

Chapter 4. Earth, Moon, and Planets

- The Moon’s orbit around the Earth is elliptical, with the orbital plane inclined by 5° relative to the ecliptic plane. The minimum distance of 363,000 km takes place at *perigee*, and the maximum distance of 405,000 km at *apogee*. The angular size of the Moon is about 0.5° . It is noticeable that the angular size of the Moon at perigee is 11% larger than at apogee.
- The Moon does not produce any light. Only the part illuminated by the Sun can shine. As the Moon orbits around the Earth, at different positions in the orbit, the amount of reflected sunlight seen from the Earth vary, producing the *phases of the Moon*.
- Think about the relative locations of the Moon, the Earth, and the Sun at different phases of the Moon.
- The Moon’s spin and the Moon’s orbit around the Earth have the same period, so the Moon always faces the Earth with the same side. The farside of the Moon is often called the “dark side”; however, the farside is fully illuminated by the Sun when we see a new Moon from the Earth.
- The earthlight can illuminate the Moon as well. This is most noticeable during the new Moon phase. *The old Moon in the new Moon’s arms*.
- Eclipses of the Moon – the Moon is in the shadow of the Earth.
Conditions for lunar eclipses – full Moon, Moon near the ecliptic.
- Eclipses of the Sun – the Moon is blocking the Sun.
Conditions for solar eclipses – new Moon, Moon near the ecliptic.
- The diameter of the Moon is so much smaller than the shadow of the Earth that eclipses of the Moon can be either partial or total. However, the angular diameters of the Moon and the Sun are roughly equal, $\sim 0.5^\circ$; at apogee the angular diameter of the Moon is smaller than the angular diameter of the Sun, hence *annular eclipse* of the Sun is possible.
- The duration of an eclipse of the Moon is determined by the orbital speed of the Moon. From entering to leaving the Earth’s shadow, the Moon must travel 1.9° (= angular size of the Earth’s umbral shadow + the Moon’s angular diameter), and this takes about 3.7 hours.
- The duration of an eclipse of the Sun is determined by the Moon’s orbital speed minus the Earth’s spin speed. The umbral shadow of the Moon is only ~ 269 km during a total eclipse. An eclipse of the Sun lasts only ~ 7 min at one position.
- All planets, except Pluto, orbit around the Sun near the ecliptic. The planets closer to the Sun orbits faster than the planets at larger distances.
- Superior planets show retrograde motion near oppositions.
- Inferior planets go through phases like the Moon.

- Ptolemaic system was geocentric, with the world revolving around the Earth. To explain the retrograde motions, planets are assumed to move in epicycles along their orbits around the Earth.
- Six great astronomers who revolutionized our concept of the Universe:
 - (1) Nicolaus Copernicus (1473-1543); proposed heliocentric system, measured distances from planets to the Sun.
 - (2) Tycho Brahe (1546-1601); great observer; cataloged 777 stars, recorded motions of planets.
 - (3) Johannes Kepler (1571-1630); great interpreter; used Tycho's data to find his laws of planetary motion, discovered elliptical orbits of planets.
 - (4) Galileo Galilei (1564-1642); used telescopes to resolve features on the Moon and the planets, confirmed heliocentric system.
 - (5) Issac Newton (1642-1727); use *gravity* to explain the planetary motion, co-invented calculus, and found laws of motion.
 - (6) Albert Einstein (1879-1955); founded theory of *relativity*, improved Newton's theory of gravity.
- Kepler's three laws of planetary motion: law of ellipses, equal-area law, and harmonic law.
- Inequality of seasons is a direct derivative of Kepler's equal-area law. The Earth is at perihelion near the winter solstice; the faster orbital speed at perihelion makes the winter in the northern hemisphere 4 days shorter than the summer.