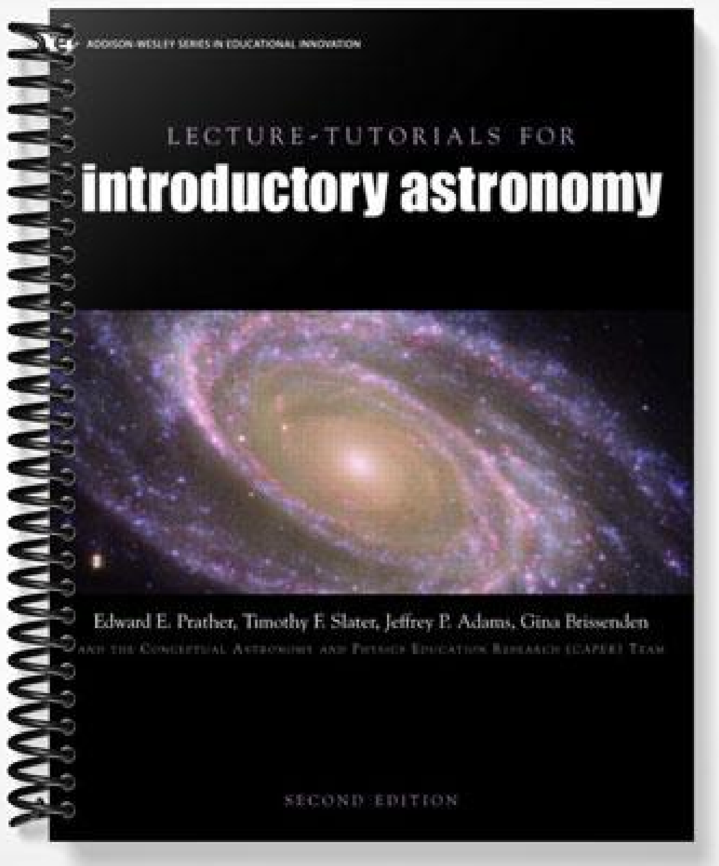
SOLUTIONS MANUAL



LECTURE-TUTORIALS FOR

introductory astronomy

Instructor's Guide

SECOND EDITION

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Research into teaching and learning increasingly suggests that engaging students in active "minds-on" participation is a crucial component for improving student learning. *Lecture-Tutorials for Introductory Astronomy, Second Education* provides instructors with a set of easy to implement, carefully constructed exercises that confront student difficulties and assist students in resolving those difficulties. This *Instructor's Guide* supplements the *Lecture-Tutorials* and its stated goals by furnishing a ready to use implementation guide that includes answer keys as well as insights into common student difficulties.

For each *Lecture-Tutorial* the *Instructor's Guide* contains three main sections: an Introduction, a Tutorial Guide and a set of Additional Questions.

- INTRODUCTION
  The Introduction lists what prerequisite knowledge and skills a student will need to complete the *Lecture-Tutorial*. Typically students are expected to acquire prerequisite knowledge from a prior lecture or from reading the course textbook, and in either case, students need only a basic familiarity with the relevant topics. In some cases a *Lecture-Tutorial* builds on the knowledge and skills gained in earlier *Lecture-Tutorials*.

  The Introduction also lists a set of goals, which describe the knowledge and skills students should acquire as a result of completing the *Lecture-Tutorial*. A pre-activity question, designed to assess whether students have already mastered the goals of the *Lecture-Tutorial*, is also provided.

- TUTORIAL GUIDE
  This section includes answers to the questions in the *Lecture-Tutorial*. When relevant, this section also includes example student reasoning, notes to the instructor, and additional discussion of figures.

  For ease of use, each Tutorial Guide follows the format described below.

  ANSWERS ARE TYPESET AS BOLD TEXT.
  Answers for every *Lecture-Tutorial* question have been provided and are typeset as bold text. Similarly, the correct selection for all multiple-choice pre-activity and follow up assessment questions are typeset as bold text.

  STUDENT REASONING IS TYPESET AS PLAIN TEXT.
  Many *Lecture-Tutorial* questions request that students provide reasoning for their answers. In those cases, reasoning one might expect from a better than average student is given immediately after the answer and is typeset as plain text. In every case that we provide student reasoning, we strive to use wording an instructor could expect non-science majors to use, and in fact, we often paraphrase actual reasoning provided by real students. However, use of advanced ideas that go beyond the ability of typical non-science majors occasionally supplements the provided reasoning.

