USESO 2026

Training Camp Exam

Section II

Instructions:

- Section II consists of 5 multipart problems that further assess geoscience knowledge in the form of free-response and multiple choice questions.
- A calculator is allowed. Show all work for calculations.
- Any space on the page may be used for scratch paper, but only work on your Answer Sheet will be graded.
- Print your **USESO Student ID** on every page of the Answer Sheet.

Problem 1

Question	1	2	3	4	Total
Points	10	1	4	5	20 (20%)

This problem examines various aspects of Earth's interior.

1. The depth of magma formation can be inferred from the signatures of rare earth elements (REEs) in aluminous minerals.

   (a) (1 point) The table below shows the properties of three selected aluminous minerals at depth in the mantle. Order the three minerals by increasing depth at which they would typically be found. **Briefly justify** your ordering.

Mineral	**Chemical Formula**	**Substitution Sites**	**Density (g/cm^3)**	**P-wave Velocity (km/s)**
Spinel	$(Mg, Fe)(Al, Cr)_2O_4$	(Al^{3+}, Cr^{3+})	3.6	9
Garnet	$(Mg, Fe, Ca)_3Al_2Si_3O_{12}$	$(Mg^{2+}, Fe^{2+}, Ca^{2+})$	4.0	10
Plagioclase	$CaAl_2Si_2O_8$	Ca^{2+}	2.7	7

   (b) The tendency of each REE to be incorporated into a given mineral, known as compatibility, can be expressed by its mineral-specific partition coefficient P, shown in Figure 1.

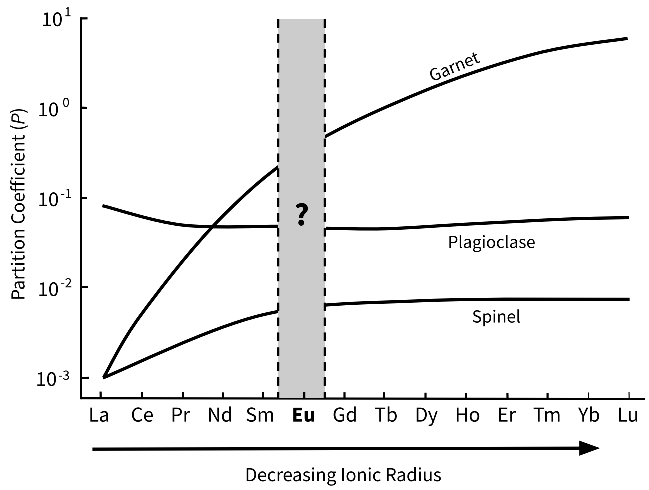

Figure 1: Mineral-specific partition coefficients (P) across the lanthanides for three selected aluminous minerals. Displayed coefficients per element are an average over all oxidation states. The partition coefficients for Europium are not shown.

P is used mathematically in the following equation:

$$\frac{C_L}{C_0} = \frac{1}{P(1-F)+F}$$

where C_L is the concentration of the element in the melt, C_0 is the concentration of the element in the melt's source rock, and F is the melt fraction.

   i. (2 points) Does low or high P indicate that an element is highly incompatible? **Briefly explain**. *Hint: Use the provided equation in your reasoning.*

   ii. (2 points) Using your answers to 1(a) and 1(b)i, **explain** whether elements with smaller ionic radii are relatively enriched or depleted in partial melts derived from a deep source.

(c) While most REEs are commonly found only in their 3+ oxidation states, europium is unique because it can often exist in both 2+ and 3+ oxidation states, with the 2+ ion having a significantly larger ionic radius than the 3+ ion. This unique property gives rise to an anomalously high partition coefficient for europium compared to other REEs in certain minerals, known as the "europium anomaly."

i. (3 points) For which of the graphed minerals would you expect there to be a europium anomaly? For each mineral, **explain** why or why not.

ii. (2 points) **Briefly describe** the formation of the lunar highlands and maria. Would you expect the lunar maria to be enriched, depleted, or comparable in europium to the bulk composition of Earth upon formation? **Justify** your response.

2. (1 point) Scientists recently analyzed diopside grains from Hawaiian basalts and found that europium was more concentrated at the edges of the grains compared to their centers. This anomaly is unusual due to the diopside's relatively low partition coefficient for europium. To understand this observation, they considered the diffusion coefficient (D) for various elements in diopside, defined as the rate at which elements diffuse from regions of higher to lower concentration.

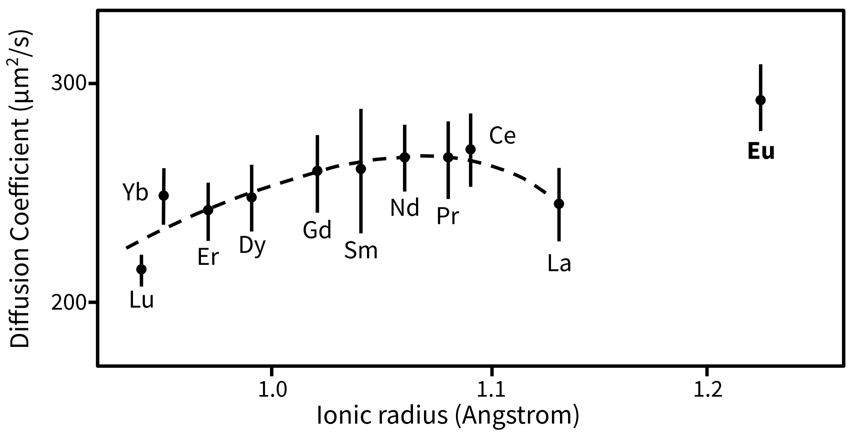

Figure 2: Diffusion coefficients for selected rare earth elements in diopside plotted against ionic radius.

Based on Figure 2, **propose** a likely explanation for the scientists' observation.

