# Heat Transfer

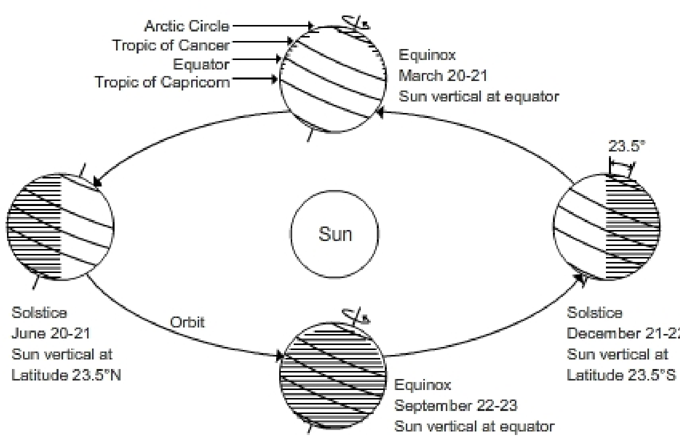
## Energy from the Sun

### *Introduction*

The sun rises in the east and sets in the west, but its exact path changes over the course of the year, which causes the seasons. In order to use the sun's energy in a building, we need to know where it is in the sky at different times of the year.

There are two ways to think about the sun's path in the sky. One way is to study the tilted Earth traveling around the sun viewed from outer space and figure out where the sun would appear in the sky at your latitude at different times of the day and year. If you have time, give this a try with your class.

Walk around a light source, real or imagined, with a globe that's tilted at the right angle. Turn the globe at different positions (times of the year). Try to picture the length of the day and the angle of the sun.



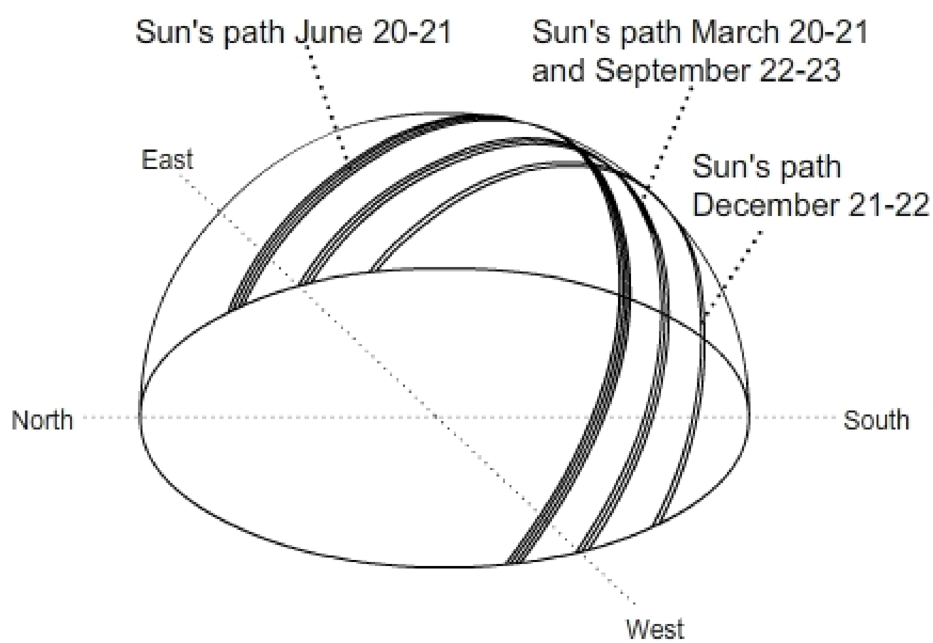

The other way is to stand on the Earth and plot the path of the sun from your point of view on the ground. This is easier to apply to a building, although, of course, the two ways give the same results.

We will use the earth-centered approach in this workbook.

Note: This is one section of the "Science of Heat Transfer" chapter of the Engineering Energy Efficiency Project. See: http://concord.org/engineering

Here is a diagram of the sun's path in the sky at different times of the year. It is roughly correct for a northern latitude of 40°. Note the three lines showing the sun's path. One is the summer solstice, one is the spring and fall equinoxes, and one is the winter solstice.

One is the summer solstice (June 21), one is the spring and fall equinoxes (March 20 and September 23), and one is the winter solstice (December 21). The exact dates change a little bit from year to year.



