Engineering and Technology: Second-round Sample Tasks for the Open Doors Bachelor's Track

This sample test comprises 45 tasks, including 28 entry-level tasks with a single correct answer (each correct answer is assigned 1 point), 13 intermediate-level tasks with multiple correct answers (the correct answer is assigned 3 points), and 4 advanced-level tasks requiring a detailed answer (the correct answer is assigned 8-9 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. Automation and Control Systems

Task 1
Entry level (1 point)

Which factor affects the dynamic characteristics of the system?
a) Ambient temperature
b) Mass of the control object
c) Acceleration
d) All of the above
Answer: d

Task 2
Entry level (1 point)

Solve the equation $\sin(2\pi x) = 0.5$.
a)   1/12 and 5/12
b)   12/5 and 12
c)   7/12 and 5
d)   1/12 and 7/12
Answer: a

Task 3
Entry level (1 point)

Three numbers are given in different number systems: 12_{16}, 14_8, 11100_2.
Find the maximum number in decimal notation.

a)   28
b)   12
c)   18
d)   16
Answer: a

Task 4
Entry level (1 point)

What is the probability that an automated system is working correctly if the probability of error is 5%?
a)   0.5
b)   0.45
c)   0.95
d)   0.05
Answer: c

Task 5
Intermediate level (3 points)

Select examples of automation in manufacturing.

a) Welding of parts by an operator
b) Printing documents using a printer
c) Harvesting crops by farmers
d) Packaging of goods using robotic systems
e) Coloring of products by an operator
f) Use of programmable logic controllers in the process control system
Answer: d, f

Task 6
Intermediate level (3 points)

What methods allow for automated real-time monitoring of equipment status?
Select all that apply.

a) Calendar plan
b) Inspection reports on the external condition of the equipment
c) Predictive maintenance
d) Weekly photographic records
e) Daily inspection of the equipment by a specialist
f) Utilization of various sensors
Answer: c, f

Field of Science 2. Robotics

Task 7
Entry level (1 point)

What is a servo?
a) A device for measuring temperature
b) A device for transmitting data
c) A device for storing data
d) A device for motion control
Answer: d

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Task 8
Entry level (1 point)

What is the device used to determine the orientation and angular movement of an object?
a) Gyroscope
b) Ultrasonic sensor
c) Color sensor
d) Temperature sensor
Answer: a

Task 9
Entry level (1 point)

What is the smallest nonnegative integer A, for which the expression (x + 2y < A) OR (y > x) OR (x > 30) evaluates to 1 for any nonnegative integers x and y?
a)　　43
b)　　91
c)　　11
d)　　14
Answer: b

Task 10
Entry level (1 point)

A natural number N is given as input to an algorithm, which computes a new number R according to the following algorithm:
1. A binary representation of N is constructed.
2. Two additional binary digits are appended to the right of this representation using the procedure described as follows:
a) The sum of the digits in the binary representation of N is calculated, and the remainder of this sum divided by 2 is appended to the end of the binary string. For example, the binary string 11100 becomes 111001.
b) The same operation is repeated on a new string: the sum of its digits is computed, and the remainder when divided by 2 is appended to the right.
The resulting binary string represents the number R.

Select from the given options the smallest number R (in decimal notation) that exceeds 97 and could result from this algorithm.

a)　　233
b)　　102
c)　　640
d)　　201
Answer: b

Task 11
Entry level (1 point)

Select the incorrect equation from the list below:

a) $\sin^2(x) + \cos^2(x) = 1$
b) $\tan(x) = \sin(x)/\cos(x)$
c) $\sin(90^0 - x) = \cos(x)$
d) $\sin(x + y) = \sin(x) + \sin(y)$

Answer: d

Task 12
Intermediate level (3 points)

The points A (1; -1; 1), B (3; 4; -1), C (3; -2; -3), D (5; 3; -5) are given.
Determine the geometric relationship between vectors CA and BD.
Select all that apply.

