Introduction
Exploring the Heavens

Units of the Introduction

The "Obvious" View

Earth's Orbital Motion

The Motion of the Moon

The Measurement of Distance

Scientific Theory and the Scientific Method

E.1 The "Obvious" View

- **Earth** is average – we don't occupy any special place in the universe
- **Universe**: totality of all space, time, matter, and energy
  - **Astronomy**: study of the universe
  - **Scales** are very large: measure in light-years, the distance light travels in a year – about 10 trillion miles

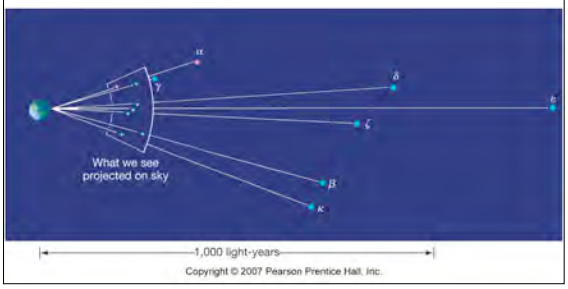
Light Facts

- Speed - 186,000 miles /second
- How far is a light year?
- Consider the speed and time in a year
- 60 seconds in a minute
- 60 minutes in a hour
- 24 hours in a day
- 365 days per year

- So….there are 31536000 seconds / year
- Multiply by Speed of light
- To get
- 5,865,696,000,000 miles/year
- 5.865 x 10^{12} miles/yr

E.1 The "Obvious" View

Stars that appear close in the sky may not actually be close in space:

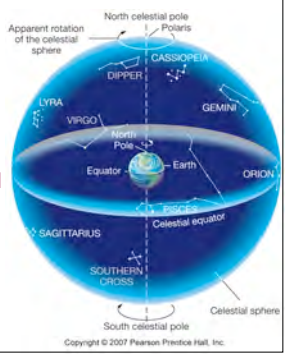


E.1 The "Obvious" View

The **celestial sphere**:

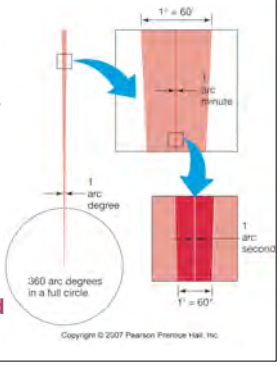
Stars ***seem*** to be on the inner surface of a sphere surrounding the Earth

They aren't, but can use two-dimensional spherical coordinates (similar to latitude and longitude) to locate sky objects



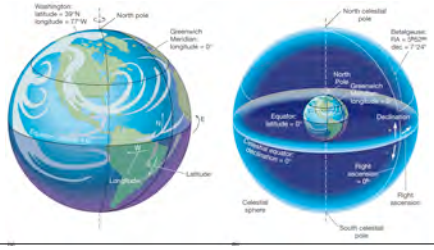
More Precisely E.1: Angular Measure

- full circle contains 360° (degrees)
- each degree contains 60_ (arc-minutes)
- each arc-minute contains 60__ (arc-seconds)
- angular size of an object depends on actual size and distance away



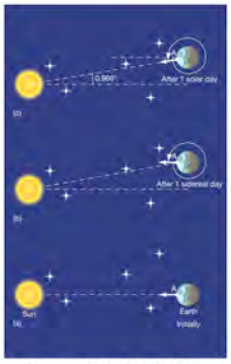
E.1 The "Obvious" View

- **Declination**: degrees north or south of celestial equator
- **Right ascension**: measured in hours, minutes, and seconds eastward from position of Sun at vernal equinox



E.2 Earth's Orbital Motion

- Daily cycle, noon to noon, is **diurnal motion – solar day**
- Stars aren't in quite the same place 24 hours later, though, due to Earth's rotation around Sun; when they are, one **sidereal day** has passed



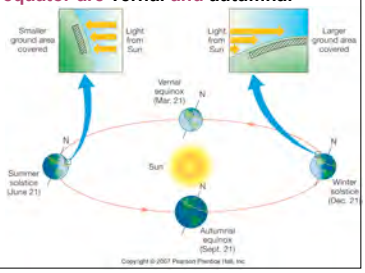
E.2 Earth's Orbital Motion

12 constellations Sun moves through during the year are called the zodiac; path is ecliptic

- Given constellation falls directly behind sun during its month.
- Example - Pices - Sign for March would never be seen in March as it is behind the sun in the daytime sky.

