

## Earth and Environmental Sciences: Second-round Sample Tasks for the Open Doors Master's and Doctoral Track

This sample test comprises 44 tasks, including: 27 entry-level tasks with a single correct answer, each correct answer assigned 1 to 3 points; 13 intermediate-level tasks with multiple correct answers, each correct answer is assigned 3 points; 4 advanced-level tasks requiring a detailed answer, each answer is assigned 9 to 10 points, depending on its correctness and completeness. For advanced-level tasks requiring a detailed answer, assessment criteria and a standard answer are provided.

### Field of Science 1. Water Resources

#### Task 1

##### Entry level (1 point)

What will happen to the water level in a vessel when ice, which is less dense than water, floats on the surface and melts?

- a) It will increase.
- b) It will decrease.
- c) It will not change.
- d) It will first decrease and then increase.

**Answer:** c.

#### Task 2

##### Entry level (1 point)

Choose ONE answer to complete the sentence: “The composition of municipal wastewater differs from runoff because it contains...”

- a) a greater amounts of suspended solids
- b) surfactants
- c) a larger amounts of microflora
- d) salts and minerals

**Answer:** c.

#### Task 3

##### Entry level (1 point)

Choose ONE answer to complete the sentence: “The UV spectroscopy method is used to determine the concentration of pollutants and is based on the measurement of...”:

- a) excitation spectrum.
- b) optical density.
- c) atomic spectrum.
- d) radiation waves.

**Answer:** b.

**Task 4**  
**Intermediate level (3 points)**

Scientific studies have confirmed the existence of “water memory” associated with the formation of clathrate hydrates. Which TWO factors play a key role in the formation of these structures? Select TWO answers:

- a) The ability of water to dissolve salts
- b) Polarity of water molecules
- c) The presence of a covalent bond in a molecule
- d) Formation of hydrogen bonds between molecules
- e) Dimensions of a water molecule
- f) Flat molecular structure

**Answer:** b, d.

**Field of Science 2. Geology**

**Task 1**  
**Entry level (1 point)**

What of the following types of rocks exist?

- a) Igneous, sedimentary, and metamorphic
- b) Volcanic, clastic, and crystalline
- c) Stratified, folded, and faulted
- d) Effusive, intrusive, and extrusive

**Answer:** a.

**Task 2**  
**Entry level (1 point)**

Which of the following processes are classified as geodynamic?

- a) Movement of lithospheric plates, earthquakes, volcanism
- b) Formation of rocks, relief formation
- c) Change in the chemical composition of the atmosphere
- d) Sedimentation

**Answer:** a.

**Task 3**  
**Entry level (1 point)**

Which rock contains a mineral consisting of calcium carbonate ( $\text{CaCO}_3$ )?

- a) Granite
- b) Basalt
- c) Limestone
- d) Labradorite

**Answer:** c.

**Task 4**  
**Intermediate level (3 points)**

Which TWO rocks can contain organic remains?

- a) Limestone
- b) Basalt
- c) Marble
- d) Granite
- e) Argillite
- f) Gabbro

**Answer:** a, e.

**Task 5**  
**Intermediate level (3 points)**

Which TWO of the following methods are associated with relative geochronology?

- a) Steno's principle
- b) Rubidium-strontium dating
- c) Potassium-argon dating
- d) Radiocarbon dating
- e) Uranium–lead dating
- f) Biostratigraphic method

**Answer:** c, e.

**Field of Science 3. Geochemistry and Geophysics**

**Task 1**  
**Entry level (1 point)**

Identify the primary constituent of Mars' atmosphere.

- a) CO<sub>2</sub>
- b) CO
- c) H<sub>2</sub>O
- d) Xe

**Answer:** a.

**Task 2**  
**Entry level (1 point)**

Which term describes the ability of atoms in a molecule to attract electrons?

- a) Electron affinity
- b) Electrical conductivity

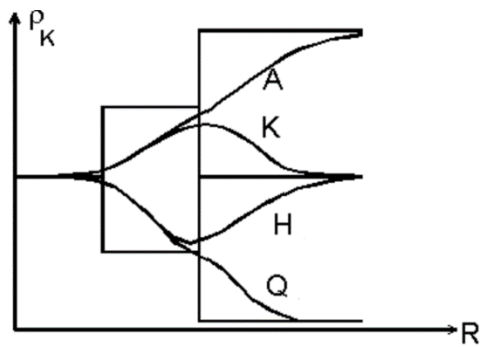
- c) Conductivity
- d) Electronegativity

**Answer:** d.

**Task 3**  
**Entry level (1 point)**

Which layer resistance ratio corresponds to a type Q curve?

