

Urbanism and civil engineering: Second-round sample tasks for the Open Doors undergraduate track

You will be asked to complete 31 tasks, including:

- 18 entry-level tasks, each correct answer worth 1-3 point;
- 10 intermediate-level tasks, each correctly answered task worth 3-7 points;
- 3 advanced tasks (constructed response), each correctly completed task valued at 8–15 points.

Evaluation criteria and standard answers are provided for the advanced tasks requiring constructed responses.

Civil Engineering and Construction

Task 1 Entry level (2 points)

What is the name of the roof design of the sports and concert complex in Japan shown in the picture?



- a) Shell Of Positive Curvature
- b) Hypar
- c) Cylindrical Shell
- d) Dome**
- e) Folds

Answer: d.

Task 2 Entry level (2 points)

In which year was the first passenger elevator introduced in New York, paving the way for skyscraper construction?

- a) 1827
- b) 1857**
- c) 1927

d) 1957

Answer: b.

Task 3
Entry level (1 point)

Which international classification group do buildings with 10 to 16 stories fall under?

- a) Low-rise
- b) Mid-rise
- c) **Multi-rise**
- d) High-rise

Answer: c.

Task 4
Entry level (2 points)

What is insolation?

- a) It is the amount of natural light entering residential or non-residential areas inside a facility
- b) It is the amount of fresh air infiltration into residential or non-residential areas inside a facility
- c) **It is the amount of sunlight entering residential or non-residential areas inside a facility**
- d) It is the amount of water vapor diffusion into residential or non-residential areas inside a facility

Answer: c.

Task 5
Intermediate level (2 points)

Fill in the blank. A _____ is a fundamental system of structures that create an interior space designed for various activities involving direct human interaction: residential home, manufacturing plant, theater, and more.

Answer: building.

Task 6
Intermediate level (5 points)

Select all the structural components that constitute the frame of a building and support various loads within the frame structural system. Multiple answers may apply.

- a) **Columns**
- b) Walls
- c) **Slabs**
- d) Partitions
- e) Staircase
- f) **Beams**

Answer: a, c, f.

Task 7
Advanced level (10 points)

The required thermal resistance of the external wall of a residential building in Moscow, based on energy efficiency conditions, is $R_{req.} = 3.40 \text{ m}^2 \cdot \text{°C}/\text{W}$. Assess the appropriateness of the external wall composition listed in the table for a residential building in Moscow (disregarding the thermal resistances of both the exterior and interior surfaces of the wall). When calculating, round the final result to two decimal places.

Note that the evaluation will consider how you solve the task; providing only the final answer is not sufficient.

Layer №	Layer material	Thickness δ , MM	Thermal Conductivity λ , $\text{W}/(\text{m} \cdot \text{°C})$
1	Cement-sand grout	20	0,58
2	Brickwork	250	0,56
3	Insulation: polystyrene foam	100	0,041
4	Compound solution	10	0,52

Solution:

1. Determine the actual thermal resistance of the structural layers that make up the wall. Convert the layer thickness into meters.

$$R_1 = \delta_1 / \lambda_1 = 0,02 / 0,58 = 0.03 \text{ m}^2 \cdot \text{°C}/\text{W}$$

$$R_2 = \delta_2 / \lambda_2 = 0,25 / 0,56 = 0.45 \text{ m}^2 \cdot \text{°C}/\text{W}$$

$$R_3 = \delta_3 / \lambda_3 = 0,12 / 0,041 = 2.93 \text{ m}^2 \cdot \text{°C}/\text{W}$$

$$R_4 = \delta_4 / \lambda_4 = 0,01 / 0,52 = 0.02 \text{ m}^2 \cdot \text{°C}/\text{W}$$

2. Determine the total thermal resistance of the external wall R_0 (R_{tot}). It is the sum of the thermal resistances of the structural layers.

$$R_{tot} = R_1 + R_2 + R_3 + R_4 = 0,03 + 0,45 + 2,93 + 0,02 = 3.43 \text{ m}^2 \cdot \text{°C}/\text{W}$$

3. The construction can be used if $R_{tot.} \geq R_{req.}$

$$R_{tot.} = 3.43 \text{ m}^2 \cdot \text{°C}/\text{W} \geq R_{req.} = 3.40 \text{ m}^2 \cdot \text{°C}/\text{W}$$

Answer: This wall structure can be used as an external wall for a residential building in Moscow.

