

## Interactive Physics Manual

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### What is Interactive Physics?

Interactive Physics is a simulation program that allows for exploration and analysis of “physical” situations. The student may model the physical world on any scale, from atomic to astronomical, and even experiment with physical situations not found in our universe.

The program opens up to an “infinite” world-space (limited primarily by available memory), and using relatively simple paint-and-draw techniques a laboratory may be constructed. The default settings of the program allow for nearly immediate manipulation of the “real-life” world of tables, balls, springs and pulleys. A bit of work will allow analysis of the orbit of Jupiter’s moons. The truly motivated user may create an astronomical situation where the force of gravity repels, rather than attracts massive bodies.

The Interactive Physics world has two levels: the Physical level and the Interface level. The Physical level is where you will put the Mass Objects; figures drawn to represent physical objects such as tables and balls; and Constraints, such as springs, joints, and pulleys. The Interface level allows you to monitor the Physical level with meters and controls.

This manual serves as an introduction to the capabilities of the Interactive Physics program. You may want to read through it before using the software, and refer back to it as needed. If you find something missing, there is an excellent **Help** section within the program, and as a last resort your instructor has an official manual.

Have Fun and Good Luck!

## Mass Objects

### Drawing Mass Objects

Mass objects are geometric shapes that have a number of parameters defining their behavior. In the Interactive Physics simulation program, mass objects are created much in the same way as in a draw or paint program.

### Anchoring Mass Objects

The Anchor tool limits an object’s motion in the environment. To use: Select the Anchor tool then click inside the mass object. To remove the Anchor, repeat this process.



### Mass Properties

Each mass object in the environment behaves according to its own set of properties. Mass properties are changed using the Properties utility window. Double-clicking on a mass object will bring up said window.

Holding down the shift key allows you to select numerous objects at once. Double-clicking on one of the objects (with the shift key held down) will bring up a Properties utility window. The pop-up menu at the top of the utility window is labeled **mixed selection**. This allows you to change properties for these mass objects in one fell swoop (ex. turn all objects’ material from *standard* to *wood*). You may then change properties for individual objects simply by selecting the desired object from the pop-up menu.

You may change the following properties:

- Initial Position:  $x, y, \phi$
- Initial Velocity:  $V_x, V_y, V_\phi$
- Material
- Mass
- Static Friction
- Kinetic Friction
- Elasticity
- Charge
- Density
- Moment of Inertia

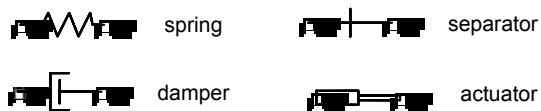
## Mass Appearance

You may change the appearance of a mass object by selecting that object, and choose **Appearance** from the **Window** menu. You may change an object's Pattern or Color. You may show an object's Name, Center of Mass, or Charge. You may Track on object's Center of Mass with a series of dots, Connect the dots with a solid line, and/or Track the Outline of the object.

## Constraints

There are four classes of constraints in Interactive Physics:

**Linear Constraints** have two endpoints and apply a force along the line connecting the two endpoints. They include **Springs, Dampers, Ropes, Rods, Separators, Actuators** and **Pulleys**.

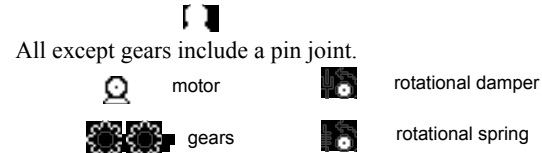


Forces produced by these constraints act equally and in opposite directions upon the mass objects at either endpoint.

To construct a linear constraint:

- Select the appropriate tool.
- Position the pointer in an empty area of the screen.
- Hold down the mouse button to create the first endpoint.
- Drag the mouse to the desired location of the second endpoint.
- Release the mouse button to create the second endpoint.

**Rotational Constraints** apply a twisting force (torque) between two objects. They include **Motors, Gears, Rotational Springs** and **Rotational Dampers**.



All except gears include a pin joint.

