

Name and section: _____

- Failure to follow these directions will cause your grade to be lowered.
- All science tests, including this one, are cumulative by nature.
- Answers must be based on models developed in this course.
- You may not access a computer during the test.
- This test is closed book, closed notes.
- Read each problem or question carefully before attempting a solution.
- Illegible or disorderly responses will be counted as incorrect.
- Responses written anywhere other than the provides space will be ignored.
- Make written responses complete, but concise and to the point.
- You have more than enough space for all your answers, so do not use your own paper.
- Unless otherwise explicitly stated, explanations must consist of complete sentences.
- Unless otherwise explicitly stated, responses must not contain personal opinions.

1. (LCTTA-03HW01) Suppose you observe the sky from Miami, FL, which has a latitude of 26° north. Base your answers on this location. It is essential that you draw a meridian diagram to understand this problem. Express angle measures as a whole number of degrees. Include a unit with your numerical answers where appropriate.

The *altitude* of an object in the sky means *the angle between the horizon and the object*. The term *azimuth* is just another way of specifying the direction one must face to see an object in the sky. We conventionally assign north an azimuth of 0° , east an azimuth of 90° , south an azimuth of 180° , and west an azimuth of 270° .

- (a) [2 points] What is the value of the north celestial pole's altitude above the north horizon?
- (b) [2 points] What is the value of the azimuth of the north celestial pole?
- (c) [2 points] There is a point in the sky where the celestial equator intersects the celestial meridian. On the northern hemisphere, this point is easiest to find if you're facing south. What is the value of the altitude of this point above the south horizon?
- (d) [2 points] Suppose your favorite star is on the celestial meridian when you are observing and suppose this star is located right on the celestial equator. What is the value of this star's altitude?
- (e) [2 points] If you were facing east, what would be the value of the angle between the celestial equator and the east horizon? There are actually two such angles, and we want the smaller one. You may find it useful to temporarily consider a location on the equator (latitude 0°), face east, and see where the celestial equator is relative to the horizon. Then temporarily consider the north pole (latitude 90°) and see where the celestial equator is relative to the horizon (As you already know, you can't face east at the north pole!). Facing east from your original location, you should now be able to make an educated assumption (not a wild guess!) about the value of the angle between the celestial equator and the east horizon at your original location.
- (f) [2 points] What is the value of the angle between the point on the celestial equator where it intersects the celestial meridian, and the zenith?
- (g) [2 points] What is the value of the angle between the north celestial pole and the zenith?
- (h) [2 points] Explain how the north star's visibility would change as you walk from the equator to the north pole. Assume that the north star is located precisely at the north celestial pole (it isn't in reality but it's very, very close). Note that in this context, *visibility* does not refer to the star's brightness (stellar brightness is a topic covered in AST152). Instead, *visibility* refers to where in the sky we have to look to see the star.

- (i) [2 points] In a single complete sentence, state the numerical relationship between the north celestial pole's altitude over the north horizon and the celestial equator's altitude over the south horizon.
- (j) [2 points] In a single complete sentence, state the numerical relationship between the observer's latitude and the angle between the celestial equator and the observer's zenith.

LCTTA Test
Student Version

2. [5 points] (LCTTA-03HW02) Recall that the celestial equator is represented by the seam between the two hemispheres. Also recall that the horizon is represented by the top of the paper fence you put around your celestial sphere. Twist your celestial sphere around the stick a few times and observe the orientation of the celestial equator with respect to the horizon. Remember that twisting the sphere clockwise as seen from above the north pole simulates the passage of time (one complete twist equals one day). Which of the following statements accurately reflect your observations? Select all that apply.
- The celestial equator always passes through the same constellations.
 - The angle between the horizon and the celestial equator does *not* change over the course of a day.
 - The celestial equator *always* intersects the horizon at the east and west points.
 - An observer *at your current location* can *always* expect to look in the same part of the sky to find the celestial equator.
 - The celestial equator passes through the zenith *as seen from your current location*.
 - The angle between the horizon and the celestial equator changes over the course of a day.
 - The celestial equator *always* intersects the horizon at the north and south points.
 - The celestial equator *sometimes* intersects the horizon at the east and west points.

