



USESO 2024

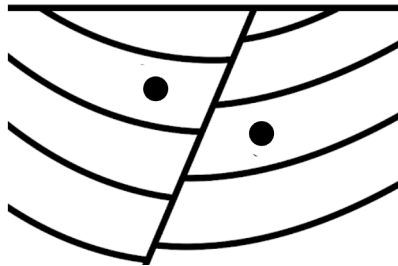
National Open Exam

Section I

Instructions:

- Section I consists of 30 multiple choice questions. Each question is worth 2 points.
- Questions are **not** ordered by difficulty.
- Print your **USESO Student ID** on the ZipGrade answer sheet and the cover of this test.
- Bubble your answers clearly on the ZipGrade answer sheet. Pencil or pen is fine; if you use pencil, push down as you write to make the scan easier to read.
- You have **2 hours** to complete both sections in any order, and you may flip back and forth between sections.

1. Shown below is a sketch of a geologic cross-section. The dots indicate two fossils located in the same rock unit.



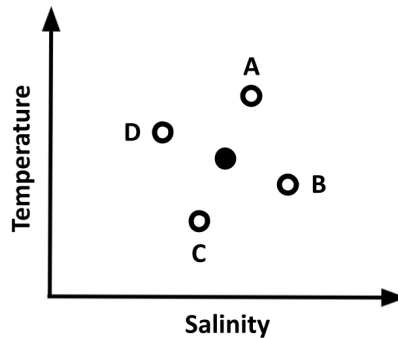
Identify the type of fold and fault, respectively, present in the cross-section above.

- A. Anticline, normal fault
- B. Anticline, reverse fault
- C. Syncline, normal fault
- D. Syncline, reverse fault

2. Which of the following is most likely true regarding the flow of groundwater?

- A. Groundwater flows away from streams in desert environments
- B. Groundwater flows parallel to lines of equal pressure beneath Earth's surface
- C. Groundwater flows faster through silt compared to sand
- D. The presence of karst topography decreases groundwater flow rates

3. Consider the following temperature-salinity (T-S) diagram. Each labeled point represents a possible combination of temperature and salinity conditions.



If the solid black point represents conditions measured at the surface of a subtropical water column, which of the labeled points most likely represents the conditions at the bottom of the water column?

- A. A
- B. B
- C. C
- D. D

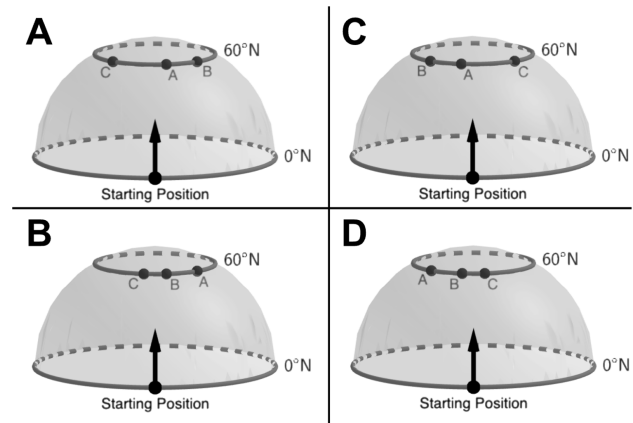
4. Io is a moon of Jupiter subjected to immense tidal forces due to its interactions with nearby moons Europa and Ganymede. Which of the following is/are true of Io?

- I) Io's surface displays extensive evidence of impact cratering
- II) Io's atmosphere is predominantly composed of CH₄ gas

- A. I only
- B. II only
- C. I and II
- D. None

5. Paige the pilot explores three planets identical to Earth except with different directions of rotation (when viewed from above the North Pole) and day lengths as shown in the table below.

