Planetary motions: Kepler’s Laws

Which best describes Earth’s movement in the solar system?

A. Earth revolves around the Sun in a perfect circle.

B. The Sun revolves around the Earth.

C. Earth revolves around the Sun in an elliptical path.

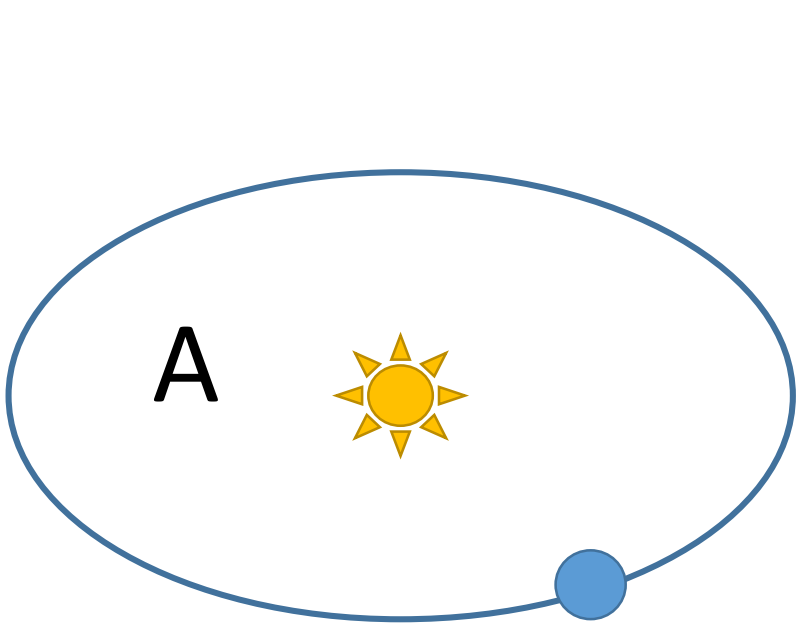
Which best describes Earth’s movement in the solar system?

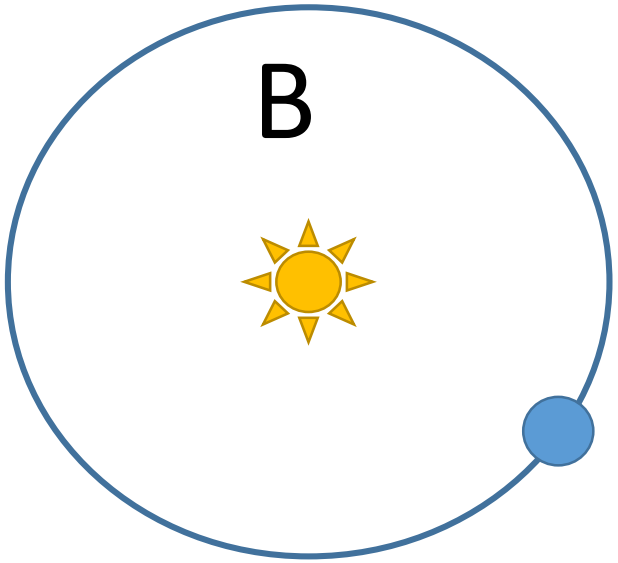
A. Earth revolves around the Sun in a perfect circle.

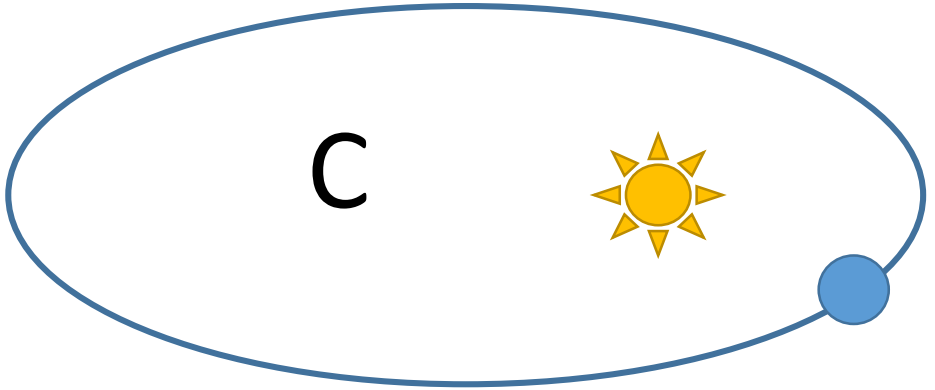
B. The Sun revolves around the Earth.

C. Earth revolves around the Sun in an elliptical path.

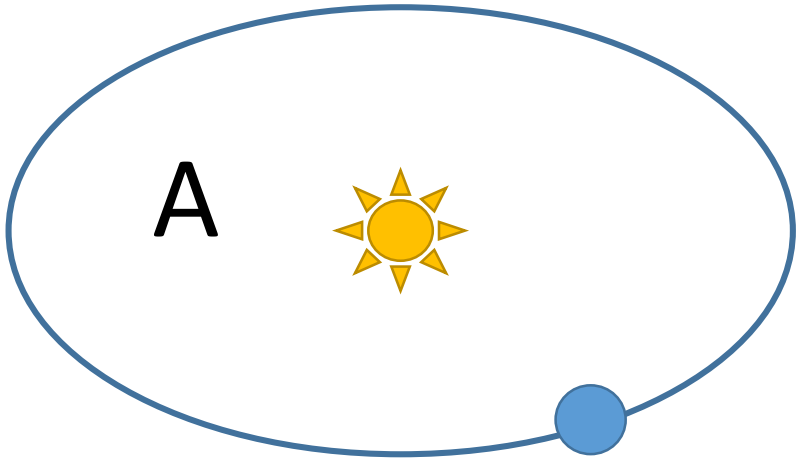
Which shape below best represents Earth's orbit around the Sun