a) **linearly dependent**
b) orthogonal
c) equal in modulus
d) **opposite**
e) There is no correct answer
Answer: a, d

Field of Science 3. Telecommunications

Task 13
Entry level (1 point)

An event that may or may not occur as a result of some test/experience is called ....
a) reliable
b) random
c) possible
d) probable
Answer: b

Task 14
Entry level (1 point)

A system administrator oversees three servers. The likelihood that each server will need the administrator's attention within an hour is 0.1 for the first server, 0.2 for the second, and 0.15 for the third. Determine the probability that at least one of the servers will require the administrator's attention within that hour.

a)   93.5 %

b)   82.5 %
c)   61.2 %
d)   38.8 %

Answer: d

Task 15
Entry level (1 point)

Which expression corresponds to F in the truth table?

X	Y	Z	F
0	1	1	0
1	1	1	1
0	0	1	1

a)   X & ¬Y & ¬Z
b)   ¬X & ¬Y & Z
c)   ¬X v ¬Y v Z
d)   X v ¬Y v ¬Z

Answer: d

Task 16
Intermediate level (3 points)

Select all formulas that can be used to calculate conditional probability:

a)   P(A/B) = P(A) / P(B)
b)   P(B/A) = P(B) / P(A)
c)   P(A/ B) = P(A·B) / P(B)
d)   P(B/A) = P(A·B) / P(A)
e)   P(A/B) = P(A) – P(B)
f)   P(B/A) = P(B) – P(A)
g)   P(A/B) = P(A) – P(B) + P(A·B)
h)   P(B/A) = P(B) – P(A) + P(B·A)

Answer: c, d

Task 17
Intermediate level (3 points)

Consider the logical expression: A = (X AND Y) OR (Z AND NOT W), where: X, Y, Z, W are logical variables that can take the values "true" (1) or "false" (0).
Select all combinations of variable values for which A = 1.

a)   X = 1, Y = 1, Z = 0, W = 0

b)   X = 0, Y = 1, Z = 1, W = 1
c)   X = 1, Y = 0, Z = 1, W = 0
d)   X = 0, Y = 0, Z = 0, W = 1
e)   X = 1, Y = 1, Z = 1, W = 1
f)   X = 1, Y = 0, Z = 0, W = 0

Answer: a, c, e

**Field of Science 4. Electrical and Electronic Engineering**

Task 18
Entry level (1 point)

Determine the electric field intensity E given that a point charge q = 15 nC experiences a force F = 3 mN.

a)   45 V/m
b)   0.2 MV/m
c)   0.2 V/m
d)   5 V/m

Answer: b

Task 19
Entry level (1 point)

A graph of the current in the inductor with L = 30 mH is shown in the figure. Determine the maximum modulo value of self-induction EMF over a period of 40 ms.
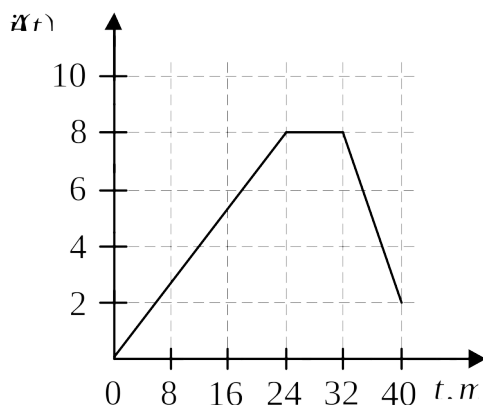
a)   30 V
b)   10 V
c)   10 mV
d)   22.5 V

Answer: d

Task 20
Entry level (1 point)

Determine the voltage U applied across a conductor and the power P it consumes, given that the current through the conductor is I = 2 A and its resistance is R = 15 Ohm.

a)   U = 30 V, P = 60 J
b)   U = 0.133 V, P = 60 W
c)   U = 60 V, P = 30 W
d)   U = 30 V, P = 60 W

