

PRACTICE EXAM 59: EARTH AND SPACE SCIENCES REGENTS SIMULATION (50 QUESTIONS)

1. Astronomers detect the cosmic microwave background radiation coming uniformly from all directions in space at a temperature of about 2.7 K. Which of the following best describes what this background radiation represents?

- A. The combined light from every active star in the Milky Way galaxy, which has been stretched out and cooled to near absolute zero over the time it has taken to reach Earth
- B. The cooled remnant of radiation released when the universe first became transparent to light, providing strong evidence that the universe began in a hot, dense state
- C. The combined light from every planet in the solar system, which has been stretched out and cooled to near absolute zero over the time it has taken to reach the Earth's telescopes
- D. The energy released by the Sun's nuclear fusion that has gradually built up in space over many billions of years, with no relationship to any earlier stage of the universe

2. A scientist describes a star whose mass is many times greater than that of the Sun. Which of the following best describes how this star's lifetime will compare with that of the Sun?

- A. The more massive star will live for the same amount of time as the Sun, because the lifetime of a star depends only on its location in the galaxy and never on its overall mass
- B. The more massive star will live many billions of years longer than the Sun, because more mass always means a star has more hydrogen to fuse over a much longer period of time
- C. The more massive star will live for a much shorter time than the Sun, because more massive stars burn through their nuclear fuel at far higher rates than smaller, low-mass stars
- D. The more massive star will live for exactly the same amount of time as the Sun, since the lifetime of any star depends only on its color and never on the mass of the star

3. A scientist explains that nearly every chemical element heavier than helium was formed inside stars. Which of the following best describes one important consequence of this fact for living things on Earth?

- A. The carbon in living organisms and the oxygen we breathe were once part of earlier generations of stars, which produced these elements before scattering them into space when they died
- B. The carbon in living organisms and the oxygen we breathe were all manufactured by chemical reactions in Earth's atmosphere shortly after the planet's formation, with no role played by stars
- C. The carbon in living organisms and the oxygen we breathe were all created during the Big Bang, since the Big Bang produced every element in exactly the same proportions seen today
- D. The carbon in living organisms and the oxygen we breathe were all produced by ongoing chemical reactions in the Earth's mantle, with no role at all played by the Sun or any other stars

4. Kepler's Second Law states that a line connecting a planet to the Sun sweeps out equal areas in equal times. Which of the following correctly describes one consequence of this law?

- A. A planet's speed remains exactly constant throughout its entire elliptical orbit, regardless of how close or how far it happens to be from the Sun, since equal areas always mean equal speeds
- B. A planet moves more slowly when it is closer to the Sun and more quickly when it is farther from the Sun, since covering equal areas in equal times requires less arc when the planet is close
- C. A planet completely stops moving at the far point of its orbit, then suddenly reverses direction and travels back toward the Sun, since equal areas can only be swept when the planet is moving inward
- D. A planet moves faster when it is closer to the Sun and slower when it is farther from the Sun, since covering equal areas in equal times requires more arc when the planet is close to the Sun

5. An asteroid orbits the Sun with an orbital period of 8 years. Using Kepler's Third Law ($T^2 = a^3$ in solar units), what is its approximate average distance from the Sun?

- A. About 8 AU, because the orbital period in years is always equal to the average distance from the Sun in AU, regardless of the actual length of the orbit or any other property
- B. About 2 AU, because the average distance from the Sun is always equal to the orbital period in years divided by 4, regardless of the actual length of the orbit being analyzed
- C. About 4 AU, because 8 squared is 64, and the cube root of 64 is 4 AU

D. About 64 AU, because the average distance from the Sun is always equal to the square of the orbital period in years, regardless of the actual length of the orbit being analyzed

6. During the June solstice, the Northern Hemisphere experiences its longest day of the year. Where on Earth does the Sun reach its highest point in the sky at noon on this day?

A. The Tropic of Capricorn, located at about 23.5 degrees south latitude, where the Sun appears directly overhead at noon on the June solstice every year that the cycle of seasons continues

B. The Tropic of Cancer, located at about 23.5 degrees north latitude, where the Sun appears directly overhead at noon on the June solstice

C. The equator, located at 0 degrees latitude, where the Sun appears directly overhead at noon on the June solstice every year that the regular cycle of seasons continues without interruption

D. The North Pole, located at 90 degrees north latitude, where the Sun appears directly overhead at noon on the June solstice every year that the regular cycle of seasons continues uninterrupted

7. A scientist looking up at the night sky sees the Moon as a full disk, brightly illuminated and rising in the east just as the Sun sets in the west. About one week later, what phase will the Moon be in?

A. A new moon, the phase of the Moon during which the side facing Earth is dark, so the Moon cannot easily be seen anywhere in the sky at any time of day or night for the entire day

B. A waxing crescent, the phase of the Moon during which a thin sliver is lit on the right side of the visible disk in the early evening sky just after sunset along the western horizon

C. A first quarter, the phase of the Moon during which exactly the right half of the visible disk is illuminated in the early evening sky just after sunset along the western horizon every night

D. A last quarter, the phase of the Moon during which exactly the left half of the visible disk is illuminated in the early morning sky just before sunrise along the eastern horizon

8. During a solar eclipse, only certain regions of Earth's surface experience totality, while observers elsewhere see only a partial eclipse or no eclipse at all. Which of the following best explains why the totality path is so narrow?

A. The Moon is much smaller than the Earth, so the Moon casts only a small, narrow shadow on Earth's surface, and only the region directly under this small umbra experiences totality

- B. Most of the Earth's surface is naturally too bright during an eclipse, which prevents observers far from the totality path from being able to see any sign of a solar eclipse at any time at all
- C. The Sun produces a beam of light during eclipses that is only wide enough to cover a narrow strip of Earth's surface, which is the reason that totality is observed only along a narrow path
- D. The Earth's atmosphere blocks all sunlight at certain regions of the surface at random during eclipses, with no relationship to the actual geometry of the Sun, the Earth, and the Moon during eclipses

9. A coastal city has a tide gauge that shows two high tides and two low tides every day, with their timing shifting by about 50 minutes each day. Which of the following best explains why high tides at a given location shift by about 50 minutes each day?