NOTES TO THE INSTRUCTOR ARE TYPESET AS ITALICS TEXT.
When relevant, instructor notes follow immediately after the example student reasoning and are typeset as italics text. These notes typically address student difficulties an instructor will likely encounter and offer suggestions for helping students resolve their misunderstandings. When appropriate, instructor notes also identify which *Lecture-Tutorial* questions require a correct student response and which *Lecture-Tutorial* questions are only intended to elicit students thinking about a particular issue.

- ADDITIONAL QUESTIONS
  At the conclusion of each *Lecture-Tutorial*, instructors are strongly encouraged to engage their class in a brief discussion about the particularly difficult concepts in the activity, an essential implementation step that brings closure to the activity. This last section provides additional multiple-choice questions for assessing student mastery of the *Lecture-Tutorial* goals.

INTRODUCTION

Prerequisite Knowledge

- Basic familiarity with the celestial sphere model with an emphasis on diurnal motion of stars

Goals

- Relate stars' positions on the celestial sphere to locations in the observer's sky.
- Practice spatial reasoning skills.

Pre-activity Question

You observe a star rising due east. When this star reaches its highest position above the horizon, where will it be?

a) high in the northern sky
b) high in the eastern sky
c) **high in the southern sky**
d) high in the western sky
e) directly overhead

For Northern Hemisphere observers, the correct answer is c.

TUTORIAL GUIDE

Figures 1

Figure 1 shows the celestial sphere and Earth with an observer located somewhere in Earth's Northern Hemisphere. Note that the rotation axis of the celestial sphere is tilted so the observer stands upright, and the observer's horizon lies in the horizontal plane as shown. Also note that this tilt angle of the celestial sphere determines the observer's angle of latitude and does not in any way relate to the tilt of Earth's rotation axis with respect to Earth's orbital plane.

The numbered dots on the figure show the positions of two stars at 6-hour intervals as they are carried on the celestial sphere. Star A rises directly to the observer's east and sets directly west, while Star B is directly overhead at Position 2. For both stars, Position 1 is on the far side of the celestial sphere. Star A is a seasonal star and Star B is a circumpolar star. Because star B is directly overhead at Position 2 *and* on the horizon at Position 4, the observer must be at 45° N latitude. One might encourage stronger students to determine the observer's latitude by considering the path of Star B; however, this knowledge is not needed to complete the tutorial.

1) **[Imaginary]** The horizon the observer sees is real but the one shown denotes where the observer's line-of-sight along the real horizon intersects the celestial sphere.

   The observer's line-of-sight along Earth's surface in Figure 1 does not intersect the horizon drawn because Figure 1 cannot be drawn exactly to scale and is only intended to help students with spatial reasoning. Ideally, imagine the observer shrinking to the size of a microbe and the celestial sphere growing to the size of a city block. In that limit the real and imaginary horizons coincide. Use of a physical celestial sphere model may be helpful.

2) **[No]** Only stars in the grey region (above the horizon) can be seen by the observer.

3) **[Yes, A4]** Star B is never below the horizon and so is never in an *unobservable position*. Star A is unobservable when it is below the horizon at A4.

   Star A is in an unobservable position from just after A3 to just before A1 but questions about rising and setting are addressed in questions 4 through 10. Students, perhaps seeing similarities in the motions of Stars A and B, may have the idea that that B4 is in an unobservable position also. This particular issue is addressed specifically in Questions 7 and 8. There are times when Star B cannot be seen, but that is caused by the Sun's glare, not Star B's position.

4) **[Rising]**

5) **[Setting]**

   These two questions ask students to consider the technical definition for rising and setting necessary for the following questions. It may seem trivial but some students will say that stars rise at dusk and set at dawn.

6) **[A3]**

   This question helps students orient the cardinal directions as seen by the observer in Figure 1. This information is needed for question 9.

7) **[None]** Star B is always above the horizon—it is circumpolar.

   Cuing in to the behavior of Star A, some students will claim incorrectly that Star B is rising and setting at Positions 1 and 3 respectively. While it is true that Star B is only visible at night, it is always above the horizon and so does not rise or set in the way suggested by Question 5. Typically, students with the correct idea are compelled to explain the situation to their peers. Students may benefit by looking back to Question 3. The next question addresses this issue directly.

8) **[Student 2 is correct]** Rising and setting are defined with respect to a horizon. A star's path must cross the horizon to rise and set. Star B never crosses the horizon, and in fact, is nearest the horizon only when it is due North.

   If the group misses Question 7, then Question 8 provides correct reasoning via a debate between two students. Student 2's reasoning is designed to sound more compelling.

Students agreeing with Student 1 may be cuing in to an important similarity shared by Stars A and B. Stars A and B both trace out circles centered on the celestial sphere's axis. (More generally, in one 24 hour period, all celestial objects trace out circles centered on the rotation axis of the celestial sphere.) However, discussion of rising and setting requires an additional step, namely, inclusion of an observer-dependent horizon.