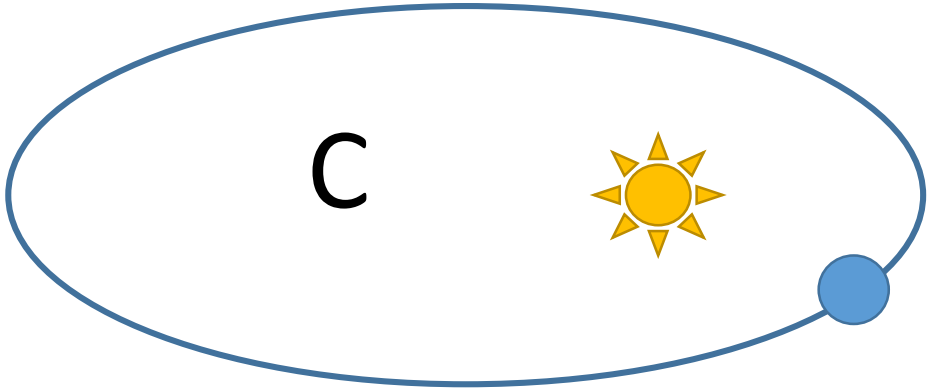


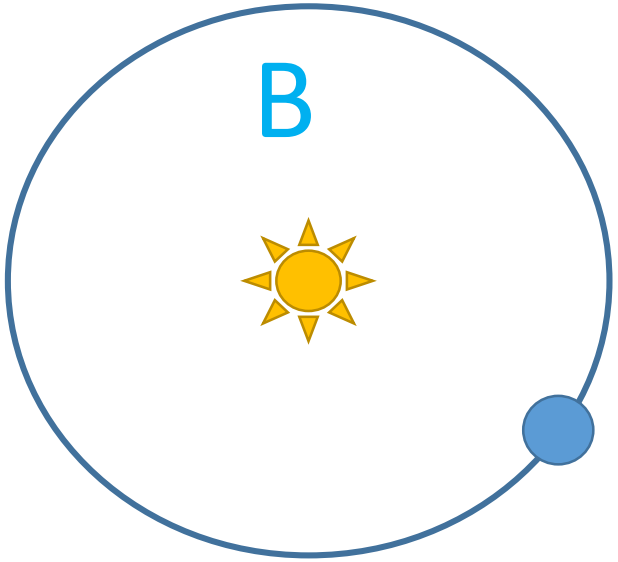




Which shape below best represents Earth's orbit around the Sun



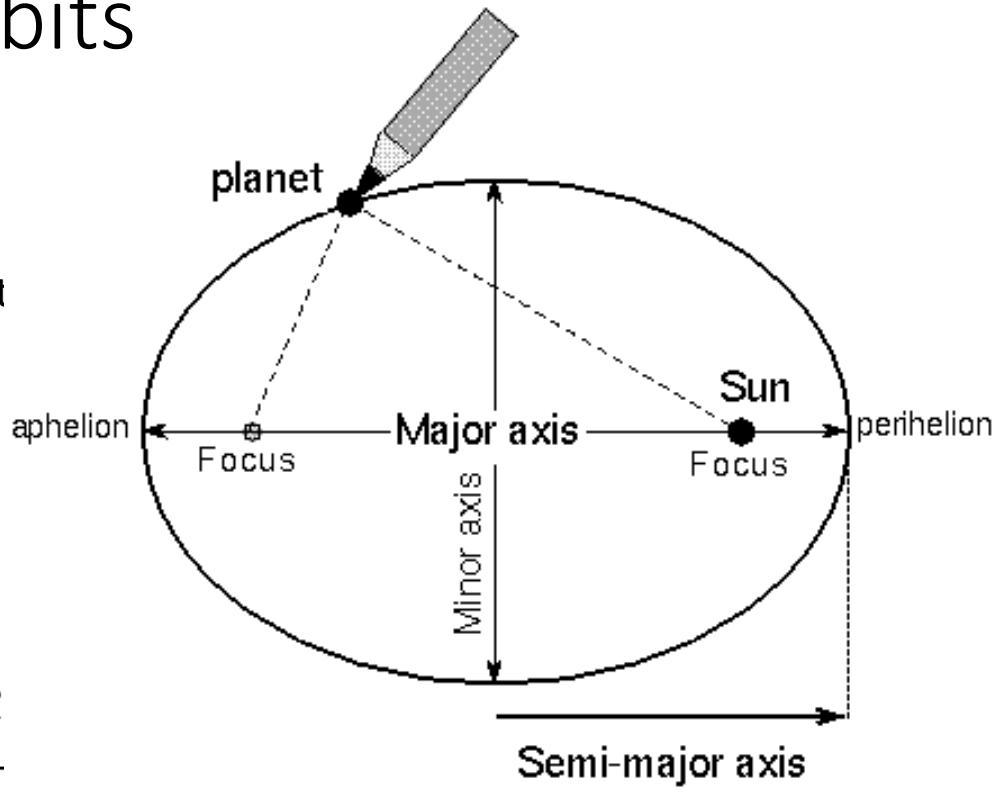




Earth orbits the Sun in an elliptical path, but that path is very close to circular.

Kepler's Three Laws of Planetary Orbits

- 1) All planets orbit in ellipses, with the Sun at one focus.
  - Semi-major axis (a) describes half of the long axis of a planet's orbit
  - c = half of the separation of the ellipse's two focii.
  - Eccentricity (e) describes how non-circular an orbit is:
    - 0 = perfect circle, closer to 1 means skinnier oval.
  - Perihelion = closest part of an orbit to the Sun;
  - Apehelion = farthest part of an orbit from the Sun;



