



Conference May 2004

Introduction to Creating Simulations

using

**Interactive Physics
2000**

Support

- created by the world's leader in physics software simulation
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MSC SOFTWARE
SIMULATING REALITY

The advertisement for Interactive Physics 2000 features a blue background with a faint image of a car wheel and a speedometer. The speedometer shows a needle pointing to 4.50. The text 'Interactive Physics 2000' is prominently displayed in a large, bold, yellow font. Below this, the word 'Support' is written in a smaller font, followed by two bullet points. The website address 'www.interactivephysics.com' is provided in blue text. At the bottom left, there is a copyright notice for MSC Software Corporation. At the bottom right, the MSC Software logo is shown, with the tagline 'SIMULATING REALITY'.

by Roland Meisel and Paul Passafiume 2004/05/20

Introduction:

Interactive Physics™ 2000 is a powerful software package that allows teachers and students to simulate physical systems of many kinds. You can construct objects of various shapes, and adjust properties such as mass, coefficient of friction, initial velocity, material, elasticity, and charge. You can adjust the geometry of an object after it is created, as well as its appearance. You can measure position, velocity, acceleration, momentum, angular momentum, force, torque, gravitational force, electric force, air resistance, and kinetic energy. You can also define other quantities. You can control quantities in real time using sliders. You can write scripts that control a simulation. As you can see, Interactive Physics™ 2000 is not a package that can be completely mastered in an introductory session. However, this tutorial will give you a solid basis for a continued exploration of the breadth and power of Interactive Physics™ 2000.

Tutorial:

This tutorial is designed as a self-paced, hands-on introduction to Interactive Physics™ 2000. The examples are selected from the Ontario secondary school physics curriculum, but are applicable to any introductory physics course. The tutorial assumes no previous experience with Interactive Physics™ 2000. However, should you already be familiar with certain features of the program, you may safely skip ahead until you find a topic of interest.

Further Information:

You can find further information, links to web sites of interest, and packaged simulations, many of which are freeware, at the following sites:

<http://www.interactivephysics.com/>

<http://ist-socrates.berkeley.edu:7521/projects/IPPS/Contents.html>

<http://www.scienceman.com/>

<http://www.enc.org/resources/records/full/0,1240,004489,00.shtm>

Interactive Physics 2004

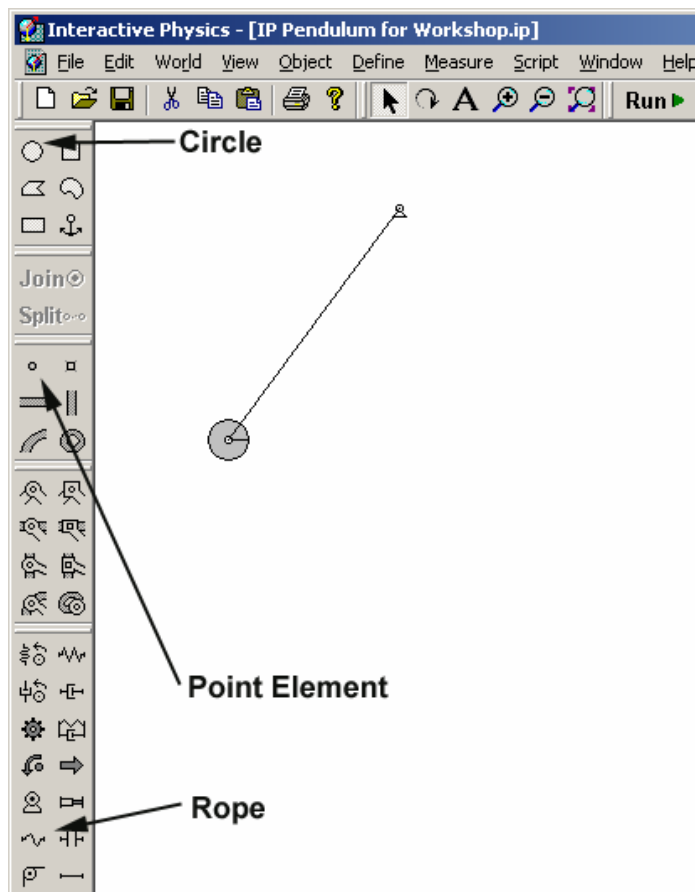
As of this writing, a new version, Interactive Physics 2004, has been released. A demonstration copy may be downloaded from

<http://www.interactivephysics.com/>

Getting Into the Swing:

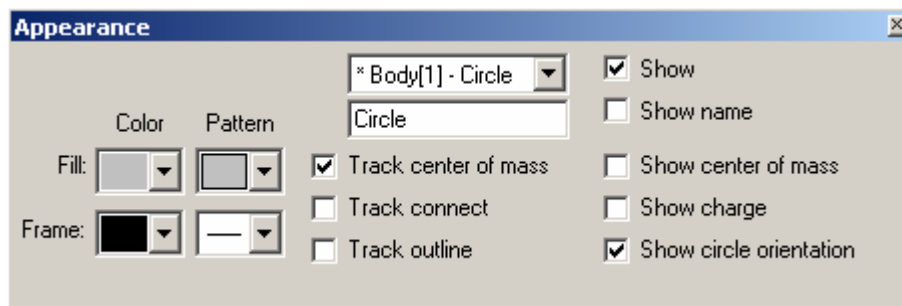
You will use the familiar pendulum as a vehicle for exploring the basics of IP 2000. Launch the program. A blank workspace will appear. To make a pendulum, you will need a fixed point, a bob, and a string. Start with the bob. Select the Circle tool. Move to a convenient spot in the workspace, click and hold the left mouse button, and drag the mouse to form a circle of appropriate size. Release the mouse button. Select the Point Element. Move to a suitable location, and click the left mouse button. Select the Rope. Move the mouse to the centre of the circle. Click and drag the rope to the point. Release the mouse button. Your workspace will look much like the screen shot at the right.

This is a good place to save your simulation. NOTE: If you are using the demo version of IP 2000, the Save function is disabled. Use the File pull-down menu, select Save As, navigate to a suitable directory, give your simulation a suitable name, and click Save.



Click on the Run button. Your pendulum will swing. When you get tired of watching it go back and forth, click on the Stop button, and then the Reset button. This will return you to the initial conditions.

IP 2000 can track objects as they move. Pull down the World menu and select Tracking, then Every frame. Run the simulation. Note that both the bob and the rope are tracked. Stop and Reset. You can erase the track by holding down the CTRL key and pressing the e key.



