Physical and Technical Sciences: Second-round Sample Tasks for the Open Doors Bachelor's Track

This sample test comprises 45 tasks, including 27 entry-level tasks with a single correct answer (each correct answer is assigned 1 point), 13 intermediate-level tasks with a standard correct answer (each correct answer is assigned 2 – 4 points), and 5 advanced-level tasks requiring a detailed answer (the answer is assigned 5 – 6 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. Mechanics

Task 1
Entry level (1 point)

A truck and a passenger car are travelling at speeds υ_1 = 36 km/h and υ_2 = 108 km/h, respectively. The mass of the truck is m=3000kg. What is the mass of the car if the momentum of the truck is greater than the momentum of the passenger car by 15000 kg · m/s?

1. 1000 kg
2. **500 kg**
3. 1500 kg
4. 2000 kg

Answer: 2.

Task 2
Entry level (1 point)

A boy pushed a sled from the top of a hill. The height of the hill is 15 m, and the speed of the sled at the bottom of the hill was 20 m/s. The friction between the sled and the snow is negligible. What was the speed of the sled immediately after the push? Assume the acceleration due to gravity is 10 m/s^2.

1. 20 m/s
2. 15 m/s
3. **10 m/s**
4. 25 m/s

Answer: 3.

Task 3
Entry level (1 point)

In rectilinear motion, the dependence of the body's coordinate x on time t is as follows:
$x= 5+3t+4t^2$.
What is the velocity of the body at time t = 3 c in this motion?

1. **27 m/s**
2. 30 m/s

3. 20 m/s
4. 50 m/s

Answer: 1.

Task 4
Entry level (1 point)

A body is launched vertically upward with the initial velocity of 30 m/s. What is the modulus of the body's velocity 2.5 seconds after it was launched? Ignore air resistance.

1. 10 m/s
2. **5 m/s**
3. 15 m/s
4. 20 m/s

Answer: 2.

Task 5
Entry level (1 point)

How much will a spring with a stiffness of k = 103 N/m stretch under the action of a force of 10,000 N?

1. 10 sm
2. 100 sm
3. **1000 sm**
4. 1 sm

Answer: 3.

Task 6
Entry level (1 point)

At what distance from each other are two identical balls, each with a mass of 10 tons, if the gravitational force acting between them is $6.67 \cdot 10^{-5}$ N? The universal gravitation constant G = $6.67 \cdot 10^{-11}$ N•m^2/kg^2.

1. 20 m
2. **10 m**
3. 15 m
4. 25m

Answer: 2.

Task 7
Entry level (1 point)

A pine bar with a volume of V = 0.6 m^3 is floating in water, half submerged. What is the buoyant force acting on the bar? Assume the acceleration due to gravity is 10 m/s^2, and the density of water is ρ = 1000 kg/m^3.

1. 30 kN
2. **3 kN**

3. 6 kN
4. 60 kN

Answer: 2.

Task 8
Intermediate level (3 points)

A body decelerated at a constant rate, and 100 seconds prior to coming to a stop, its velocity had decreased by 10 m/s. What distance did the body travel in this time? Give the answer in meters.

Answer: 500 m.

Task 9
Intermediate level (3 points)

Two balls, with masses m1 = 1.5 kg and m2 = 2 kg, are approaching each other, both travelling at the same speed of v = 10 m/s. Determine the velocity of the balls after they undergo a completely inelastic collision. Please provide your answer in meters per second, rounded to the nearest hundredth.

Answer: 1.43 m/s

Task 10
Advanced level (5 points)

An object is launched from the Earth's surface at a 30^0 angle to the horizontal with an initial velocity of 10 m/s. Calculate the duration of the object's flight before it impacts the ground.

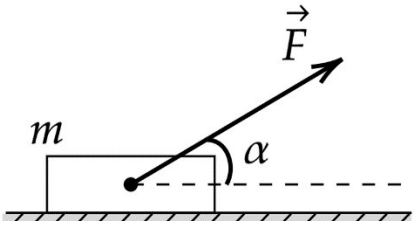
Note: A complete solution must include your method and reasoning. Providing the final answer alone will not suffice.

Answer: 1 s

Assessment criteria:
Criterion 1 – 2 points. Theoretical principles and physical laws, the application of which is necessary for solving the problem, are stated. All new literal designations of physical quantities introduced in the solution are described.
Criterion 2 – 2 points. Mathematical transformations and calculations are performed correctly.
Criterion 3 – 1 point. The correct answer is presented with the indication of units of measurement.