- A. The Sun's gravitational pull is always strongest at exactly the same time of day, which is the main reason that the high tides at any given location always shift by exactly 50 minutes each day
- B. The Earth's rotation rate gradually changes throughout each day, which is the main reason that the high tides at any given location shift by about 50 minutes from one day to the next
- C. The Moon moves about 13 degrees eastward along its orbit each day, so Earth must rotate about 50 extra minutes to bring a given location back to the same alignment with the Moon
- D. The Moon stays still in the sky while Earth rotates beneath it, with no relationship to any aspect of the Moon's orbit, which is the main reason that the high tides shift by exactly 50 minutes each day

10. A scientist explains that the planets, moons, and asteroids in our solar system are all very old, having formed about 4.6 billion years ago. Which of the following best describes how scientists determined this approximate age?

- A. The age of the solar system was determined by counting back through a continuous record of every event ever observed by humans, with no role at all played by any other kind of evidence at all
- B. The age of the solar system was determined using radiometric dating of the oldest rocks and meteorites, which provide samples of material formed at the very beginning of the solar system
- C. The age of the solar system was determined by counting craters on the Moon and assuming that exactly one crater forms on the Moon each year, with no role at all played by any other evidence
- D. The age of the solar system was determined by adding together the ages of every individual planet currently orbiting the Sun, with no role at all played by radiometric dating or any other method

11. A scientist explains that the Sun's hot, faint outer atmosphere extends millions of kilometers into space and is far hotter than the visible surface beneath it. What is this outer atmosphere called?

A. The corona, the Sun's hot, faint, outer atmosphere, which extends millions of kilometers into space and reaches temperatures of about a million kelvin or more

B. The chromosphere, the thin reddish layer of the Sun's atmosphere just above the visible surface, which is far cooler than the Sun's visible surface and only visible during a total solar eclipse

C. The photosphere, the bright visible surface of the Sun at a temperature of about 5,800 K, which is the layer that emits most of the visible light that reaches the Earth across space

D. The core, the central region of the Sun, where nuclear fusion produces the energy that the Sun gradually releases over billions of years, at temperatures of millions of kelvin

12. A geologist describes a particular rock layer as 50 million years old based on radiometric dating of a volcanic ash bed within it. This kind of age determination, expressed in years, is best described as which of the following?

A. Relative dating, which compares the ages of rocks in order and identifies which is older or younger, without giving the exact number of years that have passed since the rocks first formed at all

B. Stratigraphic correlation, which uses the order of rock layers from bottom to top to compare ages between regions, without giving the exact number of years that have passed since they formed

C. Index fossil dating, which uses the presence of specific fossil species to identify the relative age of a rock layer, without giving the exact number of years that have passed since the layer formed

D. Absolute dating, which gives the exact numerical age of a rock or fossil sample in years, using methods such as radiometric dating of certain unstable isotopes in the rock

13. A geologist notes that an igneous dike contains fragments of older sedimentary rock that have been included within the dike. According to the principle of inclusions, which of the following is true about the dike and the fragments?

A. The dike and the fragments must be exactly the same age, because the rock fragments and the dike rock formed at the same time, with no time difference between them at all

B. The fragments must be much younger than the dike, since fragments always form long after any igneous rock that contains them, regardless of any other geologic features in the region

C. The fragments must be older than the dike, because the fragments existed as rock before they were caught up in the magma that later cooled to form the dike

D. The fragments must be exactly 50 million years younger than the dike, since the inclusion of any rock fragments in any igneous dike always adds exactly 50 million years to the age of the dike

14. A radioactive isotope has a half-life of 750 years. A sample now contains one-sixteenth of the original amount of this isotope. About how much time has passed since the sample formed?

A. About 3,000 years, because four half-lives are needed to reduce the isotope to one-sixteenth of its original amount

B. About 750 years, because reducing the original amount of a radioactive isotope to one-sixteenth of its original amount requires only one full half-life of the isotope's decay process

C. About 1,500 years, because reducing the original amount of the radioactive isotope to one-sixteenth of its original amount requires only two full half-lives of the isotope's decay process

D. About 12,000 years, because reducing the original amount of the radioactive isotope to one-sixteenth of its original amount requires exactly sixteen full half-lives of the isotope's decay process

15. Carbon-14 has a half-life of about 5,700 years. Which of the following best explains why carbon-14 is generally useful only for dating relatively young samples that contain organic material?

A. Carbon-14 has a very long half-life of about 1 billion years, so it is useful only for samples that are billions of years old and not for any sample that is younger than that age

B. Carbon-14 is not found in any organic material on Earth, so it cannot be used to date the age of even the very youngest of any organic samples that contain carbon of any kind

C. Carbon-14 is too dangerous to handle in any laboratory, so scientists never use it to determine the age of any sample at any time, regardless of the age of the sample being analyzed

D. Carbon-14 has a relatively short half-life, so after roughly 50,000 years almost no carbon-14 remains in a sample, making it useful only for relatively recent organic material

16. A scientist explains that the appearance and disappearance of organisms over geologic time provides a record of evolution and extinction. Which of the following best describes the meaning of "extinction"?

- A. Extinction is the temporary disappearance of a species from a single region, after which the species always returns to that region within just a few decades of the original disappearance
- B. Extinction is the permanent disappearance of a species from Earth, occurring when no individuals of that species remain alive anywhere on the planet
- C. Extinction is the appearance of a brand-new species in the rock record, with no relationship at all to the disappearance of any species that may have lived earlier on the planet
- D. Extinction is the process by which a single species splits into many new species, with no relationship at all to the disappearance of any species that may have lived earlier on the planet

17. Wegener noted that distinctive Permian-age glacial deposits are found today on continents that span both hemispheres and a wide range of latitudes. Which of the following best describes what this distribution supported in his hypothesis of continental drift?

- A. The continents have always remained in their present positions, and the distribution of Permian glacial deposits across multiple continents reflects nothing more than random variations in past climate
- B. The continents currently sit at exactly the same latitudes that they occupied in the Permian, and the distribution of Permian glacial deposits across multiple continents is simply due to coincidence
- C. The continents were once joined together in a southern landmass near the South Pole, where a single ice sheet could deposit glacial material that is now scattered across separated continents
- D. The continents have always been moving so rapidly across Earth's surface that the distribution of any past glacial deposits has no relationship to the position of the continents in the deep past

18. Which of the following lines of evidence directly supports the idea that organisms on Earth have changed over geologic time?