$$e = \frac{c}{a}$$

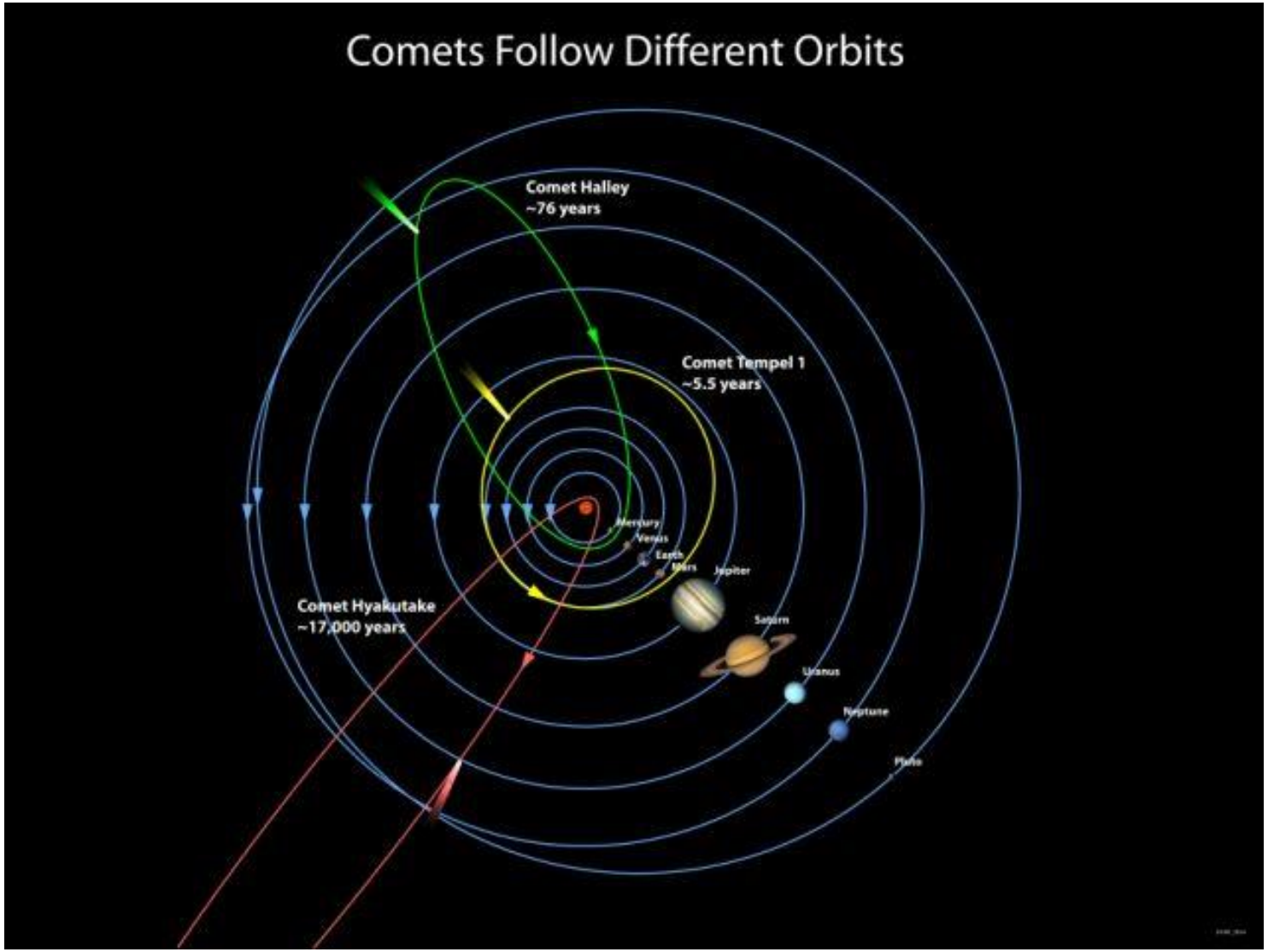
1st law ---- Demo with string,

http://astro.unl.edu/classaction/animations/renaissance/ellipsedemo.html

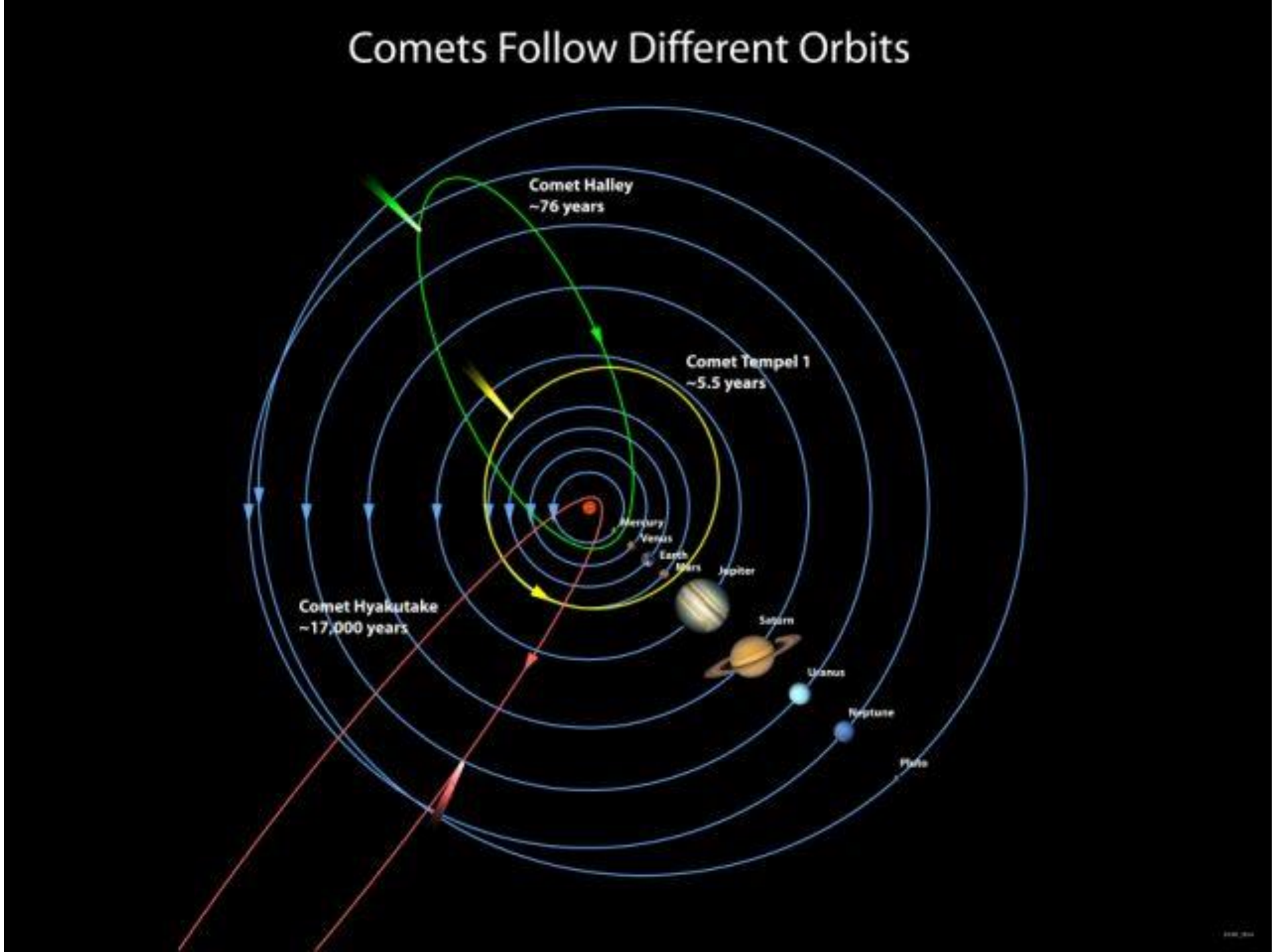
$$R_{perihelion} = a(1 - e)$$

$$R_{apohelion} = a(1 + e)$$

Planets in our solar system have low eccentricity orbits that are hard to distinguish from perfect circles. Comets have much higher eccentricities, where the ellipsoidal nature of their orbits is easier to see.



