Lab

3

Sun Angle and Solar Energy Transfer

Hypothesizing about sun angle

Today we will be utilizing a traditional lab report method to record our initial thoughts, analytical work and procedures and finally document our results and analysis. The lab report will be a group project and it will require input and active participation from all group members.

Some of you conducted experiments in your lectures concerning sun angle during various times of the year and how it effects then light at different locations around a globe. If you participated in these experiments, great! If not, please share with your group members what happened and what it meant in terms of the earth-sun relationships.

Consider what you have already learned in lecture and in lab, as well as your understanding of the earth you live in everyday. This is your starting basis for forming a hypothesis about how the earth-sun relationships have an impact of the temperature (and light) conditions we experience annually around the globe.

A **hypothesis** is a supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation. In other words, it is the informed guess about something that you will perform experiments on to see you can **disprove** the hypothesis or not. Students often wonder why we don't instead try to prove the hypothesis is true. This is because science is always pushing for better and more in-depth answers and thus, very few hypothesis rise to the level of scientific laws (proven, accepted universal facts.)

In small groups assigned by the lab instructor you will explore these ideas as you move towards creating a hypothesis based on your understanding of the world around you.

We will begin by discussing and undertaking the following questions. At least one member of your group must be tasked with writing down and/or illustrating these answers and at least one person will be expected to share these results with the class. Here are the starting questions, but feel free to explore beyond these as your discussion may lead.

- What have you noticed about the way the angle of the sun changes over the course of the year?
- What is different about the way the light looks, the feel of the sun?
- What time do you expect the sun to set tonight? How about 6 months ago?

After a few minutes your lab instructor will be asking for your presentation and you will turn in these findings. Your written questions will also be entered into the appropriate portion of your lab report.

Creating a starting hypothesis

The entire class will brainstorm and discuss these ideas. The best ideas should be those that help to best explain the world around us, while others will be less successful. This is the normal way all scientists try and find the best paths to follow in order to solve the mysteries of our universe. You are now part of that mission!

The best ideas will be vetted and then we will, as a class, formulate a hypothesis regarding sun angle. This hypothesis should be based on the discussion of sun angles and the changes seen across the globe and throughout the year, especially as they pertain to seasonality. This is to be a concise, well crafted hypothesis, which will be entered into your lab report.

Seasons and Angle of Insolation Lab

Have you ever wondered why temperatures are cooler in the winter and warmer in the summer? This happens because the Earth's axis is tilted. The Earth remains tilted as it revolves around the sun.

Because of this tilt, different locations on the Earth receive different amounts of solar radiation at different times of the year. The amount of solar radiation received by the Earth or another planet is called **insolation**.

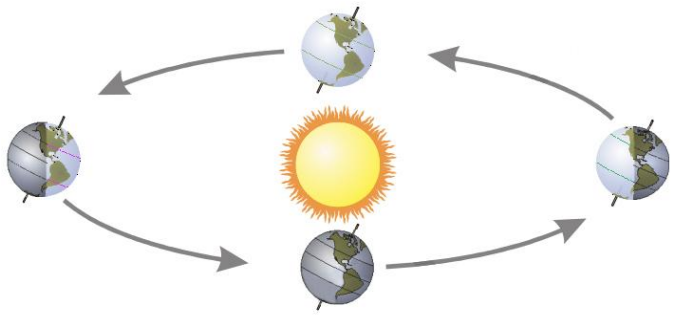


Figure 1

The angle of insolation is the angle at which the sun's rays strike a particular location on Earth. When the north end of the Earth's axis points toward the sun, the Northern Hemisphere experiences summer. At the same time, the south end of the axis points away from the sun and the Southern Hemisphere experiences winter

In this experiment you will investigate the relationship between angle of insolation and temperature change due to energy absorption from a simulated sun—a light bulb.

