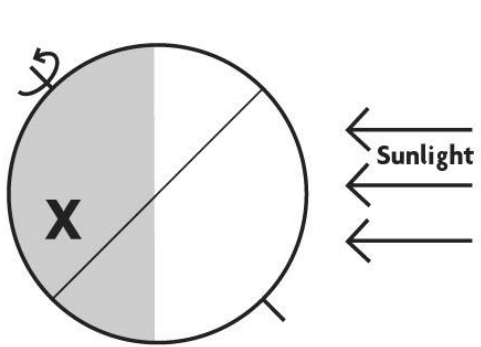
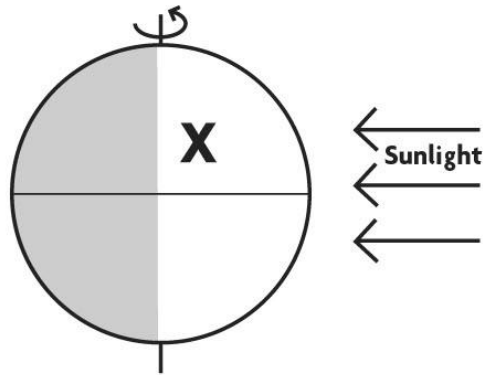


What day is today?

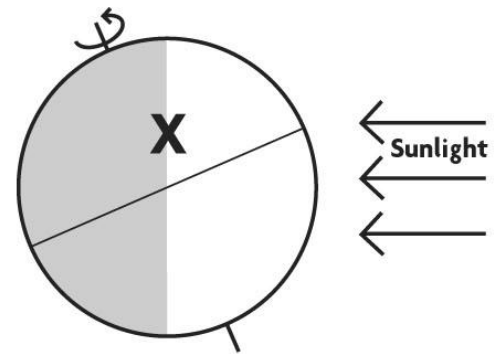
- September 22
- The Autumnal Equinox!
- The Sun, as it creeps along the ecliptic, passes through the celestial equator...
(happened at 9:44AM MDT)
- How much daylight do we get?



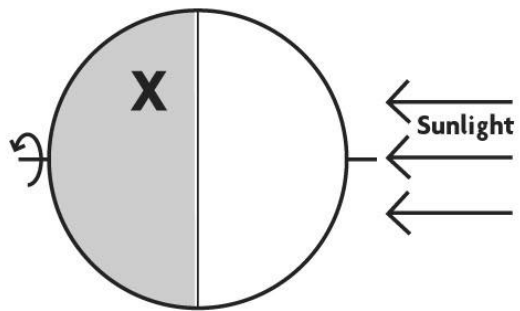
A: Tilt=45°



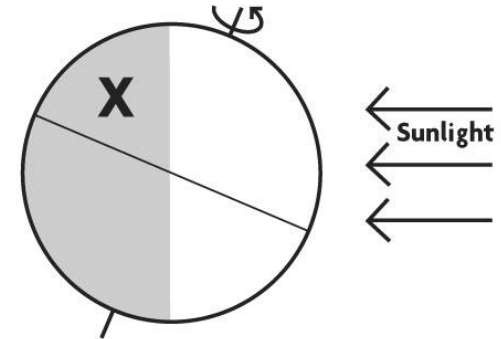
B: Tilt=0°



C: Tilt=23°



D: Tilt=90°



E: Tilt=23°

Gravity – the most important force in the universe.

“... it surrounds us and penetrates us. It binds the galaxy together.” – Obi-wan Kenobi

