

**Massachusetts
Tests for Educator Licensure® (MTEL®)**



Earth Science (14)

PRACTICE TEST

APPENDIX:

Multiple-Choice

Question Analyses



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MULTIPLE-CHOICE QUESTION ANALYSES

1. A hypothesis provides which of the following in a scientific investigation?
 - A. a question that can be answered by researching existing literature
 - B. a format for outlining the approach to be used in the investigation
 - C. a summary of previous research on the topic being investigated
 - D. a proposed explanation for the phenomena being investigated

Correct Response: D. A scientist puts forward a hypothesis as a reasonable explanation of a natural phenomenon. The goal of a scientific investigation based on a particular hypothesis is to prove or disprove the hypothesis as a way for furthering understanding of the phenomenon being investigated. Answering a question that was addressed by previously completed research (**A**) does not require a scientific investigation. While the hypothesis underlying a scientific investigation may affect the investigation's design, it does not provide a format that outlines what particular approach should be used (**B**). A summary of existing research on the topic (**C**) is useful for developing a hypothesis, but it is not in itself a hypothesis.

2. In order to isolate the relationship between two variables in an experiment, scientists must:
- A. carry out the experiment in a laboratory setting.
 - B. predict the full range of possible outcomes of the experiment.
 - C. control the conditions under which the experiment is carried out.
 - D. limit the scope of the experiment to the investigation of known facts.

Correct Response: C. An experiment designed to isolate the relationship between two variables requires controlled conditions to ensure that no other factors are influencing the relationship between the variables. An experiment need not be conducted in a laboratory (**A**), as long as it is carried out under controlled conditions. Predicting the full range of outcomes (**B**) is unnecessary in an experiment designed to evaluate a specific relationship. Scientific experiments seek to reveal information about unknowns so limiting the scope of the experiment to known facts (**D**) would not aid in the evaluation of the relationship being investigated.

3. A climatologist is investigating the causes of an extended drought in a particular region. Which of the following questions would provide the best foundation for the climatologist's investigation into the causes of the drought?
- A. How could the drought conditions in the region best be managed?
 - B. What variables affect the region's precipitation during droughts?
 - C. How long did other droughts in the region last?
 - D. Why do droughts strike only in certain regions and not others?

Correct Response: B. To investigate the causes of an extended drought, the climatologist first needs to establish the variables that have affected the region's precipitation during the drought. The management of drought conditions (**A**) is a practical concern unrelated to the drought's causes and the duration of previous droughts (**C**), while useful information, does not get at the underlying causes of the current extended drought. Similarly, why droughts strike certain regions and not others (**D**) is an interesting question, but not the strongest foundation for investigating the causes of the current drought.

4. A scientist is investigating the source of a petroleum contaminant in a high-yield drinking-water well. The well is deep and draws from a confined aquifer. Test wells drilled immediately to the north and to the east of the well are found to be contaminated. Test wells drilled to the south and west are not. The scientist concludes that the contaminant must be coming from the north and east. Which of the following factors would most reduce the validity of the scientist's conclusion?
- A. The contaminated test wells are on the up-gradient side of the drinking-water well where groundwater in the confined aquifer flows toward the well.
 - B. The uncontaminated samples were collected when the pump for the drinking-water well was on, while the other samples were collected when it was off.
 - C. The contaminated samples were collected on the same day by different people.
 - D. The uncontaminated test wells were drilled to a depth that is above the confined aquifer supplying water to the drinking-water well.

Correct Response: D. The scientist's conclusion would be undermined if the uncontaminated test wells were found to be drawing water from a different aquifer than the contaminated confined aquifer that supplies the drinking-water well. The test wells that are up-gradient from the drinking water well (**A**) would flow down-gradient to the drinking water well so that does not affect the validity of the scientist's conclusion. The fact that the pump at the contaminated test well was off when samples were collected (**B**) does not undermine the scientist's conclusion as contaminant levels would be higher if anything in a pumping well. There are strict protocols for collecting water samples that professional scientists are required to follow and the samples are processed in a laboratory, so having more than one person collect the samples (**C**) does not reduce the validity of the scientist's conclusion either.

5. A researcher is analyzing data collected for a study of climate change. Which of the following actions by the researcher would most strongly bias the analysis?
- A. noting flaws in the research design that may have generated faulty data
 - B. removing data that significantly differ from expected results
 - C. altering the graphical presentation of the data set to make it more readable
 - D. summarizing data collected on a daily basis into a weekly average

Correct Response: B. Removing data because it differs from expected results would most strongly bias the researcher's analysis. Noting flaws in the research design that may have generated faulty data (**A**) does not introduce bias into the researcher's analysis of the data, but does suggest there are possible problems with the data set. Changing the way the data is presented graphically to improve readability (**C**) or how the data is summarized and averaged (**D**) does not bias the analysis as long as graphics are clearly labeled and averaged values are clearly described as averages.

6. A hydrologist is collecting water samples to determine the dissolved oxygen content of a pond that has become choked with weeds. To most closely reflect the actual dissolved oxygen content of the pond water, which of the following methods should the hydrologist use to collect the water samples?
- A. The water should be collected from below the pond's surface in various locations, filling and then sealing the containers rapidly and recording the locations.
 - B. The samples should be collected from the pond's surface near the outlet where the water is moving rapidly and few weeds are growing.
 - C. The water should be collected from near the bottom, making sure to leave some air space in the container and including some of the organic matter found in the pond.
 - D. The samples should be collected near the pond's inlet and should avoid including any organisms or debris that may be in the water.

Correct Response: A. To ensure the dissolved oxygen in the water samples is representative of the pond as a whole, several samples should be collected from different locations below the pond's surface, filled completely, and then sealed. This avoids collecting the most oxygenated water at the pond surface and it prevents oxygen from dissolving into the sample from air in the sample jar. Fast moving water from the surface that is near the pond's outlet (**B**) or inlet (**D**) will not be representative of the pond's water as the water samples will likely contain more dissolved oxygen. Similarly, the dissolved oxygen content of water samples that do not fill the jar and include organic matter from the bottom (**C**) may change over time and will likely not provide representative samples.

7. A researcher investigating the geologic history of a region collects data on the orientation of a limestone layer exposed along a highway. The convention for reporting the orientation of the limestone layer typically would include which of the following information?
- A. the meters below the land surface of different sections of the top of the exposed part of the limestone
 - B. the angle between an imaginary vertical line and the uppermost surface of the limestone
 - C. the degree measurements that show the strike and dip of the bedding plane of the limestone
 - D. the thickness of the limestone and how it has changed from its original horizontal position

Correct Response: C. Strike and dip measurements are the conventional data that a geologist collects to report a geologic layer's bedding orientation in terms of the cardinal directions and the horizontal plane. An imaginary vertical plane is not referenced in recording the orientation of geologic strata (**B**). The depth below the land surface of the limestone strata exposed in the road cut (**A**) is not relevant information for reporting the bedding orientation of the limestone strata. While the thickness of a limestone bed is recorded in the field if possible, the original orientation of the bedding (**D**) is an interpretation of geologic history that is not typically part of mapping the orientation of geologic strata.

8. Hydrologists are helping establish the variability of discharge on a particular river. They determine the average discharge of the river over the past 100 years using historical data. Which of the following is the best measure of the variability of this data set?
- A. the median
 - B. the standard deviation
 - C. the mode
 - D. the arithmetic mean

Correct Response: B. Standard deviation is a measure of the variability of a data set. It is the square root of the variance of the data set, where the variance represents how spread out a data set is from the mean. In this way standard deviation is useful for determining the variability of a river's discharge over a period of time. The median (**A**) measures the middle value of a data set not its variability, while the mode (**C**) is the most common value in the data set, and the arithmetic mean (**D**) is the average of the data set, a value that the hydrologists have already calculated and that does not measure variability.

9. A scientist collects 50 years of temperature data from the Midwest that show a steady increase in daytime summer temperatures. Which of the following is the best way for the scientist to use these data to make predictions about how the average temperatures may increase in the coming years?
- A. Plot the data set and extend the line of best fit into the coming years.
 - B. Take the median of the data set and add that to the average temperature for each coming year.
 - C. Determine the range of the data set and assume any future increases will be within that range.
 - D. Calculate the total change over time in the data set and assume it reflects the minimum increase in the future.

Correct Response: A. The scientist collecting the data can plot a line of best fit for the data set and then extend the line of best fit to predict likely future trends. It is impossible to know the average temperature for each coming year (**B**) and therefore adding it to the median of the data set is not possible. The range of the data set (**C**) is the difference between the highest and lowest values and does not provide information useful for predicting future trends if the temperature is increasing over time. Calculating the total change over time in the data set to predict the minimum future increase in temperature (**D**) is vague and does not specify over what time period that minimum increase can be expected so it is not the best tool for predicting future trends.

10. Which of the following is the best example of using a physical model to understand a complex natural system?
- A. Paleontologists reconstruct the habitat of an extinct fossilized animal by examining the type of rock in which the animal was found and the associated plant fossils.
 - B. Meteorologists use historical data correlating sunspot cycles with short-term temperature changes to predict winter weather several years in advance.
 - C. Geologists measure changes in the speed and direction of seismic waves produced by explosions or earthquakes to locate deposits of oil and natural gas.
 - D. Oceanographers study damage produced when 25 cm waves are generated in a scaled-down replica of San Francisco Bay to assess how a tsunami might affect the region.

Correct Response: D. The scaled-down replica of San Francisco Bay is a physical model that the oceanographers use to investigate how the real San Francisco Bay may respond to a tsunami. Reconstructing habitat based on geologic clues (**A**) does not involve the use of a physical model and the correlation of sunspot data with past weather to make predictions about future weather (**B**) also does not involve the use of a physical model. Measuring the characteristics of seismic waves to locate fossil fuel deposits also (**C**) does not involve a physical model as it is an analysis of real-world phenomena.

11. Use the graphic below to answer the question that follows.



The map symbol shown above typically appears at the bottom of a topographic map and is known as the declination. A scientist reading the map in the field uses the declination for which of the following purposes?

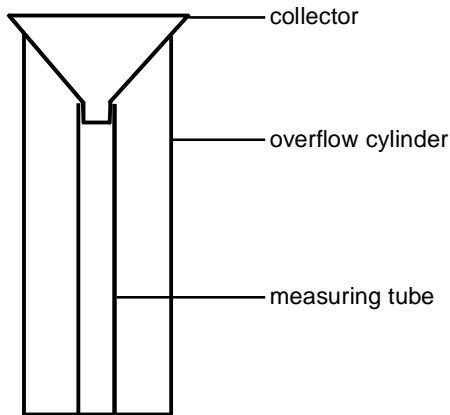
- A. estimating the relief between two distant points on the map
- B. adjusting the latitude and longitude values on a flat map to account for Earth's spherical shape
- C. assessing the approximate distance to locations represented on the map
- D. determining the difference between true north as it is represented on the map and magnetic north

Correct Response: D. The declination value that is listed on topographic maps refers to the magnetic declination that represents the difference between true north and magnetic north as measured by a compass. Declination does not provide information on the relief shown on a map (**A**). Latitude and longitude on a flat topographic map are unrelated to declination and do not need to be adjusted to accommodate Earth's curved surface (**B**). The numeric and graphic scale given on a topographic map and not the declination (**C**) are used to estimate distances on the map.

12. Which of the following would be an appropriate use of global positioning system (GPS) technology?
- A. monitoring the motion and development of a storm system
 - B. locating the latitude and longitude of a geologic outcrop in the field
 - C. estimating the percent of land area covered in forest vegetation
 - D. calculating the moisture content of soil over a large geographic area

Correct Response: B. The global positioning system (GPS) is a satellite-based navigational system that can give the latitude and longitude of a particular location. A handheld device receives signals from the satellites. This makes GPS technology useful for determining the latitude and longitude of a particular geologic outcrop. A storm system is typically monitored by Doppler radar (**A**) and not GPS because GPS requires a receiver to calculate position. Although GPS is useful in locating where field data is being collected by foresters and soil scientists, GPS is not in itself a tool for estimating the extent of forest cover (**C**) or calculating the soil's moisture content (**D**) because it only provides latitude, longitude, and time of day.

13. Use the graphic below to answer the question that follows.



The standard rain gauge shown above has a long, narrow measuring tube and a funnel-shaped collector at the top. The area of the top of the collector is 10 times greater than that of the measuring tube. This difference between the cross-sectional area of the measuring tube and the collector is designed to:

- A. ensure that the rainfall measured represents a realistic average.
- B. reduce the effect of wind on rainfall accumulation.
- C. minimize the amount of splashed rainwater that can enter the device.
- D. provide a more precise measurement of total rainfall.

Correct Response: D. The larger cross-sectional area of a rain gauge's collector as compared with its measuring tube is designed to provide more precise measurements, especially of light rain. Since the cross-sectional area of the top of the collector is 10 times greater than the cross-sectional area of the measuring tube, the amount of rain deposited in the measuring tube is divided by ten to provide a measurement of rainfall. The design does not necessarily provide a more realistic measure of the average rainfall (**A**) and it will not reduce the effect of wind (**B**) or minimize the amount of splashed rainwater that can enter the device (**C**). Both wind and splash are typically controlled by appropriate placement of the device.

14. Before using a pH meter to determine the pH of a water sample, it is important to do which of the following to ensure the resulting reading will be accurate?
- A. The sample should be refrigerated in a sealed container.
 - B. The meter should be calibrated with a buffer solution.
 - C. The sample should be filtered to remove any organic matter.
 - D. The meter should be allowed to warm up.

Correct Response: B. A pH meter must be calibrated with one or more buffer solutions of known pH before use because the meter will not give accurate readings when used repeatedly or if not stored properly. This is because pH meters use the voltage between two electrodes to determine the pH of a solution. The electrodes will not give consistent results if the meter is used repeatedly or the probes containing the electrodes are not stored properly or kept clean. Refrigeration is not a good idea (**A**) because samples should be tested at standard temperature and pressure since temperature affects pH. Filtering organic matter from a sample (**C**) is also not necessary and may introduce error. A pH meter does not need to warm up (**D**) because as soon as it is turned on it records the voltage between the two electrodes.

15. Following an outdoor field trip, a student reports to the teacher that he has a tick imbedded in his skin. The appropriate procedure for the teacher to follow upon discovering the imbedded tick is to:
- A. have the student call his parents to inform them that he has possibly contracted Lyme disease.
 - B. leave the tick alone and inform the student that he needs to visit his doctor as soon as possible.
 - C. have the school nurse remove the tick from the student immediately and save it for identification.
 - D. encourage the student to remove the tick himself and report the matter to his parents.

