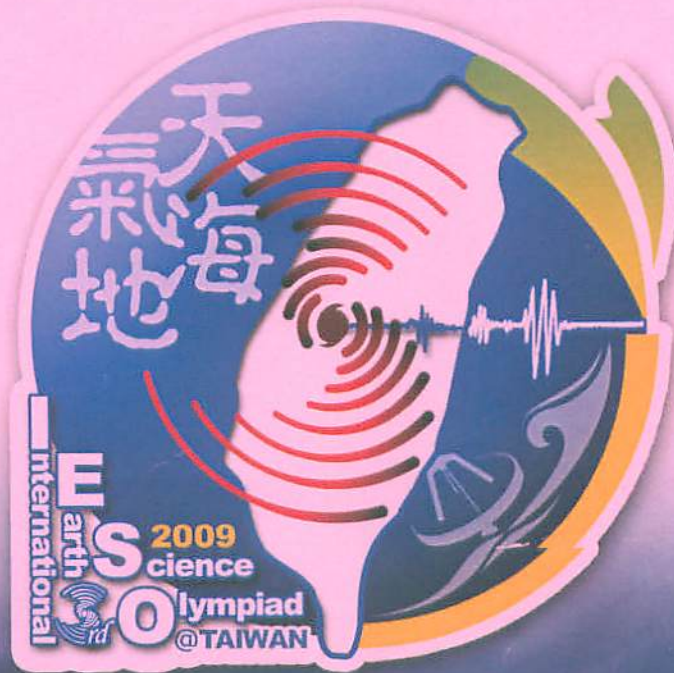


The 3rd International Earth Science Olympiad



Written Test

16 September 2009

Taipei, Taiwan

Student Name:

Nationality:

Mentor's Signature: _____



希言自然，故飄風不終朝，驟雨不終日。孰爲此者？天地。

To seldom speak is the essence of nature. Why the winds and storm do not last whole day?
Because the earth that manifests the winds and storm are constantly changing.

《老子道德經》第廿三章

Laozi Tao Te Chin 4th Century BC

南方有倚人焉曰黃繚，問天地所以不墜不陷，風雨雷霆之故。惠施不辭而應，不慮而對，遍爲萬物說。

In the south, there was a man of extraordinary views, named Huang Liao, who asked Shi how it was that the sky did not fall nor the earth sink, and what was the cause of wind, rain, and the thunder's roll and crash. Shi made no attempt to evade the questions, and answered him without any exercise of thought, talking about all things.

《莊子雜篇》天下第三十三

Zhuangzi Tian Xia 4th Century BC.



Instructions:

1. Please write your name and nationality in English on the cover page.
2. The time allocated for this examination is three hours.
3. Please write your answers legibly. Illegible answers will be counted as incorrect.
4. Please keep your answers short and focus on the key points.
5. Please write your answers only on the white test booklet provided.
6. You may respond to questions either in English, your native language, or a combination of both.
7. Read the entire question group carefully before starting to answer. Each question has a point value assigned, for example, (1 pt).
8. For some questions, you will be asked to provide your answers on the figures. Please do so carefully.
9. Any inappropriate examination behavior will result in your withdrawal from the IESO.

Formulae for references:

$m - M = -5 + 5 \cdot \log(d)$; 1 parsec (pc) = 3.26 ly;

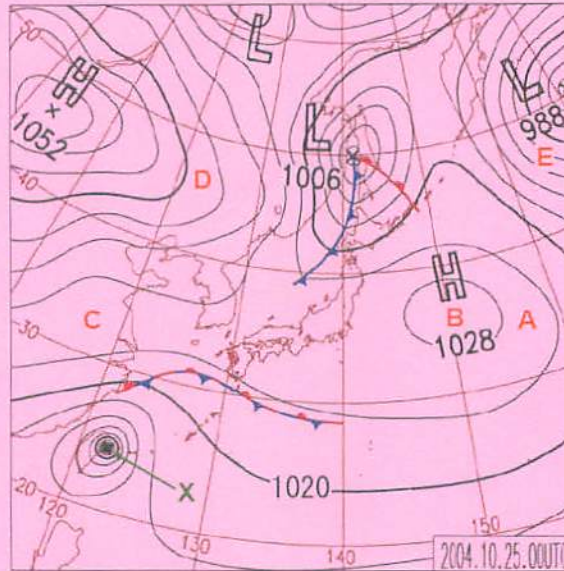
where m is apparent magnitude, M is absolute magnitude and d is distance measured in pc.

Stefan-Boltzmann Law $E = \sigma T^4$,

where σ is the Stefan-Boltzmann constant and T is temperature in K.

Atmosphere and Hydrosphere (total of 35 pts)

1. The figure below is the surface weather map for the region of western North Pacific at 00 UTC (Coordinated Universal Time, same as the Greenwich Mean Time), 25 October 2004. Please answer the following questions:



- (i) The contour lines on the map are produced by analyzing which of the following meteorological variables? (1 pt)

(A) Altitude
(B) **Pressure**
(C) Temperature
(D) Humidity
(E) Wind speed

Answer: _____

- (ii) The weather system labeled as "X" (in green color) in the above figure should be which of the following? (1 pt)

(A) An extra-tropical cyclone
(B) A continental anticyclone
(C) **A tropical cyclone**
(D) A migratory anticyclone
(E) A front

Answer: _____

- (iii) The wind direction at point "A" should be close to which of the following? (1 pt)

(A) Easterly wind
(B) Southerly wind
(C) Westerly wind
(D) **Northerly wind**
(E) The wind is calm at point A

Answer: _____

- (iv) Among the five locations labeled from "A" to "E" in the map, which should have the strongest wind of all? Please write down the letter of that location. (1 pt)

Answer: **(E)**

2. Which of the following gases in the atmosphere has the largest variations in spatial and daily-time scales and has strong impact on local weather? (1 pt)

- (A) CO₂ (B) CO **(C) H₂O** (D) O₃ (E) He

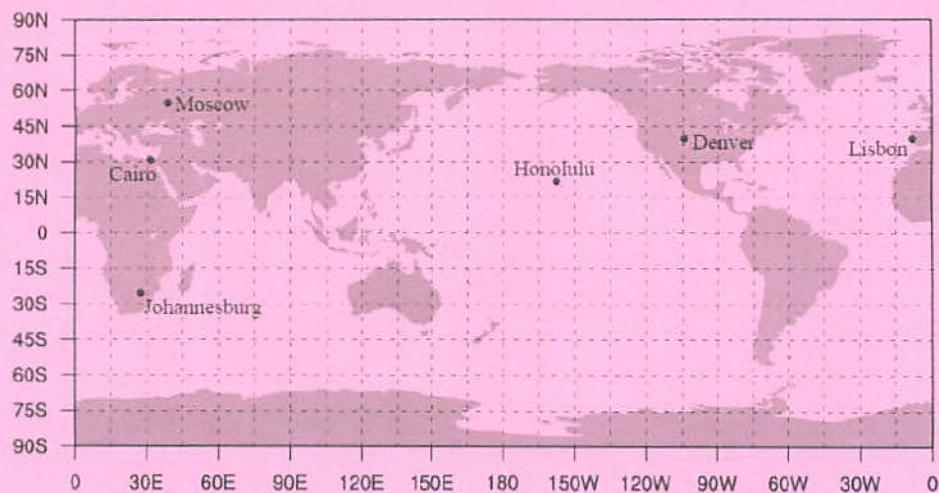
Answer: _____

3. What is the most likely reason why typhoons are rarely observed over the ocean near the Equator? (1 pt)

- (A) Sea surface temperature is too high (B) Pressure gradient is too weak
(C) Coriolis force is too small (D) Convection is not strong enough
(E) Wind is too weak

Answer: _____

4. Regarding the mean value and the range of annual temperature cycle, please answer all the true/false questions below. For your information, a world map is provided below and the locations of the cities mentioned in the questions are also marked.



(i) The annual temperature range in the northern hemisphere, as a whole, is larger than that in the southern hemisphere. True or false (T/F)? (1 pt)

Answer: **T**

(ii) The annual mean temperature at Moscow (56°N, 38°E) is lower than that at Cairo (30°N, 31°E). True or false (T/F)? (1 pt)

Answer: **T**

(iii) The annual temperature range at Denver (40°N, 105°W) is smaller than that at Lisbon (39°N, 9°W). True or false (T/F)? (1 pt)

Answer: **F**

(iv) The average temperature in July at Honolulu (21°N, 158°W) is slightly lower than that at Johannesburg (26°S, 28°E). True or false (T/F)? (1 pt)

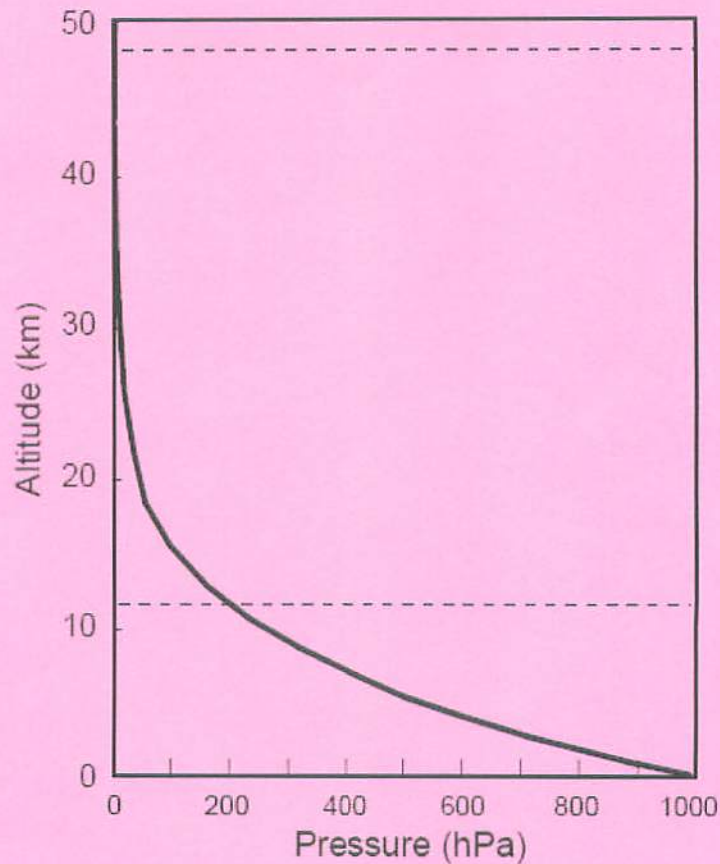
Answer: **F**

5. Which time of a day in the lower troposphere has the highest possibility for clear air turbulence to occur? (1 pt)

- (A) Morning (B) Noon **(C) Afternoon** (D) Evening (E) Midnight

Answer: _____

6. The figure below shows the globally-averaged vertical profile of atmospheric pressure from the sea level to 50 km in altitude. Please answer the questions below:



(i) The term “pressure” on the horizontal axis is equivalent to which of the following? (1 pt)

- (A) Force divided by area** (B) Mass divided by area
(C) Density multiplied by temperature (D) Mass multiplied by distance
(E) Weight divided by volume

Answer: _____

(ii) Which of the following pressure layer has the greatest altitude difference (i.e., thickness)? (1 pt)

