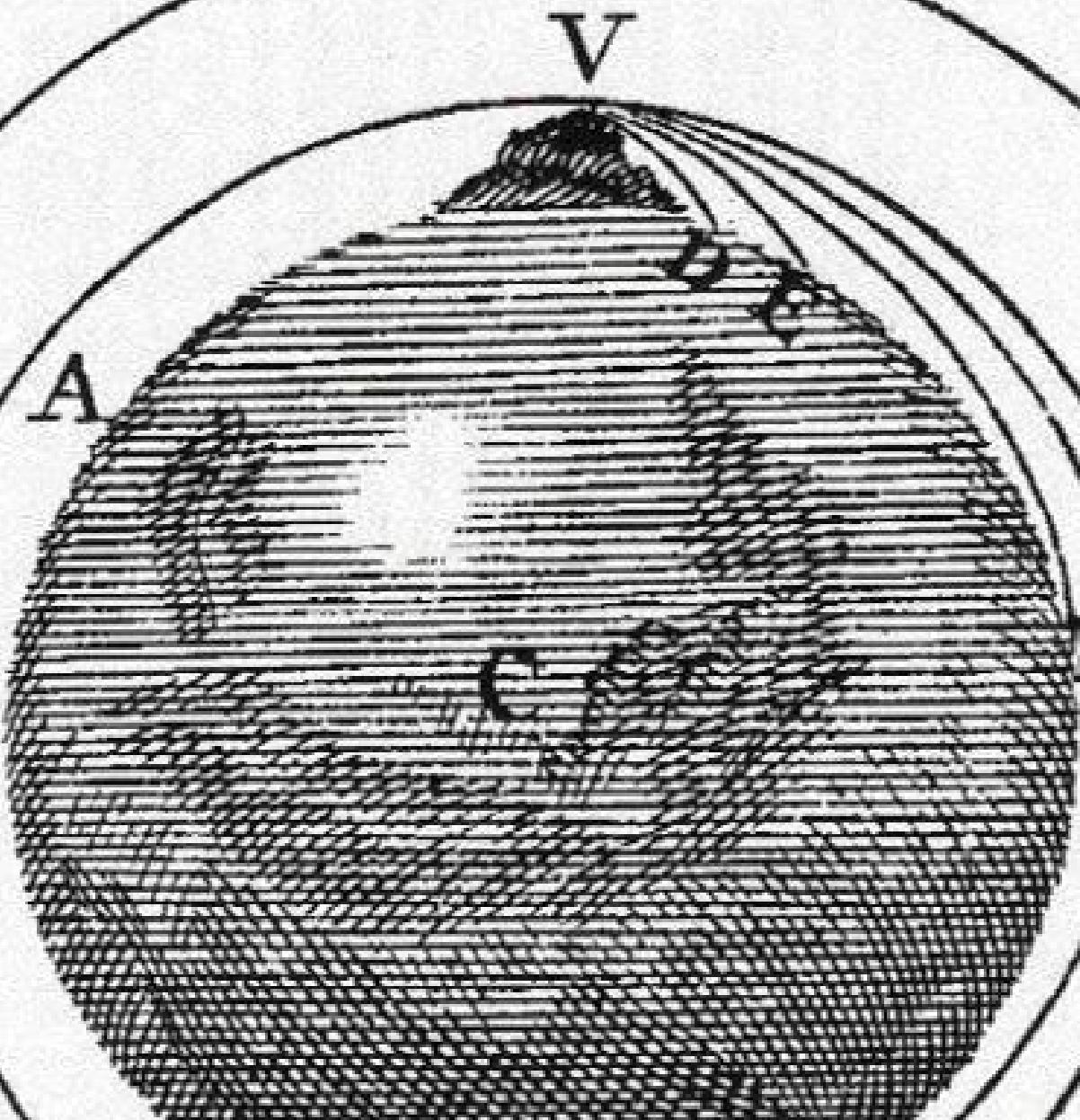
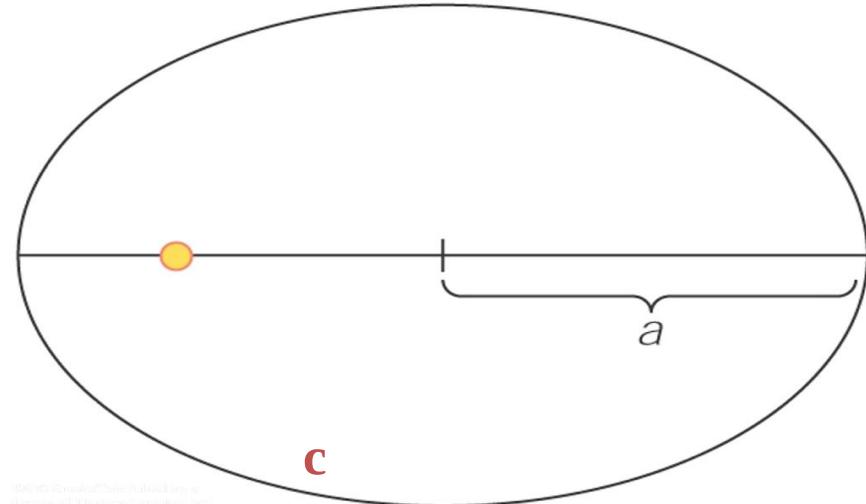


