AST 301
Introduction to Astronomy

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Go to Department of Astronomy courses,

AST 301 (Lacy), course website

Topics for this week

How did Kepler improve on Copernicus' model?

State (and define the term in) Kepler's laws.

Speed, velocity, acceleration, mass, force, weight

Newton's three laws of motion

Newton's law of gravity

Orbital motion explained with Newton's laws

Falling objects explained with Newton's laws

The test on Friday will cover chapters 1-4, including Newton's laws

Prograde and retrograde motion

Remember: all objects in the sky move east-to-west during a night due to the west-to-east rotation of the Earth.

Prograde motion is when a planet moves west-to-east relative to the stars, so from night to night it falls behind the stars around it.

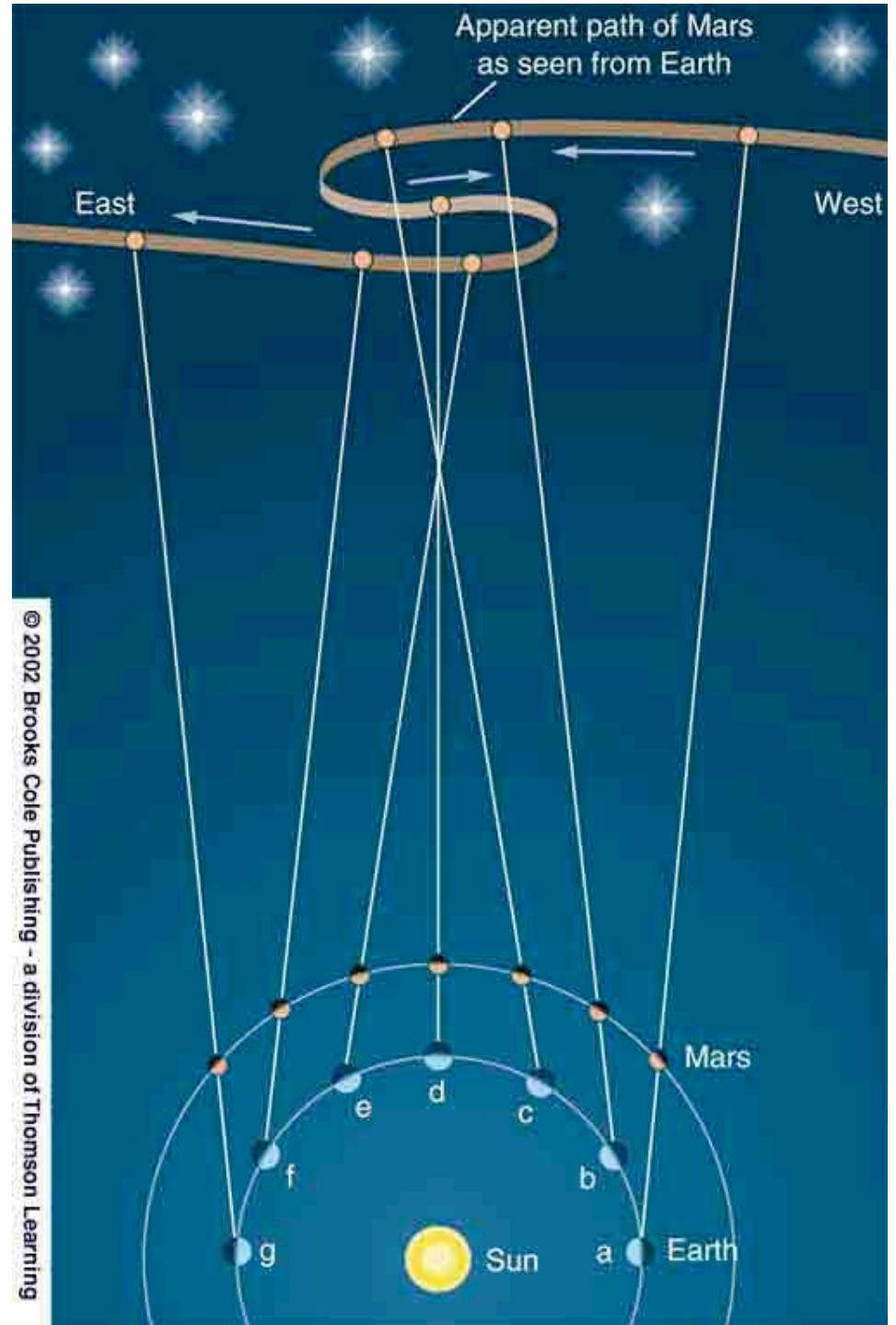The Sun and Moon always move prograde.

Retrograde motion is when a planet moves east-to-west relative to the stars.

Looking down on the solar system from the north, prograde motion occurs when the line from the Earth to the object rotates counterclockwise (in the same way the planets actually move).

Retrograde motion occurs when the line rotates clockwise because the Earth passes the planet.

The heliocentric explanation of the motions of the planets relative to the stars

Note that retrograde motion only occurs if the Earth is moving faster than Mars.

Mars appears to move backwards when we pass it.

Apparent path of Mars as seen from Earth

East   West

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Mars

e   d   c

f   b

g   Sun   a   Earth

Retrograde and prograde motion

Mars' normal (prograde) motion is caused by its counterclockwise motion around the Sun.

