Orbits – Jason Hwang and Daniel DuBrow

Purpose

This activity introduces the use of computers to simultaneously simulate several systems; specifically, some number of Solar System planets and a rocket, where we make the approximation that all the objects are affected only by the star's gravitational potential. Rather than having the students attempt to interact with the code itself, this activity encourages the use of a computer program to explore concepts in a novel manner; specifically, being able to visually see the time evolution of systems driven by gravity and how rocket-motion differs by changing the initial angle and velocity.

This method reinforces the concept that computer simulations are useful in solving many problems quickly and are able to visualize the results in a way that allows for a more intuitive understanding of the physics, especially since many of the results may be unexpected for a student beginning to learn about orbits.

Overview

-Before the activity, the students should have had some lessons on orbital motion and an introduction to satellites.

-Prior to running the activity the instructor should have experience running the program and be comfortable with the initial setup.

-The teacher should either install processing (including Python mode) or create an easily downloadable file with the program and processing. Having a larger number of computers prepared allows for smaller groups which will be beneficial, as direct interaction with the program is encouraged.

-At the beginning of the main activity, the instructor should present examples of how to interact with the program. We recommend using the default planets (Earth to Mars).

-The first step for the students is to log into the computers and open processing. The students should then open the program, 'Orbits' within processing and begin exploring the program.

-The students should then, in pairs or in groups, discuss the strategies for collecting data and answering the main questions of solving for the optimal launch angle. The data and exploration of the software should then be collected and recorded in their lab books.

-The students should solve for the optimal launch angle, and any students that finish early should begin working on the extra credit questions which require using the additional setups in the software.

Student Outcomes

1) Review and supplement to lessons on orbital motion
2) Experience with using computer simulations to understand a physical system
3) Constructing a plan to solve problems, including designing problem-solving strategies
Applications of learning – The students apply their knowledge of orbital motion to influence their approach towards finding the optimal launch angle.

Communicating – The students must explain thoroughly and defend their reasoning behind their strategy.
Using technology – The students learn to use a program written in processing that simulations the physics of several systems, similar to methods used in modern research.
Working on teams – The students will work in groups to develop a strategy for solving the questions presented in the worksheet.
Making connections – We introduce to the students the advantages to using a computer simulation to model a physical system.

Standards Addressed
HS-ESS1-2 – Develop and use a model to describe the role of gravity in the motions within galaxies and the Solar System.
MS-ESS1-3 – Analyze and interpret data to determine scale properties of objects in the solar system. HS-ETS1-4 – Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Time
The total time for the activity is two class periods, preferably together for the students to explore the simulation. The activity will require more time if Processing is not already installed or easily installed on the computers.

Level
This activity works best for students that have been exposed to orbital motion and projectile motion.

Materials and Tools
A computer lab or personal laptops with processing already installed or in an easily downloadable folder with all the files required. The worksheet given during the class period may be given earlier to allow the students time to develop a strategy to answer the main question.

More information on Processing can be found here. (https://processing.org/)
Pre-lab worksheet and all required Processing files can be found here.

Preparation
The instructor needs to download and use the program to become comfortable enough to answer both physics and technical questions. The instructor should also document how to download and run the program on the school's computers, as this may require a different setup.

Prerequisites
Since students will not be directly interacting with the code (but are encouraged to do so if there is interest!), there are no dependencies on prior activities. Reviewing the physics of orbital motion will help students link the physics with the computer simulations.

Background
Students should be familiar with the physics of orbital motion. Exposure to experiment design and computer simulations will also be useful, although this activity is fine as a first look at computer simulations.

Teaching Notes
The students will work at different paces, and while there is less technical skill required to complete this experiment than other, more programming-focused activities, students with exposure to physics simulations will likely work faster than other students. Be sure to check in often during the setup process as students may be stuck on technical issues such as installing the software, which can cause frustration and rapid loss in interest in the activity. Students that finish quickly should be directed to the extra credit questions that explore the other options available in the software. Students are highly encouraged to fully document their reasoning behind their experimental design used to solve the nominal problem and to record the results of all experiments. Encourage the students to work together, potentially splitting up students that have had prior experience with computer simulations.

Assessment

-The students are primarily assessed on their experiment design in solving the nominal problem; specifically finding the optimal launch angle to minimize the velocity required to travel from Earth to Mars.
-Students are given the tools required to solve the problem, and must describe their approach in detail in their lab books.
-While obtaining the correct answer is the most objective way to measure success, this activity emphasizes thinking through the problem, and students must give details of the data collected and how they use the results to drive future decision-making.
-Advanced students can attempt the extra credit questions, where the assessment is left up to the discretion of the instructor.

Additional Information
N/A