Shape, Size and Motions of the Earth

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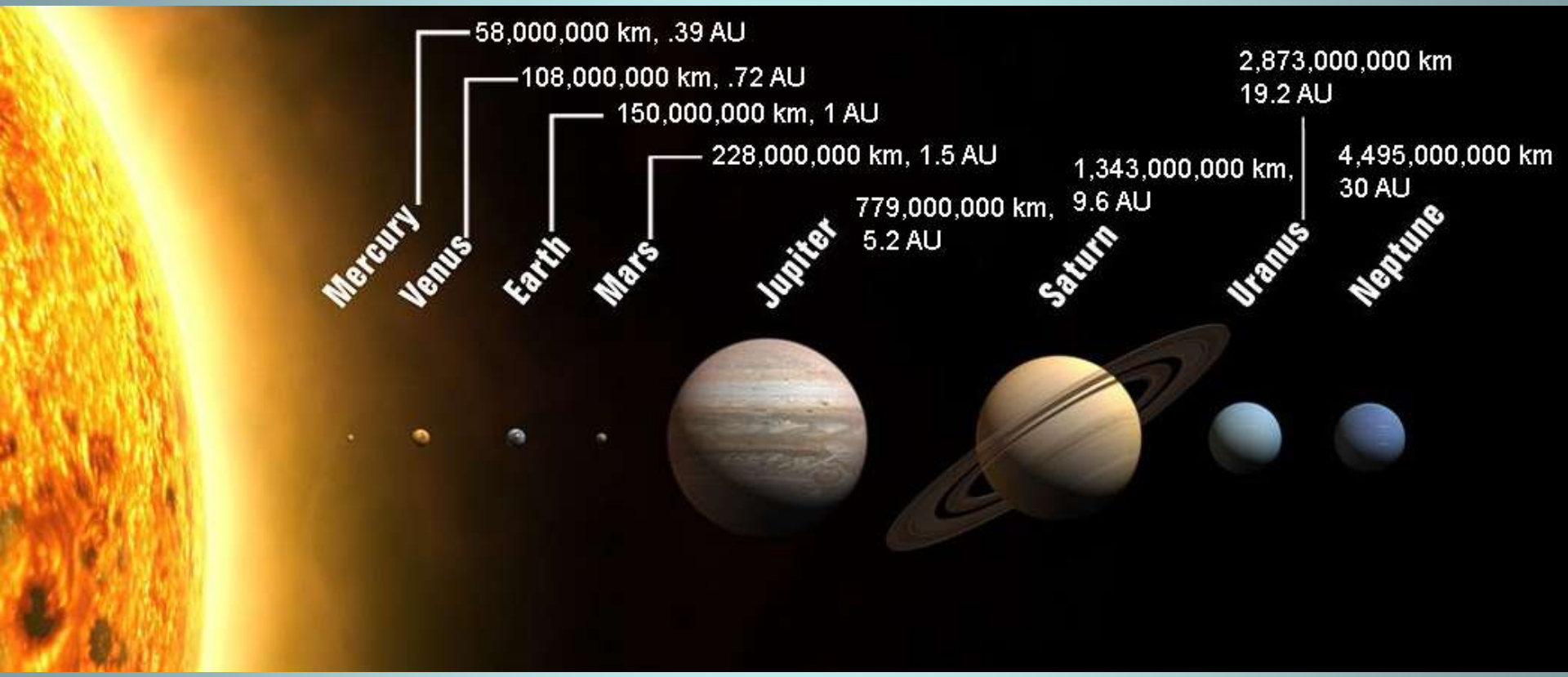
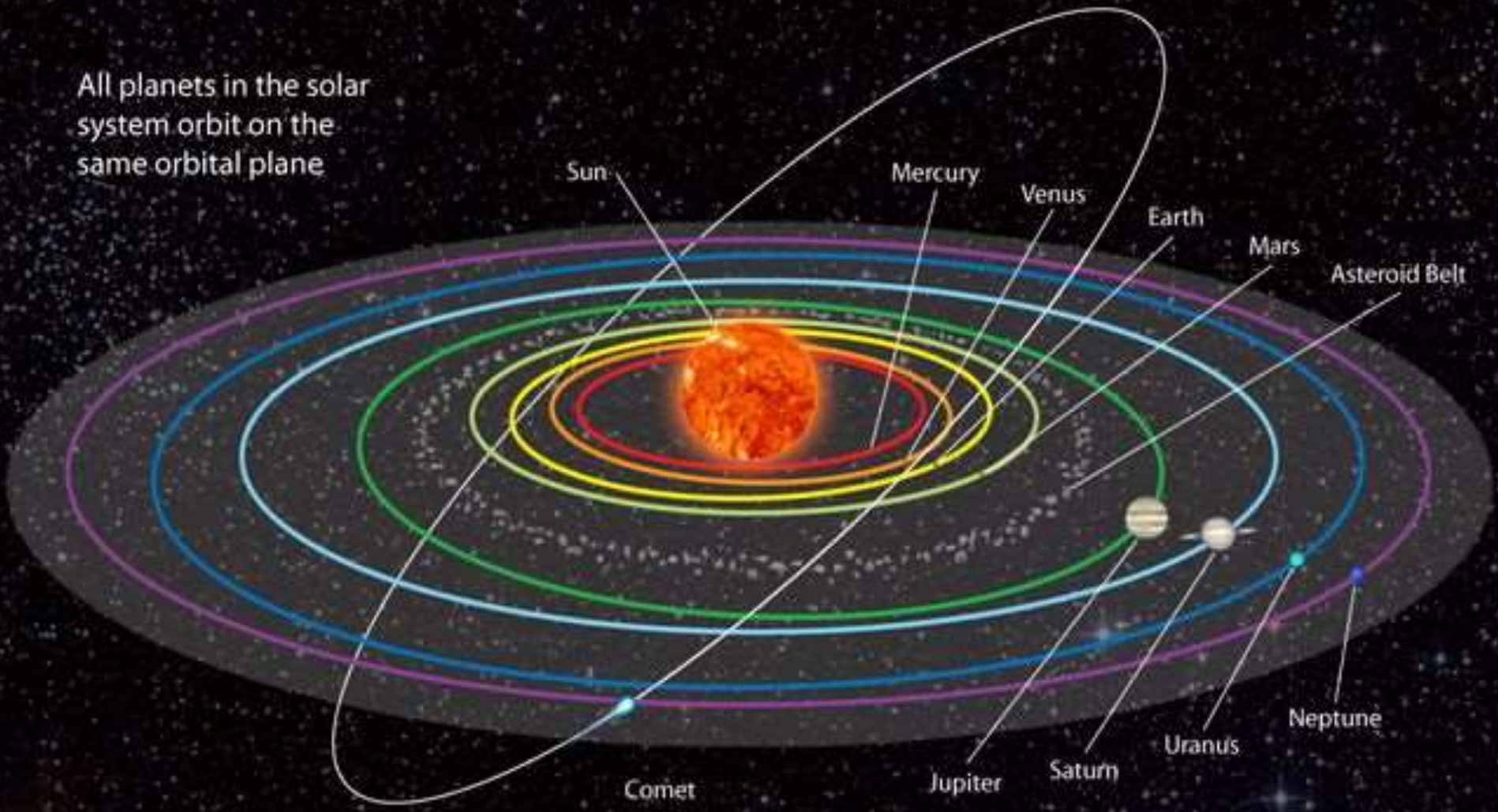
Introduction