Mars moves in the retrograde direction when the Earth passes it up, making it appear to move in a clockwise direction.

Venus' prograde motion is caused by the Earth's motion around the Sun. This causes a counterclockwise apparent motion of Venus (and the Sun). Venus moves in the clockwise (retrograde) direction when it passes us.

In both cases, retrograde motion occurs when the Earth and planet are lined up on the same side of the Sun.

Kepler's laws (or rules)

1. The planets move on elliptical paths with the Sun at one focus of the ellipse for each planet.

2. The speed of a planet changes during its orbit, moving fastest when it is closest to the Sun and slowest when it is farthest from the Sun.
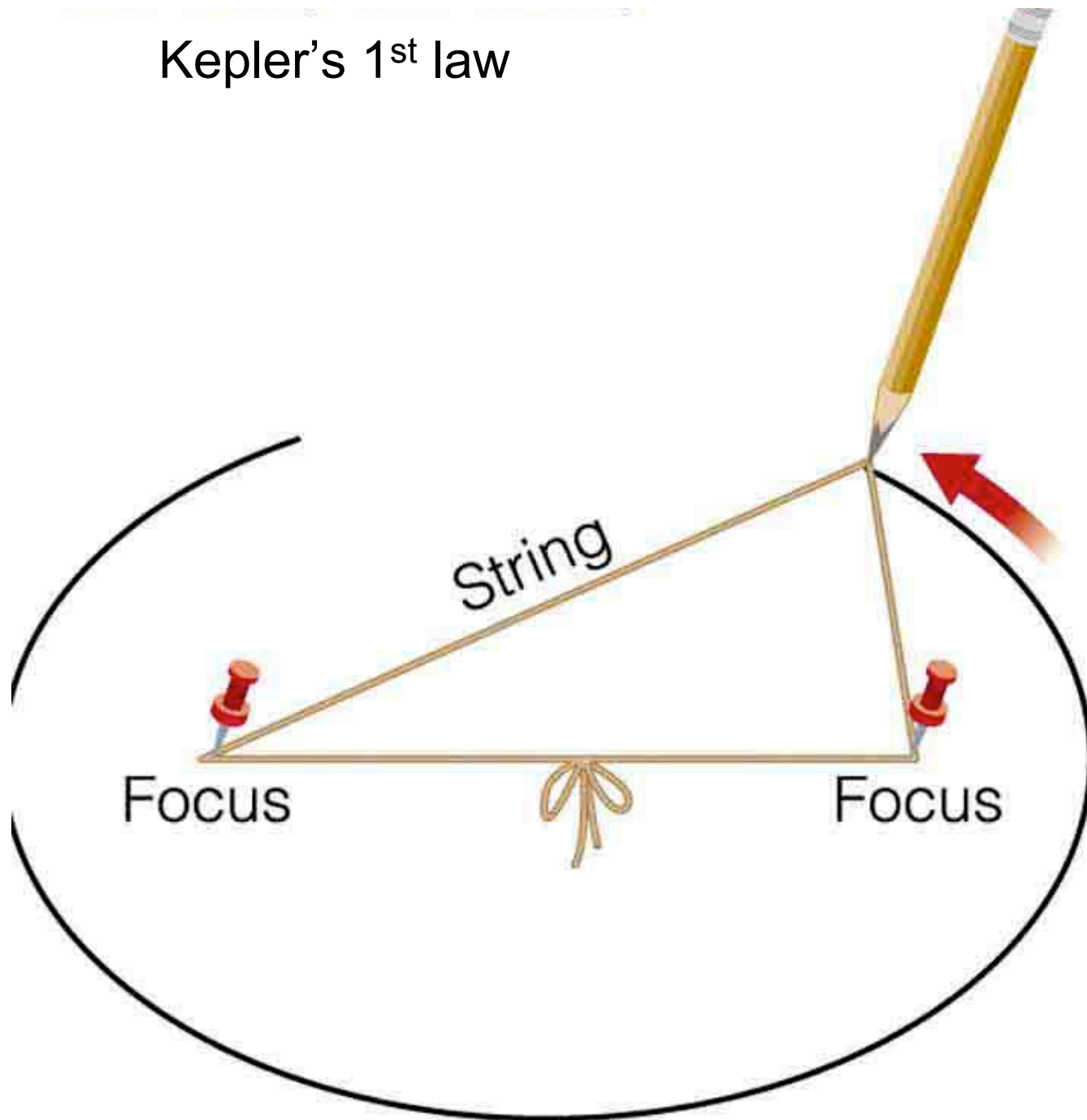
   A line from the Sun to the planet sweeps out equal areas in equal times.
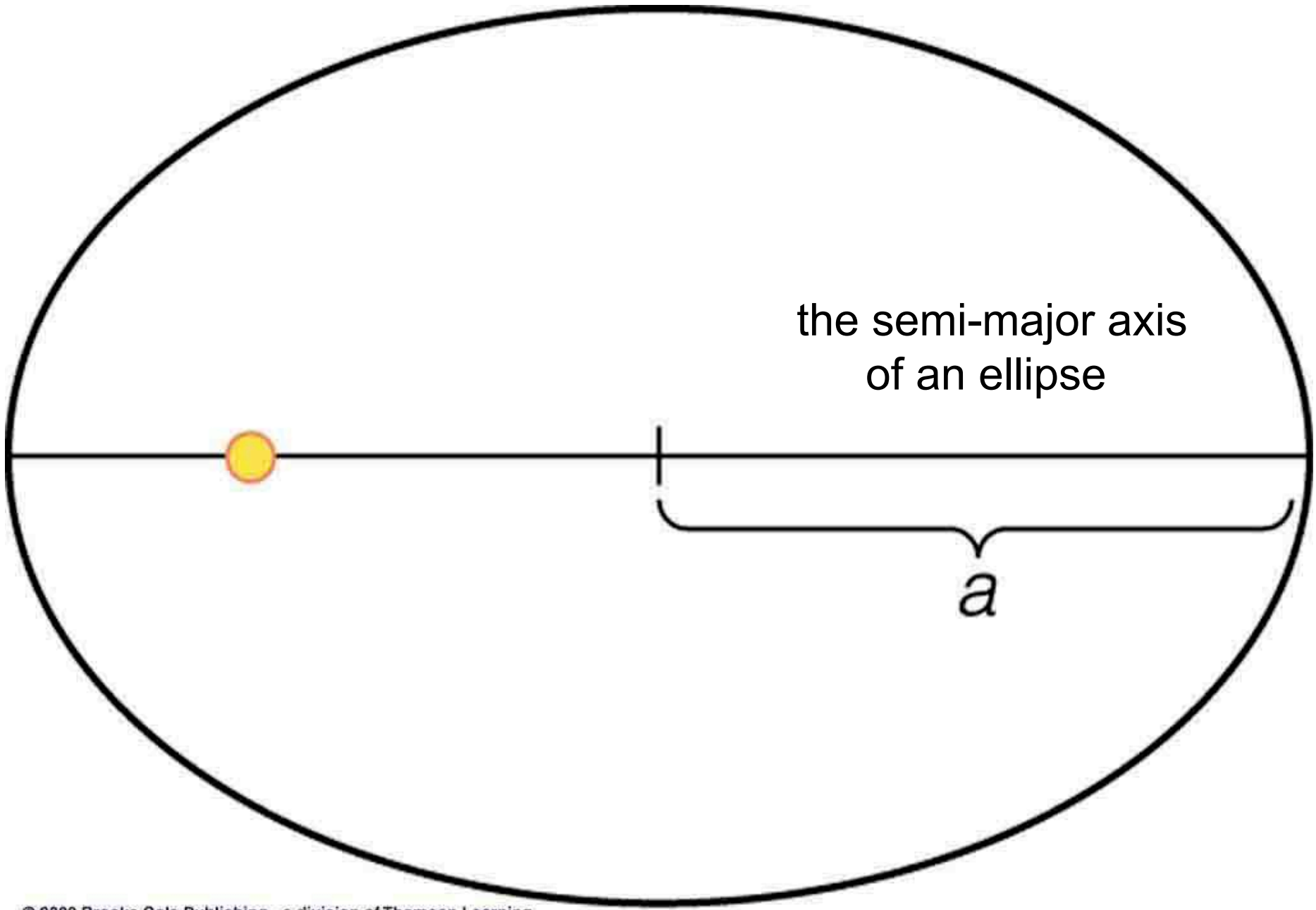
3. Different planets move at different speeds, with a planet in a smaller orbit moving faster than one in a larger orbit.

