

# PRACTICE EXAM 20: EARTH AND SPACE SCIENCES REGENTS SIMULATION (50 QUESTIONS)

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1. Which statement best explains why we observe the spectral lines of distant galaxies shifted toward longer wavelengths?
  - A. The galaxies are composed of different elements than those found in our own galaxy
  - B. The galaxies are moving away from us, stretching the light waves to longer wavelengths
  - C. The galaxies are much hotter than nearby stars, emitting more red light overall
  - D. The light from these galaxies passes through dust clouds that filter out shorter wavelengths
  
2. A main sequence star fuses hydrogen into helium in its core. What primarily determines how long a star remains on the main sequence?
  - A. The distance of the star from the center of its host galaxy and nearby companions
  - B. The color of the light the star emits during the early stages of its formation process
  - C. The number of planets orbiting the star and the total mass contained in those planets
  - D. The star's mass, since more massive stars consume their hydrogen fuel far more rapidly
  
3. Which sequence correctly traces the origin of a calcium atom found in a human bone?
  - A. Big Bang produced hydrogen and helium, then fusion in stars produced calcium, later dispersed by stellar death
  - B. Earth's core produced calcium through radioactive decay, which then migrated upward to the crust over time

C. Calcium formed entirely during the Big Bang and has remained unchanged in abundance ever since then

D. Comets manufactured calcium in deep space and delivered it to Earth during planetary formation stages

4. A comet has an orbital period of 8 Earth years. Using Kepler's Third Law ( $T^2 = a^3$  in solar units), what is the comet's approximate average distance from the Sun?

A. Approximately 2 AU, placing the comet's average orbit within the inner asteroid belt region

B. Approximately 8 AU, placing the comet's average orbit near the orbit of the planet Saturn

C. Approximately 4 AU, placing the comet's average orbit between the orbits of Mars and Jupiter

D. Approximately 16 AU, placing the comet's average orbit beyond the orbit of the planet Uranus

5. On the day of the summer solstice in New York State, which statement about the Sun's apparent path is correct?

A. The Sun reaches its highest noon altitude of the year and daylight lasts longer than darkness

B. The Sun rises due east and sets due west, with day and night being exactly equal in length

C. The Sun reaches its lowest noon altitude of the year and daylight is shorter than darkness

D. The Sun remains below the horizon for the entire day across all of New York State's latitudes

6. An observer in New York sees a thin crescent Moon with the right side illuminated, low in the western sky just after sunset. Which phase is this, and what comes next?

A. A waning crescent that will continue to shrink toward the new moon over the following nights

B. A full moon that will rise opposite the Sun and remain visible throughout the entire night

C. A last quarter moon that will rise near midnight and be highest in the sky around dawn

D. A waxing crescent that will grow toward first quarter as illumination increases each night

7. Which feature of the solar system is best explained by the conservation of angular momentum during the collapse of the solar nebula?

- A. The presence of a rocky core within each of the four large outer gas giant planets
- B. The wide variation in surface temperatures among the planets at different orbital distances
- C. The flattened disk shape and the common direction of rotation shared by most planets
- D. The existence of impact craters preserved on the surfaces of the Moon and Mercury

8. A lunar eclipse occurs only under which specific set of conditions?

- A. New moon phase, with the Moon passing directly between Earth and the Sun in alignment
- B. Full moon phase, with the Moon passing through Earth's shadow when alignment is exact
- C. First quarter phase, with the Moon at a right angle to the Earth-Sun line at that time
- D. Any phase, since Earth's shadow is large enough to reach the Moon at any point monthly

9. During which lunar phases do neap tides — the smallest difference between high and low tides — occur?

- A. New moon and full moon, when the Sun and Moon pull along the same straight line together
- B. Only during total lunar eclipses, when Earth's shadow completely covers the Moon's surface
- C. Waxing and waning gibbous phases, when more than half the Moon's face is illuminated
- D. First quarter and last quarter, when the Sun and Moon pull at right angles to each other

10. The energy released in the Sun's core takes thousands of years to reach the surface. Which statement best explains the source of this energy?

- A. Hydrogen nuclei fuse into helium, converting a small amount of mass into energy
- B. Helium atoms split into hydrogen, releasing energy through a fission chain reaction
- C. Solar wind particles collide in the corona, generating heat that radiates outward
- D. Magnetic field lines snap and reconnect, producing all of the Sun's radiant output

11. Two locations receive sunlight on the same day. Location X receives sunlight striking at  $80^\circ$  above the horizon; Location Y receives sunlight at  $30^\circ$  above the horizon. Which statement is correct?