- a)  $\rho_1 < \rho_2 < \rho_3$
- b)  $\rho_1 < \rho_2 > \rho_3$
- c)  $\rho_1 > \rho_2 < \rho_3$
- d)  $\rho_1 > \rho_2 > \rho_3$



**Answer:** d.

**Task 4**  
**Intermediate level (3 points)**

Which TWO nuclear reactions are classified as exothermic?

- a) Fission of heavy nuclei by neutrons
- b) Fission of virtual particles
- c) Formation of molecules
- d) Formation of virtual particles
- e) Elastic scattering
- f) Synthesis of light nuclei

**Answer:** a, f.

**Task 5**  
**Intermediate level (3 points)**

Select TWO main formats of seismic data storage:

- a) SEG-B
- b) SEG-C
- c) SEG-D
- d) SEG-X
- e) SEG-Y

f) SEG-Z

**Answer:** c, e.

## **Field of Science 4. Meteorology and Atmosphere Science**

### **Task 1**

#### **Entry level (1 point)**

Which climate zone is characterized by a hot and humid climate throughout the year?

- a) Equatorial
- b) Tropical
- c) Temperate
- d) Arctic

**Answer:** a.

### **Task 2**

#### **Entry level (1 point)**

In which climate zones is Pakistan situated?

- a) Tropical to equatorial
- b) Arctic to subtropical
- c) Antarctic to tropical
- d) Subtropical to temperate

**Answer:** d.

### **Task 3**

#### **Entry level (1 point)**

Which term refers to the atmospheric layer that forms the boundary between the stratosphere and the mesosphere?

- a) Karman line
- b) Exobase
- c) Stratopause
- d) Mohorovičić discontinuity

**Answer:** c.

### **Task 4**

#### **Intermediate level (3 points)**

Which of the following are not classified as an atmospheric phenomenon? Select all that apply.

- a) Thunderstorm
- b) Aurora
- c) Wind speed

- d) Squall
- e) Drought
- f) Landslide

**Answer:** c, f.

### Task 5 Advanced level (8 points)

Explain why mercury is preferred over water in liquid barometers. Provide a detailed justification outlining the selection of mercury and the advantages it holds over water. Your response should address the relevant physical and chemical properties that make mercury suitable for this application.

**Note:** A complete solution must include your method and reasoning. Providing the final answer alone will not suffice.

#### **Solution**

The size of a barometer depends on the density of the liquid it contains. The greater the density of the barometric liquid, the smaller the dimensions of the device. Mercury, with a density of  $13,595.1 \text{ kg/m}^3$  at  $0^\circ\text{C}$ —approximately 13.5 times that of water—has one of the highest natural liquid densities. As a result, barometers using mercury are more compact in size.

**Answer:** As mercury has a much higher density than water, it allows for a more compact barometer design.

#### **Assessment criteria**

1. Providing the reasons for choosing mercury and its density relative to water (up to 4 points):
  - demonstrating a clear understanding of the choice of mercury over water in liquid barometers;
  - emphasizing the importance of mercury's higher density ( $13.6 \text{ g/cm}^3$ ) compared to water ( $1 \text{ g/cm}^3$ ), explaining how this difference influences the barometer's design and effectiveness.
2. Logical justification for the choice of mercury (up to 4 points):
  - coherent and logical explanation for selecting mercury, focusing on its physical properties.
  - discussion of mercury's advantages—such as low vapor pressure, non-wetting characteristics, and wide liquid temperature range—and connection of these properties to their practical benefits in barometric measurements.

## Field of Science 5. Mineralogy

### Task 1 Entry level (1 point)

Which of the following is a mica?

- a) Olivine
- b) Quartz
- c) Halite
- d) Muscovite

**Answer:** d.

**Task 2**  
**Entry level (1 point)**

Which rock is characteristic of local metamorphism?

- a) Hornfels
- b) Cataclasite
- c) Magnesian skarn
- d) Green shale

**Answer:** a.

**Task 3**  
**Entry level (1 point)**

Which of the following is a rock-forming mineral for andesite?

- a) Fluorite
- b) Calcite
- c) Plagioclase
- d) Olivine

**Answer:** c.

**Task 4**  
**Intermediate level (3 points)**

Which TWO minerals are part of the upper mantle?