If a rotational constraint is drawn over a single mass object it will attach the mass object to the background beneath (behind) it. If a rotational constraint is drawn over two (overlapping) mass objects, it will attach to both objects.

To draw a rotational constraint:

- Select the tool or constraint you wish to draw.
- Position the pointer in over the mass(es) you wish, and click once.

**Joints** connect two mass objects and constrain their motion relative to one another. This includes **Pin Joints, Rigid Joints** and **Slot Joints**.

**Pin Joints** allow rotation while forcing points on two different mass objects to overlap. **Rigid Joints** lock two mass objects together.

To create a Pin or Rigid Joint:

- Align the mass objects that will be connected by the joint.
- Select the appropriate tool from the toolbar.
- Click the mouse to create the joint at the proper location.

In the case that more than two mass objects are overlapped, the joint will connect the top two mass objects.

**Forces and Torques:** Forces exert a linear force on a mass object at a single point. Torque exerts a twisting force on a mass object. Both are attached to the top-most mass object lying under the pointer at the time of the click.

To create a Force:

- Select the Force tool.
- Move the pointer to the location where the force is to act on the mass object.
- Drag the pointer to create a force object.

A Force can be edited by grabbing and dragging the arrow, or by using the Properties utility window. To move the force, click anywhere except on its endpoint, and drag to a new location.

To create a Torque:

- Select the Torque tool.
- Click on the mass object to which the torque is to be applied.
- Use the Properties utility window to set the magnitude of the torque.

## The Workspace

### Physical Objects and Interface Objects

The Interactive Physics simulation world has two layers: the Physical layer and the Interface, or User, layer. Physical objects, such as mass objects, points and constraints, exist on the Physical layer. The Interface layer contains user objects, such as meters, controls (sliders, text boxes, buttons), and pictures that are not attached to a physical object. The Interface layer is considered the “back” layer, and thus it is possible to position a physical object so that it obscures a user object.

### Viewing Options

Interactive Physics provides an infinite workspace that is larger than what can be displayed on screen at one time. The area occupied is called the world. What you see on the screen is only a small part of the world, called the view.

You may use the horizontal and vertical scroll bars to change your view to a different part of the world.

The zoom tools increase or decrease the magnification of the objects in the world.

## Workspace Tools and Controls

You may display the following tools and controls in your workspace:

- Toolbar
- Scroll Bars
- Coordinates and Grid Lines
- Tape Player
- Rulers
- Help Ribbon

These are accessed through the **Workspace** sub-menu of the **View** pull-down menu. To choose many options at once, choose **Workspace...**. A check mark next to the option name indicates the option is on.

The Help Ribbon is a band across the top of the workspace. It displays information about the tool or object that is currently under the pointer.

## Numbers and Units

The default of the program is to use the SI/metric system of units. However, you may change to English, astronomical, atomic, or CGS systems by choosing **Numbers and Units** from the **View** menu. Changing a system of units will affect all constants and formulas being used.

## Defining World Parameters

The Interactive Physics simulation world contains four environment parameters, accessed through the **World** menu:

- Gravity
- Air Resistance
- Electrostatics
- Force Field

The default setting for Gravity is “Earth = 9.8 m/s<sup>2</sup>”. The default for the other three is “None”.

## Meters

Measurements may be made of almost any physical property in your simulation. Once you have selected a particular object, look at the **Measure** pull-down menu to see what properties are available. For example, for a mass object you may measure position, velocity and acceleration of its center of mass.

All measurements are facilitated through the use of meters. You may choose from digital, graph or bar meters.

To create a meter:

- Select one mass object, point, or constraint object whose properties you wish to measure. To measure contact or friction force, you must select two mass objects before you create a meter.
- Choose the property you wish to measure from the **Measure** menu. A meter with a numerical display appears.
- To select the display mode (bar, graph, digital) for the meter, click on the down arrow button on the top left corner of the meter window.
- Click in the labeled buttons on the side of the meter to select which parameters to display.
- You can compare the results of multiple simulations by activating the **Retain Meter Values** option in the **World** menu.
- You may export retained meter values to another file by choosing **Export Data** from the **File** menu.