OBJECTIVES

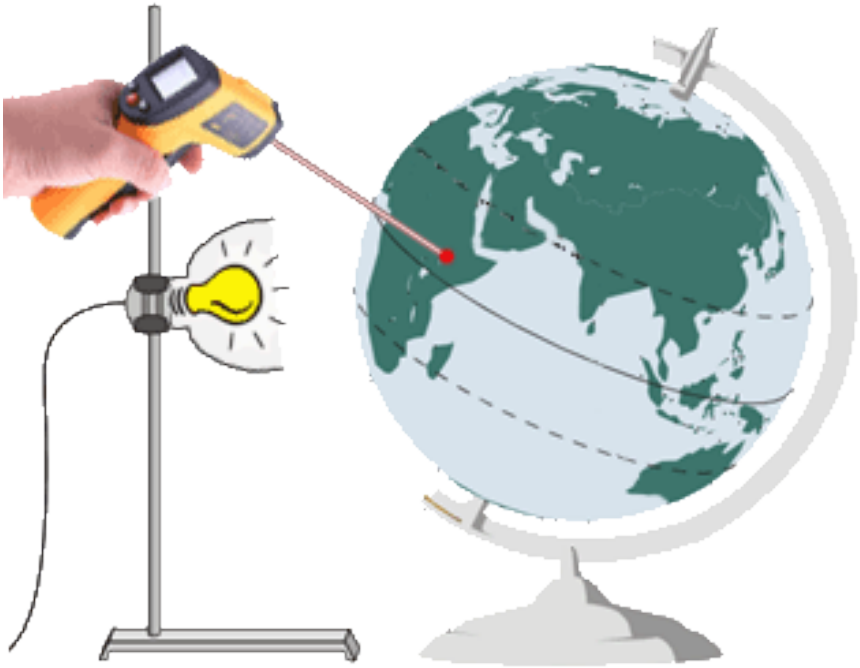
In this experiment, you will be attempting to confirm your hypothesis. There are several tools available for you to use towards this purpose. You will be responsible for creating a series of experiments to test your hypothesis and to complete your analysis.

MATERIALS AVAILABLE

Infrared Laser Temperature Gun Thermometer	Ring stand	Tape
Globe of the Earth	Utility clamp	String
Lamp (with light bulb)	Tape measurer	Protractor

PROCEDURE

In this experiment you will be responsible for devising the procedure to confirm your hypothesis. However, the basic set-up for the experiment during the winter solstice (December 21) should look something like this:



During you experiment you will need to fill in the two data tables for starting and maximum temperature for your two assigned cities.

How will you modify your set-up for the summer solstice (June 21)?

When you have completed your experiments and data collection, you will answer the following questions.

PROCESSING THE DATA

1. In the space provided in your data table, subtract to find the temperature change for each season.

2. How does the temperature change for summer compare to the temperature change for winter?

3. During which season is the sunlight more direct? Explain.

4. What would happen to the temperature changes if the Earth were tilted more than 23.5°?

5. What relationship is there between angle of insolation and temperature change?

6. Draw a picture showing the setup you would use to measure the change in temperature in the Southern Hemisphere during their winter.

7. What other factors affect the weather in a region?

Documenting your analysis

With your experiment complete it is now time to document your activities in your lab report.

The lab report should already have your original questions and answers as well as the preliminary hypothesis. Now you must document your actions in the experiment by listing the equipment used and procedures undertaken, as well as your findings and preliminary analysis.

Your preliminary analysis should include how well you did, or did not, find your hypothesis predicted the results of your experiment. No hypothesis is 100% correct the first time. Scientists spend their lives refining hypotheses and analyzing there results. In fact this ongoing process is the definition of scientific inquiry.

Calculating Solar Intensity

Your understanding of sun angle and its impact on the earth's surface is a good first step in understanding how the sun's energy affects the planet. We will now go into more depth as we seek to understand quantifiably this impact.