Answer: d

Task 21
Entry level (1 point)

Two fixed point charges q1 = 10 nC and q2 = 15 nC are located at a distance of r = 60 cm from each other. Determine the electric field intensity E at point A located midway between the charges. The medium is vacuum.

a) 500 V
b) **500 V/m**
c) 0 V/m
d) 2500 V/m

Answer: b
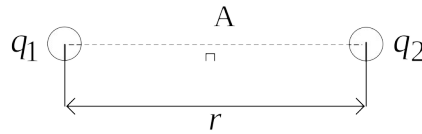
Task 22
Intermediate level (3 points)

Two series-connected capacitors with electrical capacities C1 = 2 µF and C2 = 4 µF are connected to a DC voltage source with U = 120 V. Determine the voltage of each capacitor. Assume that the capacitors were not charged before.

a)   U1 = 40 V
b)   U1 = 60 V
c)   U1 = 80 V
d)   U1 = 120 V
e)   U2 = 40 V
f)   U2 = 60 V
g)   U2 = 80 V
h)   U2 = 120 V
Answer: c, e.

Task 23
Intermediate level (3 points)

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Determine the potential and intensity of the electric field at point A, lying in the middle between two point fixed charges q1 = q2 = 100 nC located at a distance r = 80 cm in vacuum.

a) φA = 2250 V
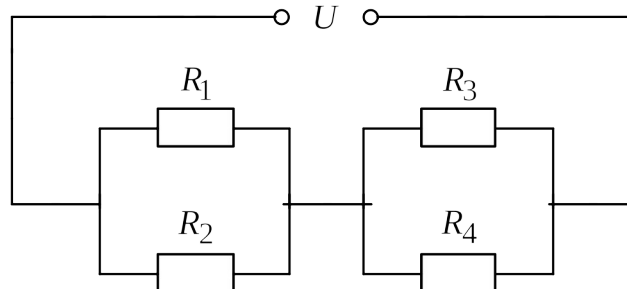b) φA = 0 V
c) φA = 4500 V
d) φA = 4500 mV
e)   E = 0 V
f)   E = 0 V/m
g)   E = 5625 V/m
h)   E = 11250 V/m
Answer: c, f

Task 24
Advanced level (8 points)

Four conductors with resistances R1 = 1 Ohm, R2 = 2 Ohm, R3 = 2 Ohm, R4 = 4 Ohm are connected to a network with a voltage of U = 60 V. Determine the current through each conductor.

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

Solution
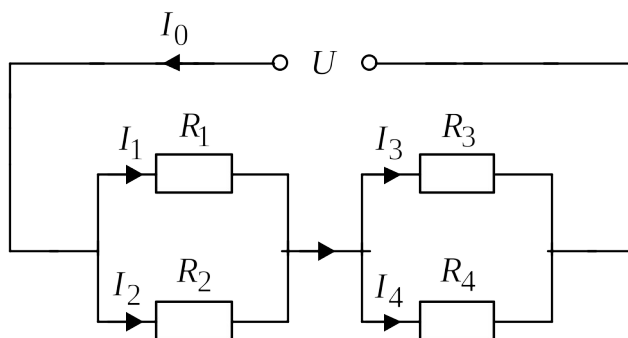
Determine the total resistance of the entire circuit:

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R0 = R1*R2 / (R1+R2) + R3*R4 / (R3+R4) = 2/3 + 4/3 = 2 Ohm;
According to Ohm's law, we determine the total current in the circuit:
 I0 = U / R0 = 60 / 2 = 30 A;
Elements R1 and R2 are connected in parallel, so U1 = U2 = U12;
Elements R3 and R4 are connected in parallel, so U3 = U4 = U34;
R12 = R1*R2 / (R1+R2) = 2/3 Ohm;
R34 = R3*R4 / (R3+R4) = 4/3 Ohm;
U12 = I0*R12 = 30*2/3 = 20 V;
U34 = I0*R34 = 30*4/3 = 40 V;
According to Ohm's law for a section of the circuit:
I1 = U1 / R1 = 20 / 1 = 20 A;
I2 = U2 / R2 = 20 / 2 = 10 A;
I3 = U3 / R3 = 40 / 2 = 20 A;
I4 = U4 / R4 = 40 / 4 = 10 A.

