

## Answers – Cosmological Models Homework

1.
  - a. Mars is brightest at opposition – it is nearest to Earth and fully illuminated, being opposite the Sun from our perspective.
  - b. Mars is moving retrograde at each opposition – this is when faster moving Earth “passes” between slower moving Mars and the Sun.
  - c. Jupiter, Saturn, and any other planet farther from the Sun behaves the same way. Mercury and Venus do not.
2.
  - a. All planets undergo conjunction.
  - b. Mercury and Venus do not undergo opposition, all other planets do reach opposition.
  - c. Mercury has smallest range of elongation, staying nearest to the Sun (within 28°).
  - d. The farther from the Sun the smaller the retrograde loop – for naked eye planets this would be Saturn.
3. Mercury and Venus never reach opposition and are always found close to the Sun. Mercury and Venus undergo retrograde motion at every other conjunction, whereas other planets never move retrograde at conjunction. Mercury and Venus are brightest at a point other than opposition, whereas other planets are always brightest at opposition.
4.
  - a. Midnight or 12 am, being opposite the Sun, the planet is highest when Sun is lowest.
  - b. Noon or 12 pm, being adjacent the Sun, the planet is highest when Sun is highest.
  - c. Sunrise or 6 am, being west of the Sun, it is high in the sky when Sun is on east horizon.
5.
  - a. Full Moon is “at opposition”, opposite the Sun.
  - b. New Moon is “at conjunction”, adjacent the Sun.
  - c. First quarter Moon is 90 degrees east of the Sun.
6. The geocentric model has earth at rest in the precise center of a series of heavenly spheres. Each sphere was thought to contain a particular celestial phenomenon (Sun, Moon, Mars, stars, etc). It is difficult to explain retrograde motion with this arrangement. Also it is difficult to explain variance in speed, size, and brightness of the various celestial bodies.
7. The most essential flaw of the Ptolemaic model is that it has Earth at the center and Sun in motion around the Earth. Another problem is the necessity for epicycles, which are now known not to exist.
8.
  - a. Deferents modeled the prograde or direct motion of various objects.
  - b. Epicycles accounted for retrograde motion of planets but also served to explain changes apparent speed and brightness of planets, Sun, and Moon.
9. Copernicus gave mankind the correct perspective of our true place in the universe – the fact that we are not at the center and that Earth is actually just a particular planet among other planets. A flaw of Copernicus was use of and epicycles – not for explaining retrograde, but rather for the necessary precision predicting and explaining apparent brightness and speed of various objects.
10. The Copernican Principle holds that Earth does not hold a special place in the universe by any measure. Put another way, any observation that seems to indicate that our circumstance in the universe is unique or special is likely to be wrong.
11.
  - a. Although planets had not been detected prior to 1995, astronomers were quite certain that other stars would have planetary systems similar to the Sun. To think otherwise violates the Copernican principle because the Sun and our local “neighborhood” would be unique.
  - b. Scientists expect that there is bound to be a planet similar to Earth with life similar to

Earth. If this were not the case it would seem Earth *does* occupy a unique and special place, contradictory to the Copernican principle.

12. Galileo confirmed the views of Copernicus and refuted the ancient Greeks by observing: Sunspots and rotation of the Sun, indicated it is not a perfect sphere; Earth-like features on the Moon (such as mountains, craters, etc.) revealed it to be another world, not a “heavenly body”; Moons orbiting Jupiter showed that there is not a common center to all spheres and motion and that not everything orbits the Earth; Phases of Venus, including a gibbous phase, showed that it travels to the side of the Sun opposite that from Earth. This last observation directly contradicted Ptolemy’s Almagest model (which if true would mean that Venus would always be crescent). (So much for “the Greatest”!)
13. a. 110 km  
b. 44,000 km  
c. 350,000 km
14. Tycho contributed to Kepler’s Laws by the accurate observations of planets, stars, etc. He basically provided Kepler with the “raw data” that he needed to formulate the 3 laws of planetary motion.
15. a. 0.983 A.U. and 1.017 A.U.  
b. 1.382 A.U. and 1.666 A.U.
16. 0.69 A.U. farther
17. 4.7 years
18. 2.52 A.U.
19. a. 0.645 A.U.  
b. 1.09 A.U.  
c. 0.518 yrs.
20. a. 3.0 A.U.  
b. 0.33  
c. 5.2 yrs.
21. 35.2 A.U.
22. 0.17 A.U.
23. Urradius is 2.08 times farther
24. 106 Gm
25. By measuring distance from Earth to Venus or Earth to Mars a conversion factor from AU to meters can be determined. Kepler had already worked out dimensions of the orbits in terms of 1 AU.
26. The baseball attracts the Earth with just as much force as Earth attracts the baseball, but the acceleration of the Earth toward the baseball is much, much, much less than the falling baseball because the Earth’s mass is so great. Because acceleration is inversely proportional to mass as stated in the 2<sup>nd</sup> Law the Earth accelerates almost zero toward the ball.
27. a. If gravity switched off the Earth would fly off into space on a line tangent to its orbit.  
b. The effect of the Sun’s gravity is to cause the Earth’s direction of travel to change – *i.e.* it causes Earth to turn and follow a curved path instead of a straight one.
28. Because Venus is closer to the Sun, according to the Law of Gravitation there is more force pulling it inward. As the mass is equal to that of Earth it must therefore have more acceleration toward the Sun. This means that it turns more rapidly toward the Sun and curves more. If it were not moving faster it would be pulled much nearer the Sun instead of orbiting in a quite circular path.

29. A comet headed away from the Sun is being affected by the Sun's gravity and as a result its speed away from the Sun decreases. However, its inertia (its tendency to maintain its state of motion) causes it to continue to move away from the Sun.
30. a. As a planet moves from aphelion to perihelion the force of gravity is pulling it at least somewhat in the same direction that it is moving and so its speed increases continuously until it reaches perihelion.
31. Kepler's 1<sup>st</sup> Law was modified to state that the Sun moves in its own much smaller ellipse and in effect follows its own orbit. The Sun and planet move in synchronization about a focus that is shared by each ellipse. Kepler's 3<sup>rd</sup> Law was modified to include the effect of mass. Newton determined that period squared is proportional to semi-major axis cubed and inversely proportional to the total mass of the Sun and planet.
32. An empirical law is based solely on observations and descriptions of noticeable patterns. Kepler's Laws describe in very technical terms what the planets are *observed* to do and what patterns of behavior are noticeable. However, Kepler's laws are missing any theoretical explanation for why the planets behave as they do. Newton's laws give us theories to explain and understand Kepler's laws. His Laws of Motion explain the behavior in terms of mass, force, and acceleration and the Law of Gravitation explains the interaction of the planets with the Sun. However, one could argue that there is an "empirical side" to Newton's Laws because there is no explanation *why* there is such a thing as gravity in the first place or *why* it should follow an inverse square law pattern.