3. [5 points] (LCTTA-03HW03) Recall that the ecliptic is represented by the paper strips on the inside of the sphere. Also recall that the horizon is represented by the top of the paper fence you put around your celestial sphere. Twist your celestial sphere around the stick a few times and observe the orientation of the ecliptic with respect to the horizon. Remember that twisting the sphere clockwise as seen from above the north pole simulates the passage of time (one complete twist equals one day). Which of the following statements accurately reflect your observations? Select all that apply.
- The angle between the horizon and the ecliptic changes over the course of a day.
 - The ecliptic *sometimes* intersects the horizon at the east and west points.
 - An observer *at your current location* would have to look in different places in the sky to see the ecliptic at different times of day or night.
 - The ecliptic always passes through the same constellations.
 - The angle between the horizon and the ecliptic does *not* change over the course of a day.
 - The ecliptic *always* intersects the horizon at the east and west points.
 - The ecliptic passes through the zenith *as seen from your current location*.
 - The ecliptic *always* intersects the horizon at the north and south points.

4. (LCTTA-03HW04) Now you are going to consider Sun's motion on the celestial sphere. Place the pin that represents Sun where Sun would be on the day of the September equinox (roughly September 20 or 21). Now simulate sunrise on this date by twisting the sphere to bring Sun to the eastern horizon.
- (a) [4 points] On this date (day of the September equinox), in what direction does Sun rise along the horizon?
- almost exactly east
 - north of east
 - south of east
 - almost exactly north
 - almost exactly west
 - almost exactly south
 - north of west
 - south of west
- (b) [4 points] On this date (day of the September equinox), where does Sun set along the horizon?
- north of east
 - south of east
 - almost exactly east
 - almost exactly north
 - almost exactly west
 - almost exactly south
 - north of west
 - south of west

5. (LCTTA-03HW05) Place the pin that represents Sun where Sun would be on the day of the December solstice (roughly December 20 or 21). Now simulate sunrise on this date by twisting the sphere to bring Sun to the east horizon.

(a) [4 points] On this date (day of the December solstice), where does Sun rise along the horizon?

- almost exactly east
- north of east
- south of east
- almost exactly north
- almost exactly west
- almost exactly south
- north of west
- south of west

(b) [4 points] On this date (day of the December solstice), where does Sun set along the horizon?

- north of east
- south of east
- almost exactly east
- almost exactly north
- almost exactly west
- almost exactly south
- north of west
- south of west

6. (LCTTA-03HW06) Place the pin that represents Sun where Sun would be on the day of the March equinox (roughly March 20 or 21). Now simulate sunrise on this date by twisting the sphere to bring Sun to the east horizon.

(a) [4 points] On this date (day of the March equinox), where does Sun rise along the horizon?

- almost exactly east
- north of east
- south of east
- almost exactly north
- almost exactly west
- almost exactly south
- north of west
- south of west

(b) [4 points] On this date (day of the March equinox), where does Sun set along the horizon?

- north of east
- south of east
- almost exactly east
- almost exactly north
- almost exactly west
- almost exactly south
- north of west
- south of west

7. (LCTTA-03HW07) Place the pin that represents Sun where Sun would be on the day of the June solstice (roughly June 20 or 21). Now simulate sunrise on this date by twisting the sphere to bring Sun to the east horizon.

(a) [4 points] On this date (day of the June solstice), where does Sun rise along the horizon?

- almost exactly east
- north of east
- south of east
- almost exactly north
- almost exactly west
- almost exactly south
- north of west
- south of west

(b) [4 points] On this date (day of the June solstice), where does Sun set along the horizon?

- north of east
- south of east
- almost exactly east
- almost exactly north
- almost exactly west
- almost exactly south
- north of west
- south of west

8. [4 points] (LCTTA-03HW08) Observe the arc that Sun makes in the sky from sunrise to sunset on the day of the June solstice and the arc that Sun makes in the sky from sunrise to sunset on the day of the December solstice. Which of the following statements are true? Select all that apply.
- On the day of the December solstice, Sun rises at a shallower angle with respect to the east horizon than on the day of the June solstice.
 - On the day of the December solstice, Sun spends less time above the horizon than on the day of the June solstice.
 - On the day of the December solstice, Sun has a lower noontime altitude than on the day of the June solstice.
 - On the day of the December solstice, Sun spends more time above the horizon than on the day of the June solstice.
 - On the day of the December solstice, Sun has a higher noontime altitude than on the day of the June solstice.
 - On the day of the December solstice, Sun rises at a steeper angle with respect to the east horizon than on the day of the June solstice.

