



USESO 2026

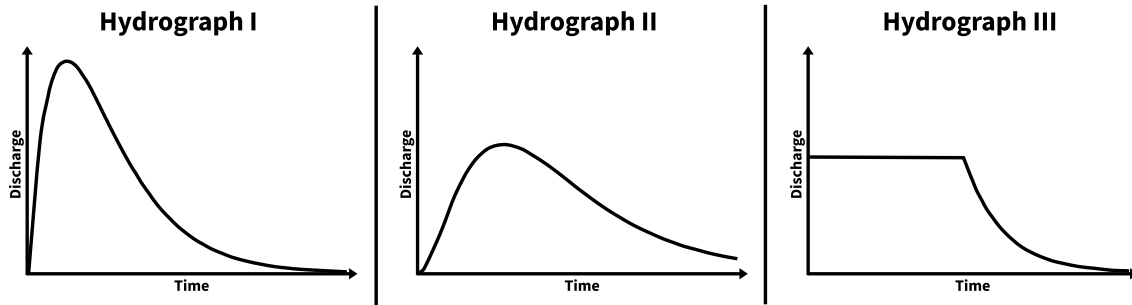
National Open Exam

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.
- 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. Vishnu is interested in how different types of urban developments influence flood duration and flood intensity. To do so, he models a precipitation event in three hypothetical watersheds. Which option correctly matches each hydrograph to its corresponding watershed type?



- A. I is a highly urbanized watershed; II is a forested rural watershed; III is a dam-controlled river reach
 B. I is a forested rural watershed; II is a highly urbanized watershed; III is a dam-controlled river reach
 C. I is a dam-controlled river reach, II is a highly urbanized watershed, III is a forested rural watershed
 D. I is a forested rural watershed, II is a dam-controlled river reach, III is a highly urbanized watershed

Solution: Hydrograph III is the only hydrograph that has a cap on maximum discharge, indicating that it is likely dam-controlled. Since rural regions tend to have more permeable ground and vegetation to slow runoff than urban regions, they likely have a lower peak discharge corresponding to hydrograph II. A is the correct answer.

2. The P/E_p ratio is the ratio of precipitation to maximum evapotranspiration assuming an unlimited water supply. Suppose you were trying to calculate this ratio, but you accidentally substituted the actual evapotranspiration E_a instead of E_p . What would be the resulting error, and where would the largest percent errors be?

- A. An overestimate of the P/E_p ratio, mainly in dry climates
 B. An overestimate of the P/E_p ratio, mainly in wet climates
 C. An underestimate of the P/E_p ratio, mainly in dry climates
 D. An underestimate of the P/E_p ratio, mainly in wet climates

Solution: The actual evapotranspiration E_a is always less than or equal to potential evapotranspiration E_p . Thus, $P/E_a \geq P/E_p$, which is an overestimate. In dry climates, evaporation tends to be moisture-limited, and the difference between E_a and E_p is larger. In wet climates, evaporation is usually not a limiting factor in evaporation, so $E_a \approx E_p$. A is the correct answer.

3. Of the terrestrial planets, only Earth and Mercury have appreciable global magnetic fields. However, Mercury's magnetic field is much weaker than Earth's (about 1/100th the strength of Earth's magnetic field). Which of the following choices correctly explains why?
- A. Mercury's larger core relative to its size results in stronger Coriolis forces upon core convection currents
 - B. Mercury's slow rotation compared to Earth results in weaker convection columns within the core**
 - C. Mercury's large inner core temperature gradient results in stronger core convection currents
 - D. Mercury has a thick outer core relative to its overall core size, resulting in weaker convection currents

Solution: The planetary magnetic fields of Earth and Mercury are generated by the motion of the liquid metal outer cores of these planets. This motion is driven by convection and forced into alignment by the Coriolis effect. A and C would both make this effect stronger on Mercury. A larger depth of the convecting layer also promotes stronger convection, so D is incorrect as well. Slower rotation weakens the Coriolis effect, which explains the difference in strength. The correct answer is B.

