# USESO 2023

Training Camp Exam

Multiple Choice

Instructions:

– Section I consists of 20 multipart questions that assess geoscience knowledge in the form of multiple choice questions. Each question is worth 2 points.

– You have 45 minutes.

– Any type of calculator is allowed.

– Participating in this exam is agreement to our academic integrity policy.

1. Oxbow lakes can indicate a hypothetical maximum meander size somewhere along a river. Which of the following processes is responsible for keeping meander size below this limit?

    A. Deposition at outer bank

    B. Erosion at outer bank

    C. Deposition at inner bank

    D. Erosion at inner bank

2. Planck's law gives the intensity of light as a function of its frequency ν emitted by a blackbody at a temperature T. At high frequencies, the intensity is proportional to $\nu^3 e^{-k\nu/T}$ where k is a constant. The following figure shows the relative intensity of light as a function of wavelength for four blackbodies with temperatures labeled.
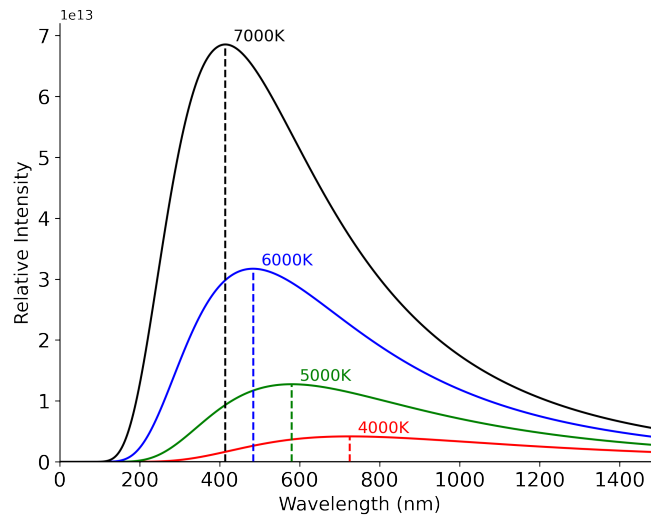

Which of the following statements are true?

    I) At small wavelengths such as those shown here, peak wavelength is inversely proportional to temperature.

    II) As the temperature of the object increases, the intensity at any wavelength increases.

    III) If the maximum intensity of light emitted by a blackbody is at 5000 nm, then its temperature, to one significant figure, is 600 K.

    A. II only

    B. I and II

    C. I and III

    D. I, II, and III

3. You are using a machine learning algorithm that takes in satellite imagery to map out river basins from different climate regions. You find that the rate of meander formation tends to decrease with aridity. Why might this be the case?

    A. Regions with lower aridity tend to have increased bank strength

    B. Regions with lower aridity tend to have decreased bank strength

    C. Aridity has no effect on bank strength

    D. Bank strength has no effect on rate of meander formation

4. After the Great Oxidation Event approximately 2.3 billion years ago, greater carbon burial resulted in global lubrication of tectonic activity due to the ductile nature of organic shales and their metamorphism to low-friction graphite. Which of the following would **not** be expected to increase as a result of this change?

      A. Formation of volcanic andesites

      B. Global sea level

      C. Metamorphic grade of continental orogens

      D. Ocean magnesium concentration

5. Consider the following upper-level isobaric map. Based on the inferred surface conditions from this map, the surface wind at point A is most likely blowing toward which of the following directions?
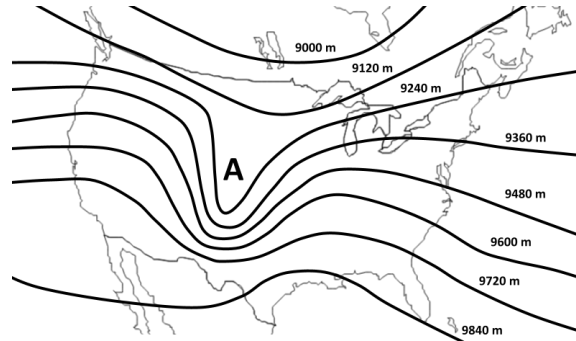

      A. Northeast

      B. Northwest

      C. Southeast

      D. Southwest

6. A hyperpycnal plume is a type of turbidity current that forms when sediment-rich river water enters the ocean and sinks. The formation of these plumes is rarely consistent, often depending on seasonal factors. Which of the following summertime conditions would favor hyperpycnal plume formation?

