Engineering and Technology: Second-round sample tasks for the Open Doors undergraduate track

You will be asked to complete 45 tasks, including:

- 28 entry-level tasks, each correct answer worth 1 point;
- 13 intermediate-level tasks, each correctly answered task worth 3 points;
- 4 advanced tasks (constructed response), each correctly completed task valued at 8-9 points.

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

Automation & 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, which are written 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)

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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. There are several possible answers.

a) Welding of parts by operator
b) Printing documents using a printer
c) Harvesting crops by farmers
d) Packaging of goods using robotic devices
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? There are several possible answers.

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.

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.

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)

For what smallest nonnegative integer A, the expression $(x + 2y < A)$ OR $(y > x)$ OR $(x > 30)$ takes the value 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 to the input of the algorithm and the program calculates a new number R according to the following algorithm:
1. A binary notation of the number N is constructed.
2. Two more digits are added to the right side of this record according to the following rule:
a) All digits of the binary notation of the number N are added up, and the remainder of the sum divided by 2 is added to the end of the number (on the right). For example, the entry 11100 is converted into the entry 111001;
b) the same actions are performed on this entry - the remainder of the sum of its digits divided by 2 is added to the right.
The resulting record is a binary representation of the number R.
Choose from the given variants the minimum number R in decimal notation system, which exceeds the number 97 and can be the result of this algorithm.

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

Task 11
Entry level (1 point)

Select the incorrect equation

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. What can be said about the mutual arrangement of vectors CA and BD? There are several possible answers.

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

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)

A fragment of the truth table of the expression F is given. Which expression corresponds to F?

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)

Conditional probability is calculated using the formula (select 2 or more answer choices):
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)
Ответ: 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 the answer choices with 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

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Answer: a, c, e

Electrical & Electronic Engineering

Task 18
Entry level (1 point)
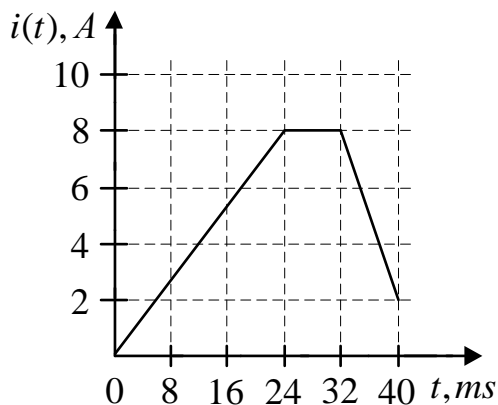
Determine the electric field intensity E if a point charge q = 15 nC is affected by a force F = 3 mN.

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)

The graph of the current in the inductor with L = 30 mH is shown in the figure. Determine the largest modulo value of the 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 applied voltage U and the power consumption P of the conductor with a resistance R = 15 Ohm when a current of I = 2 A flows through it.
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 the point A lying in the middle between the charges. The medium is a 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 of the capacitors. 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)

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.
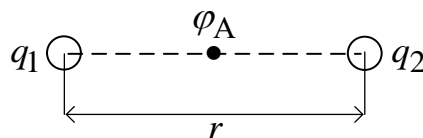
a) φA = 2250 V
b) φA = 0 V
c) φA = 4500 V

d) $\varphi A = 4500$ 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.
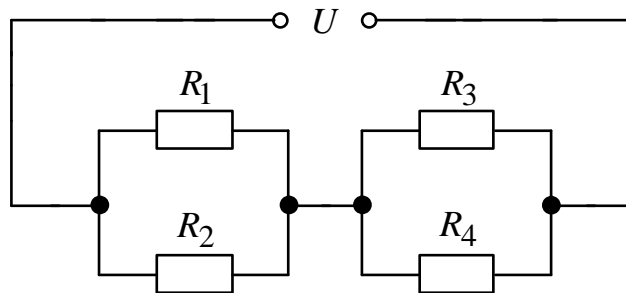
Note that the evaluation will consider how you solve the task; providing only the final answer is not sufficient.

