

PRACTICE EXAM 24: EARTH AND SPACE SCIENCES REGENTS SIMULATION (50 QUESTIONS)

1. The light from a distant galaxy is shifted toward the red end of the spectrum, and a closer galaxy shows a smaller shift. What does comparing these two redshifts tell astronomers?

- A. The distant galaxy is made of hotter gas than the nearer galaxy, which produces the larger shift
- B. The more distant galaxy is moving away faster, which fits a universe that is expanding overall
- C. The distant galaxy is approaching us rapidly, while the nearer galaxy is moving away slowly
- D. The two galaxies are exactly the same distance away but contain different chemical elements

2. Stars are born within vast clouds of gas and dust in space. What causes a portion of such a cloud to begin forming a star?

- A. Gravity pulls the gas and dust together, and the collapsing material heats up until fusion begins
- B. Sunlight from nearby stars chemically bonds the gas particles together into a solid young star
- C. The magnetic field of the galaxy freezes the cloud in place until it suddenly ignites as a star
- D. Collisions between fully formed planets within the cloud release the energy needed to form a star

3. Inside a star, the fusion of lighter elements into heavier ones releases energy, but this process stops once the star's core builds up which element?

- A. Hydrogen, the lightest element, beyond which no further fusion of any kind can ever take place
- B. Helium, which cannot be fused into any heavier element under any conditions found in stars
- C. Carbon, which marks the absolute upper limit of all fusion reactions in every type of star

D. Iron, because fusing iron into heavier elements absorbs energy rather than releasing it

4. A planet orbits the Sun at an average distance of 25 AU. Using Kepler's Third Law ($T^2 = a^3$ in solar units), which expression gives the planet's orbital period in years?

A. The period equals 25 multiplied by 3, since the period is always three times the average distance

B. The period equals the square root of 25, since the period is the square root of the average distance

C. The period equals the square root of 25 cubed, since T squared equals a cubed in these units

D. The period equals 25 divided by 2, since the period is always half of the average distance value

5. At noon on the summer solstice, the Sun appears much higher in the sky for an observer in Florida than for an observer in northern Canada. What is the main reason for this difference?

A. Florida is much closer to the Sun than northern Canada because it lies at a lower elevation

B. The Sun emits more radiation toward Florida than toward northern Canada on that single day

C. Florida experiences summer while northern Canada experiences winter on the same calendar day

D. Florida is at a lower latitude, so the Sun's rays strike it from a more nearly overhead angle

6. About one week after a new moon, an observer in New York sees the Moon exactly half illuminated on its right side, high in the sky at sunset. What phase is this?

A. First quarter, the phase that occurs about one week after new moon as the Moon waxes toward full

B. Last quarter, the phase that occurs about one week after the full moon as the Moon wanes toward new

C. Waning crescent, the thin sliver phase that occurs just before the Moon returns to the new phase

D. Waxing gibbous, the more-than-half phase that occurs between the first quarter and the full moon

7. The inner planets (Mercury, Venus, Earth, Mars) are small and rocky, while the outer planets (Jupiter, Saturn, Uranus, Neptune) are large and made mostly of gas and ice. Which statement about their densities is correct?

- A. The outer gas giants are far denser than the inner rocky planets because of their enormous size
 - B. All eight planets have nearly identical densities because they all formed from the same materials
 - C. The inner rocky planets are generally denser than the outer gas giants, which are large but low in density
 - D. Density has no relationship to a planet's composition, so it cannot be predicted from planet type
8. During one type of eclipse, Earth passes directly between the Sun and the Moon, casting Earth's shadow onto the Moon. What is this event called, and during which moon phase does it occur?
- A. A solar eclipse, which occurs during the new moon phase when the Moon blocks the Sun from view
 - B. A lunar eclipse, which occurs during the full moon phase when Earth's shadow falls on the Moon
 - C. A solar eclipse, which occurs during the full moon phase when the Moon passes through the shadow
 - D. A lunar eclipse, which occurs during the new moon phase when the Moon lies between Earth and Sun
9. At a certain harbor, the difference between high and low tide is unusually small this week. The Moon is currently at first quarter. What best explains the small tidal range?
- A. The Sun and Moon are pulling at right angles, so their gravitational effects partly cancel, producing neap tides
 - B. The Sun and Moon are aligned in a straight line, so their pulls combine to produce the largest tides
 - C. The Moon is at its closest point to Earth, which always reduces the size of the tides at every coast
 - D. Strong winds are blowing offshore this week, which is the only thing that ever changes the tidal range
10. Dark spots called sunspots appear on the Sun's visible surface and are cooler than the surrounding areas. On which layer of the Sun do sunspots appear?
- A. The core, the central region where the Sun's energy is generated by the fusion of hydrogen
 - B. The corona, the faint outer atmosphere that becomes visible during a total solar eclipse
 - C. The radiative zone, the deep interior layer through which energy slowly travels toward the surface
 - D. The photosphere, the visible surface layer of the Sun from which most of its light is emitted

11. Two identical solar panels are set up in the same city, one lying flat on the ground and one tilted to face the Sun directly at noon. The tilted panel collects more energy. Why?