Gravity

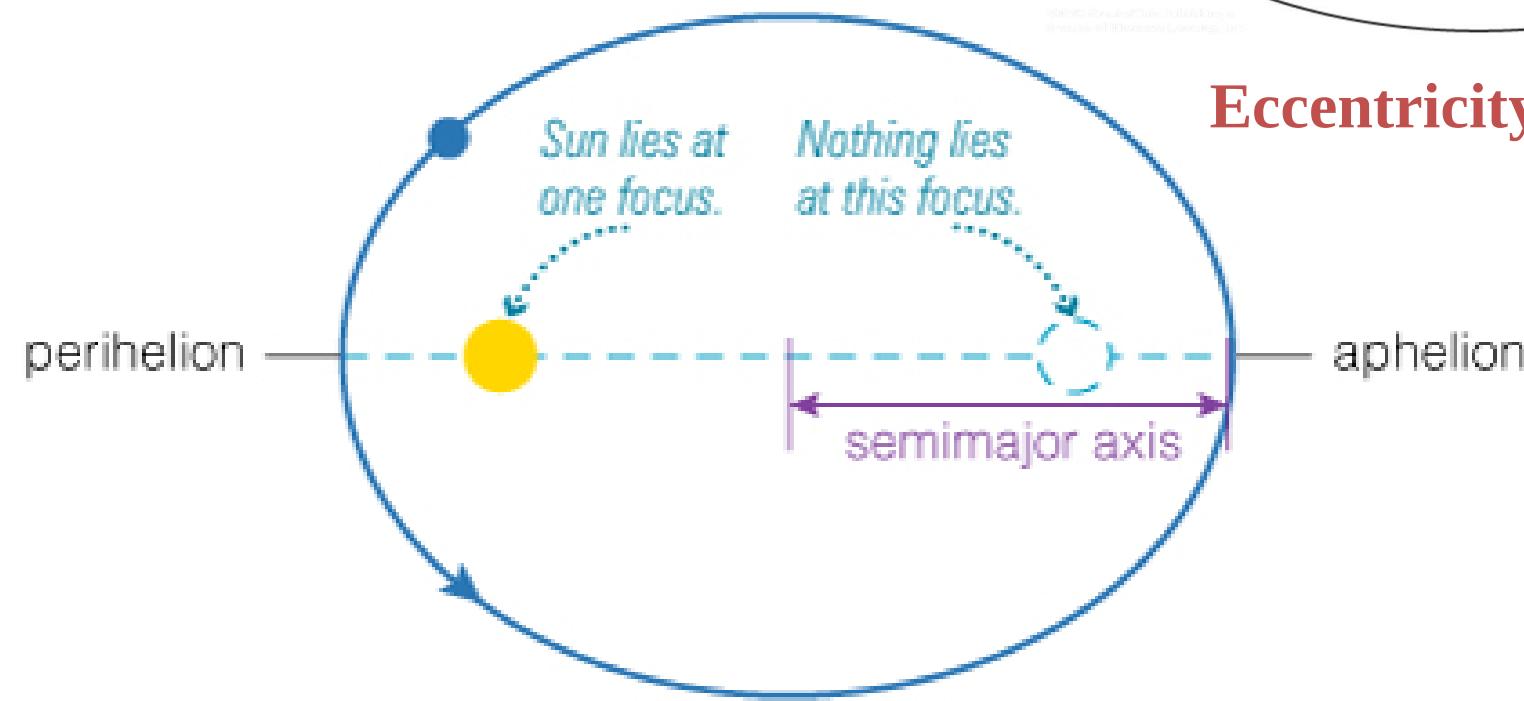


Kepler's 1st Law

Law #1: The orbits of the planets are ellipses with the Sun at one focus.



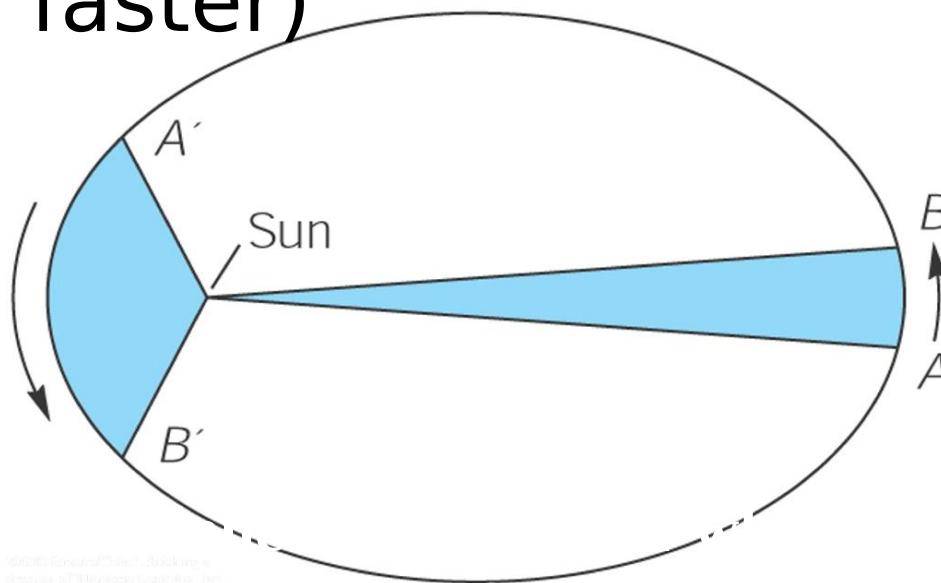
$$\text{Eccentricity } e = c/a$$



Kepler's 2nd Law

Law #2: A line from a planet to the sun sweeps over equal areas in equal intervals of time.

(When it's closer to the Sun, a planet moves faster)



Kepler's 3rd Law

A planet's orbital period (P) squared is proportional to its average distance from the sun (a) cubed:

Closer orbits go faster

$$P_y^2 = a_{AU}^3$$

(P_y = period in years; a_{AU} = distance in AU)

<http://www.solarsystemscope.com/>

[http://astro.unl.edu/naap/pos/animations/
kepler.html](http://astro.unl.edu/naap/pos/animations/kepler.html)

Concept Quiz

Which planet will orbit in the smallest amount of time?

- a) Something with the mass of Jupiter at the orbital distance of Jupiter
- b) Something with the mass of Earth at the orbital distance of Jupiter
- c) Something with the mass of Earth at the orbital distance of Earth
- d) Something with the mass of Jupiter at the orbital distance of Earth
- e) c) and d) would be equal

Concept Quiz

Which planet will orbit in the smallest amount of time?

- a) Something with the mass of Jupiter at the orbital distance of Jupiter
- b) Something with the mass of Earth at the orbital distance of Jupiter
- c) Something with the mass of Earth at the orbital distance of Earth
- d) Something with the mass of Jupiter at the orbital distance of Earth
- e) c) and d) would be equal

Concept Quiz

How long does it take Mars to orbit the Sun?

