MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

O. M. BEKETOV NATIONAL UNIVERSITY
of URBAN ECONOMY in KHARKIV

METHODICAL RECOMMENDATIONS

for the organization of independent work, carrying out of practical employment and performance of settlement and graphic works
on subject

BUILDING PHYSICS

(of the third-year full-time student's
specialty 191 – Architecture and urban planning)

Kharkiv – O. M. Beketov NUUE – 2021

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CONTENTS

INTRODUCTION

The purpose of the discipline Building Physics: is the perception of the formation of student's urban worldview using the natural and climatic factor. Ability to create comfortable living conditions through the study of physical phenomena and processes associated with the operation of buildings and structures.

The main tasks of studying the discipline Building Physics are the assimilation by students:

– theoretical foundations of rational design of buildings, structures and their complexes, considering the influence of natural factors;

– considering the parameters of the microclimate (the shape of buildings, types of external structures, the mode of operation of housing) in the design of the architectural environment;

– modern sanitary and hygienic requirements in the design of the architectural environment on the basis of lighting and insolation calculations;

– main acoustic categories in the design of acoustic volumes;

– legislative documents, normative, special, reference literature and resources of the world information network.

CALCULATION AND GRAPHIC TASK (Practical exercise)

The methodical recommendations present the procedure for performing calculation and graphic work (CGT) and consolidation of knowledge gained by students during the study of the section "Climatology" in lectures and practical classes. During the development of CGT students acquire practical skills to consider natural and climatic factors, in the formation of architectural and planning decisions of urban spaces, buildings, buildings and structures.

Name: *Climate passport of the city*

The purpose: *determination of the main microclimatic indicators for the architectural analysis of the climate of a certain area.*

The received theoretical knowledge the student fixes by the individual task on variants which result is settlement and graphic work.

Calculation and graphic work consist of an explanatory note with graphs and diagrams that are the basis for a comprehensive analysis of the local point on climatic grounds.

1.1 Benchmark data

This section provides basic data on the construction area and general climate indicators, which are necessary for the preparation of the construction and climatic passport of the city, which is specified in the design task. The main volume of data for

the regions of Ukraine is collected in DSTU (Reference Manual [7]) in the form of maps and tables.

1.2 Practical exercise № 1 Engineering and climatic calculations

Engineering and climatic calculations consider the main factors of the natural and climatic complex: the radiation regime of the territory (the main indicators of solar radiation); temperature regime of the territory; humidity and precipitation; wind regime of the territory.

1.2.1 Solar radiation

This section writes tabular data on the total solar radiation on the horizontal and vertical surfaces of different orientations during the year in the hottest month. The collected data on the detection of radiation are presented in the form of graphs (fig. 1–3).

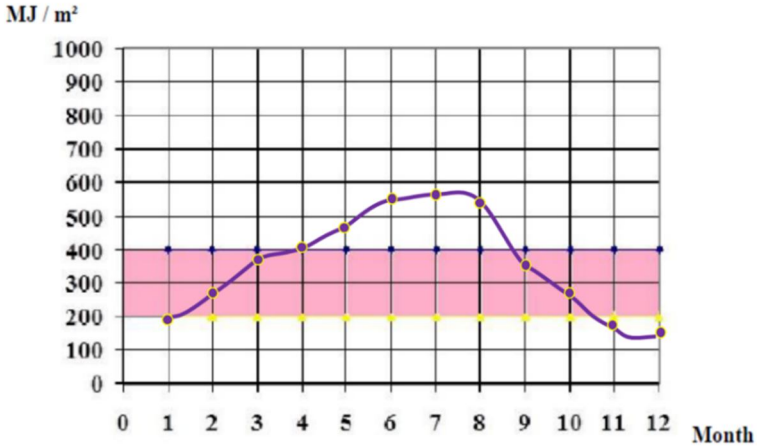


Figure 1 – Arrival of solar radiation on horizontal surfaces in cloudless skies

Mark the periods of excess and insufficient exposure. In July (the hottest month) determine the total daily amount of radiant heat, maximum and average daily radiation on the horizontal and vertical surfaces of different orientations.

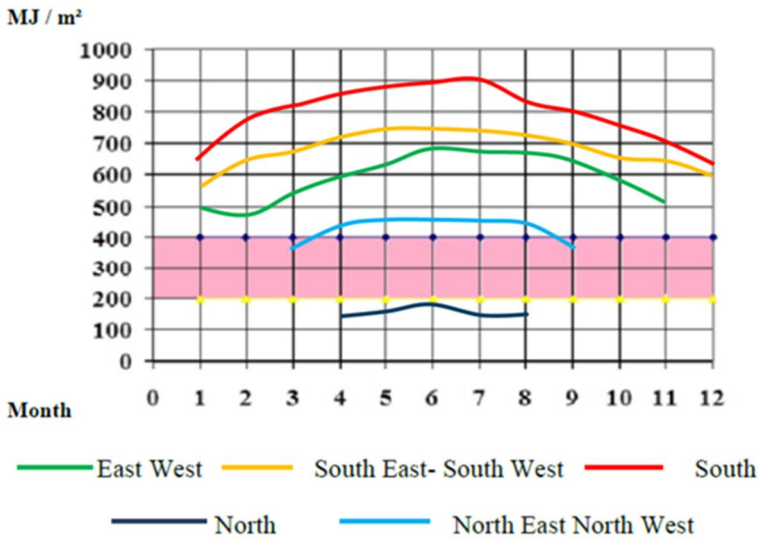


Figure 2 – Arrival of solar radiation on vertical surfaces in a cloudless sky

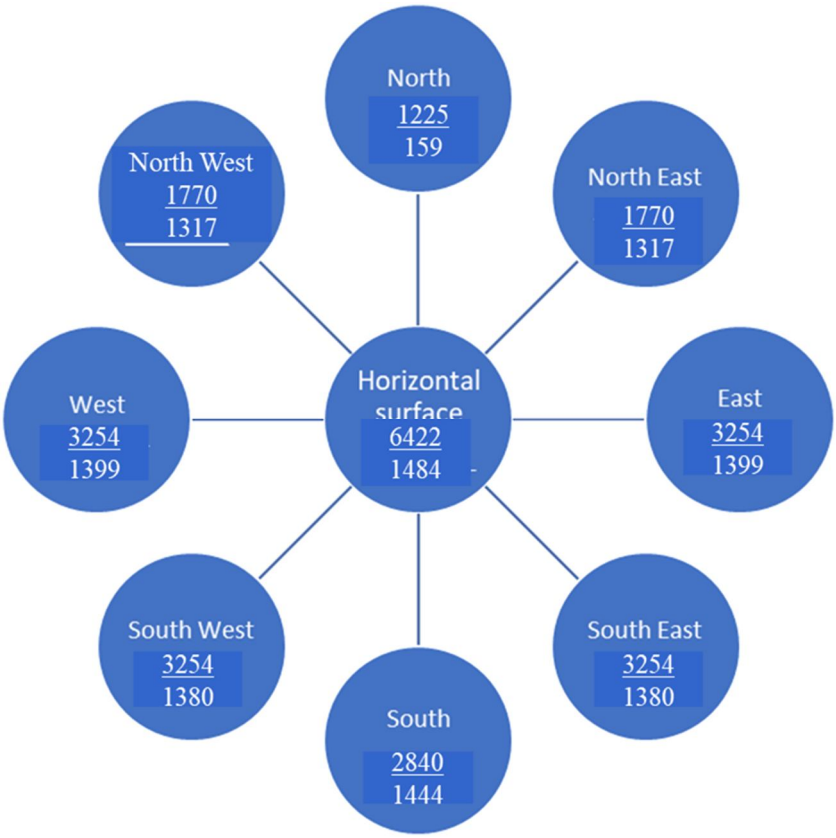


Figure 3 – Amount per day of direct and scattered radiation on horizontal and vertical surfaces of different orientations in July with clear skies

1.2.2 Temperature regime of the territory

This section writes tabular data on temperature indicators, which must first be collected in the table. The collected temperature data are presented in the form of a graph (fig. 4). The graph is based on the following indicators: average monthly temperature, absolute minimum and absolute maximum temperature, average temperature of the hottest and coldest month, temperature of the coldest five days and days. Also, at the bottom of the graph are the duration and temperature of the heating period.

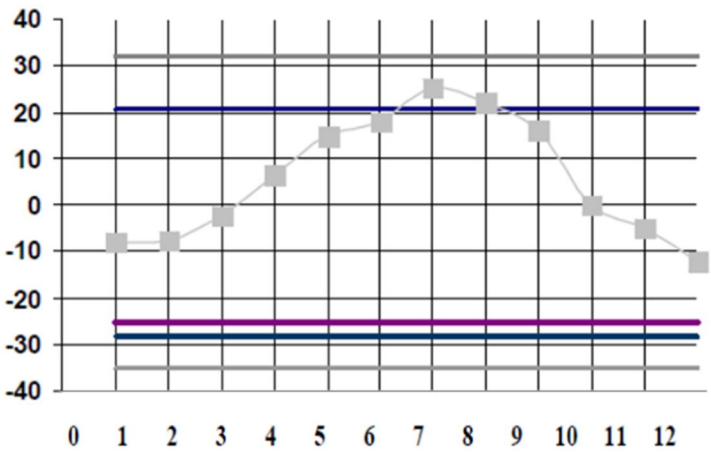


Figure 4 – Temperature characteristics

1.2.3 Humidity and precipitation

This section writes tables of data on the relative (familiar ranges of optimal values of 70–50 %) and the absolute amount of air, as well as a small number of reduced. All data must be pre-collected in tables, they are also presented in graphical graphs (fig. 5–7).

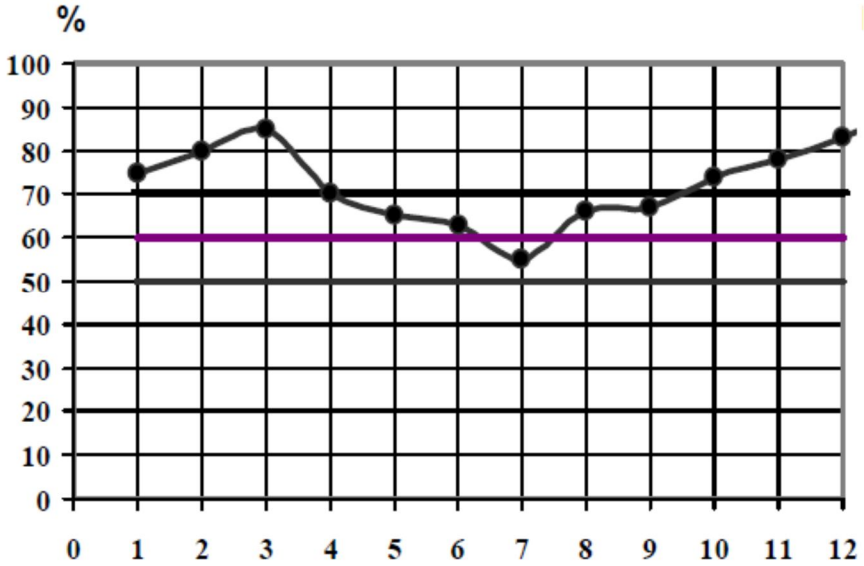


Figure 5 – Characteristics of humidity (relative humidity)

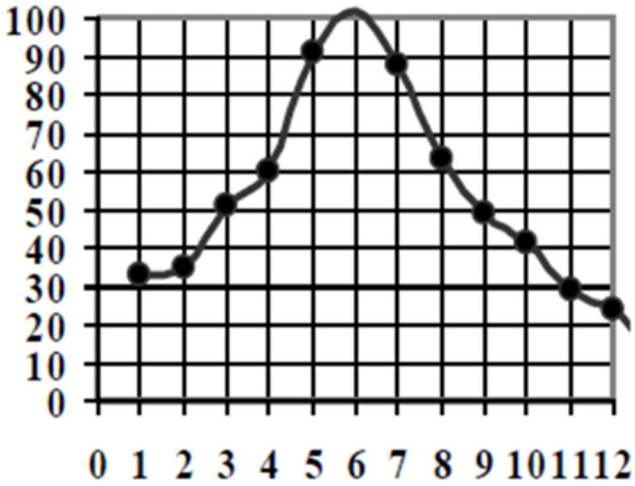


Figure 6 – Characteristics of precipitation

1.2.4 Wind regime of the territory

In this section the data from tables of the reference book of the main characteristics of wind are written out. Wind repeatability data are depicted in the form of a graphical diagram – wind roses (fig. 7). The percentage of wind repeatability and the number of calms (in the center) is indicated.

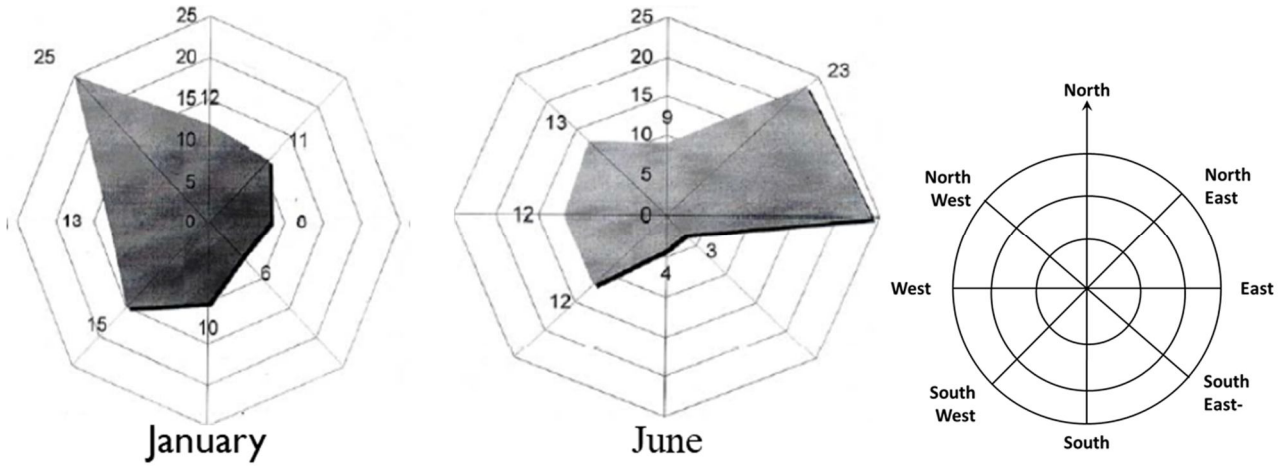


Figure 7 – Wind roses by frequency

1.3 Practical exercise № 2 Architectural analysis of the climate

This part of the climatic passport of the city provides a description of the climatic conditions of the construction area, as well as the choice of architectural and planning solutions of urban formations and the development of a comfortable architectural environment, especially residential buildings, considering sanitary and hygienic requirements.

1.3.1 Determination of types of weather and modes of operation of housing

Types of weather are determined on the basis of the following elements of climate: temperature (average monthly); humidity and wind (average wind speed in warm and cold periods). These data are reduced to tables, based on which determine the type of weather (Appendix A, Table A.1). It should be noted that in the warm period the main indicators for determining the type of weather are air temperature and relative humidity, and in the cold period - air temperature and wind speed.

According to the table determine the duration of a particular type of weather (number of months per year). According to the set of weather conditions determine the type of bioclimatic zone (Appendix A, Table A.3) and establish the need to apply general urban planning requirements.

A brief description of the mode of operation of housing in this place for the main types of weather in cold and warm periods, as well as brief recommendations on urban planning requirements (Appendix A, Table A.2) are given in the text of the climate passport.

1.3.2 Radiation mode of the solar radiation

There are light, heat and bactericidal effects on humans, favorable or undesirable depending on the duration and intensity of solar radiation. Considering radiation indicators in the design process allows to create conditions for favorable and avoid undesirable effect by appropriate building techniques, orientation of buildings (premises) relative to the sides of the horizon, wall thickness, size of light slots, arrangement of protruding elements of the house (cornices, canopies), verandas, loggias devices, etc.

1.3.3 Wind mode of the territory

The purpose of urban planning is to consider wind conditions on the basis of a comprehensive zoning map of Ukraine.

About 50 % of the entire territory of Ukraine belongs to the rugged, mountainous terrain and relief mainly with hills. In this case, considering only the background characteristics of the wind regime is not enough: it is necessary to determine the specific microclimatic features of the wind regime in certain areas of the construction site, considering these terrain conditions (fig. 8).

The terrain causes a change in air currents that dominate some flat areas. The air flow under the influence of the terrain can expand or contract, which causes a decrease in speed in the first case and increase it in the second. Maps of the wind regime of the projected area must be compiled on a hypsometric basis at a scale of 1:10 000 or 1:5 000. This considers the following morphological characteristics of the territory being designed:

– belonging to thawabs and watersheds;

– angles of inclination of the area and the division of the territory being analyzed on areas of different gradation;

– orientation of slopes relative to the prevailing wind direction (windward,

– leeward, parallel and at an angle of 45 ° to the wind direction);

– division of slopes into three parts - upper, middle and lower time;

– bottom parts of valleys, hollows, ravines, which are blown or not blown by the wind;

– flat tops of hills;

– the length of air flow lines on the mountain terrain.