- A. Location Y receives more concentrated energy because lower angles increase energy intensity
- B. Both locations receive identical energy intensity because the Sun's output is constant globally
- C. Location X receives more concentrated energy because higher angles concentrate energy over less area
- D. Location Y receives more concentrated energy because its sunlight travels a shorter atmospheric path

12. A geologist studies three undisturbed horizontal sedimentary layers. Which principle allows the geologist to conclude the bottom layer is the oldest?

- A. The principle of cross-cutting relationships, since features that cut across layers are younger
- B. The principle of superposition, since in undisturbed layers older sediments lie beneath younger ones
- C. The principle of faunal succession, since fossil organisms appear in a definite chronological order
- D. The principle of uniformitarianism, since present-day processes also operated in the geologic past

13. A radioactive isotope has a half-life of 5,700 years. A sample originally contained 80 grams of the isotope, and 10 grams remain. Approximately how much time has passed?

- A. About 17,100 years have passed, because three half-lives reduced the sample from 80 to 10 grams
- B. About 5,700 years have passed, because a single half-life reduced the sample to its current amount
- C. About 11,400 years have passed, because two half-lives reduced the original mass of the sample
- D. About 22,800 years have passed, because four half-lives reduced the sample to ten grams remaining

14. A horizontal rock layer containing 350-million-year-old fossils sits directly above a layer containing 400-million-year-old fossils, with no gap in deposition. Which statement is best supported?

- A. The two layers were deposited simultaneously during a single rapid sedimentation event
- B. The upper layer must contain igneous intrusions that disrupted the original age sequence
- C. The fossils in both layers belong to organisms that lived at exactly the same time period

D. Sediment was deposited continuously over roughly 50 million years between the two fossil ages

15. Why are organisms that were geographically widespread but existed for only a short geologic time the most useful index fossils?

A. They were always the largest organisms and therefore left the most easily identified remains

B. They lived only in deep ocean environments where fossil preservation is most reliable overall

C. Their wide distribution and brief existence allow rocks in different regions to be matched in age

D. They were the only organisms hard-bodied enough to survive the fossilization process intact

16. Layers of rock at the boundary of a major mass extinction contain shocked quartz and a thin layer rich in iridium worldwide. Which conclusion is best supported by this evidence?

A. A large asteroid or comet impact occurred, scattering iridium and shocking quartz globally

B. Sea levels gradually fell over millions of years, exposing iridium that was buried in sediment

C. Slow climate cooling concentrated iridium as glaciers advanced across the continents repeatedly

D. Ordinary volcanic eruptions produced the iridium layer through routine lava flows over time

17. Which observation about the rocks of the ocean floor provides direct evidence for seafloor spreading?

A. The oldest seafloor rocks are found in the deepest ocean trenches near the continents

B. Seafloor rocks are youngest at mid-ocean ridges and progressively older farther away

C. Seafloor rocks contain identical fossils across all oceans regardless of their location

D. Seafloor rocks are uniformly the same age across the entire floor of each ocean basin

18. A rock layer contains symmetrical ripple marks, fine sand, and fossils of shallow-water marine clams. Which past environment is most consistent with these features?

A. A deep ocean basin far from any shoreline where only the finest clay particles settled

- B. A high mountain glacier that deposited unsorted rock debris of widely varying particle sizes
- C. An arid inland desert where wind produced large-scale dunes of well-sorted quartz sand
- D. A shallow near-shore marine setting where waves moved sand back and forth over the bottom

19. The mid-Atlantic Ridge runs down the center of the Atlantic Ocean and is marked by frequent shallow earthquakes and volcanic activity. What type of plate boundary is this?

- A. A convergent boundary where one oceanic plate subducts beneath an overriding plate
- B. A transform boundary where two plates grind past one another in opposite directions
- C. A divergent boundary where two plates move apart and new oceanic crust forms between them
- D. A collision boundary where two continental plates push upward to form a mountain range

20. P-waves travel through both solids and liquids, while S-waves travel only through solids. Seismographs detect P-waves but not S-waves on the far side of Earth from an earthquake. What does this indicate?

- A. Part of Earth's interior is liquid, since the absence of S-waves reveals a liquid outer core
- B. The entire interior of Earth is solid, since both wave types travel through the deep interior
- C. Earth's interior is uniform in composition from the crust all the way down to the center
- D. The mantle is entirely molten, allowing P-waves but not S-waves to pass through it freely

21. Limestone is buried deep within Earth and subjected to intense heat and pressure during a mountain-building event. Which rock most likely forms?

