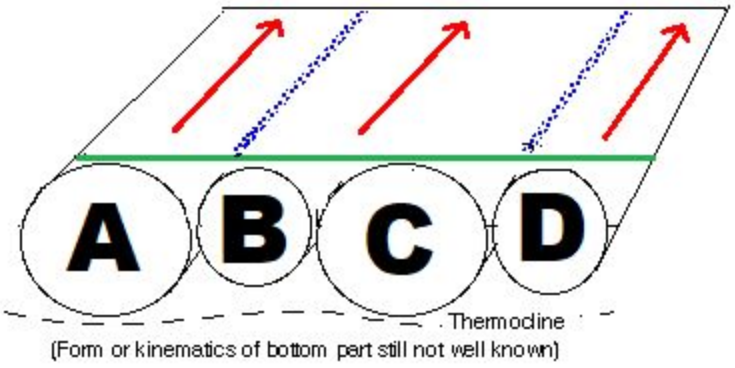
Hydrosphere and Astronomy Exam

Key: (*) = none, one, or more than one answer possible (e.g. Answer: A, D, and E)
In questions with many pictures/text, the part requiring an answer is denoted with an arrow (→) to help differentiate from background information.

Hydrosphere Section

1. Use the diagram below to answer the question that follows.



When wind blows steadily over the sea surface, a circulation pattern consisting of shallow rotating vortices known as Langmuir circulation can form. A simplified diagram of Langmuir circulation is shown, where the green line is the water surface and the red arrows represent wind direction. A cross section of the rotating vortices is shown through the circles labeled A, B, C, and D (the direction of rotation of the vortices is not shown). Langmuir circulation often leads to lines of accumulated plankton, seaweed and other material on the sea surface known as windrows, shown by the blue lines.

→ Given this information, which of the following is/are true? (*)

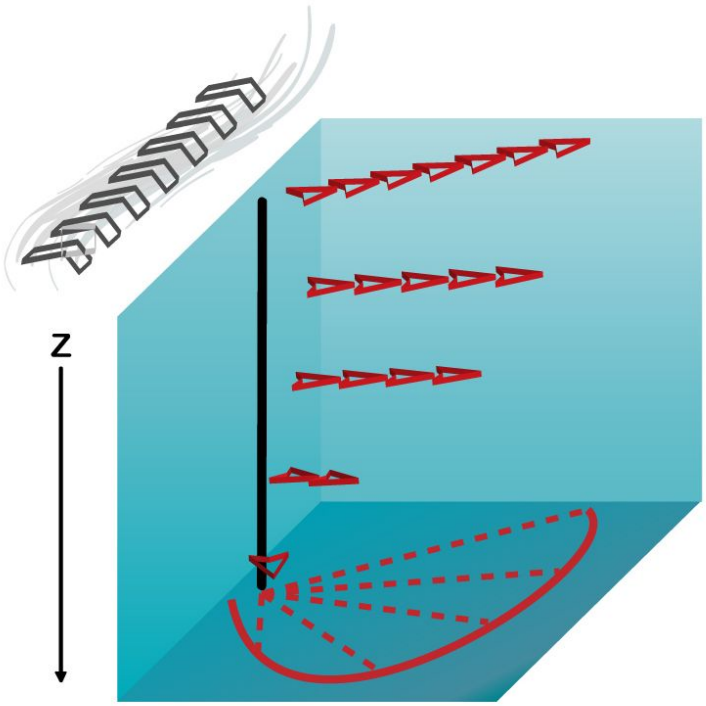
A) Windrows indicate areas of surface divergence
B) The vortices labeled A and B rotate in opposite directions
C) The vortices labeled A and C both rotate clockwise from the point of view of the diagram
D) Water moves downward between the vortices labeled B and C
E) The vortices labeled B and C both rotate clockwise from the point of view of the diagram

2. In most temperate climates, waves carry greater energy in the winter compared to the summer due to frequent storm activity. This increased energy significantly affects the structure of beaches.

   → Which of the following is/are true?(*)

   A) In the winter, sand from the beach will be deposited seaward of the beach face
   B) Most commonly, there is a net loss of sand in the beach system each year due to erosion from waves in winter
   C) In the summer, the beach is generally narrow and steep due to the low energy of the waves
   D) Winter beaches generally consist of particles of larger size than summer beaches.

3. The interaction of a persistent wind, the Coriolis force, and friction often leads to a circulation pattern known as an Ekman spiral, which is shown below:



These currents result in a net movement of water known as Ekman transport. Given this information and your knowledge of ocean circulation, which of the following is/are true? (*)

A) Water tends to move towards the center of ocean gyres, resulting in a "hill" of water at the center of gyres
B) Water tends to move away from the center of ocean gyres, resulting in a "trough" of water at the center of gyres
C) Ekman transport is generally in the same direction as the pressure gradient
D) Most major ocean currents are in a geostrophic balance between the Coriolis force and the pressure gradient
E) Winds do not have any effect on the imbalance of water between the center and edges of ocean gyres

4. Use the diagram below to answer the following question.

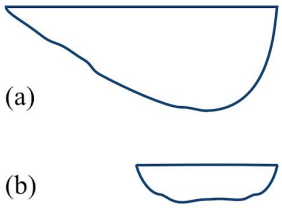


Figure 1. Cross sections from different points along a stream. Note relative sizes.