9/22 – Kepler’s First & Second Laws

9/24 – Kepler’s Third Law

9/26 – Newton’s Law of Gravity

9/29 – Review for Midterm 1

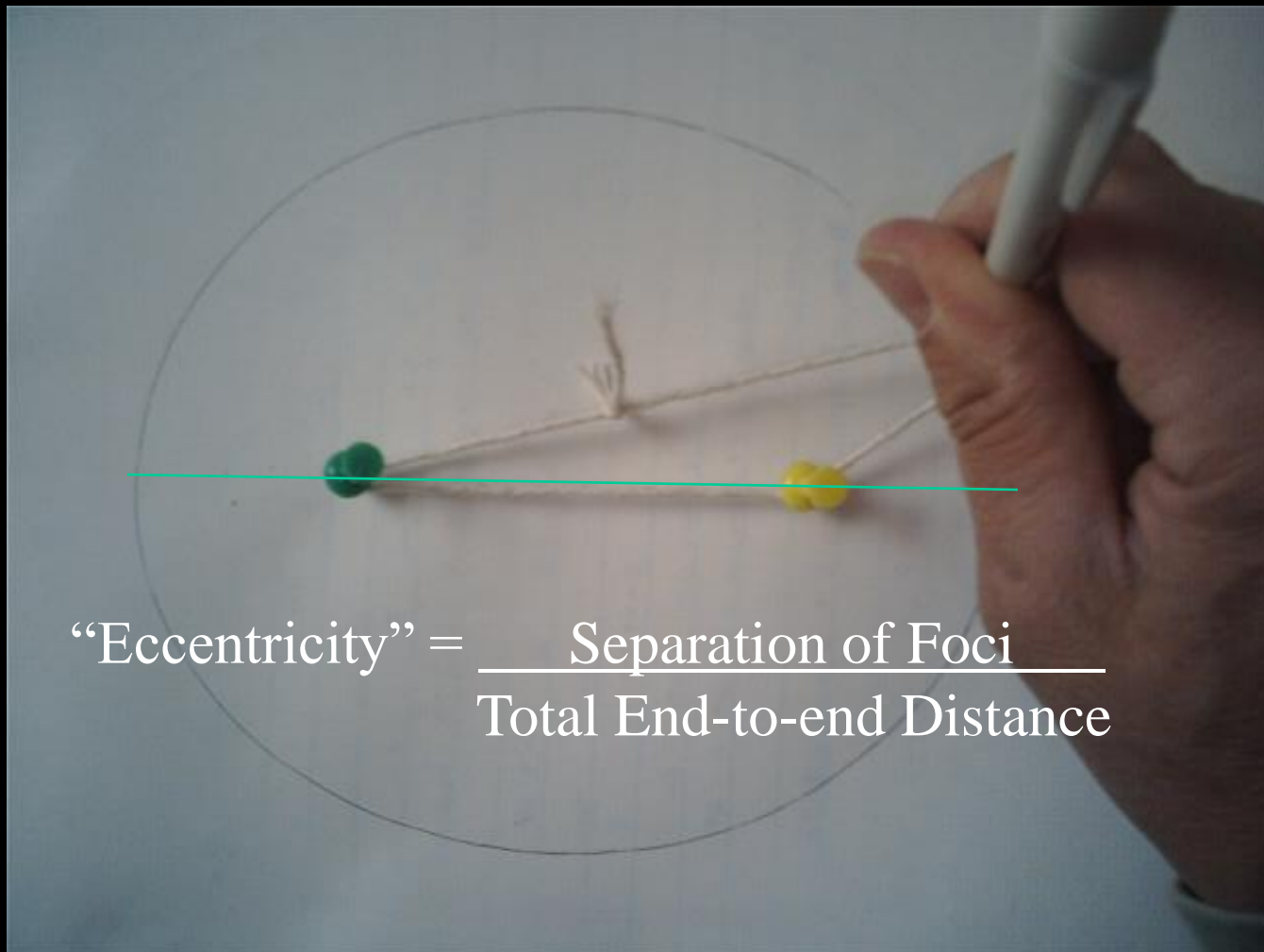
10/1 – Midterm 1

Development of Unit

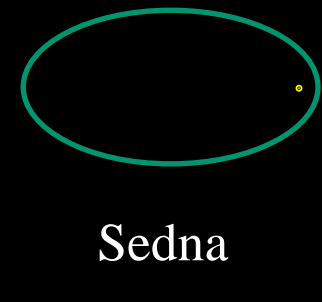
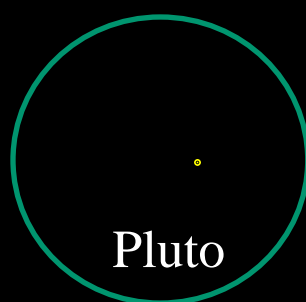
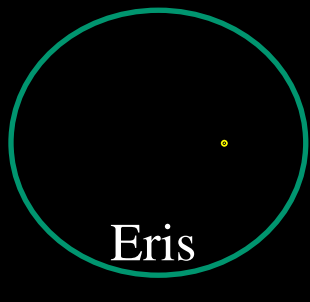
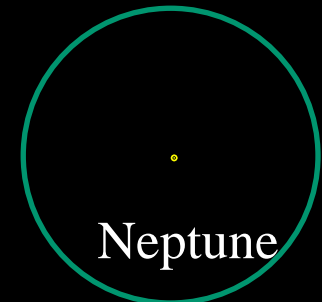
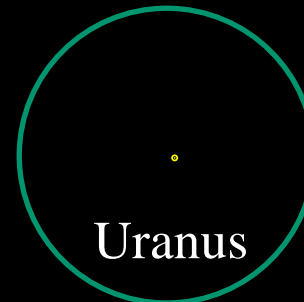
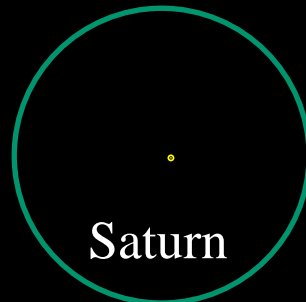
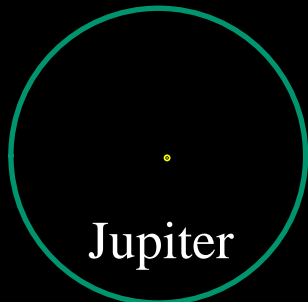
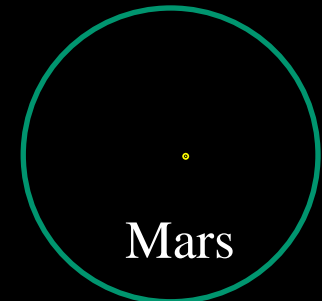