- a) More than a year
- b) Less than a year
- c) One year

Concept Quiz

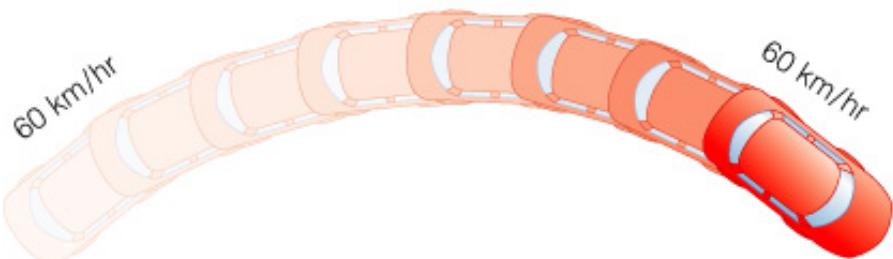
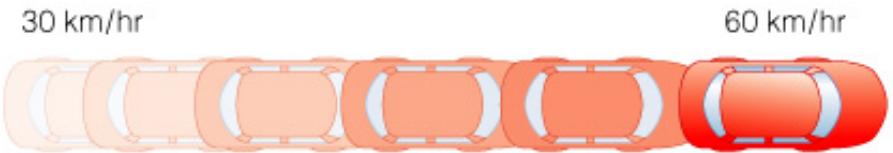
How long does it take Mars to orbit the Sun?

- a) More than a year
- b) Less than a year
- c) One year

Goals for Today

- 1) What is gravity?
- 2) What is proportionality?
- 3) What is the inverse square law?

How do we describe motion?



Speed: The rate at which an object moves
example: 10 m/s

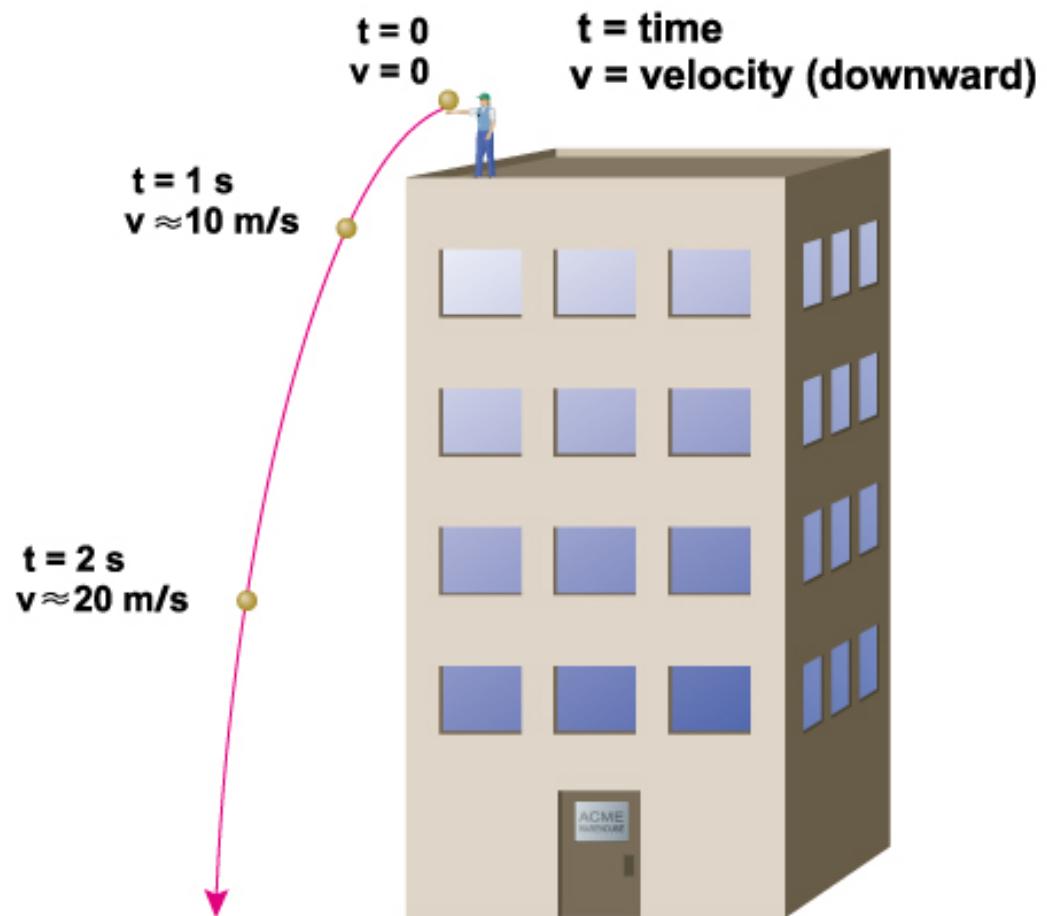
Velocity: Speed + direction
example: 10 m/s, due east