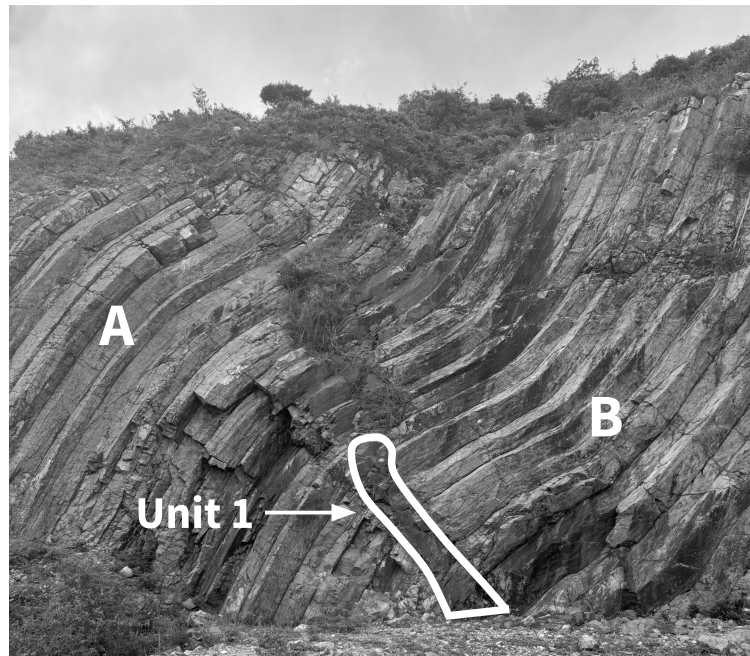
4. Max is measuring the water discharge exiting a fully saturated aquifer composed primarily of sand. Which of the following changes would increase the discharge measured by Max?
- I) Replacing the sand in the aquifer with silt
 - II) Increasing the discharge of streams feeding into the aquifer
- A. I only
 - B. II only
 - C. I and II
 - D. None**

Solution: Filling the aquifer with silt reduces its permeability, decreasing the discharge rate of the aquifer—I is false. Since the aquifer is already saturated, additional stream discharge would not cause increased aquifer discharge—II is false.

5. Sulfate aerosols are emitted into the troposphere by anthropogenic pollution. Which of the following climate impacts would you expect to observe following an increase in tropospheric sulfate aerosols?
- I) Increase in the absorbance of incoming sunlight, causing warming
 - II) Increase in low-level cloud formation rates, causing cooling
 - III) Decrease in the lifespan of low-level clouds by decreasing the average droplet mass, causing warming
- A. I and III
 - B. II and III
 - C. II only**
 - D. III only
 - E. None

Solution: Sulfate aerosols reflect sunlight—I is false. Aerosols serve as cloud condensation nuclei, thus an increase in their concentration increases cloud formation. Since stratus clouds reflect more radiation than they trap, they cause net cooling—II is true. An increase in cloud condensation nuclei decreases the average size of cloud droplets since the same mass of water is distributed over more particles. Smaller cloud droplets stay suspended in the atmosphere longer, increasing cloud lifespan—III is false.

6. Consider the following outcrop of igneous rock with intruding rock Unit 1 denoted by the white outlines. Which of the following can be reasonably inferred from this photo?



- I) Unit 1 is younger than the surrounding rock
- II) The rocks at location A are younger than those at location B

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

Solution: Unit 1 is an intrusion, so by the law of cross-cutting relationships, it can be inferred that it is younger than the surrounding rock—I is true. Since the outcrop is composed of igneous rocks, the curved lines spanning the outcrop are likely columnar jointing. Thus, A and B likely formed at very similar times—II is false.

(Note: This photo was taken at Hong Kong Global UNESCO Geopark.)

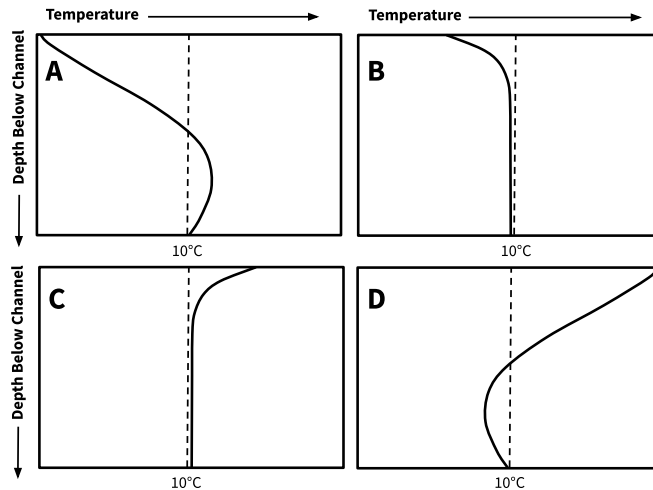
7. Blearth is a planet exactly identical to Earth except for the fact that it rotates around its axis in retrograde. Which of the following statements accurately describes patterns of ocean circulation on Blearth?