   The time for a planet to orbit the Sun depends on the size of it orbit according to the rule:

   $P^2 = a^3$, where P is in years and a is in AU

Kepler's 1st law

String

Focus

Focus

the semi-major axis
of an ellipse

a

Kepler's 2nd law

A simpler, although not exact, way to state Kepler's second law is to say:

The distance traveled by a planet in a given time is inversely proportional to the planet's distance from the Sun during that time.

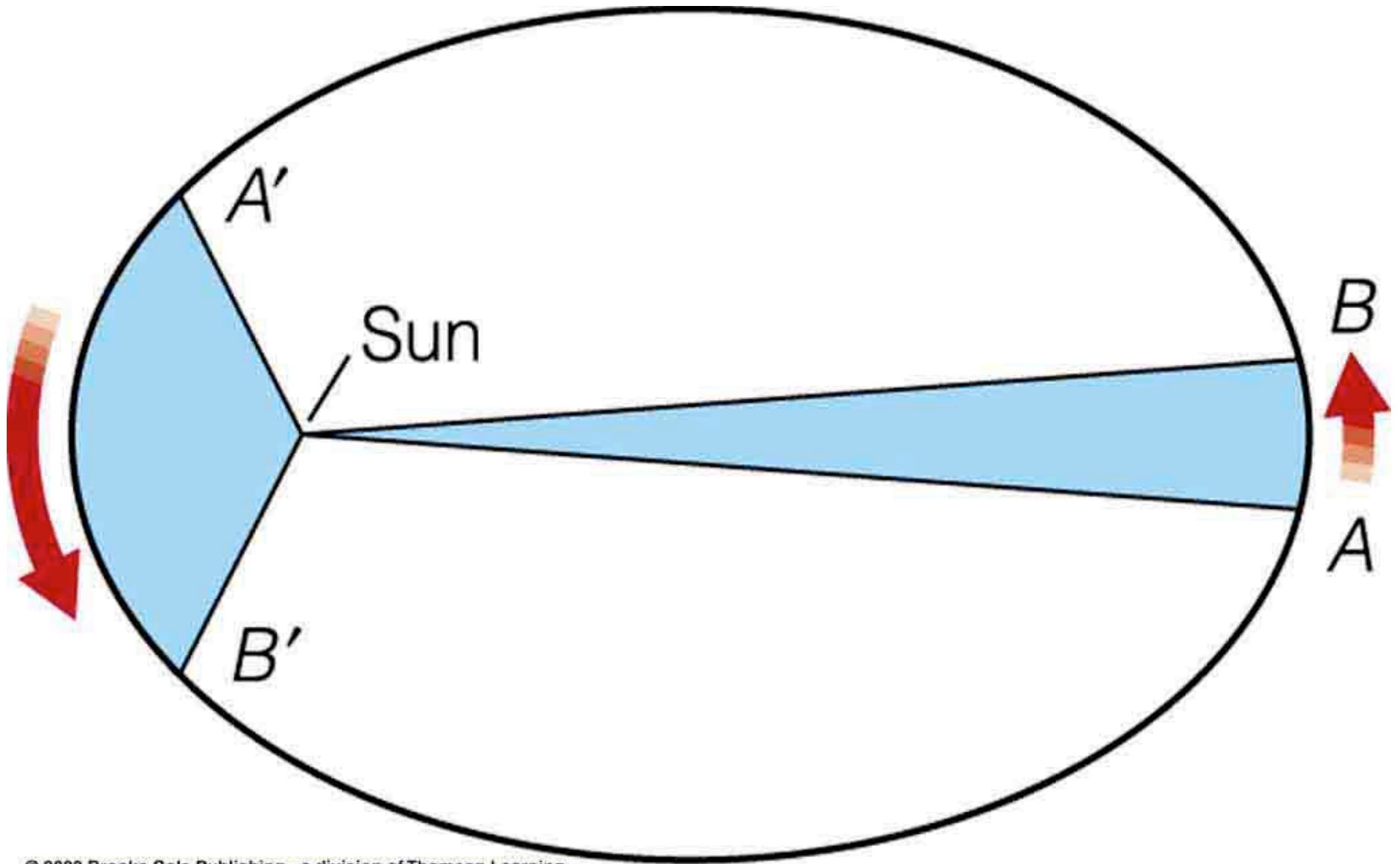Or the speed of a planet is inversely proportional to its distance from the Sun.

This means that if at one time a planet is twice as far from the Sun as at a second time, it is moving ½ as fast.

Or: closer to Sun means faster.

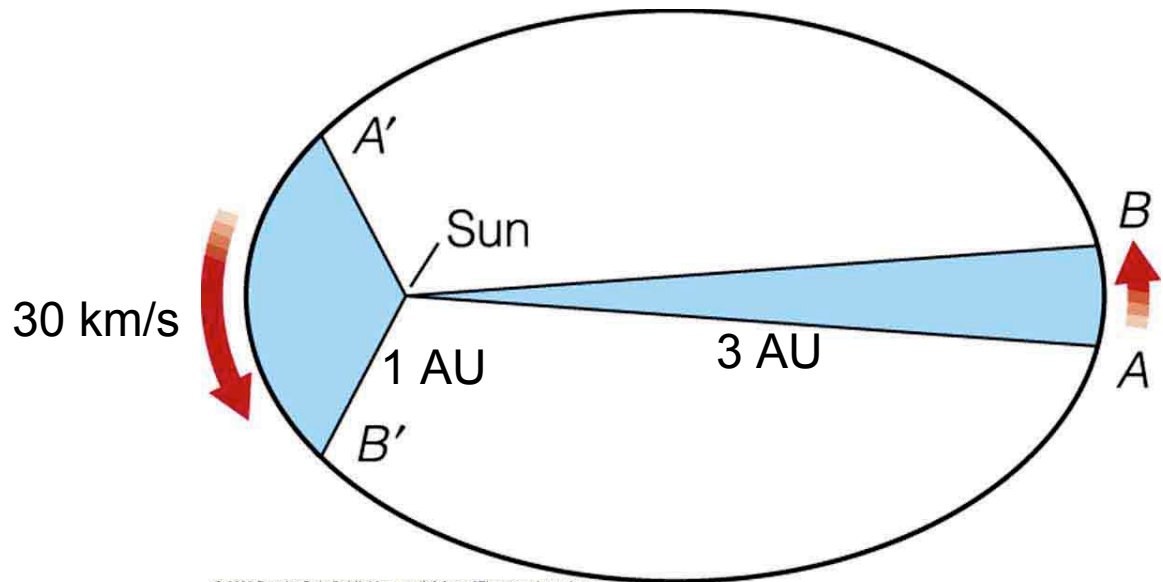twice as close means twice as fast

twice as far means ½ as fast

Kepler's 2nd law

Quiz

If the speed of the planet between A` and B` is 30 km/s, what is its speed between A and B?

