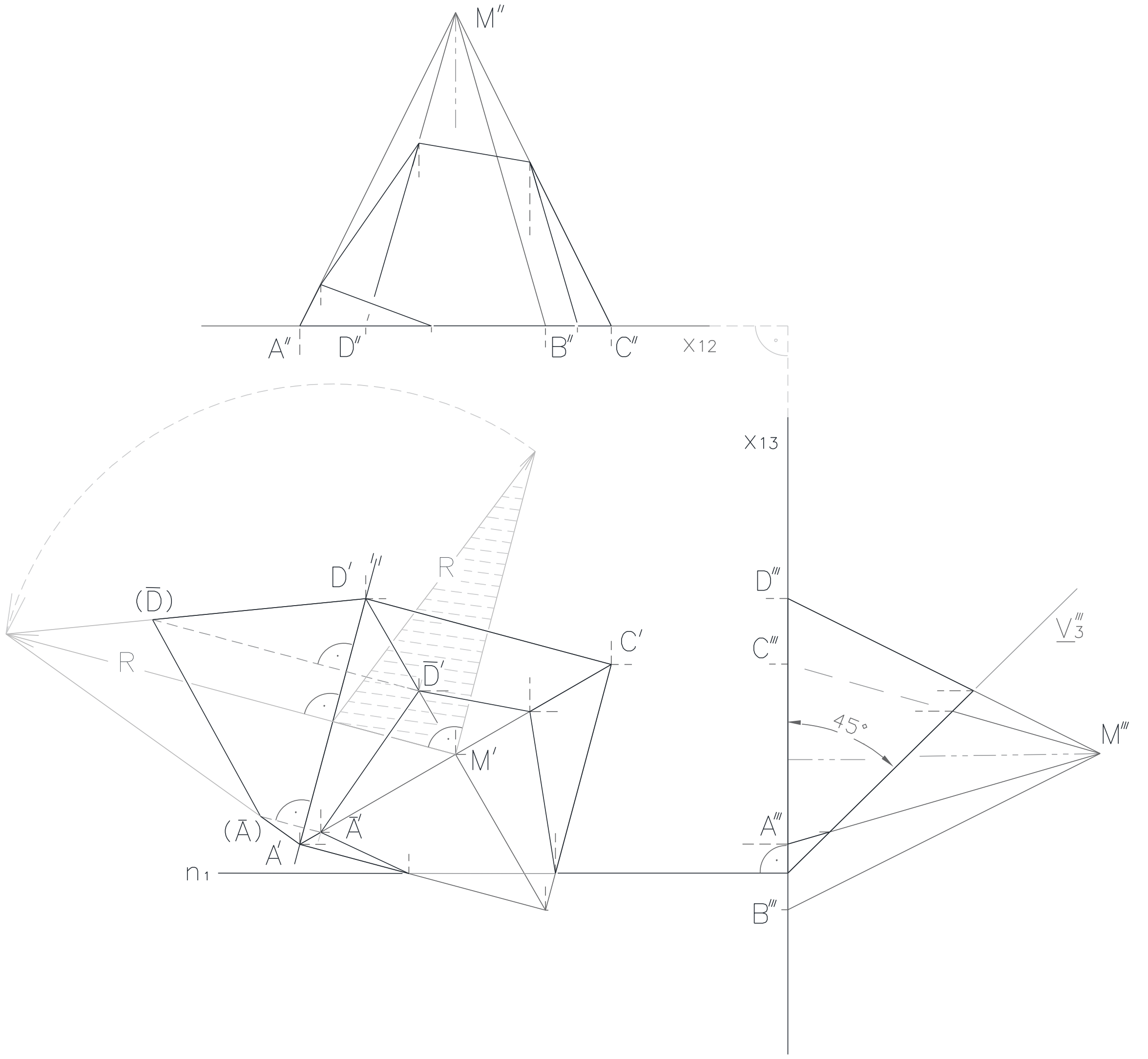
Step 3.



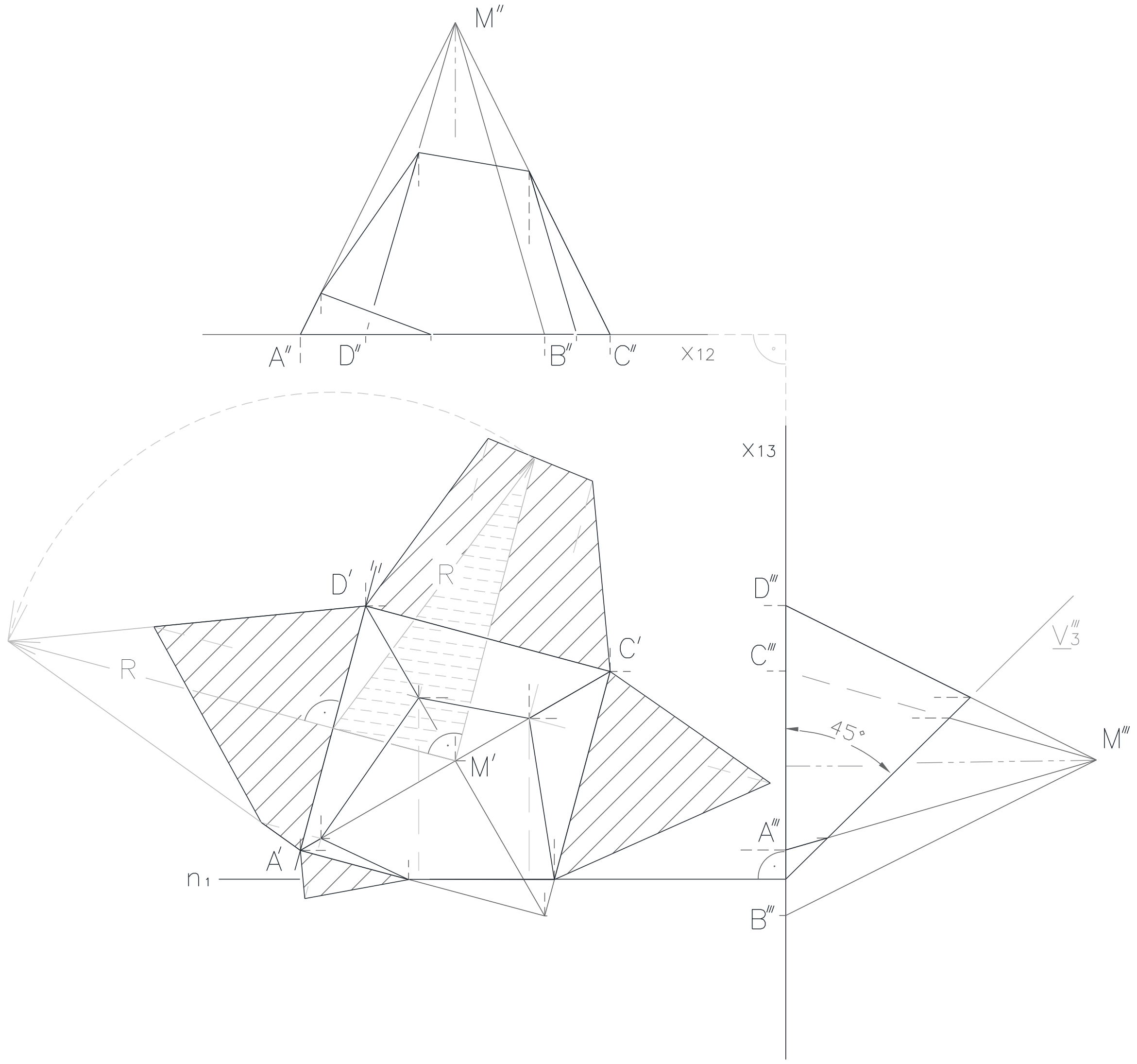
Step 4.



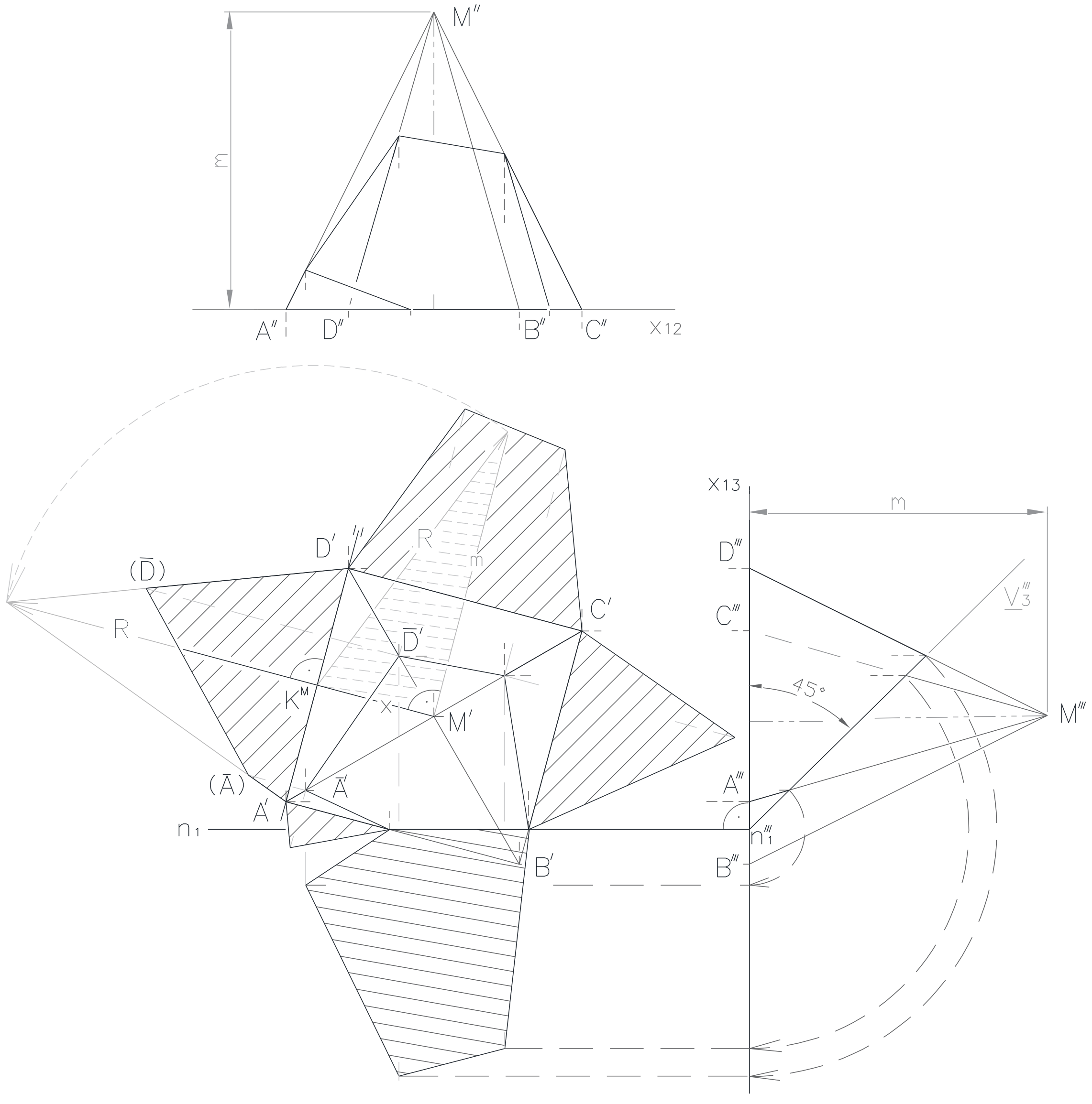
Step 5.



