ETS® PRAXIS®

The *PRAXIS®* Study Companion

Earth and Space Science (5572)

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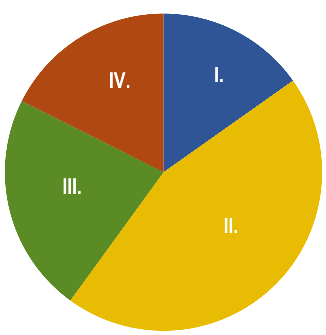
Earth and Space Science (5572)

Test at a Glance

The *Praxis*® Earth and Space Science test is designed is designed to measure knowledge and competencies important for safe and effective beginning practice as a teacher of Earth and space sciences. Test takers have typically completed a bachelor's degree program with appropriate coursework in science and education.

Test Name	Earth and Space Science
Test Code	5572
Time	2 hours 30 minutes
Number of Questions	125 selected-response questions
Format	The test consists of a variety of selected-response questions, where you select one or more answer choices, and other types of questions. You can review the possible question types in "Understanding Question Types."
Test Delivery	Computer Delivered



Content Categories	Approximate Number of Questions	Approximate Percentage of Examination
I. Nature and Impact of Science and Engineering	19	15%
II. Earth's Processes and Materials	56	45%
III. Earth's Hydrosphere and Atmosphere	28	22%
IV. Astronomy	22	18%

Half or more of the questions integrate a Science and Engineering Practice, and approximately one-quarter to one-third of the questions assess content applied to a Task of Teaching of Science.

About The Test

The content topics for the test span the Earth and space sciences curriculum, including content related to (I) Nature and Impact of Science and Engineering, (II) Physical Science, (III) Life Science, and (IV) Earth and Space Science.

The assessment is designed and developed through work with practicing Earth and space sciences teachers, teacher educators, and higher education content specialists to reflect the science knowledge teachers need to teach the Earth and space sciences curriculum and to reflect state and national standards, including the National Science Teaching Association Preparation Standards for Earth and space sciences. Content and practices measured reflect the Disciplinary Core Ideas (DCIs) and Science and Engineering Practices (SEPs) established by the National Research Council in A Framework for K-12 Science Education and included in the Next Generation Science Standards.

The 125 selected-response questions measure concepts, terms, phenomena, methods, applications, data analysis, and problem solving in science. A full list of the topics covered is provided in **Content Topics**.

Test takers will not need to use calculators in taking this test. The periodic table of the elements is available as a Help screen, along with a table of information that presents various physical constants and a few conversion factors among SI units. Whenever necessary, additional values of physical constants are included with the text of a question.

Test takers can expect half or more of the questions on the test to integrate science content knowledge with one or more of the SEPs, listed under **Science and Engineering Practices**.

Test takers will also find that approximately one-quarter to one-third of the questions call for application of Earth and space sciences content and processes within a teaching scenario or an instructional task. Such questions—designed to measure applications of science knowledge to the kinds of decisions and evaluations a teacher must make during work with students, curriculum, and instruction—situate science content questions in tasks critical for teaching. Below, in **Tasks of Teaching Science**, is a list of tasks that are a routine part of science instruction. These tasks, identified based on research on science instruction, have been confirmed by a national committee of teachers and teacher educators as important for effective teaching of secondary science.

This test may contain some questions that will not count toward your score.

Content Topics

This list details the Earth and Space Science topics that may be included on the test. All test questions cover one or more of these topics.

Discussion Questions

In this section, discussion questions are open-ended questions or statements intended to help test your knowledge of fundamental concepts and your ability to apply those concepts to classroom or real-world situations. We do **not** provide answers for the discussion questions but thinking about the answers will help improve your understanding of fundamental concepts and may help you answer a broad range of questions on the test. Most of the questions require you to combine several pieces of knowledge to formulate an integrated understanding and response. They are written to help you gain increased understanding and facility with the test's subject matter. You may want to discuss these questions with a teacher or mentor.

I. Nature and Impact of Science and Engineering

A. Nature of Science

1. Nature of scientific knowledge
   a. Based on empirical evidence collected through observation or experimentation
   b. Interdisciplinary in nature
   c. Asking questions and forming hypotheses
   d. Use of laws and theories to describe and explain natural phenomena
   e. Development and application of models to explain natural phenomena
   f. Utilizes many processes, including observing, categorizing, comparing, generalizing, inferring, and concluding
   g. Develops and changes over time based on new evidence
2. Investigation design, data collection, and analysis
   a. Standard units of measurement, dimensional analysis, unit conversion, and scale (orders of magnitude)
   b. Scientific notation and use of significant figures
   c. Investigation design, including identifying variables, planning data collection, and how design supports answering the question or testing the hypothesis
   d. Processing, organizing, and reporting of data
   e. Error analysis, including accuracy and precision, mean, and percent error
   f. Identifying the sources and effects of error (e.g., systematic, random, sampling)
   g. Interpreting, extrapolating, and drawing conclusions from data, including data presented in various forms such as maps, models, and cross sections
   h. Use and limitations of technologies to gather and analyze data
      - Mathematical and computer modeling

- Remote sensing technologies and geophysical methods (e.g., satellites, space probes, telescopes, spectral analysis, ground-penetrating radar, seismology, magnetic surveying)
- Exploration and research vehicles (e.g., submersibles, research vessels, drones, and spacecraft)

3. Appropriate and safe use of materials and equipment in the laboratory and field
   a. Preparation, use, storage, and disposal of materials
   b. Use of equipment (e.g., selection, calibration, and maintenance)
   c. Safety and emergency procedures

B. Science, Engineering, Technology, Society, and the Environment

1. Engineering design and the interdependence of science, engineering, and technology
   a. Defining problems, including identifying criteria and constraints for success
   b. Designing solutions, including proposing and evaluating in terms of criteria, constraints, ethical considerations, and limitations
   c. Optimizing the design, including systematic modification and refinement
   d. Engineering and technological advances leading to important discoveries in science
   e. How science and technology drive each other forward
2. Using science and engineering to identify and address adverse impacts on the environment and society
   a. Air pollution and acid rain (e.g., tropospheric ozone, sulfur and nitrogen oxides)
   b. Greenhouse gases and their effects (e.g., global climate change, sea-level rise, and ocean acidification)
   c. Stratospheric ozone depletion
   d. Water pollution (e.g., plastics, thermal, and excess nutrient runoff) and management of water resources (e.g., wetlands, aquifers, flooding, irrigation, treatment, and desalination)
   e. Loss of habitat and biodiversity
3. Issues associated with the use and extraction of energy and natural resources
   a. Renewable and nonrenewable energy sources
   b. Energy conservation and responsible management of natural resources
   c. Advantages and disadvantages of energy resources (e.g., fossil fuel, nuclear, hydro, solar, wind, and geothermal)
   d. Global distribution, extraction, and use of resources (e.g., ores and groundwater, mineral, and energy resources)
   e. Land surface use (e.g., urban development, recreational use, agricultural practices, degradation and erosion of soil, deforestation)

   f. Consumer products and lifecycle cost analysis (e.g., production, use, disposal, and recycling)

4. Applications and contributions of Earth and space sciences in daily life
   a. Scientific ethics and decision making
   b. Conservation of resources (e.g., recycling, sustainable technology)
   c. Waste management and remediation of contaminated sites
   d. Technology (e.g., satellites, GPS, GIS, mapping)
   e. Human health (e.g., radon mitigation, water treatment)
   f. Identification, prediction, and risk management of natural hazards (e.g., tsunamis, earthquakes, tornadoes, hurricanes, coastal erosion, wildfires)

Discussion Questions: Nature of Science

- What are the characteristics of a valid scientific hypothesis?
- How have theories about the structure of the solar system changed over time?
- What is the difference between an observation and an inference?
- Compare information obtained from television, a newspaper article, a Web site, and a scientific journal for accuracy. Compare for understandability. Compare for use in the classroom setting.
- What units of distance are used in astronomy?
- Express the number 0.002270 using scientific notation. How many significant figures does the number have in decimal notation? How many in scientific notation?
- What is the specific gravity of an aluminum cube, expressed to the correct number of significant figures, if the cube displaces $8.1\,\text{mL}$ of water and has a mass of 21.87 g?
- Design an experiment and identify the independent variable and the dependent variable. Does the experimental design include a control?
- What is the difference between the accuracy of a data set and the precision of a data set?
- How would you use a topographic map to lay out a trail of least difficulty when hiking from one place to another? How would you determine steepness, direction, and distance?
- What limitation of Earth-based telescopes has been solved by the Hubble space telescope?
- Describe how to prepare 500 mL of $1\,M\text{ HCl}(aq)$, using $12\,M\text{ HCl}(aq)$ and distilled water.
- What is a volumetric flask used for?
- What safety precautions should be taken when preparing a dilute solution of HCl from concentrated HCl?
- What is the proper way to clean up a small spill of concentrated HCl?