Answer: I1 = 20 A; I2 = 10 A; I3 = 20 A; I4 = 10 A.

Assessment criteria

Criterion 1 (3 points): The formula for total resistance is correctly stated, and the total resistance of the circuit is accurately calculated.
Criterion 2 (3 points): The total current through the circuit is correctly determined using appropriate laws and calculations.
Criterion 3 (2 points): The individual currents through each conductor are accurately calculated and correctly justified based on the circuit configuration.

Field of Science 5. Mechanical Engineering

Task 25
Entry level (1 point)
Solve the equation: $((6.25x) + 11)^2 = (6.25x + 9)^2$.
a)   -1.8
b)   -1.6
c)   1.6
d)   1.8
e)   the equation has no solution
Answer: b

Task 26
Entry level (1 point)
A block with a mass of M = 300 g is connected to a load with a mass of m = 200 g by a weightless and inextensible thread thrown over a weightless block (see figure). The block slides without friction along a stationary inclined plane that forms an angle of 30° with the horizon. Determine the acceleration of load m.

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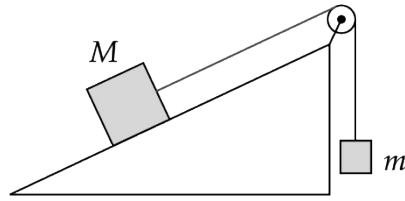
a)   **1 m/s^2**
b)   2 m/s^2
c)   3 m/s^2
d)   4 m/s^2
e)   5 m/s^2

Answer: a

Task 27
Entry level (1 point)

A heat engine performs 20 J of work in one cycle and releases 80 J of heat to the refrigerator. The temperature of the heater of the engine is 600 K, and the temperature of the refrigerator is 300 K.

How many times greater is the efficiency of an ideal heat engine operating at the same temperatures of the heater and refrigerator compared to the efficiency of the given heat engine?
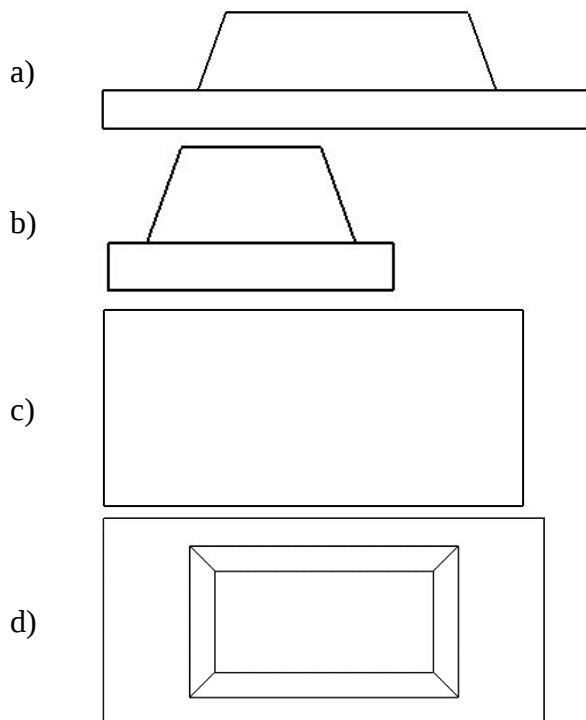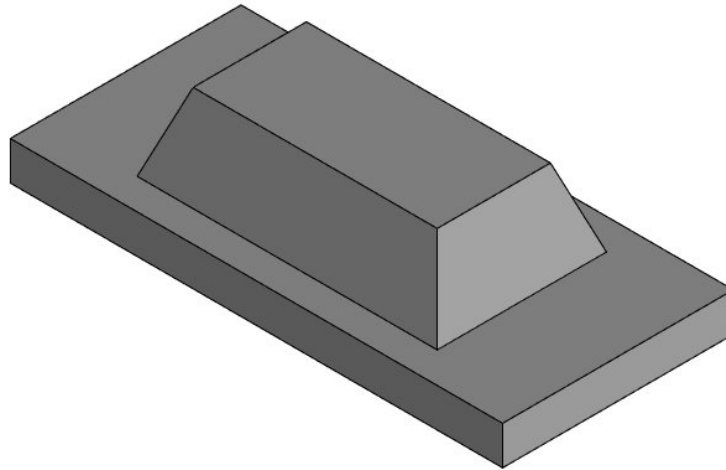
a)   5 times
b)   2.5 times
c)   2 times
d)   1.5 times
e)   The efficiency is equal