- I) Downwelling occurs at the center of gyres
- II) Currents on the Western edge of ocean basins are slower and wider than their Eastern counterparts
- III) Surface water at the latitude of the Antarctic Divergence on Earth **converges** on Blearth

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

Solution: Switching the direction of rotation reverses the direction of the Coriolis force, deflecting motion to the left in the Northern Hemisphere and to the right in the Southern Hemisphere. The reversed directions of both the Ekman transport and the gyre motion still direct water towards the center of gyres—I is true. The reversed rotation implies that Blearth experiences eastern instead of western intensification, meaning western currents are slower and wider than their eastern counterparts—II is true. Both the Ekman transport and Antarctic current directions reverse, leaving the convergence unaltered—III is false.

8. The following diagram depicts the temperature profiles for gaining and losing streams at different times of the year. Which profile represents a gaining stream in winter?



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

Solution: In gaining streams, the water at the stream bed mixes with rather than feeds the groundwater below, resulting in a more stable temperature profile. In the winter, the stream bed is likely to be colder than the groundwater. Choice B best matches these descriptions.

9. The chemical index of alteration (CIA), a weathering index for rocks, is calculated as

$$\text{CIA} = \frac{[\text{Al}_2\text{O}_3]}{[\text{Al}_2\text{O}_3] + [\text{CaO}] + [\text{Na}_2\text{O}] + [\text{K}_2\text{O}]} \times 100,$$

where $[\text{CaO}]$, $[\text{Na}_2\text{O}]$, and $[\text{K}_2\text{O}]$ are the concentrations of more easily leachable species than Al_2O_3 . Soil samples X and Y are derived from the same parent rock but were taken from different locations. Sample X has $\text{CIA} = 80$ and Sample Y has $\text{CIA} = 55$. Which of the following offers the best explanation for the cause of this discrepancy?

- A. Sample Y is older than Sample X
- B. Sample X was sampled from the E horizon, while Sample Y was sampled from the B horizon**
- C. Sample X was exposed to freeze-thaw cycles more often than Sample Y
- D. The precipitation at the location of Sample X was less acidic than the precipitation at Sample Y

Solution: Higher CIA values reflect the removal of mobile cations such as Ca^{2+} , Na^+ , and K^+ , indicating a greater degree of leaching. Therefore Sample X should be found in an environment with a greater degree of chemical weathering. Increased age and acidic precipitation result in more chemical weathering for Sample Y—A and D are incorrect. Freeze thaw cycles do not change bulk chemistry—C is incorrect. The E horizon is characterized by a high degree leaching while the B horizon is characterized by the deposition of leached chemical species—B provides the best explanation.

10. Edlyn and Flora are studying water properties in the Atlantic Ocean. Edlyn is on a boat at the equator, while Flora is on a boat at 20 degrees north. Which of the following statements is/are true about the water they are studying?

- I) If Edlyn and Flora both begin vertically descending into the ocean below their boats, Flora will experience a greater change in temperature as she descends
- II) If Edlyn and Flora have identical boats, Flora's boat will have an easier time floating due to a difference in surface water density
- III) If the strength of the Hadley circulation cell were decreased, the difference in surface water salinity at the location of the two boats would also decrease

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

Solution: Because the thermocline becomes less developed further from the equator due to lower surface heating, Flora would experience a smaller change with depth—I is false. The cooler and saltier surface water at 20 degrees north result in higher densities compared to equatorial water—II is true. A weaker Hadley cell reduces the difference in freshwater fluxes due to evaporation and precipitation at the latitudes in question. This leads to a smaller salinity difference—III is true.

11. According to Kepler’s laws of planetary motion, which of the following pairs of planets have the same orbital period?

Planet	Host Star Mass (M_{\odot})	Perihelion (AU)	Aphelion (AU)
I	1.0	1.0	1.0
II	2.0	0.5	2.0
III	4.0	1.0	4.0
IV	8.0	1.0	3.0

- A. I and II
- B. I and IV**
- C. II and III
- D. II and IV
- E. III and IV

Solution: According to Kepler’s third law, the period of a planet’s orbit is proportional to $\frac{a^3}{M}$, where M is the mass of the host star and a is the semi-major axis, calculated as the the average of the perihelion and aphelion distances. Planets I and IV both compute to a ratio of 1—B is the correct answer.

12. Scientists are investigating a sample of oceanic sediments known to be located near the equator during the start of its formation. From top to bottom, the layers are primarily composed of clay, then siliceous ooze, then calcareous ooze. Which of the following sets of events experienced by the sample is most likely to have caused the formation of this sequence?

