A Journey to Europa

IJSO MCQ Mock Test

This is an IJSO mock test, a paper made to mimic the style and difficulty of IJSO questions. Its aim is to help students in preparing for the IJSO and IJSO like competitions.
The questions in this paper were made by the following members of our team (in alphabetical order):

- Alex Jicu (Romania)
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- Jailson Godeiro (Brazil)
- Jathurshan Myuran (Sri Lanka)
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- Parthipan Kasiban (Sri Lanka)
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In solving the questions, you might need to use the following constants:

Constant	Notation	Value
Acceleration due to gravity	g	$9.8\ ms^{-2}$
Gravitational constant	G	$6.67 \cdot 10^{-11}\ m^3/\ kg \cdot s^2$
Planck's constant	h	$6.62 \cdot 10^{-34}\ J \cdot s$
Elementary charge	e	$1.6 \cdot 10^{-19}\ C$
Speed of light in vacuum	c	$3 \cdot 10^8\ ms^{-1}$
Density of water	ρ	$1000\ kg\ m^{-3}$
Stefan-Boltzmann constant	σ	$5.67 \cdot 10^{-8}\ \frac{W}{m^2K^4}$
Universal gas constant	R	$8.314\ J\ mol^{-1}\ K^{-1}$ $0.08206\ atm\ L\ mol^{-1}\ K^{-1}$
Avogadro's number	N_A	$6.022 \cdot 10^{23}\ mol^{-1}$
Faraday's constant	F	$96\ 500\ C/mol$
Pi	π	3.14
Electrical permittivity of free space	ε_0	$8.85 \cdot 10^{-12}\ F \cdot m^{-1}$
Magnetic permeability of free space	μ_0	$4\pi \cdot 10^{-7}\ H/m$
Mass of Earth		$5.97 \cdot 10^{24}\ kg$
Mass of Moon		$7.35 \cdot 10^{22}\ kg$
Mass of Sun		$1.99 \cdot 10^{30}\ kg$
Radius of Earth		$6.4 \cdot 10^6\ km$
Radius of Moon		$1.7 \cdot 10^6\ km$
Radius of Sun		$6.96 \cdot 10^8\ km$
Specific heat capacity of water	c_w	$4200\ J/kg \cdot {}^\circ C$
Average molar mass of air	M	$28.9\ g/mol$

If any other value is provided in the problem, use the value provided, not the one in the table. You can also use the following conversion formulas:

$T\ (K) = t\ ({}^\circ C) + 273$	$t\ ({}^\circ F) = \frac{9}{5} t\ ({}^\circ C) + 32$
$1bar = 1atm = 101\ 000Pa = 760mmHg$	$1u = 1Da = 1.66 \cdot 10^{-27} kg$
$1L = 10^{-3}\ m^3$	$1\ day = 24h$

If needed, you can use the periodic table given below:

IUPAC Periodic Table of the Elements

Key: atomic number / **Symbol** / name / abridged standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen 1.0080 ±0.0002																	2 **He** helium 4.0026 ±0.0001
3 **Li** lithium 6.94 ±0.06	4 **Be** beryllium 9.0122 ±0.0001											5 **B** boron 10.81 ±0.02	6 **C** carbon 12.011 ±0.002	7 **N** nitrogen 14.007 ±0.001	8 **O** oxygen 15.999 ±0.001	9 **F** fluorine 18.998 ±0.001	10 **Ne** neon 20.180 ±0.001
11 **Na** sodium 22.990 ±0.001	12 **Mg** magnesium 24.305 ±0.002											13 **Al** aluminium 26.982 ±0.001	14 **Si** silicon 28.085 ±0.001	15 **P** phosphorus 30.974 ±0.001	16 **S** sulfur 32.06 ±0.02	17 **Cl** chlorine 35.45 ±0.01	18 **Ar** argon 39.95 ±0.16
19 **K** potassium 39.098 ±0.001	20 **Ca** calcium 40.078 ±0.004	21 **Sc** scandium 44.956 ±0.001	22 **Ti** titanium 47.867 ±0.001	23 **V** vanadium 50.942 ±0.001	24 **Cr** chromium 51.996 ±0.001	25 **Mn** manganese 54.938 ±0.001	26 **Fe** iron 55.845 ±0.002	27 **Co** cobalt 58.933 ±0.001	28 **Ni** nickel 58.693 ±0.001	29 **Cu** copper 63.546 ±0.003	30 **Zn** zinc 65.38 ±0.02	31 **Ga** gallium 69.723 ±0.001	32 **Ge** germanium 72.630 ±0.008	33 **As** arsenic 74.922 ±0.001	34 **Se** selenium 78.971 ±0.008	35 **Br** bromine 79.904 ±0.003	36 **Kr** krypton 83.798 ±0.002
37 **Rb** rubidium 85.468 ±0.001	38 **Sr** strontium 87.62 ±0.01	39 **Y** yttrium 88.906 ±0.001	40 **Zr** zirconium 91.224 ±0.002	41 **Nb** niobium 92.906 ±0.001	42 **Mo** molybdenum 95.95 ±0.01	43 **Tc** technetium [97]	44 **Ru** ruthenium 101.07 ±0.02	45 **Rh** rhodium 102.91 ±0.01	46 **Pd** palladium 106.42 ±0.01	47 **Ag** silver 107.87 ±0.01	48 **Cd** cadmium 112.41 ±0.01	49 **In** indium 114.82 ±0.01	50 **Sn** tin 118.71 ±0.01	51 **Sb** antimony 121.76 ±0.01	52 **Te** tellurium 127.60 ±0.03	53 **I** iodine 126.90 ±0.01	54 **Xe** xenon 131.29 ±0.01
55 **Cs** caesium 132.91 ±0.01	56 **Ba** barium 137.33 ±0.01	57-71 lanthanoids	72 **Hf** hafnium 178.49 ±0.01	73 **Ta** tantalum 180.95 ±0.01	74 **W** tungsten 183.84 ±0.01	75 **Re** rhenium 186.21 ±0.01	76 **Os** osmium 190.23 ±0.03	77 **Ir** iridium 192.22 ±0.01	78 **Pt** platinum 195.08 ±0.02	79 **Au** gold 196.97 ±0.01	80 **Hg** mercury 200.59 ±0.01	81 **Tl** thallium 204.38 ±0.01	82 **Pb** lead 207.2 ±1.1	83 **Bi** bismuth 208.98 ±0.01	84 **Po** polonium [209]	85 **At** astatine [210]	86 **Rn** radon [222]
87 **Fr** francium [223]	88 **Ra** radium [226]	89-103 actinoids	104 **Rf** rutherfordium [267]	105 **Db** dubnium [268]	106 **Sg** seaborgium [269]	107 **Bh** bohrium [270]	108 **Hs** hassium [269]	109 **Mt** meitnerium [277]	110 **Ds** darmstadtium [281]	111 **Rg** roentgenium [282]	112 **Cn** copernicium [285]	113 **Nh** nihonium [286]	114 **Fl** flerovium [290]	115 **Mc** moscovium [290]	116 **Lv** livermorium [293]	117 **Ts** tennessine [294]	118 **Og** oganesson [294]

57 **La** lanthanum 138.91 ±0.01	58 **Ce** cerium 140.12 ±0.01	59 **Pr** praseodymium 140.91 ±0.01	60 **Nd** neodymium 144.24 ±0.01	61 **Pm** promethium [145]	62 **Sm** samarium 150.36 ±0.02	63 **Eu** europium 151.96 ±0.01	64 **Gd** gadolinium 157.25 ±0.03	65 **Tb** terbium 158.93 ±0.01	66 **Dy** dysprosium 162.50 ±0.01	67 **Ho** holmium 164.93 ±0.01	68 **Er** erbium 167.26 ±0.01	69 **Tm** thulium 168.93 ±0.01	70 **Yb** ytterbium 173.05 ±0.02	71 **Lu** lutetium 174.97 ±0.01
89 **Ac** actinium [227]	90 **Th** thorium 232.04 ±0.01	91 **Pa** protactinium 231.04 ±0.01	92 **U** uranium 238.03 ±0.01	93 **Np** neptunium [237]	94 **Pu** plutonium [244]	95 **Am** americium [243]	96 **Cm** curium [247]	97 **Bk** berkelium [247]	98 **Cf** californium [251]	99 **Es** einsteinium [252]	100 **Fm** fermium [257]	101 **Md** mendelevium [258]	102 **No** nobelium [259]	103 **Lr** lawrencium [262]

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For notes and updates to this table, see www.iupac.org. This version is dated 4 May 2022.