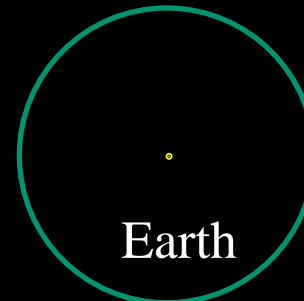
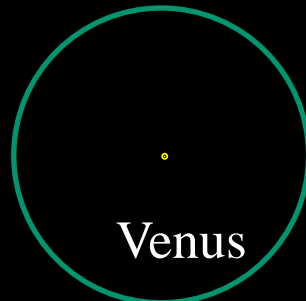
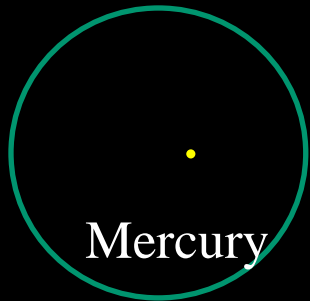
- Partly historical
 - Kepler came up with his laws using observations of the planets taken by Tycho Brahe (geocentric → heliocentric → ellipses)
 - Newton figured out his law of gravity using his own laws of motion and Kepler's laws
- Like previous unit, building up from the more foundational concepts toward the more difficult ones...

Kepler's First Law

- The planet's appear to orbit the Sun in an ellipse with the Sun at one focus.