- a) Olivine
- b) Goethite
- c) Kaolinite
- d) Zeolite
- e) Clinopyroxene
- f) Hornblende

**Answer:** a, e.

**Field of Science 6. Environmental Sciences**

**Task 1**  
**Entry level (1 point)**

Choose ONE answer to complete the sentence: “The first aerial remote sensing photograph was taken...”.

- a) from an airplane.
- b) from a hang glider.
- c) from a balloon.
- d) from a satellite.

**Answer:** c.

**Task 2**  
**Entry level (1 point)**

What is selective scattering?

- a) Light scattering that occurs when the particle size is significantly smaller than the wavelength of radiation.
- b) Coherent light scattering without a change in the wavelength of particles.
- c) Scattering of light with changes in wavelength.
- d) Light scattering that occurs when the particle size is significantly larger than the wavelength of radiation.

**Answer:** d.

**Task 3**  
**Entry level (1 point)**

What are the main functions of a GIS?

- a) Collection, storage, analysis, and visualization of spatial information
- b) Studying the surface of the Earth with the help of radio waves
- c) Studying natural resources using aerial photography
- d) Obtaining data about objects using reflected sunlight

**Answer:** a.

**Task 4**  
**Intermediate level (3 points)**

Which techniques are used to represent quantitative characteristics on a map?

- a) Geometric figures
- b) Number of icons
- c) Size of icons.
- d) Line thickness
- e) Numbers
- f) Quantitative characteristics are not represented on maps

**Answer:** c, d.

**Field of Science 6. Physical Geography**

**Task 1**  
**Entry level (1 point)**

Which lake is described in the text below?

“This lake is a remnant of an ancient sea basin. Its shallow waters are thoroughly mixed by wind, leading to oxygen saturation and the suspension of silty bottom particles. These conditions promote the development of fauna.”

- a) Balaton
- b) Baikal
- c) Caspian
- d) Lake Onega

**Answer:** c.

**Task 2**  
**Entry level (1 point)**

What is a facies as an element of the landscape?

- a) An element of the landscape defined by a specific set of natural conditions.
- b) The fundamental unit within the structure of a geographical landscape, defined by the highest degree of uniformity in natural conditions.
- c) The highest level in the hierarchy of a geographical landscape, characterized by the broadest representation of typical natural conditions.
- d) The most basic level in the hierarchy of a geographical landscape, characterized by the highest degree of typical natural conditions.

**Answer:** b.

**Task 3**  
**Entry level (1 points)**

Which of the following map types exist?

- a) Political maps
- b) Physical maps
- c) Geological maps
- d) All of the above

**Answer:** d.

**Task 4**  
**Intermediate level (3 points)**

Which TWO animals inhabit South America?

- a) Wombat and echidna
- b) Hamadryas baboon and hyrax
- c) Kinkajou and sloth

- d) Sloth bear and macaque
- e) Shoebill and giraffe
- f) Hoatzin and llama

**Answer:** c, f.

**Task 5**  
**Intermediate level (3 points)**

Which of the following are the definitions of map scale? Select all that apply.

- a) The ratio of the length of a line on a map to the length of the corresponding line on the ground
- b) Map legend
- c) The degree to which an image on a map is diminished
- d) Width of an object on a map
- e) Distance between objects on a map
- f) Length of a line on a map

**Answer:** a, c.

**Task 6**  
**Advanced level (8 points)**

Describe the pseudocylindrical projection according to the following criteria: characteristics of distortions, type of projection grid, and its primary uses.

**Note:** A complete solution must include your method and reasoning. Providing the final answer alone will not suffice.

**Solution**

Pseudocylindrical projections are categorized based on the nature of distortions into equal-area and arbitrary types. These projections are not equidistant, and they do not preserve lengths along meridians. In the normal projection grid, the parallels are straight, parallel lines, while the central meridian is a line perpendicular to the parallels. The remaining meridians are either broken lines or curves that are symmetrical relative to the central meridian. Pseudocylindrical projections are commonly used for world maps and maps of the Pacific Ocean.

**Answer:**

- 1) Types: equal-area and arbitrary projections;
- 2) They cannot be equidistant;
- 3) Type of projection map grid: the parallels of the normal grid are parallel lines; the middle meridian is a line perpendicular to the parallels; the remaining meridians are broken lines or curves symmetrical about the middle meridian.
- 4) Using: maps of the world and the Pacific Ocean

**Assessment criteria**

The types of pseudocylindrical projections are correct – 4 points.

The type of projection map grid is correct – 2 points.

Correct identification of the type of maps pseudocylindrical projections are used for – 2 points.