Use atomic masses rounded to two decimal places.

Question 01 - Anatomical Marvels from an Unseen Realm

A deep-sea exploration uncovered a previously unknown colonial organism living near hydrothermal veins and the research team decided to call it *Abyssotrochus crystallinus*. Anatomical studies of this organism reveal that individual creatures within the colony possessed a microtubule system, consisting of a network of crystalline silica tubules, internally lined with specialized cells containing high concentrations of metalloenzymes. These tubules connect to external pores and seem to facilitate direct interaction with the metal-rich vent fluids.

Given its deep-sea, chemosynthetic vent environment, and the unique structure described (silica tubules with metalloenzymes interfacing with vent fluids), what is the most plausible primary physiological function of this microtubule system in this organism?

A. To provide a rigid internal skeleton for structural support against the immense hydrostatic pressure.

B. To act as a bioluminescent organ, producing light for intraspecies communication or attracting scarce prey in the aphotic zone.

C. To facilitate the uptake and enzymatic processing of dissolved metal ions or reduced gases from the vent fluids for energy or biosynthesis.

D. To serve as a sophisticated sensory organ for detecting minute vibrations or pressure changes, alerting the colony to geological instability or predators.

Problem proposed by Parthipan Kasiban

Question 02 – Foundational Habitability

The discovery of organisms like *Abyssotrochus crystallinus*, significantly broadened our understanding of life's potential adaptability. This spurred renewed focus on celestial bodies like Europa, a moon of Jupiter, believed to harbor a vast liquid water ocean beneath its icy shell, which is kept warm by tidal forces despite surface temperatures of -160°C. The long-term stability of this potential habitat depends critically on the physical properties of water (H_2O). Which specific physical property of water is most fundamental to enabling this stable configuration of a liquid water ocean on Europa?

A. Water's high specific heat capacity.

B. The hexagonal crystalline lattice structure of ice.

C. The ability of water to act as a versatile solvent.

D. Water's strong cohesive and adhesive forces.

Problem proposed by Parthipan Kasiban

Question 03 – Plumes of Biological evidence

Evidence suggests intermittent plumes of water vapor erupts from Europa's surface in variable intervals, potentially originating from the subsurface ocean. Future missions aim to analyze these plumes using spectrometers, searching for signs of life. While simple organic molecules can form abiotically, certain complex molecular properties might serve as stronger indicators of biological activity within the ocean.

If a future orbiter analyzing Europa's plumes confirms the presence of various amino acids, which specific additional finding related to these amino acids would provide the strongest, albeit not definitive, evidence suggestive of biological processes within the subsurface ocean?

A. A significant preference for one chiral form (e.g., L-amino acids over the other (D-amino acids) – among the detected chiral amino acids.

B. Detection of amino acids, like glycine and alanine, in high abundance.

C. The presence of amino acids alongside abundant methane (CH_4) and carbon dioxide (CO_2), indicating active carbon chemistry.

D. Finding amino acids exclusively associated with sulfur compounds, pointing towards synthesis pathways linked to volcanic outgassing.

Problem proposed by Jathurshan Myuran

Question 04 - Energy in the Dark Depths

Sunlight cannot penetrate Europa's thick ice shell, ruling out photosynthesis as a primary energy source in its deep ocean. However, analogies with Earth's deep-sea hydrothermal vents suggest that similar features on Europa's seafloor could release reduced chemical compounds (e.g. H_2S, H_2, Fe^{2+}), offering a potential chemical energy source for life (chemosynthesis) in perpetual darkness.

Assuming hydrothermal vents are active on Europa's seafloor, which represents the most plausible primary energy-harvesting mechanism for a hypothetical microbial community thriving near these vents?

A. Anoxygenic photosynthesis utilizing faint infrared radiation emitted by the warm vent fluids.

B. Chemosynthesis, specifically lithoautotroph, involves the oxidation of reduced inorganic compounds from vent fluids coupled with the reduction of available oxidants in the ocean water.