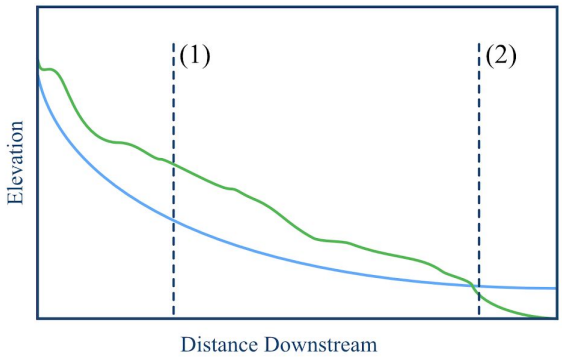
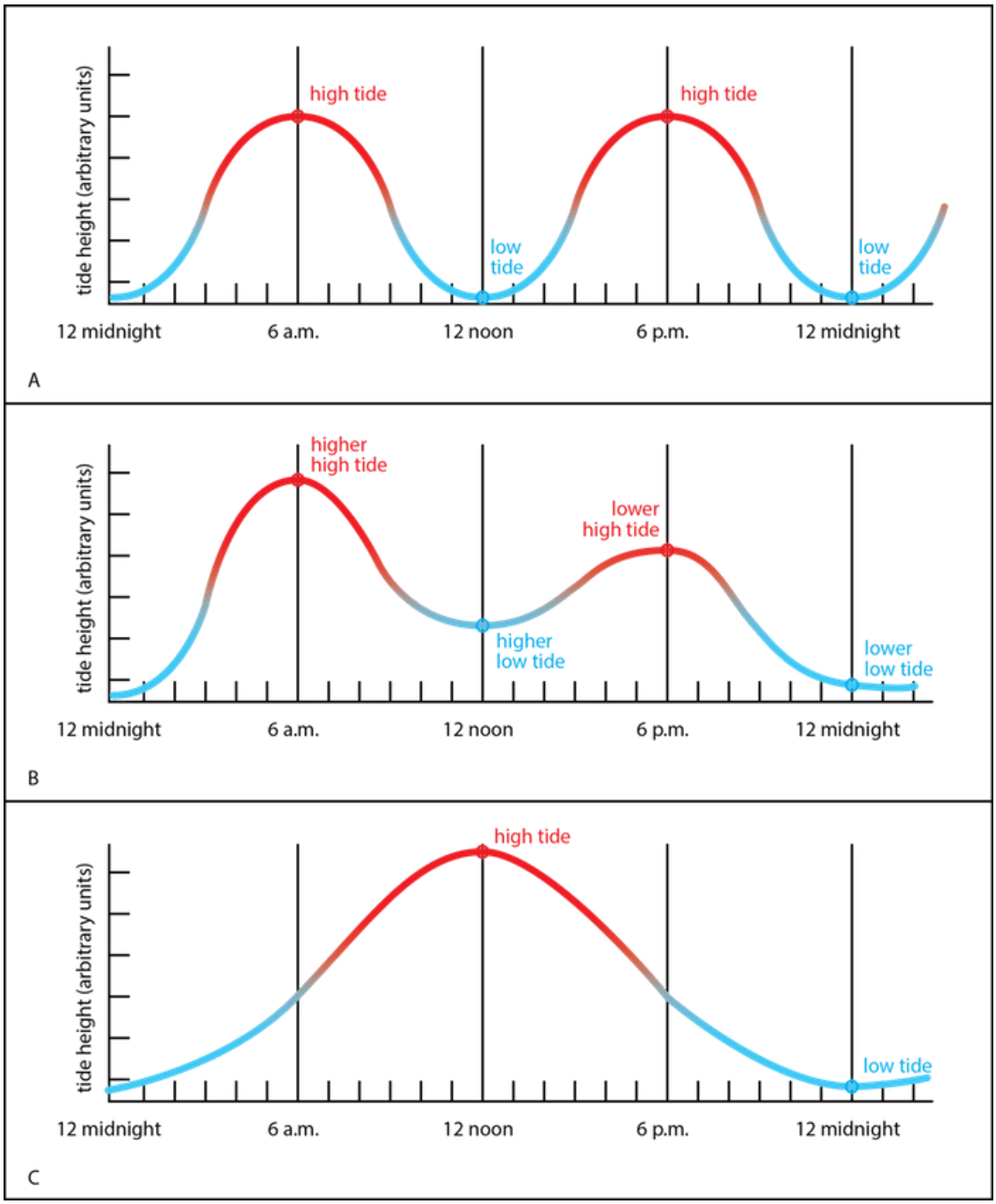


Figure 2. Longitudinal profiles of two streams, one graded and one ungraded. Dashed lines correspond to positions along each.

