

Unit 4: Earth Systems and Resources

Unit 4 explains how Earth's physical systems work. It covers plate tectonics and earthquakes, how soil forms and what makes it fertile, the composition and layers of the atmosphere, the global wind patterns that move air around the planet, how solar energy varies across latitudes and seasons, and the climate patterns that result.

AP Environmental Science

Earth Systems and Resources

About 12 minutes to read

How to use this guide

Read it in order the first time because the topics build on each other. Plate tectonics shapes the land that soil forms on, the atmosphere and solar energy drive the wind patterns, and winds plus geography produce the climates and ocean patterns like El Nino. Exam questions love to connect these pieces, so watch for the links between sections.

After the first read, use the trap boxes to review the distinctions that exam questions test most often. Finish with the practice questions, then complete the recall check on the last page out loud and note any items you cannot explain yet.

What this unit is worth. Earth Systems and Resources is about 10 to 15 percent of the AP Environmental Science exam, and it is the physical foundation for almost everything that comes after it. Ecosystems, land and water use, energy resources, and pollution all assume you understand plate tectonics, soil, the atmosphere, and climate. Later units will quietly test Unit 4 ideas without naming them, so a shaky Unit 4 makes the rest of the course harder than it needs to be.

4.1 Plate Tectonics

Earth's lithosphere is broken into tectonic plates that drift a few centimeters per year. Where plates meet, the type of boundary decides what forms. A **convergent plate boundary** is where two plates push together. When oceanic crust meets continental crust, the denser oceanic plate sinks beneath the other in **subduction**, producing volcanoes and earthquakes like those along the Andes. Two oceanic plates colliding build **island arcs** like Japan. Two continental plates colliding crumple upward into mountain ranges like the Himalayas.

A **divergent plate boundary** is where two plates pull apart. Magma rises to fill the gap, so new crust forms here. These boundaries build **mid-ocean ridges**, drive **seafloor spreading**, and open **rift valleys** like the East African Rift. Volcanoes and earthquakes occur at divergent boundaries too. A **transform plate boundary** is where two plates slide horizontally past each other. No crust is created and none is destroyed, so the signature product is earthquakes, like those on the San Andreas Fault.

BOUNDARY	MOTION	WHAT FORMS
Convergent	Plates push together	Subduction zones, volcanoes, island arcs, mountain ranges, earthquakes
Divergent	Plates pull apart	Seafloor spreading, mid-ocean ridges, rift valleys, volcanoes, earthquakes
Transform	Plates slide past each other	Earthquakes

Trap. Divergent boundaries create new crust and convergent boundaries destroy it, so it helps to remember them as constructive and destructive. Transform boundaries do neither, which is why a question listing volcanoes as a product of a transform boundary is always wrong.

Reading plate boundary maps

Plate boundary maps show where these boundaries run around the planet. Because most volcanoes, earthquakes, island arcs, and faults sit on or near boundaries, a map of boundaries doubles as a map of geologic hazards. Learn one deliberate exception: **hot spots**. Hot spots like Hawaii form over stationary plumes of hot mantle rock in the middle of a plate, not at a boundary, so they will not appear where the boundary map says to look.

Trap. If a question asks where a hot spot volcano would be found relative to plate boundaries, the answer is in the middle of a plate, far from any boundary. Boundary maps predict most geologic activity, and hot spots are the exception that proves you actually understand the rule.

How earthquakes happen

An **earthquake** occurs when stress overcomes a locked fault, releasing stored energy. The plates on either side of a fault are stuck together while tectonic motion keeps pushing, so strain energy builds up over years or decades. When the stress finally exceeds the strength of the lock, the fault slips and the stored energy releases as seismic waves. The point underground where the slip starts is the focus, and the point on the surface directly above it is the epicenter.

4.2 Soil Formation and Erosion

Soil formation begins with parent material, the rock or sediment the soil develops from. That material is **weathered** into smaller pieces by physical forces like freeze-thaw cycles and by chemical reactions like dissolution, then **transported** by wind, water, or ice, and finally **deposited** as sediment that develops into soil. The process is slow. A few centimeters of new soil can take hundreds to thousands of years to form, which means eroded topsoil is effectively nonrenewable on human time scales.