Pull down the Window menu, and select Appearance. Click on the circle to select it. Turn off Track outline by clicking on the box. Turn on Track center of mass, as shown in the screen shot. Click on the rope, and turn off Track. Run the simulation again. Notice that

this time only the centre of mass of the bob is being tracked. Turn off tracking from the World menu.

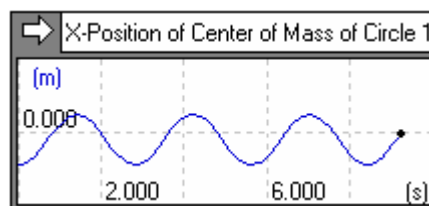
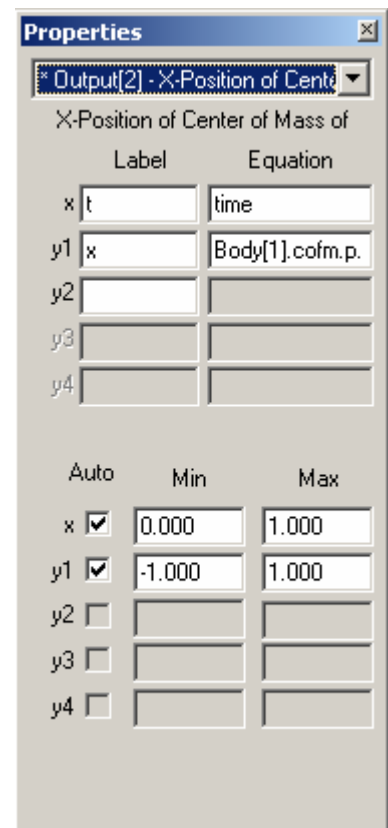
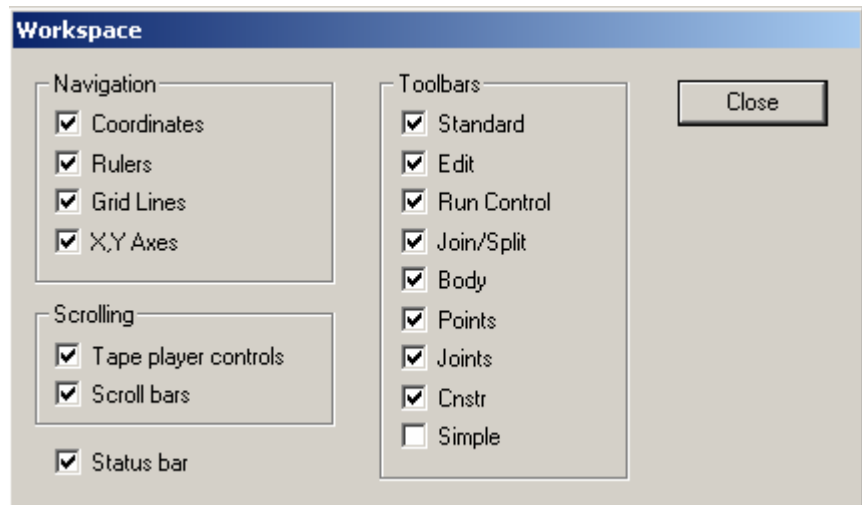
Add a coordinate system to your model. Select the View menu, then Workspace. Add Rulers, Grid lines, and X,Y Axes, as shown.

Move the origin to the middles of the workspace by adjusting the vertical and horizontal sliders. Move your bob to (0, -1), and move the fixed point to (0, 4). You may need to adjust the rope. You can also delete the rope, and redraw it.

Now you will make some measurements. Select the circle. From the Measure menu, select Centre of Mass Position, and then X-Graph. Run the simulation. Note that the graph is generated as the pendulum swings. The scales on the graph are adjusted automatically to keep the position and time on the graph. You can also adjust these properties.

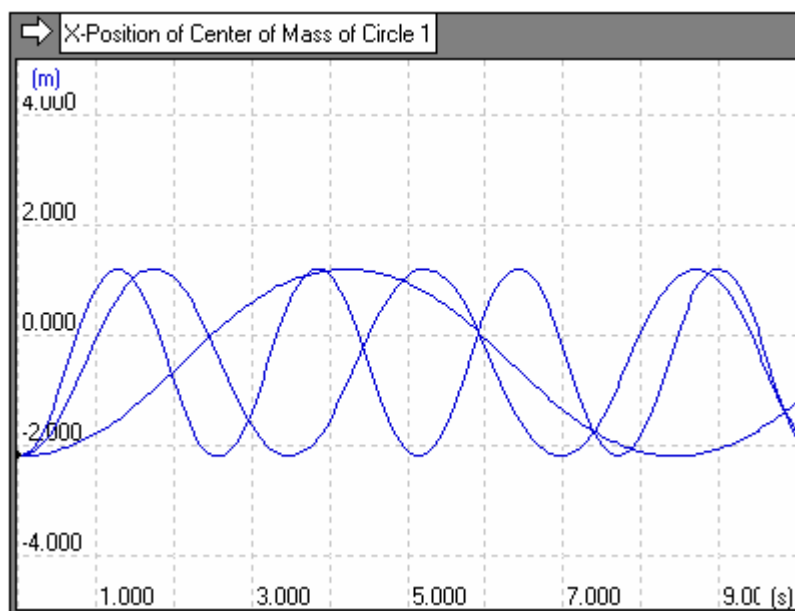
From the Window menu, select Properties. Select the graph. The Auto feature enables the domain and range to adjust automatically if the body being measured moves outside the domain and range. If you turn the Auto feature off, the domain and range will remain fixed.

Run the simulation through several cycles. You will generate a graph similar to the one shown.



You can adjust the size of the graph by selecting it, and then dragging one of the black squares that appear in the corners. Adjust the graph to a convenient size.

Now you will use IP 2000 to simulate an experiment which would be difficult to perform in the average classroom. You will try out the pendulum with varying gravitational accelerations. First, pull down the World menu and select Retain Meter Values. This will set IP 2000 to display all runs on the same graph. Run the simulation for several cycles. Select World, then Gravity. Reset the gravitational acceleration to the value on the moon. Run the simulation. Then reset gravity to a value approximately double that at the Earth's surface. Run the simulation. When finished, you will have a graph similar to that shown. You can use the graph to construct a table of period versus gravitational acceleration, and then fit an appropriate curve. It would be wise to obtain a few more data points before doing this.