→ Select all of the following that are likely true regarding the streams shown in the figures. Assume stream parameters other than those mentioned in the answer choices remain constant. (*)

A) Discharge in the *blue stream* increases from position (1) to (2).
B) Discharge in the *green stream* increases from position (1) to (2).
C) Cross section (a) is more likely to be observed than (b) at *position (1).*
D) Cross section (a) is more likely to be observed than (b) at *position (2).*
E) Cross section (a) is more likely to be observed than (b) in the *blue stream.*
F) Cross section (a) is more likely to be observed than (b) in the *green stream*.
G) The blue stream is downcutting at position (1) but at a *greater rate* than the green stream.
H) The blue stream is downcutting at position (1) but at a *lesser rate* than the green stream.
I) Horizontal erosion and deposition at position (2) is dominant in the *blue stream.*
J) Horizontal erosion and deposition at position (2) is dominant in the *green stream.*
K) The blue profile can represent the profile of the green stream after a period of time *with tectonic uplift.*
L) The blue profile can represent the profile of the green stream after a period of time *with a rise in sea level.*
M) The blue profile can represent the profile of the green stream after a period of time *with a drop in sea level.*
N) The blue profile can represent the profile of the green stream after a period of time *without environmental changes.*

5. Use the diagram below to answer the following questions.



Arpit the bathymetry expert lives on a planet that is entirely covered in water with no significant landmasses or topography. The planet rotates about its axis every 24 hours and has one moon that revolves around the planet every 30 days. Each x-axis tick mark on the diagram above represents one hour on the planet.

→ Question 5: Which tidal pattern would one expect under such conditions?

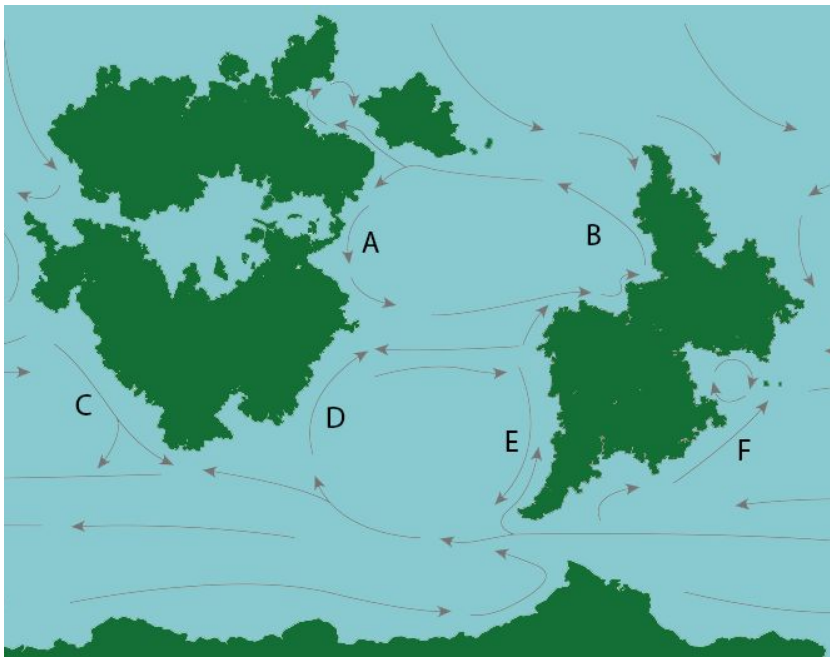
A) Pattern A
B) Pattern B
C) Pattern C

6. Scott, the International Panel on Climate Change member, is presenting on ocean acidification, a serious problem caused primarily by the release of carbon dioxide into the atmosphere from anthropogenic sources.

→ Which of the following correctly characterizes the biological consequences of this process? (*)

A) CO_2 bubbles are directly added to the water, making it harder for deep-sea fish to breathe
B) CO_2 reacts with water to form an acid, making it more difficult for some organisms to form shells
C) CO_2 reacts with water to form bicarbonate ions, which raises the pH of the water and causes sensitive organisms to suffer
D) Increased CO_2 helps some algal species that rely on this gas to perform photosynthesis

7. Use the diagram below to answer the following question.



→ Question 7: Researchers have stumbled upon a newly discovered oceanic planet, Bluzaga. Use your knowledge about ocean currents and the above world map of Bluzaga to determine all of the following statements that are true. You can assume that the top of the map is the North and that the planet has an insignificant degree of axial tilt. (*)

A) The planet is rotating clockwise looking from the planet's North Pole.
B) The planet is rotating counterclockwise looking from the planet's North Pole.
C) There is not enough information to determine the rotational direction of the planet.
D) Current A is a warm current.
E) Current B is a warm current.
F) Current C is a warm current.
G) Current D is a warm current.
H) Current E is a warm current.
I) Current F is a warm current.

8. **REPEAT** ~~Use the diagram below to answer the following question.~~

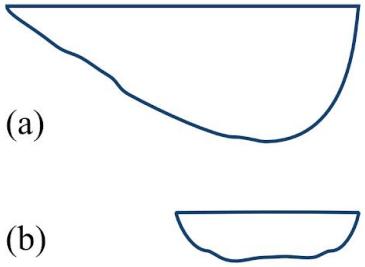


Figure 1. Cross sections from different points along a stream. Note relative sizes.

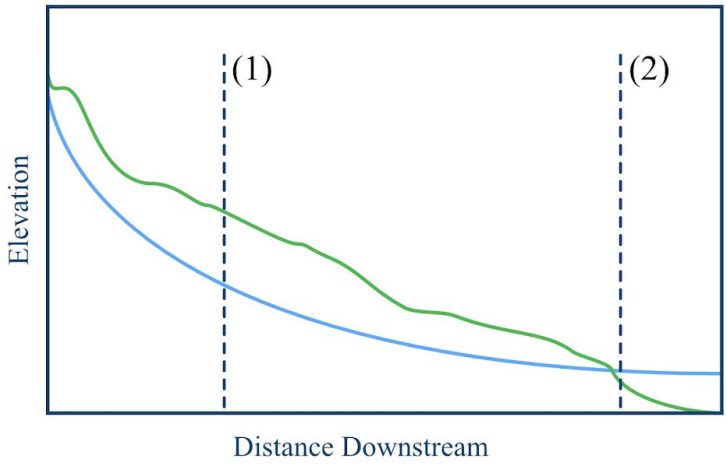


Figure 2. Longitudinal profiles of two streams, one graded and one ungraded. Dashed lines correspond to positions along each.