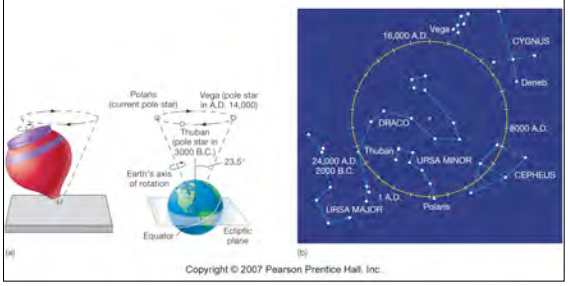
E.2 Earth's Orbital Motion

- **Ecliptic** is plane of Earth's path around Sun; at 23.5° to celestial equator
- Northernmost point (above celestial equator) is **summer solstice**; southernmost is **winter solstice**; points where path cross celestial equator are **vernal** and **autumnal equinoxes**
- Combination of day length and sunlight angle gives seasons
- Time from one vernal equinox to next is **tropical year**



E.2 Earth's Orbital Motion

Precession: rotation of Earth's axis itself; makes one complete circle in about 26,000 years



E.2 Earth's Orbital Motion

Time for Earth to orbit once around Sun, relative to fixed stars, is **sidereal year**

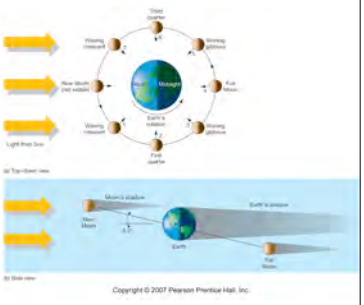
Tropical year follows seasons; sidereal year follows constellations – in 13,000 years July and August will still be summer, but Orion will be a summer constellation

E.3 Motion of the Moon

Moon takes about **29.5** days to go through whole cycle of phases – **synodic month**

Phases are due to different amounts of sunlit portion being visible from Earth

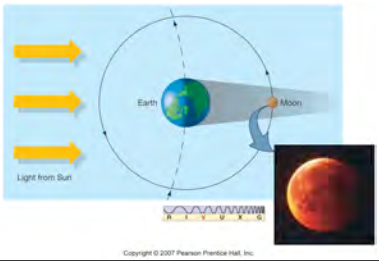
Time to make full 360° around Earth, **sidereal month**, is about 2 days shorter



E.3 Motion of the Moon

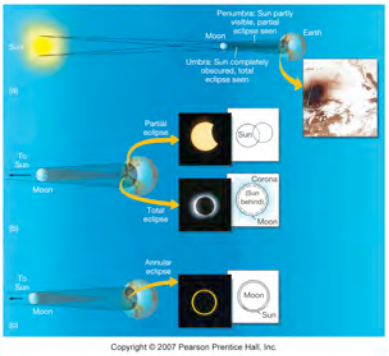
Lunar eclipse:

- Earth is between Moon and Sun
- partial when only part of Moon is in shadow
- total when it all is



E.3 Motion of the Moon

Solar eclipse: Moon is between Earth and Sun

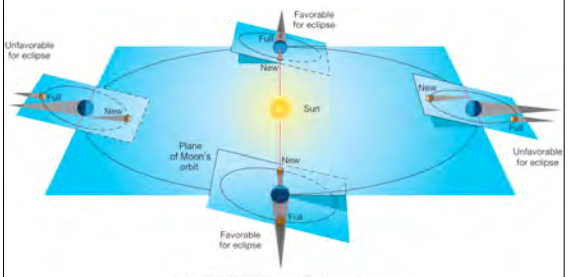


E.3 Motion of the Moon

Solar eclipse is **partial** when only part of Sun is blocked, **total** when it all is, and **annular** when Moon is too far from Earth for total

E.3 Motion of the Moon

Eclipses don't occur every month because Earth's and Moon's orbits are not in the same plane