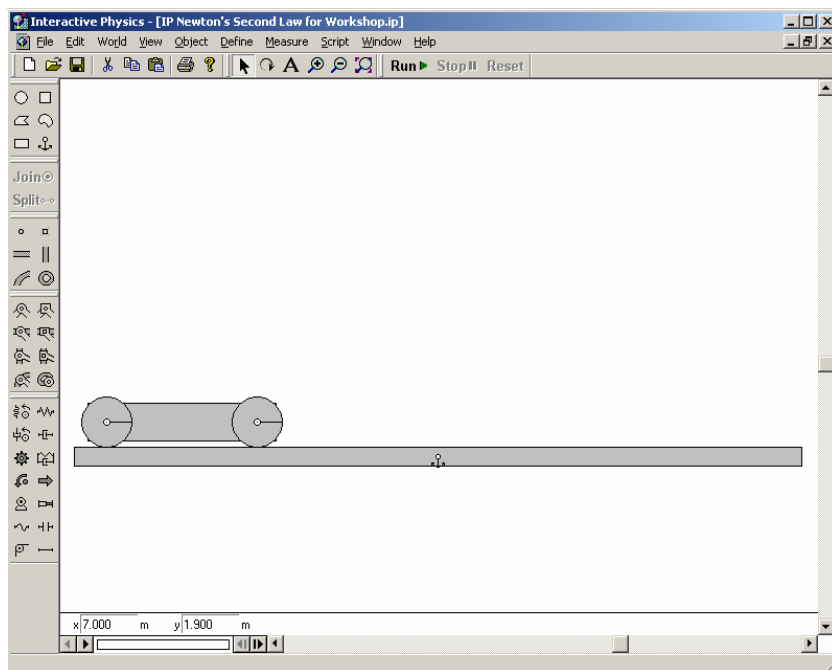
You can Undo any operation by selecting Undo from the Edit menu, or by using the keyboard shortcut CTRL-Z. This is useful if you encounter unexpected results, and would like to retreat. You can usually retreat several steps in the simulation.

You can investigate other factors that might affect the period of a pendulum, such as the mass of the bob. Select Erase Meter Values from the World menu. Reset gravity to Earth normal. Run the simulation. Select the circle, and open the Properties box from the Window menu. Reset the mass of the bob to double its value, and run the simulation. Repeat for half the normal value of the mass. What effect does the mass of the bob have on the period of the pendulum?

Reset the original mass of the bob, and erase the meter values. Select Air Resistance from the World menu. Select Standard, and run the simulation. Increase the air resistance, and run it again. Try to find the minimum value of "k" that results in critical damping, i.e., no oscillation.

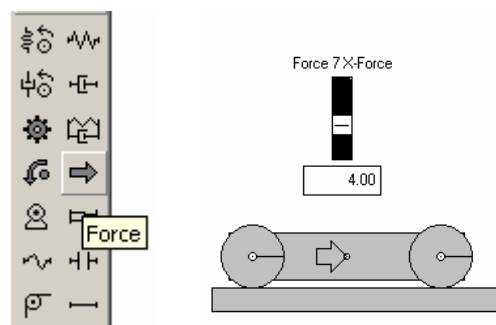
Rolling Right Along:

Your second project will be a simulation of the classic Newton's Second Law experiment. Close the current simulation from the File menu, and then open a New simulation. Select the Rectangle, and construct a track across the middle of the workspace. Just for fun, run the simulation. Notice that gravity affects your track. Reset the simulation, select the Anchor, and attach it to the centre of mass of your rectangle track. This will stop your track from falling.



You will now make a "cart". Start with a rectangle. Then create a circle for one of the wheels. Select the circle, select Copy and then Paste from the Edit menu. Position the body of the cart above the track, and the circles in position as wheels. Select the Pin Joint. Place a Pin Joint in the middle of each wheel. When you are finished, your workspace will look much like the screen shot.

Now you will add a force controlled by a slider. Select the Force. Click on the centre of mass of the cart, and drag the force to form an arrow. Select the Force arrow. Open the Properties box from the Window menu. Change F_y to zero, if it is not zero already.



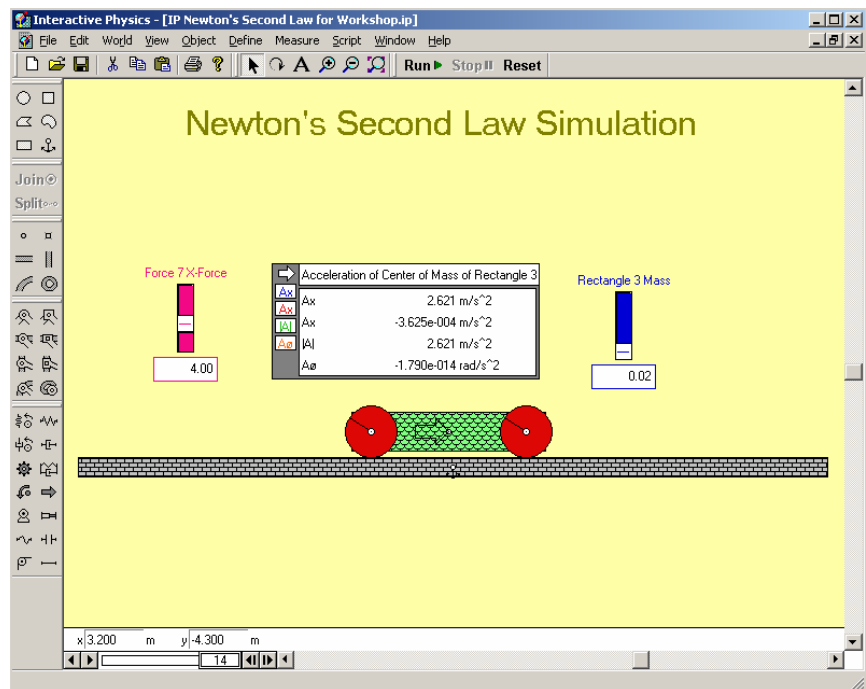
From the Define menu, select New Control, then X Force. A slider will appear, which will allow you to control the force exerted on the cart. Select the slider. Change the minimum value to zero and the maximum to 10 N. Set the slider at 5 N, and run the simulation. Reset, and try other values, including zero. Note: You can also type a value directly in the box below the slider.

Now you will measure the acceleration of the centre of mass of the cart. Select the cart. Select Center of Mass Acceleration from the Measure menu, and select All. A table will appear. Run the simulation. Note that the horizontal acceleration is measured. Due to the finite size of the intervals used by IP 2000, a small vertical acceleration is also shown.