- A. The geologic record contains the same set of species at every level, with no change from one rock layer to the next, regardless of the age of the rock layer or the location of the rock in the world
- B. The fossil record shows a progression from simpler organisms in older rock layers to more complex and diverse organisms in younger layers, indicating that life has changed over geologic time
- C. The geologic record contains no fossils at all in any rock layer of any age, which is the main reason that scientists have no evidence at all that organisms have ever changed over geologic time
- D. The geologic record contains only fossils of currently living species in every rock layer of every age, with no fossils of any extinct organisms at all in any of the rocks that have been studied

19. A divergent plate boundary in a continent can cause that continent to rift apart over millions of years, eventually forming a new ocean basin. Which of the following best describes the early stage of this process?

A. A continental rift valley begins to form as the crust thins and drops down between two pulling-apart fault blocks, gradually forming a long, narrow valley that may later flood to form a new sea

B. A high mountain range begins to form as the crust thickens and pushes upward between two pulling-apart fault blocks, gradually forming a long, narrow mountain belt that never floods to form a sea

C. A deep ocean trench begins to form as the crust thickens and pushes downward between two pulling-apart fault blocks, gradually forming a long, narrow trench that may later flood to form a new ocean

D. The crust completely freezes solid as it pulls apart, preventing the formation of any rift valley, mountain belt, or trench, regardless of the actual geologic processes operating in the region

20. The Pacific Ring of Fire is a region around the edges of the Pacific Ocean that contains most of Earth's volcanoes and the locations of most major earthquakes. Which of the following best explains why this region is so geologically active?

A. The Pacific Ocean is the largest of Earth's oceans, and its sheer size is the only reason that volcanoes and earthquakes are concentrated along its edges, with no relationship to any tectonic activity

B. The Sun's gravitational pull on the Pacific Ocean directly causes the volcanoes and earthquakes that occur along its edges, with no relationship at all to any tectonic activity in the region

C. The Moon's gravitational pull on the Pacific Ocean directly causes the volcanoes and earthquakes that occur along its edges, with no relationship at all to any tectonic activity in the region

D. The edges of the Pacific Ocean are lined with subduction zones and transform faults, where active plate boundaries produce volcanoes and earthquakes along the entire ring

21. A scientist explains that Earth's lithosphere is broken into rigid plates that move slowly across Earth's surface, riding on top of a partially molten layer beneath them. What is this partially molten layer called?

A. The crust, the thin outermost solid layer of the Earth that contains all surface rocks and minerals, and which makes up the topmost portion of the rigid lithosphere as well, on which the plates ride

B. The asthenosphere, the partially molten upper part of the mantle, which lies just below the rigid lithosphere and on which the lithospheric plates move slowly across Earth's surface

C. The outer core, a layer of molten iron and nickel that surrounds the inner core and lies far below the lithosphere, where the flow of liquid iron generates Earth's overall magnetic field

D. The inner core, the solid metal sphere at the very center of the Earth, which is far below the lithosphere and is composed mostly of solid iron and nickel under extreme pressure and temperature

22. A geologist examines a sample of fine-grained, dark igneous rock containing only very small mineral crystals that are barely visible to the unaided eye. Which of the following best describes how this rock most likely formed?

A. Magma cooled slowly deep underground over millions of years, producing very large interlocking crystals that are easily visible without any kind of magnification or microscope of any kind at all

B. Sediment was rapidly deposited and quickly cemented at the surface, producing a fine-grained sedimentary rock that closely resembles the texture of a fine-grained extrusive igneous rock

C. Lava cooled rapidly at or near Earth's surface, leaving little time for large crystals to grow, producing a fine-grained extrusive igneous rock such as basalt

D. An existing rock was buried and metamorphosed by heat and pressure, producing a foliated metamorphic rock that closely resembles the texture of a fine-grained extrusive igneous rock

23. A geologist examines a sample of sedimentary rock that contains alternating layers of fine sand and silt, with the layers becoming finer toward the top of each repeating layer. Which of the following best describes how this graded bedding most likely formed?

A. Underwater flows called turbidity currents deposited the coarser particles first as they slowed, while the finer particles continued to settle longer, producing a single layer that grades from coarse to fine

B. Sand and silt were carried into a wide, calm lake by a single steady flow of water, producing a single layer of perfectly uniform sand and silt with absolutely no grading by particle size at all

C. Strong winds carried sand and silt across an open ocean and deposited them onto the seafloor, producing a single layer of perfectly uniform sand and silt with no grading by particle size at all

D. Volcanic eruptions ejected sand and silt directly onto the surface of an ocean and deposited them onto the seafloor, producing a single layer of perfectly uniform sand and silt with no grading by particle size

24. A river slows down as it enters a calm lake and drops most of its sediment, building up a flat, fan-shaped deposit at its mouth. Which of the following best describes how the structure of this delta develops over time as more sediment is added?

- A. The delta gradually shrinks and disappears, because the still water in the lake completely dissolves all of the new sediment that the river deposits there each year, regardless of any other factors
- B. The delta moves rapidly back upstream against the flow of the river, because the still water in the lake somehow pushes the sediment back the way it came, regardless of any other factors at all
- C. The delta instantly disappears every winter, because cold weather causes any new sediment added to the delta to evaporate quickly into the surrounding air, regardless of any other factors at all
- D. The delta grows outward into the lake as new layers of sediment are added year after year, with coarser sediment usually nearer the river mouth and finer sediment carried farther into the lake

25. A geologist uses a magnifying lens to examine the grains of a sedimentary rock and finds that the grains are well rounded and roughly the same size. Which of the following best describes what these characteristics suggest about the rock's history?

- A. The grains experienced no transport at all, since well-rounded grains of similar size can only form when sediment remains completely undisturbed in one place for a very long period of time
- B. The grains were transported some distance by water or wind, which both rounded them and sorted them by size before they were deposited and cemented together to form the rock
- C. The grains were frozen and thawed many times within the sediment, since freezing and thawing are the only natural processes that round and sort sand grains by size in the natural world
- D. The grains were chemically weathered by acidic rainwater for many millions of years, since chemical weathering is the only natural process that rounds and sorts sand grains by size in nature

26. A geologist studying groundwater wants to identify a property of rock that allows water to move through it. Which of the following pairs of properties together best describe how easily groundwater can be stored in and flow through a rock?

