SHOOTING STAR

Shooting Star, an interactive computer simulation using calculation power of super computers.

Students should investigate and become familiar with Kepler's laws, Newton's theory of gravitation, motion in gravitational field, three body problem and super computers before they start to play.

Shooting Stars is a physics puzzle game where you get to control the planets of a star system. Simulate orbiting planets and gravitational forces in the searing heat of the sun. See how many planets you can keep in orbit. Test your skills in many ways, with different scenarios that give you a taste of the world of supercomputer simulation PRACE offers.

Pedagogical information

Aims

- to make observations
- to learn empirical testing
- to create the "Design for the study"
- to repeat the test
- to evaluate the reliability of prediction
- to contact the single facts and common theory
- to understand the nature of creating scientific research process
- to advance the thinking skills from concrete to more abstract understanding level

Main learning activities

- to repeat the three basic forms of kinematics: speed, acceleration and force
- to get more realistic understanding of the satellite motion in general
- to deepening the understanding of the gravity
- to understand the connection between motion and gravitational force
- to know the limits and dangers of space flights
- to do hands-on empirical testing using simulation
- to use the technical equipment for testing
- to recognize the difference between reality and symbolic simulation by the Augmenter Reality (AR)
- to learn the nature of collisions
- to summarize the idea traveling in space as scientific theory

In astronomy, Kepler's laws of planetary motion are three scientific laws describing the motion of planets around the Sun. Kepler's laws are now traditionally enumerated in this way:

The orbit of a planet is an ellipse with the Sun at one of the two foci.

A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.

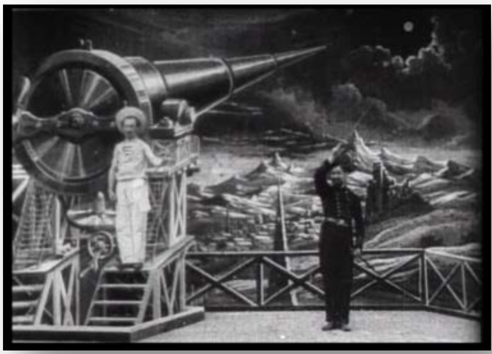
The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

Most planetary orbits are almost circles, so it is not apparent that they are actually ellipses. Calculations of the orbit of the planet Mars first indicated to Kepler its elliptical shape, and he inferred that other heavenly bodies, including those farther away from the Sun, have elliptical orbits also. Kepler's work broadly followed the heliocentric theory of Nicolaus Copernicus by asserting that the Earth orbited the Sun. It innovated in explaining how the planets' speeds varied, and using elliptical orbits rather than circular orbits with epicycles.

Isaac Newton showed in 1687 that relationships like Kepler's would apply in the solar system to a good approximation, as consequences of his own laws of motion and law of universal gravitation. Together with Newton's theories, Kepler's laws became part of the foundation of modern astronomy and

+ Provoke curiosity

Teacher ask students their opinion. Which method is better to launch a space vehicle? Cannon or rocket?



+ Define questions from current knowledge

What is the difference of star, planet, moon and satellite, if one observes their movements in space?

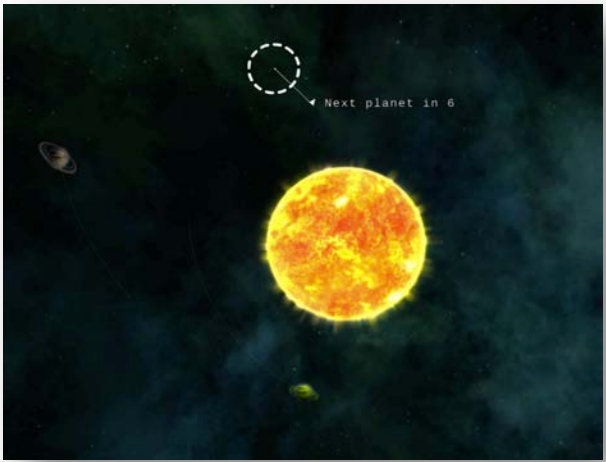
+ Propose preliminary explanations or hypotheses

Johannes Kepler published his first two laws about planetary motion in 1609, having found them by analyzing the astronomical observations of Tycho Brahe. Kepler's third law was published in 1619.