Acceleration: Any change in velocity, including a change in direction.

Gravity is an Acceleration!

On Earth, speed increases 10 m/s with each second of falling time.

This increase in speed is the acceleration due to gravity



The Acceleration due to Gravity

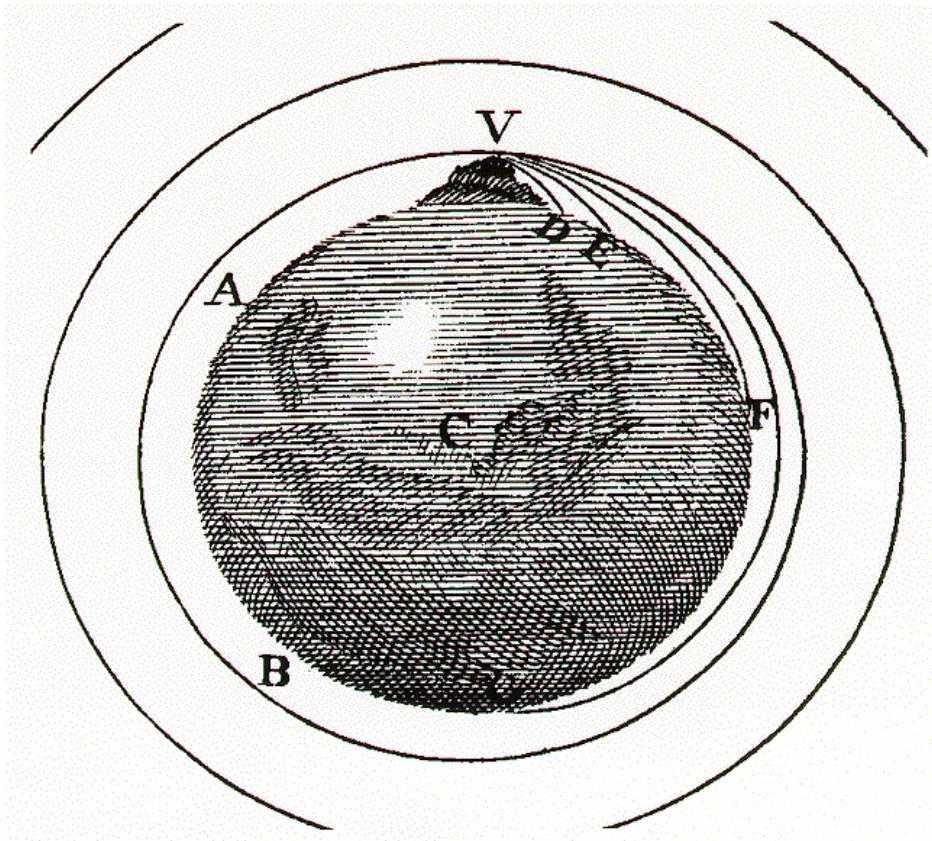
Galileo showed that the gravitational acceleration is the same for all falling objects, regardless of their mass.

Air resistance, not an object's mass, is what causes some objects to fall slower than others.



http://www.youtube.com/watch?v=-4_rceVPVSY

Why are astronauts “weightless” in space?



