Introductory Astronomy **NAME:**

Homework 4: The History of Astronomy to Newton: Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems ($\sim$ 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) YYYessss! b) Jawohl! c) Da! d) Sí, sí. e) OMG no!

2. Astronomy is often cited as the:

   a) oldest exact, empirical science. b) youngest exact, empirical science. c) oldest inexact, empirical science. d) youngest, inexact, colonial science. e) oldest form of folklore.

3. Moon-shaped cut marks on bones in groupings of order 30 from neolithic times (as long ago as 36,000 BCE) suggest that people then were doing astronomy by:

   a) whiling away the time. b) counting sheep. c) whittling. d) counting fingers and toes. e) counting days of the lunar month.

4. "Let's play *Jeopardy*! For $100, the answer is: Stonehenge and many other prehistoric monuments suggest that the makers were doing this."

   What is/are ____________, Alex?

   a) special relativity calculations b) orbital physics c) simple alignment astronomy d) casting horoscopes e) receiving alien visitors from outer space

5. Stonehenge demonstrates that some prehistoric people:

   a) could predict eclipses.
   b) knew the northernmost rising location of the Sun.
   c) knew nothing of astronomy.
   d) knew more than the ancient Greeks about the universe.
   e) suffered from back pain.

6. Sexagesimal angular units were introduced in astronomy insofar as we know by:

   a) the Mayans. b) the Pueblo Indians. c) Isaac Newton (1642/3–1727). d) Renaissance astronomers. e) the ancient Babylonians.

7. The ancient Babylonians were using a sexagesimal (number) system as early as circa 1800 BCE. We do not know why, but it may well have been to save labor in division. The many whole number factors of 60 (1 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60 for a total of 12 factors) simplifies many division problems. The sexagesimal system seems to have been used consistently only for mathematical and astronomical purposes. For everyday use, the Babylonians often or maybe mainly used other systems including the ubiquitous decimal system: counting on fingers is as old as the hills so to say. In the last centuries BCE the sexagesimal system was taken over into astronomy. Using a large base number with a lot of factors has advantages. But one needs a lot of symbols for all the numerals unless one uses some subsidiary base which is what the Babylonians did: 10. In any case 10 as a base has nothing very special to recommend it, except for the old (very old) finger exercise.

   As a non-finger exercise, subtract $61^\circ 43' 14''$ from $120^\circ 41' 03''$. Recall that $'$ stands for arcminutes and $''$ for arcseconds. **HINT:** If sexagesimal subtraction seems too tricky, you can try sexagesimal addition to recover $120^\circ 41' 03''$.

   a) $182^\circ 24' 17''$. b) $58^\circ 57' 49''$. c) $58^\circ 31' 14''$. d) $59^\circ 51' 49''$. e) $58^\circ 51' 14''$.

8. The earliest 6th century BCE names in ancient Greek science include:

   a) Thales, Copernicus, and Aristotle. b) Thales, Caesar, and Aristotle. c) Eratosthenes, Thales, and Kepler. d) Thales, Anaximander, and Pythagoras. e) Aristotle, Eratosthenes, and Ptolemy.

9. The spherical Earth theory may have been first proposed by Parmenides of Elea. Parmenides was:

   a) Mayan, but he lived in southern California. b) Babylonian, but he lived in Ur. c) Roman, but he lived in Alexandria. d) Icelandic. e) Greek, but he lived in what in what is now Italy.

10. The ancient Greek Presocratic philosophers:

a) may have hypothesized a spherical Earth in order to explain the daily rotation of the celestial sphere. But it is equally likely that they thought that a spherical Earth was proven by the axioms of geometry.
b) may have hypothesized a spherical Earth in order to explain the daily rotation of the celestial sphere. Thales of Miletus then used the spherical Earth theory to predict a solar eclipse.
c) may have hypothesized a spherical Earth because they thought the Earth needed to be spherical in order to be in balance at the center of the cosmos. Aristotle (384–322) later summarized empirical arguments for the spherical Earth. These included the varying celestial locations of the stars and planets relative to the horizon as one moved north-south and the fact that the Earth's shadow on the Moon in a lunar eclipse was always round. However, **ARISTOTLE** went on to affirm that Greece must be on top of the spherical Earth because the ground in Greece was nearly level.
d) may have hypothesized a spherical Earth because they thought the Earth needed to be spherical in order to be in balance at the center of the cosmos. Aristotle (384–322) later summarized empirical arguments for the spherical Earth. These included the varying celestial locations of the stars and planets relative to the horizon as one moved north-south and the fact that the Earth's shadow on the Moon in a lunar eclipse was always round. However, **PTOLEMY** went on to affirm that Greece must be on top of the spherical Earth because the ground in Greece was nearly level.
e) may have hypothesized a spherical Earth because they thought the Earth needed to be spherical in order to be in balance at the center of the cosmos. Aristotle (384–322) later summarized empirical arguments for the spherical Earth. These included the varying celestial locations of the stars and planets relative to the horizon as one moved north-south and the fact that the Earth's shadow on the Moon in a lunar eclipse was always round.