- A. The tilted panel is physically closer to the Sun than the flat panel, so it intercepts more radiation
- B. The flat panel reflects all sunlight while the tilted panel absorbs all of it without any reflection
- C. Sunlight strikes the tilted panel more directly, concentrating more energy on its surface area
- D. The tilted panel is cooler, and cooler surfaces always collect more solar energy than warm ones

12. A geologist examines a cliff with five undisturbed horizontal layers of sedimentary rock. Which layer is the youngest?

- A. The layer in the exact middle of the sequence, since the middle layers always form last of all
- B. The topmost layer, since in undisturbed rock the highest layer is the most recently deposited
- C. The bottom layer, since the deepest layer is always the last one to be deposited over time
- D. The youngest layer cannot be identified from position because all five layers are the same age

13. A radioactive isotope has a half-life of 1,000 years. A sample originally held 64 grams of the isotope. After 4,000 years, how many grams of the original isotope remain?

- A. About 32 grams remain, because 4,000 years represents a single half-life of the isotope decaying
- B. About 16 grams remain, because 4,000 years represents two half-lives of the isotope decaying away
- C. About 8 grams remain, because 4,000 years represents three half-lives of the isotope decaying away
- D. About 4 grams remain, because 4,000 years represents four half-lives of the isotope decaying away

14. A distinctive trilobite species is found in a rock layer in New York and in a rock layer in Morocco. Because this trilobite lived only during a narrow span of time, what can geologists conclude?

- A. The two rock layers, though far apart, formed during the same interval of geologic time
- B. The two rock layers must be made of exactly the same minerals and have the same color
- C. The trilobite must still be alive today somewhere between New York and Morocco's locations

D. The New York layer is necessarily much older than the layer found in Morocco far away

15. While studying a rock sequence, a geologist identifies an unconformity, a buried surface where rock was eroded away before new layers were deposited on top. What does an unconformity primarily represent?

- A. A period of unusually rapid deposition during which many layers piled up in a very short time
- B. A boundary between two layers that formed at exactly the same time under identical conditions
- C. A gap in the rock record representing a span of time for which no rock layers were preserved
- D. A zone where molten rock pushed upward and cooled between two older sedimentary rock layers

16. The extinction of the non-bird dinosaurs about 66 million years ago is most strongly linked to which event, based on a worldwide layer of iridium and shocked quartz?

- A. A long, gradual ice age that slowly froze the dinosaurs out over tens of millions of years
- B. A massive asteroid impact that threw debris into the atmosphere and disrupted the global climate
- C. A sudden rise in atmospheric oxygen that the large dinosaurs were unable to breathe and survive
- D. The slow drifting apart of the continents, which separated the dinosaurs from their only food sources

17. Scientists have found that the rocks of the ocean floor are far younger than the oldest rocks found on the continents. What does this discovery help explain?

- A. New ocean floor is continually created at mid-ocean ridges and later destroyed at subduction zones
- B. The continents are actually much younger than the oceans and formed only very recently in Earth's past
- C. The ocean floor has never moved or changed since it first formed early in Earth's long history
- D. The oldest rocks on Earth must all be located at the very bottom of the deepest ocean trenches

18. A rock layer consists of well-rounded, well-sorted sand grains arranged in large sweeping cross-beds, with no marine fossils present. Which past environment does this most strongly suggest?

- A. A deep, calm ocean floor where extremely fine clay particles slowly settled far from any land
- B. A coral reef in a warm, shallow tropical sea teeming with shelled organisms and other marine life
- C. A glacial valley where moving ice deposited a chaotic, unsorted jumble of rock fragments and clay
- D. A desert environment where wind piled sand into large dunes, rounding and sorting the grains by size

19. The Japanese islands include a chain of volcanoes that formed where one oceanic plate sinks beneath another oceanic plate. What type of plate boundary produces this kind of volcanic island arc?