Discussion Questions: Science, Engineering, Technology, Society, and the Environment

- What are the major contributors of acid rain?
- What is the greenhouse effect and how does it relate to climate change?
- What are the beneficial and adverse effects on humans and the environment of engineered structures such as dams, levees, and canals that are used to control or divert water?
- Give some reasons why electronic waste such as computers should be recycled.
- Would you consider resources removed from Earth renewable or nonrenewable?
- Compare the availability and limitation of the following sources of power: geothermal, nuclear, hydroelectric, solar, and fossil fuel.

II. Earth's Processes and Materials

A. Basic Principles of Matter and Energy in Earth and Space Systems

1. Structure and properties of matter
   a. Atoms, molecules, ions, elements, and compounds
   b. Mixtures, solutions, and precipitates
   c. Solids, liquids, gases, plasmas
   d. Applications of kinetic molecular theory of gases and the ideal gas law
   e. Chemical and physical properties and changes (e.g., chemical bonding, solubility, pH, oxidation, phase changes, density)
2. Relationships between energy and matter
   a. Conservation of matter in physical and chemical processes
   b. Conservation of energy
   c. Forms of energy (e.g., thermal, chemical)
   d. Waves
      - Wave properties and phenomena (e.g., wavelength, frequency, amplitude, reflection, refraction, interference, Doppler effect)
      - Mechanical waves (e.g., seismic, water, sound)
      - Electromagnetic spectrum (e.g., visible, infrared, ultraviolet, gamma)
   e. Methods and applications of energy transfer (e.g., convection, conduction, radiation)
   f. Applications of heat capacities and specific heats of Earth's materials (e.g., land versus water)
   g. Energy required for phase transitions and its implications for the water cycle and Earth's energy budget (e.g., latent heat)
   h. Temperature scales and measurement
   i. Thermal expansion and contraction

B. Tectonics and Internal Earth Processes

1. Theory of plate tectonics and its supporting evidence
   a. Plate movement (e.g., rates and direction)
   b. Convergent, divergent, and transform boundaries
   c. Potential driving forces (e.g., mantle convection, ridge push and slab pull)
   d. Evidence (e.g., seismic, magnetic, fossil, hot spots)
   e. Geographic features (e.g., trenches, mountains, rift zones)
2. Deformation of Earth's crust and resulting features
   a. Folds and faults (e.g., anticlines and synclines; normal, reverse, and strike-slip)
   b. Mountain building and rifting
   c. Compression, tension, and shear stresses
   d. Isostasy (e.g., postglacial rebound and mountain erosion)
3. Characteristics of earthquakes and how they provide information about Earth's interior
   a. Distribution (e.g., epicenter, focus, patterns in depth and location, frequency)
   b. Magnitude and intensity (e.g., Richter, Mercalli, and other measurement scales)
   c. Seismic waves, seismometers, and seismograms
   d. Natural and anthropogenic causes of earthquakes
4. Layered structure of Earth and related processes Types of solutions
   a. Characteristics of the crust, mantle, and core (e.g., relative thickness, composition, internal heat)
   b. Properties of the lithosphere and asthenosphere (e.g., plasticity, density, temperature)
   c. Evidence (e.g., seismic waves)
   d. Magnetic field and geomagnetic reversals
5. Volcanic characteristics and processes
   a. Formation and distribution of volcanoes (e.g., hot spots, subduction zones, divergent boundaries, Ring of Fire)
   b. Features of volcanoes (e.g., vent, magma chamber)
   c. Types of volcanoes (e.g., shield, composite, cinder cones) and their characteristics
   d. Eruptive products and volcanic hazards (e.g., pyroclastic flows, ash falls, lava, atmospheric ash, earthquakes, outgassing, irregular frequency)

C. Earth's Materials and Surface Processes

1. Earth's materials
   a. Minerals
      - Definition of a mineral
      - Physical properties and identification (e.g., density, streak, cleavage, luster, crystal structure, hardness)
   b. Characteristics and formation of rocks
      - Rock identification and classification

- The rock cycle - formation and characteristics of the following:
  - Intrusive and extrusive igneous rock
  - Clastic, chemical, and biological sedimentary rocks
  - Regional and contact metamorphic rocks

c. Biogeochemical cycles
- Carbon cycle processes (e.g., photosynthesis, respiration, diffusion) and reservoirs (e.g., sediments, ocean, biosphere, atmosphere)
- Nitrogen cycle (e.g., nitrogen fixation, sinks and sources)
- Nutrient cycling and the law of conservation of matter

2. Earth's surface processes and changes over time
   a. Chemical and physical weathering
   b. Erosion and deposition
   c. Interactions and feedback effects between the biosphere and the geosphere (e.g., weathering caused by plants, nutrient uptake from soil by plants, uplift changing climate and affecting local ecosystems)
   d. Interactions and feedback effects between the hydrosphere and the geosphere (e.g., cave formation, ocean salinity, streams, drainage systems, and glacial rebound)
   e. Processes of soil formation and resulting characteristics (e.g., soil profiles and factors such as geology, climate, biological components, and rate of formation)

D. History of Earth and its Life-forms

1. How rocks provide a record of Earth's history and are used to determine geologic time
   a. Principle of uniformitarianism (e.g., definition, applications, limitations)
   b. Relative age dating (e.g., principles of original horizontality, superposition, and crosscutting relationships)
   c. Absolute (radiometric) age dating and radioactive decay processes, including isotopes and half-lives
   d. Stratigraphy
2. History, theories, and supporting evidence of the formation and development of Earth's major systems
   a. Scale of geologic time (e.g., Earth's age, major divisions of time, including Cenozoic, Mesozoic, Paleozoic, Precambrian)
   b. Major events in geological history (e.g., end of the last ice age, mass-extinction events, great oxidation)
   c. Changes in atmospheric composition over time
   d. Hydrosphere (e.g., origin of ocean water and salinity)
   e. Geosphere (e.g., ages of cratons and oldest rock formations, fossil record, paleogeology)
3. Fossil record as evidence of the origin and development of early life on Earth
   a. Emergence of major groups of life-forms correlated to major divisions of geologic time (e.g., stromatolites, cyanobacteria, mammals)

b. Fossilization processes
c. Mass extinctions
d. Relationship between fossil evidence for major episodes in Earth's history and divisions in the geologic time scale

Discussion Questions: Basic Principles of Matter and Energy in Earth and Space Systems

- Compare and contrast the arrangement and motions of molecules of a substance in its solid, liquid, and gaseous states.
- List in order of increasing energy (or decreasing wavelength) the following forms of electromagnetic radiation: gamma rays, microwaves, x-rays, visible light, ultraviolet light, and infrared light.
- If a sample of gas is heated at a constant pressure, what will happen to the volume of the gas?
- Convert $350\,\text{K}$ to degrees Celsius.
- If $100\,\text{g}$ of water at 20°C absorbs $5\,\text{kJ}$ of heat, by what amount will the temperature of the water increase?
- If a substance has high heat capacity, will its temperature increase faster as heat is absorbed than that for a substance with lower heat capacity absorbing the same amount of heat?