- A. Color and density, since the color of a rock and the mass per unit volume together determine how much water the rock can hold and how easily that water can flow through the rock to a well
- B. Hardness and luster, since the hardness of a rock on the Mohs scale and the way that the rock reflects light together determine how much water the rock can hold and how easily it can flow
- C. Streak and cleavage, since the color of a powdered rock and the way the rock breaks along smooth surfaces together determine how much water the rock can hold and how easily it can flow
- D. Porosity and permeability, since porosity describes the amount of pore space available to store water, and permeability describes how easily water can flow through the connected pore spaces

27. A scientist explains that ocean waves striking a soft cliff over many years steadily erode the base of the cliff, undermining it and causing the cliff face to retreat landward over time. Which of the following best describes this process?

- A. Coastal erosion by wave action, in which the repeated energy of breaking waves wears away the base of a coastal cliff, undermining the cliff and causing the cliff face to retreat landward over time
- B. Glacial scouring, in which a thick, slow-moving sheet of ice carves out broad U-shaped valleys and pulverizes solid bedrock as it advances across the land surface of a region over time
- C. Wind abrasion, in which strong winds carrying loose sand grains grind away the surface of exposed rock, slowly wearing away the rock and changing its overall shape over many years of time
- D. Frost wedging, in which water that has seeped into cracks in the rock freezes and expands, gradually prying the rock apart into many smaller pieces over many freeze-thaw cycles over time

28. A community draws drinking water from a confined aquifer beneath an impermeable layer of clay. Which of the following best describes one important benefit of drawing water from a confined aquifer rather than from surface water in this region?

- A. The water in a confined aquifer is always saltier than any surface water in the region, which is the main reason that the community chooses to draw its drinking water from the confined aquifer
- B. The water in a confined aquifer is always warmer than any surface water in the region, which is the main reason that the community chooses to draw its drinking water from the confined aquifer
- C. The impermeable clay layer above the confined aquifer helps protect the groundwater from contamination by pollutants at the surface, making it generally cleaner than nearby surface water
- D. The water in a confined aquifer is always more polluted than any surface water in the region, which is the main reason that the community chooses to draw its drinking water from the confined aquifer

29. Soil scientists describe a soil as "fertile" when it can support healthy plant growth. Which of the following best describes a major factor that affects the fertility of a soil?

- A. The soil's color alone, since the color of any soil is the only factor that determines whether or not the soil is able to support the healthy growth of any kind of plant in any region of the world
- B. The amount of organic matter and nutrients in the soil, since dead plant and animal matter and dissolved nutrients support root growth and the development of plant tissue across an ecosystem

C. The thickness of the bedrock beneath the soil, since the thickness of the bedrock is the only factor that determines whether or not the soil is able to support healthy plant growth in a region

D. The color of the sky above the soil, since the color of the sky above any region is the only factor that determines whether or not the soil is able to support the healthy growth of any kind of plant

30. A meteorologist examines a weather map showing a region where two air masses meet but neither one is moving forward, so the boundary stays in roughly the same location for several days. What type of front is this?

A. A cold front, in which a fast-moving mass of cold air aggressively pushes underneath a warmer air mass and forces it to rise sharply, producing a narrow band of brief, intense storms across the region

B. An occluded front, in which a fast cold front catches up to and overtakes a slower warm front, lifting the warm air completely off the ground and producing complex weather over the affected region

C. A stationary front, in which two air masses meet but neither advances, so the boundary stays in roughly the same place for several days, often bringing extended periods of clouds and precipitation

D. A warm front, in which a mass of warm air slowly advances and slides up and over a retreating mass of cooler air ahead of it, producing broad layers of clouds and long periods of steady precipitation

31. A scientist explains that the air pressure measured at sea level is generally higher than the air pressure measured at the top of a tall mountain. Which of the following best explains this difference in pressure?

A. Air pressure decreases with altitude because there is less atmosphere above a high mountain than above sea level, so the column of air pushing down at the top of the mountain is much lighter

B. Air pressure increases with altitude because the air at high altitudes is denser than the air at sea level, with no relationship at all to the column of atmosphere above the location being measured

C. Air pressure is exactly the same at every altitude, since air pressure has no measurable relationship to altitude at any location on Earth, regardless of the height of the location being measured

D. Air pressure depends only on the time of day, with no measurable relationship to altitude at any location on Earth, regardless of the height of the location being measured at any given time

32. A meteorologist explains that the air around us is mostly made of two gases that together account for nearly 99 percent of the lower atmosphere. Which of the following correctly identifies these two major components of the lower atmosphere?

- A. Hydrogen and helium, which together account for nearly 99 percent of the lower atmosphere on Earth, while all of the other gases in the atmosphere together account for only the remaining 1 percent
- B. Carbon dioxide and methane, which together account for nearly 99 percent of the lower atmosphere on Earth, while all of the other gases in the atmosphere together account for only the remaining 1 percent
- C. Water vapor and argon, which together account for nearly 99 percent of the lower atmosphere on Earth, while all of the other gases in the atmosphere together account for only the remaining 1 percent
- D. Nitrogen (about 78 percent) and oxygen (about 21 percent), which together account for nearly 99 percent of the lower atmosphere on Earth

33. A weather forecaster sees a region of warm, very humid air moving northward from over the Gulf of Mexico into the southeastern United States. Which of the following types of air masses best describes this air?

- A. Continental polar (cP), a cold, dry air mass that forms over the cold, snow-covered interior of Canada, and which often brings clear skies and falling temperatures into the United States in winter
- B. Maritime tropical (mT), a warm, very humid air mass that forms over warm tropical seas such as the Gulf of Mexico, often bringing humid summer weather and afternoon thunderstorms
- C. Continental tropical (cT), a hot, dry air mass that forms over dry desert regions such as the southwestern United States, often bringing very hot and dry weather to surrounding regions in summer
- D. Maritime polar (mP), a cool, moist air mass that forms over the cold North Pacific or North Atlantic Ocean, often bringing low clouds, fog, and steady drizzle to the Pacific Northwest in winter

34. A meteorologist explains that some of the most damaging weather events are tornadoes, which form in association with severe thunderstorms. Which of the following best describes the conditions that most strongly favor tornado formation?