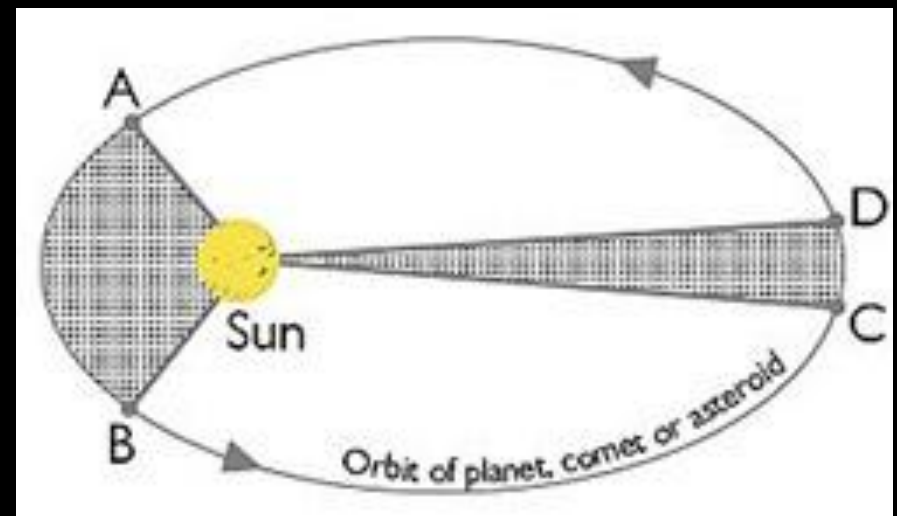
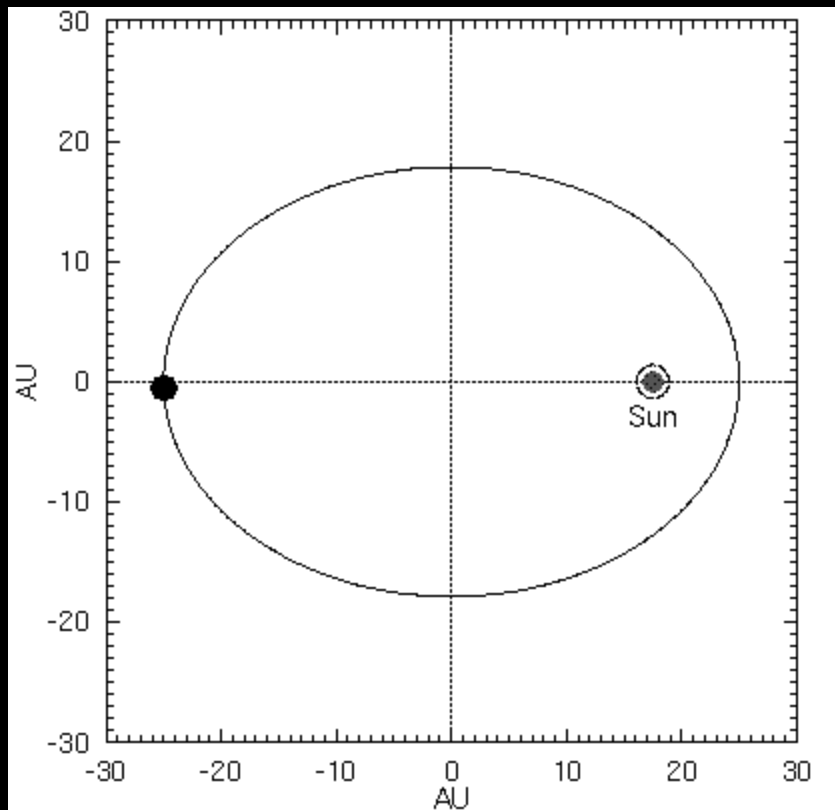
Orbital shapes for different objects...



The Sun is at one focus. What's at the other focus?

Kepler's Second Law

- A line connecting a planet and the Sun sweeps out equal areas in equal times.



Imagine dropping a ball... it falls, bounces, and rises again. Where is it travelling the fastest? Where does it spend the most time?