Discussion Questions: Tectonics and Internal Earth Processes

- What causes the motion of tectonic plates?
- Why do earthquakes occur more frequently in some places than in others?
- How are the locations of volcanoes related to plate tectonics?
- How is paleomagnetism used to determine rates of seafloor spreading?
- Have the continents always been in the location where they are today?
- What features on Earth's surface exhibit the influence of extension, compression, and shear?
- Many mountains in the eastern United States consist of eroded anticlines and synclines.
- How did the original folds form and what is responsible for the appearance of the land surface today?
- Mountain ranges in the western United States, such as the Teton Range of Wyoming and the Sierra Nevadas of California, exhibit block faulting. Explain the origin of these structures.
- How do seismologists locate the epicenter of an earthquake?
- How do seismic waves provide information about the structure and physical characteristics of Earth?
- How do oil companies use seismology to locate possible oil deposits prior to test drilling?
- What are the characteristics of Earth's internal layers?

- Explain the role of Earth's magnetic field in the concept of paleomagnetism.

Discussion Questions: Earth's Materials and Surface Processes

- How are color, streak, hardness, cleavage, specific gravity, and luster used to identify minerals? What is the acid test? What minerals does it test for?
- Which silicate minerals are the first, next, and last to form as a magma chamber cools?
- How are texture and composition used to identify an igneous rock?
- What metamorphic steps lead to the formation of gneiss?
- What is the origin of marble, and what is its composition? Would it fizz with the acid test? Why or why not?
- What is regional metamorphism? How do the rocks of a given region indicate the intensity of the pressure?
- Why do we see horizons within Earth's regolith?
- How are soil types related to climate?

Discussion Questions: History of Earth and its Life-forms

- Where are the oldest rock layers in the walls of the Grand Canyon? How do historical geologists know that these are the oldest?
- How might you correlate rock layers from the north wall of the Grand Canyon with rock layers from the south wall?
- What is radioactive dating and how is it used?
- How is the fossil record used to infer the evolution of life-forms?

III. Earth's Hydrosphere and Atmosphere

A. Earth's Hydrosphere

1. Unusual properties of water and effect on Earth systems
   a. Hydrogen bonding
   b. Density (e.g., ice floats in water)
   c. Excellent solvent
   d. High specific heat
   e. High heat of vaporization
   f. Exists as solid, liquid, and gas on Earth
2. Water cycle and the energy transfers involved Aerobic and anaerobic cellular respiration
   a. Phase changes (e.g., vaporization, condensation, sublimation)
   b. Models of the water cycle
   c. Distribution of water on Earth (e.g., surface- and groundwater, salt- and freshwater)
   d. Role of water in the transfer of heat from the equator toward the poles
3. Characteristics and processes of surface fresh water and groundwater
   a. Streams (e.g., erosion, deposition, channel migration)
   b. Lakes and wetlands
   c. Groundwater, aquifers, springs, water table, porosity and permeability

   d. Hazards (e.g., flooding, sinkholes, droughts)
   e. Human interactions (e.g., wells, levees, dams, diversion for irrigation, saltwater intrusion)
4. Characteristics of the cryosphere and changes over time
   a. Components of the cryosphere (e.g., continental ice sheets, alpine glaciers, sea ice, permafrost)
   b. Glacial-interglacial cycles, advance and retreat
   c. Depositional and erosional features of glaciers
   d. Impact of the cryosphere on Earth's systems (e.g., sea level, ocean circulation, albedo, salinity)
5. Physical and chemical characteristics and processes of the oceans
   a. Characteristics of the water column (e.g., salinity, temperature, density, and light penetration)
   b. Surface currents, deep-ocean circulation
   c. Wave formation, characteristics, and phenomena
   d. Seafloor topography (e.g., continental shelves, abyssal plains, trenches, midocean ridges)
6. Interrelationships between the oceans and the solid Earth
   a. Tidal effects (e.g., causes, tidal range, tidal patterns)
   b. Coastal processes (e.g., coastal erosional and depositional processes, longshore currents)
   c. Tsunamis
   d. Island formation and change (e.g., barrier islands, volcanic islands, atolls)
   e. Estuaries (e.g., characteristics, formation)
   f. Marine sediments (e.g., origin, rate of deposition)
   g. Sea-level changes
7. Interrelationships between the hydrosphere and the biosphere/atmosphere
   a. Photosynthesis and gas exchange in the oceans
   b. Upwelling of nutrients
   c. Coral reefs
   d. Extreme environments (e.g., hydrothermal vents, salt lakes, geysers)

B. Earth's Atmosphere

1. Basic structure and composition of the atmosphere
   a. Chemical composition
   b. Layers and physical properties (e.g., temperature and pressure profiles, ozone layers)
   c. Role of the atmosphere in biogeochemical cycles (e.g., respiration, transpiration, photosynthesis, nitrogen fixation, evaporation, precipitation, effect of the atmosphere on weathering)
2. Basic physical principles and processes involved in meteorology
   a. Variations in atmospheric temperature, pressure, and density
   b. Energy budget (e.g., energy transfer mechanisms, absorption, reflection, and scattering)
   c. The greenhouse effect and its associated gases (e.g., water vapor, methane, ozone, carbon dioxide)

   d. Global atmospheric circulation (e.g., circulation cells, surface winds, pressure gradients, Coriolis effect)
   e. Humidity (e.g., absolute and relative, dew point and frost point)
   f. Cyclical variations in weather (e.g., sea/land breezes, valley/mountain breezes, monsoons)
3. Development and movement of weather systems
   a. Cloud development and types
   b. Formation and characteristics of various types of precipitation
   c. Air masses, fronts, and associated weather patterns
   d. Severe weather (e.g., lightning, hurricanes, tornadoes, storms)
   e. Interpretation of atmospheric data (e.g., dew point, isobars, wind velocity)
4. Factors and processes that influence climate and lead to climate zones
   a. Effects of the following:
      - Latitude, geographical location, and elevation
      - Atmospheric circulation (e.g., trade winds, jet stream)
      - Ocean circulation (e.g., effects of warm and cold currents, such as the Gulf Stream and Humboldt Current)
      - El Niño Southern Oscillation (ENSO)
      - Characteristics and locations of climate zones (e.g., climographs)
   b. Natural drivers of climate variability and supporting evidence
      - Proxy data used to reconstruct climate history (e.g., ice cores, sediment cores, tree rings)
      - Volcanic eruptions
      - Asteroid impacts
      - Milankovitch cycles (e.g., variations in solar radiation, tilt of Earth's axis, and direction of Earth's axis)
      - Plate tectonics (e.g., changes in landmass positions)

Discussion Questions: Earth's Hydrosphere

- What characteristics make a soil or rock layer permeable or impermeable?
- How does a drainage basin develop?
- What are the stages in the life cycle of a river?
- What influences stream velocity?
- How deeply can a stream erode?
- Under what conditions do glaciers develop?
- What conditions would be necessary for another ice age to occur?
- How does the temperature of seawater vary with depth?
- What is salinity? How is it measured?
- How do oceanographers explain the difference in salinity of ocean water in different locations?
- What causes ocean waters to circulate?
- Explain the movement of ocean bottom currents.
- What are the causes and effects of El Niño?
- What type of sediments would you expect to find in different locations on the seafloor?

- What do core samples of seafloor sediments reveal about the past?
- Why do ocean waves form? Why do these waves break at the shoreline?
- What causes tides?
- Are there two high tides and two low tides in all locations every day? Why or why not?
- What purpose does a groin along the shoreline serve?
- How is upwelling related to wind?

