Bit of Administration ....

- **Reading**
  - Bless, pp. 142-166
  - BNSV, pp. 129-147

- **Observing Labs**
  - Lab 2 should be underway
    - 10 minutes every clear night for two weeks.
Bit of Administration ....

• **6-Week Test**
  - Monday, March 1, 7:15-8:30, 3425 Sterling
  - 50 multiple choice questions
    - 2/3 conceptual use of the material
    - 1/3 recall
  - All material in lecture, discussion, homeworks through Wednesday; readings on that material
  - Review sheet on Wednesday

• **Review Session**
  - Sunday, February 29, 6:30-7:30, 3425 Sterling
  - Will answer questions, no new presentations
The Birth of Modern Physics

• Mechanics - The Study of Motions and Forces

  – Fundamental Concepts

  • **Mass** - Amount of matter

  • **Inertia** - Property of Matter Requiring a Force to Change Motion

  • **Position** - Location in space
    - Absolute reference frame a Cartesian concept

  • **Velocity** - Rate at which position changes
    - Identified by both speed and direction

  • **Acceleration** - Rate at which velocity changes

  • **Central Force**
The Birth of Modern Physics

- Central Force

\[ F_c = \frac{m v^2}{R} \]
The Birth of Modern Physics

- Central Force

\[ F_c = \frac{m v^2}{R} \]
You are holding your little brother by his hands and swinging him around you. To increase his “excitement”, you begin to swing him faster. You have to grip his hands more tightly because

A. Your brother’s mass has increased with the increased speed
B. The radius of his circle around you has increased
C. You need to provide more central force to keep him moving in a circle
D. The centrifugal force of your brother has increased.
The Birth of Modern Physics

• **Central Force** (also known as **Centripetal Force**)

  - Central force required to keep object moving in a circle

  \[ F_c = \frac{m v^2}{R} \]
The Birth of Modern Physics

- Newton 1700 AD

1665-1666 plague was sweeping England … left Cambridge for home … in next five years he developed his ideas on ….

Mechanics
Gravity
Calculus
Discovered Spectrum of Light
Theory of Light
Reflecting Telescope

Annus Mirabilis
Newton’s Laws of Motion

1. A Body Remains at Rest or Moves at Uniform Speed in a Straight Line unless acted Upon by a Force.
The little brother that you are swinging around is beginning to annoy you. So you let go! A bird flying above you looking down will see your brother

A. Continue to travel in a circle until he hits the ground
B. Travel in a spiral pattern away from you until he hits the ground
C. Travel in a straight line until he hits the ground
D. Drop to the ground right where you let go of him
The Birth of Modern Physics

- Central Force
Newton’s Laws of Motion

2. The Change of Motion is Proportional to the Force Acting on it and in the Direction of the Force

\[ \vec{F} = m \vec{a} \]
4. Drop a ball … speed increases … acceleration … requires force

<table>
<thead>
<tr>
<th>t (sec)</th>
<th>d</th>
<th>v</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>490 cm</td>
<td>980 cm/sec</td>
<td>980 (cm/sec)/sec</td>
</tr>
<tr>
<td>2</td>
<td>1960 cm</td>
<td>1960 cm/sec</td>
<td>980 (cm/sec)/sec</td>
</tr>
<tr>
<td>3</td>
<td>4410 cm</td>
<td>2940 cm/sec</td>
<td>980 (cm/sec)/sec</td>
</tr>
</tbody>
</table>
Change of direction … acceleration … requires force

[Diagram showing a 10 km/hr vector changing direction, with a force arrow pointing downward.]
Newton’s Laws of Motion

3. To Every Action there is an Equal and Opposite Reaction
Newton’s Laws of Motion

3. To Every Action there is an Equal and Opposite Reaction

- Recoil of a gun
- Collisions
- Rockets
You are an astronaut taking a spacewalk to fix your spacecraft with a hammer. Your lifeline breaks and the jets on your back are out of fuel. To return safely to your spacecraft you should

A. Throw your hammer at your spacecraft to get someone’s attention
B. Throw your hammer in the direction away from the space ship
C. Use a swimming motion with your arms
D. Kiss your spacecraft good bye
Newton’s Law of Gravity

- Development of Law of Gravity -

It was insight of genius, not a miraculous revelation

Consider a falling apple ...