Lecture Tutorials

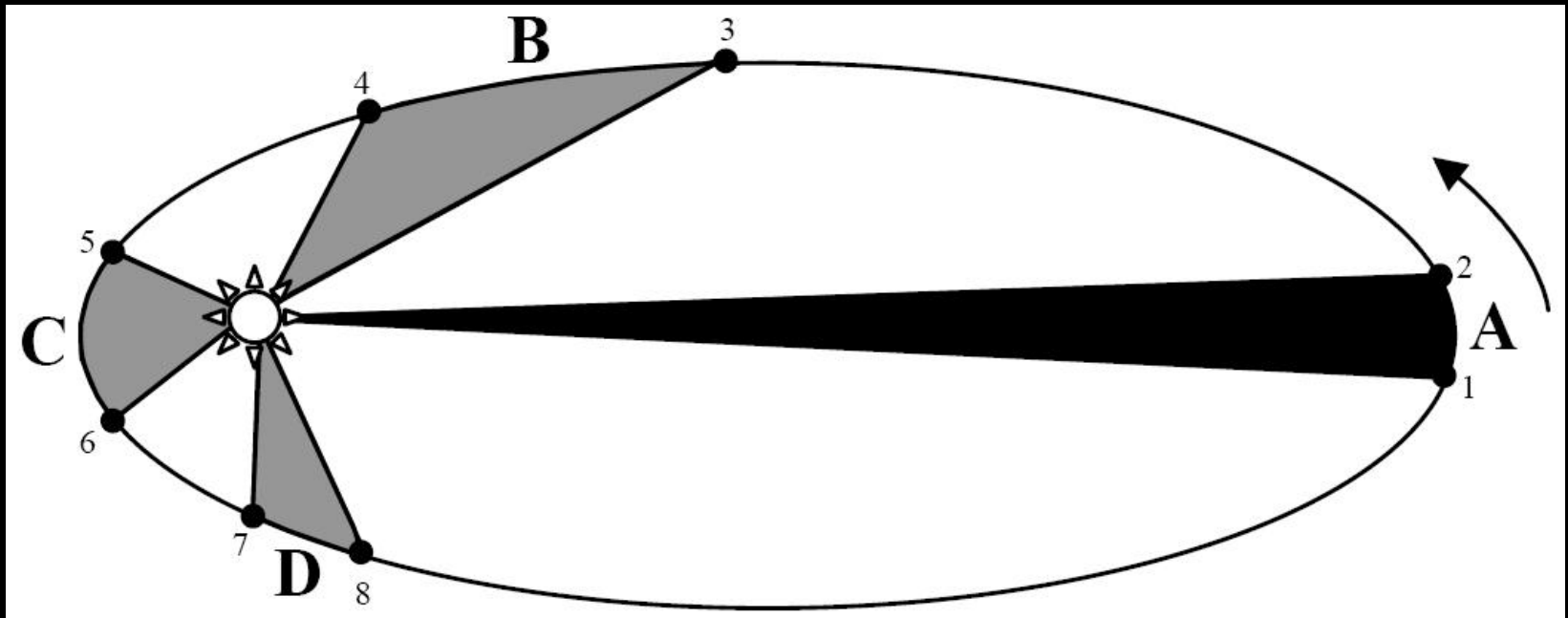
- Break up into group of 2-3
 - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
 - Kepler's Second Law (pages 21-24)
 - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help...
- If your group finishes, **check your answers with another group.**