3. The Fayalite-Magnetite-Quartz (FMQ) buffer is a standard reference for the redox conditions in igneous rocks. In this buffer, fayalite (Fe-rich olivine) reacts with oxygen to form magnetite and quartz, as shown below.

$$3\,Fe_2SiO_4 + O_2 \rightleftharpoons 2\,Fe_3O_4 + 3\,SiO_2$$

One way to quantify the state of this buffer is ΔFMQ, where a represents the effective concentration of a given mineral within the solid as in the equation below.

$$\Delta\text{FMQ} = \log_{10}\left(\frac{a_{\text{Mt}}^2 \cdot a_{\text{Qz}}^3}{a_{\text{Fa}}^3}\right)$$

(a) (2 points) Does ΔFMQ of the oceanic crust generally increase or decrease with distance from the ridge axis? **Explain**.

(b) (2 points) Using your answer to 3(a) and the information provided in 1(c), would subduction zone plagioclase show a stronger or weaker europium anomaly compared to normal mantle plagioclase? **Justify** your answer.

4. The primary method of deformation within the Earth varies significantly with depth.

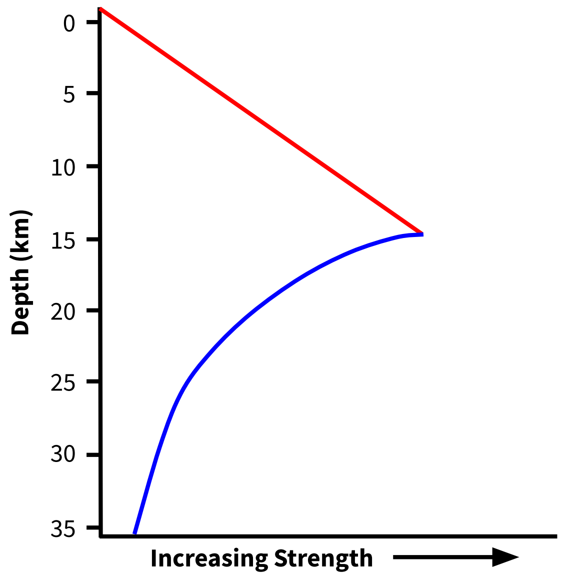

Figure 3: A piecewise graph of rock maximum tolerable stress before deformation as a function of depth, colloquially known as the "Christmas tree" diagram.

(a) (1 point) **Identify** the primary environmental factor that drives the transition between the red and blue curves.

(b) (1 point) **Explain** why the red curve displays increasing strength with increasing depth.

(c) (1 point) Based on Figure 3, at what depth do the strongest earthquakes occur? Round your answer to the nearest five kilometers and **briefly explain.**

(d) (2 points) Eclogitization has been cited as a mechanism for explaining extremely deep earthquakes, which are otherwise considered unlikely in an olivine-dominated mantle. Suppose that eclogite and an all-olivine rock have the same ductile deformation curve in Figure 3. Would eclogite strengthen with increasing depth more rapidly or more slowly than the all-olivine rock at shallow depths? **Explain.**

Problem 2

Question	1	2	3	4	5	Total
Points	1	4	2	7	6	20 (20%)

This problem explores several aspects of circulation over the Sahara.

1. (1 point) The Saharan Air Layer (SAL) is a dry and dust-laden layer of the troposphere that forms over the Saharan Desert. One characteristic of the SAL is the presence of Saharan dust. What would be the net effect of these aerosols on the temperature at and below the SAL, respectively?

    A. Increase, increase

    B. Increase, decrease

    C. Decrease, increase

    D. Decrease, decrease

2. The African Easterly Jet (AEJ) is a fast-flowing, easterly wind current in the lower troposphere that has a similar mechanism to the Northern Hemisphere's polar jet stream. The AEJ blows the SAL westward off the continent and over the Atlantic.

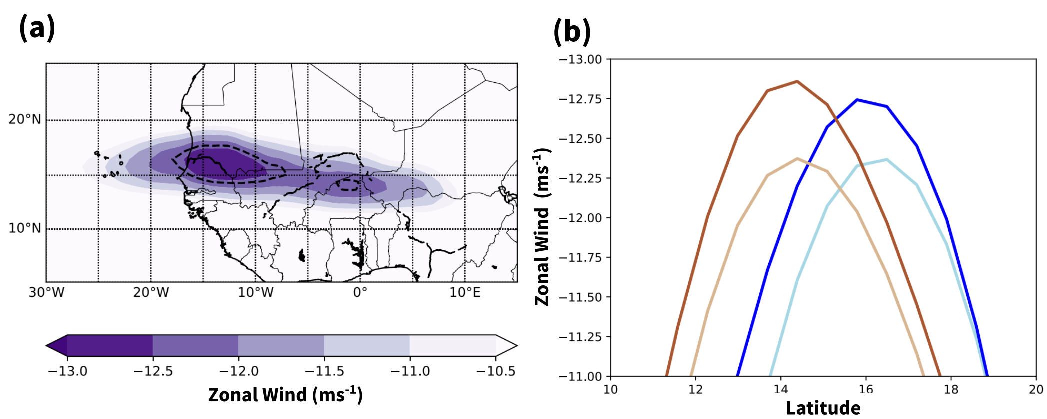

Figure 1: (a) July–September time-averaged zonal (i.e., east-west) wind composite at the altitude of the AEJ core in a particular year. (b) July–September time-averaged zonal wind profiles at the height of the AEJ for four years.

    (a) (1 point) **Briefly explain** why the AEJ blows from east to west.

    (b) (1 point) Figure 1(b) contains four curves corresponding to four "types" of years: wetter & less dusty (WLD), wetter & more dusty (WMD), drier & less dusty (DLD), and drier & more dusty (DMD). A relatively dustier year occurs due to higher SAL dust content, and a relatively wetter year is characterized by a broader latitudinal extent of tropical African precipitation. **Identify** which curve corresponds to each type.

    (c) (2 points) **Explain** your reasoning for part (b).

3. (2 points) Researchers have found that a large amount of the dust within the SAL was entrained by unique behavior associated with Saharan thunderstorms. Due to high temperatures and low humidity, many Saharan thunderstorms produce virga, rain that evaporates before reaching the ground. **Explain** how virga can create strong, dust-entraining surface winds.

4. In West Africa, the monsoon season begins in April as intense rainfall hugs the Guinean coast (Figure 2). This coastal precipitation abruptly shuts off toward the end of June, when the peak precipitation moves inland toward the Sahel (near 10°N) in a discontinuous shift known as the monsoon jump.