→ Question 8: Select all of the following that are likely true regarding the streams shown in the figures. Assume stream parameters other than those mentioned in the answer choices remain constant. (*)

A) Discharge in the *blue stream* increases from position (1) to (2).
B) Discharge in the *green stream* increases from position (1) to (2).
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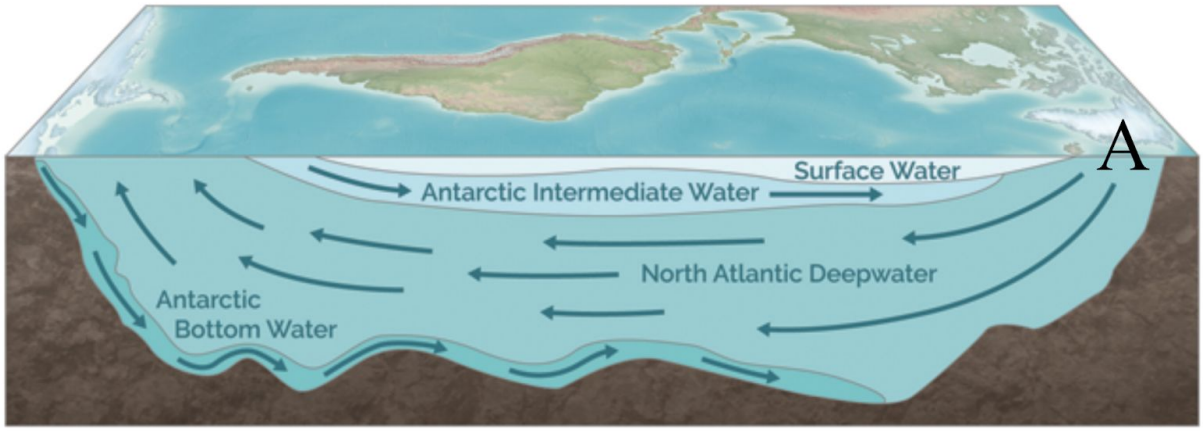
9. Use the diagram below to answer the following question.



Internal waves are oscillations that propagate within a stratified medium where frequency is dependent on density difference. In the ocean, these waves are best expressed at sharp density gradients, and are of much research interest for water mass mixing and interactions with coasts.

→ Select all of the following that are true or describe the probable effects of the given conditions on internal waves. Refer to the figure for the last two answer options. (*)

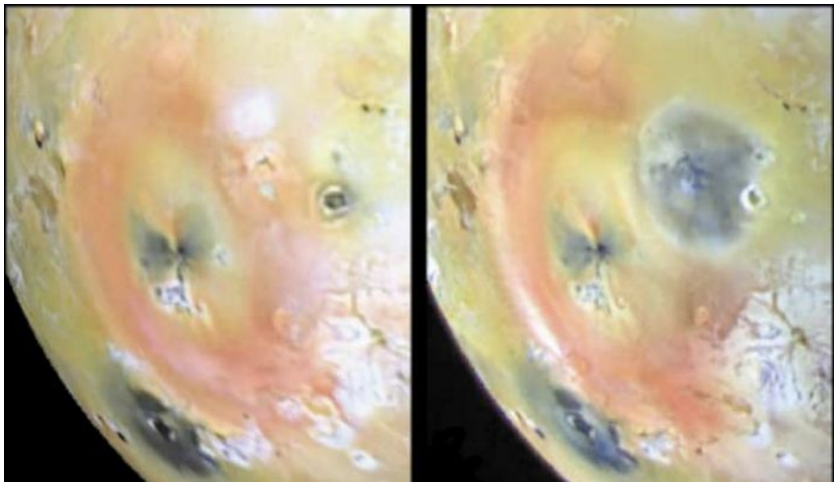
A) Storms generate internal waves with frequencies greater than the frequency of surface waves.
B) Storms generate internal waves with frequencies less than the frequency of surface waves.
C) Internal waves over mid-latitude waters are better expressed during the summer.
D) Internal waves over mid-latitude waters are better expressed during the winter.
E) Propagation along the pycnocline is more pronounced with increasing latitude.
F) Propagation along the pycnocline is more pronounced with decreasing latitude.
G) Reduced sea ice formation at A would lead to greater internal wave formation at the North Atlantic Deep Water/Antarctic Intermediate Water interface.
H) Reduced sea ice formation at A would lead to less internal wave formation at the North Atlantic Deep Water/Antarctic Intermediate Water interface.

Astronomy Section

10. Which of the following best describes the most widely accepted formation process of the solar system?

    A) A gaseous cloud contracted to form a rapidly spinning disk of matter, which later shed successive rings of matter to form the individual planets.
    B) A gaseous cloud contracted and flattened, eventually causing the protoplanetary disk around the young Sun condensed to form the individual planets.
    C) Soon after the Sun formed, a passing star ripped off matter from the Sun, which eventually formed the planets.
    D) Soon after the Sun formed, coronal mass ejections released large amounts of matter that collected to form the planets.