11. A determination of the radius of the Earth was:

a) made by **ERATOSTHENES** in the **15TH CENTURY CE**. This measurement proved the Earth was spherical and was the inspiration for Columbus's voyage.
b) made by **ARISTOTLE** in the **15TH CENTURY CE**. This measurement proved the Earth was spherical and was the inspiration for Columbus's voyage.
c) made by **ERATOSTHENES** in the **3rd CENTURY BCE**. This measurement was based on the assumption that the Earth was **SPHERICAL** and the Sun was very distant from the Earth. If the Earth was not spherical, the measurement would have required the **SAME** interpretation.
d) made by **ERATOSTHENES** in the **3rd CENTURY BCE**. This measurement was based on the assumption that the Earth was **SPHERICAL** and the Sun was very distant from the Earth. If the Earth was not spherical, the measurement would have required a **DIFFERENT** interpretation.
e) made by **ERATOSTHENES** in the **3rd CENTURY BCE**. This measurement was based on the assumption that the Earth was an **OVAL SHAPE**. When the result came out spherical, Eratosthenes was surprised.

12. A major obstacle that ancient Greek astronomers had in trying to determine the nature of the solar system was:

a) the eastward motion of the planets.
b) the inability to measure any distances beyond Pluto.
c) the inability to measure any distances beyond the Moon.
d) the lack of all theoretical biases.
e) the lack of geometrical skills.

13. Which of the following sequences is correctly ordered in time?

a) Aristotle, Ptolemy, Kepler, Copernicus, Thales.
b) Aristotle, Ptolemy, Galileo, Copernicus, Thales.
c) Thales, Aristotle, Ptolemy, Copernicus, Galileo.
d) Ptolemy, Aristotle, Thales, Copernicus, Galileo.
e) Kepler, Aristotle, Thales, Copernicus, Galileo.

14. The ancient Babylonians of the 5th century BCE probably invented horoscopic astronomy (No-41), but its main structure as passed down to the present probably evolved in the Greco-Roman world from the 2nd century BCE onward (Ne-170–171).

This Greco-Roman astrology has left some unusual imprints on modern conventions. For example, each hour of the 24-hour day—which itself came from the ancient Egyptians of the 2nd millennium BCE by no very logical process (Ne-86)—has a ruler (Ne169). The rulers are the seven moving stars which are ordered in decreasing order by their sidereal periods: Saturn, Jupiter, Mars, Sun, Venus, Mercury, and Moon. The Greco-Roman astronomers (including Ptolemy) believed this was the order of decreasing distance from the Earth: actually it is the order of decreasing distance from the Sun if Earth replaces Sun in the list and you eliminate the Moon.

The rulers of each hour are assigned using the ordered sequence of moving stars. The assignment of rulers starts with the 1st hour of Saturday being Saturn. The next hour is assigned Jupiter as its ruler and so on. When one completes assigning the sequence of 7 stars, then one starts the sequence over again.

Each day of the week has a ruler too: its ruler is the ruler of that day's first hour. A little calculation—or knowing that Jupiter's day got assigned to Thor in English—shows that the day rulers starting from Saturday's ruler Saturn are:

a) Saturn, Sun, Moon, Mars, Saturn, Sun, and Moon.
b) Saturn, Saturn, Saturn, Saturn, Saturn, Saturn, and Saturn.
c) Saturn, Sun, Saturn, Mars, Saturn, Mercury, and Saturn.
d) Saturn, Sun, Moon, Mars, Jupiter, Mercury, and Venus.
e) Saturn, Sun, Moon, Mars, Mercury, Jupiter, and Venus.