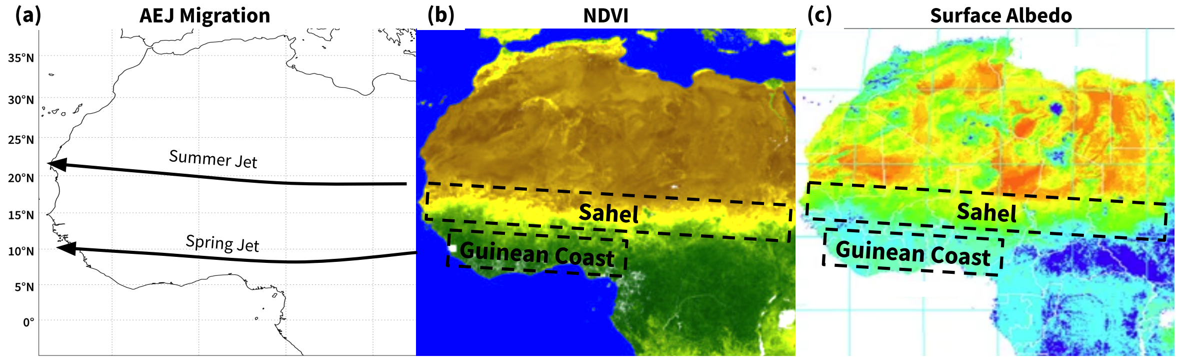

Figure 2: Three maps of Western Africa with indicated relevant regions. (a) Mapping of seasonal migration of the AEJ. (b) Normalized Difference Vegetation Index (NDVI) values where green indicates high levels of vegetation. (c) Surface albedo where red areas indicate higher albedo values.

(a) (2 points) Weeks before the monsoon jump, a shallow circulation cell exists over the Sahel but does not create much precipitation. Using Figures 2(b) and (c), **explain** the cause of this circulation **and** why it remains confined near the surface.

(b) (1 point) The monsoon jump is driven by inertial instability, a condition that occurs when $f - \frac{\Delta u}{\Delta y} < 0$, where $\frac{\Delta u}{\Delta y}$ is the northward gradient of westerly wind speed and f is a positive proxy for the strength of the Coriolis force. Using this information, **explain** why it is relatively easy for inertial instability to form along the Guinean coast.

(c) (1.5 points) Using Figure 2, **explain** why Guinean coastal air is inertially stable in the spring.

(d) Separate from the climatic variation described in 2(a), the position of the AEJ also varies seasonally and migrates northward during summer.

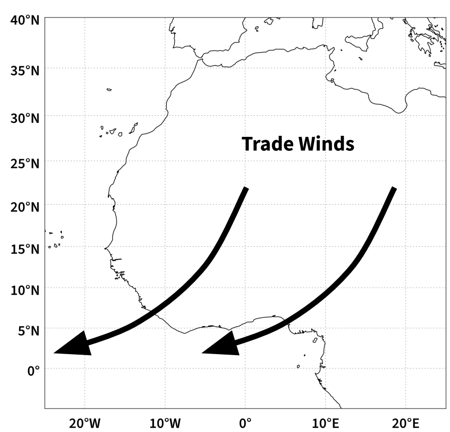

Figure 3: An idealized map of trade wind behavior over western Africa.

i. (1.5 points) Using the wind pattern depicted in Figure 3, **explain** how this seasonal migration leads to a transition into inertial instability for air over the Guinean coast.

ii. (1 point) Inertial instability in summer leads to surface air parcels rapidly moving away from the region of instability. **Explain** how this results in the abrupt shutoff of precipitation along the Guinean coast associated with the monsoon jump.

5. In the remainder of this problem, you will derive an expression for the speed c of an internal gravity wave at the boundary between the SAL and the underlying air by analogy to shallow surface gravity waves at the interface of Earth's atmosphere and oceans. We will assume the wave behaves as a shallow water waves with no variation along the z-direction (Figure 4).

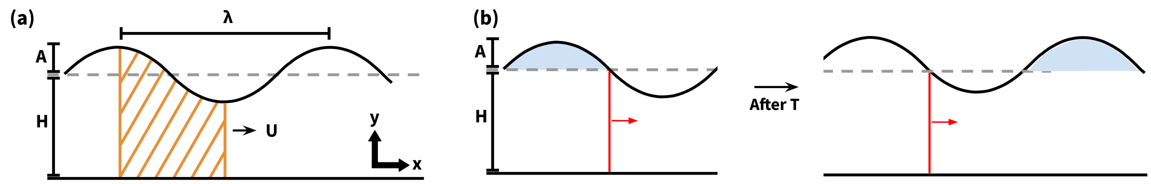

Figure 4: (a) Surface gravity wave at ocean-atmosphere interface with height H, amplitude A, wavelength λ, and velocity U labeled. Wave speed c is defined as λ/T. Assume water has density ρ and air has no density. The orange shading represents a specific water parcel to which we will apply momentum balance. (b) Evolution of the surface gravity wave after period T.

(a) (1 point) We can derive an expression for c via mass balance. Referring to Figure 4(b), **fill in the following blanks** with the appropriate variables:

By comparing the wave shape before and after time T, the mass loss through the red profile due to the movement of the shaded portion of the wave over timescale T is proportional to $A \cdot \lambda \cdot \rho$.

We can also estimate this mass loss in a different way: the mass transported out of the left portion of the wave over time T is proportional to $T \cdot H \cdot \rho \cdot$ _______.

By equating these two expressions, we derive $c \propto H \cdot U /$ _______.

(b) We can derive a second expression for c by applying horizontal momentum balance. Assume that the water velocity is independent of depth and that the pressure field is determined solely by the weight of the overlying water.

i. (1 point) **Identify** which side (left or right) of the orange parcel in Figure 4(a) experiences a greater average pressure. Hence, **identify** the direction of the net pressure force on the parcel. **Briefly justify** your answer.

ii. (1 point) Referring to Figure 4(a), **fill in the following blanks** with the appropriate variables:

Let Δp denote the pressure difference between the left and right sides of the orange parcel. The net horizontal force acting on the parcel is proportional to $\Delta p \cdot H$. Furthermore, Δp is proportional to $\rho \cdot g \cdot$ _______, where g is the gravitational acceleration.

