جمهورية العراق
وزارة التعليم العالي و البحث العلمي
جامعة بغداد
كلية العلوم
قسم الفلك و الفضاء

محاضرات علمية لمادة أساسيات الفلك / Fundamentals of Astronomy

المرحلة الأولى / قسم الفلك والفضاء

العام الدراسي 2023-2024

الفصل الدراسي الأول

مدرس المادة

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Lecture One

Fundamentals of Astronomy

The Birth of Modern Science

Copernican Revolution

Is the name given to the astronomical model developed by NICHOLAS COPERNICUS which published in 1543. The theory of planetary motions proposed by NICHOLAS COPERNICUS in which all planets(including Earth) move in circular orbits around the Sun, with the planets closer to the Sun moving faster see figure 1. Here, for example, when Earth and Mars are relatively close to each other in their respective orbits (as at position 6), Mars seems brighter; when farther away (as at position 1), Mars seems dimmer. Also, because the line of sight from Earth to Mars changes as the two planets smoothly orbit the Sun, Mars appears to loop back and forth, undergoing retrograde motion. The line of sight changes because Earth, on the inside track, moves faster in its orbit than Mars moves along its path.
In this system, the hypothesis of which helped trigger the scientific revolution of the 16th and 17th centuries, Earth was viewed not as an immovable object at the center of the universe (as in the geocentric Ptolemaic system) but rather as a planet orbiting the Sun between Venus and Mars. Early in the 17th century JOHANNES KEPLER showed that while Copernicus's heliocentric hypothesis was correct, the planets actually moved in(slightly) elliptical orbits around the Sun.

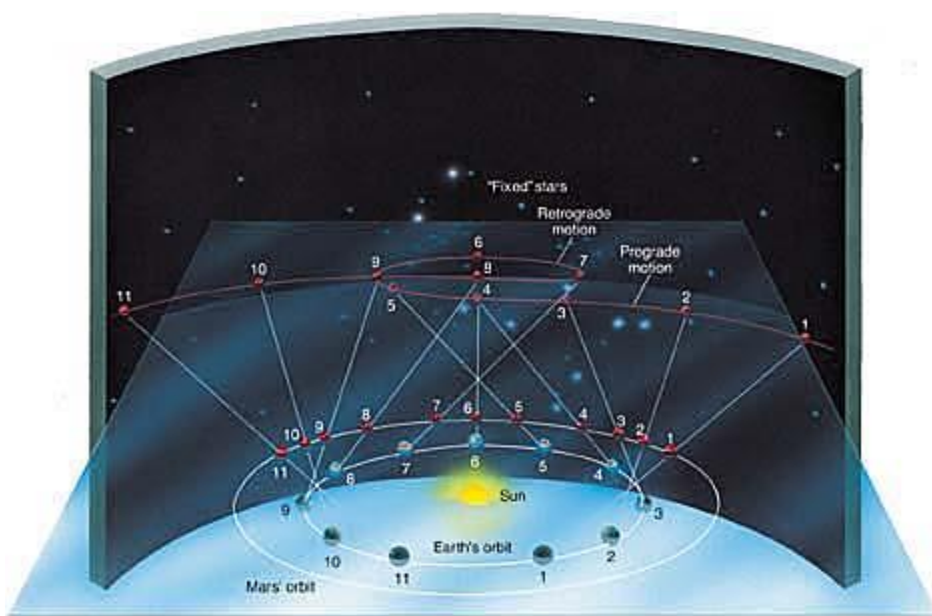


Figure 1 *The Copernican model of the solar system explains the varying brightnesses of the planets.*

Background

- In an early twentieth-century classroom at Radcliffe College, as at other schools, astronomy came into its own as a viable and important subject.
- Harlow Shapley (1885-1972), discovered our place in the "suburbs" of the Milky Way, dispelling the notion that the Sun resides at the center of the universe.
- Annie Cannon (1863-1941), one of the greatest astronomical cataloguers of all time, carefully analyzed photographic plates to classify nearly a million stars over the course of fifty years of work at Harvard.
- Maria Mitchell (1818-1889) in her observatory on Nantucket Island, made important contributions to several areas of astronomy.
- Edwin Hubble (1889-1953), here posing in front of one of the telescopes on Mount Wilson, in California, is often credited with having discovered the expansion of the universe.

LEARNING GOALS

- Explain how the observed motions of the planets led to our modern view of a Sun-centered solar system.
- Sketch the major contributions of Galileo and Kepler to the development of our understanding of the solar system.
- State Kepler's laws of planetary motion.
- Explain how Kepler's laws enable us to construct a scale model of the solar system, and explain the technique used to determine the actual size of the planetary orbits.
- State Newton's laws of motion and universal gravitation and explain how they account for Kepler's laws.

L*iving in the Space Age, we have become accustomed to the modern view of our place in the universe. Images of our planet taken from space leave little doubt that Earth is round, and no one seriously questions the idea that we orbit the Sun. Yet there was a time, not so long ago, when our ancestors maintained that Earth was flat and lay at the center of all things. Our view of the universe? and of ourselves—has undergone a radical transformation since those early days. Earth has become a planet like many others, and humankind has been torn from its throne at the center of the cosmos and relegated to a rather unremarkable position on the periphery of the Milky Way Galaxy. But we have been amply compensated for our loss of prominence—we have gained a wealth of scientific knowledge in the process. The story of how all this came about is the story of the rise of the scientific method and the genesis of modern astronomy.*

Ptolemaic system: in the second century C.E. PTOLEMY, assembling and synthesizing all of early Greek astronomy, published the first widely recognized cosmological model, often referred to as the Ptolemaic system.

In this geocentric cosmology model Ptolemy codified the early Greek belief that Earth was at the center of the universe and that the visible planets (Mercury,Venus, Mars, Jupiter, and Saturn) revolved around Earth embedded on crystal spheres. The "fixed" stars appeared immutable (essentially unchangeable)—save for their gradual motions through the sky with the seasons—so they were located on a sphere beyond Saturn's sphere. While seemingly silly in light of today's scientific knowledge, this model could and did conveniently account for the motion of the planets then visible to the naked eye. Without detailed scientific data to the contrary, Ptolemy's model of the universe survived for centuries. Arab astronomers embraced and enhanced Ptolemy's work.

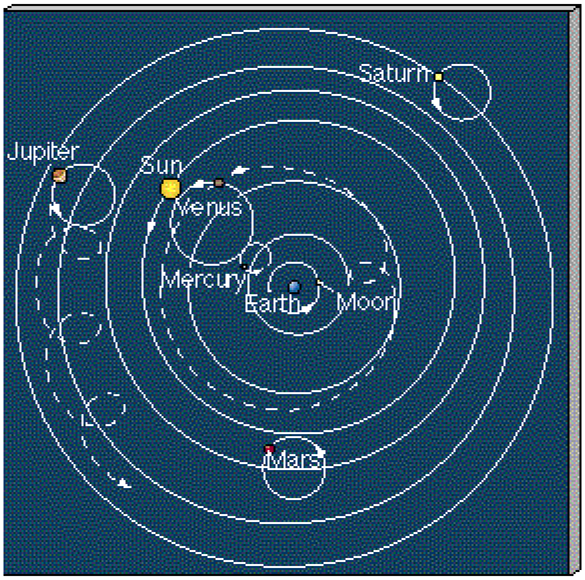


Figure 1*(geocentric model of Ptolemy) The basic features, drawn roughly to scale, of the geocentric model of the inner solar system that enjoyed widespread popularity prior to the Renaissance*

Galileo Galilei: was in many ways the first "modern" astronomer. He used emerging technology, in the form of the telescope, to achieve new insights into the universe. The telescope was invented in Holland in the early seventeenth century. Hearing of the invention, Galileo built a telescope for himself in 1609 and aimed it at the sky. What he saw conflicted greatly with the philosophy of Aristotle and provided much new data to support the ideas of Copernicus. Using his telescope, Galileo discovered that the Moon had mountains, valleys, and craters—terrain in many ways reminiscent of that on Earth. Looking at the Sun (something that should never be done directly, and which eventually blinded Galileo), he found imperfections—dark blemishes now known as sunspots. Furthermore, by noting the changing appearance of these sunspots from day to day, he inferred that the Sun rotates, approximately once per month, around an axis roughly perpendicular to the ecliptic plane. In studying the planet Jupiter, Galileo saw four small points of light, invisible to the naked eye, orbiting it, and realized that they were moons. To Galileo, the fact that another planet had moons provided the strongest support for the Copernican model; clearly, Earth was not the center of all things. He also found that Venus shows a complete cycle of phases, like those of our Moon, a finding that could be explained only by the planet's motion around the Sun. These observations were further strong evidence that Earth is not the center of the solar system, and that at least one planet orbited the Sun. Galileo published his findings, and his controversial conclusions supporting the Copernican theory, in 1610, in a book called Sidereus Nuncius (The Starry Messenger). In reporting these wondrous observations made with his new telescope.

Basic concepts

Universe: The totality of all space, time, matter, and energy.

Astronomy: Branch of science that deals with celestial bodies and studies their size, composition, position, origin, and dynamic behavior. Or **astronomy** branch of science dedicated to the study of everything in the universe that lies above Earth's atmosphere.

Astronomical unit (A.U.) The average distance of Earth from the Sun. Precise radar measurements yield a value for the A.U. of 149,603,500 km.

Arc degree: Unit of angular measure. There are 360 arc degrees in one complete circle.

Black hole: A region of space where the pull of gravity is so great that nothing-not even light-can escape. A possible outcome of the evolution of a very massive star.

Celestial sphere: Imaginary sphere surrounding the Earth, to which all objects in the sky were once considered to be attached.

Constellation: A human grouping of stars in the night sky into a recognizable pattern.

Cosmology: The study of the structure and evolution of the entire universe.

Galaxy: Gravitationally bound collection of a large number of stars. The Sun is a star in the Milky Way Galaxy.

Light year: The distance that light, moving at a constant speed of 300,000 km/s, travels in one year. One light year is about 10 trillion kilometers.

Local Group: The small galaxy cluster that includes the Milky Way Galaxy.

Milky Way Galaxy: The spiral galaxy in which the Sun resides. The disk of our Galaxy is visible in the night sky as the faint band of light known as the Milky Way.

Nebula: General term used for any "fuzzy" patch on the sky, either light or dark.

Planet: One of nine major bodies that orbit the Sun, visible to us by reflected sunlight.

Solar system: The Sun and all the bodies that orbit it—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, their moons, the asteroids, and the comets.

Star: A glowing ball of gas held together by its own gravity and powered by nuclear fusion in its core.

Telescope: Instrument used to capture as many photons as possible from a given region of the sky and concentrate them into a focused beam for analysis.

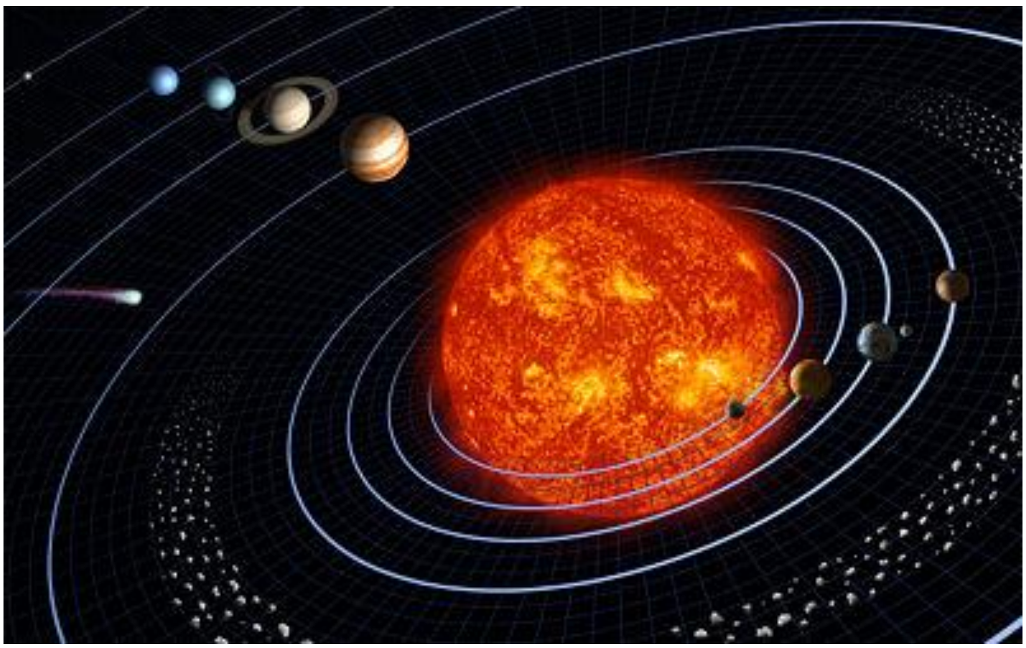
Visible light: The small range of the electromagnetic spectrum that human eyes perceive as light. The visible spectrum ranges from about 400 to 700 nm, corresponding to blue through red light.

Zodiac: The twelve constellations through which the Sun moves as it follows its path on the ecliptic.

Lecture Two

The Solar system 1

The **Solar System** consists of the Sun and the other celestial objects gravitationally bound to it: the eight planets, their 166 known moons, three dwarf planets (Ceres, Pluto, and Eris and their four known moons), and billions of small bodies. This last category includes asteroids, Kuiper belt objects, comets, meteors, meteorites, and interplanetary dust.