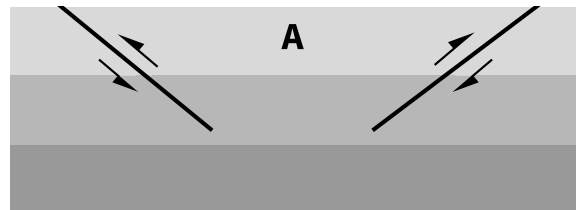
- A. Retreat of continental glaciers, followed by movement away from the equator**
- B. Movement away from the equator, followed by retreat of continental glaciers
- C. Seafloor subsidence, followed by strong ocean surface cooling
- D. Strong ocean surface cooling, followed by seafloor subsidence

Solution: A provides the only sequence of events which sufficiently explains the formation of the sequence. Retreat of continental glaciers increases ocean volume, which could cause the sample region to deepen beyond the calcite compensation depth, resulting in a transition from calcareous to siliceous ooze. Due to upwelling, the equator is particularly nutrient-rich. Movement away from the equator reduces the nutrients required by silica-based organisms, causing the deposited sediments to transition to clay.

13. A geologist wants to find rocks with strong schistosity and large mica flakes. From which of the following environments would they be most likely to find such rocks?
- A. An area of repeated marine transgressions and regressions
 - B. An area of continental rifting
 - C. **A mountain range where accreted oceanic crust is found**
 - D. An isolated mountain where tuff and rhyolite are found

Solution: Strong schistosity and large mica flakes are characteristic of areas undergoing regional metamorphism. Choices A, B, and D are not directly related to regional metamorphism. In order for accreted oceanic crust to be found, significant compressional stress must occur at an oceanic-continental tectonic plate boundary. This would likely result in the regional metamorphism required for the observed phenomena—C is the correct answer.

14. The cross-section below depicts a region *before* deformation occurred along with the faults that formed *during* deformation. What type of force resulted in the faults shown, and would you expect erosion or deposition to occur at the region labeled A?



- A. **Compressional, erosion**
- B. Compressional, deposition
- C. Extensional, erosion
- D. Extensional, deposition

Solution: Since the middle section of the cross-section is moving up relative to the footwalls, the faults are classified as reverse and the area is experiencing compressional stress. The middle section moves up relative to surrounding material and will experience higher rates of erosion. A is the correct answer.

15. Heat waves generally form when high-pressure zones stagnate, trapping hot air near the ground. Which of the following best explains how high soil moisture affects the severity of a heat wave?
- A. Increases, because the high latent heat of evaporation releases energy to the atmosphere
 - B. **Decreases, because the high latent heat of evaporation absorbs heat energy from the atmosphere**
 - C. Increases, because the high specific heat of water releases energy to the atmosphere
 - D. Decreases, because the high specific heat of water absorbs energy from the atmosphere

Solution: Soil moisture absorbs a high amount of heat from the surroundings during evaporation. This results in a net cooling effect, decreasing the severity of a heat wave. Since the latent heat of evaporation is much larger than the amount of heat stored by specific heat, the correct answer is B.

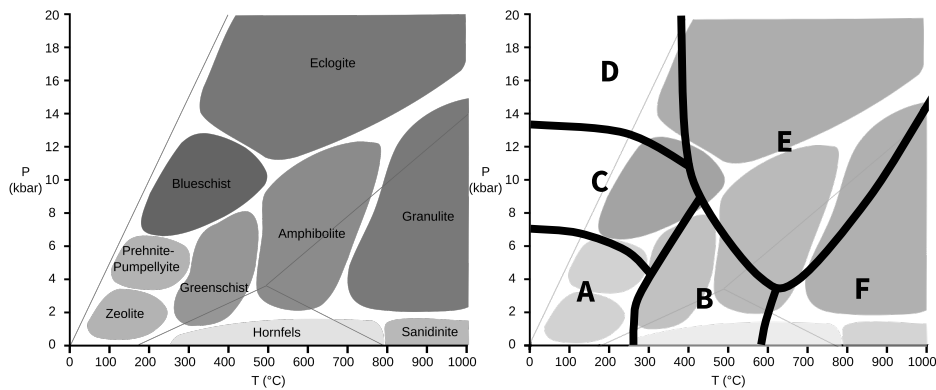
16. The velocity of a glacier can be affected by factors such as temperature, basal water pressure, and glacier mass. Which of the following conditions are associated with faster glacier flow?