We can obtain a separate expression for the net horizontal force acting on the orange parcel using Newton's second law. Assuming the characteristic acceleration of the parcel is proportional to U/T and mass is proportional to $H \cdot \lambda \cdot \rho$, the net horizontal force can be expressed as $H \cdot \lambda \cdot \rho \cdot U/T$.

By equating these two expressions, we derive $c \propto g \cdot A /$ _______.

(c) (2 points) By equating the expressions for c derived in parts 5(a) and 5(b)(ii), **derive** a proportionality relationship for c in terms of a single variable and any necessary physical constants. **Show your work.**

(d) (1 point) In the case of an internal gravity wave between two arbitrary air masses, we substitute g' for g in all of the above derivations. Would you expect g' to be smaller or larger than g? **Briefly explain.**

Problem 3

Question	1	2	3	4	5	Total
Points	3	2	7	4	4	20 (20%)

This problem considers how various processes affect circulation in the Atlantic and Pacific Oceans.

1. The positive phase of the North Atlantic Oscillation (NAO) is associated with an increased pressure difference between the Azores High and Icelandic Low, shown in Figure 1.

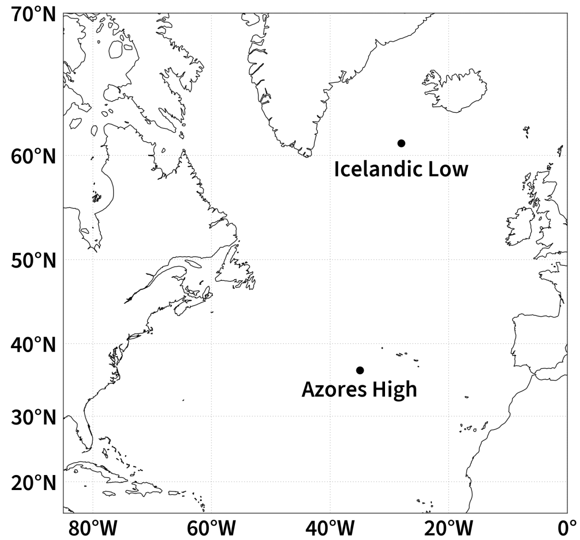

Figure 1: Locations of the Azores High and Icelandic Low.

   (a) (2 points) **Describe** the wind patterns expected during positive NAO compared to normal conditions. How does this affect the heat budget of North Atlantic water currents?

   (b) (1 point) The Atlantic Meridional Overturning Circulation, or AMOC, refers to the northern branch of Atlantic thermohaline circulation. Given your answer to part (a), how would a positive NAO affect the strength of AMOC? **Briefly explain**.

2. The Stommel box model, shown in Figure 2, is a simplified model of AMOC in the Northern Hemisphere.

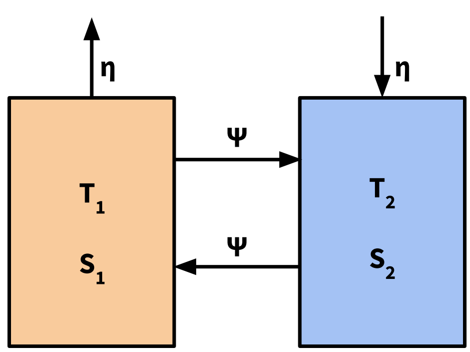

Figure 2: Simplified Stommel box model showing the temperature and salinity of two bodies of water as (T_1, S_1) and (T_2, S_2). For this model, we assume $T_1 > T_2$. Ψ represents water flux due to circulation, while η represents water flux due to precipitation and evaporation.

(a) (1 point) In which cardinal direction would you expect isopycnals to be dipping in the North Atlantic Ocean? **Explain**.

(b) (1 point) The AMOC is at risk of collapse due to climate change. **Describe** the primary forcing mechanism by which warming is thought to induce AMOC collapse. Does the Stommel box model capture this mechanism? **Explain**.

3. The Stommel model, when numerically solved, provides a bistable solution similar to that shown in Figure 3.

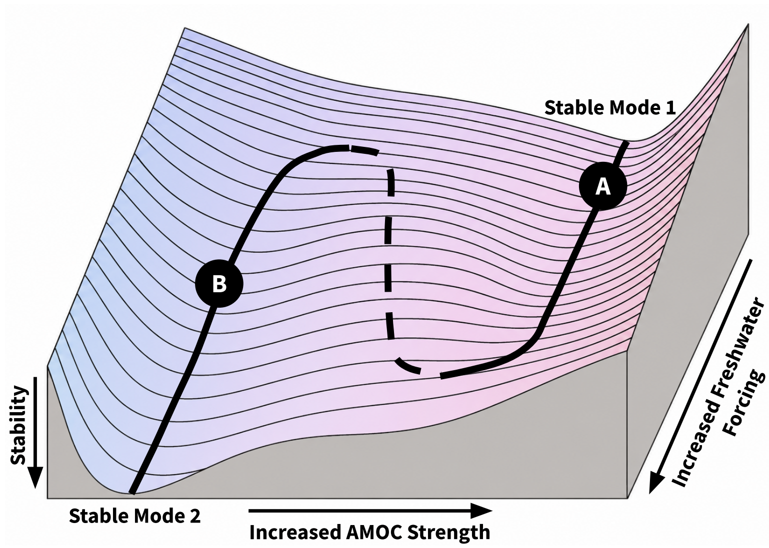

Figure 3: Stability surface plot gathered from simulations of a collapse of AMOC. Strength of AMOC at equilibrium in the stable modes is shown via the solid black lines.

(a) (2 points) Stable Mode 1 and 2 (Figure 3, solid black) are categorized as "thermal" or "haline" based on the primary cause of the circulation. **Identify** which stable mode is the thermal one and **justify** your response.

