

Introductory Astronomy**NAME:**

Homework 3: The Moon: Orbit, Phases, Eclipses, and More: Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems (~ 50–70 %) will turn up on tests.

Answer Table

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1. Did you complete reading the Introductory Astronomy Lecture before the **SECOND DAY** on which the lecture was lectured on in class?
 - a) YYYesssss! b) Jawohl! c) Da! d) Sí, sí. e) OMG no!

2. “Let’s play *Jeopardy!* For \$100, the answer is: It is the Earth’s only known natural satellite.”
 What is _____, Alex?
 - a) the Sun b) the Moon c) Cruithne d) the International Space Station (ISS)
 - e) Krypton

3. The mean lunar month is 29.53059 days. How many days are there in a year of 12 mean lunar months and approximately how many years on a lunisolar calendar before you need to insert a 13th lunar month in a year (an intercalary month) in order to keep the lunisolar calendar roughly consistent with the solar year (i.e., keep the months in the seasons they are supposed to be in)?
 - a) 29.53059 days and every twelfth of a year.
 - b) 365.25 days and every 3 solar years.
 - c) 354.367 days and every **3 SOLAR YEARS**. Note you won’t get perfect consistency with an every-3-solar-year insertion since your luni-solar calendar will be short about **33 DAYS** after 3 solar years and a mean lunar month is only 29.53059 days.
 - d) 365.25 days and every 300 years.
 - e) 354.367 days and every **4 SOLAR YEARS**. Note you won’t get perfect consistency with an every-4-solar-year insertion since your luni-solar calendar will be short about **33 DAYS** after 4 solar years and a mean lunar month is only 29.53059 days

4. The mean distance from the Earth to the Moon is:
 - a) 66 Earth radii. b) 40 Earth radii. c) 1 astronomical unit. d) negligible.
 - e) 60 Earth radii.

5. The Earth is at:
 - a) the geometrical center of the Moon’s **ELLIPTICAL** orbit.
 - b) the geometrical center of the Moon’s **ECLIPTICAL** orbit.
 - c) both foci (i.e., focuses) of the Moon’s elliptical orbit.
 - d) the perigee of the Moon’s orbit.
 - e) one of the foci (i.e., focuses) of the Moon’s elliptical orbit.

6. The plane of the Moon’s orbit is:
 - a) at an inclination of about 5° from the **ECLIPTIC PLANE**.
 - b) at an inclination of about 5° from the **ECLIPTIC POLE**.
 - c) at an inclination of about 50° from the ecliptic plane.
 - d) in the ecliptic plane.
 - e) parallel to, but far above, the ecliptic pole.

7. “Let’s play *Jeopardy!* For \$100, the answer is: A lunar time period that is 27.321661 days long.”
 What is the _____, Alex?
 - a) lunar month b) lunar sidereal month c) lunar anomalistic month d) lunar draconitic month
 - e) lunar pathetic month

8. The mean lunar month is 29.53059 days. The **ANGULAR VELOCITY** of the Moon relative to the Sun (**NOT** relative to the fixed stars) is
 - a) 12.19° per day. b) 13.18° per day. c) 29.531° per day. d) 360° per day.
 - e) 12.19°.

9. The nodes of the Moon’s orbit are:
 - a) the foci (i.e., focuses) of the orbit. b) the perigee and apogee of the Moon’s orbit. c) at the solstice positions.
 - d) where the Moon’s orbit crosses the ecliptic plane. e) always aligned with the Earth-Sun line.