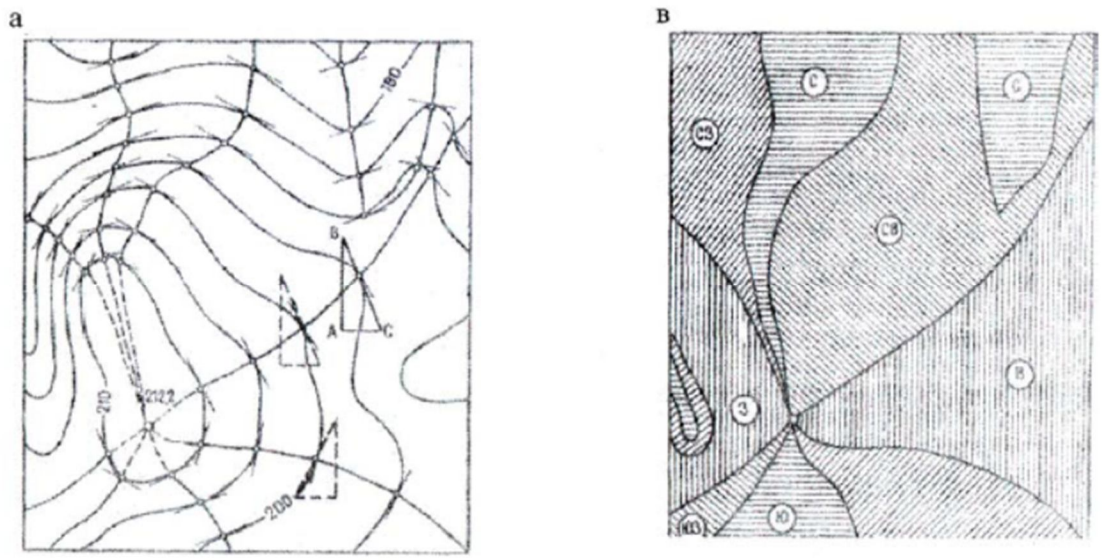


Figure 8 – The procedure for constructing the watersheds of the hills

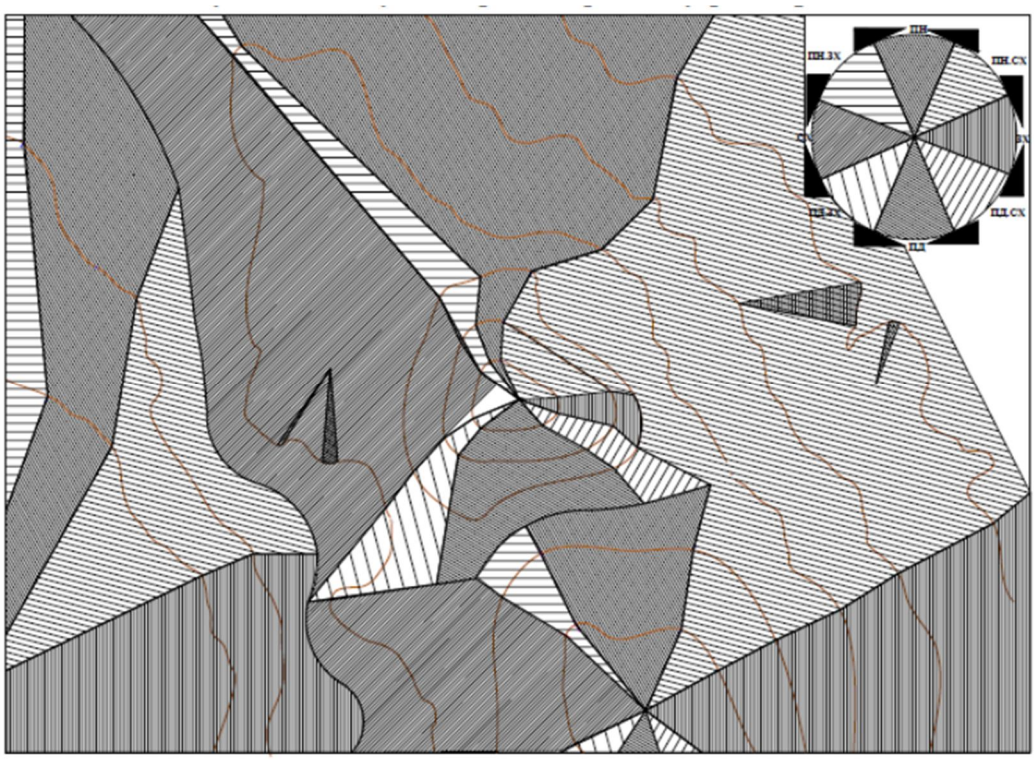


Figure 9 – Exposure of slopes on the sides of the horizon

When compiling a map of the wind regime, two schemes that were performed earlier are taken as a basis – the analysis of the distribution of slopes by exposures and the analysis of the angles of inclination of individual sections of the territory (fig. 9). To obtain a map of the wind regime (aeration) of the terrain, the exposure schemes of the slopes are combined with the angles of the relief (fig. 8), highlighting the exposure limits of the slopes along the rhumbs and the boundaries of the transition slopes (1°–3°, 3°–10°), respectively to gradations, which are accepted according to the table 1.

Table 1 – Background evaluation of the wind regime

	0	**1**	**2**	**3**
color				
m/s	More **10**	From **5 –7**	**3 – 5**	f **0 – 3**

Characteristics of the wind regime of the territory analyzed are presented by wind roses for the coldest (January) and hottest (July) months of the year (fig. 10). At the same time, first of all, it is necessary to consider the most unfavorable combinations of wind speed and repeatability of one direction, which are characteristic of the most uncomfortable period of the year (in most areas of our country this is the winter period).

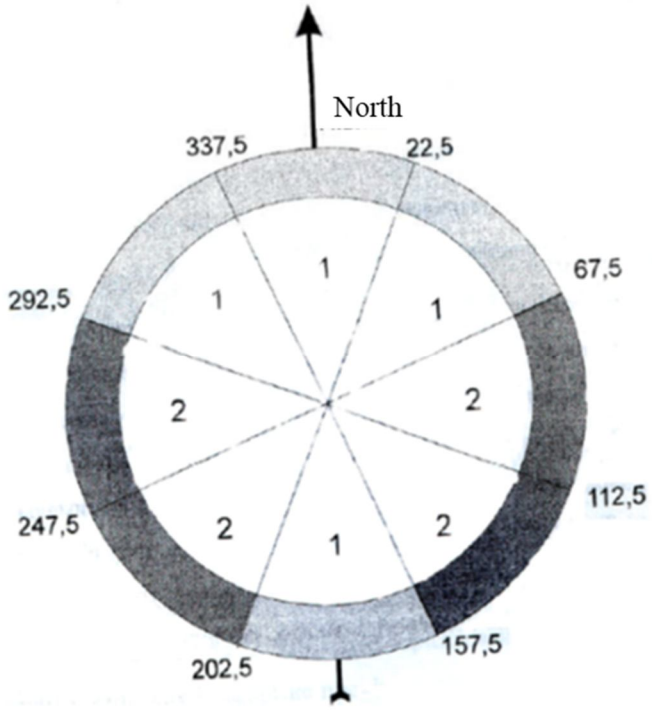


Figure 10 – Assessment of the wind regime of the territory

1.3.4 Temperature-wind mode

Assessment of the temperature and wind regime of the territory is carried out according to the nomogram, see Appendix A, Table A.4.

It is necessary to establish the average temperature in winter and summer and determine the necessary means of protecting the home from the negative effects of the temperature of its interaction with the wind.

1.4 Comprehensive assessment of the territory

Comprehensive analysis of the territory is carried out on the basis of previous research: analysis of the terrain, analysis of radiation and wind regime of the territory. The research results should be entered in the relevant tables and diagrams (fig. 11), as well as marked on the graphical diagram (terrain plan).

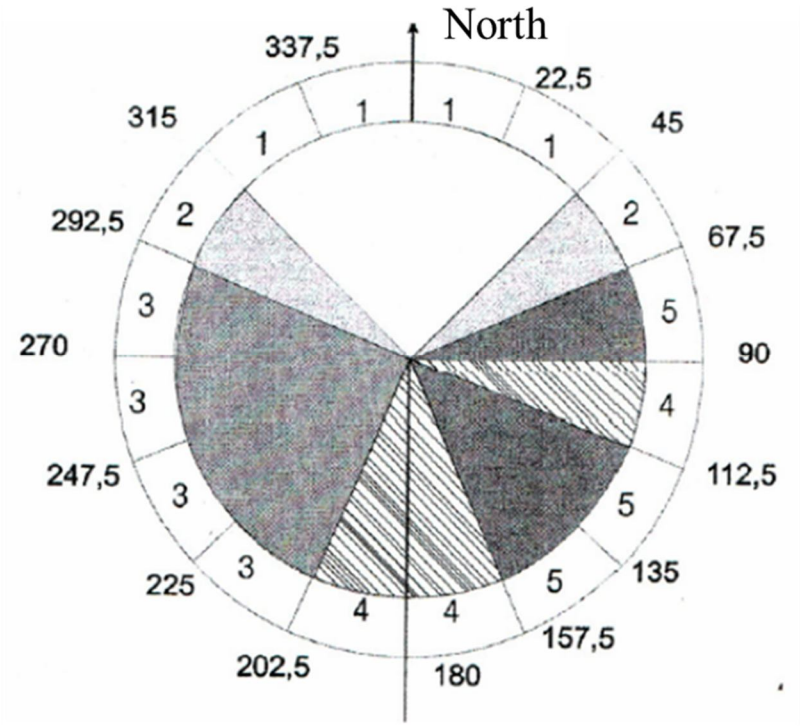


Figure 11 – Diagram of a comprehensive assessment of the territory

Comprehensive analysis of the territory is carried out with the help of data (Appendix A of table A.1–A.4). This section also conducts the establishment of the local climate in order to establish the means to create a comfortable living environment and during the modeling of the urban environment, in accordance with the requirements specified in the annexes.

1.5 Practical exercise № 3. Thermal calculations

Thermal engineering calculation of barrier structures

The purpose of Thermal engineering calculation is a measurement of resistance to the heat transfer Ro, together with the thickness of heated barrier layers. Under these circumstances, assigned temperature conditions is ensured in the premises of the building, considering desired economic indicators. The calculations are performed in accordance with Ukrainian cods B.2.6-31:2016 requirements – Thermal insulation of buildings.

For thermal engineering calculation we have chosen multi-layered construction scheme of exterior wall, and main thermophysical indicators of building materials. These indicators should be applied in the design of energy-efficient residential building.

Output data (Kharkov) [example]:

t – estimated winter temperature of the five coldest days per week (exceedance probability) 0,92; t = -23° C;

t_2 – estimated temperature of the coldest day (exceedance probability) 0,92;

t_2 = -28° C;

t_3 – average temperature of 3 coldest days; t_3 = -11° C.

Average wind speed -6,1 m/s.

Humidity area-dry.

The number of degrees / a day of heating season – 3 799.

Temperature zone according to the temperature zoning map of Ukraine – I.

Air humidity in residential building premises – normal.

(φ = 50–60 %), therefore, according with Ukrainian cods B.2.6-31:2006 we take the facility operating conditions – A.

In accordance with the Ukrainian cods B.2.6-31:2016 requirements – «Thermal insulation of buildings» – in order to examine the health and sanitary standards implementation, we calculate required resistance to the heat transfer using the following formula:

$$R_0^{req} = \frac{(t_{int} \cdot t_{ext})}{\Delta t^n \cdot \alpha_{int}} n \qquad (1)$$

where t_{int} – is a heated premises distinctive temperature; we take 18° C;

t_{ext} – external air temperature of the five coldest days per week, ° C, is taken according to the DSTU-N B V.1.1-27: 2010;

n – the coefficient, whose value depends on the barrier exterior surface position towards outdoor air, ***n = 1*** (according to Ukrainian cods B.2.6-31:2006);

Δ_{tn} – normative temperature fluctuations between indoor air temperature and internal barrier surface temperature; for residential houses walls Δt = 6° C;

α_{int} – heat transfer coefficient of the internal wall surface, α_{int} = 8,7 W / m · ° C.

The actual resistance to the exterior wall heat transfer is determined using the following formula:

$$R_0 = R_{in} + R_1 + R_2 + R_{ex} \text{ (sq. m} \cdot {}^\circ C / W) \text{ or } R_0 = \frac{1}{\alpha_{in}} + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{1}{\alpha_{ex}} \qquad (2)$$

where α – heat transfer coefficient of the external wall surface – α_{ext}

To create an interesting architectural image of the building at the second stage it is possible to use thermal design methods. The energy simulation software tools can be important for reducing the cost of energy in buildings.

THEMES OF PRACTICAL EXERCISES

Module 1 Building Physics

Content module 1 Climatology. Thermophysics

2 PRACTICAL EXERCISES Content Module 1.2, Content Module 1.3

Execution of practical tasks and tasks for independent work contributes to the consolidation of knowledge gained by students while studying the course in lectures and practical classes. When developing practical tasks and tasks for independent work, students gain practical skills to consider insolation and acoustic factors that affect the architectural solutions of urban spaces, buildings and buildings and structures.

Theme 1 LIGHTING AND ILLUMINATION

Practical exercise № 4 Engineering and climatic calculations

Definitions

Work Surface – a surface on which work takes place and on which illumination is normalized or measured (fig. 12).

Conditional Work Surface – conditionally accepted horizontal surface, which is located at a height of 0.8 m from the floor (fig. 12).

Stock Coefficient K_b is a calculated factor that considers the reduction of ***knl*** and illumination during operation due to contamination and aging of translucent fillings of openings, light sources and lamps, as well as reducing the reflected properties of the surfaces of the premises (fig. 12).

Characteristic Section of the Room – a cross section in the middle of the room, the plane of which is perpendicular to the plane of glazing of the openings (in side lighting) or to the longitudinal axis of the spans of the room. The characteristic section of the room should include areas with the largest number of jobs, as well as points of the work area, furthest from the light slots (fig. 12).

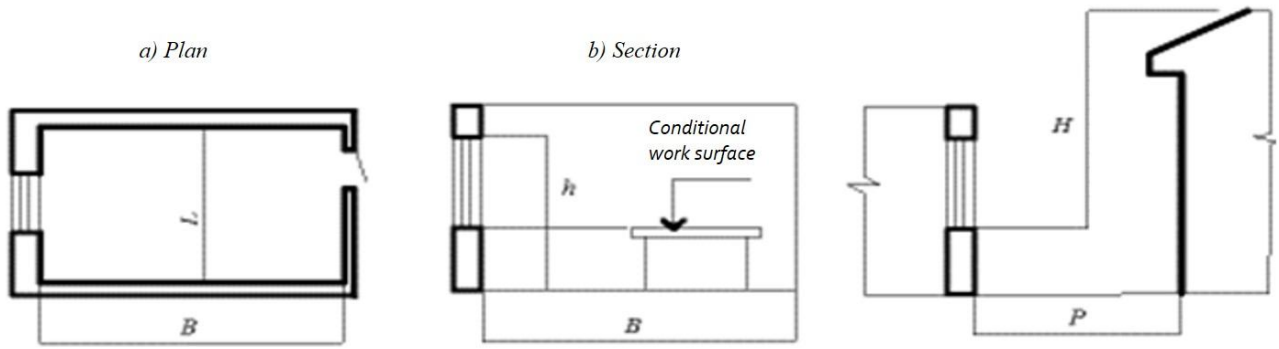


Figure 12 – Characteristic section and plan for lighting engineering calculation

LIGHTING ENGINEERING CALCULATION
(window opening dimensions)

Student _____ Course _____ Group_____

It is necessary to calculate the plane of the light slot (window) on the outer wall

_____ _____

(name of the room, its purpose, parameters)

The calculation should be performed according to formula (1), when the side lighting of the room, the plane of the light slot $\mathbf{S_w}$ is determined from the formula:

$$S_w = \frac{e_n}{100m} \cdot \frac{K_s \cdot \eta_w \cdot K_b}{\tau_{0r_1}} \cdot S_n \,, \tag{3}$$

where S_w – area of light slots (in the light) in side lighting, m ^{2};

S_n – floor area, m ^{2} (Appendix B of table B.1);

e_n – normalized value of ***cnl*** (according to the task) %;

m – ***the*** coefficient of the light climate of the aperture, which is determined by Appendix B of table B.2, figure B.2;

K_s – stock coefficient = 2 (according to ДБН В.2.5-28-2006);

η_o – light characteristics of the windows, which is determined by Appendix B of table B.3;

K_b – coefficient that considers the shading of windows from opposite buildings, which is determined by Appendix B of table B.4;

τ_o – the total light transmittance determined by formula 4:

$$\tau_0 = \tau_1 \cdot \tau_2 \cdot \tau_3 \cdot \tau_4 \cdot \tau_5 \,, \tag{4}$$

τ_1 – the light transmission coefficient of the material, which is determined by Appendix B of table B.5;

τ_2 – coefficient that considers light losses in the frames of the slots, which is determined by the formula 5:

$$\tau_2 = \frac{S_w - S_f}{S_w} \,, \tag{5}$$

S_w – area of light slots (in the light) with side lighting, m^2;

S_f – the area of the part of the aperture shaded by the frame, m ^{2};

Note: τ_2 is accepted equal for metal plastic and wooden windows – 0,75.

τ_4 – coefficient that considers the loss of light in sun protection glass, which is taken from figure B.3;

τ_3 and τ_5 – used for overhead lighting of industrial buildings.

r_1 – coefficient that considers the increase in ***cnl*** in side lighting due to light reflected from the inner surfaces of the room, and is determined by Appendix B of table B.6.

Practical exercise № 5 Determination of the coefficient of natural light

The calculation of coefficient of natural light (***cnl***) at the calculation point from each slot should be performed:

a) with side lighting according to formula 6:

$$e_p^6 = \left[\sum_{i=1}^{I} \varepsilon_{nb} q_i m + \sum_{j=1}^{J} \varepsilon_{bj} \cdot R_j \cdot m_j\right] r_1 \cdot \frac{\tau_0}{K_s} \quad , \qquad (6)$$

where $\boldsymbol{\varepsilon_{nb}}$ and $\boldsymbol{\varepsilon_{bj}}$ – geometric ***cnl*** at the calculation point, taking into account respectively, direct light from the i-th part of the sky and light reflected from the j-th facade of opposite buildings, determined by the formula (**7**);

$\boldsymbol{q_i}$ – the coefficient, taking into account the uneven brightness of the i-th section of the cloudy sky ILS is determined by the formula:

$$q_1 = \frac{3}{7}(1 + 2\sin\theta) \quad , \qquad (7)$$

where $\boldsymbol{\theta}$ – the angular height of the center of the *i*-th section of the sky relative to the calculation point;

$\boldsymbol{R_j}$ – coefficient that considers the relative brightness of the *j*-th opposite house, which is calculated by formula 8;

$\boldsymbol{m}$, $\boldsymbol{m_j}$ – coefficients of light climate according to the calculated one aperture and the *j*-th house, defined by Appendix B of table B.2, fig. B.1;

I, ***J*** – respectively, the number of individual calculated areas of the sky and facades of opposite buildings, which are observed through the aperture from the calculation point;

$\boldsymbol{r_1}$, $\boldsymbol{\tau_0}$, $\boldsymbol{K_s}$– that considers the formula 4 (according to the preliminary calculation);

N – the number of settlement points on the characteristic section of the room;

K – the number of light slots in the room.

The total value of ***cnl*** from all light slots at each calculation point is determined by formula 6:

$$e = e_1 + e_2 \cdots e_N \, , \qquad (8)$$

where $\boldsymbol{e_1}$; $\boldsymbol{e_2}$; $\boldsymbol{e_3}$; … $\boldsymbol{e_N}$ – ***cnl*** values at the points of the characteristic section of the room, determined by formula (6).

The calculated value of $\boldsymbol{e_r}$ should be rounded to tenths. The deviation of the calculated value of $\boldsymbol{e_r}$ from the normalized $\boldsymbol{e_n}$ by – 5 ÷ + 10 % is allowed.

Geometric coefficients at the calculation point are determined using graph I and graph II (fig. B.4 and B.5) as follows:

– if the aperture has an arbitrary shape, it is pre-replaced by a rectangular aperture as close as possible in proportions with two sides parallel to the working plane, which has the same area and center of gravity;

– if objects with different brightness are observed through the aperture – areas of the sky, facades of neighboring houses, the aperture is divided into areas within which the brightness can be considered the same.

At a horizontal working surface and a rectangular aperture ε is defined in such order (Practical task № 4).

a) graph I is superimposed on the section of the room so that the pole of graph O coincides with the calculation point A_2, and the base of the graph – with a trace of the working plane;

b) count the number of n_1 rays entering the calculation point through the slit according to schedule I;

c) through the center of the light slot – point C is a horizontal plane that intersects the glazing of the light slit along the segment MK and is projected on the section at point C_2;

d) determine the number $N_{p.k}$ semicircle on the graph I, passing through the point C_2 (the radius of this semicircle is equal to the distance p = A_2C_2);

e) schedule II is superimposed on the plan of the room so that the horizontal with the number $N_{p.k.}$ coincided with the line M_1K_1, and its vertical (axis of symmetry) passed through the point A_1 (with $OS_1 = p$, and the pole of the graph O usually does not coincide with the point A_1);

f) count the number of n_2 rays entering the room through the aperture on the schedule II (these are the rays crossing the segment M_1K_1);

g) according to formula 9 is determined geometric coefficient of natural light:

$$\varepsilon_n = 0{,}01 \cdot n_1 \cdot n_2, \tag{9}$$

The coefficient R, to considered the relative brightness of the facade of the opposite house, is determined by formula 10:

$$R = (0{,}396 - 0{,}01 \cdot \varepsilon_n \cdot q)\rho_{wr}\ , \tag{10}$$

where ε_n – geometric coefficient of natural light of the center of gravity of the facade of the opposite house, which is observed from the calculation point through the aperture, from the part of the sky shaded by the house in which the illuminance is calculated (9);

q – the relative brightness of the part of the sky from which it is calculated ε_n;

P_{wr} – the weighted average reflection coefficient of the facade of the opposite house, visible from the calculation point, determined by formula 11;

$$\rho_{wr} = \frac{\rho_M \cdot S_M + \rho_B \cdot S_B}{S_M + S_B} \quad , \tag{11}$$

where ρ_M; ρ_B – the reflection coefficient of the facade finishing material and the reflection coefficient of the glazed slots of the facade, considering the frames, respectively (table 3);

ρ_B – the reflection coefficient of the glazed openings of the facade, considering the frames.