Major features of the Solar System; sizes and distances not to scale. From left to right): Pluto, Neptune, Uranus, Saturn, Jupiter, the asteroid belt, the Sun, Mercury, Venus, Earth and its Moon, and Mars. A comet is also seen on the left.

In broad terms, the charted regions of the Solar System consist of the Sun, four terrestrial inner planets, an asteroid belt composed of small rocky bodies, four gas giant outer planets, and a second belt, called the Kuiper belt, composed of icy objects. Beyond the Kuiper belt is the scattered disc, the heliopause, and ultimately the hypothetical Oort cloud.

☉ The Sun

Diameter: 1 392 530 km
Average distance from Earth: 149 597 900 km
Period of rotation: 25 days at the equator;
35 days at the poles
Planets: 8
Dwarf planets: 4

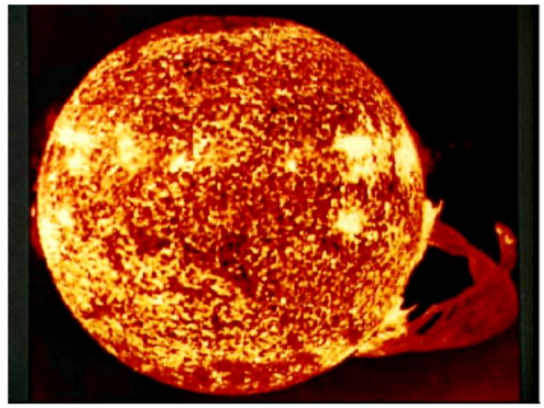


Photo courtesy NASA

With a diameter of 1 392 530 km, the Sun is a huge ball of gas which contains 99% of all the mass in the solar system. It has 333 000 times the mass of the Earth and is composed of 92% hydrogen, 7.8% helium and less than 1% heavier elements. It is the source of all the light, heat and energy that is necessary to create and sustain life on the Earth. Like the planets, the Sun rotates on its axis, but due to its gaseous nature different parts rotate at different rates. This is known as differential rotation. The equator rotates fastest, in a period of 25 days while the poles rotate the slowest at 35 days.

The Sun’s structure

1- The Core: At the centre and extending out to about a quarter of the Sun’s radius, is the core. Temperatures within the core are approximately 15 million degrees and it is here that all the energy of the Sun is created.

2- The Radiative Zone: Outside the core and extending out to within 140 000 km of the Sun’s surface. In this region the intense energy from the core is radiated outwards through a complex process of individual atoms absorbing and then re-emitting the energy at longer wavelengths which have less energy.

3- The Convective Zone: Surrounding the radiative zone. The difference in temperature from the bottom to the top of this zone means that energy is transported to the surface in giant convection cells. Convection involves the overturning of hot gases, that is, the hot gases from the bottom rise to the top layer where they cool and sink back to the bottom again to repeat the cycle.

4- The photosphere: possibly only about 200 km thick. The photosphere is the ‘surface’ that we see and is the source of all the visible light. It has a temperature of about 6000 °C.

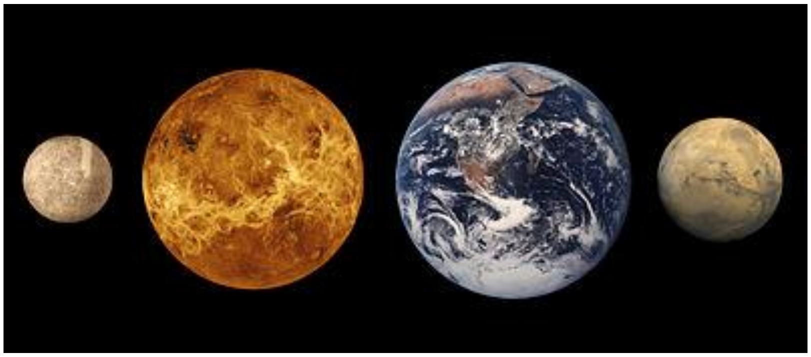
5- The chromospheres: (colour sphere). The thickness of this reddish-pink layer varies, reaching up to 30 000 km in places. It is most easily seen during solar eclipses when the Moon covers the Sun. The temperature ranges from 4200 °C at the lower edge of the sphere to about 1 000 000 °C at its higher edge.

Inner Solar System

The inner Solar System is the traditional name for the region comprising the terrestrial planets and asteroids. Composed mainly of silicates and metals, the objects of the inner Solar System huddle very closely to the Sun; the radius of this entire region is shorter than the distance between Jupiter and Saturn. This region was, in old parlance, denoted inner space; the area outside the asteroid belt was denoted outer space.

Inner planets

The four inner or terrestrial planets have dense, rocky compositions, few or no moons, and no ring systems. They are composed largely of minerals with high melting points, such as the silicates which form their solid crusts and semi-liquid mantles, and metals such as iron and nickel, which form their cores. Three of the four inner planets (Venus, Earth and Mars) have substantial atmospheres; all have impact craters and tectonic surface features such as rift valleys and volcanoes. The term *inner planet* should not be confused with *inferior planet*, which designates those planets which are closer to the Sun than Earth is (i.e. Mercury and Venus).



The inner planets. From left to right: Mercury, Venus, Earth, and Mars (sizes to scale)

☿ Mercury

Diameter: 4878 km
Average distance from Sun: 58 million km
Orbital period: 88 days
Rotation period: 59 days
Number of known satellites: 0

Photo courtesy NASA

Mercury 0.4 AU (1 Astronomical Unit = 149 597 871 kilometers) is the closest planet to the Sun and the smallest planet (0.055 Earth masses). Mercury has no natural satellites, and its only known geological features besides impact craters are "wrinkle-ridges", probably produced by a period of contraction early in its history. Mercury's almost negligible atmosphere consists of atoms blasted off its surface by the solar wind. Its relatively large iron core and thin mantle have not yet been adequately explained. Hypotheses include that its outer layers were stripped off by a giant impact, and that it was prevented from fully accreting by the young Sun's energy.

♀ Venus

Diameter: 12 104 km
Average distance from Sun: 108 million km
Orbital period: 225 days
Rotation period: 243 days
Number of known satellites: 0

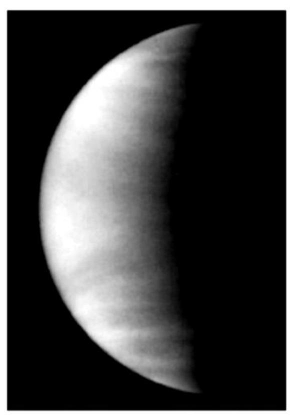


Photo courtesy NASA

Venus (0.7 AU) is close in size to Earth (0.815 Earth masses) and, like Earth, has a thick silicate mantle around an iron core, a substantial atmosphere and evidence of internal geological activity. However, it is much drier than Earth and its atmosphere is ninety times as dense. Venus has no natural satellites. It is the hottest planet, with surface temperatures over 400°C, most likely due to the amount of greenhouse gases in the atmosphere. No definitive evidence of current geological activity has been detected on Venus, but it has no magnetic field that would prevent depletion of its substantial atmosphere, which suggests that its atmosphere is regularly replenished by volcanic eruptions.

⊕ The Earth

Diameter: 12 756 km
Average distance from Sun: 149 597 900 km
Orbital period: 365.256 days (1 year)
Rotation period: 24 hr (1 day)
Number of known satellites: 1 (natural), 7000+ (artificial)

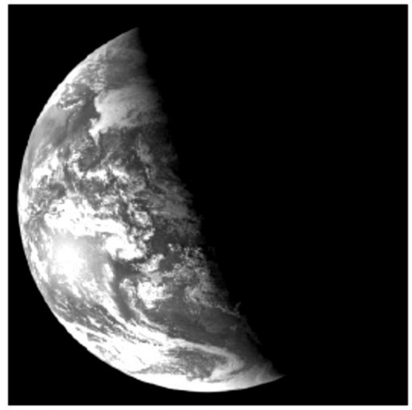


Photo courtesy NASA

Earth (1 AU) is the largest and densest of the inner planets, the only one known to have current geological activity, and the only planet known to have life. Its liquid hydrosphere is unique among the terrestrial planets, and it is also the only planet where plate tectonics has been observed. Earth's atmosphere is radically different from those of the other planets, having been altered by the presence of life to contain 21% free oxygen. It has one satellite, the Moon, the only large satellite of a terrestrial planet in the Solar System.

♂ Mars

Diameter: 6787 km
Average distance from Sun: 228 million km
Orbital period: 687 days
Rotation period: 24 hr 37 min
Number of known satellites: 2

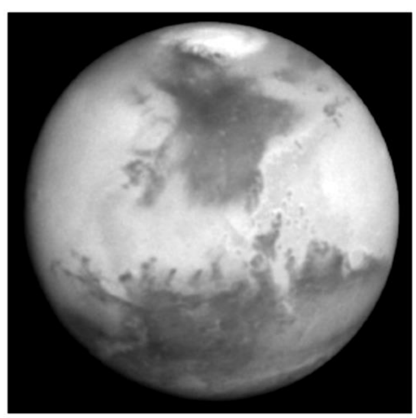


Photo courtesy STScI

Mars (1.5 AU) is smaller than Earth and Venus (0.107 Earth masses). It possesses a tenuous atmosphere of mostly carbon dioxide. Its surface, peppered with vast volcanoes such as Olympus Mons and rift valleys such as Valles Marineris, shows geological activity that may have persisted until very recently. Mars has two tiny natural satellites (Deimos and Phobos) thought to be captured asteroids.

Lecture Three

The Solar System 2

Asteroids

Asteroids are believed to be leftover material from the formation of the solar system. Around 4000 have known orbits but there may be as many as 40 000 strewn between the planets. The majority of asteroids lie between Mars and Jupiter in a region known as the asteroid belt.

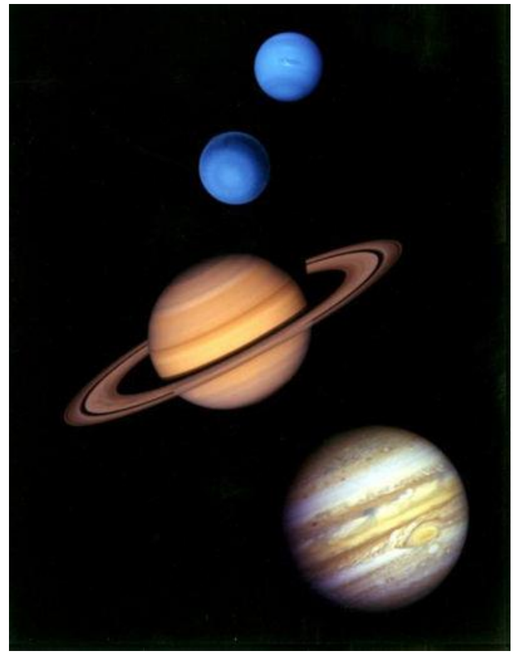
Photo courtesy NASA

Asteroids are mostly small Solar System bodies composed mainly of rocky and metallic non-volatile minerals. The main asteroid belt occupies the orbit between Mars and Jupiter, between 2.3 and 3.3 AU from the Sun. It is thought to be remnants from the Solar System's formation that failed to coalesce because of the gravitational interference of Jupiter. Asteroids range in size from hundreds of kilometres across to microscopic. All asteroids are classified as small Solar System bodies, but some asteroids such as Vesta and Hygieia may be re-classed as dwarf planets if they are shown to have achieved hydrostatic equilibrium. The asteroid belt contains tens of thousands, possibly millions, of objects over one kilometre in diameter.

Mid Solar System

The middle region of the Solar System is home to the gas giants and their planet-sized satellites. Many short period comets, including the centaurs, also lie in this region. It has no traditional name; it is occasionally referred to as the "outer Solar System", although recently that term has been more often applied to the region beyond Neptune. The solid objects in this region are composed of a higher proportion of "ices" (water, ammonia, methane) than the rocky denizens of the inner Solar System.

Outer planets



The four outer planets, or gas giants (sometimes called Jovian planets), collectively make up 99 percent of the mass known to orbit the Sun. Jupiter and Saturn's atmospheres are largely hydrogen and helium. Uranus and Neptune's atmospheres have a higher percentage of “ices”, such as water, ammonia and methane. Some astronomers suggest they belong in their own category, “ice giants.” All four gas giants have rings, although only Saturn's ring system is easily observed from Earth. The term outer planet should not be confused with superior planet, which designates planets outside Earth's orbit (the outer planets and Mars).

♃ Jupiter

Diameter: 142 984 km
Average distance from Sun: 778 300 000 km
Orbital period: 11.86 yrs
Rotation period: 9 hr 55 min
Number of known satellites: At least 63

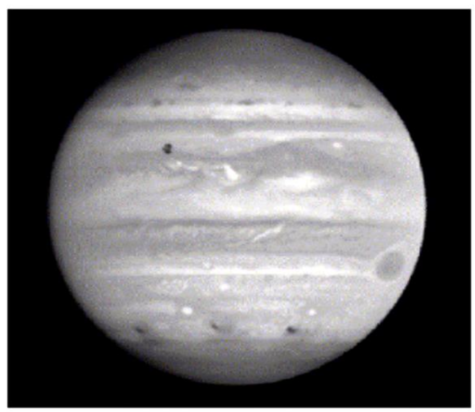


Photo courtesy STScI

Jupiter (5.2 AU), at 318 Earth masses, masses 2.5 times all the other planets put together. It is composed largely of hydrogen and helium. Jupiter's strong internal heat creates a number of semi-permanent features in its atmosphere, such as cloud bands and the Great Red Spot. Jupiter has sixty-three known satellites. The four largest, Ganymede, Callisto, Io, and Europa, show similarities to the terrestrial planets, such as volcanism and internal heating. Ganymede, the largest satellite in the Solar System, is larger than Mercury.