9. (LCTTA-03HW09) You have just observed that Sun's noontime altitude varies over the course of an entire year. Let's get a bit more quantitative about this now. Recall that Hickory's latitude is 36° . Also recall that on the day of the September equinox, Sun is right on the celestial equator.
- (a) [4 points] On which day is Sun's noontime altitude the greatest?
 - (b) [4 points] On which day is Sun's noontime altitude the least?
 - (c) [4 points] What will Sun's noontime altitude be on the day of the September equinox as seen from Hickory?
 - (d) [4 points] What angle will incoming rays from Sun make with a vertical stick at noon on the day of the September equinox as seen from Hickory? You will find drawing a diagram helpful.
 - (e) [4 points] What is the sum of the angles in the two previous questions?
 - (f) [4 points] Now suppose we go out on the day of the December solstice and observe the same stick's noon shadow. We see that the shadow is either longer or shorter than it is on the day of the September equinox.
 - (g) [4 points] If we wanted to measure the angle that incoming rays from Sun make with the stick at noon on the day of the December solstice, we need to measure the stick's height and the shadow's length. Both of these can be easily measured. We could then construct a scaled diagram and measure the desired angle with a protractor. We would find that the angle measures 59.5° . What is the difference between this angle and the angle from part (d)?

Congratulations! You have just measured the angle between the ecliptic and the celestial equator! As you'll see later, this is the same as Earth's axial tilt. Make sure you understand what you just did and how you did it.

10. (LCTTA-03HW10) Now you get to make a prediction. You already know that on the day of the September equinox, Sun's noon altitude (as observed from Hickory) is 54° . You also know that on the day of the December solstice, Sun is 23.5° below the celestial equator and its noon altitude is $54^\circ - 23.5^\circ = 30.5^\circ$.
- (a) [4 points] Make a prediction about Sun's noon altitude on the day of the June solstice. Discuss the reasoning behind your prediction and make sure it's valid.
- (b) [4 points] Based on your prediction, does Sun ever appear at the zenith as seen from Hickory?
- (c) [4 points] Based on your prediction, at what latitude would an observer have to be located in order to see Sun at his or her zenith on the day of the June solstice?

LCTTA Test
Student Version

11. (LCTTA-03HW11) Now let's consider some celestial geometry. A **great circle** on a sphere is defined as a circle whose center is at a sphere's center and whose circumference is equal to the sphere's circumference. **In other words, a great circle is the largest possible circle you can draw on the surface of a sphere.**
- (a) [4 points] Look at your model and identify exactly four great circles that serve as important references. What are the formal names of these four great circles?
- (b) [4 points] By definition, which great circle is Sun always on for all times and all dates?
- (c) [4 points] If we want to discuss sunrise or sunset, which of the great circles must we include in addition to the one in the previous part?
- (d) [0 points] You have already seen that the angle between these two great circles varies during a day on a given date. For example, the value of the angle between these two great circles three hours after sunrise this morning is different from the value of the angle between these two great circles at three hours after sunset tonight. It also varies during a year at a given time. For example, the value of the angle between these two great circles at four hours after sunset on 29 May is different from the value of the angle between these two great circles at four hours after sunset on 29 November. **Make sure you understand the distinction between these two statements before you go on! Use your model!** There is no answer to submit for this part.
- (e) [4 points] Now, any two great circles on a sphere intersect at exactly two points. As you simulate the passage of time by slowly spinning your celestial sphere, carefully observe the points of intersection between the same two great circles we're dealing with here. Carefully articulate the behavior of the positions of the two intersection points. Don't use fancy language; make it as simple and as direct as possible. Are both points always simultaneously north of, south of, or directly on the celestial equator? You will need more than one sentence.