Solution:
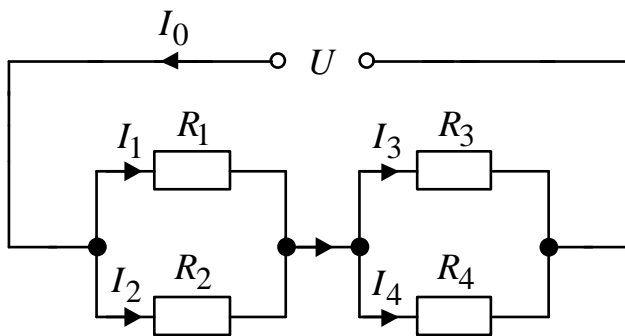
Let's determine the total resistance of the entire circuit:
R0 = R1*R2 / (R1+R2) + R3*R4 / (R3+R4) = 2/3 + 4/3 = 2 Ohm;
According to Ohm's law, we determine the total current in the circuit:
 I0 = U / R0 = 60 / 2 = 30 A;
Elements R1 and R2 are connected in parallel, so U1 = U2 = U12;
Elements R3 and 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;

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8

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.
Evaluation criteria:
Criterion 1: Clearly state the formula and accurately calculate the total resistance of the circuit (3 points).
Criterion 2: Correctly compute the total current flowing through the circuit (3 points).
Criterion 3: Accurately determine the currents passing through each conductor (2 points).

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. What is the acceleration of the load m?
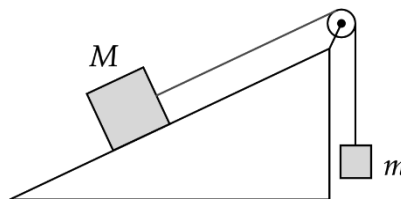
a)   1 m/s²
b)   2 m/s²
c)   3 m/s²
d)   4 m/s²
e)   5 m/s²
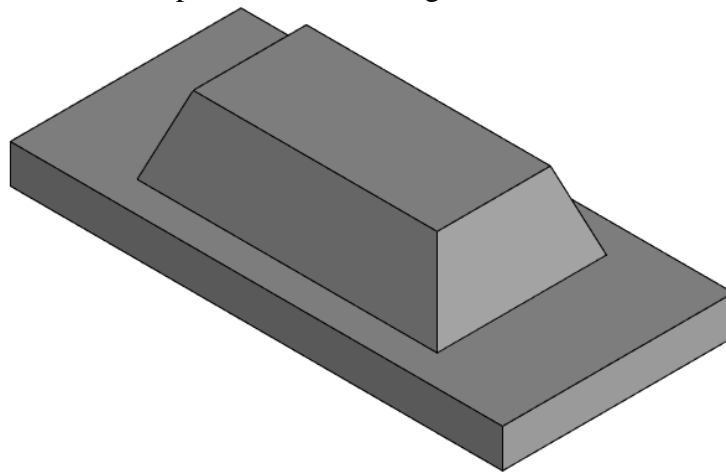**Answer**: a.

Task 27
Entry level (1 point)

A heat engine performs 20 J of work in one cycle and gives off 80 J of heat to the refrigerator. The temperature of the heater of this engine is 600 K, and the temperature of the refrigerator is 300 K. How many times is the efficiency of an ideal heat engine operating at the same temperatures of the heater and refrigerator greater than the efficiency of the heat engine under consideration?
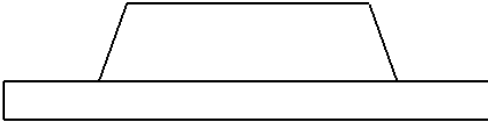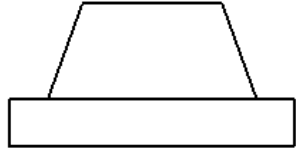
a)   5 times
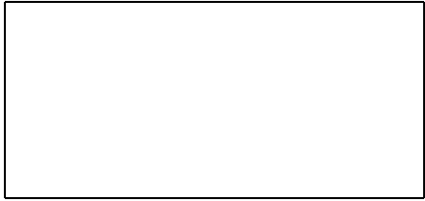**b)   2.5 times**
c)   2 times
d)   1.5 times
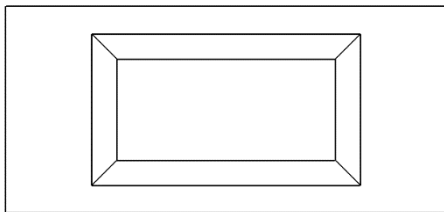e)   The efficiency is equal

Answer: b.