Discussion Questions: Earth's Atmosphere

- How does the Sun influence global and local wind patterns?
- What is the relationship between dew point and cloud formation?
- What is the difference between the behavior of the air in a high and the behavior of the air in a low? What kind of weather is associated with each?
- What happens when a continental polar air mass meets with a maritime tropical air mass?
- How do fronts form?
- How do weather satellites aid in weather forecasting? What kinds of images are available to a forecaster?
- Why do weather systems generally move across the United States from west to east?
- What kinds of weather precede and follow a passing cold front and a passing warm front?
- What influence do latitude, elevation, ocean currents, landforms, and world wind belts have on the climate of a region?
- What part does the angle of the Sun's rays as they strike Earth play in establishing climatic zones?
- How do volcanic eruptions affect both regional and worldwide climate conditions?

IV. Astronomy

A. The Sun-Earth-Moon System

1. Earth's motions and their characteristics and consequences
   a. Rotation (spin) and revolution (orbit)
   b. Observations of the sky from Earth (e.g., sunrise/sunset, seasonal stars, time zones)
   c. Effects of axial tilt (e.g., seasons, solstices, and equinoxes)
2. Relationships within the Sun-Earth-Moon system
   a. Phases of the Moon
   b. Tides (e.g., causes, cycles, spring, neap)
   c. Eclipses (solar, lunar)
   d. Effect of the solar activity on Earth (e.g., solar wind, solar flares, sunspots)
   e. Variability in Sun-Earth-Moon motions (e.g., precession, rotation, orbits)

B. The Solar System and the Universe

1. Characteristics of the components of our solar system and how they formed
   a. Laws of motion (e.g., Newton's law of universal gravitation, Kepler's laws of motion)
   b. Theory of planetary system formation

c. Location, orbits, and characteristics of the planets (e.g., relative sizes, composition, rotational rates)
d. Structure and characteristics of the Sun (e.g., layers, sunspots, prominences, fusion, composition, magnetic field)
e. Structure, characteristics, and orbit of the Moon
f. Characteristics of other solar-system objects (e.g., asteroids, meteoroids, comets, dwarf planets, minor planets, natural satellites)

2. Characteristics of stars and the processes that occur within them
   a. Stages in the life cycle of stars (e.g., nebulae, protostar, main sequence, white dwarf, supernova, black holes)
   b. Variations among stars (e.g., mass, color, temperature, luminosity, apparent brightness, Hertzsprung-Russell diagram)
   c. Nuclear fusion and the formation of elements (e.g., carbon, iron, gold)
   d. Detection and prevalence of other planetary systems
   e. Spectral evidence of composition and temperature
3. Origin, evolution, and characteristics of the universe
   a. Characteristics of galaxies (e.g., dark matter, shape, distribution, motions, supermassive black holes)
   b. Evidence for the origin and evolution of the universe (e.g., redshift, cosmic microwave background, composition)
   c. Spectral evidence of motion

Discussion Questions: The Sun-Earth-Moon System

- Why does the amount of daylight vary from day to day and from place to place?
- Why were time zones invented? Why was the International Date Line established?
- Why does the position of a planet as seen from Earth change in relation to the background of stars?
- Why do seasons exist?
- Why does the Moon appear to pass through phases as it completes one revolution around Earth?
- How does the gravity of the Sun and the Moon affect Earth's oceans?
- What are the conditions under which solar and lunar eclipses occur?

Discussion Questions: The Solar System and the Universe

- What makes a celestial object a member of the solar system?
- What is retrograde motion?
- What are the laws of planetary motion?
- Under what systems do astronomers classify the different planets?
- What is the difference between meteors, meteoroids, and meteorites? What is the origin of meteoroids?

- Why are comets referred to as dirty snowballs?
- What is the source of the Sun's energy?
- How is a star's color related to its temperature?
- Why do astronomers use the terms "apparent magnitude" and "absolute magnitude" when describing the brightness of a star?
- How do stars form? What stages does a star pass through?
- How does the Hertzsprung-Russell diagram help summarize the life cycle of stars?
- How is spectroscopy used to determine the composition of a star?
- What are black holes?
- What is parallax?
- How are Cepheid variable stars used to calculate distances in the universe?
- Why do most astronomers think that the big bang theory is the best explanation for the origin of the universe?
- How are dark line spectra used?

Science and Engineering Practices

The SEPs represent eight practices that scientists and engineers—and students and teachers—use to investigate the world and to design and build systems. Many test questions will integrate one or more of these practices.

1. Asking questions (for science) and defining problems (for engineering)
    - Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
    - Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
    - Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
    - Ask questions to clarify and refine a model, an explanation, or an engineering problem.
    - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
    - Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
    - Define a design problem that can be solved through the development of an object, tool, process or system

and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

2. Developing and using models
   - Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.
   - Design a test of a model to ascertain its reliability.
   - Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
   - Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
   - Develop a complex model that allows for manipulation and testing of a proposed process or system.
   - Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.
3. Planning and carrying out investigations
   - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
   - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
   - Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
   - Select appropriate tools to collect, record, analyze, and evaluate data.
   - Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.
   - Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
4. Analyzing and interpreting data
   - Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
- Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
- Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

5. Using mathematics and computational thinking
   - Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
   - Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
   - Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
   - Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
   - Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m^3, acre-feet, etc.).

6. Constructing explanations (for science) and designing solutions (for engineering)
   - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
   - Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
   - Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
   - Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

7. Engaging in argument from evidence
   - Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
   - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
   - Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
   - Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
   - Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
   - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

8. Obtaining, evaluating, and communicating information
   - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
   - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
   - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
   - Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

- Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Tasks of Teaching Science

This list includes instructional tasks that teachers engage in that are essential for effective Earth and Space Science teaching. Many test questions will measure content through application to one or more of these tasks

Scientific Instructional Goals, Big Ideas, and Topics

1. Selecting or sequencing appropriate instructional goals or big ideas for a topic
2. Identifying the big idea or instructional goal of an instructional activity
3. Choosing which science ideas or instructional activities are most closely related to a particular instructional goal
4. Linking science ideas to one another and to particular activities, models, and representations within and across units

Scientific Investigations and Demonstrations

5. Selecting investigations or demonstrations, including virtual, that facilitate understanding of disciplinary core ideas, scientific practices, or crosscutting concepts
6. Evaluating investigation questions for quality (e.g., testable, empirical)
7. Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question
8. Critiquing scientific procedures, data, observations, or results for their quality, accuracy, or appropriateness
9. Supporting students in generating questions for investigation or identifying patterns in data and observations

Scientific Resources (texts, curriculum materials, journals, and other print and media-based resources)

10. Evaluating instructional materials and other resources for their ability to address scientific concepts; engage students with relevant phenomena; develop and use scientific ideas; promote students' thinking about phenomena, experiences, and knowledge; take account of students' ideas and background; and assess student progress
11. Choosing resources that support the selection of accurate, valid, and appropriate goals for science learning

Student Ideas (including common misconceptions, alternate conceptions, and partial conceptions)

12. Analyzing student ideas for common misconceptions regarding intended scientific learning
13. Selecting diagnostic items and eliciting student thinking about scientific ideas and practices to identify common student

misconceptions and the basis for those misconceptions

14. Developing or selecting instructional moves, approaches, or representations that provide evidence about common student misconceptions and help students move toward a better understanding of the idea, concept, or practice

Scientific Language, Discourse, Vocabulary, and Definitions

15. Selecting scientific language that is precise, accurate, grade-appropriate, and illustrates key scientific concepts
16. Anticipating scientific language and vocabulary that may be difficult for students
17. Modeling the use of appropriate verbal and written scientific language in critiquing arguments or explanations, in describing observations, or in using evidence to support a claim, etc.
18. Supporting and critiquing students' participation in and use of verbal and written scientific discourse and argumentation

Scientific Explanations (includes claim, evidence, and reasoning)

19. Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence
20. Selecting explanations of natural phenomena that are accurate and accessible to students

Scientific Models and Representations (analogies, metaphors, simulations, illustrations, diagrams, data tables, performances, videos, animations, graphs, and examples)

21. Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals
22. Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to an instructional goal
23. Evaluating student models or representations for evidence of scientific understanding
24. Generating or selecting diagnostic questions to evaluate student understanding of specific models or representations
25. Evaluating student ideas about what makes for good scientific models and representations

Earth and Space Science (5572) Sample Test Questions

The sample questions that follow represent a number of the types of questions and topics that appear on the test. They are not, however, representative of the entire scope of the test in either content or difficulty. Answers with explanations follow the questions.