## Where is the sun?

Learn the basic facts about the sun's path at your latitude. Use the above diagram, your background knowledge, and class discussion to fill out the following table. Here are some hints.

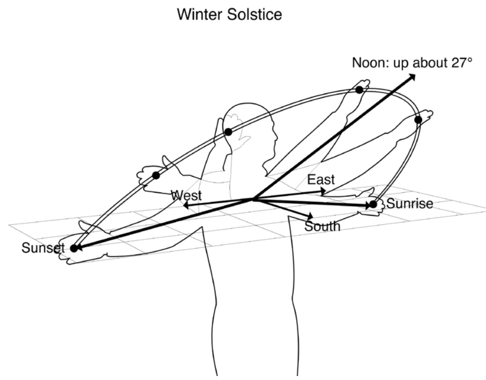
a) At the equinox at noon, the angle of the sun above the horizon is (90° minus the latitude). For example, at the equator this is 90°; at the pole this is 0°.

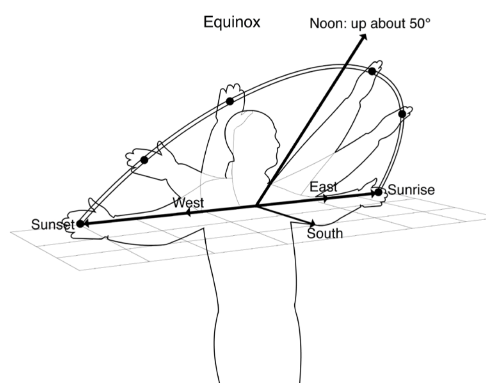
b) At the two solstices, the angular height of the sun at noon either increases or decreases by 23.5°– the tilt of the earth's axis – compared to the equinox.

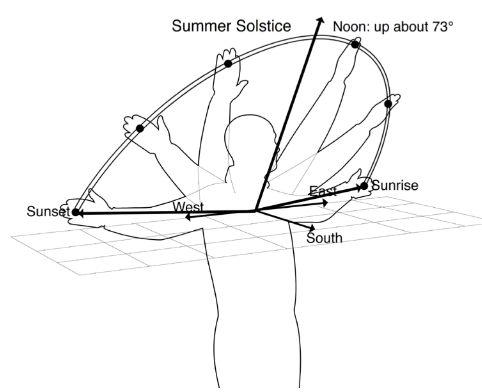
c) For the length of the day, do some Internet research. Many sites give the times of sunrise and sunset. (For 40°N, daylight is about 3 extra hours in summer and 3 fewer hours in winter.)

| Sun's path throughout the year | | | | | |
|---|---|---|---|---|---|
| Your latitude: | | | | | |
| Event | Date | Length of day | Height of sun at noon | Sun rises in what direction? | Sun sets in what direction? |
| Winter solstice | | | | | |
| Spring equinox | | | | | |
| Summer solstice | | | | | |
| Fall equinox | | | | | |

Before you continue, the teacher will lead a discussion on the Sun's Path Calisthenics so that this diagram makes more sense.



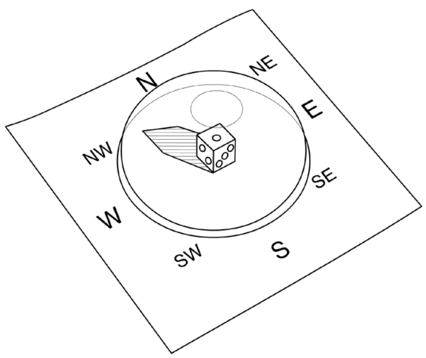



# Represent the sun's path through the sky

## Procedure & data collection

1. Place the plastic dome lid on a piece of paper.
2. Place a small cube under the center of the dome, as if it were your house.
3. Tape the dome to hold it in place.
4. Draw the directions N, S, E, W around the dome. Then add NE, SE, SW, and NW.




5. Draw the path of the sun in the sky on the dome at the spring equinox, using the marker. Do this by drawing points for the sun's position at sunrise, noon, and sunset at the equinox, using what you recorded on the table above. Estimate the angles, knowing that a right angle is 90°. Then connect the points with a smooth arc.
6. Draw the path of the sun in the sky at the summer solstice, the winter solstice, and the fall equinox, using the same procedure.