Planet	Direction of Rotation	Day Length
A	Clockwise	12 hours
B	Clockwise	36 hours
C	Counterclockwise	36 hours



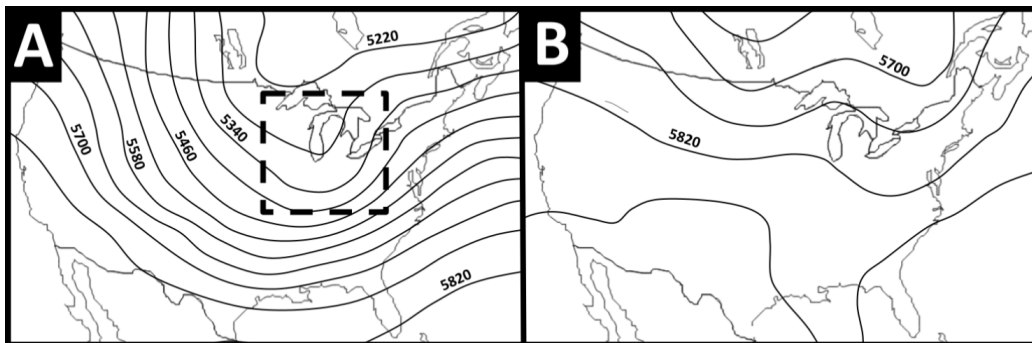
Paige begins flying at each planet's equator and travels northward until she reaches 60°N latitude. Which of the above configurations best approximates her final location on each of the three planets?

- A. A B. B C. C D. D

6. A rising magma plume enters a section of continental crust. Which of the following minerals would be the first to crystallize from the magma?

- A. Biotite B. Olivine C. Pyroxene D. Quartz

7. Shown below are two atmospheric maps of the contiguous United States. The wavy black lines represent height contours at 500 mb.



Which of the following statements is/are true regarding these diagrams?

- I) On Map A, a surface high-pressure zone can be found in the boxed region
 II) Map A is more typical of summer conditions while Map B is more typical of winter conditions

- A. I only B. II only C. I and II D. None

8. The concentrations of iron oxide and aluminum in tropical soil horizons are heavily influenced by leaching. Which of the following correctly lists the A, B, and E horizons in order of lowest to highest iron oxide and aluminum concentrations?

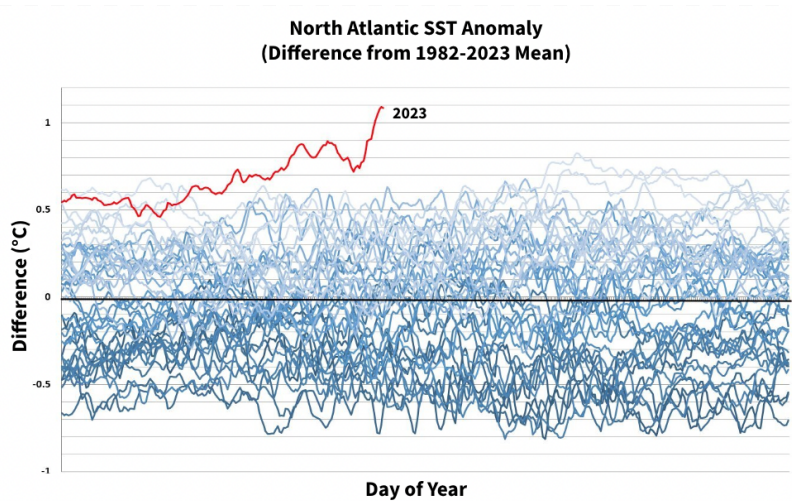
- A. A, B, E B. B, A, E C. E, B, A D. E, A, B

9. Light produced by nuclear fusion in the Sun's core powers almost all biological processes on Earth. However, this light does not follow a smooth path as it escapes the Sun. Which of the following solar layers is/are almost entirely transparent to visible light?

- I) Radiative zone
- II) Photosphere
- III) Chromosphere

- A. I only B. II only C. I and III D. II and III E. I, II, and III

10. The graph below records a remarkable 2023 anomaly in Atlantic sea surface temperature (SST), a phenomenon which has caught widespread media attention in regards to global warming: *“The Atlantic is running a fever!”*



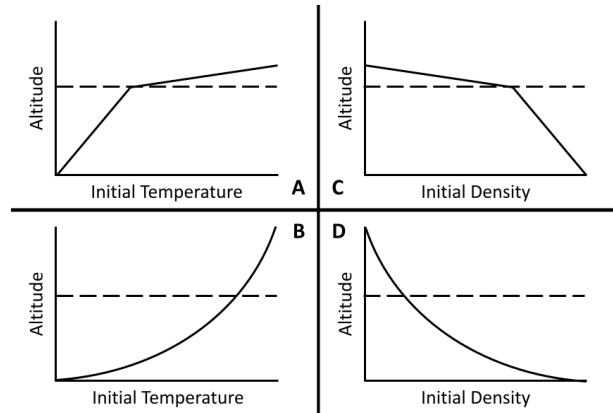
This anomaly could stem from a 2020 policy enacted by the International Maritime Organization (IMO) that impacted marine fuel sulfur content and SO_x emissions. Which of the following mechanisms best explains the Atlantic SST anomaly as an effect of this policy?