Directions: Each of the questions or incomplete statements below is followed by suggested answers or completions. Select the one that is best in each case.

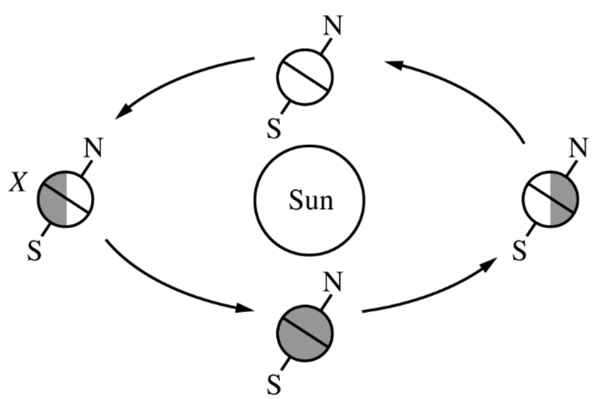
1. A student performs several tests on a sample of a mineral and concludes that the sample is quartz. The student's conclusion is an example of which of the following?

   (A) A generalization

   (B) An inference

   (C) An observation

   (D) A theory



2. A teacher shows students the preceding diagram of Earth's orbit around the Sun and asks students to make a claim about the effect of Earth's axial tilt when Earth is at position X. Which of the following student claims indicates a misconception about the effects of Earth's axial tilt?

   (A) The Sun is directly overhead at solar noon at 23.5 degrees north latitude.

   (B) There are 24 hours of daylight per day at the North Pole and 24 hours of darkness per day at the South Pole.

   (C) The Southern Hemisphere is experiencing winter because it is farther away from the Sun than the Northern Hemisphere is.

   (D) It is the summer solstice in the Northern Hemisphere and the winter solstice in the Southern Hemisphere.

3. Which **THREE** of the following features may be associated with tectonic plate convergence?

    (A) Deep-sea trenches

    (B) Earthquakes

    (C) Mid-ocean ridges

    (D) Subduction of oceanic lithosphere

4. The atmospheric concentration of which of the following gases is most likely to be directly affected by widespread deforestation?

    (A) Carbon dioxide

    (B) Ozone

    (C) Nitrous oxide

    (D) Argon

5. A teacher is most likely to use the expression "The present is the key to the past" to introduce or summarize which of the following topics?

    (A) Theory of evolution

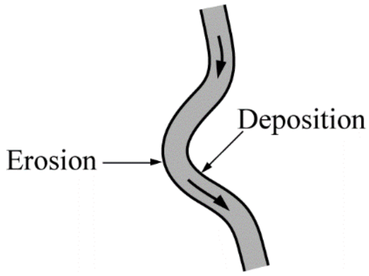
    (B) Principle of uniformitarianism

    (C) Scientific method

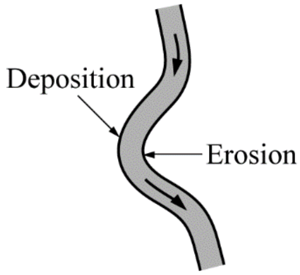
    (D) Weather prediction

6. Which of the following diagrams best shows where erosion and deposition take place on a river meander?

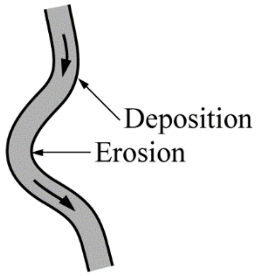
(A)



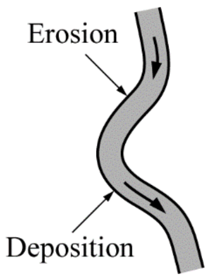
(B)



(C)



(D)



7. Which of the following structures is most susceptible to damage by acid precipitation?

    (A) A monument made of granite

    (B) A roof made of slate

    (C) A tombstone made of marble

    (D) A statue made of gabbro

8. Which of the following questions is most useful for determining whether a gas is a greenhouse gas?

    (A) Is the gas able to absorb and emit infrared radiation?

    (B) Is the gas a reactant or product of respiration or photosynthesis?

    (C) Is the gas found in both the troposphere and the stratosphere?

    (D) Is the gas a reactant or product of fossil fuel combustion?

9. After a lesson on atomic structure, a teacher asks students to determine the number of protons, neutrons, and electrons in the ion represented by the symbol $^{27}_{13}Al^{3+}$. Which of the following responses indicates the best understanding of the lesson?

	Protons	Neutrons	Electrons
(A)	10	14	13
(B)	13	14	10
(C)	13	14	16
(D)	14	13	10

10. Astronomers have proposed that the solar system formed from a vast rotating cloud of gas and dust. This explanation is known as which of the following?

    (A) Kepler's laws
    (B) Big bang theory
    (C) Cosmic string theory
    (D) Nebular hypothesis

11. A diagram illustrating Bowen's reaction series is most likely to be used for a lesson on which of the following?

    (A) The weathering of sedimentary rock
    (B) The relative reactivity of carbonates with acids
    (C) The mineral composition of igneous rocks
    (D) The metamorphic grade of rocks in a contact aureole

12. Which of the following types of stress dominates at divergent boundaries?

    (A) Compressional
    (B) Left-lateral shear
    (C) Right-lateral shear
    (D) Tensional

13. During a unit on climate, students design an investigation to test the effect of carbon dioxide on air temperature. They set up two sealable plastic bags under heat lamps, which are at the same height. Each bag contains a wireless temperature probe and a beaker of vinegar. After sodium bicarbonate is added to one of the beakers to produce carbon dioxide, both bags are quickly sealed. The temperature of the gas inside each bag is monitored. Based on this information, what are the independent and dependent variables in the students' investigation?

	Independent Variable	Dependent Variable
(A)	Volume of vinegar	Mass of sodium bicarbonate
(B)	Volume of vinegar	Amount of carbon dioxide
(C)	Temperature of the gas	Amount of carbon dioxide
(D)	Amount of carbon dioxide	Temperature of the gas

14. A well on the side of a hill penetrates the water table at an elevation of 550 feet above sea level. If someone plans to drill on the top of the hill, where would the water table most likely be found?

(A) The water table would be found at sea level.

(B) The water table would be found at an elevation lower than 550 feet above sea level but above sea level.

(C) The water table would be found at an elevation higher than 550 feet above sea level but many feet below the land surface.

(D) The water table would intersect with the land surface at the top of the hill, forming a spring.

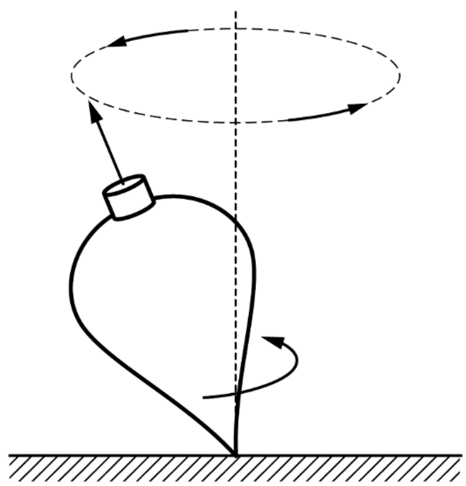
15. Which of the following sequences of events in the geologic past is consistent with the presence of a layer of sandstone in bedrock just above a layer of shale?

    (A) A volcano erupted, sending lava out over a layer of shale. The lava cooled and hardened into sandstone.

    (B) The water level of a large lake lowered. A beach then formed where previously there had been lake bottom.

    (C) One-celled organisms developed a colony on the seafloor. Shells made by these organisms accumulated and lithified, forming the sandstone.