Task 28
Entry level (1 point)

From the suggested views of the part shown in the figure, choose the frontal 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 the 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 with which the bridge acts on the car is less than 20000 N and is directed vertically downwards
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 the gas pressure p on its density ρ in a cyclic process carried out by 2 moles of an ideal gas in an ideal heat engine. The cycle consists of two straight line segments and a quarter circle.
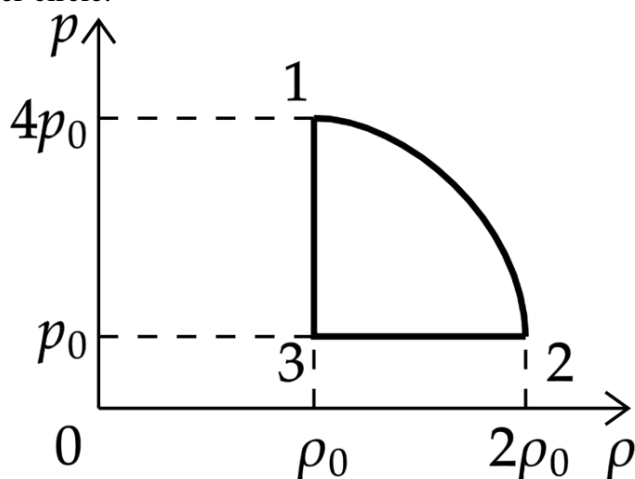
Based on the analysis of this cyclic process, select all the correct statements.
a) In process 1-2, the gas temperature decreases
b) In state 3, the gas temperature is maximum
c) In process 2-3, the gas volume decreases
d) The ratio of the maximum temperature to the minimum temperature in the cycle is 8
e) The work of the gas in process 3-1 is positive
Answer*:* a, d.

Task 31
Advanced level (9 points)
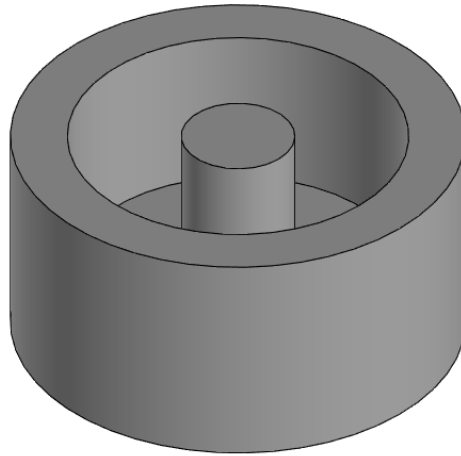
Fig. 1a
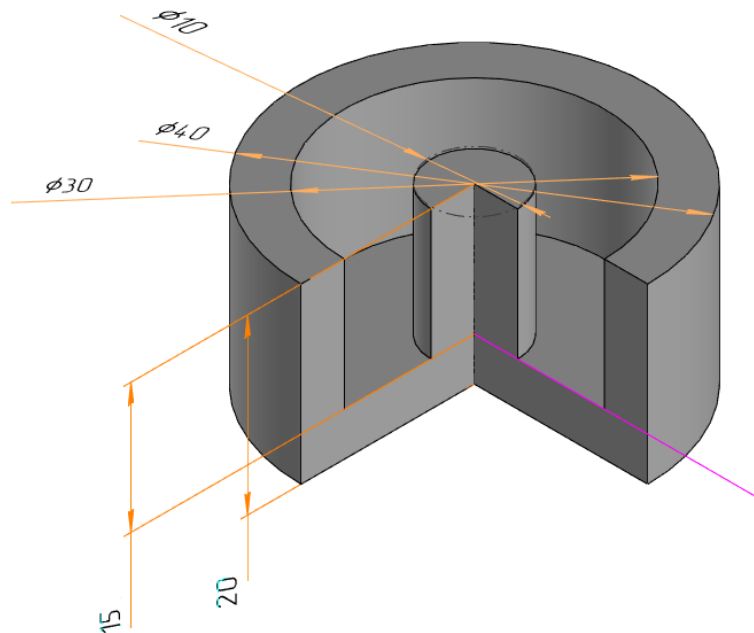
Fig. 1b

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/mm³.
Calculate the mass of the part if the filling is 15%. Express the answer in grams, round up to the nearest integer. Take =3.14 in the calculations.