15. Aristotelian cosmology:

a) consisted of perfect eternal cubes rotating about the Earth.
b) put the Earth at the center of the cosmos. The planets and fixed stars were located on sets of solid spheres that rotated about the Earth. The celestial phenomena were eternal exactly repeating motions. Beyond the sphere of the fixed stars was a **CHAOS** of primordial material in which were embedded other finite cosmoses.
c) put the Earth at the center of the cosmos. The planets and fixed stars were located on sets of solid spheres that rotated about the Earth. The celestial phenomena were eternal exactly repeating motions. Beyond the sphere of the fixed stars was **NOTHING**, not even empty space. The universe was finite.
d) was **DISCARDED** by everyone in the medieval Islamic period. It put the Earth at the center of the cosmos. The planets and fixed stars were located on sets of solid spheres that rotated about the Earth. The celestial phenomena were eternal exactly repeating motions. Beyond the sphere of the fixed stars was **NOTHING**, not even empty space. The universe was finite.
e) was never seriously considered again after Ptolemy's time.

16. Stellar parallax is:

a) the westward motion of the planets.
b) the daily westward motion of the fixed stars.
c) an optical illusion.
d) the change in angular position of a star relative to background stars due to the Earth's yearly motion around the Sun.
e) the change in magnitude of a star due to the Earth's year motion around the Sun.

17. Take a pencil (or pen or finger). Hold it upright at arm's length in front of some distant object of smallish angular size such as a wall clock. Center the pencil on the object. Then keeping your hand steady (rock steady) shift your head until the object is just out of eclipse. Neither the pencil nor the object has moved in space, but they have shifted in relative angular position because of the movement of the observer. This change in angular position of objects due the shift in the spatial position of the observer is called **PARALLAX**. (Note the term **PARALLAX** is used both for the phenomena of shift in general [e.g., "we know this from parallax"] and for particular angular shifts [e.g., "the parallax" caused by this motion is $10°$].) Try the experiment again but this time with the pencil right in front of your eye: move your head as much as before. Is the angular shift between the pencil and object larger than before? Yes/No? Well maybe after you've tried it carefully a few times it will be clear that parallax effects are bigger for closer objects since the same head movement (the same observational baseline) gives a larger angular shift or parallax. If the Earth were moving in space, would the stars show parallaxes relative to each other?

a) Yes, unless they were so distant that we couldn't detect parallax or unless they were all flying in formation with the Earth. The latter exception was so obviously **REASONABLE** that the ancient Greeks decided the Earth must be moving around the Sun.

b) Yes, unless they were so distant that we couldn't detect parallax or unless they were all flying in formation with the Earth. The latter exception was so obviously **CONTRIVED** that it doesn't seem to have been discussed in history as a means of accounting for the lack of stellar parallax in moving-Earth theories. Stellar parallax was, in fact, discovered in **1838**.

c) Yes, unless they were so distant that we couldn't detect parallax or unless they were all flying in formation with the Earth. The latter exception was so obviously **CONTRIVED** that it doesn't seem to have been discussed in history as a means of accounting for the lack of stellar parallax in moving-Earth theories. Stellar parallax was, in fact, discovered in **2008**.

d) No, never, no matter how close or far they were. Stars unlike any other object just cannot show parallax.

e) Parallax is the change in angular position of an object due to the change in spatial position of the observer.

18. "Let's play *Jeopardy*! For $100, the answer is: A cosmology became something of a philosophical dogma in Greco-Roman Antiquity, the Medieval Islamic and European societies, and in Europe up until the 17th century."

    What is ____________, Alex?

    a) Democritean cosmology b) Newtonian cosmology c) big bang cosmology
    d) inflation cosmology e) Aristotelian cosmology

19. In modern times (which here we mean to be after circa 1450), who first proposed the heliocentric theory of the solar system?

    a) Nicolaus Copernicus (1473–1543). b) Thomas Digges (c. 1546–1595).
    c) Tycho Brahe (1546–1601). d) Galileo Galilei (1564–1642).
    e) Isaac Newton (1643–1727).