A. 10 km/s

B. 28 km/s

C. 32 km/s

D. 90 km/s

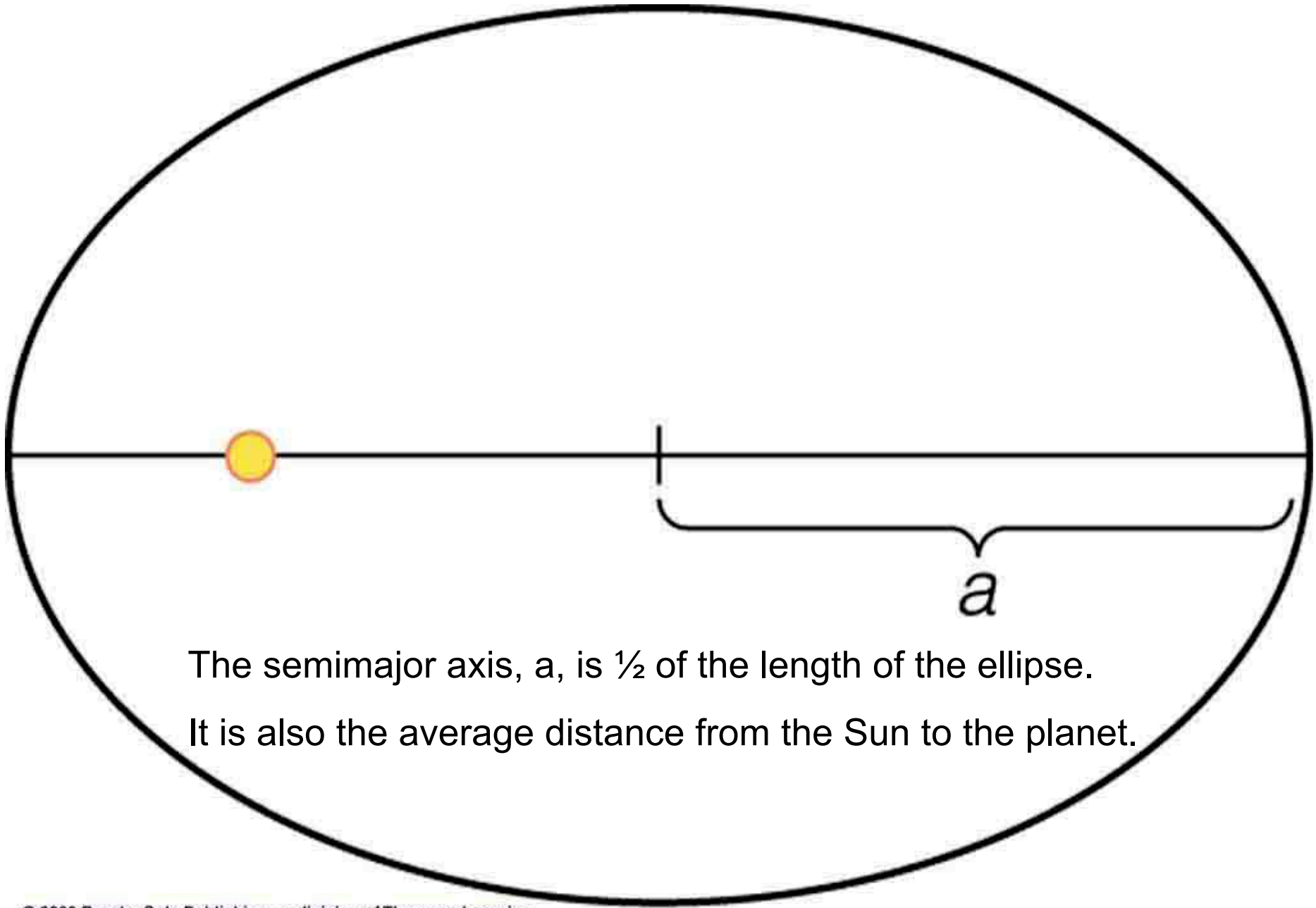© 2002 Brooks Cole Publishing - a division of Thomson Learning

Quiz

In the figure below, given that the distance from the Sun to points A and B is 3 AU, the distance to points A` and B` is 1 AU, and the distance from A to B is 0.5 AU, what is the distance from A` to B` (along the orbit)?

A. 0.5 AU

B. 1 AU

C. 1.5 AU

D. 3 AU

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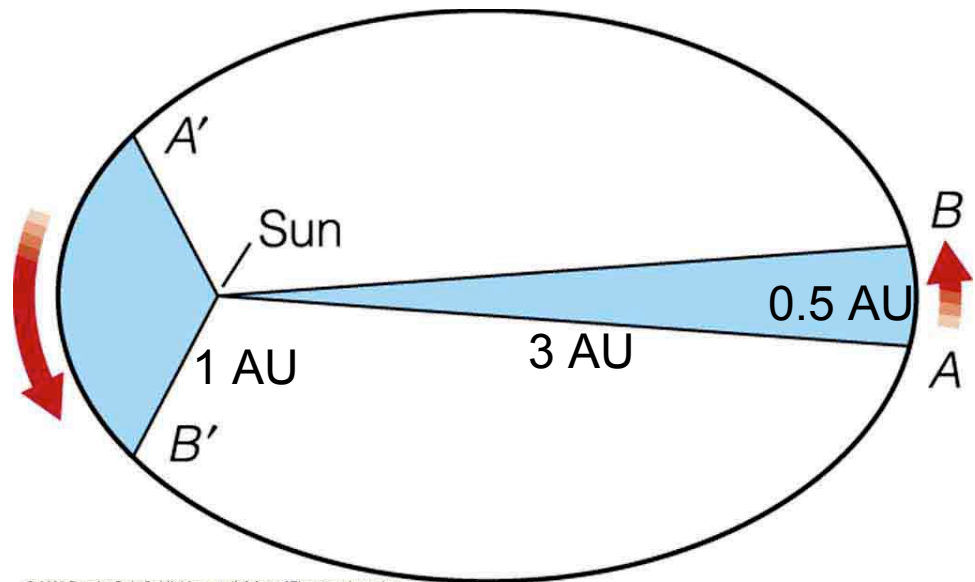
The semimajor axis, a, is ½ of the length of the ellipse.

