**How Interactive Physics Works**

This handout will discuss the basics of Interactive Physics simulation design. Interactive Physics (IP) is a computer program that lets the user design and run simulations of real-world physical events. It can be used as an excellent aid in teaching kinematics, although the user may find a few limitations when creating electrostatics simulations. IP deals only with two-dimensional objects. It allows the user to create bodies of circular or polygonal shape, to create constraints that limit the motion of the defined bodies, to specify the position of objects, apply forces, and impart velocities and accelerations. Almost any simple physical situation can be scaled down and rendered on IP. Importantly, IP allows the user to view, measure, and record the properties of motion of each defined body.

The first step is to find a real physical situation we want to model. Some simple situations that can be easily rendered on IP are collisions between two or several objects, the bouncing of a ball, a box sliding across a frictionless surface, the moon orbiting the Earth, or the repulsion of two positive charges. This approach is useful when the user wants to compare real experimental data with theoretical IP data calculated with very little error, or when the user, for example, suddenly wants to test the effects of changing the mass of a pendulum bob on the period.

Before we start building, we must remember to keep a clear goal in mind of how we want the simulation to look, and what we want it to do. It is important for everyone using this program to become familiar and comfortable with IP. Looking at a few sample IP simulations will help you to see different possibilities for designing your simulation, and will help you to see how various situations were modeled on this program.

## Starting a New Simulation

### To Create a New Simulation

To start a new simulation if the Untitled1 window is not present soon after IP starts, go to the File header at the top left of your screen and click on New. If the Untitled1 window is present, we are ready to begin.

## The General Layout of IP

IP is divided into three portions: the Menu bar at the very top of the IP window, the Constraints bar to the left of the IP window, and the World, which is an initially blank window that takes up most of the IP window. If you have not already done this, maximize the IP window so you can fully see each of these IP window components.

## The World

A very important feature of IP is the size of the World. The window you see before you is actually 1/9 the size of the World; the rest of it can be seen as a blank white background when using the scroll bars to move across the World. All of the World can be used in your simulation, but only 1/9th of it will appear in the window at any given time.

## IP Program Limitations

Although IP is a versatile program, there are some limitations that can affect simulation speed and design. These limitations were found through experience in using the program on several computers, and were not indicated in the Interactive Physics manual.

First, IP displays motion of bodies on the screen by calculating the position of the bodies after every preset interval of time. This interval is called the integration step, and represents the amount of time that passes before IP recalculates all output to the screen. Integration step is also closely related to the number of frames per second displayed on the screen. While decreasing the integration step to small values (for example, 0.075 s) seems preferable because smaller integration steps allow for more accurate calculations, smaller integration steps mean longer calculation times and slower motion of bodies on the screen. To gain run speed, a bit of accuracy must be sacrificed, and vice versa. Under the World header, click on Accuracy, and a new window will appear. Click on the Advanced Properties button, and you will find a text field where you can enter your preferred integration time.

Second, IP cannot handle masses larger than 1 e27 kg or smaller than 1 e-34 kg.

Third, IP cannot process more than 5 charged bodies when Electrostatics is turned on.

## Sample Simulations

### The Terminator

The goal of this experiment is to give the hanging block a certain velocity so that it will land on top of a moving cockroach. The cockroach appears from the bottom left corner of the screen, moving frictionlessly and at constant velocity to the right. By selecting different velocities for the hanging block, the block can be made to collide with the cockroach as it falls. A question to ask: how does changing the mass of the hanging block affect the time it takes for the block to fall to the ground (and not hitting the cockroach)? Then, when the user finds a mass that allows the block to fall on the cockroach, what is special about the time it takes for the block to fall on the cockroach and the time it takes for the cockroach to move directly beneath the falling block?

### The Overtaker

An orange block, starting from rest at the Start line, travels toward the right at constant velocity over a distance of __ m. A yellow block, also starting from rest, can move either backward or forward with different accelerations and velocities controlled by the user. Both blocks are of equal mass and travel frictionlessly. The goals of this simulation are to explore how changing the acceleration and/or velocity of one object with respect to another one moving at constant velocity affects the distance the object travels, and to find a combination of velocity and acceleration that will allow the yellow block to reach the Finish line at the same time the orange block does. Graphs to the right of the screen display the x-position of both blocks over time. From these graphs, users can determine whether the inputted velocity and acceleration combination allows both the yellow and orange block to reach the Finish line at the same time by finding the intersection of the two lines on the position vs. time graph. If the intersection occurs at __ m, then the velocity and acceleration combination is correct. The use of this simulation can be extended by asking the user to find different velocity and acceleration combinations, and determine how these combinations are related. For example, the yellow block will need a smaller initial velocity if it is given a greater acceleration. Other questions to ask: what happens when the ball is given a positive (toward the Finish line) acceleration and a negative initial velocity? How are the velocity/acceleration combinations that allow both blocks to simultaneously meet at the Finish line related in this case?

**Trajectory**

A ball is launched at different angles at a field with four holes. The four holes are located at roughly the same distance apart from each other. The goals of this simulation are to a) show that there are a pair of launch angles x and 90-x that will allow the ball to neatly fall through each hole, b) to interpret the y-velocity graph at the top right to determine whether the ball fell neatly through a hole, and c) to show that a 45 degree launch provides the furthest displacement.

**Circular Motion**

A ball swings around a pivot in a vertical circle, shown by the dotted line. While it moves at adjustable velocities, acceleration vectors swing out to show the effect of gravitational acceleration. The amount of acceleration at different times can be read from the bar graph at the top right of the screen, and directly as outputted values at the middle right of the screen. This simulation allows the user to explore how the acceleration of the ball differs at various positions on the vertical circle.

**Sun, Earth, and Mars**

This simulation allows the user to view the motion of the Sun, Earth, and Mars from either of the three frames of reference. If the Earth is chosen as the reference frame, the retrograde motion of Mars and the Sun can be seen as they travel in looped orbits around the Earth, showing the view ancient astronomers had of the geocentric solar system. Tracking can be toggled on and off at the bottom of the screen to allow full orbits and retrograde motion to be seen.

**Planetary System**

The Sun and the planets Mercury through Saturn have been scaled down in orbital period, mass, and the gravitational constant G to provide a scaled version of the solar system as known in Galileo's time. This planetary system demonstrates how angular momentum is conserved through longer orbital periods at larger distances from the Sun. To see the orbits more clearly, click the Tracking button at the bottom of the screen, and choose Tracking Off to turn off this option.