Think

Pair

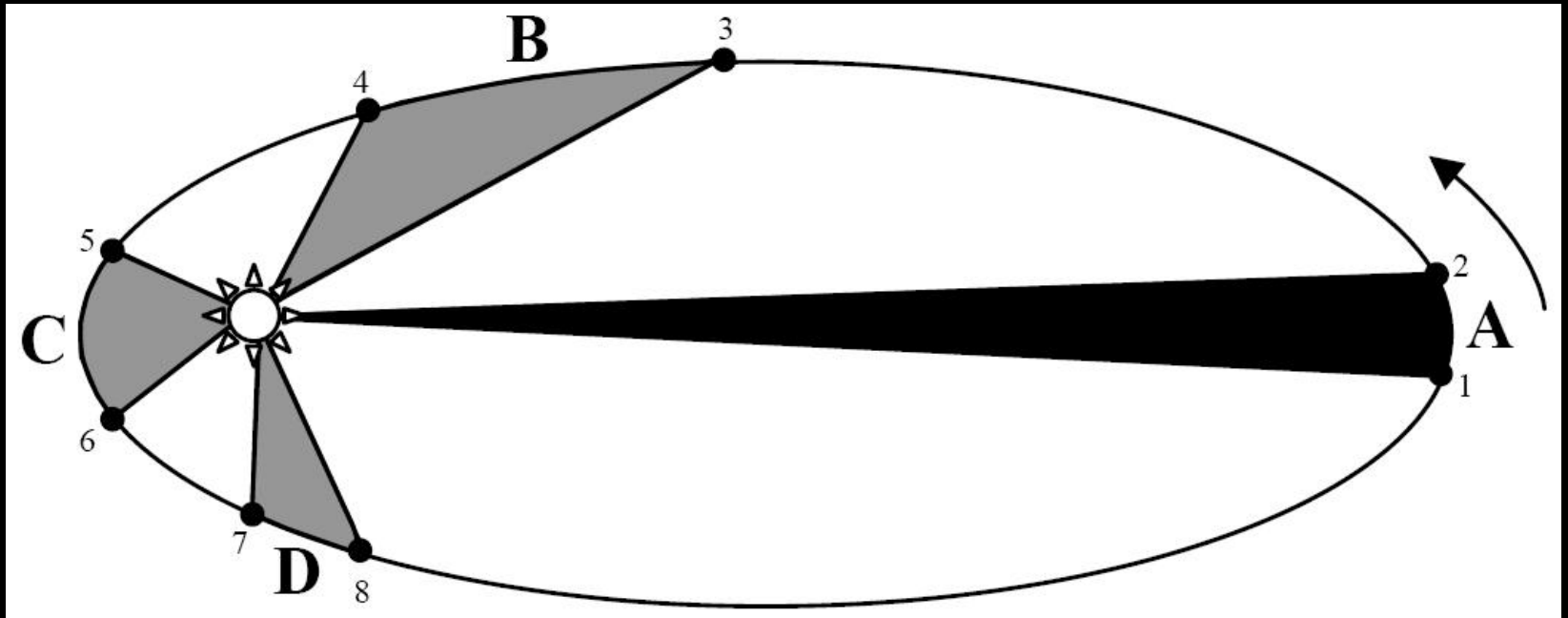
Share!

During how many portions of the planet's orbit (A, B, C, and D) would the planet be speeding up the entire time?



- A. Only during one of the portions shown.
- B. During two of the portions shown.
- C. During three of the portions shown.
- D. During four of the portions shown.
- E. None of the above.

During which part of the planet's orbit (A, B, C, or D) would the planet move with the greatest speed?



Gravity – the most important force in the universe.

“... it surrounds us and penetrates us. It binds the galaxy together.” – Obi-wan Kenobi

9/24 – Kepler’s Third Law

9/26 – Newton’s Law of Gravity

9/29 – Review for Midterm 1

10/1 – Midterm 1

Announcement about Midterm

- 42 multiple choice questions (same style as think-pair-share)

	Scales	Patterns	Gravity	Total
LT/TPS	4	18	6	28
AN	2	9	3	14
Total	6	27	9	42

- Open office hours: Sign-up sheet if you want to talk to me
- Are you freaked out about the level of math?
- Review session on Monday

Announcement about Observing

- Observing sessions Tuesday, Wednesday, Thursday (9/30-10/2)
- No labs 9/30-10/6
- Sign-up sheets
- Rain day 10/8

Kepler's Third Law

- Second law talks about what happens during an orbit.
- Third law tell us that there is a relationship between average distance in an orbit and the time is takes to go through that orbit.
- $(\text{Orbital period})^2 = (\text{average distance})^3$
- [For an ellipse, average distance is the same as the semi-major axis.]
- Objects that orbit farther out take longer to go around the Sun, and visa versa.
- These laws work in describing the anything that orbits anything else.