Acceleration of Center of Mass of Rectangle 3	
A_x	1.209 m/s ²
A_y	-7.285e-005 m/s ²
$ A $	1.209 m/s ²
A_θ	0.000 rad/s ²

You can use this simulation to collect values of force versus acceleration. You can also leave the force constant, and create a slider to change the mass of the cart. Select the cart. Pull down the Define menu, select New Control, and then Mass. Select the new Mass control, open the Properties box if necessary, and adjust the minimum to 0.02 kg and the maximum to 5.0 kg. You can set the minimum to zero, if you like, just to see what will happen. This now allows you to simulate the standard Newton's Second Law experiment, a staple feature of all introductory physics courses. Note: It is not suggested that this be used in place of a hands-on experiment involving real carts and real forces. However, the simulation can be used as a review, or as a summative assessment tool.

Add a little colour to your simulation. Select one of the wheels of the cart, and open the Appearance box under the Window menu. Change the fill colour and pattern to something that reflects your excellent taste. Do the same with the other wheel, the body of the cart, and the track. You can also adjust the colours of the sliders. Finally, you can adjust the background colour using the appropriate selection from the View menu. You can even define your own custom colour.



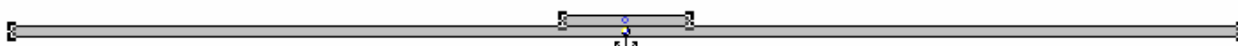
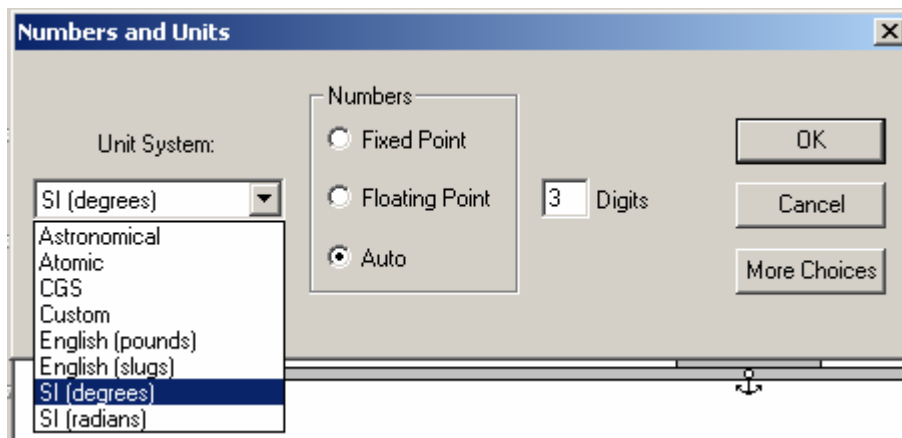
Finally, add some text. Select the text tool in the toolbar. Click and drag to open a text box in the desired location. Type in the desired text. To change the font and style, pull down the Object menu, and select Font. Set the parameters to whatever you want. When you are finished, your simulation will look much more colourful.

Sliding Down the Hill:

IP 2000 includes friction in its calculations. To see how this works, you will simulate an object sliding down an inclined plane.

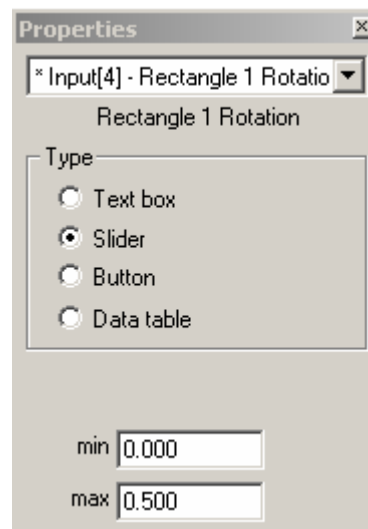
You may work in either degrees or radians. To see the unit system in use, pull down the View menu, and select Numbers and Units. SI(degrees) will be used in this tutorial.

Open a new workspace, if necessary, and use the Rectangle to draw a long, thin rectangle across the middle of the workspace to act as the inclined plane. Add an Anchor to its centre of mass. Construct a smaller thin rectangle over the centre of the inclined plane, such that their centres of mass are vertically aligned, as shown in the screen shot.



Set up a slider to control the incline angle of the plane. Select the inclined plane. Select New Control from the Define menu, and then select Initial Rotation. A slider will appear. Select the slider, and open the Properties box, if necessary. Change the minimum value to zero, and the maximum to 30° .

Note the name of the slider. It will likely be Input[4]. Select the sliding rectangle. Change the initial angle θ to match the slider, i.e., Input[4] in this example. The slider will now control the angle of the inclined plane as well as the sliding rectangle. Run the simulation, move the slider, and note the changes in the inclined plane and the sliding block.

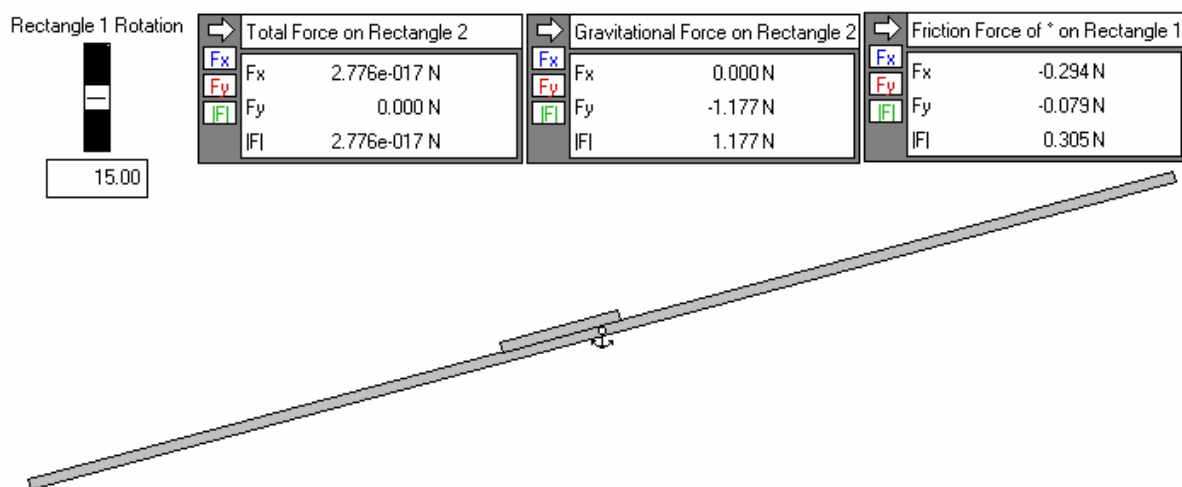


Run the simulation, and increase the angle of the inclined plane to 5° . Note that the block does not slide down the plane, since the force of friction between the block and the plane is larger than the component of the gravitational force acting down the plane. Increase the angle of the plane in increments of 5° until the block slides. Adjust the angle until you find the angle at which the block just begins to slide.