- I) A glacier with an ice shelf rather than fully grounded termination
- II) A glacier that is thinner than average
- III) A glacier with a warmer base than average

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

Solution: A glacier terminating in an ice shelf would experience a buoyant force lifting it off the bed, reducing friction—I is true. Thinner glaciers reduce the probability of pressure melting, which lubricates the bed, and are subject to less plastic flow, reducing total flow velocity—II is false. Warmer based glaciers are more likely to have wet bases providing lubrication—III is true.

17. Shown below is the pressure-temperature phase diagram for six polymorphic minerals, A, B, C, D, E, and F. For samples belonging to the same metamorphic facies, in which of the following facies would these minerals be least useful for distinguishing relative degrees of metamorphism?



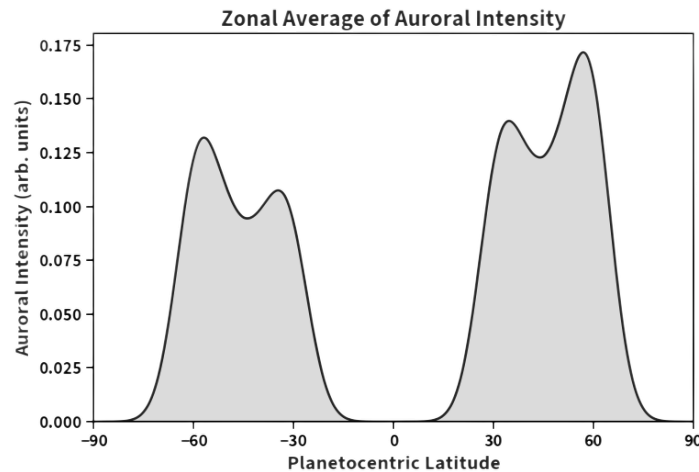
- A. Zeolite B. Blueschist C. Amphibolite D. Hornfels

Solution: If there is only a single mineral that is stable in the T-P range of a certain facies, all specimens from that facies will contain that mineral. However, if there are multiple stable minerals from that facies, we can narrow down the range of temperature and pressure within the range of the facies the specimen came from. Zeolite has only one stable mineral in its T-P range, while all other listed facies have multiple. The correct answer is A.

18. Laboratory analysis of a stony-iron meteorite shows that it is composed of roughly equal parts Fe–Ni metal and olivine–pyroxene crystals, with textures suggesting slow cooling while solid-state metal and silicate were in contact. Which of the following parent-body settings best explains this composition and texture?
- A. Fragment of an undifferentiated chondritic asteroid that never experienced large-scale melting
 - B. Regolith breccia formed in the upper crust of a small, airless body such as the Moon
 - C. Metal-rich clasts mixed into silicate material within an undifferentiated asteroid’s interior
 - D. Mixed material from the boundary between the metallic core and silicate mantle of a differentiated asteroid**

Solution: The meteorite must come from a source containing both metals and mafic silicate material in contact, but not mixed together. Choice A does not provide a separation of the two materials, choice B does not include a source of metals, and choice C does not necessitate slow cooling while the metal and silicate are in contact. Choice D provides a plausible explanation for all of the observations.

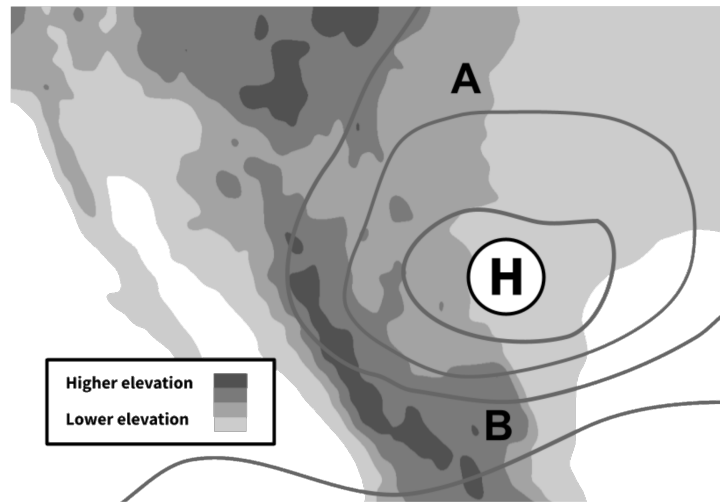
19. Shown in the figure is the zonal average of aurora intensity on an unknown planet (in a specific month) versus the latitude relative to the planet’s rotational axis. Which of the following statements can be inferred about the planet imaged during this month?