- A. A divergent boundary, where two oceanic plates spread apart and magma rises to form new seafloor
- B. A convergent boundary, where one oceanic plate subducts beneath another, melting to feed volcanoes
- C. A transform boundary, where two oceanic plates slide past each other without producing any volcanoes
- D. A passive margin, where the edge of a continent lies far from any plate boundary and is geologically quiet

20. When a large earthquake occurs, seismographs around the world detect P-waves but record a "shadow zone" where S-waves are completely absent on the opposite side of Earth. What does this absence of S-waves reveal?

- A. Earth's interior is completely solid all the way through, allowing both wave types to travel freely
- B. Earth's interior is entirely molten, which is why the slower S-waves cannot pass through any of it
- C. Earth has a liquid outer core, because S-waves cannot travel through liquids and are blocked by it
- D. Earthquakes are simply too weak to send S-waves all the way through the planet to the far side

21. Over time, fragments of older rocks are broken down, transported by water, and deposited in layers that are then compacted and cemented together. What type of rock forms through this process?

- A. A clastic sedimentary rock, formed from compacted and cemented fragments of preexisting rocks
- B. An intrusive igneous rock, formed when molten magma slowly cools far below the Earth's surface
- C. A foliated metamorphic rock, formed when existing rock is banded under intense heat and pressure
- D. An extrusive igneous rock, formed when lava erupts onto the surface and cools very rapidly there

22. When broken, one mineral splits cleanly along flat, parallel surfaces, while another breaks into curved, irregular surfaces. What two properties are being compared between these minerals?

- A. Hardness and streak, which describe scratch resistance and the color of a mineral's powder
- B. Luster and color, which describe how a mineral reflects light and its appearance to the eye
- C. Density and magnetism, which describe a mineral's mass per volume and its magnetic behavior
- D. Cleavage and fracture, which describe whether a mineral breaks along flat planes or irregular surfaces

23. A geologist examines a light-colored, coarse-grained igneous rock rich in quartz and feldspar. Which rock is this most likely to be, and how did it form?

- A. Basalt, a dark, fine-grained rock that formed when iron-rich lava cooled quickly at Earth's surface
- B. Granite, a light-colored, coarse-grained rock that formed when silica-rich magma cooled slowly underground
- C. Obsidian, a dark, glassy rock that formed when lava cooled so rapidly that no crystals could grow at all
- D. Limestone, a light-colored sedimentary rock that formed from the carbonate remains of marine organisms

24. A forested hillside is cleared and paved over to build a parking lot. How does this change most likely affect rainwater that falls on the area?

- A. More rainwater will soak into the ground, raising the local water table beneath the parking lot
- B. The total amount of rainwater falling on the area will decrease sharply because of the paving
- C. More rainwater will run off the surface as runoff, since pavement prevents it from soaking in
- D. Rainwater will evaporate before it reaches the ground, so almost none of it will run off at all

25. Which underground material would make the best aquifer, capable of both storing a large amount of water and allowing it to flow freely to a well?

- A. A thick layer of well-sorted sand and gravel, which has both high porosity and high permeability

- B. A layer of solid, unfractured granite, which has very low porosity and very low permeability
- C. A dense layer of clay, which has high porosity but extremely low permeability for water flow
- D. A sheet of solid bedrock with no cracks, which blocks water from both entering and flowing through

26. Forests are sometimes called "carbon sinks." What does this term mean in the context of the carbon cycle?

- A. Forests release large amounts of carbon dioxide into the air, raising its concentration over time
- B. Forests have no measurable effect on the amount of carbon dioxide in the Earth's atmosphere
- C. Forests convert all the carbon dioxide they absorb directly into solid rock beneath the soil
- D. Forests absorb carbon dioxide through photosynthesis and store the carbon in wood and soil

27. Warmer air can hold more water vapor, and water vapor is itself a greenhouse gas that traps heat and causes still more warming. This self-reinforcing process is best described as which of the following?

- A. A negative feedback, because the added water vapor works to cool the atmosphere back down again
- B. An external forcing, because the water vapor comes from outside the Earth's climate system entirely
- C. A positive feedback, because the added water vapor amplifies the warming that produced it in the first place
- D. A neutral process, because water vapor in the atmosphere has no effect on the planet's temperature

28. In regions with thick limestone bedrock, slightly acidic rainwater seeps into cracks and slowly dissolves the rock, forming caves and sinkholes over long periods. What type of weathering is this?