You can also reset the incline of the plane on the fly. Reset the simulation with an angle of zero. Run the simulation. *Slowly* increase the incline angle using the slider until the

block begins to slide down the plane, and then back off on the angle. Try to find the critical angle at which the block just begins to slide.

Select the block. Pull down the Measure menu, and select Total Force. Pull down the Measure menu and select Gravity Force. Use the Shift key to select the ramp while keeping the block selected. Pull down the Measure menu, and select Friction Force. Run the simulation, and find the slip angle as in the previous paragraph. Stop the simulation. From the analysis of a block sliding down a plane, you know that, at this critical slip angle, the component of gravity acting down the plane equals the frictional force. See if the simulation bears this out.



In the screen shot, $F_g = 1.177 \text{ N}$, $F_{fr} = 0.305 \text{ N}$, and $\theta = 15^\circ$. According to theory, the component of F_g acting down the plane is $F_g \sin \theta = 1.177 \sin 15^\circ = 0.305 \text{ N}$, as expected.

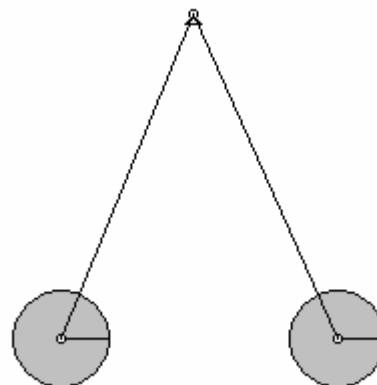
You can investigate the effect of increasing the coefficient of friction. Select the block. Hold down the Shift key to also select the ramp. If necessary, open the Properties box from the Window menu. Set the static and kinetic coefficients of friction to 0.500. Note: If two objects are in contact, and have different coefficients of friction, then IP 2000 will use the lower of the two values to calculate the friction.

Run the simulation and find the critical slip angle. Note that it is now much higher. An interesting extension is to adjust the coefficient of friction such that the force of friction exceeds the gravitational force on the block, and then Run the simulation.

Getting a Charge out of This:

IP 2000 allows you to specify a charge for objects. You will investigate this using two spheres suspended by strings from a common point. Pull down the World menu, and select Electrostatics... . Select the ON button, if it is not already selected.

Select the Point Element, and create a point. Select the Circle, and create a circle below and to the left of your point. Copy the circle, and paste it to a corresponding location below and to the right of your point. Select the Rope. Join each of the circles to the point. When you are finished, your workspace should look much like the screen shot.



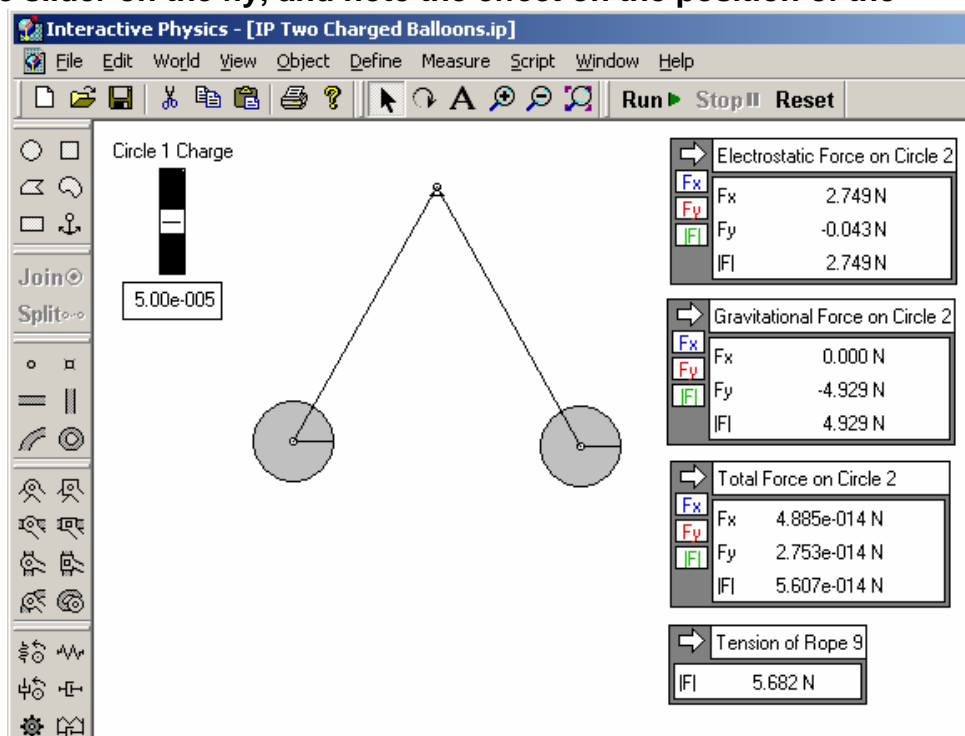
Select the left circle, and select New Control from the Define menu. Select Charge. Select the new control, and note its name. It should be something like Input[10]. Change the minimum value to zero, and the maximum value to 0.0001 C.

Select the right circle, and open the Properties box from the Window menu, if necessary. Change the charge property to the same input as the left circle.

Set the slider near the middle of its range, and Run the simulation. Note that the circles bob up and down. To dampen this motion, select Air Resistance from the World menu, and set it to standard. You may also need to change 'k' to something less than one. Run the simulation. Adjust the slider on the fly, and note the effect on the position of the circles.

Now add some measurements. Select the right circle. Use the Measure menu to create meters for Electrostatic Force, Gravity Force, and Total Force. Select the right rope, and create a meter to measure the Tension.

