Ocean exploration and studies of water

IJSO Theory mock test

Answer sheet

Problem 1 – Little Timmy again (3.50 points)

Part A. Optimizing the cell

A.a. What should the value of R_{cell} be such that the power delivered to the electrochemical cell is maximum?

(1.10 points)

Calculation:

$R_{cell} =$

A.b. In the conditions found above, what is the maximum power delivered?

(0.40 points)

Calculation:

Maximum power is $P_{max} =$

Part B. Desalination rate

B.a. At a power of 50W, what is the maximum possible amount of charge delivered to the cell per hour?

(1.20 points)

Calculation:

B.a. continuation:

Maximum charge per hour:

B.b. At a maximum power, what mass of NaCl can be removed per hour using this setup?

(0.5 points)

Calculation:

Mass of NaCl per hour:

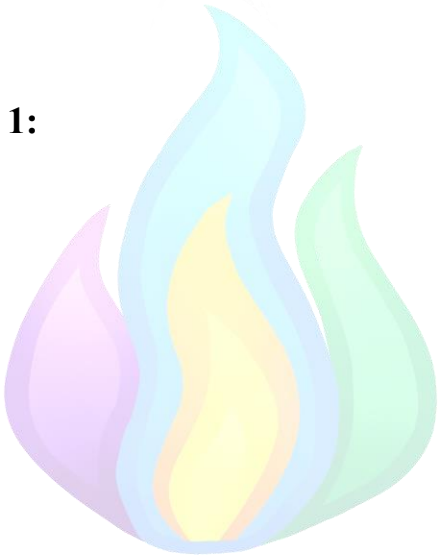
B.c. If the system operates at an efficiency of 70%, what mass of NaCl is actually removed per hour using this setup?

(0.3 points)

Calculation:

Mass of NaCl per hour:

Extra space for Problem 1:



Problem 2. The research team (4.00 points)

Part A. Thermoelectric voltage

A.a. Calculate the voltage generated by one thermocouple if T_{hot} = 390K and T_{cold} = 275K.

(0.25 points)

Calculation:

$V =$

A.b. Calculate the voltage generated by the 30 thermocouples in series.

(0.25 points)

Calculation:

$V_{total} =$

A.c. Calculate the total internal resistance of the thermocouple array

(0.25 points)

Calculation:

$r_{total} =$

Part B. Magnetic field interaction with thermoelectric circuit

B.a. Using the right hand rule, sketch a picture which clearly shows the direction of the magnetic field lines.

(0.50 points)

B.b. Calculate the magnetic force acting on the wire.

(0.50 points)

Calculation:

F =

Part C. Communicating using ultrasonic waves

C.a. Calculate the wavelength of the ultrasonic signal used by the probe.

(0.50 points)

Calculation:

Wavelength =

C.b. If the probe is located 2000m below the surface of the water, calculate the time delay in receiving the signal at the ship on the surface of the water.

(0.30 points)

Calculation:

$\Delta t =$

C.c. Calculate the frequency detected by the submersible

(1.45 points)

Calculation:

C.c. continuation

$f' =$

Extra space for problem 2:

The other research team (5.00 points)

Part A. Determining characteristics of water

Find the value of constant α.

(0.25 points)

Calculation:

α =

Part B. Sending the probe

Find the value of depth y_0

(0.50 points)

Calculation:

y_0 =

Part C. Moving the probe

C.a. Find the resultant force acting on the probe at depth $y_0 + \Delta y$

(0.60 points)

Calculation:

$F =$

C.b. Find the speed of the probe after it gets back in the equilibrium position.

(1.15 points)

Calculation:

C.b. continuation:

v =

Part D. The results

D.a. Convert the known concentrations to molar concentrations

(0.30 points)

Calculation:

Fill the table:

Ion	Sodium	Potassium	Chloride
Concentration (mol/L)			

D.b. Find the concentration (g/L) of calcium ions.

(0.80 points)

Calculation:

Concentration of calcium ions is

D.c. Find the salinity (sodium chloride w/w% concentration) of the sea water considering the density to be ρ_0 = 1kg/L

(0.50 points)

Salinity:

D.d. Find the value of A and the abundances of the two isotopes.