♄ Saturn

Diameter: 120 540 km
Average distance from Sun: 1 429 400 000 km
Orbital period: 29.42 years
Rotation period: 10 hr 40 min
Number of known satellites: 61

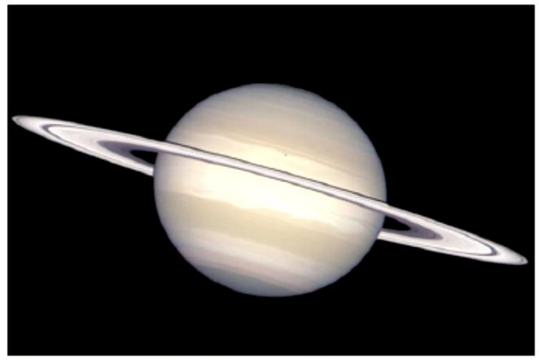


Photo courtesy Hubble heritage Team

Saturn (9.5 AU), famous for its extensive ring system, has similarities to Jupiter, such as its atmospheric composition. Saturn is far less massive, being only 95 Earth masses. Saturn has sixty known satellites (and 3 unconfirmed); two of which, Titan and Enceladus, show signs of geological activity, though they are largely made of ice. Titan is larger than Mercury and the only satellite in the Solar System with a substantial atmosphere.

⛢ Uranus

Diameter: 51 120 km
Average distance from Sun: 2 875 000 000 km
Orbital period: 83.75 years
Rotation period: 17 hr 14 min
Number of known satellites: 27

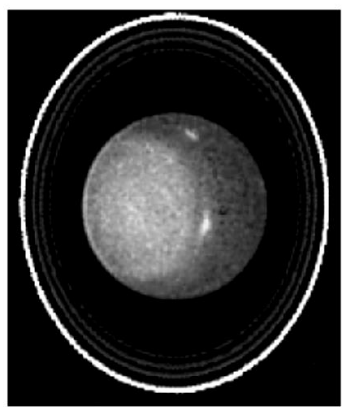


Photo courtesy STScI

Uranus (19.6 AU), at 14 Earth masses, is the lightest of the outer planets. Uniquely among the planets, it orbits the Sun on its side; its axial tilt is over ninety degrees to the ecliptic. It has a much colder core than the other gas giants, and radiates very little heat into space. Uranus has twenty-seven known satellites, the largest ones being Titania, Oberon, Umbriel, Ariel and Miranda.

♆ Neptune

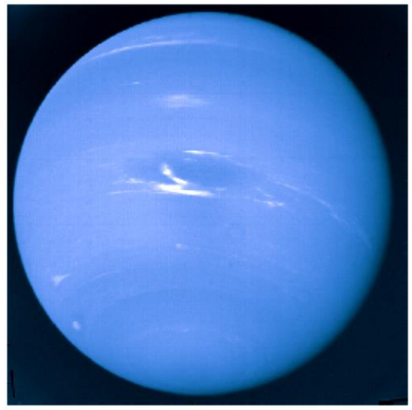


Photo courtesy NASA

Diameter: 49 530 km
Average distance from Sun: 4 504 400 000 km
Orbital period: 163.73 years
Rotation period: 16 hr 7 min
Number of known satellites: 13

Neptune (30 AU), though slightly smaller than Uranus, is more massive (equivalent to 17 Earths) and therefore denser. It radiates more internal heat, but not as much as Jupiter or Saturn. Neptune has thirteen known satellites. The largest, Triton, is geologically active, with geysers of liquid nitrogen. Triton is the only large satellite with a retrograde orbit. Neptune is accompanied in its orbit by a number of minor planets in a 1:1 resonance with it, termed Neptune Trojans.

Pluto and Charon

♇ (134340)Pluto

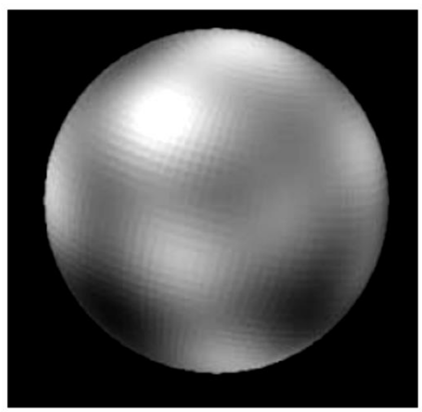
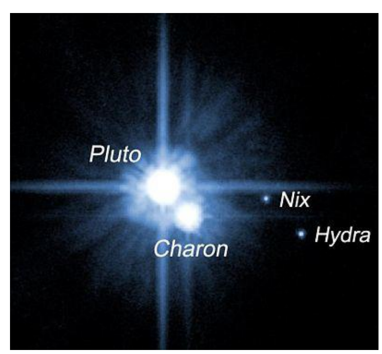


Photo courtesy STScI

Diameter: 2274 km (approx)
Average distance from Sun: 5 915 800 000 km
Orbital period: 248.03 years
Rotation period: 6 days 9 hr 18 min
Number of known satellites: 3

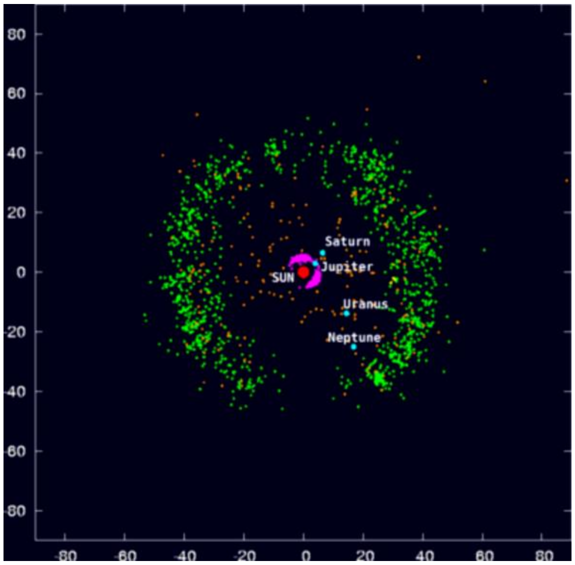


Pluto (39 AU average), a dwarf planet, is the largest known object in the Kuiper belt. When discovered in 1930 it was considered to be the ninth planet; this changed in 2006 with the adoption of a formal definition of planet. Pluto has a relatively eccentric orbit inclined 17 degrees to the ecliptic plane and ranging from 29.7 AU from the Sun at perihelion (within the orbit of Neptune) to 49.5 AU at aphelion. It is unclear whether Charon, Pluto's largest moon, will continue to be classified as such or as a dwarf planet itself. Both Pluto and Charon orbit a barycenter of gravity above their surfaces, making Pluto-Charon a binary system. Two much smaller moons, Nix and Hydra, orbit Pluto and Charon.

Comets

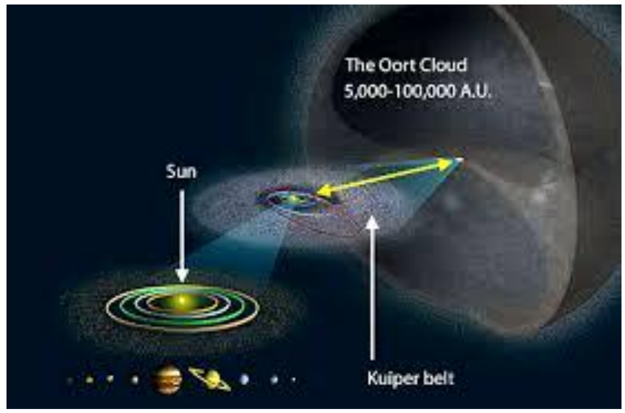
Comets are small Solar System bodies, usually only a few kilometres across, composed largely of volatile ices. They have highly eccentric orbits, generally a perihelion within the orbits of the inner planets and an aphelion far beyond Pluto. When a comet enters the inner Solar System, its proximity to the Sun causes its icy surface to sublimate and ionise, creating a coma: a long tail of gas and dust often visible to the naked eye. Short-period comets have orbits lasting less than two hundred years. Long-period comets have orbits lasting thousands of years. Short-period comets are believed to originate in the Kuiper belt, while long-period comets, such as **Hale-Bopp**, are believed to originate in the Oort cloud. Some comets with hyperbolic orbits may originate outside the Solar System, but determining their precise orbits is difficult.

Kuiper belt



The Kuiper belt, the region's first formation, is a great ring of debris similar to the asteroid belt, but composed mainly of ice. It extends from the orbit of Neptune at 30 AU to approximately 50 AU from the Sun. This region is thought to be the source of short-period comets. It is composed mainly of small Solar System bodies, but many of the largest Kuiper belt objects, such as Quaoar, Varuna, , and Orcus, may be re-classified as dwarf planets. There are estimated to be over 100 000 Kuiper belt objects with a diameter greater than 50 km, but the total mass of the Kuiper belt is thought to be only a tenth or even a hundredth the mass of the Earth. Many Kuiper belt objects have multiple satellites, and most have orbits that take them outside the plane of the ecliptic.

Oort cloud



The hypothetical Oort cloud is a great mass of up to a trillion icy objects that is believed to be the source for all long-period comets and to surround the Solar System at around 50,000 AU, and possibly to as far as 100,000 AU. It is believed to be composed of comets which were ejected from the inner Solar System by gravitational interactions with the outer planets. Oort cloud objects move very slowly, and can be perturbed by infrequent events such as collisions, the gravitational effects of a passing star, or the galactic tide.

Lecture Four

Terrestrial, Celestial and Horizon Coordinate Systems

The position of an observer on the earth's surface can be specified by the terrestrial coordinates, **latitude** and **longitude**. Lines of latitude are imaginary lines which run in an east-west direction around the world (Figure below). They are also called parallels of latitude because they run parallel to each other. Latitude is measured in degrees (°).

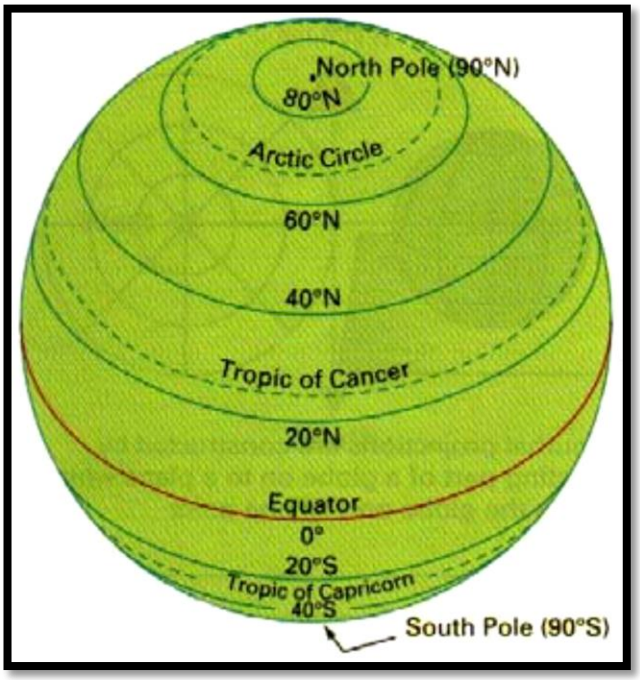


Figure Lines of latitude.

The most important line of latitude is the **Equator** (0°). The North Pole is 90° North (90°N) and the South Pole is 90° South (90°S). All other lines of latitude are given a number between 0° and 90°, either North (N) or South (S) of the Equator. Some other important lines of latitude are the Tropic of Cancer (23.5°N), Tropic of Capricorn (23.5°S), Arctic Circle (66.5°N) and Antarctic Circle (66.5°S).

Lines of longitude are imaginary lines which run in a north-south direction, from the North Pole to the South Pole (Figure below). They are also measured in degrees (°).

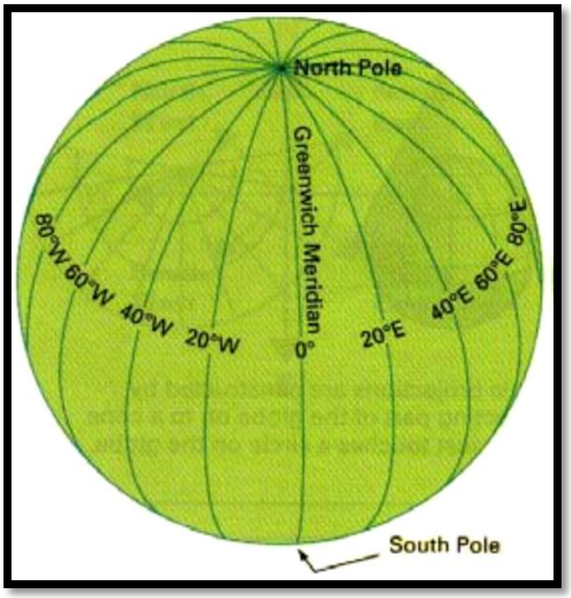


Figure: Lines of longitude.

