Ocean exploration and studies of water

IJSO Theory mock test

Solutions

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:

Using $I = \frac{E}{R+r}$ and $P = RI^2$, we have the formula $P = R\frac{E^2}{(R+r)^2} = \frac{R}{(R+r)^2}E^2$.

(0.40 points)

Because E is constant, we want to maximize the ratio $\frac{R}{(R+r)^2}$. Mathematically there is a number of ways to do this. One way is the following:

$\frac{R}{(R+r)^2} = \frac{1}{\frac{1}{R}(R+r)^2} = \frac{1}{\frac{1}{R}(R^2+2Rr+r^2)} = \frac{1}{R+2r+\frac{r^2}{R}}$. The product of the variable terms R and $\frac{r^2}{R}$ is constant (r^2). To maximize the power we want to minimize $R + 2r + \frac{r^2}{R}$. A mathematical theorem says that when the product of two variables is constant, their sum will be minimum when the variables are equal to each other. So $R = \frac{r^2}{R}$, so $R = r$.

(0.70 points)

There is a lot of ways to show that power is maximum for $R = r$. Any correct proof will get full marks.

Only writing the relationship $R_{cell} = r$ should also be awarded full marks.

$R_{cell} = \mathbf{0.5\ \Omega}$

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

(0.40 points)

Calculation:

$P_{max} = r \cdot \frac{E^2}{4r^2} = \frac{E^2}{4r}$

(0.30 points)

Numerically, $P_{max} = 72W$

(0.10 points)

Maximum power is P_{max} **= 72.0W**

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:

$P = R\frac{E^2}{(R+r)^2}$. By mathematical manipulations we get to the second degree equation $PR^2 + (2rP - E^2)R + r^2P = 0$.

(0.40 points)

For $P = 50W$, the two solutions of the equation are $R_1 = 1.74\Omega$ and $R_2 = 0.14\Omega$.

(0.20 points)

To have a maximum charge, we need a higher current, so a lower resistance. We therefore chose the solution R_2.

(0.30 points)

The current is $I = \frac{E}{R+r} = 18.75A = 18.75C/s$, so the charge delivered per hour is $Q = I \cdot 3600s/h = 67500C/h$.

(0.30 points)

B.a. continuation:

Maximum charge per hour: **67500 C/h**

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

(0.60 points)

Calculation:

At maximum power, $R_{cell} = r = 0.5\Omega$, $I = \frac{E}{2r} = 12A$

(0.10 points)

The charge delivered per hour is $Q = 43200 C/h$.

(0.10 points)

Because the removal of salt involves 1 mole of electrons per moles NaCl, from the first law of electrolysis we get:

Mass of NaCl removed per hour $= \frac{Q}{F} \cdot M(NaCl) = \frac{43200 \frac{C}{h}}{96500 \frac{C}{mol}} \cdot 58.44 \frac{g}{mol} = 26.2 \frac{g}{h}$

(0.40 points)

Mass of NaCl per hour: **26.2 g/h**

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

(0.20 points)

Calculation:

At an efficiency of 70%, the mass of NaCl removed per hour is $70\% \cdot 26.16 = 18.3\frac{g}{h}$

Mass of NaCl per hour: **18.3 g/h**

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:

Applying the equation for voltage $V = \alpha(T_{hot} - T_{cold})$

$V = 2.5 \cdot 10^{-4}\,V \cdot K^{-1} \times (390\,K - 275\,K) = 0.0288\,V$

V = **0.0288V**

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

(0.25 points)

Calculation:

When thermocouples are connected in series, the voltage adds up.

$V_{total} = V \times 30 = 0.0288\,V \times 30 = 0.864\,V$

V_{total} = **0.864V**

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

(0.25 points)

Calculation:

Total internal resistance is 30 times the resistance of a single thermocouple.

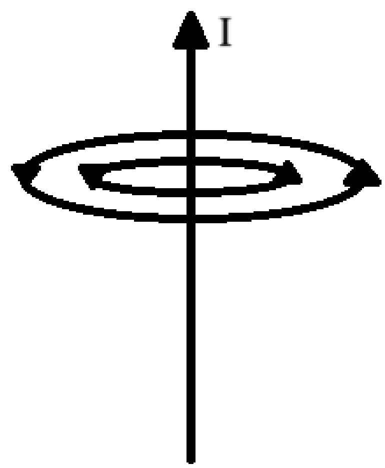
$r_{total} = r \times 30 = 0.8\Omega \times 30 = 24\Omega$

r_{total} = **24Ω**

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:

To calculate the magnetic force on a current-carrying wire placed in a magnetic field, you can use the formula:

$$F = ILB \sin\theta$$

Where F is the magnetic force, I is the current, L is the length of the wire, θ is the angle between the wire and the magnetic field.