Correct Response: C. Having a medical professional and not the student (**D**) carefully remove the tick is the best approach. This ensures that the entire tick will be removed properly and that it can be identified. This is important as Lyme disease is carried by deer ticks, but not dog ticks. Scaring parents with misinformation (**A**) is unprofessional conduct for a teacher and could lead to unnecessary medical treatments. The probability of acquiring Lyme disease from an infected deer tick embedded in the skin increases dramatically after 24 hours. For this reason, telling the student to leave the tick in until he sees his doctor (**B**) is a bad idea.

16. In 1965, two researchers detected cosmic background radiation coming from all directions in space. This discovery provided the first direct evidence of the:
- A. earliest formation and expansion of the universe.
 - B. presence of black holes at the center of the Milky Way galaxy.
 - C. massive size and homogeneity of the universe.
 - D. bending of light by large gravitational fields.

Correct Response: A. The discovery of cosmic background radiation coming from all directions in space by Arnold Penzias and Robert Wilson provided the first observational evidence supporting the Big Bang theory of the universe. The Big Bang theory suggests the universe started with a massive explosion and rapid expansion. The discovery of a black hole at the center of the Milky Way (**B**) was based on observations of an intense radio source at the middle of the Milky Way galaxy and is not related to the work of Penzias and Wilson. The homogeneity and absolute size of the universe (**C**) is still a matter of conjecture and study. The bending of light by large gravitational fields (**D**) was first observed in 1919 during a solar eclipse, but had been proposed by Isaac Newton and later calculated by Albert Einstein.

17. When Alfred Wegener proposed that the continents had changed position over time, many scientists rejected his proposal even though some of the evidence he presented was compelling. Which of the following describes the primary scientific reason many geologists originally rejected Wegener's continental drift proposal?
- A. He was trained in a different scientific discipline and was considered an amateur.
 - B. His hypothesis lacked a convincing mechanism to explain what forces moved the continents.
 - C. He did not defend and argue the merits of his ideas since the evidence was strong.
 - D. His field work was poorly executed and lacked the rigor associated with most sciences of the day.

Correct Response: B. The primary reason so many scientists rejected Alfred Wegener's idea of continental drift was that his idea lacked a mechanism that could cause continents to move. Without a convincing mechanism to support his hypothesis the geologic community was not ready to accept such a radical idea. Some scientists did consider Wegener an outsider in the field of geology, but because he was a respected scientist with strong evidence, he was never considered an amateur (**A**). Wegener frequently and enthusiastically defended his theory of continental drift (**C**), publishing a book on the topic and giving lectures. Though Wegener struggled to come up with a mechanism, he was an accomplished scientist and the evidence he collected was widely accepted even if his theory explaining it was not (**D**).

18. The significant increase of which of the following interactions between Earth systems has the greatest potential to indirectly cause a rise in sea level?
- A. deforestation of tropical regions, reducing carbon sequestration by the biosphere
 - B. pollution of coastal waters with agricultural runoff, triggering algal blooms
 - C. eruption of low-latitude volcanoes, producing a change in atmospheric chemistry
 - D. desertification of semi-arid lands, generating wind-blown dust in the troposphere

Correct Response: A. Deforestation significantly reduces the sequestration of carbon dioxide, a potent greenhouse gas. With less forest to sequester carbon dioxide, the concentration of carbon dioxide in the atmosphere increases, warming the atmosphere. A warmer atmosphere warms the oceans, causing the volume of water to increase. This and the melting of land-based glaciers from a warmer atmosphere raise sea level. Algal blooms triggered by coastal runoff (**B**) increase carbon sequestration and so would have little effect on sea-level rise. Similarly, volcanic eruptions in the tropics (**C**) typically cool the atmosphere and consequently cool the oceans, reducing glacial melt and decreasing the rate of sea-level rise. An increase in wind-blown dust from desertification (**D**) typically reduces the temperature of the troposphere, which would also not lead to a rise in sea level.

19. The development and marketing of new technologies have often been done without understanding the long-term consequences that adopting such technologies may have on society. The most serious example of a technology that ultimately had a major effect on human health and the environment was the introduction and use of:
- A. radioactive isotopes for tracing the location of diseased tissue.
 - B. chlorofluorocarbons for air-conditioning.
 - C. lithium-ion batteries for powering digital devices.
 - D. electromagnetic waves for sending data across great distances.

Correct Response: B. Chlorofluorocarbons (CFCs) developed for air conditioning systems eventually became concentrated enough in the atmosphere to reduce the extent and concentration of the stratospheric ozone layer. This layer of ozone protects life from harmful solar radiation. The threat was so serious that nations acted to ban chlorofluorocarbons. Radioactive isotopes used in medicine (**A**), while potentially dangerous, have been widely hailed as being an important tool for doctors and their use is not seen as having unintended consequences. Lithium-ion batteries are considered safer for the environment and people than other types of batteries that typically contain toxic metals, such as lead or cadmium (**C**). The use of electromagnetic waves for transmission of data (**D**) has produced no serious unintended consequences for human health.

20. Media accounts of major hurricanes often mention a growing concern that global warming will increase the frequency of major hurricanes affecting the United States. Most climatologists are uncomfortable with this kind of statement from the media primarily because it is:
- A. a generalization that does not accurately reflect the complexity of research on the topic.
 - B. an unsubstantiated rumor without any support in the broader scientific community.
 - C. a government issue that only official agencies should address to avoid unnecessarily scaring the public.
 - D. an unethical strategy for selling news that may cause disruption to the larger economy.

Correct Response: A. Climatologists generally do not directly attribute changes in the climate system, such as an increase in hurricane frequency, to global warming. This is because the climate system is a highly complex system that responds to change through numerous feedback loops that are still only partially understood. The idea isn't entirely made-up (**B**) as warmer oceans do increase the probability of hurricane formation, but ocean temperature is only one part of the complex sequence of events that leads to the development of a major hurricane. Most climatologists do not see climate change issues as only being a government concern (**C**), and while they do not like it when the media inaccurately reports science (**D**), it is the accuracy of the reporting that primarily concerns the scientific community and not the consequences of the reporting.

21. Bowen's reaction series helps geologists explain the occurrence of various minerals in a particular igneous rock primarily because it defines the:
- A. temperature at which different minerals in a magma will solidify.
 - B. rate at which crystals grow within a cooling magma.
 - C. chemical changes that occur after a rock has solidified.
 - D. crystal systems that will develop as a rock forms under pressure.

Correct Response: A. Bowen's reaction series is a system that identifies the temperature at which specific minerals in a cooling magma will solidify. The system helps geologist approximate the thermal conditions that an igneous rock formed under based on the specific minerals it contains. The rate at which minerals grow in a cooling magma (**B**) is determined by the chemistry of the magma and the rate that the temperature and pressure of the magma change during cooling. Bowen's reaction series does not account for changes in the mineral composition of rocks that occur after the magma solidifies (**C**) and it does not define which crystal systems that the minerals in a magma will crystallize into (**D**).

22. Which of the following is a characteristic of muscovite mica and biotite mica that makes them easy to identify?
- A. specific gravity
 - B. chemical reactivity to acid solutions
 - C. conchoidal fracture
 - D. perfect cleavage in one direction

Correct Response: D. Muscovite mica and biotite mica are most easily identified by their perfect cleavage in one direction. They are both phyllosilicate minerals (also called sheet silicates) that form in thin layers. The specific gravity of these two related minerals (**A**) are similar, but specific gravity is not, in itself, a characteristic that can be used to identify the two minerals. Unlike carbonate minerals, these mica minerals cannot be identified by their reactivity to acids (**B**) and, unlike amorphous or fine-grained rocks such as obsidian and chert, muscovite and biotite mica do not exhibit conchoidal fracturing when broken (**C**).

23. Economically valuable minerals, such as gold and silver, are often found in the country rock surrounding large plutons. The formation of these types of minerals under these conditions is commonly the result of:
- A. isostatic readjustment.
 - B. magmatic differentiation.
 - C. hydrothermal alteration.
 - D. chemical weathering.

Correct Response: C. Hydrothermal alteration of minerals in the country rock surrounding a pluton occurs as hot mineral-rich fluids move from a cooling pluton into the surrounding country rock. The process alters the chemistry and makeup of the surrounding rock and can deposit precious metals within fractures as the fluids cool. By adding, removing, and redistributing chemical elements in the surrounding country rock, hydrothermal fluids alter the minerals in the rock and can concentrate precious metals, such as gold and silver. Isostatic readjustments (**A**) that cause vertical changes in the crust do not directly affect local geochemical processes involved in the formation of economically valuable minerals. Magmatic differentiation changes the magma's composition as minerals crystallize during cooling (**B**), but does not directly form concentrations of precious metals. Chemical weathering (**D**) does not occur extensively within country rock and therefore does not play a role in concentrating precious metals found in country rock.

24. Carbon is cycled through the atmosphere, the hydrosphere, the biosphere, and the lithosphere. Which of the following describes one step in the movement of carbon from the atmosphere to the lithosphere?
- A. the production of carbonic acid from limestone during weathering
 - B. the extraction of bicarbonate ions from seawater during coral reef formation
 - C. the formation of carbon dioxide during the decay of biomass
 - D. the absorption of atomic carbon in seawater by deep-ocean sediments

Correct Response: B. When atmospheric carbon dioxide dissolves in seawater, it reacts with the water to produce carbonate and bicarbonate ions. The bicarbonate ions combine with calcium ions as marine invertebrates, such as corals, make their protective shells. This is an important step in the cycling of carbon between the atmosphere and lithosphere because the reef carbonates formed by corals eventually become the extensive limestone deposits of the lithosphere. Carbonic acid produced during the weathering of limestone moves into the hydrosphere not the lithosphere (**A**). The decay of biomass (**C**) moves carbon from the biosphere to the atmosphere and atomic carbon is highly reactive and so by itself is not directly absorbed by deep-ocean sediments (**D**).

25. Small-scale geothermal heating and cooling systems for individual homes have become popular throughout the United States. These home geothermal systems primarily rely on the:
- A. high temperature of groundwater found deep within Earth.
 - B. compression of steam pumped underground.
 - C. infrared energy given off by soils at night.
 - D. year-round stability of the temperature underground.

Correct Response: D. Geothermal heating and cooling systems rely on the relatively stable temperature twenty to thirty feet underground. Although the temperature varies geographically with latitude, temperatures at this depth do not vary much seasonally and are never below freezing. This provides a source of heat in the winter and in the summer the same system can be used for cooling. Temperatures deep underground are hot (**A**), but the depth is too great to provide an economically feasible source of heat energy for small-scale geothermal air-conditioning systems. Compression of water vapor (**B**) is used in heat pumps to increase the temperature of the water coming out of the ground not going into the ground. Soils are too close to the surface to be a heat source in the winter or a heat sink in the summer (**C**).

26. Seismologists first established the physical character of Earth's outer core based on the fact that:
- A. S waves do not pass through liquid substances.
 - B. P and S waves are reflected from solids at different angles.
 - C. P waves do not pass through high-temperature materials.
 - D. P and S waves are refracted differently from irregular surfaces.

Correct Response: A. Earthquakes generate P waves (compressional waves), S waves (shear waves), and surface waves. S waves penetrate Earth's crust and mantle, however S waves do not travel through liquids so they do not penetrate the liquid outer core. Seismologists examining seismic data collected from major earthquakes noticed a shadow zone where S waves were absent on the opposite side of the planet from where the seismic waves were generated. This led to the conclusion that the outer core was liquid. Although P and S waves are reflected differently from solids (**B**), this difference does not provide information on the physical character of the outer core. P waves can pass through high-temperature materials (**C**) and while P and S waves are refracted at different angles from irregular surfaces (**D**), this fact does not provide evidence of the liquid character of the outer core.

27. Studies during the 1950s and 1960s showed that the ferromagnetic minerals in ocean-floor basalts aligned with Earth's magnetic field when the basalts were still molten. This information provided evidence supporting:
- A. the theorized stability of Earth's rotational velocity.
 - B. a four-billion-year-old estimate of Earth's age.
 - C. the hypothesized liquid state of the upper mantle.
 - D. a mechanism to help explain how lithospheric plates moved apart.

Correct Response: D. The magnetic orientation of ferromagnetic minerals in ocean-floor basalts demonstrated that oceanic lithosphere was moving apart as new basalt was generated at ocean spreading centers. This provided a mechanism to help explain two important components of plate tectonic theory; the movement of tectonic plates and the formation of new oceanic crust. Astronomical evidence and not geologic evidence indicates that, as a result of gravitational interactions, Earth's rotational velocity is decreasing very slowly over time (**A**) and is not stable. Because ocean crust is recycled at subduction zones, ocean-floor basalt is typically younger than 200 million years old and therefore does not provide evidence of Earth's age (**B**). The physical character of the upper mantle was not determined through analysis of the magnetism of ocean-floor basalt (**C**). The upper mantle is solid and together with oceanic crust constitute oceanic lithosphere.

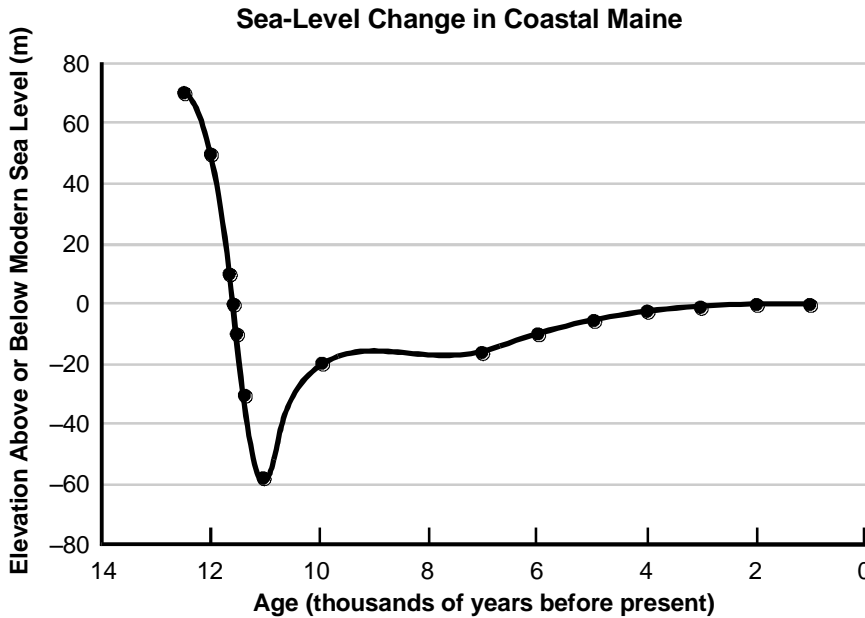
28. The broad shape and gentle slope of Hawaiian volcanoes are, to a great extent, a result of the erupted magma's:
- A. high gas content.
 - B. mafic composition.
 - C. low iron content.
 - D. felsic composition.