Specifics for Graph Meters:

- Changing the scale of a displayed graph:
  - Select the meter
  - Choose **Properties** from the **Window** menu.
  - Enter Min and Max values for the quantity you wish to scale
- Changing the color of lines on a graph
  - Select the meter.
  - Choose **Appearance** from the **Window** menu.
  - Select the desired color for each parameter by clicking in the color pop-up menu.

## Controls

Controls allow you to adjust simulation parameters before and while a simulation is running. A control may take the form of a slider (default), a text box, or a button.

To create a control:

- Select the object whose properties you want to change.
- Select the **New Control** menu item from the **Define** menu.
- Choose the desired property.
- Change the properties of the control by double clicking or selecting the control, and choosing **Properties** from the **Window** menu.

- You may change the title or color of a control by choosing **Appearance** from the **Window** menu.
- You can specify minimum and maximum values for the slider bars. “Number of snaps” indicates how many discrete values are available in the range of the slider.
- A text box allows you to enter a precise numerical input of the property value.
- Using a button, you can quickly select one of the two values specified in min and max boxes. A button can be a toggle switch or a press-and-hold button.

## Menu Buttons

Creating menu buttons allows you to place a shortcut to common commands directly on the workspace.

To create a menu button:

- On a Macintosh:
  - Choose **New Menu Button** from the **Define** menu.
  - Choose a command from an **Interactive Physics** menu.
- On Windows:
  - Choose **New Menu Button** from the **Define** menu.
  - Choose a command from the list.
  - Click OK.

## Vectors

The following properties can be represented graphically with vectors:

- Velocity
- Acceleration
- Total force
- Gravitational Force
- Electrostatic Force
- Air Force (Air Resistance)
- Force Field
- Contact Force
- Friction Force

Vectors that designate velocity and acceleration are always drawn pointing out from a mass object’s center of mass. Vectors displaying force quantities can be drawn either pointing from or toward a mass object’s center. Vectors that display forces encountered when objects contact one another can be displayed at the point of contact or at the mass center of each object.

To display vectors:

- Select one or more objects whose vectors you want to display graphically.
- Choose the type of vector to display from the **Vectors** sub-menu of the **Define** menu. The vectors will be displayed the next time the simulation is run.
- The length of a vector may be altered by choosing **Vector Lengths** from the **Define** menu. Use sliders or enter a number to adjust lengths for velocity, force and acceleration vectors.
- Vector color may be changed by choosing **Vector Display** from the **Vectors** menu.
- Choose inward or outward pointing vectors from the **Vector Display** menu.

## Running Simulations

### To Run a Simulation

Click **Run** in the toolbar or choose **Run** from the **World** menu.

### To Stop a Simulation

You can stop a simulation in various ways:

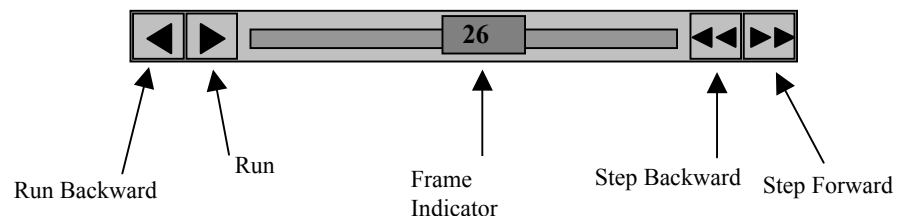
- Click **Stop** in the tool palette.
- Click the **Stop** icon on the tape player controls.
- Click anywhere in the window if the cursor appears as a stop sign.
- Choose **Stop** from the **World** menu.
- Click on a **Stop** menu button, if one exists.
- Automatically stop the simulation using the **Pause** feature.
- Macintosh only: Press **Command** and . (period) from the keyboard.

### Using Tape Player Controls

While playing a simulation, Interactive Physics also records it using a feature called the Tape Player. This allows you to play simulations backward or frame by frame, to skip frames of the simulation, and to play the simulation more quickly after all calculations have been completed.