Any circle on the surface of a sphere whose plane passes through the center of the sphere is called a **great circle**. Thus, a great circle is a circle with the greatest possible diameter on the surface of a sphere. Any circle on the surface of a sphere whose plane does not pass through the center of the sphere is called a **small circle**.

A **meridian** is a great circle going through the geographic poles, the poles where the axis of rotation (polar axis) intersects the earth's surface. The **upper branch** of a meridian is the half of the great circle from pole to pole passing through a given position; the **lower branch** is the opposite half. The equator is the only great circle whose plane is perpendicular to the polar axis. Further the equator is the only parallel of latitude being a great circle. Any other parallel of latitude is a small circle whose plane is parallel to the plane of the equator.

The **Greenwich meridian**, the meridian passing through the Royal Greenwich Observatory in London (closed in 1998), was adopted as the prime meridian at the International Meridian Conference in October 1884. Its upper branch (0°) is the reference for measuring longitudes, its lower branch (180°) is known as the **International Dateline**. All the lines of longitude are given a number between 0° and 180°, either East (E) or West (W) of the Greenwich Meridian.

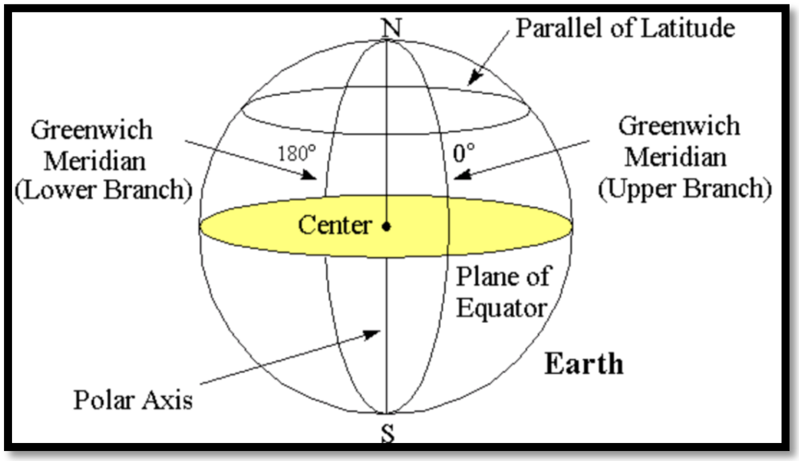


Figure: The Greenwich meridian

Celestial sphere

The **celestial sphere** is an imaginary sphere whose center coincides with the center of the Earth. It represents the entire sky; all celestial bodies other than the earth are imagined as being located on its inside surface. If the earth's axis is extended, the points where it intersects the celestial sphere are called the celestial poles; the **north celestial pole** is directly above the earth's north pole, and the **south celestial pole** is directly below the earth's south pole. The great circle on the celestial sphere halfway between the celestial poles is called the **celestial equator**; it can be thought of as the earth's equator projected onto the celestial sphere figure below.

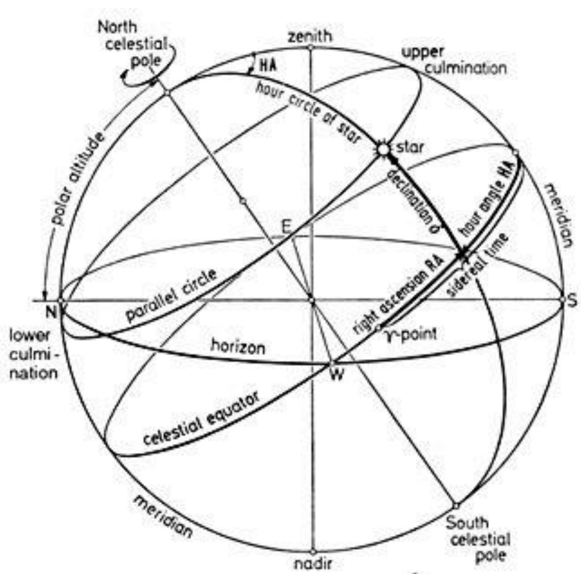


Figure: The celestial sphere

Other Reference Markers on the Celestial Sphere

The earth orbits the sun in a plane called the **ecliptic**. From our vantage point, however, it appears that the sun circle us once a year in that same plane. Hence, the ecliptic may be alternately defined as "the apparent path of the sun on the celestial sphere".

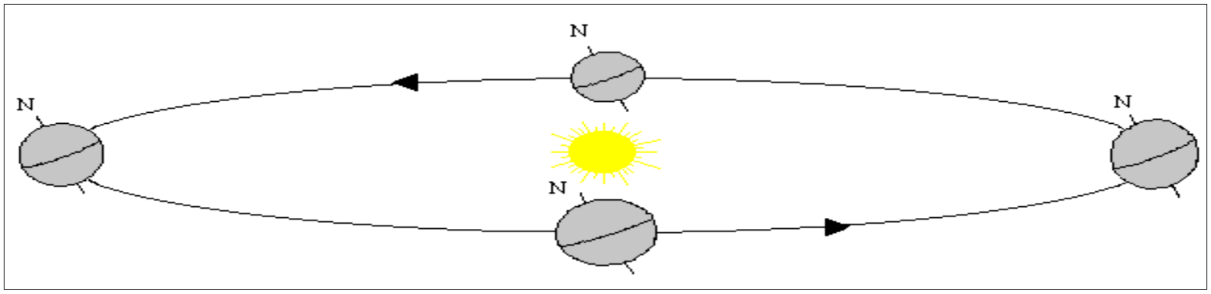
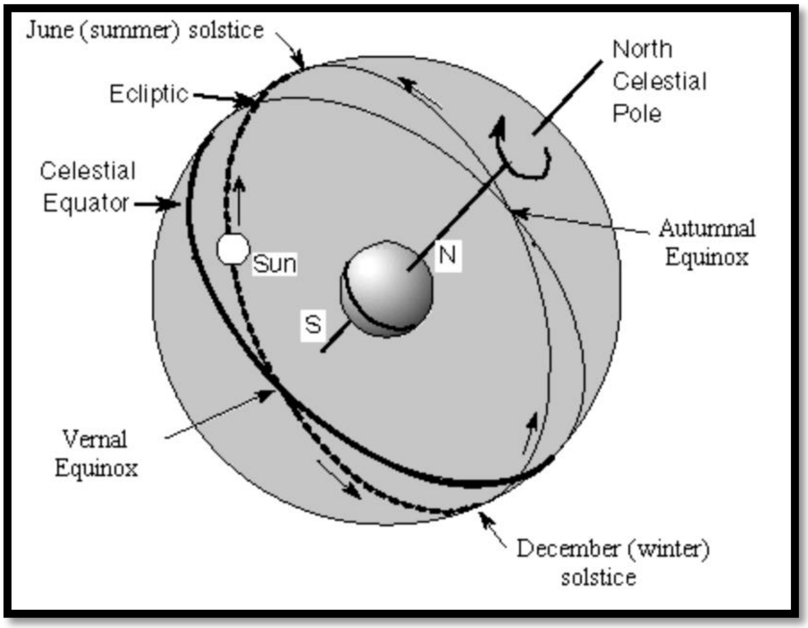


Figure: Earth orbits the sun in an ecliptic plane.

The ecliptic is tilted 23.5 degrees with respect to the celestial equator because the earth's rotation axis is tilted by 23.5 degrees with respect to its orbital plane.

The ecliptic and celestial equator intersect at two points: the **vernal (spring) equinox** and **autumnal (fall) equinox**. The sun crosses the celestial equator moving northward at the vernal equinox around March 21 and crosses the celestial equator moving southward at the autumnal equinox around September 22. When the sun is on the celestial equator at the equinoxes, everybody on the earth experiences 12 hours of daylight and 12 hours of night. The day of the vernal equinox marks the beginning of the three-month season of spring on our calendar and the day of the autumn equinox marks the beginning of the season of autumn (fall) on our calendar.



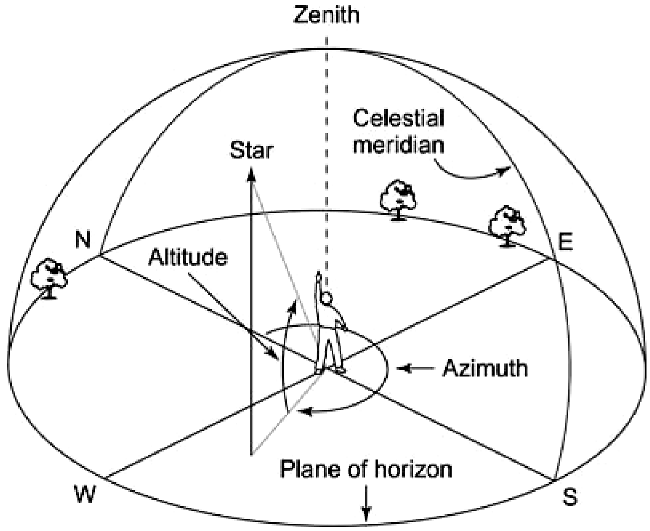


Figure: Horizon System

Chapter Five

The Celestial Coordinate System

The celestial coordinate system is used for indicating the positions of celestial bodies on the celestial sphere.

Equatorial system

To designate the position of a celestial body, consider an imaginary great circle passing through the celestial poles and through the body. This is the body's **hour circle**, analogous to a meridian of longitude on earth. Then measure along the celestial equator the angle between the vernal equinox and the body's hour circle. This angle is called the body's **right ascension (RA)** and is measured in hours, minutes, and seconds rather than in the more familiar degrees, minutes and seconds. (There are 360 degrees or 24 hours in a full circle.) The right ascension is always measured eastward from the vernal equinox.

The relation between the **RA** and the hour angle:

$$RA + H = S_t$$

Where:

The hour angle (H): The angle (measured in a westward direction along the celestial equator) between an observer's meridian and the hour circle of a celestial object. Generally, the hour angle is expressed from 0 to 24 hours in hours, minutes, and seconds.

sidereal time(S_t): Time measured by the rotation of Earth with respect to the stars, which are considered "fixed" in position. Sidereal time may be designated as local or Greenwich, depending on whether the local meridian or the Greenwich meridian is used as the reference.

Next measure along the body's hour circle and the angle between the celestial equator and the position of the body. This angle is called the **declination** (δ) or (Dec) of the body and is measured in degrees, minutes and seconds north or south of the celestial equator, analogous to latitude on the earth.

Right ascension and declination together determine the location of a body on the celestial sphere.

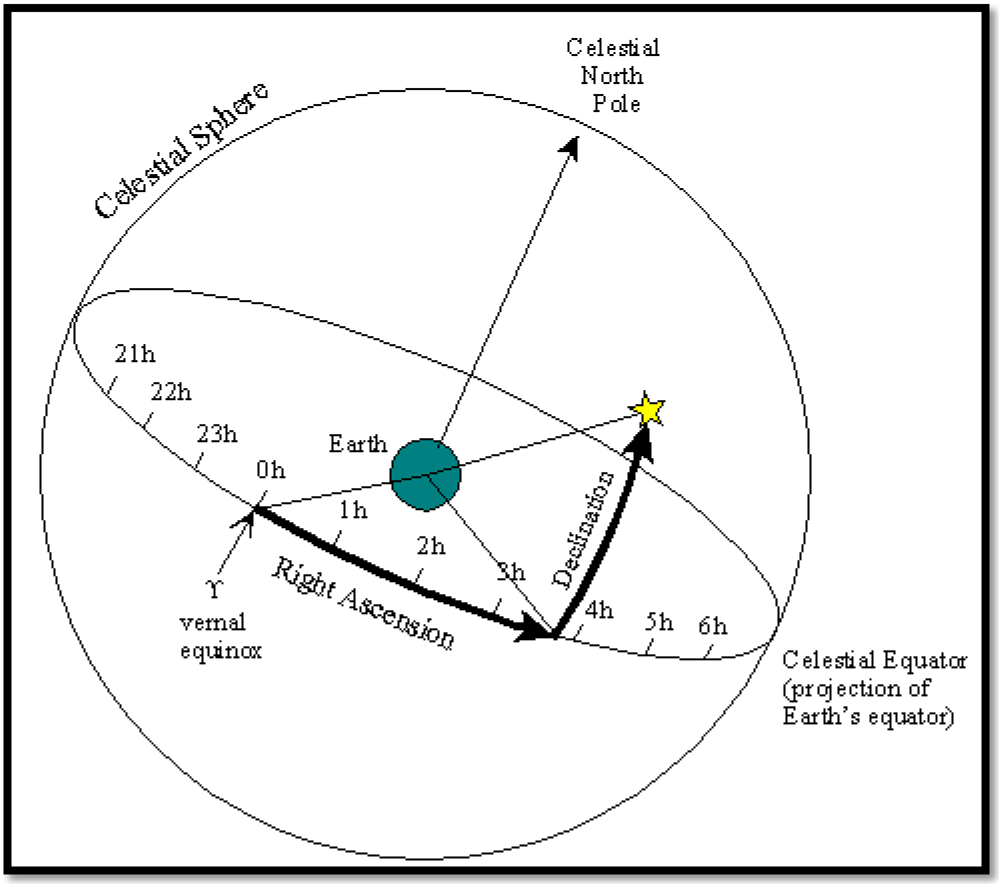


Figure: Equatorial system

Horizon (The Altitude-Azimuth) Coordinate System

The apparent position of a body in the sky is defined by the horizon coordinate system the **altitude**, **a**, is the vertical angle between the horizontal plane to the line of sight to the body. The point directly overhead the observer is called the **zenith**. The **zenith distance**, **z**, is the angular distance between the zenith and the body. **a** and **z** are complementary angles (**a + z = 90°**). The **azimuth**, **A**, is the horizontal direction of the body with respect to the geographic (true) north point on the horizon, measured clockwise through 360°.