   I) High sea surface temperature

  II) Decreased precipitation over the ocean

 III) Glacial meltwater feeding the river

      A. II only

      B. III only

      C. I and II

      D. I and III

      E. None

7. Which of the following strata is least likely to be found in a fold?

    A. Near-surface quartzite strata

    B. Near-surface shale strata

    C. Deep quartzite strata

    D. Deep shale strata

8. The figure below is a profile of the Laika ice cap in Canada showing temperature contours in °C. X1-X5 are drilling sites where the temperature vs. depth was measured.
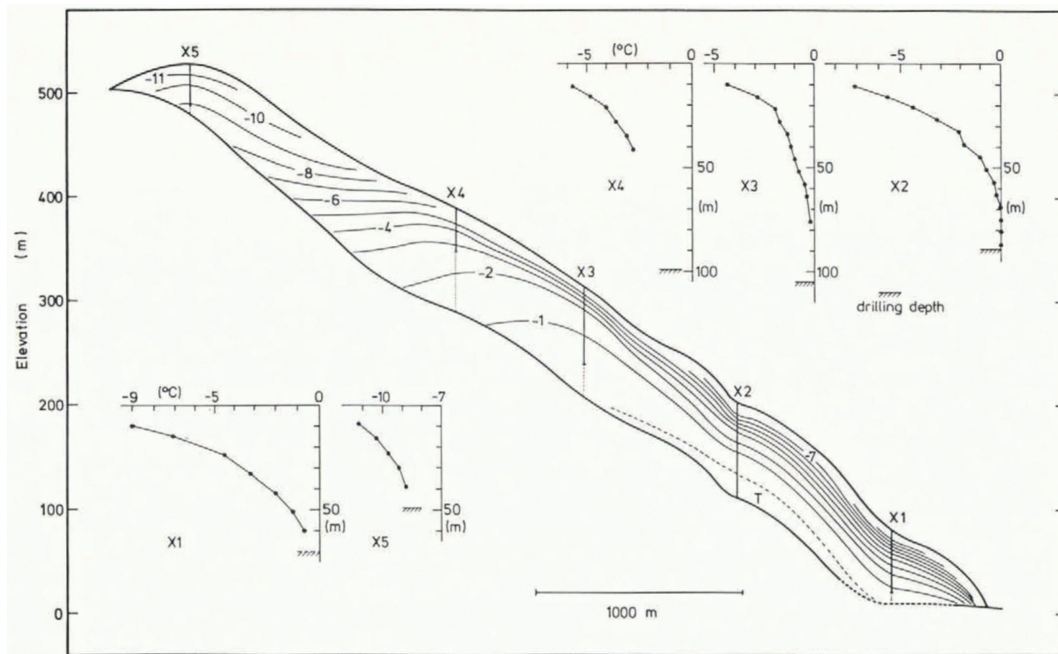

Which of the following accurately compares the ice at X2 relative to other drill sites?

    A. Ice at X2 likely entrains more sediments than at X4.

    B. More liquid at the base of the glacier was generated by surface melt at X1 than X2 at the time of data collection.

    C. A glacial surge is more likely to occur at X3 than X2.

    D. X2 only flows by basal slip while X4 flows only by internal deformation.

9. The light-colored areas of the lunar surface are composed of anorthosite, a rock mostly composed of Ca-rich plagioclase feldspar, formed billions of years ago. Which of the following mechanisms best explains how this anorthosite formed?

    A. Large mantle plumes pushed ultramafic mantle material through early crust

    B. Lunar crust solidified before differentiation due to heat loss from radiation

    C. Impacts exposed ultramafic mantle material that solidified into anorthosite

   D. Anorthite crystals formed early in crystallization and floated upwards

10. Which of the following statements are typically true about clouds in the presence of an atmospheric inversion?

   I) Most updrafts under these conditions will form cumuliform clouds.

   II) Air lifted up to the inversion forms clouds similar to some at warm fronts.

    A. I only

    B. II only

    C. I and II

    D. None

11. Potassium-40 can decay into argon-40 or calcium-40, with the decay to argon occurring 10.7% of the time. The *overall* half-life of the decay of potassium-40 is 1.25×10^9 years. You find a sample of dacite from the Mount St. Helens eruption from 1980. The concentrations of potassium-40 and argon-40 in the rock is measured to be 1.35 ppm and 0.017 ppm, respectively. Calculate the age of the sample, in years.