To display the Tape Player controls:

- Choose **Workspace** from the **View** menu.
- Select the **Tape Player Controls** option
- Click **OK**



**Stepping Through Frames** may be done in two ways:

- Click on the forward or backward step in the tape player control to move one frame at a time.
- Press + to step forward and – to step backward.

To select the number of frames to skip with the step controls:

- Choose **Skip Frames** from the **World** menu.
- Choose one of the numbers from the sub menu.

To skip frames for faster animation:

- Choose **Skip Frames** from the **World** menu without letting go the mouse button.
- Choose the number of frames you wish to skip from the **Skip Frames** sub-menu.

### Playing a Simulation Backward

After you have run a simulation, you may play it backward by clicking the *play backward* control on the tape player. If you do not stop the simulation first, it will stop by itself when it reaches the first frame. As the animation runs backward, the frame indicator moves to the left while displaying the number of the current frame of animation.

### Speeding up Playback

When a simulation is run for the first time, Interactive Physics not only draws the animation on the screen, but also calculates the motion. For complicated simulations, this may slow down the animation the first time it is run. You can increase the playback speed by playing the recorded simulation again (calculations are stored and need not be recalculated) or by

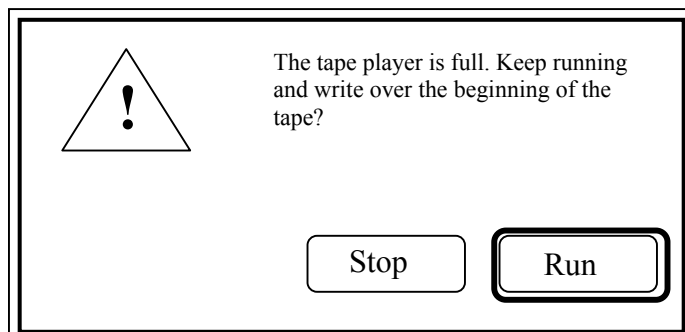
using the **Skip** feature. **Skipping** increases animation speed by removing frames from the calculation.

Other tips for making your simulation run faster:

- Use the **Fast** simulation method, and set the time step to the largest value that allows stable simulation and acceptable accuracy.
- Reduce the number of objects that are in contact. Make sure to use the **Do Not Collide** command (in the **Object** menu) with all groups of objects that do not need to collide.
- Set the frictional coefficients of contacting objects to 0.0 if friction is not needed in your simulation.
- Use rigid joints to build complex objects. Using two pin joints to lock objects together introduces extra simulation overhead and redundant constraints.
- Use rods instead of ropes wherever possible.
- Use rods instead of pinned mass objects wherever possible. A truss constructed of small mass objects connected by rods will simulate more quickly than a truss constructed of pinned rectangles.
- Make your window size smaller. A smaller window size requires less graphics-processing time.

### Recording a Simulation

Recording a simulation requires a great deal of memory. Interactive Physics automatically uses all available memory to store large simulations. If your simulation has used up all available memory, you will see the following dialogue box:



If the tape player memory is full, you can continue running your simulation in several ways:

- Close other Interactive Physics documents to make more memory available to the tape player.
- Make more memory available to Interactive Physics.
- Let the tape player “loop” and continue running the simulation.
- Increase the time step of the simulation, resulting in more spacing between frames. An increase in space between frames allows you to record the simulation for a longer time in the tape player. When doing this, the simulation may have to be run in a more accurate mode.

### Running a Simulation Beyond What can be Recorded

When the memory allocated for recording a simulation is full, you can either stop the simulation or continue the simulation while erasing the initial frames of the recording.

### Using the Settings of an Existing Simulation for a New One

You can use the current condition of a simulation as the initial condition for a new simulation:

- Drag the frame indicator to the desired starting point.
- Choose **Start Here** from the **World** menu.

The current frame becomes frame zero, and the original initial conditions are lost. Save your simulation with a new name before setting new initial conditions if you wish to re-use the old initial conditions at some later time.

### Tracking

Tracking leaves an image trace of moving objects at adjustable time intervals. You can track individual objects or all objects. Objects can leave visible tracks of their outline, center of mass, or vectors so that you can follow the physical action throughout a simulation.

