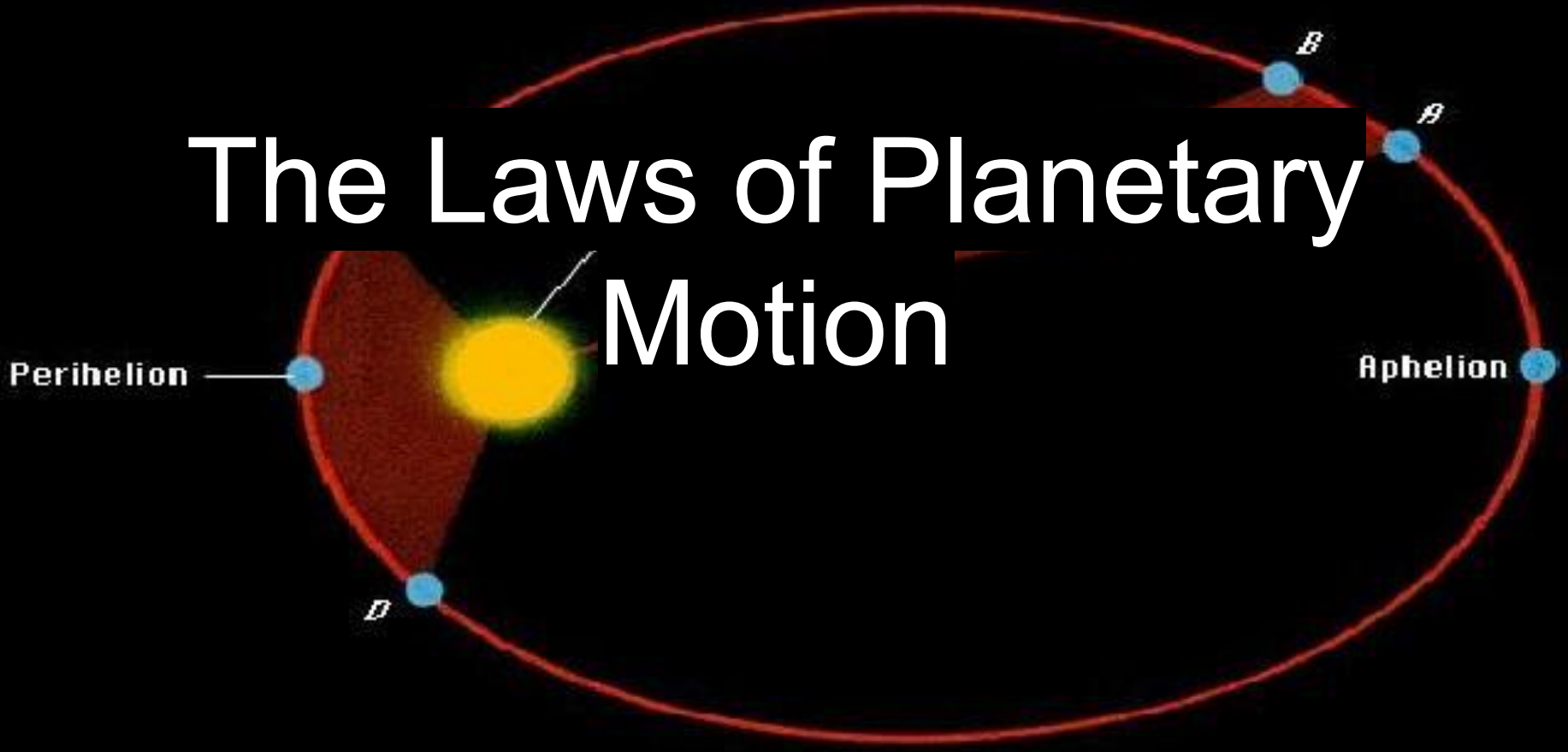
The Laws of Planetary Motion



Poll everywhere

When poll is active respond at **PollEv.com/nikhilpatten355**

Send **nikhilpatten355** to **22333**

Poll everywhere

results

Poll everywhere

$$\alpha = 88.792939\ ^\circ$$

$$\alpha = 88.792939\ ^\circ \times \frac{1\ \mathrm{h}}{15\ ^\circ}$$

$$\alpha = 5.9195\ \mathrm{h}$$

$$\alpha = 5\ \mathrm{h} + 0.9195\ \mathrm{h}$$

$$\alpha = 5\ \mathrm{h} + 0.9195\ \mathrm{h} \times \frac{60\ \mathrm{m}}{1\ \mathrm{h}}$$