Run the simulation, and allow the system to come to rest. According to the analysis for this

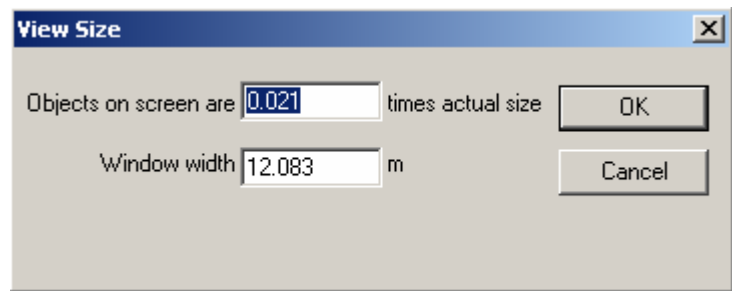


experiment, the tension in the rope, the gravitational force, and the electrostatic force should satisfy a Pythagorean relationship. Check if they do.

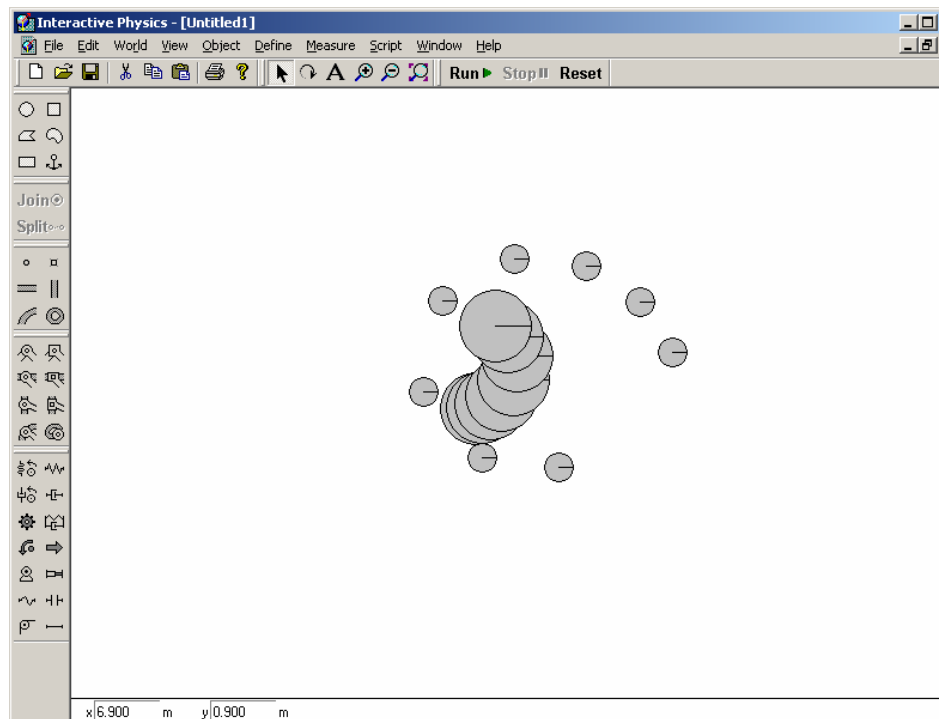
Moving Towards the Centre:

IP 2000 allows you to represent gravity as a central force. This is useful for simulating the movements of heavenly bodies, escape velocity, and other phenomena that depend on the inverse-square nature of Newton's law

of Universal Gravitation. You can change the scale of the workspace window in IP 2000 to reflect real distances, masses, and other parameters. You can do this by adjusting the View Size under the View menu, and object properties using the Properties box. For example, you can set the window to a real Earth-moon system, with distances and masses equivalent to the real Earth and moon. However, that means that you would have to wait 29+ days to see one orbit of the moon around the Earth. Although the View Size adjustment can be useful for making smaller scale simulations more realistic, astronomical phenomena are better simulated in a way that speeds up their apparent motions.



Set up the Earth-moon system using two circles. Change the gravitational model to Planetary in the Gravity submenu under the World menu. Give the moon a suitable velocity, and Run the simulation. Unless you are very lucky, the moon will not follow a circular or even apparently elliptical orbit. It is necessary to scale the gravitational constant to match the scale of the workspace. With a workspace width of about 12 m, a



gravitational constant of about $5 \text{ Nm}^2/\text{kg}^2$, and an initial moon velocity perpendicular to the radius of orbit, you will get something like the screen shot shown.

Add a slider to control the initial velocity of the moon. Using the slider, try for a circular orbit.

Notice that the Earth does not sit still. The Earth and the moon rotate around their common centre of mass. You can add a slider to control the mass of the Earth. Try orbits with a massive Earth, with an Earth mass equal to the moon's mass, and several in between, for a given initial velocity. Then, try a very light moon, and simulate the orbit of a comet. You might even add in a third or fourth body. The possibilities are endless. Investigations of Lagrangian or Trojan points can be simulated.

You can also simulate the decaying orbit of a satellite by introducing air resistance. Track the object's path to view its orbital decay.

The Monkey Bites the Dust:

One of the most popular physics problems is the problem of the Monkey and the Hunter. A monkey is hanging from a branch on a tree. The hunter fires his gun, knowing that the monkey will let go of the branch and fall freely just as the bullet leaves the barrel. How should the hunter aim in order to hit the monkey?

Use the Circle to create a "bullet". Select the bullet, and open the Properties box. Set the x and y coordinates to zero. This will ensure that the bullet begins at the origin. Use the workspace sliders to move the bullet near the lower left hand corner of the workspace. Use the Circle to create a "monkey" in the upper right hand corner of the workspace.

You could use sliders to control V_x and V_y for the bullet, but it is more realistic to use sliders to control the speed $|V|$ and the angle θ at which the bullet is fired. To do this, create two generic sliders using New Control under the Define menu. Select the first slider, open the Appearance box from the Window menu, and rename it Speed. Repeat this procedure to rename the second slider Angle. Also take note of their computational names, which will be something like Input[3] and Input[4]. Use the Properties box to change the limits on the Speed slider to cover the range 0 m/s to 20 m/s, and those on the Angle slider to cover 0° to 90° .