9) **A1: east, low**
A2: south, high
A3: west, low
A4: not visible
North Star: north, high
B1: northeast, high
B2: directly overhead
B3: northwest, high
B4: north, low

Question 9 gives students practice taking locations on the celestial sphere and describing them from the observer's perspective. Four examples are provided. Some students will claim that A2 is directly overhead but it is stated explicitly that B2 is the only position directly overhead.

10) **[No]**

Question 10 serves to stimulate wrap up discussion, addressing one last time the issue of rising and setting for Star B and what rising and setting mean. Students may wonder if day and night matter and some may argue that stars rise at dusk and set at dawn. Students are often skeptical about the idea that stars rise and set constantly as the celestial sphere rotates, even when the Sun is up.

ADDITIONAL QUESTIONS

1) How much of the celestial sphere can an Earth observer see at one time?
   a) less than half
   b) **exactly half**
   c) more than half

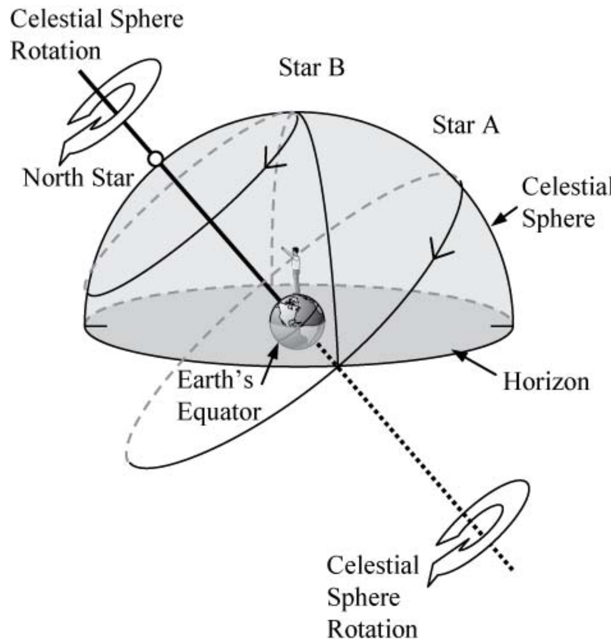
2) You are observing the sky from your southern hemisphere location in Australia. You see a star rising directly to the east. When this star reaches its highest position above the horizon, where will it be?
   a) **high in the northern sky**
   b) high in the eastern sky
   c) high in the southern sky
   d) high in the western sky
   e) directly overhead

3) Stars that never appear to set are called circumpolar. As you move from Earth's equator toward the North Pole, the number of stars that are circumpolar
   a) **increases.**
   b) decreases.
   c) stays the same.

4) Imagine you are standing at the North Pole. Of the stars that you can see, roughly how many of these stars are circumpolar?
   a) none
   b) less than half
   c) more than half
   d) **all**

5) Imagine you are standing somewhere on the Equator. Of the stars that you can see, roughly how many of these stars are circumpolar?
   a) **none**
   b) less than half
   c) more than half
   d) all

For Questions 6 through 8, use the figure at right showing the motions of Stars A and B in the sky.



6) In what direction would you face (look) to see Star A when it is highest in the sky?
   a) toward the north
   b) **toward the south**
   c) toward the east
   d) toward the west
   e) directly overhead

7) In what direction would you face (look) to see Star B when it is highest in the sky?
   a) toward the north
   b) toward the south
   c) toward the east
   d) toward the west
   e) **directly overhead**

8) Which of the stars will set on the western horizon?
   a) both Star A and Star B
   b) **only Star A**
   c) neither Star A nor Star B
   d) only Star B

INTRODUCTION

Prerequisite Knowledge

- Basic familiarity with the celestial sphere model with an emphasis on diurnal motion of stars
- Ability to relate stars' positions on the celestial sphere to locations in the observer's sky, as practiced in the *Position Lecture-Tutorial*

Goals

- Use the celestial sphere model to predict the motions and positions of stars.
- Use the celestial sphere model to explain the differences in motions of circumpolar and seasonal stars.

Pre-activity Question

Imagine you are standing in the Northern Hemisphere. Looking directly north, you see a star just above the horizon. A little later you notice that it has shifted position slightly. Which way did it move?

a) **to the right, (east)**
b) to the left, (west)
c) up, (rising)
d) down, (setting)

TUTORIAL GUIDE

Figures 1& 2

Figure 1 shows what the observer in Figure 2 sees as he looks toward the north. Figure 2 shows the path of two stars (A and B) as they are carried around by the celestial sphere. The ×'s in Figure 2 on the path of Star B correspond to the ×'s in Figure 1, although they are not numbered in Figure 1.