Soils are described in **horizons**, layers defined by composition and organic content. The **O horizon** is mostly organic litter at the surface. The **A horizon** is topsoil, a mix of organic matter and mineral particles, and it holds most plant roots and biological activity. The **B horizon** is subsoil, where minerals leached from above accumulate. The **C horizon** is weathered parent material, and the **R horizon** is bedrock. A question about fertility or crop growth usually points at the A horizon, since that is the layer agriculture depends on.

Soil can be **eroded** by wind and water. Bare or disturbed soil washes away in rain and blows away in dry wind, carrying nutrients and sediment into streams and lakes. Protecting soil also protects water quality, because soil filters and cleans water that moves through it, trapping sediment and some pollutants before they reach groundwater and surface water.

Trap. Students remember water erosion and forget wind erosion entirely. Both move soil, and both appear on the exam. If a question mentions a dry, flat region with degraded soil, wind is the erosive force to reach for.

4.3 Soil Composition and Properties

How much water soil holds depends on **particle size**. Sand grains are the largest, silt is in the middle, and clay particles are the smallest. The tiny particles of clay pack together with many small pore spaces, so clay has the greatest **water holding capacity** and sand the least. **Loam**, a blend of sand, silt, and clay in roughly balanced proportions, holds enough water for crops while still draining well, which is why it is the preferred texture for farming.

Particle size also controls two properties that students constantly mix up. **Porosity** is the fraction of the soil volume that is empty pore space. **Permeability** is how easily water moves through those spaces. Clay has high porosity because its fine particles leave many tiny pores, but low permeability because those pores are so narrow that water moves slowly. Sand is the reverse: lower porosity, higher permeability. The **soil texture triangle** names a soil from its percentages of sand, silt, and clay. Read each percentage on its own axis and find where the three lines meet. A soil that is about 40 percent sand, 40 percent silt, and 20 percent clay reads as loam.

Trap. High porosity does not mean high permeability. Clay is the counterexample the exam keeps using: lots of pore space, but water barely moves through it. If a question asks which soil drains fastest, answer sand, not clay.

Soil testing measures the chemical, physical, and biological properties of a sample. Farmers and land managers test before deciding how much to irrigate or fertilize, because adding fertilizer a soil does not need wastes money and sends excess nutrients into waterways. Testing replaces guessing about what the soil actually needs.

4.4 Earth's Atmosphere

The **composition of the atmosphere** is mostly nitrogen and oxygen: about 78 percent nitrogen and 21 percent oxygen, with argon making up most of the remaining 1 percent. Trace gases like carbon dioxide, methane, and ozone are present in tiny amounts but do outsized work. Carbon dioxide and methane trap heat near the surface, and ozone absorbs incoming ultraviolet radiation.

The atmosphere is divided into **layers** based on how temperature changes with altitude. The **troposphere** is the lowest layer, where weather happens and temperature falls as you go up. Above it is the **stratosphere**, which holds the ozone layer; temperature rises with altitude here because ozone absorbs UV. Next is the **mesosphere**, where temperature falls again and meteors burn up. Then the **thermosphere**, where temperature rises sharply and auroras occur. The **exosphere** is the outermost, thinnest layer, where satellites orbit and gases gradually escape into space.

Trap. Weather happens in the troposphere, but the ozone layer sits in the stratosphere. Questions that describe a phenomenon and ask for its layer are testing whether you keep those two straight.

4.5 Global Wind Patterns

Global wind patterns start with uneven solar heating. The equator receives the most intense solar radiation, so air there warms, becomes less dense, and rises. That rising air flows toward the poles, cools, sinks, and returns toward the equator, forming large **convection cells**. The **Coriolis effect**, caused by Earth's rotation, deflects these moving air masses: to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The result is the planet's prevailing winds: the **trade winds** blowing toward the equator, the **westerlies** blowing toward the poles in the mid-latitudes, and the **polar easterlies** near the poles.

Trap. The Coriolis effect deflects air that is already moving; it does not start the wind. The wind starts with uneven heating. If a question asks what causes global wind patterns, the complete answer needs both the solar heating and the Coriolis deflection.

4.6 Watersheds

A **watershed** is an area of land that drains into a common body of water. Rain that falls anywhere inside the boundary eventually flows to the same river, lake, or estuary. Watersheds are described by their area, length, slope, soil, vegetation types, and the **divides** that separate them from adjoining watersheds. What happens on the land ends up in the water, so farming, paving, and construction anywhere in a watershed affect the water body it drains into. Managing water quality means managing land use across the whole watershed, not just at the shoreline.