The exception? Pluto!

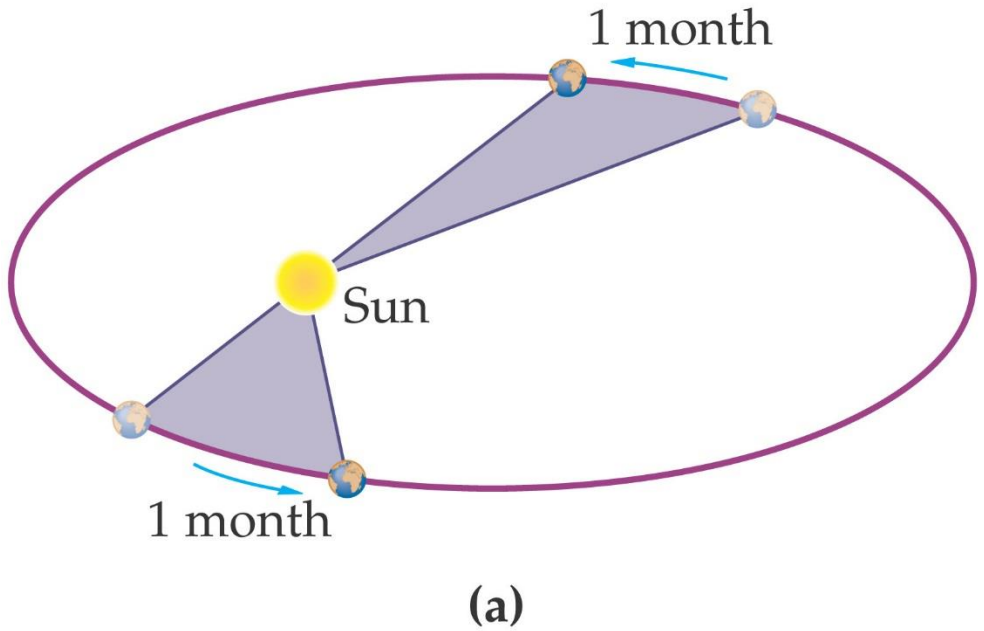


Kepler's Three Laws of Planetary Orbits

- 1) All planets orbit in ellipses, with the Sun at one focus.

- 2) In its orbit, a planet sweeps out ***equal areas*** in ***equal times***.
  - When a planet is in the part of its orbit that is closer to the Sun, it moves more quickly.

http://3.bp.blogspot.com/-IN5bFXNnsVo/UJVznVIiI/AAAAAAAAAA5c/lnOyxLNbJfk/s1600/kepler2law.JPG

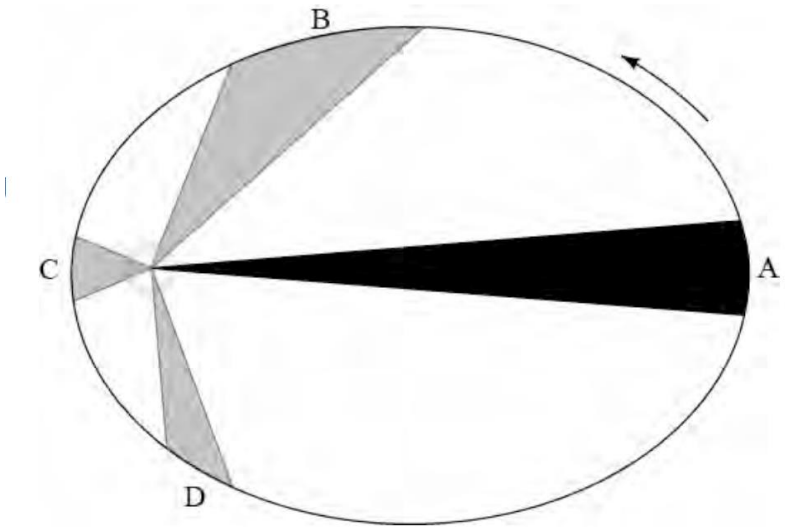


Let's do an astronomy simulation

http://astro.unl.edu/interactives/kepler/KeplerSecondLaw.htmlperiods

Kepler's 2nd Law: Quick Poll Questions

1. Which *one* of the planet's orbital segments will last as long as the time it takes for the planet to sweep through the arc 'A'?



A. Can't be determined

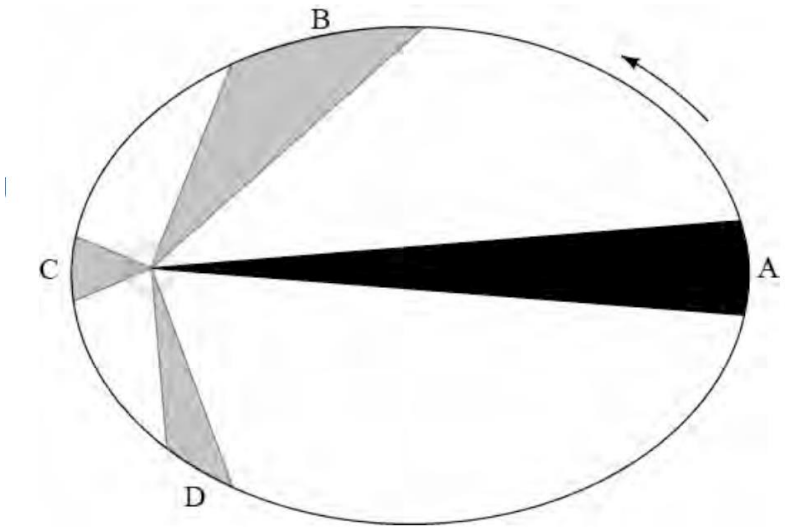
B. Arc B

C. Arc C

D. Arc D

Kepler's 2nd Law: Quick Poll Questions

1. Which *one* of the planet's orbital segments will last as long as the time it takes for the planet to sweep through the arc 'A'?