- A. Sandstone, a sedimentary rock that forms when sand grains are cemented together over time
- B. Marble, a metamorphic rock that forms when limestone recrystallizes under heat and pressure
- C. Obsidian, a glassy igneous rock that forms when silica-rich lava cools extremely rapidly
- D. Conglomerate, a sedimentary rock that forms when rounded pebbles are cemented together

22. A student tests an unknown mineral. It is softer than a fingernail, has one perfect cleavage direction, peels into thin flexible sheets, and is transparent to light. Which mineral best matches?

- A. Quartz, which has a hardness of 7, no cleavage, conchoidal fracture, and a glassy luster
- B. Pyrite, which has a metallic luster, a hardness near 6, and a characteristic cubic crystal form
- C. Mica, which has a hardness near 2.5, one perfect cleavage, and splits into thin flexible sheets
- D. Calcite, which has a hardness of 3, three cleavage directions, and reacts strongly with acid

23. A light-colored igneous rock contains large, interlocking crystals all easily visible to the naked eye. Where did this rock most likely form?

- A. At Earth's surface, where lava cooled rapidly after a volcanic eruption broke the surface
- B. In a shallow vent, where rising magma was quenched almost instantly by contact with seawater
- C. In the upper atmosphere, where droplets of molten rock solidified before falling to the ground
- D. Deep underground, where magma cooled very slowly, allowing large crystals to grow over time

24. During condensation in a cloud, water vapor changes into liquid droplets. What happens to energy during this process?

- A. Energy is absorbed from the surroundings, which cools the air and prevents further cloud growth
- B. Latent heat is released into the surrounding air, which can warm the air and fuel storm development
- C. Energy is created within the water molecules themselves, increasing the total energy of the system
- D. No energy change occurs, since condensation is a purely physical rearrangement of molecules only

25. A geologist is searching for a layer that will allow groundwater to flow easily and supply a well. Which property of a material is most important for the water to move through it?

- A. High permeability, which describes how easily water can pass through connected pore spaces
- B. High density, which describes how much mass the rock contains within a given unit of volume
- C. Dark color, which describes how much solar radiation the rock absorbs at the land surface

D. Low porosity, which describes a small total volume of empty pore space within the material

26. Over very long geologic timescales, which process removes carbon dioxide from the atmosphere and stores the carbon in rock?

A. Combustion of fossil fuels in vehicles and power plants returns stored carbon to the air rapidly

B. Respiration by animals and decomposers releases carbon dioxide back into the atmosphere daily

C. Weathering of silicate rocks combines with carbon dioxide to form carbonate minerals over time

D. Volcanic eruptions transfer carbon from deep within Earth into the atmosphere during eruptions

27. As global temperatures rise, warmer air holds more water vapor, and water vapor is itself a greenhouse gas that traps additional heat. This relationship is an example of which type of feedback?

A. A negative feedback, because the added water vapor eventually cools the atmosphere back down

B. An external forcing, because water vapor originates from a source outside the climate system

C. A neutral feedback, because water vapor has no measurable effect on atmospheric temperature

D. A positive feedback, because the added water vapor amplifies the original warming even further

28. Caves and sinkholes commonly form in regions underlain by thick limestone bedrock. Which process is primarily responsible for creating these features?

A. Chemical weathering, as slightly acidic groundwater slowly dissolves the soluble limestone

B. Frost wedging, as water freezing in cracks mechanically shatters the limestone into fragments

C. Glacial scouring, as moving ice sheets grind away the limestone from the surface downward

D. Wind abrasion, as airborne sand particles wear away the exposed limestone over long periods

29. A fast-moving mountain stream flows into a flat valley, abruptly slows down, and drops its sediment in a fan-shaped deposit. Which statement best explains why deposition occurs at this location?

A. The water chemically dissolves the sediment as soon as it reaches the flat valley floor below

- B. The stream loses velocity on the flat ground, reducing its ability to carry sediment, so it drops it
- C. The flat valley floor pulls sediment downward through a sudden increase in gravitational force
- D. The cooler temperatures of the valley cause dissolved minerals to crystallize out of the water

30. A maritime tropical (mT) air mass forms over the Gulf of Mexico and moves into the southeastern United States during summer. What characteristics would this air mass bring?

- A. Cold and dry conditions producing clear skies and sharply falling temperatures across the region
- B. Cool and dry conditions producing crisp clear mornings followed by mild sunny afternoons
- C. Warm and humid conditions producing high humidity and the potential for heavy thunderstorms
- D. Cold and humid conditions producing persistent snow showers and freezing rain in the region

31. A warm front approaches a region as a warm air mass advances and rides up over a retreating cold air mass. What weather typically accompanies the passage of a warm front?