4.7 Solar Radiation and Earth's Seasons

Insolation is incoming solar radiation, Earth's main energy source. It varies with latitude and season, and the variable that controls it is the **solar angle**, the angle at which the sun's rays strike the surface. Radiation is most intense where the rays hit perpendicularly, directly overhead, because the same amount of energy lands on the smallest area. Where the rays strike at an angle, the energy spreads over a larger area and the intensity falls.

The **latitudinal radiation gradient** follows directly. The equator receives the most solar radiation per unit area, and the amount decreases steadily toward the poles. This gradient is the engine behind the global wind patterns in topic 4.5 and the ocean currents that move heat around the planet. Almost every large-scale circulation on Earth traces back to the fact that the equator gets more energy per square meter than the poles.

At any one location, the solar radiation received also changes through the year. The most arrives on the longest day of summer and the least on the shortest day of winter. This **seasonal variation** comes from **Earth's axial tilt**, not from distance to the sun. The tilt points one hemisphere toward the sun for half the year and away for the other half, which changes both the solar angle and the number of daylight hours.

Trap. Earth is actually farthest from the sun in July, during the Northern Hemisphere's summer. Distance does not cause the seasons. Tilt does. Any answer choice that explains summer by closeness to the sun is wrong no matter how reasonable it sounds.

4.8 Earth's Geography and Climate

Weather is the short-term state of the atmosphere and **climate** is the long-term pattern, and both respond to more than the sun's energy. Mountains reshape precipitation: moist air forced up a slope cools and drops its moisture as rain or snow on the **windward** side. The air that descends on the other side is dry, leaving a **rain shadow**, a region made drier because the higher elevation blocked precipitation from reaching it. The arid land east of the Sierra Nevada exists for exactly this reason. Ocean temperature matters too. Warm currents warm the air above them and cold currents cool it, so coastal regions near cold currents tend to be cooler and drier than their latitude alone would predict.

Trap. The wet side and the dry side of a mountain have specific names, and questions expect you to use them correctly. Precipitation falls on the windward side. The rain shadow is on the leeward side. Sketch the mountain and label both sides before you answer.

4.9 El Nino and La Nina

El Nino and La Nina are the two phases of the El Nino-Southern Oscillation, or **ENSO**, a periodic shift in Pacific Ocean surface temperatures. In a normal year, trade winds push warm surface water westward, and cold, nutrient-rich water wells up along the coast of South America. During **El Nino**, the trade winds weaken, warm water sloshes back eastward, and the upwelling weakens. During **La Nina**, the trade winds strengthen and the eastern Pacific gets cooler than normal. Both phases shift rainfall, wind, and ocean circulation patterns around the globe.

The **effects of ENSO vary by location**. El Nino can bring heavy rain to the southern United States while causing drought in Australia and Indonesia, and La Nina tends to flip that pattern. Geological and geographic features like mountain ranges and ocean currents shape how strongly each region feels the shift, so the same phase can mean floods in one place and drought in another. A question that asks about ENSO impacts is really asking whether you know that the effects are regional, not uniform.

Trap. El Nino means warmer water in the eastern Pacific, La Nina means cooler water there. Students swap them constantly. Anchor it to the trade winds: weak trade winds let warm water pool in the east (El Nino), strong trade winds push it west and let cold water upwell (La Nina).

Confusions That Cost Points

PAIR	HOW TO KEEP THEM STRAIGHT
Convergent vs divergent boundary	Convergent: plates push together, crust is destroyed in subduction, mountains and island arcs form. Divergent: plates pull apart, new crust is created, ridges and rift valleys form.
Porosity vs permeability	Porosity is how much empty space the soil has. Permeability is how easily water flows through it. Clay has high porosity and low permeability.
Troposphere vs stratosphere	Weather happens in the troposphere. The ozone layer sits in the stratosphere.
El Nino vs La Nina	El Nino: warmer eastern Pacific, weaker trade winds, weaker upwelling. La Nina: cooler eastern Pacific, stronger trade winds.
Weather vs climate	Weather is the short-term state of the atmosphere. Climate is the long-term pattern.
Windward side vs rain shadow	Moist air rises and rains on the windward side. The dry leeward side sits in the rain shadow.

Practice Questions

Original questions written for this guide in the style of the AP exam. Answers and explanations are on the next page, so complete the questions before checking them.

