

INTRODUCTION

Prerequisite Knowledge

- Basic familiarity of the Sun’s annual path is along the Ecliptic
- The definitions for Solstices and Equinoxes.

Goals

- Develop a coherent model of the Sun’s annual path.

Pre-activity Question

When does a vertical flagpole not cast a shadow at your current location?

- a) every day at noon
- b) every day at the time when the Sun is highest in the sky
- c) when the Sun is highest in the sky on the summer solstice
- d) when the Sun is highest in the sky on the winter solstice
- e) none of the above

With the exception of equatorial regions, the correct answer will be choice e.

TUTORIAL GUIDE

Figure Discussion

The figure presents a 180 degree view along the horizon and a 90 degree view from the horizon to the zenith. Students usually do not have a problem with this projection of half the sky onto a plane, but some may need reminding that the figure represents a sort of “fish-eye” view.

- 1) [**Directly south**] The point where the Sun is highest in the sky lies along the dotted line.

Many students believe that the Sun is overhead at noon, which is intentionally not provided as a possible answer. Many, of course, will answer this question without reference to the figure.

- 2) [**Increases**]

Some students will confuse the quantity (the Sun’s altitude is low in wintertime) with the way that the quantity is changing (the altitude is increasing). This difficulty is pervasive in introductory physics and astronomy and can be the source of the response “decreases” in this particular example. Although not formally defined as an angle, students’ naïve understanding of the concept of “altitude” is normally sufficient.

3) [No]

This directly confronts a common misconception that the Sun is always directly overhead at noon in all locations.

4) [March 21 and September 21]

Students immediately recognize that the date will fall between the two extremes. Simple answers of “March” and “September” are acceptable. Students sometimes fail to recognize that this question has two answers.

5) [No] As seen from the northern hemisphere, the Sun will set south of west in winter months, due west on the equinoxes, and north of west in the summer months.

Students extrapolate their results from question 4 to answer this. Some will fail to recognize that they are now asked about setting rather than rising.

Figure 2

This is a diagram of a standard shadow plot. Students can fail to make the connection between the physical arrangement and the resulting figure and will, for instance, think of the shadow as pointing toward the Sun (which also means they have failed to recognize that the top of the page is north). This is easily identified in their resulting responses, which have north-south and east-west reversed.

6) [Northwest]

This is very close to the case in Figure 2, which would be shortly after sunrise. This is a good check question, since an answer of “southeast” indicates a failure to understand how the Sun’s position determines the resulting shadow.

7) [Circle the x’s on the north – south line in the diagram.]

8) [Shadow Plot B] When the Sun is higher in the sky, light rays from the Sun are more steeply inclined. As a result, the stick will cast a shorter shadow.

Students answering “A” are typically seeing that curve A is higher on the page and are not accounting for how the shadow is actually created.

9) [B → summer path; A → winter path] As answered in question 8 above, the Sun is higher in the sky at noon for path B than for path A. A higher noontime Sun suggests summertime.

10) [Winter] From question 9, path A corresponds to the Sun’s path during winter. As answered in question 6, the shadow points opposite the direction of the Sun. For path A, the shadow points northwest when the Sun rises, so the Sun must rise in the southeast.

11) Answers will depend on the date.

Note that plots A and B are never defined as the solstice paths, although students typically assume this to be the case. Therefore, points outside the boundaries of these two paths could be correct provided the student could articulate this reasoning.

12) [**No**] As seen from the U.S., the Sun never reaches the Zenith.

This is meant as a wrap-up question that most students answer correctly. Individual intervention will likely be required for any student answering this question incorrectly.

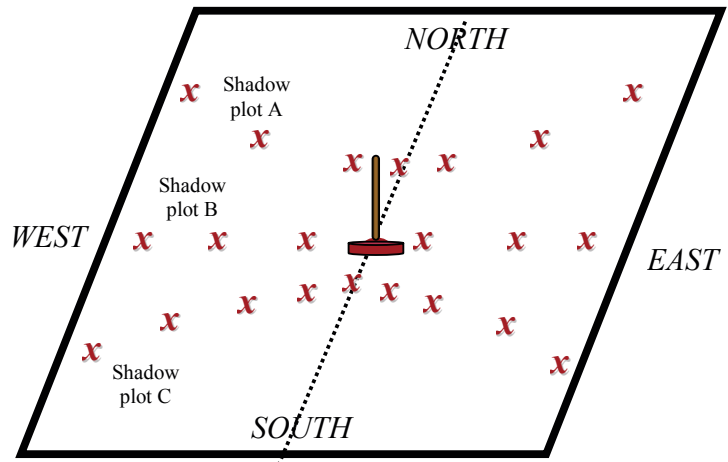
ADDITIONAL QUESTIONS

- 1) Which of the following statements is true about the location of the Sun at sunrise during the middle of winter?
 - a) The Sun will rise north of east.
 - b) The Sun will rise directly in the east.
 - c) **The Sun will rise south of east.**
 - d) None of the above.

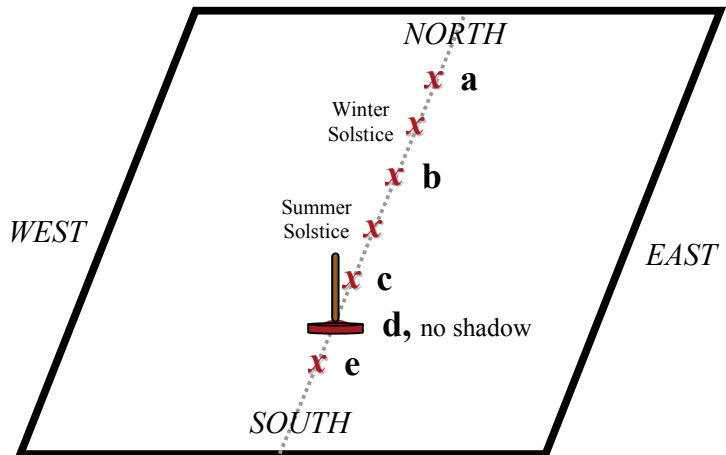
- 2) Which of the following statements is true about the location of the Sun at sunset during the middle of summer?
 - a) **The Sun will set north of west.**
 - b) The Sun will set directly in the west.
 - c) The Sun will set south of west.
 - d) None of the above.

- 3) If it is summertime right now, how does the altitude of the noontime Sun change (if at all) as winter approaches?
 - a) It increases.
 - b) **It decreases.**
 - c) It stays the same.

- 4) For an observer in the continental U.S., which of the three shadow plots, shown at right, correctly depicts the Sun's motion for one day?
- Shadow plot A**
 - Shadow plot B
 - Shadow plot C
 - All three plots are possible, on different days of the year.
 - None of the plots are possible.



- 5) For an observer in the continental U.S., which, if any, of the x's (a – e) in the figure at right correctly shows the position of the Sun's shadow at noon? Choose all that could be correct. Note that the position of the Sun's shadow at noon on the Winter and Summer Solstices are shown.



- a
- b**
- c
- d
- e