1) **[3]** Figure 1 shows that Star B is due north and close to the horizon at 6 PM. The corresponding location in Figure 2 is Position 3.

   This question checks that students have mastered the skills practiced in the Position Lecture-Tutorial*.*

2) Starting from the × labeled 6 PM in Figure 1, move counterclockwise labeling the ×'s as "Midnight", "6 AM", and "Noon". In Figure 2, 1 → "6 AM", 2 → "Noon", 3 → "6 PM", and 4 → "Midnight".

Some students may struggle relating the ×'s *from Figure 1 with corresponding Positions 1 through 4 in Figure 2. The words "about" and "approximately" appear because the celestial sphere does not rotate exactly 360° in 24 hours as addressed in later activities.*

3) **[Directly overhead]**

When answering this question, many students will confuse overhead with the cardinal direction north.

4) **[Zenith is located at the "x" located at the top of Figure 1.]**

It is important that students reconcile any inconsistencies between their answers for Questions 3 and 4. Some students may need help recognizing that the flat representation of Figure 1 distorts the actual view of the observer. Superficial discussion of "fish-eyed" lenses may help make this point. Also, this distortion of the observer's view is often easier for students to grasp when shown an extended view of the horizon as in Figure 3. A quick reference to Figure 3 may be helpful.

5) **[Toward the south, high in the sky]**

A correct answer to this question is critical to the student debate in Question 8 where the position of Star A halfway between rising and setting (high in the southern sky) is used in Student 2's reasoning. There is a check to this question in Question 7.

6) **[At the × for 6 PM the arrow points right. Moving counter clockwise the ×'s have an upward arrow, leftward arrow, and downward arrow.]**

Here is the pre-activity question again. Many students will incorrectly draw curved arrows which would indicate the motion of the star over many hours rather than at the instant it would appear at the location of the ×, *as is asked in this question. We avoid using the words "vector" and "instantaneous velocity."*

<u>**Figure 3**</u>

Figure 3 shows what the observer sees as he turns to face northeast, with north on the left and east on the right. The × in the east corresponds to the × on the path of Star A in Figure 2. The arrow students drew in Question 6 is included to provide a check on their work so far.

7) **[A right leaning arrow inclined about 45° from the horizon.]**

The first sentence in this question acts as a check to Question 5. Many students will incorrectly draw a vertical arrow for Star A. This misconception is addressed directly in Question 8. Allow students to work though Question 8 before trying to help groups with their incorrect thinking regarding Question 7.

8) **[Student 2 is correct]**

Many students are attracted to Student 1's comment that "stars move east to west." These students have difficulty using spatial reasoning skills and instead survive by memorizing *answers and poorly understood rules of thumb. It may be useful to have a physical celestial sphere model in the room.*

9) **[Down, toward the horizon]** This revisits the pre-activity question, in which many students incorrectly rely on a naïve "stars move east to west" reasoning.

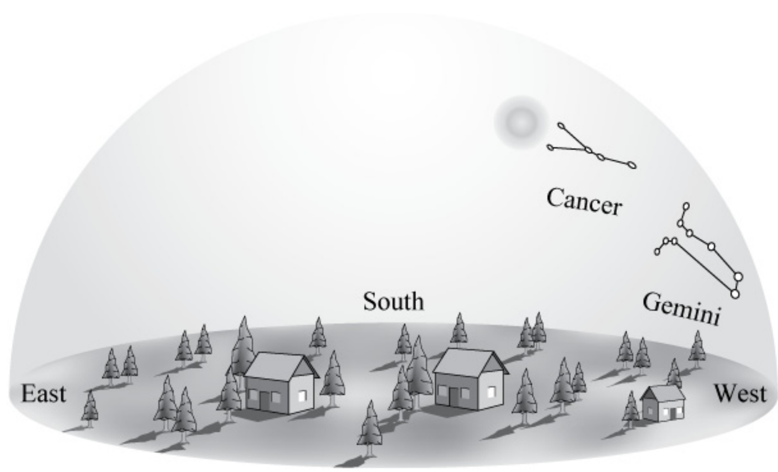
For students struggling with this question, have them look at Questions 2 and 6. Check to see whether they can identify Position 2 as the location described in this question. If so, then ask these students to describe the direction that Star B moves when at Position 2. It may be useful to have them consider the direction their arrow was drawn in Question 6 for Position 2 of Star B.

10) **[Disagree]** The amount of time a star is above the horizon will vary depending on where, or if, it rises or sets. Circumpolar stars are always above the horizon, where as stars that rise very south of east may only be above the horizon for a short time before they set.