- A. A clear, sunny afternoon with high pressure and very light winds, the typical conditions under which most tornadoes are observed to form across the central United States during the spring and summer
- B. A stationary front that has not moved for several days, where steady gentle drizzle creates the strong rotation needed to produce a tornado, which is how nearly all tornadoes form across the world
- C. Severe thunderstorms called supercells, where strong wind shear and rotating updrafts create the conditions needed to spin up a tornado, especially across the central United States in spring
- D. The calm center of a hurricane, where light winds and clear skies make tornado formation particularly likely during the slow passage of the hurricane's eye across the affected coastal region

35. A scientist explains that climate models predict that continued increases in greenhouse gas emissions will lead to a number of long-term changes in Earth's climate. Which of the following best describes one such projected change?

A. Continued warming of the surface, rising sea levels, and more frequent or intense extreme weather events such as heat waves, droughts, and heavy rains, all of which are projected to continue

B. A sudden long-term return to a global ice age, since adding greenhouse gases to the atmosphere always cools the Earth's surface, regardless of any other factors in the climate system at all

C. A sudden and complete elimination of every form of severe weather worldwide, since adding greenhouse gases to the atmosphere always stabilizes the Earth's weather, regardless of other factors

D. No measurable change in Earth's climate, since the atmosphere is so vast that human emissions of greenhouse gases cannot possibly have any effect on the climate of the planet at any time

36. A scientist explains that the ozone layer in the upper atmosphere is essential for life on Earth's surface. Which of the following best describes one important role of the ozone layer?

A. The ozone layer warms the surface of the Earth to comfortable temperatures by absorbing most of the visible sunlight that would otherwise pass through the atmosphere and reach the surface

B. The ozone layer permanently traps all of the heat radiated by the Earth's surface, which is the main reason that the surface of the Earth is warm enough for liquid water and life to exist at all

C. The ozone layer reflects all of the visible sunlight back into space before it can reach the surface of the Earth, which is the main reason that the surface of the Earth is cool enough for life to exist

D. The ozone layer absorbs most of the Sun's harmful ultraviolet radiation, which would otherwise damage living tissue and DNA in organisms on Earth's surface

37. A community is considering several different options to supply heat to its homes. Which of the following options would most directly reduce the community's greenhouse gas emissions?

A. Installing oil-burning furnaces in every home, since oil-burning furnaces release significant amounts of carbon dioxide and other air pollutants when they are used to heat the homes of the community

B. Installing heat pumps powered by electricity from renewable sources, which can heat and cool homes efficiently without burning fossil fuels and with low direct greenhouse gas emissions

C. Installing coal-burning furnaces in every home, since coal-burning furnaces release significant amounts of carbon dioxide and other air pollutants when they are used to heat the homes of the community

D. Installing natural gas furnaces in every home, since natural gas furnaces release significant amounts of carbon dioxide and methane when they are used to heat the homes of the community

38. A region's freshwater supply depends on its precipitation, evaporation, and water use. Which of the following best describes one important way that climate change can affect a region's freshwater supply?

A. Climate change has no measurable effect on freshwater supplies in any region of the world, since precipitation, evaporation, and water use are all completely independent of any changes in climate

B. Climate change always permanently and instantly doubles the freshwater supply of every region of the world, since warming always brings more rainfall to every region of the world at the same rate

C. Climate change can alter precipitation patterns, increase evaporation, and reduce snowpack and glacier storage, all of which can affect the amount of fresh water available to people in a region

D. Climate change always permanently and instantly halves the freshwater supply of every region of the world, since warming always reduces rainfall in every region of the world at exactly the same rate

39. A coastal community is considering ways to protect itself from sea-level rise and stronger storm surges in the future. Which of the following best describes one example of a "nature-based" adaptation strategy?

A. Building a tall, solid concrete sea wall directly along the entire coastline of the community, with no consideration at all of any natural ecosystems or any habitat for wildlife in the area at all

B. Filling in all of the community's natural wetlands to create more space for buildings and parking lots, regardless of any consequences for natural flood protection or coastal habitats in the area at all

C. Removing all of the natural vegetation from the community's beaches and dunes, regardless of any consequences for natural flood protection or coastal habitats in the area at all in the future

D. Restoring coastal wetlands, mangroves, and oyster reefs to absorb wave energy and reduce flooding, which protects communities while also providing habitat for many species

40. A factory has installed equipment to capture and reuse much of the water it once discharged into a nearby river. Which of the following best describes the most direct environmental benefit of this kind of water reuse?

- A. The factory's annual greenhouse gas emissions are eliminated entirely, since reusing water has been shown to directly remove all of the carbon dioxide and methane from the factory's industrial operations
- B. The factory reduces its withdrawal of fresh water from local sources and reduces the amount of polluted discharge it releases into the river, helping to conserve water and protect the local water quality
- C. The factory's annual electricity use is eliminated entirely, since reusing water has been shown to directly eliminate all of the electricity used by every industrial process in any factory in any region
- D. The factory's annual production of solid waste is eliminated entirely, since reusing water has been shown to directly remove all of the solid waste from every industrial process in any factory anywhere

41. Many countries have signed international agreements aimed at reducing the use of substances that damage the ozone layer. Which of the following best describes one important reason for these international agreements?

- A. The ozone layer is unaffected by any human activity, so international agreements have no real role in protecting the ozone layer or in reducing the emission of any chemicals at all
- B. The ozone layer is shared globally and substances that damage it can travel through the entire atmosphere, so international cooperation is needed to effectively reduce damage to the ozone layer
- C. The ozone layer is shared globally and substances that damage it can travel through the entire atmosphere, so international cooperation has been shown to be effective at protecting the ozone layer
- D. The ozone layer affects only a few small regions of Earth's surface, so international cooperation is not actually necessary in order to protect the ozone layer from damage by any chemicals at all

42. A national park system protects large areas of land and the species that live there. Which of the following best describes one important benefit of protected areas like national parks for biodiversity?