    (D) Mud was deposited and lithified. Subsequent contact metamorphism resulted in localized recrystallization of the shale into sandstone.



16. A teacher has students observe the motion of a spinning top, which is represented by the preceding diagram. The goal of this activity is most likely to help students understand which of the following phenomena?

    (A) Axial precession causes the north celestial pole to shift.

    (B) The gravitational pull of Jupiter affects the eccentricity of Earth's orbit.

    (C) The tilt of Earth's axis causes the seasons on Earth.

    (D) The Moon rotates on its axis once during a complete orbit around Earth.

17. Which of the following rocks forms from the metamorphism of shale?

    (A) Granite
    (B) Marble
    (C) Quartzite
    (D) Schist

Relative Humidity

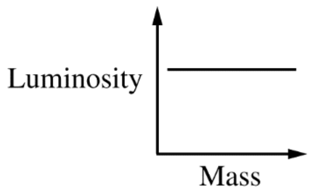
T_{db} (°C)	$T_{db} - T_{wb}$ (°C)						
	0	3	6	9	12	15	18
0	100	46					
8	100	63	29				
16	100	71	46	23			
24	100	77	56	37	20	5	
32	100	80	62	46	32	20	9

18. Based on the information in the preceding table, which of the following dry-bulb temperatures (T_{db}) and wet-bulb temperatures (T_{wb}) corresponds to air with the highest relative humidity?

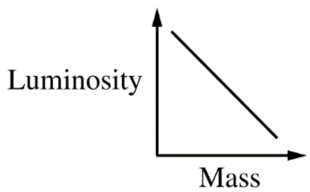
	T_{db} (°C)	T_{wb} (°C)
(A)	32	23
(B)	14	21
(C)	16	10
(D)	8	5

19. Which of the following graphs best shows the relationship between mass and luminosity for main sequence stars? (Axes for all graphs have logarithmic scales.)

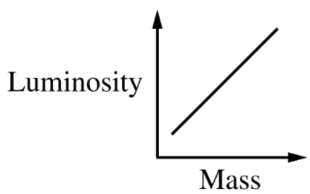
(A)



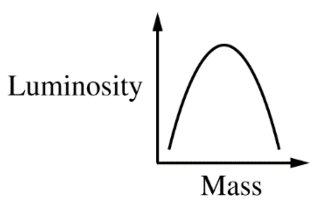
(B)



(C)



(D)



Latent heat of fusion	334 kJ/kg
Latent heat of vaporization	2,260 kJ/kg

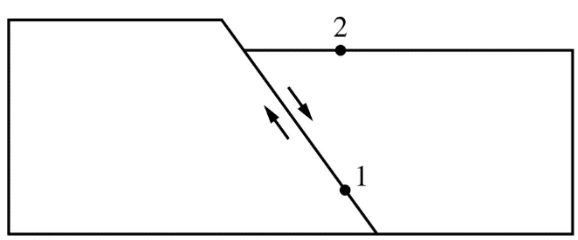
20. The latent heats for water are given in the preceding table. Which of the following statements about the heat transfer that occurs when 1kg of water condenses during cloud formation is accurate?

(A) 334 kJ of heat is absorbed from the surroundings.

(B) 334 kJ of heat is released to the surroundings.

(C) 2,260 kJ of heat is absorbed from the surroundings.

(D) 2,260 kJ of heat is released to the surroundings.



21. A teacher shows students the preceding diagram illustrating a fault where vertical displacement has occurred. Point 1, deep within the crust, is where the rocks of the fault have ruptured. Point 2 is on the surface above point 1. Which of the following terms should students use to label each point?

	Point 1	Point 2
(A)	Dip	Slip
(B)	Slip	Dip
(C)	Epicenter	Focus
(D)	Focus	Epicenter

22. Which of the following activities is likely to have the greatest impact on biodiversity?

    (A) Open-pit mining of copper in Chile and other locations in the Andes
    (B) Offshore drilling for crude oil in the Persian Gulf
    (C) Large-scale deforestation of tropical forests in the Amazon or Congo River basins
    (D) Use of existing fields in the United States to grow corn for ethanol

23. The mineral pyrite is commonly known as fool's gold. Which **THREE** of the following properties would best help distinguish between a piece of gold and a piece of pyrite?

    (A) Hardness
    (B) Luster
    (C) Specific gravity
    (D) Streak

24. The dissolved salts in Earth's oceans are principally derived from

    (A) marine biological activity
    (B) atmospheric deposition
    (C) the weathering of continental rocks
    (D) the eruptions of undersea hot spot volcanoes

25. Jupiter has the largest magnetic field of the planets in the solar system. Which of the following is hypothesized to be the source of the magnetic field for Jupiter?

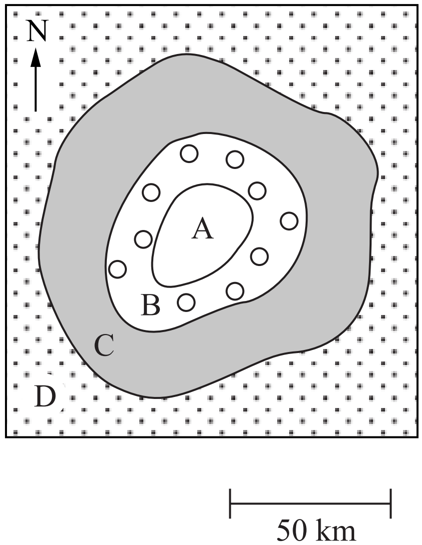
    (A) The motion of highly compressed liquid hydrogen deep within Jupiter
    (B) The motion of molten iron and nickel in Jupiter's inner core
    (C) The revolution of cosmic debris within the rings around Jupiter
    (D) The interaction of cosmic rays with Jupiter's atmosphere

26. Which of the following has provided the most information about the structure of Earth's core, mantle, and lower crust?

    (A) Measurement of the intensity and fluctuations of Earth's magnetic field
    (B) Examination of flowing lava from hot spot volcanoes
    (C) Collection of samples from deep boreholes drilled into Earth
    (D) Studies of the speeds and travel paths of seismic waves passing through Earth

27. Cumulonimbus clouds that extend to the top of the troposphere and have an anvil shape are most often associated with which of the following weather conditions?

    (A) Thunderstorms that may produce hail and tornadoes
    (B) Extended periods of drizzle and light rain
    (C) Blankets of fog caused by thermal inversions
    (D) Subtropical high-pressure cells with anticyclonic motion



28. The preceding geologic map, of an area with low topographic relief, shows four rock units, labeled A through D, in order from oldest to youngest. What structure is represented on the map?

    (A) Basin

    (B) Dome

    (C) Anticline

    (D) Syncline

29. Kaolinite is a common and commercially important clay mineral. Which of the following weathering processes produces kaolinite?

    (A) Abrasion of quartz

    (B) Oxidation of pyrite

    (C) Dissolution of calcite

    (D) Hydrolysis of feldspar

30. The Burgess Shale, a rock formation in Canada, has a large number of fossils from the Cambrian period preserved in exquisite detail. Many primitive members of modern phyla, including arthropods, mollusks, and chordates, can be found among the fossils exposed in this region. Based on these fossils, it can be concluded that most of the modern groups of animal life first appeared roughly

    (A) 3 billion years ago
    (B) 540 million years ago
    (C) 65 million years ago
    (D) 200,000 years ago

31. Which of the following statements could a teacher use to help explain why some localities have normally large tidal ranges (up to 60 feet) and others have one- to two-foot tidal ranges?

    (A) The position of the Sun is different at different localities.
    (B) The Coriolis effect and rotation of Earth tend to enhance tidal flow in the higher latitudes.
    (C) Ocean floor topography and the shape of the coastline serve to amplify tidal flow at specific localities.
    (D) Trade winds push the water into large tidal bulges near rocky shorelines.