Evaluation criteria

Criterion 1 – Correct algorithm for solving the problem 0-6 points.

Criterion 2 – Correctly selected and written formulas 1-4 points.

Criterion 3 – Correctly performed calculations 1-2 points.

Construction Technology

Task 8

Entry level (2 points)

What is the weight difference between wood and concrete in terms of how many times lighter wood is?

a) 4

b) 10

c) 20

d) 50

Answer: a.

Task 9
Entry level (1 points)

What is the most important factor in assessing the stability of an earthworks structure?

- a) **soil properties**
- b) dimensions of the earthworks structure
- c) technical conditions
- d) quality of workmanship

Answer: a.

Task 10
Entry level (2 points)

What is the term for the height of a point, measured in millimeters, in relation to the level of the Baltic Sea?

- a) **absolute elevation**
- b) relative elevation
- c) coordinates of the point
- d) conditional elevation

Answer: a.

Task 11
Entry level (1 point)

How many kg of steel is required to produce 1 m³ of reinforced concrete?

- a) **100**
- b) 10
- c) 1
- d) 0.1

Answer: a.

Task 12
Intermediate level (6 points)

A barometer shows 98 696 Pa on the ground surface and 97 341 Pa on the top floor of a high-rise building. Using this data, determine the height of the building, given that atmospheric pressure decreases by 130 Pa for every 10 m ascent. Provide the answer in meters.

Answer: 100.

Task 13
Intermediate level (5 points)

The sole area of a construction worker's boot is 100 cm². If the worker weighs 100 kg, what pressure does he exert on the ground? Provide the answer in kPa.

Answer: 49.

Task 14
Advanced level (8 points)

Inside the concrete mix used to form the building foundation, air bubbles may remain, which reduces its strength and may eventually lead to cracks. Therefore, builders must compact the concrete to “squeeze out” these bubbles. The foundation of a building has the following

dimensions: length 100 m, width 20 m, height 2 m. The mass of the poured concrete is 9154 tons. Are there any bubbles in the concrete formwork? Write down the volume of these bubbles. If there are no bubbles, write 0. The density of concrete is 2300 kg/m^3 . Provide the answer in m^3 and round to the nearest integer.

Solution:

Volume of formwork: $V = 2 \cdot 20 \cdot 100 = 4000 \text{ m}^3$.

Volume of poured concrete: $V = m/\rho = 9154000/2300 = 3980 \text{ m}^3$

Volume of air bubbles: $4000 - 3980 = 20 \text{ m}^3$.

Answer: 50 m^3 .

Evaluation criteria

The solution to a complex problem is assessed as follows:

Criterion 1: The solution is thorough, encompassing all necessary reasoning, formulas, and steps to solve the problem, along with the correct numerical answer – 1-6 points.

Criterion 2: The problem is solved, and the correct numerical answer is given, but the intermediate calculations are not shown – 1 point.

Criterion 3: The solution to the problem is incorrect – 1 point.

Road Construction

Task 15

Entry level (1 points)

Depending on the classification of the terrain, choose the landscape solution most suitable for a flat plain:



- a) A
- b) B
- c) C
- d) D
- e)

Answer: a.

Task 16
Entry level (1 points)

