13.1 The Earth-Sun System

1) Energy from the sun

Observe the models of the Earth, Moon, and Sun in the room.

a) Imagine that the distance between the Earth and the Sun is represented by the length of a football field (100 yards or 91 meters). Choosing this distance to set the scale, the Sun, at one goal line, is represented by a ball 85 cm in diameter (the size of a large beach ball or exercise ball).

What would be the diameter of a model of the Earth at the opposite goal line?

b) It takes radiation from the Sun about 8.3 minutes to reach the Earth. How far away is the Earth from the Sun?

2) How much energy does the Earth receive from the Sun?

a) What form of energy does the sun give off? ________________________

b) What is the source of the Sun's energy? ____________________________

c) The Sun emits $3.90 \times 10^{26}$ joules of energy each second ($3.90 \times 10^{26}$ watts).

Only a small fraction of this energy actually reaches the outer atmosphere of the Earth. If this energy is about $1.76 \times 10^{17}$ watts, what fraction is this of the total energy produced by the Sun?

d) Why does such a small fraction of the Sun’s energy reach the Earth? Hint: If you were to look toward the Sun and extend one finger at arm’s length, your finger just covers the Sun.

i) Extend your arm. Does your finger just cover a light bulb across the room? __

ii) The diameter of the Sun is about 110 times larger than the diameter of the Earth. If the Sun were as big as the light bulb, how many times smaller would an object be that represents the Earth? ____________________________

iii) Imagine a sphere with radius equal to our room size covered with pencil dots. That sphere would have over 2 billion pencil dots on it ($1/4.5 \times 10^{-10}$) with the light bulb in the center shining on each one.

What fraction of the radiant energy from the light bulb would each pencil dot receive? ____________________________
iv) Raise the tip of your pencil to see what a small fraction of all of the radiant energy emitted from the light bulb reaches your pencil’s tip!

e) Group Discussion Question: Where does the rest of the Sun’s energy go?

13.2 How Is the Earth Illuminated by the Sun?

3) Sunlight incident on the Earth

Your instructor will explain the distribution of sunlight incident on different regions of the Earth.

a) Point a flashlight light horizontally at the equator of the globe. Stand the peg board between the light and the globe about 5 cm from the globe’s equator and 20 cm from the flashlight. Hold the small brown square flat along the equator.

   How many dots of light on the globe fit inside the brown square? ______

b) Keeping the peg board the same distances from the flashlight and the globe, raise the flashlight to point it horizontally at the high northern latitudes (for example, at Alaska). Hold the brown square flat along this area.

   Now how many dots of light on the globe fit inside the brown square? ______

c) How does the amount of sunlight striking the Earth at higher latitudes compare to the sunlight striking the Equator?

d) What effect do your findings in part c) have on the weather?

e) Group Discussion Question: What is another reason that the higher latitudes receive less sunlight?
13.3 The Earth’s Atmosphere

4) Atmospheric Layers

a) On the diagram above, fill in the names of the layers of the Earth’s atmosphere and the approximate percent of the Earth’s air that is contained in each region. (Hint: note what fraction of the total pressure of the air is measured for each air layer.)

b) In which atmospheric layer(s) can life exist? __________________________

c) In which atmospheric layer is the Earth’s ozone layer? __________________

d) Make a prediction as to how thick the atmosphere would be if the Earth were as large as the globe on your table. **Prediction:** __________ **Answer:** __________

e) What is the chemical composition of the atmosphere?

f) Group Discussion Question: The percent of carbon dioxide in the atmosphere is very small (0.033%). Why does this small concentration make increasing the atmosphere’s carbon dioxide concentrations potentially dangerous?
5) Earth's energy balance

a) From the energy balance diagram, fill in the percentages of incoming energy from the Sun and outgoing energy from the Earth.

<table>
<thead>
<tr>
<th>Incoming energy from Sun</th>
<th>Outgoing energy from Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>% reflected into space</td>
<td>% radiated from clouds and air</td>
</tr>
<tr>
<td>% absorbed by land and sea</td>
<td>% radiated directly to space</td>
</tr>
<tr>
<td></td>
<td>% to conduction and rising air</td>
</tr>
<tr>
<td></td>
<td>% as latent heat of water vapor</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

b) What are the consequences for the Earth if not all of the incoming radiation is radiated back into space?

6) Energy Emitted by the Sun and Earth

a) The Sun emits radiant energy from all portions of the electromagnetic spectrum. The majority of the Sun's energy is represented by which portion of the spectrum? ____________________________

b) The Earth also emits radiant energy. Which portion of the spectrum represents the energy emitted by the Earth? ______________________________________

c) How does the temperature of an object relate to the frequency of the energy it gives off (its electromagnetic spectrum)?

d) The surface temperature of the Sun is about 5,800 kelvin and the average surface temperature of the Earth is about 300 kelvin. Use these facts to explain the difference in radiant energy emitted by each body.

7) The Greenhouse Effect

a) Ideally, the amount of energy absorbed by the Earth is equal to the amount of energy emitted by the Earth. What can block the radiation emitted by the Earth from escaping into space?

b) What is the Greenhouse Effect?

c) Group Discussion Question: Is the Greenhouse Effect helpful or harmful to life on Earth?
Period 13 Exercises: Earth as an Energy System

1) Calculating astronomical distances

The distance between Mars and the Earth depends on where these planets are in their orbits about the Sun. At a particular tie, a rover on the surface of Mars requires 4.3 minutes to transmit data to the Earth using radiant energy signals. Calculate how far away the rover is from the Earth.

(Hint: the speed of light = $3 \times 10^8$ meters/second)

2) Examining the relationship between temperature and wavelength

We experience the Sun’s energy as infrared, visible, and ultraviolet radiation.

a) How would this change if the Sun’s surface temperature were hotter?

b) How would this change if the Sun’s surface temperature were cooler?

3) Explaining the Earth’s energy balance

a) What is meant by the energy balance of the earth?

b) What could happen if this balance is upset?