C. Direct absorption and utilization of the thermal energy (heat) gradient between the vent fluids and the colder surrounding ocean water.

D. Photoheterotrophy driven by bioluminescence generated by other organisms within the vent community.

Problem proposed by Jathurshan Myuran

Question 05 – Rover on the loose

Under the leadership of renowned Romanian scientist Jicu, a team of brilliant scientists has successfully entered orbit around Europa and landed near its equatorial ice plains. Their first task is to determine the gravitational acceleration on Europa to calibrate the onboard instruments. To do this, they use a simple pendulum. A 2.00 m long pendulum is suspended from a lander, and it completes 20 full oscillations in 154.98 seconds.

Later, a 180 kg rover glides across Europa's icy plains at 4.5 m/s, but its motors fail, and it slows down due to kinetic friction, with $\mu_k = 0.03$. Approximately how far will the rover travel before coming to rest?

A. 221.9 m

B. 256.7 m

C. 314.6 m

D. 443.8 m

Problem proposed by Thenura Wickramaratna

Question 06 – Temperature of Cebalrai

Before their Europa expedition, the team analyzed Cebalrai—a bright orange giant located in the constellation Ophiuchus. Curious about its energy output, they began estimating its luminosity based on Earth-based observations and known stellar data:

One measure of a star's brightness is its luminosity. The luminosity is defined as the electromagnetic energy radiated per unit time and it's given by the Stefan-Boltzmann Law: $L = 4\pi\sigma R^2 T^4$

Another way to measure a star's brightness is its absolute magnitude, a logarithmic measure of its luminosity. It is defined as $M = -2.5\log(k \cdot L)$ where k is a constant and L is the star's luminosity.

The star Cebalrai (β Ophiuchi) has an absolute magnitude $M = 2.76$ and a radius $R = 12.42R_\odot$ where $R_\odot$ is the sun's radius. If the sun's absolute magnitude is $M_\odot = 4.83$ and its average temperature is $T_\odot = 5700K$, find the average temperature of Cebalrai.

You may find the following equations useful:

$$\log(xy) = \log x + \log y$$
$$\log\left(\frac{x}{y}\right) = \log x - \log y$$

A. 2480 K

B. 2605 K

C. 8105 K

D. 12471 K

Problem proposed by Alex Jicu

Question 07 - Identifying a Mysterious Gas

During a simulated Europa surface experiment, a mineral sample—suspected to contain halide salts—is gradually heated to 100°C in a controlled lab chamber. As the temperature increases, a yellowish gas is observed evolving from the sample.

One curious intern notes the smell as “sharply pungent, like a swimming pool but worse.” As part of standard testing, a strip of moist blue litmus paper is introduced into the chamber. The paper first turns red, indicating acidity, then becomes colorless, suggesting a secondary chemical interaction.

Based on these observations, which of the following gases was most likely released?

A. Hydrogen

B. Oxygen

C. Sulfur Dioxide

D. Chlorine

Problem proposed by Thenura Wickramaratna

Question 08 – Drilling Through the Icy Crust

The team wants to drill through the 15-kilometer-thick icy crust and reach the subsurface ocean believed to harbor extraterrestrial microbial life.

To accomplish this, the team deploys an advanced nuclear-powered thermal drill capable of delivering a continuous 2.5 megawatts (MW) of thermal power. However, Europa's surface is brutally cold, with an average temperature of –160°C, which presents a significant thermal energy barrier.

The drill has a cross-sectional area of 0.5 square meters and must bore through a vertical ice layer 15 km thick. The density of ice is approximately 920 kg/m³, the specific heat capacity of ice is 2.1×10^3 J/kg°C, and the latent heat of fusion of ice is 3.3×10^5 J/kg. Assume the drill operates with 80% energy efficiency.

Approximately how long (in days) will it take the drill to reach the ocean?

A. 10.5 days

B. 21.3 days

C. 26.6 days

D. 28.9 days

Problem proposed by Thenura Wickramaratna

Question 09 - Drilling Through the Icy Crust (Continued)

Instead of the drill, Jicu and his team decided to use a laser to melt through the ice (to make a hole identical to that in Q8). The laser emits monochromatic light (λ = 550 nm) emits a flux f = 7.5×10^{24} photons per second. Unlike the drill, the laser works with a 100% efficiency.

