

OpenStax Astronomy, Ch.2: WS Solutions (Apr-2021)

Solutions

1. From where on Earth could you observe all of the stars during the course of the year? What fraction of the sky can be seen from the North Pole?

You can observe all of the stars from the equator over the course of a year, although high-declination stars will be difficult to see so close to the horizon. Only half the sky can be seen from the North Pole, and that half does not change throughout the year.

2. Explain, according to both geocentric and heliocentric cosmologies, why we see retrograde motion of the planets.

In the geocentric model, Mars orbits outside of the Sun on its deferent path, but it also moves in a circular motion on its epicycle as it follows the deferent. If the planet moves faster “backward” on the epicycle than it moves forward on the deferent, then it can appear to move in a retrograde manner while still retaining the overall pattern of prograde motion in the sky. In the heliocentric model, Mars moves somewhat slower than Earth. During periods of time when Earth passes Mars, Mars appears to move backward on the sky relative to the background stars. This is confirmed by the fact that Mars appears at its brightest during this motion (due to it being at its closest approach to Earth) and is also on the opposite side of the sky from the Sun during retrograde motion.

3. What were four of Galileo’s discoveries that were important to astronomy?

His observation of the phases of Venus, which supported the heliocentric model; his observations of Jupiter’s moons, which showed not everything orbits Earth; his observations of features on the surface of the Moon, which showed it has similarities to Earth; and his discovery that the Milky Way is simply a mass of unresolved stars.

4. Explain the origin of the magnitude designation for determining the brightness of stars. Why does it seem to go backward, with smaller numbers indicating brighter stars?

The system originated with Hipparchus, who ranked the brightest stars as being “first magnitude,” fainter stars being of the “second magnitude,” then “third magnitude,” and so on as the stars grew progressively fainter.

5. Ursa Minor contains the pole star, Polaris, and the asterism known as the Little Dipper. From most locations in the Northern Hemisphere, all of the stars in Ursa Minor are circumpolar. Does that mean these stars are also above the horizon during the day? Explain.

Yes, they are always above the horizon; but during the day, the sunlight makes them invisible to us.

6. How many degrees does the Sun move per day relative to the fixed stars? How many days does it take for the Sun to return to its original location relative to the fixed stars?

The Sun moves about 1° per day. It takes about 360 days (actually 365.25 days) to return to its original location.

7. How many degrees does the Moon move per day relative to the fixed stars? How many days does it take for the Moon to return to its original location relative to the fixed stars?

The Moon moves about 12° per day. It takes the Moon about 30 days to return to its original position relative to the fixed stars (actually 27.3 days).



8. Explain how the zodiacal constellations are different from the other constellations.

These constellations intersect with the ecliptic, the Sun's apparent annual path in the sky. So from Earth, the Sun appears to move through the zodiacal constellations, but not the others.

9. Is the ecliptic the same thing as the celestial equator? Explain.

The celestial equator is the projection of Earth's equator onto the sky whereas the ecliptic is the Sun's apparent annual path in the sky. These two circles are separated by an angle of 23.5° (see Figure 2.7, The Celestial Tilt).

10. What is an asterism? Can you name an example?

An asterism is a small, easily recognizable group of stars within a larger constellation. Examples include the Little Dipper inside Ursa Minor and the Big Dipper inside Ursa Major.

11. What are two ways in which Aristotle deduced that Earth is spherical?

He noticed that the shadow Earth casts on the Moon during a lunar eclipse is always circular, which is only possible if a spherical body casts the shadow. He also noted that as travelers go farther south, fewer stars are circumpolar and more stars are visible to them overall.

12. How did Hipparchus discover the wobble of Earth's axis, known as precession?

He compared his careful observations of the stars with those of earlier observers and noticed that the positions of the fixed stars had changed slightly and systematically over the course of about 150 years, consistent with the direction of the celestial pole changing relative to the stars.

13. Why did Ptolemy have to introduce multiple circles of motion for the planets instead of a single, simple circle to represent the planet's motion around the Sun?

He had to account for the observed occasional retrograde motion of the planets.

14. What phases would Venus show if the geocentric model were correct?

Venus would only show crescent phases because the illuminated side would only ever partially be visible from Earth.