$$\alpha = 5\ \mathrm{h} + 55.171756\ \mathrm{m}$$

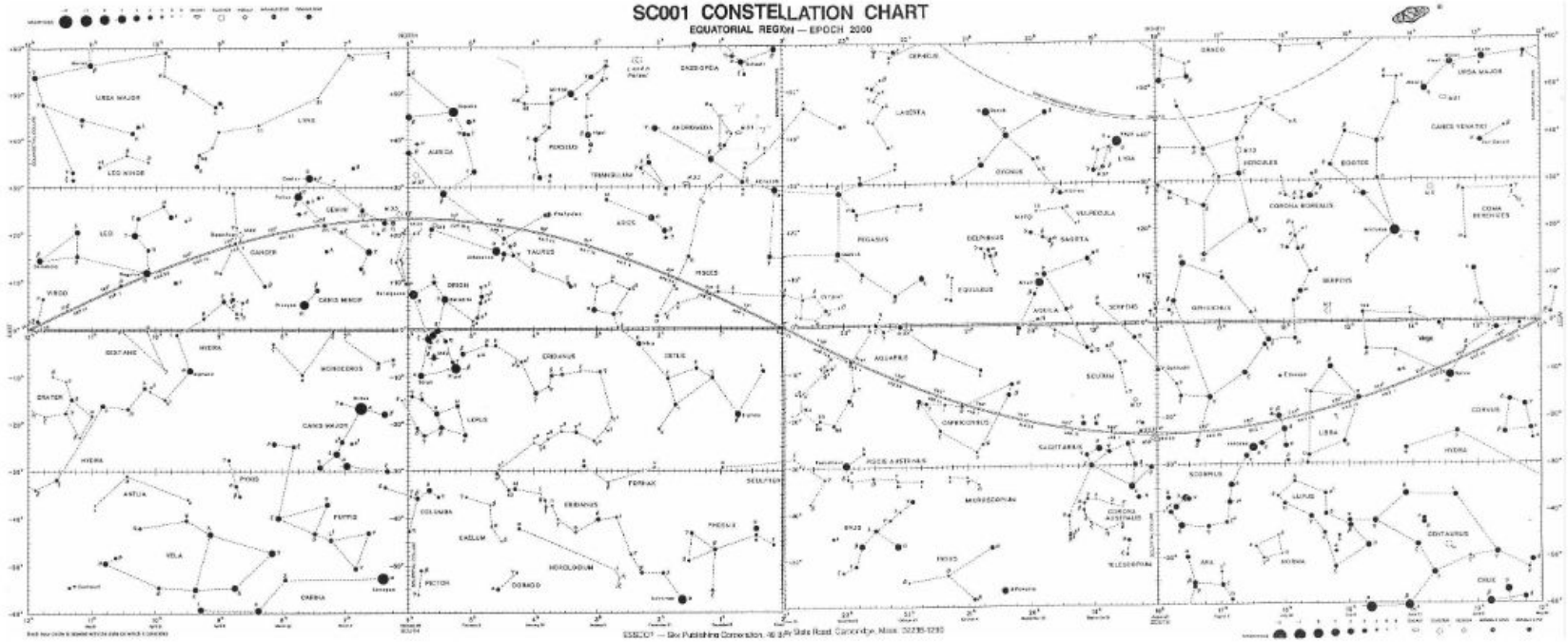
$$\alpha = 5\ \mathrm{h} + 55\ \mathrm{m} + 0.171756\ \mathrm{m}$$

$$\alpha = 5\ \mathrm{h} + 55\ \mathrm{m} + 0.171756\ \mathrm{m} \times \frac{60\ \mathrm{s}}{1\ \mathrm{m}}$$

$$\alpha = 5\ \mathrm{h} + 55\ \mathrm{m} + 10.31\ \mathrm{s}$$

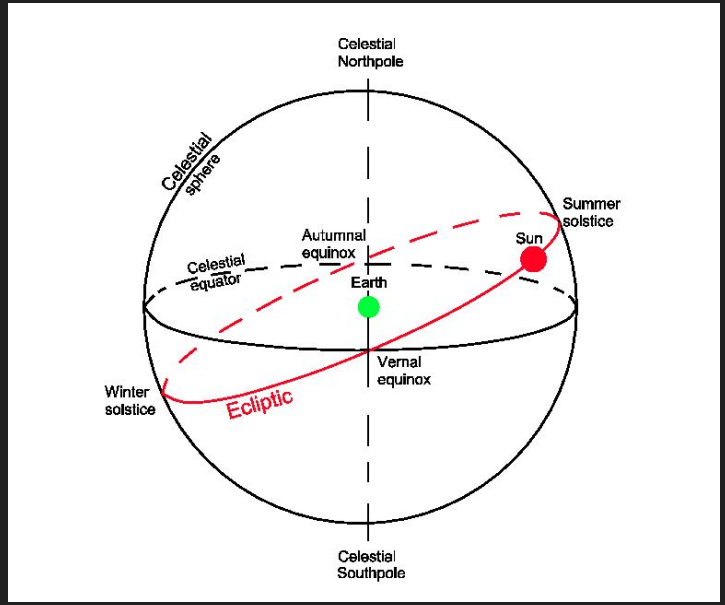
$$\boxed{\alpha = 5\mathrm{h}\ 55\mathrm{m}\ 10.31\mathrm{s}}$$

The ecliptic



The ecliptic

- Plane above and below the celestial equator.
- Path the Sun takes throughout the year.
- Eclipses occur when the Sun and Moon intersect on the ecliptic.