How much time would the laser take to melt all the ice?

A. 14.8 days

B. 19.6 days

C. 21.3 days

D. 24.5 days

Problem proposed by Alex Jicu

Question 10 - Signatures of life found in Europa

A lander successfully drills through Europa's ice and collects a liquid sample from a subsurface pocket or the ocean itself. Onboard microscopy examines the sample for structures resembling microbial life. Distinguishing between genuine cells, dormant forms, complex non-living vesicles, or mineral grains is a crucial analytical challenge.

Which of the following observed features, if consistently identified across multiple microscopic structures (0.5 - 2 μm) in the sample, would provide the most compelling evidence for classifying these structures as being of biological origin, analogous to cellular life?

A. The structures exhibit a perfectly uniform size and crystalline surface texture.

B. Chemical analysis shows the structures are primarily composed of complex silicate minerals and ice.

C. The structures are observed to passively aggregate but show no evidence of internal compartmentalization.

D. High-resolution imaging confirms a distinct, continuous boundary layer (~8-10 nm thick), enclosing internal contents chemically distinct from the external brine.

Problem proposed by Parthipan Kasiban

Question 11 - Depth of the Ocean Layer

During a mission to map Europa's subsurface ocean, Jicu's team fires a monochromatic laser ($\lambda = 532$ nm in vacuum) vertically downward through the icy crust into the ocean layer. The crust is 15 km thick, and the ocean has a refractive index of 1.39, while the ice has a refractive index of 1.31. A detector array at the surface measures the round-trip time taken by the laser pulse: 152.0 microseconds.

Assume the laser travels in a straight path, reflects off a mirror placed on the ocean floor, and returns.

What is the depth of the ocean layer beneath the 15 km ice crust?

A. 2.17 km

B. 2.27 km

C. 2.58 km

D. 3.11 km

Problem proposed by Thenura Wickramaratna

Question 12 - Currents in the Ocean

A research satellite is in a circular orbit around Europa, one of Jupiter's moons. As it flies over the moon's surface, it passes over a large loop of superconducting wire embedded just below the ice.

As the satellite approaches, its onboard plasma thruster generates a steady magnetic field pointing downward. As the satellite gets closer, the magnetic flux through the loop increases.

What direction of induced current will develop in the loop (as viewed from above Europa), and what is the physical effect of this current?

A. Clockwise, creating a magnetic field that reinforces the satellite's field.

B. Counterclockwise, creating a magnetic field that increases the flux.

C. Counterclockwise, creating a magnetic field that opposes the increase in flux.

D. Clockwise, creating an electric field that accelerates the satellite.

Problem proposed by Thenura Wickramaratna

Question 13 - Genetic Diversity in a Vast Ocean

Europa's subsurface ocean is potentially vast, likely containing hydrothermal vents scattered about hundreds of km from each other. Ocean currents, driven by tidal forces and geothermal heat gradients, might exist but their strength over such distances are unknown, potentially being very slow or stratified. An autonomous underwater vehicle found some microbial communities around such geographically distant vent sites.

Considering the immense potential scale of Europa's ocean and the likely separation of habitable vent 'islands', which evolutionary factor, potentially operating alongside natural selection, would likely play a crucial role in driving genetic differentiation *between* the microbial populations inhabiting these separate vent systems?

A. High rates of horizontal gene transfer mediated by viruses, leading to genetic homogenization across all vents despite the distance.

B. Strong stabilizing selection favoring identical traits in all vent environments, thus preventing any significant genetic divergence between populations.

C. Frequent mutations caused by background radiation, leading to random but similar genetic changes in all populations simultaneously.

D. Genetic drift, acting powerfully in potentially small, geographically isolated populations, leading to random divergence in allele frequencies between the separate vent communities over time.

