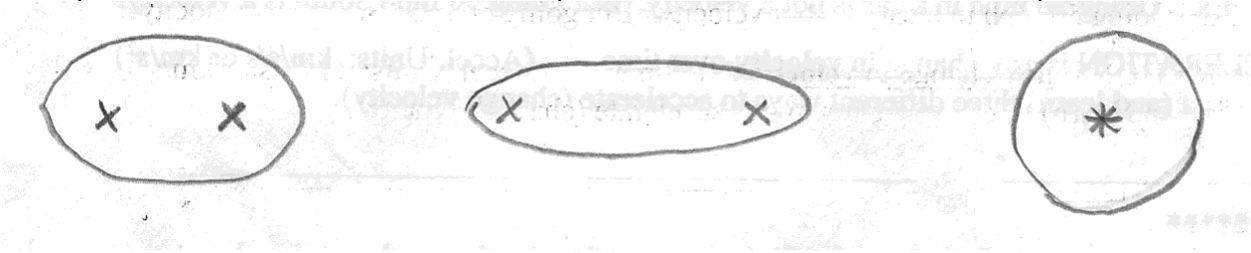
Johannes Kepler (1571-1639 AD)
He replaced the complex early models of the solar system with 3 simple rules.

Kepler's Three Laws of Planetary Motion (Provides the foundation for how orbits work.)

1) The planets move in ellipses with the sun at one focus. (the other focus is empty).
Note: the plural of focus is foci (in Latin). Every orbit has two foci.
Note: a circle is also one kind of an ellipse.
Note: the more elongated the ellipse, the farther off-center the foci and the sun will be. Only a circular ellipse will have sun at center.
(Roby demonstrates how to make any orbit using 2 foci and a loop of string of fixed length.)

Example A Example B Example C

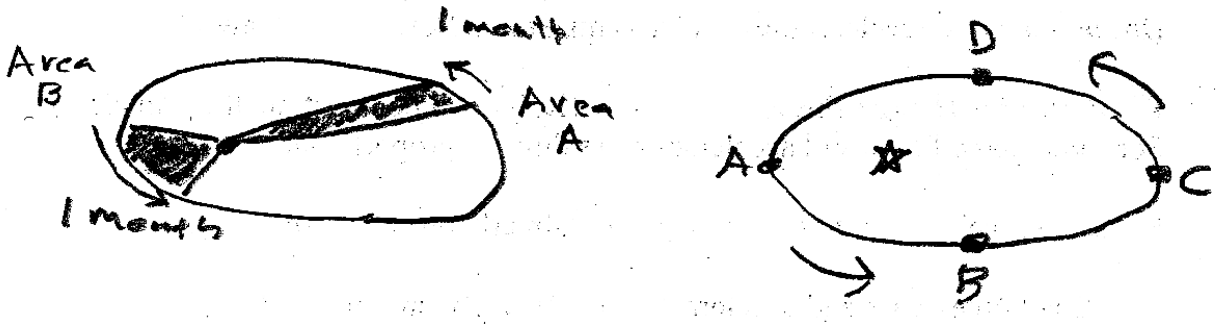


with 2 foci overlapping

Note that the semi-major axis (A) is half the long axis of an ellipse.
It is used to measure the size of an orbit.
It is also equal to the average planet-sun distance averaged over one orbit.

The semi-major axis of the Earth's orbit is 93 million miles and defines a distance unit call the Astronomical Unit or AU for short. This distance unit is useful for the solar system and other star systems including Binary Star Systems (two stars orbiting each other).

2) Equal area is swept out in equal time by a line connecting a planet to the sun.
See diagram in textbook and below **(equal areas in equal times law.)**
Bottom line: a planet moves faster near the sun and slower farther from the sun.