Answer: b

Task 28
Entry level (1 point)

From the given views for the part shown in the figure, select the front view.

a)

b)

c)

d)

Answer: a

Task 29
Intermediate level (3 points)

A car weighing 2 tons passes the top of a convex bridge with a radius of curvature of 40 m at a speed of 36 km/h. From the list below, select all correct statements characterizing the car's motion at this point in time and indicate their numbers.

a)   The resultant force acting on the car is directed opposite to its speed.
b)   The force exerted by the bridge on the car is less than 20,000 N and is directed vertically downward.
c)   The weight of the car is 35000 N
**d)   The centripetal acceleration of the car is 2.5 m/s^2**

e) **The weight of the car is directed vertically downwards**
Answer: d, e

Task 30
Intermediate level (3 points)

The figure shows the dependence of gas pressure p on its density ρ in a cyclic process involving 2 moles of an ideal gas in an ideal heat engine. The cycle consists of two straight-line segments and a quarter-circle segment.
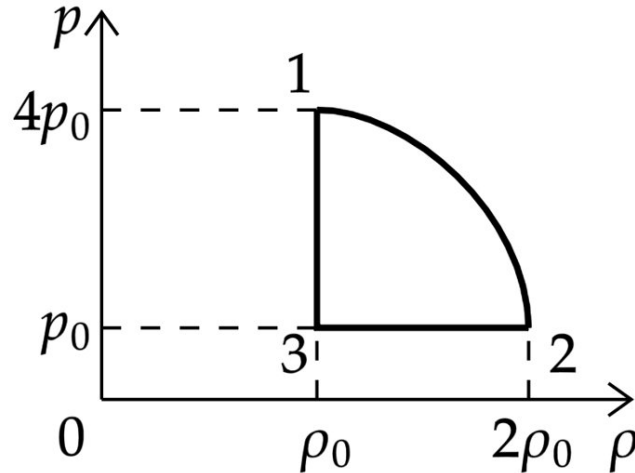
Based on the analysis of this cyclic process, select all correct statements.
a) **In process 1-2, the gas temperature decreases.**
b) In state 3, the gas temperature is maximum.
c) In process 2-3, the gas volume decreases.
d) **The ratio of the maximum temperature to the minimum temperature in the cycle is 8**
e) The work of the gas in process 3-1 is positive.