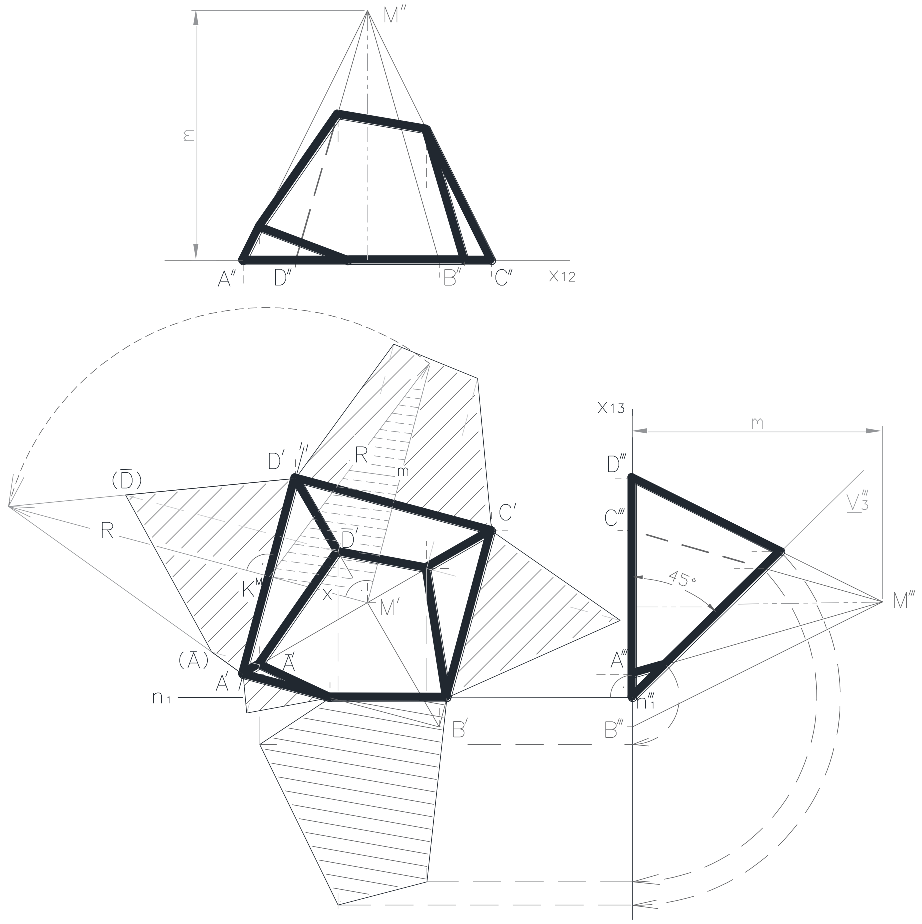
Step 6.



Step 7.

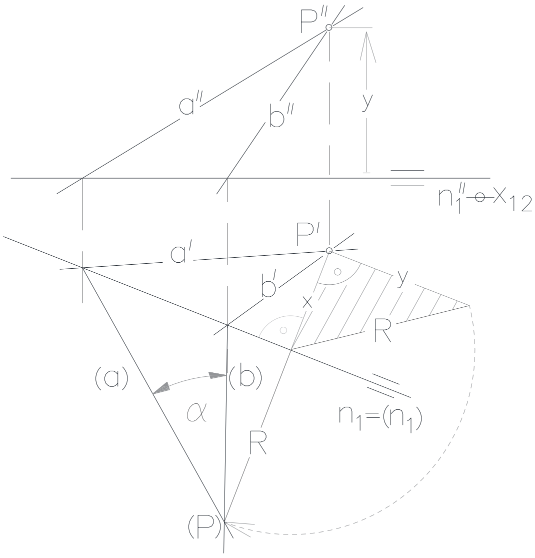


Step 8.

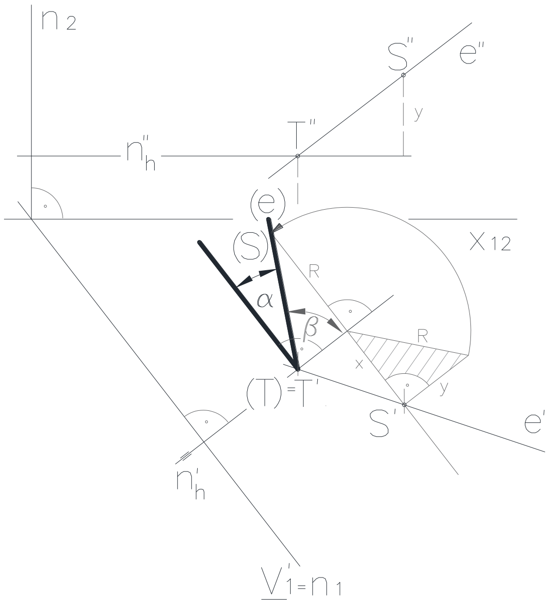


5.2. SOLUTION

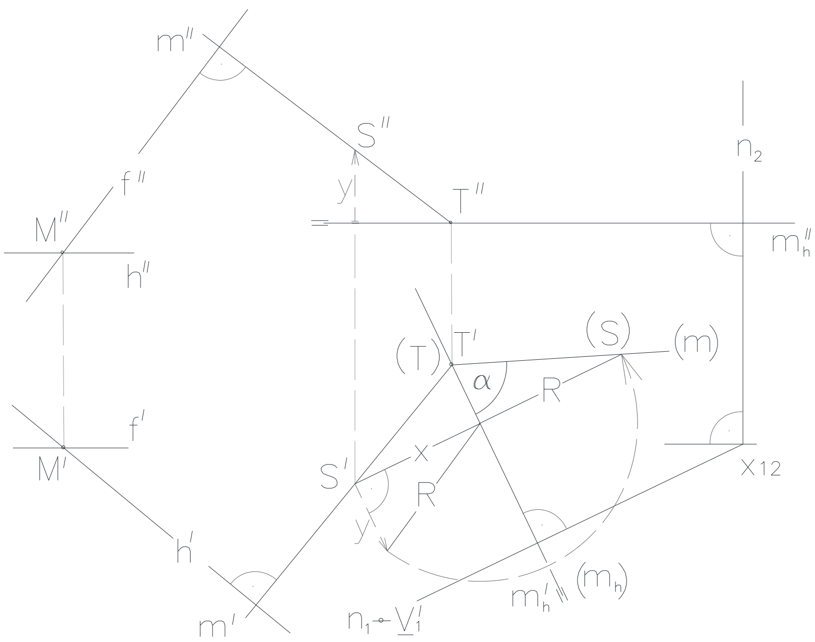
Construct the true size angle ***α*** between the intersecting lines **a** and **b**!



Construct the true size angle ***α*** between the plane given by it's main lines and the first projection plane given by it's trase lines!



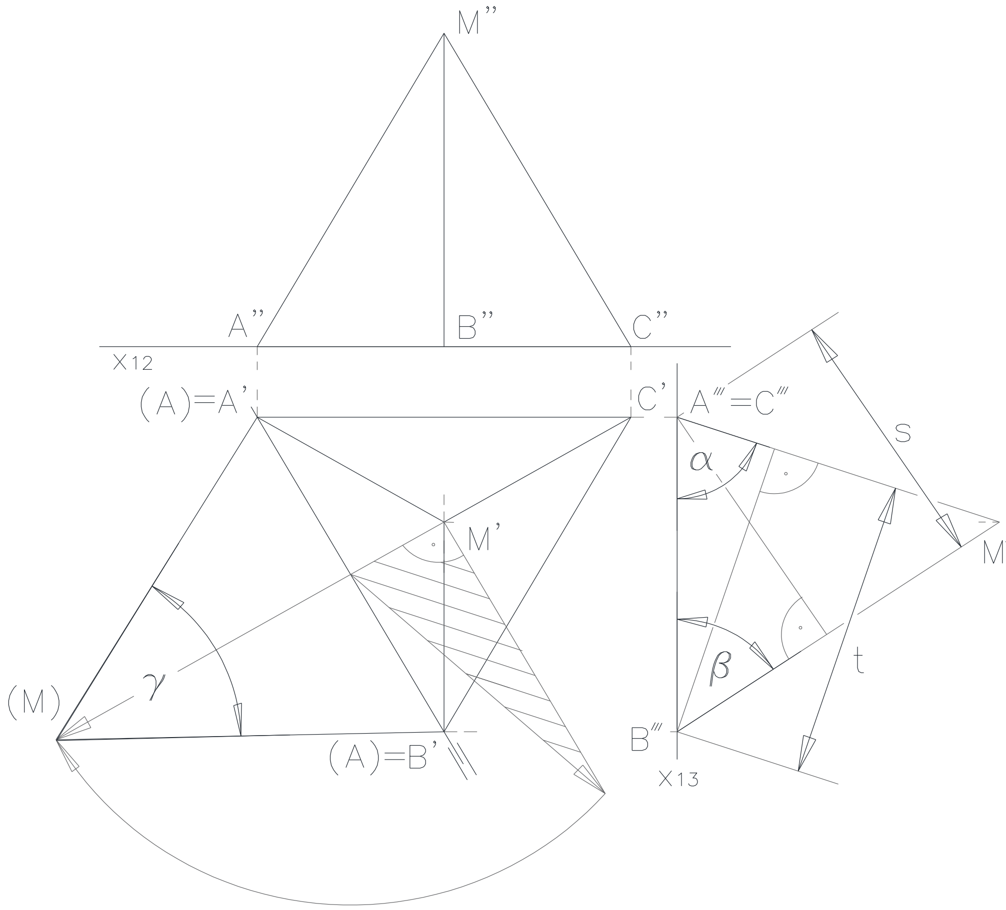
Construct the true size angle ***α*** between the plane given by it's main lines and the first projection plane given by it's trase lines!