- Earth, the third planet from the sun, is the fifth largest planet in the solar system; only the gas giants Jupiter, Saturn, Uranus and Neptune are bigger.
- Earth is the largest of the terrestrial planets of the inner solar system, bigger than Mercury, Venus and Mars.
- Earth, with average distance of 92,955,820 miles (149,597,890 km) from the sun, is the third planet and one of the most unique planets in the solar system.
- It formed around 4.5-4.6 billion years ago and is yet the only planet known to sustain life.
- This is because factors like its atmospheric composition and physical properties such as the presence of water over 70.8% of the planet allow life to thrive


58,000,000 km, .39 AU
108,000,000 km, .72 AU
150,000,000 km, 1 AU
228,000,000 km, 1.5 AU
779,000,000 km, 5.2 AU
1,343,000,000 km, 9.6 AU
2,873,000,000 km 19.2 AU
4,495,000,000 km 30 AU
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune

Orbital Plane

All planets in the solar system orbit on the same orbital plane



* Many comets exist outside the orbital plane

- **Geodesy** is the science that studies the shape and size of the Earth. The shape of the earth was long known to be round. Aristotle and Pythagoras both argued that the earth was a sphere from the curved shadow it cast during lunar eclipses.
- About two thousand years later, Sir Isaac Newton suggested that the earth was not a perfect sphere, but rather somewhat flattened at its poles.
- From mathematical considerations of the combined gravitational and centrifugal forces which the earth experiences, Newton computed that the Earth's shape should be an **oblate spheroid** (see figure 1), a solid formed when an ellipse is rotated about its axis.
- The earth's equatorial diameter is 7,926 miles, while its polar diameter is 7,900 miles. Although the difference between equatorial and polar diameters is only 26 miles, the oblate shape of the earth complicates geographical matters.

Shape of the Earth

- Earth is not perfect circle it is an **oblate spheroid,** it is like a sphere, but the distance from pole to pole is less than the distance around the equator (middle). This gives it a slightly flattened shape.
- Earth's circumference and diameter differ because its shape is classified as an oblate spheroid or ellipsoid, instead of a true sphere.
- This means that instead of being of equal circumference in all areas, the poles are squished, resulting in a bulge at the equator, and thus a larger circumference and diameter there.
- The equatorial bulge at Earth's equator is measured at 26.5 miles (42.72 km) and is caused by the planet's rotation and gravity.

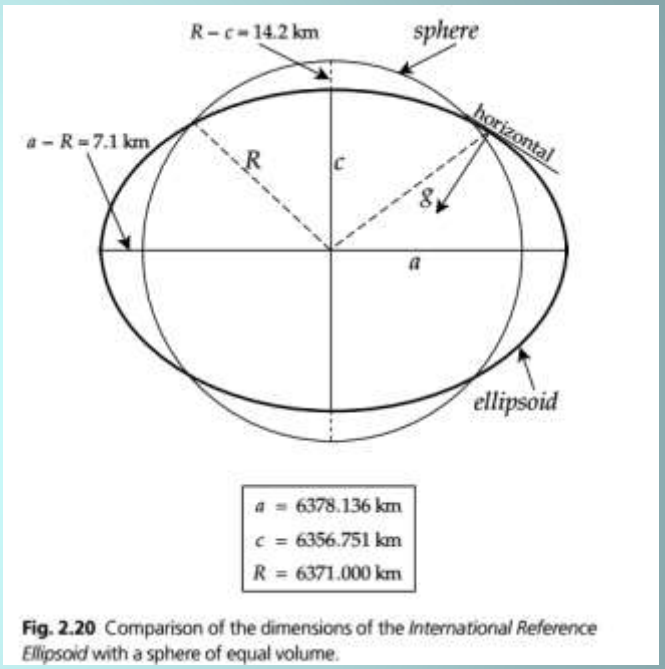


Fig. 2.20 Comparison of the dimensions of the *International Reference Ellipsoid* with a sphere of equal volume.

- Gravity itself causes planets and other celestial bodies to contract and form a sphere. This is because it pulls all the mass of an object as close to the center of gravity (the Earth's core in this case) as possible.
- Because Earth rotates, this sphere is distorted by the centrifugal force. This is the force that causes objects to move outward away from the center of gravity.