20. The Aristotelian and Ptolemaic cosmologies were:

    a) mutually **COMPLETELY CONSISTENT**. Together they gave a reasonable explanation of celestial phenomena. In the Medieval Islamic and European cultures, they were regarded as totally satisfactory. The heliocentric model of Copernicus was introduce only due to Copernicus' personal eccentricity. He merely made a lucky guess.

    b) **ABANDONED** almost as soon as they were proposed. In the Medieval Islamic and European cultures, no theoretical interpretation was put on celestial phenomena at all. The prediction of celestial events was done entirely using Babylonian cycles.

    c) were largely accepted during in the Medieval Islamic and European cultures despite their **PARTIAL INCONSISTENCY** and their lack of any definite size scale or ordering for the planets. Occasional attempts to improve these cosmologies came to little. The Copernican theory was a **RADICAL ALTERNATIVE**.

    d) were largely accepted during in the Medieval Islamic and European cultures despite their **PARTIAL INCONSISTENCY** and their lack of any definite size scale or ordering for the planets. Occasional attempts to improve these cosmologies came to little. The Copernican theory was **NOT A RADICAL ALTERNATIVE**. It was completely consistent with Aristotelean physics and even kept epicycles.

    e) were largely accepted during in the Medieval Islamic and European cultures despite their **PARTIAL INCONSISTENCY** and their lack of any definite size scale or ordering for the planets. Occasional attempts to improve these cosmologies **ALWAYS SUCCEEDED** in making their quantitative predictions much more accurate. The Copernican theory was only the lucky last of these attempts. Sheer bias kept the Aristotelean and Ptolemaic cosmologies dominant until then.

21. A key reason (perhaps the most important reason) that led Copernicus to propose the heliocentric solar system was to:

    a) get rid of uniform circular motion.
    b) appease the Sun god.
    c) answer Galileo's insult.
    d) get a prediction of the relative positions of the planets.
    e) prove that the universe was infinite.

22. Apparent retrograde motion is:

    a) the **westward** motion of a **star** on the sky.
    b) the **westward** motion of a **planet** on the sky.
    c) the **eastward** motion of a **planet** on the sky.
    d) the **eastward** motion of a **star** on the sky.
    e) the result of an inter-planetary collision.

23. "Let's play *Jeopardy*! For \$100, the answer is: He/she discovered that the planets orbited the Sun in elliptical orbits."

    Who is ____________, Alex?

    a) Apollonios of Perga (circa 3rd century BCE) b) Nicolaus Copernicus (1473–1543)
    c) Johannes Kepler (1571–1630) d) Galileo Galilei (1564–1642)
    e) Caroline Herschel (1750–1848)

24. Kepler's three laws of planetary motion:

    a) **PROVED** the Copernican theory. But this was not immediately realized because it was difficult to master the mathematical techniques and data needed to verify the three laws.
    b) were partially empirical discoveries made by analyzing Tycho's data. The laws were inconsistent with the Tychonic model, and hence **PROVED** the Copernican model.
    c) were partially empirical discoveries made by analyzing Tycho's data. The laws were consistent geometrically with both the Tychonic and Copernican theories. Thus they were **INSUFFICIENT** by themselves to prove the Copernican theory. Nevertheless, since the Earth fit so well as a planet obeying the three laws and was so exceptional as the center of the solar system (given the three laws), an unbiased person might well have said that the three laws strongly favored the Copernican theory.
    d) were partially empirical discoveries made by analyzing Tycho's data. The laws were consistent geometrically with both the Tychonic and Copernican theories. Thus they were **SUFFICIENT** by themselves to prove the Copernican theory.
    e) were partially empirical discoveries made by analyzing Tycho's data. The laws were consistent geometrically with both the Tychonic and Copernican theories. Thus they were **SUFFICIENT** by themselves to prove the Copernican theory. Realizing this Kepler **SUPPRESSED** them for term of his life.

25. According to Kepler's 3rd law, the orbital period of a planet (i.e., the planet's year) depends on planet:

    a) mass. b) diameter. c) distance from Sun. d) color. e) axis tilt.

26. Kepler's 3rd law for the solar system planets can be conveniently written

$$P_{\text{year}} = A_{\text{AU}}^{3/2} \qquad \text{or, less conveniently,} \qquad P_{\text{year}}^2 = A_{\text{AU}}^3 \ ,$$

    where P_{year} is the orbital period in Earth years and A_{AU} is the mean Sun-planet distance in astronomical units (AU) (i.e., in mean Sun-Earth distances). If an asteroid is 9 AU from the Sun, what is its orbital period in years?

    a) 9. b) 3. c) 27. d) 729. e) 1.

27. If a planet has a mean distance from the Sun of 9 astronomical units, what is its orbital period in years?

    a) 28 years. b) 3 years. c) 9 years. d) 81 years. e) 27 years.