5.3. SOLUTION

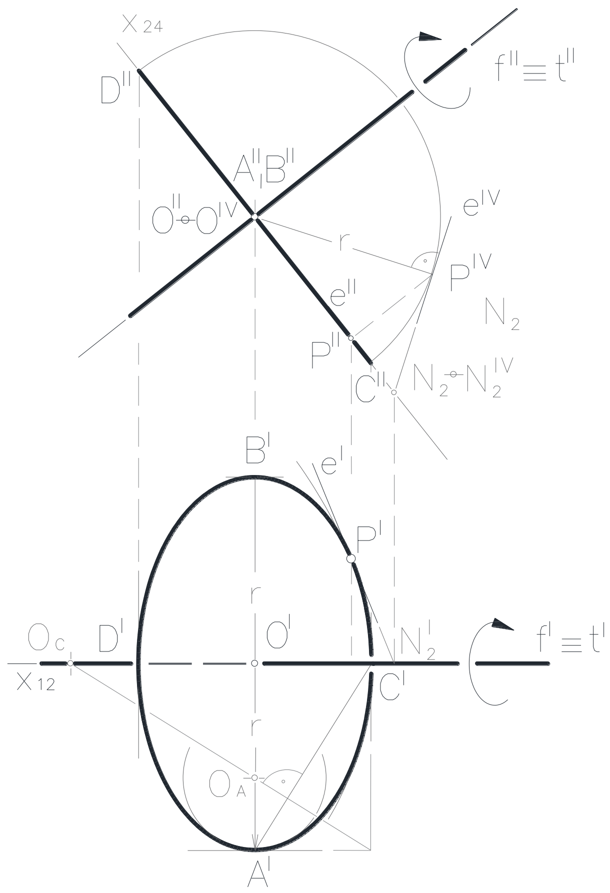
Construction of the:

- the distance $\boldsymbol{t}$ between the point **B** and lateral plane [**ACM**],
- the distance $\boldsymbol{n_t}$ between the base edge I**AC**I and lateral edge I**BM**I,
- the angle $\boldsymbol{\alpha}$ between the first plane of projection $\underline{K}_1$ and the lateral plane [**ACM**],
- the angle $\boldsymbol{\beta}$ between the first plane of projection $\underline{K}_1$ and lateral edge I**BM**I,
- the angle $\boldsymbol{\gamma}$ between the lateral edges I**AM**I and I**BM**I!



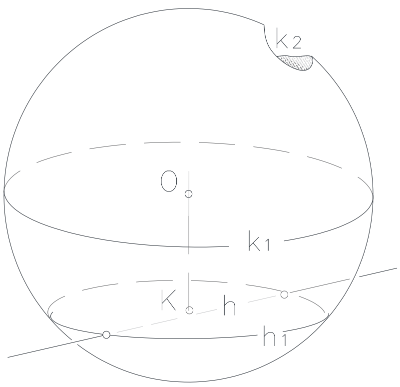
6.1. SOLUTION

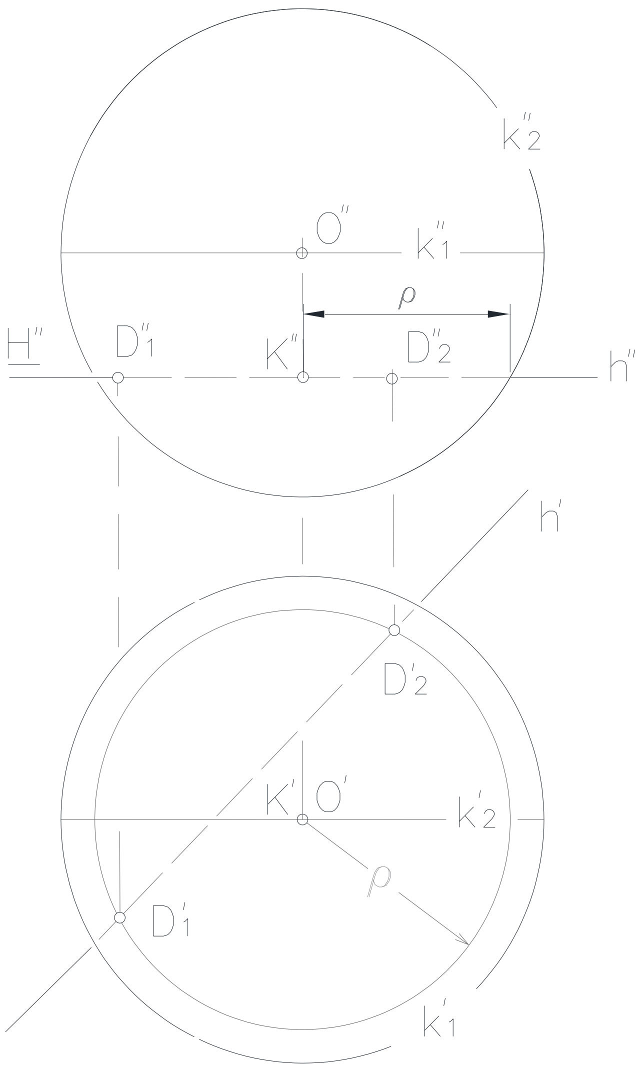
Represent the circular disc with the axis **t** in frontal position and the point **P** on the perimeter line!
Construct the major axis **AB** and the minor axis **CD** of the first projection ellipse.
Determine the tangents and hyperosculating circles at the axis endpoints, furthermore the tangent **e** at the point **P**!
Draw the first projection ellipse!
Show the visibility of the axis **t** and the circular disc with continues and dashed lines!



7.1. SOLUTION

Construct the intersection points D_1 and D_2 of the given sphere and horizontal line **h**!
Show the visibility!

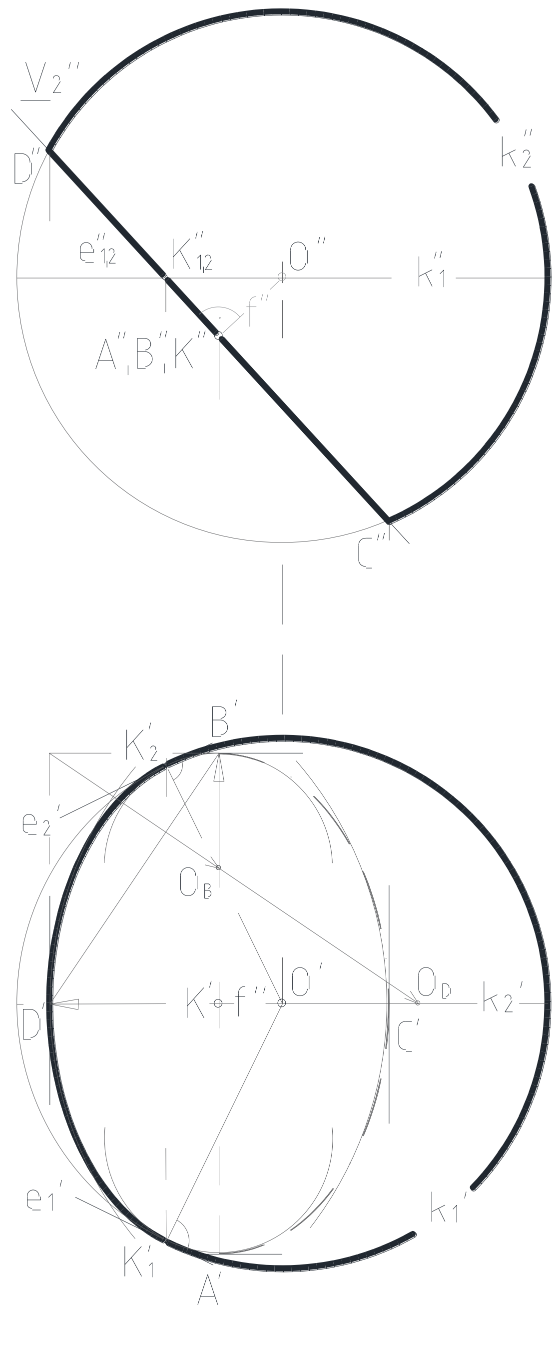




7.2. SOLUTION

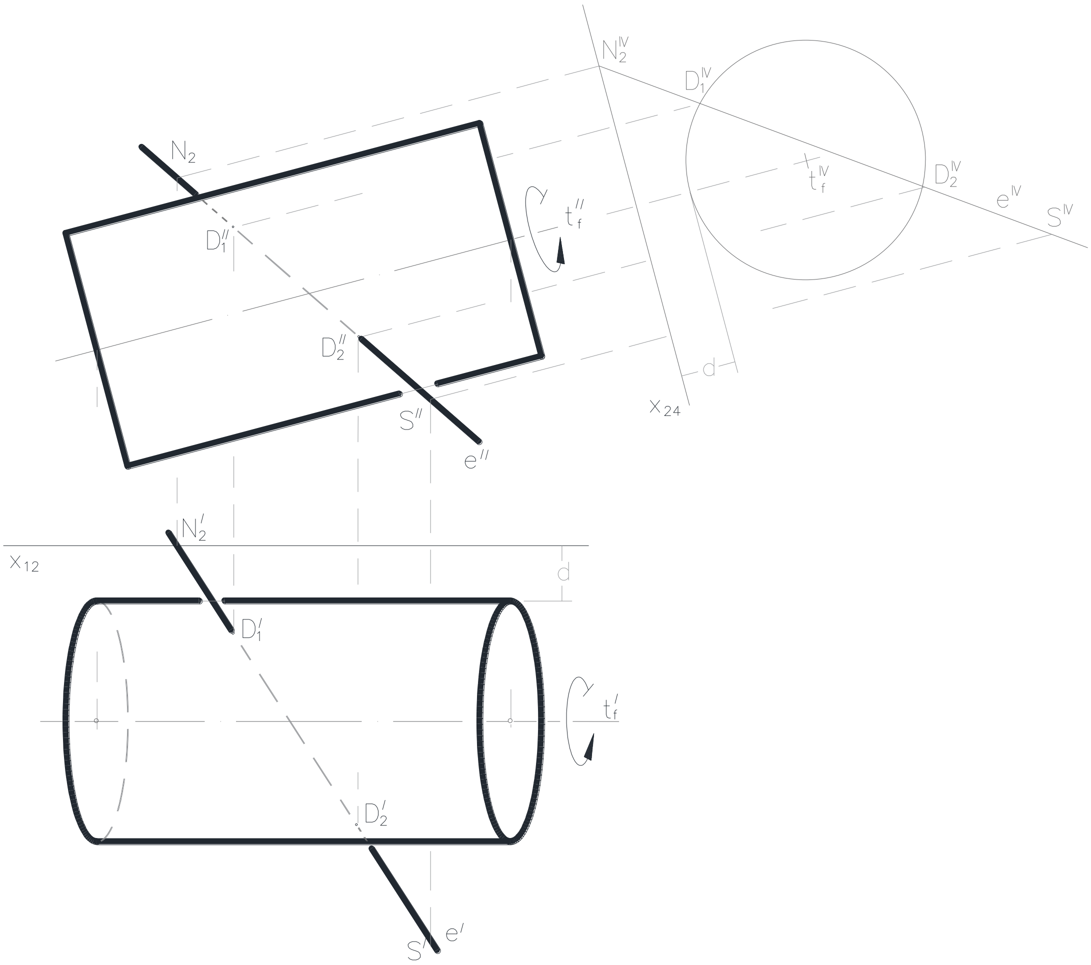
Construct the intersection between the given sphere and the given plane $\underline{V}_2$!

