

Strings Across the Spheres: Modeling Energy and Matter Flows

Investigation question: Where does energy enter Earth's four systems, where does it leave, and why does matter keep going around while energy passes through?

Collaborative systems modeling

Groups of 4

1 session

Setup 5 · Activity 40 · Cleanup 5 min

MS-ESS2-1 · assesses

MS-ETS1-4 · supports

MS-LS2-3 · supports

Name _____

Group _____

Date _____

Your role today

- ☐ **Cartographer:** Lays out the seven signs (four systems, Sun, interior, space) and keeps the layout readable; redraws the final model on the recording sheet.
- ☐ **Card reader:** Reads each card aloud, proposes the starting and ending system, and leads the group to agreement before any string is placed.
- ☐ **String runner:** Cuts and tapes the yellow and blue strings, attaches the card number and mechanism flag to each string.
- ☐ **Auditor:** Fills in the string log for every card, counts the strings for the tally table, and runs the three perturbation tests by lifting strings.

Safety

- Scissors only; cut away from fingers and keep them closed on the table when not in use.
- Keep string off the floor walkways between groups so no one trips; tape strings down if the model is built on the floor.
- No heat, chemicals or liquids are used.

Procedure

1. Lay out the seven signs: the four systems in a square in the middle, the Sun on one edge, Space on the opposite edge, and Earth's interior tucked under the geosphere sign. Leave hand-widths of space between signs.
2. The card reader reads card 1 aloud. The group decides: where does this process start, where does it end, and does it move energy, matter or both? Record the decision in the string log before placing any string.
3. The string runner tapes a yellow string from the start to the end if energy moves, a blue string if matter moves, or both strings side by side if both move. Attach a flag with the card number and the mechanism (conduction, convection, radiation, or another word such as eating, eruption or gravity).
4. Repeat for cards 2 through 15. A process that stays inside one system gets a string that loops out and back to the same sign; a process with two destinations gets two strings.

5. When all cards are placed, the auditor counts: yellow strings arriving from the Sun or the interior, yellow strings leaving to Space, blue strings leaving to Space, and blue strings that cross from one system to another. Fill in the tally table.
6. Perturbation 1: lift the strings that begin at the Sun. Trace forward: which other cards could no longer happen if those strings stayed lifted? List their numbers. Put the strings back.
7. Perturbation 2: lift the string from Earth's interior. Which cards stop? Put it back.
8. Perturbation 3: imagine a glass dome sealed over the four system signs that lets light and heat through but no matter. Which strings would the dome cut? Which would keep running? Discuss what would happen to the air inside over a year if decomposers kept working.
9. The cartographer draws the finished model on the recording sheet with every string shown as a labeled arrow. Each student answers the recording-sheet questions, then the analysis questions individually.

Record your observations

Lab 2 recording sheet: Strings across the spheres

Color code: **yellow string = energy moves**, **blue string = matter moves**. Log every card before you place its string. A process that happens inside one system still gets a string, looping out of that sign and back in.

Process cards

1 Card 1: Sunlight on the sea

Light from the Sun crosses empty space and is absorbed by the surface of the Pacific Ocean, which warms.

2 Card 2: Sunlight on bare ground

Light from the Sun is absorbed by a dry hillside in the Mojave; the rock and soil surface warms.

3 Card 3: Warm ground, warm air

Air touching the hot hillside is warmed by it. The warmed air becomes less dense and is pushed upward by cooler air sinking around it.

4 Card 4: Evaporation

Water leaves the warm ocean surface as invisible vapor and rides upward in warm air, carrying energy with it.

5 Card 5: Clouds and rain

High up, the rising air cools; the vapor condenses into droplets and clouds, and gravity brings rain and snow back to the ocean and the land.

6 Card 6: Heat from the core

Energy from Earth's hot metal core passes into the bottom of the solid mantle, particle to particle.

7 Card 7: Mantle rock rises

Hot, less dense mantle rock creeps upward beneath an ocean ridge, a few centimeters per year, while cooler denser rock sinks elsewhere. The moving rock carries energy with it.

8 Card 8: Eruption

A volcano throws ash, gas and lava from inside Earth into the air and onto the surface.

9 Card 9: Cold salty water sinks

Near Antarctica, surface water loses energy to freezing air and becomes saltier as sea ice forms. The dense water sinks and creeps along the sea floor toward the equator.

10 Card 10: Kelp makes food

Kelp off Monterey captures sunlight and uses carbon dioxide and water from the sea to build sugar, storing energy in it.

11 Card 11: Otter eats urchin

A sea otter eats a sea urchin that ate kelp. Some of the stored energy and some of the matter pass into the otter; the rest leaves the otter as heat and waste.

12 Card 12: Decomposers at work

Bacteria and fungi break down dead kelp and leaves on the shore, releasing carbon dioxide to the air and nutrients to the sand and soil. Energy leaves them as heat.

13 Card 13: Living things give off heat

Every organism, from kelp to otter to bacteria, releases energy as heat into the water or air around it.

14 Card 14: Steam at The Geysers

In Sonoma County, groundwater seeping into hot rock is heated by it and rises as steam through cracks to the surface.

15 Card 15: Earth glows in infrared

Earth's surface and air send invisible infrared light outward into space, day and night.

String log

Card	Starts in	Ends in	Energy, matter or both?	Mechanism (conduction, convection, radiation, other)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				

Card	Starts in	Ends in	Energy, matter or both?	Mechanism (conduction, convection, radiation, other)
14				
15				

-  Draw your finished model: the seven signs and every string as an arrow, yellow (or solid) for energy and blue (or dashed) for matter, each labeled with its card number.

String tally

What you are counting	Number of strings	Card numbers
Energy strings arriving from outside the four systems (Sun or interior)		
Energy strings leaving to Space		
Matter strings leaving to Space		
Matter strings crossing from one system to a different system		
Strings tagged convection		

- Which card was hardest to place, and what did your group disagree about? How did you settle it?
- Perturbation 1: list the cards that stop when the Sun's strings are lifted. Perturbation 2: list the cards that stop when the interior's string is lifted.

Analysis questions

3. Use your tally. How many energy strings enter the four systems, how many leave, and how many matter strings leave? Explain what this pattern says about energy and matter on Earth.

4. List every string you tagged convection. What do all of those processes have in common, and what two things does each one need in order to keep going?

5. Perturbation 3: a sealed glass dome lets light and heat through but no matter. Which of your strings does it cut? Using cards 10, 12 and 13, explain what could go wrong with the air inside over a year, and connect it to what happened in Biosphere 2.

6. Follow cards 10, 11, 12 and 13 with your finger. Where does the energy that started as sunlight end up? Where does the carbon end up? Explain why we say energy flows through the biosphere while matter cycles.

- 7.** Another group added a yellow energy string from the decomposers in card 12 back to the kelp in card 10. Is that string correct? Explain what should connect decomposers to kelp, if anything.

- 8.** Name two things about the real Earth that this string model cannot show, and say for each why it matters.