(0.40 points)

$$F = 70 \cdot 10^{-3} A \times 1.5 m \times 0.02\ T = 2.10 \cdot 10^{-3}\ N$$

(0.10 points)

$F = \mathbf{2.10 \cdot 10^{-3}\ N}$

Part C. Communicating using ultrasonic waves

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

(0.50 points)

Calculation:

$v = f \cdot \lambda$

$\lambda = \frac{v}{f} = 3.00 \cdot 10^{-3}\text{m}$

Wavelength = $\mathbf{3.00 \cdot 10^{-3}m}$

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:

$\Delta t = \frac{d}{v} = 1.33\text{s}$

$\Delta t =$ **1.33s**

C.c. Calculate the frequency detected by the submersible

(1.45 points)

Calculation:

To solve this, we use the Doppler effect formula:

$f' = f \cdot \frac{v \pm v_o}{v \pm v_s}$ – proof is not required

(0.80 points)

(only 0.40 points for reversing v_o and v_s)

C.c. continuation

The source is stationary but the observer is moving towards the source at a speed of 5m/s, so $f' = f \cdot \frac{v+v_o}{v}$

(0.40 points)

(only 0.10 points for choosing the wrong sign)

Numerically, we get $f' = 502\text{kHz}$

f' = **502kHz**

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:

For the bottom of the ocean, $y = 8000\text{m}$ and $\rho = 1080\ \text{kg} \cdot \text{m}^{-3}$.

From the ρ(y) law given, we have $\alpha = \frac{1}{y} \cdot \frac{\rho - \rho_0}{\rho_0} = 1.00 \cdot 10^{-5}\ \text{m}^{-1}$

$\alpha = \mathbf{1.00 \cdot 10^{-5}\ m^{-1}}$

Part B. Sending the probe

Find the value of depth y_0

(0.50 points)

Calculation:

The density of the probe is $\rho_p = \frac{M}{\frac{4}{3}\pi R^3} = 1027\ \text{kg} \cdot \text{m}^{-3}$

(0.25 points)

The probe floats in equilibrium at a depth where the density of the water is equal to that of the probe. So, we have $\rho_p = \rho_0(1 + \alpha y_0)$

(0.40 points)

$y_0 = \frac{1}{\alpha} \cdot \frac{\rho_p - \rho_0}{\rho_0} = 2700\text{m}$

(0.10 points)

$y_0 = \mathbf{2700m}$

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:

At $y_0 + \Delta y$, the density of the water is given by $\rho = \rho_0(1 + \alpha y_0 + \alpha \Delta y) = 1027.5\ \text{kg} \cdot \text{m}^{-3}$

(0.10 points)

The weight of the probe is $W = Mg = 42.14\text{N}$

(0.15 points)

The buoyant force is $F_b = \rho V g = \rho \frac{4}{3}\pi R^3 g = 42.16\text{N}$

(0.25 points)

The resultant force is $F = F_b - W = 0.02\text{N}$

(0.10 points)

$F = \mathbf{0.02N}$

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

(1.15 points)

Calculation:

Because the buoyant force will decrease linearly (with distance) as the probe moves up, the resultant force will decrease linearly. So, the average resultant force is the arithmetic mean of the initial and final values $R_{avg} = \frac{0.02+0}{2} = 0.01\text{N}$ (the resultant force in the equilibrium position is zero).

(0.35 points)

The work done by this resultant is $W_{tot} = R_{avg}\Delta y = 0.5\text{J}$.

(0.25 points)

By the work-energy theorem, the kinetic energy of the probe in the equilibrium position is $KE = W_{tot}$.

(0.35 points)

Using $KE = \frac{1}{2}Mv^2$, we get $v = \sqrt{\frac{2W_{tot}}{M}} = 0.068\ m \cdot s^{-1}$

(0.20 points)

Note: the problem can also be solved by showing that the movement of the movement of the probe is a harmonic oscillation, but that goes beyond the IJSO syllabus.