Correct Response: B. The shape of Hawaiian shield volcanoes results from the mafic composition of the magma that generates low-viscosity magma flows during eruptions. This lava's viscosity is low so the lava generated is very fluid and flows easily over long distances before solidifying. The gas content (**A**) of magmas feeding Hawaiian-style eruptions is low and although it does affect viscosity, is not as important as the magma's silica content. Hawaiian lavas are mafic and their relatively high iron content (**C**) is not a major factor in the lava's low viscosity. Lava with a felsic composition (**D**) is more viscous than mafic lava and is associated with more explosive stratovolcanoes and not Hawaiian-style shield volcanoes.

29. Which of the following are landscape features typically associated with an active strike-slip fault?
- A. hanging valleys and tarns
 - B. kame terraces and eskers
 - C. horsts and grabens
 - D. scarps and sag ponds

Correct Response: D. Scarps and sag ponds are typical features associated with strike-slip faults. As the land surrounding the faults is offset by lateral movement along the fault, some vertical movement of the land on either side of the fault creates fault scarps. Sag ponds are small water bodies that occupy depressions created where fault movements have created depressions that impound drainage. Hanging valleys and tarns (**A**) and kame terraces and eskers (**B**) are landforms associated with glaciers, not faulting. Horst and graben (**C**) refer to landforms where normal faulting has pushed some blocks of crust upward (horst) and caused some blocks to drop down (graben). Horst and graben features are not typically associated with strike-slip faults.

30. Use the graph below to answer the question that follows.



The graph above shows the approximate change in sea level along the coast of central Maine over the past 13,000 years. Which of the following is primarily responsible for the sudden drop in sea level that occurred along Maine's coast between 12,500 years ago and 11,500 years ago?

- A. isostatic rebound of the bedrock crust resulting from the melting of continental glaciers
- B. rapid erosion of unconsolidated glacial deposits due to climate changes
- C. tectonic uplift of the region resulting from the subduction of the North American plate
- D. sudden resurgence of continental glaciers due to major shifts in ocean circulation

Correct Response: A. In regions where continental glaciers existed for millennia, such as coastal Maine, the weight of thousands of feet of ice pushed down the bedrock, causing isostatic adjustment of the crust. When the glaciers melted during the late Quaternary, the weight on the crust was reduced and it rose by isostatic readjustment. This caused a local drop in sea level as continental crust throughout the northeast rose relative to the ocean surface. Rapid erosion of glacial sediments (**B**) was not a major factor in the isostatic rebound of the region. The eastern seaboard does not have a subduction zone (**C**) and tectonic uplift typically operates on longer time scales. Retreating continental glaciers did re-advance between 12,900 and 11,700 years ago due to changes in ocean circulation (**D**) in an event called the Younger Dryas. This event reduced the rate of sea-level rise, but did not cause a drop in sea level.

31. Lichens, plant roots, and fungi are able to chemically weather rock. These organisms typically accomplish this by:
- A. drawing molecular water from the crystals that make up the rock.
 - B. producing acids that cause the decomposition of the rock.
 - C. extracting minerals directly from the rock through osmosis.
 - D. manufacturing salts that alter the rock's crystal structure.

Correct Response: B. Lichens, plant roots, and fungi can produce weak acids to break down rock. This is an important part of weathering that makes the minerals in rocks available for use by these organisms and others. Molecular water that exists in the crystal structure of some minerals is bound to the minerals and typically not available for biological activity (**A**). These organisms cannot extract minerals directly from rocks through osmosis because osmosis is the diffusion of water (**C**), and while salts can cause chemical weathering they are not produced by these organisms (**D**).

32. Which of the following properties of water is primarily responsible for its role in mechanical weathering?
- A. Water increases in density as it goes from 0°C to 4°C and then decreases above 4°C.
 - B. The capacity of liquid water to store heat energy is very high.
 - C. The hydrogen bonding between water molecules gives it a high surface tension.
 - D. Water increases in volume as it goes from a liquid to a solid state.

Correct Response: D. Water expands its volume as it freezes. This property causes water that has moved into rock fractures and crevices to push against the rock when temperatures drop below freezing. The pressure created by the expansion of water is an important cause of mechanical weathering in regions where temperatures drop below freezing. The slight change in water's density and volume as it warms above freezing (**A**) is not a major factor in mechanical weathering. Water's high specific heat (**B**) and relatively high surface tension (**C**) are not primarily responsible for water's ability to mechanically weather rock.

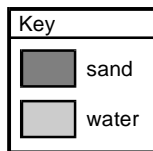
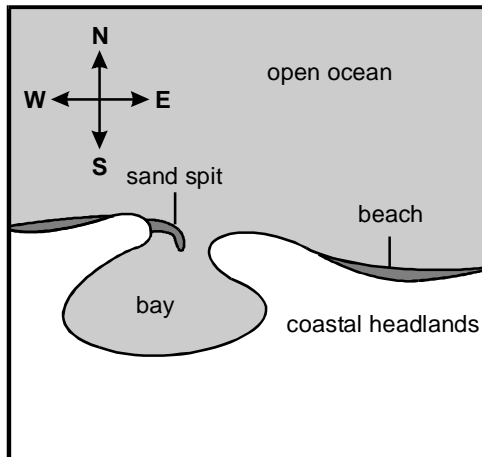
33. In some desert regions, a thin layer of closely packed pebbles and cobbles covers the ground surface. This phenomenon, known as desert pavement, is primarily caused by the:
- A. differential erosion of sediments by wind.
 - B. slow dispersal of material from the base of alluvial fans by gravity.
 - C. breakup of bedrock under hot and dry conditions.
 - D. deposition of coarse-grained sediments during flash flooding.

Correct Response: A. Scientists believe desert pavement forms by different processes, however the most common process is believed to be differential erosion of the surface by wind; a process called deflation. Over thousands of years, smaller particles are removed from the surface by wind, leaving behind a flat surface primarily composed of pebbles and cobbles. Dispersal of alluvial fan deposits from the base of an alluvial fan as sediments move downward due to gravity is not thought to play a direct role in desert pavement formation (**B**) and although alternating hot and cold temperatures in the desert can support mechanical weathering (**C**), the process is not thought to play a role in desert pavement formation either. Although water carrying fine sediments in sheet flows may play a role in forming some types of desert pavement, flash floods carrying coarse sediments do not (**D**).

34. In New England, it is common to find striations in the surface of exposed rock outcrops. These linear grooves are primarily produced by:
- A. ice that is well below its freezing point at the base of surging glaciers.
 - B. extreme temperature changes that produce fractures in the bedrock underlying glaciers.
 - C. large rocks that are embedded in the base of glaciers.
 - D. silt-rich water under tremendous pressure at the base of continental glaciers.

Correct Response: C. Striations in the bedrock of glaciated regions are linear gouges and scratches in bedrock produced by rocks stuck to the bottom of a cold-based glacier. Glacial ice is capable of eroding rock, but is not strong enough to create long linear gouges (**A**) in bedrock. Extreme temperature changes can cause mechanical weathering, but do not produce the long linear scratches and gouges that comprise striations (**B**). Although sub-glacial, sediment-rich water can erode the bedrock beneath a glacier, it does so relatively evenly and does not produce striations (**D**).

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



Which of the following best explains the formation of the sand spit across the entrance to the bay shown in the above diagram?

- A. Coastal winds blowing from the east move sand from the beach to the entrance of the bay where tides alter the shape of the deposit.
- B. Longshore currents flowing from the west slow down and deposit sand where they cross the entrance to the bay.
- C. Tidal currents flowing north and south slow down and deposit sand where they flow in and out of the entrance of the bay.
- D. Ocean waves move the beach sand toward the west where it is carried into the entrance of the bay and modified by tidal currents.

Correct Response: B. As an eastward-flowing longshore current carries sediment along the coastline depicted in the diagram, the current slows where it flows across the bay inlet. The current's reduced velocity causes deposition of sand at the bay mouth. Wind certainly redistributes coastal sand, but the sand that forms spits arrives primarily through deposition from the prevailing longshore current (**A**). Tidal currents tend to be stronger at the mouth of a bay and not weaker, so they tend to work against the formation of spits (**C**). If ocean waves were flowing toward the west in the diagram, the sand spit would be forming on the east side of the bay mouth (**D**) and, although the tidal currents can modify the spit, they would not move the sand across the bay mouth to its west side.

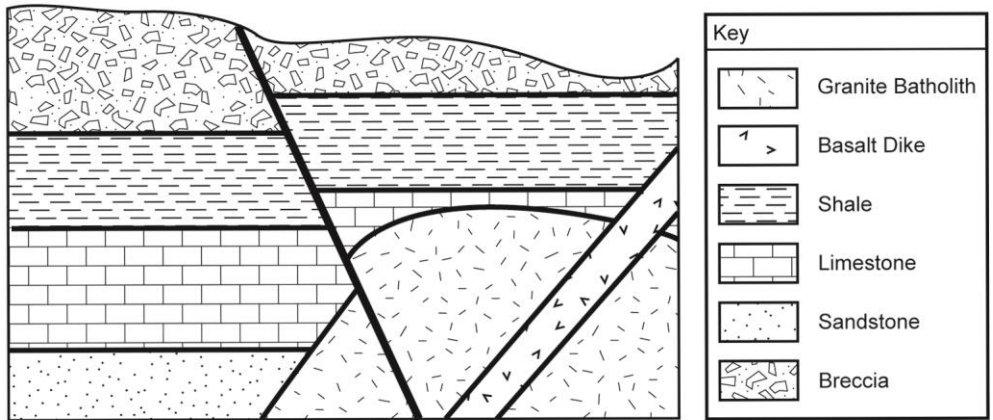
36. During which of the following epochs was Long Island, Cape Cod, and Martha's Vineyard formed?
- A. Eocene
 - B. Miocene
 - C. Pliocene
 - D. Pleistocene

Correct Response: D. Cape Cod and the nearby islands of Martha's Vineyard and Nantucket are largely composed of sand deposited during the advance and retreat of the last continental ice sheet (i.e., the Laurentide ice sheet). This occurred toward the end of the Pleistocene Epoch of the Quaternary Period. Cape Cod and the islands did not exist during the much earlier Eocene Epoch of the Paleogene Period (**A**). The Miocene Epoch (**B**) and the Pliocene Epoch (**C**) are part of the Neogene Period. The Neogene lasts until the onset of the Pleistocene Epoch glaciations approximately 2.6 million years ago. This was a period of gradual cooling that ultimately led to the continental glaciations of the Pleistocene Epoch, but Cape Cod and the islands did not yet exist at this time.

37. The extensive coal beds that formed during the Pennsylvanian period are primarily made from:
- A. the compressed remains of microscopic marine organisms.
 - B. solidified oil deposits that were slowly heated over millions of years.
 - C. the fossilized remains of swamp vegetation.
 - D. lithified mud deposited when shallow seas covered parts of North America.

Correct Response: C. The coal deposits of the Pennsylvanian Period (also known as the Upper Carboniferous) are sedimentary deposits formed primarily from swamp vegetation. The period lasted from approximately 320 million years ago until 300 million years ago and was a time when equatorial regions were covered in forest swamps of seedless plants. These plants provided most of the carbon for the coal characteristic of the period. The movement of tectonic plates eventually shifted these deposits northward. The remains of microscopic marine organisms (**A**) are the primary source for the compounds that make up natural gas and petroleum, not coal. Solidification of oil deposits does not produce coal (**B**), but slow drying out of petroleum deposits can form natural asphalt (also known as bitumen). Lithification of mud (**D**) produces siltstone, claystone, and shale, but not coal.

38. Use the graphic below to answer the question that follows.



No overturned strata. Not to scale.

In the geologic cross section shown above, a fault has offset the geologic features exposed in the cross section. Which of the following statements about the sequence of geologic events is confirmed by the relationships in the cross section?

- A. The basalt dike was intruded after the faulting occurred.
- B. The granite batholith was intruded after the breccia was deposited.
- C. The fault occurred while the shale was being deposited.
- D. The basalt dike was intruded after the sandstone was deposited.

Correct Response: D. The only statement that can be confirmed by the relationships depicted in the geologic cross-section is that the basalt dike was intruded after the sandstone was deposited. The cross-section shows that the batholith intruded into the sandstone and therefore must have occurred after the sandstone was deposited. Since the dike intrudes the batholith, the intrusion of the dike must have happened after the sandstone was deposited as well. The cross-section does not indicate when the faulting occurred relative to the intrusion of the dike (**A**) and since the granite does not intrude the breccia, it is impossible to say if it occurred before or after the breccia deposition (**B**). Since the breccia is offset by the fault, the faulting could not have occurred until after the shale was deposited (**C**).

39. Measuring the age of a lava flow by radiometric dating requires:
- A. comparing the proportion of radioactive parent isotope to stable daughter product in the rock.
 - B. assessing the level of radioactivity emitted by the isotopes in a sample of the rock with a Geiger counter.
 - C. evaluating the changes in the rock's mineral structure to determine the sample's exposure to ionizing radiation.
 - D. analyzing changes in the atomic number of the radioactive isotopes in the rock by measuring beta and alpha emissions from a sample.

Correct Response: A. Radiometric dating techniques, including those used to date lava flows, compare the amount of radioactive parent isotope to the amount of stable daughter product in a sample of the rock. Radioactive decay of a particular isotope into its daughter products occurs at a known rate called the isotope's half-life. Once the lava flow has cooled, radioactive isotopes are locked into the crystal structure and the daughter products begin to build up in the rock. Measuring the lava's radioactivity (**B**) or measuring alpha and beta particle emissions and the change in the isotope's atomic number (**D**) do not provide an age estimate tool because the amount of isotope originally in the rock is unknown and the amount of radioactive material in the rock may be extremely small. Ionizing radiation can alter the composition of a rock (**C**) and this fact is used in thermoluminescence dating, but not radiometric dating.