1. Which of the following is characteristic of a divergent plate boundary?

- A. Subduction of oceanic crust beneath continental crust
- B. Seafloor spreading and the formation of rift valleys
- C. Two plates sliding horizontally past each other
- D. Collision of two oceanic plates forming an island arc

2. A soil sample is 40 percent sand, 40 percent silt, and 20 percent clay. Using the soil texture triangle, this soil is best classified as

- A. Loam
- B. Sandy loam
- C. Clay loam
- D. Silt loam

3. The ozone layer is located in which atmospheric layer, and how does temperature change with altitude in that layer?

- A. Troposphere; temperature decreases with altitude
- B. Stratosphere; temperature increases with altitude
- C. Mesosphere; temperature decreases with altitude
- D. Thermosphere; temperature increases with altitude

4. In July, the Northern Hemisphere experiences summer even though Earth is near its farthest point from the sun. This is best explained by

- A. Earth's axial tilt angling the Northern Hemisphere toward the sun
- B. Increased solar output during the summer months
- C. The greenhouse effect trapping extra heat in summer
- D. Weakened trade winds allowing warm air to move north

Answer Key

- 1. B.** At a divergent boundary the plates pull apart, magma rises, and new crust forms, producing seafloor spreading, mid-ocean ridges, and rift valleys. A describes a convergent boundary where oceanic crust subducts. C describes a transform boundary. D describes a convergent boundary between two oceanic plates.
- 2. A.** On the soil texture triangle, 40 percent sand, 40 percent silt, and 20 percent clay falls in the loam region, a roughly balanced blend that supports a variety of crops. B would require a higher sand percentage. C would require substantially more clay. D would require silt above about 50 percent.
- 3. B.** The ozone layer sits in the stratosphere, where temperature increases with altitude because ozone absorbs ultraviolet radiation. A names the weather layer, where temperature falls with altitude. C is the layer where meteors burn up, also with falling temperature. D has rising temperature but contains auroras, not the ozone layer.
- 4. A.** Seasons come from Earth's axial tilt, which angles one hemisphere toward the sun for half the year, changing both the solar angle and the hours of daylight. B is wrong because solar output does not rise and fall with the seasons. C is wrong because the greenhouse effect does not vary seasonally to produce summer. D confuses trade winds, which drive ENSO and ocean patterns, with the cause of the seasons.

One-Page Recall Check

- Name the three types of plate boundaries and state what each one produces.
- Explain how a plate boundary map predicts where earthquakes and volcanoes occur, and name the one feature it will not predict.
- Describe the earthquake mechanism from a locked fault to released energy.
- Explain how soil forms from parent material and why the process takes so long.
- List the soil horizons in order and describe what is in the A horizon.
- Distinguish porosity from permeability, using clay and sand as examples.
- Use the soil texture triangle to identify loam from sand, silt, and clay percentages.
- State the composition of the atmosphere with approximate percentages.
- List the atmospheric layers in order and describe how temperature changes in each.
- Explain how uneven solar heating and the Coriolis effect produce the global wind patterns.
- Define a watershed and list the characteristics used to describe one.
- Explain how the solar angle controls radiation intensity and produces the latitudinal gradient.
- Explain why seasons happen, using Earth's axial tilt.
- Describe the rain shadow effect and state which side of the mountain stays dry.
- Contrast El Nino and La Nina in terms of trade winds and eastern Pacific temperatures.

Where to go next. Turn every missed item above into flashcards and drill them spaced out over several days rather than in one sitting. In Rycal, open the Earth Systems and Resources deck under AP Environmental Science. The deck covers the terms in this guide, and its practice questions target the same traps named here. If you have a test date, add it in the Test Planner. You can also start your next review with a Brain Dump, then check what you missed against this guide.

Key terms for this unit

Convergent plate boundaries, Divergent plate boundaries, Transform plate boundaries, Plate boundary maps, Earthquake mechanism, Soil formation, Soil horizons, Soil erosion and water filtration, Water holding capacity, Particle size and soil properties, Soil testing, Soil texture triangle, Loam, Composition of the atmosphere, Layers of the atmosphere, Causes of global wind patterns, Watershed, Insolation, Solar angle and radiation intensity, Latitudinal radiation gradient, Seasonal variation in solar radiation, Earth's axial tilt and seasons, Geographic factors in climate, Rain shadow, El Nino and La Nina (ENSO), Variable effects of ENSO.

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