To activate tracking:

- Set-up or load a simulation.
- Choose **Track** from the **World** menu.
- Select how often you wish to track from the **Track** sub-menu.

To control which individual components of each object are tracked:

- Select the object whose individual tracking behavior you want to define.
- Choose **Appearance** from the **Window** menu.
- Click on the desired tracking options.

If you want to track only one or more objects, after activating **Tracking** select all constraints and mass objects and deselect all tracking options shown in the **Appearance** window. Then select just the mass objects and constraints you want to track and check the tracking options you want enabled for those objects.

### **Running multiple simulations with multiple tracks**

The default behavior for Interactive Physics is to erase tracks whenever something that may affect the results of the simulation is modified (such as changing a mass object's property). Disabling the **AutoErase Track** item in the **World** menu will allow simulations with multiple overlapping tracks. Selecting **Erase Track** from the **World** menu will erase all tracks and refresh all meters and other objects on the Interface layer.

## **Printing Simulations**

You can print a frame of your simulation to any printer supported by your Macintosh or Windows system using the **Print** command.

### **Macintosh Printing**

#### **Selecting page size and orientation:**

Before choosing **Print**, you can specify options for printing, such as the size of the paper and the orientation of objects on the printed pages.

To specify print options:

- Create or open up a simulation.
- Choose **Page Setup** from the **File** menu.

The information you see in the **Page Setup** dialogue box varies depending on the system and printer you are using.

### **Printing**

After you have positioned your simulation within the window at the desired Zoom and location, you are ready to print the simulation.

To print:

- Open a simulation.
- Choose **Print** from the **File** menu.
- Click **OK**.

### **Windows Printing**

After you have positioned your simulation within the window at the desired Zoom and location, you are ready to print.

To print:

- Create or open a simulation.
- Choose **Print** from the **File** menu.
- Select any other **Print** options by clicking the **Setup...** button.
- Click **OK**.

## Useful Tips and Shortcuts

### Using Modifier Keys

#### Macintosh

##### Using the Shift Key

To select more than one item, hold down the **Shift** key while clicking the items you want. Clicking on an already selected object while holding down the **Shift** key deselects the object.

##### Using the Option Key

To maintain the rest length of a constraint while resizing, hold down the **Option** key.

##### Using the Command Key

To maintain current connections of constraints and mass objects when dragging, hold down the **Command** key.

##### Using the Tab Key

Use the **Tab** key to select the first value in a utility window without having to click the field.

#### Windows

##### Using the Shift Key

To select more than one item, hold down the **Shift** key while clicking the items you want. Clicking on an already selected item while holding down the **Shift** key deselects the item.

##### Using the Control Key

Holding down the **Control** key while dragging the end point of a constraint will maintain its current length. Control-drag will also maintain current connections of constraints and mass objects.

## Keyboard Shortcuts

### Macintosh

Key	Action
+	Steps forward one frame
-	Steps backward one frame
Shift-Command-R	Runs from the last computed frame
F1 or Command-Z	Undo
F2 or Command-X	Cut
F3 or Command-C	Copy
F4 or Command-V	Paste
Space Bar	Selects the Arrow tool
r	Selects the Rotation tool
a	Selects the Anchor tool
z	Selects the Zoom in tool
Z	Selects the Zoom out tool

### Windows

Key	Action
+	Steps forward one frame
-	Steps backward one frame
Shift-Control-R	Runs from the last computed frame
Space bar	Selects the Arrow tool
r,R	Select the Rotation tool
a,A	Select the Anchor tool
z	Select the Zoom in tool
Z	Select the Zoom out tool
Alt-Enter, Ctrl-I	Invokes the Object Properties window
Alt-Backspace	Undo
Delete	Clear
Shift-Delete	Cut
Control-Insert	Copy
Shift-Insert	Paste
F1	Help
F2	New document
Alt-F4	Quit
F5	Run/Stop
F12	Save As
Shift-F12	Save
Control-F12	Open
Control-Shift-F12	Print