(b) On your answer sheet, **clearly sketch** the path taken by the system in the scenarios below.

i. (1 point) Rapid increase in freshwater forcing, causing AMOC to shift from Stable Mode 1 to Stable Mode 2, starting from point A.

ii. (1 point) Slow decrease in freshwater forcing, causing AMOC to shift from Stable Mode 2 to Stable Mode 1, starting from point B.

(c) (3 points) Assume AMOC collapses via a shift from Stable Mode 1 to Stable Mode 2. In the context of the Stommel model, **describe** how this shift would impact the freshwater forcing shown in Figure 3. Does this increase or decrease the likelihood of recovery from AMOC collapse?

4. Scientists have proposed building a physical dam across the entire Bering Strait between Russia and Alaska. A map of the proposed location is shown in Figure 4.

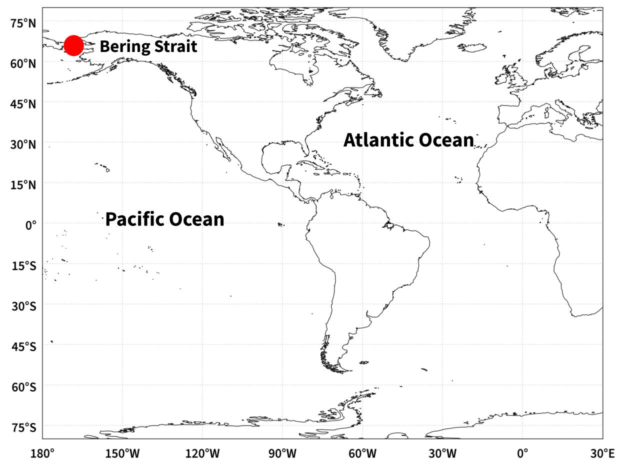

Figure 4: Global map with the Bering Strait marked with a red dot.

   (a) (2 points) Considering the global distribution of the landmasses and prevailing winds, is there a net movement of water by precipitation from the Atlantic to the Pacific or vice versa? **Explain**.

   (b) (2 points) The movement described in (a) is one of the primary causes of density differences between the Pacific and Atlantic. What is the expected impact of the construction of this dam on the strength of AMOC? **Explain**.

5. Climate modeling can help us understand how ocean circulation will be impacted by climate change. Figure 5 depicts a model of sea surface temperature (SST) rise under an abrupt warming scenario.

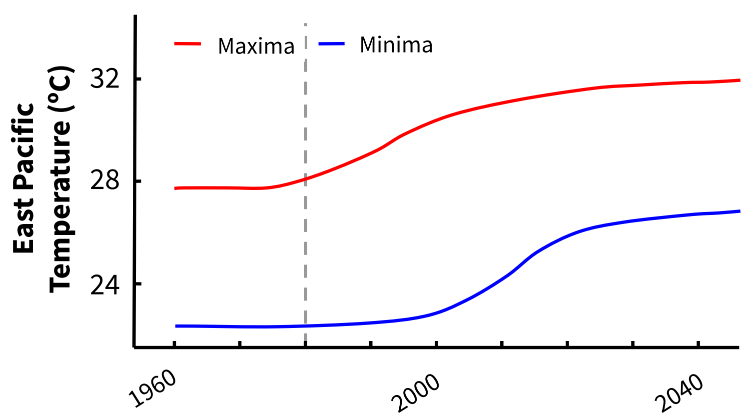

Figure 5: Results from a global climate model starting in 1960, assuming an abrupt increase in atmospheric CO_2 in 1980. Minima and maxima curves represent the minimum and maximum SST recorded each year in the equatorial East Pacific (within 5° of the equator).

   (a) (1 point) **Briefly explain** how the predicted minimum and maximum SST correlate with the El Niño Southern Oscillation (ENSO) cycle.

   (b) (2 points) **Briefly explain** why the rise in minimum SST lags behind the rise in maximum SST.

   (c) (1 point) Would the lag in (b) increase or decrease ENSO strength, defined as the difference between the El Niño and La Niña temperatures, during times of abrupt warming? **Briefly explain**.

Problem 4

Question	1	2	3	Total
Points	7	7	6	20 (20%)

This question explores the properties and orbital mechanics of satellites.

1. The Hill sphere is the region within which a satellite can be gravitationally bound to a body without being pulled away by a larger body. The formula for the radius of the Hill sphere is:

$$r_H \approx r_{\text{orbital}} \sqrt[3]{\frac{m}{3M}}$$

It can be desirable to place a satellite outside Earth's Hill sphere for remote-sensing applications. One way to maintain a satellite outside this radius is with a solar sail, pictured below. In the case of a solar sail, the radiation pressure (F_{rad}) on the sail opposes the Sun's gravity, expanding the effective Hill sphere of Earth.

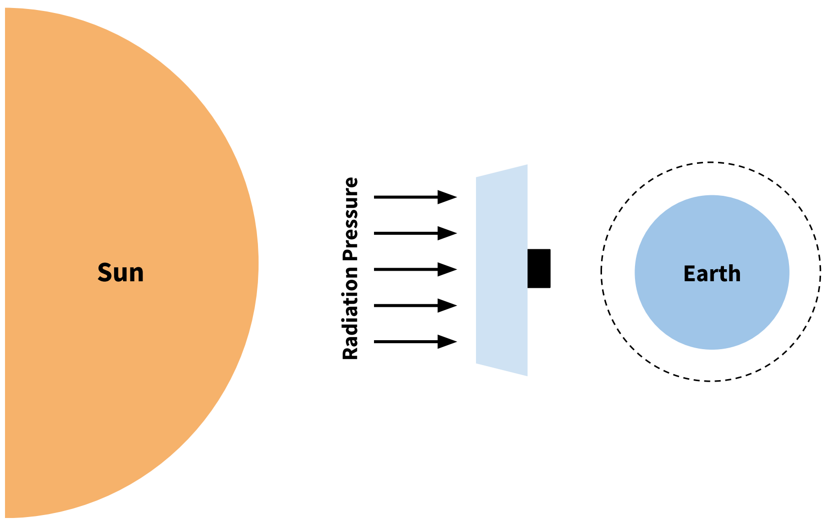

Figure 1: Proposed satellite outside Earth's Hill sphere.