Determine the center point the intersected circle, the axes of first projected ellipse, the points $K_{1,2}$ with tangents $e_{1,2}$ on the first contour circle k_1! Represent the spherical cap above the second projection plane $\underline{V}_2$, indicating the visibility!



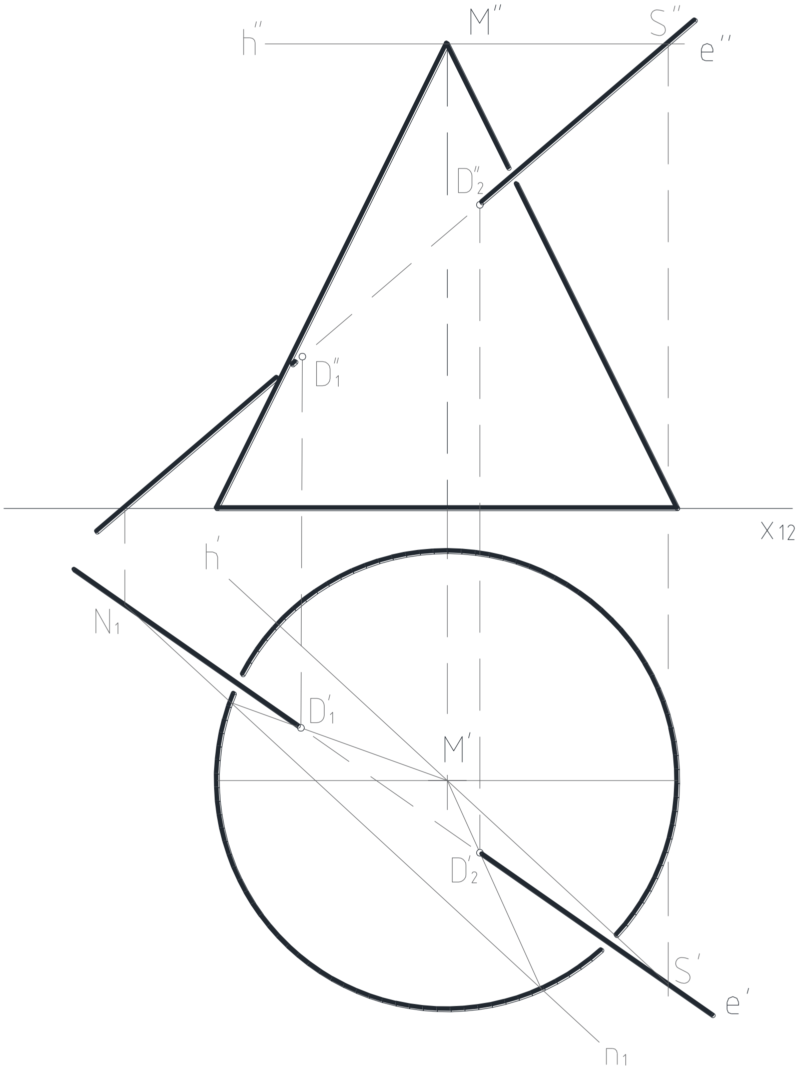
8.1. SOLUTION

A cylinder is given, with the axis t_f in frontal position, and a straight line **e** in general position.
Construct the intersection points!
Indicate the visibility!



9.1. SOLUTION

Determine the points of intersection of the cone on the plane <u>**K**</u>$_1$ and the line **e**!
Indicate their visibility!



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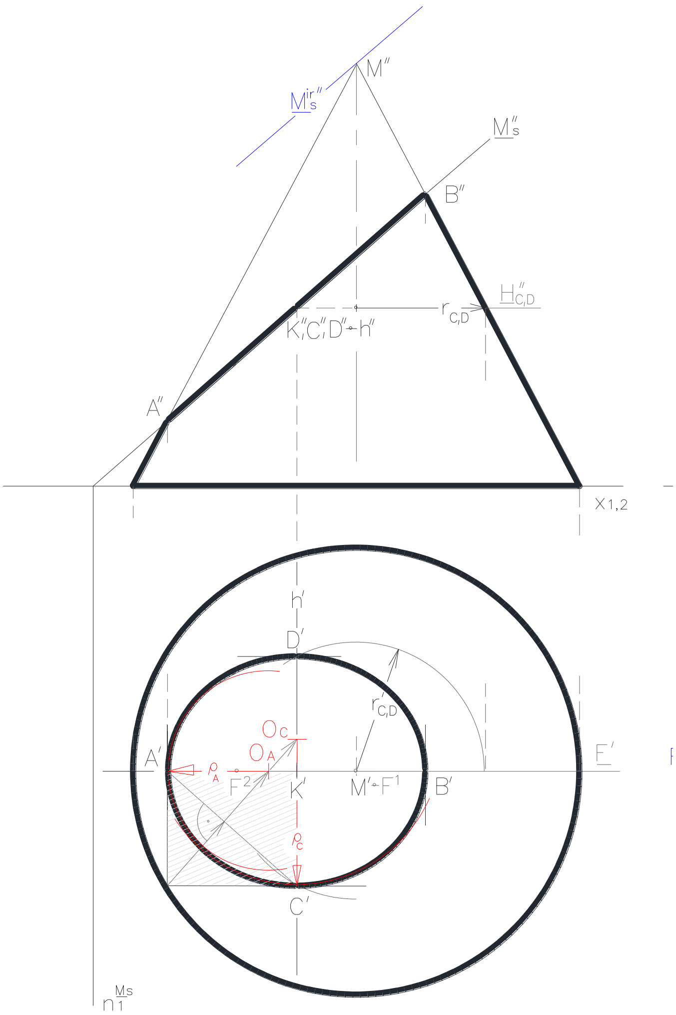
9.2. SOLUTION

The rotation cone on the plane of projection $\underline{K}_1$ is given. Determine a second projector plane $\underline{V}_2$ that intersects the cone in an ellipse!

Construct the first projection of the ellipse intersection ***e***! Determine the major axis **AB** and the minor axis **CD** of the ellipse, then its focus points F_1 and F_2, and a general point with its tangent!

Draw the first projection of the section using the hyper osculating circles!

Visually describe the conic section between the base plane and the section plane.



9.3. SOLUTION

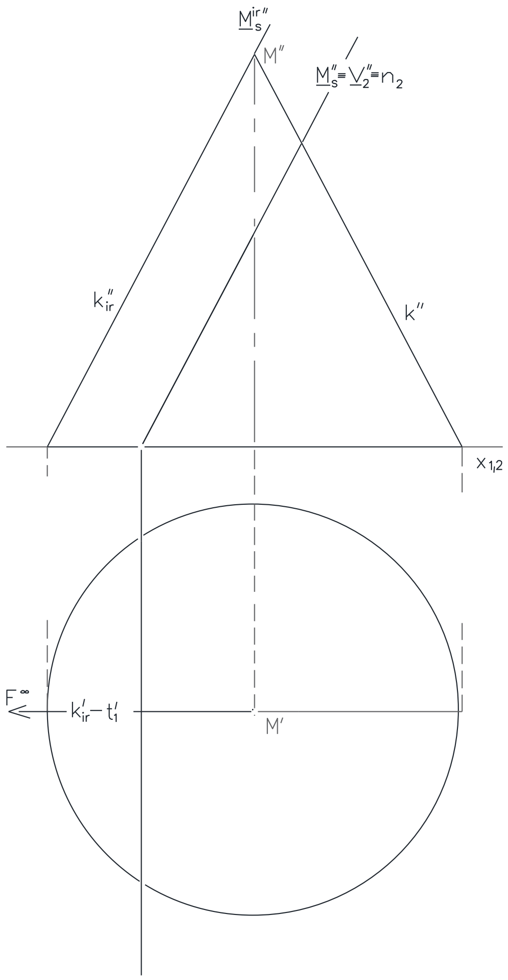
The rotation cone on the plane of projection $\underline{K}_1$ is given. Determine a second projector plane $\underline{V}_2$ that intersects the cone in parabola!

Construct the first projection of the parabola section **p**, its **T** axis point and **t** axis, furthermore, draw the directrix **d**, as well as some general points, and the tangent at one of them!!