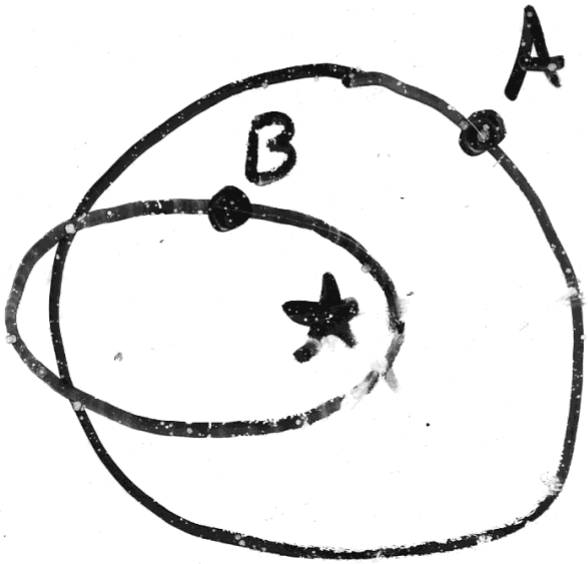


What is the only orbit shape that can give a planet constant speed? _____

3) The square of the orbital period (P) and the cube of the semi major axis (A) are in a fixed ratio for all planets. This equation is the third law: $\mathbf{A^3 / P^2 = 1}$

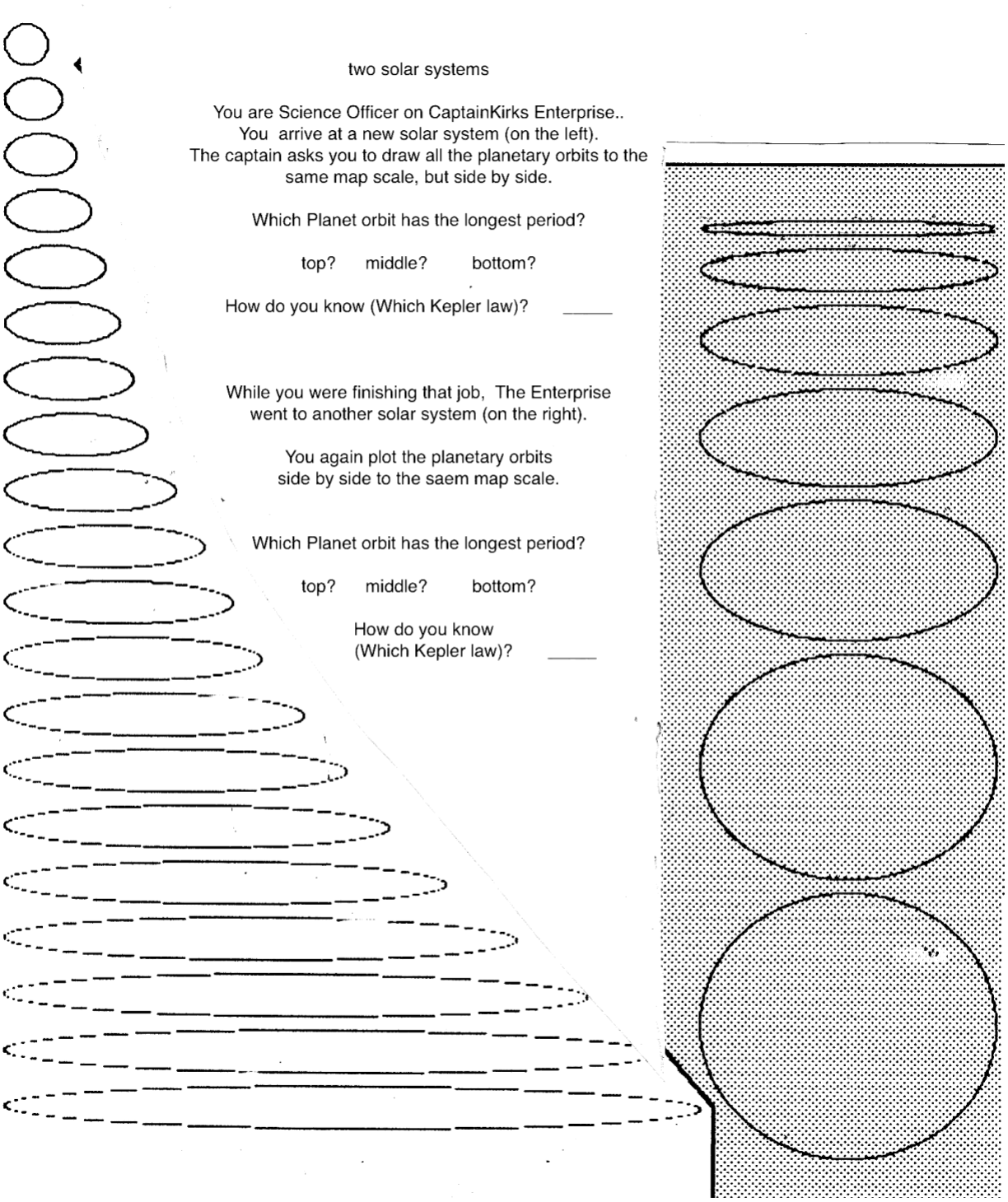
Units for K3 law: we measure P in years and measure A in AU's.
Bottom line: The bigger the orbit size (A), the longer the orbital period (P).