- A. A sudden violent line of thunderstorms followed within hours by much colder, drier air behind it
- B. Clear skies and steady high pressure that persist for several days without any precipitation at all
- C. Strong gusty winds and rapidly falling temperatures as dense cold air pushes underneath warm air
- D. A long period of widespread light to moderate precipitation followed by warmer, more humid air

32. A weather station reports that the air temperature and the dew point temperature are exactly equal at 15°C. What does this condition indicate?

- A. The air is extremely dry, holding almost no water vapor, so clouds and fog are very unlikely
- B. The air is saturated and at 100% relative humidity, so condensation, fog, or clouds are likely
- C. The air temperature must rise sharply before any condensation can begin to form in the region
- D. The barometric pressure is falling rapidly, which guarantees that a severe storm will soon arrive

33. A barometer at a coastal station shows the air pressure dropping rapidly over several hours as a storm approaches. What does this rapid pressure drop most strongly suggest?

- A. An intense low-pressure system is approaching, often associated with strong winds and heavy rain
- B. A strong high-pressure system is building, which typically brings clear skies and calm conditions
- C. The air temperature is about to fall sharply, producing a hard freeze across the entire region
- D. The relative humidity is dropping toward zero, signaling the arrival of very dry desert-like air

34. Which statement correctly describes how greenhouse gases such as carbon dioxide and water vapor warm Earth's lower atmosphere?

- A. They block incoming sunlight from reaching the surface, trapping the heat high in the upper atmosphere
- B. They chemically react with oxygen to generate new heat energy within the troposphere continuously
- C. They absorb infrared energy radiated from Earth's surface and re-radiate part of it back downward
- D. They reflect incoming ultraviolet radiation back toward the surface, adding extra solar heating below

35. Global winds such as the trade winds do not blow in straight north-south lines but instead curve to one side. Which factor causes this curving of global wind patterns?

- A. The gravitational pull of the Moon drags the atmosphere sideways as Earth orbits around the Sun
- B. The Coriolis effect, produced by Earth's rotation, deflects moving air from a straight-line path
- C. The varying chemical composition of the atmosphere bends winds toward areas of lower density air
- D. Ocean currents physically push the overlying winds into curved paths across the entire planet

36. Scientists studying long-term climate change rely on which of the following to reconstruct temperatures from before instrument records existed?

- A. Daily satellite photographs of cloud cover taken continuously over the past several centuries
- B. Direct thermometer readings recorded at weather stations stretching back tens of thousands of years
- C. Live measurements of ocean temperature taken by deep-diving research submarines in ancient times
- D. Proxy data such as ice cores, tree rings, and ocean sediments that preserve past climate signals

37. Which of the following lists contains only nonrenewable energy resources?

- A. Coal, petroleum, and natural gas, which form over millions of years and cannot be quickly replaced
- B. Solar, wind, and geothermal, which are continuously replenished by natural processes on Earth
- C. Hydroelectric, biomass, and tidal, which all rely on the steady input of energy from natural cycles
- D. Wind, natural gas, and solar, which together can be sustained indefinitely on human timescales

38. A factory lowers its production costs by releasing untreated waste into a nearby river. The downstream communities then pay to clean their drinking water. The cleanup cost paid by those communities is best described as which of the following?

- A. A direct production cost that the factory itself pays as part of manufacturing its goods
- B. A government subsidy provided to the factory to encourage continued industrial production
- C. A negative externality, a cost imposed on others who are not party to the factory's activity
- D. A renewable resource that the downstream communities can use repeatedly without any cost

39. In a particular freshwater lake, a fish species native to another continent was released and rapidly multiplied, eating the eggs of native fish until several native species disappeared. Which cause of biodiversity loss does this scenario illustrate?

- A. Habitat fragmentation, in which a continuous habitat is broken into smaller disconnected pieces
- B. Invasive species, in which an introduced organism outcompetes or preys upon native organisms
- C. Overharvesting, in which humans remove organisms faster than the population can reproduce
- D. Climate change, in which shifting temperatures force organisms beyond their tolerance ranges

40. Healthy soil microorganisms break down dead organic matter and recycle nutrients so that plants can grow. Which category of ecosystem service does this nutrient cycling represent?