A. Can't be determined

B. Arc B

C. Arc C

D. Arc D

Kepler's Three Laws of Planetary Orbits

http://hyperphysics.phy-astr.gsu.edu/hbase/kepler.html

- 1) All planets orbit in ellipses, with the Sun at one focus.

- 2) In its orbit, a planet sweeps out ***equal areas*** in ***equal times***.
  - When a planet is in the part of its orbit that is closer to the Sun, it moves more quickly.

- 3) Planets' orbital periods increase with the semi-major axis of the orbit.
  - Planets that are farther from the Sun have larger orbital periods.

- **3rd law**…..
- http://astro.unl.edu/classaction/animations/renaissance/keplers_third.html

Orbital Properties of Solar System Bodies

- Table courtesy AstronomyNotes.com (http://www.astronomynotes.com/tables/tablesb.htm)

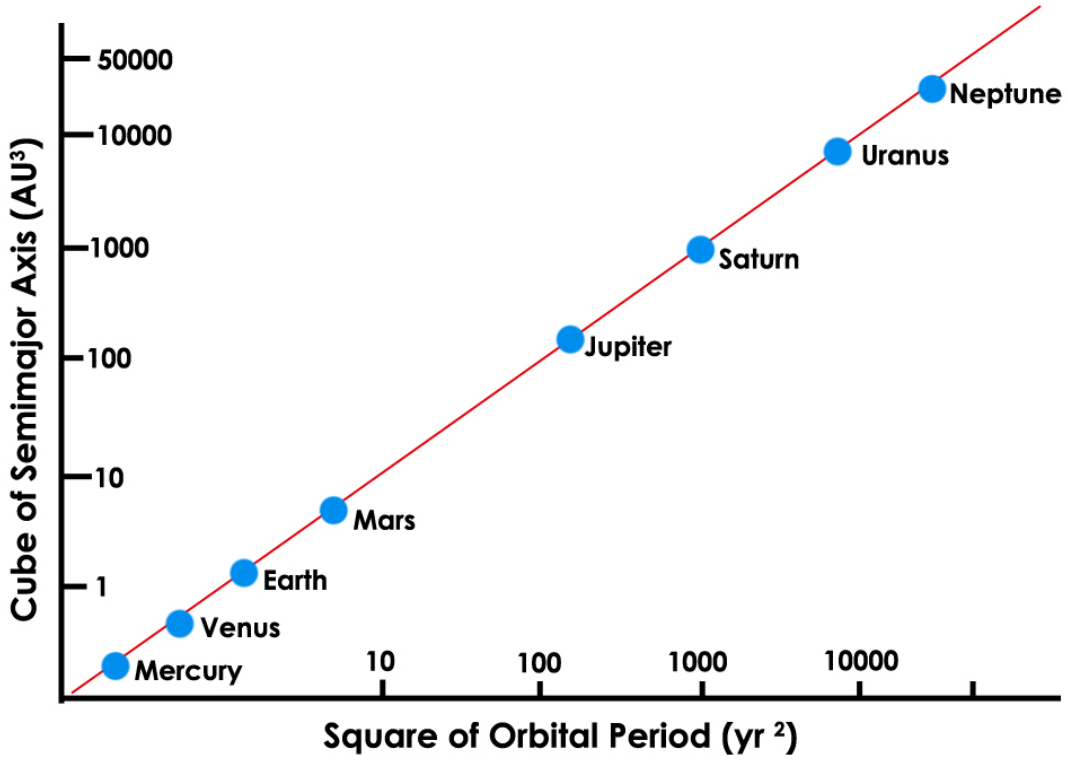
Planets: Orbital Properties

Planet	distance (A.U.)	revolution	eccentricity	inclination (deg)
Mercury	0.387	87.969 d	0.2056	7.005
Venus	0.723	224.701 d	0.0068	3.3947
Earth	1.000	365.256 d	0.0167	0.0000
Mars	1.524	686.98 d	0.0934	1.851
Jupiter	5.203	11.862 y	0.0484	1.305
Saturn	9.537	29.457 y	0.0542	2.484
Uranus	19.191	84.011 y	0.0472	0.770
Neptune	30.069	164.79 y	0.0086	1.769
Pluto	39.482	247.68 y	0.2488	17.142

- Note use of the Astronomical Unit: 1.5×10^8 km

Orbital Properties of Solar System Bodies

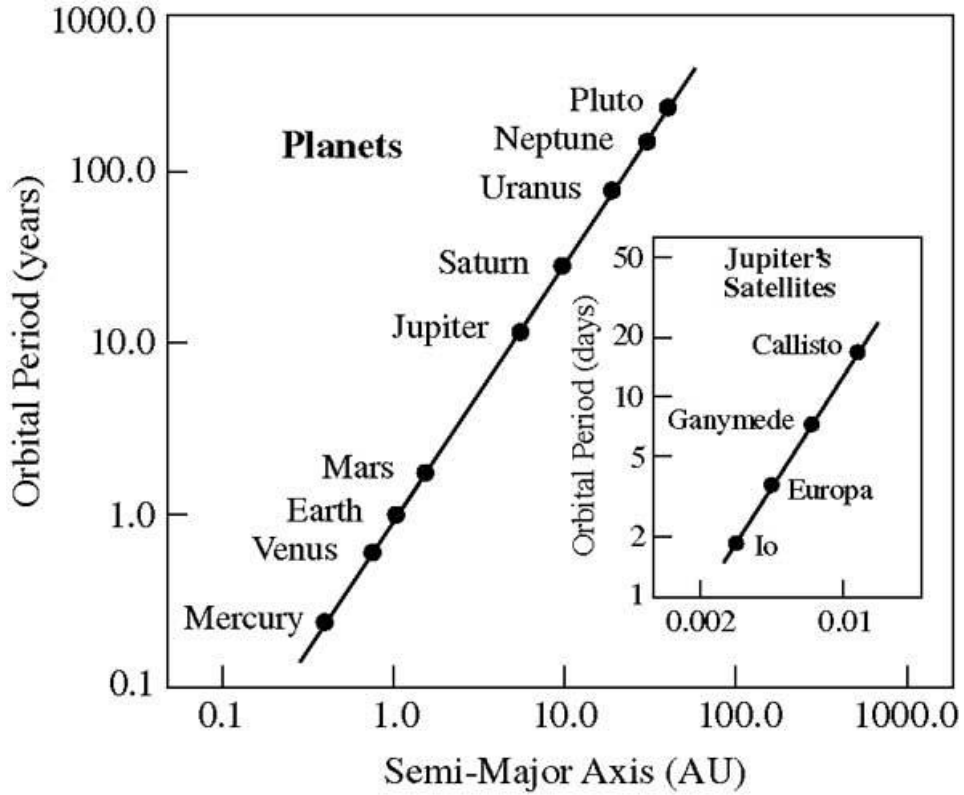
- Figure courtesy TeachAstronomy.com (http://www.teachastronomy.com/astropedia/article/Keplers-Laws)