(a) (3 points) To calculate the effective Hill sphere, it can be useful to define an effective solar mass ($M_{\odot,\text{eff}}$) felt by the satellite after accounting for the effect of the solar sail. **Write** an expression for $M_{\odot,\text{eff}}$ in terms of the actual solar mass $M_{\odot}$, the force of radiation pressure F_{rad}, and the force of gravity from the Sun F_g.

(b) (4 points) A proposed satellite of total mass 100 kg is being designed for an orbit with radius 2.0×10^9 m. Given the constants below, use the formula for F_{rad} to **calculate** the minimum area A of the solar sail required to allow the sail to maintain orbit around Earth. **Show your work.**

$$F_{\text{rad}} = \frac{2IA}{c}$$

Mass of Earth	6.0×10^{24} kg
Mass of the Sun	2.0×10^{30} kg
Orbital Radius of Earth (R_E)	1.5×10^{11} m
Solar Constant (I)	1360 $\frac{\text{W}}{\text{m}^2}$
Speed of Light (c)	3.0×10^8 m/s
Gravitational Constant (G)	6.7×10^{-11} m^{3}kg^{-1}s^{-2}

2. Mimas and Enceladus are moons of Saturn each with a subsurface liquid water ocean sealed beneath a surface ice shell.

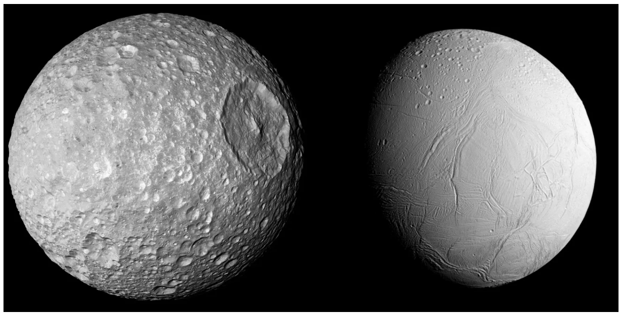

Figure 2: Images of Mimas (left) and Enceladus (right). Note that the images are not to scale; Enceladus is significantly larger than Mimas.

   (a) Tidal heating on these bodies is resulting in the melting of their ice shells.

      i. (2 points) What kind of stress will the melting of the ice shell put on the ductile inner layers of their ice shells? **Explain.**

      ii. (1 point) What kind of stress will the thinning of the ice shell put on the brittle surface layers of their ice shells? **Explain.**

      iii. (1 point) Over time, these stresses can build up, resulting in tectonic activity. Based on the images in Figure 2, which of Mimas and Enceladus releases this stress via tectonic activity? **Explain.**

   (b) A recent model has suggested that the stresses described in (a) may be relieved by boiling of the subsurface ocean. For this question, assume that the thickness of the ice shell is the same for both moons.

      i. (1 point) **Briefly describe** the mechanism that results in this boiling.

      ii. (2 points) **Explain** why the moon you selected in 2(a)(iii) is unable to relieve stress via this mechanism.

3. Iapetus is the third most massive moon of Saturn with a radius of 735 km. Scientists observed a perfectly equatorial ridge on Iapetus's surface that wraps around approximately 75% of the moon. It is around 20 km tall and 100 km wide.

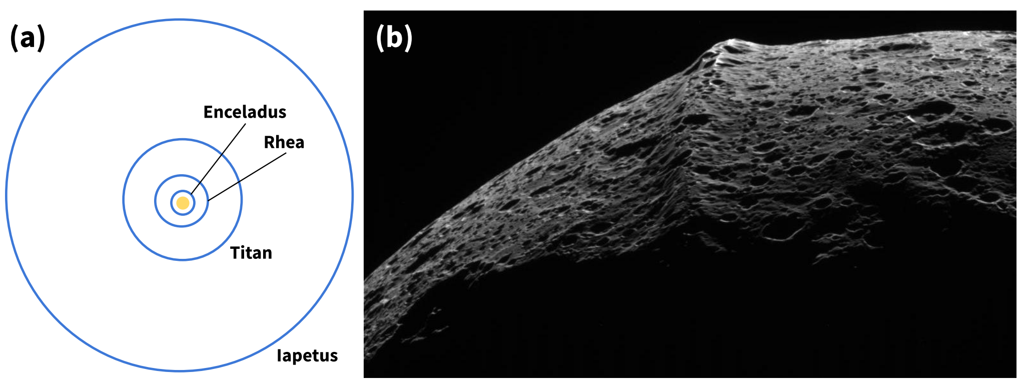

Figure 3: (a) Orbital paths of selected moons of Saturn. (b) Image of equatorial ridge of Iapetus.

   (a) (1 point) Given the following table, **calculate** the orbital period of Iapetus in days. **Show your work.**

Enceladus orbital radius	2.3×10^5 km
Enceladus orbital period	1.4 days
Iapetus orbital radius	3.6×10^6 km

Scientists have attempted to understand the evolution of Iapetus's equatorial ridge by modeling heat transfer throughout the moon.

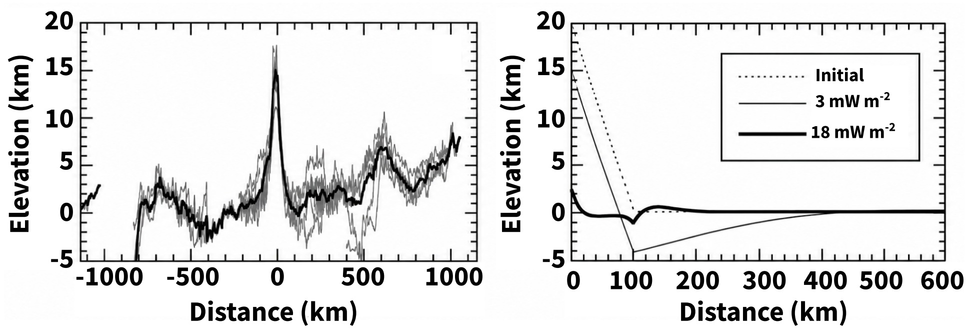

Figure 4: (a) Cross-section topography of Iapetus's equatorial ridge. (b) Simulated topographies of one side of the ridge based on different heat flow rates experienced after ridge formation.