Looking at the behavior of Star B is sufficient to disagree with the reasoning. Asking students questions like, "Are there any stars that never set?", and, "Are stars up during the day?" may help.

11) **[Student 2 is correct]** All celestial objects take about 24 hours for one revolution so the Sun and stars must travel more or less together.

12) **[See below]**



It is not so important that students draw the constellations rotated as here. The main point is that the Sun and stars travel together, more or less. These last questions are a prelude to the next tutorial, Seasonal Stars. *Some students may want to know which constellations they should draw in the are above the esastern hoizon and high in the sounthern sky. Point them to Figure 1 of the* Seasonal Stars *activity for assistance with identifying these constellations.*

ADDITIONAL QUESTIONS

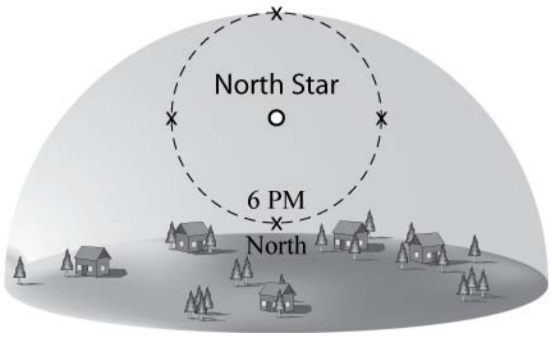
1) Imagine you are located in the Northern Hemisphere and see a star directly overhead (zenith). In what direction will you have to look to see this star set?
   a) southwest
   b) west
   c) **northwest**
   d) **This star will never set.**

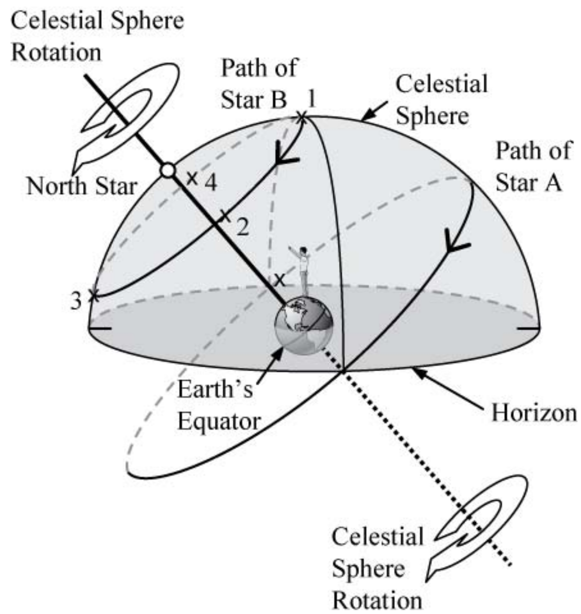
   *The correct answer (**c** or **d**) will depend on your latitude.*

2) You are looking toward the north and see the Big Dipper to the right of Polaris. Fifteen minutes later, the Big Dipper will appear to have moved in roughly what direction?
   a) east (to your right)
   b) west (to your left)
   c) **up (away from the horizon)**
   d) down (closer to the horizon)

3) How much time is there between when a star rises and when it sets?
   a) less than twelve hours
   b) about twelve hours
   c) more than twelve hours
   d) **It depends on the star.**

For Questions 4 through 6, use the two figures provided below, which show the motion of Stars A and B in the sky.





4) What direction is Star A moving when it is highest in the sky?
   a) north
   b) south
   c) east
   d) **west**

5) When Star A is just above the eastern horizon, in what direction is Star A moving?
   a) up and to the north
   b) west
   c) **up and to the south**
   d) south

6) At what time will Star B appear highest in the sky?
   a) **early in the morning**
   b) around noon
   c) in the afternoon
   d) in the evening
   e) around midnight

INTRODUCTION

Prerequisite Knowledge

- Basic familiarity with the zodiacal and seasonal constellations
- Thorough understanding of the celestial sphere model (for Question 10 only)

Goals

- Use the heliocentric model to explain why different zodiacal constellations appear in the night sky as the year progresses.
- Use the heliocentric model to explain daily changes in the night sky.
- Account for the daily changes in the celestial sphere model.

Pre-activity Question

You go out tonight and see the brightest star in the constellation Orion just rising above your eastern horizon at 10 PM. One week later at 10 PM this same star will be

a) **slightly higher in the sky.**
b) at the same height as before.
c) below your horizon.
d) setting on your western horizon.

