Announce/Remind

- **Reading:** Section 6.1, 6.2 for today.

- **Adjusted Exam 1 Grades + buy-back results on course “Grades” tab.** 569 points bought back!
**Extra Credit Opportunity**

- If you didn’t do “Monsters of the Milky Way”

- **Dr. Robert C. Dempsey**, Flight Director for the International Space Station, and UT graduate, will give a talk “Houston, We Have a Problem! Now What Do We Do?”.

- **Tomorrow night: 7:30 PM on Thursday, October 2, 2008, Driscoll Auditorium.**

- Attend the talk, type up 3 or more paragraphs about what you learned.

- **Worth 2% on final grade. Due Monday.**
Free public lecture

Thursday, October 2, 2008, 7:30 PM
Driscoll Auditorium, The University of Toledo Main Campus

Dr. Robert C. Dempsey
Flight Director, International Space Station
NASA Johnson Space Center
Ph. D. 1991, The University of Toledo
Outstanding Arts & Sciences Alumnus for the Natural Sciences 2008

“Houston, We Have a Problem! Now What Do We Do?”

Space can be unforgiving. One small error or failure can ruin billions of dollars’ worth of equipment or, worse, kill someone. It is up to NASA’s flight control team in Houston to prevent or fix these
Earth, Sun, and the A.U.

The text says that an A.U. (astronomical unit) is the average distance of the Earth to the Sun.

In fact, it’s defined as 149,597,870,691 meters.

But the Earth’s orbit is not precisely circular.

In fact, the Earth moves from .98 to 1.02 A.U. from the Sun throughout the year.
**Last Time**

- **Motion, and Gravity**
  - All objects accelerated by gravity at the same rate.

- **Momentum:** mass x velocity.

- **Force:** changes momentum (including change in direction!).
Mass: Amount of matter, doesn’t change no matter where you are.

Weight: Force of gravity acting on an object. Changes (e.g. the moon).

“Weightlessness” same as “free-fall”. There is gravity in space, but you are falling freely around the earth.
LAST TIME

Newton’s Laws:

1. Object stays at rest or in constant motion unless acted on by some force.
2. Force = mass x acceleration.
3. For every force, equal and opposite force.

Conservations laws: Momentum, angular momentum, and energy.
Imagine that you throw a ball directly upward. Which of the following statements best describes how Newton’s Second Law accounts for the motion of the ball when it reaches its maximum height?

A) The ball has a velocity that is zero and an acceleration that is zero.

B) The ball has a velocity that is upward and an acceleration that is downward.

C) The ball has a net force that is downward and an acceleration that is downward.

D) The ball has a net force that is downward and a velocity that is downward.

E) The ball has a net force that is downward and an acceleration of zero.
Imagine that you throw a ball directly upward. Which of the following statements best describes how Newton’s Second Law accounts for the motion of the ball when it reaches its maximum height?

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C) The ball has a net force that is downward and an acceleration that is downward.
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E) The ball has a net force that is downward and an acceleration of zero.
EXAMPLES

\[ F_G = G \frac{M_1 M_2}{d^2} \]

**Double Mass #2:** \[ F_G^{\text{new}} = G \frac{M_1 (2M_2)}{d^2} = 2F_G \]
**Examples**

\[ F_G = G \frac{M_1 M_2}{d^2} \]

**Double the distance:**

\[ F_{G_{\text{new}}} = G \frac{M_1 M_2}{(2d)^2} = G \frac{M_1 M_2}{4d^2} = \frac{1}{4} F_G \]
Examples

The force of gravity between the Earth and an apple is given by,

\[ F_G = G \frac{M_{Earth} M_{apple}}{R_{Earth}^2} \]

Newton’s Second Law: \( F = ma \)

\[ F_G = M_{apple} a_{apple} \] Give me \( F \), and I will tell you how an object moves (a).

Gravity causes an apple to fall (accelerate) from a tree.
Explaining Kepler’s Laws

Newton’s laws of motion and gravity together explain Kepler’s laws of planetary motion.

Newton’s laws work everywhere: not just for planets orbiting the sun, but satellites orbiting planets, etc.

Newton’s version of Kepler’s third law is an improvement: you can calculate the mass of the object being orbited!
How does Newton’s Law of Gravity Extend Kepler’s Laws?

- Newton also showed that Kepler’s Laws apply to all orbiting objects, including moons, stars, galaxies.
- Ellipses are not the only orbit possible
  - Bound: ellipses
  - Unbound: parabola hyperbola
How does Newton’s Law of Gravity Extend Kepler’s Laws?

The same thing that causes apples to fall to the Earth keeps the planets in orbit around the Sun.

Newton was the first to show that the laws of physics work in the heavens.
Newton’s Version of Kepler’s Third Law

If a small object orbits a large object, and you can measure the smaller objects orbital period and average distance from the larger object, then you can measure the mass of the larger object.

- Measure the mass of the Sun using the Earth
- Measure the mass of the Earth from observations of satellites
- Measure the mass of Jupiter from its moons
Thought Question:

The gravity of the Earth pulls on you and your gravity pulls on the Earth.

Is the force you exert on the Earth, larger, smaller, or the same as the force the Earth exerts on you?
Thought Question:

- The gravity of the Earth pulls on you and your gravity pulls on the Earth

- Is the force you exert on the Earth, larger, smaller, or the same as the force the Earth exerts on you?

The same!

\[ F_G = G \frac{M_{\text{you}}M_{\text{Earth}}}{d^2} \]
How does gravity cause tides?
Newton gives the answer!

$$F_G = G \frac{M_1 M_2}{d^2}$$

Not to scale! The real tidal bulge raises the oceans by only about 2 meters.
Tides vary with the phase of the moon.