The weighted average reflection coefficient of the glazed openings of the facade $\rho_в$ considering the frame in the calculations is taken as 0,2.

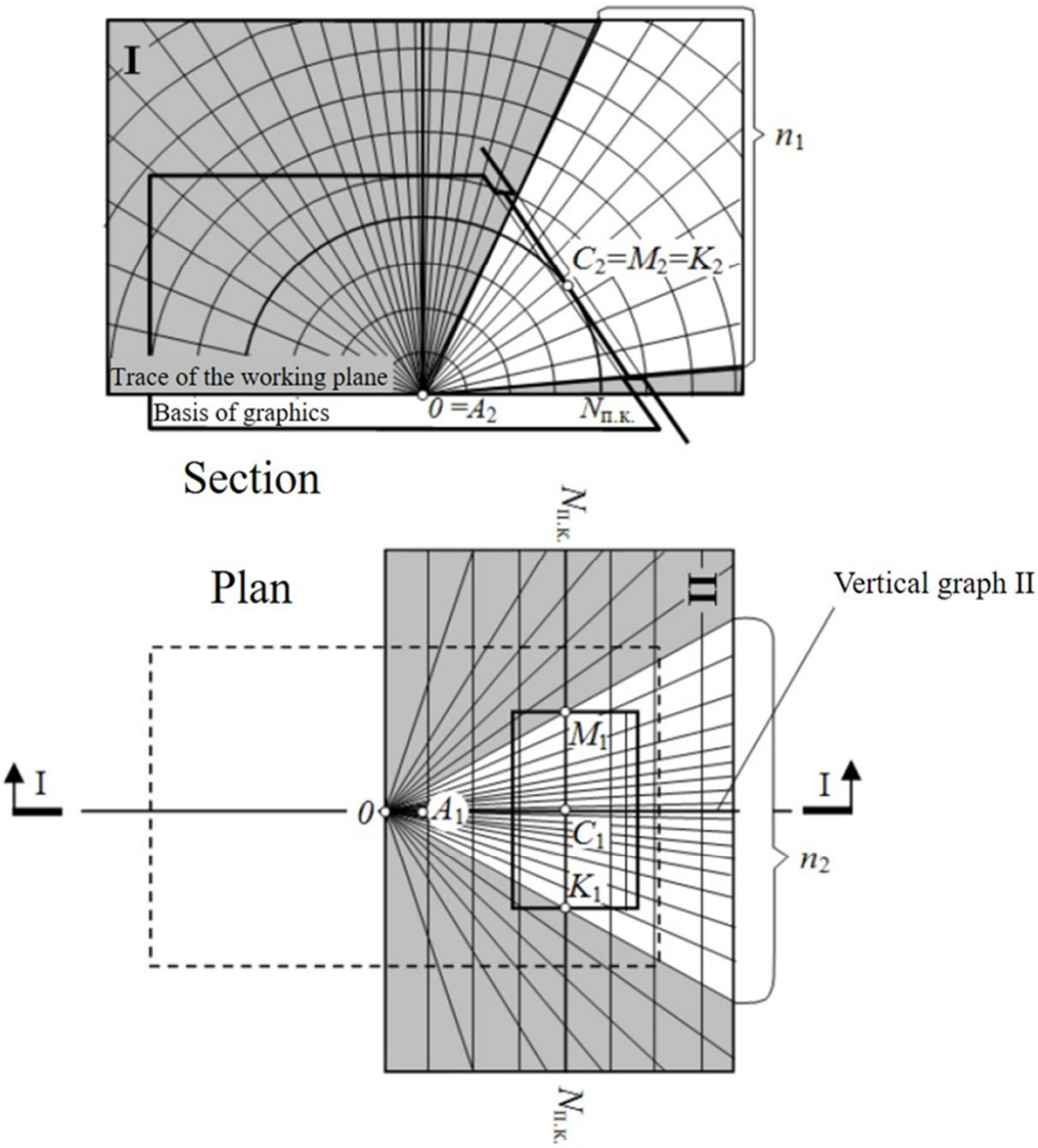


Figure 13 – Determination of the number of rays n_1 and n_2 passing through the slit according to graphs I and II Danilyuk (figs. B.4, B.5) with a horizontal working plane

Table 2 – The coefficient of the light climate

light slots	Orientation of the building around the world	the coefficient of the light climate	
		Autonomous Republic of Crimea, Odessa	The whole territory of Ukraine
exterior walls of the building	North	0,85	0,90
	North-East; North-West	0,85	0,90
	East; West	0,80	0,85
	South-West; South-East	0,80	0,85
	South	0,75	0,85

$S_M S_B$ – the area of the facade without light slots and the area of the light slots, respectively.

The geometric coefficient of natural light is defined as follows (Fig. 14):

a) from the calculation point ***A*** the visible contour of the skylight is projected on the plane of the facade of the opposite building;

b) the center of gravity C_1 of the obtained projection is determined;

c) schedule I is superimposed on the general plan of the building so that the pole of schedule ***O*** coincides with the point C_1, and the base of the schedule - with a trace of the facade of the shading house;

d) count the number of rays coming on schedule I to point C_1 from the facade of the house, which calculates the illumination;

e) determine the center of gravity C2 of the house, which calculates the illumination located above the point C_1;

f) determine the number $N_{p.k}$ semicircle on the graph I, passing through the point C_2;

g) a vertical cutting plane I-I is made through points C_1 and C_2 and a conditional section is constructed by this plane;

h) graph II is superimposed on section I-I so that the pole of the graph coincides with the point C_1, and the horizontal with the number $N_{p.k}$ coincides with the trace of the facade of the house, in which the illuminance is calculated;

i) count the number of rays coming to point C_1 from the shaded part of the sky according to schedule II;

j) ε_n' is determined by formula 12:

$$\varepsilon_{n'} = 0{,}01 \cdot n''_1 \cdot n''_2 \quad , \tag{12}$$

Table 3 – The values of the reflection coefficients of the facade ρ_M

Surface materials or facade color	The weighted average reflection coefficient $\boldsymbol{\rho}$
White: weatherproof facade paints, gypsum, ceramic tile, brushed aluminum, stainless steel	0,7
Light: paints, marble, white stone (limestone, dolomite, sandstone), concrete and decorative plasters on white cement and light fillers, ceramic tiles, silicate brick, matte brass, travertine	0,6
Medium light: paints, marble, stone (tuff, sandstone, limestone), concrete, colored plasters, ceramic bricks, blocks, tiles, wood	0,5
Dark: paints, marble, granite, clay bricks, decorative plasters and ceramic tiles, darkened wood, copper, tree leaves	0,3
Black: paints, stone (gabbro, labradorite, diorite, basalt, granite) cast iron, mountain bronze, decorative plasters, tree leaves	0,15

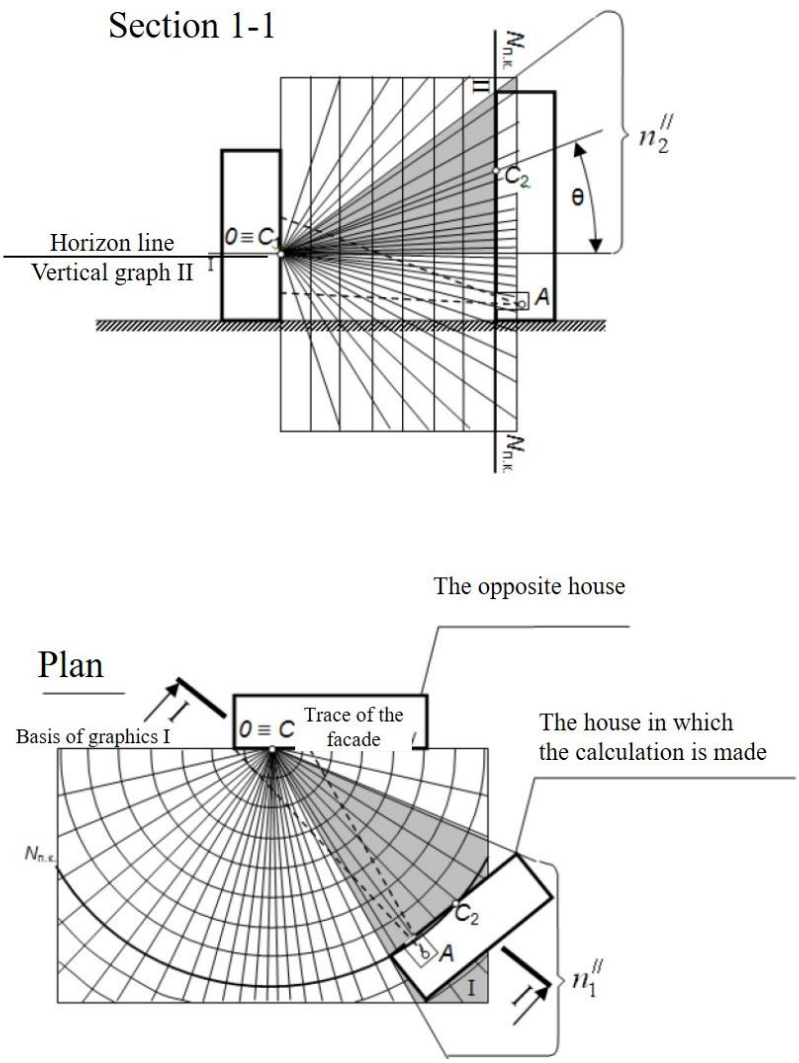


Figure 14 – Determining the number of rays $\boldsymbol{n_1''}$ and $\boldsymbol{n_2''}$ for the calculation the relative brightness of the opposite house

Theme 2 THE INSOLATION OF BUILDINGS AND AREAS

Practical exercise № 6 Construction of a daily envelope of shadows

Devices (insolation rulers), which are used to perform calculations of insolation by graphical methods, allow to determine the direction and length of shadows, from a vertical structure, which is located on a horizontal plane at a point, which is considered at a given latitude.

Insolation rulers can be made for different dates of the year for any latitude. The simplest construction is performed for the equinox period on March 22 and September 22 (fig. 15), because these days the boundaries of the shadows throughout the day are in a straight line, which are parallel lines East-West.

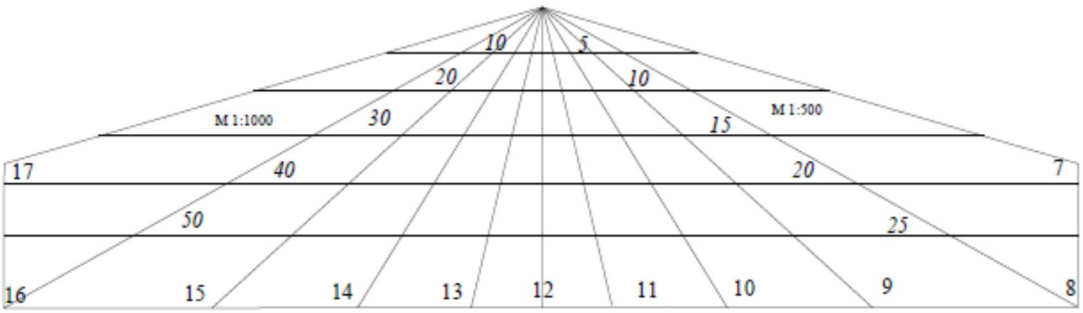


Figure 15 – The equinox period on March 22 and September 22

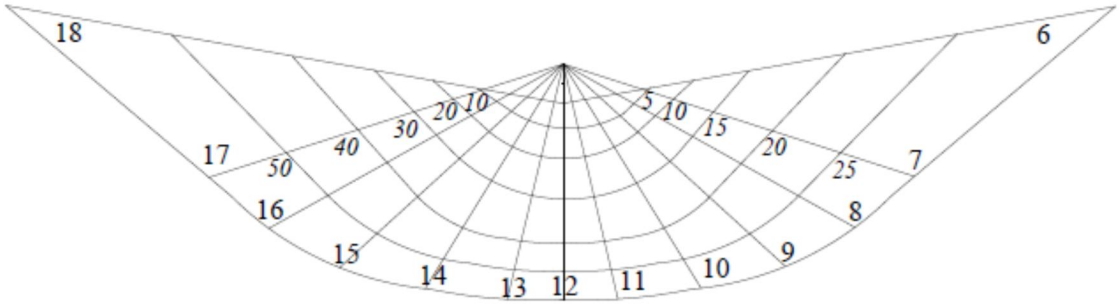


Figure 16 – On the day of the summer stage, the line is tilted down to a bent shape to the point where the object is displaced

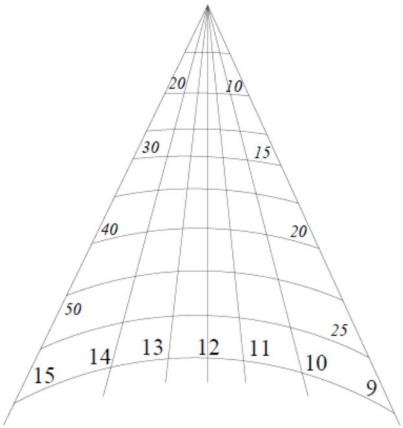


Figure 17 – On the day of the winter dream, the line takes on an opaque shape

Insolation rulers are made on tracing paper, photographic film and other transparent material. They are superimposed on the plan of a building or group of houses, which are drawn on a certain scale.

Construction of insolation rulers for equinox days at any given latitude φ begins with the construction of a horizontal projection of the Sun's orbit, which is performed using the tools that were considered in the previous practical task, but with a rotation of 90°.

Procedure for performing the exercise № 6 (fig. 18):

1. Two mutually perpendicular lines are drawn, the intersection of which is the point O. From this point a semicircle of free radius is formed.

2. From the point O at an angle ***φ*** (latitude °C) to the vertical straight to the intersection with the semicircle. The defined point A is projected vertically to point B.

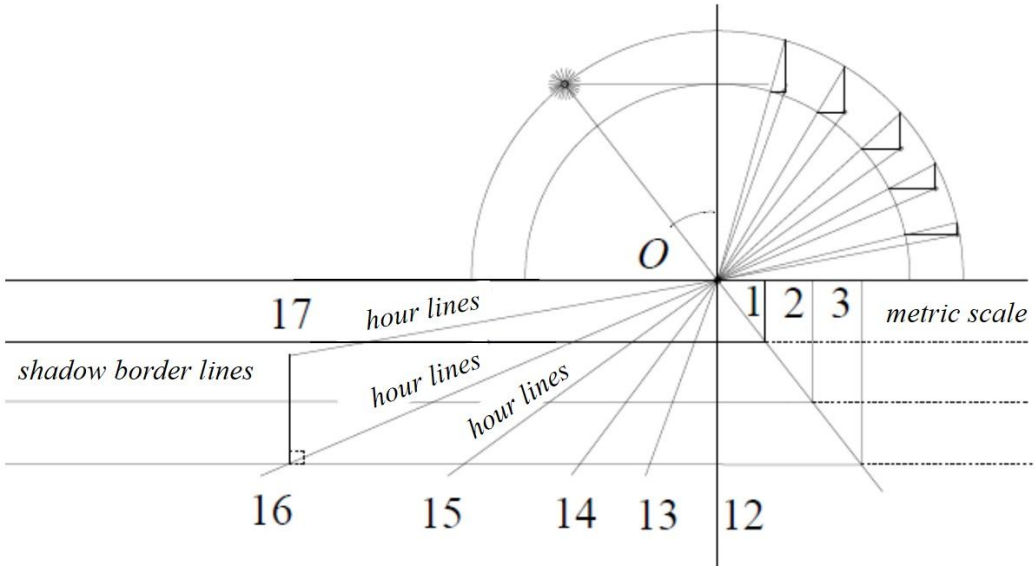


Figure 18 – Construction of insolation ruler at latitude ***φ*°** for the equinox days on March 22 and November 22

3. An auxiliary semicircle is drawn by the radius OB.

4. A quarter of a larger circle should be divided into 6 equal parts, draw radial lines to the intersection with the auxiliary semicircle and build an ellipse in the usual way.

5. Everywhere the time points of the ellipse should be drawn sectoral lines, which should be extended through the point O beyond the semicircle down. These lines determine the direction of the shadows at the appropriate times of day.

6. To the right of point O horizontally the metric scale which is the height size of a construction in the accepted scale is postponed.

(1 cm – 1 m (S 1:100); 10 m – (S 1:1000), 5 m (S 1:500), etc.).

Next, continue the direction of the line OA down and project sections of the metric scale on it. Horizontal lines should be drawn through the points of division, which will determine the lengths of the shadows

7. Depending on the height of the structure, they are depicted in the accepted scale of the drawing.

8. The construction results are repeated in the mirror image on the right of the insolation rulers.

When transferring the schedule to tracing paper, the plots located within sectors 6 to 7 and 17 to 18 hours are not copied, because the insolation within the first and last hours of World Day is not considered.