- A. Sulfate aerosols maintain acidity of rain, which controls phytoplankton growth. Reduced SO_x emissions increased surface algae biomass, lowering ocean albedo and increasing mean SST.
- B. Reduced SO_x emissions reduced aerosols and cloud condensation nuclei, decreasing cloud cover and solar reflectivity, increasing absorption of sunlight by the ocean and mean SST.
- C. Greater deposition of sulfate aerosols darkened Arctic sea ice, decreasing polar albedo and increasing absorption of solar radiation, increasing mean SST.
- D. Greater SO_x emissions enhanced the greenhouse effect by forming sulfuric acid aerosols that trap infrared radiation, increasing mean SST.

11. Gwen the geologist measures temperature profiles of the crust in three regions and finds geothermal gradients of 20°C/km, 30°C/km, and 40°C/km. Which of the following tectonic environments most likely correspond to these three profiles, respectively?

- A. Continental hotspot, subduction zone, mid-ocean ridge
- B. Mid-ocean ridge, continental hotspot, subduction zone
- C. Mid-ocean ridge, subduction zone, continental hotspot
- D. Subduction zone, continental hotspot, mid-ocean ridge

12. Mike the meteorologist creates and releases two sets of balloons into the atmosphere. The first set contains air heated to different temperatures, while the second set contains gases of different densities at room temperature. Mike then graphs the height each balloon reached compared to the variable he changed, with the tropopause shown as a dashed line. Which of the following pairs of graphs most accurately represents his findings?

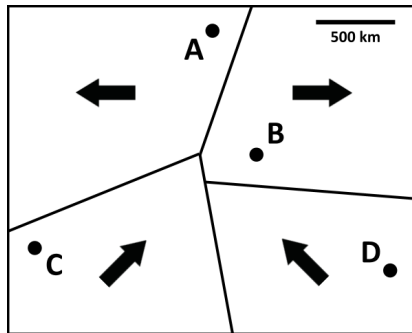


- A. A and C B. A and D C. B and C D. B and D

13. A gyre consists of ocean currents circulating around a central region. Which of the following best describes the motion of water at the center of the gyre in the subtropical South Atlantic?

- A. Upwelling due to convergence of water at the center of the gyre C. Downwelling due to convergence of water at the center of the gyre
 B. Upwelling due to divergence of water at the center of the gyre D. Downwelling due to divergence of water at the center of the gyre

14. The following map displays four oceanic tectonic plates and their boundaries, with arrows showing each plate's direction of motion. At which of the four labeled points on the map would an island arc most likely be present?



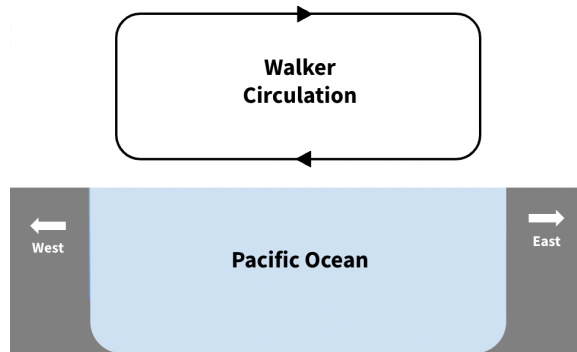
- A. A B. B C. C D. D

15. Mass movements tend to occur more frequently on slopes that have been destabilized. Which of the following would likely increase the probability of a mass movement occurring?