- Note units: Periods in years, semi-major axis in AUs.

Orbital Properties of Solar System Bodies

- Figure courtesy Prof. Kenneth Lang @ Tufts University
  (http://ase.tufts.edu/cosmos/view_picture.asp?id=929)



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

For both planets & Jupiter's moons – following the same law, just with different constants involved!

- Note units (Periods in years, semi-major axis in AUs) and different scales for planets & Jupiter's moons.

Kepler's Three Laws of Planetary Orbits

- 1) All planets orbit in ellipses, with the Sun at one focus.

- 2) In its orbit, a planet sweeps out ***equal areas*** in ***equal times***.
  - When a planet is in the part of its orbit that is closer to the Sun, it moves more quickly.

- 3) Planets' orbital periods increase with the semi-major axis of the orbit.
  - Planets that are farther from the Sun have larger orbital periods.

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

FOR FRIDAY:

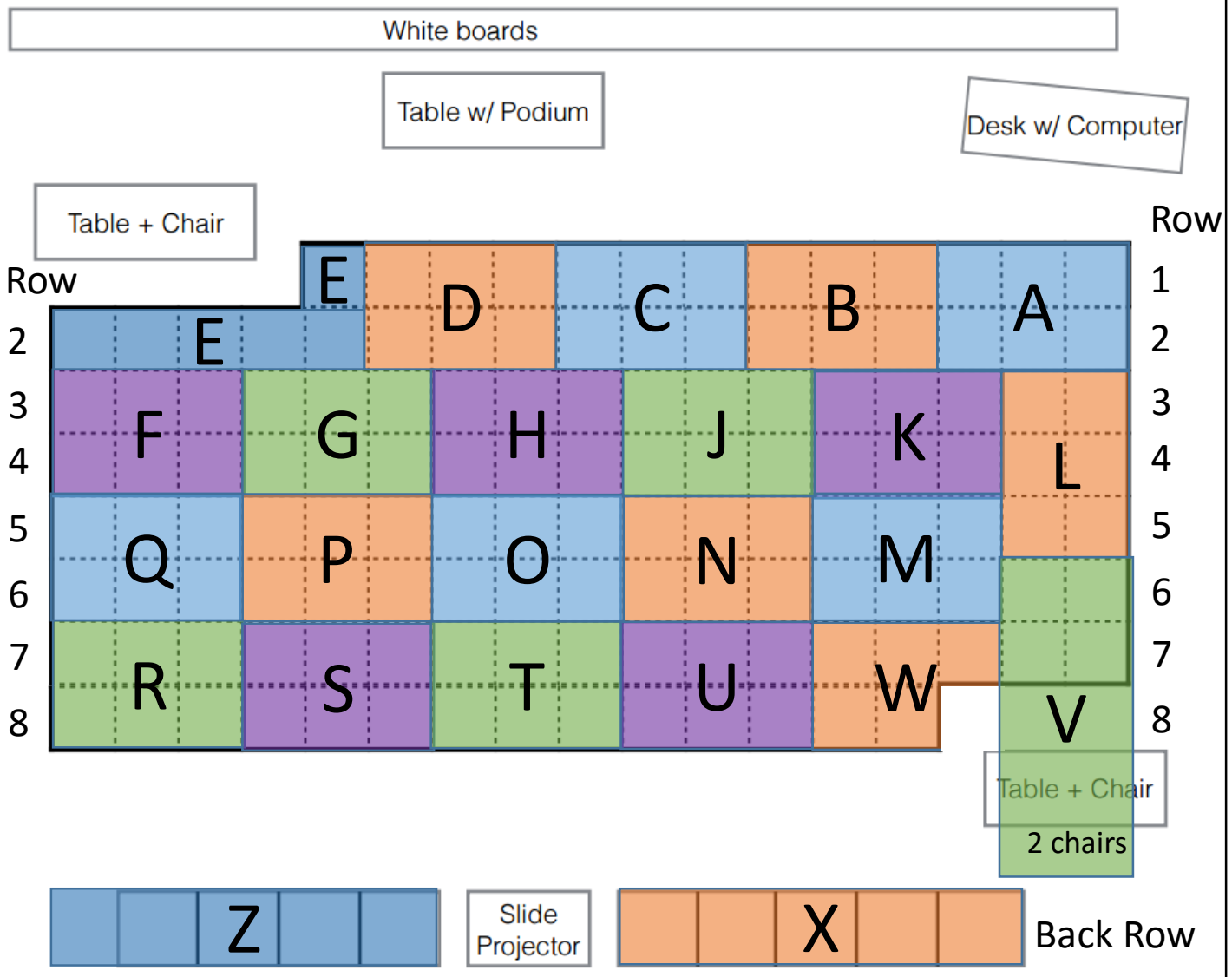
- I will post the next group activity this evening
  - Please read through it before class on Friday
  - I will provide you with handouts for your groups in class

- The next homework is posted and is due by 11PM Friday night; Late assignments will not be accepted