The ecliptic

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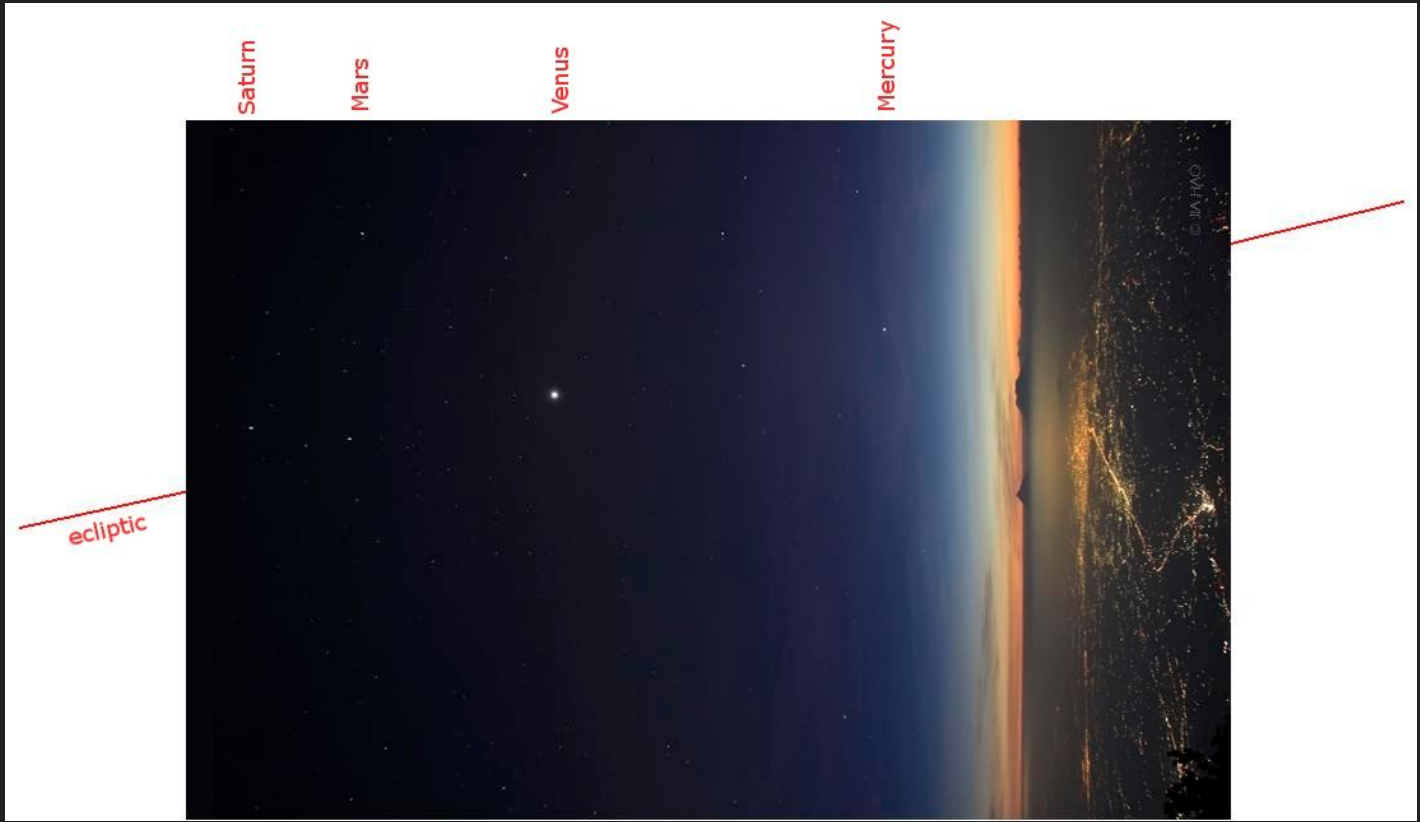