It is also the average distance from the Sun to the planet.

Galileo

Lived about 400 years ago, while Kepler lived.

Made several observations and arguments which supported the Copernican model:

Venus has phases like the Moon's, which can only be explained if it orbits the Sun, not a point between the Earth and the Sun.

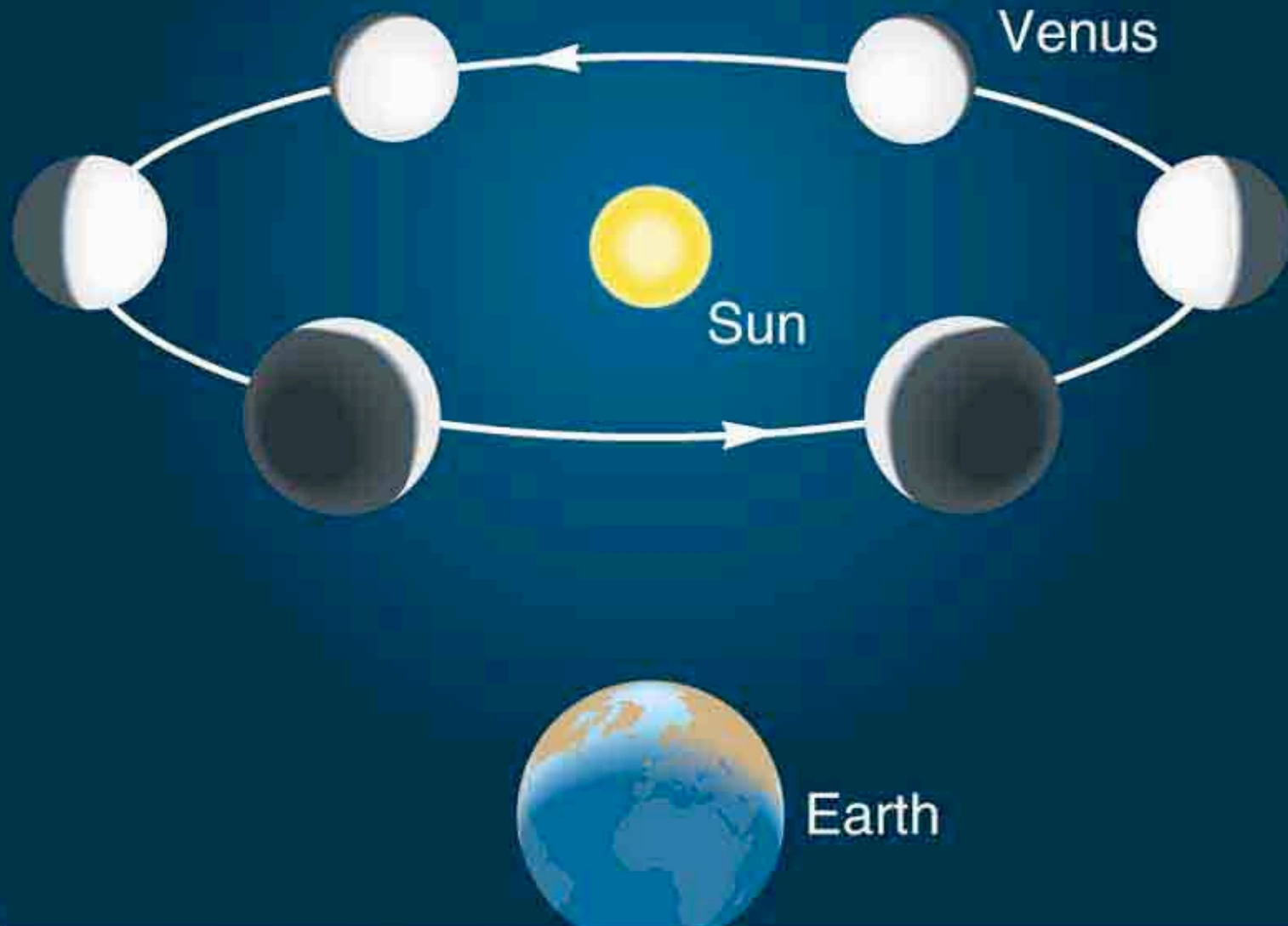Jupiter has moons, which orbit it, not the Earth.

The Moon has mountains, so is imperfect, like the Earth.

More generally, Galileo argued for basing science on observations and experiments, not pure thought.