- A. A provisioning service, because it directly supplies food, fresh water, and raw materials to people
- B. A regulating service, because it controls floods, diseases, and the quality of the air and water

- C. A cultural service, because it provides recreational, spiritual, and educational benefits to society
- D. A supporting service, because it underlies and makes possible all of the other ecosystem services

41. Which projected outcome of continued global warming is supported by strong scientific consensus?

- A. Global sea levels will continue to rise as ocean water warms and expands and land ice melts
- B. The total amount of land ice on Earth will increase as snowfall grows heavier across the poles
- C. Average global surface temperatures will fall steadily as cloud cover blocks more incoming sunlight
- D. Ocean water will become more alkaline as it absorbs increasing amounts of carbon dioxide gas

42. The thinning of the stratospheric ozone layer over Antarctica during the late twentieth century was caused primarily by which class of human-made chemicals?

- A. Carbon dioxide molecules released by the burning of coal, oil, and natural gas worldwide
- B. Sulfur dioxide molecules released from coal-burning power plants in the industrial regions
- C. Chlorofluorocarbons (CFCs) once widely used in refrigerants, aerosol sprays, and foam products
- D. Nitrogen fertilizers applied to agricultural fields that then washed into rivers and oceans

43. A fishing community wants to manage its local fishery so that the fish population remains healthy for future generations. Which practice best supports this goal of sustainability?

- A. Catching as many fish as possible each season to maximize the community's immediate income
- B. Removing all natural predators of the target fish so that more of the target fish survive to adulthood
- C. Ignoring fish population data entirely and basing the annual catch only on current market prices
- D. Setting catch limits at or below the rate at which the fish population can naturally reproduce

44. Although water covers most of Earth's surface, only a small fraction is fresh water available for human use. Approximately what portion of all of Earth's water is readily accessible fresh water in lakes, rivers, and shallow groundwater?

- A. About half of Earth's water is readily accessible fresh water in lakes, rivers, and groundwater
- B. Less than 1 percent of Earth's water is readily accessible fresh water available for human use
- C. About 30 percent of Earth's water is readily accessible fresh water held mostly in large lakes
- D. About 15 percent of Earth's water is readily accessible fresh water stored in flowing rivers

45. A coastal city, expecting higher sea levels, raises its roads and installs flood barriers around vulnerable neighborhoods to cope with flooding that is already beginning to happen. Which climate change strategy does this best represent?

- A. Mitigation, because the city is reducing the greenhouse gas emissions that drive climate change
- B. Geoengineering, because the city is deliberately altering the global climate at a planetary scale
- C. Adaptation, because the city is adjusting its infrastructure to cope with changes already underway
- D. Prevention, because the city's actions will stop sea level from rising anywhere in the future

46. As the ocean absorbs more carbon dioxide from the atmosphere, the water becomes more acidic. How does this change most directly threaten organisms such as corals and shellfish?

- A. The acidity makes it harder for these organisms to build the carbonate shells and skeletons they need
- B. The acidity raises the surface water temperature so sharply that these organisms overheat and die off
- C. The acidity blocks the sunlight these organisms need, preventing the photosynthesis they depend upon
- D. The acidity strips all dissolved oxygen from the water, causing these organisms to suffocate quickly

47. Earth's recent geologic history includes a period of relatively stable, mild climate during which agriculture and cities first developed. Which statement best describes the significance of this period for human society?

- A. The stable climate caused the first appearance of multicellular life forms on the planet Earth
- B. The stable climate triggered the breakup of the supercontinent Pangaea into separate landmasses
- C. The stable climate produced the oxygen-rich atmosphere that animals first breathed on land
- D. The stable climate allowed reliable farming and permanent settlements that civilization required

48. After defining a problem, an engineering team brainstorms and builds several different prototype solutions, then tests each one under realistic conditions and records how well each performs. What is the main purpose of this testing stage?

- A. To skip directly to manufacturing the very first prototype the team happened to build first
- B. To gather evidence on how each design performs so the team can compare them and improve the best one
- C. To prove that the original problem definition was unnecessary and can now be safely discarded
- D. To select a design based only on which prototype looks the most visually attractive to the team

49. An engineering team must design a bridge that is strong enough to carry heavy traffic but must also stay within a limited budget. The budget limit in this situation is best described as which of the following?

- A. A constraint, because it is a limit or restriction that the final design is required to satisfy
- B. A criterion, because it is a desirable feature used to judge which design performs the best
- C. An externality, because it is a cost imposed on people unrelated to the bridge project itself
- D. A prototype, because it is an early test model built to evaluate how the design will perform

50. A team of scientists builds a computer model to forecast how a coastline will change over the next fifty years under different sea-level scenarios. Which statement best describes how such a model should be understood and used?