Task 11
Advanced level (5 points)

What is the modulus of the force F with which a block of mass m = 3 kg is moved, the coefficient of friction μ = 0.2 and the force F is directed at an angle α = 30^0 to the horizon (see the figure). The modulus of the friction force acting on the block = 4 N.



Note: A complete solution must include your method and reasoning. Providing the final answer alone will not suffice.
Answer: 20 N.

Assessment criteria:
Criterion 1 – 2 points. Theoretical principles and physical laws, the application of which is necessary for solving the problem, are stated. All new literal designations of physical quantities introduced in the solution are described.
Criterion 2 – 2 points. Mathematical transformations and calculations are performed correctly.
Criterion 3 – 1 point. The correct answer is presented with the indication of units of measurement.

Field of Science 2. Thermodynamics

Task 12
Entry level (1 point)

To melt 200 g of ice, 900 g of water at a temperature of 20 ^{0}C is required. What was the initial temperature of the ice? The specific heat capacity of water is 4200 J/(kg•^{0}C), the specific heat capacity of ice is 2100 J/(kg•^{0}C), the latent heat of fusion of ice is 340 kJ/kg. Select the answer that is nearest to your calculation.

1. -20 ^{0}C
2. -18 ^{0}C
3. -9 ^{0}C
4. -2 ^{0}C

Answer: 2.

Task 13
Entry level (1 point)

The pressure of a rarefied gas in the container rose by a factor of 8, while the average energy of the translational thermal motion of its molecules increased by a factor of 4. How did the concentration of gas molecules in the container change?

1. Did not change
2. Decreased by 2 times
3. Increased by 2 times
4. Increased by 4 times

Answer: 3.

Task 14
Entry level (1 point)

The thermodynamic system performed 300 J of work, while its internal energy decreased by 100 J. How much heat did the thermodynamic system exchange with the environment?

1. -200 J
2. -100 J
3. 0 J
4. 100 J
5. **200 J**

Answer: 5.

Task 15
Entry level (1 point)

A heat engine operating at an efficiency of 20% receives 100 J of heat from the heater in each cycle. How much work does the engine produce per cycle?

1. **20 J**
2. 50 J
3. 80 J
4. 100 J

Answer: 1.

Task 16
Intermediate level (2 points)

The container is divided into two equal sections by a porous stationary partition. Initially, the left section holds 4 moles of helium, while the right section contains 40 grams of argon. The partition can pass helium molecules but is impermeable to argon molecules. The temperature of both gases is identical and remains constant. Helium has a molar mass of 4 g/mol, whereas argon has a molar mass of 40 g/mol. Identify all the correct statements that characterize the state of the gases once the system reaches equilibrium.

1. The concentration of helium in the right section of the vessel is half that of argon.
2. **The pressure ratio of the gas in the right section to that in the left section is 1.5.**
3. The total number of gas molecules in the right section is lower than in the left section.
4. The internal energy of helium and argon is identical.
5. **Upon reaching equilibrium, the pressure in the right section of the vessel increased threefold.**

Answer: 2, 5.
You earn 1 point for each correct statement and lose 1 point for each incorrect one.

Task 17
Intermediate level (3 points)

An ideal gas is compressed at constant pressure. Choose all the correct statements. ΔU represents the change in the gas's internal energy, A denotes the work done by the gas, and Q indicates the amount of heat exchanged between the gas and its surroundings.

1. $\Delta U=0$
2. $\Delta U>0$

3. **ΔU<0**
4. A=0
5. A>0
6. **A<0**
7. Q=0
8. Q>0
9. **Q<0**

Answer: 3, 6, 9.
For each correct answer you get 1 point, for each incorrect answer you lose 1 point.

Task 18
Advanced level (6 points)

One mole of helium undergoes isobaric expansion, performing 4.2 J of work. Following this, its temperature is decreased isochorically, and then it is compressed adiabatically, returning to its original state. Find the efficiency of the cycle, given that 2.1 J of work is done on the gas during the adiabatic process.

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

Answer: 20%

Assessment criteria:
Criterion 1 – 3 points: All essential relationships are written down, including thermal and caloric equations of state, the first law of thermodynamics, and the formula for calculating efficiency. It should be clear whether the system absorbs or releases heat at each stage of the cycle.
Criterion 2 – 2 points: The total work per cycle and the amount of heat exchanged must be calculated correctly.
Criterion 3 – 1 point: The efficiency is calculated correctly.