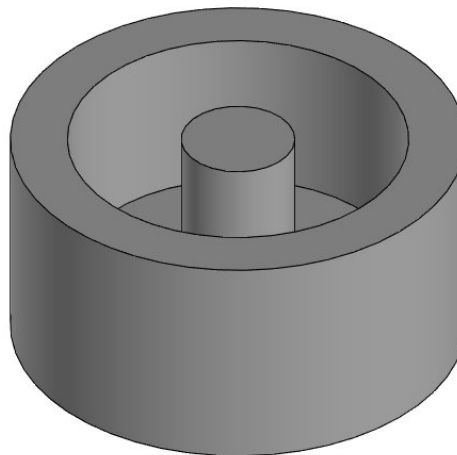**Answer:** a, d

Task 31
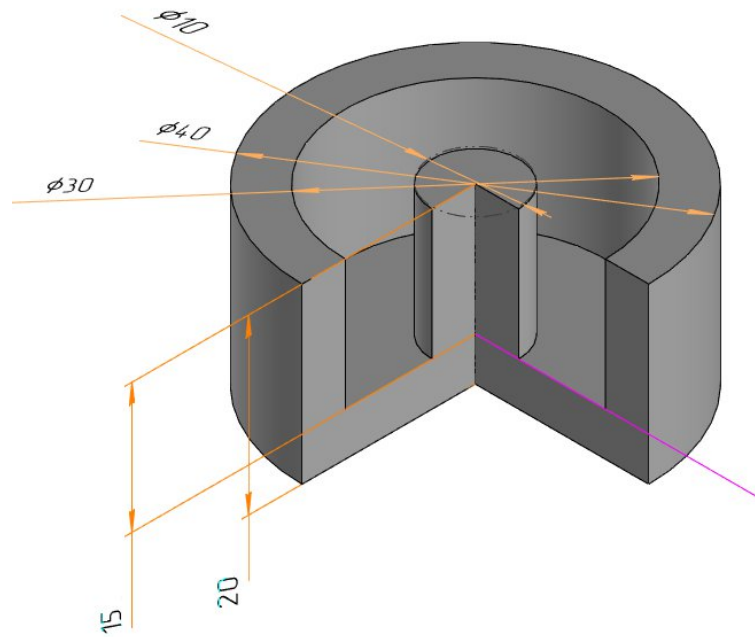### Advanced level (9 points)

Fig. 1a

Fig. 1b

The part shown in Figure 1a was printed on a 3D printer. Its dimensions (in millimeters) are shown in Figure 1b. The part is made of polycarbonate with a density of 0.00112 g/mm^3. Calculate the mass of the part if the filling is 15%. Express the answer in grams, round up to the nearest integer. Use π=3.14 in the calculations.

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

Solution

To find the mass of a part, you need to know its volume.

Let us calculate the volume of the outer cylindrical part V_c. For this purpose, we subtract the volume of the cylindrical cavity V_{c2} from the volume of the larger cylinder V_{c1}:

$$V_{ц} = V_{ц1} - V_{ц2} = \pi r_1^2 h_1 - \pi r_2^2 h_2 = 3,14 \times 20^2 \times 20 - 3,14 \times 15^2 \times 15 = 25120 - 10597,5 = 14522,5 \text{ mm}^3,$$

where r is the radius of the cylinder, and h is the height of the cylinder.

To obtain the total volume of part V, it is necessary to add the volume of the inner cylinder V_{in}, located in the center of the cavity, to the volume of the outer cylindrical part V_c:

$$V = V_{ц} + V_{вн} = 14522,5 + \pi r_3^2 h_2 = 14522,5 + 3,14 \times 5^2 \times 15 = 15700 \text{ mm}^3.$$

Given that the part is filled with a fill factor, the actual material volume is defined as:

$$V_{факт} = V \times k = 15700 \times 0,15 = 2355 \text{ mm}^3.$$

Then the mass of the part is calculated as follows:

$$m = V_{факт} \times r = 2355 \times 0,00112 = 2,64 \text{ g}.$$

After rounding, we get $m = 3$ g.

Answer: $m = 3$ g.

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Assessment criteria

Criterion 1 (5 points)**:** The formulas for calculating the volumes of the individual components are correctly stated, and the total volume of the part is accurately computed.
Criterion 2 (2 points)**:** The fill factor is correctly applied, and the actual volume of material is calculated correctly. The answer is worth 2 points.
Criterion 3 (2 points)**:** The formula for determining mass from volume is correctly stated, and the mass is accurately calculated, taking into account the fill factor. The final result is appropriately rounded.