12. [4 points] (LCTTA-03HW12) Now let's turn away from Sun for a while and consider the movement of a star. Choose any convenient star on your celestial sphere, but make sure it's visible to your imaginary observer. Don't pick a star that is always above the horizon, and don't pick a star that is always below the horizon. Now simulate the star's rising and setting just as you did with Sun and observe the arc that the star makes as it moves across the sky from rising to setting. Which of the following statements accurately reflect your observations? Select all that apply.

- The star makes an arc that is parallel to the celestial equator.
- The star makes the same arc regardless of the date.
- The star's maximum altitude above the horizon is the same regardless of the date.
- The star makes an arc that is parallel to the ecliptic.
- The star makes a different arc on different days of the year.
- The star's maximum altitude above the horizon is different on different days of the year.

LCTTA Test Version
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13. [10 points] (LCTTA-03HW13) Use the information in the diagram below to prove that $\angle e \cong \angle p$. You must give a justification for each step of your proof. There may be more than one correct proof. You may wish to recall things like the properties of parallel lines, transversals, complementary angles, supplementary angles, corresponding angles, alternate interior angles, alternate exterior angles, and vertical angles. Shorter proofs are sometimes considered “better” than longer proofs, but all proofs that are correct are equally valid.

LCTTA Test
Student Version

Lines L, M, and N are parallel.