Problem proposed by Parthipan Kasiban

Question 14 - Power for Instruments in Europa

To power instruments on Europa, researchers design a voltaic cell that operates in the moon's icy, salty environment. The cell is made of Zinc, Silver half cells. The standard electrode potentials for the half cells are given below.

$$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s) \qquad E^\circ = -0.76V$$

$$Ag^+(aq) + e^- \rightarrow Ag(s) \qquad E^\circ = +0.80V$$

However, due to low ionic mobility in Europa's cold brine (approx. 223 K), the ion concentrations are not standard:

$$[Ag^+] = 0.0010M$$

$$[Zn^{2+}] = 0.100M$$

Using the Nernst equation

$$E_{cell} = E^\circ{}_{cell} - \frac{RT}{zF} ln\ Q$$

Calculate the actual cell potential at this temperature.

A. + 0.07 V

B. + 0.04 V

C. + 1.45 V

D. + 1.56 V

Problem proposed by Thenura Wickramaratna

Data for problems 15, 16, 17 and 18:

Mass of Europa	$4.800 \cdot 10^{22}\ kg$
Radius of Europa	$1561\ km$
Distance between Earth and Europa	$6.283 \cdot 10^{8}\ km$
Period of Rotation	$84\ hours$

Question 15 – Satellite in Europa

A satellite has been launched to provide internet connection and facilitate communication with earth for Europa. The satellite is in a circular orbit 550 km above the surface. Determine the orbital velocity of the satellite and how long would it take for a message sent from earth to reach Europa.

A. 1.2 km/ s and 35 minutes

B. 1.7 km/s and 40 minutes

C. 1.2 km/s and 40 minutes

D. 1.7 km/s and 35 minutes

Problem proposed by Jailson Godeiro

Question 16 - More about the Satellite

To develop faster communication in Europa, Jicu's team placed a geosynchronous (has the same period as Europa) sphere-like satellite of diameter D = 1 km to orbit around Europa. Calculate the difference in gravitational force that an object of 1 kg feels at each end of the ship.

A. $8.6 \cdot 10^{-7}$ N

B. $17.2 \cdot 10^{-7}$N

C. $25.9 \cdot 10^{-7}$ N

D. $34.5 \cdot 10^{-7}$ N

Problem proposed by Mateo Sancho

Question 17 - The Satellite Receives a Message

When Europa received a radio signal from earth, they registered a frequency of 95.6956 MHz, however, the responsible for sending the signals back on earth claims that the source sent out a signal with frequency 95.7000 MHz, what is the explanation for this?

A. Earth is moving away from Europa with radial speed of 13.74 km/s

B. Earth is moving towards Europa with radial speed of 13.74 km/s

C. Earth is moving away from Europa with radial speed of 5.42 km/s

D. Earth is moving towards Europa with radial speed of 5.42 km/s

Problem proposed by Jailson Godeiro

Question 18 – Travelling Around Europa

Some of the scientists who arrived at Europa are competing to determine who can travel around the whole moon (throughout the circumference of latitude: 6° 6’ 36’’ South) in the lowest time possible, however, they should be careful to not accidentally enter orbit, since the mass of the moon is small and speeds can be high. Assuming they can choose their speed, what is the minimum time someone can perform the trip while staying on the surface?

A. 1h 33m

B. 1h 44m

C. 1h 53m

D. 2h 3m

Problem proposed by Jailson Godeiro

Question 19 - Limits in a Chemically Fueled Ecosystem

Near a Europan hydrothermal vent, a constant efflux of geothermally produced chemical reductants (e.g., H_2, H_2S) into the surrounding ocean water provides the primary energy source for a local chemosynthetic microbial community. Assume other necessary nutrients and oxidants are available in the vicinity but are not immediately limiting compared to the energy source itself.

For a microbial population establishing itself and utilizing a newly formed, continuous, localized hydrothermal vent, what pattern of population size change would be expected over time, and what ultimately dictates the maximum sustainable population size?

A. The population would grow exponentially without limit, constrained only by the microbes' intrinsic reproductive rate.

B. The population would grow linearly, adding a fixed number of individuals per unit time, limited by the diffusion rate of microbes away from the vent.

C. The population size would increase initially then stabilize, exhibiting logistic growth, with the maximum size determined by the rate at which the vent supplies the usable chemical energy.

D. The population would likely remain very small and fluctuate randomly due to the inherent instability of hydrothermal vent chemistry.

Problem proposed by Jathurshan Myuran

Question 20 – Jicu Takes a Walk

After a heated argument with one of his team members, Romanian physicist Jicu, stormed off into the icy plains of Europa to ‘clear his head.’