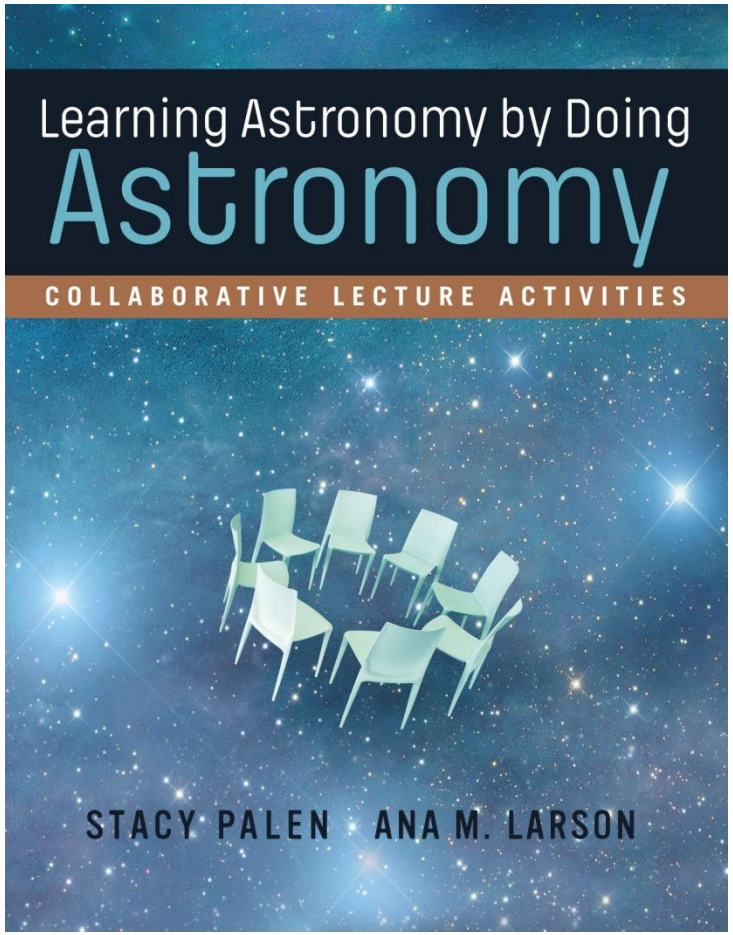
Group Assignments

Student	Grp	Student	Grp	Student	Grp	Student	Grp
Garrett Knoll	A	Connor Chapman	G	Valentina Cubillos	N	Dairely Camacho	T
Abigail Bailey		Rosalie Lander		Eulogio Gonzalez		Michael Krenning	
Jordan Stello		Brooke Carlson		Kathleen Sullivan		Miki Green	
Emelia Monahan		Nolan Walker		Megan Gross		Zane Gooding	
Falena Walker		Magdalena Maziarz		Madison Armitage		Madison Rigby	
Brooke Covello		Makenzi Schuerholz		Raleigh Hansen		Kelsey Gipson	
Samuel Kaplan	B	Blake Zender	H	Christina Parslow	O	Angel Ferrer	U
Mary Miller		Cynthia Sahagun		Sean Rita		Sarah Wyrick	
Julia Jones		Elizabeth Rice		Hayden Ramsay		Andrew Hoff	
Callen Farrell		Sierra West		Kendra Aronson		Sierra Howard	
Mark Callender		Rachael Shanahan		Emmett Bonifazi		Jordan Anderson	
Thomas Hauser		Olivia Sterne		Mamesa El		Douglas Keough	
Anjali Grutzius	C	Jared McMinn	J	Christopher Charles	P	Emily Wanner	V
Sarah Hawthorne		Daniel Duran		Nora Curran		Nathen Grimm	
Andy Lee		David Gago		Alex Montgomery		Benjamin Haak	
Cheyanne Bennett		Margaret Stepaniants		Lauryn Paoli		Bradley Stanchfield	
Sara Von Krosigk		Daniel Brunzell		Daniel Piker		Reece Budinich	
Corey Pargeter		Karmiel Weste		Tristan Thamm		Madison Teefy	
Spencer Stepniewski	D	Megan Ewert	K	Hannah Shaffer	Q	Tony Bhangal	W
Elliette Kee		Samuel Sawyer		Matthew Stinson		Paul Goins	
Kimberly Kiefer		Rachel Mason		Cameron Balli		Nikolai Birchler	
Hallie Black		Madison Waters		Anthony Menghi		Autumn Nash	
Mya Bruso-Radosevich		Andrew Boedigheimer		Spencer Dolecki		Lindsey Fujiwara	
Nicolas Morales		Jason Maki		Matthew Schneider			
Kevin Yates	E	Nicholai Whippo	L	Madison Taylor	R	Jordan Lucia	X
Karisa Stapp		Riley McLoughlin		Jonathan Dacy		Karalyn Poulsen	
Clare Janetzki		Quinn Comstock		Taylor Brackinreed		Bradlee Thielen	
Jenna Leu		Jenny Chang		Teylor Lowe		Grey Hannah	
Cameron Hall		Kylisa Hull		Sarah H Dean		Estelle Nelson	
Marisa Gooding		Nathan Sanders		Rees Alferd			
Wilson Stolle	F	Samuel Meyer	M	Eleanor Seaman	S	John Stone	Z
Richele Young		Abbigail Phelps		Emily Shere		Zena Moran	
Jessica Mantchev		Tristanne Droege		Damien Bassett		Chase Gartner	
Sophie Callens		Alliandra Hermans		Mireya Perez-Garcia		Douglass Shumaker	
Rebecca Trostad		Parker Verhoff		Jonah Bettger		Zachary Kalousis	
Matthew DiLoreto		Emma Michel		Thien Bui			

ROOM MAPS: Please sit in the seats assigned to your group.



Activity 6: Working with Kepler's Laws



Pre-6.1: Kepler's first law states that the orbits of the planets are

a. always perfectly circular with the Sun in the center.
b. ellipses with the Sun in the center.
c. ellipses with Earth at one of the foci.
d. ellipses with the Sun at one of the foci.

Pre-6.1: Kepler's first law states that the orbits of the planets are

a. always perfectly circular with the Sun in the center.
b. ellipses with the Sun in the center.
c. ellipses with Earth at one of the foci.
d. ellipses with the Sun at one of the foci.

Pre-6.2: Kepler's second law states or implies that while traveling in their orbits, the planets

a. sweep out equal areas in equal times.
b. move fastest when they are the closest to the Sun.
c. move slowest when they are the farthest from the Sun.
d. All of these answers are correct

Pre-6.2: Kepler's second law states or implies that while traveling in their orbits, the planets

a. sweep out equal areas in equal times.
b. move fastest when they are the closest to the Sun.
c. move slowest when they are the farthest from the Sun.
d. All of these answers are correct

Pre-6.3: Kepler's third law tells us that

a. there is a correlation between a planet's distance from the Sun and the period of its orbit.

b. there is the possibility that there is a tenth planet that can be discovered by measuring its orbit.