(0.90 points)

Calculation:

A =

Abundance of $_{A}Cl$:

Abundance of $_{A+2}Cl$:

Extra space for problem 3:

Problem 4 – Carbon dioxide in oceanic ecosystems (6.50 points)

Part A. $CaCO_3$ dissolution

Choose the effects of an atmospheric CO_2 concentration increase by marking with an X the correct option regarding the concentration of each species.

(1.00 points)

Species	Decreases	Stays the same	Increases
Atmospheric CO_2			X
Aqueous CO_2			
CO_3^{2-}			
$CaCO_{3(s)}$			
H^+			

Part B. Carbon dioxide absorber

B.a. Characterize CO_2 as either an acidic or basic oxide.

(0.50 points)

Mark the correct answer with an X:

Acidic	
Basic	

B.b. Calculate the volume (in L at STP) of $CO_{2(g)}$ that was absorbed by the solution, as well as the amount (mol) of the formed precipitate.

(1.50 points)

Calculation:

B.b. continuation:

Volume of CO_2:

Amount of precipitate:

Part C. Photosynthesis

C.a. Calculate the enthalpy change (ΔH°) of the photosynthesis reaction.

(0.80 points)

Calculation:

Enthalpy change of the photosynthesis reaction:

C.b. Choose the right option explaining the slowing of alcoholic fermentation after a particular temperature is reached.

(0.50 points)

Mark the right answer with an X:

1. High temperatures increase the solubility of CO_2, which increase the concentration of CO_2, which shifts equilibrium to the left.	
2. High temperatures favour the inverse reaction combining carbon dioxide and ethanol to yield glucose in a photosynthesis-like reaction.	
3. High temperatures denature the enzymes catalyzing the reaction.	
4. By the Le Chatelier principle, high temperatures shift the equilibrium of this exothermic reaction to the reactants side.	

C.c. If we assume that all of this CO_2 is converted directly into glucose, how long will it take to produce 1.8 g of glucose?

(1.20 points)

Calculation:

Time taken:

Part D. Starch

D.a. What is the color of the starch iodine complex?

(0.25 points)

The color of the iodine starch complex is ……...

D.b. What is the reaction between iodine and sodium thiosulfate?

(0.50 points)

Equation of reaction:

D.c. What is the chemical formula of compound X?

Chemical formula of compound X - ……...

Extra space for problem 4:

Problem 5 – Species in the Palawan archipelago (2.80 points)

Part A. Food web

A.a. Based strictly on the food web provided, identify all the organisms that function as tertiary consumers and quaternary consumers (List the species names).

(0.80 points)

Mark the correct species with T and/or Q:

Phytoplankton	Zooplankton	Silver sardine	Blue mackerel
Crimson grouper (juvenile)	Crimson grouper (adult)	Barracuda	Reef sharks

A.b. Which single species from the food web provided would likely be the most informative for studying the cumulative physiological effects resulting from the persistence of this pollutant over time?

(0.50 points)

Mark the correct species with an X:

Phytoplankton	Zooplankton	Silver sardine	Blue mackerel
Crimson grouper (juvenile)	Crimson grouper (adult)	Barracuda	Reef sharks

Part B. Ecological disruptions

B.a. What evolutionary mechanism most suitably describes the random survival of selected traits after the pollution event? Mark the right answer with an X.

(0.30 points)

1. The bottleneck effect	
2. Genetic drift	
3. Stabilizing selection	
4. Speciation	

B.b. Find the frequency of individuals which are heterozygous for the above gene.

(0.80 points)

Calculation:

Frequency:

B.c. State whether a strong regulatory system which controls all changes in DNA effectively or a not so developed system which is prone to make mistakes is better in this condition for the population.

(0.40 points)

Mark the correct answer with an X:

Strong regulatory system	
Not well developed regulatory system	

A regulation system which is prone to make mistakes is better, because mistakes allow for a high mutation rate which is beneficial for the population when facing high competition in an unstable environment.

Extra space for problem 5:

Problem 6 – Adaptations to temperature (4.70 points)

Part A. Metabolism in Yellowfin Tuna (*Thunnus albacares*)

A.a. Calculate the Q_{10} value for tuna respiration.