There *is* gravity in space
Weightlessness is due to a constant state of free-fall

The Universal Law of Gravitation

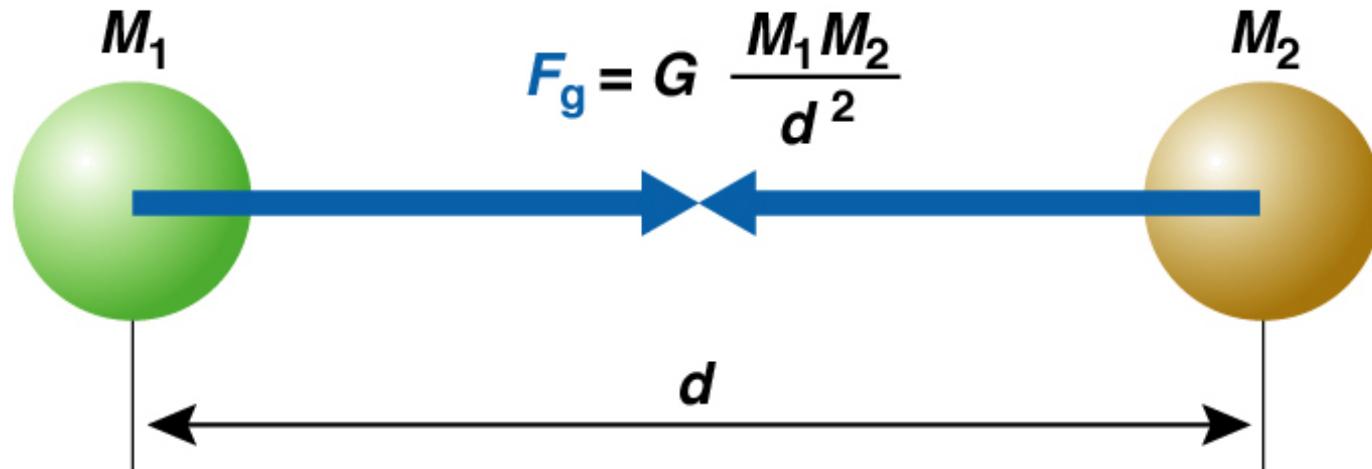
Every mass attracts every other mass.

Attraction is directly proportional to the product of their masses.

- As the masses increase, so does the gravitational force

Attraction is inversely proportional to the square of the distance between their centers.

- As the distances decrease, the gravitational force increases quickly



Proportionality

When two terms are proportional, as one increases the other one increases
Terms can be inversely proportional: as one increases the other decreases.

Important!!!

Concept Quiz

The force of gravity is proportional to _____ and inversely proportional to _____.

- a) acceleration, distance between objects
- b) distance between objects, product of object masses
- c) product of object masses, acceleration
- d) product of object masses, distance between objects

Concept Quiz

The force of gravity is proportional to _____ and inversely proportional to _____.

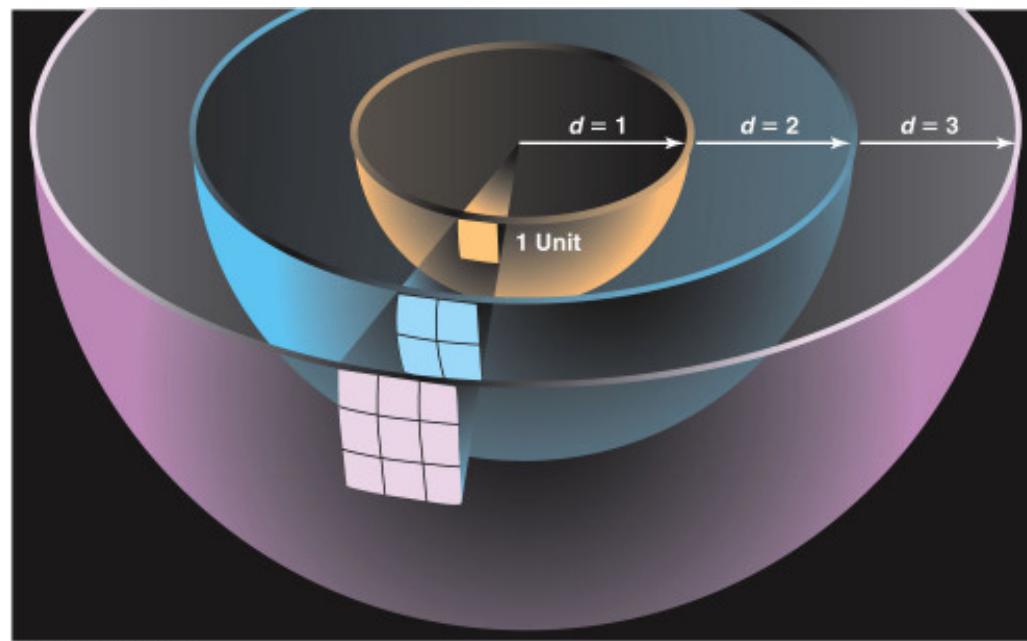
- a) acceleration, distance between objects
- b) distance between objects, product of object masses
- c) product of object masses, acceleration
- d) product of object masses, distance between objects