- I) Presence of a stream near the bottom of the slope
 II) Presence of an internal schist bed with planes dipping perpendicular to the slope

- A. I only B. II only C. I and II D. None

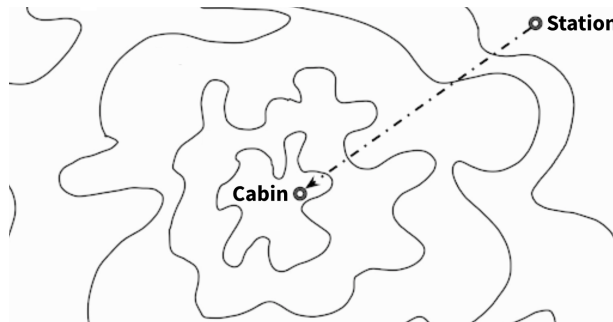
16. El Niño is a recurring climate phenomenon that alters the circulation pattern of air over the Pacific Ocean. This pattern is known as the Walker Circulation and is shown below.



Which of the following best characterizes the effect of El Niño on the strength of the Indian Summer Monsoon, a large-scale climate event that brings heavy rains to the Indian subcontinent between June and September?

- A. Strengthens, because the Walker circulation is strengthened
- B. Strengthens, because the Walker circulation is weakened
- C. Weakens, because the Walker circulation is strengthened
- D. Weakens, because the Walker circulation is weakened

17. Gerry the geologist stumbles upon a rare exposed gabbro pluton surrounded by a region of metamorphic rock. After setting up a station on the unaltered shale and mudstone around the pluton, he notices that his friend Sherry has built a cabin on top of the pluton. Gerry maps out the region and his path to Sherry’s cabin as shown below.



Given that the region had uniform composition before the pluton intruded, which of the following sequences would Gerry most likely find as he walks toward Sherry’s cabin?

- A. Shale, phyllite, greenschist, blueschist
- B. Shale, slate, greenschist, gneiss
- C. Shale, slate, phyllite, greenschist
- D. Shale, zeolite, hornfels, sanidinite

18. Comet Hale–Bopp reached its perihelion in April 1997, becoming visible to the naked eye for 18 months. In the year 4385 CE, Hale–Bopp is expected to reach its perihelion once again. Which of the following statements about Hale–Bopp is most likely true?

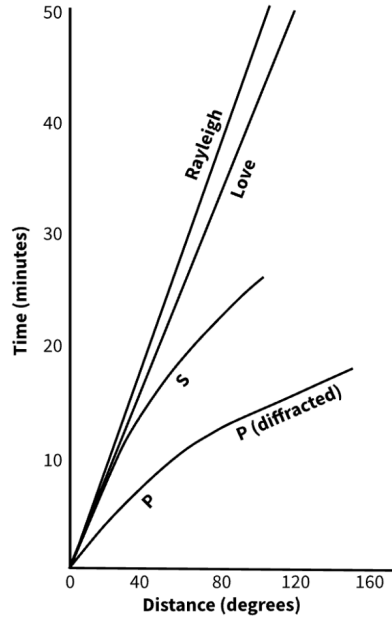
- A. Comet Hale–Bopp is approximately confined to the ecliptic plane
- B. Comet Hale–Bopp was set into motion by a passing star
- C. Comet Hale–Bopp has a hyperbolic orbit
- D. Comet Hale–Bopp will be nearly depleted of volatiles by 4385 CE

19. Which of the following statements accurately describe(s) radiation in the Earth system?

- I) Greenhouse gases increase surface temperatures mainly by reducing the amount of shortwave radiation emitted to space
- II) An increase in the global mean surface temperature results in more longwave radiation being emitted from Earth's surface

A. I only B. II only C. I and II D. None

20. The diagram below shows travel time curves for selected types of seismic waves released during an earthquake. Distance is measured from the epicenter and time is measured from the onset of the earthquake.



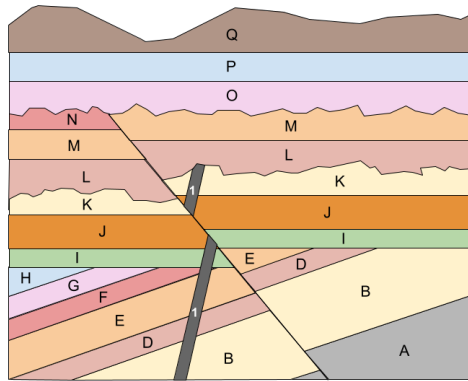
Which of the following is true regarding these seismic waves?