Kepler in 1622 and Godefroy Wendelin in 1643 noted that Kepler's third law applies to the four brightest moons of Jupiter. The second law ("area law" form) was contested by Nicolaus Mercator in a book from 1664; but by 1670 he was publishing in its favour in Philosophical Transactions, and as the century proceeded it became more widely accepted. The reception in Germany changed noticeably between 1688, the year in which Newton's Principia was published and was taken to be basically Copernican, and 1690, by which time work of Gottfried Leibniz on Kepler had been published.

+ Plan and conduct simple investigation

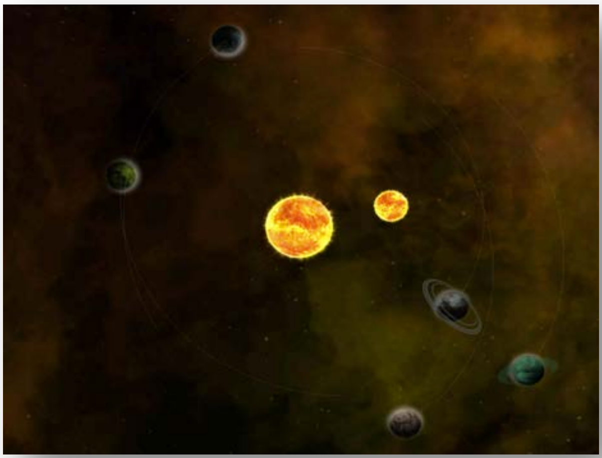
Students try to get off so many levels as possible. Every level is more difficult than previous ones, but every level deepens students knowledge of planetary motion, even many particle planetary motion. As a game every new level is also challenging.



+ Gather evidence from observation

Students should prepare to answer questions like

1. How did the Kepler's laws realized in the program?
2. What is the main difference in motion in gravitational field, when there is only one massive center object + one or more orbiting light satellites compared to the situation, when there is two or more massive objects?
3. How is the need of the calculating power solved on a program?
4. How many different types of forces are present?
5. What are the formulas of the forces?



+ Explanation based on evidence

Good source of an explanation based on evidence http://hyperphysics.phy-astr.gsu.edu/hbase/kepler.html

+ Consider other explanations

A stellar system of two stars is known as a binary star, binary star system or physical double star. If there are no tidal effects, no perturbation from other forces, and no transfer of mass from one star to the other, such a system is stable, and both stars will trace out an elliptical orbit around the center of mass of the system indefinitely. See Two-body problem. Examples of binary systems are Sirius, Procyon and Cygnus X-1, the last of which probably consists of a star and a black hole.

A multiple star consists of three or more stars which appear from the Earth to be close to one another in the sky. This may result from the stars being physically close and gravitationally bound to each other, in which case it is a physical-multiple star, or this closeness may be merely apparent, in which case it is an optical-multiple-star. Physical multiple stars are also commonly called multiple stars or multiple star systems. Most multiple star systems are triple stars. Systems with four or more components are less likely to occur. Multiple-star systems are called triple, trinary or ternary if they contain three stars; quadruple or quaternary if they contain four stars; quintuple or quintenary with five stars; sextuple or sextenary with six stars; septuple or septenary with seven stars, and so on.

These systems are smaller than open star clusters, which have more complex dynamics and typically have from 100 to 1,000 stars. Most multiple star systems known are triple; for higher multiplicities, the number of known systems with a given multiplicity decreases exponentially with multiplicity. For example, in the 1999 revision of Tokovinin's catalog of physical multiple stars, 551 out of the 728 systems described are triple. However, because of selection effects, our knowledge of these statistics is very incomplete.

Multiple-star systems can be divided into two main dynamical classes: hierarchical systems which are stable and consist of nested orbits that don't interact much and so each level of the hierarchy can be treated as a Two-body problem, or the trapezia which have unstable strongly interacting orbits and are modeled as an n-body problem, exhibiting chaotic behavior. The three-body problem is a special case of the n-body problem, which describes how n objects will move under one of the physical forces, such as gravity. These problems have a global analytical solution in the form of a convergent power series. Among classical physical systems, the n-body problem usually refers to a galaxy or to a cluster of galaxies; planetary systems, such as star(s), planets, and their satellites, can also be treated as n-body systems.

This an another point of view to planetary motion in our own Solar system. In 1772 an astronomer named Titius living in Wittenberg wrote to a colleague named Bode who was in Berlin. Titius had discovered a very interesting relationship between the average distances of the planets from the Sun.