Inverse Square Law

An **inverse square law** is a relation where the quantity decreases with the square of the distance

OR: Intensity decreases with distance, quickly

Examples: Light, gravity, and sound



Concept Quiz

If the Earth were moved to 2AU, how would the force of gravity between it and the Sun change?

- a) Impossible to know
- b) Decrease by a factor of 2
- c) Increase by a factor of 4
- d) Decrease by a factor of 4

Concept Quiz

If the Earth were moved to 2AU, how would the force of gravity between it and the Sun change?

- a) Impossible to know
- b) Decrease by a factor of 2
- c) Increase by a factor of 4
- d) Decrease by a factor of 4

Twice as far away = 4 times less (2^2)

Concept Quiz

If the Earth were moved to 0.5AU, how would the force of gravity between it and the Sun change?

- a) Impossible to know
- b) Decrease by a factor of 2
- c) Increase by a factor of 4
- d) Decrease by a factor of 4

Concept Quiz

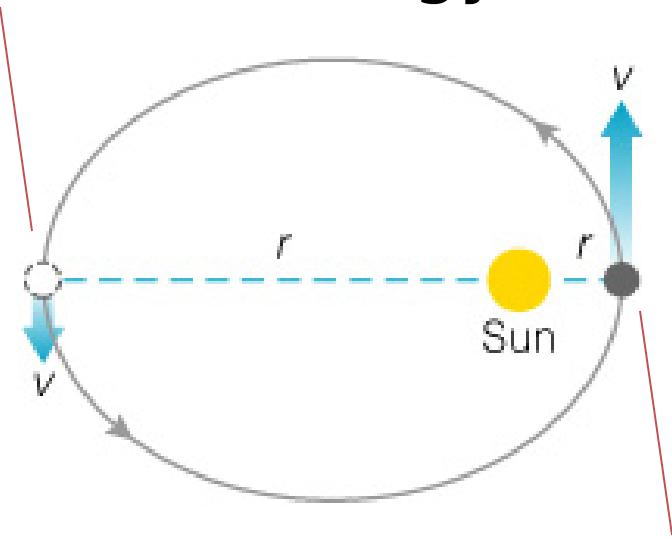
If the Earth were moved to 0.5AU, how would the force of gravity between it and the Sun change?

- a) Impossible to know
- b) Decrease by a factor of 2
- c) Increase by a factor of 4
- d) Decrease by a factor of 4