- (A) 1-10 hPa** (B) 101-110 hPa (C) 501-510 hPa
(D) 510-1010 hPa (E) 1001-1010 hPa

Answer: _____

(iii) In the static atmosphere, the change in pressure with height is governed by the hydrostatic equation, expressed as $\Delta p = \rho g \Delta z$, where g is the gravitational acceleration in m/s^2 ($g = 9.81 \text{ m/s}^2$), ρ is air density in kg/m^3 , and Δp and Δz are pressure difference in Pa and thickness in meter at two fixed altitudes. If the averaged air density from the 1000 hPa to 500 hPa (where 1 hPa = 100 Pa) is about 0.910 kg/m^3 , please apply this equation to find the height of the 500-hPa pressure level. Please show your calculation. (2 pts)

Answer:

Correct Answer:

From the figure on the right, $\Delta p \approx 1000 \text{ hPa} - 500 \text{ hPa} = 50000 \text{ Pa}$, thus from the equation:

$$\Delta z = \Delta p / (\rho g) = 50000 \text{ Pa} / (0.91 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2) = 5600.923 \text{ m} \approx 5601 \text{ m}.$$

7. If the temperature for the air released from a bicycle tire hole is T_1 and the temperature of air around this bicycle is T_2 , which temperature is lower? (1 pt)

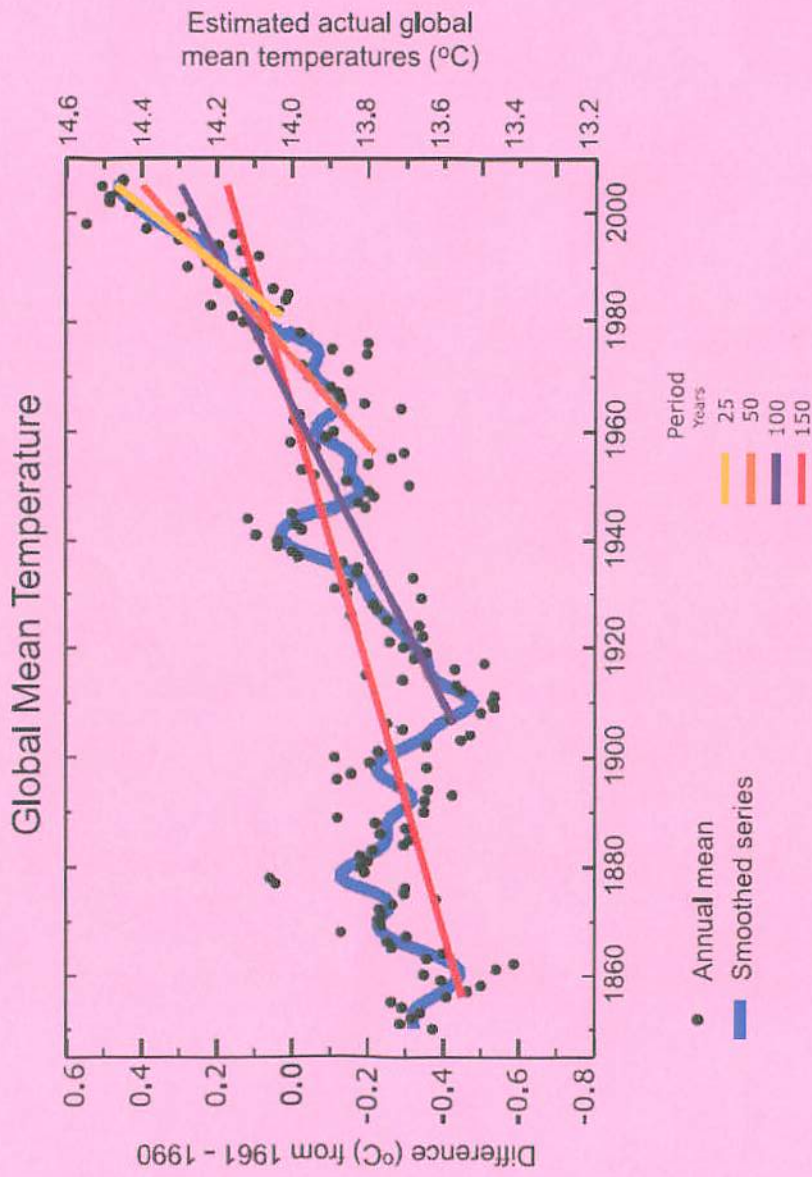
Answer: T_1

8. If lots of dust is blown into the atmosphere during a volcano eruption, how will it change the atmospheric temperature in the local area surrounding the volcano due to the dust effect? (1 pt)

(A) Increase **(B) Decrease** (C) Remain the same (D) Not certain

Answer:

9. The figure below depicts the time variation of annual global mean surface temperatures (black dots) from 1850 to 2005. The long term variation of global average surface temperature includes decadal variation (smooth blue curve) and linear trends (straight lines). The right hand axis shows estimated actual temperature. The left hand axis shows temperature anomalies relative to 1961-1990 average. Please answer the following questions.



(Source: IPCC AR4, 2007)

- (i) Linear warming trends (°C/year) in global average surface temperature for the last 25, 50, 100 and 150 years are shown as yellow, orange, purple and red lines, respectively.
- Which period has the greatest linear warming trend? (1 pt)
- (A) the last 25 years
(B) the last 50 years
(C) the last 100 years
(D) the last 150 years

Answer: _____

- (ii) Please calculate the linear warming trend ($^{\circ}\text{C}/\text{year}$) in global average surface temperature for the last 50 years (1956-2005), the last 100 years (1906-2005) and their ratio (the last 50 years /the last 100 years). (2 pts)

Answer:

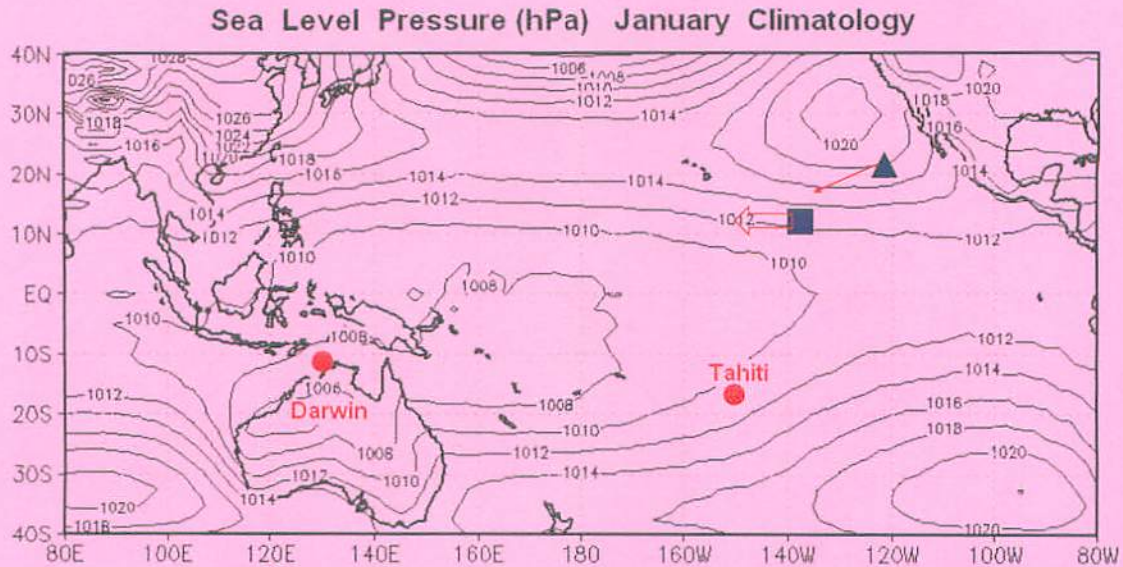
Solution: [intermediate]

50 years trend : $(14.4-13.8)/50 = 0.6 \text{ }^{\circ}\text{C} /50 \text{ years} = 1.2 \text{ }^{\circ}\text{C} /100 \text{ years} = 0.012 \text{ }^{\circ}\text{C} /\text{year}$

100 years trend : $(14.3-12.6)/100 = 0.7 \text{ }^{\circ}\text{C} /100 \text{ years} = 0.007 \text{ }^{\circ}\text{C} /\text{year}$

The ratio is $1.2/0.7 = 1.7$.

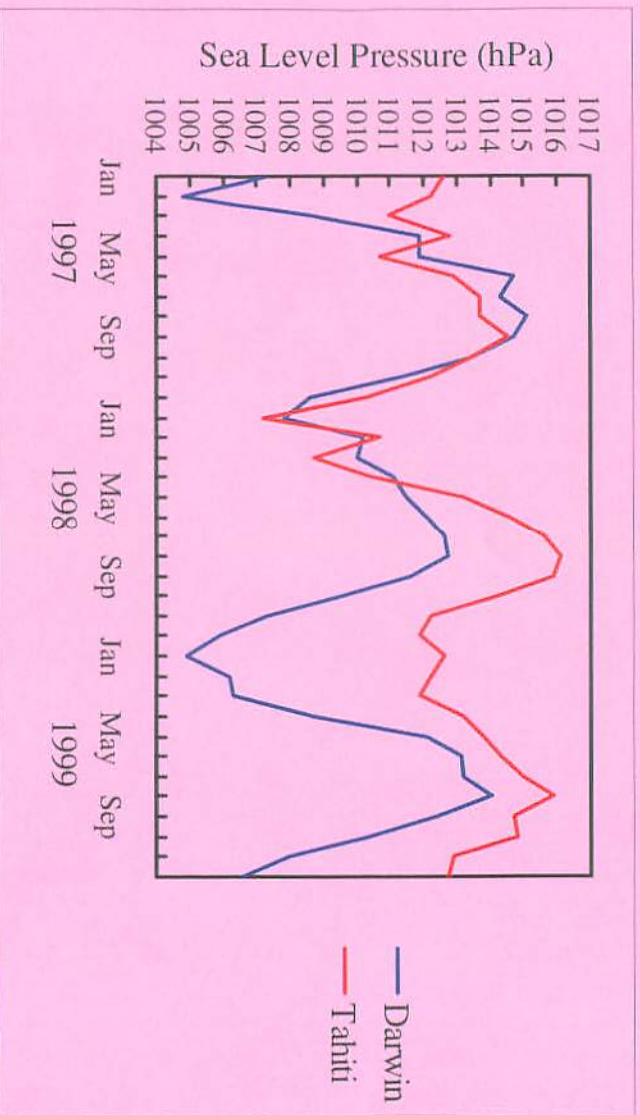
10. The figure below shows the distribution of sea level pressure in January averaged for 40 years (climatology) over the tropical Pacific. Surface wind, ocean currents and sea surface temperature (SST) are closely related in the tropical Pacific Ocean. Please answer the following questions. (Refer to the following figure for questions 10(i), 10(ii), and 10(iii))



(i) Please plot the direction of trade wind at point labeled as “▲” and equatorial current at point labeled as “■” in the above figure.