- A. Mechanical weathering, in which the rock is physically broken into smaller pieces without changing chemically
- B. Chemical weathering, in which acidic water reacts with and dissolves the limestone, changing it chemically
- C. Frost wedging, in which water freezing within the cracks expands and physically pries the rock apart
- D. Abrasion, in which sand carried by wind or water grinds against the rock surface and wears it down

29. A slow-moving river flowing across a flat landscape develops large, looping bends called meanders. Over time, what commonly happens to these meanders?

- A. The river erodes the outer banks and deposits sediment on the inner banks, causing the meanders to migrate
- B. The meanders straighten themselves automatically as the river water gradually speeds up over the years
- C. The meanders cause the river to flow uphill against gravity along the outer edge of each curving bend
- D. The meanders have no effect on the river's banks, since slow rivers cannot erode or deposit any sediment

30. The characteristics of an air mass (its temperature and moisture) are determined mainly by which factor?

- A. The speed at which the air mass travels across the surface after it has fully formed
- B. The time of day at which the air mass first begins to move away from its place of origin
- C. The type of surface over which the air mass forms, such as warm ocean, cold land, or desert
- D. The direction in which the air mass happens to be moving as it crosses over a given region

31. As a warm front slowly approaches, an observer notices high, wispy clouds appear first, followed hours later by progressively lower and thicker clouds, and finally steady rain. What causes this orderly sequence of clouds?

- A. The cold air ahead of the front sinks rapidly, scattering clouds randomly across the entire sky
- B. The warm air sinks beneath the cold air, so the thickest clouds always appear at the highest altitudes
- C. The front pushes all the existing clouds away, leaving completely clear skies just before the rain begins
- D. Warm air rides gradually up over the retreating cold air, forming clouds at decreasing heights as it nears

32. Relative humidity compares the amount of water vapor in the air to the maximum the air could hold at that temperature. On a day when the air holds exactly half of the water vapor it could hold, what is the relative humidity?

- A. The relative humidity is 0 percent, because the air is only partly filled with water vapor
- B. The relative humidity is 50 percent, because the air holds half of its maximum possible water vapor
- C. The relative humidity is 100 percent, because any water vapor present means the air is fully saturated
- D. The relative humidity is 200 percent, because the air could still hold twice as much water vapor

33. The strongest winds and heaviest rainfall in a hurricane are found in which part of the storm?

- A. The eyewall, the ring of towering thunderstorms that immediately surrounds the calm central eye
- B. The eye, the calm clear center of the storm where the winds are weakest and the skies are clearest
- C. The outermost edge of the storm, hundreds of kilometers from the center, where the storm first begins
- D. The region directly above the storm in the upper atmosphere, far above where any rain can ever fall

34. Which of the following correctly lists gases that act as greenhouse gases by trapping heat in Earth's atmosphere?

- A. Oxygen and nitrogen, the two most abundant gases, which together trap nearly all of Earth's heat
- B. Helium and argon, two inert gases that strongly absorb and re-radiate the infrared energy from Earth
- C. Carbon dioxide, water vapor, and methane, which absorb and re-radiate outgoing infrared energy
- D. Hydrogen and neon, two light gases that rise to the top of the atmosphere and reflect heat downward

35. Air naturally flows from areas of high pressure toward areas of low pressure. What do we call this horizontal movement of air across the surface?

- A. Precipitation, the movement of water from the atmosphere down to the surface as rain or snow
- B. Wind, the horizontal movement of air driven by differences in air pressure from place to place
- C. Convection, the vertical rising of warm air and sinking of cold air within a single column
- D. Conduction, the transfer of heat directly between two objects that are physically touching

36. A scientist states that a single cold, snowy winter does not disprove global warming. What is the best reasoning behind this statement?

- A. Cold winters never actually happen anymore now that the global climate has begun to warm up
- B. A single winter's weather is more important than long-term data when judging the global climate
- C. Global warming means every single day everywhere on Earth must be warmer than the day before
- D. Climate is the long-term average of weather, so one cold winter is short-term weather, not a climate trend

37. Which of the following best describes the key difference between renewable and nonrenewable energy resources?

- A. Renewable resources are always cheaper to use, while nonrenewable resources are always more expensive
- B. Renewable resources produce no energy at all, while nonrenewable resources produce all of the world's energy
- C. Renewable resources are replenished by natural processes on human timescales, while nonrenewable ones are not
- D. Renewable resources are found only underground, while nonrenewable resources are found only above ground

38. A factory saves money by releasing smoke into the air, but nearby residents experience increased asthma and higher medical bills. The residents' medical costs are an example of which of the following?