The zodiac

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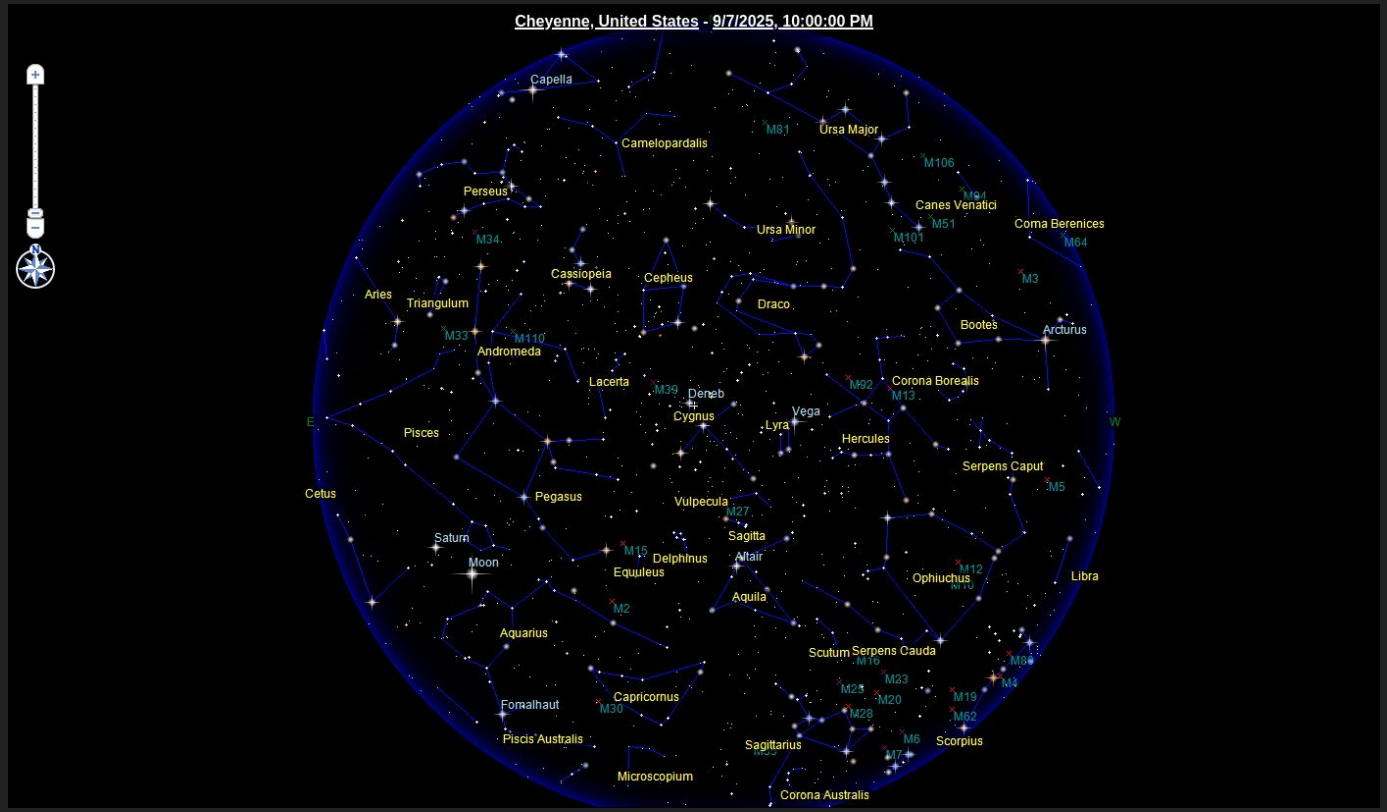
- Constellations along the ecliptic.

Zenith

- Position on the sky straight up.
- Declination of the zenith is always your observation latitude on Earth