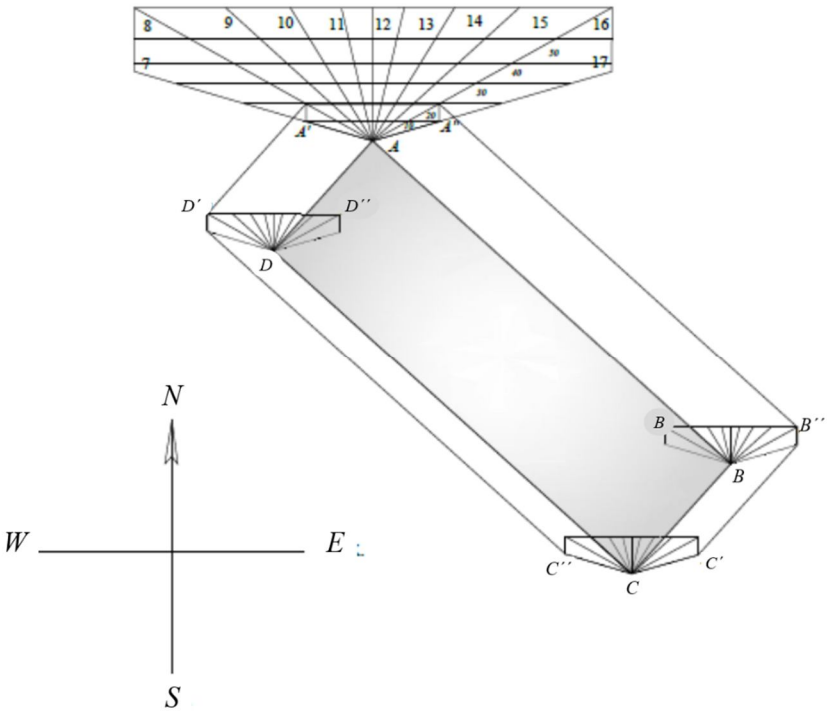


Figure 19 – Construction of a daily envelope of shadows

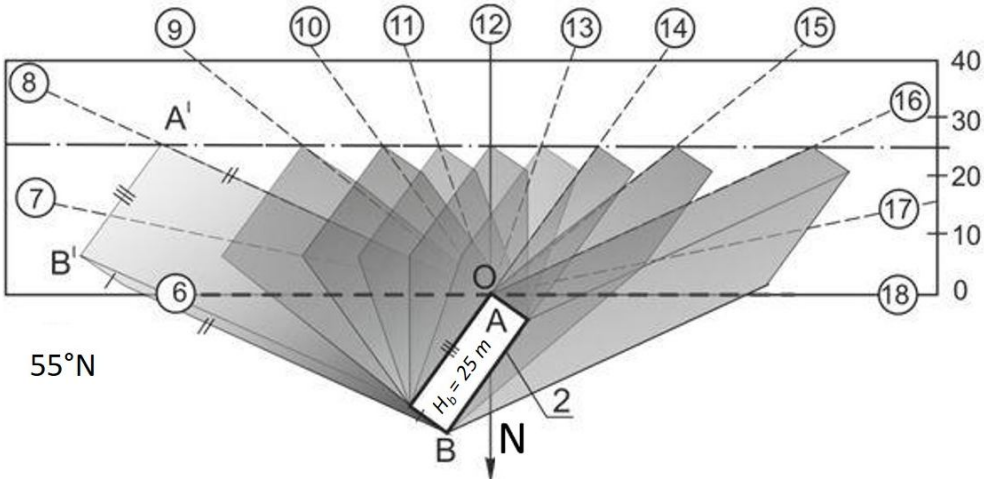
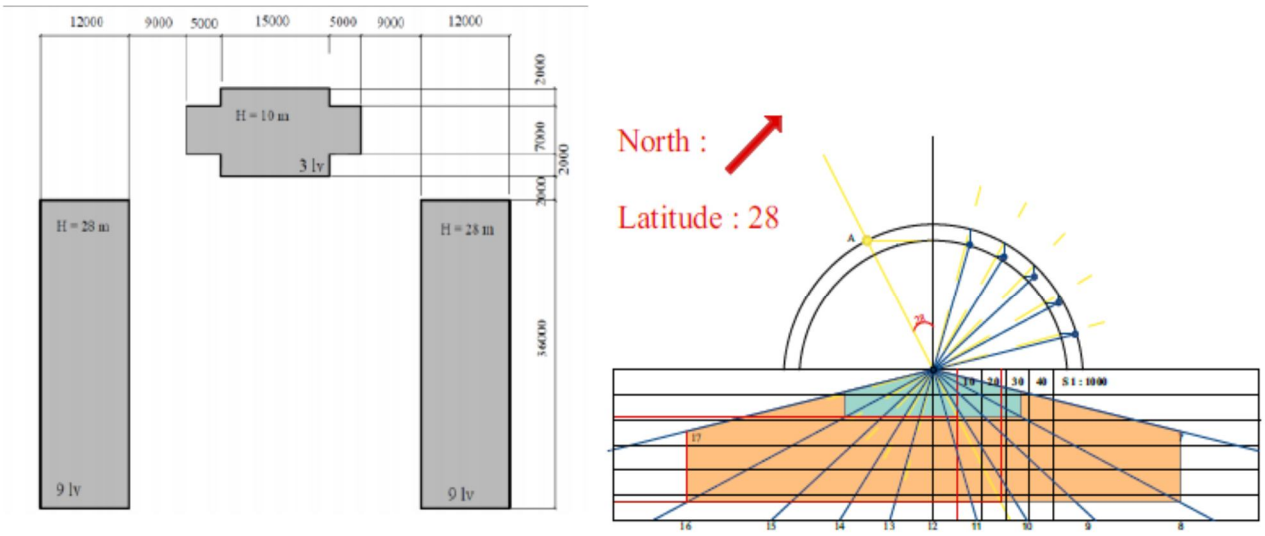


Figure 20 – Example Construction of a daily envelope of shadows



Option 2

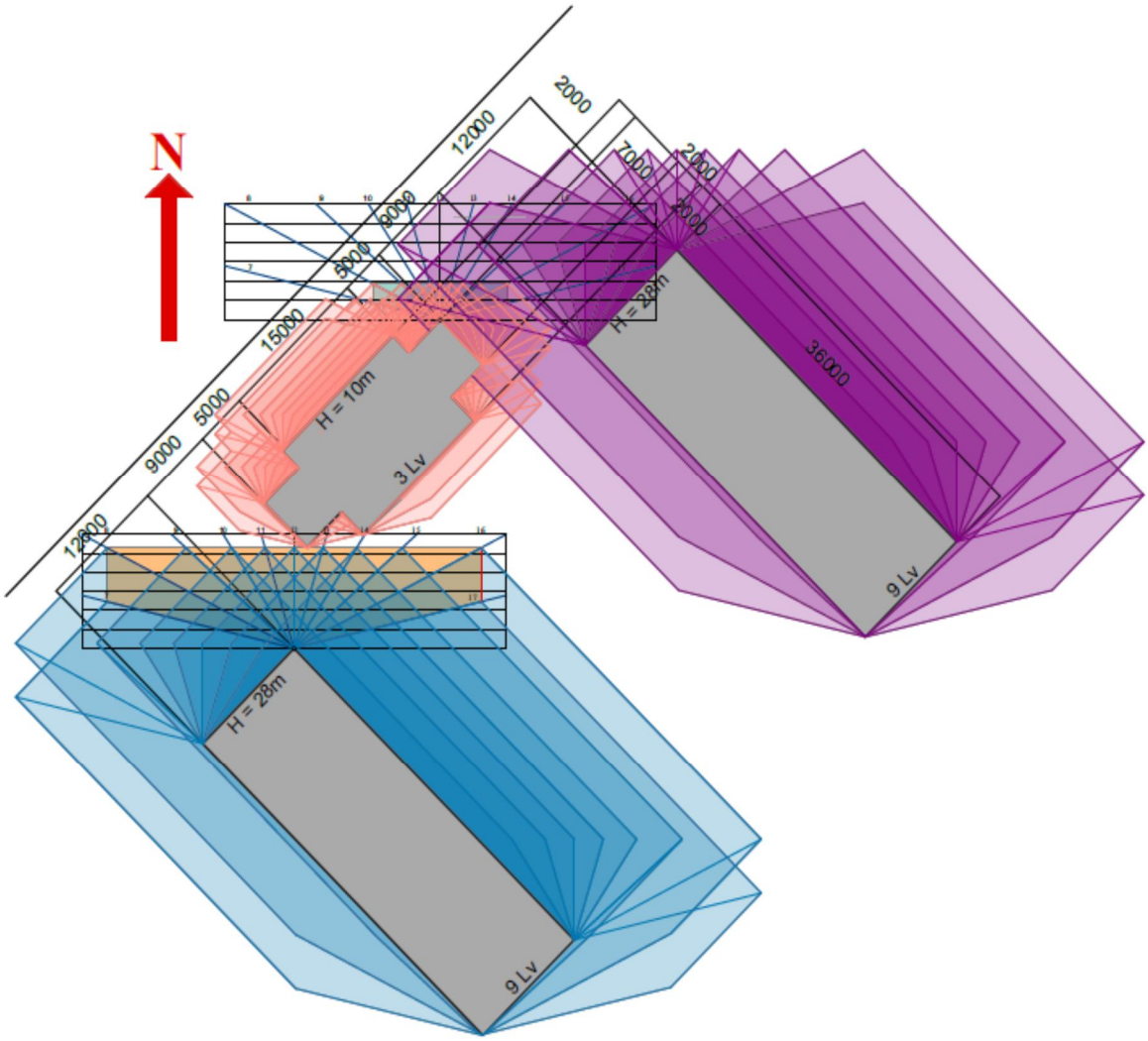


Figure 21 – Example of construction of a daily envelope of shadows

Theme 3 ACOUSTIC CALCULATIONS OF AUDITORIUMS AND HALLS

Building a hall for spectators, of any purpose, largely determines the spatial planning decision as a whole. The well-thought-out and correct arrangement of the auditorium provides comfortable placement of spectators, good acoustics and full visibility of the screen without noticeable distortions, and providing a convenient entrance, distribution of seats and safety of evacuation of spectators.

To determine the optimal shape of the hall you need to know the components of the hall for different purposes and the order of geometric construction of this hall. The geometric construction of the auditorium is based on the laws of optics (visual perception).

Stage forms

Full stage: more than 100 m^2 of stage area.

Stage ceiling more than 1 m above top of proscenium arch.

Small stage: area no more than 100 m^2, no stage extension (secondary stage), no stage ceiling not more than 1 m above top of proscenium

Set areas: raised acting areas in rooms without ceiling projection.

The peculiarity with set areas is in the regulations with respect to curtains and scenery. They affect the operation, not the planning. Of set areas.

Experimental auditoria fall within the set area definitions.

Scenes must have a proscenium – the space in front of the curtain – at least 1 m deep. For a type B stage, it is necessary to arrange a hold for stage effects.

The formation of the hall is based on the conditions of film projection and visual perception of the image, which determines the construction of its section and plan. Unobstructed visibility of the screen is provided by an overestimation of a beam of sight of each row of spectators over a beam of sight of sitting spectators in front of 12 cm. Construction of the rows corresponding to this condition is defined by a graphic or analytical method.

The volume of the hall is determined by its proportions. The ratio of the length of the hall l to the average width ***b*** is optimal:

$$1{,}3 \leq \frac{l}{b} \leq 1{,}6\ , \qquad (13)$$

Within the following limits and the ratio of the width of the hall b to the average height ***h***:

$$1{,}3 \leq \frac{b}{h} \leq 1{,}6\ , \qquad (14)$$

The halls in the plan are usually trapezoidal in shape with a side opening angle walls 50–120. A rectangular shape with a horizontal ceiling is only permissible for lecture halls with a capacity of not more than 200 people.

Possibilities of various construction of a hall in a section are defined regulatory restrictions on visibility conditions. Current regulations provide considerable freedom in this matter. The position of the first row is limited vertical angle of 22° to the normal in the center of the screen. This determines the low position of the lower edge of the screen (1,5 – 2 m above floor level).

When all the seats for spectators are located on the ground floor, the entrances to the hall are most frequent are arranged in the rear wall, and the exits - in the side walls near the screen. In small halls with a capacity of up to 400 seats can be arranged a passage along the wall with a dead end of cities, but necessarily together with two entrances, which should be located on opposite sides of the hall.

Seats for spectators can be arranged in 40 cities in a row at bilateral evacuation of a number and on 20 places at unilateral placement. Row width (distance between the backs of seats in adjacent rows) is taken 90 cm, and the width of each place is 50 cm. Let's increase the length continuous series of cities up to 50 with a corresponding increase in the uprising between rows up to 95 cm. The optimal area of the hall for spectators is determined from calculation of 0.7 m² for 1 place.

Keep in mind that compact and efficient urban planning reduces the remoteness of the last row and the volume of the hall, which improves its acoustics.

The auditorium consists of several functional areas depending from the purpose of the hall itself and the number of cities in these areas can be either more or less. So, the main areas: stage, visual part (the hall itself), auxiliary rooms,

Practical exercise № 7 Acoustic calculations of halls for spectators (fig. 22)

1. Determining the length of the auditorium D (from the screen to the back of the chair of the last row) (m):

$$D = 1{,}1\sqrt{N}\ , \tag{15}$$

where N is the capacity of the ground floor of the auditorium (number of people according to the task – see Appendix D of table D.1).

2. Determining the width of the working field of the wide screen She (chord) (m):

$$W_s = 0{,}43 \cdot \mathrm{D}\,, \tag{16}$$

3. Determination of the radius of the sphere M, which limits the area of spectators (m):

$$M = 0{,}92\sqrt{N}\,, \tag{17}$$

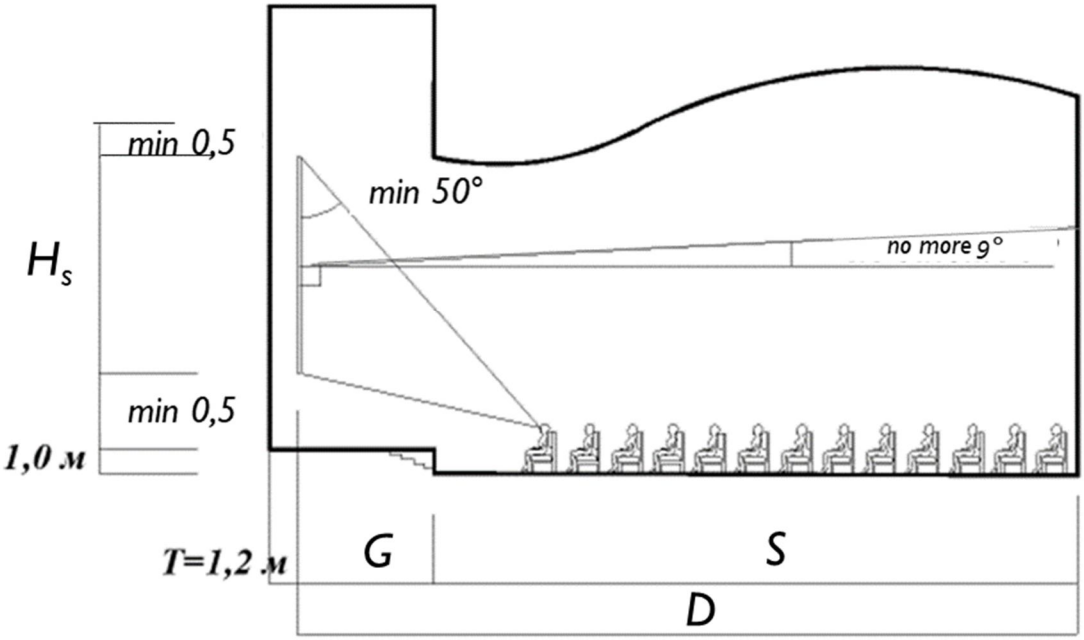
4. Determining the height of the working field of the wide screen Vsh (m):

$$H_s = \frac{W_s}{2{,}35}\ , \tag{18}$$

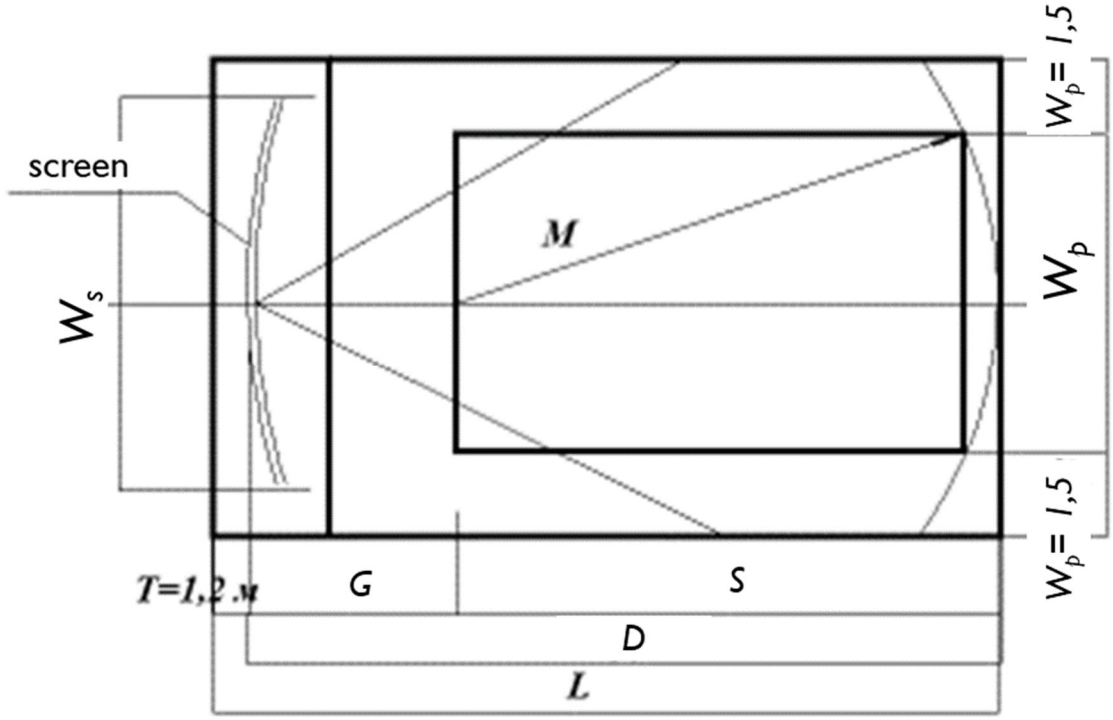
The resulting value should be rounded.

5. Determining the minimum distance G from the screen to the back of the chair of the first row of spectators:

$$G \geq 0{,}84 \cdot W_s \ , \tag{19}$$



a



b

Figure 22 – Defining the parameters of the hall:

a) the scheme of the section of the auditorium;
b) b) the scheme of the plan of the auditorium

Proportions of hall (auditorium)

These are obtained from the spectator's psychological perception and viewing angle, as well as the requirement for a good view from seats (fig. 23).

Good view without head movement, but slight eyemovement of about 30°.

Good view with slight head movement and slight eyemovement approx 60°.

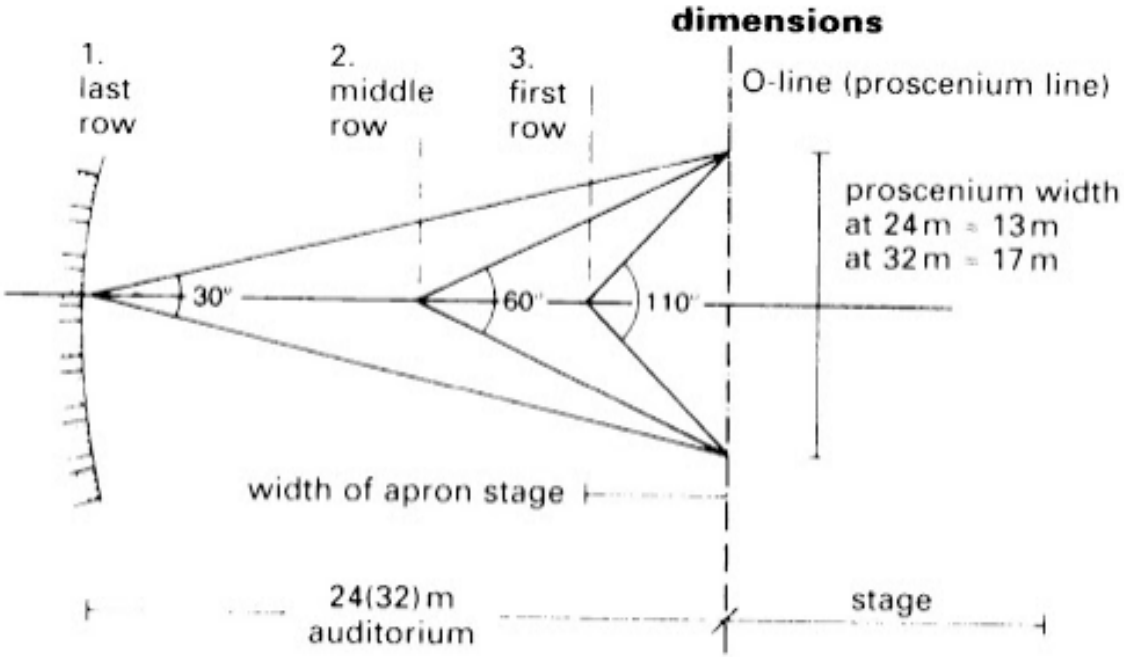


Figure 23 – Proportions of the traditional auditorium (view)

When choosing the main size of the hall to ensure good acoustics should follow the following rules:

- the ratio of the length of the hall to its average width corresponds to the range 1–2;
- the ratio of the average width of the hall to its average height is within the same limits (in the range of 1-2), but does not exceed 3;
- the length of the halls (from the back wall to the front) is recommended to be no more than 28–30 m, in the philharmonic halls no more than 45 m, and the halls with a stage box - no more than 26–35 m (from the back wall to the curtain).