- A. The model gives one exact and certain outcome that will occur no matter what choices people make
- B. The model is worthless because the future coastline cannot be studied with mathematics in any way
- C. The model projects likely outcomes under stated assumptions and is a useful tool for guiding decisions
- D. The model should replace all real-world measurements, which are no longer needed once it is built

## ANSWERS KEY AND EXPLANATIONS

1. B — Redshift, the stretching of light to longer wavelengths, occurs when a source moves away from the observer. Distant galaxies show this shift, and the shift grows with distance, which is direct evidence the universe is expanding. This relationship (Hubble's Law) is the cornerstone observation supporting Big Bang cosmology.
2. D — A star's mass is the primary control on its main sequence lifetime. More massive stars have far greater core temperatures and pressures, fusing hydrogen much faster, so they exhaust their fuel in millions rather than billions of years. This inverse relationship between mass and lifespan is fundamental to stellar evolution.
3. A — Light elements (hydrogen, helium) formed in the Big Bang, but heavier elements like calcium were forged by fusion inside stars and scattered into space when those stars died. This enriched material later became part of new solar systems, including Earth. Every calcium atom in bone therefore traces back to a previous generation of stars.
4. C — Kepler's Third Law states  $T^2 = a^3$  in solar units. With  $T = 8$ ,  $T^2 = 64$ , so  $a^3 = 64$  and  $a = 4$  AU, placing the comet's average distance between Mars and Jupiter. This law links orbital period to distance for any body orbiting the Sun.
5. A — At the summer solstice the Northern Hemisphere is tilted maximally toward the Sun, giving New York its highest noon Sun altitude and longest daylight of the year. The increased angle and duration of insolation drive summer warming. Equal day and night occur only at the equinoxes, not the solstice.
6. D — A crescent illuminated on the right side and visible in the western sky after sunset is a waxing crescent, with the lit fraction growing nightly toward first quarter. "Waxing" means increasing illumination as the Moon moves from new toward full. Evening visibility in the west is the signature of the early waxing phases.
7. C — As the solar nebula collapsed, conservation of angular momentum forced it to spin faster and flatten into a rotating disk. Planets condensed from this disk, which is why they orbit in nearly the same plane and the same direction. This shared geometry is the hallmark prediction of the nebular hypothesis.
8. B — A lunar eclipse requires the full moon phase, when Earth lies between the Sun and Moon and the Moon can pass through Earth's shadow. It does not happen every full moon because the Moon's orbit is tilted, so exact alignment is needed. This distinguishes lunar eclipses (full moon) from solar eclipses (new moon).
9. D — Neap tides, the smallest tidal range, occur at first and last quarter when the Sun and Moon pull at right angles, so their tidal forces partly cancel. At new and full moon the two pull in line, producing the larger spring tides instead. Tidal range therefore tracks the changing Sun-Moon-Earth geometry.
10. A — The Sun's energy comes from nuclear fusion, in which hydrogen nuclei combine into helium and a small amount of mass is converted to energy via  $E = mc^2$ . This proton-proton process operates in the dense, hot core. Fusion, not fission or chemical burning, sustains the Sun's enormous output.
11. C — Solar energy is most concentrated when sunlight strikes at a high angle, because the same beam covers a smaller surface area. Location X at  $80^\circ$  concentrates energy far more than Location Y at  $30^\circ$ , where the beam spreads over a larger area. This angle-of-insolation effect explains latitudinal and seasonal temperature differences.

