Announcements

Have Cleared All People on Waiting List

Recitation Place and Time Still TBD
Robyn’s Office Hours Now Posted on Website

Website
http://casa.colorado.edu/~wcash/APS1120/APS1120.html

First Homework Due January 23
First Observatory Opportunity January 23
Work Sheet for Observatory is on web.

This Thursday!!
Newton’s Laws

• Law #1: A body at rest or in motion remains that way unless acted upon by an outside force.

• Law #2: \( a = \frac{F}{m} \)

• Law #3: For every action there is an equal and opposite reaction.
Law #1

A body in motion remains that way unless acted upon by an outside force.

No Forces

Contact Forces (electrical)

Gravity
Law #2

F = Force
m = mass
a = acceleration

\[ a = \frac{F}{m} \]

- Have a mass
- Apply a force
- Acceleration Results

Note: Law #1 is special case of Law #2 \( (F=0 \Rightarrow a=0) \)
Law #3

For every action there is an equal and opposite reaction.
For every \( ma \) there is an equal and opposite \( ma \).

Big one doesn’t move much

Equal Mass Implies Equal Acceleration
But What is F?

\[ a = \frac{F}{m} \] not enough because we don’t know what F is.

Need a new law to describe forces

There are Four *KNOWN* Forces

Gravity
Weak Nuclear Force
Electromagnetism
Strong Nuclear Force

In order of strength
Gravity Weakest
Newton’s Law of Universal Gravitation

\[ F_{12} = \frac{G m_1 m_2}{r^2} \quad F_{21} = \frac{G m_1 m_2}{r^2} \]

(Law #3 Satisfied)

\( G = 6.7 \times 10^{-8} \text{ dyne}\cdot\text{cm}^2/\text{g}^2 \) in cgs units

Value of \( G \) is measured. Nobody knows why it is the value it is.

Electrical Force Equation Similar

\[ F_e = \frac{e_1 e_2}{r^2} \]
But What is a Force?

Newtons Laws Give Value, and Show what to do.

Force is an Exchange of Virtual Particles
Orbits

Falls Freely

Hits Surface

Misses Surface From Sideways Motion
Physics of Orbits

sideways velocity

central acceleration

If you balance things just right, you have an orbit.

Too Little Sideways V = Crash
Too Much = Escape to Infinity
Circular Orbit

circle implies

\[ \frac{v}{a} = \frac{r}{v} \]

\[ a = \frac{v^2}{r} \]

\[ F = ma \]

\[ F = \frac{Gm_1m_2}{r^2} \]

\[ ma = \frac{GMMm}{r^2} \]

\[ \frac{mv^2}{r} = \frac{GMMm}{r^2} \]

\[ v = \sqrt{\frac{GM}{r}} \]

\[ P = \frac{2\pi r}{v} = 2\pi \sqrt{\frac{r^3}{GM}} \]

Kepler’s Law
Example

Calculate the period of a planet that is the same distance from the star Sirius that the Earth is from the Sun.

\[ r = 1.5 \times 10^{13} \text{cm} \]
\[ G = 6.7 \times 10^{-8} \]
\[ M = 4 \times 10^{33} \text{g} \]

\[
P = 6.28 \sqrt[3]{\frac{(1.5 \times 10^{13})^3}{6.7 \times 10^{-8} \times 4 \times 10^{33}}} = 6.3 \sqrt[3]{\frac{4 \times 10^{39}}{2.5 \times 10^{26}}} = 6.3 \sqrt[3]{15} \times 10^{13} = 25 \times 10^6 = 2.5 \times 10^7 \text{s}
\]

About 9 Months
Non-Circular Formula

Same Formula for P
Use half orbit length for r

Focus

2r

Fast

Slow
Escape Velocity

Escape velocity is the speed at which an object must be thrown upward to escape and never come down.

\[ \frac{1}{2} mv^2 = \frac{GMm}{R} \]

Fall from Large Height

Same Energy Needed to Reverse and Fly Away

\[ v_e = \sqrt{\frac{2GM}{R}} \]
Example

Earth

R = 6 \times 10^8 \text{cm}
M = 5 \times 10^{27} \text{g}

\[ v_e = \sqrt{\frac{2 \times 6.7 \times 10^{-8} \times 6 \times 10^{27}}{6.4 \times 10^8}} \]

\[ v_e = \sqrt{\frac{8 \times 10^{20}}{6 \times 10^8}} = 1.1 \times 10^6 \text{ cm/s} = 11 \text{ km/s} \]
Surface Gravity

The force of gravity at the surface of a body is

\[ F = \frac{GMm}{R^2} \]

So

\[ ma = \frac{GMm}{R^2} \]

or

\[ a = \frac{GM}{R^2} \]

The acceleration of a body near the surface is independent of mass.

Remember Galileo and the Leaning Tower of Pisa.
Gravity on Earth

\[ a = \frac{GM}{R^2} = \frac{6.7 \times 10^{-8} \times 6 \times 10^{27}}{(6.4 \times 10^8)^2} = 980 \text{cm/s/s} \]

1 gee is 9.8 m/s per second
Spin Up

When a body is spinning “Angular Momentum” is conserved

For spherical body:

\[ A = \frac{2}{5} MR^2 \left( \frac{2\pi}{P} \right)^2 \]

As \( R \) decreases \( P \) decreases

Spin up of ice skater. \hspace{1cm} Same for Collapsing Stars