- A. Protected areas preserve habitat for many species, support natural ecological processes, and help maintain biodiversity by limiting development, hunting, and other human activities within their boundaries
- B. Protected areas guarantee that no species in any region of the world will ever go extinct again, regardless of any environmental changes that may occur anywhere on the planet for the rest of time
- C. Protected areas make it possible to develop the surrounding region without any environmental review, since the protected area itself fully compensates for any damage that may occur in the wider region
- D. Protected areas have no relationship at all to biodiversity, since protecting any single area of land never has any effect on the long-term survival of any species in any region of the world

43. A region is experiencing a sharp decline in pollinating insects such as bees and butterflies. Which of the following best describes the most direct environmental consequence of such a decline for the region's ecosystems and agriculture?

- A. The region's groundwater becomes immediately cleaner, since a decline in pollinators always permanently and instantly improves the water quality of every aquifer beneath every farm and natural area
- B. The region's air quality immediately improves, since a decline in pollinators always permanently and instantly improves the air quality of every region of the world that experiences any kind of decline
- C. The region's average temperature falls sharply, since a decline in pollinators always permanently and instantly cools the climate of every region of the world that experiences any kind of decline at all
- D. Many flowering plants in the region, including important crops, may produce less fruit and fewer seeds, reducing both the productivity of natural ecosystems and the yields of agricultural lands

44. A scientist explains that the human population has grown rapidly over the past two centuries and now exceeds 8 billion people. Which of the following best describes how this growth has affected the demand for energy?

- A. Demand for energy has remained completely unchanged over the past two centuries, since growth in the human population has no measurable relationship to energy demand of any kind in any country
- B. Demand for energy has grown sharply over the past two centuries, both because there are more people and because each person on average uses more energy than people used in earlier centuries
- C. Demand for energy has fallen sharply over the past two centuries, since population growth always reduces the total energy demand of any country, regardless of any other factors involved at all
- D. Demand for energy is now perfectly balanced with the available supply of fossil fuels, since population growth has been carefully matched to the supply of fossil fuels in every country in the world

45. A community wants to reduce the amount of paper, glass, and metal sent to its landfill. Which of the following actions, taken at the household level, would most directly reduce the amount of these materials sent to local landfills?

- A. Discarding all paper, glass, and metal materials into ordinary household trash without sorting any of them for recycling or reuse, which has been shown to be the most environmentally friendly disposal method

- B. Burning all paper, glass, and metal materials in an open pile in the backyard, which has been shown to be the cleanest and most environmentally friendly way to handle the waste from any household ever
- C. Separating paper, glass, and metal items into recycling bins so that these materials can be recovered and processed into new products, diverting them from the landfill and conserving raw materials
- D. Storing all paper, glass, and metal items indefinitely in the attic or basement of the house, with no recycling, reuse, or disposal at all, which has been shown to be the safest way to handle waste

46. Some lakes and rivers have become highly acidic over the past century due to acid rain. Which of the following best describes the main human source of the pollutants that cause acid rain?

- A. The burning of fossil fuels, which releases sulfur dioxide and nitrogen oxides that react with atmospheric water vapor to form sulfuric and nitric acids that fall to Earth as acid rain
- B. The decay of food waste in landfills, which is the main human source of the pollutants that cause acid rain to fall on lakes and rivers around the world, regardless of any other sources at all
- C. The cultivation of crops in fields, which is the main human source of the pollutants that cause acid rain to fall on lakes and rivers around the world, regardless of any other sources at all
- D. The construction of new roads and highways, which is the main human source of the pollutants that cause acid rain to fall on lakes and rivers around the world, regardless of any other sources at all

47. A city has built bike paths, planted trees along streets, and expanded its public transportation system. Which of the following best describes the most direct environmental benefit of this combination of actions?

- A. The city's average rainfall is permanently changed, since changes to bike paths, street trees, and public transportation have been shown to directly alter long-term precipitation patterns over the surrounding region
- B. The city's residents no longer need to use any source of energy of any kind for any of their daily lives, since changes to bike paths, street trees, and public transportation fully replace every other source of energy demand
- C. The city's average temperature falls sharply in the summer, since changes to bike paths, street trees, and public transportation have been shown to directly cool the climate of every region of the world that experiences them
- D. The city reduces air pollution and greenhouse gas emissions from cars, while also creating green spaces that absorb stormwater and provide cooler outdoor environments during hot weather

48. An engineering team has been asked to design a new system to provide clean drinking water to a small village. Before they begin sketching solutions, the team meets with village leaders to learn about the community's water sources, available materials, budget, and the skills of local technicians. Which step of the engineering design process is the team performing in this meeting?

- A. Building the final product, since meeting with village leaders to gather information is the same step as delivering a fully completed water system to the community that will eventually use it for many years
- B. Defining the problem, since gathering information about the community's needs and identifying the criteria and constraints the solution must address is a key part of the early problem-definition phase
- C. Releasing the prototype, since meeting with village leaders to gather information is the same step as installing a small early test version of a water system in the village for an extended period of time
- D. Brainstorming solutions, since meeting with village leaders to gather information is the same step as generating a wide range of possible water system designs from which the team will later choose

49. An engineering team has tested several prototypes of a new wind turbine blade and has found that one particular blade shape produces the most electricity but also makes the most noise. The team must decide which blade shape to use. Which of the following best describes how the team should make this decision?

- A. The team should evaluate each blade shape against the criteria and constraints, weighing the trade-offs between power output, noise, cost, and other relevant factors before choosing a final design
- B. The team should always choose the blade shape that produces the most electricity, regardless of how much noise it makes or any other factor, since power output is always the only important criterion for any wind turbine
- C. The team should always choose the blade shape that produces the least amount of noise, regardless of how little electricity it produces or any other factor, since noise is always the only important criterion for any wind turbine
- D. The team should choose one of the blade shapes completely at random, since there is no reliable way to compare competing engineering designs to one another in any kind of meaningful or systematic way at any time

50. A scientist explains that science and engineering, although related, have different but complementary goals. Which of the following best describes how science and engineering complement each other?