- A. P waves speed up over time due to increasing mantle rigidity with depth
- B. S waves slow down over time due to mineral phase transitions in the mantle
- C. Both P and S waves cannot propagate through the outer core
- D. Surface waves have the longest travel times due to their elliptical paths through the mantle

21. An exoplanet is observed transiting a Sun-like star every 3.54 days, dimming the star by about 1% each time it passes in front. Given that the change in brightness during transit can be approximated as $(\frac{R_p}{R_s})^2$, where R_p represents the exoplanet's radius and R_s represents the star's radius, which of the following statements is/are likely true?

- I) The exoplanet contains large amounts of water, methane, and ammonia ices
 - II) The exoplanet has a rotational period of 3.54 days
 - III) The exoplanet migrated inward after its initial formation
- A. I only B. III only C. I and II D. II and III E. I, II, and III

22. Roger the rock hound collects samples from the rock layers shown below to be radiometrically dated. After processing the samples, he obtains the data in the table to the right.

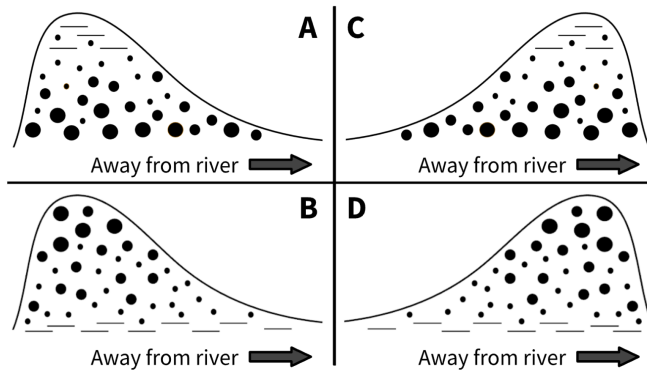


Structure	Approximate Age of Formation
A	5.5×10^8 years ago
I	3.1×10^8 years ago
K	2.7×10^8 years ago
N	2.0×10^8 years ago
O	1.1×10^8 years ago

How many millions of years ago (mya) could Structure 1 have formed?

- A. 400 mya B. 300 mya C. 250 mya D. 150 mya

23. A meandering river repeatedly overflows, leading to the formation of natural levees along its banks. Which of the following cross-sectional views of the resulting levees, with dots representing individual sediment grains, is most accurate?



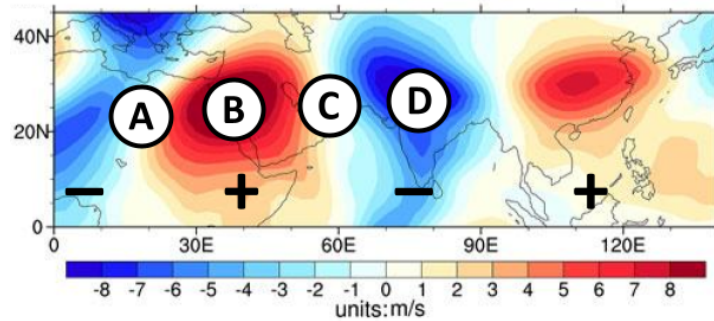
- A. A B. B C. C D. D

24. Estuaries are water bodies most commonly found in regions where rivers and oceans meet. Which of the following statements is/are true regarding estuaries?

- I) Well-mixed estuaries have nearly vertical isohalines, lines connecting points of equal salinity
- II) The onset of dry offshore winds reduces the salinity gradient of highly stratified estuaries
- III) Internal waves are more prevalent in well-mixed estuaries compared to highly stratified estuaries

- A. I only B. III only C. I and II D. II and III E. None

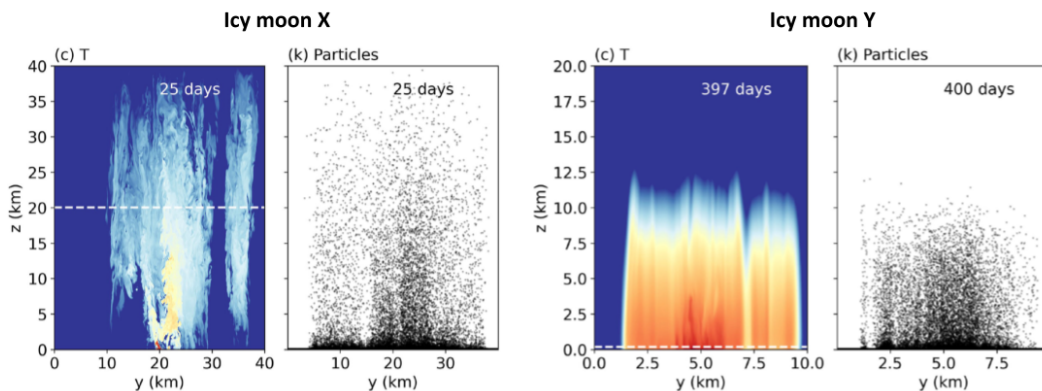
25. Shown below is a map of average meridional wind speed at a pressure of 250 mb (v_{250}). Positive v_{250} corresponds to northward winds and negative v_{250} to southward winds. The sign of each shaded region is indicated on the map.