1) Galileo’s experiment - at the surface of the Earth a wood ball and a lead ball have the same acceleration due to gravity

From Newton’s Second Law

\[ F_{g,\text{lead}} = m_{\text{lead}} \cdot a_{\text{lead}} \]
\[ F_{g,\text{wood}} = m_{\text{wood}} \cdot a_{\text{wood}} \]

Since \( a_{\text{lead}} = a_{\text{wood}} \), then the force of gravity must be proportional to the mass of the falling object. So, the Law of Gravity must in part look like ...

\[ F_g = m_{\text{apple}} \]
2) Newton’s Third Law says that…

the force of gravity from the Earth on the apple
must equal
the force of gravity from the apple on the Earth

so the Law of Gravity must treat both the Earth and the apple the same way …

\[ F_g = m_{\text{apple}} m_{\text{Earth}} \]
Newton’s Law of Gravity

• Development of Law of Gravity -

3) How does the Law of Gravity depend on distance?

\[ F_G = \frac{M_{\text{apple}} M_{\text{Earth}}}{D^2} \]
 Newton’s Law of Gravity

• Development of Law of Gravity -

3) How does the Law of Gravity depend on distance?

\[
F_{g,\text{apple}} = \frac{M_{\text{apple}}M_{\text{Earth}}}{D_{\text{apple}}} = M_{\text{apple}} \cdot a_{\text{apple}}
\]

\[
F_{g,\text{Moon}} = \frac{M_{\text{Moon}}M_{\text{Earth}}}{D_{\text{Moon}}} = M_{\text{Moon}} \cdot a_{\text{Moon}}
\]
3) How does the Law of Gravity depend on distance?

\[ F_{g,\text{apple}} = \frac{M_{\text{Earth}}}{D_{\text{apple}}} = a_{\text{apple}} \]

\[ F_{g,\text{Moon}} = \frac{M_{\text{Earth}}}{D_{\text{Moon}}} = a_{\text{Moon}} \]

\[ \left( \frac{D_{\text{Moon}}}{D_{\text{Apple}}} \right)^2 = \frac{a_{\text{apple}}}{a_{\text{moon}}} \]
Newton’s Law of Gravity

Development of Law of Gravity -

4) What are accelerations of apple and Moon?

• Acceleration of apple is 980 (cm/sec)/sec

• Acceleration of moon?
  • For a circular orbit, must have a central force

\[ F_{\text{central}} = \frac{M_{\text{Moon}} \cdot V_{\text{Moon}}^2}{D_{\text{Moon}}} = M_{\text{Moon}} \cdot a_{\text{Moon}} \]

\[ \frac{V_{\text{Moon}}^2}{D_{\text{Moon}}} = a_{\text{Moon}} \]

0.27 (cm/sec)/sec = \( a_{\text{Moon}} \)
Newton’s Law of Gravity

• Development of Law of Gravity -

4) What are accelerations of apple and Moon?

\[
\frac{a_{\text{apple}}}{a_{\text{moon}}} = \frac{980 \text{ (cm/sec)/sec}}{0.27 \text{ (cm/sec)/sec}} = 3600
\]

\[
\frac{D_{\text{Moon}}}{D_{\text{apple}}} = \frac{384000 \text{ km}}{6378 \text{ km}} = 60
\]

\[
\left(\frac{D_{\text{Moon}}}{D_{\text{apple}}}\right)^2 = \frac{a_{\text{apple}}}{a_{\text{moon}}} \quad ? = 2
\]
Newton’s Law of Gravity

\[ F_g = \frac{G M_1 M_2}{D^2} \]

- \( M_1 \) = Mass of object 1 (grams)
- \( M_2 \) = Mass of object 2 (grams)
- \( D \) = Distance between objects (cm)
- \( G = 6.67 \times 10^{-8} \) cm\(^3\)/sec\(^2\)/gm
Suppose that the mass of the Earth were to suddenly double. The force of gravity between the Earth and Moon would

A. Increase by 2 times
B. Increase by 4 times
C. Decrease by 2 times
D. Decrease by 4 times
E. Stay the same

\[ F_g = \frac{GM_1M_2}{D^2} \]
ConcepTest!

Suppose that the Moon were to orbit at twice its present distance.
The force of gravity between the Earth and the Moon would

A. Increase by 2 times
B. Increase by 4 times
C. Decrease by 2 times
D. Decrease by 4 times
E. Stay the same

\[ F_g = \frac{G M_1 M_2}{D^2} \]
ConcepTest!

Suppose that the Earth’s radius were to shrink by a factor of 2. The force of gravity between the Earth and the Moon would

A. Increase by 2 times
B. Increase by 4 times
C. Decrease by 2 times
D. Decrease by 4 times
E. Stay the same

\[ F_g = \frac{GM_1 M_2}{D^2} \]
ConcepTest!

Suppose that the Earth’s radius were to shrink by a factor of 2. The force of gravity between you and the Earth would

A. Increase by 2 times
B. Increase by 4 times
C. Decrease by 2 times
D. Decrease by 4 times
E. Stay the same

\[ F_g = \frac{GM_1 M_2}{D^2} \]