

Energy in Earth's Systems: Mastery Check

Learning target: I can show that I know Earth's four systems and the geosphere's layers, tell the three energy transfers apart, explain convection with density and gravity, and describe how energy from the sun and Earth's interior moves matter within and between the systems.

Retrieval and mastery check

About 40 min

Individual

MS-ESS2-1 · assesses

MS-LS2-3 · supports

MS-ETS1-4 · supports

independent practice

writing

Standards connections

MS-ESS2-1 (assesses, the flow-of-energy half of the PE): Items 4, 7, 11 and 13 ask students to explain and draw the energy flow that drives convection of mantle rock, which is evidence toward the model this PE requires. The rock-cycle processes in the clarification statement are not assessed here; they belong to a later lesson.

MS-LS2-3 (supports): Item 9 checks the accurate statement that matter cycles while energy flows through a food chain, background for this PE's ecosystem model.

MS-ETS1-4 (supports): Item 8 checks the meaning of a closed system as used in the Biosphere 2 story, background for the iterative-testing practice in this PE.

Purpose: assess · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

Part A: Retrieval (12 items)

1. Which energy transfer can cross the nearly empty space between the sun and Earth?

Answer: C. Radiation, because energy travels as light that needs no matter.

Why: Conduction and convection both need matter; space between the sun and Earth is nearly empty.

Also acceptable: None.

2. Which statement about the geosphere's layers is correct?

Answer: B. The core is the densest layer and is made mostly of iron and nickel.

Why: Density increases with depth; the mantle is solid rock that creeps, not liquid magma.

Also acceptable: None.

3. True or false: In a pot of water heated from below, heat itself floats upward, which is why the water at the top gets warm.

Answer: False.

Why: Heat is energy and does not float. The warm water near the bottom becomes less dense; gravity pulls the denser, cooler water down, which pushes the warm water up, carrying its energy to the top.

Also acceptable: Students who write 'false' with the correct reason earn full credit; 'false' alone earns the point on a quiz.

4. In a mantle convection cell, what directly causes the cooled rock near the crust to move back down?

Answer: B. Gravity pulling more strongly on the rock because it has become denser.

Why: Cooling raises the rock's density; gravity acts more strongly on denser material, so it sinks.

Also acceptable: None.

5. Complete each sentence with the name of an Earth system. A cloud is part of the _____ and the _____. A worm in garden soil is part of the _____ living inside the _____.

Answer: A cloud is part of the hydrosphere and the atmosphere. A worm in garden soil is part of the biosphere living inside the geosphere.

Why: Clouds are water in the air; a worm is a living thing in rock-derived soil. Accept the two cloud answers in either order.

Also acceptable: Accept 'geosphere' for soil with 'biosphere' for the worm in either blank order if the meaning is clear.

6. A 500 cm³ sample of warm water has a mass of 495 g. A 500 cm³ sample of cold water has a mass of 500 g. Calculate the density of each (density = mass ÷ volume) to two decimal places, and state which sample would sink if the two were gently combined.

Answer: Warm water: $495 \text{ g} \div 500 \text{ cm}^3 = 0.99 \text{ g/cm}^3$. Cold water: $500 \text{ g} \div 500 \text{ cm}^3 = 1.00 \text{ g/cm}^3$. The cold sample is denser, so it would sink and the warm sample would end up on top.

Why: Same volume, different mass, so the one with more mass per cm³ is denser. The values are realistic for water at roughly 45 °C and 5 °C.

Also acceptable: Accept 0.99 and 1.0 g/cm³; the unit must be g/cm³ or g per cm³.

7. A fluid is heated from below. Explain why energy enters the fluid by conduction **before** convection can begin.

Answer: The heat source touches only the bottom layer of fluid, so energy passes into that layer by conduction. Only after that layer has warmed does it expand and become less dense, and only then can gravity pulling the denser fluid above it down push the warm layer up. Convection is the movement that follows the warming, so conduction must come first.

Why: The sequence is the mechanism behind every convection cell in the lesson.

Also acceptable: Accept 'the fluid has to get warm before it can rise, and it gets warm by touching.'

- Energy enters at the contact by conduction
- Density must change before movement
- Convection is the movement that follows

8. Biosphere 2 was built as a closed system. What does that mean?

Answer: B. Matter could not enter or leave, but energy such as sunlight and heat could cross.

Why: This is the accurate meaning of closed system; sunlight entered Biosphere 2 through its glass.

Also acceptable: None.

9. In a food chain, decomposers return something to the soil that plants can use again, but there is something they cannot send back. Name both and say where the second one goes.

Answer: Decomposers return matter (nutrients from dead organisms and wastes) that plants can reuse. They cannot send back energy; energy flows one way through the food chain and leaves living things as heat, which eventually radiates into space, so plants need fresh sunlight.

Why: Matter cycles; energy flows. This corrects the textbook figure's 'energy and matter' return arrow.

Also acceptable: Accept 'nutrients' for matter and 'it is lost as heat' for the exit.