$v = \mathbf{0.068\ m \cdot s^{-1}}$

Part D. The results

D.a. Convert the known concentrations to molar concentrations

(0.30 points)

Calculation:

To get the mol/L concentration from the g/L concentration, we divide by the molar mass of the respective ion:

$[Na^+] = \frac{13.75}{22.99} = 0.60\ mol/L$

$[K^+] = \frac{0.40}{39.10} = 0.01\ mol/L$

$[Cl^-] = \frac{23.50}{35.45} = 0.66\ mol/L$

(3 concentrations x 0.10 points)

Fill the table:

Ion	Sodium	Potassium	Chloride
Concentration (mol/L)	**0.60**	**0.01**	**0.66**

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

(0.80 points)

Calculation:

From the electroneutrality principle, the overall charge of the solution is zero. So, the sum of the concentrations of positive charges is equal to that of the negative charges:

$[Na^+] + [K^+] + 2[Ca^{2+}] = [Cl^-]$

From this we get $[Ca^{2+}] = \frac{1}{2}([Cl^-] - [Na^+] - [K^+]) = 0.025 mol/L$

(0.60 points)

(only 0.30 points for not multiplying $[Ca^{2+}]$ by 2)

Multiplying by the molar mass, $c_{Ca^{2+}} = 1\ g/L$

(0.20 points)

Concentration of calcium ions is **1 g/L**

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)

Because the only significant anion is the chloride anion, we can assume that all cations are present as their chlorides. So, the sodium chloride concentration is given by the sodium ions concentration.

$[NaCl] = 0.60\ mol/L$

(0.20 points)

Salinity = $\frac{[NaCl] \cdot 58.44\ g/mol}{1000\ g/L} = 3.51\%$

(0.30 points)

Salinity: **3.51%**

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

(0.90 points)

Calculation:

From the given periodic table, the relative mass number of chlorine is 35.45. This value has to be between A and A+2, so A is either 34 or 35.

(0.10 points)

Because 35.45 is closer to 35 than 37, but not closer to 34 than 36 and we know the isotope of mass number A is the most abundant, $\mathrm{A} = 35$, so the two isotopes are $_{35}\mathrm{Cl}$ and $_{37}\mathrm{Cl}$.

(0.10 points)

Let a_{35} and a_{37} be their two respective abundances. We can clearly state that $a_{37} = 1 - a_{35}$.

(0.10 points)

From the definition of the relative mass number, $35a_{35} + 37a_{37} = 35.45 \Leftrightarrow 35a_{35} + 37(1 - a_{35}) = 35.45 \Leftrightarrow 37 - 2a_{35} = 35.45 \Leftrightarrow a_{35} = 0.775 = 77.5\%$

$a_{37} = 1 - a_{35} = 0.225 = 22.5\%$

(0.60 points)

A = **35**

Abundance of $_{\mathrm{A}}\mathrm{Cl}$: **77.5%**

Abundance of $_{\mathrm{A+2}}\mathrm{Cl}$: **22.5%**

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			**X**
CO_3^{2-}	**X**		
$CaCO_{3(s)}$	**X**		
H^+			**X**

(4 options x 0.25 points)

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	**X**
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:

The amount of $Ca(OH)_2$ in the initial solution is $2.5 \cdot 10^{-3}$ mol.

(0.20 points)

Final solution: pH = 11, $[H^+] = 10^{-11}M$, $[HO^-] = \frac{K_W}{[H^+]} = 10^{-3}M$

(0.50 points)

B.b. continuation:

$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$ so the concentration of $Ca(OH)_2$ in the final solution is half that of the hydroxide ions, so $5 \cdot 10^{-4}$M

(0.20 points)

The amount of $Ca(OH)_2$ in this final solution is $2.5 \cdot 10^{-4}$ mol

(0.20 points)

The amount of $Ca(OH)_2$ that reacted is $2.25 \cdot 10^{-3}$ mol. From the equation of the reaction, $2.25 \cdot 10^{-3}$ mol of CO_2 reacted and $2.25 \cdot 10^{-3}$ mol of $CaCO_3$ precipitated.