Based on these wind patterns, at which of the labeled regions would an upper-level ridge most likely be present?

- A. A B. B C. C D. D

26. Shown below are simulated hydrothermal vent plumes in subsurface oceans of two icy moons. The plumes both originated from point heat sources on the ocean floor and diffused into the surrounding ambient water, but they display very different shapes. Which of the following statements is/are likely true of the two moons?



(Note: Buoyancy force on the plume can be modeled as $b \approx \frac{g(\rho_{\text{ambient}} - \rho_{\text{plume}})}{\rho_0}$, where g is acceleration due to gravity and ρ_{ambient} , ρ_{plume} , and ρ_0 are the density of the ambient, plume, and reference water, respectively.)

- I) Icy moon X has stronger gravity than icy moon Y
 II) Icy moon X has a weaker heat source than icy moon Y

- A. I only B. II only C. I and II D. None

27. Which of the following sets of conditions would be most favorable for the formation of a nighttime radiation fog?

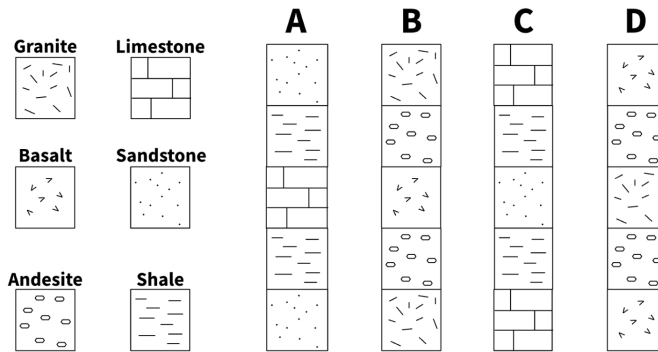
- A. Slight breeze and clear sky C. Strong breeze and clear sky
 B. Slight breeze and cloudy sky D. Strong breeze and cloudy sky

28. Eustatic sea level change is largely driven by freezing and thawing in polar regions. Rank the following ice masses in increasing order of effect on instantaneous, local sea level change if 10,000 km³ of ice was melted from each mass.

- I) Greenland Ice Sheet
- II) Ross Ice Shelf
- III) North Atlantic sea ice

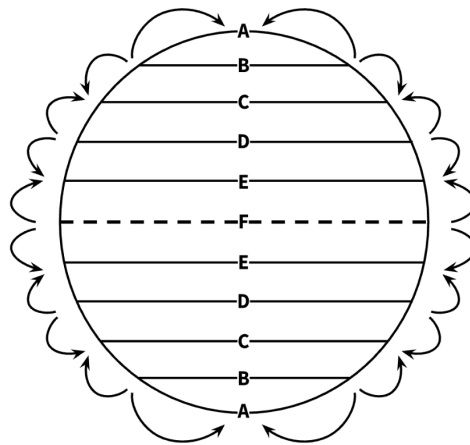
- A. I, II, III B. II, I, III C. II, III, I D. III, II, I

29. Diana knows that, beginning one million years ago at a particular section of tectonically inactive coastline, the sea level fell from its initial position and then rose back up. If Diana dug to rocks formed around one million years ago, which of the following sequences would she most likely find? Assume that layers on top are younger.



- A. A B. B C. C D. D

30. A new planet, similar to Earth and possessing both liquid water and an atmosphere, is discovered. However, it is found to have five instead of three atmospheric circulation cells as shown below.



At which regions on this planet would arid climates most likely be present?

- A. A, B, and C B. D, E, and F C. A, C, and E D. B, D, and F

END OF SECTION I