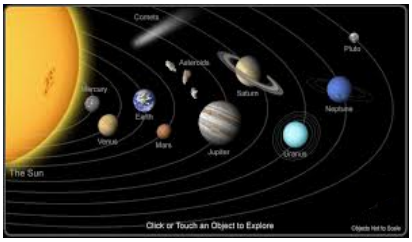
5.7 Kepler's Laws of Planetary Motion



Alter Homework Slide
Escape Velocity derivation Rabbit Hole?

Johannes Kepler (1571 - 1630)

German astronomer and mathematician.

Devised three empirical (data driven) laws of planetary motion, based on 20 years of astronomical data gathered by Danish astronomer Tycho Brahe (1546 - 1601).

First two laws published in 1609.

Third published 1619.

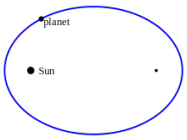
These laws took about 15 years to deduce from observational data, but can now be derived theoretically in a couple pages.

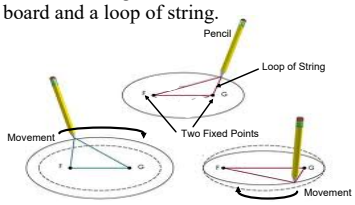
Kepler's 1st Law - Law of Orbits

Planets move in elliptical orbits with the sun as one of the focal points.

An ellipse is like a squashed circle, and can be drawn like this:

Demo: use magnets on the board and a loop of string.

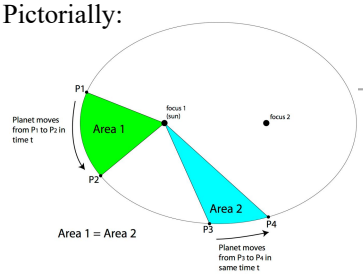


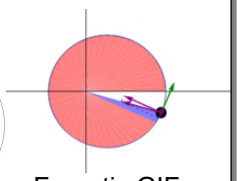


Kepler's 2nd Law - Law of Areas

A line from the sun to a planet sweeps out equal areas in equal amounts of time, showing that a planet's orbital speed varies.

Pictorially:





Frenetic GIF

Kepler's 3rd Law - Law of Periods

A planet's orbital period squared is proportional to the average distance of the planet from the sun cubed.

Mathematically: $T^2 \propto r^3$

$T^2 = K \bullet r^3$	T = Period (s) K = 2.97 E -19 s^2/m^3 r = radius (m)

Note 1: K applies to all planets in our solar system **NOT** satellites around planets (have their own K values)

Note 2: Period comes out in seconds: more useful to convert to days or years.

Jupiter Example

What is the average distance of Jupiter from the sun: its period is 11.8618 earth-years?

Jupiter Answer:

Convert 11.8618 years to seconds, then plug it in:

$$11.8618\,years \bullet \frac{365\ days}{1 Year} \bullet \frac{24\,h}{1.0\,day} \bullet \frac{3600\,s}{1.0\,hr} = 3.74E8\,s$$

$$T^2 = K \bullet r^3$$

$$r = \sqrt[3]{\frac{T^2}{K}} = \sqrt[3]{\frac{(3.74E8\,s)^2}{2.97E-19\,s^2/m^3}} = 7.78E11\,m$$

Earth's Satellites

To get a satellite into orbit, lots of planning happens: it must be positioned with the correct speed for the altitude.

What happens if too much energy is added, and it drifts off into space?

Question: how fast would an object have to be fired from a cannon on Earth in order to reach escape velocity: minimum speed necessary to leave a planet's gravity well?

Escape Velocity

For any massive object(obj.), escape velocity is calculated thusly:

$$v_{esc} = \sqrt{\frac{2 \bullet G \bullet M_{obj}}{R_{obj}}}$$

G = 6.67 E -11 N•m^2/kg^2
M_{obj} = Object's Mass (kg)
R_{obj} = Object's Radius (m)

Rabbit Space Launch!
(Not Rabbit Hole)

Weightlessness vs. Body

Orbital astronauts areweightless: centripetal acceleration equals the rate at which they fall to earth.

Some health concerns:
1. Muscles atrophy (shrink) from lack of use, as much as 5% a week,

2. Bone loss reaches about 1% a month. Could reach maximum of 40 - 60% over time,

3. Bone loss can lead to excess calcium in blood, leading to kidney stones,

Further Down the Rabbit Hole!

So ya wanna be an astronaut. . .

4. Blood goes to astronaut's heads, leading to swollen facial features and thinner legs,

5. Greater cranial blood pressure triggers the body to slow blood cell production. Astronauts can lose up to 22% of their blood as a result.

6. Heart atrophies: doesn't have to work as hard.

SO: If you want to be an astronaut, start a robust physical fitness routine now!

Help! I went into space without training!

Homework 5.7

Problems 5.7 in your Booklet
ERRORS!!
#1 should be: **4.4 E 11 m**; #4 is better as $\sqrt{10}:1$
Due: Next Class

Finish Unit 5 Review Problems
Scanned Monday 11/26