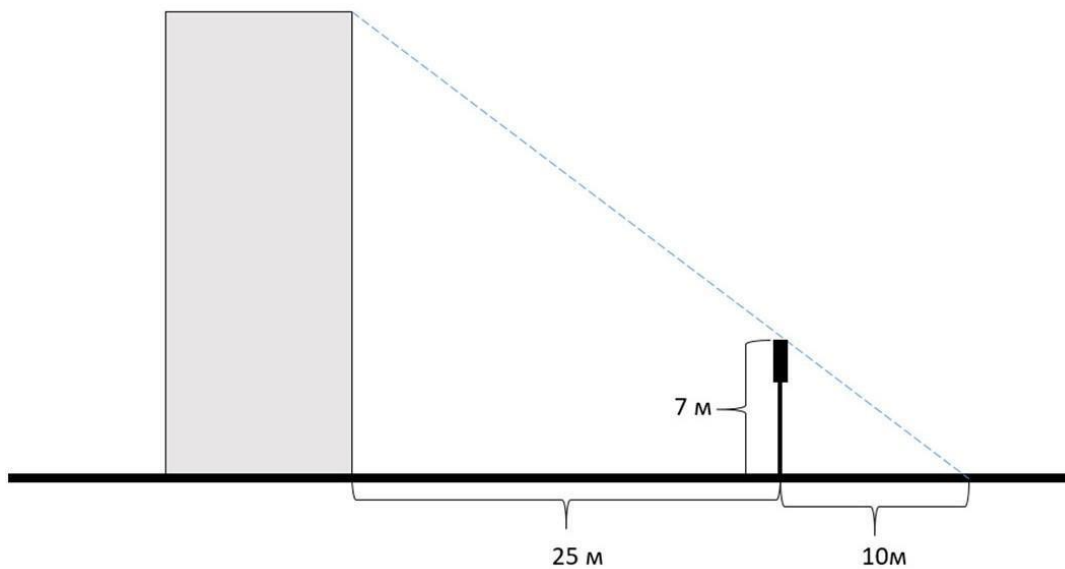
Cargo turnover is an economic measure of transportation activity, reflecting the volume of goods transported. It is calculated by multiplying the weight of the cargo moved over a specific time period by the distance it has traveled. Among the various modes of transport listed, which one accounts for the largest share of global cargo turnover?

- a) railway transport
- b) maritime transport**
- c) river transport
- d) pipeline transport

Answer: b.

Task 17
Entry level (2 points)

What is the height of the building if the length of the shadow from the street lamp is 10 m, and the distance from the building to the street lamp is 25 m, given that the height of the lamp is 7 m? Provide the answer in meters.



a) 25,0

b) 24,5

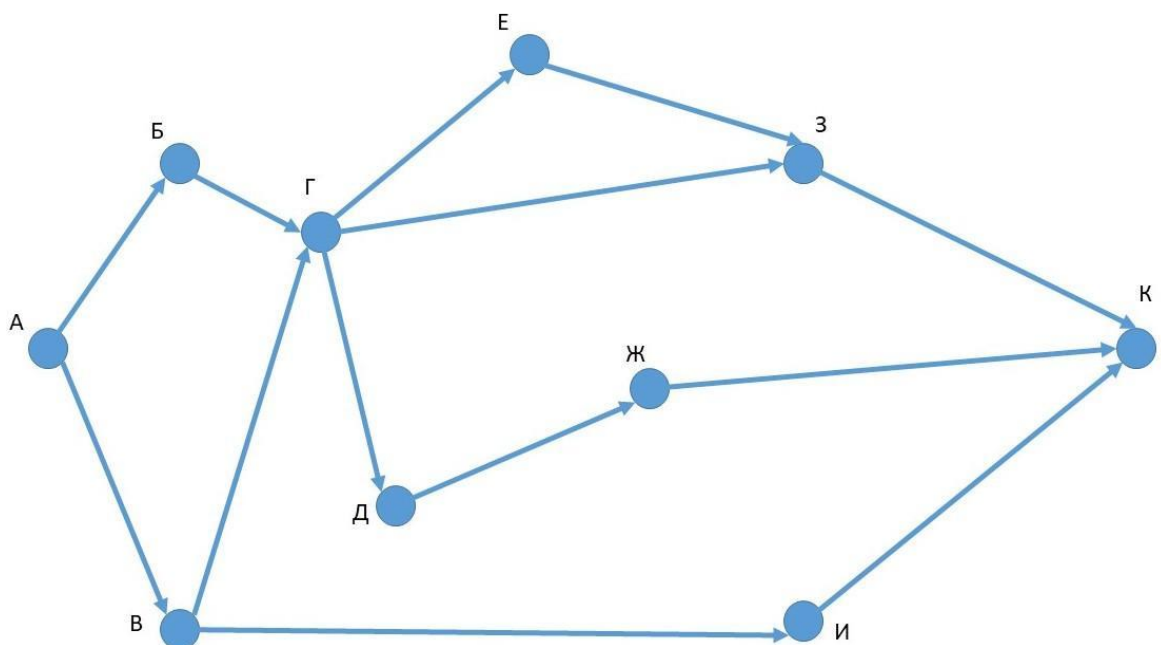
c) 24,0

d) 25,5

Answer: b.