He grabs an oxygen tank containing 10.0 L of oxygen gas at a pressure of 30.0 atm and a temperature of 300 K. However, he forgets to account for Europa’s much colder ambient conditions. His spacesuit operates by supplying oxygen at 1.0 atm and 250 K, and he consumes oxygen at a steady rate of 3.0 L per minute (measured under suit conditions: 1.0 atm and 250 K). Assuming ideal gas behavior and no oxygen losses, how long can Jicu walk before he runs out of breathable oxygen?

A. 65.4 minutes

B. 83.3 minutes

C. 90 minutes

D. 100 minutes

Problem proposed by Thenura Wickramaratna

Question 21 - The Consequences of the Walk

After Jicu's oxygen mishap during his walk on Europa, Jicu blacks out after travelling at a constant speed of 3 km/h for time specified in Problem 20. Filip, the mission's engineer, immediately launched the HydroRover, a rescue vehicle powered by a hydrogen-oxygen fuel cell that combines the gases to produce water vapor and electrical energy.

The HydroRover consumes 0.0040 g of hydrogen per meter traveled. Filip reaches Jicu, administers oxygen and drives back to the base with him.

Assuming the reaction goes to completion with no losses and that the rover travels the same path back.

What is the total volume of water vapor produced at 1.0 atm and 250 K?

A. 250.4L

B. 341.8L

C. 350.6L

D. 373.4L

Problem proposed by Thenura Wickramaratna

Question 22 - Biomass Production Estimate

A microbial community near a Europan hydrothermal vent performs chemosynthesis using hydrogen sulfide (H_2S) supplied by the vent and dissolved oxygen (O2) supplied by downwelling currents. The reaction is $2H_2S + O_2 \rightarrow 2S + 2H_2O$, yielding ΔH ≈ −420 kJ per mole of O_2. The community captures energy with 20% efficiency and requires 40 kJ of captured energy per gram of Carbon fixed. Dry biomass is ~50% Carbon. Site analysis estimates sustained fluxes into the ecosystem volume: H2S flux = 500 moles/year; O_2 flux = 200 moles/year.

Based on these estimates and reaction stoichiometry, what is the maximum theoretical rate of *total dry biomass* production (in kilograms per year) supported by this community, considering potential reactant limitations?

A. 0.21 kg / year

B. 0.42 kg / year

C. 0.53 kg / year

D. 0.84 kg / year

Problem proposed by Parthipan Kasiban

Question 23 - Europa Simulation Lab

In a Europa simulation lab, the decomposition of hydrogen peroxide is investigated:

The rate constant k is measured at two different temperatures:

- $k_1 = 1.20 \times 10^{-4}\ s^{-1}$ at $T_1 = 298$ K
- $k_2 = 1.45\ \times 10^{-6}\ s^{-1}$ at $T_2 = 223$ K

Assume this is a first-order reaction and follows the Arrhenius equation (shown below).

$$\ln \frac{k_2}{k_1} = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Using these values, estimate the rate constant k_3 at a new temperature of 273 K.

A. $1.84 \times 10^{-4} s^{-1}$

B. $1.48 \times 10^{-4} s^{-1}$

C. $3.61 \times 10^{-5} s^{-1}$

D. $3.83 \times 10^{-5} s^{-1}$

Problem proposed by Filip Kilibarda

Question 24 - Europa Simulation Lab (Continued)

At the newly estimated rate constant k_3 for the decomposition of hydrogen peroxide at 273 K, a 1.0 mol/L solution is monitored during the experiment.

Assume the reaction is first order. Using the rate constant k_3 you determined in the previous question, estimate how long (in seconds) it would take for the concentration of hydrogen peroxide to decrease from 1.0 mol/L to 0.25 mol/L.

Use $[A] = [A]_0 e^{-kt}$

A. 580 min

B. 600 min

C. 640 min

D. 660 min

Problem proposed by Thenura Wickramaratna and Filip Kilibarda

Question 25 - Selection Pressures

A population of Europan chemoautotrophs living near the ice-ocean interface was found by the underwater vehicle. This region experiences fluctuations: periods of stable, low-nutrient conditions disrupted by pulses of high-concentration salts and concentrated nutrients. Microbes vary some are tough against shocks (but it costs energy), others grow fast with nutrients (but are vulnerable to shocks). Over a long time, what type of selection pressure is most likely?