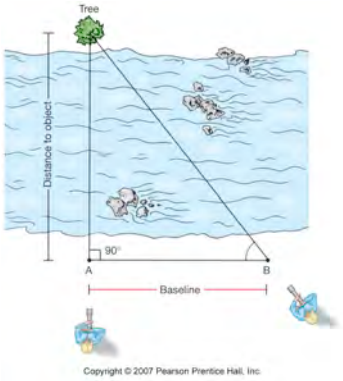


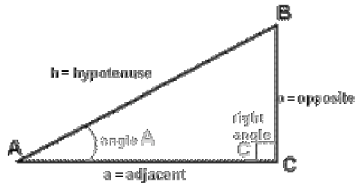
E.3 Motion of the Moon

Eclipse tracks, 2000 - 2020

E.4 The Measurement of Distance

Triangulation: measure baseline and angles, can calculate distance

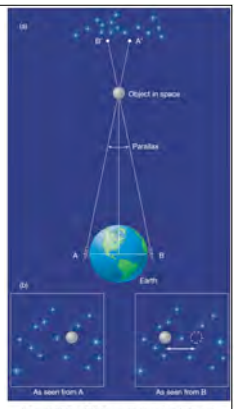




- sin A = opposite/hypotenuse
- cos A = adjacent/hypotenuse
- tan A = opposite/adjacent

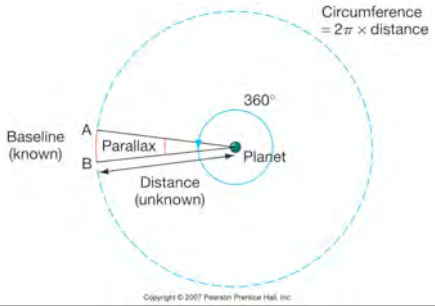
E.4 The Measurement of Distance

Parallax: similar to triangulation, but look at apparent motion of object against distant background from two vantage points



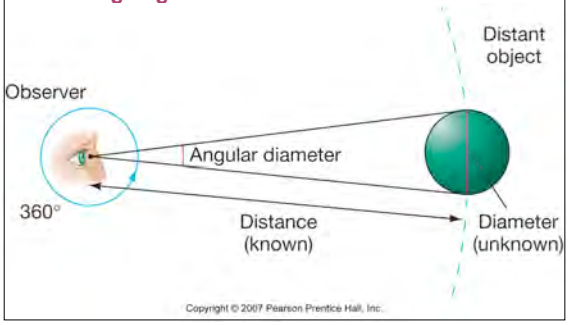
More Precisely E-2 Measuring Distances with Geometry

Converting baselines and parallaxes into distances:



More Precisely E-2 Measuring Distances with Geometry

Converting angular diameter and distance into size:



E.5 Scientific Theory and the Scientific Method

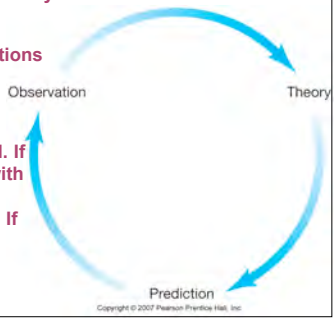
Scientific theories:

- must be testable
- must be continually tested
- should be simple
- should be elegant

Scientific theories can be proven wrong, but they can never be proven right with 100% certainty

E.5 Scientific Theory and the Scientific Method

- **Observation** leads to theory explaining it
- **Theory** leads to predictions consistent with previous observations
- **Predictions** of new phenomena are observed. If the observations agree with the prediction, more predictions can be made. If not, a new theory can be made.



Summary of the Introduction

- **Astronomy**: study of the universe
- Stars can be imagined to be on inside of **celestial sphere**; useful for describing location
- Plane of Earth's orbit around Sun is **ecliptic**; at 23.5° to celestial equator
- Angle of Earth's axis causes **seasons**
- Moon shines by reflected light, has **phases**
- **Solar day ≠ sidereal day**, due to Earth's rotation around Sun

Summary of the Introduction

- **Synodic month ≠ sidereal month**, also due to Earth's rotation around Sun
- **Tropical year ≠ sidereal year**, due to precession of Earth's axis
- **Distances can be measured through triangulation** and **parallax**
- **Eclipses of Sun and Moon** occur due to alignment; only occur occasionally as orbits are not in same plane
- **Scientific method**: observation, theory, prediction, observation, …