12. B — The principle of superposition states that in undisturbed sedimentary sequences, each layer is younger than the one beneath it, so the bottom layer is oldest. Sediments accumulate from the bottom up over time. This principle is the foundation of relative dating in horizontal strata.
13. A — Each half-life halves the remaining isotope:  $80 \rightarrow 40 \rightarrow 20 \rightarrow 10$  grams is three halvings. Three half-lives  $\times 5,700$  years equals 17,100 years. Counting the number of halvings is the key to solving half-life problems.
14. D — Because the layers are in normal order with no depositional gap, the 50-million-year difference between the fossil ages represents continuous sediment accumulation. The younger layer sits directly atop the older one, consistent with superposition. There is no evidence the layers formed at the same time or were disturbed.
15. C — The best index fossils are both geographically widespread and short-lived geologically, so finding one pins a rock to a narrow time interval and lets distant rocks be correlated. Wide distribution allows matching across regions; brief existence makes the age estimate precise. Size or habitat alone does not confer this usefulness.
16. A — A global iridium-rich layer plus shocked quartz points to a large extraterrestrial impact, since iridium is rare in Earth's crust but common in asteroids, and shocked quartz forms under impact-level pressures. The worldwide distribution rules out localized volcanism. This is the classic evidence for an impact-driven mass extinction.
17. B — Seafloor rocks are youngest at mid-ocean ridges and grow progressively older with distance from the ridge, exactly what seafloor spreading predicts as new crust forms and moves outward. This age pattern is direct physical evidence of plate divergence. Uniform-age or trench-centered patterns would contradict spreading.
18. D — Symmetrical ripple marks, fine sand, and shallow-water marine clam fossils together indicate a shallow near-shore marine setting where back-and-forth wave action shaped the sediment. The fossils confirm marine conditions, and symmetrical ripples specifically indicate oscillating wave currents. Deep-sea, desert, and glacial settings each conflict with one or more of these clues.
19. C — The mid-Atlantic Ridge is a divergent boundary where two plates separate and rising magma forms new oceanic crust between them. The shallow earthquakes and volcanic activity are characteristic of this spreading. This is the type setting where seafloor spreading actively occurs.
20. A — S-waves cannot travel through liquids, so their failure to reach the far side of Earth reveals a liquid layer—the outer core—blocking them, while P-waves pass through both solids and liquids. The S-wave shadow zone is the primary evidence for a liquid outer core. This wave behavior lets seismologists map Earth's internal structure.
21. B — When limestone is subjected to heat and pressure, its calcite recrystallizes into marble, a metamorphic rock. Metamorphism changes existing rock without melting it, so the original limestone becomes a denser, recrystallized form. Sandstone, obsidian, and conglomerate form by different processes.
22. C — The combination of very low hardness, one perfect cleavage, and splitting into thin flexible sheets identifies mica. The single cleavage plane is what allows it to peel into transparent sheets. Quartz, pyrite, and calcite each fail one or more of these diagnostic tests.
23. D — Large, visible interlocking crystals indicate slow cooling deep underground, which gives mineral grains ample time to grow. Rapid surface cooling instead produces fine-grained or glassy textures. Crystal size is therefore a direct clue to cooling rate and depth of formation.
24. B — Condensation releases latent heat into the surrounding air as water vapor changes to liquid. This released energy warms the air and is a key driver of storm and cloud development. Evaporation absorbs this same energy; condensation reverses it by releasing it.

25. A — Permeability—how easily water moves through connected pore spaces—is the property that determines whether groundwater can flow to a well. A material can hold water (porosity) yet still not transmit it if pores are poorly connected. High permeability is essential for a productive aquifer.
26. C — Over geologic time, chemical weathering of silicate rocks consumes atmospheric carbon dioxide and locks the carbon into carbonate minerals. This slow drawdown is a long-term carbon sink. Combustion, respiration, and volcanism instead add CO<sub>2</sub> back to the atmosphere.
27. D — Warming that increases water vapor, which then traps more heat and causes further warming, is a positive feedback because it amplifies the original change. The effect reinforces rather than dampens the initial warming. Water vapor feedback is one of the most important amplifiers in the climate system.
28. A — Caves and sinkholes in limestone form by chemical weathering, as slightly acidic groundwater dissolves the soluble calcium carbonate over time. This dissolution creates the underground voids characteristic of karst landscapes. Physical processes like frost wedging or wind abrasion do not produce these features.
29. B — When a stream slows on reaching flat ground, it loses the energy needed to carry sediment, so it deposits the load as a fan-shaped alluvial fan. Sediment-carrying capacity depends directly on water velocity. The drop in velocity, not chemistry or gravity changes, causes the deposition.
30. C — A maritime tropical air mass forms over warm tropical water and carries warm, humid air, bringing high humidity and thunderstorm potential to the southeastern U.S. in summer. "Maritime" indicates moisture and "tropical" indicates warmth. This contrasts with the cold, dry continental polar air masses.
31. D — A warm front brings a prolonged period of widespread light to moderate precipitation as warm air gradually rises over the retreating cold air, followed by warmer, more humid conditions once it passes. The gentle slope of the front produces steady rather than violent weather. This contrasts with the abrupt storms of a cold front.
32. B — When air temperature equals the dew point, the air is saturated at 100% relative humidity, so condensation, fog, or cloud formation becomes likely. At saturation the air can hold no additional water vapor. This convergence of temperature and dew point is a standard fog and cloud indicator.
33. A — A rapidly falling barometer signals an approaching low-pressure system, which is commonly associated with strong winds, clouds, and precipitation. Rising air in a low cools and condenses moisture, producing stormy weather. Falling pressure is one of the most reliable short-term storm indicators.
34. C — Greenhouse gases absorb outgoing infrared radiation from Earth's surface and re-radiate part of it back downward, warming the lower atmosphere. They act on outgoing longwave energy, not by blocking or reflecting incoming sunlight. This selective absorption and re-emission is the essence of the greenhouse effect.
35. B — The Coriolis effect, a consequence of Earth's rotation, deflects moving air from a straight path, causing global winds to curve. Without rotation the winds would flow directly between pressure zones. This deflection shapes the trade winds and all large-scale wind belts.
36. D — Proxy data such as ice cores, tree rings, and ocean sediments preserve indirect records of past climate, allowing reconstruction of temperatures from before instruments existed. These natural archives extend the climate record far beyond direct measurements. They are essential tools for studying long-term climate change.
37. A — Coal, petroleum, and natural gas are fossil fuels that form over millions of years and cannot be replenished on human timescales, making them nonrenewable. The other lists each include