From the ideal gas law, at STP, the volume of CO_2 is 50.6mL

Volume of CO_2: **50.6mL**

Amount of precipitate: **$2.25 \cdot 10^{-3}$ mol**

Part C. Photosynthesis

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

(0.80 points)

Calculation:

We reverse equation (1) and also reverse equation (2) after multiplying it by 2:

$2C_2H_5OH + 2CO_2 \rightarrow C_6H_{12}O_6$

$6H_2O + 4CO_2 \rightarrow 2C_2H_5OH + 6O_2$

(0.40 points)

After adding up these equations, we get the photosynthesis reaction, so, by Hess's law, we have:

$\Delta H° = - \Delta H°_1 - 2\ \Delta H°_2 = 2820\frac{kJ}{mol}$

Enthalpy change of the photosynthesis reaction: $\mathbf{2820\ \frac{kJ}{mol}}$

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.	**X**
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:

In an hour, from the stoichiometry of the reaction, an amount of $\frac{4.8 \cdot 10^{-3}}{6} =$

$8 \cdot 10^{-4}$mol of glucose is produced per hour.

(0.50 points)

Knowing the molar mass of glucose, $M = 180.18 \frac{g}{mol}$, the mass of glucose produced per hour is $180.18 \cdot 8 \cdot 10^{-4} = 0.144g$

(0.30 points)

So, the time required for the production of 1.8g of glucose is $\frac{1.8}{0.144} = 12.5h$

(0.40 points)

Time taken: **12.5 hours**

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 **blue/black/dark blue/deep blue**

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

(0.50 points)

Equation of reaction:

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

(only 0.25 points for unbalanced reaction)

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

Chemical formula of compound X – **KI**

Explanation:

Iodine (I_2) has very low solubility in pure water, but it dissolves readily in aqueous potassium iodide (KI) due to the formation of a soluble triiodide ion (I_3^-):

$$I_2 + I^- \rightleftharpoons I_3^-$$

The triiodide ion is much more soluble in water than molecular iodine, allowing iodine to dissolve in KI solution.

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
			T
Crimson grouper (juvenile)	Crimson grouper (adult)	Barracuda	Reef sharks
T	**T, Q**	**T, Q**	**Q**

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
			X

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	**X**
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:

The frequency of the genotype aa was found to be 2.25%

From the Hardy-Weinberg equilibrium, this frequency is q^2, where q is the frequency of allele a. So $q = \sqrt{2.25\%} = 15\%$

(0.30 points)

The frequency of allele A is $p = 100\% - 15\% = 85\%$

(0.20 points)

The frequency of the heterozygous Aa genotype is $2pq = 25.5\%$

(0.30 points)

If the frequency of the heterozygous genotype is calculated as pq, only 0.10 points out of the 0.30 points are awarded.

Frequency: **25.5%**

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	**X**

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:

$$Q_{10} = \left(\frac{330}{150}\right)^{\frac{10}{30-20}} = 2.2$$

Q_{10} = **2.2**

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

(0.50 points)

Calculation:

$$Q_{10} = \left(\frac{r_3}{r_1}\right)^{\frac{10}{T_3-T_1}}$$

$$r_3 = r_1 \cdot Q_{10}^{\frac{T_3-T_1}{10}} = 101 \text{ mL } O_2\text{/kg/h}$$

r_3 = **101 mL O_2/kg/h**

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	**X**
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	**X**	
Group B		**X**

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 = 4.5·RMR = 36 mL O_2/kg/min

DMR = **36 mL O_2/kg/min**

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

(0.40 points)

Calculation:

ADL = Total usable oxygen stores/DMR = $\frac{100}{36} = 2.8\text{min}$

ADL = **2.8min**

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:

Oxygen consumed = 75%·ADL·DMR = 75.6 mL O_2 / kg body mass.

Or

Oxygen consumed = 75%·Total usable oxygen stores = 75mL O_2 / kg body mass

Volume of oxygen used = **75.6 / 75 mL O_2 / kg body mass** (depends on approximations)

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:

Maximum time = 2.8 min + 1.5 min = 4.3 min

Absolute maximum possible dive duration = **4.3min**

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 distance = $v \cdot \Delta t = 1.5 m/s \cdot 4.3 \cdot 60 = 387 m$

(0.30 points)

B.e. continuation:

Maximum depth = 387m/2 = 193.5m

(0.10 points)

Maximum depth = **193.5 m**

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

(1.30 points)

Calculation:

The dolphin's available oxygen reserves are equal to:

Total usable oxygen stores - RMR · 8 min = 36 mL O_2/kg

That means he can chase the squid for $\frac{36}{DMR} = 1\text{min}$

(0.20 points)

For the squid, $x(t) = 15 + 2.5t - \frac{1}{2}0.025t^2 = 15 + 2.5t - 0.0125t^2$

(0.25 points)