32. Which of the following has provided evidence that the Sun's atmosphere contains sodium atoms?

    (A) Absorption lines in the solar spectrum are consistent with the presence of sodium.
    (B) Stars in the same spectral class as the Sun are made mostly of sodium.
    (C) Solar samples returned to Earth by the Voyager spacecraft contained sodium.
    (D) The Sun gives off energy produced by the nuclear fusion of sodium in its core.

Earth and Space Science (5572) Answers

1. Option (B) is correct. An inference is a conclusion based on evidence and reasoning.

Content	1 A
Science and Engineering Practice	7
Task of Teaching Science	18

2. Option (C) is correct. It is a misconception that the summer and winter seasons result from one hemisphere being significantly closer to or farther from the Sun as a result of Earth's tilt. Rather, it is the angle at which the Sun's rays strike Earth's surface that plays the largest role in determining the seasons. When Earth is at position X, the Southern Hemisphere receives the least direct, or oblique, rays of the Sun and experiences the fewest hours of daylight.

Content	IV A
Science and Engineering Practice	2
Task of Teaching Science	12

3. Options (A), (B), and (D) are correct. Convergent boundaries form where two lithospheric plates collide. When an oceanic plate converges with another oceanic plate or a continental plate, the denser oceanic plate is subducted, forming a deep-sea trench. Earthquakes are common at convergent boundaries, and the foci may be deep under the overlying plates where subduction is occurring.

Content	II B

4. Option (A) is correct. Deforestation is most likely to result in an increase in the concentration of carbon dioxide, which is a trace gas in Earth's atmosphere. Forests are natural carbon sinks. Through photosynthesis, they transform carbon dioxide into biomass. Deforestation not only decreases the amount of carbon dioxide in the atmosphere that can be sequestered by photosynthesis, but methods of deforestation, such as slash and burn, release carbon (as carbon dioxide) that has been stored as biomass.

Content	II C

5. Option (B) is correct. The principle of uniformitarianism is the concept that the geological processes and natural laws that operate today also operated in the geologic past. The principle is often summarized by the expression "The present is the key to the past."

Content	II D
Task of Teaching Science	4

6. Option (A) is correct. The bends in rivers are called meanders. Meanders grow by erosion on the outside of the bends and by deposition on the inside of the bends because the current is faster on the outside than on the inside.

Content	III A
Science and Engineering Practice	2

7. Option (C) is correct. Marble is particularly susceptible to acid rain because it is composed primarily of the mineral calcite, which readily dissolves in acid. The other materials, which contain mostly silicate minerals, would also be affected, but over a longer period of time.

Content	I B
Science and Engineering Practice	1

8. Option (A) is correct. A greenhouse gas is a gas that absorbs and emits infrared radiation. Since most of the infrared radiation absorbed by greenhouse gases in Earth's atmosphere is emitted from Earth's surface, greenhouse gases effectively trap heat, making Earth warmer than it would be in the absence of the greenhouse effect. Greenhouse gases can be produced through both natural processes and human activities.

Content	III B
Science and Engineering Practice	1
Task of Teaching Science	16

9. Option (B) is correct. The symbol $^{27}_{13}\text{Al}^{3+}$ represents an ion of aluminum. The atomic number is 13, which is equal to the number of protons. The mass number is 27, which is equal to the total number of protons plus neutrons; therefore, the number of neutrons is 14. A neutral atom has the same number of electrons and protons. An ion with a $+3$ has three fewer electrons than the neutral atom; therefore, the number of electrons is 10.

Content	II A
Science and Engineering Practice	2
Task of Teaching Science	23

10. Option (D) is correct. The nebular hypothesis is a model of planetary system formation. A rotating cloud of gas and dust collapses to form a young star and protoplanetary disk. As the disk cools, planetesimals undergo accretion and collisions to form the inner terrestrial planets. Beyond the frost line, protoplanets composed of ices accrete gases, forming the massive outer gas and ice giants.

Content	IV B

11. Option (C) is correct. Bowen's reaction series describes the order in which minerals crystallize from molten rock as the melt cools.

Content	II C
Task of Teaching Science	10

12. Option (D) is correct. Tensional stress dominates at divergent boundaries, where two plates are moving away from each other in opposite directions. Tensional stress produces normal faults.

Content	II B

13. Option (D) is correct. The independent variable is the amount of carbon dioxide in the sealed bags. The bag with the added sodium bicarbonate has a larger amount of carbon dioxide in the gas contained in the bag. The dependent variable is the temperature, which is measured to determine if having a larger amount of carbon dioxide in the gas affects the temperature of the gas given the same input of energy through radiation by the heat lamps.

Content	I A
Science and Engineering Practice	3
Task of Teaching Science	7

14. Option (C) is correct. The water table, which is the upper surface of the zone of saturation, often follows the topography of the land surface to some extent. Thus, the well drilled at the top of the hill is likely to intersect the water table at an elevation higher than 550 feet above sea level.

Content	III A
Science and Engineering Practice	6

15. Option (B) is correct. Shale is a fine-grained sedimentary rock made of clay-sized particles. Sandstone is a sedimentary rock made of sand-sized particles. For sandstone to form on top of shale, a change in the environment must have occurred from one that would allow the deposition of clay (such as a lake bed) to one that would allow the deposition of sand (such as a beach).

Content	II D
Science and Engineering Practice	7

16. Option (A) is correct. A spinning top can be used to model the axial precession of Earth. Axial precession is one of the long-term changes to Earth's motions that are included in the Milankovitch cycles that help explain changes in Earth's climate. The orientation of Earth's axis with respect to the position of stars has a cycle of approximately 26,000 years.

Content	IV A
Task of Teaching Science	2

17. Option (D) is correct. Schist is a foliated metamorphic rock derived from shale. Granite is an igneous rock, marble is a metamorphic rock derived from limestone, and quartzite is a metamorphic rock derived from quartz sandstone.

Content	II C

18. Option (B) is correct. The difference between the dry-bulb temperature and wet-bulb temperature is equal to $24°C - 21°C = 3°C$, which corresponds to a relative humidity of 77 percent.

Content	III B
Science and Engineering Practice	4

19. Option (C) is correct. For stars on the main sequence, the relationship of mass to luminosity is that the more massive a main sequence star is, the higher its surface temperature and the more luminous it is.

Content	IV B
Science and Engineering Practice	5

20. Option (D) is correct. The latent heat of vaporization is the amount of heat absorbed by a given mass of water when it undergoes a phase change from liquid to vapor at a constant temperature. When a similar mass of water vapor condenses, an equivalent amount of heat is released.

Content	II A
Science and Engineering Practice	5

21. Option (D) is correct. The point where the rupture begins is called the focus, or hypocenter. The point on the surface above the focus is called the epicenter.

Content	II B
Science and Engineering Practice	2
Task of Teaching Science	22

22. Option (C) is correct. Biodiversity refers to the richness of living systems as a function of genetic variation within and among species in an ecosystem, a biome, or on Earth. The tropical rainforest biome has tremendous species richness and thus tremendous biodiversity. Large-scale deforestation would destroy the habitats of more species than would the other choices.

Content	I B

23. Options (A), (C), and (D) are correct. Both gold and pyrite have metallic luster and similar color. Gold is typically found in its pure form as a native metal and is notable for its softness (Mohs hardness of 2.5) and density (specific gravity of approximately 19). Gold produces a gold streak. In contrast, pyrite has a hardness of 6 to 6.5 and a specific gravity of approximately 5. Pyrite produces a green-black streak.

Content	II C
Science and Engineering Practice	3

24. Option (C) is correct. The salinity of Earth's oceans is attributed primarily to dissolved salts produced by the weathering of continental rocks and transported to the oceans by rivers. The other choices list plausible sources of salts, but they are all insignificant compared with the continental source.

Content	III A
Science and Engineering Practice	6

25. Option (A) is correct. Jupiter is a gas giant that is largely composed of hydrogen and helium. Astronomers hypothesize that it is the motion of highly compressed liquid hydrogen, referred to as metallic hydrogen, that is the source of Jupiter's magnetic field, analogous to the way molten iron in Earth's outer core produces Earth's magnetic field.