(Please use the symbol “ → ” for trade winds, and the symbol “ ⇨ ” for equatorial currents) (2 pts)

- (ii) Trade winds are related to the surface pressure gradient. Figure below displays the time series of sea-level pressure at Darwin (12°S, 131°E) and Tahiti (17°S, 149°W). Please write down the surface pressure gradient and the speed of the trade wind between Tahiti and Darwin in January 1998, 1999 and C (climatology) in descending order (example: 1998 > 1999 > C). (2 pts)



Answer: Surface pressure gradient : 1999 > C > 1998

Trade winds : 1999 > C > 1998

- (iii) In January of which year, 1998 or 1999, is the SST over the eastern equatorial Pacific Ocean warmer? (1 pt)

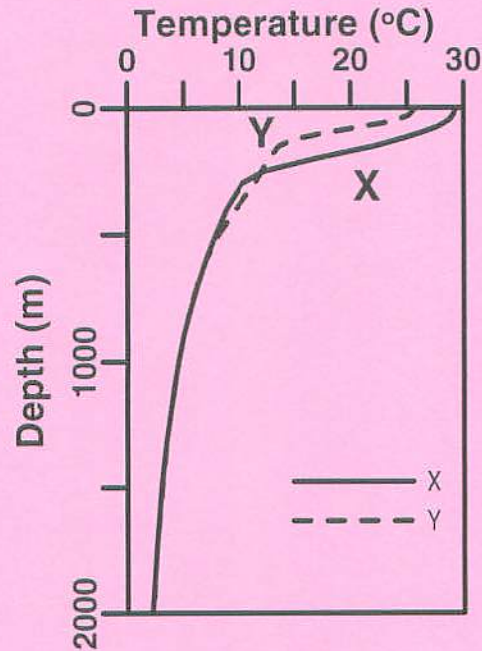
Answer: 1998

11. The following figure shows the long-term average temperature profiles from the surface down to the depth of 2,000 m compiled at two stations – Station A in the western equatorial Pacific Ocean at 140°E and Station B in the eastern equatorial Pacific Ocean at 120°W. Which of the following statements is true? (2 pts)

(A) Profiles compiled at Station A and B can be presented by X and Y respectively.

(B) Profiles compiled at Station A and B can be presented by Y and X respectively

Answer: _____



12. A strong ocean current flows northwards in the Northern Hemisphere as shown in the figure below. Which one of the arrows is correct? (1 pts)

(A) A

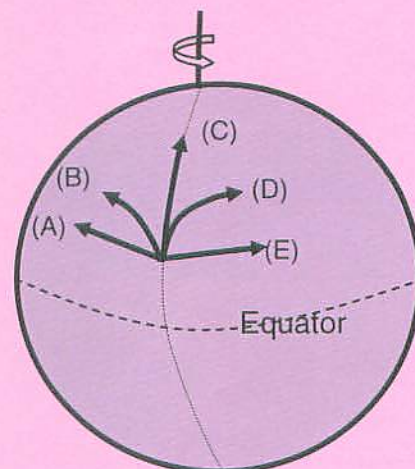
(B) B

(C) C

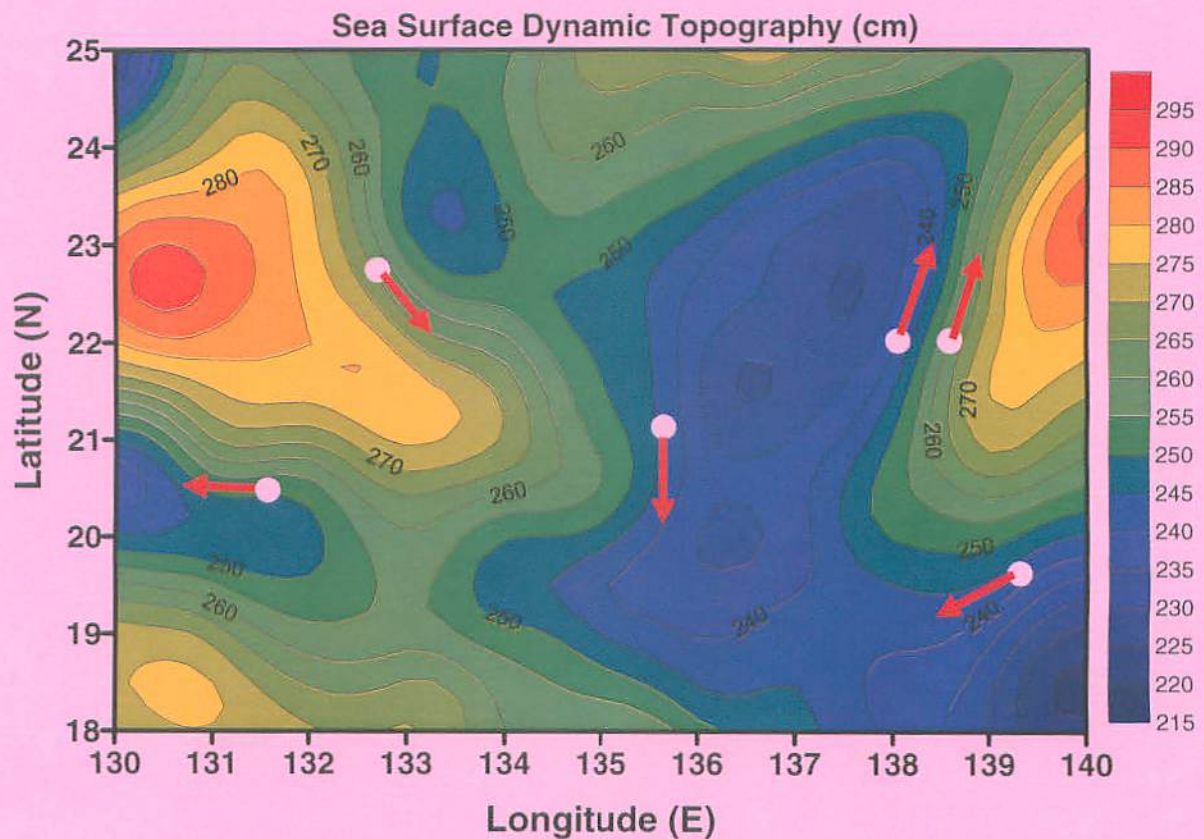
(D) D

(E) E

Answer: _____



13. Mesoscale eddies in the ocean can be detected by satellite altimeters. The color figure below shows contours of the sea surface dynamic topography at an area in the western North Pacific Ocean. The contour interval is 5 cm. Generally speaking, the surface flow field of these eddies can be depicted based on geostrophic equilibrium. Please draw arrows (\rightarrow) to indicate the directions of surface currents at the six white dots in the figure below. (3 pts)



14. It is known that the salinity of the Mediterranean seawater is always higher than that of the Atlantic Ocean.

- (i) The relation among evaporation (E), precipitation (P) and river runoff (R) for the Mediterranean can be expressed by (2 pts)

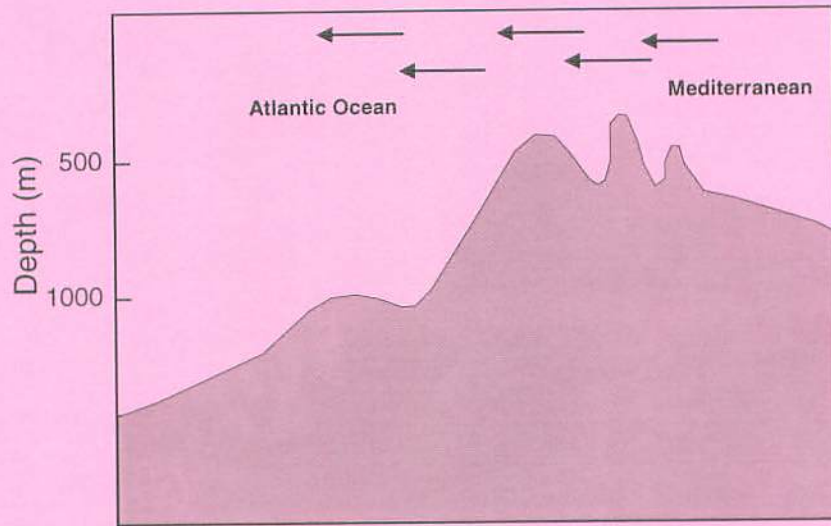
(A) $E > P + R$ (B) $E < P + R$ (C) $P > E + R$ (D) $R > E + P$

Answer: _____

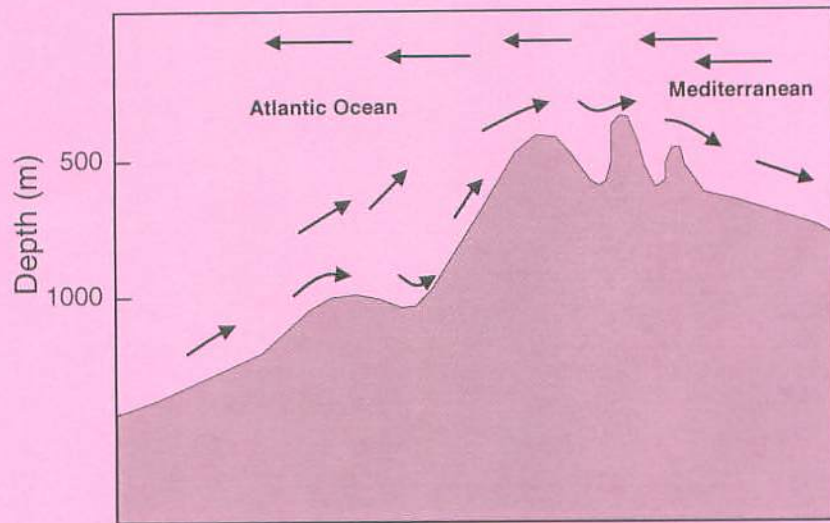
- (ii) Which of the following flow patterns between the Mediterranean Sea and the Atlantic Ocean is correct? (2 pts)

Answer: D

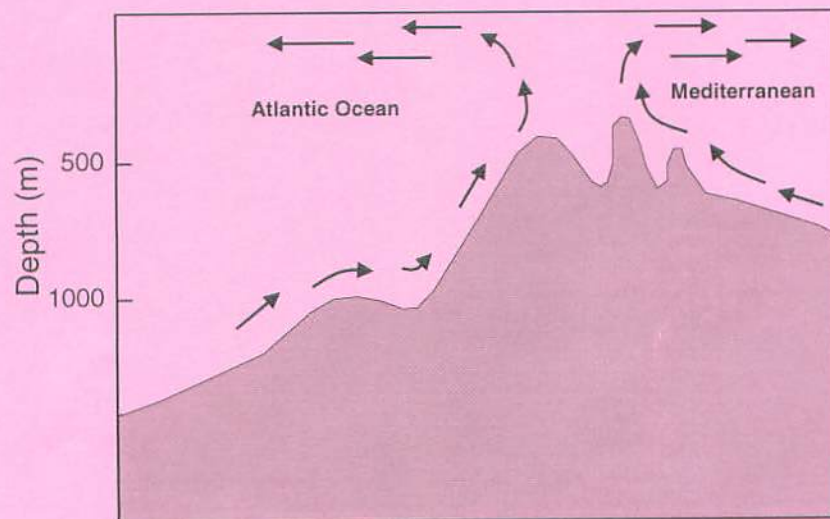
(A)