Field of Science 3. Electrical Engineering and Electronics

Task 19
Entry level (1 point)

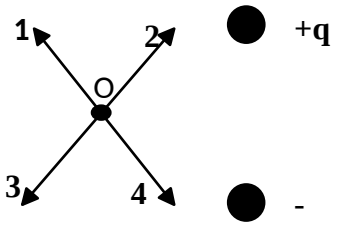
Consider three charges q_1, q_2 and q_3 are positioned at the vertices of an equilateral triangle with a side length of a. A test charge Q is placed in the center of the triangle. What amount of work is required to gradually move the charge Q to infinity?

1. $\mathbf{k\frac{3Q}{\sqrt{3}a}(q_1+q_2+q_3)}$
2. $k\frac{Q}{\sqrt{3}a}(q_1+q_2+q_3)$
3. $k\frac{4Q}{a\sqrt{3}}(q_1+q_2+q_3)$
4. $k\frac{2Q}{\sqrt{3}a}(q_1+q_2+q_3)$

Answer: 1.

Task 20
Entry level (1 point)

Indicate the direction of the resultant electric field at point O created by two stationary point charges (see the figure).

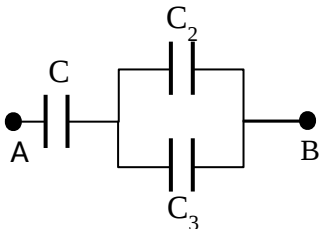


1. 1
2. 2
3. 3
4. 4

Answer: 4

Task 21
Entry level (1 point)

Find the capacitance of the circuit section AB consisting of the three capacitors $C_1 = C_2 = C$, and $C_3 = 3C$ shown in the figure.



1. $\frac{7}{4}C$
2. $\frac{9}{5}C$
3. $\frac{4}{5}C$
4. $\frac{3}{4}C$

Answer: 3.

Task 22
Entry level (1 point)

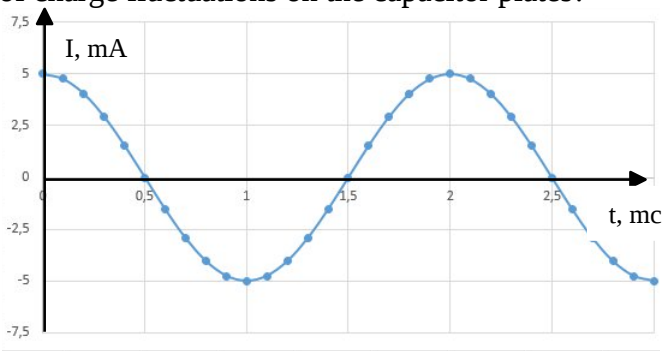
How does the resistance of two parallel wires, which are identical in shape and size, change if the length of one wire is tripled?

1. The resistance increases by 1.5 times.
2. The resistance decreases by 1.5 times.
3. The resistance increases by 2 times.
4. The resistance decreases by 2 times.
5. The resistance does not change.

Answer: 1.

Task 23
Entry level (1 point)

The figure shows a graph of the time dependence of the current in a LC circuit. What is the period of charge fluctuations on the capacitor plates?

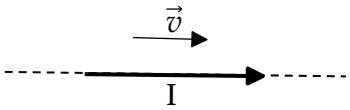


1. 1 ms
2. **2 ms**
3. 2 s
4. 1 s

Answer: 2.

Task 24
Entry level (1 point)

A positively charged particle is moving horizontally with velocity $\vec{V}$ along a straight long wire with current I (see the figure). Find the direction of the magnetic force exerted on the particle.



1. Up
2. **Down**
3. Left
4. Right
5. From the observer
6. To the observer
7. The force does not exert

Answer: 2.

Task 25
Intermediate level (3 points)

A charged particle with a mass of $5 \cdot 10^{-27}$ kg and a charge of $6.4 \cdot 10^{-19}$ C enters a uniform electric field with a strength of 100 V/m. If the initial velocity is zero, how long does it take a particle to travel a distance of 2 m along the electric field lines? Round the answer (in μs) to the nearest whole number.