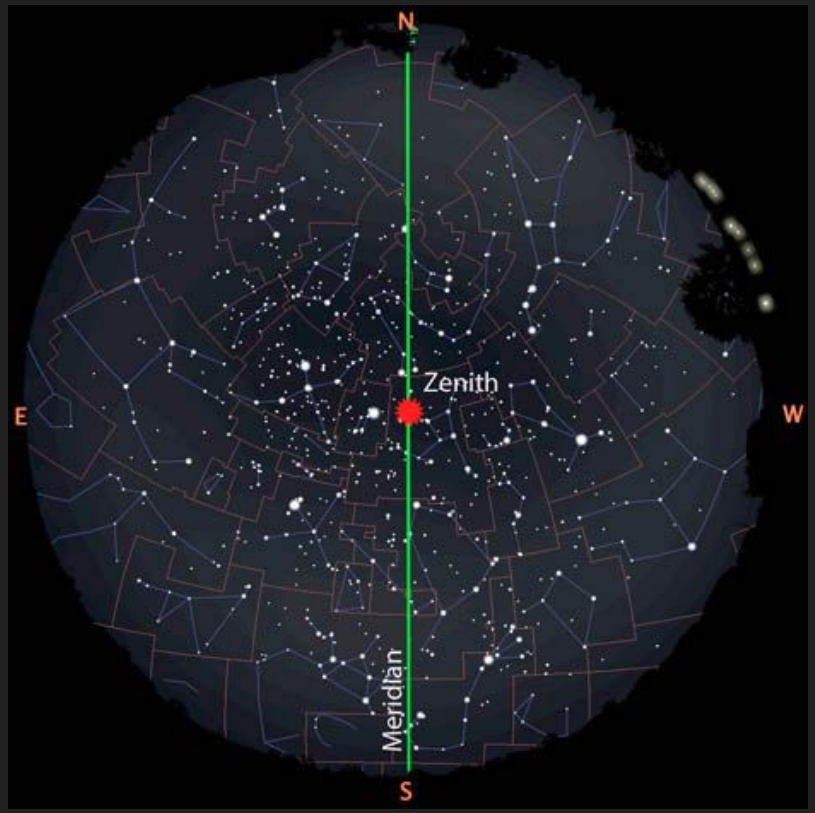
Zenith


Cheyenne, United States - 9/7/2025, 10:00:00 PM
Capella
Camelopardalis
M81
Ursa Major
M106
Perseus
M34
Canes Venatici
M94
M51
M101
Ursa Minor
Coma Berenices
M64
Cassiopeia
Cepheus
M3
Aries
Triangulum
Draco
Bootes
Arcturus
M33
M110
Andromeda
Lacerta
M39
Deneb
M92
Corona Borealis
M13
Cygnus
Vega
Lyra
E
W
Pisces
Hercules
Serpens Caput
M5
Cetus
Pegasus
Vulpecula
M27
Sagitta
Saturn
M15
Delphinus
Altair
Moon
Equuleus
Ophiuchus
M12
Libra
Aquila
M2
Aquarius
Scutum
Serpens Cauda
M16
M8
M4
M23
M25
M20
M19
Capricornus
M30
Fomalhaut
M28
M62
Piscis Australis
M6
Scorpius
Sagittarius
M7
Microscopium
Corona Australis

Sidereal Time

- Measure of time of Earth’s rotation rate with respect to fixed background stars.
- Local Mean Sidereal Time (LMST)- Right Ascension of stars crossing the meridian

Sidereal Time



The Sun throughout the year

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- Right Ascension and Declination of the sun are changing throughout the year.
- The Sun has 0 ° Declination on the equinoxes
- The Sun has +23.5 ° declination on the summer solstice (higher in the North).
- The Sun has -23.5 ° declination on the winter solstice (lower in the North).
- The Sun’s right ascension is 0 ° on the vernal equinox

The Sun throughout the year

Date	Right Ascension of the Sun
21 March	0 h
21 May	4 h
21 July	8 h
21 September	12 h
21 November	16 h
21 January	20 h

- Sun’s right ascension increases two hours every month.

Question

1. Find the speed of the Sun (only in right ascension, ignore declination) per day.
   a. 3.94’ per day b. 0.0657’ per day c. 30.4’ per day d. 237’ per day

Question

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   a. **3.94’ per day** b. 0.0657’ per dayc. 30.4’ per day d. 237’ per day

Question

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{speed} = \frac{24 \text{ h}}{365.25 \text{ days}}$$

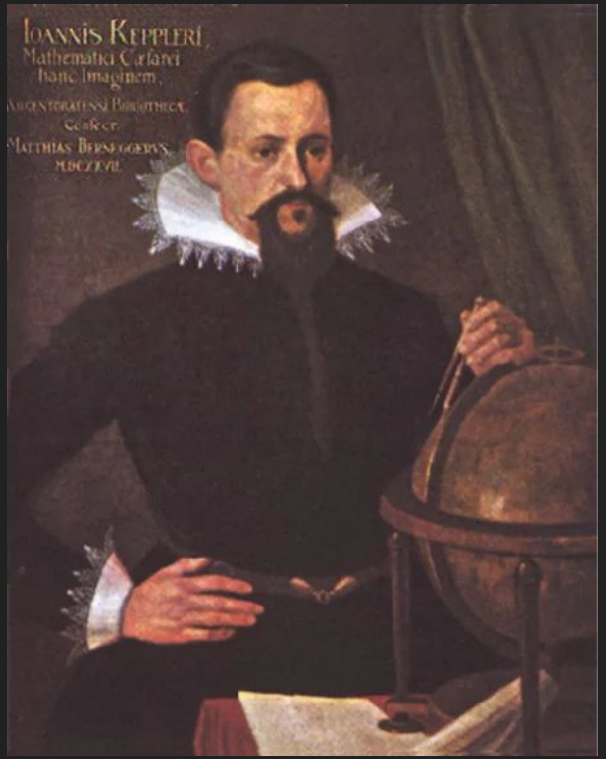
$$\text{speed} = 0.065708 \text{ h per day}$$