11. Following the discovery of active volcanism on Io by the Voyager spacecraft, the Galilean moon became the subject of volcanology research. The Galileo spacecraft collected invaluable thermal emission data and took detailed images that have been analyzed to further understand Io's surface volcanism and internal structure (McEwen *et al.*).



Question 11, Figure 1. Two of Galileo's visible spectrum images of the active volcano Pele and Pillan Patera, an Ionian caldera. The left image was obtained in April 1997, whereas the image on the right was obtained five months later, notably exhibiting a newly formed pyroclastic deposit produced by the Pillan 1997 summer eruption. The Galileo mission data revealed that the lava temperature at Pillan exceeded 1500 K and the pyroclastic materials were rich in orthopyroxene.

→ Question 11: Which of the following statements regarding Io is true, assuming that Pillan-type eruptions are widespread on the surface of Io? (*)

A) The Galileo mission findings indicate that the lava extruded at Pillan is intermediate in composition.
B) The Galileo mission findings indicate that the lava extruded at Pillan is ultramafic in composition.
C) Based on the inferred magma composition, Io's interior is likely similar to that of the early Earth.
D) Based on the inferred magma composition, Io's interior is likely similar to that of the present Earth.
E) The majority of the energy driving Io's internal processes comes from radioactive decay.
F) Absolute dating of Io's volcanic features can be conducted by studying adjacent impact craters.

12. The freezing point of ammonia (NH_3) is 195.42 K, while the freezing point of methane (CH_4) is 90.7 K. The mean surface temperature of Jupiter (1 bar level) is 165 K, while Neptune's surface temperature is 72 K. The temperatures of the atmospheres of Uranus and Neptune increase with depth.

→ Given this information and your knowledge of the solar system, which of the following is/are true? (*)

A) Saturn has more gaseous ammonia in its atmosphere than Uranus
B) In the troposphere of Uranus, ammonia clouds will be found higher in the atmosphere than methane clouds
C) Of the Jovian planets, Jupiter has the lowest amount of gaseous ammonia in its atmosphere
D) When sunlight reflected from Neptune is studied spectroscopically, very little ammonia is present
E) Methane clouds are not present on Jupiter

13. The planets of Jupiter, Saturn, and Neptune have been found to radiate significantly more heat into space than they absorb from the Sun.

    → Which of the following could explain or contribute to this imbalance?

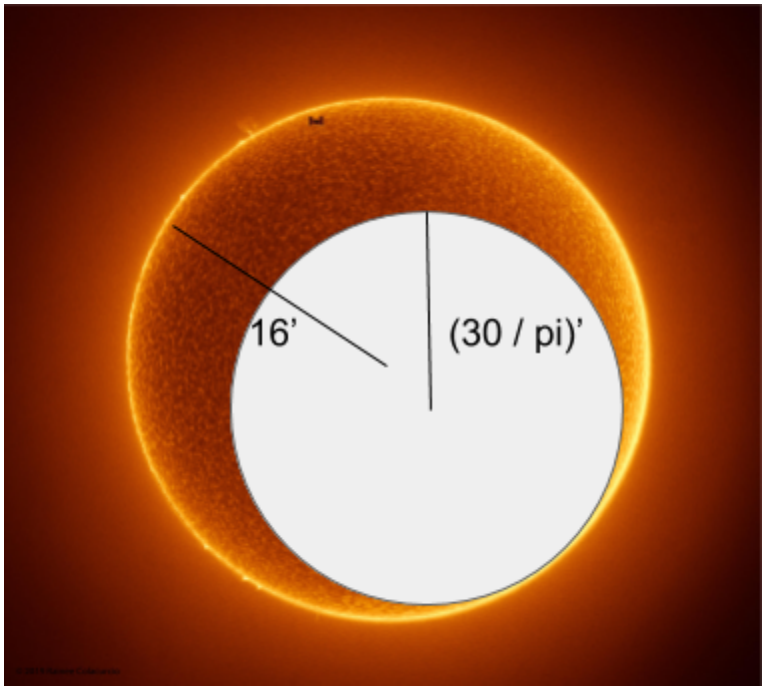
    A) These planets have been expanding since the formation of the Solar System, releasing potential energy.
    B) Heavier elements fall towards the center of the planets, releasing potential energy.
    C) The planets are far enough from the sun that the amount of energy they absorb from the Sun is less than the amount radiated through blackbody radiation.
    D) Lighter elements rise towards the surfaces of the planets, absorbing potential energy.
    E) The planets have been contracting since the formation of the Solar System, releasing potential energy.

14. Ben the comet enthusiast is studying a new comet called Comet USESO-2020. When the comet makes its closest approach to the Sun (i.e. perihelion), it is 16 AU from the Sun. The comet has a sidereal period (i.e. orbital period with respect to background stars) of 512 Earth years. The eccentricity of an orbit is defined as $\frac{aphelion - perihelion}{aphelion + perihelion}$.

    → To two significant figures, estimate the eccentricity of the comet, and state the comet's most likely origin.

    A) 0.16, spherical Oort cloud region outside the Solar system
    B) 0.16, flat Kuiper belt region at the edge of the Solar system
    C) 0.40, spherical Oort cloud region outside the Solar system
    D) 0.40, flat Kuiper belt region at the edge of the Solar system
    E) 0.60, spherical Oort cloud region outside the Solar system
    F) 0.60, flat Kuiper belt region at the edge of the Solar system
    G) 0.80, spherical Oort cloud region outside the Solar system
    H) 0.80, flat Kuiper belt region at the edge of the Solar system

15. Use the diagram below to answer the following question.



An astronomer is watching the ISS transit the sun when suddenly, a mysterious new planet (gray circle) comes into view. The astronomer makes some measurements, and realizes that the planet is 3.6 * 10^8 meters away.