(0.30 points)

Calculation:

$Q_{10} =$

A.b. Predict the mean oxygen consumption rate (in mL O_2/kg/h) for Yellowfin Tuna if they were acclimated to a temperature $T_3 = 15℃$.

(0.50 points)

Calculation:

$r_3 =$

A.c. Based on your calculated Q_{10} value, would you describe the metabolic rate of Yellowfin Tuna as highly sensitive or relatively insensitive to temperature changes within this range?

(0.30 points)

Mark the right answer with an X:

Highly sensitive	
Relatively insensitive	

A.d. Explain whether a high Q_{10} value would likely be physiologically beneficial or detrimental for *each* of these two specialized groups.

(0.80 points)

Mark the right answers with an X:

	Beneficial	Detrimental
Group A		
Group B		

Part B. Diving of the spinner dolphin (*Stenella longirostis*)

B.a. Calculate the average Diving Metabolic Rate (DMR) for the Spinner Dolphin in mL O_2 / kg / minute.

(0.20 points)

Calculation:

DMR =

B.b. Calculate the theoretical ADL for the Spinner Dolphin in minutes.

(0.40 points)

Calculation:

ADL =

B.c. If a Spinner Dolphin performs a foraging dive that lasts for 75% of its calculated ADL (from part B.b), what volume of its usable oxygen stores (in mL O_2 / kg body mass) would have been consumed during this dive?

(0.30 points)

Calculation:

Volume of oxygen used =

B.d. Taking into account the dolphin's tolerance for anaerobic metabolism, what is the absolute maximum possible dive duration (aerobic + anaerobic) for this Spinner Dolphin in minutes?

(0.20 points)

Calculation:

Absolute maximum possible dive duration =

B.e. calculate the maximum depth (in meters) it could potentially reach during a dive of the maximum possible duration calculated in part B.d.

(0.40 points)

Calculation:

Maximum depth =

B.f. Find whether the dolphin will catch the squid before completely exhausting its natural oxygen reserve

(1.30 points)

Calculation:

Circle the right answer:

The dolphin can / can’t catch the squid.

Problem 7 – Species in the Mariana Trench (3.00 points)

Part A. Constructing a cladogram

Construct the most likely cladogram (phylogenetic tree) showing the evolution of species A, B, C, D from their common ancestors. On the cladogram, show the points where the different characteristic evolved.

(1.00 points)

Part B. Structural observations

B.a. Rank the three specimens by likely depth of habitat.

(0.30 points)

Complete the following table with species A, B, C:

	>		>	

B.b. Choose the right option explaining how reduced skeletal density is an energy-efficient adaptation at high pressure.

(0.50 points)

Mark the right answer with an X:

1. Reduced skeletal density minimizes the energy required for muscle contraction, allowing organisms to move more easily in high-pressure environments	
2. Lower skeletal density decreases the energy needed for bone formation, which allows more energy to be allocated for other vital processes in deep-sea organisms.	
3. A lighter skeleton requires less energy to support the organism's structure under high-pressure conditions, thus conserving metabolic resources.	
4. Reduced bone density enhances the efficiency of respiration by allowing the organism to have a greater volume of gas exchange surface area in the skeletal structure.	

B.c. Species C has minimal visual organs but enhanced lateral line structures. Choose the right explanation for this observation.

(0.50 points)

1. The specimen lives in high-altitude aquatic environments where visual input is reduced by rapid water flow, so it relies on lateral lines to detect chemical gradients.	
2. The specimen inhabits low-light or turbid environments where vision is less effective, so it relies on lateral line mechanoreceptors to detect water movement and vibrations.	
3. The specimen uses lateral line structures primarily for detecting prey in clear, shallow water, where visual signals are overwhelmed by surface reflections.	
4. The specimen evolved in arid subterranean regions and uses lateral lines to compensate for its inability to detect electromagnetic signals underwater	

Part C. Sensory adaptations

C.a. Which of the tissues is likely part of an electroreceptive organ?

(0.70 points)

Mark the right answer with an X:

Tissue A	Tissue B	Tissue C

C.b. Which part of the neuron most likely served as the receptor for the stimuli?

(0.50 points)

Mark the right answer with an X:

Axon terminals	Myelin sheath	Schwann cells	Cell body	Dendrites

-- End of answer sheet --