An example of defining the parameters of the hall in figure 24.

$D = 1.1\sqrt{N}$
$N = 600$
$D = 1.1\sqrt{600}$
$D = 26.94m$

$Bw = We/2.35$
$Bw = 11.58/2.35$
$Bw = 4.93m$

$We = 0.43*D$
$We = 0.43*26.94$
$We = 11.58m$

$r \geq 0.84*We$
$r \geq 0.84*11.58$
$r \geq 9.73$

$M = 0.92\sqrt{N}$
$M = 0.92\sqrt{600}$
$M = 22.53m$

$Z = D-r$
$Z = 26.94 - 9.73$
$Z = 17.21m$

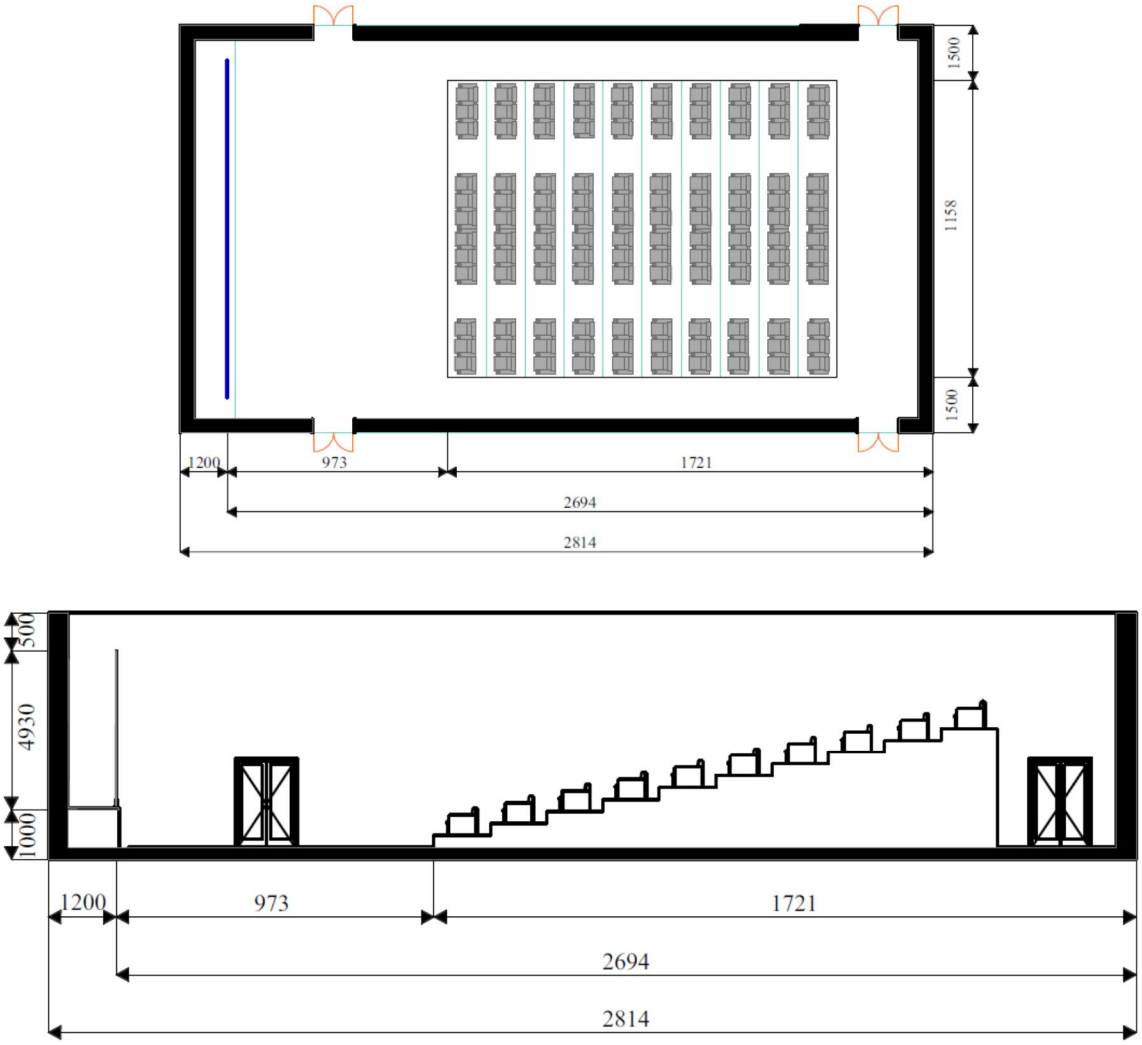


Figure 24 – Example of defining the parameters of the hall

Practical exercise № 8 Calculation of reverberation time

To perform the practical task № 6 can also be done on the basis data given in Annex D (table D.1, D.2).

Reverberation time is the main criterion of the acoustic properties of the hall in general. The latter criteria are complementary to us or local.

The phenomenon of *reverberation* – the process of formation and attenuation of sound after cessation of the sound source as a result of repeated reflection from enclosing surfaces. This process is characterized by three main one's periods (fig. 25):

1. The increase in the density of sound energy, due to the summation of the reflected energy with the original
2. A period of dynamic equilibrium between sound energy gain and sound absorption
3. Decay period due to the attenuation of sound energy during multiple reflections

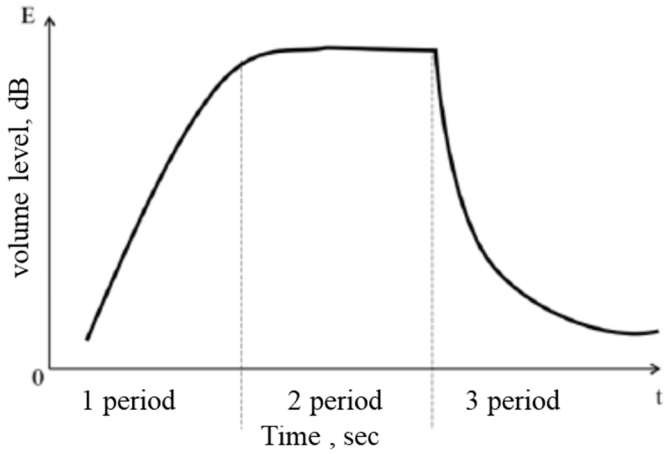


Figure 25 – Curve of sound formation in indoors due to reverberation

Reverberation time is calculated using the Sabine equation (20):

$$T = \frac{V}{\sqrt{\alpha \cdot S}} 0{,}63 \ , \qquad (20)$$

The sound absorption coefficient describes the ability of a material to absorb sound power

Sound absorption coefficient, α, is defined as the sound power incident on a surface A divided by the sound power that is not reflected from the surface $A_1 - A_2$: Sabine equation assumes a diffuse sound field in the room

Diffuse sound field: equal sound pressure level at each point in the room

– Condition is satisfied in cubic spaces with dimensions sound wavelength and with hard sound reflecting surfaces.

– Condition is not satisfied is the space is large and highly absorb in go refill the absorption materials situated on one surface while the other surfaces are sound reflecting.

Highly absorbing refill, the absorption materials situated on one surface while the other surfaces are sound reflecting (table 5).

Sabine equation can, however, be applied in most spaces with sufficient accuracy (19):

$$T_{125} = \frac{0{,}163 \cdot V}{S_g \cdot ln(1-\alpha_{ad})} 0{,}63 \ , \qquad (21)$$

First you need to determine the time of reverberation:

1) calculation of reverberation time (equation 21);
2) selection of sound absorption coefficients according to materials and equipment (table 4);
3) determining the optimal reverberation time.
4) the values of the coefficients are presented in table 5.

Table 4 – Selection of sound absorption coefficients according to materials and equipment

	Surface area of sound absorption ($м^{2)}$	Sound absorption coefficient on the	Sound absorption c o (α_{2S}) e
s			

Table 1 – Coefficients of sound-clay materials *a*

s	,		
Parquet floor and podium wall			
Rubber coating 5 mm thick			
Carpet of usual type			
Carpet 5 mm thick			
Linoleum			
a			
Concrete			
The concrete is painted			
Brick wall without plaster			
The brick wall is plastered			
Marble			
Plasterboard			
Dry plaster at a distance of 5 cm from Surface			
Pine-thick wood paneling 19 mm			
filling door and window openings			
Curtains and drapes			
Free-hanging fabric in the form of a drape			
weigh 70 %			

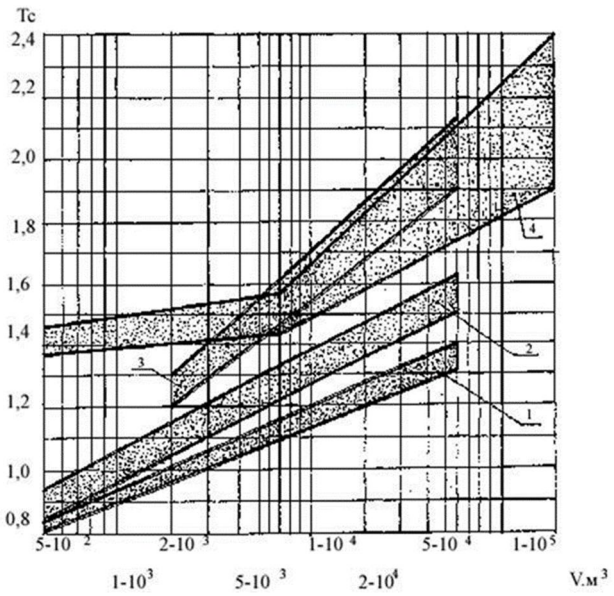


Figure 26 – Recommended the reverberation time for the fillings of a growth rate from a fallen volume in the frequency range 500 ... 2000 Hz:

1 - lecture halls, halls of passenger rooms of stations; 2 - halls of drama theaters, halls of multipurpose function of average capacity, cinemas; 3 - halls of opera and ballet theaters, concert halls; 4 – gyms

1. Visually, the reverberation time is standard reverberation time (T) according to the volume of the hall behind the drawing, the first reverberation time for a frequency of 125 Hz, 500 Hz

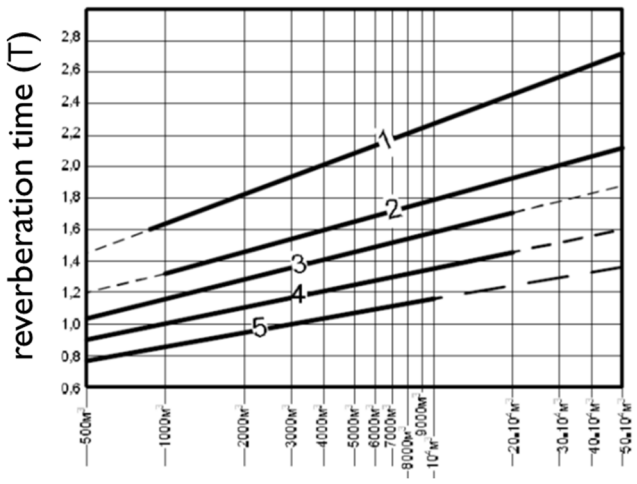


Figure 27 – Hall volume

1 - halls for oratorios and organ music;

2 - halls for symphonic music;

3 - halls for chamber music, halls of opera houses;

4 - multipurpose halls,

5 - lecture halls, meeting rooms, halls of drama theaters, cinemas, passenger halls

Deviation from the optimal value is allowed:

- at medium frequencies (500-2000 Hz) by no more than 10 %;
- at low frequencies (125 Hz), the reverberation time can be increased by 20 %.

Visually, the reverberation time is standard reverberation time (***T***) according to the volume of the hall behind the drawing, the first reverberation time for a frequency of 125 Hz, 500 Hz.

2. Determining the optimal reverberation time.

The optimal reverberation time depends on the mileage of the sounds, the volume of the room and purpose:

Optimal reverberation time for 500 Hz sounds is calculated using the equation 20:

$$T_{opt}^{500} = K \cdot lg \cdot V, \tag{22}$$

V - volume of the room, m³;

K - coefficient, which depends on the indication of the premises, which is equal to the opera houses and concert halls 0.41; drama halls – 0.36; cinemas and audiences – 0.29.

The equivalent absorption plane of the surface ***A*** is the product of the plane this

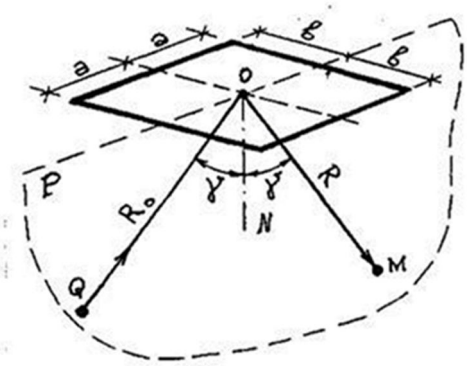


Figure 28 – Scheme sound absorption assumptions radiant reflections

$$A = \alpha S, \tag{23}$$

The equivalent absorption plane of the surface A is the product of the plane this surface S by its sound absorption coefficient α;

$$A = \alpha \cdot S,$$

A the equivalent sound absorption plane is a plane a surface that completely absorbs sound energy; this surface absorbs the amount of sound energy, just like the surface ***S***.

Sound absorption by some of the items which are indoors (chairs, armchairs etc.), as well as evaluated by students.

Surface ***S*** by its sound absorption coefficient ***α***.

The scheme of sound absorption directly equivalent sound absorption plane A (Fig. 28).

Total sound absorption ΣαS consists of a permanent part of the A_p and variable A_v, which depend on the number viewers, the estimated time of reverberation at 70 % of the filling of the hall must coincide with optimal 70 %.

The test should be performed at different frequencies (125, 500, 2 000 Hz).

For these frequencies it is possible to use the ratio:

$$T_{opt}^{500} : T_{opt}^{2\,000} : T_{opt} = 1{,}5 : 1 : 1 \qquad (24)$$

At high coefficients of absorption of protections (that it is necessary to accept in halls of the big sizes) it is expedient to use the universal Eyring equation (25):

$$T = \frac{0{,}163 \cdot V}{\sum S_n \cdot ln(1-\alpha_{ad})}, \qquad (25)$$

where α_{ad} – weighted average sound absorption coefficient, which is determined from the equation 26:

$$\alpha_{ad} = \frac{\sum \alpha_n \cdot S_n}{\sum S_n}, \qquad (26)$$

where $\sum \alpha_n \cdot S_n = \alpha_1 \cdot S_1 + \alpha_2 \cdot S_2 + \cdots + \alpha_n \cdot S_n$ – the total sound absorption is the sum of the sound absorption coefficients for the corresponding plane of the finishing materials.

$\sum S_n$ – the total plane of facing materials.

$l_n(l - \alpha_{ad})$, find on the table 7

Table 6 – Equivalent sound absorption area for armchairs in the hall (m^2)

Viewers and armchairs	Equivalent sound absorption, A_{ar} (m^2)					
	125	250	500	1 000	2 000	4 000
Viewers on a soft armchairs or semi-soft armchairs	0,25	0,3	0,4	0,45	0,45	0,4
On a soft armchair	0,2	0,25	0,3	0,35	0,35	0,35
Soft armchairs	0,15	0,2	0,2	0,25	0,3	0,3
Semi-soft armchairs	0,08	0,1	0,15	0,15	0,2	0,2
Armchairs upholstered in faux leather	0,08	0,1	0,12	0,1	0,1	0,08
Armchairs with a rigid back	0,02	0,02	0,03	0,04	0,04	0,05

Table 7 – The value of the function l_n $(l - \bar{\alpha}_{ad})$ depending on the value of the sound absorption coefficient a in the hall

$\bar{\alpha}$	0,00	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09
0,1	0,1	0,12	0,13	0,14	0,15	0,16	0,17	0,19	0,2	0,21
0,2	0,22	0,24	0,25	0,26	0,27	0,29	0,3	0,32	0,33	0,34
0,3	0,36	0,37	0,39	0,4	0,42	0,43	0,45	0,46	0,48	0,49
0,4	0,51	0,53	0,54	0,56	0,58	0,6	0,62	0,64	0,65	0,67
0,5	0,69	0,71	0,73	0,76	0,78	0,8	0,82	0,84	0,87	0,89
0,6	0,92	0,94	0,97	0,99	1,02	1,05	1,08	1,11	1,14	1,17

Example:

$\bar{\alpha}$ = 0,24 find on the table 7 ln (l - $\bar{\alpha}_{ad}$) = 0,27; and $\bar{\alpha}$ = 0,32 find on the table 7 ln (l - $\bar{\alpha}_{ad}$) = 0,39

Requires sound absorption:

in the frequency 500 Hz:

$$\sum \alpha S = \frac{0{,}163 \cdot V}{T_{opt}}$$

in equation

$$T_{opt}^{500} = \frac{0{,}163 \cdot V}{\sum \alpha \cdot S}$$

Requires sound absorption:

in the frequency 125 Hz

$$T_{opt}^{125} = 1{,}5 \cdot T$$

T – standard reverberation time

An example of calculating the reverberation time is shown in Figure 29.

8.1 Articulation of speech

When articulating, move the sound, the hour of reverberation, the background noise in the primitive, the form of the primitive. The efforts of the parameters to rotate in the form of performance, such as the process itself.

Articulation of speech - A:

$$A = 0{,}96 \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4$$

The values of the coefficients are presented in table 8

K_1 – coefficient that considers the volume level;

K_2 – coefficient, which considers the reverberation time;

K_3 – coefficient, which considers the noise background in the room;

K_4 – coefficient, which considers the shape of the premises (in rectangular and sector rooms K4 = 1,0, in small rooms with a large sound reflector K4 = 1,06).

96 % – excellent, good – 96–85, satisfactory – 85–75, difficult to hear – 76–65, inadmissible – 65 % and below.

Table 8 – Values of coefficients K_1, K_2, K_3, K_4 and percentage component articulation

Reverberation time, sec	Coefficients			Percent articulation	
	K_1	K_2	K_3	K_4 = 1,0	K4 = 1,06
1,0	0,95	0,96	0,83	72,5	77
1,5	0,95	0,94	0,83	71	75
2,0	0,95	0,90	0,83	68	72
2,5	0,95	0,86	0,83	65	69

The optimal reverberation time should be checked according to the normative nomogram (fig. 26, 27).

$$T = \frac{V}{\sum aS} 0.63$$

Volume= L*b*h
= 32.31*16.38*5.7
= 30.16m3

Material (Equipment)	Surface area of sound absorption (m^2)	Sound absorption coefficient on the frequency 125 Hz ($a1S$)	Sound absorption coefficient in the frequency 500 Hz ($a2S$)
The walls (Concrete)	538.46	0.01	0.02
The floor (Carpet 5mm)	474.942	0.04	0.15
The ceiling (Concrete)	529.542	0.01	0.02
Doors (Wooden)	7.5	0.15	0.10
Windows (Wooden)	-	-	-
The carpet (Usual type)	285.35	0.08	0.20
The curtains (Velvet0.6)	-	-	-
The soft armchair(Soft)	191.49	0.11	0.28
People 70%	-	0.18	0.47
Total	2027.28	0.58	1.24

Frequency 125Hz :

∑Sa=Surface area of sound absorption
*Sound absorption coefficient
on the frequency 125 Hz
= 2027.28*0.58
= 1175.8
T= (30.16/1175.8)*0.63
= 0.016

$$T_{127} = \frac{0.163*V}{S*\ln(1-a)}$$

Frequency 125Hz :

T127 =
0.163*30.16/2027.28*ln(1-0.58)
= -0.0021

$$T^{500} = \frac{0.163*V}{\sum aS}$$

Frequency 500Hz :

T^{500} = 0.163*30.16/2027.28*0.58
= 0.0041

Frequency 500Hz :

∑Sa=Surface area of sound absorption
*Sound absorption coefficient on
the frequency 500Hz
= 2027.28*1.24
=2513.8
T= (30.16/2513.8)*0.63
= 0.0076

$$T^{125} = 1.5*T$$

T^{125} = 1.5*0.016
= 0.024

Determining the total reverberation time

K= Cinemas = 0.29
T500 = 0.29*log(30.16)
= 0.429

$$T^{500} = K*\log*v$$

Figure 29 – Example of calculating the reverberation time

3 INDEPENDENT WORK

The simplest way to increase knowledge in the discipline of Building Physics is an independent in-depth study of the theoretical material of lectures and the implementation of calculation and graphic exercises and practical exercises. The theme of the student's independent work corresponds to the content of the topics of the discipline.