→ Estimate the diameter of the planet.

A) 10^4 meters
B) 10^5 meters
C) 10^6 meters
D) 10^7 meters
E) 10^8 meters
F) 10^9 meters

16. Carbonaceous chondrites are a rare type of meteorite that are notable for containing water and organic compounds such as carboxylic acids and glycine. Given this information, one can hypothesize that these kinds of meteorites were formed:

    A) Compared to other meteorites, relatively close to the Sun
    B) Compared to other meteorites, an average distance from the Sun
    C) Compared to other meteorites, relatively far from the Sun
    D) Not enough information to make a reasonable hypothesis

17. If the moon were to orbit the Earth in retrograde direction (i.e. clockwise viewed from above), which of the following statements would be true? (*)

    A) After a new moon, the left half of the moon would be lit up first in the Northern hemisphere
    B) After a new moon, the right half of the moon would be lit up first in the Northern hemisphere
    C) After a new moon, the left half of the moon would be lit up first in the Southern hemisphere
    D) After a new moon, the right half of the moon would be lit up first in the Southern hemisphere
    E) After a full moon, the left half of the moon would darken first in the Northern hemisphere
    F) After a full moon, the right half of the moon would darken first in the Northern hemisphere
    G) After a full moon, the left half of the moon would darken first in the Southern hemisphere
    H) After a full moon, the right half of the moon would darken first in the Southern hemisphere

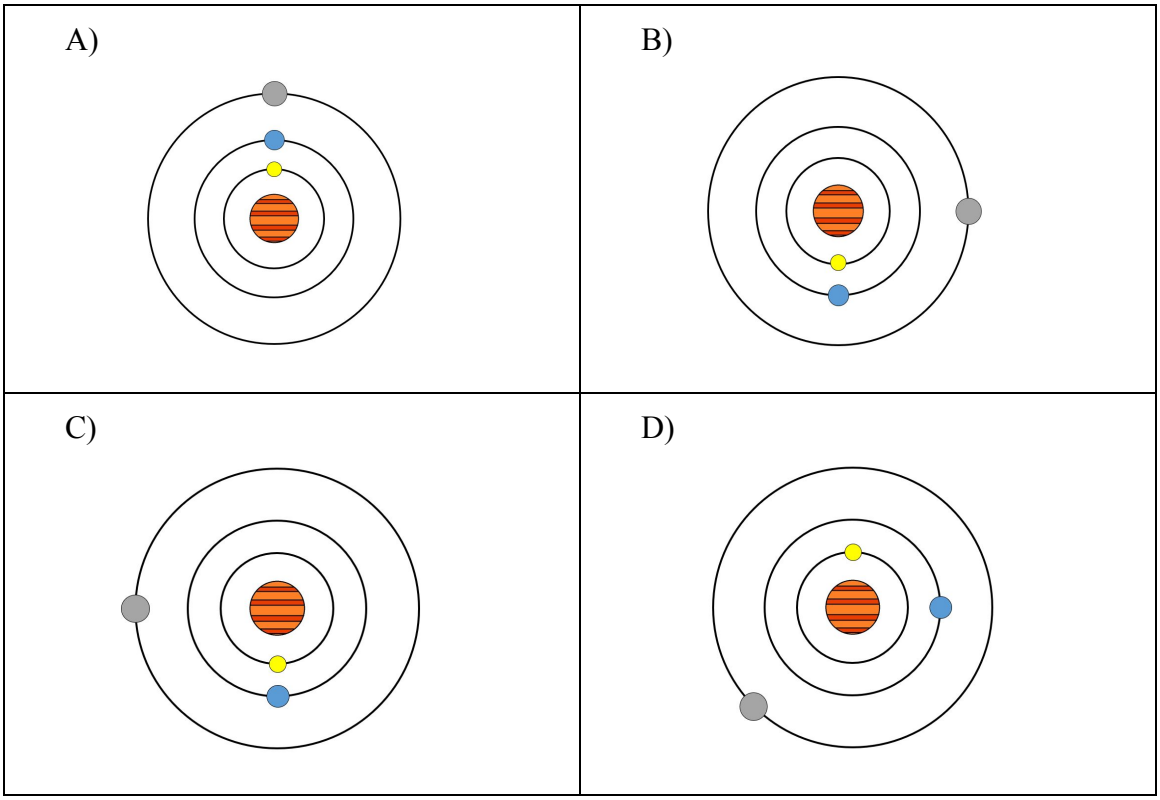
18. You travel to a parallel universe and there you find an Earth, but you realize, through your astronomical wisdom, that the planet experiences retrograde motion, the eccentricity of the planet's orbit is decreasing from 0.01 to 0.002, its axial tilt is increasing from 20.5° to 29°, and it incredibly does not have any axial precession. Assuming all other things equal, what can one predict will happen to the global climate on this Earth?