Answer: 18 μs

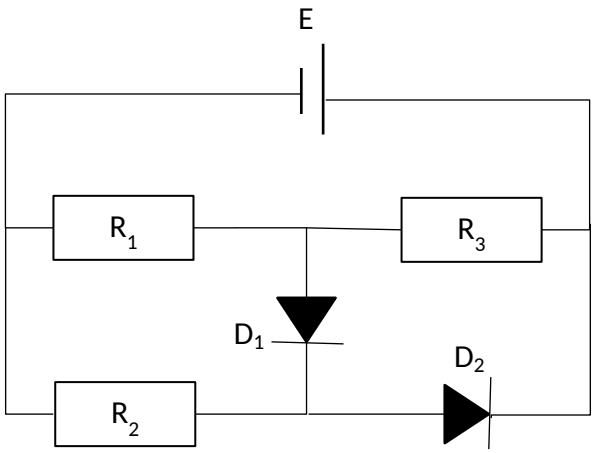
Task 26
Intermediate level (4 points)

A capacitor in an ideal oscillating circuit has capacitance $C = 20$ μF. The charge on the capacitor plates changes according to the law $q(t) = 4 \cdot 10^{-4} \sin(2500t)$ (all values are expressed in SI). Find the value of the magnetic field energy of the coil at the time $t = \frac{T}{2}$.

Answer: 0.004 J

Task 27
Advanced level (6 points)

Find the current flowing through a battery in the circuit depicted below. The diodes are considered ideal, the internal resistance of the battery is r = 2R, the battery EMF E = 21 V. The values for the other circuit components are also provided in the figure, where $R_1 = R_2 = R_3 = R = 5$ Ω.



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

Answer: 1.2 A

Assessment criteria:

Criterion 1 – 3 points: The potential directions of current in the circuit are identified correctly, and the equivalent circuit is drawn.

Criterion 2 – 3 points: The total resistance of the circuit is calculated correctly.

Criterion 3 – 1 point: The current is calculated correctly.

Task 28
Advanced level (5 points)

A wire ring with a diameter of 0.3m is placed in a uniform magnetic field that is changing in magnitude. The plane of the ring is perpendicular to the magnetic field lines. What is the modulus of the rate at which the magnetic field is changing? The current flowing through the wire is 5 A, and the resistance of the wire is 0.03 Ω.

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

Answer: 2.1 T/c

Assessment criteria:
Criterion 1 – 2 points: The formula for calculating the induced EMF and current is given correctly.
Criterion 2 – 2 points: The formula for the rate of change of the magnetic field is given correctly.
Criterion 3 – 1 point: The calculations are done correctly.

Field of Science 4. Optics

Task 29
Entry level (1 point)

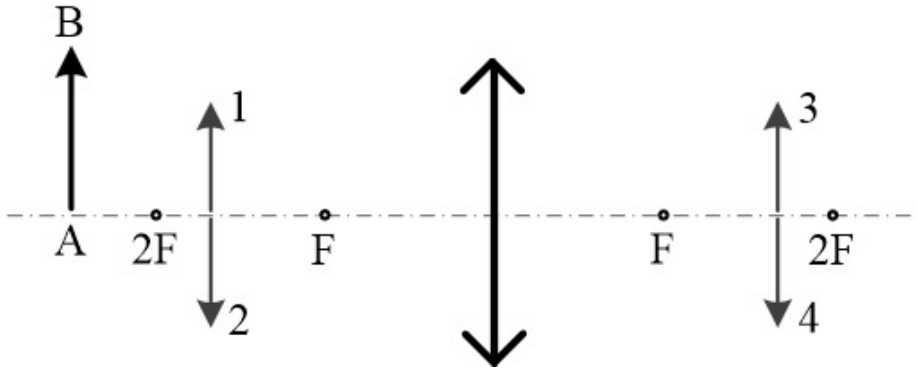
The light beam falls from water onto a flat glass surface. The angle between the incident beam and the surface is 50°. Find the angle between the reflected beam and the refracted beam. The refractive indices of glass and water relative to air are 1.5 and 1.33, respectively.

1. 74.7°
2. 86.5°
3. 87.2°
4. 93.5°
5. **105.3°**

Answer: 5.

Task 30
Entry level (1 point)

Which of the objects labeled 1-4 represents the image of arrow AB when viewed through a thin lens with a focal length of F?



1. Arrow 1.
2. Arrow 2.
3. Arrow 3.
4. **Arrow 4.**

Answer: 4.

Task 31
Entry level (1 point)

A plane monochromatic wave from the green part of the visible spectrum (with a wavelength of 550 nm) falls normally on a slit that is 2 μm wide. A converging lens is placed behind the slit so that its focal plane is parallel to the plane of the screen with the slit. How does the distance between the second-order and third-order diffraction minima in the focal plane of the lens change when the width of the slit is increased by a factor of 1.5?