40. Graded bedding in a sedimentary rock is an indication of which of the following depositional environments?
- A. desert
 - B. high-energy beach
 - C. marginal marine
 - D. alluvial fan

Correct Response: C. Graded bedding in sedimentary rock strata is the change in sediment grain size from the base of the bed to the top. Normal graded bedding is the most common and shows coarser grain size at the bottom with increasingly finer sediments toward the top of the bed. This kind of bedding is often associated with sedimentary rocks that formed in marginal marine environments, such as coastal deltas and turbidity flows. Desert depositional environments (**A**) such as a dune and high-energy beach deposits (**B**) are more likely to exhibit cross-bedding with little change in grain size. Alluvial fan sediments (**D**) are typically deposited rapidly during flash floods and as a consequence are usually composed of heterogeneous sediments that have poorly defined bedding or no bedding at all.

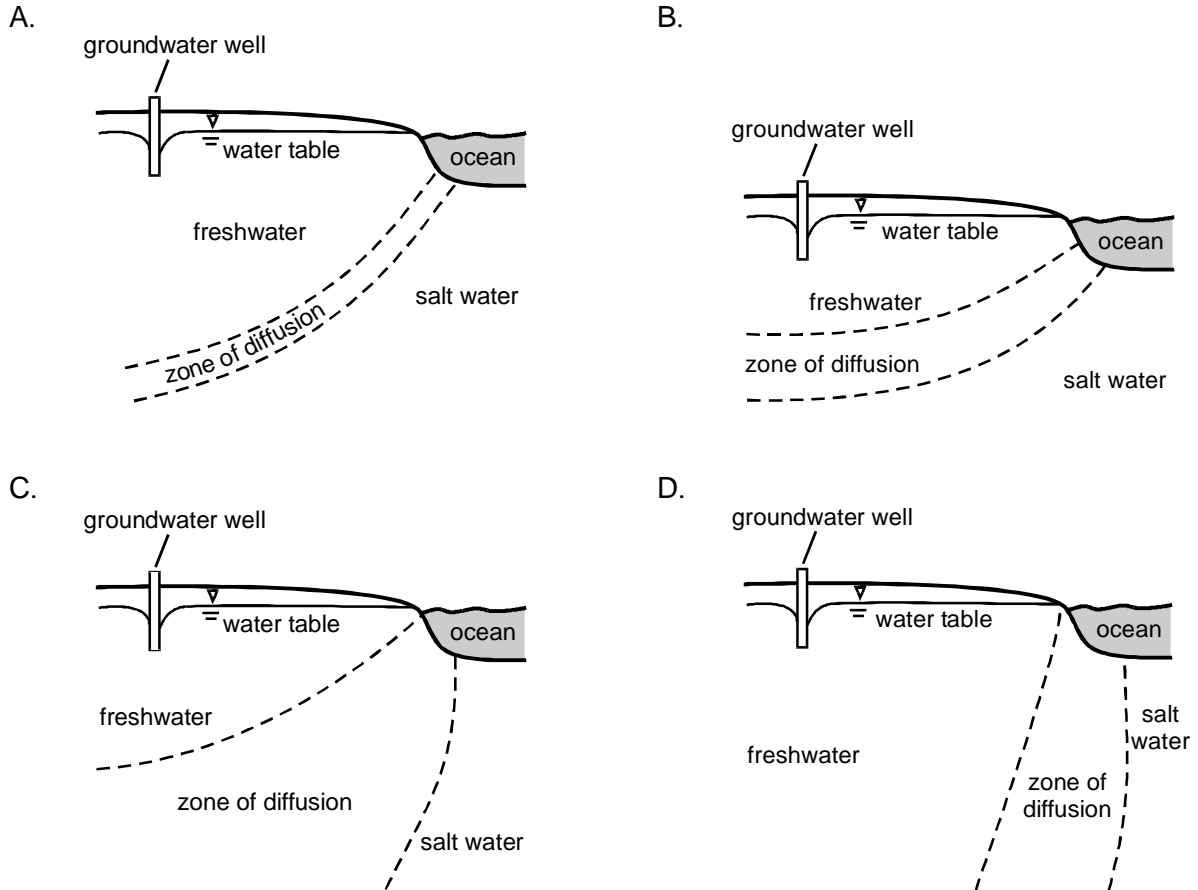
41. Water in its solid form is less dense than water in its liquid form. This characteristic is primarily a result of the:
- A. rigid three-dimensional structure of ice that keeps water molecules from getting too close to each other.
 - B. high viscosity of liquid water that makes its molecules more closely packed than other liquids.
 - C. internal kinetic energy of ice that keeps the molecules in ice relatively far apart due to their rapid vibration.
 - D. high heat capacity of liquid water that allows it to store energy with only a small change in volume.

Correct Response: A. Unlike most other substances, water becomes less dense as it is cooled below freezing to form ice. The rigid crystal structure of ice makes it less dense than liquid water because molecules in liquid water are constantly changing position and maximizing hydrogen bonding between water molecules. This allows liquid water molecules to pack more closely than water molecules that are frozen into a crystal structure. Viscosity is a measure of the internal friction of a substance and the viscosity of water (**B**) is not a factor directly responsible for the relatively low density of ice. Although the water molecules in ice are constantly vibrating (**C**), it is not that characteristic of ice that is responsible for its low density. The high heat capacity of liquid water (**D**) results from the hydrogen bonding between water molecules and is not directly the cause of ice's low density.

42. The High Plains Aquifer extends from South Dakota to central Texas. Since the early 1900s, the surface of the aquifer has dropped significantly in parts of Texas, Oklahoma, and Kansas. This change in the aquifer is primarily due to which of the following?
- A. a reduction in forest cover from logging that has increased evaporation rates from exposed soils overlying the aquifer
 - B. a shift in climate conditions during the past 100 years that has reduced the water available for aquifer recharge
 - C. the compaction of soils from mechanized farming that has reduced the permeability of soils overlying the aquifer
 - D. the withdrawal of water for agricultural use that has been greater than the aquifer's recharge rate from precipitation

Correct Response: D. The depletion of the High Plains Aquifer has been caused primarily by water withdrawals for agriculture in a geographic region that does not have sufficient precipitation to recharge the aquifer. Much of the water in the aquifer entered the aquifer during the last ice age when precipitation in the region was greater. There is limited forest cover in the semi-arid High Plains so changes in forest cover (**A**) are not responsible for the depletion of the aquifer. Although periods of drought have not benefited the aquifer in recent years (**B**), recent climate change is not the primary cause of the aquifer's depletion. Soil compaction (**C**) has likely played a very small role in reducing recharge rates in the area, but this is not a significant factor when compared with the tremendous water withdrawals for agriculture.

43. In a coastal freshwater aquifer where withdrawals are in equilibrium with the recharge rate, which of the following diagrams best represents the interface between salt water and freshwater?

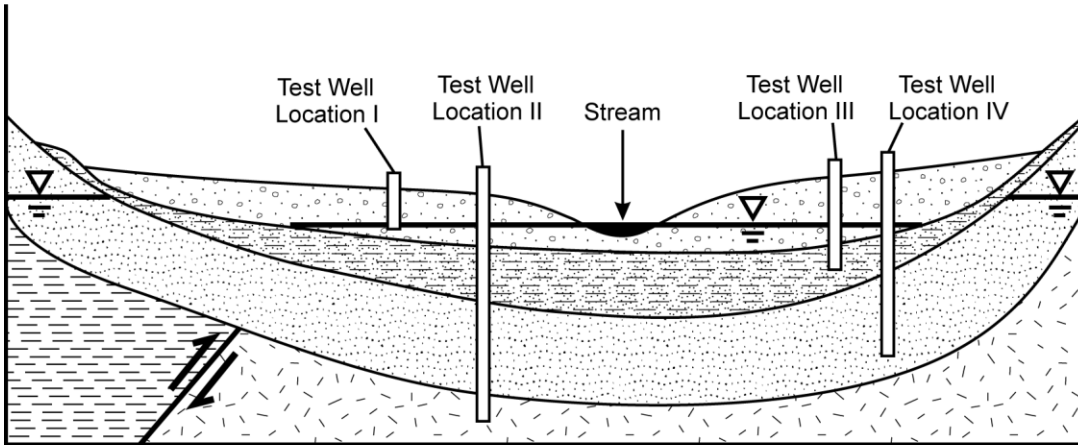


Correct Response: A. The zone of diffusion between a freshwater aquifer underlying a coastal area and the salt water of the ocean is relatively thin and slopes under the freshwater aquifer in areas near the coast. Excessive pumping of freshwater over the zone diffusion can cause the zone of diffusion to move inland and closer to the well intake. In extreme cases this can cause the abandonment of coastal wells as salt water intrudes into the freshwater aquifer. In the second diagram (**B**) the zone of diffusion is illustrated as nearly horizontal beneath the well and that is not accurate. In the third diagram, the zone of diffusion is depicted as being too broad (**C**) and in the final diagram (**D**) the salt water is shown as being entirely offshore, which also does not accurately depict the zone of diffusion.

44. The hydraulic conductivity of a sediment is a measure of the rate at which the sediment can transmit water. Which of the following sediments is likely to have the greatest hydraulic conductivity?
- A. a poorly sorted mixture of fine- and medium-sized sand grains
 - B. a well-sorted silt deposit
 - C. a poorly sorted mixture of clay and small gravel
 - D. a well-sorted coarse-sand deposit

Correct Response: D. A well-sorted coarse-sand deposit will have the largest pore spaces between grains and the pore spaces will be better connected because of the uniform grain size in a well-sorted sand. This combination means both the porosity and hydraulic conductivity of the sand will be high, allowing for relatively rapid transmission of water through the sediment. A poorly sorted mixture of fine- and medium-grain sediments (**A**) will have a relatively low porosity as many spaces between the coarser grains will be filled with fine-grain sediments. This also blocks water transmission and leads to relatively low hydraulic conductivity. Silt deposits (**B**) are too fine-grained to have a high hydraulic conductivity and the tiny particles of clay in a clay-and-gravel deposit (**C**) will effectively fill the pore spaces and greatly reduce transmission of water through the sediment.

Use the information below to answer the three questions that follow.



No overturned strata. Not to scale.

Key	
	Granite
	Shale
	Medium Sand
	Sand and Gravel
	Clay Aquitard
	Water Table Surface
	Fault Zone

The above geologic cross section of a New England river valley shows two distinct aquifers, the underlying bedrock geology, and the sedimentary deposits overlying the bedrock. Four test wells have been drilled in the valley to different depths in an attempt to locate a high-yield groundwater supply for a town in the area.

45. Which of the following explains the primary reason why the water table surfaces of the two different aquifers are at different elevations?
- A. The water in the medium sand is confined by the clay layer and does not interact with the unconfined surface aquifer.
 - B. The water from the stream is seeping into the surrounding sand and gravel, keeping it at the same level as the stream surface.
 - C. The recharge of groundwater on the hillsides of the valley is greater than it is in the center of the valley due to the greater slope.
 - D. The recharge volume of both aquifers is affected by differences in the sediments through which surface waters percolate into the ground.

Correct Response: A. The medium sand aquifer is a confined aquifer separated from the surface aquifer by a clay aquitard that does not transmit water. Since the two aquifers are not connected hydrologically and the confined aquifer is under pressure, the two aquifers will usually have different water-table surface elevations. The unconfined surface aquifer is hydrologically connected to the river (**B**), but that does not explain the difference in elevation of the two water tables. It is unlikely that recharge is greater on a slope than down in the river valley (**C**) and there is nothing in the diagram that indicates there is a difference in the recharge rate of the two aquifers. The difference in the sediments of the two aquifers (**D**) does not significantly affect the volume of water that recharges each aquifer or the aquifers' different surface elevations.

46. In which of the following test well locations will the depth and location of the well shown in the cross section be most likely to yield a regular and abundant source of groundwater throughout the year?
- A. test well location I
 - B. test well location II
 - C. test well location III
 - D. test well location IV

Correct Response: D. Test well location IV is in the confined aquifer and is the most likely to provide a regular and abundant supply of water year-round. This is because test well location I (**A**) is near the top of the surface aquifer and so even a small drop in the water table during the summer will stop the flow of water into the well. Test well location II (**B**) is drilled into the granite, a material with a relatively low ability to transmit water (hydraulic conductivity), so it is likely it will also be a poor source of groundwater. Test well location III (**C**) is drilled into the clay aquitard, a layer of clay sediment that by definition has very low hydraulic conductivity.

47. Other than precipitation, which of the following is the most likely direct source of water for the aquifer composed of the medium sand deposit?
- A. shale
 - B. stream
 - C. fault
 - D. granite

Correct Response: C. The fault in the granite can be a source of recharge for the medium sand aquifer because geologic faults often contain water under pressure that can flow upward into an overlying aquifer. Although it is hard to predict whether a particular fault will provide substantial recharge for an aquifer, faults are often an important source of recharge in a variety of geologic settings. Shale (**A**) and granite (**D**) typically have poor hydraulic conductivity and are an unlikely source of significant recharge for the medium sand aquifer. Since the stream (**B**) is separated from the confined medium sand aquifer, it could not be a direct source of water for that aquifer.

48. Which of the following ocean surface water masses is likely to have the greatest density?
- A. cold and relatively high salinity waters of the North Atlantic Ocean
 - B. warm and high salinity waters of the Caribbean Sea
 - C. cold and moderately saline waters of the equatorial eastern Pacific Ocean
 - D. warm and low salinity waters of the South China Sea

Correct Response: A. The cold, high salinity water of the North Atlantic has the greatest density because higher salt concentration and cold temperature increase water's density. Below 4°C the density of water drops slightly, but most of the water of the north Atlantic is above that temperature. As a result of this relationship between density and the salinity and temperature of water, warm high salinity water (**B**) will have a lower density than cold, high salinity water. Cold water with moderate salinity (**C**) will have a lower density than cold water with high salinity and warm water with relatively low salinity (**D**) will also be less dense than cold water with high salinity.