**Field of Science 7. Ecology**

**Entry level (1 point)**

Choose ONE answer and continue the sentence: “The vertical structure of communities is determined by...”.

- a) Layering of vegetation cover
- b) The size of adults
- c) Location on vertical surfaces
- d) Helio- and geotropism of individuals

**Answer:** a.

**Task 2**  
**Entry level (1 point)**

What is the name of the transition zone between the two communities?

- a) Ecotone
- b) Ecocline
- c) Ecotope
- d) Coenocline

**Answer:** a.

**Task 3**  
**Entry level (1 point)**

What level of biological diversity is alpha diversity?

- a) Genetic
- b) Ecosystem
- c) Biome
- d) Species

**Answer:** d.

**Task 4**  
**Intermediate level (3 points)**

Which TWO cycles are of the sedimentary type?

- a) Hydrogen cycle
- b) Nitrogen cycle
- c) Oxygen cycle
- d) Phosphorus cycle
- e) Carbon cycle
- f) Sulfur cycle

**Answer:** d, e.

### Task 5

#### Advanced level (8 points)

Water treatment of drinking water involves several stages depending on the source and intended use. Propose a water treatment procedure for water sourced from a surface body (river, reservoir storage) intended for municipal water supply.

**Note:** A complete solution must include your method and reasoning. Providing the final answer alone will not suffice.

#### Solution

Water drawn from surface sources contains various mechanical impurities, dissolved gases, bacteria, viruses, salts, heavy metals, and other substances. To make it safe for consumption, water must undergo purification to enhance its quality. When taken from a surface source, the treatment process should include several stages [1]:

1. Mechanical purification (sedimentation and/or filtration process);
2. Softening (in the case of hard water; ion-exchange resins replace Ca and Mg ions with Na ions);
3. Removal of heavy metal ions, salts, and other chemical compounds;
4. Clarification and odorization (removal of foreign odors);
5. Disinfection.

Clarification, odor removal, and elimination of heavy metal ions are achieved through a complex fine water purification system involving microfiltration, sorption on activated carbon, membranes, and/or electrochemical methods. Disinfection in the water supply system is carried out through reagent treatment with chlorine or by UV irradiation.

#### Reference:

1. Drinan J.E., Spellman F. Water and Wastewater Treatment: A Guide for the Nonengineering Professional. 2<sup>nd</sup> Edition. CRC Press, 2012.

#### Assessment criteria

Stages of water treatment are accurately identified (4 points).

Appropriate methods used at each stage are correctly described (4 points).

### Field of Science 8. Mining and Mineral Processing

#### Entry level (1 point)

The collar of a vertical exploration well is situated at an elevation of 733 meters above sea level. The well has a depth of 834 meters. Determine the absolute elevation of the well bottom.

- a) 1567 m
- b) The data are insufficient to solve the task.
- c) -101 m
- d) 101 m

**Answer:** c.

### Task 2

#### Entry level (1 point)

Which of the listed models consists of points and line segments connecting them?

- a) Block model
- b) Statistical model
- c) Wireframe model
- d) Vector model

**Answer:** c.

### **Task 3**

#### **Entry level (1 point)**

Which of the following is the definition of the skin factor in a well?

- a) A hydrodynamic parameter that characterizes additional filtration resistance to fluid flow in the near-wellbore zone of a formation.
- b) A characteristic of downhole equipment operation as water cut increases during production.
- c) A characteristic of fluid flow between formations within the well.
- d) A thermodynamic parameter reflecting formation cooling during operation.

**Answer:** a.

### **Task 4**

#### **Intermediate level (3 points)**

In which TWO ways do surfactants affect the deposit?

- a) Alteration in surface tension at the oil–water interface
- b) Enhancement of the rock's hydrophilicity
- c) Variation in water viscosity
- d) Modification in rock permeability
- e) Alteration in oil viscosity
- f) Enhancement of the rock's hydrophobicity

**Answer:** a, b.

### **Task 5**

#### **Intermediate level (3 points)**

Which TWO of the following statements are correct?

- a) Wireframe models are primarily used for mine planning within mining and geological information systems.
- b) A wireframe model cannot be created without an existing block model.
- c) In mining and geological information systems, a block model is represented as a collection of points with associated attributes.
- d) Ore bodies are typically contoured in sections to construct wireframe models.
- e) A block model may exclusively store information on the concentration of a valuable component.
- f) The quantity of mineral resources delineated by a wireframe model is always greater than that indicated by a block model constructed within the same wireframe.