## Tools & materials

- Clear dome lid from soft drink or ice cream cup
- Clear tape
- Marker
- Die or small cube
- Piece of white paper

## *Analysis*

The sun always travels at the same speed across the sky (15° per hour). If that's true, why does the length of the day change from summer to winter?

How would the path on the dome lid appear if you were on the equator?

How would the path on the dome lid appear if you were at the North Pole?

Based on your sun's path diagram, explain why it's warmer in summer than in winter when you are not near the equator.

# Solar radiation through windows

Now that you know the path of the sun in the sky at different times of year, how can you use this information to use solar energy for heating your house?

The simplest form of solar space heating is windows that face the sun. Sunlight passes through the windows and is absorbed by surfaces within the house. There are no moving parts and no mechanical systems. **This is called passive solar heating.**

In this experiment you will investigate the best orientation for windows for passive solar heating by measuring how much the radiation meter is heated up by the gooseneck light at different orientations.

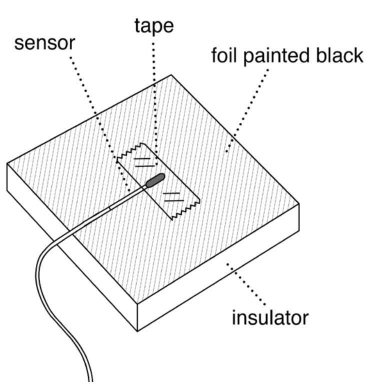
## Tools & materials

- One fast-response temperature sensor (for example, the Vernier surface temperature sensor STS-BTA)
- Computer or other graphing interface for temperature sensor
- "Radiation meter": foil-faced rigid insulation, about 5 cm square, painted black
- One 150-300 W light bulb in a gooseneck fixture (note: this will exceed the fixture's wattage rating, but it's on for a short time.)
- Sun angle template

## Procedure & data collection

Part I: Winter

1. Tape your temperature sensor to a "radiation meter." The clear tape should cover the sensor so that it is held tight against the black surface.




2. Place the radiation meter on a table facing straight up.
3. Use the sun angle template (page 11) to position the sun light bulb 20 cm away from the radiation meter at the winter sun angle. Picture the direction of the light as being south at noon in the winter.
4. Connect the temperature sensor to your computer.
5. Turn on the light and start collecting data.

6. Every 30 seconds, change the angle of the radiation meter, in the following sequence:
7. In 30 seconds, the temperature will approach a new value but not quite stop changing. After you have finished the sequence, stop collecting data and write down the temperature for each orientation at the end of its 30 seconds.
8. Save your data.

| Winter sun angle | | |
|---|---|---|
| Time | Orientation of radiation meter | Ending temperature |
| 0-30 s | Horizontal | |
| 30-60 s | Vertical facing NORTH | |
| 60-120 s | Vertical facing EAST | |
| 120-180 s | Vertical facing SOUTH | |
| 180-240 s | Perpendicular to light rays | |

Part II: Summer

9. Connect the temperature sensor to your computer.
10. Reposition the sun light bulb to the summer test angle, using the sun angle template. Repeat the sequence and fill out the following table.

| Summer sun angle | | |
|---|---|---|
| Time | Orientation of radiation meter | Ending temperature |
| 0-30 s | Horizontal | |
| 30-60 s | Vertical facing NORTH | |
| 60-120 s | Vertical facing EAST | |
| 120-180 s | Vertical facing SOUTH | |
| 180-240 s | Perpendicular to light rays | |

## *Results*

Compare winter and summer by filling out the following table. Rank the various orientations from most to least solar heating.

| Summer vs. winter solar heating | | |
|---|---|---|
| Solar heating | Orientation (winter) | Orientation (summer) |
| 5 (most) | | |
| 4 | | |
| 3 | | |
| 2 | | |
| 1 (least) | | |

What is the best orientation for windows so that a building will gain heat in the winter but not in the summer?

Explain a strategy for using shades or overhangs to control winter heat loss and summer heat gain.

What are the advantages and the drawbacks of passive solar heating?

## Summary

Think about a house you'd like to design. What directions and slopes (vertical, sloped, horizontal) would you choose for large windows? What directions and slopes would you choose for smaller windows? Why?

CUT OUT THE QUARTER-CIRCLE
& GLUE IT TO CARDSTOCK