(b) (2 points) Based on Figures 3 and 4, did this equatorial ridge likely form shortly or long after Iapetus's formation? **Explain.**

(c) Scientists have proposed the existence of a former "subsatellite" (a satellite orbiting a moon) orbiting Iapetus's equator in order to explain the equatorial ridge.

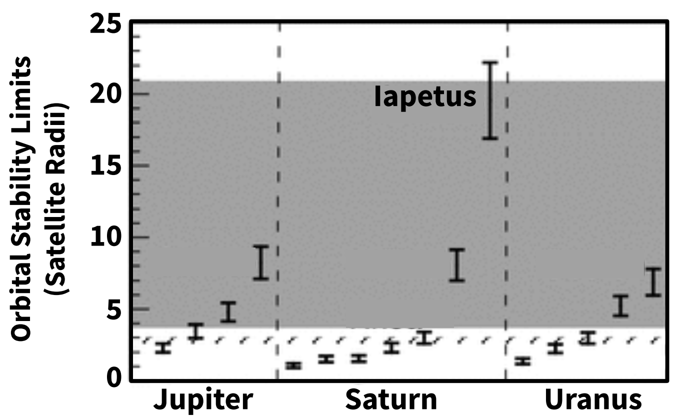

Figure 5: Orbital stability limits of notable moons in orbit of Jupiter, Saturn, and Uranus.

i. (2 points) **Explain** why subsatellites are generally rare. What two primary parameters contribute to Iapetus being more able to sustain a subsatellite compared to other moons?

ii. (1 point) The subsatellite is proposed to have undergone orbital decay around Iapetus. **Briefly explain** how this could have ultimately led to the formation of the equatorial ridge.

Problem 5

Question	1	2	3	4	5	Total
Points	6	3	3	3	5	20 (20%)

In September 2025, NASA scientists published a discovery hinting at the possibility of life in Mars's Jezero Crater, a region that the Perseverance rover has been exploring since 2021. This question explores several aspects of that discovery and its geologic, hydrologic, and meteorologic context.

1. Mars's atmospheric circulation is highly seasonal, with cells appearing and disappearing as well as changing in size between seasons. Figure 1 depicts Mars's global meridional circulation in four different seasons.

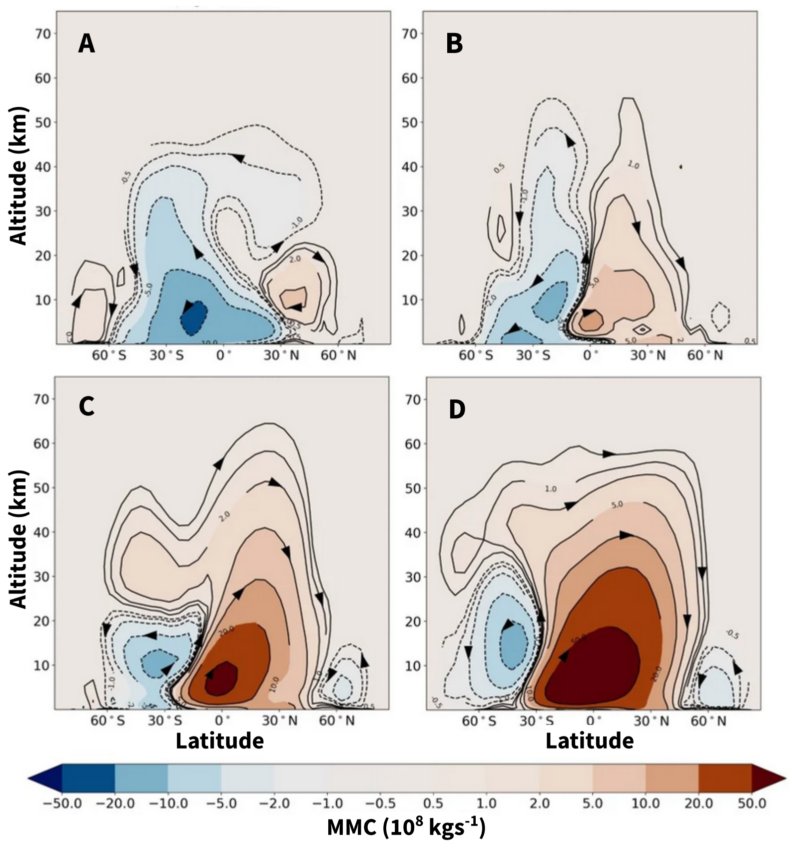

Figure 1: A model of Martian atmospheric circulation across latitudes at four points in its orbit. The shading represents mean meridional circulation (MMC); positive values represent clockwise northward flow, while negative values represent counterclockwise southward flow.

(a) (1 point) The most prominent circulation cells in Figure 1 are most directly analogous to which of the following types of cells on Earth?

A. Hadley

B. Ferrel

C. Polar

(b) (2 points) **Identify** which panels of Figure 1 represent Northern Hemisphere winter and Northern Hemisphere summer, respectively. **Explain.**

(c) (1 point) The orbit of Mars has a relatively high eccentricity. Is Mars closer to the Sun during Northern Hemisphere summer or winter? **Explain** how you know using Figure 1.

(d) (2 points) Jezero Crater is located at about 20°N on Mars. Ventifacts and aeolian landforms on the crater surface suggest that the dominant wind pattern has varied over time, with some landforms suggesting easterly winds and some suggesting southwesterly winds. **Identify** which of the two wind patterns is most consistent with Mars's global circulation as shown in Figure 1. **Explain** your reasoning.

2. (3 points) Jezero Crater is on the edge of Isidis Basin, a planetary-scale depression that likely hosted an ancient ocean. The crater is thought to be a location where an ancient river (now Neretva Vallis) met the sea. The satellite map in Figure 2 shows the geology of the western Jezero Crater, with the far western edge of the crater rim seen on the left.