Field of Science 6. Nuclear Science and Technology

Task 32
Entry level (1 point)

How does the binding energy of a nucleus change during the fission of heavy nuclei?
a) Increases
b) Decreases
c) Does not change
d) It can both increase and decrease

Answer: a

Task 33
Entry level (1 point)

A body of mass m slides down an inclined plane with an angle of inclination α. The coefficient of friction between the body and the plane is μ. Determine the acceleration of the body.
a) $a = g * \sin(\alpha)$
b) $a = g * (\sin(\alpha) + \mu * \cos(\alpha))$
c) $a = g * \cos(\alpha) - \mu * g * \sin(\alpha)$
d) $a = g * (\sin(\alpha) - \mu * \cos(\alpha))$
Answer: d

Task 34
Entry level (1 point)

Calculate the amount of heat required to heat 1 kg of water from 20°C to 100°C. The specific heat capacity of water is 4200 J/(kg·°C).
a)   336000 J
b)   403200 J
c)   168000 J
d)   268800 J
Answer: a

Task 35
Entry level (1 point)

What does the period of a simple pendulum depend on?
a) Depends on the amplitude of oscillations
b) Depends on the mass of the pendulum
c) **Depends on the acceleration due to gravity**
d) Depends on the material of the pendulum's thread
Answer: c

Task 36
Intermediate level (3 points)

What are the advantages and disadvantages of nuclear energy compared to other energy sources?
Select all that apply.

a) Advantages: Nuclear energy has a high energy density, allowing for the production of large amounts of electricity from relatively small amounts of fuel
b) Advantages: Nuclear power plants do not emit greenhouse gases, making them a cleaner energy source compared to thermal power plants
c) Disadvantages: Nuclear waste poses a threat to the environment and requires long-term safe storage
d) Advantages: Nuclear energy provides a stable and reliable supply of electricity, independent of weather conditions

Answer: a, b, d

Task 37
Intermediate level (3 points)

Which of the following statements about temperature is correct?
Select all that apply.

a) Temperature of a body is a measure of the average kinetic energy of the random motion of its molecules
b) The temperature of a body does not depend on the speed of the molecules
c) Absolute zero corresponds to the complete cessation of the thermal motion of molecules
d) The Kelvin scale starts at zero degrees
Answer: a, c

Task 38
Advanced level (8 points)

A 0.01 mol sample of an ideal gas is contained in a cylinder under a piston. The piston has a mass of m = 0.1 kg and a cross-sectional area of S = 0.002 m². The cylinder is placed in a thermostat at

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a temperature T = 300 K. The piston is slowly lowered by a small distance Δh = 0.01 m. Determine the amount of heat Q released by the gas during the isothermal compression process.

Note that the evaluation will take into account the following criteria:
a) Each step of the solution is described in detail.
b) The dimensional consistency of the final result (in joules, J) is verified.

Solution
1. Process analysis:
Isothermal Process: The temperature of the gas remains constant.
Compression: The gas volume decreases due to the movement of the piston.
Work Done on the Gas: External forces do work on the gas, causing compression.
Heat Transfer: The gas releases heat to the surroundings (thermostat).

For an isothermal process, the change in internal energy is zero (ΔU = 0). Therefore, the first law simplifies to:
Q = -A, where Q is the heat exchanged with the surroundings and A is the work done by the gas.

3. Calculating work:
The work done on the gas during compression is: $A = F\Delta h = pS\Delta h$.
4. The gas pressure can be found from the ideal gas law: $pV = nRT$.
5. Substituting pressure into the work formula and simplifying: $A = nRT * (\Delta h / h) \approx nRT$.
6. Calculating heat: Q = - A = - nRT.
Substituting numerical values: Q = - 0.01 mol * 8.314 J/(mol·K) * 300 K = - 24.94 J.
Substituting the given values into the equation, we find that the amount of heat released by the gas during the isothermal compression is - 24.94 J. The negative sign indicates that heat is being lost by the system.