Be careful: the assessment will take into account the progress of the solution; writing only the answer is not enough.
Solution:
To find the mass of a part, you need to know its volume.

Let's 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}:

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

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

To obtain the total volume of the 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:

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

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

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

Then the mass of the part is found as follows:

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

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

Answer: $m = 3$ g.

Evaluation criteria:

Criterion 1: The formulas for calculating the volumes of the individual components are correctly stated, and the total volume of the part is accurately computed. The answer is worth 5 points.

Criterion 2: The fill factor is appropriately considered, and the actual volume of material is calculated correctly. The answer is worth 2 points.

Criterion 3: The formula for calculating mass from volume is correctly presented, and the mass is accurately calculated while accounting for the fill factor. The final result is rounded appropriately. The answer is worth 2 points.

Nuclear Science & 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? There are several possible answers.
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? There are several possible answers.

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 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 consider:

a) Each step of the solution is described in detail.

b) The dimensionality of the obtained result (J) is checked.

Solution:

1. Process analysis:

- Isothermal process: The gas temperature remains constant.

- Compression: The gas volume decreases due to piston movement.

- Work done on the gas: External forces perform work on the gas, compressing it.

- Heat transfer: The gas releases heat to the surroundings (thermostat).

2. First law of thermodynamics:

For an isothermal process, the change in internal energy ΔU = 0. Therefore, the first law becomes: Q = - A.

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.

Evaluation criteria:

Criterion 1: The equation of state is accurately formulated. The answer is worth 3 points.

Criterion 2: The formula for the heat released by the gas is correctly documented The answer is worth 3 points.

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Criterion 3: The final calculation is accurate, and the dimensional consistency of the result is verified. The answer is worth 2 points.

Materials Science, Characterization & Testing

Task 39
Entry level (1 point)

The number of electrons in an iron ion Fe^{2+} is equal to:
a) 26
b) 28
c) 24
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 … ? There are several possible answers.
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? There are several possible answers.
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 that the evaluation will consider how you solve the task; providing only the final answer is not sufficient.

Solution:
1) Let's draw a unit cell.
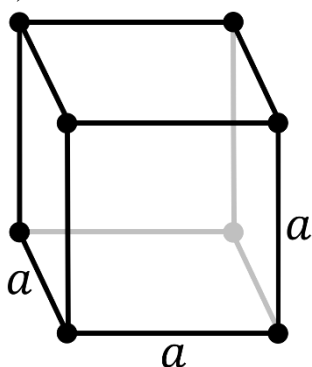
A cell with no atoms inside, and atoms are placed only at the vertices of the cube.

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2)   Each atom in the node of the crystal lattice belongs to it only by 1/8, since it belongs simultaneously to 8 cubes converging at a given vertex. And there are 8 vertices in the cube. Therefore, the number of atoms per unit cell is $1/8 \cdot 8 = 1$ (K = 1).

3)   The number of atoms per unit volume can be found as:

$N = K / a^3$;

$N = 1 / (1.851 \cdot 10^{-9})^3 = 1.577 \cdot 10^{26}$ m^{-3}.

4)   Let's find the concentration of electrons:

$n = 1 \cdot N = 1.577 \cdot 10^{26}$ m^{-3}.

"1" because there is <u>one</u> free electron for each atom of the crystal lattice.

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

Evaluation criteria:

Criterion 1: The unit cell is accurately illustrated. The answer is worth 2 points.

Criterion 2: The number of atoms within the unit cell is correctly identified. The answer is worth 2 points.

Criterion 3: 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. The answer is worth 4 points.