- A. The planet’s southern hemisphere is tilted toward the Sun
- B. The planet experiences retrograde rotation
- C. The planet’s magnetic pole is offset from its rotational axis**
- D. The planet exhibits a lower rotational axial tilt than Earth

Solution: Auroras form around magnetic poles where magnetic field lines converge and funnel charged solar particles into the atmosphere. The northern hemisphere has stronger auroras in the figure—A is incorrect. The rotational direction and axial tilt of the planet cannot be inferred from the image—choices B and D are eliminated. Peak auroral activity is centered around 45N° in the graph, indicating the magnetic pole of this planet is offset from the geographic pole. The correct answer is C.

20. The North American monsoon is a seasonal weather phenomenon which impacts the southwestern United States and Mexico. The following figure shows one phase of the monsoon, with surface-level isobars overlain on a topographic map of Mexico. Which of the following correctly describes the effect of this phase of the monsoon on precipitation levels at locations A and B, respectively?



- A. Relatively high; relatively low
- B. Relatively high; relatively high
- C. Relatively low, relatively high
- D. Relatively low, relatively low

Solution: In the Northern Hemisphere, winds circulate clockwise around high-pressure systems. Prevailing winds would travel from the Gulf to location A after passing over the mountain range. Similarly, winds would pass over the mountain range while traveling over location B. The rain shadow effect causes increased precipitation on the windward side of the mountain range and decreased precipitation on the leeward side—C is correct.

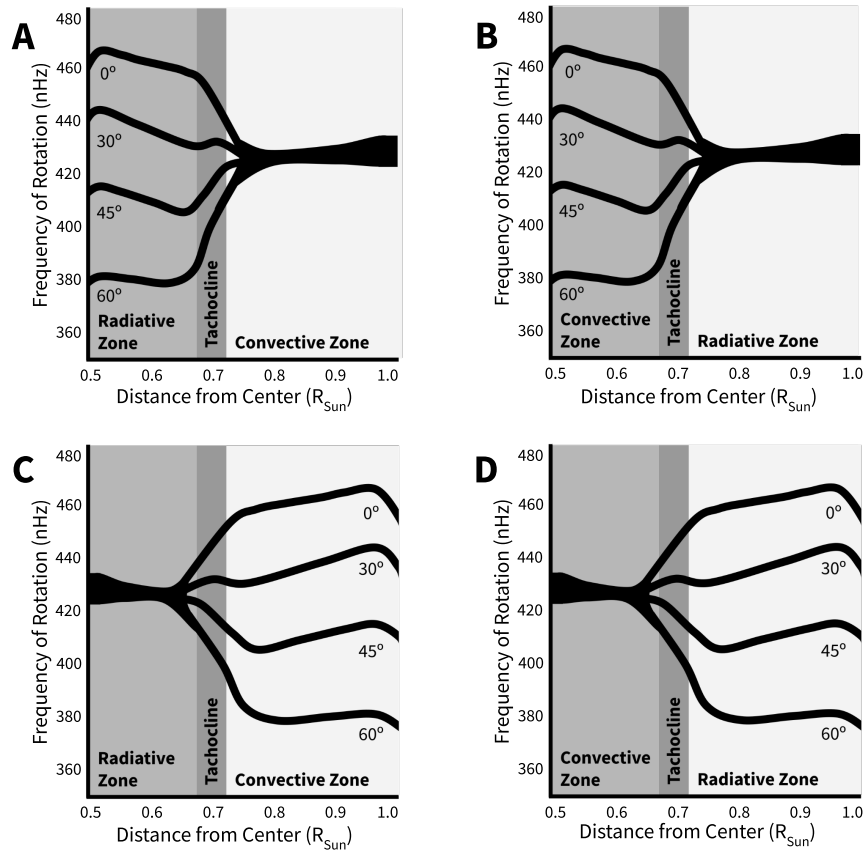
21. Winds subject to which of the following conditions would be expected to flow across isobars?

- I) Large pressure gradient aloft in the mid-latitudes
- II) Located within the planetary boundary layer in the Antarctic
- III) Located at the surface beneath a developing anticyclone in the mid-troposphere

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

Solution: A large pressure gradient in the mid-latitudes aloft supports strong winds that flow parallel to isobars, as they are in geostrophic balance with the Coriolis force—I is false. Flow below the planetary boundary layer is primarily influenced by friction and the pressure-gradient force, supporting cross-isobaric flow—II is true. A newly developing anticyclone generates wind that diverges outward from the center of the anticyclone, crossing isobars before geostrophic balance is attained—III is true.