New Planetary System



1.) Which planet has longer Orbital Period? How do you know?

2.) Which planet has the <u>least</u> variation in Orbital Speed? How do you know?



two solar systems

You are Science Officer on CaptainKirks Enterprise..
You arrive at a new solar system (on the left).
The captain asks you to draw all the planetary orbits to the same map scale, but side by side.

Which Planet orbit has the longest period?

top? middle? bottom?

How do you know (Which Kepler law)? _____

While you were finishing that job, The Enterprise went to another solar system (on the right).

You again plot the planetary orbits side by side to the saem map scale.

Which Planet orbit has the longest period?

top? middle? bottom?

How do you know (Which Kepler law)? _____

Isaac Newton (1642-1727) A true genius in astronomy history (like Einstein or Hawking). His book, *The Principia*, covered Mechanics, Optics, Gravity, and more.

First some **Basic Definitions**
The MASS of an object is the amount of material in the object. (Units: grams or kg)
Mass is NOT necessarily correlated with size.
Consider lead ball and styrofoam ball of equal sizes – they have different mass.
Mass is NOT necessarily correlated with weight. (Weight Units: lbs or Newtons)
Your weight is the Earth's gravitational force pulling on your mass.
If you moved to the Moon, your weight would change, but your mass is the same.

VELOCITY is a vector that has two parts: speed and direction. (Speed units: km/s)
Ex.: Going 50 mph in a car is not a velocity. But going 50 mph South is a velocity.

ACCELERATION is **any** change in **velocity** over time (Accel. Units: km/s/s or km/s^2)
List (and learn) three different ways to accelerate (change velocity):

_____ _____ _____

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Newton's Three Laws of Motion (applies to any motion anytime and anywhere)

Newton's First Law of Motion: The velocity of an object is unchanged unless acted upon by a *net (unbalanced)* external force.
Note that standing still is also a form of constant velocity (speed is a constant 0 km/s)
Note that if the forces cancel out, then net force = 0. (same effect as no forces)
So, the natural state of motion if there are no forces is constant velocity or standing still.

[Dr. Roby uses example of jet plane at constant velocity (i.e., constant speed and direction) to demonstrate that you can have forces and yet the net force (horizontally and vertically) can still be zero if the forces cancel out.]

Newton's Second Law of Motion: The acceleration of an object is equal to the force acting on it divided by the mass of the object and is in the direction of the force.

F = ma **(force = mass x acceleration)** (This equation is Newton's 2nd law.)

Relationships (Learn these) (Roby will demonstrate them in class)

m ↑ a ↓ For same Force, mass and acceleration are inversely proportional

F ↑ a ↑ For same mass, Force and acceleration are directly proportional

F ↑ m ↑ For same acceleration, Force and mass are directly proportional

Newton's Third Law of Motion: For every action, there is an equal and opposite reaction.

Examples: Rocket going up because of thrust of engine going down.
Or when you open a balloon's nozzle, the balloon moves in a direction opposite of the nozzle air outflow.

Note: this law is seen in most everything we discuss, so we won't mention it often, but you should still know it.