a = angle between line L and line O

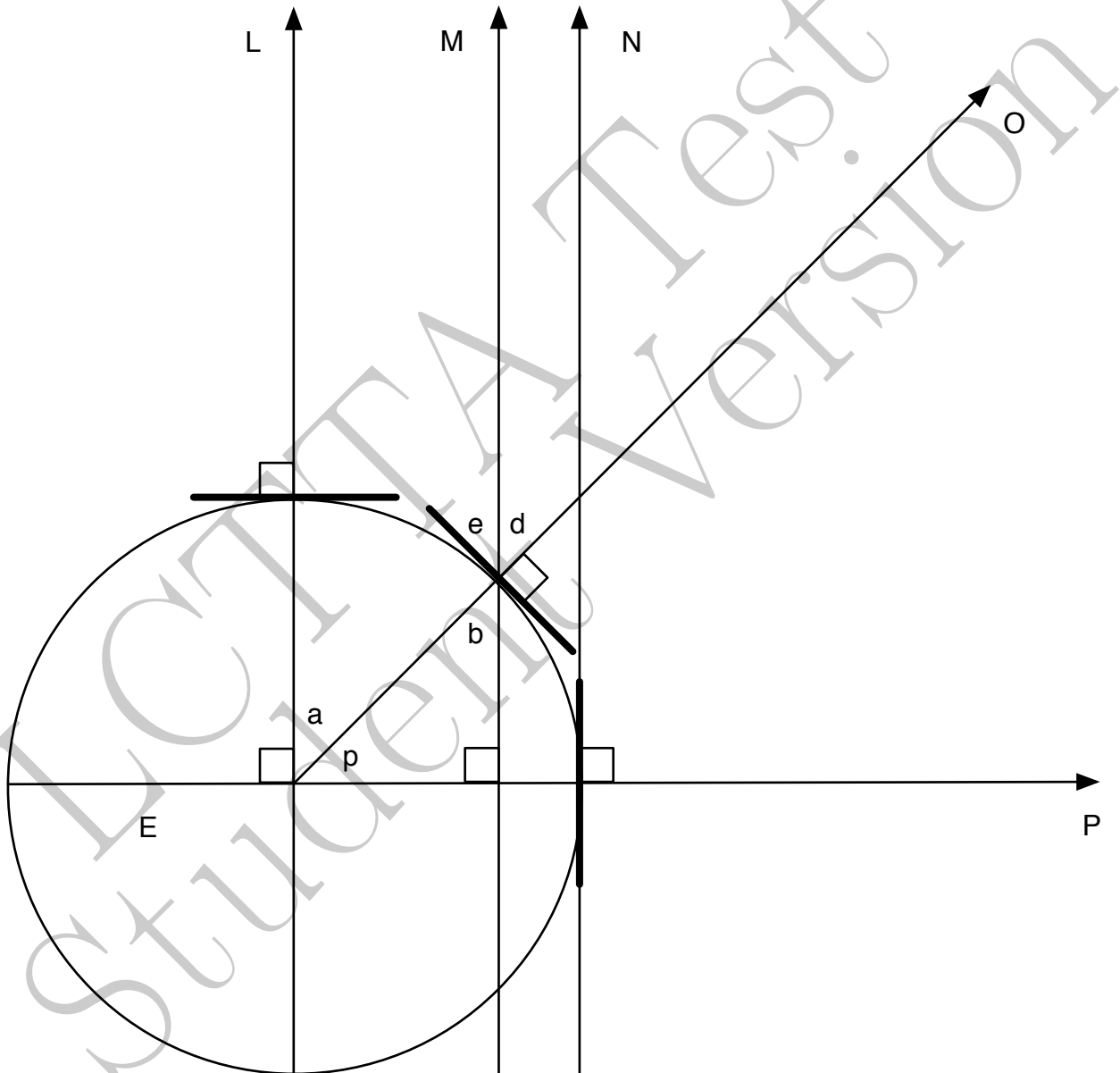
b = angle between line O and line M

d = angle between line M and line O

p = angle between line O and line P

e = angle between line M and the corresponding segment

Prove that angle e is congruent to angle p.



After your proof, here's how to apply this diagram to astronomy. *Assume*, without any supporting evidence at this point, that the circle represents the circular cross section of a *spherical* Earth. Line E (same as line P) represents Earth's equator. The thick black segments represent three different observers'

horizons. Note that each one is tangent to Earth. Lines L, O, and P represent lines of sight to each observer's zenith. Each of these lines of sight is perpendicular to its respective horizon. Lines L, M, and N represent lines of sight from each observer to the north celestial pole. That these lines of sight are parallel is evidence that the north celestial pole is very, very far away. $\angle p$ is the middle location's latitude. $\angle e$ is the angle between the middle location's north horizon and the north celestial pole.

LCTTA Test
Student Version

14. [10 points] (LCTTA-03HW14) Explain how you can ascertain Earth's shape by making careful observations of the night sky (certain stars) while walking along the north-south line.

LCTTA Test
Student Version

15. [10 points] (LCTTA-03HW15) You're outside on a clear night facing east (west). Using only observations of rising (setting) stars, determine your latitude.

LCTTA Test
Student Version

16. (LCTTA-03HW01)

- (a) [10 points] Using your celestial sphere, determine a rule for predicting whether an object will rise north of east, exactly east, or south of east and articulate that rule here as concisely as possible, using complete sentences.
- (b) [10 points] Using your celestial sphere, determine a rule for predicting whether an object will set north of east, exactly east, or south of east and articulate that rule here as concisely as possible, using complete sentences.
- (c) [10 points] Test your rules for validity for observers on both northern and southern hemispheres. Explicitly state whether the rules are valid for both hemispheres. If they need to be adjusted, restate them here with the appropriate adjustments.
- (d) [10 points] Can an object rise north of east and set south of east on the same day? You may wish to consider “fixed” objects such as stars separately from moving objects such as Sun or Moon.

17. [10 points] (LCTTA-03HW02) Can you now present any observation(s) that clearly distinguish between the northern and southern hemispheres?

LCTTA Test
Student Version

18. [10 points] (LCTTA-03HW05) Consider the following argument: All major crimes occur within two weeks of a full moon. Therefore, people are more prone to commit major crimes because of full moons. This is a frequently stated argument. As an astronomer, comment on its veracity (truthfulness).

LCTTA Test
Student Version

19. (LCTTA-03HW06) One of the most famous albums of all time is Pink Floyd's *Dark Side of the Moon*.
- (a) [5 points] Music aside, what is wrong with this album's title that most people may not notice? (HINT: it has nothing at all to do with the word *the*)
- (b) [5 points] What effect, if any, should this error have on your attitude toward the album and its music?

LCTTA Test
Student Version

20. (LCTTA-02TQ04) You will need your celestial sphere for this question.

(a) [5 points] Clearly, correctly, and briefly describe the behavior of a stick's sunrise shadow, as seen from Hickory, over an entire year beginning on the first day of spring. You may use more than one sentence. Be as descriptive as possible, but be brief. You must mention both the shadow's length and its direction in your description.