**Answer:** c, d.

**Task 6**  
**Advanced level (10 points)**

During deposit exploration, borehole drilling uses a fluid with a density of 1100 kg/m<sup>3</sup>, composed of technical water and bentonite clay. Upon encountering Cretaceous rocks, the fluid density must be increased to 1250 kg/m<sup>3</sup> by adding dolomite. The total volume of the weighted fluid required is 160 m<sup>3</sup>. Calculate the volumes of bentonite clay, dolomite, and water needed to prepare 160 m<sup>3</sup> of the weighted drilling fluid. Provide each answer in the format XX.XX m<sup>3</sup>. The required data for the calculations are provided in Table 1.

Table 1. Densities of Drilling Fluid Components

Component	Density, kg/m <sup>3</sup>
Technical water	1002
Bentonite clay	1780
Dolomite	2800

Calculation formulas:

$$\rho_{\text{component}} = \frac{m_{\text{component}}}{V_{\text{component}}}$$

$$m_{\text{component}} = \frac{\rho_{\text{component}} \cdot (\rho_{\text{liquidmixedwithcomponent}} - \rho_{\text{liquid}})}{\rho_{\text{component}} - \rho_{\text{liquid}}}$$

**Note:** A complete solution must include your method and reasoning. Providing the final answer alone will not suffice.

**Solution**

1. The amount of bentonite clay to prepare 1 cubic meter of the drilling fluid is:

$$q_{\text{clay}} = \frac{\rho_{\text{clay}} \cdot (\rho_{\text{drillingfluid}} - \rho_{\text{water}})}{\rho_{\text{clay}} - \rho_{\text{water}}} = \frac{1780 \cdot (1100 - 1002)}{1780 - 1002} = 224.2 \text{ kg}$$

The volume of bentonite clay in 1 cubic meter of drilling fluid is described by the expression.

$$V_{\text{clay}} = \frac{q_{\text{clay}}}{\rho_{\text{clay}}} = \frac{224.2}{1780} = 0.126 \text{ m}^3$$

To prepare 160 cubic meters of weighted drilling fluid, the **required volume of clay** is:

$$V_{\text{clay}}^{160\text{m}^3} = V_{\text{clay}} \cdot 160 = 0.126 \cdot 160 = 20.16 \text{ m}^3$$

**(4 points)**

2. The amount of dolomite required to increase the drilling fluid density from 1100 kg/m<sup>3</sup> to 1250 kg/m<sup>3</sup> is calculated as follows:

$$q_{\text{dolomite}} = \frac{\rho_{\text{dolomite}} \cdot (\rho_{\text{weighdrillingfluid}} - \rho_{\text{drillingfluid}})}{\rho_{\text{dolomite}} - \rho_{\text{weighdrillingfluid}}} = \frac{2800 \cdot (1250 - 1100)}{2800 - 1250} = 271.0 \text{ kg}$$

The volume of dolomite in 1 cubic meter of the weighted drilling fluid is:

$$V_{\text{dolomite}} = \frac{q_{\text{dolomite}}}{\rho_{\text{dolomite}}} = \frac{271.0}{2800} = 0.097 \text{ m}^3$$

Therefore, to prepare 160 cubic meters of weighted drilling fluid, the **required volume of dolomite** is:

$$V_{\text{dolomite}}^{160\text{m}^3} = V_{\text{dolomite}} \cdot 160 = 0.097 \cdot 160 = 15.52\text{m}^3$$

**(4 points)**

3. The **required volume of water** in the weighted drilling fluid is described by the expression:

$$V_{\text{water}}^{160\text{m}^3} = V_{\text{weighdrillingfluid}} - V_{\text{clay}}^{160\text{m}^3} - V_{\text{dolomite}}^{160\text{m}^3} = 160 - 20.16 - 15.52 = 124.32\text{m}^3$$

**(2 points)****Answer:**

$$V_{\text{clay}}^{160\text{m}^3} = 20.16\text{m}^3$$

$$V_{\text{dolomite}}^{160\text{m}^3} = 15.52\text{m}^3$$

$$V_{\text{water}}^{160\text{m}^3} = 124.32\text{m}^3$$

**Assessment criteria**

1. The amount of bentonite clay required to prepare 160 cubic meters of weighted drilling fluid is calculated correctly (4 points).
2. The amount of dolomite needed to prepare 160 cubic meters of weighted drilling fluid is calculated correctly (4 points).
3. The volume of water in the weighted drilling fluid is calculated correctly (2 points).