- A. Science and engineering are completely unrelated, since each one develops in complete isolation from the other in every situation, with no shared methods or shared goals between the two fields at all
- B. Science and engineering have exactly the same goal of designing new products, with no real distinction between the two fields in terms of their methods, their questions, or their final products
- C. Science seeks to understand natural phenomena, while engineering applies that understanding to design solutions to problems, and each field provides knowledge and tools that support the other
- D. Science and engineering have exactly the same goal of explaining nature, with no real distinction between the two fields in terms of their methods, their questions, or the products that they create

Practice Exam 59: Answer Key with Explanations

1. B — The cosmic microwave background is the cooled remnant of radiation released when the universe first became transparent to light, providing strong evidence that the universe began in a hot, dense state. Its uniform presence across the whole sky supports the Big Bang model. It is one of the most powerful pieces of cosmological evidence.
2. C — A more massive star lives a much shorter time than the Sun because massive stars burn through their nuclear fuel at far higher rates. Higher core temperatures and pressures accelerate fusion. Mass, not fuel supply alone, sets a star's lifetime.
3. A — The carbon in living organisms and the oxygen we breathe were once part of earlier generations of stars, which produced these elements before scattering them into space when they died. Stellar nucleosynthesis is the origin of nearly every element heavier than helium. Living things are literally made of stardust.
4. D — Kepler's Second Law means a planet moves faster when closer to the Sun and slower when farther away, because covering equal areas in equal times requires more arc near the Sun. Speed adjusts so the sweep rate stays constant. This explains the changing pace along an elliptical orbit.
5. C — Kepler's Third Law gives $T^2 = a^3$, so with $T = 8$, T^2 equals 64 and a is the cube root of 64, exactly 4 AU. The square of the period sets the cube of the distance. This relationship applies to any object orbiting the Sun.
6. B — On the June solstice the Sun appears directly overhead at noon along the Tropic of Cancer, about 23.5° north latitude. The Northern Hemisphere is then tilted most toward the Sun. This solstice marks the start of Northern Hemisphere summer.
7. D — A full moon is followed about a week later by the last quarter, with exactly the left half of the visible disk illuminated in the early morning sky before sunrise. The lunar cycle proceeds new \rightarrow first quarter \rightarrow full \rightarrow last quarter \rightarrow new. Seven days after full places the Moon at last quarter.
8. A — The Moon is much smaller than Earth, so it casts only a small, narrow shadow on Earth's surface, and only the region directly under this umbra experiences totality. Outside the umbra observers see only a partial eclipse. Shadow geometry sets the narrow totality path.
9. C — The Moon moves about 13 degrees eastward along its orbit each day, so Earth must rotate an extra ~ 50 minutes to bring a given location back to the same alignment with the Moon. This is why high tides shift by about 50 minutes daily. The lunar day is longer than the solar day for this reason.

10. B — The age of the solar system was determined by radiometric dating of the oldest rocks and meteorites, which provide samples of material formed at the very beginning. Lunar samples and meteorites give consistent ages near 4.6 billion years. This is how the age is established.
11. A — The Sun's hot, faint outer atmosphere, which extends millions of kilometers into space and reaches temperatures of about a million kelvin or more, is the corona. It is visible during total solar eclipses when the bright photosphere is blocked. Its high temperature remains an active area of research.
12. D — Absolute dating gives the exact numerical age of a rock or fossil sample in years using methods such as radiometric dating of unstable isotopes. Relative dating, by contrast, only orders ages. Radiometric ash-bed dating is a classic example of absolute dating.
13. C — By the principle of inclusions, fragments included within an igneous rock must be older than the rock that contains them, because the fragments had to exist before they could be incorporated into the magma. The host rock formed last. This rule helps establish relative ages in mixed rock bodies.
14. A — One-sixteenth remaining means four half-lives have passed, since $1 \rightarrow 1/2 \rightarrow 1/4 \rightarrow 1/8 \rightarrow 1/16$. Four half-lives \times 750 years equals 3,000 years. Counting halvings is the key to radiometric age problems.
15. D — Carbon-14 has a relatively short half-life of about 5,700 years, so after roughly 50,000 years almost no carbon-14 remains, making it useful only for relatively recent organic material. Older rocks must be dated with longer-lived isotopes. The choice of isotope matches the expected age range.
16. B — Extinction is the permanent disappearance of a species from Earth, occurring when no individuals of that species remain alive anywhere on the planet. It ends a species' presence in the fossil record. Extinction is irreversible on human timescales.
17. C — Permian-age glacial deposits across continents that span both hemispheres support the idea that those continents were once joined into a southern landmass near the South Pole, where a single ice sheet could deposit material now scattered across separated continents. The reassembly makes the distribution coherent. This was key evidence for continental drift.
18. B — The fossil record shows a progression from simpler organisms in older layers to more complex and diverse organisms in younger layers, indicating that life has changed over geologic time. This orderly change reflects evolution and extinction. It is a foundation of biostratigraphy.
19. A — In the early stage of continental rifting, a rift valley forms as the crust thins and drops between fault blocks, gradually creating a long, narrow valley that may later flood to form a new sea. The East African Rift is a present-day example. Further rifting can produce a new ocean basin.
20. D — The Pacific Ring of Fire is geologically active because its edges are lined with subduction zones and transform faults, where active plate boundaries produce volcanoes and earthquakes. Tectonic activity, not ocean size or tidal pull, drives the pattern. Most of Earth's seismic and volcanic activity concentrates there.
21. B — The asthenosphere is the partially molten upper part of the mantle, lying just below the rigid lithosphere, on which the lithospheric plates move slowly. Its plastic behavior allows plate motion above. Lithosphere riding on asthenosphere is the geometry behind plate tectonics.
22. C — A fine-grained dark igneous rock with tiny crystals barely visible to the eye, like basalt, forms when lava cools rapidly at or near Earth's surface, leaving little time for large crystals to grow. Rapid cooling limits crystal size. Slow, deep cooling, by contrast, yields coarse-grained rocks like gabbro.