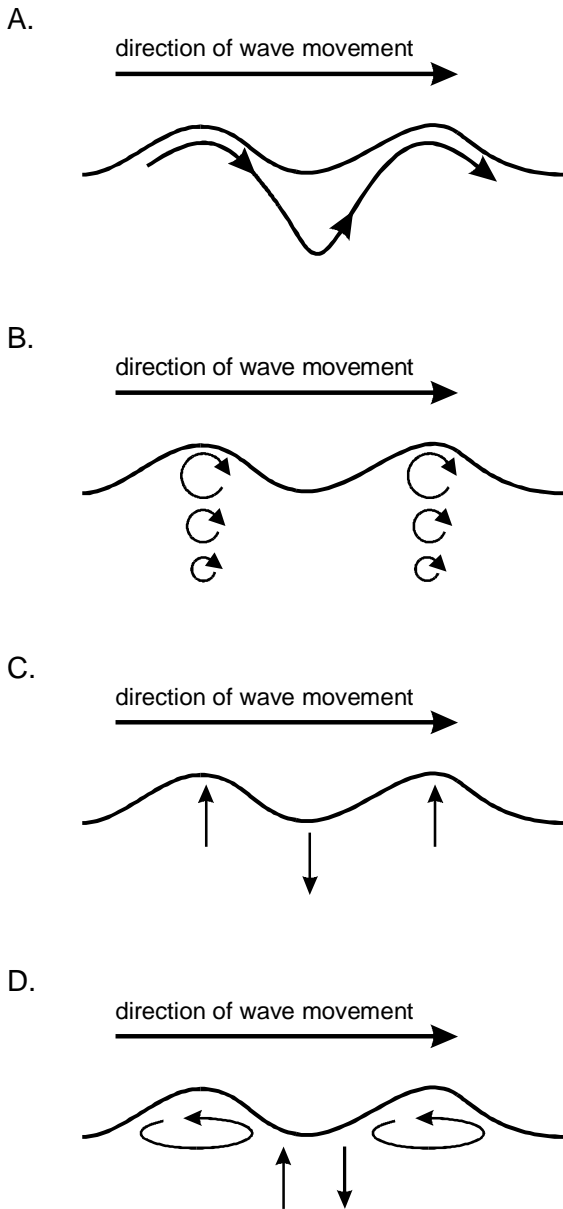
49. In recent years, scientists have documented a drop in the salinity of the North Atlantic Ocean. The primary concern of scientists studying this phenomenon is that a large drop in the salinity of North Atlantic water would affect the:
- A. acidity of the surface water in one of the world's most important fisheries.
 - B. amount of precipitation in the temperate latitudes of the Northern Hemisphere.
 - C. rate at which heat is transferred northward by the Gulf Stream.
 - D. formation of sea ice in a region already under stress from climate change.

Correct Response: C. The slight decrease in salinity of North Atlantic surface waters has reduced the water's density. This change likely results from increased freshwater influx from Greenland's melting ice sheet. A substantial drop in salinity will reduce the rate at which North Atlantic surface waters sink. Since this sinking water pulls the Gulf Stream's warm water northward as part of the ocean's thermohaline circulation, this change could alter the region's climate. Salinity does affect water pH (**A**), but it is not the primary concern of scientists studying changes in salinity in the region. The change in salinity would be unlikely to directly affect precipitation in the region (**B**) and although it would increase the formation of sea ice (**D**) in far northern areas, this is not a concern for scientists studying the phenomenon.

50. The movement of deep-ocean currents is driven primarily by which of the following?
- A. the transfer of surface wave energy through friction
 - B. gravitational effects of the Moon
 - C. the orbit and rotational motion of Earth
 - D. temperature and salinity gradients

Correct Response: D. Deep-ocean currents are part of the ocean's thermohaline circulation, which is driven by temperature and salinity gradients in the oceans. Deep-ocean currents are not affected by surface wave energy (**A**) as the energy of surface waves dissipates rapidly with depth. The Moon's gravitational pull is a major driver of ocean tide cycles, but it does not have a significant effect on deep-ocean currents (**B**). Although Earth's orbital and rotational motion affects ocean circulation (**C**), it is not a primary driver of the thermohaline circulation that produces deep-ocean currents.

51. Which of the following cross-sectional diagrams best depicts the motion of water particles in a nonbreaking ocean wave?



Correct Response: B. Non-breaking waves on the surface of the deep ocean are generated by wind blowing along the surface. While these waves propagate across the surface, the water in the waves does not. The fluid particles of water within the undulating surface waves move in place in an orbital motion around their average position. The diameter of this orbital path decreases with increasing distance from the surface. The particles do not propagate in the direction of wave motion (**A**) and do not rise up and down in straight vertical paths (**C**). Nor do the particles in a propagating wave combine elliptical orbital motion and vertical displacement (**D**) as the surface of the water undulates up and down.

52. Over the past 50 years, the Mississippi Delta has diminished in size as the Gulf of Mexico has flooded many areas that were previously above sea level. This has been primarily the result of which of the following processes?
- A. overuse of groundwater resources and the consequent sinking of the land surface of the delta
 - B. downwarping of the North American plate and the resulting drop in the overlying delta deposits
 - C. increased frequency of major tropical storms and the related increase in erosion of the delta
 - D. reduced replenishment of sediment and ongoing compaction of delta deposits

Correct Response: D. The sediments of the Mississippi Delta are constantly compacting under their own weight. Regular input of new sediment from the Mississippi River maintained the areal extent of the delta for millennia by adding sediment to the surface. Flood control levees, changes in land use, and channelization of the lower Mississippi have substantially reduced sediment input. Without sediment input, wave action and compaction have caused the Mississippi River Delta to rapidly decrease in areal extent as it drops below the water's surface. Overuse of groundwater in the region (**A**) is not a major factor affecting the delta's size and the North American plate is not downwarping in the region (**B**). Although major storms play a role in eroding the delta, they have not increased in frequency (**C**) and are not the primary cause of the delta's relatively rapid decrease in size.

53. The narrow longshore currents that transport sand grains along the immediate coastline are primarily produced by:
- A. tidal forces that fluctuate throughout the day.
 - B. local winds that blow parallel to the beach.
 - C. waves that strike the beach at an angle.
 - D. beach runoff that carries water back into the surf.

Correct Response: C. Longshore currents that transport sand grains and other sediments along the immediate coastline are driven by the waves striking the shore at an angle. When a wave reaches a beach or coastline, it releases a burst of energy that generates a current, which runs parallel to the shoreline. This type of current is called a longshore current. Tidal forces that affect local sea level are not a primary factor driving longshore currents (**A**) and while prevailing winds (**B**) do produce the waves, they do not release the energy that generates the current. Beach runoff or backwash (**D**) is a source of sediment for longshore drift (the movement of sediment down the shoreline), but is not the source of energy for longshore currents.

54. Which of the following sedimentary rocks would most likely have formed from sediments accumulating in a deep-ocean trench?
- A. shale
 - B. sandstone
 - C. breccia
 - D. limestone

Correct Response: A. A deep-ocean trench is an offshore environment with very still water. Shale is a sedimentary rock that forms by compaction of fine-grained sediments that have slowly settled out of very slow moving water. Of the response choices, shale is the only likely sedimentary rock that would be expected to have formed in such a depositional environment. Sandstone (**B**) is typically associated with higher energy depositional conditions such as beaches and rivers. Breccia (**C**) is a sedimentary rock composed of angular fragments cemented together with finer grained sediments and is most often associated with high-energy depositional environments, such as desert flash floods or sheet wash deposits from steep hillsides. Limestone (**D**) is a carbonate sedimentary rock that most often forms from the shells of marine organisms in relatively shallow and warm marine environments and is not associated with deep-ocean trench depositional environments.

55. Submerged flat-topped seamounts called guyots are found in a variety of locations in the world's oceans. These guyots are typically formed through which of the following processes?
- A. the growth of coral reefs
 - B. the accumulation of marine diatoms
 - C. the erosion of volcanic islands
 - D. the uplift of tectonic plate fragments

Correct Response: C. Guyots are the submerged and eroded remnants of volcanoes that originally grew up from the ocean floor to build above the ocean surface. As ocean volcanoes become inactive and cool they slowly sink into the oceanic crust. The evidence suggests that guyots start out as isolated volcanoes that grew above the ocean surface and then slowly sank. During the first stages of subsidence, fringing reefs develop around them. With continued subsidence, they become coral atolls and, finally with continued subsidence, they become entirely submerged flat-topped seamounts. Although reefs grow around guyots (**A**), guyots are not formed through the growth of coral reefs. As they are primarily composed of volcanic rock, guyots are not accumulations of marine diatoms (**B**). Tectonic plate fragments are typically uplifted at active plate margins and not within oceanic plates (**D**) and so are not associated with guyot formation.

56. Scientists believe that submarine canyons that formed well below sea level and cut to the bottom of the continental rise most likely were produced when:
- A. fine-grained marine sediments of the continental shelf were fractured by the weight of the overlying water.
 - B. geologic faults lying perpendicular to the continental shelf ruptured, offsetting overlying sediments.
 - C. turbidity currents scoured channels in the unconsolidated sediments of the continental shelf.
 - D. dense freshwater from coastal rivers flowed down over the continental shelf, eroding soft marine muds.

Correct Response: C. Turbidity currents form when gravity and seafloor currents move massive volumes of river sediment over the continental shelf. Turbidity currents can occur when large amounts of sediment accumulated near the edge of the continental shelf collapse due to their own weight or from the shaking of an earthquake. The sediments rapidly flow down the slope, carving out a submarine canyon in the process. Although earthquakes and settling can cause cracks in shelf sediments (**A**), this mechanism is not in itself sufficient to create submarine canyons. Movement along offshore faults (**B**) may trigger a turbidity current, but in itself faulting is not what forms submarine canyons. Freshwater is less dense than saline ocean water and therefore does not play a role in scouring out submarine canyons (**D**) that cut to the bottom of the continental rise.

57. The Atlantic Ocean began to form as a result of which of the following geologic events?
- A. the erosion of a plate margin from repeated continental glaciations
 - B. the subduction of one continental plate beneath another
 - C. the development of a large syncline east of the Appalachian Mountains
 - D. the growth of a rift valley along a major fracture zone in the crust

Correct Response: D. The Atlantic Ocean formed as a consequence of the breakup of Pangaea. The breakup occurred in several stages over millions of years, beginning 175 million years ago in the Middle Jurassic. Pangaea began to break into separate continents as a consequence of geologic rifting of continental crust. The rift developed into a divergent plate boundary that pushed the plates apart, eventually forming the Atlantic Ocean basin. Erosion caused by continental glaciations (**A**) is not a process capable of initiating the formation of a major ocean basin and no continental glaciations occurred during the Middle Jurassic. Subduction (**B**) occurs along convergent plate boundaries and could not have initiated the formation of the Atlantic Ocean basin. The development of a syncline to explain the initial formation of the Atlantic Ocean basin (**C**) is not consistent with modern plate tectonic theory.

58. Which of the following geologic structures is characteristic of a passive continental margin?
- A. a thick sedimentary platform
 - B. an inundated forearc basin
 - C. a complex accretionary wedge
 - D. an active fault zone

Correct Response: A. Passive plate margins of continents, such as the eastern coast of the United States, are composed of continental crustal rocks covered in thick sedimentary deposits. A geologic platform is the part of a continent covered by horizontal or gently tilted, mostly sedimentary, strata. Along passive plate margins these deposits make up the thick sediments of the continental shelf. Forearc basins (**B**) form in association with subduction zones at active and not passive plate margins. An accretionary wedge (**C**) is also associated with subduction zones at convergent plate boundaries where an oceanic plate is subducted beneath a continental plate. Passive continental plate margins are not associated with active fault zones (**D**) because the continental crust at these margins is typically not being fractured or compressed by tectonic forces.

59. Which of the following organisms is most responsible for fixing atmospheric carbon dioxide to create organic molecules?
- A. coral polyps
 - B. bacteria
 - C. phytoplankton
 - D. protozoa

Correct Response: C. Phytoplankton are microscopic marine plants that fix atmospheric carbon dioxide as they use sunlight to make organic molecules during photosynthesis. Coral polyps are marine animals in the phylum Cnidaria and do not fix atmospheric carbon dioxide (**A**). While one phylum of bacteria (**B**) (i.e., cyanobacteria or blue-green algae) do photosynthesize and fix carbon dioxide, the vast majority of bacteria do not. Protozoa (**D**) digest the food they take in from their environment in vacuoles and do not fix atmospheric carbon dioxide. Although protozoa constitute a complex and diverse group of microscopic eukaryotes, they were traditionally considered to be animal-like to distinguish them from photosynthesizing phytoplankton and because of their motility and predatory behavior.

60. Which of the following is a critical part of the increase in primary productivity that occurs during the summer months in the Arctic Ocean?
- A. Increased sunlight supports sustained growth of phytoplankton.
 - B. Seasonal influx of nutrients from snowmelt stimulates the rapid growth of algae.
 - C. Mixing of deep water with surface water brings essential nutrients up to the photic zone.
 - D. Spring winds cause increased oxygenation of the surface waters, promoting zooplankton blooms.

Correct Response: A. Primary productivity of the Arctic Ocean increases during summer as warming temperatures melt sea ice, allowing sunlight to penetrate surface waters. The increased light stimulates growth of phytoplankton, triggering a rapid increase in primary productivity. Primary productivity is affected by the availability of sunlight, carbon dioxide, and nutrients, but nutrients from snowmelt are not a critical factor in the seasonal increase in primary productivity (**B**) in this region. Although upwelling of nutrient-rich deep water does bring essential nutrients to the surface (**C**), it primarily occurs in a small area of the Beaufort Sea in the Arctic Ocean and is not a critical component of the phytoplankton growth that increases primary productivity throughout the Arctic Ocean. Wind-driven oxygenation of Arctic Ocean surface waters (**D**) is also not a critical component of summer increases in the primary productivity of the Arctic Ocean.

61. The colorful displays in the atmosphere known as the aurora borealis result from which of the following?
- A. the nuclear disintegration of radioactive isotopes in the thermosphere during solar storms
 - B. the combustion of dust particles in the stratosphere during the peak of the sunspot cycle
 - C. the chemical reaction of molecules in the troposphere from ionizing solar radiation
 - D. the excitation of gases caused by the interaction of the solar wind and the magnetosphere

Correct Response: D. The aurora borealis results from electrons in the solar wind interacting with Earth's magnetosphere. The electrons travel along Earth's magnetic field to the poles where they collide with oxygen and nitrogen atoms and molecules in the upper atmosphere. The electrons transfer their energy to the atmosphere, exciting the atoms and molecules to higher energy states. As the atoms and molecules return to lower energy states, they give off light energy. Solar storms do not trigger the nuclear disintegration of radioactive isotopes in the thermosphere (**A**) and peaks in the solar cycle do not cause stratospheric dust to combust (**B**). Although solar radiation causes photoionization of molecules in the thermosphere, it is not a cause of the aurora borealis (**D**).