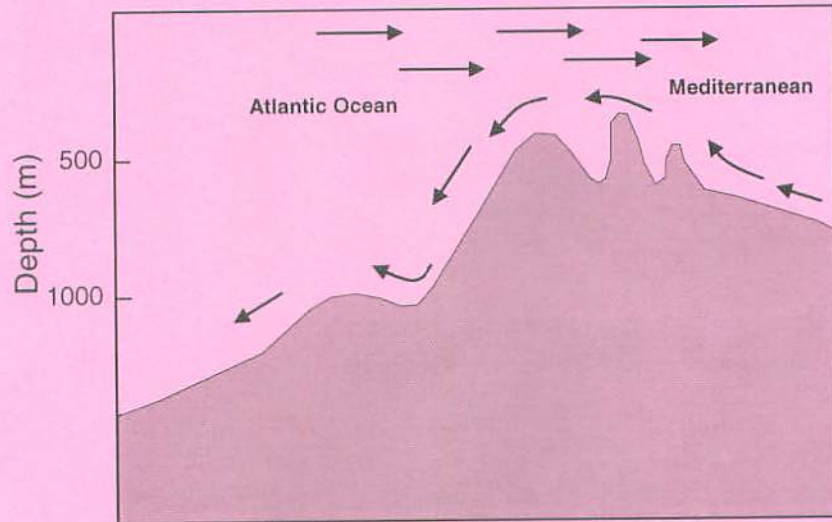
(B)



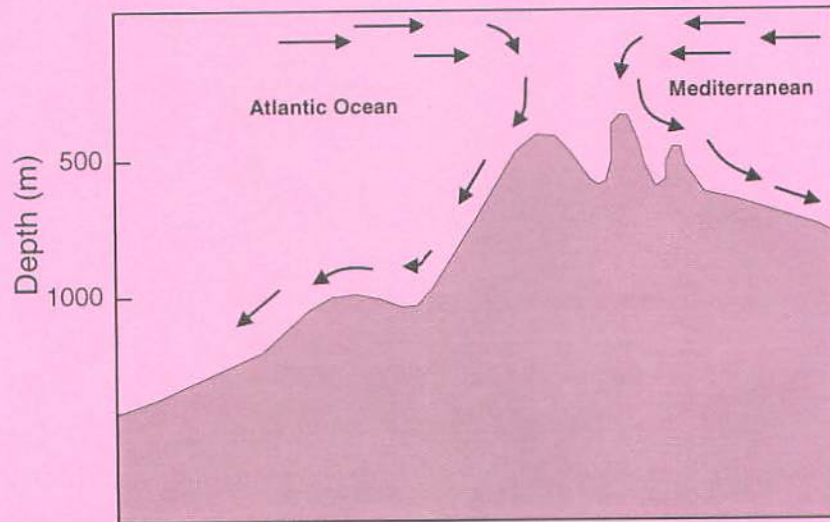
(C)



(D)

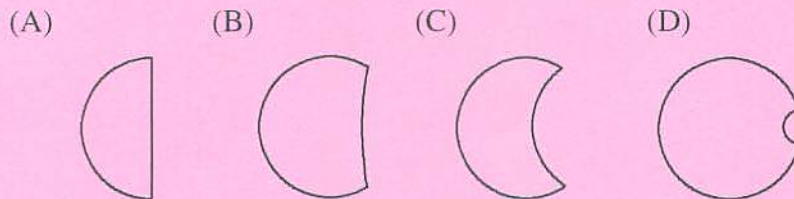


(E)



Astronomy (total of 20 pts)

15. The diameter of the Moon is about a quarter of that of the Earth, and the diameter of the Sun is about 100 times of that of the Earth. The distance from the Earth to the Sun is about 400 times of the distance from the Earth to the Moon. At each astronomical event, which of the following bright shapes will be observed? Choose one suitable item from A to D.



(i) solar eclipse (0.5 pt)

Answer: **C**

(ii) lunar eclipse (0.5 pt)

Answer: **B**

(iii) In the future, people will be able to watch a solar eclipse on the surface of the moon. Which of A to D patterns would the shape of the Sun be observed on the moon? (0.5 pt)

Answer: **B**

(iv) Under the condition of (iii), what phenomenon is seen then from the Earth? (0.5 pt)

(A) Solar eclipse (B) Lunar eclipse (C) Earth eclipse

Answer: **B**

16. At the present time, the energy of the Sun is generated by thermonuclear fusion reactions in the central core. The thermonuclear processes convert four nuclei "X" into a heavier nucleus and also produce energy. What is the nucleus "X"? (1 pt)

(A) Hydrogen (B) Helium (C) Oxygen (D) Carbon (E) Uranium

Answer: _____

17. If the temperature inside the umbra of a sunspot is 1500 K cooler than the solar photosphere (its temperature ~ 5800 K) outside the sunspot, let B1 be the energy flux out of the umbra and B2 be the energy flux from the area surrounding the sunspot. What will be the ratio, B2/B1? (1 pt)

(A) 0.004 (B) 1.35 (C) 0.74 **(D) 3.31** (E) 223

Answer: _____

18. Circle the leap year(s) in the following list. (0.5 pt)

1890 **1972** 1998 **2000** 2002 2100

19. There are four celestial objects shown in the following pictures. Arrange the size of objects from the smallest to the largest. Fill your answer in A, B, C and D. (1 pt)

(D) < (C) < (A) < (B)

(A) Pleiades Star Cluster



(B) Andromeda Galaxy



(C) Sun



(D) Saturn



20. Continued from the preceding question, arrange the objects according to their distances from the Earth in the ascending order. Fill your answer in A, B, C and D. (1 pt)

(C) < (D) < (A) < (B)

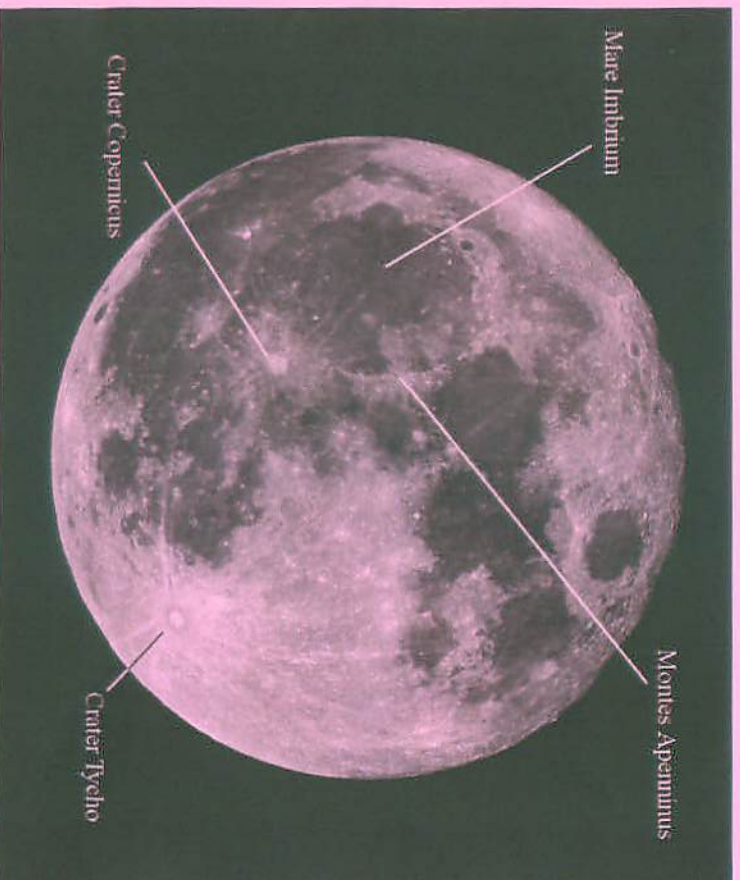
21. If we observe the planets through a telescope on the Earth, which planets' images will appear to be similar to the lunar phase, $\text{)}\text{)}\text{)}$. Circle the planets. (1 pt)

Mercury **Venus** Mars Jupiter Saturn Uranus Neptune

22. The celestial coordinates of Vega are R.A. $18^{\text{h}} 36^{\text{m}} 56.2^{\text{s}}$ and Dec $+38^{\circ} 47' 1''$. Assume the Sun passes the meridian at noon (12:00:00), on which date will Vega transit the meridian at midnight (00:00:00)? Note that the vernal and autumnal equinoxes in 2009 are March 20 and September 23, respectively. (2 pts) (Show calculation with your answer)

Answer: July 4

23. The following photo shows the lunar surface of the side facing the Earth. Four surface features are marked and they are Mare Imbrium, Crater Tycho, Crater Copernicus and Montes Apenninus. Apply the cross-cutting principle to estimate the ages of these surface features. Determine the relative age of these features from old to young. (1.5 pts)



The moon

- (A) Crater Copernicus > Mare Imbrium > Montes Apenninus > Crater Tycho
(B) Crater Tycho > Crater Copernicus > Mare Imbrium > Montes Apenninus
(C) Mare Imbrium > Montes Apenninus > Crater Copernicus > Crater Tycho
(D) Montes Apenninus > Crater Copernicus > Mare Imbrium > Crater Tycho
(E) **Montes Apenninus > Mare Imbrium > Crater Copernicus > Crater Tycho**

Answer: _____






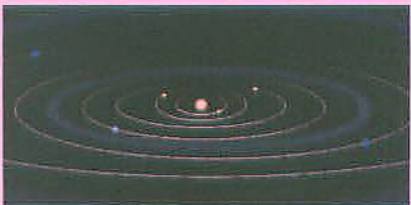
24. Any object as large as a star will collapse under its own weight unless some other force stops it. The Sun has maintained its appearance for a long time. Under what condition is the interior of the Sun in balance? (1 pt)
- (A) The interaction of the atoms prevents the gravitational collapse.
(B) The repulsive forces between ions prevent the gravitational collapse.
(C) The strong forces in nuclei prevent the gravitational collapse.
(D) **The thermal pressure prevents the gravitational collapse.**
(E) The magnetic field prevents the gravitational collapse.