    A) The climate will have milder seasons
    B) The climate will have more extreme seasons
    C) The climate will have an overall warming trend
    D) The climate will have an overall cooling trend

19. 4 Vesta is a large asteroid suspected to have once been in hydrostatic equilibrium but has since been altered by major impact events. Select all of the following that could support Vesta's hypothesized past hydrostatic equilibrium. (*)

    A) The unimpacted portions of Vesta fit an oblate spheroidal shape.
    B) The average radius of Vesta is less than the potato-to-sphere transition radius of about 300 km.
    C) Vesta's rotational period is significantly shorter than it was in the past.
    D) Many eucrites, a basaltic achondrite, originate from the surface of Vesta as a result of the above mentioned impacts.
    E) Stony meteorites from Vesta show evidence of thermoremanent magnetization, or magnetization that occurs when a substance cools below its Curie temperature.
    F) Long-lived radionuclides continue to decay within Vesta's interior.

20. Three of Jupiter's moons, Io, Europa, and Ganymede, are in a Laplace resonance of 1:2:4. Which of the following is NOT a possible configuration of their three moons (Io in yellow, Europa in blue, Ganymede in grey)

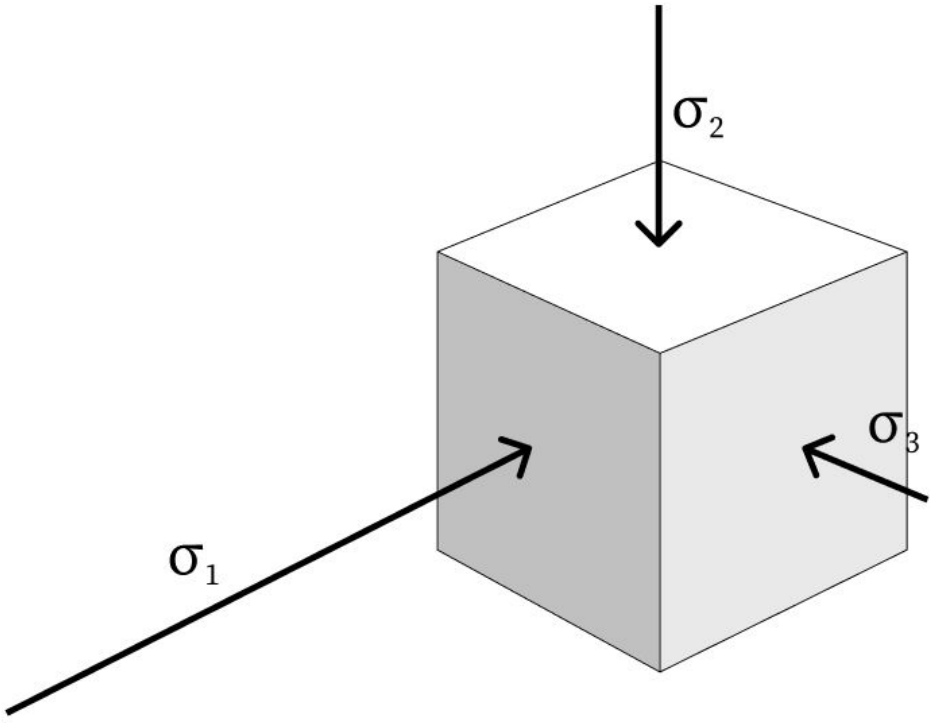


21. Consider a perfectly spherical, despinning (i.e. spinning is slowing down), cooling planetary body with a lid tectonics regime (a single tectonic plate for the entire planet). This model is useful in predicting tectonic environments in lid tectonics bodies like Mars and the Earth's moon.

    → Identify all of the following that are likely **true** regarding this model (*):

    A) Crustal extension occurs in equatorial regions
    B) Crustal compression occurs in equatorial regions
    C) Crustal extension occurs in polar regions
    D) Crustal compression occurs in polar regions
    E) There is expected to be little to no strike-slip faulting

22. Furthermore, Andersonian fault theory can be applied to this model. Andersonian fault theory classifies faults based on the identity of σ_v, or the vertical stress vector. This vertical stress vector may be equal to either of the three principal stress vectors, denoted σ_1, σ_2, and σ_3, where σ_1 is the maximum compressive stress, σ_3 is the minimum compressive stress, and σ_2 is the intermediate compressive stress. The figure below shows an example of principal stresses on a cube.



→ Question 22: Using Andersonian fault theory and considering the context from the previous model for lid tectonics, identify all of the following that are likely **true** (*):

A) $\sigma_v = \sigma_1$ for normal faults
B) $\sigma_v = \sigma_3$ **f**or normal faults
C) $\sigma_v = \sigma_1$ for strike-slip faults
D) $\sigma_v = \sigma_3$ for strike-slip faults
E) $\sigma_v = \sigma_1$ for reverse faults
F) $\sigma_v = \sigma_3$ for reverse faults

23. The polar ice caps of Mars host a variety of interesting features, including swiss cheese terrain, spider structures, and perhaps most captivating of all, the polar layered deposits (PLD). The PLD are sequences of alternating dark (dust-rich, ice-poor) and light (dust-poor, ice-rich) layers that can be found within both the North and South ice caps of Mars (**Figure 1**).

