Today's Class: Energy

- Reading on Gravity & Spacecraft Trajectories: *Cosmic Perspective,* Section 4.5.
- Homework #1 is due on Wednesday, Sep. 9.
- Complete Daily Health Form

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Space in the News: "ORIGIN" and the search for extraterrestrial life

Presented by: Natalie Margaros

Features of ORIGIN that make it unprecedented:
- Capable of analyzing mass at the location
- Able to find amino acids

If ORIGIN is the key to finding life on other planets:
- What are some ethical or moral ramifications that could arise from finding extraterrestrial life?

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Our last class

- **Why do objects move at constant velocity if no force acts on them?**
  - –Conservation of momentum
- **What keeps a planet rotating and orbiting the Sun?**
  - –Conservation of angular momentum

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Class Exercise: What is required to change an object's angular momentum?

a) a force.
b) a gravitational force.
c) a twisting force or torque.
d) It is not possible to change an object's angular momentum.
e) There is no such thing as "angular" momentum.

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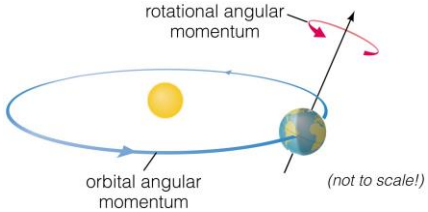
Moving in Circles

- **Angular momentum** describes objects that are spinning or moving in circles.
- A twisting force, a **torque**, is needed to change an object's angular momentum.



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Today's Learning Goals

- Where do objects get their energy?
  - –Energy makes matter move.
  - –Energy is conserved, but it can:
    - transfer from one object to another
    - change in form

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Basic Types of Energy

- Kinetic (motion)
- Radiative (light)
- Potential (stored)

Energy can change type, but cannot be created or destroyed

(1st law of thermodynamics: *Conservation of Energy*)

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Kinetic Energy (KE)

- Kinetic Energy depends upon both the mass (m) and the *square* of the velocity (v). KE = ½ mv^2.
- Class Exercise: Why did a piece of foam thermal insulation breaking off the main fuel tank and hitting the left wing result in the destruction of the Columbia Space Shuttle?

Space Shuttle external tank foam block

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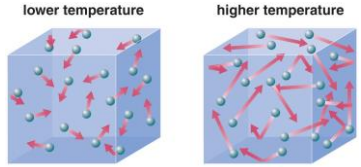
Thermal Energy

- The collective kinetic energy of many particles (for example, in a rock, in air, in water)
  - –**Temperature** is the *average* kinetic energy of the many particles in a substance ($T \propto v^2$).



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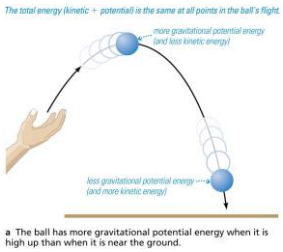
Gravitational Potential Energy

- On Earth, depends on:
  - – object's *mass (m)*
  - – strength of gravity *(g)*
  - – distance object could potentially fall
- In space, depends on
  - – object's *mass (m)*
  - – planet's (or star's) *mass (M)*
  - – distance from center of planet (or star) *(d)*



a The ball has more gravitational potential energy when it is high up than when it is near the ground.

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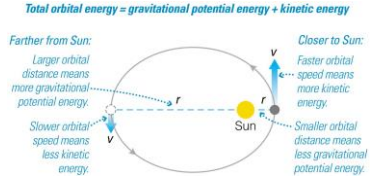
How do gravity and energy together allow us to understand orbits?

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



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Mass-Energy

- Mass itself is a form of potential energy (E):

$$E = mc^2$$

where m = mass, c = speed of light.

- A small amount of mass can release a great deal of energy (for example, an H-bomb).
- Concentrated energy can spontaneously turn into particles (for example, in particle accelerators).

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Energy Problems for Interstellar Travel

- Travel in interstellar space might mean spacecraft (S/C) has v > 0.9c. The required KE = ½ m$(0.9c)^2$ = 0.4 mc^2 or 40% conversion of mass into energy!
  - Fusion efficiency is *only* 0.1%.
  - Assume spacecraft (S/C) is NASA's Orion with a mass of 9000 kg. Total KE = 3×10^{20} Joules if it travels at 0.9c. Entire U.S. population energy consumption in 1 year is 9×10^{16} Joules!

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What have we learned?

- **Where do objects get their energy?**
  - Conservation of energy: energy cannot be created or destroyed but only transformed from one type to another.
  - Energy comes in three basic types: kinetic, potential, radiative.

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