Answer: _____

25. The synodic period for outer planets can be determined by the time interval between two successive oppositions. Based on observations, the synodic period of the Mars is about 779.9 days. The Earth's revolution period is 365.2564 days. What is the revolution period of the Mars in days ? (2 pts) (Show calculation with your answer)

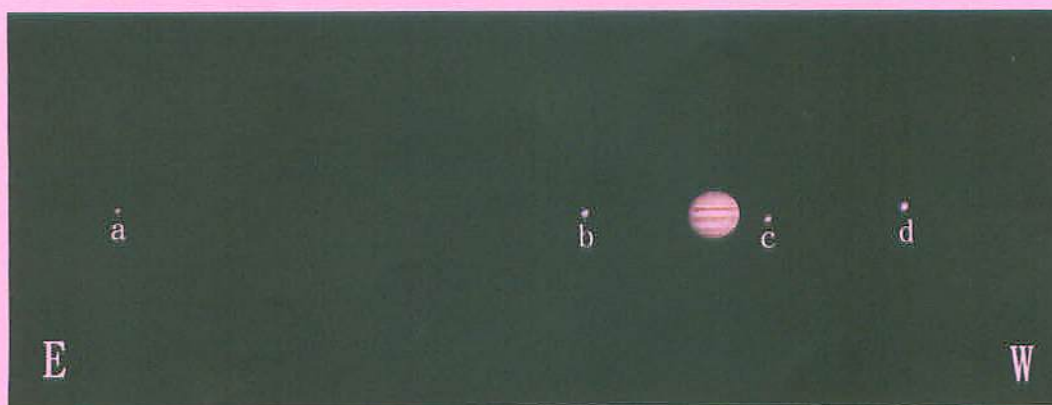
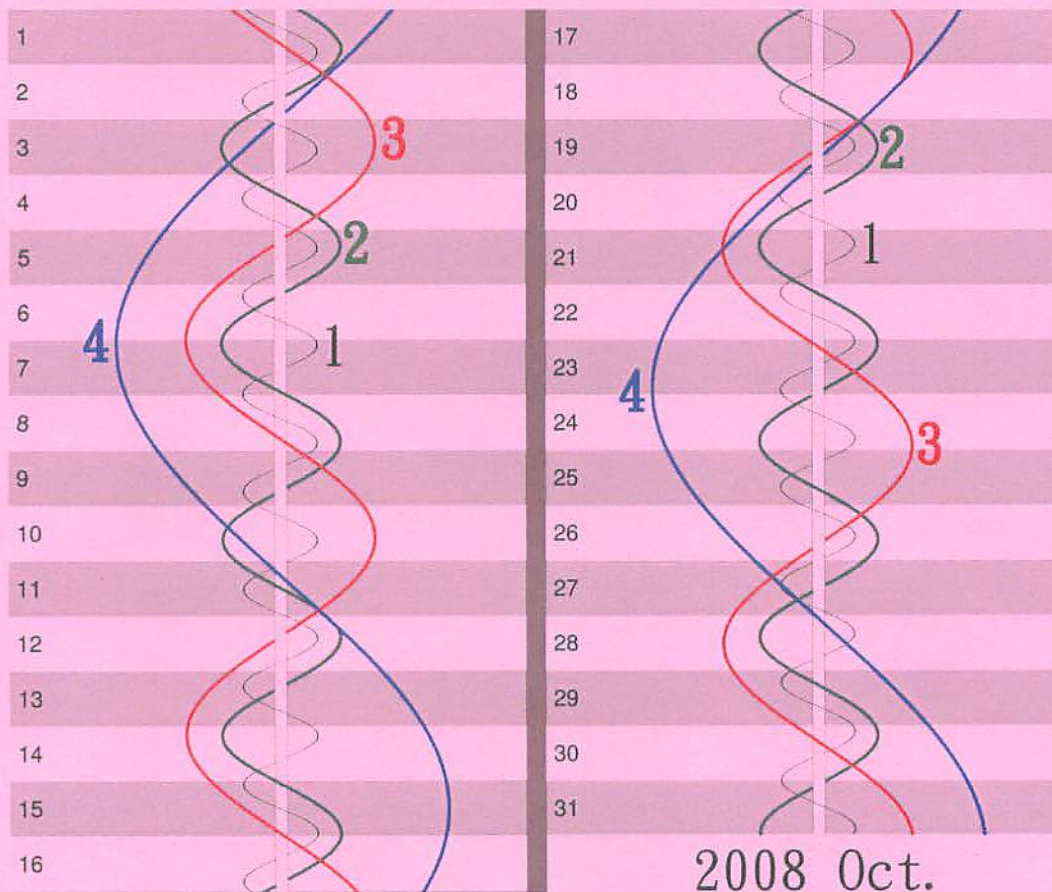
687 days

26. Nowadays, astronomers believe that the solar system formed from a cloud of interstellar gas and dust about 4.6 billion years ago. The pictures below show the representative stages in the phases of the formation. Arrange the order of the pictures to demonstrate the formation process. (2 pts)

 <p>Figure (a). The Sun became hotter and drifted the gas from the inner region, leaving heavier debris revolving in orbits.</p>	 <p>Figure (d). The protosun has begun to shine, with a flattened disk of gas and dust surrounding it.</p>
 <p>Figure (b). The planets have been accreting in their orbits.</p>	 <p>Figure (e). The protosun formed at the center and the cloud rotated faster.</p>
 <p>Figure (c). A cold, slowly rotating cloud began to contract under its own gravity.</p>	 <p>Figure (f). The planets were formed and orbit the Sun.</p>

Answer: (c) → (e) → (d) → (a) → (b) → (f)

27. The following diagram gives the predicted positions of the four moons relative to Jupiter. The number 1, 2, 3 and 4 indicate the tracks of Io, Europa, Ganymede and Callisto respectively. The width defined by the two lines marks the visual disk of Jupiter. The E and W give the east and the west as view from the Earth. The ordinate marks the date. Now, we have a photo of Jupiter and its moons taken in 2008 October but the date is unknown. Use the predicted diagram to allocate the four moons and to estimate the date for photography.



Answer: The photo was taken at the night of 2008 Oct. (23) (1 pt)

The satellites are a: (Callisto) ; b: (Io) ; c: (Europa) ; d: (Ganymede) (1 pt)

28. The apparent magnitude of a star is a measure of how bright the star appears to be. This depends on its luminosity and distance. On the other hand, the absolute magnitude of a star is the brightness defined that if the star were 10 parsecs (pc) from the Earth, which is independent of the star's actual distance. The table presents apparent magnitude and distance of four stars. Calculate their absolute visual magnitude (give the answers in two decimal places, e.g. the format XX.XX) and answer the following questions.

(i) Use the data in the table to find out which star is actually the brightest? (0.5 pt)

Answer: Star D

(ii) Among these stars, which star has a luminosity about 100 times brighter than the Sun? (0.5 pt)

Answer: Star A

(iii)

Star	apparent visual magnitude	distance(pc)	absolute visual magnitude
A	2.1	29.75	-0.27
B	0.5	42.94	-2.66
C	0.8	19.94	-0.70
D	-0.7	95.09	-5.59
Sun	-26.7	—	4.83

(Each answer in the table is 0.25 pt)

Geosphere (total of 45 pts)

29. We have four mineral specimens. All four are Mohs' scale standard minerals, both topaz and apatite are absent. Hardness tests show that: (1) only one out of the four is harder than topaz, and (2) only one is softer than apatite. Furthermore, the above two are both isometric crystals. Among the four specimens, the one softer than apatite is _____. (1 pt)

- (A) calcite (B) gypsum (C) fluorite (D) quartz (E) talc

Answer: _____

30. What is the major greenhouse gas trapped in the frozen soils of the tundra and continental shelf sediments? (1 pt)

- (A) methane (B) carbon dioxide (C) water vapor (D) ethane (E) nitrogen

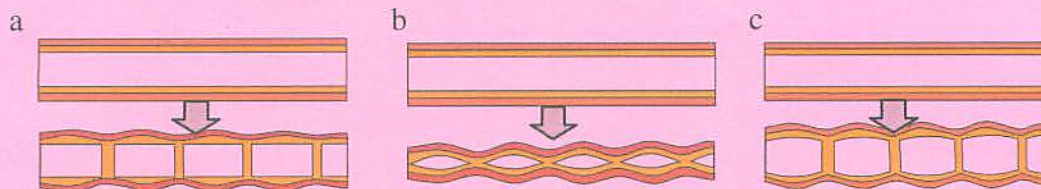
Answer: _____

31. Based on the geochemical equilibrium of the Earth system, the increase in burial rate of organic matter in the sediments could most likely result in _____. (1 pt)

- (A) a reduction in the Earth's atmospheric N_2 and an increase in CO_2 levels
(B) an increase in the Earth's atmospheric N_2 and reduction in CO_2 levels
(C) a reduction in the Earth's atmospheric CO_2 and an increase in O_2 levels
(D) an increase in the Earth's atmospheric CO_2 and a decrease in O_2 levels
(E) a reduction in both CO_2 and O_2 levels

Answer: _____

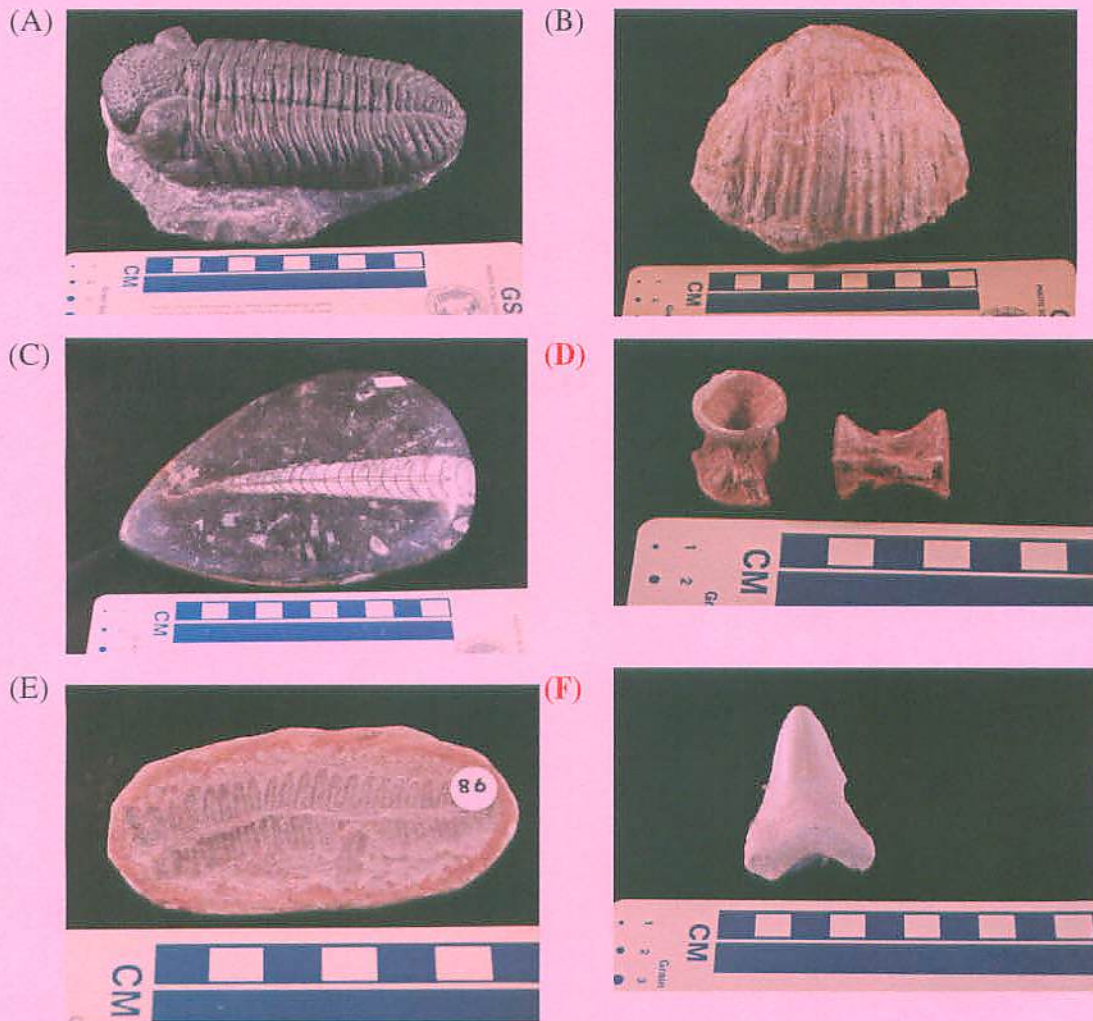
32. When the strength of rock material is greater, it tends to fracture or break more easily; conversely, when the rock is softer, it tends to bend and change its shape more easily. Based on that, assume the outer layers in a, b and c have the same strength and are under the same stress conditions for every sample. Please rank the strength for deformation of the following geological structures (a, b and c) from low to high. (1 pt)