Content	IV B
Science and Engineering Practice	6

26. Option (D) is correct. The structure of Earth has been inferred indirectly based on the movement of the different kinds of seismic waves through different parts of Earth. P waves and S waves travel at different speeds and can pass through different Earth materials. When they move from one material to another material, they are reflected or refracted. The speeds and actions of these waves are used to determine the characteristics of the different layers of Earth. For example, P waves can travel through solids and liquids, slowing in liquids, while S waves can travel only through solids. Since S waves are eliminated and P waves slow down at the outer core, it is inferred that the outer core acts as a liquid; since P waves speed up in the inner core, it is inferred that it is solid.

Content	II B

27. Option (A) is correct. An anvil-shaped cumulonimbus cloud forms when the atmospheric conditions are favorable for strong updrafts, such that the cloud expands vertically to the top of the troposphere. Once the cloud mass reaches the tropopause, it expands horizontally, giving the anvil cloud its characteristic flat-topped shape. Anvil clouds are notable for their potential to produce more extreme weather elements, including heavy rainfall and hail, dangerous cloud-to-ground lightning, high winds, and tornadoes.

Content	III B

28. Option (B) is correct. Domes are geologic features that result from upward-acting pressure that produces an uplifted portion of the crust that dips downward on all sides. After the area has been eroded and there is low topographic relief, the area of the dome is characterized by concentric strata that grow progressively older from the outside to the inside, with the oldest rocks exposed at the center.

Content	I A
Science and Engineering Practice	2

29. Option (D) is correct. During chemical weathering of feldspar by hydrolysis, ions such as Na^{+}, and K^{+}, and Ca^{2+} are leached away, producing the clay mineral kaolinite.

Content	II C
Science and Engineering Practice	6

30. Option (B) is correct. The Cambrian period began approximately 540 million years ago. The early period is notable for the rapid increase in biodiversity, known as the Cambrian explosion, that included the first members of many modern animal phyla.

Content	II D
Science and Engineering Practice	6

31. Option (C) is correct. The configuration of ocean basins and the shape of the coastline can affect the tides, causing phenomena such as standing waves and resonance. The extreme tidal range typical of localities in the Bay of Fundy is a well-known example of the influence of ocean floor topography and coastline shape on tides.

Content	III A
Science and Engineering Practice	6
Task of Teaching Science	20

32. Option (A) is correct. The chemical composition of the Sun's atmosphere has been inferred primarily from absorption lines observed in the solar spectrum.

Content	IV B
Science and Engineering Practice	7

Understanding Question Types

The *Praxis*® assessments include a variety of question types: constructed response (for which you write a response of your own); selected response, for which you select one or more answers from a list of choices or make another kind of selection (e.g., by selecting a sentence in a text or by selecting part of a graphic); and numeric entry, for which you enter a numeric value in an answer field. You may be familiar with these question formats from taking other standardized tests. If not, familiarize yourself with them so you don't spend time during the test figuring out how to answer them.

Understanding Selected-Response and Numeric-Entry Questions

For most questions, you respond by selecting an oval to select a single answer from a list of answer choices.

However, interactive question types may also ask you to respond by:

- Selecting more than one choice from a list of choices.
- Typing in a numeric-entry box. When the answer is a number, you may be asked to enter a numerical answer. Some questions may have more than one entry box to enter a response. Numeric-entry questions typically appear on mathematics-related tests.
- Selecting parts of a graphic. In some questions, you will select your answers by selecting a location (or locations) on a graphic such as a map or chart, as opposed to choosing your answer from a list.
- Selecting sentences. In questions with reading passages, you may be asked to choose your answers by selecting a sentence (or sentences) within the reading passage.
- Dragging and dropping answer choices into targets on the screen. You may be asked to select answers from a list of choices and to drag your answers to the appropriate location in a table, paragraph of text or graphic.
- Selecting answer choices from a drop-down menu. You may be asked to choose answers by selecting choices from a drop-down menu (e.g., to complete a sentence).

Remember that with every question you will get clear instructions.

Understanding Constructed-Response Questions

Some tests include constructed-response questions, which require you to demonstrate your knowledge in a subject area by writing your own response to topics. Essays and short-answer questions are types of constructed-response questions.

For example, an essay question might present you with a topic and ask you to discuss the extent to which you agree or disagree with the opinion stated. You must support your position with specific reasons and examples from your own experience, observations, or reading.

Review a few sample essay topics:

- *Brown v. Board of Education of Topeka*

  "We come then to the question presented: Does segregation of children in public schools solely on the basis of race, even though the physical facilities and other 'tangible' factors may be equal, deprive the children of the minority group of equal educational opportunities? We believe that it does."

  A. What legal doctrine or principle, established in *Plessy v. Ferguson* (1896), did the Supreme Court reverse when it issued the 1954 ruling quoted above?

  B. What was the rationale given by the justices for their 1954 ruling?

- *In his self-analysis, Mr. Payton says that the better-performing students say small-group work is boring and that they learn more working alone or only with students like themselves. Assume that Mr. Payton wants to continue using cooperative learning groups because he believes they have value for all students.*

  - Describe **TWO** strategies he could use to address the concerns of the students who have complained.
  - Explain how each strategy suggested could provide an opportunity to improve the functioning of cooperative learning groups. Base your response on principles of effective instructional strategies.

- *"Minimum-wage jobs are a ticket to nowhere. They are boring and repetitive and teach employees little or nothing of value. Minimum-wage employers take advantage of people because they need a job."*

  - Discuss the extent to which you agree or disagree with this opinion. Support your views with specific reasons and examples from your own experience, observations, or reading.

Keep these things in mind when you respond to a constructed-response question:

1. **Answer the question accurately.** Analyze what each part of the question is asking you to do. If the question asks you to describe or discuss, you should provide more than just a list.
2. **Answer the question completely.** If a question asks you to do three distinct things in your response, you should cover all three things for the best score. Otherwise, no matter how well you write, you will not be awarded full credit.
3. **Answer the question that is asked.** Do not change the question or challenge the basis of the question. You will receive no credit or a low score if you answer another question or if you state, for example, that there is no possible answer.
4. **Give a thorough and detailed response.** You must demonstrate that you have a thorough understanding of the subject matter. However, your response should be straightforward and not filled with unnecessary information.
5. **Take notes on scratch paper** so that you don't miss any details. Then you'll be sure to have all the information you need to answer the question.
6. **Reread your response.** Check that you have written what you thought you wrote. Be sure not to leave sentences unfinished or omit clarifying information.

General Assistance For The Test

Praxis® Interactive Practice Test

This full-length *Praxis®* practice test lets you practice answering one set of authentic test questions in an environment that simulates the computer-delivered test.

- Timed just like the real test
- Correct answers with detailed explanations
- Practice test results for each content category

ETS provides a free interactive practice test with each test registration. You can learn more here.

Doing Your Best

Strategy and Success Tips

Effective *Praxis* test preparation doesn't just happen. You'll want to set clear goals and deadlines for yourself along the way. Learn from the experts. Get practical tips to help you navigate your *Praxis* test and make the best use of your time. Learn more at Strategy and Tips for Taking a *Praxis* Test.

Develop Your Study Plan

Planning your study time is important to help ensure that you review all content areas covered on the test. View a sample plan and learn how to create your own. Learn more at Develop a Study Plan.

Helpful Links

Ready to Register – How to register and the information you need to know to do so.

Disability Accommodations – Testing accommodations are available for test takers who meet ETS requirements.

PLNE Accommodations (ESL) – If English is not your primary language, you may be eligible for extended testing time.

What To Expect on Test Day – Knowing what to expect on test day can make you feel more at ease.

Getting Your Scores – Find out where and when you will receive your test scores.

State Requirements – Learn which tests your state requires you to take.

Other Praxis Tests – Learn about other *Praxis* tests and how to prepare for them.

To search for the *Praxis* test prep resources
that meet your specific needs, visit:

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