28. Galileo's discovered that Venus showed a full set of phases like the Moon. But it was already known since Antiquity that Venus is never opposite the Sun on the sky and in fact is never further than 46° degrees from the Sun. Thus, Galileo's discovery proved:

    a) Venus orbited the Earth.
    b) Venus orbited the Moon.
    c) Venus orbited the Sun.
    d) Venus executed an orbit about an empty point in space that always lies between the Earth and Sun on the Sun-Earth line.
    e) Venus is falling into the Sun perpetually.

29. Galileo did **NOT** discover:

    a) the four largest moons of Jupiter. b) the phases of Venus. c) the moons of Mars. d) sunspots. e) the mountainous surface of the Moon.

30. Galileo's discovery of the moons of Jupiter:

    a) had no bearing on the debate over the Copernican theory.
    b) meant that the Earth was the center of Jupiter's orbit.
    c) explained the phases of Venus.
    d) meant that the Earth was not the physical center of all motion in the solar system, and that Earth could have a moon and still be on an **EPICYCLE**.
    e) meant that the Earth was not the physical center of all motion in the solar system, and that Earth could have a moon and still be a **PLANET**.

31. From his observations of Saturn in 1610, Galileo's discovered:

    a) that Saturn had an obvious ring.
    b) that Saturn had odd protuberances, but he couldn't make out what they were. Christiaan Huygens later in the **17TH CENTURY** concluded that Saturn had a ring.
    c) that Saturn had odd protuberances, but he couldn't make out what they were. Christiaan Huygens later in the **20TH CENTURY** concluded that Saturn had a ring.
    d) that Saturn had 3 obvious rings that he labled A, B, and C.
    e) that Saturn's rings, which are visible to the naked eye were green.

32. Galileo's telescopic discoveries:

    a) **PROVED** Copernicanism absolutely. Resistance to this proof was simply irrational.
    b) proved that the ancients had been wrong about the cosmos and that they had not had all the evidence. But Kepler's laws had already **PROVEN** Copernicanism to all the mathematically-minded including Galileo. Not everyone had accepted these proofs, of course. Soon—but not soon enough for Galileo—they would.
    c) proved that the ancients had been wrong about the cosmos and that they had not had all the evidence. Now Tycho's demonstrations that the heavens were mutable and the crystalline spheres had no existence in a strong sense had already proved some of the ancient beliefs wrong. And Kepler's first two laws, published 1609 just a year before the telescopic discoveries were published in 1610, were so much better descriptions—that is they were more accurate, more unique, and simpler (with a certain interpretation of "simpler" of course)—that they made the ancient descriptions seem implausible. But Tycho's work and Kepler's work (at least prior to the publication of the *Rudolphine Tables* [1627]) was **NOT EASILY VERIFIABLE** by anyone else. The telescopic discoveries could be verified fairly easily (some very easily) by anyone and no expertise with mathematical astronomy was needed. Thus, the telescopic discoveries tore the mask from the cosmos (well a bit anyway) and opened minds to new ideas, even Copernicanism.
    d) proved that the ancients had been wrong about the cosmos and that they had not had all the evidence. Now Tycho's demonstrations that the heavens were mutable and the crystalline spheres had no existence in a strong sense had already proved some of the ancient beliefs wrong. And Kepler's first two laws, published 1609 just a year before the telescopic discoveries were published in 1610, were so much better descriptions—that is they were more accurate, more unique, and simpler (with a certain interpretation of "simpler" of course)—that they made the ancient descriptions seem implausible. But Tycho's work and Kepler's work had been mostly ignored because they were **BOTH COPERNICANS** when Copernicanism was still considered to be **COMPLETELY DISCREDITING**. The telescopic discoveries, on the other hand had been made by a Copernican whose Copernicanism was still secret (a closet Copernican), and therefore were generally taken as being well founded. Thus, the telescopic discoveries tore the mask from the cosmos (well a bit anyway) and opened minds to new ideas, even Copernicanism.
    e) were completely irrelevant to the debate over Copernicanism. The fact that they were made at about the same time that Copernicanism became a hot topic is a historical coincidence.

33. Newtonian physics unified:

    a) thermodynamics and special relativity. b) terrestrial and celestial physics. c) terrestrial and substantial physics. d) terrestrial and Martian physics. e) talking and walking physics.