Types of the tasks
Content Module 1.1 **Climatology and Building Thermophysics**
Task to independent work № 1 Engineering and climatic calculations
Task to independent work № 2 Comprehensive assessment of the territory
Task to independent work № 3 Thermal calculation of external walls for winter conditions
Individual task
Content Module 1.2 **Lighting and illumination and acoustics**
Task to independent work № 4 Placement of window openings in one-sided lighting
Task to independent work № 5 Application of methods for determining the coefficient of natural light
Task to independent work № 6 Construction of a daily envelope of shadows
Content Module 1.3 **Acoustics**
Task to independent work № 7 Calculation of reverberation time
Task to independent work № 8 Calculation Room attenuation (Articulation of speech)

RECOMMENDED LITERATURE

1. Dushan Katunskiy, Marek Zozulyak / Building Physics December 2012 Edition: university textbookPublisher: Technical University of Kosice, SlovakiaISBN: 978-80-553-1261-3 https://www.researchgate.net/publication/301479044_Building_Physics
2. International Commission on Illumination, Commission Internationale de l'Eclairage (CIE) (2007). A Guide to Masterplanning Urban Lighting. TC5.21. Draft Report 8. Prepared by CIE Technical Committee 5-21 of Division 5 (Exterior and other lighting applications). [Electronic resource] – journal homepage: https://www.iso.org/committee/55238.html
3. Defining the acoustic requirements and regulations for noise control in buildings [Electronic resource]. - Access mode: https://www.rockwool.com/north-america/advice-and-inspiration/blog/acoustics-requirements-in-building-codes/
4. Hussain H. Alzoubi a, Abdulsalam A. Alshboul. Low energy architecture and solar rights: Restructuring urban regulations, view from Jordan. Renewable Energy 35 (2010) 333–342 p. [Electronic resource]– journal homepage: www.elsevier.com/locate/renene
5. CLIMATE-DATA.ORG [Electronic resource]. - Access mode: https://en.climate-data.org/info/sources/
6. Digital repository of O. M. Beketov NUUEK [Electronic resource]. - Access mode: http://eprints.kname.edu.ua
7. Tetiana Apatenko. Reference Manual for practical works to the discipline Building Physics (It is intended for students of Specialty 191 – Architecture and urban planning) O. Beketov National University of Urban Economy in Kharkiv – Kharkiv: O. M. Beketov NUUE, 2021 – 57 p.

APPENDIX A (tables for the section Climatology)

Table A.1– Nomogram for determining whether classes

Temperature, °C	Warm period					
	Upper border	Lower limit	Relative humidity, %			
			24 and below	25–49	50–74	75 and more
	47,9	44,0	H – hot			
	43,9	40,0				
	39,9	36,0	H_d hot dry			
	35,9	32,0				
	31,9	28,0	W – warm			
	27,9	24,0			W	
	23,9	20,0	C – comfortable			W
	19,9	16,0				
	15,9	12,0				
	Cold period					
	Upper border	Lower limit	Wind speed, m/s			
			1,9 and below	2,0–4,9	5,0–9,9	10 and more
	11,9	8,0	Cl – cool			
	7,9	4,0				
	3,9	0,0	Cd – cold			
	– 0,1	– 3,9				
	–4,0	– 11,9				
	–12,0	– 19,9				
	– 20,0	– 27,9				
	– 28,0	– 35,9				
	– 36,0	– 47,9	S – severe			
	– 48,0	– 59,9				
	– 60,0	– 71,9				

Table A.2 – Typological requirements for the choice of architectural solutions and modes of operation of the territory and buildings for the cities of Ukraine

Weather classes	Regime operation	Typological requirements		
		Architectures solutions	Constructions solutions	Engineering - technical solution
1	2	3	4	5
Hot (moisture) **H_m**	***Open mode*** (summer)	Maximum aeration of territories and buildings. Compact spatial planning solutions, open spaces for evening and night recreation. Through ventilation. Shading of pedestrian paths with buildings Protection of territories from overheating by green plantings. Shading and active aeration of urban spaces	Single or double glazing. "Breathable" protections of high heat-protective properties	Full air conditioning, artificial microclimate in the premises, maximum aeration. Intensive ventilation
Hot dry **H_d**	***Closed*** (summer)	Compact spatial planning solutions, reduced heat input. Intensive thermal protection of the territory and buildings. Flooding and landscaping. Protection against dry winds	To protect against overheating of the structure, heat-protective and airtight properties are required. Sun protection of walls and windows of buildings	Artificial cooling of air without reduction of its humidity. Air conditioning, mechanical fans, hair dryers
Warm **W**	***Semi-open*** (summer)	free by city-planning decisions of building; bilateral planning of apartments with active ventilation; sun protection and aeration of the territory and buildings	Transformation of enclosing structures; sun protection on the facades of buildings; protection of premises from overheating	Mechanical fans, hair dryers; artificial cooling of premises
Comfortable – Warm - **CW**	***Open*** with protection from overheating	Free by city-planning decisions of building; flooding and landscaping; sun protection and aeration of territories and buildings; through and angular ventilation; open rooms, loggias, galleries, verandas, semi-open stairs without vestibules	Transformation of fences; sun protection on the facades of buildings; protection of premises from overheating; fences that reduce heat input	Mechanical fans, hair dryers and air conditioners
Comfortable **C**	***Open***	Open spaces, loggias, verandas, balconies; household processes outdoors	Transformation of protections (requirements to thermal insulation are not put forward)	Not used

Table A.2 (continuation)

1	2	3	4	5
Cold – Comfortable **CC**	***Semi-open with protection against slight overheating***	Moderately compact spatial planning solutions; protection of the territory from the wind by green plantings or semi-enclosed buildings	Single or double glazing; enclosing constructions of average heat-protective properties	Electric hair dryers; natural ventilation, air conditioners
Cool **C_l**	***Semi-open (winter)***	Orientation in the sun; moderately compact spatial planning solutions; protection of the territory from the wind by green plantings	Single glazing; enclosing constructions of average heat-protective properties	Low power heating; natural ventilation.
Cool – Cold **C_lC_d**	***Semi-open with protection against easy cooling***	Orientation of buildings to the north - south; through ventilation, open rooms, loggias, galleries, verandas, semi-open stairs without vestibules	Double glazing; enclosing structures of necessary heat-protective and airtight properties; modern energy-saving windows	Regular central heating of average power; air conditioners
Cold **C_d**	***Closed (winter)***	Closed compact building scheme. Protection of the territory from dangerous winds by buildings. Focus on the sunny side. Reduction heat loss, warm stairs, vestibules	Fencing of necessary heat-protective and airtight properties; double and triple glazing	Regular central heating of average power; natural ventilation
Cold – Severe **C_dS**	***Closed - with active wind-heat-moisture protection***	Protection against hypothermia; closed compact building with wind protection; reducing the size of the yard (not more than two heights of buildings); protection of the territory from dangerous winds by high-rise buildings plus landscaping; reduction of dangerous winter winds and moisture; orientation to the sunny sides; reduction of heat loss; warm stairs and vestibules	Protections with high heat-protective and airtight properties; double and triple glazing; modern energy-saving windows with high heat-insulating properties	Regular high-power central heating
Severe **S**	***Isolated (winter)***	Maximum compactness of building. Protection of the territory from winds by buildings. Warm transitions between buildings, warm public transport stops. Minimum heat loss: closed heated stairs, minimum number of entrances to the building, double vestibules	Protections with high heat-protective and airtight properties; Triple glazing, modern windows with high thermal insulation. In the conditions of permafrost certain foundations	Regular high-power central heating. Mechanical supply ventilation with heating and humidification

Table A.3 – Bioclimatic zones and urban requirements for architectural planning decisions

№ of zones	Bioclimatic zones	General urban planning requirements
1	*Cold climate* The total duration of cooling weather is moderate, significant and excessive for more than 4 months	Maximum protection of the person against hypothermia: activation of solar influence; protection against low temperatures (limiting the time a person is outdoors in the cold period to 15–30 minutes); protection of the territory from wind and blizzard
2	*Moderate climate* No weather type excessive cooling; duration of cooling weather is moderate, significant from 2 to 4 months; in the Baltics, Belarus, southern Ukraine and southern European Russia for less than 2 months	Moderate protection against hypothermia in the cold and against overheating in the warm period; use of favorable climatic conditions; activation of solar influence north of 57° latitude and moderate sun protection in the warm period north of this latitude; moderate wind protection, moisture protection on the sea coast
3	*Hot climate* There are no type of weather excessive and significant cooling; duration of weather significant and moderate overheating more than 1-2 months; in Central Asia, the duration of weather is significant, moderate and excessive overheating more than 2 months	Maximum protection against overheating: sun protection (protection against excess thermal radiation); protection against high air temperatures (reduction of time spent in the open air in desert areas); activation of ventilation; protection against low humidity in desert areas and high in humid subtropics; use of favorable weather conditions

Notes: The minimum duration of weather is 1 month

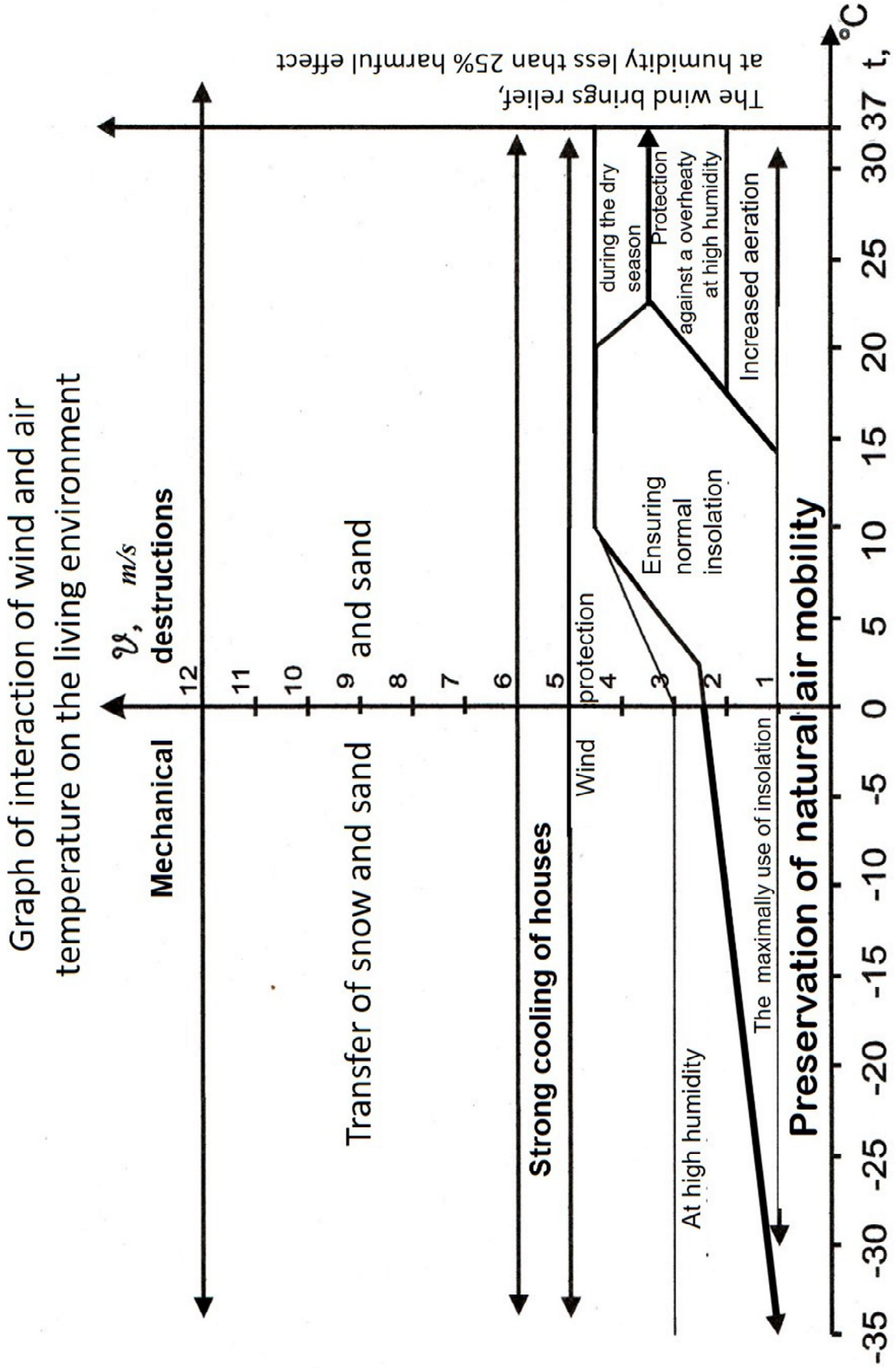


Figure A.1 – Assessment of the temperature and wind regime of the territory

Table A.4 – Evaluation of the horizon circle by thermal exposure to solar radiation in the summer period (may-august)

Orientation in the sun	Score, points			
	1	2	3	4
	Prohibited sector for one-way apartments in all areas	Conditionally favorable	Favorable	Unfavorable
65–52º	North North-East North-West	West	South-West	East; South South-East
From 52º to South		South West South-West	South-East	East

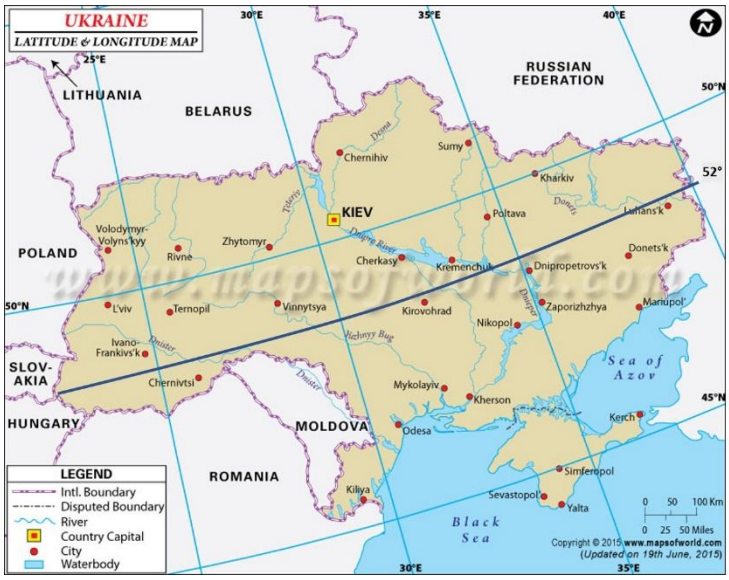


Figure A.2 – Map of latitude of Ukraine

Table A.5 – Assessment of the territory by the thermal exposure of solar radiation

Bioclimatic zone		Degree of favorable radiation		
		Favorable	Unfavorable	Conditionally favorable
Score, points		**1**	**2**	**3**
1	Cold climate	292,5° – 67,5º (North-West; North; North-East)	202,5° – 292,5º (South-West; West)	67,5° – 202,5º (East; South-East; South)
2;3	Moderate climate Hot climate	157,5° – 292,5º (South; South-West; West)	292,5° – 22,5º (West-North; North)	22,5° – 157,5º (North-East; East; South-East)

APPENDIX B (Theme 1 LIGHTING AND ILLUMINATION)

Table B.1 – Benchmark data for performing lighting calculations

№№ option	Rooms	Plane (G, V), the height of the plane above the floor	e_n	The weighted average reflection coefficient ρ	S (m^2) rooms	P (m) distance between buildings	H (m) The height of the opposite buildings	$h_г$ (m) The height from the floor to the top of the window	Orientation of the building around the world
1	2	3	4	5	6	7	8	9	10
1	Project hall	G – 0,8	2	0,5	80	10	30	2,5	North-East
2	Library	G – 0,8	1	0,4	120	–	–	4	East
3	Conference room	G – 0,8	0,5	0,5	500	–	–	4	North-West
4	Classroom (School)	G – 0,8	1,5	0,5	40	–	–	2,8	East
5	Exhibition hall	Exhibition G – 0,8	–	0,3	600	–	–	5	North
6	Dining room	G – 0,8	0,5	0,5	100	–	–	2,8	South
7	Trade hall of the store	G – 0,8	0,5	0,4	400	20	21	3,3	North-East
8	Doctor's office	G – 0,8	1	0,5	20	–	–	2,5	North-West
9	Recreation hall	Floor	-	0,5	40	–	–	2,5	North
10	Lecture audience at the university	G- 0,8	1,5	0,4	300	50	21	3	North-West
11	Drawing classroom	G- 0,8	2	0,4	100	–	–	2,8	East
12	Indoor pool*	G – on the surface of the water	1	0,3	400	15	36	5	North-West
13	Laboratory of Inorganic Chemistry	G – 0,8	1,5	0,5	60	20	21	2,5	North
14	Editorial department	G – 0,8	2	0,3	30	–	–	2,5	North-East
15	Sewing shop	G – 0,8	1,5	0,4	300	–	–	2,5	North-West
16	Operating room	G – 0,8	1,5	0,5	60	–	–	2,8	North-West
17	Hairdresser's	G – 0,8	1	0,3	40	–	–	2,5	East
18	Model workshop	G – 0,8	1,5	0,3	50	–	–	2,5	South

Table B.1 (continuation)

1	2	3	4	5	6	7	8	9	10
19	Meeting room	G – 0,8	0,5	0,4	400	10	36	3,0	North - West
20	Design office	G – 0,8	1,5	0,4	100	-	-	2,8	East
21	Hotel room	G – 0,8	0,5	0,3	25	-	-	2,5	South-East
22	Dry cleaning room	G – 0,8	0,3	0,4	50	15	28	2,5	West
23	Play room of children's preschool institution	G – 0,5	1,5	0,5	40	-	-	2,5	South-East
24	Bookstore trading hall	G – 0,8	0,5	0,4	200	15	48	3	North-East
25	Hot shop of the restaurant	G – 0,8	1	0,5	150	25	21	3	North-East
26	Sport`s room of a children's preschool institution	G – 0,5	1,5	0,4	40	-	-	2,5	North - West
27	Carpentry workshop	G – 0,8	1,5	0,3	50	10	36	2,5	West
28	Classroom for the drawing	G – 0,8	2	0,4	150	-	-	2,7	South-East
29	Classroom for fabric processing (sewing) of secondary school	G – 0,8	1,5	0,3	45	-	-	2,5	South-East
30	Metalworking workshop	G – 0,8	1,5	0,3	80	15	28	2,6	West
31	Insulator for sick children in a sanatorium-type orphanage	G – 0,5	1,5	0,4	30	–	–	2,5	South-East
32	Laundry	G – 0,8	0,3	0,4	180	–	–	2,6	North-East
Note: * b = – 500 mm (fig. B.1)									

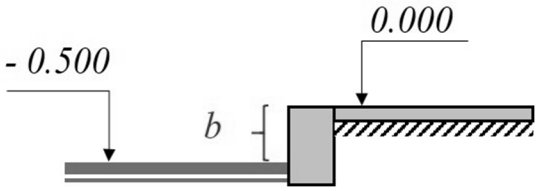


*Figure B.1 - Value **b** for the Indoor pool*

Table B.2 – The indicators of the coefficient of light climate ***m***

Light-climatic area	The value of ***m*** for the slots								
	Verticals, focused on:								Focus on the zenith
	North	North-East	East	South-East	South	South-West	West	North-West	
I	0,95	0,98	1,02	1,04	1,05	1,04	1,02	0,98	1,01
II	1,00	1,04	1,09	1,11	1,12	1,12	1,10	1,04	1,08
III	1,06	1,11	1,18	1,22	1,24	1,22	1,19	1,12	1,16
IV	1,15	1,21	1,29	1,32	1,33	1,32	1,30	1,22	1,27

Figure B.2 – Map of light-climatic zoning of the territory of Ukraine.