- Matter or nutrients returned
- Energy not returned
- Energy leaves as heat

10. On a sunny day, how does most of the air near the ground get warm?

Answer: B. Sunlight is absorbed by the ground and water, which then warm the air touching them.

Why: Air absorbs little sunlight directly; the surface absorbs it and warms the air by conduction, after which the warm air rises.

Also acceptable: None.

11. Draw a side view of the ocean between the equator (left) and a pole (right). Show one convection loop with arrows. Label: where the sun's energy enters and by what method; where water is warm and less dense; where water becomes cold, salty and denser; where gravity pulls water down; and the direction of the deep current.

Answer: A side view with the equator at left and a pole at right; an arrow from the sun entering at the equator labeled 'radiation'; surface water at the equator labeled 'warm, less dense'; surface water at the pole labeled 'cold, salty, denser'; a downward arrow at the pole labeled 'gravity'; a deep arrow along the bottom pointing from the pole toward the equator; a surface arrow from equator toward the pole completing the loop.

Why: The loop must close, with sinking at the pole and the deep current flowing back toward the equator.

Also acceptable: A student who adds surface winds dragging the surface current is correct and beyond the lesson's minimum.

- Radiation labeled at the equator
- Warm, less dense at the equator surface
- Cold, salty, denser at the pole
- Gravity on the sinking arrow
- Deep current toward the equator; loop closes

12. Give two reasons polar surface water becomes denser than the water around it, and name the one force that then makes it sink.

Answer: The surface water loses energy to the cold air and gets colder, and when sea ice forms it leaves its salt behind, making the remaining water saltier. Both changes raise its density. Gravity then pulls the denser water down.

Why: Temperature and salinity are the two real causes; the sinking force is gravity.

Also acceptable: Accept 'it gets cold and salty' with gravity named.

- Colder
- Saltier from ice formation
- Gravity named

Part B: Synthesis

13. Write a paragraph (6-8 sentences) answering: **How does energy move matter within and between Earth's systems?** Your paragraph must name both energy sources, use all three transfer methods correctly, explain one convection loop with density and gravity, and give one example of matter crossing from one system into another.

Answer: Model paragraph: Earth's systems run on two energy sources, the sun and Earth's hot interior. Energy from the interior leaves the core by conduction into the rock touching it, and the sun's energy arrives as radiation, light that crosses space and is absorbed mostly by the ground and sea, which warm the air touching them by conduction. In the mantle, the ocean and the air, warmed material expands and becomes less dense, while cooler material is denser; gravity pulls the denser material down, and that sinking pushes the less dense material up, so a convection loop forms that carries energy along with the moving matter. In the mantle this loop moves solid rock a few centimeters a year and feeds volcanoes; in the ocean it sinks cold, salty polar water and returns it toward the equator. Matter crosses between systems all the time: sunlight warms the sea and water evaporates from the hydrosphere into the atmosphere, then condenses and falls back as rain. In the biosphere, plants capture the sun's energy, it flows through the food chain, and it leaves as heat, while matter is recycled by decomposers.

Why: Full credit requires both sources, all three transfer methods used correctly, a loop explained with density and gravity (not 'heat rises'), and one border crossing of matter. Six to eight sentences.

Also acceptable: Any accurate border crossing (eruption putting rock into the air, a plant taking carbon dioxide from the air, groundwater seeping into rock) is acceptable.

- Both energy sources named
- Conduction, convection and radiation each used correctly
- A loop explained with density and gravity
- One example of matter crossing between systems
- No 'heat rises' or 'energy cycles' errors

Teacher notes

Items 1 to 12 are scored one point each (q6, q11 and q13 can be weighted more). The answers deliberately hold the accurate positions where the textbook simplifies: the core is metal, not rock (q2); heat does not float (q3); a closed system is closed to matter only (q8); energy flows and matter cycles in a food chain (q9); the surface, not the air, absorbs most sunlight (q10); polar water sinks because it is colder and saltier (q12). For q6 the realistic densities are about 0.99 g/cm^3 for water near 45°C and 1.00 g/cm^3 near 5°C . Compare q13 with each student's W1 q5 'before' explanation to see whether 'heat rises' has been replaced by density and gravity; that comparison is the extension.

Scaffold offered to students: A map for Part B

Plan the paragraph as four lines on scrap paper before writing: Line 1, the two sources (interior, sun). Line 2, the three methods and one place each happens. Line 3, one loop: warm, less dense, rises; cools, denser, gravity pulls it down. Line 4, one border crossing (water evaporating into the air, rock erupting into the air, carbon dioxide taken from the air by a plant). Then turn each line into one or two sentences.

Extension: Revise your day-one explanation

Find your answer to the first explanation question from W1 (why the warm red water rose and the cold blue water sank). Rewrite it using what you know now, then underline every phrase that changed and write a sentence for each explaining why the old version was incomplete or wrong. Finish with one question about convection that the lesson has not answered for you yet.