- A. A negative externality, a cost of the factory's activity that is borne by people outside the transaction
- B. A private benefit, a gain that the factory earns directly from selling the goods that it manufactures
- C. A renewable resource, something the residents can use over and over without it ever running out
- D. A government subsidy, a direct payment the factory receives to help cover its production expenses

39. A river running past several factories becomes contaminated with toxic chemicals, and over time many fish and amphibian species disappear from the river. Which driver of biodiversity loss does this best illustrate?

- A. Habitat fragmentation, in which a habitat is divided into small isolated pieces by human development
- B. Overharvesting, in which organisms are removed from the wild faster than they are able to reproduce
- C. Invasive species, in which a non-native organism is introduced and outcompetes the native species
- D. Pollution, in which harmful substances released into the environment poison and kill living organisms

40. Bees and other insects pollinate flowering plants, including many of the crops that humans depend on for food. This pollination is best classified as which category of ecosystem service?

- A. A provisioning service, because pollination is itself a physical product that humans harvest and consume
- B. A regulating service, because pollination is a natural process that supports and maintains crop production
- C. A cultural service, because pollination provides people with recreation, beauty, and spiritual inspiration
- D. A nonrenewable resource, because pollination is used up permanently each time an insect visits a flower

41. Which of the following is a projected consequence of continued global warming that has strong scientific support?

- A. The total area of Arctic sea ice will steadily increase as global temperatures continue to climb
- B. Average global temperatures will soon drop sharply as rising carbon dioxide cools the atmosphere
- C. Sea levels will continue to rise as ocean water warms and expands and as land-based ice melts
- D. The oceans will become steadily more alkaline as they absorb more carbon dioxide from the air

42. Stratospheric ozone is important to life on Earth. What essential function does the ozone layer perform?

- A. It absorbs most of the Sun's harmful ultraviolet radiation before it can reach Earth's surface
- B. It traps outgoing heat from Earth's surface and is the main cause of the global greenhouse effect
- C. It supplies the oxygen that humans and animals breathe by releasing it slowly into the lower atmosphere
- D. It reflects incoming sunlight back into space, which is the primary cause of Earth's changing seasons

43. A country wants to reduce its dependence on fossil fuels and lower its greenhouse gas emissions. Which strategy would most directly accomplish both goals?

- A. Building additional coal-fired power plants to meet the country's rising demand for electricity quickly
- B. Encouraging citizens to use more gasoline-powered vehicles to keep the national economy growing
- C. Removing all environmental regulations so that fossil fuel companies can expand without any limits
- D. Expanding solar, wind, and other renewable energy sources to replace fossil fuel power generation

44. Deforestation, the large-scale clearing of forests, contributes to climate change for which main reason?

- A. Removing trees increases the amount of oxygen in the atmosphere, which traps additional heat near the surface
- B. Trees store carbon, so cutting and burning them releases carbon dioxide and removes a future carbon sink
- C. Cleared land reflects far less sunlight than forest, which is the single largest cause of global warming
- D. Deforestation has no real connection to climate change, since trees do not interact with atmospheric gases

45. A farming region expecting longer droughts switches to drought-resistant crops and builds new irrigation reservoirs to store water. Which climate change strategy does this best represent?

- A. Mitigation, because the region is reducing the greenhouse gas emissions that are driving climate change
- B. Geoengineering, because the region is deliberately altering the global climate system on a planetary scale
- C. Adaptation, because the region is adjusting its practices to cope with climate impacts that are already arriving
- D. Prevention, because these actions will completely stop droughts from ever occurring in the region again

46. As the ocean absorbs more carbon dioxide and becomes more acidic, oyster farmers notice that young oysters struggle to form their shells. What is the direct cause of this problem?

- A. The more acidic water reduces the carbonate minerals that oysters need to build their shells
- B. The more acidic water becomes far too warm for the young oysters to survive in any longer
- C. The more acidic water removes all the oxygen that the young oysters need in order to breathe
- D. The more acidic water blocks the sunlight that the young oysters depend on for their photosynthesis

47. Human agriculture, permanent settlements, and the rise of civilizations all began during the Holocene Epoch. Which characteristic of the Holocene made these developments possible?

- A. The Holocene had a rapidly and unpredictably changing climate that forced humans to keep moving constantly
- B. The Holocene has had a relatively warm and stable climate, allowing reliable farming and settled communities
- C. The Holocene was an extremely cold ice age period during which most of the planet was covered in thick ice
- D. The Holocene saw atmospheric oxygen first rise to a breathable level, which finally allowed humans to survive

48. An engineering team is designing a wheelchair ramp. The ramp must not be too steep for safe use (a requirement for success) and must cost less than a set budget (a limit they cannot exceed). The steepness requirement and the budget limit are examples of which two things, in order?