62. Which of the following explains why the sky appears blue?
- A. Air molecules selectively scatter the shorter wavelengths of visible light.
 - B. Air molecules reflect the longer wavelengths of visible light.
 - C. Water vapor refracts visible light into its component frequencies.
 - D. Water vapor selectively absorbs visible light at certain wavelengths.

Correct Response: A. When sunlight strikes Earth's atmosphere, it is scattered by molecules in the atmosphere. These molecules are much smaller than the wavelengths of visible light in sunlight. This is called Rayleigh Scattering and it selectively affects shorter wavelengths at the blue-violet end of the visible spectrum more than longer wavelengths. As a result, blue wavelengths are much more widely scattered across the sky than other wavelengths, giving the sky its blue color. Although some long wavelengths in sunlight are reflected, reflection of longer wavelengths (**B**) is not responsible for the sky's color. Sunlight is refracted as it passes through water droplets, but it is not refracted by gaseous water vapor (**C**) and therefore does not affect the sky's color. While water vapor accounts for up to 70% of the absorption of incoming sunlight, its selective absorption of different wavelengths does not cause the sky to appear blue (**D**).

63. Overcast nights tend to be warmer than clear nights even when temperatures on the preceding day have been the same. This is primarily because on overcast nights:
- A. evaporation rates are substantially reduced.
 - B. clouds radiate infrared energy downward.
 - C. convection currents are unable to develop.
 - D. water vapor condenses, releasing energy.

Correct Response: B. Cloud cover at night reduces the amount of heat that radiates into space by absorbing the heat radiating from the surface and re-radiating some of it back down toward the ground. The process slows the rate of surface cooling and traps heat near Earth's surface, keeping temperatures warmer than they otherwise would be. Evaporation rates (**A**) and hence evaporative cooling are usually lower at night in general, but this does not account for the warming effect of nighttime cloud cover. Atmospheric convection currents are not significant at night because solar heating is not available to warm the air near the surface and cause it to rise (**C**) and cloud cover at night tends to reduce condensation, consequently reducing the release of heat energy from condensation (**D**).

64. As a result of the Coriolis effect, wind currents tend to:
- A. cool off as they converge and rise.
 - B. flow in a straight path as they cross lines of longitude.
 - C. heat up as they diverge and sink.
 - D. curve as they flow over Earth's surface.

Correct Response: D. The Coriolis effect is an apparent deflection of objects moving in a straight line on a rotating frame of reference. The Coriolis effect is an important factor affecting the movement of water and air as they travel across Earth's curved and rotating surface. It affects the flow of air around atmospheric pressure systems and in prevailing wind currents, as well as the flow of ocean currents. The cooling of rising air (**A**) results from the decrease in pressure with increasing elevation and the conduction of heat energy into the surrounding cooler air and has nothing to do with the Coriolis effect. Air currents rarely travel in a straight path for very long (**B**) no matter where they are because of the Coriolis effect and other geographic factors. Air heats up as it sinks as a result of compressional heating as the pressure in the sinking gas increases (**C**) and it is unrelated to the Coriolis effect.

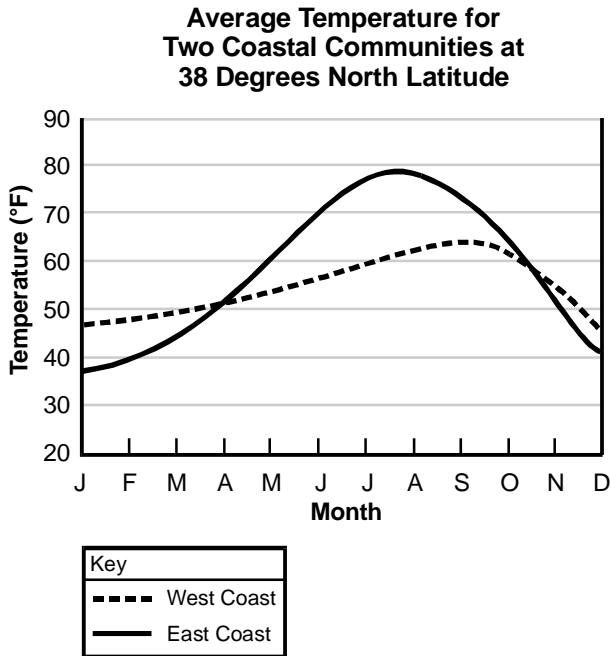
65. An occluded front typically forms under which of the following conditions?
- A. A wedge of cool air between two warm fronts is forced upward as one of the fronts overtakes the other.
 - B. A cold front catches up with a warm front, forcing warm air between the fronts upward and producing rain.
 - C. A wedge of cold air between two warm fronts is forced upward as one of the fronts overtakes the other.
 - D. A cold front overrides another cold front, trapping warm air at the surface and producing rain.

Correct Response: B. A developing low pressure system typically has a warm front marking the leading boundary of relatively warm moist air and a cold front that marks the leading edge of colder air wrapping around the developing low pressure system. This is the process of cyclogenesis that leads to storm formation. When the faster moving cold front catches up with the warm front, it forces the less dense warm air upward, triggering precipitation along the now occluded front. Occluded fronts do not develop when one warm front catches up with another (**A, C**) or when a cold front catches up with another cold front (**D**). In all of these examples the similar fronts would typically reinforce each other and not form a new kind of front.

66. Which of the following climate characteristics is the primary factor controlling the type of vegetation in the prairie of the upper Midwest?
- A. strong seasonal winds
 - B. limited annual precipitation
 - C. regular grass fires
 - D. temperature extremes

Correct Response: B. Annual average precipitation in the prairie of the upper Midwest is sufficient to support a grassland ecosystem and isolated trees in some favored locations. The fairly low average annual precipitation and its often erratic nature can create extremely hot and dry summer conditions that give grasses a competitive advantage over tree species. For this reason, precipitation is the primary climate characteristic that controls the types of vegetation that can successfully compete in the prairie. The strong winds that often blow across the region (**A**) increase evaporation in summer, further reducing available soil moisture, but it is the relatively low precipitation that makes this a problem. The grass fires in the region (**C**) result from the very dry summer conditions caused by low and erratic rainfall as well. The wide variation in temperature over the course of the year (**D**) does not prevent trees from growing in the area.

67. Use the chart below to answer the question that follows.



The chart above shows the average temperature over the course of a year in a West Coast community and an East Coast community at 38 degrees north latitude. Which of the following is the most significant factor responsible for the difference between the patterns of temperature change of the two coastal locations over the course of the year?

- A. the inland topography adjacent to the two locations
- B. the amount of precipitation at different times of the year
- C. the direction of large-scale winds throughout the year
- D. the moderating effect of near-shore waters in each location

Correct Response: C. The prevailing large-scale winds over the United States blow from west to east. This is the most significant factor affecting the different seasonal temperature patterns along the East and West Coasts. The prevailing winds tend to blow relatively warm marine air from the Pacific Ocean to the West Coast, moderating both winter and summer temperatures, while prevailing winds in the central and eastern United States tend to bring cold continental air masses to the East Coast in the colder months and hot continental air masses in the warmer months. Neither the inland topography of the two coasts (**A**) or their different seasonal precipitation patterns (**B**) are primarily responsible for the difference in their seasonal temperature patterns. Although near-shore waters on both coasts play an important part in moderating local temperatures along the coastlines (**D**), the phenomenon is not responsible for the larger-scale yearly temperature patterns depicted in the graph.

68. The polar jet stream typically has a major effect on the weather of the northern half of the United States. Which of the following is a major factor responsible for increasing the wind speed in the region of the polar jet stream?
- A. the geographical shift in temperature patterns associated with the different phases of the Arctic Oscillation
 - B. the gradual drop in pressure that occurs between the troposphere and stratosphere
 - C. the steep pressure gradient that exists between very cold northern air and warmer southern air
 - D. the seasonal change in atmospheric instability over temperate and tropical oceans

Correct Response: C. Colder and warmer air masses have different densities and consequently different atmospheric pressures. Where cold and warm air masses meet, such as along the polar front, the difference in atmospheric pressure causes wind. The strong pressure gradient along the polar front drives the concentrated winds of the polar jet stream near the altitude of the tropopause. Although fluctuations in the Arctic Oscillation can affect the position and strength of jet stream winds, it is not a major factor driving their development (**A**). The decrease in atmospheric pressure between the troposphere and stratosphere (**B**) is also not a major factor driving the polar jet stream. Seasonal changes in atmospheric instability in temperate and tropical regions (**D**) can be affected by the position of the polar jet stream and subtropical jet stream, but are not a factor in their development.

69. Fossil evidence indicates that tropical conditions once existed across the United States during the late Paleozoic era. This difference in the climate of North America today and the climate during the Paleozoic era was caused primarily by changes in the:
- A. concentration of oxygen in the atmosphere.
 - B. intensity of solar radiation.
 - C. directions in which ocean currents flow.
 - D. positions of the continents.

Correct Response: D. The geographic area of the United States was located near the equator and subtropics during the Paleozoic era. The shift in tectonic plates that formed Gondwanaland in the Early Paleozoic and Pangea in the Late Paleozoic is responsible for the tropical climate conditions in the region at that time. The concentration of oxygen in the atmosphere (**A**) and the intensity of solar radiation (**B**) during the Paleozoic era were not primarily responsible for the region's tropical climate. Ocean currents during the 300 million years of the Paleozoic era likely changed dramatically over that time period and certainly must have affected climate. However, it was primarily the geographic location that was responsible for changes in ocean currents and the region's tropical climate (**C**).

70. Approximately 14,000 years ago, warmer conditions began to melt the Pleistocene ice sheets. This warming was suddenly interrupted around 12,700 years ago by 1,000 years of below-average temperatures in northeastern North America and northern Europe. The onset of this sudden and prolonged cold snap, known as the Younger Dryas event, was caused primarily by which of the following?
- A. a reduction in tropical air masses moving north due to a shift in the position of the subtropical jet stream
 - B. a change in the ocean currents in the North Atlantic caused by an increased input of freshwater
 - C. a decrease in the intensity of solar energy output due to changes in the Sun's magnetic field
 - D. a change in the timing of the seasons caused by variations in Earth's orbital parameters

Correct Response: B. As continental glaciers melted at the end of the Pleistocene epoch, vast amounts of freshwater flowed into the North Atlantic, altering the salinity of ocean water and consequently thermohaline ocean circulation. The Younger Dryas cooling event was caused by a change in northward flowing ocean currents connected to the larger thermohaline circulation of the Atlantic Ocean. The cooling of the Younger Dryas Event altered atmospheric circulation patterns and likely the position of the subtropical jet stream (**A**), but the Younger Dryas Event was not caused by those changes. Changes in the intensity of the solar energy output (**C**) were not involved in the Younger Dryas Event and although Earth's orbital parameters (**D**) were responsible for the major glacial cycles of the Pleistocene, they were not responsible for development of the relatively short-lived Younger Dryas Event.

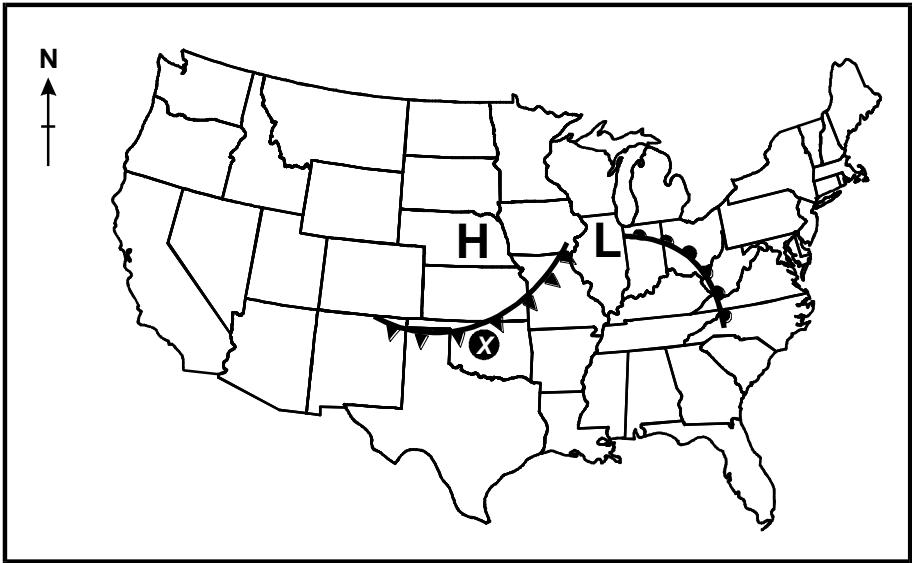
71. In which of the following situations is energy absorbed by water?
- A. Dew forms on a lawn just before dawn in the summer.
 - B. Ice crystals grow on a window pane on a cold winter night.
 - C. Fog dissipates as the Sun rises on a fall morning.
 - D. Clouds develop over a mountain range on a warm spring day.

Correct Response: C. Fog is composed of small droplets of liquid water suspended in the atmosphere. When fog dissipates, the droplets evaporate and become gaseous water vapor molecules. To move from the liquid phase to the gas phase the water absorbs energy from its surroundings. This makes evaporation an endothermic process. The other three responses all involve exothermic processes in which heat energy is given off by water to its surroundings as it changes phase. When dew forms (**A**), heat is given off as water vapor condenses into liquid water. During the process of deposition, ice crystals form directly from water vapor (**B**), releasing heat. Cloud formation (**D**) occurs as water vapor condenses into liquid water droplets around condensation nuclei, giving off heat energy.

72. Under which of the following conditions is advection fog most likely to form?
- A. Cold air becomes trapped beneath a layer of warmer air.
 - B. Hot dry air in contact with the surface cools after sunset.
 - C. Cool moist air warms as it flows down a mountain side.
 - D. Warm moist air flows over cold ocean water.

Correct Response: D. In meteorology, advection is the bulk movement of energy or mass horizontally through the atmosphere, and advection fog is fog that forms when relatively warm moist air flows over a colder surface such as the ocean. When cold air becomes trapped beneath warm air (**A**), an inversion results (and not advection fog). Hot, relatively dry air can produce fog (**B**) if it is cooled below its dew point. This type of fog is called radiation fog because it forms in place as the ground radiates its heat and cools down. When cool, moist air flows down a mountain (**C**), the pressure on the parcel of air increases, reducing its volume and increasing its temperature. This type of adiabatic warming causes the relative humidity of the parcel to decrease and would not produce fog.

73. Use the map below to answer the question that follows.



The weather map shown above depicts a cold front moving across the center of the United States during the late spring. The temperature north of the front is in the low 60s and the air mass is dry, while south of the front the temperature is in the mid-80s and it is very humid. As the cold front approaches and passes through the location marked with an X, which of the following weather conditions is most likely to develop?