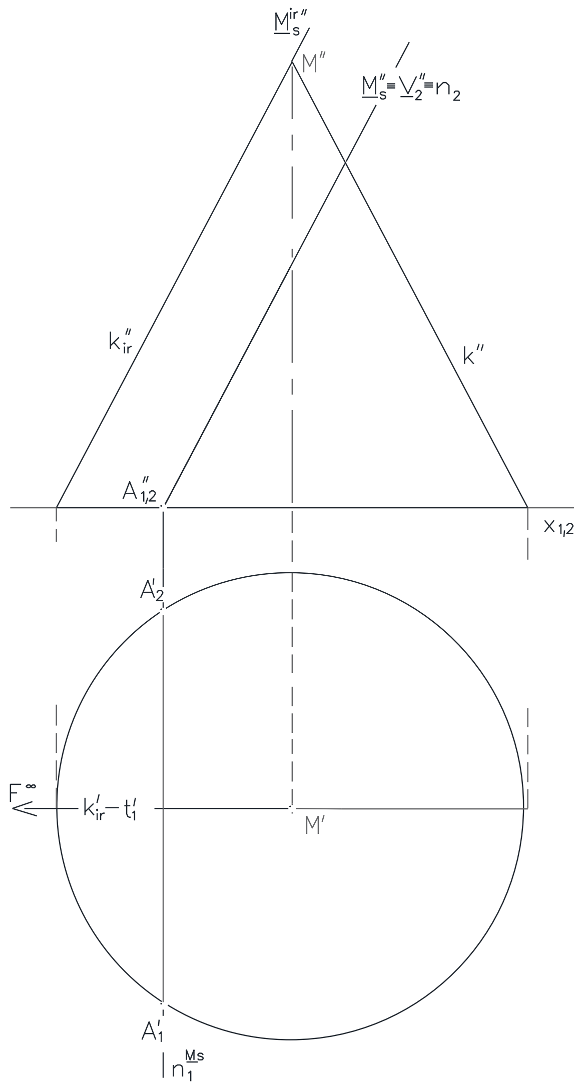
Draw the first projection of the section using the hyper osculating circles!

Visually describe the conic section between the base plane and the section plane.

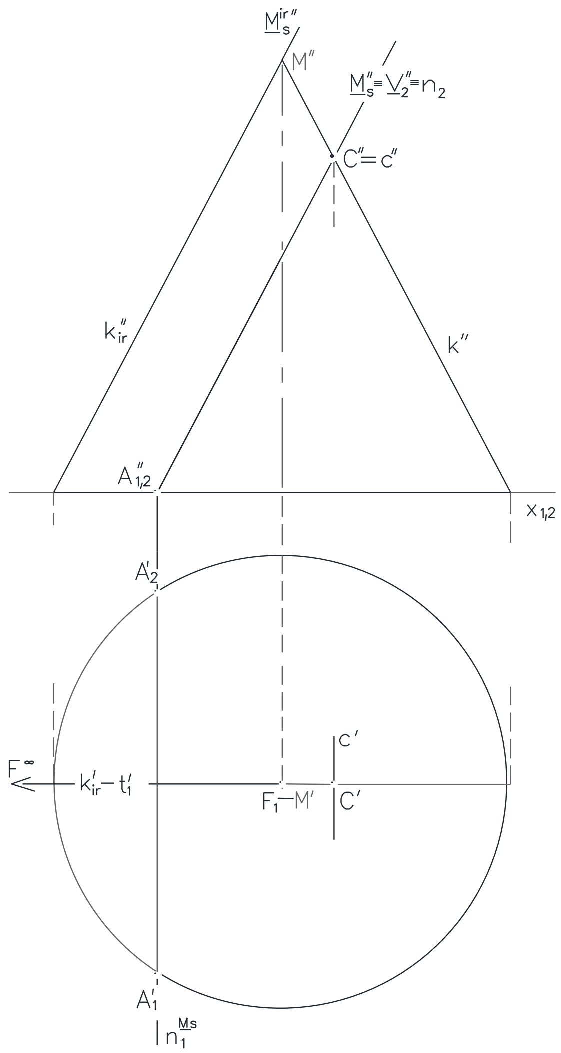
Step 1.:



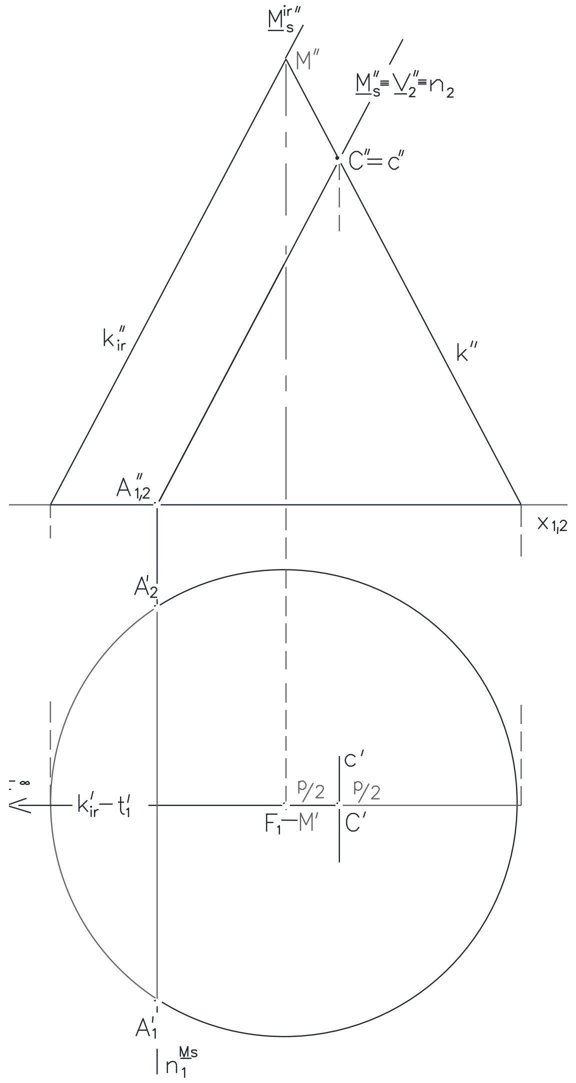
Step 2.:


M_s^ir″
M″
M_s″≡V_2″≡n_2
k_ir″
k″
A″_1,2
x_1,2
A′_2
F∞
k′_ir—t′_1
M′
A′_1
n_1^Ms

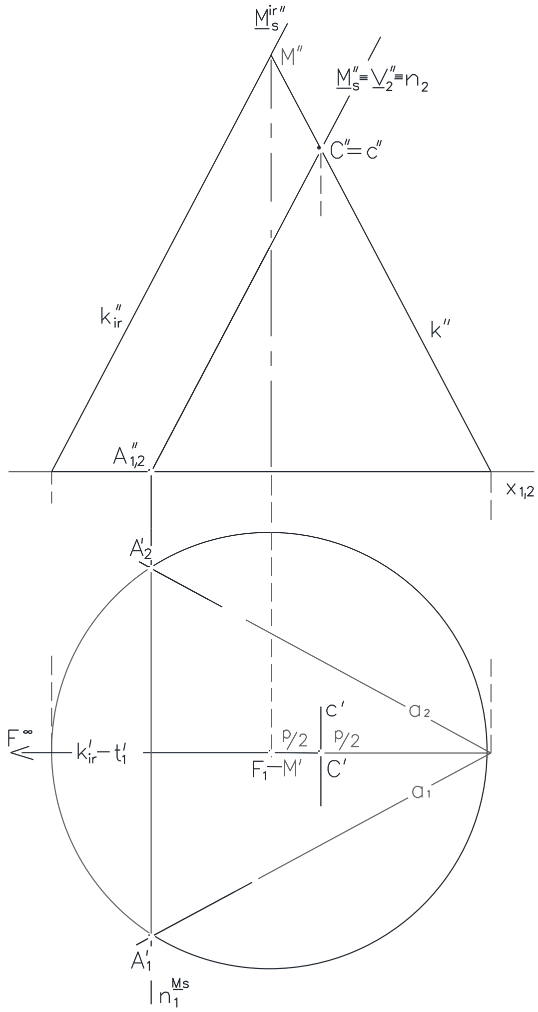
Step 3.:


M_s^ir″
M″
M_s″≡V_2″≡n_2
C″= c″
k_ir″
k″
A″_1,2
x_1,2
A′_2
c′
F∞
k′_ir—t′_1
F_1—M′
C′
A′_1
n_1^Ms

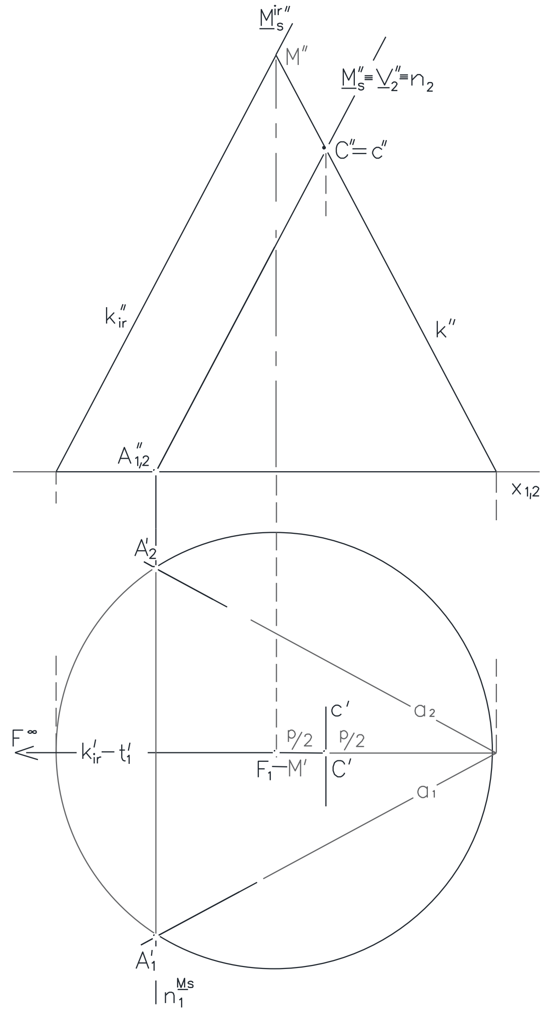
Step 4.:


$\underline{M}_s^{ir}{}''$
M''
$\underline{M}_s'' = \underline{V}_2'' = n_2$
C'' = c''
k_{ir}''
k''
$A_{1,2}''$
$x_{1,2}$
A_2'
c'
p/2
p/2
$k_{ir}' - t_1'$
$F_1 - M'$
C'
A_1'
$n_1^{\underline{M}s}$