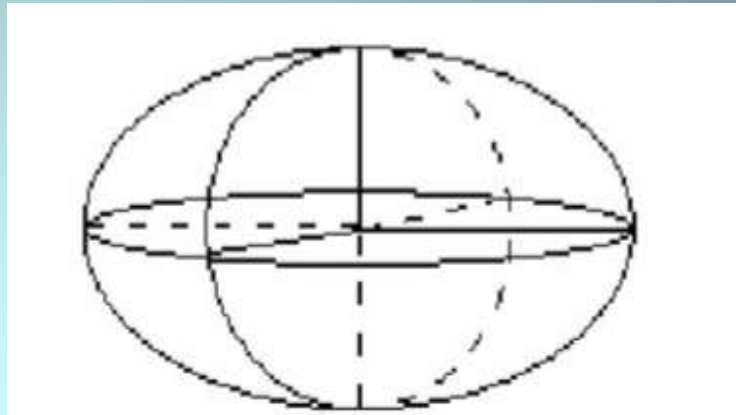


Figure 1: An **oblate spheroid** is a rotationally symmetric ellipsoid having a polar axis shorter than the diameter of the equatorial circle whose plane bisects it.

- Therefore, as the Earth rotates, centrifugal force is greatest at the equator so it causes a slight outward bulge there, giving that region a larger circumference and diameter

Size of the Earth

- The size of Earth, like the size of all of the celestial bodies, is measured in a number of parameters including *mass*, *volume*, *density; surface area*, *mean diameter*, *density and circumference* (see Table 1).
- Earth's circumference and diameter differ because its shape is classified as an oblate spheroid or ellipsoid, instead of a true sphere.
- This means that instead of being of equal circumference in all areas, the poles are squished, resulting in a bulge at the equator, and thus a larger circumference and diameter there.
- Earth orbits with a perihelion of 147,098,290 km, and an aphelion of 152,098,232 km, making for a semi-major axis of 149,598,261 km.

Various parameters related to Earth

- **Table 1: The compositions of the size of the earth.**

Mass	5.9736×10^{24}kg
Volume	1.083×10^{12} km^3
Mean diameter	12,742 km
Surface area	510,072,000 km^2
Density	5.515 g/cm^3
Circumference	40,041 km

Radius, diameter and circumference

- The mean radius of Earth is 3,959 miles (6,371 kilometers). However, Earth is not quite a sphere. The planet's rotation causes it to bulge at the equator. Earth's equatorial diameter is 7,926 miles (12,756 km), but from pole to pole, the diameter is 7,898 miles (12,714 km) — a difference of only 28 miles (42 km).
- The circumference of Earth at the equator is about 24,874 miles (40,030 km), but from pole-to-pole — the meridional circumference — Earth is only 24,860 miles (40,008 km) around. This shape, caused by the flattening at the poles, is called an oblate spheroid.

Density, mass and volume

- Earth's density is 5.513 grams per cubic centimeter. Earth is the densest planet in the solar system because of its metallic core and rocky mantle. *Jupiter, which is 318 more massive than Earth, is less dense because it is made of gases, such as hydrogen.*
- Earth's mass is 6.6 sextillion tons (5.9722×10^{24} kilograms). It volume is about 260 billion cubic miles (1 trillion cubic kilometers).
- The total surface area of Earth is about 197 million square miles (510 million square km). About 71 percent is covered by water and 29 percent by land.

Motions of the Earth

- Motion is the action or process of moving or of changing place or position. The earth has two movements, rotation and revolution;
- **Rotation-** A **rotation** is a circular movement of an object around **a center (or point) of rotation**.
- A three-dimensional object rotates always around an imaginary line called a rotation axis.
- If the axis is within the body, and passes through its center of mass the body is said to rotate upon it, or spin.

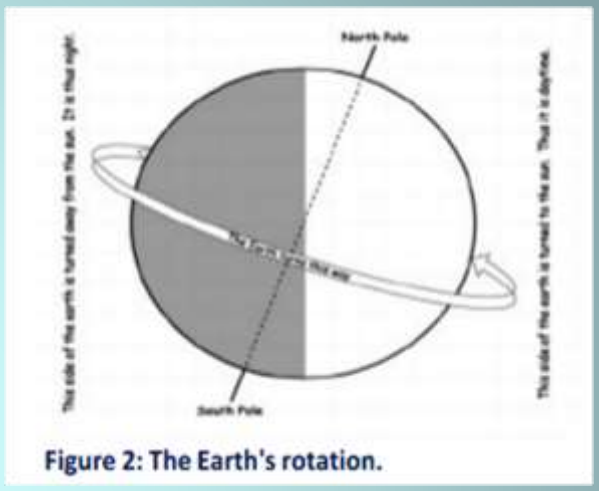


Figure 2: The Earth's rotation.