- A. Two prototypes, because each one is a working model that is built and tested before the final design
- B. Two externalities, because both are costs that fall on people who are not involved in the project at all
- C. Two feedback loops, because each describes how the ramp responds to changes in its surroundings over time
- D. A criterion and a constraint, because one defines a goal the design must meet and the other sets a fixed limit

49. A team designing a new bicycle must choose between a lightweight frame that is expensive and a heavier frame that is much cheaper. Choosing between these options best illustrates which idea in engineering design?

- A. The idea that the most expensive option is always the best choice regardless of any other factors
- B. The idea that engineers should always choose the heaviest and strongest material available to them
- C. The idea that engineering design involves trade-offs, since improving one feature often worsens another
- D. The idea that cost should never be considered when designing any product meant for everyday public use

50. Scientists build a computer model to predict how a city's air quality would change if it added more electric buses and fewer diesel buses. What is the main benefit of testing this idea with a model first?

- A. The model lets scientists explore the likely effects of the change before the city spends money to make it
- B. The model guarantees the exact air quality the city will have, so no real measurements are ever needed again
- C. The model proves with complete certainty that electric buses will have no effect on the city's air quality
- D. The model replaces the need for the city to ever monitor its actual air quality once the buses are added

ANSWERS KEYS WITH EXPLANATIONS

1. B — A larger redshift means a galaxy is receding faster, so the more distant galaxy moving away faster fits a universe that is expanding uniformly (Hubble's Law). Redshift, the stretching of light to longer wavelengths, indicates motion away from us. This distance-velocity relationship is key evidence for cosmic expansion.
2. A — A star begins to form when gravity pulls a region of a gas and dust cloud together, and the collapsing material heats up until temperatures are high enough to ignite nuclear fusion. Gravitational contraction is what concentrates and heats the matter. This is the standard model of star birth from nebulae.
3. D — Fusion releases energy only up to iron, because fusing iron into heavier elements absorbs energy rather than releasing it. Once a massive star's core fills with iron, it can no longer generate energy by fusion, leading to collapse. This iron limit explains why supernovae mark the end of massive stars.
4. C — Kepler's Third Law states $T^2 = a^3$, so the period equals the square root of a^3 , which here is the square root of 25 cubed. Solving gives about 125 years, but the expression itself is the square root of 25^3 . This law links a planet's distance from the Sun to its orbital period.
5. D — Florida sees a higher noon Sun because it is at a lower latitude, so the Sun's rays strike it from a more nearly overhead angle than at high-latitude northern Canada. Latitude controls the maximum Sun angle. The more direct angle also makes lower latitudes warmer overall.

6. A — A Moon that is half lit on its right side about a week after new moon and high in the sky at sunset is the first quarter phase. The Moon is waxing, moving from new toward full, with illumination increasing. Right-side illumination in the evening sky is the signature of first quarter for Northern Hemisphere observers.
7. C — The inner rocky planets are generally denser than the outer gas giants, which are large but composed mostly of low-density gas and ice. Rock and metal pack more mass into a given volume than gas. This density difference reflects how and where each planet type formed in the solar nebula.
8. B — When Earth passes between the Sun and Moon and casts its shadow on the Moon, a lunar eclipse occurs, and this happens at the full moon phase. The full moon lies opposite the Sun, where Earth's shadow can reach it. A tilted lunar orbit is why this does not happen every full moon.
9. A — A small tidal range at first quarter is a neap tide, occurring because the Sun and Moon pull at right angles, so their gravitational effects partly cancel. The misaligned pulls produce smaller bulges. Neap tides contrast with the large spring tides at new and full moon.
10. D — Sunspots appear on the photosphere, the visible surface layer of the Sun that emits most of its light. They look dark because they are cooler than the surrounding photosphere. Sunspots are linked to the Sun's magnetic activity at its surface.
11. C — The tilted panel collects more energy because sunlight strikes it more directly, concentrating more energy onto its surface area. A flat panel receives sunlight at a glancing angle, spreading the energy out. The angle of incidence, not distance to the Sun, controls how concentrated the energy is.
12. B — In undisturbed sedimentary rock, the topmost layer is the youngest because it was deposited most recently, by the principle of superposition. Layers accumulate from the bottom upward over time. The highest undisturbed layer therefore represents the most recent deposition.
13. D — Dividing 4,000 years by the 1,000-year half-life gives four half-lives, so the sample halves four times: $64 \rightarrow 32 \rightarrow 16 \rightarrow 8 \rightarrow 4$ grams. After four half-lives, about 4 grams of the original isotope remain. Counting the number of half-lives is the key to these calculations.
14. A — Because the trilobite lived only briefly in geologic time, finding it in widely separated layers means those layers formed during the same interval of time and can be correlated. Such short-lived, widespread organisms make excellent index fossils. Correlation lets geologists match rock ages across distant regions.
15. C — An unconformity represents a gap in the rock record, a span of time for which no rock was preserved because erosion removed material before new layers were deposited. The missing rock corresponds to missing time. Unconformities show that the geologic record is often incomplete.
16. B — The worldwide iridium layer and shocked quartz point to a massive asteroid impact that threw debris into the atmosphere and disrupted the global climate, driving the end-Cretaceous extinction. Iridium is rare in Earth's crust but common in asteroids. This evidence ties the dinosaur extinction to an impact event.
17. A — The young age of ocean floor compared to continental rock is explained by new ocean floor continually forming at mid-ocean ridges and being destroyed at subduction zones. The seafloor is constantly recycled, so it never gets as old as the continents. This recycling is central to plate tectonics.
18. D — Well-rounded, well-sorted sand in large cross-beds with no marine fossils indicates a desert environment, where wind piled sand into dunes and sorted and rounded the grains. Wind transport produces this distinctive sorting and cross-bedding. The absence of marine fossils rules out an ocean setting.