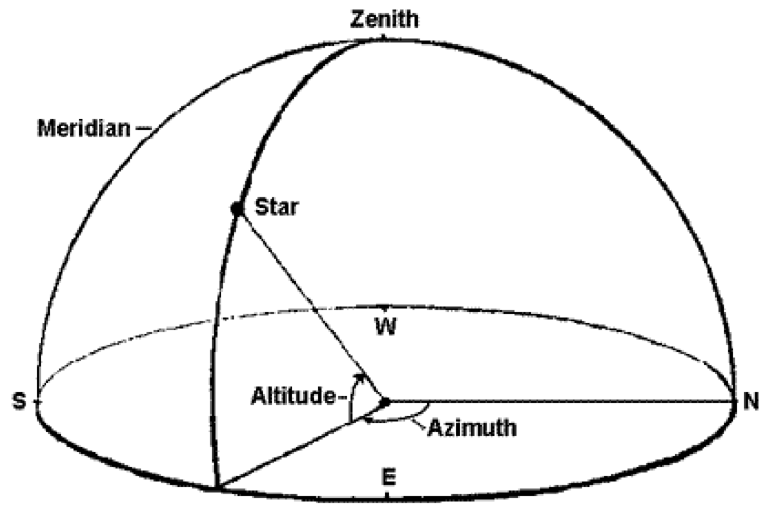


Figure: Horizon system

Transformation between Equatorial and Horizon coordinates:

The transformation from hour angle (H) and declination (δ) to horizon system: azimuth (**A**), zenith distance (**z**)

cos z = cos δ cos φ cos H + sin φ sin δ..................... (1)

Sin δ = cos φ cos A sin z + sin φ cos z……………… (2)

Or

cos A = sin δ – sin φ cos z / cos φ sin z

Where

Dec (δ): the celestial objects declination.

φ: the latitude of observer's position.

Z**:** zenith distance (a=90-z)

H: Hour angle.

A: Azimoth of celestial object.

Example:

A star has a dec. 42 21 N in a region at latitude 60 N, hour angle is 8h 16m 42s , find the following:

1- The star altitude (a)

2- The star Azimuth(A)

Angular Units	Time Units
Deg° , min' , sec"	**Hour ^{h}, min ^{m} , sec ^{s}**
360°	**24 ^{h}**
15°	**1 ^{h}**
1°	**4 ^{m}**
15'	**1 ^{m}**
1'	**4 ^{s}**
15'	**1 ^{s}**

Example:

1- convert 13h 16m to degrees.

Ecliptic system

The orbital plane of the Earth, the ecliptic, is the reference plane of another important coordinate frame. The ecliptic can also be defined as the great circle on the celestial sphere described by the Sun in the course of one year. This frame is used mainly for planets and other bodies of the solar system.

Galactic coordinates system

They describe the position of a celestial object in terms of its galactic latitude and longitude with respect to the galactic equator. *Galactic latitude* (*b*) gives the angular position (0° to 90°) of a celestial object north (considered positive) or south (considered negative) of the galactic equator. The *galactic equator* is the great circle on the celestial sphere that denotes the plane of the Milky Way galaxy. The galactic longitude (*l*) provides a measure of the angular position (0° to 360°) of a celestial object when measured clockwise along the galactic equator, starting from the point that marks the galactic center (or nucleus) of our galaxy (as seen from Earth), which is some 26,000 light-years away in the constellation Sagittarius.

Lecture Six

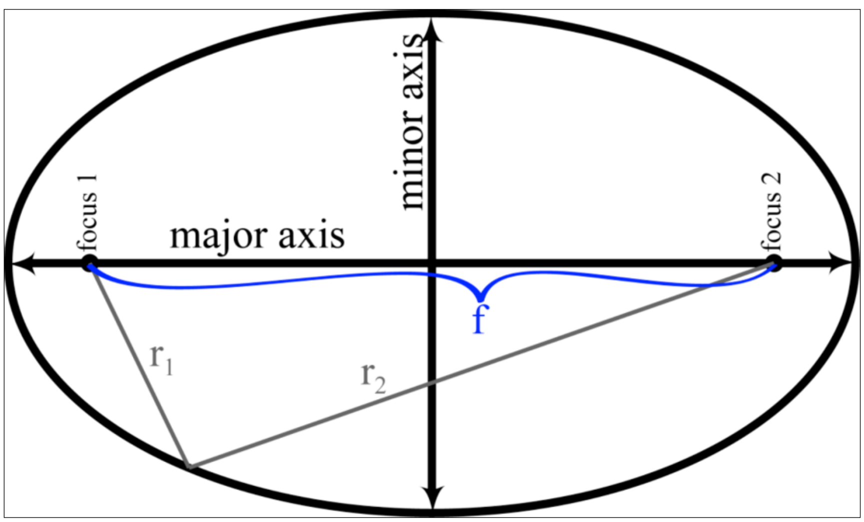
Kepler's Three Laws of Planetary Motion

Johannes Kepler was a German mathematician, astronomer, and astrologer in the 17th century. He used the astronomer Tycho Brahe's detailed observations of the planets develop a mathematical model to predict the positions on the sky of the planets. He published this model as three "laws" of planetary motion.

First Law

1st Law: "The orbit of every planet is an ellipse with the Sun at one of the two foci."

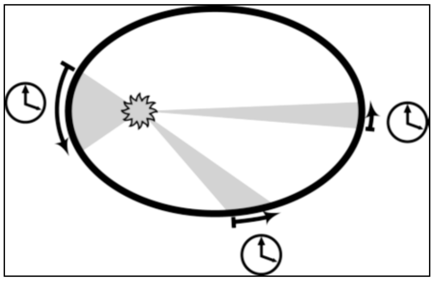
Ellipses are ovals with a long axis (the "major axis") and a short axis (the "minor axis"). More technically, an ellipse is the set of points where the sum of the distances to each of the foci (r^1 and r^2 in Figure 1) is always the same. Sometimes we refer to the semi-major axis, which is just half of the major axis.



The term "eccentricity" refers to how oval-shaped an ellipse is. Eccentricity ranges from 0 for circular orbits to 1 for an orbit so oval-shaped that it is actually just a line. The larger the eccentricity the more oval-shaped (and less circular) the ellipse. The eccentricity, e, separation between foci, f, and the semi-major axis, a, are related to each other,

$$e = \frac{f}{2a}$$

Second Law



2^{nd} Law: "A line joining a planet and the Sun sweeps out equal areas during equal intervals of time."

What does that mean? Why would it take a planet the same amount of time to cover the different parts of its orbit shown in Figure above?

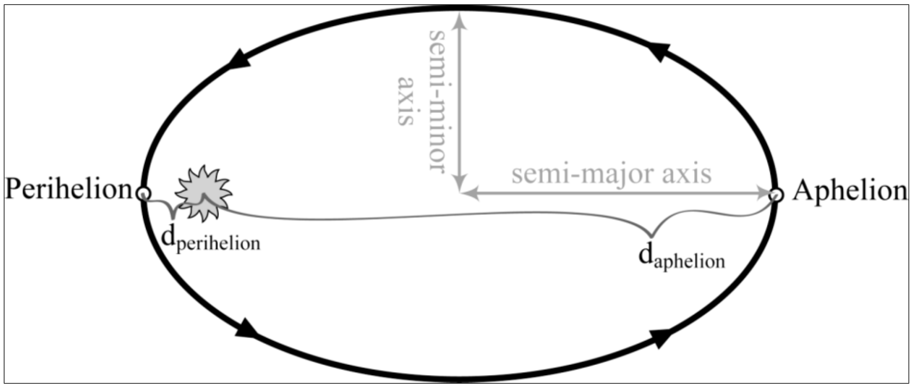
Firstly, let's cover some terminology for planetary orbits. In our solar system the Sun sits at one focus while nothing sits at the other. Astronomers use certain terms to refer to a planetary orbit, shown in Figure 6.4. The size of the orbit is described by the semi-major axis, which is also the average distance between the planet and the Sun. The eccentricity describes the shape of the orbit.

There are two special places in a planet orbit:

• perihelion ("peri-heleon"), when the planet is closest to the Sun

• aphelion ("ap-heleon"), when the planet is furthest from the Sun

To help you remember these terms, keep in mind "a" like "away" for aphelion, the farthest distance.



To calculate the perihelion and aphelion distances, you use the following:

$$d_{aphelion} = (1+ e)\, a$$

$$d_{perihelion} = (1- e)\, a$$

Just like you would measure the distance between cities in kilometers rather than centimeters, there is a typical unit for measuring planetary orbits: **the Astronomical Units (AU)**. Astronomers define 1 AU as the average distance between the Earth and the Sun and equals 93 million miles or 150 million kilometers. It is far easier to give planetary orbit sizes in AU than in kilometers

Q: Consider a mythical planet orbiting our Sun with a = 4 AU and e = 0.5.

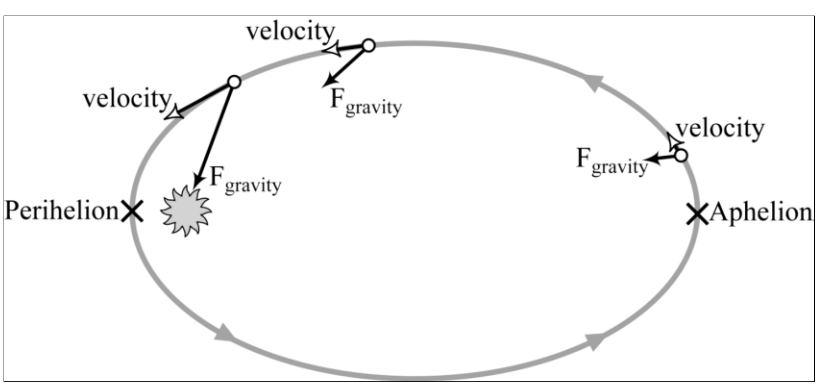
a: Given the semi-major axis, is this planet's orbit larger or smaller than Earth's orbit?

b: What is the aphelion distance?

c: What is the perihelion distance?

The phrase "sweeping equal area in equal time" means planet must be moving faster when it is closer to the Sun and slower when it is farther from the Sun as shown in Figure below. What causes this changing distance and velocity? As Newton found out, this is all caused by gravity. The planets are attracted to the Sun due its large mass. However, since the planets have momentum -the quantity of motion of a moving body, measured as a product of its mass and velocity-(meaning that they're moving and not standing still) they won't fall directly into the Sun. The result is a dance between gravity and momentum that we call an orbit. The force of gravity on a planet from a star can be calculated if you know the mass, ***M***, of the star, the distance between the star and the planet, ***d***, and the gravitational constant, ***G***:

$$F_{gravity} = \frac{GMm}{d^2}$$



Third Law

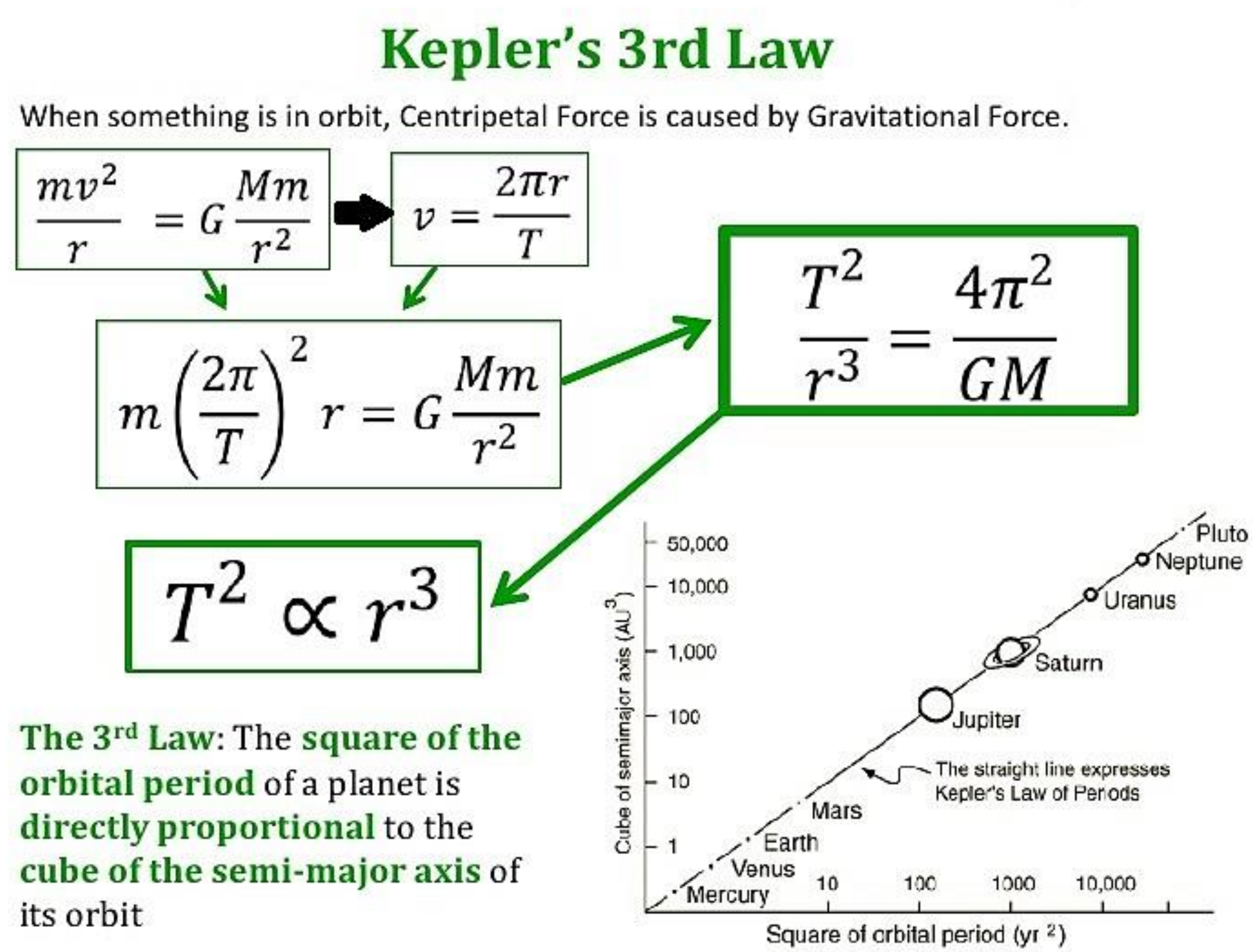
3rd Law: "The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit."

$$K = \frac{P^2}{a^3}$$

P = period (in any unit, usually seconds)

a = radius (in any unit, usually metres)(the distance of the semi-major axis)

K = Kepler's Constant



Example 1: Based on the values on the following table, **determine** the value of Kepler's constant for objects orbiting the Sun. **Explain** the significance of the values you obtain.