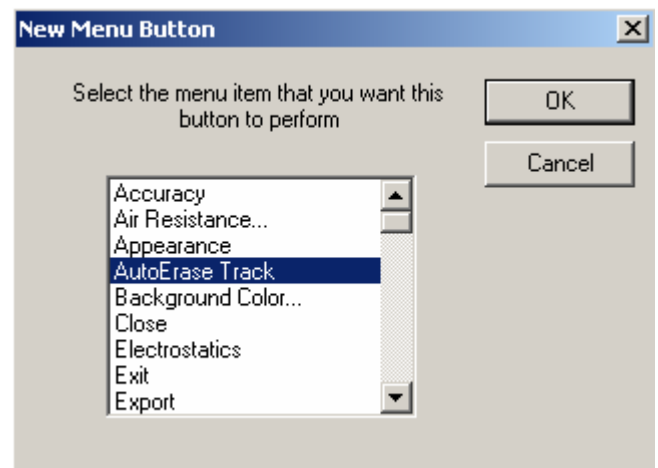
Select the bullet, and open the Properties box, if necessary. Type in the following formulas:

$$V_x: \text{Input}[3] \cdot \cos(\text{Input}[4] \cdot 3.14159/180)$$

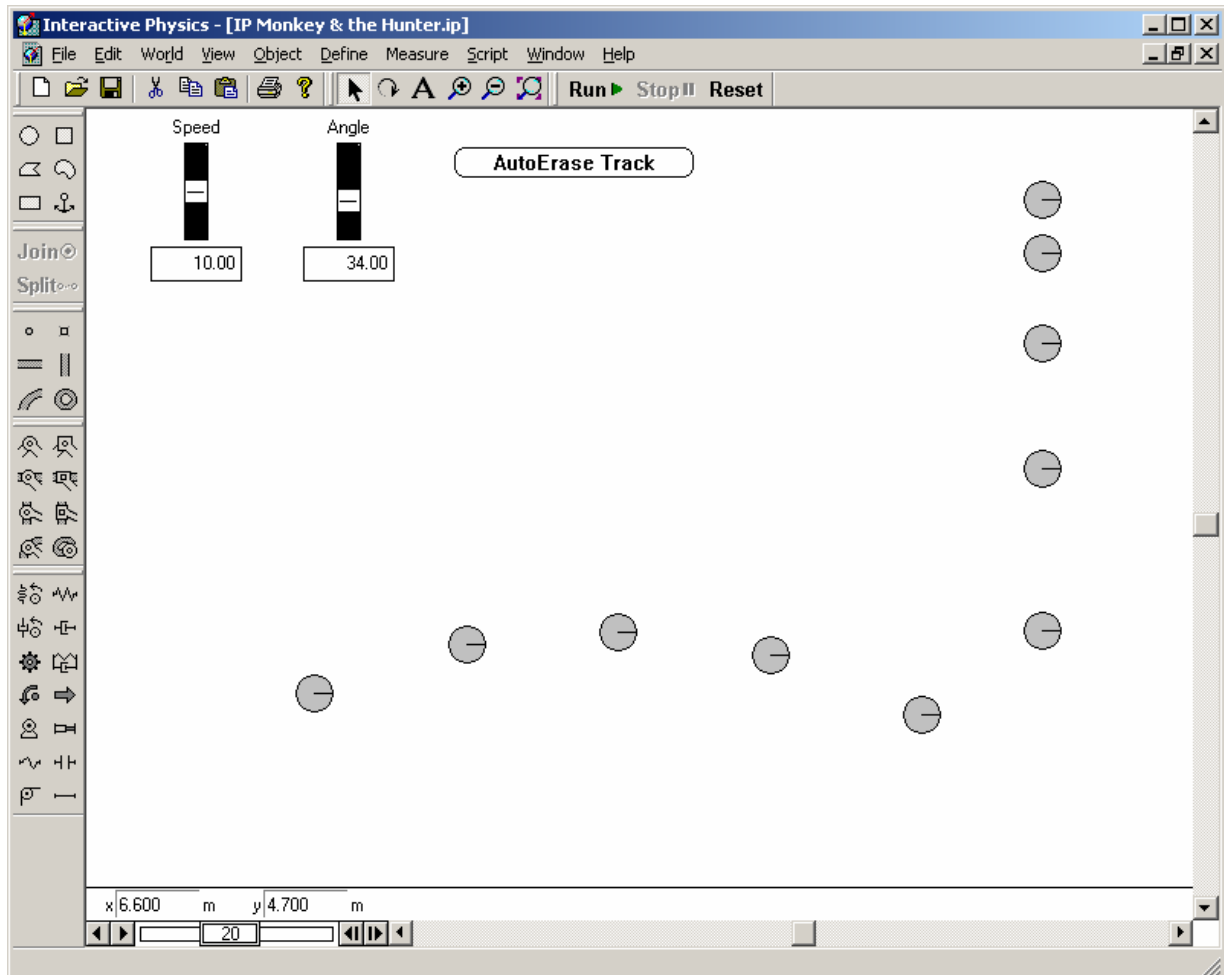
$$V_y: \text{Input}[3] \cdot \sin(\text{Input}[4] \cdot 3.14159/180)$$

Note: Although you are setting the slider Angle in degrees, IP 2000 performs internal calculations in radians. Therefore, the angle must be converted to radians in the formula.

This might be a good place learn how to insert a button. Select New Button from the Define



menu, and then Menu Button. Select Autoerase Track. You can now erase tracks by pushing this button.



Set the speed to 10 m/s, and pick an angle. Turn on tracking, and Run the simulation. If you didn't hit the monkey, pick another angle, and run the simulation. Once you find an angle that works, note it down.

You can select another speed, and find the angle that works with that speed. Note any patterns that occur.

Of course, you can cheat, and do the analysis first. In that case, you know that:

$\tan \theta = \frac{y}{x}$, where x and y are the coordinates of the monkey. Select the monkey, note its coordinates, and check against the angle that you found empirically.

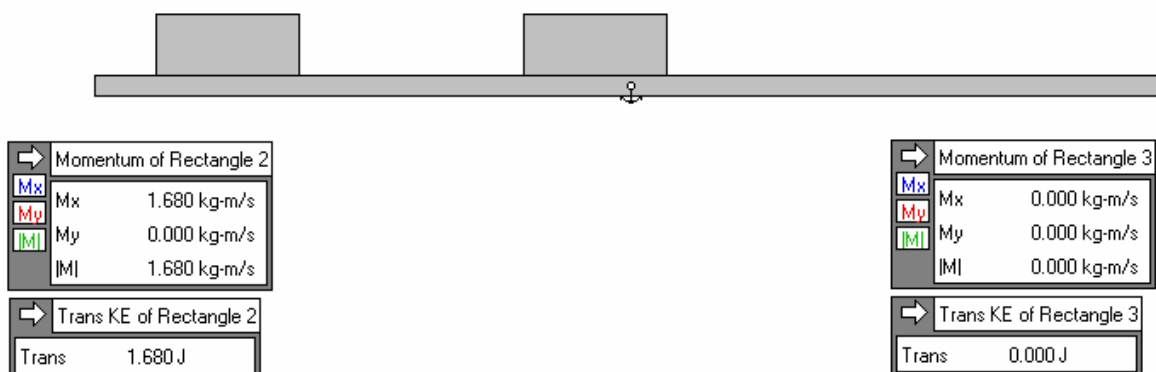
A variation on this is to change the position of the monkey, rather than the speed of the bullet, and see what happens to the angle.