Starting with the series 0, 3, 6, 12, 24,.. etc and then adding four and dividing by 10, the resultant series was very close to the actual distances of the planets from the Sun when measured in astronomical units. (An astronomical unit or AU is the mean distance of the Earth from the Sun.)
The table below compares the actual distances to three significant figures with the distances given by the series formula:

Planet	Actual	Formula
Mercury	0.387	0.4
Venus	0.723	0.7
Earth	1.00	1.0
Mars	1.52	1.6
???		2.8
Jupiter	5.20	5.2
Saturn	9.55	10.0
Uranus	19.2	19.6
Neptune	30.1	38.8

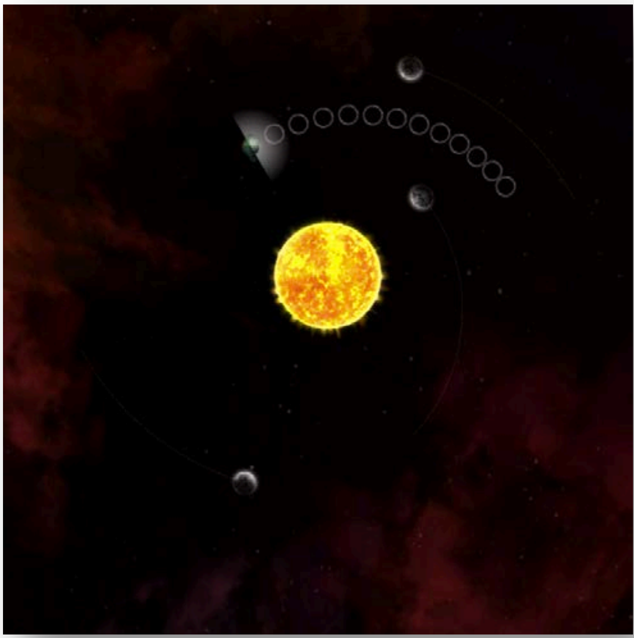
Students can discuss, what is the connection between observations and theory. Every observation, which has an mathematical model does not necessarily lead to a scientific theory. At least to one, which is approved in science community.

+ Communicate explanation

The students should report on the realized activities. The will need to prepare a report that includes the rational of the experiment, the initial design of the experimentation, the experimental set-up, the realization of the process, the analysis of the findings and a detailed discussion on the results.
Students could work in groups, prepare their reports and then present them in the classroom.

Teacher should encourage the students to use photos and videos as research tools. The modern cell phones have many useful properties, not only photo and video camera.
Shooting Stars program demonstrates fine and understandable, how the predictable movement of planets orbiting a massive central body like Sun changes suddenly to an unpredictable and chaotic movement, when objects are added by one. In the program is also very clever solution to the need of calculation power. It works over the Internet and uses the processing power of super computers.
To get more than the pleasure of playing very addictable game the student should have some knowledge about gravitation and motion in gravitational field. Therefore program gives best educational use for students age 16 or over. For instance in Finland topic gravitation is in national

curriculum for upper secondary school, and even there for second years students.



Summa summarum. The game has fulfilled it's educational goals, if student (player) gets an idea, that one most simple force, which has only one direction, pulling, can cause most complex, unpredictable and chaotic movement even when there are only three bodies attracting each others. Thinking about that can lead someone's mind to the galactic spheres.

Follow-up activities and materials

Good links and tests

http://en.wikipedia.org/wiki/Gravitation

http://www.physicsclassroom.com/class/circles/u6l4a.cfm

http://en.wikipedia.org/wiki/Ellipse

http://www.physicsforums.com/showthread.php?t=586069

http://en.wikipedia.org/wiki/Three-body_problem

http://en.wikipedia.org/wiki/Supercomputer

eLearning element

The following links shows the possibilities to expand Shooting star to the astronomy in general

https://www.youtube.com/watch?feature=player_embedded&v=KHgfEaUKuds

https://www.youtube.com/watch?feature=player_embedded&v=tMVDWvHlrRc

https://www.youtube.com/watch?feature=player_embedded&v=0QX9CXTqiiM

Big Idea of Science

1. **Objects can affect other objects at a distance.**

   It is obvious, that planets interact with the satellites from distance. It is as obvious, that the interact also when they are in contact, but in different way. They collide and results are totally different when satellite is orbiting the palnet.

2. **Changing the movement of an object requires a net force to be acting on it.**

   This is seen very clearly, when satellite has two or more planets near it. The net gravitational force orders the changes of the satellites movement.