- (A) a-b-c (B) b-a-c (C) c-b-a (D) a-c-b (E) b-c-a

Answer: _____

33. Circle the specimen(s) that is/are from vertebrate organisms? (2 pts)



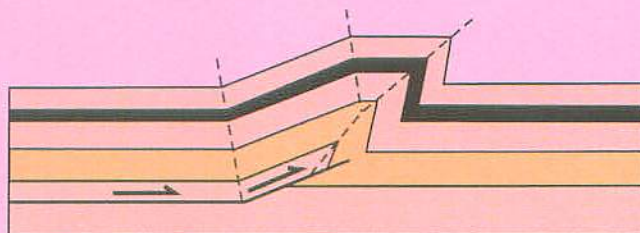
34. What type of material or celestial body gives us the most information in order to estimate the bulk chemical composition of the Earth? Choose the most suitable one from the list below. (1 pt)

- (A) comets (B) Mars (C) Moon (D) **meteorites** (E) oceanic crust

Answer: _____

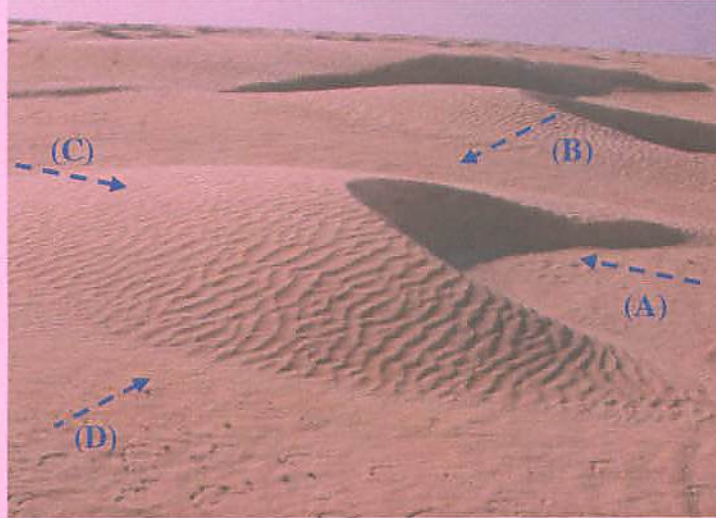
35. Which one of the following terms best describes the structure illustrated? (1 pt)

- (A) upright fold
 (B) antiformal anticline
 (C) synformal syncline
 (D) **fault propagation fold**
 (E) normal fault



Answer: _____

36. The figure below shows a type of landform which consists of sand. What is the most likely prevailing local wind direction? (1 pt)
- (A) from low right to upper left (B) from upper right to lower left
(C) from upper left to lower right (D) from lower left to upper right
 (E) no prevailing wind direction can be identified.



Answer: _____

37. The photographs below were taken from a low-lying basaltic island in the subtropical zone. On this island, horizons A and B in the soil profile are characterized by reddish-brown color. Which is the most important factor for such a soil to develop? (1 pt)
- (A) plant type **(B) climate** (C) relief (D) sea breeze



Answer: _____

38. The figure below shows the typical hill slopes developed on a massive mudstone bedrock. Two major processes could have contributed to erosion in this area and one of them is sheet wash. Please identify the other major process. (1 pt)

- (A) debris flow (B) rockfall **(C) rill erosion**
 (D) channel cutoff (E) river bank erosion



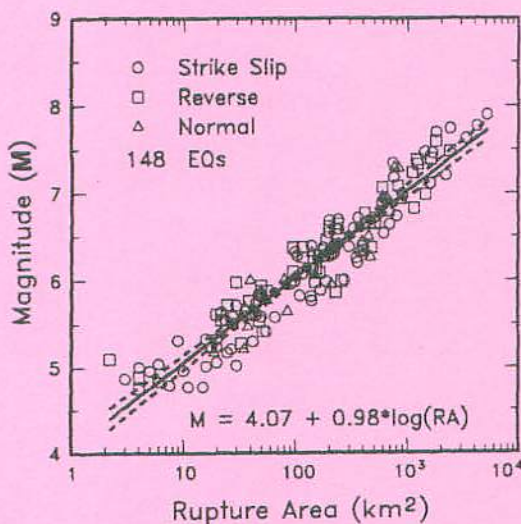
Answer: _____

39. Which type of rock is most commonly found at a mid-ocean ridge? (1 pt)

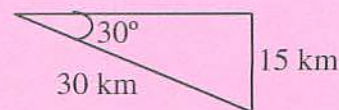
- (A) granite (B) rhyolite (C) dacite **(D) basalt** (E) sandstone

Answer: _____

40. The figure below illustrates the empirical relationship between the earthquake magnitude and the rupture area (RA) along the fault plane. Assume that the rupture of the May 12, 2008 Wenchuan, China earthquake ($M=8$) occurred within a rectangular plane with a maximum depth of 15 km and a dip angle of 30° . Estimate the rupture length on the surface if the fault plane penetrated the ground surface. (Show your work in the space next to the figure; 3 pts)



Answer:



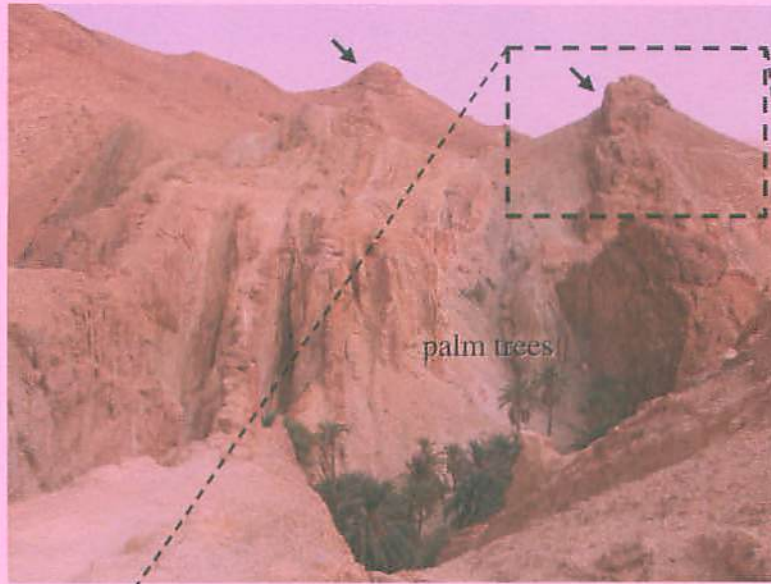
$$M = 4.07 + 0.98 \cdot \log(RA)$$

$$RA = 10^{(8 - 4.07) / 0.98} = 10238 \text{ km}^2$$

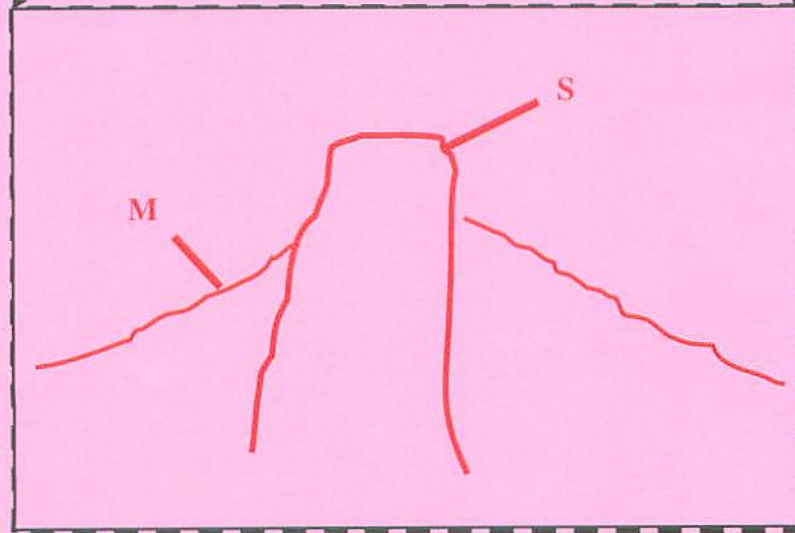
$$RW = 15 \text{ km} / \sin(30^\circ) = 30 \text{ km}$$

$$RL = 10238 / 30 = 341.3 \sim 341.3 \text{ km}$$

41. Assume that you are travelling along the northern margin of the Sahara Desert where vegetation cover is poor and the bedrock is exposed and readily observed (see photograph below). This rugged topography is characterized by many small ridges (indicated with arrows). Please draw a cross section to show the relationship between the lithology and topography. Use 'M' for mudstone and 'S' for sandstone to label the rocks. (2 pts)



Answer:



42. Which one of the following is a primary structure? (1 pt)

(A) fold axial plane



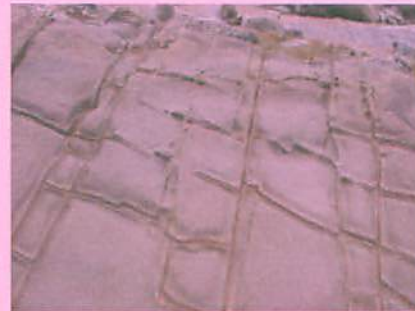
(B) fault



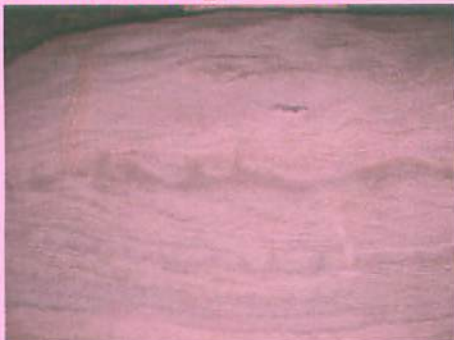
(C) mineral stretching lineation



(D) joint



(E) flame (loading) structure



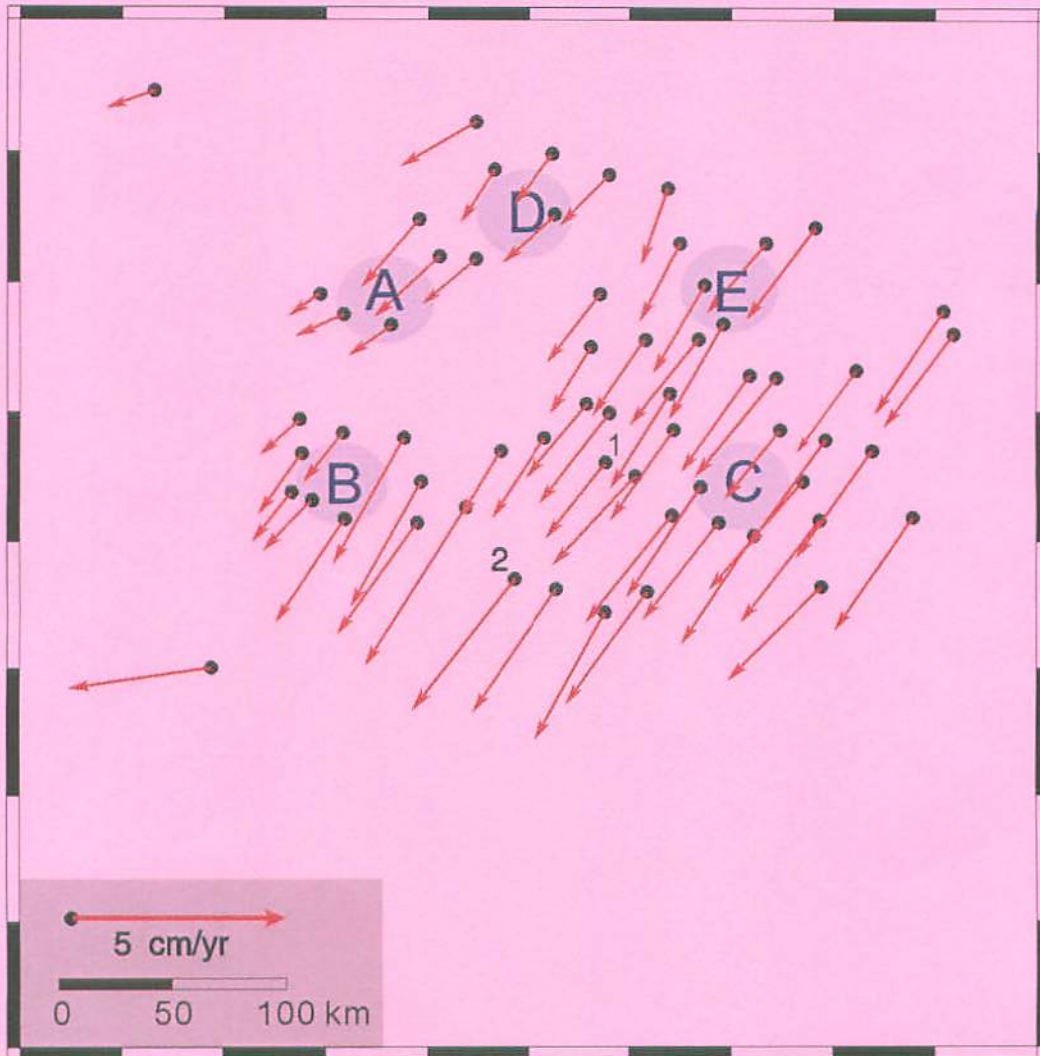
Answer: _____

43. What is likely to occur (Highly probable – H or Least probable – L) in a *low* oxygen atmosphere environment older than 2 billion years ? (1 pts)

(i) **L** Photosynthetic prokaryotes

(ii) **H** formation of banded-iron formations

44. The following map shows the surface horizontal velocity obtained from GPS measurements. The vector length at each point is proportional to the magnitude of the velocity, and the arrow indicates the direction of movement. Please answer the following questions.



(i) Based on the spatial variations of velocities, which stress environment setting is correct? (1 pt)

- (a) A: compressive, B: extensional, C: shearing
- (b) A: shearing, B: compressive, C: extensional
- (c) A: extensional, B: shearing, C: compressive
- (d) A: compressive, B: shearing, C: extensional**

Answer: _____

- (ii) According to the surface velocity, please roughly estimate the strain rate between points 1 and 2. Please show your calculations and give your answer in scientific notation in 2 significant figures. (Hint: the unit for strain rate is per year) (3 pts)

Distance scale: 100km \rightarrow 2.35 cm \Rightarrow 43.4783 km/cm
 Velocity scale: 5 cm/yr \rightarrow 2.2 cm \Rightarrow 2.273 cm/yr /cm
 Map length between p1 and p2 \rightarrow 2.04 cm \Rightarrow 88.696 km
 Vector length for P1 \rightarrow 0.95 cm \Rightarrow 2.159 cm/yr
 Vector length for P2 \rightarrow 1.70 cm \Rightarrow 3.864 cm/yr
 Strain rate between P1 and P2 = $[(3.8652 - 2.159) \text{ cm/yr}] / 88.696 \text{ km}$
 $= 1.92 \times 10^{-7} \text{ yr}^{-1}$

- (iii) Assume higher strain rate indicates higher earthquake activities. Which area C, D, or E in map has the highest earthquake activity? (1 pt)

Answer: C

45. We know the pattern of radiated seismic waves depends on the fault geometry. The polarity (direction) of the first P-wave arrival varies between seismic stations at different direction from an earthquake. Figure (a) illustrates this concept for a strike-slip earthquake on a vertical fault. The first motion is either “push”, for stations located such that material near the fault moves toward the station, or “pull”, where the motion is “away from” the station. The downward first motion indicates that the P-wave is radiated from a region where the focal source is being relatively compressed, as shown in the lower-right quadrant in Figure (a).

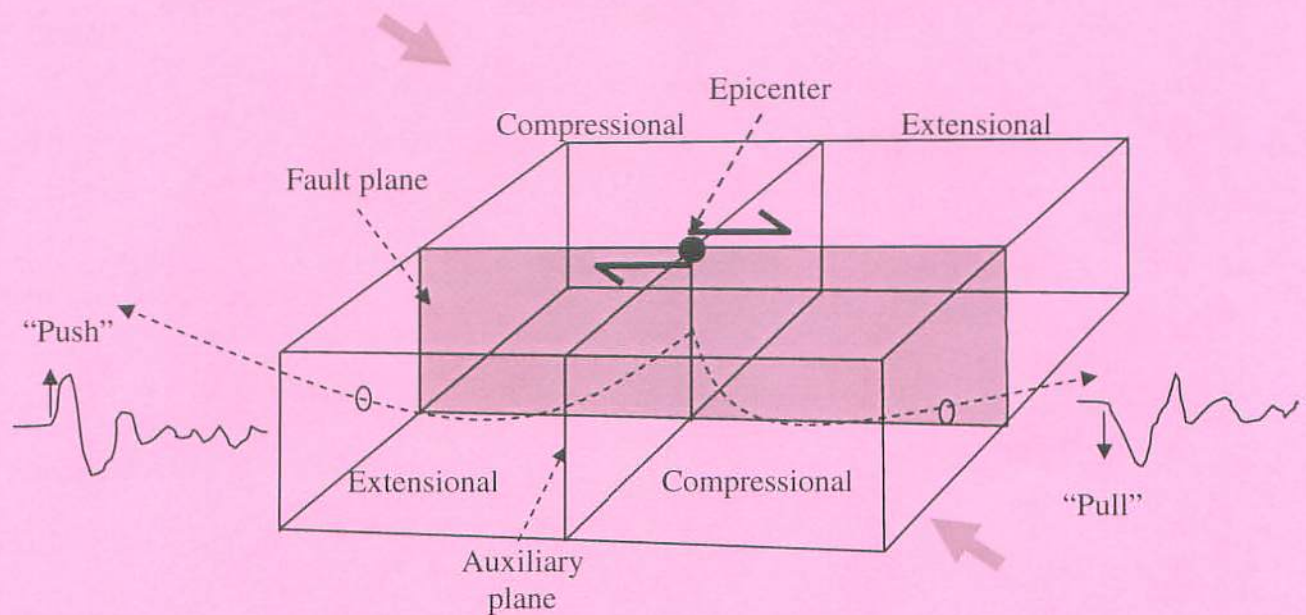


Figure (a)

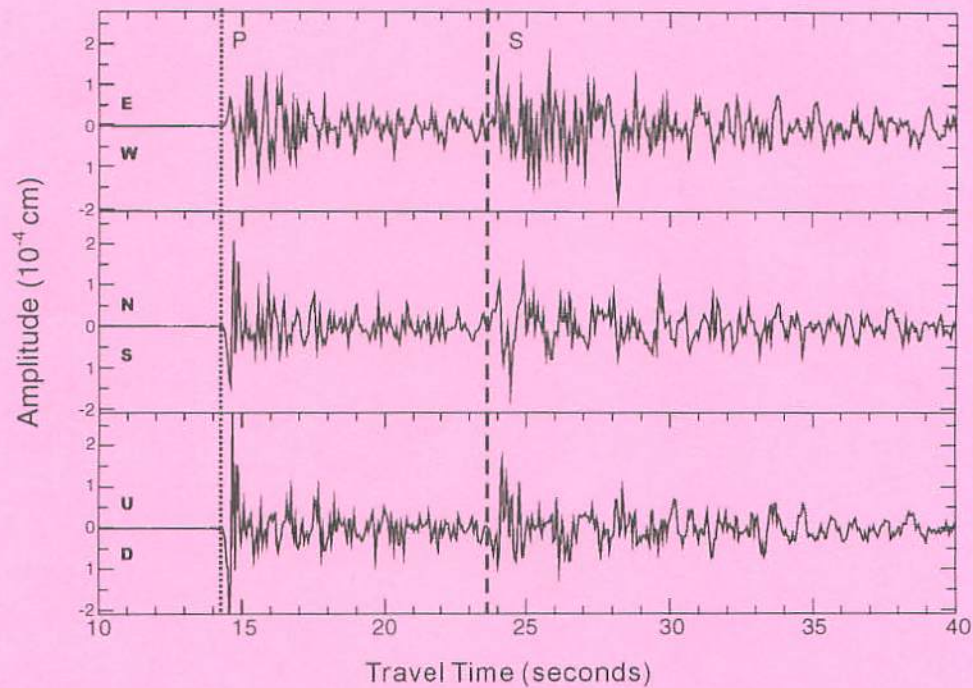


Figure (b)

Figure (b) shows 3-component seismograms recorded at a station 85 km away from the epicenter. They are east-west, north-south and up-down, respectively. Please answer the following questions according to Figures (a) and (b).