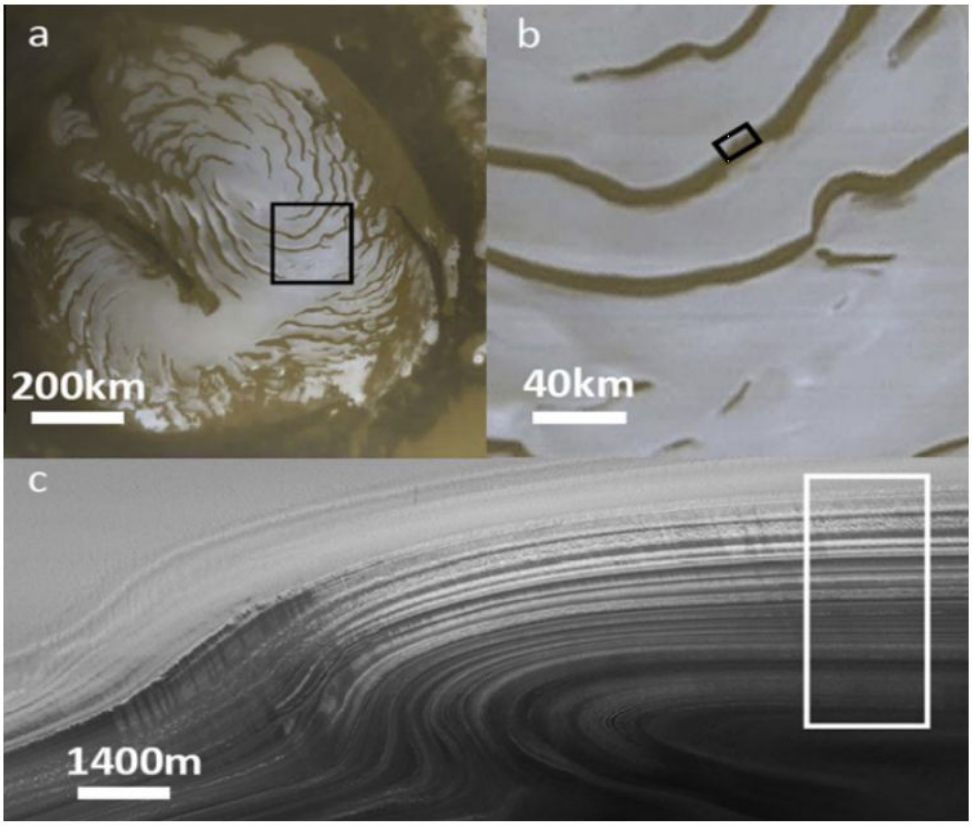


Figure 1 [courtesy to Hvidberg *et al.* 2012]**:** The PLD of the North Polar Cap at varying scales. (a) shows the entire North Polar Cap, (b) shows a trough in which PLD is exposed, while (c) shows a close view of alternating dark and light bands of the PLD.

Though a definite model for the deposition of the PLD as a result of climate forcing has yet to be confirmed, we will consider a model proposed by Hvidberg *et al*. that defines the dust and ice deposition fluxes as functions of the solar insolation. Ice deposition may be complicated due to atmospheric circulation, so to simplify the model, the annual deposition of ice can be assumed to be constant, while only the sublimation rate of ice may vary. The rate of net dust accumulation is always positive and can be approximated to be proportional to the atmospheric meridional (i.e. north-south) temperature gradient.

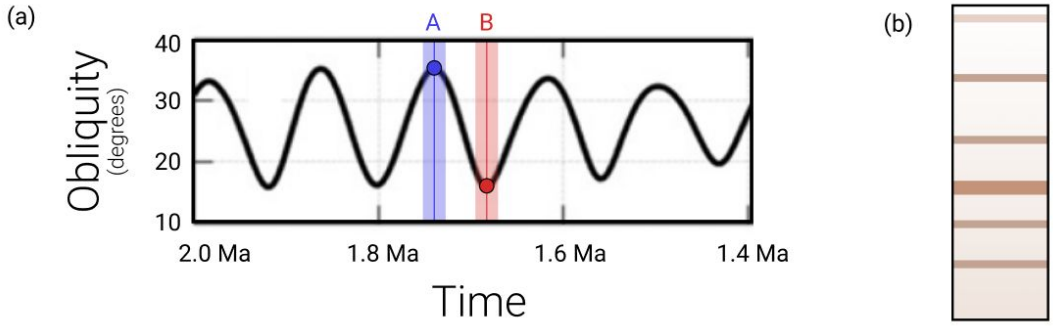


Figure 2 (a): The obliquity of Mars as a function of time. Notice positions **A** and **B**, which will be referenced in the question. Time periods **A** and **B** refer to the colored bands around times **A** and **B**. (b): A model ice core of the PLD.

→ Question 23: Using **Figure 2** and the provided model for ice and dust deposition, identify all of the following statements that are likely **true**: (*)

A) At position A, the rate of net dust accumulation is at a local minimum
B) At position A, the rate of net dust accumulation is at a local maximum
C) At position A, the rate of net dust accumulation is neither at a local minimum or maximum because obliquity is not the main forcing factor of dust accumulation
D) At position A, ice loss from sublimation is at a local minimum
E) At position A, ice loss from sublimation is at a local maximum
F) At position A, ice loss from sublimation is neither at a local minimum or maximum because obliquity is not the main forcing factor of ice loss
G) The layer deposited during time period A (the blue band) will be thicker than the layer deposited during time period B (the red band)
H) The layer deposited during time period B (the red band) will be thicker than the layer deposited during time period A (the blue band)
I) Layers deposited during time period B and time period A will be equal in thickness
J) There is not enough information to make conclusions regarding relative thicknesses of layers deposited during time periods A and B