(b) [5 points] Repeat the process, but this time assume that the ecliptic coincides with the celestial equator.

(c) [15 points] Based on your observations, articulate an explanation for how we could conclude that the ecliptic and the celestial equator must not coincide. You may use more than one sentence. **The conclusion must follow from observations or you will not get credit.**

21. [10 points] (LCTTA-02TQ11) Explain, in a single syntactically and grammatically correct sentence, the cause of the change in where along the eastern horizon Sun rises over the course of a year. There may be more than one correct answer.

LCTTA Test
Student Version

22. [10 points] (LCTTA-02TQ03) Consider this statement:

When you point to Polaris, you are pointing north.

What is wrong with or potentially confusing about this statement? If necessary, rewrite the statement to remove any potential confusion or contradiction with previously established concepts.

LCTTA Test
Student Version

23. It is an observational fact that if you observe Sun rising every morning for an entire year, the point on the horizon at which Sun rises varies in a cyclical and predictable way. A similar phenomenon occurs for Sun setting.
- (a) [0 points] Use your celestial sphere to model this phenomenon. It doesn't matter whether you use sunrise or sunset. It is absolutely essential that you verify that this phenomenon is real before proceeding to the rest of this question.
- (b) [5 points] **Pretend** that Sun follows the celestial equator rather than the ecliptic. Using your celestial sphere, observe and articulate the effect this has on where along the horizon sunrise (or sunset) occurs on different dates throughout the year. You already know four astronomically significant dates, so use them and the four dates midway between them for a total of eight dates during the year.
- (c) [5 points] Now, observations show us that Sun really follows the ecliptic rather than the celestial equator (think about the observations necessary to establish that fact). Using your celestial sphere, observe what effect this has on where along the horizon sunrise (or sunset) occurs on different dates throughout the year. Use the same dates you used in the previous question. Based only on the observations you have made (you *simulated* them because you can't do a year's worth of actual observation in a one semester course), establish and articulate the factors playing a role in where along the horizon sunrise (or sunset) occurs on different dates throughout the year. List these factors here as complete sentences. There may be space for more factors than you have, and that's okay.
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- (d) [5 points] In a single correct and coherent sentence, articulate an explanation, incorporating all of the key factors enumerated above, addressing why the point on the horizon where sunrise (or sunset) occurs changes throughout the year. Your explanation must include all of the key factors.
- (e) [5 points] Almost all introductory astronomy students think they "know" that Earth's rotation axis is somehow tilted, and they think they "know" by how much. One problem is that they rarely "know"

with respect to what is Earth's rotation axis tilted (one thing can only make an angle relative to another thing). At this point in the course, we have no evidence that Earth really rotates. Even if we did, we still can't directly observe Earth's rotation axis; we can only observe where it (probably) intersects the celestial sphere (at the celestial poles). Another problem is that when questioned about *how* students "know" all this, they can only say that they read it somewhere or were told by a teacher.

Consider the following facts:

1. When one object moves around another object in a circular path (such as Sun moving around Earth in your model), the imaginary line connecting the two objects sweeps out a **plane** that contains both objects.
2. Imagine sitting in a swivel chair at the center of a large room with lights randomly placed on the walls, ceiling, and floor. With your finger, you flip a switch that makes the chair, and you, move so that you see the lights moving from your left to your right and the lights leave trails that you can see. If you move this way fast enough (but not so fast as to get motion sickness), the lights' trails become circles all the way around you, and any one of these circles defines a **plane** swept out by a light. All these planes are parallel to one another and so can be considered to be just one plane. They're all equivalent.
3. Now, imagine someone walking around you **while** you're in the chair watching the lights leave trails all around you. **The plane swept out by the imaginary line between you and the walking person will coincide with the plane swept out by the lights' trails.**
4. Finally, imagine doing this same experiment again, but this time with your swivel chair secured to a large wooden platform that is inclined in an arbitrary direction in the room. You are safely secured to the chair so you can't fall out. Once again, you flip the switch that starts the chair moving and you observe the lights' trails and the person once again begins walking on the floor around you. **Will the plane swept out by the imaginary line between you and the walking person still coincide with the plane swept out by the lights' trails?**

Assume that Earth is spherical and indeed rotates as you have probably been told it does. Construct a logically valid chain of reasoning that leads from our simple naked eye observations (e.g. that Sun's path around the sky does not coincide with the celestial equator) to the conclusions that Earth's rotation axis is tilted with respect to something, what that something is, and a numerical value of the angle between Earth's rotation axis and the that something.