23. A — Graded bedding, with coarser particles below and finer above, forms when underwater flows called turbidity currents deposit the coarser grains first as they slow, while finer grains continue to settle longer. The single layer grades from coarse to fine upward. Turbidites are common in submarine fans.
24. D — A delta grows outward into a lake as new layers of sediment are added year after year, with coarser sediment near the river mouth and finer sediment carried farther in. Deposition exceeds erosion at the river's mouth. The Mississippi Delta is a classic example.
25. B — Well-rounded grains of similar size indicate that the sediment was transported some distance by water or wind, which both rounded the grains and sorted them by size before deposition. Transport energy works the grains; sorting reflects consistent flow. Cementation later turns the deposit into sandstone.
26. D — Porosity describes the amount of pore space available to store water, and permeability describes how easily water can flow through the connected pore spaces. Together they determine how much water a rock holds and how readily it moves. A good aquifer has high values of both.
27. A — Ocean waves striking a cliff's base, undermining it, and causing the cliff face to retreat landward is coastal erosion by wave action. Wave attack at the base is the primary driver. Glacial, wind, and frost processes operate elsewhere.
28. C — The impermeable clay layer above a confined aquifer helps protect the groundwater from surface contamination, making it generally cleaner than nearby surface water. The confining layer blocks downward percolation of pollutants. This is a major advantage of confined aquifers as drinking water sources.
29. B — A soil's fertility is strongly affected by the amount of organic matter and nutrients it contains, since dead plant and animal matter and dissolved nutrients support root growth and plant tissue development. Decomposers concentrate these inputs in the topsoil. Losing topsoil to erosion strips fertility.
30. C — A stationary front is one in which two air masses meet but neither advances, so the boundary stays in roughly the same place for several days, often bringing extended clouds and precipitation. Movement of either air mass would convert it into a cold or warm front. Stalled fronts can produce long-duration flooding.
31. A — Air pressure decreases with altitude because there is less atmosphere above a high mountain than above sea level, so the column of air pushing down is lighter at higher elevations. Pressure measures the weight of the overlying air. This is why barometric pressure falls as you climb.
32. D — The lower atmosphere is about 78 percent nitrogen and 21 percent oxygen by volume, which together account for about 99 percent of dry air. Argon and trace gases including CO₂ make up the rest. These proportions are remarkably uniform up through the troposphere.
33. B — Warm, very humid air moving northward from the Gulf of Mexico is a maritime tropical (mT) air mass, which forms over warm tropical seas and often brings humid summer weather and afternoon thunderstorms. "Maritime" indicates moisture and "tropical" indicates warmth. This contrasts with cold, dry continental polar air.
34. C — Tornadoes form most often in severe thunderstorms called supercells, where strong wind shear and rotating updrafts create the rotation needed to spin up a tornado. Shear tilts horizontal rotation into the vertical. The central United States in spring is especially prone to such storms.
35. A — Continued warming of the surface, rising sea levels, and more frequent or intense extreme weather such as heat waves, droughts, and heavy rains are projected impacts of rising greenhouse gas emissions. These trends follow from added greenhouse gases. They are well supported by climate models and observations.

36. D — The ozone layer absorbs most of the Sun's harmful ultraviolet radiation, which would otherwise damage living tissue and DNA. UV is the specific danger ozone screens out. Without it, surface life would face dramatically higher cancer rates and ecosystem harm.
37. B — Installing heat pumps powered by electricity from renewable sources can heat and cool homes efficiently without burning fossil fuels and with low direct greenhouse gas emissions. Heat pumps move heat rather than generating it by combustion. Combined with clean electricity, they greatly reduce emissions.
38. C — Climate change can alter precipitation patterns, increase evaporation, and reduce snowpack and glacier storage, all of which affect a region's available fresh water. Warming dries some regions and intensifies floods in others. Water management must adapt to these shifts.
39. D — Restoring coastal wetlands, mangroves, and oyster reefs absorbs wave energy and reduces flooding while providing habitat for many species, making it a nature-based adaptation strategy. These ecosystems work with natural processes rather than against them. They often complement built defenses.
40. B — Capturing and reusing water reduces the factory's withdrawals from local sources and reduces polluted discharge into the river, helping conserve water and protect local water quality. Both inflow and outflow improve. Water reuse is a key sustainability practice.
41. C — The ozone layer is shared globally and substances that damage it travel through the entire atmosphere, so international cooperation has been shown to be effective at protecting it. The Montreal Protocol successfully reduced CFC emissions worldwide. The ozone layer is now slowly recovering.
42. A — National parks and other protected areas preserve habitat for many species, support natural ecological processes, and help maintain biodiversity by limiting development, hunting, and other human activities within their boundaries. Protected lands are key tools for conservation. They cannot prevent every extinction but greatly improve odds.
43. D — A decline in pollinators reduces the production of fruit and seeds in many flowering plants, including important crops, lowering both natural ecosystem productivity and agricultural yields. Pollination links plant reproduction to ecosystem services. Pollinator loss is a serious biodiversity and food-security issue.
44. B — Energy demand has grown sharply over the past two centuries because there are more people and each person on average uses more energy than people used in earlier centuries. Both numbers and per-capita use rose. This is a key driver of rising emissions.
45. C — Separating paper, glass, and metal into recycling bins lets these materials be recovered and processed into new products, diverting them from landfills and conserving raw materials. Recycling cuts both waste and resource extraction. It is a core household sustainability practice.
46. A — Acid rain forms mainly from sulfur dioxide and nitrogen oxides released by burning fossil fuels, which react with atmospheric water vapor to form sulfuric and nitric acids that fall to Earth. Power plants and vehicles are major sources. Cutting these emissions has reduced acid rain.
47. D — Bike paths, street trees, and improved public transportation together reduce air pollution and greenhouse gas emissions from cars while creating green spaces that absorb stormwater and provide cooler outdoor environments. Each element targets different urban challenges. Combined, they advance environmental and public-health goals.
48. B — Gathering information about the community's needs and identifying the criteria and constraints the solution must address is part of defining the problem, the early phase of the engineering design process. A well-defined problem guides all later steps. Skipping it leads to wasted effort on poorly aimed designs.

49. A — The team should evaluate each blade shape against the criteria and constraints, weighing trade-offs between power output, noise, cost, and other relevant factors before choosing a design. Structured trade-off analysis is at the heart of engineering judgment. Single-criterion or random choices ignore real-world complexity.
50. C — Science seeks to understand natural phenomena, while engineering applies that understanding to design solutions to problems, and each field provides knowledge and tools that support the other. Scientific findings enable new technologies, and engineering tools enable new science. The two fields advance together.