- Rotation causes days and nights (see Figure 2). It takes 23 hours, 56 minutes, and 4.09 seconds for a sidereal day and an exact 24 hours for a mean solar day.
- Earth spins towards the east to west. The speed of **Earth's rotation** is 1,674.4 km/h or 1,040.4 miles per hour at the equator. The earth has a 23.45° tilt of axis.

Revolution

- The movement of the Earth around the Sun in a fixed orbit is called as revolving. One full orbit around the sun is one revolution.
- The shape of the earth's orbit is a closed curve called an ellipse.
- The Earth revolves around the Sun because of gravity.
- It takes 365 ¼ days for the earth to complete its revolution or what we call a year.

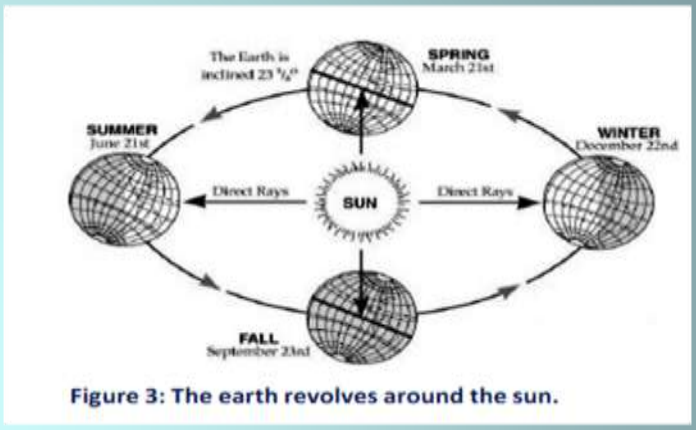


Figure 3: The earth revolves around the sun.

- This phenomena result to **the earth's different seasons.**
- It travels around the sun at 18 mi. per sec., or 66,000 mph.

Figure of the Earth

- Earth's shape and gravity are intimately associated. The figure of the Earth is the shape of an equipotential surface of gravity, in particular the one that coincides with mean sea level. The best mathematical approximation to the figure is an oblate ellipsoid, or spheroid (Fig 2.20). The precise determination of the dimensions of the Earth (e.g., its polar and equatorial radii) is the main objective of the science of *geodesy*. It requires an exact knowledge of the Earth's gravity field, the description of which is the goal of *gravimetry*.

- Modern analyses of the Earth's shape are based on precise observations of the orbits of artificial Earth satellites. These data are used to define a best-fitting oblate ellipsoid, called the *International Reference Ellipsoid*.
- In 1930 geodesists and geophysicists defined an optimum reference ellipsoid based on the best available data at the time. The dimensions of this figure have been subsequently refined as more exact data have become available.

- In 1980 the *International Association of Geodesy* adopted a *Geodetic Reference System* (GRS80) in which the reference ellipsoid has an equatorial radius (a) equal to 6378.137 km and a polar radius (c) equal to 6356.752 km.
- Subsequent determinations have resulted in only minor differences in the most important geodetic parameters.
- The radius of the equivalent sphere (R) is found from $R=(a^2c)^{1/3}$ to be 6371.000 km. Compared to the best-fitting sphere the spheroid is flattened by about 14.2 km at each pole and the equator bulges by about 7.1 km.
- The polar flattening f is defined as the ratio The flattening of the optimum reference ellipsoid defined in 1930 was exactly 1/297. This ellipsoid, and the variation of gravity on its surface, served as the basis of gravimetric surveying for many years, until the era of satellite geodesy and highly sensitive gravimeters showed it to be too inexact. A recent best estimate of the flattening is f=3.352 87 103 (i.e., f=1/298.252).

$$f = \frac{a - c}{a}$$