Task 18
Entry level (2 points)

How many different paths can be laid from city A to city K?



a) 7

b) 9

c) 18

d) 14

Answer: a.

Task 19
Intermediate level (3 points)

Fill in the blank. Landscape degradation is characterized by an extreme degree of change in its _____, which results in the complete loss of its ability to perform resource-reproducing and environment-forming functions.

Answer: structure.

Task 20
Intermediate level (4 points)

Match different types of urban noise with their sources. Write down the answer as a combination of numbers and letters separated by commas. For example: 1A, 2B, 3CD.

1. Household noise
2. Urban transportation noise
3. Industrial noise

- A. Operation of household items
- B. People talking
- C. Movement of trucks
- D. Movement of people around the city and in residential buildings
- E. Movement of trams
- F. Sound alarm
- G. Operation of machines and equipment

Answer: 1ABD, 2CEF, 3G

Task 21
Advanced level (15 points)

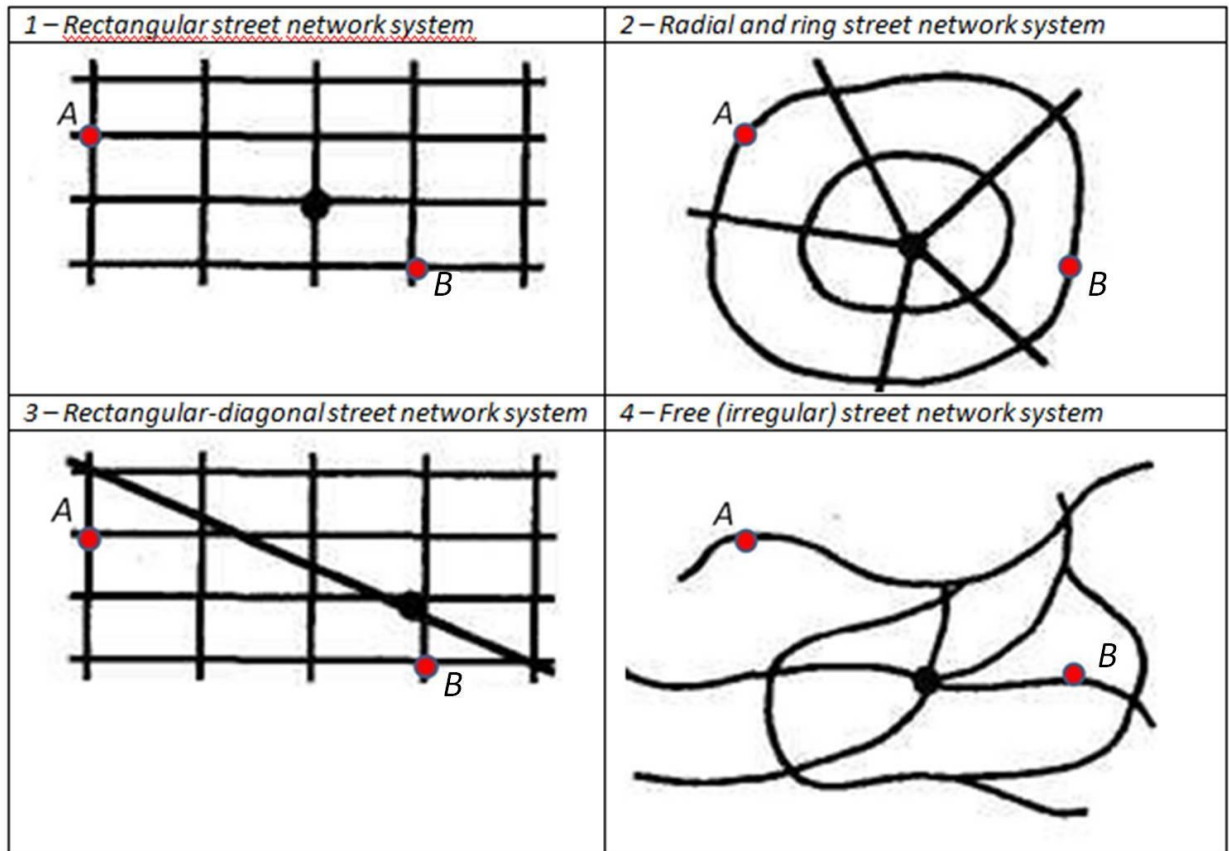
The primary task of the city's transportation planning organization is to ensure connections of all functional zones with the least amount of time and the greatest comfort. At the same time, transport networks differ in configuration and are characterized by the coefficient of non-linearity:

$$K_{nAB} = L_{\text{real}} / L_{\text{air}},$$

K_{nAB} – coefficient of non-linearity for AB

L_{real} - distance between points A and B via the city transport network,

L_{air} - the distance between points A and B in a straight line (air distance).



Question 1:

Given that all the diagrams are drawn to the same scale, and the air distance between points A and B remains consistent across them, identify which street configuration has the lowest coefficient of non-linearity. To do this, create a route from point A to point B that goes through the administrative center of the settlement (indicated by a black dot).

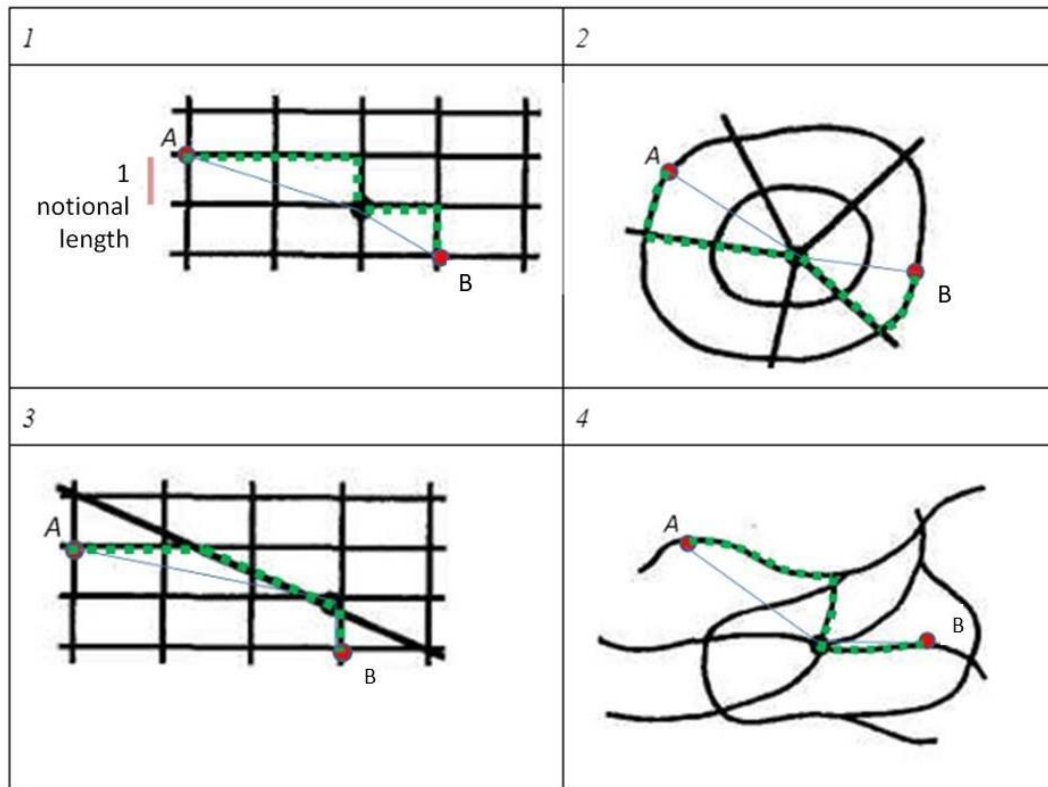
Question 2:

Using the obtained coefficients of non-linearity of the streets from the previous solution, identify which street systems have a coefficient of non-linearity less than 1.3?