$$\text{speed} = 0.065708 \text{ h per day} \times \frac{60'}{1 \text{ h}}$$

$$\boxed{3.94' \text{ per day}}$$

Kepler’s Laws of Planetary Motion

- Johannes Kepler began studying the precise position of planets.
- Only allowed access to data when his mentor, Tycho Brahe, died in 1601.
- Copernican model was winning more and more supporters (Galileo's observations took place around 1609).
- Published his analysis in 1609.



Kepler’s Laws of Planetary Motion

1. Each planet orbits the Sun in an ellipse, with the Sun at one focus.
2. A planet sweeps out equal areas in equal times in its orbit.
3. The square of the planet’s orbital period is proportional to the cube of it’s semi-major axis.

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Kepler’s Laws of Planetary Motion- 1st Law

- His analysis of Mars was accurate to within two arcminutes.
- He became convinced that circles could not explain the predicted positions of planets precisely.
- Imagining the Sun as the source of planetary motion (weakens with distance) he then conceived of elliptical orbits.
- This new conception fit the data perfectly.
- All planets move in elliptical orbits.

Kepler's Laws of Planetary Motion- 1st Law

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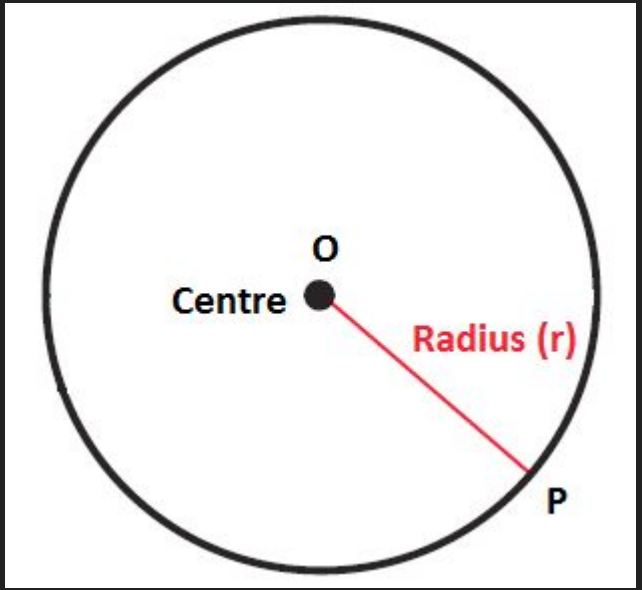

Kepler's Laws of Planetary Motion- 1st Law

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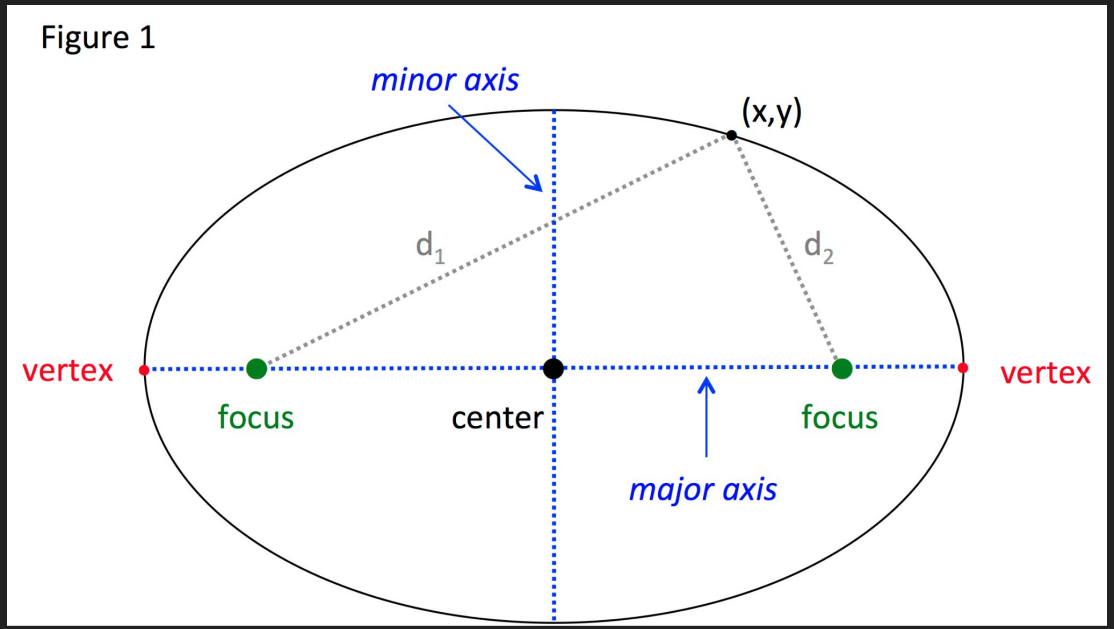

- When the minor axis equals the major axis, the ellipse reduces to a circle, focus is at the center.