The main reason why certain areas on Earth are warmer than other areas is because they receive a greater intensity of solar radiation, which is directly related to the sun angle. Sun angle (altitude angle) is very important because it affects the intensity of solar radiation reaching the ground. When altitude angles are large (i.e. closer to 90°) solar rays are more direct. As altitude angle decreases, radiation is spread over a larger surface area. When more surface area "shares" the solar energy, the intensity of the energy received is less. Figure 3.5 illustrates this idea by comparing the surface area

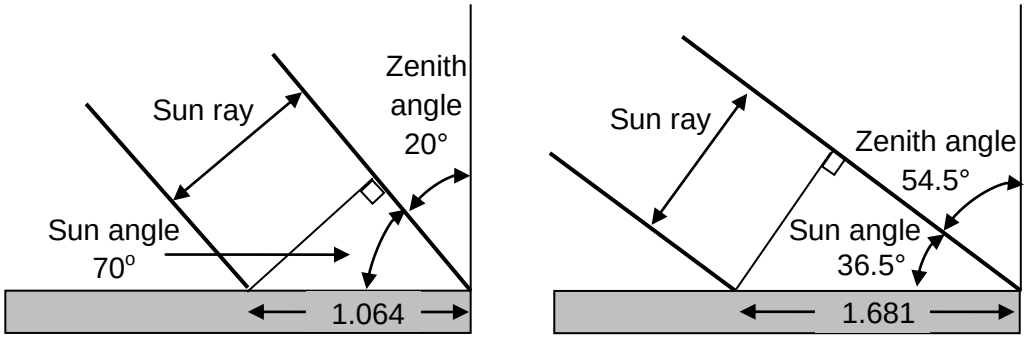


Fig. 3.5 Solar Angle and Surface Area

of radiation for sun angles of 70° and 36.5°. The surface area of radiation for the higher sun angle is less than for the lower sun angle, meaning that the higher the sun angle, the more intense the radiation is at the surface.

The surface area that the beam of solar radiation covers changes with the solar altitude angle and can be determined through trigonometry. The following equations are used to determine the surface area:

$$\sin(\angle A) = \frac{1 \text{ unit width}}{\text{surface area}} \quad \text{and} \quad \text{surface area} = \frac{1}{\sin(\angle A)}.$$

For example, if the altitude angle = 50° then

$$\text{surface area} = \frac{1}{\sin(50°)} = \frac{1}{0.766} = 1.305;$$

this means that 1 unit area of sunshine striking the earth with an altitude angle of 50° will be spread over an area of 1.305 (i.e. an area 30.5% larger). As solar radiation is spread over more of the Earth's surface, the intensity of the beam decreases according to the following equation:

Percent of beam intensity = sin(∠A) × 100

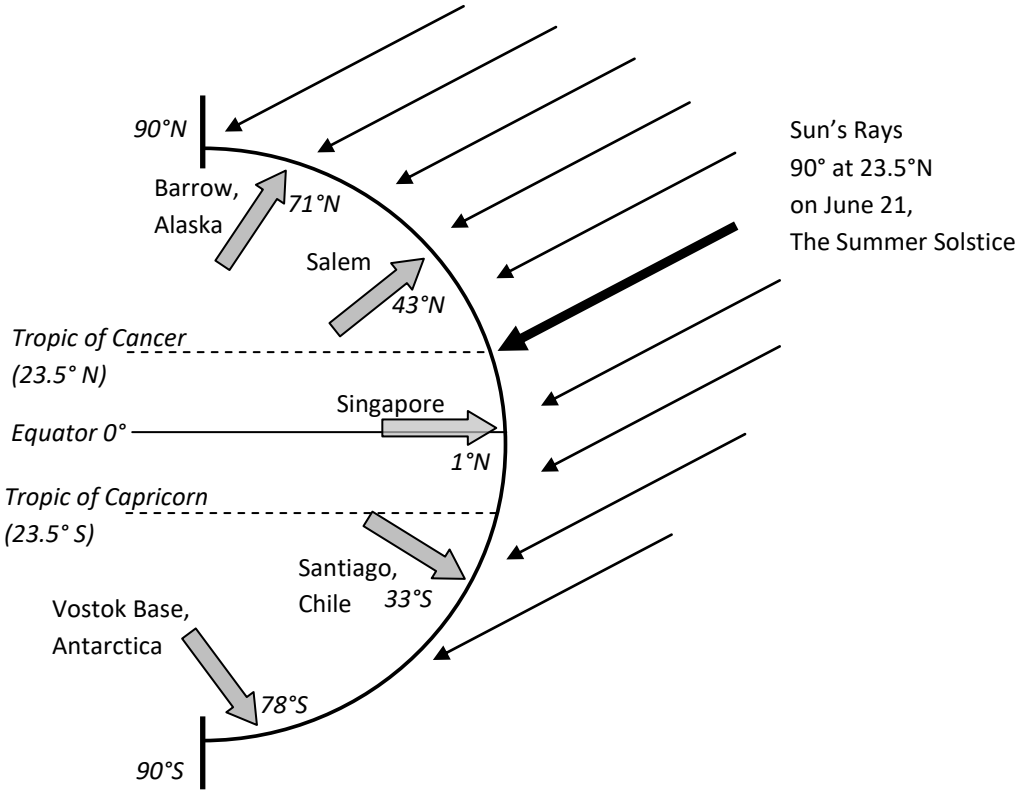
For example, if the altitude angle = 50° then