10. The sidereal period of a low-Earth-orbit satellite is about 90 minutes. Say we have such a satellite and it is orbiting the Earth in basically an eastward direction relative to the fixed stars. What is its angular speed relative to the **FIXED STARS**? Where does it rise and set?
- Its angular speed is $\sim 4^\circ$ per minute. It **RISES EAST AND SETS WEST** like all other astronomical bodies due to the daily rotation of the Earth.
 - Its angular speed is $\sim 360^\circ$ per minute. It **RISES EAST AND SETS WEST** like all other astronomical bodies due to the daily rotation of the Earth.
 - Its angular speed is $\sim 4^\circ$ per minute. It **RISES WEST AND SETS EAST**.
 - Its angular speed is $\sim 360^\circ$ per minute. It **RISES WEST AND SETS EAST**. This retrograde motion is simply because the satellite revolves faster to the east than the Earth rotates east.
 - Its angular speed is $\sim 0.25^\circ$ per minute. It **RISES EAST AND SETS WEST** like all other astronomical bodies due to the daily rotation of the Earth.
11. Why is the lunar month (i.e., the synodic period of the Moon) longer than the lunar orbital period relative to the fixed stars (i.e., the lunar sidereal period)? **Hint:** draw a diagram of the top (i.e., high-northern-celestial-sphere) view of the Earth-Moon-Sun system.
- The gravitational attraction of the Sun causes the Moon to slow down when it is nearest the Sun. The stars are too remote to have such a gravitational effect.
 - The difference has no known explanation. It was just established by the unknown initial conditions of the Solar System.
 - Both the Earth and the Moon revolve **COUNTERCLOCKWISE** when viewed from the **NORTH ECLIPTIC POLE**: the Earth about the Sun and the Moon about the Earth. Say we think of new moon, when the Moon is in the line between Sun and Earth (i.e., is in conjunction with the Sun). One sidereal period later the Moon has done a complete orbit with respect to the fixed stars. But the Sun relative to the Earth has moved further in the **CLOCKWISE DIRECTION** due, of course, to the Earth's **COUNTERCLOCKWISE MOTION**. Thus the Moon has to travel a bit farther than 360° relative to the fixed stars in order to come back into alignment with the Sun-Earth line and complete a lunar month. Traveling this extra bit takes more time, of course, and thus the lunar month is longer than the Moon's sidereal period.
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12. "Let's play *Jeopardy!* For \$100, the answer is: It is the appearance of the sunlit portion of the Moon as seen by an observer usually located on the Earth."
- What is _____, Alex?
- the terminator
 - lunar month
 - the leaping rabbit
 - a mare
 - lunar phase
13. Full moons occurring at particular times of the year often have traditional names associated with them that varying with culture. A folkloric (or maybe pseudo folkloric) name for a full moon in or near January is:
- June Moon
 - Wolf Moon
 - Juney Moon
 - Green Cheese Moon

- e) Waning Moon
14. Describe the Moon's phase on 1999 January 20. **HINT:** You could look up the answer (except in a test mise en scène, of course), but do you really have to?
- Waning crescent in the western sky at sunset.
 - Waxing crescent in the western sky at sunset.
 - A new moon in opposition.
 - A full moon in the western sky at sunset.
 - Waning gibbous moon in the eastern sky at sunrise.
15. At sunset, you see the Moon in the western sky. It is:
- a waning crescent.
 - a waxing crescent.
 - a full moon.
 - a gibbous moon.
 - partially eclipsed.
16. At sunrise, you see the Moon in the eastern sky. It is:
- partially eclipsed.
 - a waxing crescent.
 - a full moon.
 - a gibbous moon.
 - a waning crescent.
17. The Sun is setting; the Moon is 180° away from the Sun on the sky. The Moon is:
- setting too.
 - half-full.
 - a crescent.
 - being eclipsed.
 - rising and it is full.
18. The Moon is rising, the Sun is setting. The Moon is:
- a crescent.
 - a waning crescent.
 - about to be eclipsed.
 - full.
 - blue.
19. The Moon is a crescent—the horned Moon. Which way, in a rough sense, do the horns point relative to the Sun?
- Toward the Sun.
 - Away from the Sun.
 - They can have any orientation depending on the time of year.
 - They can have any orientation depending on the time of day.
 - Perpendicular to the line from the Moon to the Sun.
20. A lunar eclipse can occur only when the Moon is:
- a crescent.
 - half full.
 - gibbous.
 - full.
 - waning gibbous.
21. From the umbra of the Earth, the:
- Sun's photosphere cannot be seen.
 - Moon cannot be seen.
 - stars cannot be seen.
 - planets cannot be seen.
 - Sun is partially visible. It appears as a bright crescent.
22. For lunar eclipses (any of partial, total, annular, or penumbral) to occur, the Moon's orbital nodes do **NOT** have to be exactly on the Earth-Sun line: i.e., the line drawn through the centers of Earth and Sun. This is because the light-emitting body, the eclipsing body, and the eclipsed body all have finite sizes. The eclipse season is the period during which nodes are sufficiently close to an exact nodal alignment that an eclipse is possible. The eclipse season for the Moon (for partial and total eclipses, and **NOT** including penumbral eclipses) is about 24 days: 12 days before exact nodal alignment and 12 days after. Why is there **NOT** a partial or total lunar eclipse during every lunar eclipse season?
- Lunar eclipses can only happen very near exact **FULL MOON**. If the Moon is just past an eclipsable **FULLISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **FULLISH MOON** only somewhat less than **29.5 DAYS** later and so miss the eclipse season. Consequently, there doesn't have to be either of a total or partial lunar eclipse in every lunar eclipse season albeit usually there **IS**.
 - Lunar eclipses can only happen very near exact **NEW MOON**. If the Moon is just past an eclipsable **NEWISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **NEWISH MOON** only somewhat less than **29.5 DAYS** later and so miss the eclipse season. Consequently, there doesn't have to be either of a total or partial lunar eclipse in every lunar eclipse season, and, in fact, there usually **IS NOT**.
 - Lunar eclipses can only happen very near exact **NEW MOON**. If the Moon is just past an eclipsable **NEWISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **NEWISH MOON** only somewhat less than **22 DAYS** later and so miss the eclipse