Ptolemaic universe

Sun

Venus

Center of epicycle

Earth

a
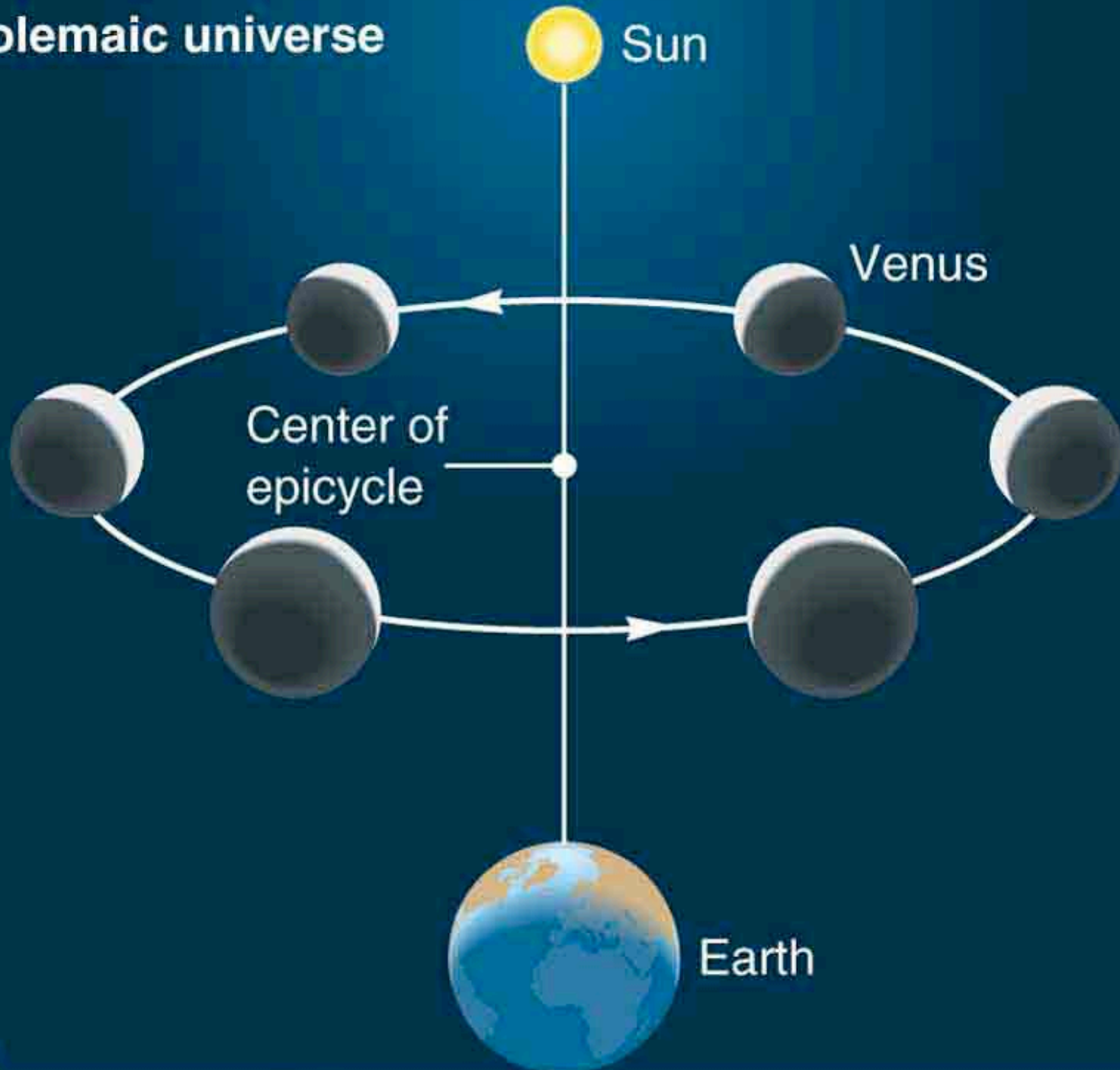
Copernican universe

Venus

Sun

Earth

b

Newton's theory of motion

Common experience tells us that you have to push on an object to make it move and the harder you push the faster it goes.

If you stop pushing on an object it will stop moving.

Newton realized that this is a result of a complicated situation involving friction.

In a simple situation (like an object in space or a very smooth ball rolling) the rules are different.

And the rules for simple situations can be combined to explain motion in complicated situations.

Newton also realized that his laws of motion when applied to the planets could explain Kepler's laws.