    A. 2.4×10^6 years

    B. 2.3×10^7 years

    C. 2.0×10^8 years

    D. 4.1×10^9 years

12. The surface of Ceres shows several small bright spots (depicted below) which have been shown to be primarily composed of hydrated salts. Given the reconstructed image below, which of the following gives a reasonable explanation for the formation of these salt deposits?
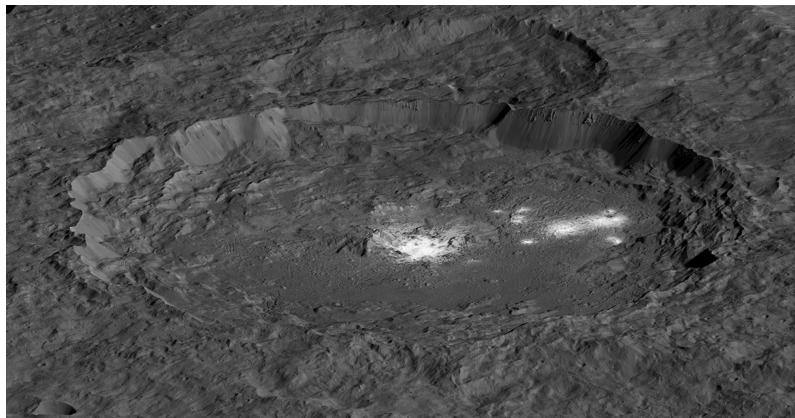
Cerealia and Vinalia Faculae, two bright spots in the Occator Crater

    A. Addition of material during impact cratering

    B. Brine release from the mantle in localized events of cryovolcanism

    C. Uplift of a salt dome

    D. Melt of dispersed ice deposits during solar storms

13. Consider the following plot of climatologically averaged, zonal mean (i.e., averaged east-west) streamfunction ψ of the Hadley cells. The magnitude of ψ is related to the circulation strength, and the northward wind velocity v is related to the vertical gradient $\dfrac{\Delta\psi}{\Delta p}$.
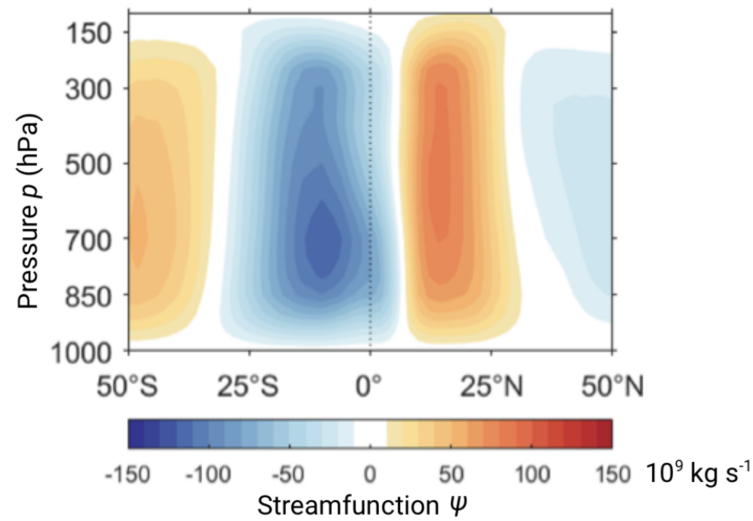
(adapted from Li et al. 2022)

Additionally, idealized models show that both cells have the same poleward mass fluxes when solar heating is centered at the equator. Which of these is/are true about Hadley cell dynamics?

  I) Surface convergence occurs below a region with a positive streamfunction gradient ($\dfrac{\Delta\psi}{\Delta\phi} > 0$ where ϕ is latitude)

 II) At 300 hPa, maxima in westerly winds can be found at latitudes directly above the highest magnitude ψ values in each hemisphere

  A. I only

  B. II only

  C. I and II

  D. None

14. A commonly studied analogue for the effects of modern-day climate change is the Paleocene-Eocene Thermal Maximum, a short time period approximately 55 million years ago in which global temperatures rose by 5-8 °C. One of the proposed causes for this event is large-scale volcanic activity injecting both CO_2 and CH_4 into the atmosphere. After the phase of temporary cooling, which of the following best describes how this injection affected oceanic primary productivity and then dissolved oxygen concentrations, respectively?

  A. Increase; increase

  B. Increase; decrease

  C. Decrease; increase

  D. Decrease; decrease

15. Since the length of a day on Earth is much shorter than the length of a year, the sidereal day on Earth is almost exactly the same as a solar day. However, on other planets, such as Mercury and Venus, the length of the sidereal day is significantly different from the solar day. Which of the following statements is true?