resources like solar, wind, or geothermal that are continuously renewed. Formation time is what defines a resource as nonrenewable.

38. C — When the factory's pollution forces downstream communities to pay cleanup costs, that cost is a negative externality—a burden imposed on parties outside the original transaction. Externalities are real costs not reflected in the factory's own expenses. Accounting for them is essential to a complete cost-benefit analysis.
39. B — A non-native organism released into an ecosystem where it outcompetes or preys on native species illustrates the invasive species cause of biodiversity loss. Free of natural controls, the introduced fish drives native populations to collapse. This differs from habitat loss, overharvesting, or climate-driven decline.
40. D — Nutrient cycling by soil organisms is a supporting service because it underlies and enables all other ecosystem services, such as food production and clean water. Supporting services are the basic processes that sustain the functioning of ecosystems. Without nutrient cycling, the other service categories could not operate.
41. A — Strong scientific consensus holds that global sea levels will continue rising as ocean water warms and expands and as land ice melts. Both thermal expansion and ice melt add to sea level. The other options contradict observed trends and the direction of ocean chemistry (which becomes more acidic, not alkaline).
42. C — Chlorofluorocarbons (CFCs), once used in refrigerants, aerosols, and foams, released chlorine in the stratosphere that catalytically destroyed ozone, thinning the Antarctic ozone layer. Their role led to the global phase-out under the Montreal Protocol. CFCs, not CO<sub>2</sub> or sulfur compounds, are the ozone-depleting agents.
43. D — Sustainable fishing sets catch limits at or below the rate the population can naturally reproduce, ensuring the stock persists for future generations. Harvesting within the reproductive capacity prevents collapse. Maximizing short-term catch or ignoring population data undermines sustainability.
44. B — Less than 1 percent of Earth's water is readily accessible fresh water in lakes, rivers, and shallow groundwater; most water is salt water, and most fresh water is locked in ice or deep underground. This scarcity makes fresh water a critically limited resource. The small accessible fraction underscores the importance of water conservation.
45. C — Raising roads and installing barriers to cope with flooding already occurring is adaptation, since the city is adjusting to climate impacts rather than reducing emissions. Adaptation responds to changes underway; mitigation would target the cause. The action manages consequences, fitting the definition of adaptation.
46. A — Ocean acidification lowers the availability of carbonate ions, making it harder for corals and shellfish to build and maintain their calcium carbonate shells and skeletons. The chemistry directly impairs calcification. This threat to shell-building organisms is the central consequence of a more acidic ocean.
47. D — The stable, mild climate of the recent geologic past allowed reliable agriculture and permanent settlements, the conditions that civilization required to develop. Predictable growing seasons made farming and cities possible. Climatic stability, not changes in oxygen or continental position, was the key enabling factor.
48. B — The purpose of building and testing prototypes is to gather performance evidence so designs can be compared and the best one improved. Testing under realistic conditions reveals strengths and weaknesses that guide refinement. This iterative evaluation is central to the engineering design process.

49. A — A budget limit is a constraint—a restriction the final design must satisfy—rather than a criterion used to rank performance. Constraints define the boundaries within which any acceptable solution must fall. Distinguishing constraints from criteria is fundamental to evaluating engineering designs.
50. C — A climate model projects likely outcomes under stated assumptions and scenarios, making it a useful tool for planning and decision-making rather than an exact prediction. Models inform policy by exploring possibilities, not by guaranteeing one certain future. They complement, rather than replace, real-world measurements.