

OpenStax Astronomy, Ch.4: WS Solutions (Apr-2021)

Solutions

1. Make a list of each main phase of the Moon, describing roughly when the Moon rises and sets for each phase. During which phase can you see the Moon in the middle of the morning? In the middle of the afternoon?

New moon rises at sunrise and sets at sunset. Waxing crescent rises midmorning and sets between sunset and midnight. First quarter rises at noon and sets at midnight. Waxing gibbous rises midafternoon and sets between midnight and sunrise. Full moon rises at sunset and sets at sunrise. Waning gibbous rises between sunset and midnight and sets midmorning. Third quarter rises at midnight and sets at noon. Waning crescent rises between midnight and sunrise and sets midafternoon. You can see the Moon midmorning during third quarter and waning crescent. You can see the Moon mid-afternoon during waxing crescent and first quarter.

2. What are the two ways that the tilt of Earth's axis causes the summers in the United States to be warmer than the winters?

The tilt during northern summer results in more direct sunlight for land in the Northern Hemisphere, so more solar energy per square meter reaches us, making Earth's surface warmer. Also, the amount of daylight is longer for Northern Hemisphere sites during summer months, allowing the Sun to illuminate this part of Earth for a longer time, resulting in further warmth.

3. Why is it difficult to construct a practical calendar based on the Moon's cycle of phases?

The monthly cycle of the Moon (29.5 days) does not evenly divide into the seasonal solar cycle of 365.25 days, so there is no easy way to construct a practical calendar that keeps track of the seasons using only the lunar cycle as a guide.

4. Explain why there are two high tides and two low tides each day. Strictly speaking, should the period during which there are two high tides be 24 hours? If not, what should the interval be?

The tidal force of the Moon creates bulges on both the near and far sides of Earth, so there are two high tide bulges. As Earth rotates, a person would be carried through both of these bulges during any given 24-hour period (actually, more like 24 hours and 50 minutes due to the changing position of the Moon in the sky).

5. What is the phase of the Moon during a total solar eclipse? During a total lunar eclipse?

During a solar eclipse, the Moon is new. During a lunar eclipse, the Moon is full.

6. What is the origin of the terms "a.m." and "p.m." in our timekeeping?

These terms refer to the Sun's crossing of the meridian, a line in the sky that extends from the southernmost point on the horizon, through the zenith, to the northernmost point on the horizon. The Sun crosses the meridian at "local noon," which is approximately noon on our clocks (not counting daylight saving time), so prior to that time, the Sun hasn't crossed the meridian. We refer to that as "ante meridiem" (*ante* means "before"), and we call the time after the Sun crosses the meridian "post meridiem" (*post* means "after").



7. Explain the origin of the leap year. Why is it necessary?

Since the solar year is 365.25 days, if we allow for only 365 days in a year, our calendar will be off by one full day after four years have passed. So every four years we add an additional day to take off the four 0.25 days. If we use the calendar to keep track of seasons for the purposing of planting crops, this could lead to big problems over time, so the leap year was introduced so that certain dates on the calendar would always correspond with the same seasons.

8. Explain why the year 1800 was not a leap year, even though years divisible by four are normally considered to be leap years.

According to the Gregorian calendar reform, having a leap year every four years wasn't quite accurate enough, since Earth's orbital period is slightly different from 365.25 days. So, the rule is that century leap years occur only in years divisible by 400, which 1800 is not.

9. What fraction of the Moon's visible face is illuminated during first quarter phase? Why is this phase called first quarter?

Half of the visible face of the Moon is illuminated, not a quarter of it. The phase is called first quarter because the Moon at this time has completed the first quarter of its phase cycle (solar month).

10. Why don't lunar eclipses happen during every full moon?

The Moon's orbital plane is tilted about 5° with respect to Earth's orbital plane (the ecliptic), so most of the time during full phase, the Moon is either above or below the ecliptic, not in Earth's shadow.

11. Why does the Moon create tidal bulges on both sides of Earth instead of only on the side of Earth closest to the Moon?

The differential force of gravity exerted by the Moon has the effect of stretching Earth out along a line connecting Earth and the Moon, so both sides of Earth bulge out. Another way of saying this is that the near side of Earth feels a stronger pull than the center of Earth, and the center of Earth feels a stronger pull than the far side, so the near side is pulled toward the Moon somewhat and the far side is left behind somewhat, elongating Earth.

12. Why do the heights of the tides change over the course of a month?

Both the Sun and Moon affect Earth's tides, though the Sun's effect is less than half that of the Moon. When the Moon and Sun are lined up, during either full or new moon, the tidal effects augment one another, resulting in higher tide amplitudes than normal. During quarter phases, the Sun's and Moon's effects partially cancel, resulting in below-average tide amplitudes.

13. Explain how tidal forces are causing Earth to slow down.

The tidal bulges of Earth want to continue to point toward the Moon, which orbits Earth every 27.3 days. Earth, however, spins faster than this, about once per day. Friction between the rapidly spinning Earth and slowly moving tidal bulges results in a slight slowing of Earth's spin.

14. Explain how tidal forces are causing the Moon to slowly recede from Earth.

The Earth-Moon system must conserve total angular momentum, so as Earth loses angular momentum due to its rotation slowing, the Moon increases its angular momentum by drifting slightly farther away from Earth.