Kepler's Laws of Planetary Motion- 1st Law

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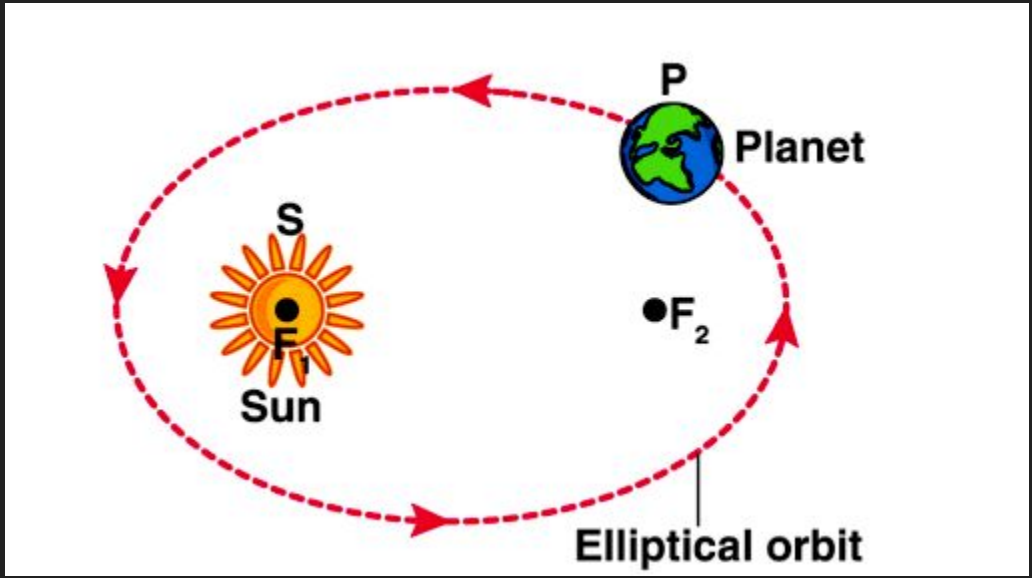

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Kepler's Laws of Planetary Motion- 2nd Law

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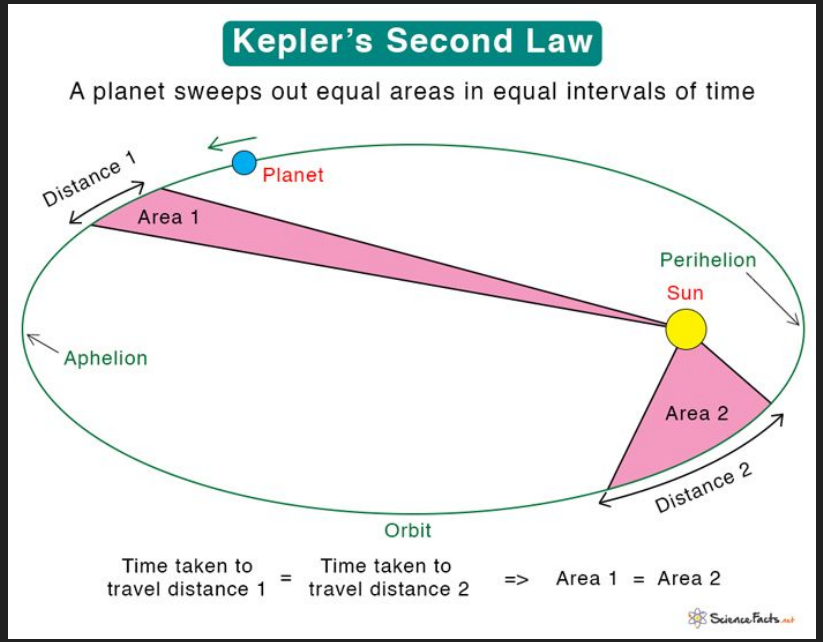

- Planet's speed up closer to the Sun, move slower when further away.

Kepler's Laws of Planetary Motion

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3. **The square of the planet's orbital period is proportional to the cube of it's semi-major axis.**

Kepler's Laws of Planetary Motion- 3rd Law

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The square of the planet's orbital period is proportional to the cube of it's semi-major axis.