- season. Consequently, there doesn't have to be either of a total or partial lunar eclipse in every lunar eclipse season albeit usually there **IS**.
- d) Lunar eclipses can only happen very exact **FULL MOON**. If the Moon is just past an eclipsable **FULLISH MOON** when a lunar eclipse season begins, it will only get back to an eclipsable **FULLISH MOON** only somewhat less than **29.5 DAYS** later and so miss the eclipse season. Consequently, there doesn't have to be either of a total or partial lunar eclipse in every lunar eclipse season, and, in fact, there usually **IS NOT**.
- e) The Bos Domesticus effect in which the Sun sort of dodges the Earth happens frequently near nodal alignment. This often prevents lunar eclipses.
23. Given clear skies everywhere, from what part of the Earth is a lunar eclipse visible?
- a) From almost the entire day side. b) From a small region near the equator. c) From half of the night side. d) From almost the entire night side. e) It is not visible at all.
24. The Moon in a total lunar eclipse tends to be darkest when the Moon:
- a) goes through the center of the Earth's umbra.
 b) goes through the edge of the Earth's umbra.
 c) doesn't go through the Earth's umbra at all.
 d) doesn't go through the Earth's penumbra at all.
 e) eclipses the Sun at the same time.
25. When totally eclipsed, the Moon often appears reddish or coppery. Why?
- a) Reddish is the Moon's natural color. When the glaring white light of the Sun is removed, we see this natural color.
 b) Some sun light is **REFLECTED** from the Earth's atmosphere and re-directed toward the Moon. Light reflected by the atmosphere tends to be reddish. Thus the atmosphere reflected light gives the Moon its reddish color. The direct white light from the Sun completely (or almost completely) washes out any reddish color when the Moon is not totally eclipsed.
 c) Some sun light is **REFRACTED** from the Earth's atmosphere and toward the Moon. (Refraction bends light beams toward the normal to the media interface when the medium the light is entering has a higher index of refraction. In the case of the Earth's atmosphere, refraction tends to bend the light beams around the Earth.) The atmosphere preferentially scatters blue light (hence the blue of the day-time sky) and transfers red light (hence the red color of the Sun at sunrise and sunset when more of the blue has been scattered out of the line of sight). Thus, the refracted light is reddish. This reddish light is reflected by the Moon, and hence we see the Moon as reddish. The direct white light from the Sun completely (or almost completely) washes out any reddish color when the Moon is not totally eclipsed.
 d) The reddish color is an optical illusion caused by the human eye's tendency to see as red that which is not green.
 e) The Moon is actually red hot: i.e., it is emitting red light due to high surface temperature. The eclipsed face of the Moon is after all the day side of the Moon, and we all know about day-time temperatures on the Moon. The direct white light from the Sun completely (or almost completely) washes out any reddish color when the Moon is not totally eclipsed.
26. Why did Aristotle (384–322 BCE) conclude that lunar eclipses prove or at least strongly suggest that the Earth was a sphere?
- a) Based on the duration of total lunar eclipses Aristotle was able to deduce the diameter of the Earth.
 b) From the reddish color of some total lunar eclipses, Aristotle deduced that the a circular limb of the Earth's atmosphere was refracting light onto the Moon. Since the limb was circular, it was reasonable that the whole atmosphere and Earth was spherical.
 c) If you have parallel light beams (which is nearly the case for beams from the Sun at the Earth because of the Sun's remoteness), then the shadow they cause from sphere has a circular cross section for all orientations of source and sphere. The sphere shadow will tend to look circular on most objects on which it falls. Now the shadow (i.e., the umbra) of the Earth on the Moon is circular or nearly circular in all cases: i.e., for all times of day when the partial lunar eclipse is seen and all locations of the Sun on the celestial sphere. Ergo it seems that the Earth must be spherical, unless there is some strange other way to arrange a circular or nearly circular umbra on Moon's face.

- d) Only perfect bodies can cause eclipses. Spherical bodies are perfect. Ergo only spherical bodies can cause eclipses.
- e) We don't know. The argument was given in a lost work: *De Caelo* (*On the Heavens*).
27. "Let's play *Jeopardy!* For \$100, the answer is: In this kind of solar eclipse a ring of photosphere of the Sun is seen around the dark moon."