15. What is a constellation as astronomers define it today? What does it mean when an astronomer says, "I saw a comet in Orion last night?"

A constellation is a well-defined area of the sky with borders, much like provinces have borders on a map of Canada. Seeing a comet in Orion means the comet was seen in the sky within the defined borders of the constellation Orion.

16. Draw a picture that explains why Venus goes through phases the way the Moon does, according to the heliocentric cosmology. Does Jupiter also go through phases as seen from Earth? Why?

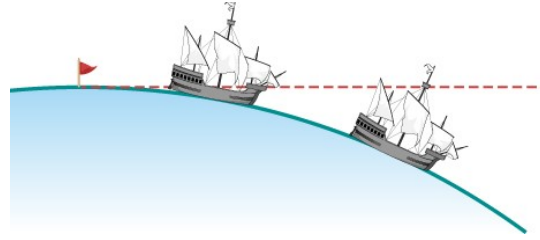
Refer to Figure 2.18 Phases of Venus for the picture of Venus going through its phases. Jupiter, which is farther from the Sun than Earth is, does not experience phases because it is always fully illuminated as seen from Earth.

17. Show with a simple diagram how the lower parts of a ship disappear first as it sails away from you on a spherical Earth. Use the same diagram to show why lookouts on old sailing ships could see farther from the masthead than from the deck. Would there be any advantage to posting lookouts on the mast if Earth were flat? (Note that these



nautical arguments for a spherical Earth were quite familiar to Columbus and other mariners of his time.)





For the observer at the flag, the horizontal dashed line indicates the horizon. Two ships are shown at different distances. The closer ship still has a part of the hull visible whereas the farther ship only has the crow's nest visible. Someone in the crow's nest can see much farther around the curvature of Earth. For the farther ship, the flag is visible from the crow's nest, but not from the main deck. If Earth were flat, elevation would not matter in terms of what is visible from the ship, so there would be no advantage to posting a lookout on the mast of the ship. Note that the size of the ship is greatly exaggerated in this drawing.

18. Parallaxes of stars were not observed by ancient astronomers. How can this fact be reconciled with the heliocentric hypothesis?

The parallax is the shift of an object in the sky when seen from two separated vantage points. It depends inversely on the distance to the object. Stars are so far away, compared to the size of Earth's orbit, that their parallax angle could not be measured to the necessary precision attainable at the time.

19. Although the Copernican system was largely correct to place the Sun at the center of all planetary motion, the model still gave inaccurate predictions for planetary positions. Explain the flaw in the Copernican model that hindered its accuracy.

Copernicus assumed all motion must be uniform circular motion. Because planets orbit the Sun in elliptical paths with varying speeds, there is no way to reproduce that motion faithfully with the planets in circular motion at constant speed around the Sun.

20. During a retrograde loop of Mars, would you expect Mars to be brighter than usual in the sky, about average in brightness, or fainter than usual in the sky? Explain.

Retrograde motion is seen due to the faster-moving Earth passing Mars in orbit, so the two planets must be next to each other (closer to each other than usual). Thus, Mars should appear brighter than usual.

21. The Great Pyramid of Giza was constructed nearly 5000 years ago. Within the pyramid, archaeologists discovered a shaft leading from the central chamber out of the pyramid, oriented for favorable viewing of the bright star Thuban. Thinking about Earth's precession, explain why Thuban might have been an important star to the ancient Egyptians.

Five thousand years ago, Thuban occupied a position in the sky very close to the north celestial pole, so for the ancient Egyptians, it served a purpose similar to the one Polaris serves for us.

22. Explain why more stars are circumpolar for observers at higher latitudes.

Circumpolar stars tend to be higher declination stars that move in very small circles in the sky centered on the celestial poles. At higher latitudes, when the celestial pole is higher in the sky, these small circular paths are more likely to be completely above the horizon. As latitude increases and the altitude of the pole above the horizon

increases, so does the size of the circular motion for stars that will remain above the horizon, and so more stars are circumpolar from higher latitudes.



23. Suppose Eratosthenes had found that, in Alexandria, at noon on the first day of summer, the line to the Sun makes an angle 30° with the vertical. What, then, would he have found for Earth's circumference?

Because 30° is $1/12$ of 360° , he would have found that Earth's circumference was 12 times the distance between the two cities.