19. B — A volcanic island arc forms at a convergent boundary where one oceanic plate subducts beneath another and melts, feeding volcanoes that build the islands. The sinking plate generates magma that rises to the surface. This process created island chains like Japan.
20. C — The S-wave shadow zone shows that Earth has a liquid outer core, because S-waves cannot travel through liquids and are blocked by it. P-waves pass through, but the missing S-waves on the far side reveal the liquid layer. Seismic wave behavior is how scientists mapped Earth's internal structure.
21. A — Compacting and cementing transported fragments of older rock forms a clastic sedimentary rock. The process involves breaking down, transporting, depositing, and lithifying rock fragments. Clastic rocks like sandstone and shale are built from these accumulated particles.
22. D — Splitting along flat parallel surfaces versus breaking into curved irregular surfaces compares cleavage and fracture. Cleavage describes breakage along smooth planes; fracture describes irregular breakage. Both are diagnostic physical properties used to identify minerals.
23. B — A light-colored, coarse-grained rock rich in quartz and feldspar is granite, which formed when silica-rich magma cooled slowly underground. Slow cooling allowed the large, visible crystals to grow. Granite is the typical rock of the continental crust.
24. C — Paving a forested hillside causes more rainwater to run off as surface runoff, because the impervious pavement prevents water from soaking into the ground. Less infiltration means more water flows across the surface. This increase in runoff is a common cause of urban flooding.
25. A — Well-sorted sand and gravel makes the best aquifer because it has both high porosity, to store water, and high permeability, to let water flow freely to a well. Storage and flow are both needed for a productive aquifer. Granite and clay each lack one of these properties.
26. D — A "carbon sink" is a system that absorbs more carbon than it releases; forests do this by taking in carbon dioxide through photosynthesis and storing the carbon in wood and soil. This removes carbon from the atmosphere. Protecting forests helps limit the buildup of atmospheric carbon dioxide.
27. C — Warming that increases water vapor, which traps more heat and causes still more warming, is a positive feedback because it amplifies the original change. The process reinforces itself rather than counteracting the warming. Water vapor feedback is a major amplifier in the climate system.
28. B — Acidic water dissolving limestone to form caves and sinkholes is chemical weathering, because the rock is chemically altered and dissolved rather than merely broken apart. The reaction changes the rock's composition. This dissolution produces the karst landscapes typical of limestone regions.
29. A — A meandering river erodes its outer banks, where water moves fastest, and deposits sediment on its inner banks, where water slows, causing the meanders to migrate over time. This combination of erosion and deposition reshapes the floodplain. Meander migration is a key process in river landscapes.
30. C — An air mass takes on the temperature and moisture of the surface over which it forms, such as a warm ocean, cold land, or hot desert. The source region imprints the air mass's basic character. This is why air masses are classified by their region of origin.
31. D — The orderly cloud sequence ahead of a warm front occurs because warm air rides gradually up over the retreating cold air, forming clouds at decreasing heights as the front approaches. The gentle slope produces high clouds first, then progressively lower ones and steady rain. This is the classic warm-front cloud progression.
32. B — If the air holds exactly half of its maximum possible water vapor, the relative humidity is 50 percent, since relative humidity is the ratio of actual to maximum vapor. Holding half the

maximum gives a ratio of one-half, or 50 percent. Relative humidity measures how close the air is to saturation.