22. The tachocline acts as the division between the Sun's radiative and convective zones. Which of the following four figures most accurately models the rotation of the Sun as a function of distance from the Sun's center?



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

Solution: The diverging frequency curves represent areas of differential rotation. Since the convective zone undergoes differential rotation and is the outer layer of the sun, C is the correct answer.

23. Which of the following best describes upper tropospheric energy transfer over the Western Pacific ocean during La Niña conditions?

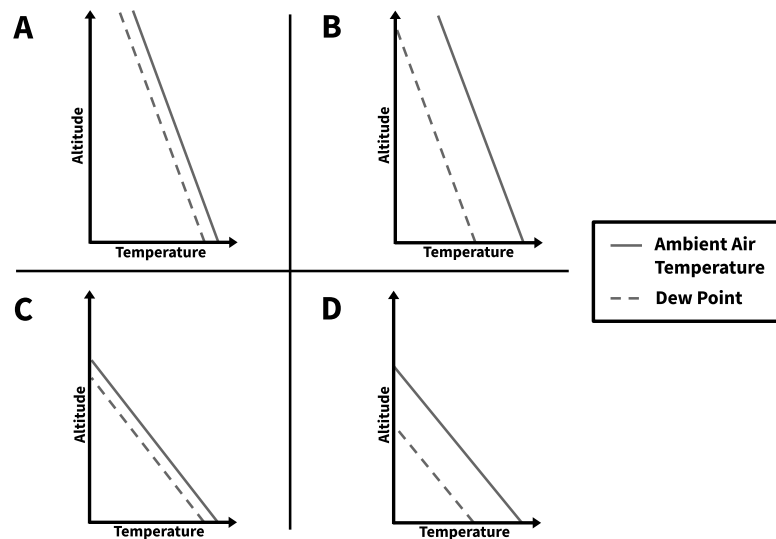
- A. Net meridional heat movement towards the equator, net zonal heat movement eastward
- B. Net meridional heat movement towards the equator, net zonal heat movement westward
- C. **Net meridional heat movement towards the poles, net zonal heat movement eastward**
- D. Net meridional heat movement towards the poles, net zonal heat movement westward

Solution: The Hadley cell circulation results in upper atmospheric hot air moving poleward regardless of ENSO conditions—A and B can be eliminated. During La Niña, the neutral Pacific Walker circulation is strengthened, resulting in a net movement of the hot Western Pacific air eastwards. The correct answer is C.

24. Adakites are a rare class of silica- and sodium-rich igneous rock. Ratios of trace elements in adakites indicate that they are derived from partial melting of metamorphosed basalt. Which of the following is most likely to be the bulk composition of the material left behind by an adakite-forming partial melt?
- A. Alkali feldspar and chlorite
 - B. Amphibole and garnet**
 - C. Muscovite and quartz
 - D. Perovskite and bridgmanite

Solution: Partial melting occurs when a rock is heated above the solidus and some of its minerals begin to melt. As more felsic minerals have lower melting points, they are less likely to be left behind by a partial melt—A and C can be eliminated. Minerals in choice D are primarily found in the lower mantle and are not stable under conditions of basalt formation. Choice B includes minerals representative of basalt with high melting temperatures. B is therefore the best answer.

25. The following diagram shows four upper air soundings at different locations. At which location are thunderstorms most likely to occur?



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

Solution: Thunderstorms form in moist, unstable environments. The differences between the temperature and dew point is lower at locations A and C, indicating more humid air. The change in temperature with height, or the environmental lapse rate, is highest at locations C and D, indicating more unstable air. Because location C has a high lapse rate and humid air, it is most likely to form thunderstorms.

26. Cold air damming occurs when cold air gets trapped by easterly winds along the windward side of a mountain range. Which of the following statements is/are true about cold air damming configurations in the Northern Hemisphere?

I) Cold air damming configurations typically have high pressure to the south

II) Cold air damming is associated with freezing rain

A. I only

B. II only

C. I and II

D. None

Solution: High pressure to the south would create a southwesterly wind, moving air away from the mountain—I is false. In a cold air damming setup, the warmer air overruns the colder air, producing drizzle that becomes supercooled upon entering the colder air below—II is true.