15. Explain why the Gregorian calendar modified the nature of the leap year from its original definition in the Julian calendar.

The average year length using the Julian method is 11 minutes off from a true year, and this is a large enough error to add up over a century or more, so the frequency of the leap day had to be slightly modified to correct for this error.

16. The term *equinox* translates as “equal night.” Explain why this translation makes sense from an astronomical point of view.

On the date of the equinox, everyone on Earth experiences an equal-length day and equal-length night of roughly 12 hours each.

17. The term *solstice* translates as “Sun stop.” Explain why this translation makes sense from an astronomical point of view.

If you observe the sunset on the horizon, you will notice that during spring and early summer, the sunset position of the Sun moves slowly northward, slowing as June 21 nears. On June 21, the Sun’s setting position stops moving north and, on later days, begins moving south, so “Sun stop” is referring to the halt of the Sun’s migration along the horizon.

18. Why is the warmest day of the year in the United States (or in the Northern Hemisphere temperate zone) usually in August rather than on the day of the summer solstice, in late June?

Earth has some thermal inertia. It takes some time for Earth’s temperature to rise in response to the increased energy it receives from the Sun, in the same way the hottest part of the day is usually much later than the maximum solar energy received at noon.

19. Where are you on Earth if you experience each of the following? (Refer to the discussion in Observing the Sky: The Birth of Astronomy as well as this chapter.)

A The stars rise and set perpendicular to the horizon.

B The stars circle the sky parallel to the horizon.

C The celestial equator passes through the zenith.

D In the course of a year, all stars are visible.

E The Sun rises on September 21 and does not set until March 21 (ideally).

A. Earth’s equator (0° latitude); B. either the North or the South Pole (90° North or South latitude); C. Earth’s equator (0° latitude); D. Earth’s equator (0° latitude); E. the North Pole (90° North latitude).

20. What is the right ascension and declination of the vernal equinox?

Since the vernal equinox marks the starting point of our measurement of right ascension (much like the Greenwich meridian marks the starting point for longitude), it has a right ascension of zero. On the vernal equinox, the Sun is crossing the celestial equator heading north, so it is at a declination of zero.

21. What is the right ascension and declination of the autumnal equinox?

The autumnal equinox occurs half a year after the vernal equinox, so in that time, the Sun will have moved 180° around the celestial sphere to a right ascension of 180° or 12 hours. The declination will be zero since the Sun is again crossing the celestial equator.





22. What is the right ascension and declination of the Sun at noon on the summer solstice in the Northern Hemisphere?

On the day of the summer solstice, the Sun will have moved halfway from the vernal equinox (0 hours) toward the autumnal equinox (12 hours). Since right ascension is measured in the direction of the apparent motion of the Sun, the Sun will be halfway between these points, at a right ascension of 6 hours (or 90°). The declination is 23° N of the celestial equator, just as the Tropic of Cancer is 23° N of Earth's equator.

23. Regions north of the Arctic Circle are known as the "land of the midnight Sun." Explain what this means from an astronomical perspective.

For latitudes north of the Arctic Circle, there are some days during the year, around the time of the summer solstice, when the day length is a full 24 hours, so the Sun can be above the horizon at midnight at some times.

24. In a part of Earth's orbit where Earth is moving faster than usual around the Sun, would the length of the sidereal day change? If so, how? Explain.

No, the sidereal day length depends only upon Earth's rotation speed, which is uniform. It will always be approximately 23 hours and 56 minutes, no matter what time of year it is.

25. In a part of Earth's orbit where Earth is moving faster than usual around the Sun, would the length of the solar day change? If so, how? Explain.

The length of the solar day will increase slightly. Typically, as Earth spins, it moves a little bit in its orbit around the Sun, so it takes a little extra time for some point on Earth to see the Sun directly overhead: 4 minutes extra compared to Earth's rotation period of 23 hours and 56 minutes. If Earth is moving faster in its orbit, the change in position of the Sun in the sky relative to the fixed stars will be greater, meaning it will take longer for the Sun to return to its overhead position from the previous day.

26. If Sirius rises at 8:00 p.m. tonight, at what time will it rise tomorrow night, to the nearest minute? Explain.

It will rise at 7:56 p.m. on the following night. The sidereal day is the time it takes for a star to return to the same position in our sky, and that is 23 hours and 56 minutes, or 4 minutes less than 24 hours.

27. If the Moon rises at a given location at 6:00 p.m. today, about what time will it rise tomorrow night?

About 6:50 p.m.; the Moon rises about 50 minutes later each day.

28. Explain why some solar eclipses are total and some are annular.

The Moon's orbit around Earth is slightly elliptical. When the Moon is farther from Earth, the cone of its umbra does not quite reach Earth's surface, resulting in an annular eclipse. When the Moon is closer to Earth, we can experience a total solar eclipse.

29. Why are lunar eclipses more common than solar eclipses?

Earth's shadow is much larger than the Moon's shadow on Earth, so it is far more likely for the Moon to intersect Earth's shadow than for any given location on Earth to intersect the Moon's shadow.

30. What is the altitude of the Sun at noon on December 22, as seen from a place on the Tropic of Cancer?



Between 44° and 45° .