Finally, you can make a prediction about the effect of air resistance. Check your prediction by adding in air resistance from the World menu. You can even change the amount of air resistance, and see what effect that has.

Momentous and Energetic Thinking

To finish off this introductory tutorial, you will simulate a one-dimensional elastic collision to investigate measurement of momentum, kinetic energy, and the export of data from IP 2000.

Create a horizontal track, and anchor it to the background. Create a rectangular object on the left end of the track. Copy the object, and place the copy near the middle of the track. Select the left object, and create a meter to measure Momentum from the Measure menu. Do the same for the other object. Select the left object, and create a meter to measure translational Kinetic Energy. Do the same for the other object. When you are finished, your workspace will look much like that shown:



From the Window menu, open the Properties window. Select the left object. Set the coefficients of static and kinetic friction to zero. Set the elasticity to 1, to simulate a perfectly elastic collision. Repeat for the other object, and the track.

Run the simulation. Note the values of the momenta and kinetic energies as the collisions occurs.

You can export data from IP2000 in two ways. Pull down the File menu, and select Export. A dialog box will appear. Pull down the Export Type menu. Note that you have a choice of exporting raw meter data, or video for Windows data. The former creates a tab-delimited text file, with the extension *.dta, which can be read into a word processor, spreadsheet, or many other programs. Once imported into another program, it can be manipulated into any kind of desired, graphs, tables, images, or other formats.

An import of the raw data from the collision experiment into Microsoft® Excel is shown in this partial screen shot:

	A	B	C	D	E	F	G	H
1	Toggles grid snap on/offUntitled1							
2	Grid Snap							
3	Momentum of Rectangle 2				Momentum of Rectangle 3			
4	t	Mx	My	M	t	Mx	My	M
5	0	1.68	0	1.68	0	0	0	0
6	0.05	1.68	-0.03	1.68	0.05	0	-0.03	0.03
7	0.1	1.68	-0.031	1.68	0.1	0	-0.031	0.031
8	0.15	1.68	-0.022	1.68	0.15	0	-0.022	0.022
9	0.2	1.68	-0.012	1.68	0.2	0	-0.012	0.012
10	0.25	1.68	-0.005	1.68	0.25	0	-0.005	0.005

The second export option creates a standard *.avi file of the experiment, which can be played back using Windows Media Player, or other multimedia software. A user does not need to own IP2000 in order to view these *.avi files, making them useful for posting on a web site for student access. You can also convert the *.avi files to Shockwave *.swf files, which allow you to use streaming video. You can achieve this using a utility such as Camtasia, available at

<http://www.techsmith.com/products/studio/default.asp>

This is a simple collision, involving two bodies of the same mass, a perfectly elastic collision, and no friction of any kind. You can introduce sliders to control the masses of the two objects. You can introduce sliders to control the coefficients of friction. You can introduce sliders to control the elasticities of the two bodies. Use what you have learned to extend this simulation to more interesting cases.

The Next Steps:

Interactive Physics includes many "canned" simulations, conveniently organized into topics by folder. Select Open from the File menu, and navigate to the directory containing IP2000. Select the folder Physics Experiments, and browse through the collection of simulations included.

You can find an analysis, rating, and suggested uses for some of the experiments packaged with IP2000, prepared by Paul Passafiume, in Appendix A at the end of this tutorial.

There is a wealth of Interactive Physics support material available on the Internet. Type the keywords "interactive physics" into your favourite search engine, and you will find a plethora of sites, most with free downloads. To get you started, you can visit

<http://www.interactivephysics.com/>

<http://ist-socrates.berkeley.edu:7521/projects/IPPS/Contents.html>

<http://www.scienceman.com/>

<http://www.enc.org/resources/records/full/0,1240,004489,00.shtm>

You can often download a simulation that is close to what you are looking for, and then make adjustments to suit your own needs.

This completes your introductory tutorial. IP2000 has many more features for you to explore. This is only the beginning.

Analysis of IP Physics Experiments

by Paul Passafiume

Here is an overview of several canned IP scripts available as part of the IP2000 software package. These scripts can be found in the IP2000 folder that should be located on the C: drive following a standard install. The following path should assist you in locating these files: C:\Program Files\IP2000\PhysicsExperiments.

The *folder* column below indicates the folder in which the simulation may be found. The *program* column indicates the program to which the script may apply (10 = grade 10; 3U = grade 11 physics; 4U = grade 12 physics).

Note: 4 Star Rating given below is based on applicability to the high school curriculum.

Folder	Program	Overview of Folder Contents	4 Star Rating
Advanced	Other	Simulations of gears, machines, and statics	☆☆
Cams	Other	1 simulation	☆
Collisions	4U	13 simulations	☆☆☆☆
Electrostatics	4U	4 simulations	☆☆☆
Equilibrium	4U	4 simulations	☆☆
Evaporation/Condensation	Other	3 simulations	☆
External Data	4U	Shows how exp. data can be imported to IP for simulation purposes (1 simulation)	☆
Friction	4U	2 simulations	☆
Fun Stuff	Other	4 simulations	☆
Kinematics	10/3U/4U	2 simulations	☆☆☆
Kinetic Theory of Gas	Other	3 simulations	☆
Magnetics	4U	3 simulations	☆☆☆
Math	Other	1 simulation	0
Miscellaneous	3U/4U	15 simulations	☆☆
Momentum	4U	4 simulations	☆☆
Motion in One Dimension	10/3U	2 simulations	☆☆
Motion in Two Dimensions	4U	1 Simulation	☆
Newton's Laws	4U	2 simulations	☆☆
Oscillations	4U	9 simulations	☆☆☆
Particle Dynamics	3U/4U	3 simulations	☆☆
Projectiles and Rockets	4U	4 simulations	☆☆
Pulley Systems	4U	2 simulations	☆
Rotational Dynamics	4U/Other	9 simulations	☆☆☆
Sound	3U	1 simulation	☆
Waves	3U	1 simulation	☆☆☆
Work and Energy	3U/4U	3 simulations	☆☆☆☆