TUTORIAL GUIDE

Figure 1

The heliocentric view in Figure 1 shows the relationship between Earth's orbital and rotational motions. Earth's rotation axis is shown tilted at the correct angle with respect to its orbital plane. Also, Taurus is carefully shown high in the observer's sky at midnight since Earth's axis is tilted away from the Sun indicating mid-winter. These features are included for accuracy but are not important in terms of this activity's goals, which depend only on Earth's orbital and rotational motion.

The ring represents the ecliptic but the term is not used in this activity. Only 12 zodiacal constellations are represented. For simplicity, Ophiuchus, which lies between Scorpius and Sagittarius, has been omitted, and the remaining 12 zodiacal constellations have been evenly spaced around the ecliptic. These simplifications do not affect the fundamental pedagogy and can be easily addressed later without conflicting with students' underlying models.

1) **[Taurus]** The observer is facing south and points at Taurus.

2) **[East: Gemini; West: Aries]**

   Establishing the relationship between the cardinal directions and the observer's perspective can be difficult for some students.

3) **[Midnight]**

   The relationship between location and time is first introduced here. Correctly answering this question can be difficult for some students.

4) **[Yes, to the east]**

   6 hours after the time shown in Figure 1 it will be 6 AM and the Sun will just be rising in the east.

5) **[Scorpius]**

6) **[Scorpius]**

   During the course of a day there is little change in the position of the Sun with respect to the constellations.

7) **[Gemini]**

   The relationship between the cardinal directions and the orbital motion of Earth is first introduced here. Correctly answering this question can be difficult for some students.

8) **[West]**

9) **[Earlier]** Since Taurus is farther west, it must have risen earlier than it did last month.

10) **[Above]** Using reasoning similar to Question 9.

   Many students will claim that stars are in the same position from one night to the next. It is not important that students answer this correctly, just that they commit to an answer. The following questions will help resolve incorrect answers.

11) **[Student 2 is correct]**

   Student 2's answer is intentionally written to sound more compelling to help those students inclined toward Student 1's naïve thinking.

ADDITIONAL QUESTIONS

1) One night, you see the star Sirius rise at exactly 7:36 PM. The following night it will rise
   a) **slightly earlier.**
   b) at the same time.
   c) slightly later.

2) One evening at midnight, you observe Leo high in the southern sky at midnight. Virgo is to the east of Leo and Cancer is to the west. One month earlier, which of these constellations was high in the southern sky in at midnight?
   a) Leo
   b) Virgo
   c) **Cancer**

3) What component of Earth's motion causes the stars to rise earlier on successive nights?
   a) its rotation about its axis
   b) **its orbit around the Sun**
   c) the tilt of its rotation axis

INTRODUCTION

Prerequisite Knowledge

- The definition of solar day
- The definition of sidereal day

Goals

- Explain, with diagrams, the reason a sidereal day is shorter than a solar day.
- Understand how Earth's rotational and orbital motions determine the solar day.

Pre-activity Question

Through how many degrees does Earth rotate in exactly 24 hours?
a) less than 360
b) exactly 360
c) **more than 360**

TUTORIAL GUIDE

Figure 1

The heliocentric view in Figure 1 shows the relationship between Earth's orbital and rotational motions in a "top-down" view. In this view, the tilt of Earth's rotational axis is not displayed. An observer is positioned so that it is noon and the Sun is directly overhead.

1) **[About 1° per day]**

   Students need not worry about being exact. An answer of 1° per day is adequate.

2) **[More than 360°]** Earth revolves about the Sun while also rotating about its axis.

   Many students may naively answer with "360°." This is fine for now, as this issue is addressed more fully in the next questions.

3) **[Less than 24 hours]** If Earth rotates more than 360° in 24 hours, it must take less than 24 hours to rotate exactly 360°.

4) **[Student 2 is correct]**

   Student 1 expresses the common student misconception. Student 2's response is intended to sound more compelling to help students re-evaluate their thinking.

Note: Questions 5 through 12 in Part II provide a thought experiment that extends the model in Part I. The instructor may choose to use only Part I with weaker students.

5) **[Solar day]**

   Really a restatement of Question 2.

6) **[Sidereal day]**

   This is a restatement of Question 3.

7) Students' sketches should be identical to Figure 1, except the arrow indicating orbital direction is now clockwise.

   The statement "Earth rotates at the same rate" is not intended to mean that a day is still 24-hours long, rather that Earth does not spin about its axis any faster or slower than before. This means a sidereal day takes the same time and a solar day is shorter.

8) **[360°]** A sidereal day is always a 360° rotation with respect to the stars.

   Note that the time for a sidereal day is the same as before. See Question 10.

9) **[Less than 360°]** When Earth has rotated 360° counterclockwise, it has moved a small amount **clockwise** around the Sun, which means the Sun **has already past** its highest point. The Sun was at its highest point when Earth had rotated slightly less than 360°.