33. A — The strongest winds and heaviest rain occur in the eyewall, the ring of towering thunderstorms surrounding the calm eye. The eyewall is where rising, moisture-laden air is most intense. The contrast between the violent eyewall and the calm eye is characteristic of hurricanes.
34. C — Carbon dioxide, water vapor, and methane are greenhouse gases that absorb and re-radiate outgoing infrared energy, warming the atmosphere. The abundant gases oxygen and nitrogen do not trap heat this way. These greenhouse gases are central to both the natural and the enhanced greenhouse effect.
35. B — The horizontal movement of air from high pressure to low pressure is wind, driven by pressure differences from place to place. Wind always flows in response to a pressure gradient. This contrasts with vertical convection and with heat-transfer processes like conduction.
36. D — Climate is the long-term average of weather, so a single cold winter is short-term weather, not a climate trend, and cannot by itself disprove global warming. Long-term data, not one season, reveals climate change. Distinguishing weather from climate is essential to interpreting climate trends correctly.
37. C — The key difference is that renewable resources are replenished by natural processes on human timescales, while nonrenewable resources are not. Renewability depends on how quickly a source is naturally restored. This distinction, not cost or location, defines the two categories.
38. A — The residents' medical costs from the factory's smoke are a negative externality, a cost of the factory's activity borne by people outside the transaction. Externalities are real costs not paid by the producer. Including them is essential for honest cost-benefit analysis.
39. D — Toxic chemicals from factories killing river species illustrates pollution, in which harmful substances released into the environment poison and kill living organisms. The contamination directly harms the aquatic life. This differs from habitat loss, overharvesting, or invasive species as a biodiversity threat.
40. B — Insect pollination that supports crop production is a regulating service, a natural process that maintains and supports the functioning of ecosystems and agriculture. Regulating services include processes like pollination, water purification, and climate control. This natural service is vital to global food supplies.
41. C — Strong scientific support backs continued sea level rise as ocean water warms and expands and land-based ice melts. Both thermal expansion and ice loss add water to the oceans. The other options contradict observed trends and ocean chemistry, which is becoming more acidic rather than alkaline.
42. A — The ozone layer absorbs most of the Sun's harmful ultraviolet radiation before it reaches the surface, protecting living things from its damaging effects. This shielding is its essential function. It is distinct from the greenhouse effect, which involves trapping outgoing heat, not absorbing incoming ultraviolet.
43. D — Expanding solar, wind, and other renewables to replace fossil fuel power directly reduces both fossil fuel dependence and greenhouse gas emissions. Generating electricity without burning fossil fuels cuts emissions at the source. This is a core mitigation strategy for climate change.
44. B — Trees store carbon, so cutting and burning them releases carbon dioxide and removes a sink that would have absorbed future emissions. Deforestation thus adds carbon to the air while reducing future uptake. This double effect makes forest loss a significant contributor to climate change.

45. C — Switching to drought-resistant crops and storing water to cope with expected droughts is adaptation, since the region is adjusting to climate impacts already arriving. Adaptation manages consequences rather than reducing causes. Mitigation, by contrast, would target greenhouse gas emissions.
46. A — More acidic seawater reduces the carbonate minerals that oysters need to build their shells, which is why young oysters struggle to form shells. Ocean acidification lowers carbonate availability. This chemical effect threatens shellfish, corals, and other shell-building organisms.
47. B — The Holocene's relatively warm and stable climate allowed reliable farming and settled communities, enabling agriculture, permanent settlements, and civilizations. Predictable growing seasons were essential for settled life. Climatic stability, not oxygen changes or an ice age, made these developments possible.
48. D — The safe-steepness requirement is a criterion, defining a goal the design must meet, while the budget limit is a constraint, a fixed restriction the design cannot exceed. Criteria define success; constraints set boundaries. Distinguishing the two is fundamental to framing an engineering problem.
49. C — Choosing between a light, expensive frame and a heavy, cheap one illustrates trade-offs, since improving one feature (weight) worsens another (cost). Engineers must balance competing criteria that conflict. Recognizing trade-offs is central to real-world design decisions.
50. A — The main benefit is that the model lets scientists explore the likely effects of the change before the city spends money to implement it. Models allow ideas to be tested safely and cheaply in advance. They guide decisions while acknowledging uncertainty, and they support rather than replace real measurements.