I) Unlike the Earth, the sidereal day on Venus is shorter than its solar day.

II) A planet tidally locked to its parent star will have an infinitely long solar day.

    A. I only

    B. II only

    C. Both I and II

    D. None

16. The following image shows how the velocity of a slow, deep-seated landslide (top, bold lines) depends on sub-surface pore pressure (top, thin line) and rainfall (bottom). Which of the following human-related factors would likely increase the velocity of this landslide?
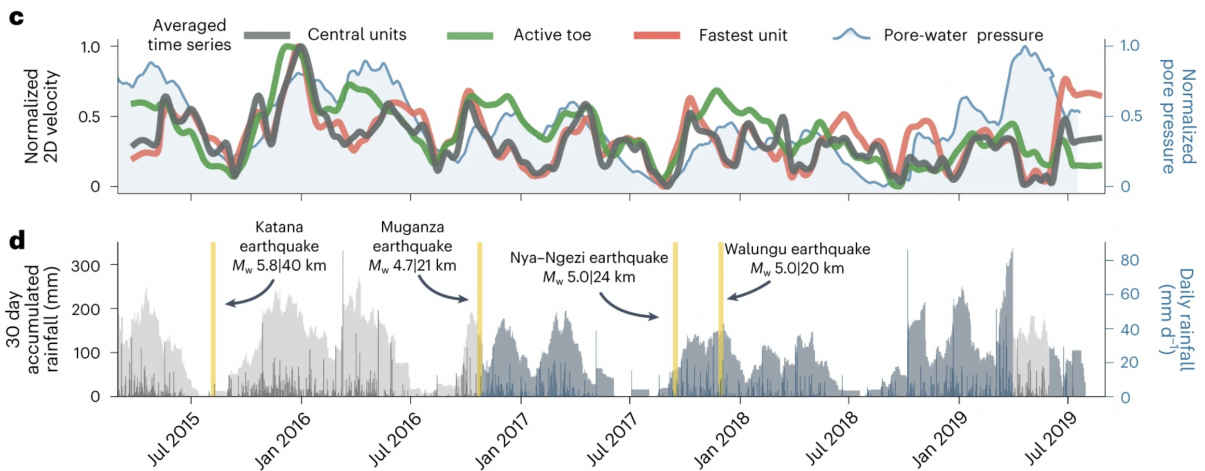

I) Increase in road and building cover

II) Storm drains rerouting runoff via restricted channels

III) Climate change-induced shortening of wet season

    A. II only

    B. III only

    C. I and II

    D. I and III

    E. None

17. A continuously-pumped well reduces pressure around it, creating a cone of depression where water is drawn down. The shape of the cone depends on the transmissivity of the aquifer, defined as the volumetric rate of flow per unit thickness per unit hydraulic gradient. Given the same flow rate, how would the steepness of a cone of depression in an aquifer with lower transmissivity compare to that with a higher transmissivity?

    A. Steeper, since the hydraulic gradient compensates for transmissivity

    B. Shallower, since the hydraulic gradient compensates for transmissivity

    C. Steeper, since lower transmissivity increases the permeability of the aquifer

    D. Shallower, since lower transmissivity decreases the permeability of the aquifer

18. Suppose you are testing different models of Earth's radiative budget, and notice that some models overestimate the global mean surface temperature T_{sfc} compared to observations. Assuming no other errors are made in each case, which of these errors will result in an overestimate of T_{sfc}?

    I) Overestimating the concentration of tropospheric ozone, with an absorption peak within the atmospheric window

    II) Overestimating energy flux from convection and latent heat transfer

    III) Overestimating coverage of cirrus clouds, which are thin and located in the upper troposphere