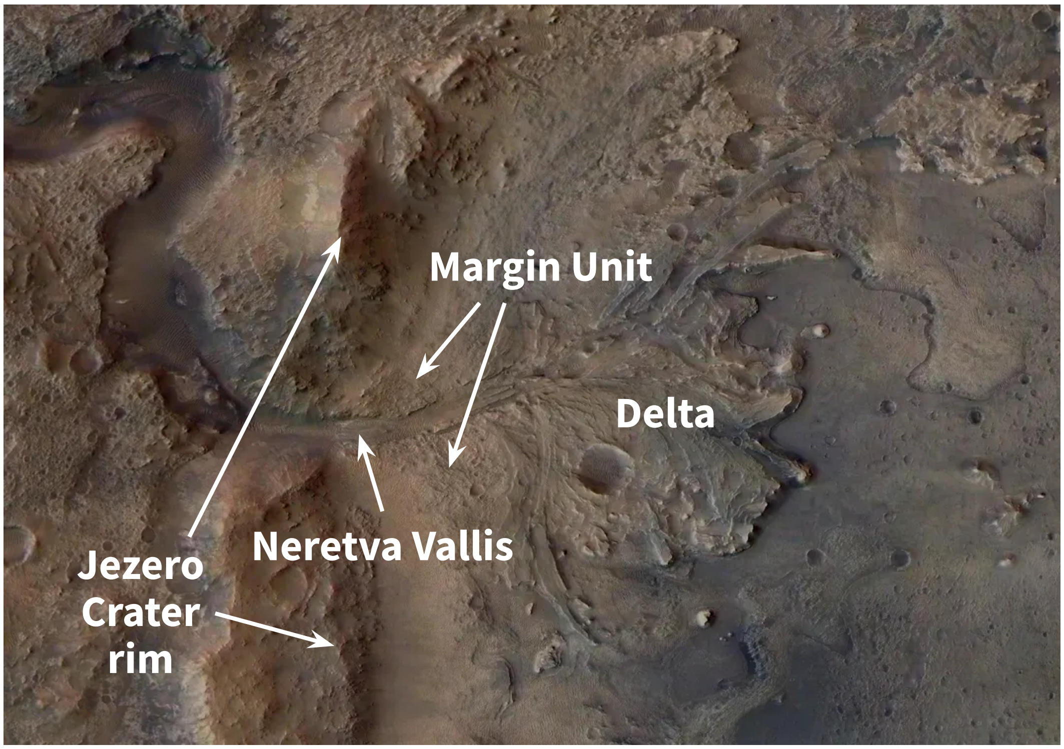

Figure 2: A map of Jezero Crater.

The highlands on both sides of the river are composed of the Margin Unit, consisting mostly of olivine and carbonate. Its olivine is assumed to be of intrusive igneous origin, while its carbonate likely originated from hydrothermal alteration of the olivine.

Using Figure 2 and the descriptions provided, **order** the following events in chronological order. **Explain** your reasoning.

I) Formation of Jezero Crater

II) Formation of Neretva Vallis

III) Deposition of Curvilinear Unit delta remains

IV) Formation of olivine-containing igneous intrusions in the Margin Unit

V) Formation of carbonate minerals in the Margin Unit

3. In 2024, Perseverance came across an outcrop in the Margin Unit called Cheyava Falls that has several unusual features. In particular, the rock contains large olivine clasts as well as so-called "leopard spots," which contain iron sulfide minerals in their interior. Scientists believe these spots may represent reaction fronts produced by ancient anoxic bacteria feeding on iron and sulfate.

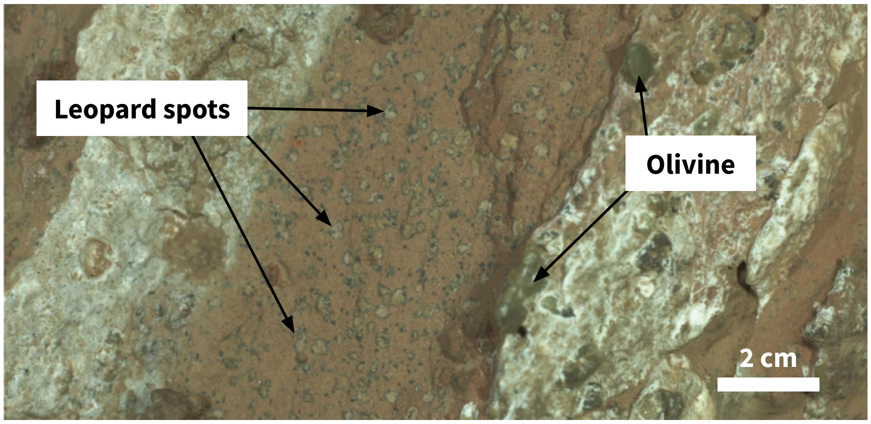

Figure 3: A photo of a small section of the Cheyava Falls rock taken by the Perseverance rover.

(a) (1 point) **Explain** why it is rare to find olivine in sedimentary rocks on Earth but not in modern Martian sedimentary rocks.

(b) (1 point) Are the leopard spots more reduced or oxidized than the surrounding rock? **Explain** how you know.

(c) (1 point) If the iron sulfide minerals observed in the leopard spots were produced abiotically, an external source of sulfur must have been present. **Propose** a possible external source of sulfur consistent with the origin of the Margin Unit.

4. The river that created Neretva Vallis fed into Mars's ancient ocean, which is thought to be nearly ten times as saline as Earth's oceans today.

(a) (1 point) **Briefly describe** the expected structure typical of an estuary fed by a freshwater river entering this saline ocean.

(b) (2 points) Potential Martian microorganisms are thought to have thrived in anoxic conditions. **Explain** why high salinity in the Jezero Crater lake would likely produce anoxic conditions below the lake's surface.

5. It is believed that Martian tectonic activity stopped about 4 billion years ago, while water remained on the surface until about 2 billion years ago.

(a) (2 points) During the period when water existed without plate tectonics, did geological processes produce a net increase or decrease in the carbon in Mars's atmosphere? **Explain.**

(b) The location of the solar habitable zone does not explain the loss of liquid water on Mars. In fact, the Sun has brightened over time, extending the habitable zone closer to Mars.

i. (1 point) **Explain** how the loss of Martian surface tectonic activity eventually led to the loss of its surface water.

ii. (2 points) **Explain** how the loss of Martian internal heat eventually led to the loss of its surface water.

END OF SECTION II