- Orbital period- time it takes the planet to move around the Sun once.
- Semi-major axis- Half the major axis of the planet's ellipse.

Kepler's Laws of Planetary Motion- 3rd Law

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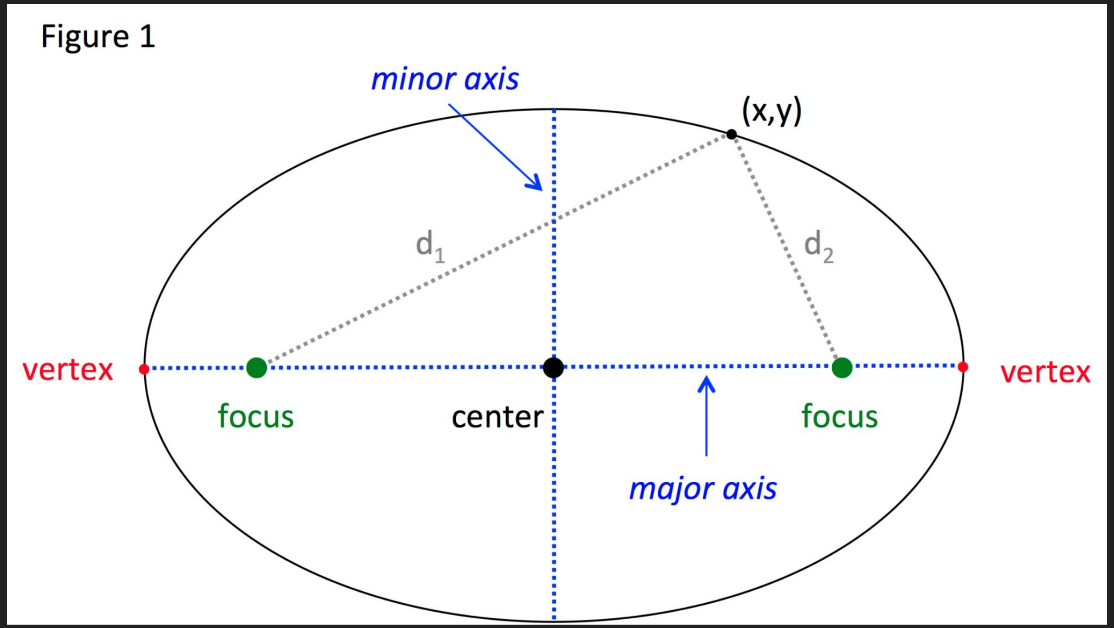

Kepler's Laws of Planetary Motion- 3rd Law

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The square of the planet's orbital period is proportional to the cube of it's semi-major axis.

- Orbital period- time it takes the planet to move around the Sun once.
- Semi-major axis- Half the major axis of the planet's ellipse.
- For circular orbits, the radius of the orbit is the semi-major axis.

Kepler's Laws of Planetary Motion- 3rd Law

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The square of the planet's orbital period is proportional to the cube of it's semi-major axis.

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$$P^2 \propto a^3$$

Kepler's Third Law- Example problem

- When dealing with unknown orbits, compare to another orbit around the same body.
  - Question about orbits around the Sun, use the Earth's semi-major axis (1 AU) and period (1 year).
  - Question about orbits around Earth, use the Moon's semi-major axis (3.844E8 m) and orbital period (27.3 days)
- Call reference body P_1,a_1 and unknown body P_2,a_2.

$$\frac{P_1^2}{P_2^2} = \frac{a_1^3}{a_2^3}$$

Kepler's Third Law- Example problem

2. How many years is Neptune's orbital period? Neptune's semi-major axis is 30.07 AU.

   a. 203.7 years b. 164.9 years c. 84.02 years d. 247.9 years

Kepler's Third Law- Example problem

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Kepler's Third Law- Example problem

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$$\frac{P_1^2}{P_2^2} = \frac{a_1^3}{a_2^3}$$

$$P_1^2 = P_2^2 \frac{a_1^3}{a_2^3}$$

$$P_2^2 = P_2^2 \frac{a_2^3}{a_1^3}$$

$$P_2 = \sqrt{P_1^2 \frac{a_2^3}{a_1^3}}$$

$$P_2 = P_1 \sqrt{\frac{a_2^3}{a_1^3}}$$

$$P_2 = P_1 \left(\frac{a_2}{a_1}\right)^{3/2}$$

$$P_2 = (1) \left(\frac{30.07}{1}\right)^{3/2}$$

$$\boxed{P_2 = 164.9 \text{ years}}$$

Announcements

- You should be able to do the homework now (let me know if you have any questions).
- Next class will be in the planetarium!

Next time

- Orbits in the Solar System