    A. I only

    B. III only

    C. I and II

    D. I and III

    E. II and III

    F. I, II, and III

19. Below is a phase diagram for calcium carbonate.
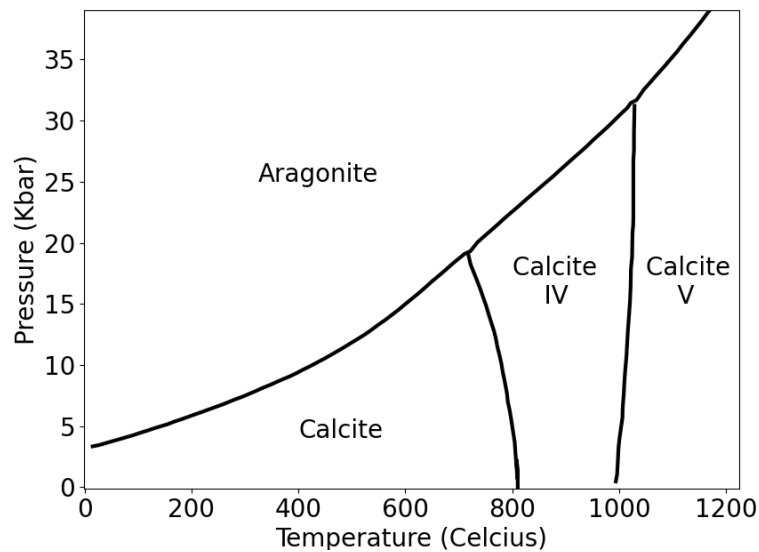
A proposed process for the production of elemental carbon in the earth's crust involves the reaction of $CaCO_3$ with SiO_2 to form $CaSiO_3$ during subduction. Reactions with which of the following polymorphs of $CaCO_3$ would be least energetically favorable per mol carbon produced during subduction? A pressure-temperature diagram for metamorphic facies is provided for reference.
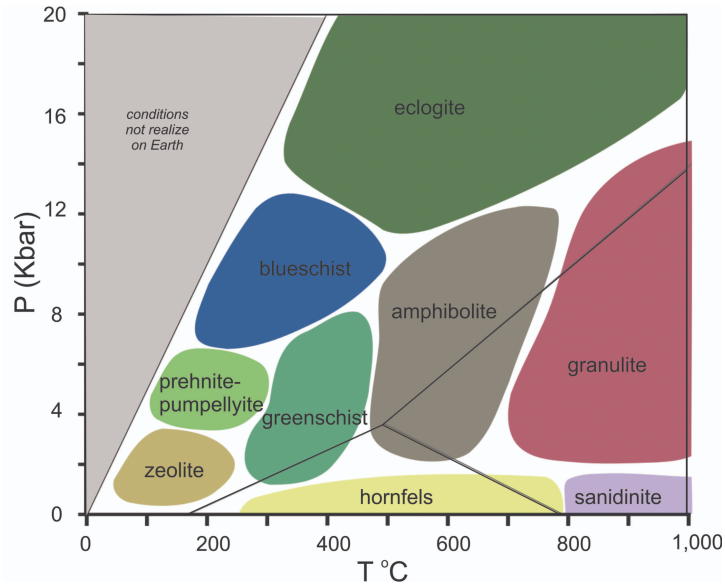
A. $CaCO_{3\,(\text{Calcite})} + SiO_2 \longrightarrow CaSiO_3 + C + O_2$

B. $CaCO_{3\,(\text{CalciteIV})} + SiO_2 \longrightarrow CaSiO_3 + C + O_2$

C. $CaCO_{3\,(\text{CalciteV})} + SiO_2 \longrightarrow CaSiO_3 + C + O_2$

D. $CaCO_{3\,(\text{Aragonite})} + SiO_2 \longrightarrow CaSiO_3 + C + O_2$

20. Now determined to be highly unlikely, near-Earth object 99942 Apophis was once thought to have a small chance of impacting the Earth in the near future. The uncertainty came from the Yarkovsky effect, a mechanism for the propulsion of rotating Solar System bodies through thermal emission (and resulting transfer of momentum). The propulsion relies on solar heating of the surface of a rotating body, shown in the figure below.
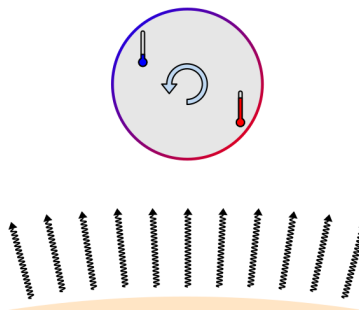
Simplified depiction of the surface heat profile of a rotating body orbiting the sun.

Identify all of the following that are true of the Yarkovsky effect on approximately spherical near-Earth asteroids.

I) The Yarkovsky effect accelerates near-Earth asteroids in prograde rotation in their direction of motion.

II) Larger asteroids experience greater acceleration.

III) Amor asteroids (perihelion greater than 1 AU) are generally more affected than Atria objects (aphelion less than 1 AU).

A. I only

B. II only

C. I and III

D. II and III