If a small weather satellite and the large International Space Station are orbiting Earth at the same altitude, which object takes longer to orbit once around the Earth?

- A. The large space station
- B. The small weather satellite
- C. They would take the same amount of time

Lecture Tutorials

- Break up into group of 2-3
 - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
 - Kepler's Third Law (pages 25-27)
 - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help...
- If your group finishes, **check your answers with another group.**
- If you are confident that your answers are correct, **help another group** that is struggling to find their own answers.

Think

Pair

Share!

Consider a planet orbiting the Sun. If the mass of the planet doubled but stayed at the same orbital distance, then the planet would take

- A. More than twice as long to orbit the Sun.
- B. Exactly twice as long to orbit the Sun.
- C. The same amount of time to orbit the Sun.
- D. Exactly half as long to orbit the Sun.
- E. Less than half as long to orbit the Sun.

Which of the following best describes what would happen if Mercury and Jupiter were to switch places in their orbits about the Sun?

- A. Jupiter, the larger planet, would have a shorter orbital period than before.
- B. Mercury, the smaller planet, would have a shorter period than before.
- C. Neither of the two planets would have any change in their orbital periods.

Imagine a new planet in our solar system located 3 AU from the Sun. Which of the following best approximates the orbital period of this planet?

- A. 1 year
- B. 3 years
- C. 5 years
- D. 9 years

Gravity – the most important force in the universe.

“... it surrounds us and penetrates us. It binds the galaxy together.” – Obi-wan Kenobi

9/26 – Newton’s Law of Gravity

9/29 – Review for Midterm 1

10/1 – Midterm 1

Newton's Law of Gravity

- Newton (among many other interests) studied how things move in every day life.
 1. An object at rest tends to remain at rest, and an object in motion tends to remain in motion (in a straight line), unless acted upon by an external force.
 2. The acceleration of an object is equal to the (net) force acting upon it divided by its mass.
 3. Any action has an equal and opposite reaction.

Newton's Law of Gravity

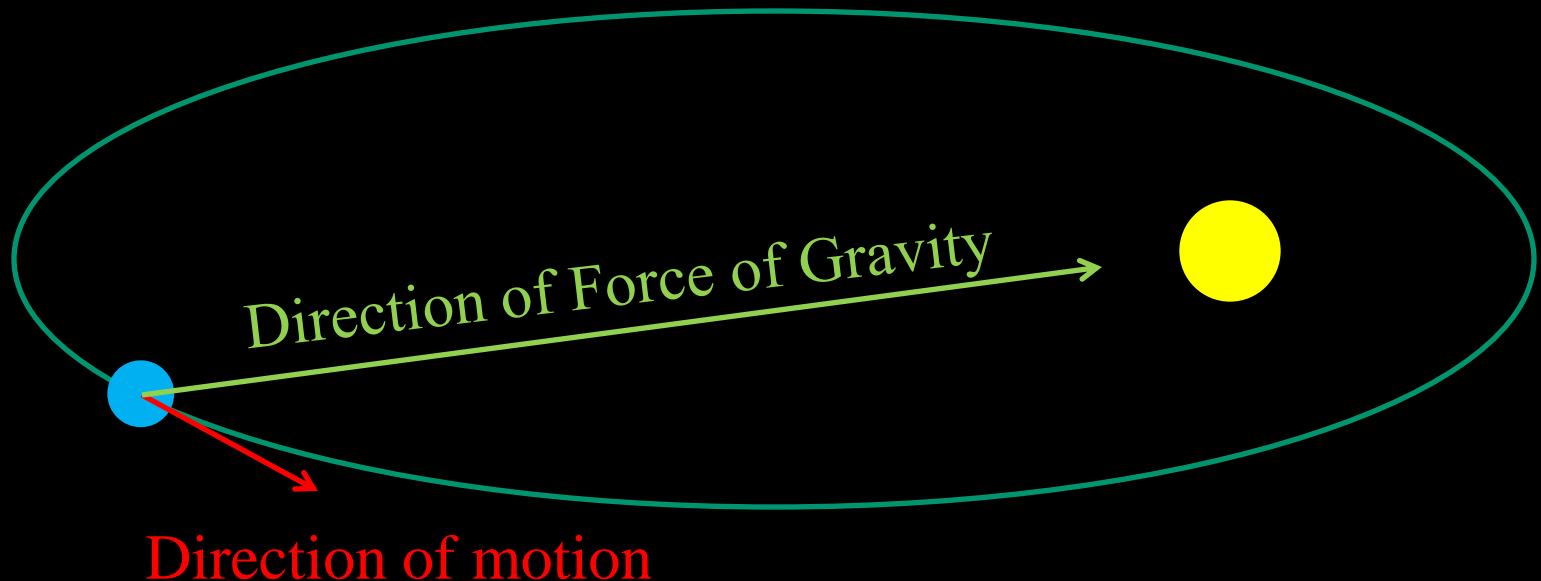
- Newton used these laws describing how things moved and Kepler's laws describing orbits to derive a law of gravity:

$$F_G = \frac{GMm}{r^2}$$

- The force of gravity depends on the product of the masses of both objects involved and the inverse-square of their separation, and nothing else.

Newton's Law of Gravity

- Gravity versus Newton's First Law...
 - Consider a ball...
 - In astronomy, consider the orbits of planets around the Sun...



Newton's Law of Gravity

$$F_G = \frac{GMm}{r^2}$$

- Example: Consider the gravitational force between you and the Earth.
 - Need mass of Earth, mass of you, separation between you and Earth (not zero!)
 - Find:
 - $(GM_{\oplus}/r_{\oplus}^2) = 32 \text{ ft/sec/sec} = \text{gravitational acceleration} = \text{“1 g”}$
 - $F_G = \text{your weight} = \text{your mass times gravitational acceleration} = \text{Newton's second law}$

Newton's Law of Gravity

- Newton's Law of Gravity vs. Newton's Third Law of Motion (Every action has...)
- Gravity is a force that acts between two objects.
 - Action: The Earth tugs on you with a force

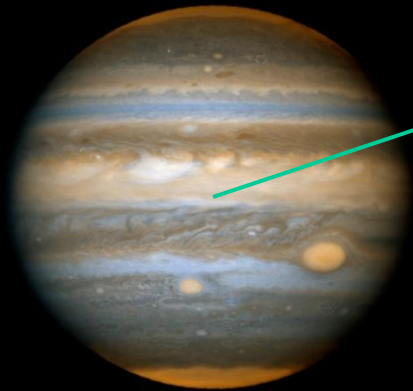
$$F_G = \frac{GM_{Earth}m_{you}}{r_{Earth}^2}$$

- Reaction: You tug back with the same force.
- The difference: It is easier for the Earth to move you, than it is for you to move the Earth.

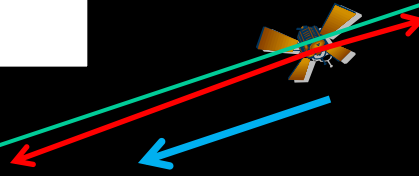
Newton's Law of Gravity

- Newton's Law of Gravity and the addition of forces...

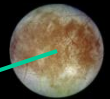
$$F_G = \frac{GM_{Jupiter}m}{r^2}$$



r



$$F_G = \frac{GM_{Europa}m}{r^2}$$



r

Lecture Tutorials

- Break up into group of 2-3
 - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
 - Newton's Law of Gravity (pages 29-31)
 - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help...
- If your group finishes, **check your answers with another group.**
- If you are confident that your answers are correct, **help another group** that is struggling to find their own answers.

Think

Pair

Share!

Which of the following would cause the force on the Moon by Earth to increase by the largest amount?

- A. Double the mass of the Moon.
- B. Double the mass of the Earth.
- C. Move the Moon two times closer.
- D. Due to Newton's third law, the Moon's force on Earth will always be the same size as the Earth's force on the Moon so none of the changes listed in choices A-C could cause the force to increase.