27. Which of the following regions are likely to display anomalously high seismic velocities in the lower lithosphere?

I) Below the Canadian Shield

II) Below Kilauea, Hawaii

A. I only

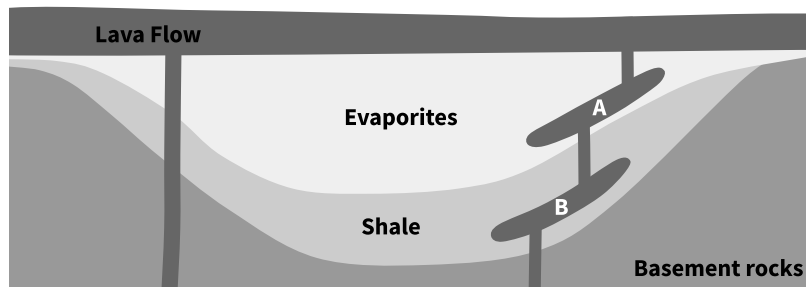
B. II only

C. I and II

D. None

Solution: The Canadian Shield is underlain by a cold, rigid lithospheric root, which produces high seismic velocities—I is correct. Hawaii's volcanoes are fed by a hot, low rigidity mantle plume, and therefore would have lower seismic velocities—II is incorrect.

28. The Siberian Traps are a large region of volcanic rock formed by mantle plume volcanism. These eruptions are often stated to be the primary cause of the Permian-Triassic mass extinction event. The image below shows a simplified cross-section of a portion of the Siberian Traps, including the underlying strata.



Identify all of the following statements that are true of the Siberian Traps:

I) The mass extinction was partially caused by long-term global warming due to the eruption's high greenhouse gas content

II) A sample of the intrusion from location A would likely be more enriched in volatiles than a sample from location B

A. I only

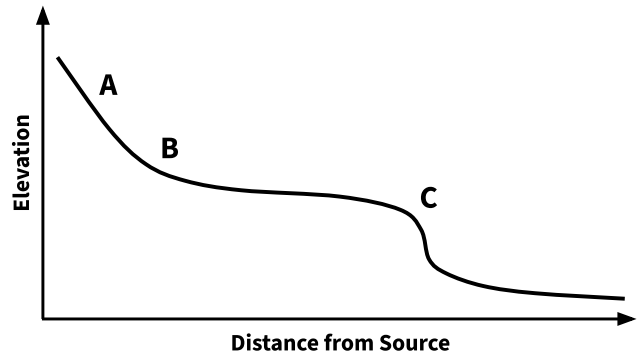
B. II only

C. I and II

D. None

Solution: As is typical of flood basalts, a vast amount of greenhouse gases were released in the Siberian Traps eruption, causing a sudden global warming that led to the Permian-Triassic extinction—I is correct. Since evaporites are often enriched in volatiles, the presence of the magma chamber in an evaporite bed is likely to increase samples from A relative to B—II is correct.

29. Shown in the figure is a simplified topographic profile of a river that originates in the mountains and flows out to the sea over uniform bedrock. Which of the following choices best identifies the points where the highest net erosion and deposition occur, respectively?



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

Solution: Erosion occurs most rapidly at knickpoints like point C where stream gradient changes abruptly. Sediment deposition rates depend on the rate of change of flow velocity, which is primarily determined by the slope of the river. The slope can be seen decreasing most sharply at point B. The correct answer is D.

30. Rohit is studying a mysterious exoplanet—a perfect black body with no atmosphere—that has an average surface solar flux of 2100 W/m^2 . He measures its ratio of absorbed radiation to reflected radiation to be 1.75. Taking the Stefan Boltzmann constant to be $5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$, which of the following is closest to the equilibrium temperature of Rohit’s planet?

- A. 280 K
- B. 390 K
- C. 410 K
- D. 440 K
- E. 500 K

Solution: To determine the temperature at equilibrium we must find the temperature where the net surface energy flux, the difference between absorbed radiation and emission, is zero. The magnitude of absorbed radiation can be calculated as $2100 \text{ Wm}^{-2} \cdot \frac{1.75}{1.75+1} = 1336.36 \text{ Wm}^{-2}$. We can calculate the emission, M , via the Stefan-Boltzmann law and set the difference to zero.

$$1336.36 \text{ Wm}^{-2} - \sigma T^4 = 0$$

$$T = \sqrt[4]{\frac{1336.36}{5.67 \times 10^{-8}}} \text{ K}$$

$$T = 391.8 \text{ K} \approx 390 \text{ K}$$

Note: This question has a minor error in describing the planet as a perfect blackbody while it is simultaneously quite reflective. The intention of this was to describe the planet as having an emissivity of 1 (a characteristic of blackbodies) which allows the use of the Stefan-Boltzmann law. The question has not been edited to preserve the contents as they were administered during the exam window.

END OF SECTION I