1. The distance increases by 3 times.
2. The distance increases by 1.5 times.
3. The distance decreases by 1.5 times.
4. **The distance decreases by 3 times.**

Answer: 4.

Task 32
Intermediate level (4 points)

An object is positioned 12.5 cm away from a thin converging lens. The image of the object is real. The magnification produced by the lens is 2.5. Calculate the power of the lens and round your answer to the nearest whole number.

Answer: 11 D

Task 33
Intermediate level (4 points)

In a Fresnel mirror experiment on the interference of light waves, the distance from the intersection line of the mirrors to the actual narrow light source is 8 cm, while the distance to the screen is 120 cm. The wavelength of the monochromatic light used is 0.48 μm. Calculate the angle of inclination between the mirrors, given that the width of the interference fringe on the screen is 1.3 mm. Give the answer in angular minutes, rounded to the nearest whole number.

Answer: 10

Field of Science 5. Condensed Matter Physics

Task 34
Entry level (1 point)

The vessel under the piston contained air with a relative humidity of 50%. The air was compressed isothermally, and its volume was reduced by 3 times. What was the relative humidity of the air in the vessel after the compression?

1. 17%
2. 25%
3. 50%
4. 75%
5. **100%**
6. 150%

Answer: 5.

Task 35
Entry level (1 point)

How do amorphous solids behave when heated?
1. amorphous substances remain in a solid state up to a certain temperature, then begin to melt and change to a liquid state.
2. amorphous substances remain in a solid state up to a certain temperature, then begin to sublimate, changing to a gaseous state.
3. amorphous substances soften when heated, smoothly changing from a solid to a liquid state.
4. amorphous substances remain in a solid state up to a certain temperature, then undergo chemical reactions.
5. amorphous substances remain solid at any temperature.

Answer: 3.

Task 36
Intermediate level (3 points)

Select all the correct statements that define boiling:

1. Boiling is the vaporization that occurs solely from the surface of a liquid at temperatures above its melting point**.**
2. **Boiling happens when the saturated vapor pressure matches atmospheric pressure.**
3. **When ascending a high mountain, the boiling point of water decreases; conversely, when descending into a deep mine, the boiling point of water increases.**
4. During the boiling process, the internal energy of the substance remains unchanged.
5. **During the boiling process, the temperature stays constant, and the heat absorbed is used to increase the potential energy of the molecules.**

Answer: 2, 3, 5.

You earn 1 point for each correct statement and lose 1 point for each incorrect one.

Task 37
Intermediate level (4 points)

In a sauna with a volume of 10 m^3, the thermometer reads 100^0C, the hygrometer reads 30%. Find the mass of water vapor in the sauna. The density of saturated steam at 100^0C is 0.59 kg/m^3. Give the answer in kilograms, rounded to the nearest tenth.

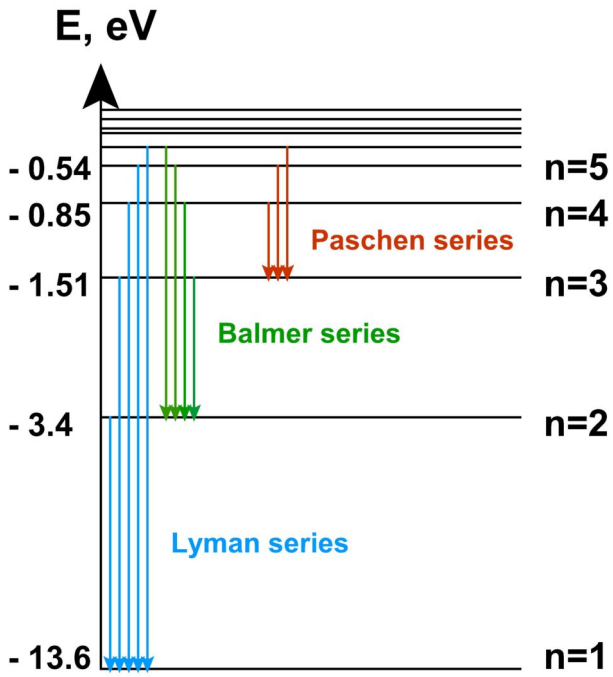
Answer: 1.7 kg.

Field of Science 6. Atomic, Molecular and Chemical Physics

Task 38
Entry level (1 point)

The diagram shows the energy levels scheme of a hydrogen atom. What frequency photon must the atom absorb to transition from the ground state to the fourth excited state?