Note that the evaluation will consider how you solve the task; providing only the final answer is not sufficient.

Solution:

1. Construct the paths of travel through the streets along the following route: point A - center - point B for all 4 diagrams (green dashed line).
2. Draw straight lines between the same points (A-Center-B), connecting them "by air", without considering the street configuration (blue line).



3. Calculate the length of the actual path (sum the length of all segments of the resulting path) and the aerial path (perform a similar action) in arbitrary units for all 4 diagrams. You can choose any arbitrary unit of measurement. For example, as shown in Diagram 1, the width of the street grid. You may also use a scale of a helper measuring tool, such as a ruler.

For Circuit 1:

$L_{real} = 7.1$ arb. units ; $L_{air} = 5.5$ arb. units

For Scheme 2:

$L_{real} = 8.0$ arb. units ; $L_{air} = 6.6$ arb. units

For Circuit 3:

$L_{real} = 6.4$ arb. units ; $L_{air} = 6.3$ arb. units

For Circuit 4:

$L_{real} = 7.0$ arb. units ; $L_{air} =$ arb. units

4. Using the formula, calculate the coefficients of non-linearity for all 4 diagrams:

$K_n(1) = 7,1 / 5,5 = 1,29$; $K_n(2) = 8,0 / 6,6 = 1,21$; $K_n(3) = 6,4 / 6,3 = 1,02$; $K_n(4) = 7,0 / 5,4 = 1,30$

5. Compare the values obtained and choose the variant of the diagram that corresponds to the question.

$K_n(3) < K_n(1,2,4)$ Conclusion: The rectangular-diagonal system of the street network (diagram 3) has the lowest coefficient of non-linearity.

6. Compare the obtained values of the coefficients of non-linearity with the value given in the question: $K_n < 1.3$

7.

Several values were obtained: $K_n(1,2,3) < 1,3$

Answers:

Question 1:

- a) 1
- b) 2
- c) 3
- d) 4

Question 2:

- a) 1
- b) 2
- c) 3
- d) 4

Evaluation criteria:

The solution of the complex task is assessed as follows:

Criterion 1 - "sequence of task execution":

The solution process adheres closely to the provided algorithm - 1 point.

Score range: 0-1

Criterion 2 - "correct application of the formula Calculation of the coefficients of non-linearity for each diagram: 3 points for each coefficient.

Score range: 1-12

Criterion 3 - "multiple choice" (selection of all possible answers):

All correct answers selected - 2 points. Only one correct answer selected - 0 points. Score range: 1-2.

Mechanics

Task 22

Entry level (1 point)

Which of the following formulas describes uniform rectilinear motion?

- a) $S = 5 - 2t$
- b) $V = 5 - 2t$
- c) $X = 5 - 2t$
- d) $L = 5 - 2t$

Answer: c.

Task 23

Entry level (1 point)

Hooke's law: $F = -kx$. This fundamental law in physics describes the behavior of elastic bodies during deformation. What does the minus sign in this formula mean?

- a) The sign minus (-) indicates that the elastic force does not depend on the deformation
- b) The sign minus (-) is a mathematical artifact and has no physical meaning in this context
- c) The sign minus (-) means that the elastic force is always positive.
- d) The sign minus (-) in the formula $F = -kx$ indicates that the elastic force (F) always acts in the opposite direction to the deformation (x)**

Answer: d.

Task 24
Entry level (1 point)

A carriage is moving forward along the rails and a heavy bag of coal is thrown out of the carriage from behind. How will the speed of the carriage change if its weight with the bag is 200 kg and its speed is 4 m/s, and the weight of the bag is 20 kg and is thrown with a speed of 3 m/s?