In the 6s accelerating, the dolphin had an average speed of $\frac{1.75}{2} = 0.875\text{m/s}$, so it swam a distance $D = 0.875 \cdot 6 = 5.25\text{m}$

(0.20 points)

After this, for the dolphin, $x(t) = 5.25 + 1.75t$

(0.25 points)

To find the moment when the dolphin catches the squid, we solve the equation:

$15 + 2.5t - 0.0125t^2 = 5.25 + 1.75t \Leftrightarrow 0.0125t^2 - 0.75t - 9.75 = 0$ with solutions $t_1 = -11\text{s}$ and $t_2 = 71\text{s}$. We choose the second solution (the only one that physically makes sense)

(0.30 points)

Because $t_2 = 71\text{s} > 60\text{s} = 1\text{min}$ (time before O_2 runs out), the dolphin can't catch the squid.

(0.10 points)

Circle the right answer:

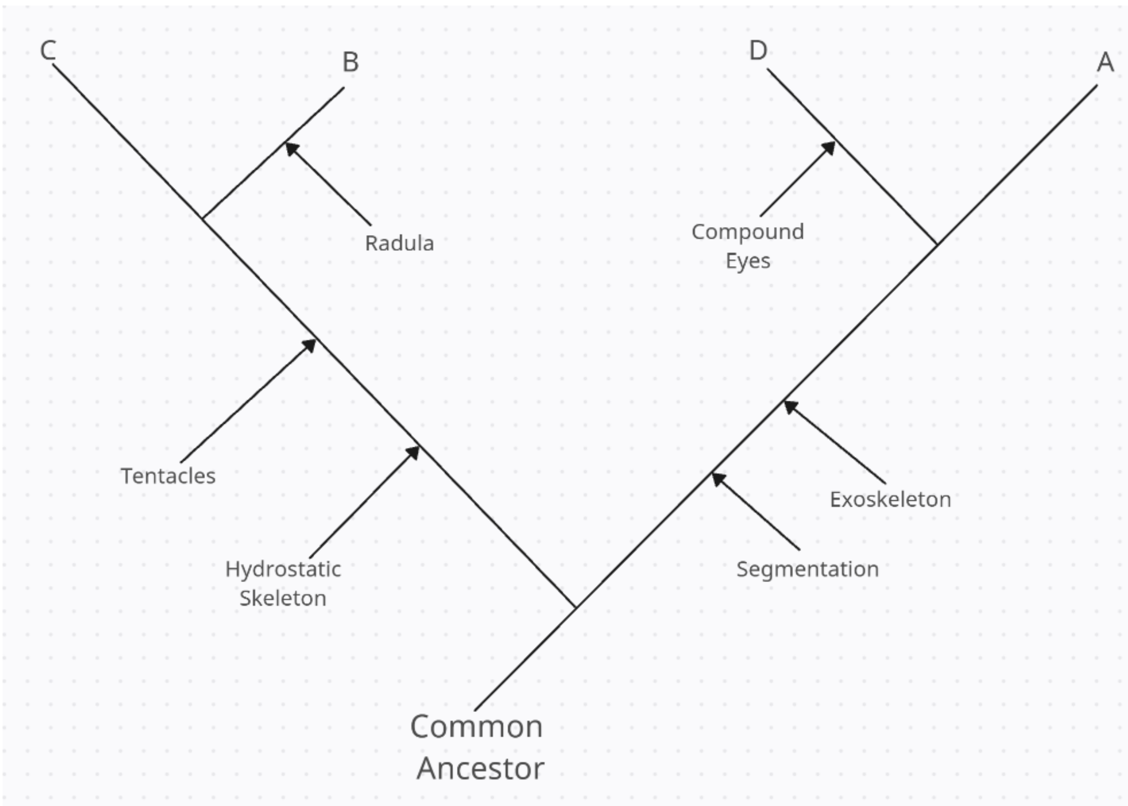
The dolphin can / **can't** catch the squid.

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)



0.70 points – the “skeleton” of the cladogram

0.30 points – showing the points where each characteristic evolved

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:

C	>	**B**	>	**A**

Explanation: while depth increases, the amount of light reaching the species is decreasing so the necessity of complex eyes decreases. Species with a deeper habitat have mor rudimentary eyes.

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.	**X**
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.	**X**
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
X		

Explanation: Electroreceptive tissues show the shortest response latencies.

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
				X

Explanation: Schwann cells and the myelin sheath only protect and insulate the neuron, the cell body only processes nervous signals, while the axon only conducts nervous influx from the cell body.