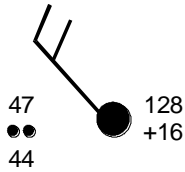
- A. clear skies and light wind
- B. thunderstorms and high wind
- C. thick fog and moderate drizzle
- D. low clouds and steady light rain

Correct Response: B. The cooler dry air behind the approaching cold front is denser than the warmer moist air it is advancing into. The denser cool air undercuts the warmer air, forcing it upwards. As the warm moist air ascends, it expands and cools. This triggers condensation, releasing heat that makes the parcel more buoyant. If the atmosphere is destabilized in this way, the rising moist air forms cumulonimbus clouds that generate thunderstorms. The changing conditions along the advancing front would typically cause wind gusts and cloud formation, not clear skies and light wind (A). Fog would typically not form under these conditions (C) because of winds along the advancing front and because the moist air mass is being forced upward. Low clouds and light rain (D) would be likely to develop as a warm front advances over a receding cold front and not as a cold front undercuts a warm air mass.

74. The psychrometer is based on which of the following principles?
- A. Relative humidity can be calculated by comparing the evaporative cooling that occurs in a particular location to the air temperature.
 - B. The apparent temperature can be determined by comparing the actual temperature in a location with the relative humidity.
 - C. The density of an air mass can be calculated by comparing the molecular weight of dry air to the molecular weight of the actual air.
 - D. The adiabatic cooling of an air mass can be determined by comparing the actual pressure in a location to the theoretical sea-level pressure.

Correct Response: A. The traditional sling psychrometer consists of two thermometers attached to a handle in a way that allows the thermometer to be spun rapidly. The two thermometers are identical except that one of the thermometers is covered in a wick that is moistened (the wet-bulb thermometer). As the device is spun, the water in the wick evaporates and evaporative cooling reduces the temperature of the wet-bulb thermometer. The difference in the temperature recorded by the two thermometers is used to calculate the relative humidity. Apparent temperature (**B**) is perceived temperature and its calculation takes into account relative humidity and wind speed, but it is not related to the working principle of a psychrometer. Air mass density is not an underlying principle upon which a psychrometer works (**C**) and air-pressure is not involved in psychrometer calculations or the underlying principle of the psychrometer's operation (**D**).

75. Use the graphic below to answer the question that follows.



The station model plot shown above indicates which of the following weather conditions?

- A. clear skies, light northwesterly winds, and rising atmospheric pressure
- B. overcast skies, light rain, moderate northwesterly winds, and rising atmospheric pressure
- C. partly cloudy skies, poor visibility, strong northwesterly winds, and rising temperature
- D. scattered clouds, light southwesterly winds, and falling atmospheric pressure

Correct Response: B. The station model is a symbolic representation of weather conditions at a particular location. In the example, the central circle is filled in, indicating total cloud cover. Two small black dots to the left of the central circle indicate light rain is occurring and the 16+ on the right indicates a pressure rise of 16 tenths of a millibar in the past 3 hours. The temperature of 47°F shows over dew point to the left of the central circle. The example shows wind direction from the northwest and of moderate strength as indicated by the angle of the line coming out of the central circle and the two short lines attached to it. Examination of the station model plot in this example shows that the sky is not clear (**A**), it is not partly cloudy with strong winds (**C**), and light winds are not blowing out of the southwest (**D**).

76. Climatologists have used computer models to investigate possible consequences of increased average global temperatures on various Earth systems. According to the models, which of the following changes in an Earth system is likely to occur in association with an increase in average global temperatures?
- A. Regions prone to drought will become drier, due to longer periods without adequate rainfall.
 - B. Jet stream winds will shift position more frequently, causing rapid changes in weather conditions.
 - C. Hurricanes will become less common in tropical areas, due to a strengthening of the Coriolis effect.
 - D. El Niño events will occur at longer intervals, causing anomalous weather conditions to last longer.

Correct Response: A. One of the strongest hypotheses of the climatologists studying climate change and the predictions of climate models is that weather events will become more extreme. This means longer and more severe droughts for some areas already prone to drought, such as the Southwest, while other regions typically prone to seasonal flooding, such as the Ohio River Valley, can expect more intense floods more often. Climate models suggest that the decreased equator-to-pole temperature gradient will actually make weather systems more persistent as the jet stream slows (**B**) and hurricanes are more likely to increase in frequency than decrease as sea-surface temperatures increase (**C**). El Niño events are precipitated by major changes in the oceans and atmosphere and climate models have not indicated that the intervals at which they occur (**D**) will change significantly as a result of global warming.

77. The distinguishing characteristic of the atmospheric pollutant known as particulate matter is that it comprises:
- A. acidic liquids and gases generated by fixed sources.
 - B. fragments of natural substances visible to the unaided eye.
 - C. droplets and solids small enough to be suspended in the air.
 - D. heat-trapping chemicals that absorb infrared energy.

Correct Response: C. The Environmental Protection Agency defines particulate matter as "a complex mixture of extremely small particles and liquid droplets." The small size of the droplets and particles keeps them suspended in the atmosphere, where they reduce air quality and can cause serious health problems of the heart and lungs when inhaled. The mixture can contain a variety of human-made and natural compounds, including metals, soot, dust, petroleum residues, sea salt, and a variety of sulfur and nitrogen compounds. Particulate matter may include acidic liquids (sulfuric acid droplets, for example) and gases (**A**), but it also includes solids and its defining characteristic is its small size. Visible fragments of natural substances (**B**) are not considered particulate matter and while the mixture does typically include heat-trapping chemicals (**D**), they are only one possible component of particulate matter.

78. Which of the following is an effective way to reduce the acid precipitation resulting from power plant emissions?
- A. reacting sulfur dioxide with calcium hydroxide by forcing exhaust through a spray of lime and water
 - B. filtering the dust particles generated by the breakdown of coal through fine mesh filtration systems
 - C. converting carbon monoxide to carbon dioxide with smokestack catalytic converters
 - D. removing volatile hydrocarbon compounds found in coal before the fuel is burned

Correct Response: A. A major source of acid precipitation is the production of oxides of sulfur and nitrogen during fossil fuel combustion. These compounds combine with water in the atmosphere to form acid precipitation. Sulfur dioxide is the primary pollutant involved and power plants use flue-gas desulfurization (FGD) technologies to remove sulfur dioxide from smokestack emissions. Reacting sulfur dioxide with calcium hydroxide in a lime-water spray is a wet-scrubbing technique that can remove 95% of the sulfur dioxide in emissions. Since dust particles (**B**) are not the cause of acid precipitation, removing them does not diminish the problem. Carbon monoxide (**C**) is a pollutant produced by fossil-fuel combustion, but it is not a major cause of acid precipitation and while volatile hydrocarbons (**D**) are produced during fossil-fuel combustion, they are not a primary cause of acid precipitation and their removal prior to combustion is not feasible.

79. Which of the following is a major challenge for climate researchers trying to establish the effect that human activities have had on global climate?
- A. determining the effect that water vapor generated from natural sources has had on climate change
 - B. compiling the evidence of climate change from different countries with a variety of concerns and priorities
 - C. measuring the subtle changes in the environment that have occurred as the global climate has warmed
 - D. distinguishing what shifts in the climate system might be exclusively due to natural long-term changes

Correct Response: D. Scientists have long predicted that increasing carbon dioxide levels in the atmosphere will change Earth's climate. One of the greatest scientific challenges, however, is to determine which changes are related to the climate system's natural variability and which changes are caused by human activities. The effect of water vapor on climate change (**A**) is complex, but it is accounted for in most climate models. Most climate data is generated by countries with data standards considered acceptable by the scientific community (**B**). Measuring these changes (**C**) is not challenging, but has been ongoing and has provided some of the best evidence for global warming.

80. Which of the following resources can be considered renewable or nonrenewable depending on how it is managed?
- A. metallic ore deposits
 - B. solar energy
 - C. freshwater aquifers
 - D. wind power

Correct Response: C. Freshwater aquifers are potentially renewable resources if they are protected and well managed. Groundwater pollution, overuse, and certain farming practices can reduce or destroy an aquifer's usefulness, however, making it nonrenewable. Many industrialized and urbanized areas of the world have contaminated groundwater aquifers so seriously that the aquifers no longer provide potable water. Severe depletion of aquifers where recharge is not adequate to keep up with water withdrawals is also common. In this way freshwater aquifers can be seen as a renewable resource that may become nonrenewable depending on how it is managed. Metallic ores (**A**) are seen as exclusively nonrenewable because the supply of metallic ores is finite. Solar energy (**B**) and wind power (**D**) are both considered entirely renewable because their use does not diminish their availability.

81. According to prevailing theory, which of the following led to the formation of the Moon?
- A. A minor planet orbiting between Mars and Earth was captured by Earth's gravitational field.
 - B. Debris was ejected from Earth following a collision with an interplanetary body.
 - C. A massive meteor with an elliptical orbit that passed near Earth was pulled in by Earth's gravity.
 - D. Clouds of gas and dust circling the Sun coalesced into the planets and their satellites at the same time.

Correct Response: B. The prevailing hypothesis of the Moon's formation is that a protoplanetary body the size of Mars collided with Earth approximately 4.5 billion years ago, ejecting debris into Earth's orbit that coalesced into the Moon. Such collisions are thought to have been relatively common in the early solar system and this hypothesis is well-supported by the available evidence. The planetary-capture model (**A**) and the idea that a massive meteor was pulled in by Earth's gravitational field (**C**) do not appear to be physically likely as the velocity and mass of any such object would be too great to be captured by Earth's gravitational field. While the satellites nearest to the gas giants Jupiter and Saturn are thought to have formed from circumplanetary clouds of gas and dust (**D**), lunar evidence and Earth's composition suggest this was not how the Moon formed.

82. The rotational period of the Moon exactly equals its orbital period in a phenomenon known as synchronous rotation. This characteristic of the Moon's motion is responsible for which of the following?
- A. the timing of the Moon rise being about 50 minutes later each day
 - B. the path of the Moon across the sky being from east to west
 - C. the full Moon always rising at the approximate time of sunset
 - D. the same side of the Moon always facing Earth

Correct Response: D. The synchronous rotation of the Moon means that it rotates on its axis at approximately the same rate as it orbits Earth. As a result, the same side of the Moon always faces Earth. The change in the time of Moon rise on successive days (**A**) is caused by the Moon's eastward motion during its orbit. Since the Moon has moved eastward by 13.18 degrees over the course of a 24-hour day, Earth must rotate eastward for approximately fifty extra minutes each day to catch up with the Moon's new orbital position. The Moon's apparent east-to-west path across the sky (**B**) results from Earth's axial rotation from west to east and the full Moon always rises at about sunset (**C**) because the Moon appears full when it is on the opposite side of Earth from the Sun.

83. Two high tides occur almost simultaneously on opposite sides of Earth. Which of the following best describes the underlying reason that a high tide occurs on the side of Earth that faces away from the Moon?
- A. the difference in the gravitational pull on either side of Earth
 - B. the drag caused by frictional forces between water and the ocean floor
 - C. the strength of the Sun's gravitational pull on ocean water
 - D. the tilt of Earth's axis relative to the Moon's orbit

Correct Response: A. There is a high tide on the side of Earth facing the Moon, but there is also a high tide on the side of Earth facing away from the Moon. The underlying reason for the formation of this opposite-side high tide is that the Moon's gravitational pull varies across Earth, creating one tidal bulge where the Moon's gravitational pull is strongest and one on the opposite side, where the Moon's gravitational pull is weakest. Frictional interactions between ocean water and the ocean floor (**B**) can affect local tide cycles, but not global-scale tidal phenomena. The Sun plays a supporting role in ocean tides (**C**), however its effects are much smaller than the Moon's in forming the tidal bulge that faces away from the Moon. Earth's axial tilt relative to the Moon (**D**) is not a major factor in the formation of ocean tides.

84. Which of the following explains why lunar eclipses typically occur only two or three times a year instead of each month?
- A. Earth's axis is tilted relative to the plane of its orbital path around the Sun.
 - B. The time it takes Earth to orbit the Sun is much longer than the orbital period of the Moon.
 - C. The Moon's orbital path is tilted relative to the plane of Earth solar orbit.
 - D. The time it takes for the Moon to orbit Earth is much longer than Earth's rotational period.

Correct Response: C. Lunar eclipses occur when the Moon moves across the Sun, producing a shadow on Earth. A lunar eclipse can only occur when the Moon is in a direct line between the Sun and Earth. Since the Moon's orbit of Earth is tilted 5 degrees relative to Earth's orbital plane (the ecliptic), this lineup can only occur two or three times a year and not each time the Moon completes its orbit of Earth. Neither Earth's axial tilt relative to the plane of its orbit (**A**) nor the different orbital periods of Earth and the Moon (**B**) affect the relationship between Earth, the Moon, and the Sun that produces lunar eclipses. The Moon's orbital period (27 days) is much longer than Earth's 24-hour rotational period (**D**), but that difference is also not responsible for the rarity of lunar eclipses each year.

85. The energy output of the Sun is maintained by which of the following processes?
- A. the conversion of hydrogen into helium in the core
 - B. the combustion of gases drawn into the chromosphere
 - C. the explosion of volatile compounds in the corona
 - D. the breakdown of high-energy particles in the photosphere

Correct Response: A. The Sun's energy output is maintained by nuclear fusion occurring in the core. Nuclear fusion converts the Sun's most abundant element, hydrogen, into helium, producing energy that then flows outward from the core. This nuclear process occurs at extremely high temperatures through a multistep reaction called the proton-proton chain reaction. The chromosphere (**B**) is the middle layer of the Sun's atmosphere and while it does transmit energy produced in the core, it does not generate energy from combustion of gases. None of the processes that occur in the corona, the outermost layer of the solar atmosphere (**C**), are important in maintaining the Sun's energy output. The photosphere (**D**) is the lowest layer of the solar atmosphere (the Sun's "surface") and does not generate energy from the breakdown of high-energy particles, though it does transmit energy carried outward through the convective zone.

86. Scientists believe that the asteroids of the asteroid belt formed when:
- A. debris from outside the solar system was captured by the Sun's gravity.
 - B. fragments of planetesimals failed to coalesce into one or more planets.
 - C. several moons orbiting Jupiter were destroyed by meteor impacts.
 - D. dust and ice in the early solar system clumped together.