$$\sin(50°) = \ 0.766 \times 100 = 76.6 \text{ or } 76.6\%.$$

Surface Area of Radiation and Beam Intensity Exercises

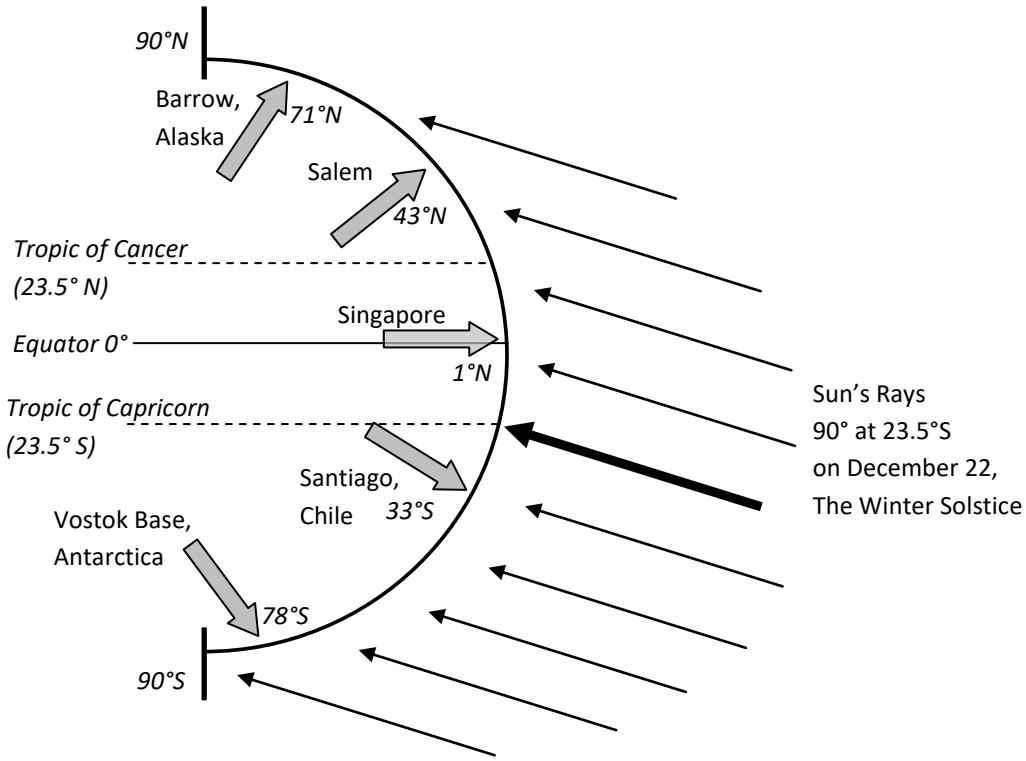
Calculate the Surface Area of Radiation (SAR) and Beam Intensity (BI%) for the following locations on the dates specified.