24. (LCTTA-03TQ02) You will need your celestial sphere for this question. Assume that Moon's path around the sky coincides with the ecliptic.
- (a) [14 points] You get credit for this part just for bringing your sphere! No sphere, no points here.
 - (b) [6 points] Describe the path through the sky (where does it rise relative to east, where does it set relative to west, where does it cross the meridian relative to the zenith) you would expect Moon to follow as observed from Hickory if a full moon occurred on the December solstice.
 - (c) [6 points] Answer the same question for a full moon on the June solstice.

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Student Version

25. (LCTTA-03TQ03) On May 28, 1900 a total solar occultation took place. The eclipse track crossed central North Carolina and actually passed very close to my hometown but I wasn't around to see the eclipse.
- (a) [5 points] How much of Moon's illuminated side faced Earth on that date and how do you know?

 - (b) [5 points] Give **one** other year in which the same phase will occur on the same calendar date and briefly explain your reasoning. There is more than one correct answer.

 - (c) [5 points] In what constellation was Moon during this occultation? (HINT: Use your sphere!)

 - (d) [5 points] In what constellation was Moon approximately two weeks later?

26. (LCTTA-03TQ04)

(a) [5 points] Explain what we mean by *lunar nodes*.

(b) [5 points] What are the two conditions that must exist for a solar eclipse to occur?

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27. (LCTTA-03TQ05)

(a) [10 points] Briefly explain what the *Golden Number* is and why it is significant.

(b) [5 points] Calculate the Golden Number for the year 1994. Show all your work.

LCTTA Test
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28. [10 points] (LCTTA-03TQ06) In a single correct and complete sentence, explain why we do not have eclipses every month. There may be more than one correct way to articulate the answer.

LCTTA Test
Student Version

29. [10 points] (LCTTA-03TQ07) In one sentence, explain why we see Moon's visual appearance change over the course of a month. Avoid the words *phase*, *orbit*, *new*, *full*, *crescent*, *quarter*, *gibbous*, *rotate* and any form thereof, and *revolve* and any form thereof in your explanation. There may be more than one correct way to articulate the answer.

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30. (LCTTA-03TQ08) A total lunar eclipse occurred on 2000 January 21 and it was visible from Hickory.

(a) [3 points] Give another year in which this same lunar phase will be the same date.

(b) [7 points] On what date will Hickory observers see this *same* eclipse once again? I will allow an error of plus or minus two days in the date. Defend your prediction with a brief sentence.

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31. (LCTTA-03TQ09)

- (a) [10 points] This morning I observed a waning crescent Moon. Approximately when did it rise?
- (b) [10 points] Use your celestial sphere to simulate and observe noon on the first day of each season. Using your observations, articulate a **one sentence** explanation for why the length of a stick's noontime shadow varies in length during a year.
- (c) [10 points] Suppose there is a full Moon on the first day of summer. It won't happen this year, but it has happened in the past. Where along the horizon would you expect this Moon to rise and set? Assume Moon follows the ecliptic just like Sun does.
- (d) [10 points] Suppose there is a full Moon on the first day of autumn. It won't happen this year, but it has happened in the past. Where along the horizon would you expect this Moon to rise and set? Assume Moon follows the ecliptic just like Sun does.

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32. [10 points] (LCTTA-03TQ10) Explain, in a single syntactically and grammatically correct sentence, the cause of the change in where along the eastern horizon Sun rises over the course of a year. There may be more than one correct answer.

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33. [10 points] (LCTTA-03TQ11) Explain, in a single syntactically and grammatically correct sentence, why we see different constellations at night at different times of the year. There may be more than one correct answer.

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34. [5 points] (LCTTA-03SQ01) In one complete, coherent, and correct sentence, articulate why we never see a sunrise shadow pointing south of west and, on the same day, a sunset shadow pointing north of east.

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