Correct Response: B. Scientists hypothesize that the asteroids of the asteroid belt are remnants of planetesimals from the early formation of the solar system that were unable to coalesce into a planet because of the influence of Jupiter's strong gravitational field. The large number and concentrated location of asteroids in the asteroid belt make it highly unlikely that the asteroids were captured by the Sun's gravitational field (**A**). While the asteroids are abundant, their total mass is a fraction of the mass of Earth's moon and suggests they did not form from the destruction of multiple Jovian moons (**C**). Although dust and ice did clump together in the early solar system according to the nebular hypothesis, the composition and characteristics of asteroids in the asteroid belt suggest they were formed after this earliest stage from the remains of planetesimals and not just dust and ice (**D**).

87. The Oort cloud is a region in space that scientists have determined is:
- A. the source of most comets.
 - B. an area where new stars form.
 - C. the location of the asteroid belt.
 - D. an area where a supernova occurred.

Correct Response: A. Long-period comets and many other types of comets are believed to have originated in the Oort cloud. The Oort cloud is outside the orbits of the planets and extends to the solar system's outer boundary where the Sun's gravitational influence is very weak. The region contains mostly icy planetesimals and at its outer edge the orbits of these objects can be perturbed by passing stars, occasionally causing them to travel toward the inner solar system. New stars would not form in this region (**B**) because of the Sun's proximity and the lack of sufficient dust and gas. The asteroid belt (**C**) is in a different region of the solar system than the Oort cloud. A supernova covers an enormous area and would have obliterated the solar system had it occurred in the region occupied by the Oort cloud (**D**).

88. Which of the following is a characteristic of Venus that distinguishes it from the other seven planets?
- A. The temperature extremes on Venus are the greatest in the solar system.
 - B. Venus's orbital path is well outside of the plane of the ecliptic.
 - C. Venus's axial rotation is opposite in direction to its orbital path.
 - D. The crust of Venus is primarily composed of iron and nickel.

Correct Response: C. Venus is unique among the planets of the solar system in having an axial rotation that is opposite in direction to its orbital motion. If the Sun could be seen through its thick atmosphere, it would appear to rise in the west. Venus' thick atmosphere makes it the hottest planet in the solar system, but it is always hot and unlike Mercury does not experience both hot and cold extremes (**A**). Venus' orbital path is inclined 3.4 degrees from the plane of the ecliptic (**B**). This is within several degrees of the other planets and less than the inclination of Mercury's orbit. Although the core of Venus is believed to be similar to Earth's and composed of nickel and iron, Venus' crust is composed primarily of silicate rocks (like Earth's crust), much of which were produced by volcanism (**D**).

89. Which of the following groups of substances makes up most of a comet's nucleus?
- A. soot particles, sodium, and complex hydrocarbons
 - B. nickel, iron, and hydrogen compounds
 - C. methane, carbon, and elemental oxygen
 - D. ice, carbonaceous dust, and frozen gases

Correct Response: D. The solid part of a comet, the comet nucleus, is composed of a mixture of water ice, dust, rock, and several frozen gases. The significant proportion of frozen gases and ice are responsible for the tail produced as comets approach the Sun. While there is evidence that complex hydrocarbons, soot, and sodium may exist on some comets in small amounts (**A**), they are not major constituents of comet nuclei. Hydrogen, likely from water, does occur in the comet envelope, and nickel and iron can be constituents of the rock and dust part of a comet, but they are not primary components of most comet nuclei (**B**). Frozen methane can be one of the gases in comet nuclei and carbon is also present. However, elemental oxygen is not found in comet nuclei and as a group these substances do not make up most of a comet's nucleus (**C**).

90. Which of the following best summarizes Newton's first law of motion as it relates to the Moon's orbit around Earth?
- A. The Moon's inertia keeps it moving tangent to its orbit, while Earth's gravitational field deflects it from a straight path.
 - B. The Moon's rotation keeps it on the same path, while its velocity is maintained by Earth's gravity.
 - C. The Moon's acceleration is driven by its mass, while its circular motion is maintained by its gravitational attraction to Earth.
 - D. The Moon's weight causes it to fall toward Earth, while centripetal force accelerates it away from Earth.

Correct Response: **A.** Newton's first law of motion, the Law of Inertia, states that an object either remains at rest or continues to move at a constant speed in the same direction, unless acted upon by an external force. Earth's gravitational field exerts an external force on the Moon, pulling it toward Earth. This force deflects the Moon from moving in a straight line tangent to the curved path of its orbit. Although the Moon's orbital path, velocity, and rotation (**B**) are affected by its inertia and rotational inertia, the interaction of these factors does not summarize Newton's first law. The Moon does accelerate as it falls toward Earth during its orbit (**C**), but the gravitational interaction that causes the acceleration does not summarize Newton's first law any more effectively than do the concepts of weight and centripetal force (**D**).

91. An astronomer observes rapidly fluctuating radio signals from distant galaxies that occur as precisely spaced bursts of radiation. It is likely that the astronomer has located:
- A. an expanding planetary nebula.
 - B. an oscillating black hole.
 - C. a rotating neutron star.
 - D. an eclipsing binary star system.

Correct Response: C. Neutron stars are the remnant stars that remain following the collapse and supernova eruption of a massive star. The majority of known neutron stars are pulsars, emitting regular and rapid radio pulses as they spin at very high speeds. Neutron stars conserve the angular momentum of the original star they formed from and because they are so small and dense, their rotational speed is very great. An expanding planetary nebula (**A**) would not be a likely source of rapidly pulsing radio signals from a neutron star. Black holes do emit fluctuating radio signals as they consume mass (**B**), but not in the regular rapid way that pulsars do. An eclipsing binary star system (**D**) changes brightness as one star of the pair moves in front of the other, but the regular change in brightness would be much slower than the pulses emitted by a rapidly pulsating neutron star.

92. A main sequence star becomes a red giant when which of the following events occurs?
- A. the hydrogen in the star's core is used up
 - B. expansion of the core causes it to cool down
 - C. the helium in the outer layers of the star begins to fuse
 - D. combustion of gases on the star's surface causes it to expand

Correct Response: A. A main sequence star eventually uses up the hydrogen fuel in its core and switches to fusion of hydrogen in a shell surrounding the core. This initiates the transition to the red giant stage as the core contracts and its temperature increases, triggering fusion of helium. The energy produced by helium fusion in the core causes the star to expand outward to many times its original size. Although a main sequence star does expand and cool as it becomes a red giant, the core (**B**) actually contracts and heats up initially as hydrogen fusion comes to an end. The density and temperature are too low in the outer layers of main sequence stars to support nuclear fusion of helium (**C**). The hydrogen and helium in the visible surface layer of a main sequence star does not combust (**D**) or react in any way that could initiate red giant development.

93. When a star such as the Sun reaches a late stage of its life, it typically becomes a:
- A. neutron star comprising the nuclei of fused iron and carbon atoms.
 - B. white dwarf comprising mainly carbon and oxygen.
 - C. black hole produced by compression of the extremely dense core.
 - D. Cepheid variable star produced by instability in the star's dying core.

Correct Response: B. A main sequence star like the Sun becomes a white dwarf stellar remnant composed primarily of carbon and oxygen. The carbon and oxygen are produced by nuclear processes during the fusing of helium as the star leaves the main sequence and develops into a red giant. The remnant core of the red giant is a white dwarf. The Sun's mass is too low either to produce a supernova that would leave behind a neutron star (**A**) or to form a black hole (**C**). Classical Cepheid variables (**D**) are from four to twenty times as massive as the Sun, and youthful, and therefore could not form from a star like the Sun as it aged.

94. Astronomers use which of the following properties of stars to plot them on the Hertzsprung-Russell diagram?
- A. proximity to Earth and age
 - B. lifecycle stage and spectral class
 - C. temperature and luminosity
 - D. size and composition

Correct Response: C. The Hertzsprung-Russell diagram (H-R diagram) is a scatter plot of different types of stars that graphs a star's brightness against its temperature. Brightness is a measure of a star's luminosity and the temperature is dependent on the star's color or spectral class. Both of these characteristics depend on the particular star's composition. With some additional observational data, a star's distance and age (**A**) and its lifecycle stage (**B**) can be estimated by analyzing the star's position on the H-R diagram. These properties, however, are not used to plot a star's position on the diagram. The size and composition of a star (**D**) are also properties that can be estimated using information from the H-R diagram in combination with information from astronomical observations; however, they are not properties used to plot the star's position on the H-R diagram.

95. Use the table below to answer the question that follows.

Star	Apparent Magnitude	Absolute Magnitude
Sirius	-1.4	1.5
Deneb	1.3	-6.9
Betelgeuse	0.8	-5.5
Arcturus	-0.1	-0.3

The table above lists the apparent and absolute magnitudes of four stars. From this information, which of the following stars can be assumed to be the farthest from Earth?

- A. Sirius
- B. Deneb
- C. Betelgeuse
- D. Arcturus

Correct Response: B. The apparent magnitude of a star is a measure of how bright that star appears as viewed from Earth. The absolute magnitude of that star is the theoretical brightness it would have if it were 10 parsecs from an Earth-based observer. The stars with the greatest difference between apparent and absolute magnitude are likely the farthest away because the difference in brightness is so great between their real distance and the theoretical distance of 10 parsecs. For the star Sirius (**A**), the difference between apparent and absolute magnitude is 2.9. For Betelgeuse (**C**) the difference is 6.3 and for Arcturus (**D**) the difference is 0.2. Deneb, with a difference of 8.2, has the greatest difference between apparent and absolute magnitude and is therefore the farthest from Earth.

96. Redshift for some galaxies is larger than for other galaxies in different parts of the universe. This difference shows that galaxies are:
- A. concentrated in the region of space closest to Earth.
 - B. developing at different rates depending on how their mass is distributed.
 - C. clustered in different regions of space by their age.
 - D. receding from each other at different rates depending on how far away they are.

Correct Response: D. The Doppler effect causes light emitted by galaxies that are moving away from an observer to be shifted toward the red end of the spectrum. This is the same phenomenon that causes the sound produced by a receding ambulance siren to drop in frequency as its distance increases. The shift toward lower frequency wavelengths observed from galaxies that are moving away from Earth is greatest for galaxies that are the farthest from Earth. This shows that more distant galaxies are receding at a faster speed than galaxies that are closer to Earth. Since redshift by itself only provides evidence of a galaxy's rate of recession, it does not directly provide the location of galaxies (**A**) or information on their mass distribution and stage of development (**B**). Comparison of the redshifts of galaxies in different regions of space (**C**) has not provided evidence of galaxies clustered by age.

97. Astronomers have speculated about what creates different types of galaxies. The leading hypothesis is that the:
- A. collision of disk-like, relatively small galaxies produces larger spiral and elliptical galaxies.
 - B. presence or absence of a black hole determines whether a galaxy will develop into an elliptical or spiral type of galaxy.
 - C. gravitational attraction of the matter in galaxies causes them to change type as they age.
 - D. abundance or scarcity of heavy elements determines whether elliptical or spiral galaxies will form from preexisting gas clouds.

Correct Response: A. There is observational evidence that mergers and collisions of galaxies played a major role in the formation of different types of galaxies in the early universe and that these types of gravitational interactions have continued, especially in galaxy clusters. The composition and structure of different types of galaxies indicate that the structure of large spiral galaxies, elliptical galaxies, and some irregular galaxies results from gravitational interactions during mergers and collisions. Black holes (**B**) at the center of galaxies are not believed to determine whether a galaxy has a spiral or elliptical structure. Gravitational attraction of the matter in a galaxy is central to that galaxy's evolution (**C**), but does not explain the origin of different types of galaxies. The relative amount of heavy elements in a galaxy (**D**) relates to the evolution of the stars in the galaxy, but is not responsible for the evolution of its large-scale structure.

98. Which of the following provides evidence of the existence of dark matter in the universe?
- A. the redshift of distant galaxies
 - B. the high energy emitted by quasars
 - C. the rotational velocity of galaxies
 - D. the size of superclusters

Correct Response: C. The rotational velocity of galaxies can be estimated by calculating how gravity should be affecting the observable mass in a particular galaxy. In the 1970s, the calculated value for galactic rotational velocity predicted from the visible mass of stars and gas in a galaxy was shown to be different from the observed rotational velocity of the galaxy. Astronomers concluded that dark matter in galaxies was the missing mass responsible for the discrepancy between the calculated and observed rotational velocities. Redshift of distant galaxies (**A**) provides evidence of an expanding universe, but not dark matter. The high energy emitted by quasars (**B**) is produced by supermassive black holes at the center of massive galaxies and has not provided evidence of dark matter. The size of galaxy superclusters (**D**) results from the gravitational attraction that draws galaxy clusters together and has not provided evidence for the existence of dark matter.

99. Which of the following supported the scientific conclusion that the universe began with an inflationary expansion?
- A. the proportion of the different elements found in asteroids
 - B. the motion of galaxies receding from Earth in all directions
 - C. the variation in the density of different regions of space
 - D. the release of energy observed in nuclear fusion reactions

Correct Response: C. Variations in the density of space support the theory that a period of rapid inflation of the universe occurred fractions of a second into the Big Bang. Astronomers inferred that the universe rapidly expanded at the start of the Big Bang during a period of cosmic inflation. At the start of this brief period of inflation, quantum fluctuations occurred in the closely packed universe that later became the variations in density seen in today's greatly expanded universe. The proportion of elements in asteroids (**A**) provides information on the solar system's formation, not the inflationary period. The motion of receding galaxies (**B**) provides evidence of the universe's ongoing expansion, but not of the earliest inflationary period of its formation. Energy released from nuclear fusion (**D**) supports understanding of stellar evolution, but not the conditions hypothesized to have existed during cosmic inflation.

100. Which of the following provides evidence that the universe is expanding?
- A. the changing distance between stars in the Milky Way
 - B. the calculated distance to the cosmic horizon
 - C. the shifting of the spectral lines of galaxies
 - D. the emptiness of most regions of space

Correct Response: C. Edwin Hubble's observation of the redshift of galaxies proved that galaxies were moving away from Earth at an increasing speed directly proportional to their distance. This observation provides the basic evidence for an expanding universe. The distance between stars in the Milky Way (**A**) relates to the evolution of the Milky Way and local gravitational influences, not the expansion of the universe. The calculated distance to the cosmic horizon (**B**) is a theoretical boundary that does not provide direct evidence of the universe's expansion. The emptiness of most regions of space (**D**) is an observed property of the universe that is consistent with the idea of an expanding universe, but does not provide evidence for it.