The Summer Solstice, June 21



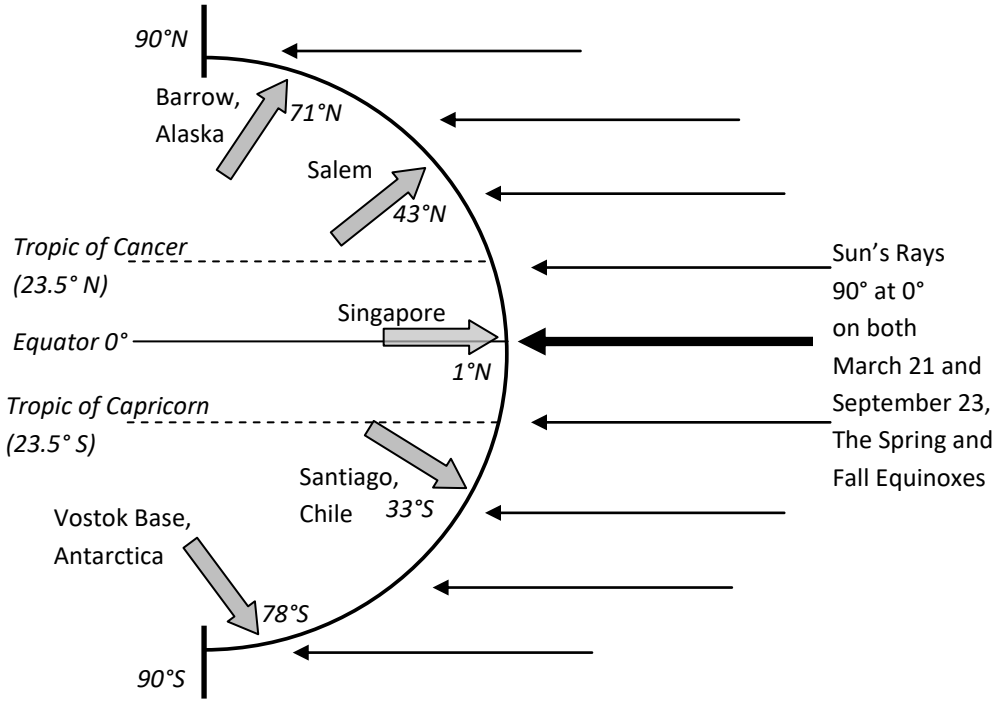
Place	Lat of Place	Lat. Of 90° Sun	Ang. Dist / Zenith Ang.	Alt. Ang.	SAR	BI%
Barrow, AK	**71° N**	**23.5° N**				
Salem, MA	**43° N**	**23.5° N**				
Singapore	**1° N**	**23.5° N**				
Santiago, Chile	**33° S**	**23.5° N**				
Vostok Base, Antarctica	**78° S**	**23.5° N**				

The Winter Solstice, December 21



Place	Lat of Place	Lat. Of 90° Sun	Ang. Dist / Zenith Ang.	Alt. Ang.	SAR	BI%
Barrow, AK	**71° N**	**23.5° S**				
Salem, MA	**43° N**	**23.5° S**				
Singapore	**1° N**	**23.5° S**				
Santiago, Chile	**33° S**	**23.5° S**				
Vostok Base, Antarctica	**78° S**	**23.5° S**				

The Spring Equinox (March 21) and the Fall Equinox (September 23)



Place	Lat of Place	Lat. Of 90° Sun	Ang. Dist / Zenith Ang.	Alt. Ang.	SAR	BI%
Barrow, AK	**71° N**	**0°**				
Salem, MA	**43° N**	**0°**				
Singapore	**1° N**	**0°**				
Santiago, Chile	**33° S**	**0°**				
Vostok Base, Antarctica	**78° S**	**0°**				