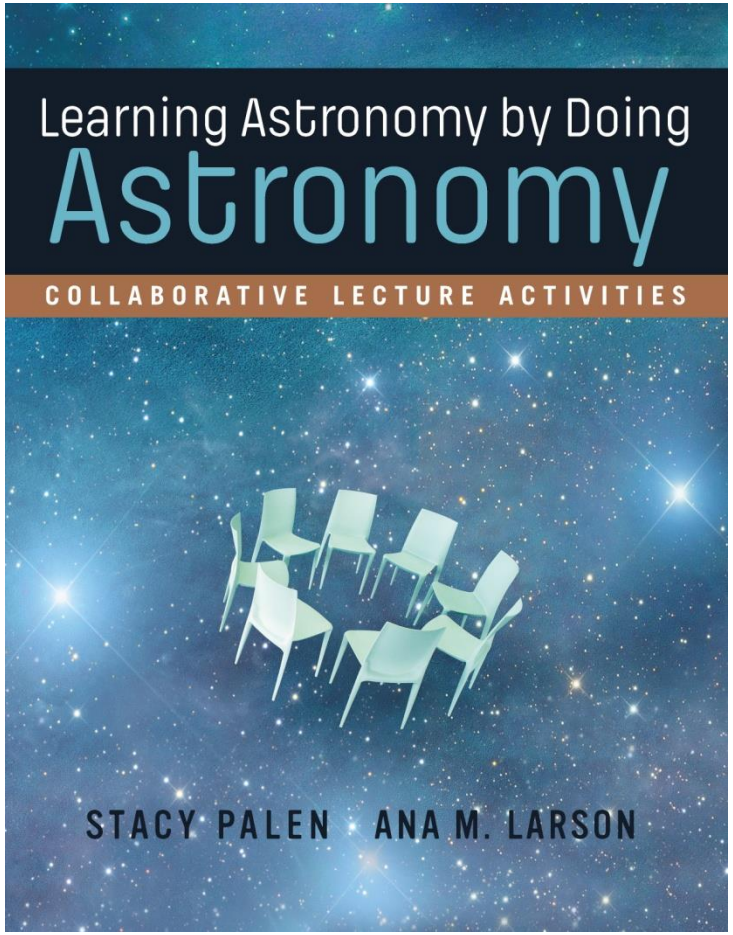
c. there is a relationship among the distances of the planets from the Sun and the number of moons they have.

d. a planet at a given distance from the Sun would have a different orbital period if its orbit were more eccentric.

Pre-6.3: Kepler's third law tells us that

a. **there is a correlation between a planet's distance from the Sun and the period of its orbit.**
b. there is the possibility that there is a tenth planet that can be discovered by measuring its orbit.
c. there is a relationship among the distances of the planets from the Sun and the number of moons they have.
d. a planet at a given distance from the Sun would have a different orbital period if its orbit were more eccentric.

Activity 6: Working with Kepler's Laws



- Do as many steps as you can in a group
- Turn in one set of solutions per group
- Make sure to have your group name and the first and last names of all group members present

Post-6.1: The difference between the semimajor axis and the minor axis is

a. the semimajor axis is always much longer.
b. determined by the eccentricity of the ellipse.
c. the minor axis of an orbit can't usually be measured.
d. None of these answers is correct

Post-6.1: The difference between the semimajor axis and the minor axis is

a. the semimajor axis is always much longer.
b. determined by the eccentricity of the ellipse.
c. the minor axis of an orbit can't usually be measured.
d. None of these answers is correct

Post-6.2: As a planet orbits the Sun in a noncircular orbit, it will slow down as it moves away from the Sun and speed up as it moves toward the Sun. A more physical way of stating this motion is that the planet

a. decelerates during half of its orbit and accelerates during the other half.
b. is not accelerated when it is the closest to the Sun or when it is at its farthest distance.
c. stays in its orbit due to the Sun's gravitational pull.
d. slows down and speeds up during only a small fraction of its time in orbit.

Post-6.2: As a planet orbits the Sun in a noncircular orbit, it will slow down as it moves away from the Sun and speed up as it moves toward the Sun. A more physical way of stating this motion is that the planet

a. **decelerates during half of its orbit and accelerates during the other half.**
b. is not accelerated when it is the closest to the Sun or when it is at its farthest distance.
c. stays in its orbit due to the Sun's gravitational pull.
d. slows down and speeds up during only a small fraction of its time in orbit.

Post-6.3: Kepler's third law means that all orbits with the same semimajor axis have the same period. This applies to both perfectly circular orbits and highly eccentric ones because

a. Kepler's laws have been repeatedly tested and found to be true for all orbital eccentricities.
b. the speeding up and slowing down of the planet in the eccentric orbit offsets the constant motion of the planet in the circular orbit.
c. the masses of the planets are all approximately the same no matter what the shapes of their orbits are.
d. the Sun is so much more massive than all of the rest of the Solar System bodies combined.

Post-6.3: Kepler's third law means that all orbits with the same semimajor axis have the same period. This applies to both perfectly circular orbits and highly eccentric ones because

a. Kepler's laws have been repeatedly tested and found to be true for all orbital eccentricities.

b. the speeding up and slowing down of the planet in the eccentric orbit offsets the constant motion of the planet in the circular orbit.

c. the masses of the planets are all approximately the same no matter what the shapes of their orbits are.

d. the Sun is so much more massive than all of the rest of the Solar System bodies combined.

Post-6.4: Jupiter's present orbital period is 11.6 years. Jupiter is 318 times more massive than Earth. If Jupiter were moved to Earth's orbit, how long would Jupiter's orbital period be?

a. 1 year

b. 5.8 years

c. 11.6 years

d. 0.12 years

Post-6.4: Jupiter's present orbital period is 11.6 years. Jupiter is 318 times more massive than Earth. If Jupiter were moved to Earth's orbit, how long would Jupiter's orbital period be?

a. **1 year**

b. 5.8 years

c. 11.6 years

d. 0.12 years

This concludes Activity 6: Working with Kepler's Laws