Planet	Period (days)	Mean Radius of Orbit (m)
Earth	**365**	**$1.49 x 10^{11}$**
Mars	**684**	**$2.28 x 10^{11}$**
Jupiter	**4331**	**$7.78 x 10^{11}$**

For each planet's data, we will need to use the formula to solve for K. The values we would get are...

Planet	Kepler's Constant (d^2/m^3)
Earth	**$4.03 \text{ x } 10^{-29}$**
Mars	**$3.95 \text{ x } 10^{-29}$**
Jupiter	**$3.98 \text{ x } 10^{-29}$**

You can see that all three planets give us approximately the same value for Kepler's Constant. This confirms that Kepler's Third Law is correct in predicting that there is a constant ratio between the squared period and cubed radius of objects orbiting the same object. We could take the average of these three values (**$3.99 x 10^{-29}$** d^2/m^3) to get our final answer.

Example 2: Neptune has an mean radius of orbit of $4.5 x 10^{12}$ *m* from the Sun. Using the average value for Kepler's Constant.

The answer is: **$6 \text{ x } 10^4$ day** → **165 year**

Example 3: If the orbit of Mars is 1.52 times greater than the orbit of Earth, determine how many days it takes Mars to complete one orbit.

Sol:

$a_m = (1.52)\, a_e$

$p_e = 365$ day

$$K = \frac{P^2}{a^3} \longrightarrow \frac{P^2{}_m}{P^2{}_e} = \frac{a^3{}_m}{a^3{}_e} \longrightarrow ?$$

Newton's Laws

Kepler's three laws, which so simplified the solar system, were discovered *empirically*. In other words, they resulted solely from the analysis of observational data and were not derived from any theory or mathematical model. Indeed, Kepler did not have any appreciation for the physics underlying his laws. Nor did Copernicus understand the basic reasons *why* his heliocentric model of the solar system worked. Even Galileo, often called the father of modern physics, failed to understand why the planets orbit the Sun.

The heliocentric system was secured when, in the seventeenth century, the British mathematician Isaac Newton developed a deeper understanding of the way *all* objects move and interact with one another as they do.

The laws of motion

Isaac Newton was born in Lincolnshire, England, on Christmas Day in 1642, the year that Galileo died. Newton studied at Trinity College of Cambridge University, but when the **bubonic plague** reached Cambridge in 1665, he returned to the relative safety of his home for 2 years. During that time he made probably the most famous of his discoveries, the law of gravity (although it is but one of the many major scientific advances Newton is responsible for). However, either because he regarded the theory as incomplete or possibly because he was afraid that he would be attacked or plagiarized by his colleagues, he did not tell anyone of his monumental achievement for almost 20 years. It was not until 1684, when Newton was discussing with Edmund Halley (of Halley's comet fame) the leading astronomical problem of the day—Why do the planets move according to Kepler's laws?—that he astounded his companion by revealing that he had solved the problem in its entirety nearly two decades before!
Prompted by Halley, Newton published his theories in perhaps the most influential physics book ever written: *Philosophiae Naturalis Principia Mathematica (The Mathematical Principles of Natural Philosophy*—what we would today call "science"), usually known simply as Newton's *Principia*. The ideas expressed in that work form the basis for what is now known as **Newtonian mechanics**.

Newton's first law of motion: a moving object will move forever in a straight line unless some external force changes its direction of motion.

Newton's second law: the acceleration of an object is directly proportional to the applied force and inversely proportional to its mass.

Thus, if two objects are pulled with the same force, the more massive one will accelerate less; if two identical objects are pulled with different forces, the one experiencing the greater force will accelerate more.

Newton's third law: if body A exerts a force on body B, then body B necessarily exerts a force on body A that is equal in magnitude, but oppositely directed.

Newtonian mechanics provides an excellent description of the motion of planets, stars, and galaxies through the cosmos.

Newton's law of gravity

Every particle of matter in the universe attracts every other particle with a force that is directly proportional to the product of the masses of the particles and inversely proportional to the square of the distance between them.. As a proportionality, Newton's law of gravity is:

$$gravitational\ force \propto \frac{mass\ of\ object1 \times\ mass\ of\ object2}{distance^2}$$

That is

$$F_G = \frac{GMm}{d^2}$$

Equation above, Newton's law of gravity can be used to calculate the force, F, exerted by to bodies on each other if their masses and the distance between them are known.

Example:

Suppose the masses M and m of two bodies are each 1000 kg and the distance between them d, is 10 m. where G= 6.67×10^{-11} Nm^2/kg^2, find F_G.

$$F_G = \frac{6.67\ \times\ 10 - 11 \times 1000 \times 1000}{10^2}$$

$$F_G = 6.67\ \times\ 10^{-7}\ N$$

Lecture Seven

Newton's Laws

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That is

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Equation above, Newton's law of gravity can be used to calculate the force, F, exerted by to bodies on each other if their masses and the distance between them are known.

Example:

Suppose the masses M and m of two bodies are each 1000 kg and the distance between them d, is 10 m. where G= 6.67×10^{-11} Nm^2/kg^2, find F_G.

$$\mathbf{F_G} = \frac{\mathbf{6.67 \times 10 - 11 \times 1000 \times 1000}}{\mathbf{10^2}}$$

$$\mathbf{F_G = 6.67 \times 10^{-7}\ N}$$

Lecture Eight

Exercises

Q1/ Galileo is often credited with the early discovery of four of Jupiter's many moons. The moons orbiting Jupiter follow the same laws of motion as the planets orbiting the sun. One of the moons is called Io - its distance from Jupiter's center is 4.2 *units* and it orbits Jupiter in 1.8 Earth-days. Another moon is called Ganymede; it is 10.7 units from Jupiter's center. Make a prediction of the period of Ganymede using Kepler's law of harmonies.

Answer: **T = 7.32 days**

Given:

Io: $R_{io} = 4.2$ and $T_{io} = 1.8$

Ganymede: $R_g = 10.7$ Tg=???

Use Kepler's 3rd law to solve.

(T_{io})^2/$(R_{io})^3 = 0.04373$;

so (T_g)^2 / $(R_g)^3 = 0.04373$

(T_g)^2 = 0.04373 • $(R_g)^3$

$(T_g)^2 = 53.57$ so T_g = SQRT(53.57) = 7.32 days

Q2/ Suppose a small planet is discovered that is 14 times as far from the sun as the Earth's distance is from the sun (1.5×10^{11} m). Use Kepler's law of harmonies to predict the orbital period of such a planet. GIVEN: $T^2/R^3 = 2.97 \times 10^{-19}\ s^2/m^3$

Answer: **T_{planet} = 52.4 yr**

Use Kepler's third law:

(T_e)^2/(R_e)^3 = (T_p)^2/$(R_p)^3$

Rearranging to solve for T_p:

(T_p)^2=[$(T_e)^2$ / $(R_e)^3$] • $(R_p)^3$
or $(T_p)^2 = (T_e)^2$ • $[(R_p) / (R_e)]^3$ where $(R_p) / (R_e) = 14$

so $(T_p)^2 = (T_e)^2$ • $[14]^3$ where T_e=1 yr

$(T_p)^2$ =$(1\ yr)^2$ *[14]^3 = 2744 yr^2
T_p = SQRT(2744 yr^2)

T_p = 52.4 yr

Q3/ The average orbital distance of Mars is 1.52 times the average orbital distance of the Earth. Knowing that the Earth orbits the sun in approximately 365 days, use Kepler's law of harmonies to predict the time for Mars to orbit the sun.

Given: $R_{mars} = 1.52 \cdot R_{earth}$ and T_{earth} = 365 days
Use Kepler's third law to relate the ratio of the period squared to the ratio of radius cubed
$(T_{mars})^2 / (T_{earth})^2 \cdot (R_{mars})^3 / (R_{earth})^3$
$(T_{mars})^2 = (T_{earth})^2 \cdot (R_{mars})^3 / (R_{earth})^3$
$(T_{mars})^2 = (365 \text{ days})^2 * (1.52)^3$
(Note the R_{mars} / R_{earth} ratio is 1.52)
T_{mars} = 684 days

Q5/ Imagine a place in the *cosmos* far from all gravitational and frictional influences. Suppose that you visit that place (just suppose) and throw a rock. The rock will

a. gradually stop.
b. continue in motion in the same direction at constant speed.

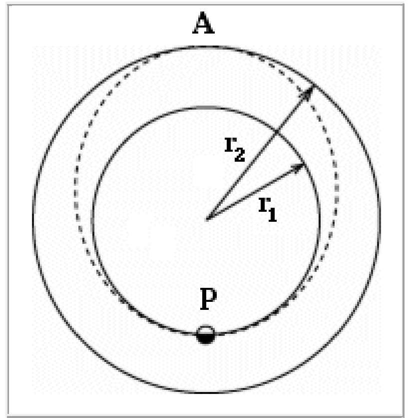
According to Newton's first law, the rock will continue in motion in the same direction at constant speed.

…………………………………………………………..

All sorts of problems can be solved with Kepler's 3rd law. Here are a few:

1. **How long does it take to reach Mars,** *in the most efficient orbit? This is called the "Hohmann Transfer Orbit" (Wolfgang Hohmann, 1925).* The spaceship must first get free of Earth (it still orbits the Sun together with Earth, at 30 km/s, at a distance of 1 AU), then it adds speed so that its aphelion (in its orbit around the Sun) just grazes the orbit of Mars, A = 1.524 AU (ignoring ellipticity).

2. For the Hohmann orbit, the smallest distance is 1.00 AU (Earth), the largest one 1.524 AU (Mars), so the semi-major axis is



The Hohmann Transfer Orbit

3. A = 0.5(1.00 + 1.524) = 1.262 AU

4. $A^3 = 2.00992 = T^2$

5. The period is the square root **T = 1.412** years
To reach Mars takes just half an orbit
or **T/2 = 0.7088** years it equals about **8.5** months.

3. **How long would it take for a spacecraft from Earth to reach the Sun?** The Sun is the **hardest object** in the solar system to reach! It's far easier to escape to interstellar space . To reach the Sun directly from Earth, we need shoot the spacecraft free of Earth. It still orbits the Sun with Earth, at 30 km/sec (low Earth orbit only takes 8 km/s), so we need give it an opposing thrust, adding (-30 km/s) to its velocity. It then falls straight into the Sun.

   That orbit is also an ellipse, though a **very skinny** one. Its total length is 1 (AU), so the semimajor axis is A = 0.5 AU. By the 3rd law, **$A^3 = 0.125 = T^2$,**and taking the square root , T=0.35355 years. We need divide this by 2 (it's a one-way trip!) and multiply by 365.25 to get days. Multiplying:

$$T/2 = (0.5)\ 0.35355\ (365.25) = 64.6 \text{ days}$$

4. **How far (from the center of Earth) do synchronous satellites**(of a satellite or its orbit) making or denoting an orbit around the earth or another celestial body in which one revolution is completed in the period taken for the body to rotate about its axis.) **orbit?** These are (mostly) communication satellites and have a 24 hour period, which helps them hang above the same station? The Moon is at 60 (earth radii) away and has a period of **T = 27.3217** days. The synchronous orbit is circular, so A is also its radius R. We get

$$(R/60)^3 = R^3 / 216{,}000 = (1 / 27.3217 \text{ days})^2$$
$$= 1/ (27.3217 \text{ days})^2 = 1 / 746.5753$$

so

$$R^3 = 216{,}00/746.5753 = 289.32$$

This number is between $6^3 = 216$ and $7^3 = 343$, so when the calculator gives R = 6.614 RE. you know you've got it about right.