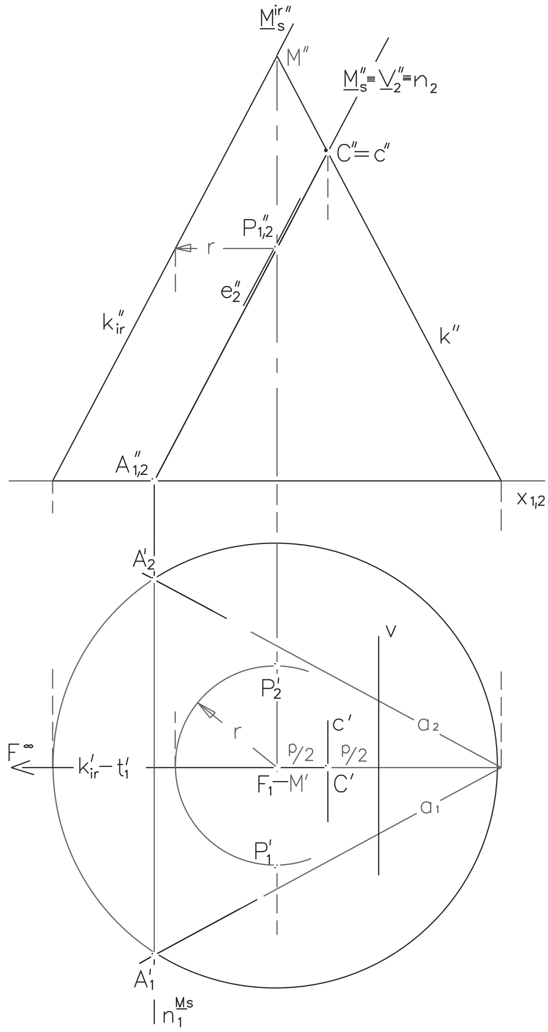
Step 5.:


$\underline{M}_s^{ir}{}''$
M''
$\underline{M}_s'' = \underline{V}_2'' = n_2$
C'' = c''
k_{ir}''
k''
$A_{1,2}''$
$x_{1,2}$
A_2'
c'
a_2
F^∞
$k_{ir}' - t_1'$
p/2
p/2
$F_1 - M'$
C'
a_1
A_1'
$n_1^{\underline{M}s}$

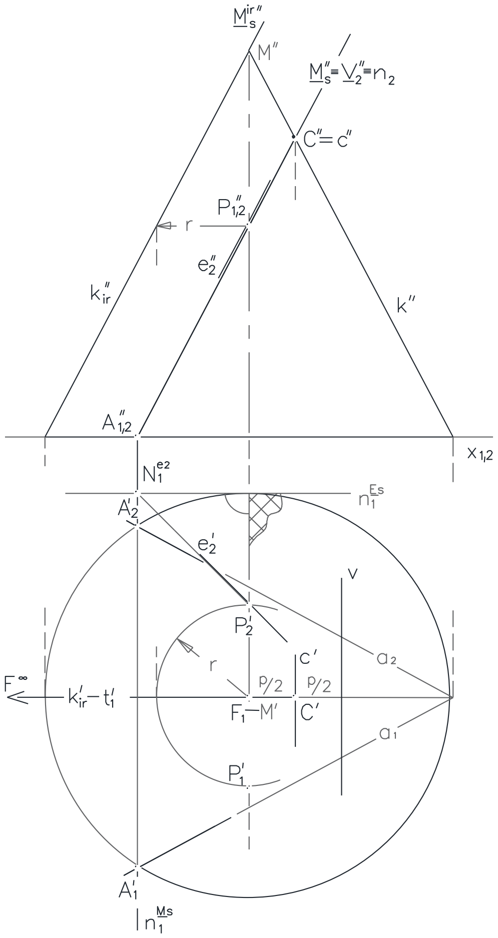
Step 6.:


M″
C″= c″
k″
A″1,2
x1,2
A′2
c′
a2
p/2
p/2
F∞
k′ir – t′1
F1–M′
C′
a1
A′1

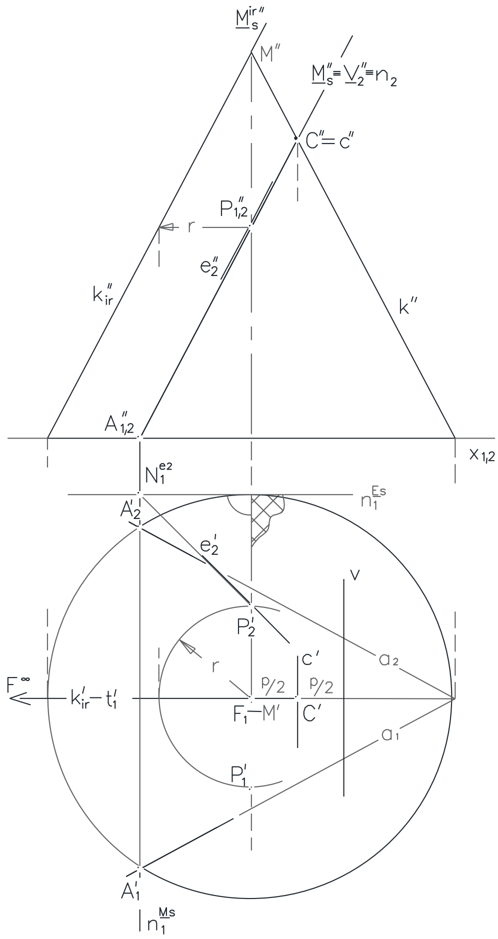
Step 7.:


M″
C″= c″
P″1,2
r
e″2
k″
A″1,2
x1,2
A′2
v
P′2
c′
r
a2
p/2
p/2
F∞
k′ir – t′1
F1–M′
C′
a1
P′1
A′1

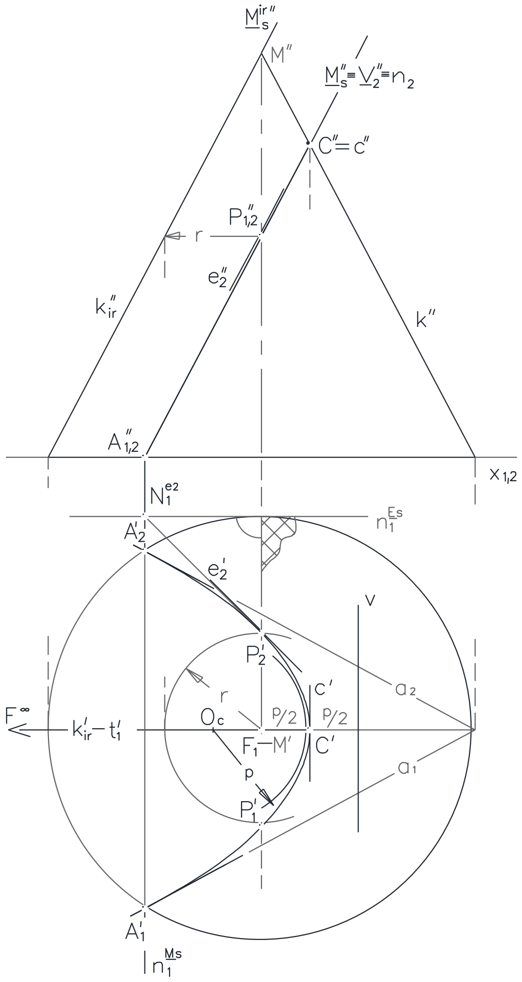
Step 8.:


$\underline{M}_s^{ir''}$
M''
$\underline{M}_s'' = \underline{V}_2'' = n_2$
$C'' = c''$
$P_{1,2}''$
r
e_2''
k_{ir}''
k''
$A_{1,2}''$
$x_{1,2}$
N_1^{e2}
n_1^{Es}
A_2'
e_2'
v
P_2'
r
c'
a_2
F^∞
$k_{ir}' - t_1'$
p/2
p/2
$F_1 - M'$
C'
a_1
P_1'
A_1'
n_1^{Ms}

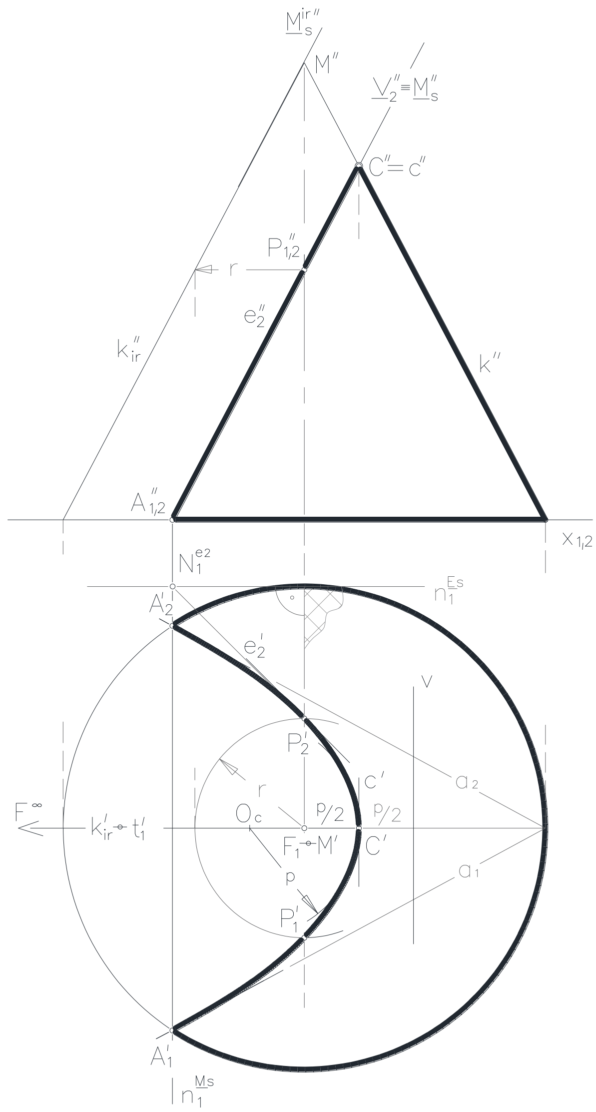
Step 9.:


$\underline{M}_s^{ir''}$
M''
$\underline{M}_s'' = \underline{V}_2'' = n_2$
$C'' = c''$
$P_{1,2}''$
r
e_2''
k_{ir}''
k''
$A_{1,2}''$
$x_{1,2}$
N_1^{e2}
n_1^{Es}
A_2'
e_2'
v
P_2'
r
c'
a_2
F^∞
$k_{ir}' - t_1'$
p/2
p/2
$F_1 - M'$
C'
a_1
P_1'
A_1'
n_1^{Ms}

Step 10.:

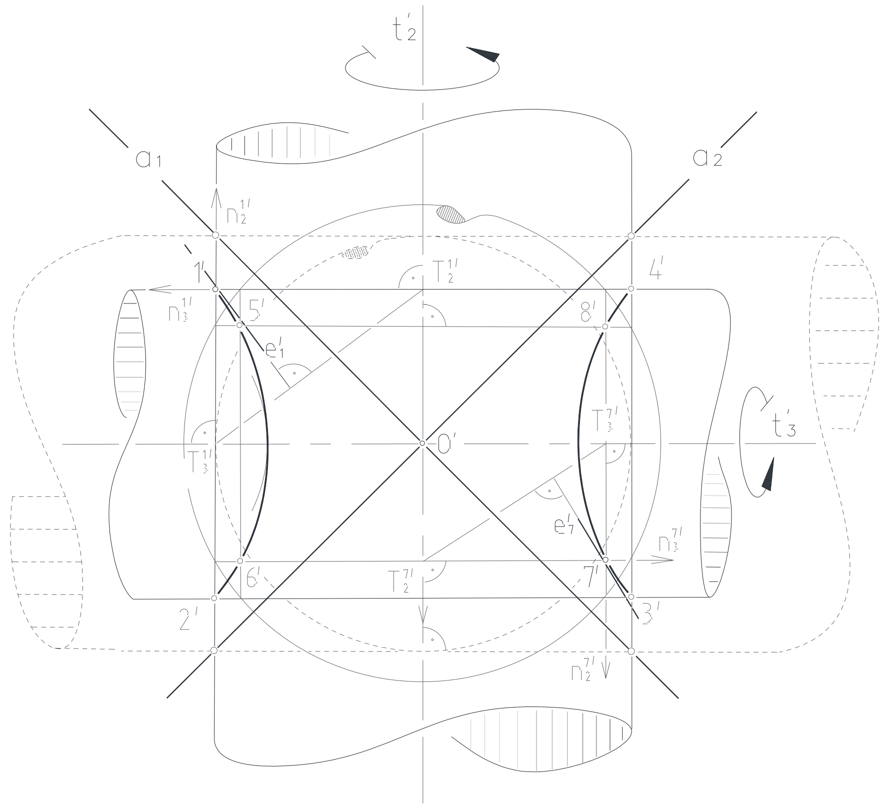


Step 11.:



10.1. SOLUTION

Determine the intersection of the given rotational cylinders!
Construct
- the points on the second contours of the cylinders, mark them by **1, 2, 3, 4,** then the tangent in one of them,
- the points ***d mm*** from the intersection of the axes, mark them by **5, 6, 7, 8,** and then the tangent in one of them,
- the asymptotes of $\boldsymbol{a}_{1,2}$ defining the double projection!
Draw the double projection of the intersection curve!



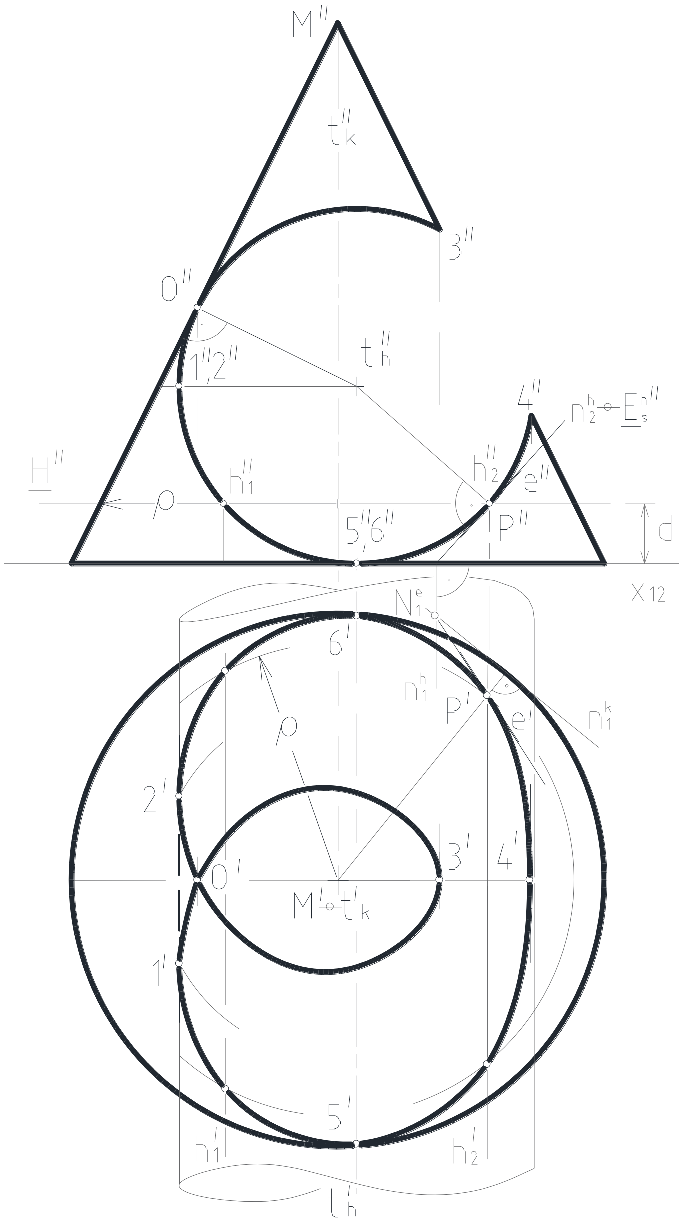
Given the right cone with the first projection position axis standing on the plane $\underline{K}_1$, and the right cylinder of rotation with the second projection position axis, which tangents both the cone and the plane $\underline{K}_1$.

Construct

- the self-intersection point **O**,
- points **1**, **2** which lie on the first contour line of the cylinder, indicating their tangents,
- the points **3**, **4** with the tangent, at which the cylinder creator line is the tangent of the intersection curve,
- - the lowest points **5**, **6** and the highest points **7**, **8**,
- - the points **8 mm** above the base plane of the cone, and the tangent of the curve in one of them!

Draw the second and first projections of the intersection curve!

Represent the cone surface outside the cylinder according to visibility!



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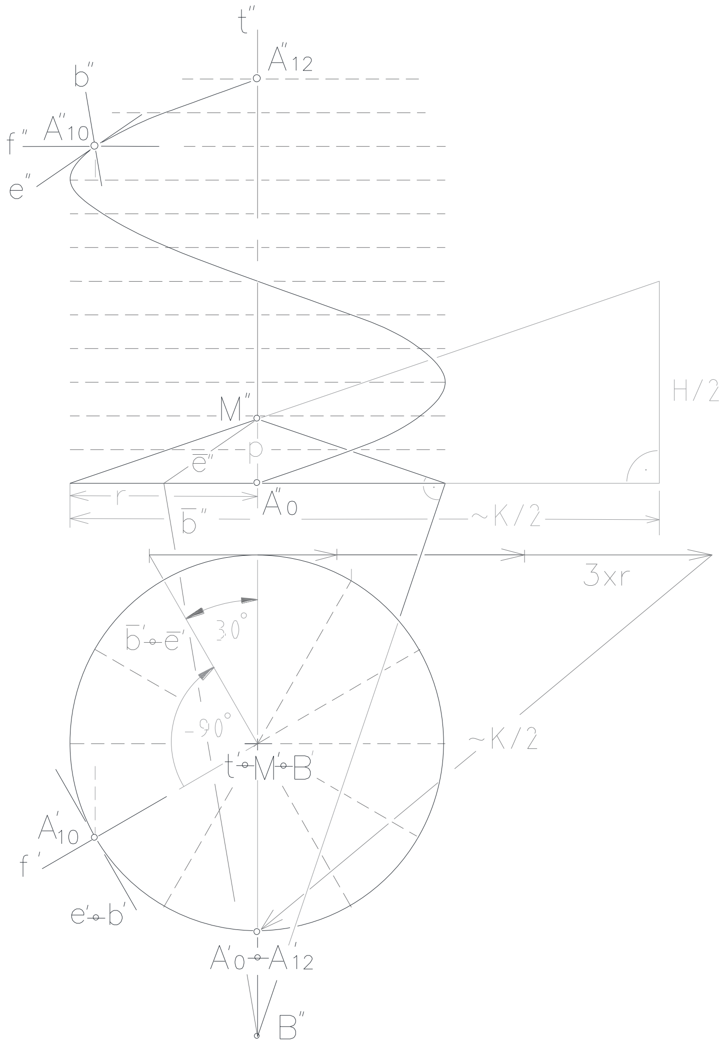
11.1. SOLUTION

Given the axis **t** at the first projector line position of a **right-handed** helix, the base circle lying on the $\underline{K}_1$, and the points A_0 and A_{12} of one complete thread.

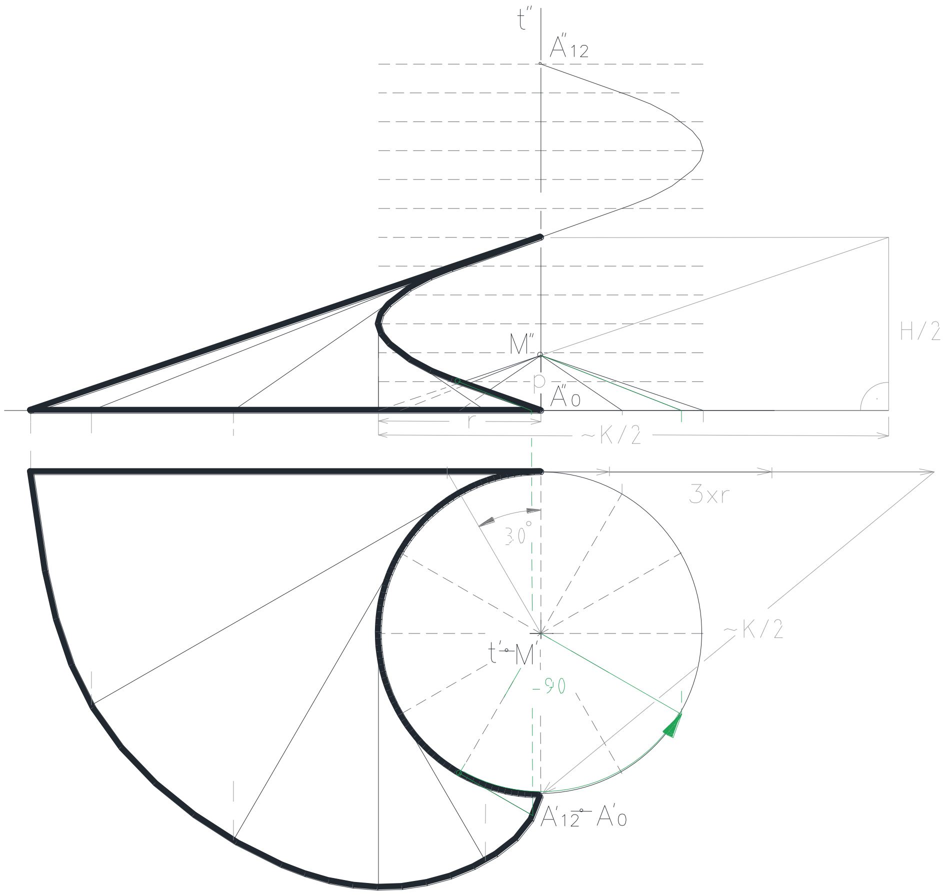
Draw

- the thread between the A_0 and A_{12},
- the approximate expansion of its base circle,,
- the vertex **M** of the cone of the tangents,
- the leading trihedron at point A_{10}!