The value of Planck's constant: $h = 4.135\,668 \cdot 10^{-15}$ eV · s, $\hbar = 6.582\,120 \cdot 10^{-16}$ eV · s.



1. $\nu = 2.466$ Hz
2. $\nu = 2.923$ Hz
3. $\nu = 3.083$ Hz
4. **$\nu = 3.158$ Hz**

Answer: **4.**

Task 39
Entry level (1 point)

An α particle with an energy $T_\alpha = 10$ MeV collides with a stationary silver atom nucleus ${}_{47}Ag$ positioned directly in the path of the α particle. Find the minimum distance the α particle can approach the nucleus, treating the nucleus as a point particle. Express the answer in femtometers (fm).

The Coulomb constant $k = 8.987552 \cdot 10^9 \frac{N \cdot m^2}{C^2}$, the charge of the electron $|e| = 1.602177 \cdot 10^{-19}$ C. 1 eV $= 1.602177 \cdot 10^{-19}$ N · m.

1. 3.68 fm
2. 6.77 fm
3. **13.54 fm**
4. 27.07 fm

Answer: 3.

Task 40
Intermediate level (4 points)

A neutral atom is formed by the nucleus $^{16}_{8}O$ and electrons. Find the mass of this atom $M_{atom}\left(^{16}_{8}O\right)$, given that the binding energy of the nucleus $\Delta W\left(^{16}_{8}O\right) = 127.617$ MeV. Give the answer in energy equivalent $M_{atom}\left(^{16}_{8}O\right) \cdot c^2$ in megaelectronvolts (MeV), rounded to the nearest unit.
The mass of the proton $m_p \cdot c^2 = 938.272$ MeV, the mass of the neutron $m_n \cdot c^2 = 939.565$ MeV, the mass of the electron $m_e \cdot c^2 = 0.511$ MeV.

Answer: 14899 MeV

Task 41
Intermediate level (4 points)

Calculate the energy released as a result of the reaction:

$$p + p \rightarrow d + e^+ + \nu_e$$

The mass of the proton $m_p \cdot c^2 = 938.272$ MeV, the mass of the deuteron $m_d \cdot c^2 = 1875.612$ MeV, the mass of the electron $m_e \cdot c^2 = 0.511$ MeV. Neglect the mass of the neutrino ν_e.
Give the answer in MeV, rounded to the nearest hundredth.

Answer: 0.42 MeV

Field of Science 7. Quantum Technologies

Task 42
Entry level (1 point)

Monochromatic light with a wavelength of 200 nm falls onto the surface of a metal. The wavelength that corresponds to the red limit of the photoelectric effect for this metal is 300 nm. What portion of the photon energy is used to give kinetic energy to the electron?
1. 2/3
2. 1/3
3. 1/2
4. 3/4

Answer: 2.

Task 43
Entry level (1 point)

When the cathode of a vacuum photocell is exposed to a stream of monochromatic radiation, it emits photoelectrons. How will the saturation photocurrent be affected if the frequency of the incident radiation is doubled?

1. Will increase by 2 times
2. Will increase by more than 2 times
3. Will increase by less than 2 times
4. Will decrease by 2 times
5. Will decrease by more than 2 times

6. Will decrease by less than 2 times
7. **The value of the saturation photocurrent does not depend on the frequency of the incident radiation**

Answer: 7.

Task 44
Entry level (1 point)

Find the work function of a specific metal surface if the maximum velocities of the emitted photoelectrons vary by a factor of 4 when exposed alternately to radiation with wavelengths of 400 nm and 600 nm.
Planck's constant is $h = 4.136 \cdot 10^{-15}$ eV · s, the speed of light is $c = 2.998 \cdot 10^{8}$ m/s.

1. **2.00 eV**
2. 2.76 eV
3. 3.51 eV
4. 4.01 eV

Answer: 1.

Task 45
Intermediate level (4 points)

The longest wavelength of light at which the photoelectric effect can still be observed in a nickel photocell is 249 nm. Find the speed of electrons ejected by light with a wavelength of 150 nm.
The electron mass is $m_e \cdot c^2 = 0.511$ MeV, Planck's constant is $h = 4.136 \cdot 10^{-15}$ eV · s, the speed of light is $c = 2.998 \cdot 10^{8}$ m/s
Give the answer in Mm/s and round to the nearest hundredth.

Answer: 1.08 Mm/s