5. **How far does Halley's comet go?**

Its period is about 75 years, and $75^2 = 5625$. Take the cube root: A = 17.784 AU. That, however is the semi major axis. The length of the entire orbital ellipse is 2A = 35.57 AU. Perihelion is inside the Earth's orbit, less than 1 AU from the Sun, so aphelion is about 35 AU from the Sun--as the table shows, somewhere between Neptune's orbit and Pluto's

Newton's law of gravity exercises

1. Suppose that two objects attract each other with a gravitational force of 16 units. If the distance between the two objects is doubled, what is the new force of attraction between the two objects?

Answer: **F = 4 units**

If the distance is increased by a factor of 2, then force will be decreased by a factor of 4 (2^2). The new force is then 1/4 of the original 16 units.

F = (16 units) / 4 = 4 units

2. Suppose that two objects attract each other with a gravitational force of 16 units. If the distance between the two objects is reduced in half, then what is the new force of attraction between the two objects?

Answer: **F = 64 units**

If the distance is decreased by a factor of 2, then force will be increased by a factor of 4 (2^2). The new force is then 4 times the original 16 units.

F = (16 units) • 4 = 64 units

3. Suppose that two objects attract each other with a gravitational force of 16 units. If the mass of both objects was doubled, and if the distance between the objects remained the same, then what would be the new force of attraction between the two objects?

Answer: **F = 64 units**

If each mass is increased by a factor of 2, then force will be increased by a factor of 4 (2*2). The new force is then 4 times the original 16 units.

F = (16 units) • 4 = 64 units

4. Suppose that two objects attract each other with a gravitational force of 16 units. If the mass of object 1 was doubled, and if the distance between the objects was tripled, then what would be the new force of attraction between the two objects?

Answer: **F = 3.56 units**

If the mass of one object is doubled. then the force of attraction will be doubled as well. But this affect is more than offset by the tripling of the separation distance. Tripling the distance would cause the force to be decreased by a factor of 9 (3^2). The net affect on force is that it decreased by a factor of 2/9.

F = (16 units) • 2 / 9 = 3.56 units

Sidereal vs. Synodic Motions

Seasonal motion of the sun comes from a combination of the rotation of the earth about its axis and the orbital revolution of the earth around the sun. A full understanding of the motions of the sun requires understanding the geometry and nature of sidereal and synodic motion.

Sidereal Motion

The word sidereal derives from the Latin word for “star”. This is because sidereal motion is motion with respect to the stars. One ***sidereal day*** is the time it takes for a star in the sky to come back to the same place in the sky. Because, for all intents and purposes, the sky is “fixed”, a sidereal day is when the earth rotates 360°. A sidereal day is 23 hours 56 minutes and 4.09 seconds long.

A ***sidereal year*** is the time it takes for the sun to return to the same position with respect to the stars. Due to the precession of the equinoxes the sidereal year is about 20 minutes longer than the tropical year. The tropical year is the interval at which seasons repeat and is the basis for the calendar year.

Synodic Motion

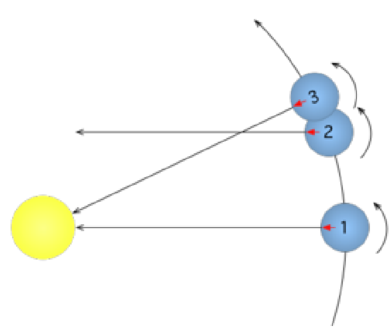
The word synodic derives from the Greek word for meeting or assembly. It is motion relative to a conjunction or alignment of sorts. A synodic or solar day is the time it takes the sun to successively pass the meridian (astronomical noon). A mean solar day is 24 hours. The earth has to rotate ***more than*** 360° for the sun to come back to “noon”.

A synodic year is the time it takes for a planet-sun alignment to reoccur. For the case of the sun, it is the time it takes the sun to come to the same place on the ecliptic (equinox to equinox) and is called a Tropical Year. A tropical year is 365.242 mean solar days (366.242 sidereal days). It is just over 20 minutes shorter than a sidereal year (again, the effect of precession).

Leap Year (Optional)

Because a tropical year is 365.242 mean solar days long, the vernal equinox would be later and later every year if our calendar year were strictly 365 days long. In an attempt to keep the Vernal Equinox very near March 21st, the Leap Year was introduced. According to the Gregordian calendar a leap year occurs every 4 years except years evenly divisible by 100, unless that year is evenly divisible by 400. The year 1900 was not a leap year, but 2000 was.

1 → 2: globe rotates 360° (sidereal)
1 → 3: globe repoints to sun. (synodic)



Hour Angle

The *Right Ascension* of an object indicates the Sidereal Time at which it will transit across your Local Meridian. An object's *Hour Angle* is defined as the difference between the current Local Sidereal Time and the Right Ascension of the object:

$HA_{obj} = LST - RA_{obj}$

Thus, the object's Hour Angle indicates how much Sidereal Time has passed since the object was on the Local Meridian. It is also the angular distance between the object and the meridian, measured in hours (1 hour = 15 degrees). For example, if an object has an hour angle of 2.5 hours, it transited across the Local Meridian 2.5 hours ago, and is currently 37.5 degrees West of the Meridian. Negative Hour Angles indicate the time until the *next* transit across the Local Meridian. Of course, an Hour Angle of zero means the object is currently on the Local Meridian.

Q1/ In one of the summer nights, want to know the Crescent position, In the western sky after sunset it was found that the declination 08° 37' 17", RA $14^h\ 10^m\ 4^s$ when the LST $19^h\ 18^m\ 1.4^s$, find

1- The altitude (a) of the crescent.

2- The Azimuth (A) of the crescent.

The geographic latitude in Baghdad is 33.21°.

Q2/ In one of the summer nights, want to know the Crescent position, In the western sky after sunset it was found that the declination 12° 00' 423", RA $14^h\ 58^m\ 55^s$ when the LST $19^h\ 20^m\ 41^s$, find

1- The star altitude (a)

2- The Azimuth (A) of the crescent.

The geographic latitude in Baghdad is 33.21°.

Q3/ If we want to observe a star in Baghdad, its altitude (a), the declination (δ) and the azimuth of the star is (A), prove the following:

$100 \sin\delta = 55 \sin a + 84 \cos a \cos A$

The geographic latitude in Baghdad is 33.21°.

Hint: Sum and Difference Formulas
sin(A+B)=sin A cos B + cos A sin B
sin(A-B)=sin A cos B - cos A sin B
cos(A+B)=cos A cos B - sin A sin B
cos(A-B)=cos A cos B + sin A sin B

Lecture Nine

Galaxies and magellanic Cloud

The present view of galaxies is that ***they are large collections of stars, brown dwarfs, planets, gas and dust bound together by their common gravitational pull. Galaxies range from 1,000 ly (300 pc) to 500,000 ly (150,000 pc) in size, containing between a million and a trillion stars, and between 10^9 and 10^{14} solar luminosities in brightness***.

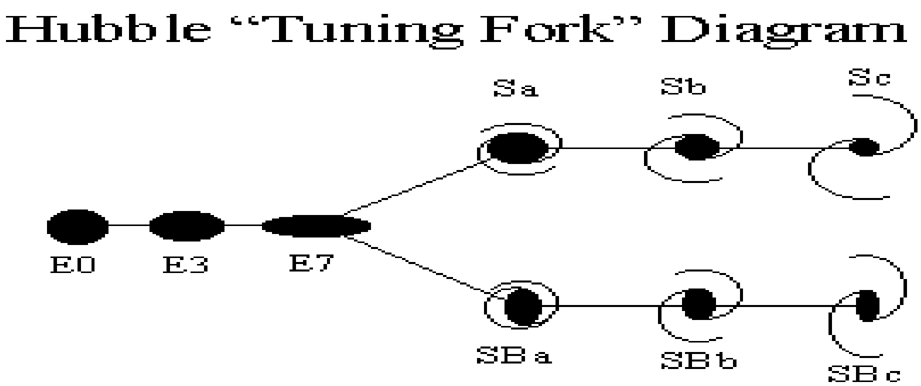
CLASSIFICATION OF GALAXIES

The classification of galaxies can be based on a variety of criteria: morphological, photometric, and spectroscopic. The first and common classification scheme of galaxies has been founded on purely morphological criteria based on the examination of their blue photographic images.

Classification by Morphology

The Hubble Classification

The principal bases of this classification were introduced and improved by Hubble (1926, 1936), as later revised and expanded upon by Sandage (1961) and de Vaucouleurs (1959). Sandage (1975) has argued that one reason Hubble's view prevailed is that he did not try and account for every superficial detail, but kept his classes broad enough that the vast majority of galaxies could be sorted into one of his proposed bins. These bins were schematically illustrated in Hubble's famous "tuning fork" (Hubble 1936; reproduced in Figure below) recognizing a sequence of progressive flattening from ellipticals to spirals.



This morphological approach is based on qualitative, empirical, criteria depending on the shape, light concentration, and structure of galaxies visible on blue photographs. This scheme was then modified and enlarged by Hubble in his 1936 book, “The Realm of The Nebulae” (Hubble 1936). Development of this scheme was achieved and published by Sandage in the “Hubble Atlas of galaxies”.

Four main classes are recognized: ellipticals E, lenticulars S0, Spairals S, and Irregulars I. Some of the characteristic features of each class are briefly outlined.

Ellipticals (E) the elliptical galaxies normally show a symmetric shape. The surface brightness decreases smoothly from the center to the outer parts with an intensity fall-off that varies approximately as $log\ L(r) \propto r^{1/4}$. Elliptical galaxies are classified according to the elongation of the apparent projected image; that is, if a and b are the major and minor axes of the apparent ellipse, then $10(a-b)/a$ expresses the observed ellipticity.

Figure: *The galaxies are (left to right): NGC 5898, 3115, 4623(From NED).*

Lenticulars (S0) (“lenticular”, sometimes denoted “L”) defines the transition between elliptical and spiral galaxies. S0-galaxies are lens-shaped systems, normally without any spiral structure and a typical example is NGC 4111 in Canes Venatici (Figure below). They are less flattened than the disks of spiral galaxies. The central region of S0-galaxies is spherical, similar, but less massive than the bulges of spiral galaxies (the bulge or spheroidal components) surrounded by a large region of less steeply declining brightness (the flat or disk component).

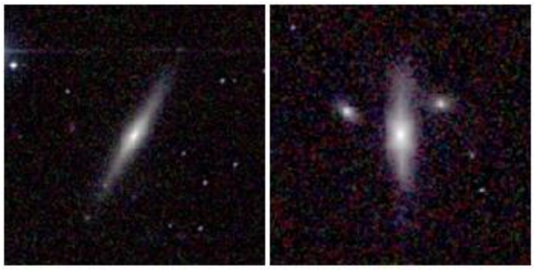


Figure: *The galaxies are (left to right): NGC 4111 in Canes Venatici and 128 in Pisces (From NED)*

Spairal (S) Common features of ordinary spiral galaxies (S) and barred spiral galaxies (SB) are the bulge (the spherical central region), and the surrounding disk containing the spiral arms. Ordinary spirals show two or more spiral arms starting smoothly from the outer bulge. The bulge of SB galaxies is bar shaped, with two spiral arms branching off.

To classify spiral galaxies, the following features are commonly used:

● the form and density of spiral arms

● the relative dimensions of bulge and disk ("bulge-to-disk ratio")

● the form of bulge: spherical for type S, bar-shaped for type SB

irregular galaxies Although classical irregular galaxies tend to be late type systems with a considerable degree of patchiness and irregularity, another class of irregular galaxies has such amorphous characteristics that some astronomers considered them to belong near the transition between S0 and spiral galaxies. An example, NGC 1569, is shown in Figure below. These objects tend to have much smoother distributions of luminosity than classical Magellanic irregulars. The distinction has been recognized since 1950, when E Holmberg suggested the term 'Irr I' be applied to normal late-type irregulars and 'Irr II' to these amorphous irregulars. de Vaucouleurs applied the term 'I0' to some of these objects, while Sandage prefers the general term 'amorphous' galaxies. Interactions may play a role in the creation of these objects (Buta 2006).

Figure: *The nearby dwarf galaxy NGC 1569 from (http://hubblesite.org/).*

The succession of morphological types E-S0-S-I is called the Hubble Sequence.

The Hubble-Sandage classification

Sandage (1961) describes the modifications that made the Hubble system more three-dimensional: the introduction of the (r) (inner ring) and (s) (pure spiral) subtypes. Continuity even with this characteristic was possible, using the combined subtype (rs). Thus, already by 1961, the Hubble classification system had become much more complicated than it was in 1926 or 1936. The addition of the S0 class was one reason for this, but the (r) and (s) subtypes were another.

The De Vaucouleurs Classification (Revised System)

De Vaucouleurs (1959) took the idea of continuity of galaxy morphology a step further by developing what he referred to as the classification volume (Figure below). In this revision of the Hubble-Sandage (1961) classification, galaxy morphology represents a continuous sequence of forms in a three-dimensional volume with a long axis and circular cross-sections of varying size. The long axis of the volume is the stage, or type, and it represents the long axis of the original Hubble tuning fork. The short axes are the family and the variety, which refer to apparent bar strength and the presence or absence of an inner ring, respectively.