- a) It will decrease and become 3.9 m/s.
- b) It will not change.
- c) It will increase by 0.1 m/s**
- d) The carriage will stop

Answer: c.

Task 25
Intermediate level (5 points)

What is centripetal acceleration and how is it related to linear and angular velocities? Multiple answers are possible.

- a) Centripetal acceleration is the acceleration directed towards the center of the circle and arising when a body moves along the circular path. It is related to the linear velocity and radius of the circle by the formula $a_c = v^2 / R$, and to the angular velocity and radius by the formula $a_c = \omega^2 R$.**
- b) Centripetal acceleration is tangential to the radius of rotation and tends to slow down the rotation of the object along the circle
- c) Centripetal acceleration is the change in direction of velocity of a body as it moves along the circular path. It is directly proportional to the square of linear velocity and inversely proportional to the radius of the circle, and directly proportional to the square of angular velocity and the radius of the circle.**
- d) Centripetal acceleration is directed away from the center of rotation and is directly proportional to the radius and inversely proportional to the square of the speed, it tends to increase the radius of rotation and increase the speed of rotation
- e) Centripetal acceleration arises from the constant change in the direction of the velocity vector when moving along a circular path. It characterizes the “force” with which the body is “attracted” to the center of the circle and is defined by the formulas $a_c = v^2 / R$ and $a_c = \omega^2 R$.**

Answer: a, c, e.

Task 26
Intermediate level (6 points)

A material point moves along a circle of radius R with a constant tangential acceleration $a\tau$. Determine the dependence of the normal acceleration on time.

a) Determination of the linear velocity dependence on time: Since the tangential acceleration is constant, the velocity changes linearly with time: $v(t) = v_0 + a\tau * t$ where v_0 is the initial velocity.

b) Expression for the normal acceleration: The normal acceleration for circular motion is defined by the formula: $a_n(t) = v^2(t) / R$

c) Substitution of $v(t)$ into the expression for $a_n(t)$: Substitute the obtained expression for $v(t)$ into the formula for normal acceleration: $a_n(t) = (v_0 + a\tau * t)^2 / R$

d) Expansion and simplification of the expression: Expand the square of the sum in the numerator: $a_n(t) = (v_0^2 + 2v_0a\tau t + a\tau^2 t^2) / R$

Answer: c, d.

Characterization & Testing

Task 27

Entry level (1 point)

What physical property is absent in a brick?



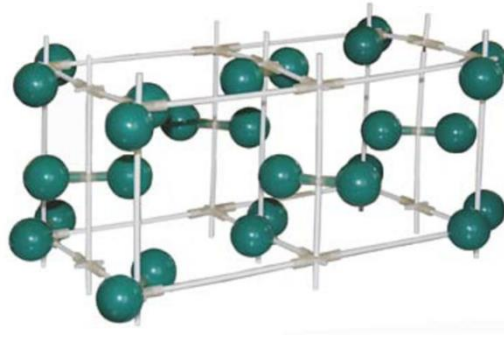
- a) Plasticity
- b) Strength
- c) Rigidity
- d) Brittleness
- e) Porosity

Answer: a.

Task 28

Entry level (1 point)

What type of crystal lattice has the properties of volatile and low melting point substances and materials? Identify its name based on the image provided.



1. Atomic
2. Ionic
3. **Molecular**
4. Metallic

Answer: c.

Task 29
Entry level (2 points)

What is the consequence of exposure of metal structures to climatic conditions and environment?

1. Abundant precipitation
2. **Corrosion**
3. Warping
4. Wind patterns

Answer: b.

Task 30
Intermediate level (4 points)

How is soluble (liquid) glass used in construction?

- a) As an additional material
- b) As a main material
- c) **As an additive for concrete hardening**
- d) **As an impregnator for soil foundations**
- e) As a loosening agent
- f) **As a material to increase elasticity and strength of a substance**

Answer: c, d, f.

Task 31
Intermediate level (3 points)

Fill in the blank. Materials derived from natural raw materials through intricate physicochemical processes that alter their original composition and structure are categorized asmaterials.

Answer: artificial.