A. Disruptive or fluctuating selection favors microbes highly specialized for either trait.

B. Strong directional selection consistently favors maximum robustness, as survival during shock events is paramount, regardless of growth efficiency.

C. Strong directional selection consistently favors the maximum metabolic rate, allowing populations to capitalize rapidly on nutrient pulses.

D. Stabilizing selection favors microbes with intermediate levels of both robustness and metabolic rate, balancing survival and growth across average conditions.

Problem proposed by Jathurshan Myuran

Question 26 - More Experiments in the Simulation Lab

In another experiment on Europa, scientists investigate the enthalpy change of a reaction involving magnesium metal reacting with aqueous hydrochloric acid, which could help generate heat in extremely cold environments.

A student adds 1.20 g of Mg to 100.0 mL of 1.0 M HCl in a calorimeter. The temperature of the solution increases from 273 K to 298 K.

Assuming 80% of the heat from the reaction is absorbed by the water, estimate the enthalpy change ΔH of the reaction per mole of Mg.

You can assume that the HCl solution has a density and a specific heat capacity equal to those of water.

A. 10.50 kJ

B. 13.13 kJ

C. 212.7 kJ

D. 265.7 kJ

Problem proposed by Thenura Wickramaratna

Question 27 - Biological Challenges of Life on Europa

Thanks to the generous sponsorship of Thenura, researchers looked for a possibility in establishing a base on Europa. A permanent human presence on Europa necessitates a highly reliable, self-sustaining, closed-loop life support system (CLSS) within a shielded habitat. This involves regenerating air, recycling water, managing waste, and crucially, producing food far from Earth resupply.

Considering the need to provide complete nutrition (macro- and micro-nutrients) reliably and efficiently within the strict mass, volume, and energy constraints of a Europan habitat, which biological challenge is MOST critical when designing the food production subsystem?

A. Preventing microbial contamination in hydroponic/aeroponic plant growth systems.

B. Achieving efficient conversion of inorganic waste back into edible biomass using microbial decomposers and subsequent plant or algal growth.

C. Ensuring the long-term genetic stability of crop plants or microbes grown under artificial light and potentially higher radiation backgrounds (even with shielding).

D. Producing the full spectrum of essential amino acids, fatty acids, vitamins, and minerals required for human health using a limited suite of rapidly growing organisms (e.g., algae, yeast, selected plants) or processes.

Problem proposed by Parthipan Kasiban

Question 28 - Life in Europa

Not surprisingly, one of the most important substances for life in Europa is Oxygen.

Even though usually found as a dioxygen, it can also be found as its allotrope, ozone. Choose the correct statement about ozone.

A. It has a linear structure, with bonds with intermediate character between a single and a double bond.

B. It's a powerful oxidizer, being able to oxidize iodine to iodide ions.

C. It can be obtained by creating an electric arc in a dioxygen atmosphere.

D. It easily reduces Fe (III) to Fe (II)

Problem proposed by Alex Jicu

Question 29 - Age of Europa

Scientists are trying to estimate the age of Europa based on radioactive decay of Uranium-238 to Lead-206, because it is important to understand such a process, they are trying to determine the number of alpha and beta particles emitted during a decay, which option correctly represents those numbers?

Option	Alpha Particles	Beta Particles
A	6	8
B	8	6
C	4	6
D	6	4

Problem proposed by Jailson Godeiro

Question 30 - Age of Europa (Continued)

After estimating Europa's age using the U-238 → Pb-206 system, scientists decide to cross-check the result using the decay of Uranium-235 (U-235) into Lead-207 (Pb-207) — a second, independent radiometric clock.

In a different mineral sample from Europa's rocky layer, they find that 1.2% of the original U-235 remains. The rest has decayed into Pb-207. The half-life of U-235 is 704 million years.

Based on this data, what is the approximate age of this mineral sample?

A. 2.9 billion years

B. 3.8 billion years

C. 4.3 billion years

D. 4.5 billion years

Problem proposed by Thenura Wickramaratna