Bit of Administration ….

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

• Review Session
  – Sunday, February 29, 6:30-7:30, 3425 Sterling
  – Will answer questions, no new presentations
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)
\( G = 6.67 \times 10^{-8} \text{ cm}^3/\text{sec}^2/\text{gm} \)
Newton’s Law of Gravity

Galileo’s Experiment

\[ F_{g,\text{lead}} = \frac{GM_{\text{Earth}}M_{\text{lead}}}{R_{\text{Earth}}^2} \]

\[ F_{g,\text{wood}} = \frac{GM_{\text{Earth}}M_{\text{wood}}}{R_{\text{Earth}}^2} \]

\[ a_{\text{lead}} = \frac{F_{g,\text{lead}}}{M_{\text{lead}}} = \frac{GM_{\text{Earth}}M_{\text{lead}}}{R_{\text{Earth}}^2} \cdot \frac{1}{M_{\text{lead}}} = \frac{GM_{\text{Earth}}}{R_{\text{Earth}}^2} \]

\[ a_{\text{wood}} = \frac{F_{g,\text{wood}}}{M_{\text{wood}}} = \frac{GM_{\text{Earth}}M_{\text{wood}}}{R_{\text{Earth}}^2} \cdot \frac{1}{M_{\text{wood}}} = \frac{GM_{\text{Earth}}}{R_{\text{Earth}}^2} \]
Newton’s Law of Gravity

Mass = Amount of Material
Weight = Force Due to Gravity

90 kg
200 lbs
Earth
30 lbs
Moon
0 lbs
0 lbs

Moon
On much of the European continent, the heft of people is called their mass and measured in kilograms. Like in the United States, they measure themselves by stepping on a bathroom floor scale.

True or False: Strictly speaking, when they step on the scale they are not measuring their mass but instead are measuring their weight.

A) True
B) False
C) Its debatable
Newton’s Law of Gravity

“Weightlessness”

200 lbs
Newton’s Law of Gravity
After jumping off the building (and before landing!), what weight will the scale read?

A) 0 pounds  
B) 20 pounds  
C) 200 pounds  
D) 300 pounds
Newton’s Law of Gravity

“Weightlessness” - No such thing; would imply no gravity
- A consequence of all objects in free fall at same acceleration

0 lbs
Newton’s Law of Gravity

Orbits
Newton’s Law of Gravity

Orbits
The simulation will let me change the mass of the cannonball. Suppose we fire a 1 kg cannonball at 1 m/sec. Then we fire a 10 kg cannonball at 1 m/sec. What will happen?

A) The 10 kg cannonball will not travel as far as the 1 kg ball.
B) The 10 kg cannonball will travel the same distance.
C) The 10 kg cannonball will travel further than the 1 kg ball.
Newton’s Law of Gravity

Orbits - Moon is constantly in free fall, as are all orbiting objects
- “Always falling to earth, but never getting closer!”
Newton’s Law of Gravity

Orbits - Astronauts are constantly in free fall!
ConcepTest!

Suppose a GPS satellite is 50 miles above Madison, and at this moment it is at rest (i.e., its velocity is 0 km/sec). In the next few minutes you would expect the satellite to

A) rise further away from the Earth.
B) move in a circular orbit about the Earth.
C) land in the center of Madison.
D) It depends on the mass of the satellite.
Newton’s Law of Gravity

Kepler’s 3rd Law

In order for planet P to travel in a circle around the Sun...

Central Force = Gravitational Force

\[ \frac{M_p V_p^2}{A} = \frac{G M_S M_p}{A^2} \]

\[ \frac{V_p^2}{A} = \frac{G M_S}{A^2} \]

Velocity depends only on distance, not on mass of planet

Velocity decreases w. greater distance
Newton’s Law of Gravity

Kepler’s 3rd Law

\[ V_p^2 = \frac{GM_S}{A} \]

\[ \frac{4\pi^2 A^2}{P^2} = \frac{GM_S}{A} \]

\[ \frac{4\pi^2 A^3}{P^2} = GM_S \]

\[ 4\pi^2 A^3 = GM_SP^2 \]

\[ \frac{4\pi^2}{G} \frac{A^3}{M_S} = P^2 \]

\[ P^2 = \frac{4\pi^2}{G} \frac{1}{M_S} A^3 \]

\[ V_p = \frac{\text{distance}}{\text{time}} = \frac{2\pi A}{P} \]
Newton’s Law of Gravity

Kepler’s 3rd Law

\[ P^2 = \frac{4\pi^2}{G} \frac{1}{M_S} A^3 \]

In general, in units of cm, sec, gms

\[ (1\text{yr})^2 = \frac{4\pi^2}{G} \frac{1}{M_o} (1\text{AU})^3 \]

For the Earth

1 Solar Mass

\[ P^2 = \frac{1}{M_S} A^3 \]

In general, in units of AU, years, solar masses

For objects orbiting the Sun \((M_c = 1 M_o)\)

\[ P^2 = A^3 \]
Nature and nature’s laws
Lay hid in the night

God said, “Let Newton be!”
And all was light!

- Alexander Pope