Definitions

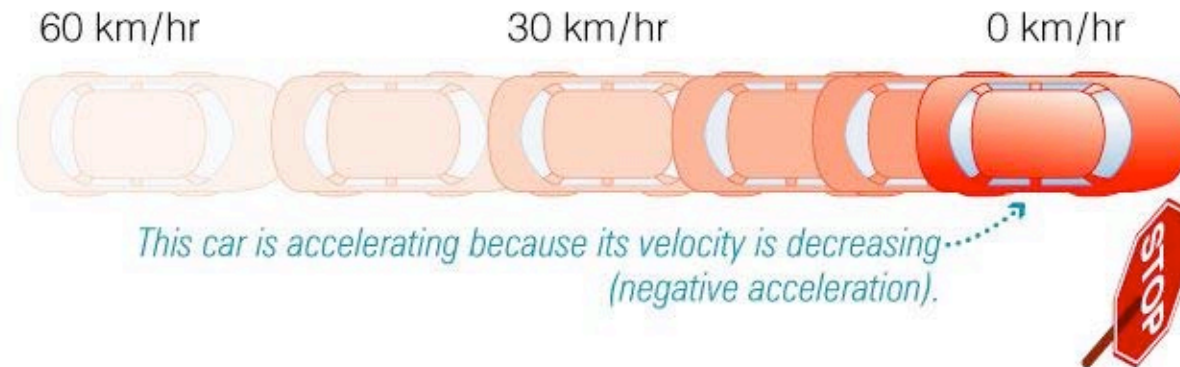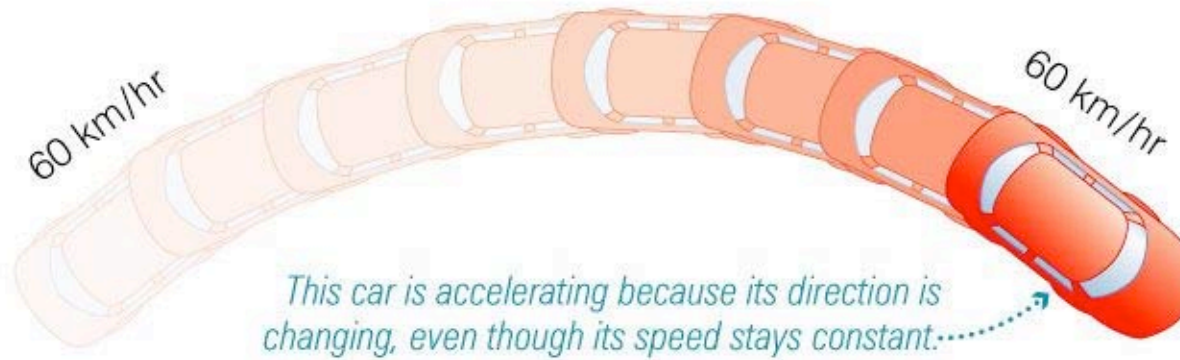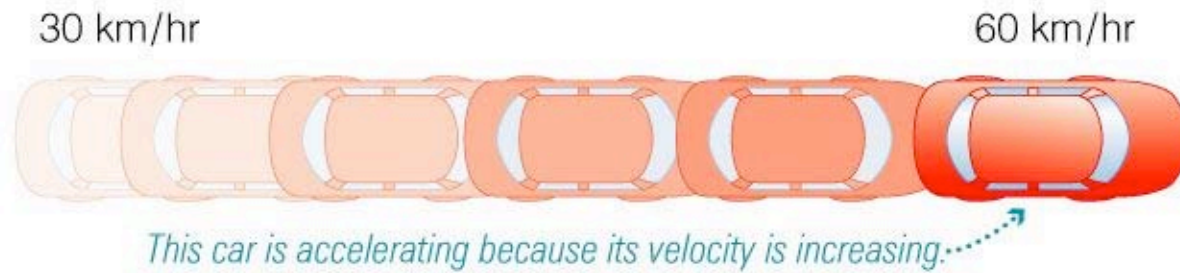speed: distance traveled / time spent traveling

acceleration: change of speed / time spent changing
   (can also be a change in direction of motion)

force: how hard one object pushes or pulls on another

mass: is a measure of the amount of matter in an object
   and how much it resists being pushed around

volume: the amount of space an object takes up
   for a box: height x width x depth

acceleration

30 km/hr 60 km/hr

This car is accelerating because its velocity is increasing.

60 km/hr 60 km/hr

This car is accelerating because its direction is changing, even though its speed stays constant.

60 km/hr 30 km/hr 0 km/hr

This car is accelerating because its velocity is decreasing (negative acceleration).

STOP

Newton's laws of Motion

1. If there are no forces acting on an object, if moving it will continue to move with constant speed and in the same direction. If not moving, it will remain stationary.

2. If a force is acting on an object, the object's acceleration (the rate of change in its speed or direction of motion) is proportional to the force acting on it and is inversely proportional to its mass.

$$a \ \alpha \ F \ / \ m$$

3. If an object exerts a force on a second object, the second object necessarily exerts the same force on the first, but in the opposite direction.

Quiz

If I step on my brakes and slow down from 60 mph to 30 mph, am I accelerating?

A. yes

B. No

By scientists' definition any change in speed is called acceleration, whether an increase or a decrease.

If I take my foot off of the gas and coast around a corner at constant speed, am I accelerating?

A. yes

B. no

A change in direction is also considered an acceleration, even if speed stays constant.

Quiz

If I push on my car for 5 seconds I can make it move at 2 mph. If I pushed for an additional 5 seconds with the same force, how fast would it then be going? Ignore all other forces acting on the car.

A. 2 mph

B. 4 mph

C. 7 mph

D. 10 mph

Quiz

If I push on my car for 5 seconds I can make it move at 2 mph. If two identical cars were lined up bumper-to-bumper, how fast could I make them move by pushing (with the same force) for 5 seconds?

A. 0 mph

B. 1 mph

C. 2 mph

D. 4 mph