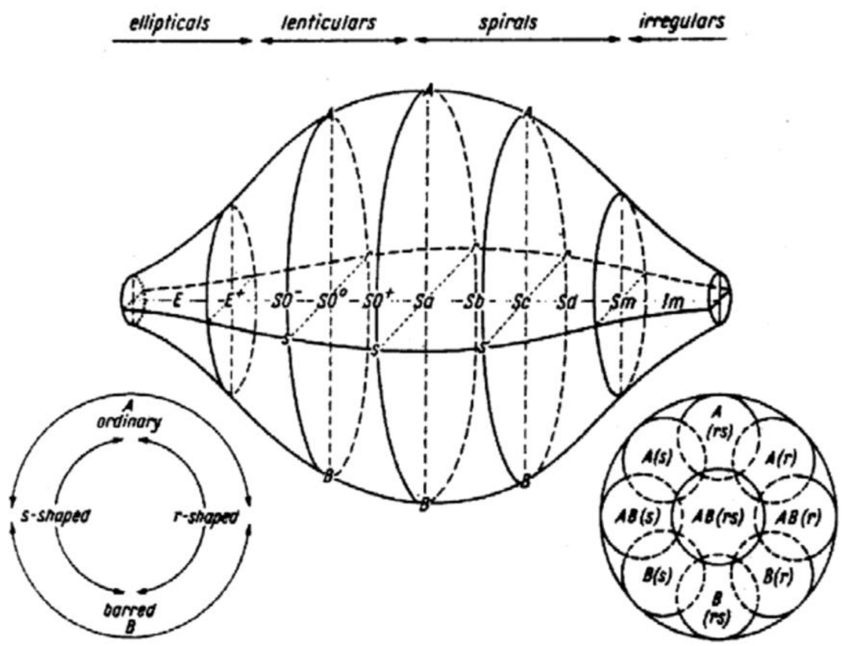


Figure: *Illustration of the de Vaucouleurs revised Hubble classification system. In this system, S0 galaxies are referred to as 'lenticulars'. The lower left and right circles illustrate the arrangement of families and varieties within a cross-section through the system.*

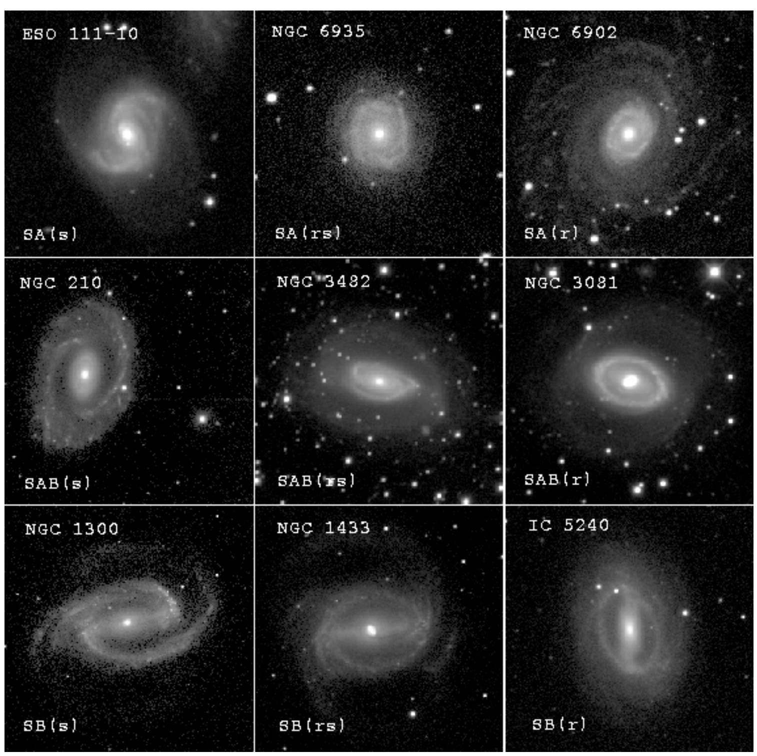


Figure: *Examples of galaxies having different families and varieties in the de Vaucouleurs revised Hubble classification system. (http://bama.ua.edu/~rbuta/gvatlas/devsys.html).*

Magellanic Clouds The two dwarf, irregularly shaped neighboring galaxies that are closest to our Milky Way galaxy. The Large Magellanic Cloud (LMC) is about 160,000 light-years away, and the Small Magellanic Cloud (SMC) is approximately 180,000 light-years away. Both can be seen with the naked eye in the Southern Hemisphere. Their presence was first recorded in 1519 by the Portuguese explorer FERDINAND MAGELLAN, after whom they are named.

Lecture 10

The Lunar

The Moon

Diameter: 3476 km
Average distance from Earth: 384 402 km
Orbital period: 29 days 12 hr 44 min (synodic) or 27 days 19 hr 18 min (sidereal)
Rotation period: 27 days 19 hr 18 min (sidereal)

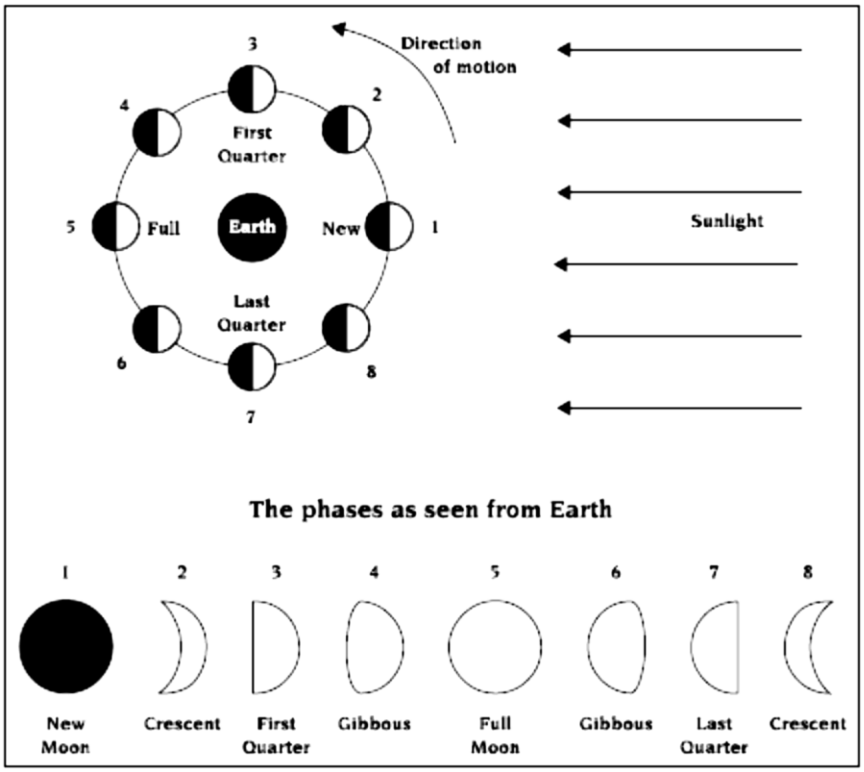
Photo courtesy NASA

The Moon is the only natural satellite of the Earth and is by far the nearest celestial body. The Moon is the fifth largest moon in the solar system. Relative to its parent planet it is quite large, being almost one-third the size of the Earth. For this reason astronomers sometimes regard the Earth-Moon system as a double planet.

The Moon travels around the Earth in an elliptical (oval shaped) orbit. Its distance from the Earth varies from 356 000 km to 407 000 km. Furthermore, having only one-eightieth of the Earth's mass, means that the surface gravity of the Moon is just one-sixth of the Earth's. This means that a 60 kg person would weigh just 10 kg on the Moon.

The phases of the Moon

Having no light of its own, the Moon shines because of the light it reflects from the Sun. At any one moment the hemisphere turned away from the Sun will be dark. The apparent shape of the Moon in the sky (its phase) therefore depends on what position it has reached in its orbit around the Earth. When the Moon lies between the Sun and the Earth, we cannot see the sunlit side of the Moon and it is said to be new (position 1 on diagram). As the Moon continues in its orbit, we begin to see a little of the day side of the Moon and it appears as a crescent (position 2). Eventually the Moon has moved through a quarter of its orbit and it appears as a half moon and is said to be at first quarter (position 3). When the Moon continues it appears between half moon and full moon, and is said to be gibbous. Eventually the Moon is at position 6 (opposite the Sun) and is then full. The process of the Moon slowly increasing its phase is called waxing. Once past full moon, the phase of the Moon then begins to diminish, as indicated in the diagram above. This process is called waning. Eventually, the Moon returns to the new moon position, and the cycle is repeated.

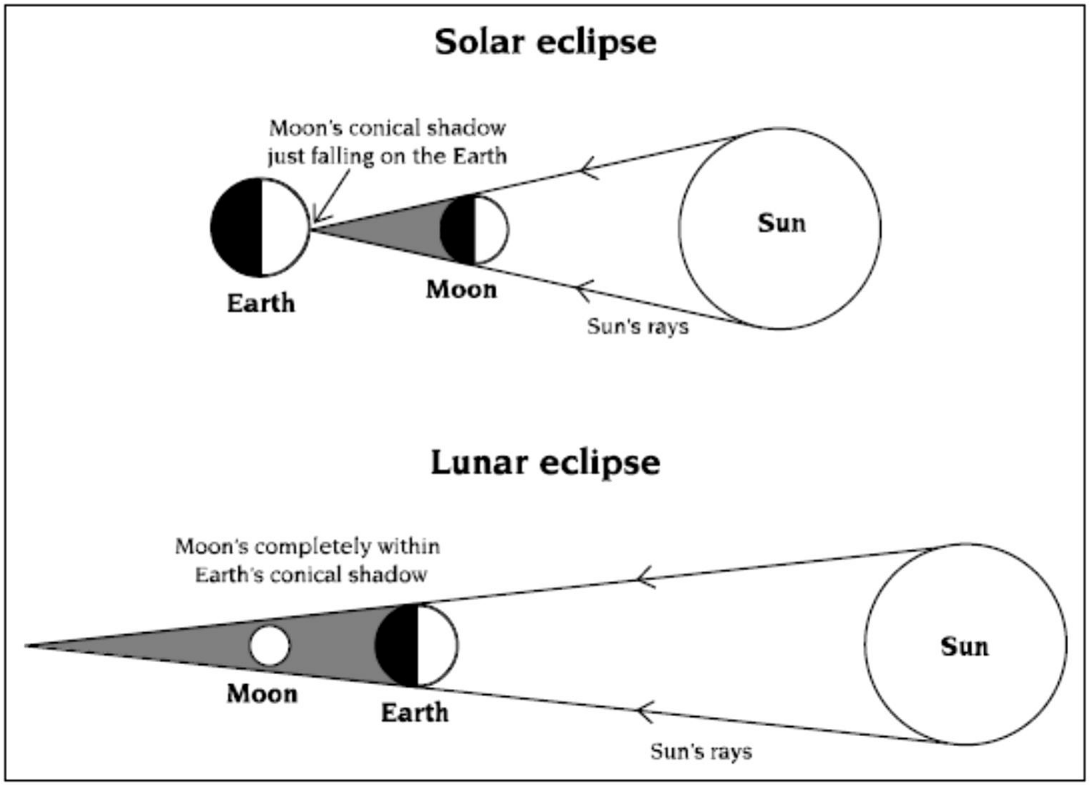


The period from one new moon to the next is referred to as the synodic or lunar month and is on average 29 days 12 hr 44 min long. However, relative to the background stars, the period of one complete orbital revolution is 27 days 19 hr 18 min and is referred to as the sidereal month. This happens to also be the Moon's period of rotation about its axis. Combine this with the Moon spinning on its axis in the same direction as it moves in its orbit, and only one side of the Moon ever faces the Earth. We never see the far side. This is known as captured rotation. During the crescent phase of the Moon, the unlit part of the Moon can be seen to be bathed in a soft light. This phenomenon is due to the reflection of sunlight onto the Moon from the Earth. It is known as earthshine (similar to moonlight on the Earth). As seen from the Earth, the Moon appears to travel from west to east along its orbit. This means that every day it has moved further east and hence rises about 50 minutes later each day.

Eclipses

Often, when the moon is new it passes directly between the Sun and the Earth resulting in the long conical shadow of the Moon falling onto the Earth's surface. Standing at that point, observers would see the disc of the Moon completely covering the Sun. This is known as a total solar eclipse. By a quirk of nature, the Moon is just the right distance from the Earth to make it appear the same size as the Sun, that is, even though the Moon is 400 times smaller than the Sun, the Sun is in turn 400 times further away, and as a result they both appear the same size as viewed from the Earth's surface. Observers only slightly removed from the Moon's shadow would only see part of the Sun covered by the Moon and this is known as a partial solar eclipse. Solar eclipses are very dangerous to observe with the unaided eye, and can result in blindness. However, with proper precautions much can be learnt about the Sun's atmosphere that can only be observed during solar eclipses.

When the Moon is full, it sometimes passes behind the Earth and into its long conical shadow. This can be seen from the entire moonfacing hemisphere of the Earth and is known as a total lunar eclipse. Often however, the alignment is not exact and only a part of the Moon's disc is covered by the Earth's shadow and is known as a partial lunar eclipse. During lunar eclipses, it is fascinating to watch the Earth's circular shadow slowly move across the Moon's face. This simple observation led the ancient Greek philosopher Pythagoras to conclude that the Earth must be a sphere since its shadow is always circular. Since the Moon's orbit is inclined 5° to the Earth's orbit, eclipses don't occur every time the Moon is new or full. Consequently, eclipses can only occur when the Moon is near the points where it crosses the Earth's orbit and is at the same time, either new or full.


Solar eclipse
Moon's conical shadow
just falling on the Earth
Earth
Moon
Sun
Sun's rays
Lunar eclipse
Moon's completely within
Earth's conical shadow
Moon
Earth
Sun
Sun's rays