Spring tides are the most extreme because the gravity of the Sun and moon combine.
A FUNDAMENTAL LAW OF PHYSICS IS THAT ENERGY MUST BE CONSERVED.

However it can:

1) Transfer from one object to another
2) Change forms
Basic Types of Energy

Energy can be converted from one form to another.

- **Basic types:**
  - Kinetic (motion)
  - Radiative (light)
  - Potential (stored)

- **Energy can change types, but not be destroyed.**
Units of Energy

In the U.S., we are used to the Calorie. (A typical adult needs 2,500 Calories)

Scientists use the joule.

1 Calorie = 4,184 joules
(A typical adult needs 10 million joules)
Kinetic Energy

Kinetic Energy is energy due to motion.
Gravitational Potential Energy

On Earth it depends on:
1) mass of the object
2) strength of gravity
3) how far an object can fall
The total energy of the ball is conserved (kinetic + potential) but the ball’s energy can shift between kinetic and potential.
Einstein found that mass itself is a form of energy.

A small amount of matter can be converted into a large amount of energy.
Examples of \( E=mc^2 \)

- Hiroshima and Nagasaki bombs fueled by an ounce of matter
- New York City could be run for a month with a newspaper
- A baseball could keep a car going at 65 m.p.h for 5,000 years
Introduction to the Solar System
The Sun
# Mass in Solar System

<table>
<thead>
<tr>
<th><strong>Sun</strong></th>
<th><strong>99.8%</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jupiter</strong></td>
<td><strong>0.1%</strong></td>
</tr>
<tr>
<td><strong>Comets</strong></td>
<td><strong>0.05%</strong></td>
</tr>
<tr>
<td><strong>All Other Planets</strong></td>
<td><strong>0.04%</strong></td>
</tr>
<tr>
<td><strong>Earth</strong></td>
<td><strong>0.0003%</strong></td>
</tr>
</tbody>
</table>
Workbook Time

“Sun Size” on page 105
Earth and moon, to scale
The image at right shows a picture of the Sun. The dark spots located on this image are sunspots. How does the size of Earth compare (approximately) to the size of the sunspot that is identified on the image of the Sun?

A) Earth and the sunspot are about the same size.

B) The sunspot is much larger than Earth.

C) The sunspot is much smaller than Earth.
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<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance</th>
<th>Temperature (top of atmosphere)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.38 AU</td>
<td>450 K</td>
</tr>
<tr>
<td>Venus</td>
<td>0.72 AU</td>
<td>330 K</td>
</tr>
<tr>
<td>Earth</td>
<td>1.00 AU</td>
<td>280 K</td>
</tr>
<tr>
<td>Mars</td>
<td>1.52 AU</td>
<td>230 K</td>
</tr>
<tr>
<td>Jupiter</td>
<td>5.20 AU</td>
<td>120 K</td>
</tr>
<tr>
<td>Saturn</td>
<td>9.54 AU</td>
<td>90 K</td>
</tr>
<tr>
<td>Uranus</td>
<td>19.22 AU</td>
<td>60 K</td>
</tr>
<tr>
<td>Neptune</td>
<td>30.06 AU</td>
<td>50 K</td>
</tr>
<tr>
<td>Pluto</td>
<td>39.5 AU</td>
<td>40 K</td>
</tr>
</tbody>
</table>
**Planet Orbits**

- **Orbits aligned in same plane (ecliptic)**
- Explains why planets always in Zodiac
- Pluto’s orbit tipped most (17 degrees)
- **All planets orbit counter-clockwise**
- Planets rotate counter-clockwise except Venus
- Rotation axis roughly perpendicular to orbit except Uranus and Pluto
Orbits to scale; planet sizes exaggerated about one million times. Sun not to scale.
Planet Orbits
Types of Planets

Two basic “flavors” of Planets:

- Terrestrial (small, rocky, close to the sun)
- Jovian (large, gas rich, far out from sun)
The Terrestrial Planets
Four Terrestrial Planets
Terrestrial Planets

Terrestrial = Earth-like

- Mercury
- Venus
- Earth (and Moon)
- Mars

Small, low mass

No large moons except for Earth’s Moon (Mars has two small ones...)

Close to Sun
**Terrestrial Planets**

- **Rocky Surface**
  - High density (3-5 gm/cm$^3$)
    - (water has density of 1 gm/cm$^3$)

- **Geologic Activity (volcanoes, continental drift)**
  - Present on larger planets (Earth and Venus)
  - Absent on smaller planets (Moon, Mercury, and Mars)

- **Atmosphere**
  - Little hydrogen and helium
  - Mostly carbon dioxide (Venus and Mars) or nitrogen (Earth)
  - Smaller planets have no atmosphere (Mercury, Moon)
Asteroids

The Asteroid Belt

About the size of Toledo
Asteroids

- **Small rocky bodies**
- **High density** (3-5 gm/cm$^3$)
- **Usually not round**
- **Primitive composition**
  - (oldest bodies in solar system)

**Asteroid Belt**

- **Found mostly between Mars and Jupiter**
- **Probably a failed planet?**
Plots from the Minor Planet Center

http://www.cfa.harvard.edu/iau/lists/InnerPlot.html

Plot prepared by the Minor Planet Center (2008 Feb.12)
Outer Solar System
THE MIDDLE SOLAR SYSTEM

This animation shows the motion of the middle part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth Mars and Jupiter are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

The individual frames were generated on an OpenVMS system, using the PGPLOT graphics library. The animation was put together on a RISC OS 4.03 system using !InterGif.
Reminders

- HW #2 Due Monday evening.
- Read Chapters 7–8 for next week.
- Extra-Credit opportunity tomorrow evening.
- Samantha Mulhall? See me after class.