Given the axis **t** at the first projector line position of a **left-handed** helix, the base circle lying on the $\underline{K}_1$, and the points A_0 and A_{12} of one complete thread.

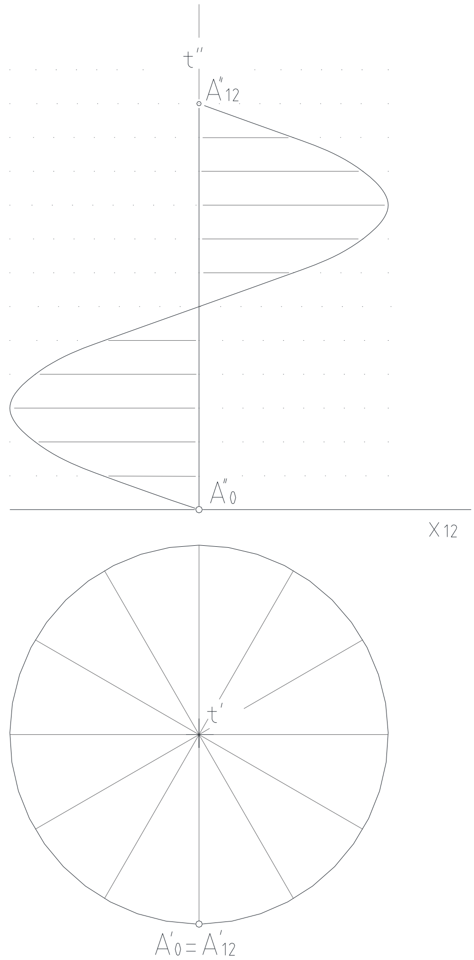
Draw
- the thread between the A_0 and A_{12},
- the approximate expansion of its base circle,,
- the vertex **M** of the cone of the tangents,
- the developable surface of the half thread ended at palne $\underline{K}_1$ with it's face section!

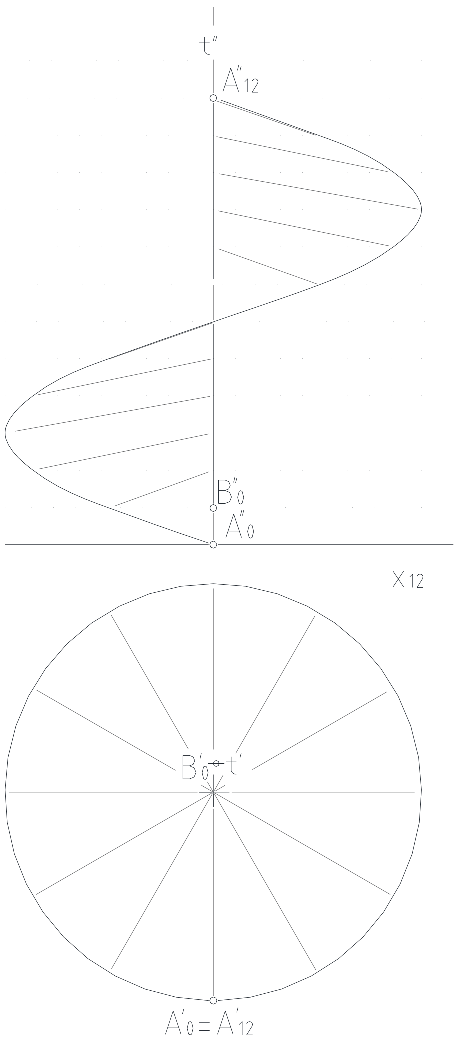


11.2. SOLUTION

The axis **t** in first projector line position and the radius **r** with the base circle on the plane <u>K</u>$_1$, and the end points **A**$_0$ and **A**$_{12}$ of a thread are given.

Draw a complete thread of the **left-hand** helix, next a complete thread of the **closed flat** helicoid surface with the given section **A**$_0$**B**$_0$!



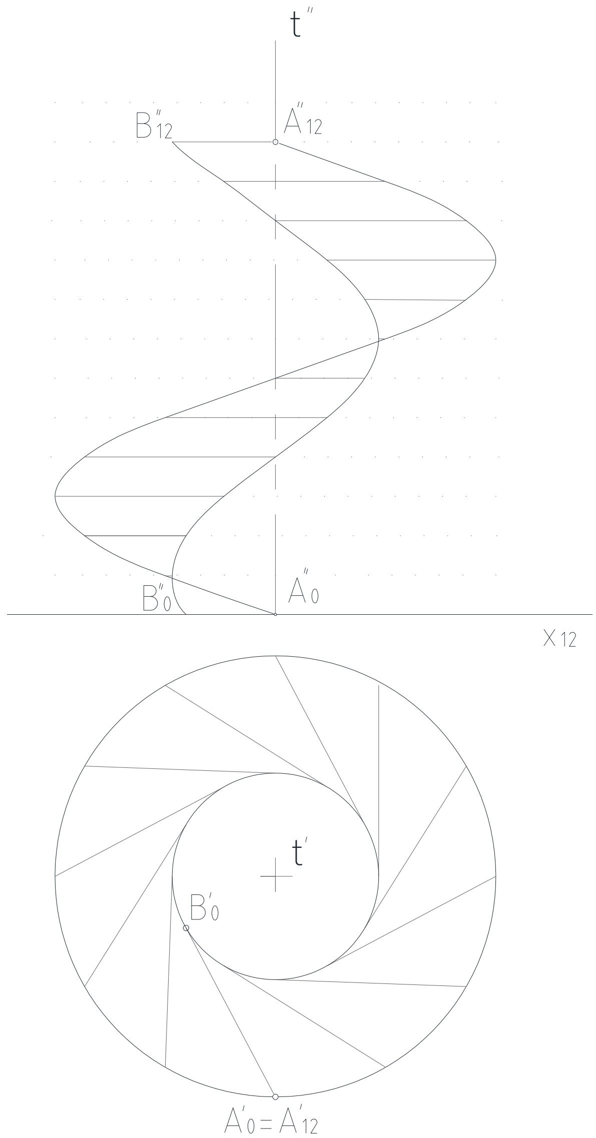


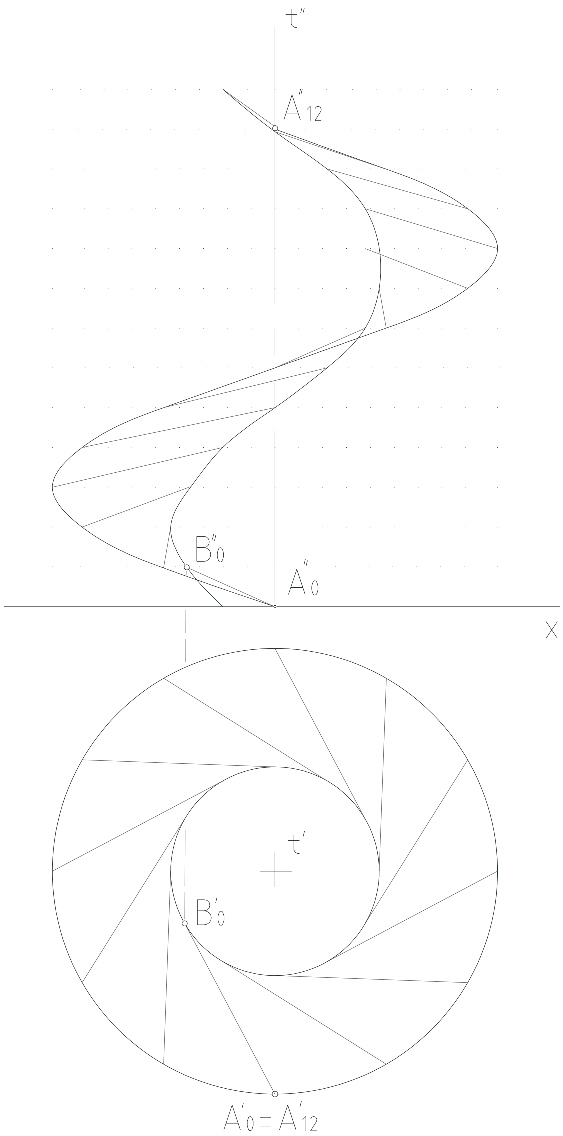
The axis **t** in first projector line position and the radius **r** with the base circle on the plane <u>K</u>$_1$, and the end points **A**$_0$ and **A**$_{12}$ of a thread are given.

Draw a complete thread of the **left-hand** helix, next a complete thread of the **closed angled** helicoid surface with the given section **A**$_0$**B**$_0$!

The axis **t** in first projector line position and the radius **r** with the base circle on the plane $\underline{K}_1$, and the end points $\mathbf{A}_0$ and $\mathbf{A}_{12}$ of a thread are given.

Draw a complete thread of the **left-hand** helix, next a complete thread of the **opened flat** helicoid surface with the given section $\mathbf{A}_0\mathbf{B}_0$!





The axis **t** in first projector line position and the radius **r** with the base circle on the lane $\underline{K}_1$, and the end points $\mathbf{A}_0$ and $\mathbf{A}_{12}$ of a thread are given.

Draw a complete thread of the **left-hand** helix, next a complete thread of the **opened angled** helicoid surface with the given section $\mathbf{A}_0\mathbf{B}_0$!