   Students should be encouraged to compare their sketches to Figure 1.

10) **[Sidereal]**

   For this thought experiment, 1 sidereal day is longer than 1 solar day based on the answers to Questions 8 and 9.

11) **[Same]**

12) **[Shorter]**

   For this thought experiment, solar days are now shorter than they were.

   On a standard clock, one solar day will now take 23 hours 52 minutes, 4 minutes less than a sidereal day, or 8 minutes less than 24 hours.

ADDITIONAL QUESTIONS

1) Which takes longer to complete?
   a) **one solar day**
   b) one sidereal day
   c) Both take the same amount of time.

2) Image that Earth begins orbiting the Sun twice as fast while maintaining the same rotation rate. It now orbits once around the Sun every 6 months. In this case, what happens to the length of the solar day?
   a) **It gets slightly longer.**
   b) It does not change.
   c) It gets slightly shorter.
   d) It is cut in half.
   e) It doubles.

3) Imagine that Earth stops orbiting the Sun but continues to rotate in place about its own axis at its current rate. In this case, what happens to the length of the solar day?
   a) **It gets shorter.**
   b) It stays the same.
   c) It gets longer.

INTRODUCTION

Prerequisite Knowledge

- The rise and set times for stars are constantly changing
- Thorough understanding of the celestial sphere model
- The definition of ecliptic

Goals

- Describe how the Sun moves on the celestial sphere.
- Distinguish between the Sun's annual motion and its diurnal motion, and demonstrate how these two motions can explain changes in the sky.

Pre-activity Question

In the celestial sphere model, the Sun's position is constantly changing; the path that it follows is called the ecliptic. About how long does it take the Sun to complete one trip around the ecliptic?

a) 23 hours 56 minutes
b) 24 hours
c) 27 days
d) **365 days**

TUTORIAL GUIDE

Figure 1

It may be helpful for students to look at Figure 1 from the *Seasonal Stars* Lecture-Tutorial, which shows an observer and the Sun encircled by the zodiacal constellations. Note that Scorpius is quite a bit farther behind the Sun. For simplicity, the Sun is assumed to be on the meridian, due south, at exactly noon.

1) **[Scorpius]** Over short time periods, all celestial objects appear fixed in place on the celestial sphere and move with it.

   Many students are uncomfortable thinking that stars move across the sky during the daytime and many will claim the Sun moves over to Libra. This issue is re-visited in the next question.

2) **[Student 2 is correct]**

   Student 2's answer is intentionally written to sound more compelling to help those students inclined toward Student 1's naïve thinking.

3) **[Yes]** The Sun moves along the ecliptic just under 1° per day. This motion is small enough to neglect for any one 24-hour period. In the context of diurnal motion it is appropriate to model the Sun as fixed on the celestial sphere.

   In the next part, students modify this idea to include the Sun's motion along the ecliptic.

4) **[On the dotted line, in Scorpius]**

   The shift in the position of Scorpius in one day is exaggerated for clarity.

5) **[On the dotted line, now in Sagittarius]**

   Students are drawn into conflict with their answer to Question 3 and must either now draw the Sun on the meridian but in the constellation Sagittarius or off the meridian in Scorpius. Also note that the changes in the Sun's altitude are irrelevant for this Lecture-Tutorial.

6) **[Student 1 is correct]**

   Student 1's answer is intentionally written to sound more compelling. The point of the discussion is to get students thinking about the connection between the daily and annual motions of the Sun.

7) **[The motion of the Sun along the ecliptic during one 24-hour period is negligible but becomes significant as this motion is observed over many days]**

   Here, the students are asked to resolve the conflict by noting that the Sun does not shift very far (about 1°, in fact) during the course of a day. The answers to Questions 3, 5, and 6 are included in the question, letting students know if they are on the right track.

Figure 4

Figure 4 shows the celestial sphere with the Sun in Scorpius. The ecliptic lies in the horizontal plane and Earth's equator is tilted at 23.5° with respect to it. This figure is similar to those in earlier *Lecture-Tutorials*, but the observer's horizon is not shown. The observer in the diagram is drawn nearly vertically, but his precise latitude on Earth is not meant to be taken literally.

8) **[In Sagittarius]** Based on the answer to Question 5, which was drawn on Figure 3.

9) Continuing the pattern suggested in Question 8, students should list the 10 remaining months in a counterclockwise fashion around the ecliptic (note that Ophiuchus has been omitted to make this easier).

10) The solid/dashed line that goes through the constellations is the ecliptic.