Answer: Q = - 24.94 J.

Assessment criteria

Criterion 1 (3 points)**:** The equation of state is correctly formulated.
Criterion 2 (3 points)**:** The formula for the heat released by the gas is accurately stated.
Criterion 3 (2 points)**:** The final calculation is performed correctly, and the dimensional consistency of the result is verified.

Field of Science 7: Materials Science, Characterization and Testing

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Task 39
Entry level (1 point)

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The number of electrons in an iron ion Fe^{2+} is :
a) 26
b) 28
c) 24

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d) 30
Answer: c

Task 40
Entry level (1 point)

Compounds with an ionic bond type include:
a) nonmetals
b) salts
c) most of the nonmetal oxides
d) metals
Answer: b

Task 41
Entry level (1 point)

The magnetic permeability of diamagnets is:
a) equal to one
b) slightly more than one
c) equal to zero
d) slightly less than one
Answer: d

Task 42
Entry level (1 point)

How does the specific surface resistance (square resistance $R_\square$) depend on the size of the square?
a) Square resistance $R_\square$ does not depend on the size of the square
b) Square resistance $R_\square$ is inversely proportional to the size of the square
c) Square resistance $R_\square$ is directly proportional to the size of the square
d) Square resistance $R_\square$ is directly proportional to the size of the square for metals and inversely proportional to the size of the square for dielectrics
Answer: a

Task 43
Intermediate level (3 points)

A semiconductor is a substance that …
Select all that apply.
a) is capable of passing only half of the electric charges
b) conducts electrical charges worse than a conductor, but better than a dielectric
c) does not conduct all electrical charges
d) has received electric charges
e) has special properties of electrical conductivity
f) insulates a charged object
Answer: b, e

Task 44

Intermediate level (3 points)

What factors influence the electrical conductivity of semiconductors?
Select all that apply.
a) Impurities
b) Electric field
c) Temperature
d) The number of measurements
e) Incident light
f) Deformation
Answer: a, b, c, e, f

## Task 45
Advanced level (8 points)

The unit cell of some substance is a simple cube with an edge a = 1.851 nm. Draw a unit cell and calculate the concentration of free electrons, assuming that there is one free electron for each atom of the crystal lattice.

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

Solution
1)   Let's draw a unit cell.
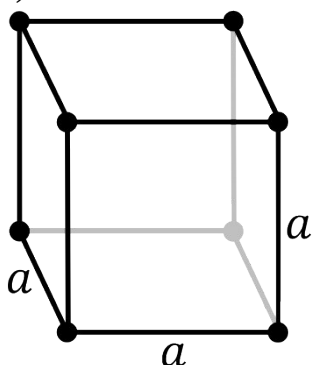
The unit cell contains no atoms within its interior; atoms are located exclusively at the vertices of the cube. Each atom positioned at a lattice vertex is shared among eight adjacent unit cells, thus contributing only one-eighth of an atom to a single unit cell. Since a cube has eight vertices, the total number of atoms per unit cell is:
$1/8 \times 8 = 1$ (K = 1).
The atomic density (number of atoms per unit volume) can be calculated as:
$N = K / a^3 = 1 / (1.851 \times 10^{-9} \text{ m})^3 = 1.577 \times 10^{26} \text{ m}^{-3}$.
The electron concentration is given by:
$n = 1 \times N = 1.577 \times 10^{26} \text{ m}^{-3}$,
where "1" denotes one free electron per atom in the crystal lattice.

Answer: $n = 1.577 \cdot 10^{26} \text{ m}^{-3}$.

Assessment criteria
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Criterion 1 (2 points**):** The unit cell is accurately illustrated.
Criterion 2 (2 points)**:** The number of atoms within the unit cell is correctly identified
Criterion 3 (4 points)**:** The formulas for calculating the number of atoms per unit volume and the concentration of electrons are correctly stated, and the calculations performed are accurate