Table B.3 – The indicators of the light characteristic η_w the windows in side lighting

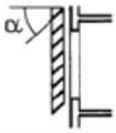
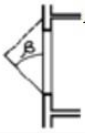
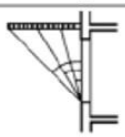
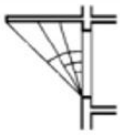
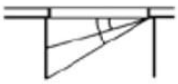
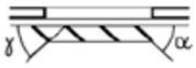
The ratio of the length of the room ***L*** to its depth ***B***	The value of η_w at the ratio of the depth of the room ***B*** to its height from the level of the work surface to the top of the window ***h***							
	1	1,5	2	3	4	5	7,5	10
4 and more	6,5	7	7,5	8	9	10	11	12,5
3	7,5	8	8,5	9,6	10	11	12,5	14
2	8,5	9	9,5	10,5	11,5	13	15	17
1,5	9,5	10,5	13	15	17	19	21	23
1	11	15	16	18	21	23	26,5	29
0,5	18	23	31	37	45	54	66	

Table B.4 – The indicators of the coefficient K_b

The ratio of the distance between the houses (***P***) to the height ***H*** of the location of the cornice of the opposite house above the window sill of the calculated room (see Fig. 1)	***Kb***
0,5	1,7
1	1,4
1,5	1,2
2	1,1

Table B.5 – The indicators of the coefficient τ_1

Type of light transparent material	Indicator τ_1
Colorless glass, mm	
2,0	0,89
3,0	0,88
4,0	0,87
5,0	0,86
6,0	0,85
8,0	0,83
10	0,81
12	0,79
15	0,76
19	0,72
25	0,67
Pattern sheet glass	0,65
Sunscreen glass	0,65
Glass is spectrally selective	0,75
Plexiglas:	
transparent	0,9
dairy	0,6
Glass blocks:	
light scattering	0,5
translucent	0,55
Glass profile:	
channel section	0,8
box section	0,65

№ schemes	Scheme	The indicators of the coefficient τ_4
1	 Horizontal blinds α = 0° α = 45°	0,75 0,35
2	 Awnings are translucent β = 45°	0,4
3	 lattice visor β = 45° β = 30° β = 15°	0,65 0,82 0,95
4	 Lattice continuous β – 45° β – 30° β = 15°	0,6 0,8 0,95
5	Vertical screens  γ = 15° γ = 30°	0,95 0,85
6	Vertical blinds  γ = 45°, α = 90° γ = 45°, α = 45°	0,70 0,60

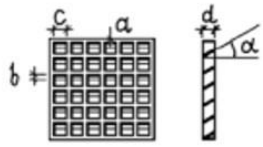
№ schemes	Scheme					The indicators of the coefficient τ_4
7	Honeycomb 					The indicators τ_4
	α	a	b	c	d	
	0°	1	11	11	5	0,57
	30°	1	8	37	5	0,61
	45°	1	7	24	5	0,54
	15°	1	9	37	7	0,62
	15°	1	10	37	5	0,70
	45°	1	7	37	5	0,55
	0°	1	11	11	7	0,48
	30°	1	8	37	7	0,54
	30°	1	7	24	7	0,52
	45°	1	5	37	7	0,45
	15°	1	9	37	10	0,61
	30°	1	6	37	10	0,50
	45°	1	7	37	7	0,57
	15°	1	10	37	10	0,56
	15°	1	9	24	10	0,49
	45°	1	2	37	10	0,32

Figure B.3 – The indicators of the coefficient τ_4

Table B.6 – The indicators of the coefficient r_1

The ratio of ***B*** to the height h_1 (see note 1)	Ratio from settlement point to ***B*** (see Note2)	The value of r_1 when illumined								
		Weighted average the coefficient reflectance ρ of ceiling, walls and floor								
		0,5			0,4			0,3		
		The ratio of the length of the room ***l*** to its depth								
		0,5	1	2 and more	0,5	1	2 and more	0,5	1	2 and more
1	2	3	4	5	6	7	8	9	10	11
From 1 to 1.5	0,1	1,05	1,05	1,05	1,05	1,05	1	1,05	1	1
	0,5	1,4	1,3	1,2	1,2	1,15	1,1	1,2	1,1	1,1
	1	2,1	1,9	1,5	1,8	1,6	1,3	1,4	1,3	1,2
More 1,5 to 2,5	0	1,05	1,05	1,05	1,05	1,05	1,05	1,05	1	1
	0,3	1,3	1,2	1,1	1,2	1,15	1,1	1,15	1,1	1,05
	0,5	1,85	1,6	1,3	1,5	1,35	1,2	1,3	1,2	1,1
	0,7	2,25	2	1,7	1,7	1,6	1,3	1,55	1,35	1,2
	1	3,8	3,3	2,4	2,8	2,4	1,8	2	1,8	1,5
More 2,5 to 3,5	0,1	1,1	1,05	1,05	1,05	1	1	1	1	1
	0,2	1,15	1,1	1,05	1,1	1,1	1,05	1,05	1,05	1,05
	0,3	1,2	1,15	1,1	1,15	1,1	1,1	1,1	1,1	1,05
	0,4	1,35	1,25	1,2	1,2	1,15	1,1	1,15	1,1	1,1
	0,5	1,6	1,45	1,3	1,35	1,25	1,2	1,25	1,15	1,1
	0,6	2	1,75	1,45	1,6	1,45	1,3	1,4	1,3	1,2
	0,7	2,6	2,2	1,7	1,9	1,7	1,4	1,6	1,5	1,3
	0,8	3,6	3,1	2,4	2,4	2,2	1,55	1,9	1,7	1,4
	0,9	5,3	4,2	3	2,9	2,45	1,9	2,2	1,85	1,5
	1	7,2	5,4	4,3	3,6	3,1	2,4	2,6	2,2	1,7
More 3,5	0,1	1,2	1,15	1,1	1,1	1,1	1,05	1,05	1,05	1
	0,2	1,4	1,3	1,2	1,2	1,15	1,1	1,1	1,05	1,05
	0,3	1,75	1,5	1,3	1,4	1,3	1,2	1,25	1,2	1,1
	0,4	2,4	2,1	1,8	1,6	1,4	1,3	1,4	1,3	1,2
	0,5	3,4	2,9	2,5	2	1,8	1,5	1,7	1,5	1,3
	0,6	4,6	3,8	3,1	2,4	2,1	1,8	2	1,8	1,5
	0,7	6	4,7	3,7	2,9	2,6	2,1	2,3	2	1,7
	0,8	7,4	5,8	4,7	3,4	2,9	2,4	2,6	2,3	1,9
	0,9	9	7,1	5,6	4,3	3,6	3	3	2,6	2,1
	1	10	7,3	5,7	5	4,1	3,5	3,5	3	2,5

Note 1: The ratio of the depth of the room ***B*** to the height from the level of the conditional work surface h1 to the top of the window.
Note 2: The ratio of the distance from the design point to the outer wall to the depth of the room ***B***. (see fig. 12)

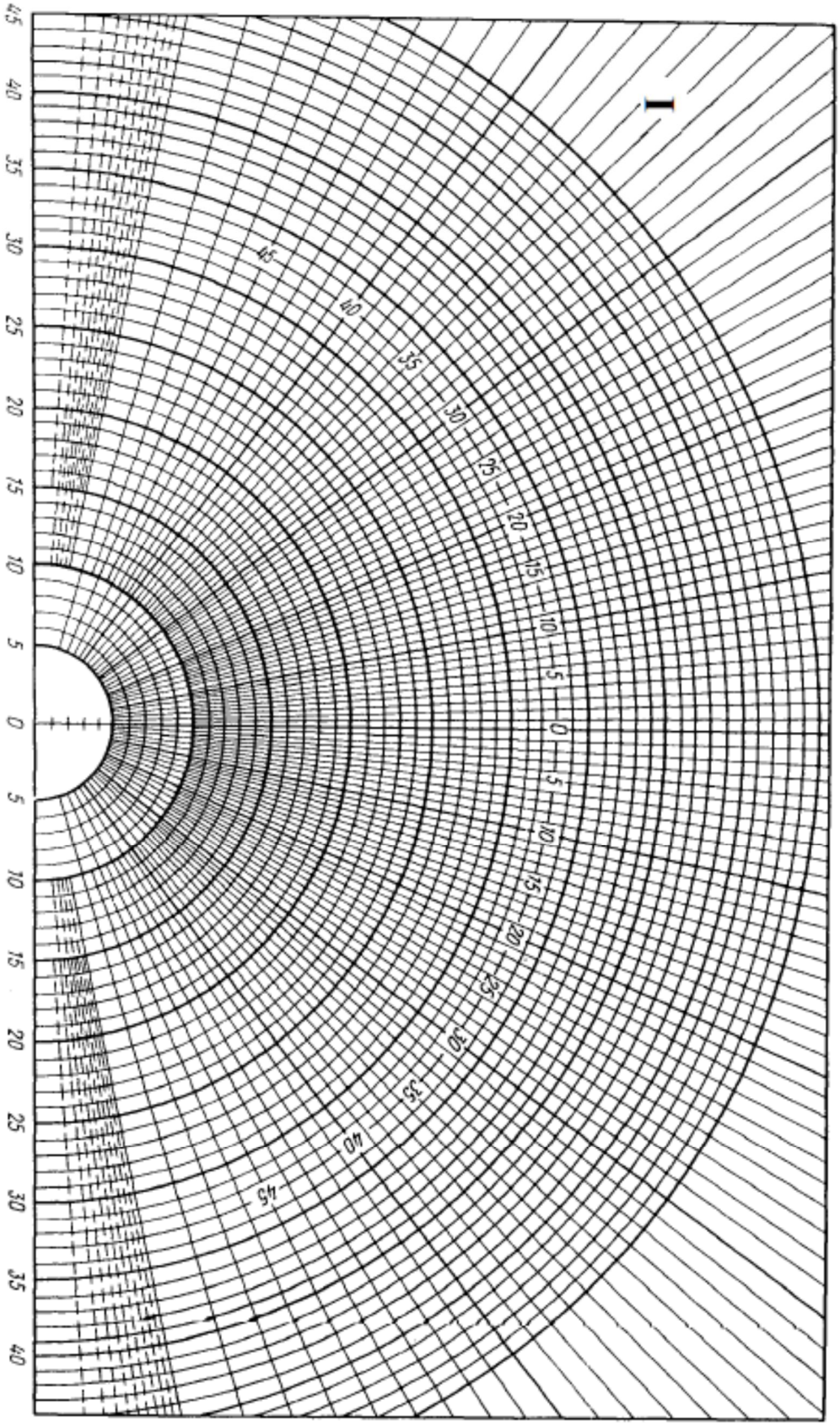


Figure B.4 – Graph Danilyuk I

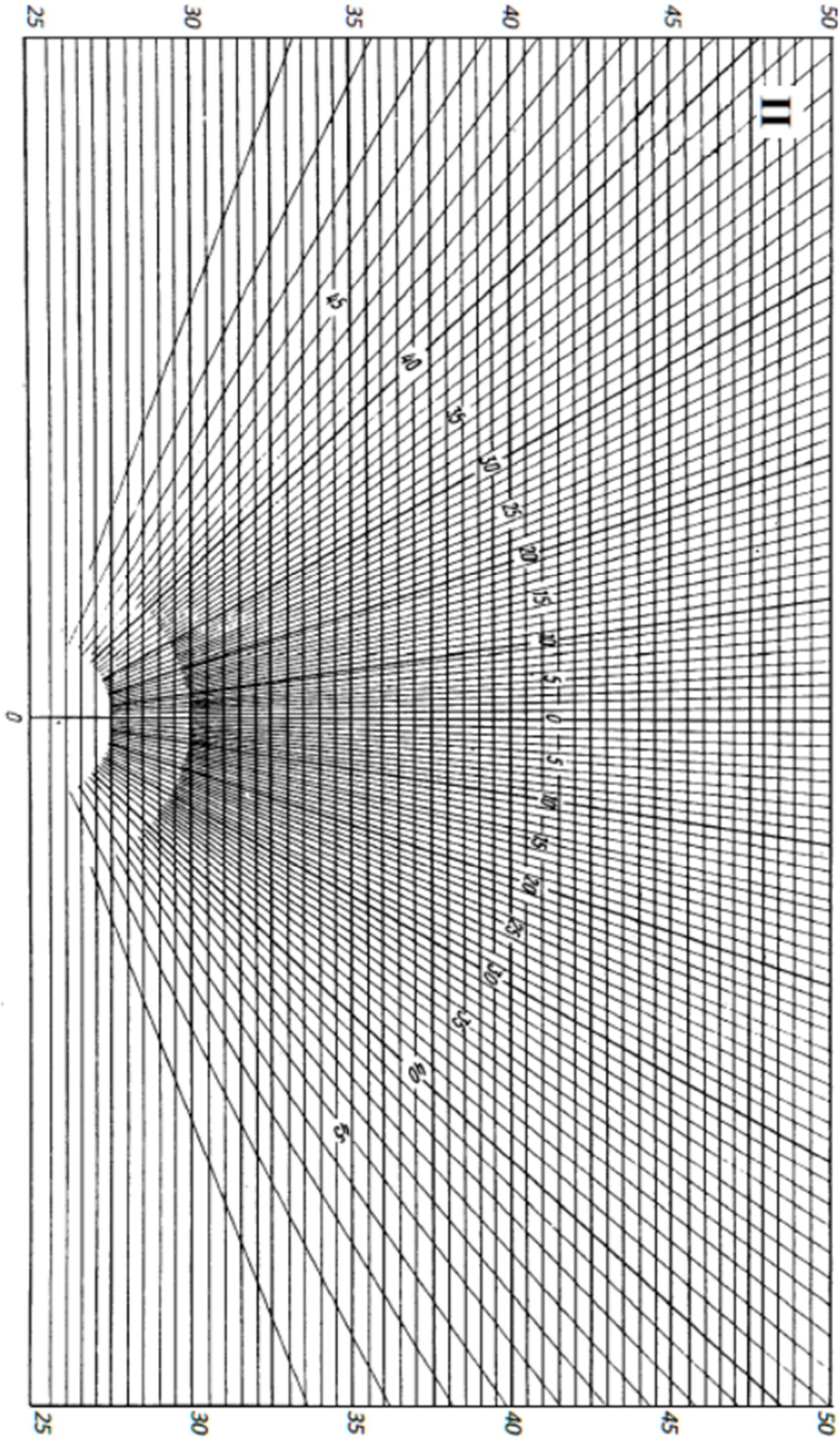


Figure B.5 – Graph Danilyuk II

APPENDIX C (Theme 2 THE INSOLATION OF BUILDINGS AND AREAS)

Table C.1 – Benchmark data for calculating the insolation of housing

№№	Latitude	Options of the building scheme	Orientation
1	**43°**	**Option 1 (fig. C.1)**	↑ N
2	**54°**		→ N
3	**51°**		↖ N
4	**47°**		← N
5	**41°**		↓ N
6	**31°**		↗ N
7	**48°**	**Option 2 (fig. C.2)**	↑ N
8	**30°**		→ N
9	**23°**		↖ N
10	**63°**		← N
11	**28°**		↗ N
12	**49°**		↓ N
13	**53°**	**Option 3 (fig. C.3)**	↗ N
14	**44°**		↖ N
15	**64°**		↑ N
16	**45°**		→ N
17	**40°**		↓ N
18	**46°**		← N
19	**33°**	**Option 4 (fig. C.4)**	↑ N
20	**35°**		→ N
21	**42°**		← N
22	**50°**		↓ N
23	**42°**		↗ N
24	**37°**		↖ N
25	**39°**	**Option 5 (fig. C.5)**	→ N
26	**38°**		↓ N
27	**29°**		← N
28	**65°**		↑ N
29	**61°**		↗ N
30	**66°**		↖ N