(i) Which description listed below is correct? (2 pts)

- (A) First direct P wave is radiated through the extensional quadrant and the first direct S wave is radiated through the compressive quadrant.
- (B) First P wave is radiated through the compressive quadrant and the first S wave is radiated through the extensional quadrant.
- (C) Both first P and S waves are radiated through the extensional quadrant.
- (D) Both first P and S waves are radiated through the compressive quadrant.**

Answer: _____

(ii) Please infer the location of the recording station with respect to the epicenter in terms of the first motions. (2 pt)

- (A) North north west** (B) South south west
- (C) North north east (D) South south east

Answer: _____

46. Choose the most characteristic rock/mineral from the list below (4 pts)

- | | | | | |
|---------------|------------|---------------|------------|-------------|
| a. quartz | b. biotite | c. hornblende | d. rutile | e. garnet |
| f. orthoclase | g. calcite | h. halite | i. beryl | j. diamond |
| k. basalt | l. gabbro | m. andesite | n. granite | o. rhyolite |
| p. shale | q. marble | r. slate | s. chalk | t. chert |

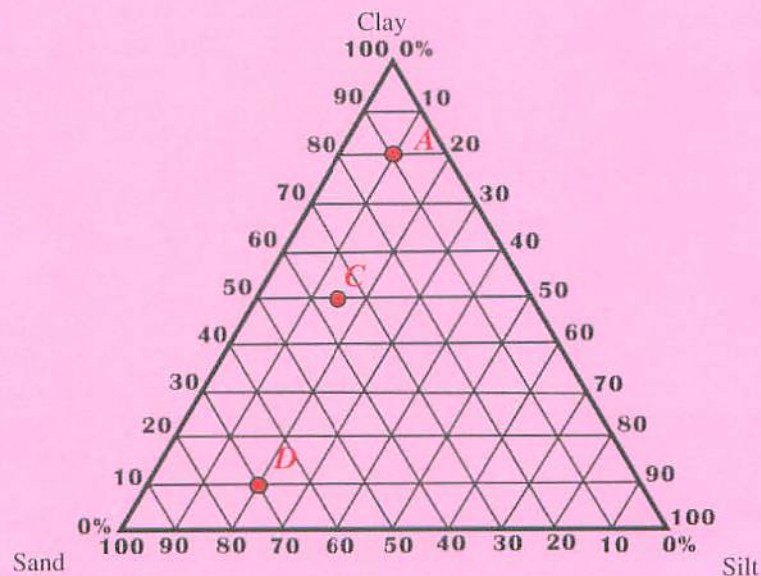
- (i) a Pure substance; two elements; common mineral; hexagonal prismatic crystal.
- (ii) m Subduction; eruptive rock; volcano; island arc.
- (iii) n Continental crust; felsic; batholith; coarse texture.
- (iv) q Metamorphic; carbonate; limestone; recrystallization.

47. The table below shows the results of grain size analysis of five soil samples.

Sample	A	B	C	D	E
Clay (%)	80	30	50	10	20
Silt (%)	10	40	15	20	65
Sand (%)	10	30	35	70	15

- (i) Use the information in the table to complete the soil texture diagram below for A, C and D samples. Plot your answer as dots (•) and label with sample name (A, C, D). (2 pts)

Answer:

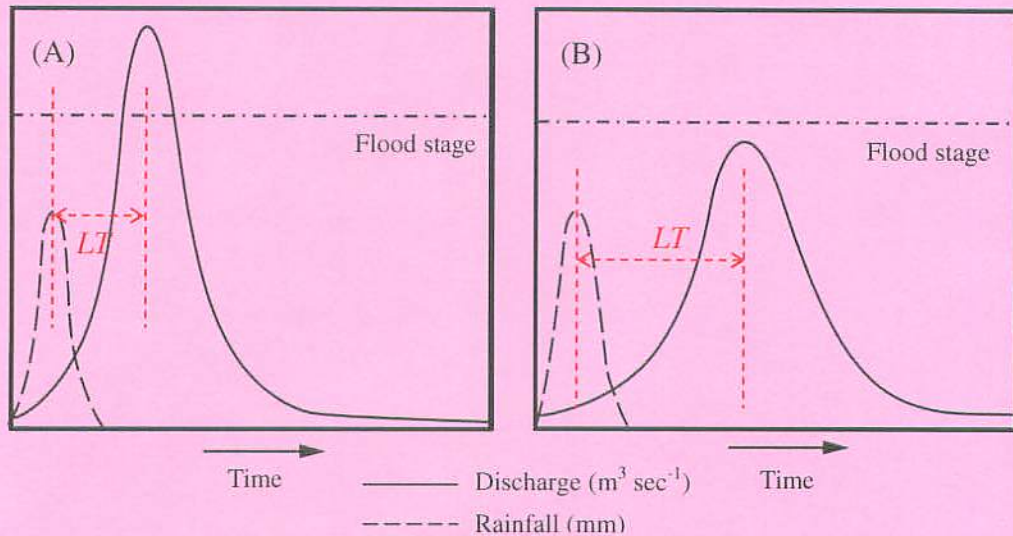


- (ii) Which sample has the highest porosity? (1 pt)

Answer: D

48.

- (i) Hydrographs below describe discharge conditions before and after urbanization in a drainage basin. In the following figures 'lag time' should be noted in both hydrographs. Please indicate the "lag time" in both of the following hydrographs using appropriate symbols. Label them "LT". Use appropriate symbols to show the 'lag time' and the label of LT (i.e., Lag time) should be added, too. (2 pt)



- (ii) Identify the hydrograph which illustrates the condition of the drainage basin before urbanization. (1 pt)

Answer: **B**

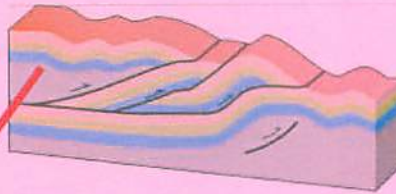
- (iii) Refer to the figures above and complete the following table using '+' to represent higher, longer or larger, '-' to represent lower, shorter or smaller and '0' to represent irrelevant. (2 pts)

Table

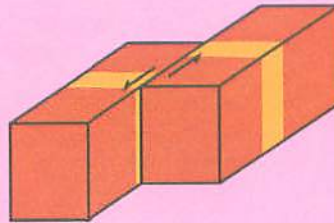
Variables	before urbanization	after urbanization
Rainfall intensity	0	0
Lag time	+	-
Flood magnitude	-	+

49. Connect the fault types with the correct figures. (2 pts)

Normal fault



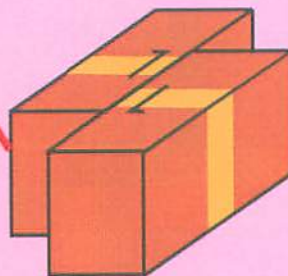
Thrust fault



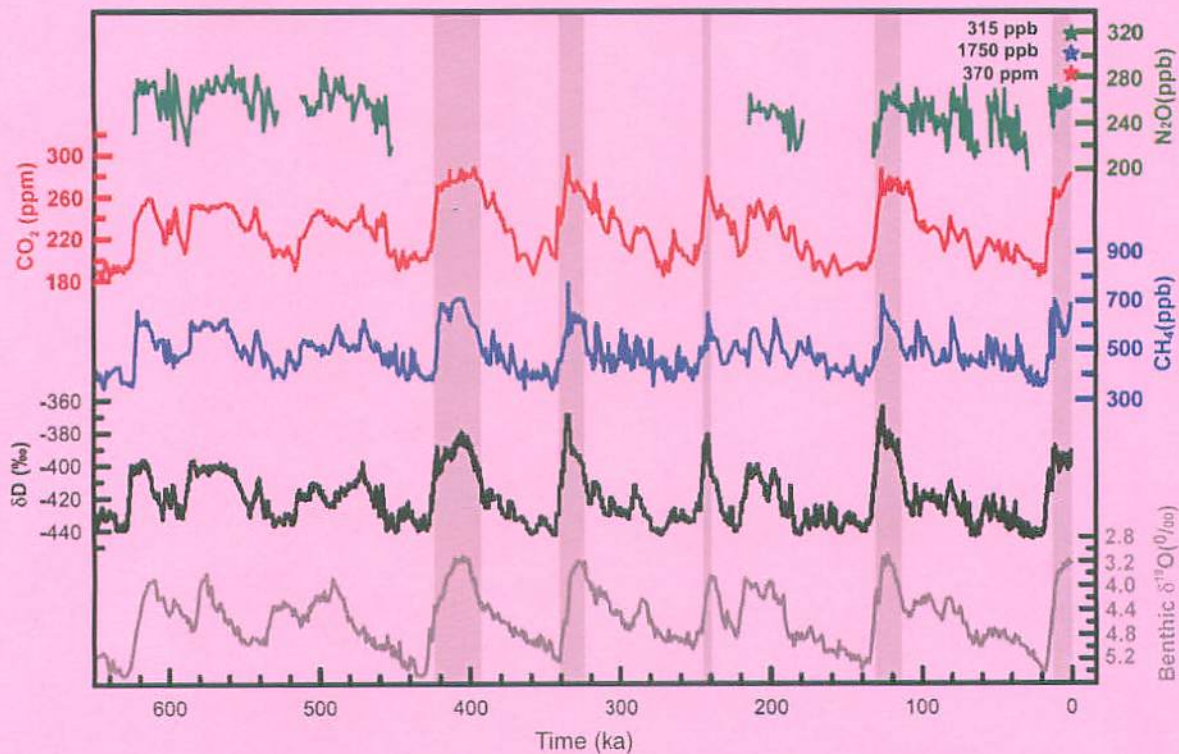
Dextral transverse fault



Sinistral transverse fault



50. The figure below shows the variations of deuterium isotope (δD), the atmospheric concentrations of the CO_2 , CH_4 , and N_2O derived from air trapped within ice cores from Antarctica. The shading indicates the interglacial warm periods. The lowest panel shows the globally distributed $\delta^{18}O$ records of benthic foraminifera, a proxy for global ice volume fluctuations. Downward trends in the benthic $\delta^{18}O$ curve reflect increasing ice volumes on land. Stars of different colors are the N_2O , CH_4 , and CO_2 concentrations in the atmosphere in the year 2007. (1 ka = 1000 years ago; 0 ka = 1950 AD) (Source: IPCC AR4, 2007).



(i) Over the last 650 ka, when did the CH_4 content exceed the current level? (1 pt)

(A) 400 ka (B) 125 ka (C) 330 ka (D) 315 ka (E) none of these

Answer: _____

(ii) The magnitude of $\delta^{18}O$ is directly proportional to the ice volume on land (note the scale on graph is inverted). When was **the most recent** time that the ice volume on land was maximum? (1 pt)

(A) 420 ka (B) 220 ka (C) 125 ka (D) 20 ka (E) 0 ka

Answer: _____

(iii) The most likely cause for the glacial-interglacial cycles shown in the figure above is _____ . (1 pt)

- (A) fluctuations in $\delta^{18}\text{O}$ of benthic foraminifera
- (B) fluctuations in the Earth's orbit**
- (C) fluctuations in plate movements of the northern landmasses
- (D) fluctuations in plate movements of the southern landmasses
- (E) burning of fossil fuel

Answer: _____

#9 (ii) Typographic Error

Solution: [intermediate]

50 years trend : $(14.4-13.8)/50 = 0.6 \text{ }^\circ\text{C} / 50 \text{ years} = 1.2 \text{ }^\circ\text{C} / 100 \text{ years} = 0.012 \text{ }^\circ\text{C} / \text{year}$

100 years trend : $(14.3-12.6)/100 = 0.7 \text{ }^\circ\text{C} / 100 \text{ years} = 0.007 \text{ }^\circ\text{C} / \text{year}$

The ratio is $1.2/0.7 = 1.7$.

Solution: [intermediate]

50 years trend : $(14.4-13.8)/50 = 0.6 \text{ }^\circ\text{C} / 50 \text{ years} = 1.2 \text{ }^\circ\text{C} / 100 \text{ years} = 0.012 \text{ }^\circ\text{C} / \text{year}$

100 years trend : $(14.3-13.6)/100 = 0.7 \text{ }^\circ\text{C} / 100 \text{ years} = 0.007 \text{ }^\circ\text{C} / \text{year}$

The ratio is $1.2/0.7 = 1.7$.

#27 Using the names or numbers

The satellites are a: (Callisto) ; b: (Io) ; c: (Europa) ; d: (Ganymede) (1 pt)

OR — The satellites are a: (4) ; b: (1) ; c: (2) ; d: (3) (1 pt)