# Purpose

|  |  |
| --- | --- |
| Most people enjoy the different seasons we experience; Spring, with the emergence of beautiful blossoms and bright green leaves; hot summer days spent at the beach, or the lake; fall, with its glorious colors; and even winter, when you are tucked up warm inside while the cold winds blow. But do you know why we have these seasons? Why is it hotter in the summer than in winter? In this activity, we’ll try to answer that question. |  |

|  |  |
| --- | --- |
|  | Why is it hotter in summer than in winter? |

# Initial Ideas

 **On your own**, write down why you think it is hotter in the summer than in the winter. Also, try to think of any evidence that may support your idea. Illustrate your thinking with a rough sketch.

 Now share your ideas with your group. Make a note of any different ideas they may have, and any evidence that might be used to support or refute any of your ideas.

# Collecting and Interpreting Evidence

## Exploration #1: When is the Earth closest to the Sun?

**STEP 1:** One idea many people have is that it is hotter in summer than in winter because the whole Earth is closer to the Sun at that time of year.

 Suppose you were to take two photographs of the Sun from the same place on Earth, one in June, the other in December. How would you expect the apparent size of the Sun to compare between these two photographs? Explain your reasoning.

**STEP 2:** Your instructor will display some photographs of the Sun, taken by a solar astronomer in England, in June and December.

 Does the Sun appear larger in June, or in December?

 Does this mean that England is nearer the Sun in June or December?

 What does this observation imply about the idea that it is hotter in summer because the Earth is nearer the Sun?

Another idea some people have is that it is hotter in summer for us because, while the distance between the Earth and the Sun does not change much, the tilt of the Earth’s axis brings the northern hemisphere nearer to the Sun in summer.

 What do the solar photographs imply about this idea? (In case you are not sure, England is indeed in the northern hemisphere of the Earth, just like the USA.) Explain your reasoning.

 Participate in a class discussion about these ideas. Make any notes you think necessary.

## Experiment #2: What difference does location on a sphere make?

You will need:

 Mini-maglite

 White index card

 Pencil

 Large ball

 Wooden block with holes

**STEP 1:** Turn on the flashlight and shine it down on the white card from a height of about 6 inches. Focus the flashlight so it produces the smallest spot of bright illumination it can from this position.

|  |  |
| --- | --- |
| Now hold the card up vertically and shine the flashlight on it from a distance of about 6 inches from the center of the card, making sure to keep the flashlight horizontal. (The figure to the right shows a side view.) | 6” |

 Have one of your group trace round the outer edge of the bright area of illumination on the card.

|  |  |
| --- | --- |
| **STEP 2:** Now tilt the card so that it makes an angle of about 45° with respect to the horizontal. Try to keep the **center** of the card about 6 inches from the flashlight. | 45°  6” |

 Again, have one of your group trace round the bright area of illumination on the card.

 Turn the flashlight off and examine the card. Which area of illumination was larger - the one where the card was vertical, or the one where it was slanted?

 The flashlight beam carried the same amount of light energy in both cases. In which orientation of the card was the energy of the flashlight beam more concentrated when it hit the card? How do you know?

Light carries energy, and when it strikes an object some of this energy is absorbed, which causes an increase in temperature. Suppose you were able to measure the increase in temperature of the illuminated areas of the white card (due to the energy delivered by the light from the flashlight).

 In which orientation of the card do you think the temperature of the illuminated area would increase most, if you kept the flashlight shining on it? Explain your reasoning

**STEP 3:** Place the large ball on the table in front of you. Now shine the focused flashlight beam on various parts of the ball, **keeping the flashlight horizontal at all times**. (The diagram below shows a side view.)

**A**

**B**

**C**

**D**

**E**

 In which area(s) of the ball (A,B,C,D,E) do you think the temperature of the illuminated area would increase most? In which area(s) do you think it would increase least? Explain your reasoning.

**STEP 3:** In this experiment, the ball can be taken as representing the Earth. On this scale, the Sun would be a very, very large ball many miles away. This means the light rays arrive at the Earth from the Sun do so as essentially parallel lines, very much like our focused horizontal flashlight beam.