What is a/an _____, Alex?

- a) total solar eclipse b) partial solar eclipse c) annular solar eclipse d) ring eclipse
e) diamond ring eclipse
28. The solar corona:
- a) is a thin surface layer of the Sun seen as a thin pink ring surrounding the totally eclipsed Sun. The corona often has eruptions of gas called solar prominences.
- b) is the outermost part of the atmosphere of the Sun. It is a very hot, rarefied gas. Although very hot (of order 10^6 K), the corona is very **FAINT** because of its low density. In **TOTAL SOLAR ECLIPSES** it becomes visible to the unaided human eye. It has a milky white color and appears rather wispy. Magnetic field lines extending out from the Sun tend to concentrate corona gas into filaments.
- c) is the outermost part of the atmosphere of the Sun. It is a very hot, rarefied gas. Although very hot (of order 10^6 K), the corona is very **BRIGHT** because of its low density. In **TOTAL SOLAR ECLIPSES** it becomes visible to the unaided human eye. It has a milky white color and appears rather wispy. Magnetic field lines extending out from the Sun tend to concentrate corona gas into filaments.
- d) is the outermost part of the atmosphere of the Sun. It is a very hot, rarefied gas. Although very hot (of order 10^6 K), the corona is very **FAINT** because of its low density. In **TOTAL AND ANNULAR SOLAR ECLIPSES** it becomes visible to the unaided human eye. It has a milky white color and appears rather wispy. Magnetic field lines extending out from the Sun tend to concentrate corona gas into filaments.
- e) was a **CROWN** awarded to the preeminent astronomer of ancient Greece. Poets have their laurel wreath; astronomers have their crown. Demosthenes (384?–322 BCE), defying tyranny, argued in his oration *On the Crown* that it should not be given to Alexander (356–323 BCE) for discovering that the Sun at sunrise in India is not a hundred times larger than in Greece. Later Ptolemy (circa 100–175 CE) was awarded the crown.
29. Why is the corona visible to the unaided eye only during a total solar eclipse?

- a) It is behind the photosphere of the Sun ordinarily, and thus cannot be seen ordinarily.
- b) The Moon's shadow usually hides it.
- c) Only during total eclipses is it compacted by magnetic fields.
- d) It is too faint to be seen when any significant part of the photosphere of the Sun is visible.
- e) Only a total solar eclipse is long enough to let it stand out.
30. The Solar System is not truly periodic and stable. Over billions of years the orbits and rotation rates even of the major planets and moons evolve significantly. The motions of smaller bodies can evolve even more quickly in some cases. Nevertheless, the motions of the major bodies over long periods of time are periodic to a very high degree of accuracy. Therefore it is not surprising that the **RELATIVE POSITIONS OF THE SUN-EARTH-MOON SYSTEM** form a sequence in time that approximately repeats itself: i.e., the relative positions occur in a cycle. This cycle when used to describe the occurrence of eclipses is called the **SAROS CYCLE**. The use of the ancient Sumerian word saros for this cycle was a historical inaccuracy on the part of Edmund Halley (1656–1742) (Neugebauer, O. 1969, *The Exact Sciences in Antiquity*, p. 142).

The Saros cycle is 6585.3213 days long (Wikipedia: Saros). This is 18 Julian years (of 365.25 days each exactly) plus 10.8213 days. In calendar years, the period is trickier to report because of leap years. It is 18 calendar years plus 10.3213 days for the 5 leap year case and 18 calendar years plus 11.3213 days for the 4 leap year case. (The two cases exist because 18 years can include 4 or 5 leap years depending on when the 18 year period begins.) If the 18 year period includes a century year not whole number divisible by 4, then the 18 year period can include 3 or 4 leap years. In the 3 leap year case, the Saros cycle period is 18 years and 12.3213 days.

If a particular eclipse (i.e., total solar, annular solar, partial solar, total lunar, partial lunar, penumbral lunar) occurs on a given day, 6585.321 days later the same eclipse will occur again with Earth, however, rotated $\sim 120^\circ$ degrees further east from where it was due the approximate third of day beyond an even number of days in the Saros cycle period. For a particular total solar eclipse in the Saros cycle to occur in approximately the same location one has to wait ____ Saros cycle periods.

There was a total solar eclipse crossing Cornwall, England and Europe on 1999 August 11. This “Cornwall” eclipse recur on very approximately the same eclipse path in _____.

- a) 4; 2071 September b) 3; 2053 September c) 3; 2053 August d) 5; 2089 October
e) 5; 2089 June