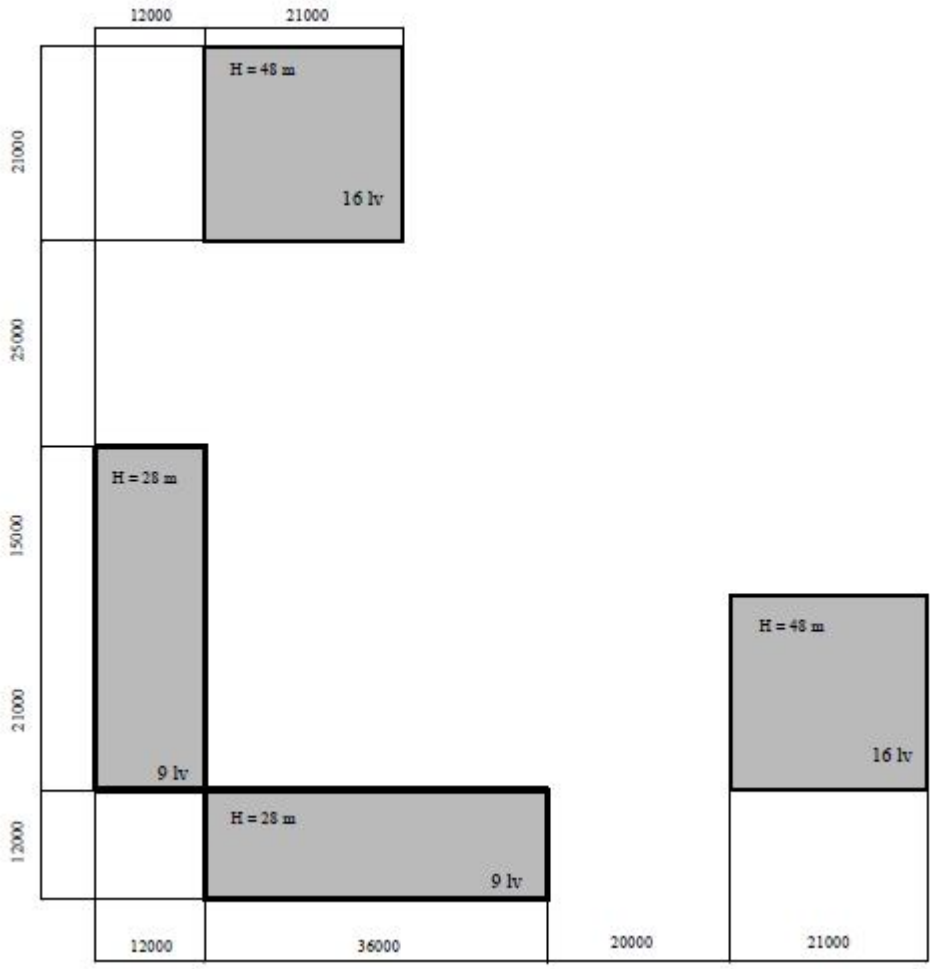


Figure C.1 – Option 1

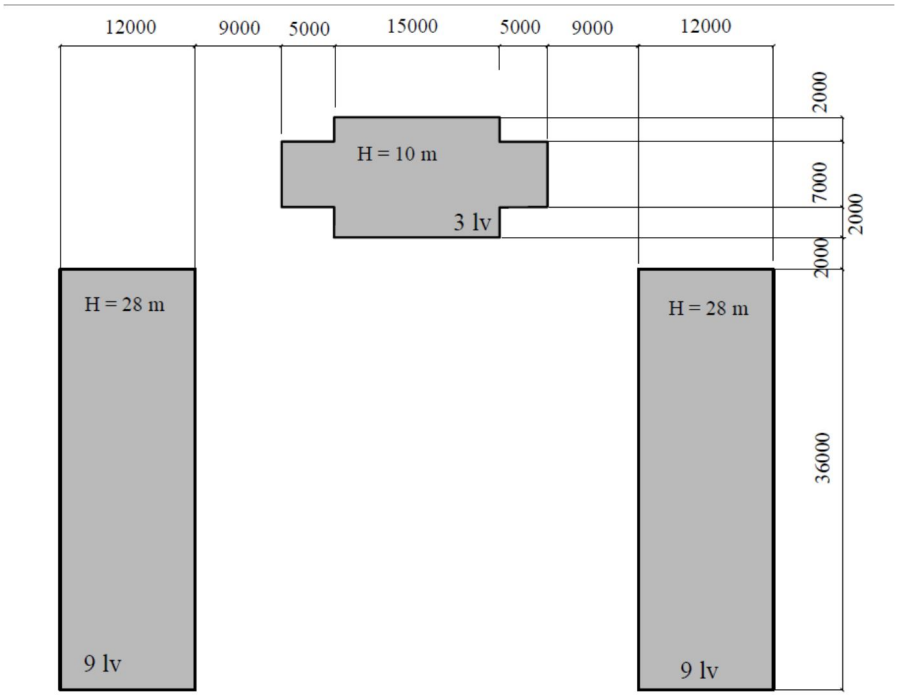


Figure C.2 – Option 2

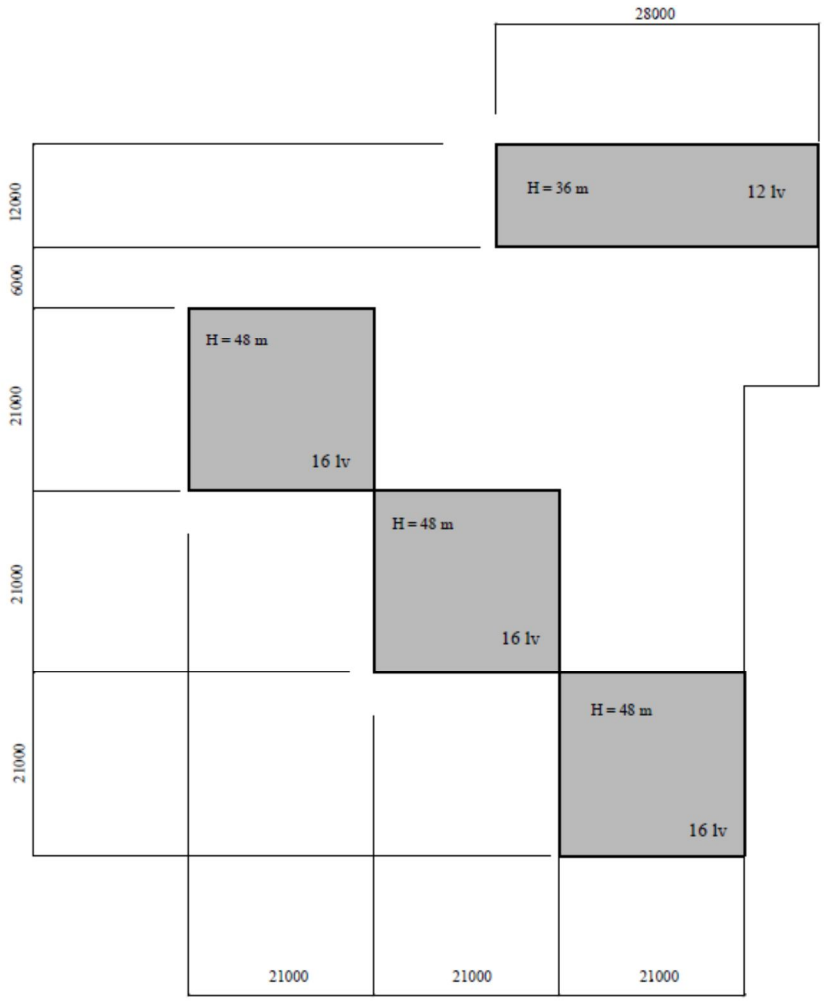


Figure C.3 – Option 3

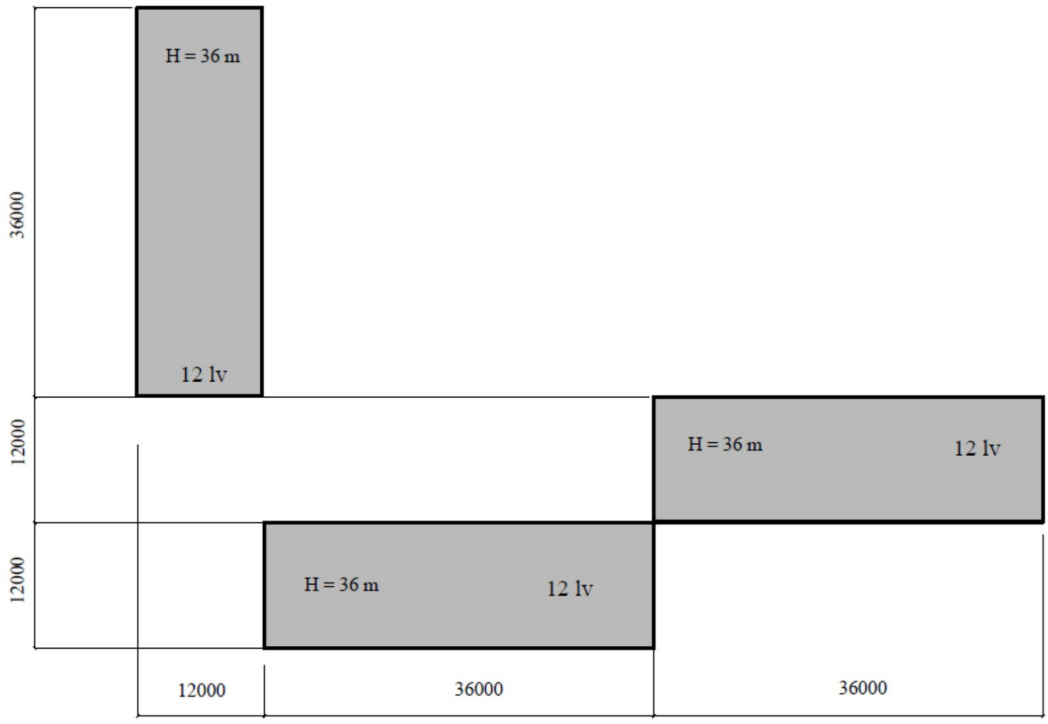


Figure C.4 – Option 4

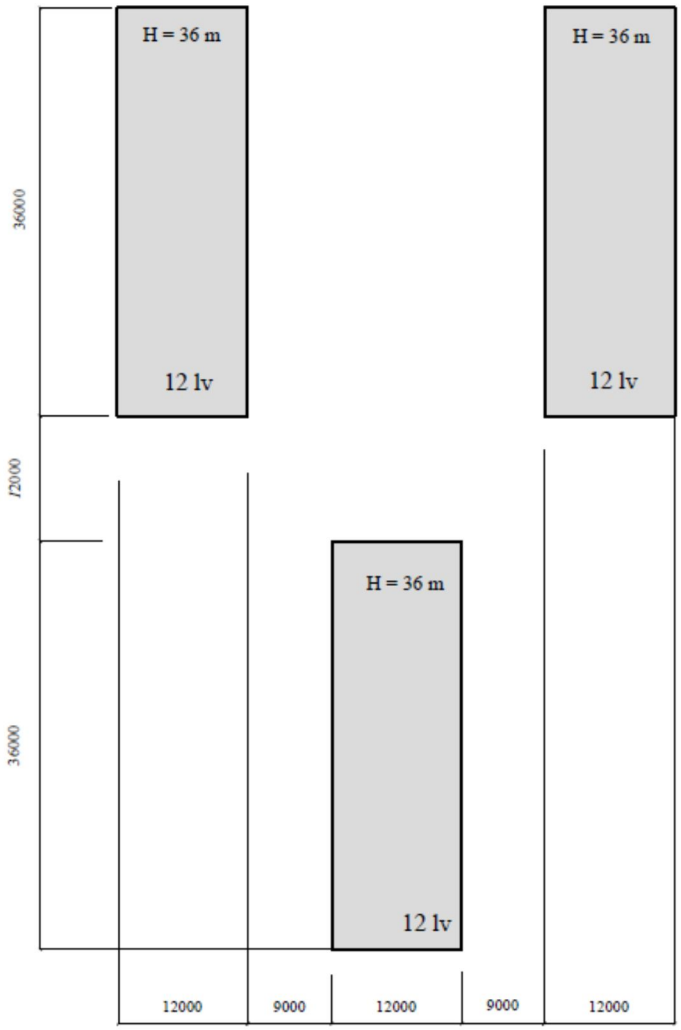


Figure C.5 – Option 5

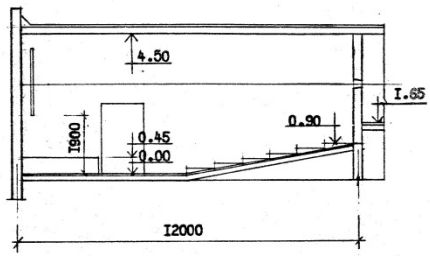
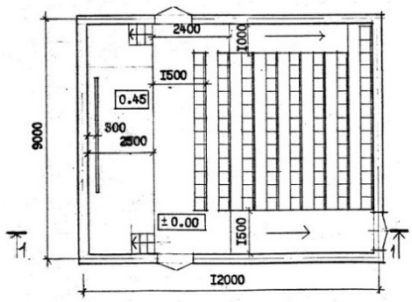
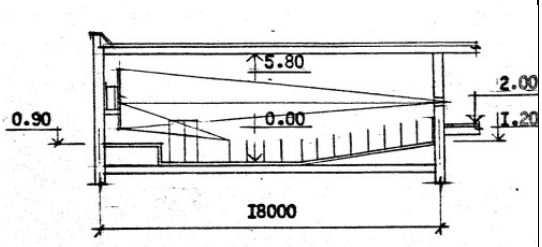
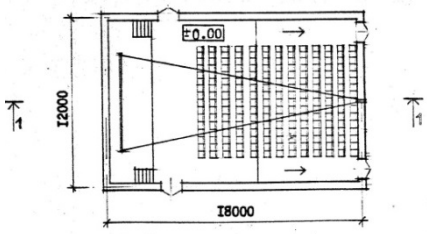
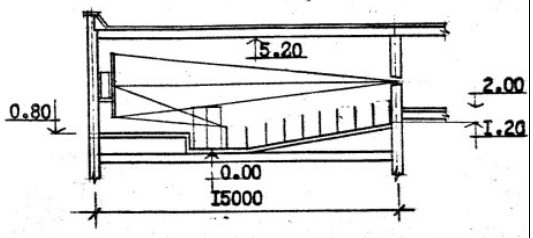
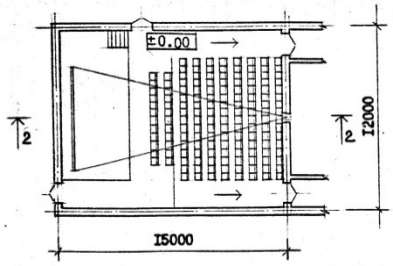
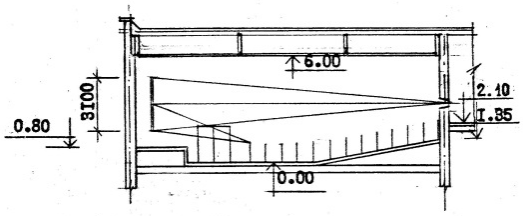
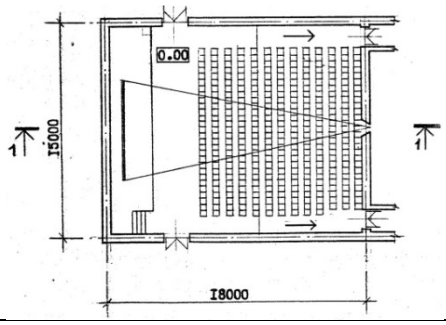
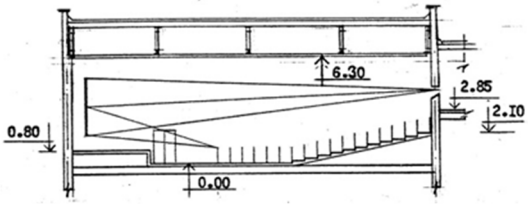
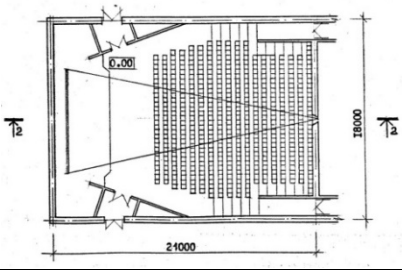
The provided graphic schemes are calculated on 6 variants, but the difference between variants is the direction of a northern orientation (see appendix 2). Graphic schemes should be performed at a scale of 1:1 000 or 1:500 on a sheet of A3 format.

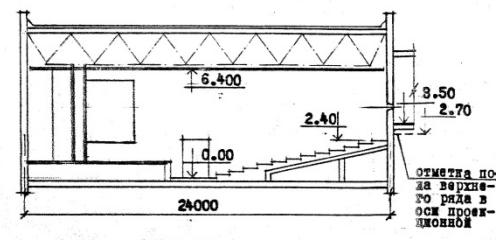
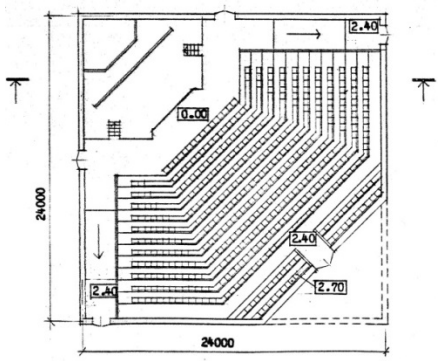
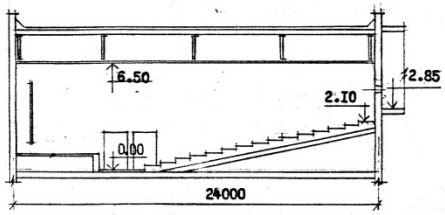
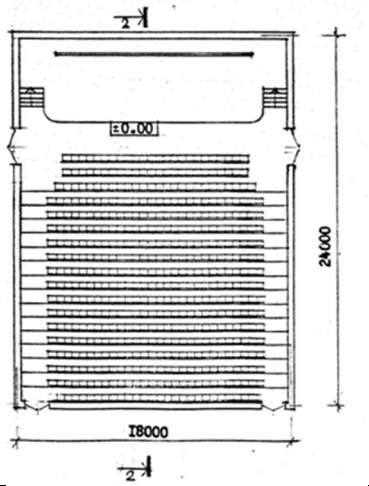
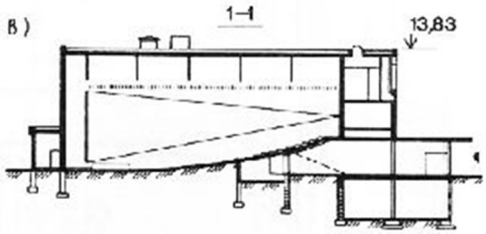
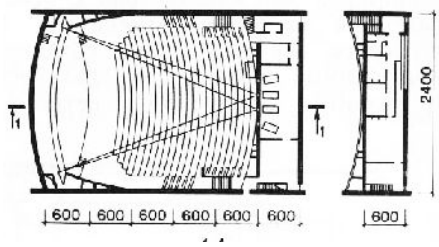
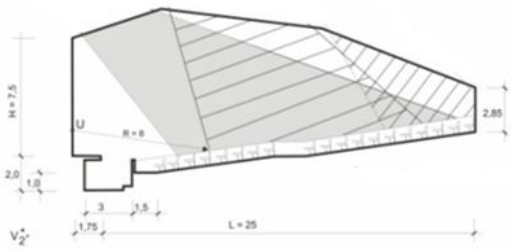
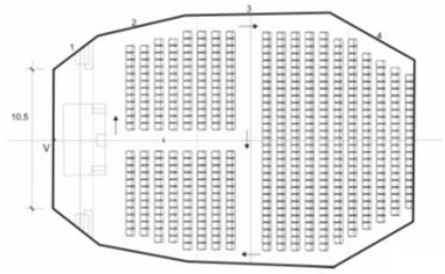
APPENDIX D (tables for the section Acoustic)

Table D.1 – Benchmark data for performing practical tasks № 7, 8

№ option	Number of seats in the hall		K_4
		–	K4 = 1,06
		Full stage	K4 = 1,0
			K4 = 1,0
			K4 = 1,0
		–	K4 = 1,06
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
		–	K4 = 1,06
			K4 = 1,0
			K4 = 1,0
		–	K4 = 1,0
			K4 = 1,0
			K4 = 1,0
		–	K4 = 1,06
			K4 = 1,06
		Small stage	K4 = 1,0
			K4 = 1,0
		–	K4 = 1,0
			K4 = 1,06
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
			K4 = 1,0
		–	K4 = 1,06

Table D.2 – Exercise for the section Acoustic

№ п/п	Building Section Diagram	Building Plan Diagram	Auditorium Capacity
1	2	3	4
1	Section 1-1 	Auditorium Plan 	Auditorium for 100 seats
2	Section 1-1 	Auditorium Plan 	Auditorium for 200 seats
3	Section 2-2 	Auditorium Plan 	Auditorium for 150 seats
4	Section 1-1 	Auditorium Plan 	Auditorium for 300 seats
5	Section 1-1 	Auditorium Plan 	Auditorium for 400 seats

1	2	3	4
6	Section 1-1 	Auditorium Plan 	Auditorium for 500 seats
7	Section 1-1 	Auditorium Plan 	Auditorium for 500 seats
8	Section 1-1 	Auditorium Plan 	Auditorium for 600 seats
9	Section 1-1 	Auditorium Plan 	Auditorium for 460 seats

Виробничо-практичне видання

Методичні рекомендації

до організації самостійної роботи, проведення практичних занять
і виконання розрахунково-графічної роботи
з дисципліни

«БУДІВЕЛЬНА ФІЗИКА»

*(для студентів денної форми навчання за спеціальністю
191 – Архітектура та містобудування)*

(англ. мовою)

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