# 

 In the situation shown above, where on the Earth would you expect the temperature to be the highest, at the equator, or somewhere north or south of the equator? Where would you expect the temperature to be the lowest? As usual, explain your reasoning.

**Note:** With the Earth oriented as shown, it is true that the equator would be very, very, slightly closer to the Sun than the poles. However, the distance to the Sun is so far that this very slight difference is ***completely insignificant***. It is equivalent to taking two steps across the room compared to the distance to Nashville from Cookeville.

## Experiment #3: What difference does the tilt of the Earth’s axis make?

You will need:

 Mini-maglite

Globe with tilted axis



 Wooden block with holes

|  |  |
| --- | --- |
| **STEP 1:** Examine the globe and note that it shows the axis of the Earth as being on a tilt. This is not an accident – the axis of the Earth is indeed tilted with respect to its orbit around the Sun, currently by about 23.5°.  As the Earth orbits the Sun during the year, the axis always points toward the same location in space. (Currently that location is near the star Polaris, though it does change slightly over a period of thousands of years.) |  |

**STEP 2:** Around June 21, the Earth is at a point in its orbit around the Sun at which the northern hemisphere is tilted toward the Sun.



Use your flashlight and Earth globe to examine the pattern of illumination of the Sun’s rays on various parts of the Earth in this orientation, and then answer the following questions.

 As the Earth rotates once a day in this arrangement, at which points on its surface is the energy delivered by sunlight most concentrated? Are they at the equator or somewhere north or south of the equator? As the Earth rotates, what particular line on the Earth globe do these points trace out?

 As the Earth rotates, which part gets more hours of sunlight, the northern or southern hemisphere?

 How would your answers to the previous two questions affect the general climate in the northern and southern hemispheres at this time of year? Explain your reasoning.

 As the Earth rotates in this orientation, are there any places that get no sunlight at all, or get sunlight the whole day? If so, where are these places?

**STEP 3:** Around December 21, the Earth is at a point in its orbit around the Sun at which the northern hemisphere is tilted away from the Sun.



Use your flashlight and Earth globe to examine the pattern of illumination of the Sun’s rays on various parts of the Earth in this orientation, and then answer the following questions.

 As the Earth rotates once a day in this arrangement, at which points on its surface is the energy delivered by sunlight most concentrated? What particular line on the Earth globe do these points trace out?

 As the Earth rotates which part gets more hours of sunlight; the northern or southern hemisphere?

 How would your answers to the previous two questions affect the general climate in the northern and southern hemispheres at this time of year? Explain your reasoning.

 As the Earth rotates in this orientation, are there any places that get no sunlight at all, or get sunlight the whole day? If so, where are these places?

# Summarizing Questions

**S1:** When asked why it is warmer in the summer, most people will reply that it is because the Earth is nearer the Sun at that time of year. (You saw in Exploration #1 that this is not so!) Why do you think most people believe that the distance of the Earth from the Sun is the cause of the seasons? What everyday experiences do you think they base their reasoning on?

**S2:** You have seen that at certain times of the year, the Earth’s polar regions receive many more than 12 hours of daylight. Yet even at the height of ‘summer’ in those regions, the climate is still very cool. Explain briefly why this is.

**S3:** As you saw from Experiment#1, the Earth’s orbit around the Sun is not quite a perfect circle. What do you think would happen to the seasons we experience if it were suddenly to change to being a perfect circle? Explain your reasoning.

**S4:** Now, suppose that instead of changing the shape of the Earth’s orbit we kept that as it is, but somehow got rid of the tilt of its axis. (That is, made it 0°.) What do you think would happen to the seasons we experience if this were done? As usual, explain your reasoning – diagrams may help here too!

**S5:** The axis of the planet Mars has a tilt of about 25°, so it experiences seasons just like the Earth does. However, it also has an eccentric orbit that takes it **significantly closer** to the Sun during summer in its southern hemisphere. How would you expect this factor to affect the climate in both the northern and southern hemispheres of Mars? Explain your reasoning.