Half as far away = 4 times greater
 $(0.5^{-2}) = 4$

Gravity and Orbits

More gravitational energy;
Less kinetic energy



Less gravitational energy; More kinetic energy

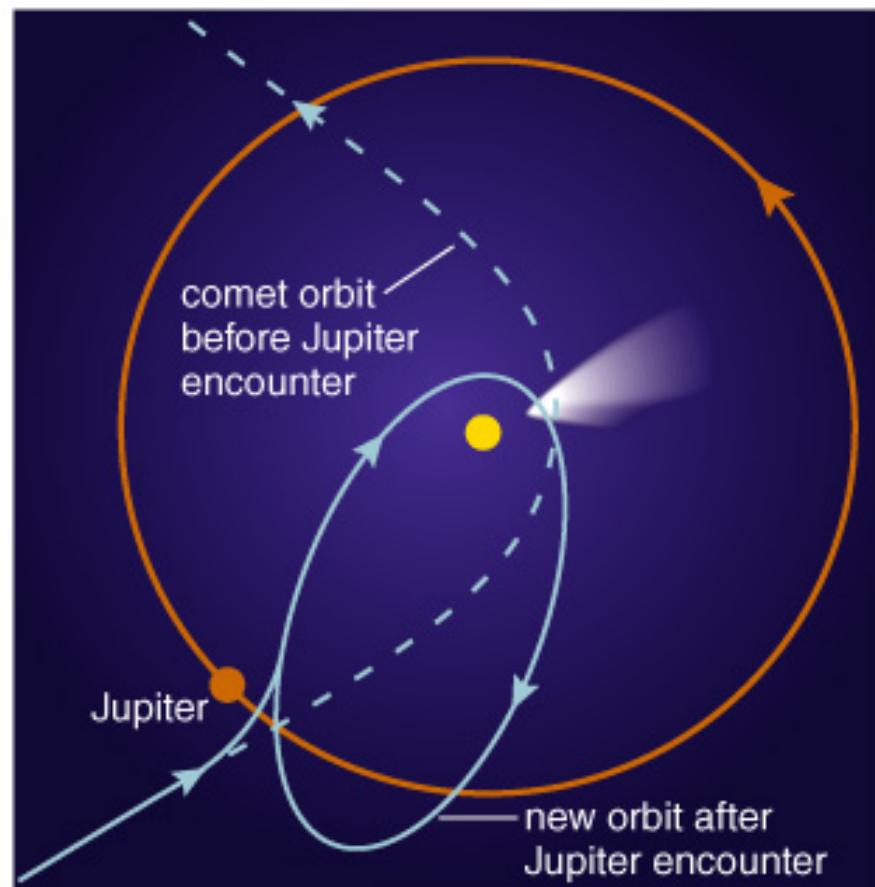
Total orbital energy
(gravitational + kinetic) stays constant if there is no external force
Orbits cannot change spontaneously.



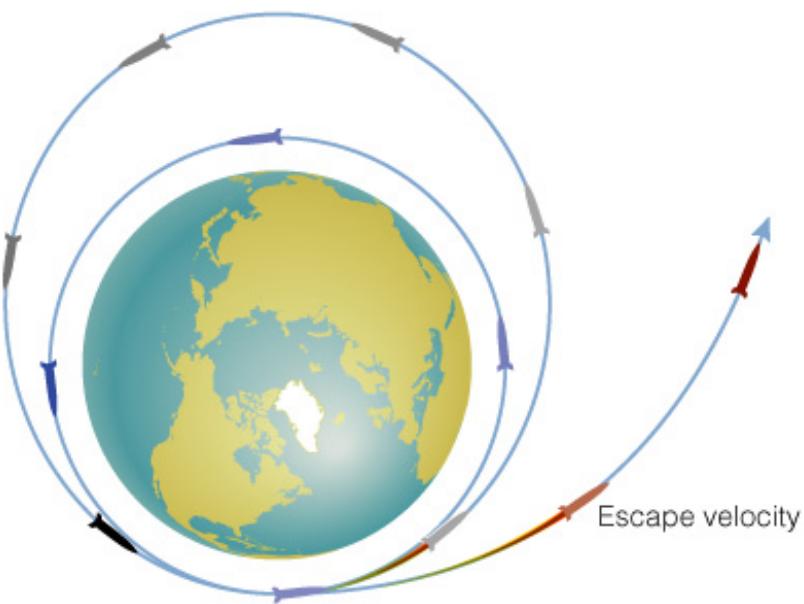
Changing an Orbit

⇒ So what can make an object gain or lose orbital energy?

- Friction or atmospheric drag
 - Reduces velocity
 - Decreases kinetic energy
 - Orbit decreases in size
- A gravitational encounter.
 - Energy can transfer to the other body



Escape Velocity



If an object gains enough orbital energy, it may escape (change from a bound to unbound orbit)

Escape velocity from Earth ≈ 11 km/s from sea level (about 40,000 km/hr)

What have we learned?

1) What is gravity?

Gravity is an acceleration due to the gravitational force.

2) What is proportionality?

Two terms are proportional if an increase in one quantity leads to an increase in the other. They are inversely proportional if an increase in one quantity leads to a decrease in the other.

3) What is an inverse square law?

An inverse square law is a relation where the quantity decreases with the square of the distance