11) **[About 30 times]**

12) **[365 days]**

   This revisits the pre-activity question. It is designed to help students confront a common confusion that the ecliptic represents a daily path.

Figure 5

Figures 5a through 5d show three quarters of a revolution of the celestial sphere with 6 hours between successive figures. The positions of the Sun on June 1 and December 1 are both shown, but not labeled, as students are asked about this in Question 12. Note that in the celestial sphere model, the ecliptic wobbles daily, like a coin spinning on a desk.

13) **[The December path is the lower dashed line, the ecliptic is the central, solid line, and the June path is the top dashed line.]**

These are complicated figures and students should be encouraged to study them carefully and think about what they mean. In a closing class discussion it is worth emphasizing that the figures show how the ecliptic fixes the Sun's position on a given day, and that the daily motion does not follow the ecliptic.

14) **[5a]**

"At noon" for the observer shown.

15) **[5c]**

"At noon" for the observer shown.

ADDITIONAL QUESTIONS

1) In the celestial sphere model, the Sun's position along the western horizon at sunset changes because
   a) Earth is stationary.
   b) the stars rotate with the celestial sphere.
   c) the tilt of Earth changes throughout the year.
   d) **the position of the Sun along the ecliptic is constantly changing.**

2) After the Sun leaves the constellation Sagittarius, how long until it returns to this constellation?
   a) one day
   b) one month
   c) six months
   d) **one year**

3) How often is the Sun directly over Earth's equator?
   a) once a day
   b) once a month
   c) **once every six months**
   d) once a year

4) If the Sun's motion along the ecliptic were reversed, how would its daily motion appear?
   a) **It would continue to rise in the east and set in the west.**
   b) It would now rise in the west and set in the east.

INTRODUCTION

Prerequisite Knowledge

- Basic familiarity with overhead view and horizon view star maps

Goals

- Understand how to use overhead view and horizon view star maps to locate objects in the observer's night sky.
- Be able to make the translation between where star groups are located on an overhead star map to their location on a horizon star map.

Pre-activity Question

The star map provided below shows the sky at midnight on July 1. What is the name of the star group that appears highest in the sky at this time?

a) Scorpius
b) Corona Borealis
c) **Draco**
d) Ursa Minor
e) Auriga

TUTORIAL GUIDE

1. **[Any of the star groups found in the center of the overhead view star map, such as Hercules, Draco, or Bootes, would be acceptable.]**

   Many students will incorrectly respond that a star group found at the top of the overhead star map (such as Scorpious) corresponds with the highest position in the night sky. Some students will resist committing themselves to an answer to this question. Encourage these students to provide an answer, and assure them that this answer is just an initial prediction that they will be able to change later. There is no need to directly challenge incorrect responses at this point, as the students will be asked to revisit this issue again in Question 5. It can, however, be helpful to ask students with incorrect responses to articulate their reasoning.

2. **[Hercules or Bootes]** This horizon view shows only the tip of Draco at the very top of the drawing.

   This question requires students to make the translation between how star groups are represented on an overhead star map with how these same star groups are represented on a horizon view star map. It is particularly important that students recognize that Figure 2 shows a south-facing horizon view star map. It may help to ask students to orient Figure 1 so it matches Figure 2.

3. The overhead star map would need to be folded in half along the east-west line, and then held with the east-west fold pointing upward while looking at the side of the map containing Scorpius near the bottom (top half of the map turned upside down).

   This portion of the Lecture-Tutorial *can be very difficult for some students. They may not understand exactly what is being asked or may provide an incomplete answer. It can be worthwhile to do this part of the lecture tutorial together as a class after students have had sufficient time to attempt an answer on their own.*

4. The map would be folded in same way as in Question 3, but this time, it would be held with the east-west fold pointing upward while looking at the side of the map containing Auriga near the bottom (bottom half of the map).

5. *Many students will have already gone back and changed their answers to Question 1 if they were initially incorrect. This question offers an excellent place to engage students that are still struggling with how an overhead view star map is used to find objects in the night sky.*

6. a) **[At the center of the overhead view star map. Draco]**

   b) **[Along the top of the overhead view star map. Scorpius]**

   c) **[Along the right side of the overhead view star map. Capricornus or Equuleus]**

ADDITIONAL QUESTIONS

1) The star map provided below shows the sky at midnight on July 1. What is the name of the star group that will be directly overhead when looking to the east at this time?
   a) Crater
   b) Ursa Major
   c) **Draco**
   d) Cygnus
   e) Equuleus

2) The star map provided below shows the sky at midnight on July 1. Which of the following star groups do you see when looking east at this time?
   a) Auriga
   b) Scorpius
   c) Draco
   d) **Equuleus**
   e) Crater